Bridging the Gap: A Survey of Agricultural Producers, Water Managers, and Others Regarding Water Usage and Water Efficiency Perceptions.

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Contents

Abstract

This paper focuses on water usage and agricultural irrigation efficiency. However, it is not exactly a research paper. Most of the study concerns the thoughts and opinions of willing participants who were asked a series of questions regarding water use and irrigation practices. The bulk of the participants were agricultural producers (i.e. farmers and ranchers) who have some interest in the topic. Water professionals working in the private or academic sectors also participated, providing individual insights, and in some instances offered a counterpoint to arguments given by producers. The purpose being not only to enlighten me as to the delicate discussion surrounding ag water on the Front Range of Colorado, but to provide me with talking points that I hope will further the discussion amongst producers, academia, and State powers. It is my hope that through discussion and education a method of meeting future water demands in Colorado can be devised that will do as little harm to all involved parties as possible.

Chapter One

Introduction

This paper was conceived to address the core values of conservation and effective management of water resources. A gap between perceived water supply and demand looms large in the eyes of developers in Colorado. I also believe there is a gap in understanding between many Colorado residents and the agricultural producers, water managers, lawyers, engineers, and hydrologists who oversee much of the State's water. The prospect of understanding Colorado water law is daunting for obvious reasons; it is quite complex, and in some instances, also open to interpretation and adaptation.

In this regard, Colorado offers an effective, and for me convenient, case study. Colorado's borders were designed to encapsulate much of the headwaters for the arid American West, and thus act as a focal point for disputes and as a model for effective management of water resources. I believe that Colorado should serve as an example to similar regions in the American Southwest and around the globe, but first the right to do so must be earned. It is important that we understand the necessity for an effective management regime that considers all aspects of the issues surrounding water use with the aim of sustainability.

The topic of sustainable practices in overall water use is quite wide open, and the term 'sustainable' leaves some room for debate. Rather, my focus with this paper aims to foster a better understanding of how water is used on farms and ranches and how water is stored and conveyed. Several questions arise at the intersection between sustainable practices and irrigation. How efficient are these canals at transmitting water, what would efficiency upgrades cost, how might they be financed, and would it be efficacious to do so? Is upgrading of conveyance systems feasible when considering the effects of that water which percolates through the soil,

and helps to recharge groundwater for us in downstream wells, or that water which fosters riparian habitats surrounding irrigation canals and ditches. Finally, how might these issues be addressed, and by whom?

The answers to some of these questions can be answered academically. The question of how efficient canals are can be determined through prior research in the field by those agriculturalists most interested in soil properties. Pertaining to those "whom" would be responsible for the preservation of habitats, man-made or not, we would find a simple explanation for the hierarchy of power in regards to water management. When it comes to water in Colorado, there is almost always more than one party involved.

Globally, agriculture consumes more water than any other Municipal & Industrial (M&I) uses, or otherwise, combined. Colorado is no exception to this rule. In fact, Colorado was founded by settlers who took up the plough, channeled the waters, and altered the landscape and soil productivity in a prolific manner. For people to thrive on the plains east of the Rocky Mountains, channeling water for irrigation is a necessity. As demand shifts toward municipal uses in growing urbanized regions across the Front Range a keen eye is cast upon agricultural water use.

When I approached this project, I had originally intended to simply quantify total areas for irrigation canals and ditches on the Front Range of Colorado; then, using estimated seepage rates for various soil types multiplied by the area of ditches mapped there, I would be able to provide a reasonable estimate of the total water leaving the system while in transit. Much of these waters pass through open-air, earthen-lined canals, which are estimated to consume considerable amounts of water due to seepage, and to a much lesser extent, evaporation. Anecdotal estimates may range anywhere from 5%-55% depending on the ditch in question. This

incredible variance in the range came as something of a surprise to me. After speaking with John McKenzie of the Ditch and Reservoir Company Alliance (DARCA) I became even more curious of this range after he estimated that probably somewhere around just 1% of all the irrigation ditches in each Colorado water district are lined.

The drastic variability in estimated seepage rates likely has much to do with the testing site and its soil properties. Although, perhaps it is attributable to human factors. During my investigation in to this matter, I had the pleasure of speaking with a few of the people most affected by water, and who have been active participants in the discussion of its use: farmers and water managers, one of whom imparted the wisdom that, "Seepage is a people problem." Which is to say, seepage, or shrink, as it is often referred to, is a common scapegoat for human error. Whether it be the young, untrained ditch riders who attain flow measurements, the farmers who record data inaccurately, or the spills by water providers that go unrecorded. The differences between the water put in to a system and the water leaving said system may be less an exact measurement of the efficiency of the system itself, and more a measure of the consistency with which it is handled and used.

At this point it became clear that determining seepage rates based on soil factors and flow rates alone would be insufficient in describing efficiency in irrigation canals. Apart from seepage rates and efficiency concerns, there is also the question of the efficacy of lining canals. In the South Platte water district, as is true in other Colorado water districts, most water users are "conjunctive" water users, meaning that both surface and groundwater are used for crops. If all irrigation canals were lined, and their seepage removed from the system, it is possible that groundwater resources would diminish to some degree. While the exact rate of depletion or accretion remain something of a mystery, there is undoubtedly some truth to it.

It behooves me then to address the issue of the efficacy of canal linings altogether. While it may be possible to obtain a reasonable estimate of canal losses to seepage, the process of determining whether lining canals is a good idea or not is more of a sociological question than I had previously anticipated. Water which seeps in to the soil around canals continues to move through the hydrologic system, contributing to wells and waterways further downstream. Clearly, there is much more to consider here than efficient conveyance itself. The human and legal element of the equation also weigh heavily upon those considering lining or piping canals.

The habitats supported by the canals must thereby be considered. There is a significant acreage of habitat created by canal seepage, and the groundwater that moves through the hydrologic system thusly. While it could be argued that these habitats sustain a great deal of flora and fauna, a similar argument might be made for the depreciation of natural environments via river withdraws for human consumption. It mostly depends who you ask. However, when speaking of the habitat in proximity to canals, it is easy to see the flora nearby, but difficult to perceive the movement of the groundwater also associated with the canals. It seemed attractive to me to say that the seepage is lost, when thinking of the system as a mass balance equation, but the term 'loss' is a bad word in the water world. Water is never lost it is merely displaced. I was told during my interviews that the South Platte dries up completely at fifteen different spots along its route, and is only replenished downstream with groundwater base-flows, which are primarily buffered with agricultural return flows and canal seepage.

I began this thesis with a wholly different research question in mind, but as it morphed in to less a quantitative analysis of ag water transmission efficiency and more a qualitative study of what efficiency means to farmers, I gained a deeper understanding of the complexities of this topic. It is my hope that my perspective will grant insight for all parties involved in water (which

for all intents and purposes means everyone), and a view of how the other half lives, so to speak. I believe that the examination of viewpoints alternative to one's own will, in time, create a deeper understanding and empathy amongst all of us who must share this most precious of resources.

Chapter Two

Background

I found it difficult to locate research identical to my own. One series of surveys conducted by the United States Department of Agriculture (USDA), while informative of related topics of types of irrigation, was performed nationally and had little room for producers' personal thoughts (Stubbs, Irrigation in U.S. Agriculture: On-Farm Technologies and Best Management Practices, 2015). I could find little research as conversational in nature as mine. Perhaps the most closely related research to my own was a bit more specific than mine. Rather than soliciting opinions of ag producers, more technical questions are asked to determine how precisely producers understand their irrigation systems and how they would rate their level of efficiency (Knox, Kay, & Weatherhead, 2012)

When speaking of irrigated agriculture, I believe it is important to discuss the prevalence of irrigated agriculture in society throughout history. Some of the oldest known societies who practiced irrigated agriculture exist still today. Irrigation along the Nile River in Egypt, and especially near the Nile delta has been recorded as far back as modern historical records go.

Figure 1. This frieze from c. 2000 B.C.E. depicts Egyptian farmers gathering water from irrigation canals in what is known as a swape or shaduf, a bucket attached to a counterweighted boom by rope, for ease of human use (Butzer, 1976).

Irrigation tends to occur, historically, where it is most needed. In more arid regions of the Middle-East, such as ancient Assyria, the use of underground irrigation channels known as qanats (in Arabic) were discovered to be in widespread use millennia ago. Historical records from this time came in the form of observations by the forces of Sargon II, while invading Armenia in 714 B.C.E. (Biswas, 1970).

In what is now the United States of America, there is evidence of ancient irrigation systems in Arizona and New Mexico that are linked to the Hohokam and Chacoan people, respectively. While natives of the region had likely been cultivating the land for thousands of years prior, evidence of irrigation does not seem to appear until c. 500 B.C.E. This is around the same time periods where evidence of irrigation and storage are recorded for peoples of ancient Mexico. Whether the Hohokam and Chacoan tribes learned these practices from Mexican farmers is still up for debate (Vivian, 1974). Suffice it to say, in areas where precipitation is low, you are likely to find evidence of irrigation.

Slightly closer to home, there is evidence of irrigation on the Colorado Plateau by what are known as Pueblo societies. In the high, dry, cold plains near Zuni Pueblo, New Mexico, archaeological evidence was uncovered of maize agriculture and associated irrigation that is estimated to date back up to 3,000 years ago (Damp, Hall, & Smith, 2002). Closer still to Colorado are the ancient settlements on the Mesa Verde. Though, not believed to be as old as other examples of irrigation in the Southwest, their transit and use of rain catchments and distribution canals remains a fascinating field of study today (Wright, 2006).

The oldest irrigation ditch in Colorado still in use today is the San Luis People's Ditch, in the San Luis Valley, one of the oldest settled regions of the State. Hispanic settlers began moving up from New Mexico after southern Colorado was acquired from Mexico in 1848 and a treaty was signed with the Utes in 1849 (Holleran, 2005). These settlers brought with them a cultural practice of creating irrigation ditches known as *acequias* (ah-SAY-kee-uhs), a term which refers to the ditches themselves as well as the ditch company managing it, and is the smallest form of civil government (Ackerly, 1996). In this tradition, the beneficiaries of the ditch are also those responsible for maintaining it. With a priority date of April 10, 1852, the ditch retains the most senior water rights in the State ((San Luis People's Ditch), n.d.), practically ensuring its continued use.

Water rights deserve some explanation at this point. In Colorado, a system of prior appropriations is used to provision water. The basic premise being a system of seniority and beneficial use. This is to say that the most senior rights command priority delivery of their water, so long as the right is not abandoned for a period exceeding 10 consecutive years. There was some perceived risk in this regard, however, and I was of course not the only one to sense it.

MaryLou Smith, who assisted so much in helping me to attain interviews for this research, had already helped produce an informative report regarding the loss of water rights due to abandonment, or what is commonly known as “use it or lose it.” The report addresses the fear that if a portion of a water right becomes unused because of efficiency gains, the State engineer will come along and snatch away that right. While it is true that unused portions of a water right, or the entire water right, may be revoked if deemed abandoned for a period of 10 consecutive years, this will only occur if there is an “intent to abandon” the rights by the owner. Even this can be avoided if the State engineer negates the intent to abandon by citing “special circumstances,” which may include, but are not limited to in-stream environmental flows (Waskom, Rein, Wolfe, & Smith, 2016).

Acequias differ from the prior appropriation system toward what may be considered a more equitable approach. In times of water shortage, all users on the ditch reduce their consumption. When the West was settled, the prior appropriations doctrine was created. This system allows senior water rights holders to consume their entire allotment of water, regardless of whether enough remains to sate downstream users. This maximizes the value of the water for the person who owns it, and makes senior water rights more lucrative and thus, more attractive, particularly to outside interests.

Figure 2. The Upper and Lower Colorado River Basins. Previously, the Colorado joined with the Gila River to create the Colorado River delta in the Gulf of California, between the Baja Peninsula and the mainland of Mexico (Cohen, Christian-Smith, & Berggren, 2013).

Many of the early irrigators of the Southwest were located in the Colorado River Basin. The study of this basin has been extensive, particularly in recent years, as water demand rises corresponding to population. Environmental concerns over baseflows in the basin have only recently allowed the Colorado River to finally, once again, reach the Gulf of California on the other side of the Mexican border, if only for a few weeks in May of 2015. Although the amount of water released from the Colorado to Mexico is only approximately 1% of the 10% of river flows promised to Mexico by the international treaty signed between the United States and Mexico in 1944, the water is welcome, and hopes are high that increasing groundwater in the

region will restore biota which had previously dried up (Witze, 2014). Current studies of the efficacy of these environmental flows are still underway.

As one can observe by the size of the Colorado River basin, several state lines are crossed by the paths of its tributaries. Because of this, and the fact that everyone needs water, an interstate compact was created to guarantee delivery of a certain volume of water across Colorado's State boundaries to bordering states based on arrangements specified by the compact agreement. Even though the Colorado River basin exists naturally on the Western slope in Colorado, it still plays an important role in irrigated agriculture on the Front Range, thus there is considerable oversight by State water interests to ensure that Colorado gets its share of the water before it passes the State line at Lee's Ferry. Deliveries beyond compact agreements are then typically pointed to as a waste by State and ag interests, who believe that if more storage were available to capture the water leaving the State above compact requirements, we would be able to close the impending supply gap.

The supply gap, which is alluded to in the title of this paper serves as a double entendre for the physical gap between water supply and demand, as well as a knowledge gap between the public and ag producers, and others with vested interests in the usage of water. I was personally made aware of the supply gap several years ago, but I became more familiar with the specifics during a class project that exposed me to Colorado's Water Plan. The most revised version of the plan from the year 2015, as produced by the Colorado Water Conservation Board (CWCB), is the specific text mentioned during my questioning of public actors.

The text of Colorado's Water Plan is a 500+ page compendium of the knowledge of a plethora of water professionals, researchers, ag producers, and State officials to name a few. The plan was formulated following an executive order by Governor John Hickenlooper in 2013, the

burden of which fell primarily on the CWCB. This is of course not to say the CWCB was alone in its production; one might say the CWCB undertook a leadership role in the Plan's publication.

The Plan itself covers practically anything one might need to know about Colorado water. Though it does not necessarily define specific details for some of the actions it proposes, it serves as a basis for understanding the complexities of Colorado's system, the limitations therein, and the possibilities for its future. As outlined in the Plan's executive summary, "[the] plan is a roadmap…", "It sets for the measurable objectives, goals, and actions by which Colorado will address its projected future water needs and measure its progress." Going on to say that "It includes a set of policies and actions that all Coloradans and their elected officials can support and help implement" (Colorado Water Conservation Board, 2015).

A comprehensive analysis of the Plan could likely warrant its own research topic, and though I would like to address the plan further I will simply hit some of the main points, and suggest the text as further reading for those interested. First, the supply-demand gap is expected to be met in its entirety, expecting to make-up as much as 560,000 acre-feet (af) of the gap, reducing it to zero by 2030. Conservation is high on the list of target objectives, with the lofty goal of a savings of 400,000af of M&I water through conservation by 2050. The plan also addresses the issue of land use, and sets a goal whereby 75% of Coloradans shall live in communities that have incorporated land-use saving actions into land-use planning by 2025 (Colorado Water Conservation Board, 2015).

Where the Plan mentions agriculture, I was given pause. The Plan aims for agriculture to "…keep pace with growing state, national, and global needs, even if some acres go out of production." (Colorado Water Conservation Board, 2015) To achieve this the State government intends to work closely with the ag community to meet the goal of attaining 50,000af of new

supply through ATM's, and goes on to postulate that without a water plan, Colorado stands to lose 700,000 acres of agricultural lands – equal to 20% of all irrigated lands statewide, 35% of which lie in the most productive region, the South Platte, the district in which most of my study participants work and live. While I would not intend to postulate the efficacy of the plan at this point, I remain somewhat skeptical of the ability of ATM's to achieve this task, particularly if production is to meet increasing demands while utilizing less land. Some of the options provided in the text are addressed later in the results section of this paper, such as water banking and water cooperatives.

Alternatives mentioned in the Plan consist primarily of methods which put lands out of use through lease-fallowing agreements, interruptible supply agreements, and deficit irrigation. These alternatives would either temporarily remove land from use, and fallow it (a process historically used to restore the land's fertility by leaving it unsown and/or allowing it to be overtaken by native plants and later burned to return nutrients to the soil) through a lease-fallowing agreement. Other methods such as deficit irrigation simply deprive the plant of all the water it could potentially use through the natural process of evapotranspiration (ET), reducing total yield.

The Water Plan also sets its sights on the creation or expansion of water storage, with the objective of providing 400,000af of new storage by 2050; an amount that will be required if for no other reason than to house supplies derived from newly Identified Projects and Processes (IPP's), which are outlined in the Plan. Finally, the Plan sets an objective to 80% of locally prioritized rivers with stream management plans, as well as 80% of critical watersheds with watershed protection plans by 2030. Public awareness and engagement is also mentioned as a

priority objective in the plan, and though some broad goals are outlined in this regard, a clear method of doing so is yet forthcoming.

To meet these needs, more funding will be required. It is estimated that additional revenue of $100 million annually will be required to achieve these ends. The Plan points to conjunctive investments by CWCB and water providers to create multi-partner, multi-purpose projects, which would be financed by CWCB funds to the tune of $50 million and later repaid by said partners. As these water provider bonds are paid down, the fund could be reduced and used to repay green bonds, which would further expand investment opportunities. Potentially, half a billion dollars could be leveraged from that initial $50 million (Colorado Water Conservation Board, 2015). This may be optimistic, but it is a start. Far be it from me to address specific economic concerns in this paper.

However, the State of Colorado is not the only one staring down future water shortages. Other states in the Southwest rely, in some capacity, on the Colorado River to deliver potable water to their residents; and as is true in Colorado, the vast majority of water consumed in the basin, 80-90%, is used to irrigate agriculture. The issue is not exactly limited to this fact, though. One must also consider that some of these regions are in one of the driest deserts on Earth. When coupling this with the fact that about 86% of the annual runoff in the basin originates above 2500m in 15% of the basin's area, the importance of surface flows in this region becomes more pronounced, even though in the more arid regions of the basin, groundwater accounts for up to 37% of all water consumption, further illuminating the issue of scarcity (Pradhanang & Samal, 2014).

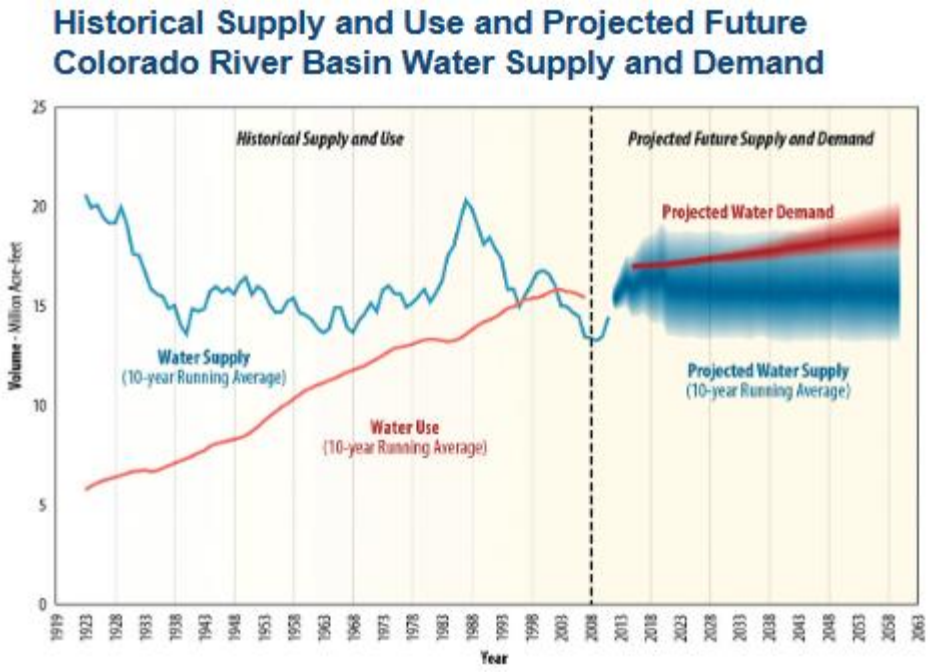
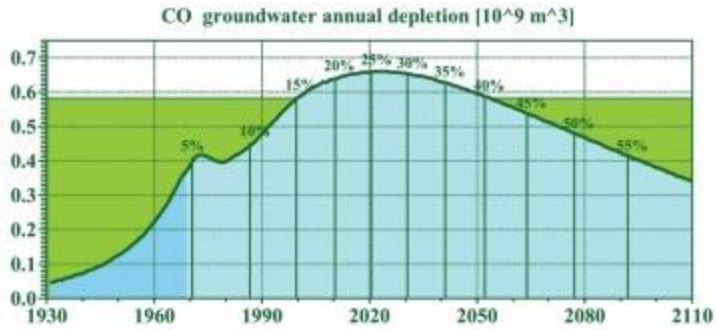


Figure 3. Colorado is not the only Western state projected to run in to water supply issues in the future. Colorado Basin supply itself is expected to be dwarfed by demand near mid-century, under status-quo usage (U.S. Department of the Interior Bureau of Reclamation, 2013).

Consumption of groundwater is of great concern on the Front Range, particularly in the northeast corner of Colorado where farmers near the Republican River rely heavily on water pumped up from the Ogallala aquifer to irrigate their crops. It has long been known that while the aquifer contains an enormous amount of water, it is not unlimited. A recent study suggests that Colorado will reach peak depletion rates by 2023, at which point pumping costs will increase as recharge rates for the aquifer fall below withdraws; an observed effect in other states, such as Texas, which is home to several ghost towns created by the overuse of the Ogallala (Steward & Allen, 2016).



state	CO	KS	NE	NM	OK	SD	TX	WY	High Plains
peak groundwater year	2023	2010	–	2002	2012	–	1999	–	2006
recharge [$10^9 m^3/yr$]	0.58	3.88	10.01	0.16	0.47	0.28	1.68	0.21	17.27

Figure 4. Blue shaded areas show depleted volume, while green shaded areas display mean annual recharge for the Ogallala in Colorado (Steward & Allen, 2016).

Considering the loss of this aquifer and the expansion of Colorado's population, I approached what I believed to be one of the area's most rife for water management gains, agricultural irrigation. After all, it stands to reason that if 80-90% of all consumed water is in ag, there must also be low-hanging fruit there. I began by focusing on simple irrigation conveyance efficiency, but soon found that even the water which seeps out of the ditch during delivery is relied upon by downstream users. While it is still doubtful that damages could be cited by water rights holders, and upheld in a water court, the potential is still felt to be real. As I began conducting my interviews, I realized that whether it was a legal issue or not, most farmers hold a deep respect for return flows.

Even defining efficiency can be difficult. Although the standard definition of efficiency is simply the work applied to a system divided by the produced output, there are a few factors to consider in irrigation. Early in the inception of irrigation science, there was simply the efficiency of the water added to the field during irrigation, and the ratio of water applied to a field relative to the water consumed by the crop through ET from the plant and topsoil. This is the basic definition of irrigation efficiency. However, it is incomplete in a modern environment that may consider an unused portion of a water right as being considered "wasted" and thus, inefficient. If

the complete use of one's water right is the determining factor of efficient use, then the type of irrigation used becomes irrelevant. Terminology must be carefully considered in relation to irrigation efficiency so that there is no room for interpretation (Jensen, 2007).

Apart from efficiency, water sustainability is, for all intents and purposes, the reason for this look in to irrigation practices. Overuse of resources is a common theme in the U.S. and around the world, particularly in "first-world" countries. To properly approach the concept, it is important to define guidelines for sustainability. While normalizing practices may be appealing for the purposes of creating guidelines, one must take in to account local processes and limitations therein. Using local knowledge tends to be the best point of entry in determining local sustainable practices. Even then, local practices can easily be dwarfed on a global scale where the trading of 'virtual water' can have significant economic impacts. When considering agricultural imports and exports, as well as other industries, there is a hidden water cost that goes in to the production of practically every product produced. Thus, the targeting of on-farm irrigation and its efficient use can have the effect of ignoring broader socio-economic processes and cultural contexts (Vos & Boelens, 2014). To avoid unnecessary confusion and the need for an elaborate explanation of the various definitions of sustainability, I shall point instead to the traditional definition, provided by the Brundtland Commission, which states that "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (Brundtland, 1987)

It may be true that specific targeting of ag irrigation overlooks a broader context, for example, how we use that agriculture, i.e. the use of ag to monoculture fields to sustain industrialized animal feedlots (an important issue for another paper). The issue of water use remains to be addressed. Larger social dilemmas addressing the root cause of consumption aside,

there are still advances in efficiency to be made. Whether these come in the form of more efficient watering systems, better crop efficiency, or the reduction of seepage in irrigation canals, the cause is worthwhile. Thus, I began conducting in-person interviews.

Chapter Three

Methods

The methodology employed for this paper evolved from a quantitative analysis toward a more human approach. After speaking with MaryLou Smith of the Colorado Water Institute, a division of the Office of Engagement at Colorado State University, I decided to shift the focus of my research. Rather than quantifying losses such as seepage and ET within irrigation canal transmission channels, I felt it would be more important to speak with some of the people most closely involved with water, the farmers and ranchers, the managers of ditches and/or ditch companies, and the academic, engineering and legal personnel whose focus regularly involves the discussion of water use in Colorado. The Division 1 water district includes the majority of those interviewed for this paper. However, many of those with whom I spoke possess a breadth of knowledge about the whole of water use and the legalities surrounding it in Colorado. While there are certainly differences in water use practices from region to region, and particularly from East Slope to West Slope, I would certainly not underestimate the level of understanding of water use and water rights from region to region, or at the state level and beyond, for any of my interviewees.

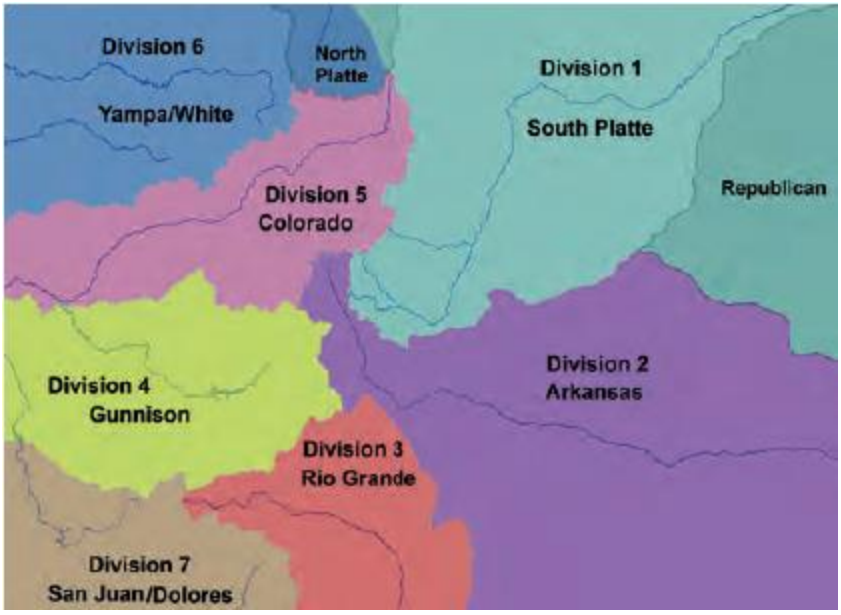


Figure 5. Colorado State water divisions. Division 1 also encompasses the Denver-Metro area. (Colorado Water Conservation Board, 2015).

I approached the interview process with a few sets of questions that I designed to be minimally intrusive. The primary purpose of the questioning line is to elicit genuine perceptions on the practices of irrigation and the general feeling of its usefulness, best practices, and public perception of agricultural irrigation water consumption from both agricultural producers and those outside the agricultural community who are also concerned with its use. Although each of the sets of questions was designed with a specific demographic in mind, there was some overlap between group types. For instance, questions for the "public" were often just as relevant for an agricultural producer, and many agricultural producers also find themselves acting as ditch managers as well, whether for a local community of ditches or for companies overseeing larger networks of ditches and reservoirs. Thus, there is some crossover between the three categories I identified for my questions, those being of 'producers,' 'water managers,' and 'public.' Several of the questions for producers and managers are aimed at gathering some statistical data, as well, but the common theme between the groups questioned ends similarly by asking for personal concerns surrounding the issue of water usage currently and in the future.

I shall include the list of approved questions below. One by one I intend to describe the responses to each of them in the results section of this paper. Most are self-explanatory, but I will provide some level of explanation for each of them. Many of the answers are matter of fact, and can be described statistically. Most of the answers will need to be described conversationally with respect to the concerns and opinions of those involved. Wherever I deem it applicable, direct results and quotes may be included. I hope that the conversations will be as informative to the reader as they were to me.

Questions for producers/stockholders:

1. How many acres do you irrigate?
2. Where do you get your water?
3. Do you usually have enough to meet your needs?
4. By which method(s) do you irrigate?
5. What would you say your interest is in irrigation efficiency on your property, on a scale from 1 to 10?
6. Have you made efficiency improvements on your farm? When? Have they been beneficial to you?
7. How were the improvements funded?
8. Are you concerned about the effects of improvements on upstream users? Downstream users?
9. (If no on 6) What are the primary prohibitive factors preventing you from making efficiency improvements?
10. How familiar are you with water transfers/leasing? What are your thoughts/concerns on the matter?
11. What are some of your primary concerns pertaining to the future of your water delivery and use?

Questions for managers:

1. How many users does your system serve?
2. How much water do you deliver on average at peak season?
3. Are you concerned with efficiency within your delivery systems? Why or why not?
4. Have your users and/or shareholders voiced opinion on this matter?
5. What do you believe would be the most beneficial changes that could be made to your delivery system? What are the prohibitive factors to this change?

6. What does your ditch maintenance typically consist of? Do you believe process changes could be made to promote greater efficiency?
7. How would more efficient delivery systems be funded, if deemed beneficial?
8. What are some of your primary concerns for the future of irrigated agriculture in your region?

Questions for public:

1. How concerned are you with ag water efficiency on a scale from 1 to 10?
2. How familiar are you with irrigation efficiency upgrades on farms in Colorado?
3. How concerned are you with the future of ag water usage in Colorado?
4. Are you familiar with the Colorado's Water Plan, released in 2015? (Familiarize for purposes of question six.)
5. On a scale from 1 to 10, how concerned are you with an expected gap between water supply and demand?
6. Please rate the efficacy of the following methods for meeting the supply gap, on a scale from 1 to 10:
    a. Newly Identified Projects & Processes
    b. Colorado River Development
    c. Conservation/Efficiency Efforts
    d. Agricultural Transfers
    e. Agricultural Leasing
7. Do you have any personal thoughts on the expected gap and/or how it might be dealt with?

Apart from three of the interviewees with whom I conducted phone interviews, in person meetings were conducted to gather responses. I gathered answers for the questions and took notes from the conversations on my tablet PC, recording responses in individual word documents along with the questions posed. For the purposes of codifying the responses, I compiled all the documents together, leaving the names of the interviewees out. For each interview, I gathered consent from participants per guidelines agreed upon between the Institutional Review Board and myself. The consent was gathered verbally at the time of the interview, and simply made participants aware of the purpose of the research and to the fact that their names would be omitted from the final draft.

Even though the participants shall remain anonymous, it is a small world when it comes to the crossroads of water and agriculture. It is even smaller when you add in the intersections of city, state, and academic interests. Many of those I interviewed felt comfortable wagering that they could tell who I had spoken with based on factors such as irrigated acreage, the ditch or ditches used for water acquisition, and general opinions expressed. Recognition amongst the participants may be likely, the fact that many of those who agreed to be interviewed expressed interest while gathered at an agricultural water workshop in the Summer of 2016. Although anonymity was not an expressed concern to me by any of the participants, I shall still do my best to adhere to the protection of their anonymity.

As I mentioned, the primary portion of my sampling group was attained at an agricultural water workshop in Northeastern Colorado in the Summer of 2016. I believe this comes through in my results. Suffice it to say, their interest in water use in ag now and into the future was important to all involved. The future of water in Colorado is under constant scrutiny and in a perpetual state of flux. There is always something going on in water court. Disputes over how much water a given individual may draw can be quite common. However, I felt that the management of water in Colorado had not changed greatly since its inception. It was, in part, this feeling that compelled me to conduct this research. I was also compelled by my desire to learn more about irrigation in agriculture, and the major part it plays in the context of statewide water consumption, not to mention the millions affected by the headwaters originating in Colorado.

Chapter Four

Results & Discussion

The first interviews I gathered were quite interesting, if not a bit unorthodox. Unfortunately, I had not yet received approval from the Institutional Review Board to conduct interviews for the purposes of this research. Therefore, the questions were less well defined, and the responses not necessarily comparable to all those received. Still, there is useful information from them that I would like to include here as a sort of preamble to the results section.

My first interview was one of my most interesting, and speaks to the nature of stewardship and collaboration, as well as the hard work performed by and required of ag producers. On this morning, I made the trek up north from Boulder to meet up with MaryLou Smith, who had arranged interviews for myself and her Australian cohort, Doon McColl. Together we toured the property of a producer who had designed and constructed a small reservoir and surrounding wetlands, with the help of the United States Department of Agriculture's (USDA) district conservationist, who also joined in our tour and discussion that day. Doon was working on her own paper at the time for her Churchill Fellowship, and wound up beating me to press by a wide margin. She was looking for examples of voluntary environmental programs in the states whose concepts and ideas she might be able to utilize back home in Australia where agricultural effluent has been exacerbating the degradation of the already endangered Great Barrier Reef (McColl, 2016).

Together, we all took a stroll around the property and got a good look at the reservoir the producer had constructed with the guidance and support of his USDA cohort. It was truly well constructed and quite beautiful, with a feeder canal for the nearby constructed marshlands, complete with headgates for water level management in the marsh, and of course reconnection to

the district ditch system. I am not including the following interviews in my results due to the difference in lines of questioning, as well as the legality of their use. However, I would like to share some of the thoughts and comments from these folks, along with the scenery and utility created by the producer and the cooperating partner within the USDA.

The owner of the land had been working there 47 years. Much of the land surrounding his home consisted of the reservoir and marshlands, leaving them with just a few acres for pinto beans. On larger plots the ever-popular hay is being produced while the increasingly popular product of hops grows nearby. We only toured the reservoir project, however, but it was not a let down by any means. You would hardly be able to tell that the land where the construction took place had been overgrazed by horses and dried up for years. Thanks to an Environmental Quality Incentives Program (EQIP) grant, supported by Pheasants and Ducks Unlimited, combined with an innovative idea and a lot of hard work, the land has been transformed. The land now provides significant habitat for waterfowl amongst a bevy of other benefits, not the least of which is a local reservoir to buffer water storage. Perhaps most importantly is the sentiment conveyed to me that conservation is "kind of contagious." Adoption of new practices are often avoided by more senior producers, and for a respected member of the community to find success in this sort of project may inspire others to follow suit.

Figure 6. The back of MaryLou Smith's head as she overlooks the reservoir (photo credit of author).

Figure 7. The offshoot from the reservoir leading to the feeder canal for the marshlands (photo credit of author).

Figure 8. The feeder canal and walkway to the constructed marshlands. If you look closely, you can also see the family dog near the middle of the shot who joined us in our tour (photo credit of author).

Figure 9. The constructed marshlands, complete with cattails and algae, and of course the occasional waterfowl (photo credit of author).

My second interview occurred on the same day, at the office of a nearby ditch company. There, MaryLou Smith, Doon McColl, the interviewee, and I spoke at length about the rich history of the company, which remains one of the oldest in Colorado. We also spoke of some changes the company had made, such as the reservoir at the tail-end of their ditch that captures unused water from the channel, as well as return flows from irrigated fields. I found this to be a clever system that serves to act as a buffer in dry years. When asked of concerns and plans for the ditch, the interviewee replied in what would turn out to be a standard response by most participants; there is an ever-pressing concern over simply receiving all the water decreed to them by right. Other concerns more directly related to ditch managers are issues of maintenance. This ditch manager mentioned their recent purchase of specialized lawn mowers whose task it will be to clear the various grasses and unwanted weeds along the banks of the company's ditches. The results of these conversations were as difficult to quantify as well as qualify as any of the others which I conducted, though I did see a common theme between them; everyone has an expressed interest in conserving water, whether it be for monetary reasons or otherwise.

The results of my study have been difficult to interpret. As this was my first "sociological study" I spent quite some time pondering how to codify and present the data gathered from my interviews. Ultimately, I believe that, aside from some statistical information, much of what I discovered will be better digested by the reader if I present the results matter-of-factly as well as from my subjective point of view. I do this because of the nature of the interviews. No matter the demographic being interviewed or the questions set being used, the lines of questioning all lead toward a conversation about water use concerns and suggestions. I feel this is better approached by speaking broadly to the reader about the opinions and ideas as I felt them expressed. Of

course, it is not my intention to misrepresent the views of any of those I interviewed, so I will include supporting quotes and/or paraphrase from conversation whenever possible.

Let us begin from the top, with questions for agricultural producers. Starting with:

1. **How many acres do you irrigate?**

   I wrote this question to gather some statistical data, however, my sample size was so low that drawing averages would not deliver any viable hypothesis as to a relation between the size and scope of a given operation and its efficiency or conservation efforts. I conducted a total of fifteen interviews, including a few I had conducted before completing my IRB application with my final list of questions. This question was therefore not asked of all the producers I interviewed. Of the ag producers I spoke with, the total irrigated acreage was significant. One producer estimated between 365 and 480 acres, while another estimated total acreage around 750 acres. The two largest farms were right around the area of 2000 irrigated acres, which would average out to $\frac{480+750+2000+2000}{4} = 1307.5$ acres.

2. **Where do you get your water?**

   This question was meant more to ask whether water for irrigation was attained through irrigation companies or via wells. Although I did receive some specific information from participants as to the ditch companies from which they draw water, I shall exclude specifics for privacy's sake. Suffice it to say, the clear majority of the producers I interviewed were in the Division 1 Water District, and relied almost entirely on ditches for irrigation water supply. The largest of these farms has water rights well over 100 years old, and thus senior to a right of 100 years or less, which may be

comparatively young, or junior if you will. With the rights to draw water limited by a flow rate of nearly 115 cfs (cubic feet per second)[1], one participant owns one of the most senior water rights in Colorado, dating back to 1874. Surprisingly, only one of the producers I interviewed claimed to be irrigating with groundwater, at a rate of around 40% total consumption.

3. **Do you usually have enough to meet your needs?**

As was noted by one interviewee, the answer to this question is likely to be yes in most instances, based on the assumption that farmers must plant crops per the amount of water available, and not so much the other way around. Accordingly, the response was typically yes. One producer did suggest that shortages do sometimes occur in drought years, when water availability may be difficult to accurately predict.

4. **By which method(s) do you typically irrigate?**

The overwhelming majority here was center-pivot. Most of the plots using flood or drip irrigation remained as such due to geographical limitations. Flood irrigation was the only alternative to center-pivot mentioned as a sizeable alternative, and even then was only estimated to consume ~5% of the individual's total irrigation water.

5. **What would you say your interest is in irrigation efficiency on your property, on a scale from 1 to 10?**

This was always expressed to me as being of great interest. Based on my responses, I received an average answer of 9.5.

[1] 100 cfs equates to nearly 200 acre-feet in a 24-hour period (CFS to AF Conversion Instructions, n.d.).

6. **Have you made efficiency improvements on your farm? When? Have they been beneficial to you?**

Some of the more senior farmers first upgraded to center-pivot sprinkler systems in the 1980's, while another cited sometime around 2000. Although several also mentioned completing further upgrades only 4-5 years ago. I also received some words of wisdom in response to this question that should go without saying, "Never feel too confident that there is enough water. It is always to our [producer's] benefit to be as efficient as possible."

7. **How were the improvements funded?**

The answer to this was nearly unanimously privately funded. One participant cited receiving funding from EQIP for one center-pivot. The largest grant provided through EQIP of all my interviewees was responsible for the project cited at the beginning of the results section.

8. **Are you concerned about the effects of improvements on upstream users? Downstream users?**

There was considerable concern around this rather complicated question. Primarily, producers were concerned with full utilization of their water right, and achieving the greatest "crop per drop" possible. Efficiency is a concern on multiple levels in agriculture. Above efficiency in transmission and on the field, overall system efficiency within an irrigation was also expressed as a concern. The example used would be of a producer achieving 85% efficiency on their field while seeing their conjoined ditch company's reservoir filling at 65% efficiency. This may leave those spending the most on efficiency upgrades on their local ditch feeling like they are getting a raw deal, while other users reap the benefits.

There is also potential concern that as delivery and consumption approach 100% there will be no groundwater to recharge wells, upon which many producers rely. Adversely, those with junior water rights who pump wells on their property are often seen as being to blame when a senior water right is unable to fully utilize their allotment, Factors of timing in watering fields can be an issue in this regard.

9. **(If no on 6) What are the primary prohibitive factors preventing you from making efficiency improvements?**

This was not applicable for my sampling group, as they had all made efficiency improvements at one point.

10. **How familiar are you with water transfers/leasing? What are your thoughts/concerns on the matter?**

Answers to this question ranged from familiar to very knowledgeable. A few of the producers I interviewed were also heavily involved in irrigation companies, acted as managers of ditch companies and/or were involved in shaping policy through the Inter-Basin Compact Committee (IBCC) roundtable process.

The importance of respecting the original water right ranked highest in regards to concerns with leasing. It is of great importance to those rights holders that the right should not depreciate, an issue that is likely influenced by the sense that you must "use it or lose it." Some I spoke to regarding this issue point to this motto as an excuse for waste. There seems to be a school of thought that if one is not diverting their entire decreed amount of irrigation water the unused portion may be lessened in the Historical Consumptive Use (HCU) evaluation, should they ever want to change use of the water in court. This issue was pointed to me as standing at the heart of the problem. For, if there is

fear of losing water rights due to non-use, there is little, or even negative, motivation to leave water in the stream.

Some participants also pointed to the struggle of farms to turn a profit. Leasing of a portion of one's water right can help in a pinch, and tends to be preferred over a permanent sale of a water right. The term "buy-and-dry," which is associated with the permanent sale of a water right, leaves a bad taste in the mouths of all involved parties. There is some expressed concern that this will be the direction the State government is heading to meet the expected water supply gap by 2050 and beyond (Colorado Water Conservation Board, 2015).

One producer I interviewed pointed to the inflation of water prices, perhaps because of competition with cities. Indicating a reduction in farmer owned supply in the North Poudre by 5%, one user said that a share on their ditch had grown in cost from $17,000 to $95,000 over a ten-year period. With this sort of inflation, it is no wonder that water sales have become more attractive in recent years. Low or no-irrigation crops also become more attractive in this environment. One producer lauded the switch to a hemp crop, which can thrive on much less water than corn or hay, some of the most commonly planted crops.

11. What are some of your primary concerns pertaining to the future of your water delivery and use?

Some of those I interviewed expressed little concern over the future of their water delivery, while others expressed a variety of concerns. Those least concerned tended to have the most senior water rights, though they did point to the fact that there is some level of uncertainty there. The most common concern was that of population growth in

cities that would precipitate the buying of ag water shares, also known as buy-and-dry. The concentration of farming operations was also of concern, which is believed inevitable if ag is set to compete with cities for water. The importance of reservoirs on ditch systems acting as a buffer for producers was also a common theme. Producers point to water leaving Colorado above current inter-state compact agreements, as well as the need to capture early Spring meltwater that tends to arrive earlier each year due to a changing climate. Finally, water quality was an expressed concern. As water becomes more scarce it typically also becomes more saline.

Questions for managers:

1. **How many users does your system serve?**

The low sampling size makes averaging results inconsequential in this instance. Two of the interviewees were attached to the management of ditches for agricultural or municipal use. However, one served more than twice as many users as the other. Larger still was a conservancy district, which typically measures its scope in area rather than users, and provided an estimated coverage area of more than 400,000 total acres. Without giving away a name, I can say that I also interviewed an individual who oversees an even larger portion of the State and its water usage. Anomalies aside, average users served per ditch equates to $\frac{(30+130)+140+260}{3} = 186.66$.

2. **How much water do you deliver on average at peak season?**

I cannot draw upon averages for this discussion, either. Of the few water managers I interviewed, the range of water delivered between them varied drastically, and I believe that defining the entire range would compromise participant(s) identities.

3. **Are you concerned with the efficiency within your delivery system? Why or why not?**

The response to this was primarily in the affirmative. However, a caveat was pointed out to me. Efficiency is a moot point in irrigation if a water right already has an established HCU. Meaning that, the water consumed by a producer over the span of a decade must remain constant to be maintained (or at least that is often the perception), and likewise, the return flows associated with this HCU must also be maintained. Therefore, if a producer uses their water more efficiently there is little incentive to leave water in the stream. However, they would still be obligated to provide previous historic return flow rates. As I was told by one participant, greater efficiency in the system does not necessarily equate to excess water. In a "water-short" system, return flows must be maintained to avoid causing injury to another user's water right.

Evaporation and seepage are also always of concern to users on a ditch system regardless of whether HCU is maintained. Losses from a system that are truly lost do not serve downstream users as assumed historic return flows do. Adversely, water removed from a system due to inefficient ditch maintenance that feeds unwanted flora serves only to short the entire system. One manager said that weed overgrowth on a poorly maintained ditch has previously reduced patches of their ditch capacity to one-third of its full capacity. The same individual also cited seepage due to soil types, particularly alluvial/sandy soils that are significantly more porous than other soil types. Theft was also a concern for this interviewee. This was less because of concern over poor accounting at headgates, as one might imagine on an agricultural ditch. In this instance, losses are attributed to the fact that large portions of this ditch pass through the backyards

of many city residents who do not realize that they are not supposed to be tapping this water source.

4. **Have your users and/or shareholders voiced opinion on this matter?**

This was a strong yes between all those interviewed. Some participants simply reiterated the importance of maintaining historic return flows. Others pointed to some of the new structuring of water rights that tend to be favoring firms that buy up water rights for private use, often leasing it to M&I users. I was given the following example: three users remain on the end of the Brighton lateral ditch after a commercial expansion, and because the senior rights above the users were bought for the purposes of commercial enterprises on the ditch (shopping malls, etc.) it is possible that the ag users on the end of the ditch will receive little to no water in lean years. This sort of adversarial position between producers and municipalities serves only to perpetuate the overall feeling of unease between the producers who believe that cities are after their water, often for, what some consider, purely cosmetic reasons such as ornamental bluegrass lawns.

One interviewee pointed to the preference of maximizing gains in crop efficiency, as it tends to be more reliably profitable than gains in water efficiency. The interviewee also praised the potential of Alternative Transfer Mechanisms (ATM's), saying that a lease arrangement that does not cause a revenue loss to farmers is always a welcome alternative. Another respondent was more dubious of ATM's, stating that there must be very little perceived risk on the water law side; going on to say that this practice can pose a significant risk to producers. The respondent expressed that in change of use cases, where the beneficial use of the water right is changed from agricultural use to municipal use, there is potential for exploitation.

5. **What do you believe would be the most beneficial changes that could be made to your delivery system? What are the prohibitive factors to this change?**

There was a consensus on this as well. Most would like to see greater investment on infrastructure. Many producers would like to see new storage in the form of reservoirs. They point to any amount above and beyond our compact obligations that pass the Colorado State line. However, others deny the usefulness of the creation of more dams and reservoirs, and are quite sure there is sufficient storage for the Front Range already and that capturing the water leaving the Colorado in excess of the compact is not as easy as believed. Conversely, there is significant storage in shallow and deep aquifers along the Front Range. One interviewee estimated storage available to the tune of 300,000af. Of course, making withdrawals from deep aquifers can prove to be quite costly. Unfortunately, a cost comparison between new storage and aquifer storage and associated pumping costs could not be attained during this research. Storage remained on the tips of producers' tongues, however. To paraphrase one interviewee, timing is an issue; no one has control over when recharge water will return, reservoirs are obviously much more manipulatable in this regard. Timing may also pose an issue for sprinkler systems when high winds are prohibitive to their use. No one wants to watch their water blow away.

Some alternative investments to infrastructure were seemingly welcomed by all. Excavation of ditches to expand waterway and reduce clogging. Clearing and flushing of ditches and canals is part of required maintenance, however. To take things a step further, there is room for expansion in the field of technological upgrades on ditches. Automated and remote controlled headgates offer convenience and greatly improved administration of irrigation waters. Going a step further on irrigation canals, lining or piping canals

would also considerably reduce seepage. In the same breath, this concept could be shot down as being cost prohibitive and legally troublesome, when considering the needs of downstream well users.

6. **What does your ditch maintenance typically consist of? Do you believe process changes could be made to promote greater efficiency?**

There has been significant funding of ditch maintenance projects in the past few years. This maintenance is beyond typical recovery programs as it was funded because of the massive flooding that took place in September 2013, when massive storm fronts pushed up from the Gulf of Mexico causing the Front Range to receive approximately an entire year's worth of precipitation in the span of about two weeks. The subsequent flooding reportedly caused nearly $4 billion in damage across Colorado (Aguilar & Bunch, 2015). Thus, an expanded ditch maintenance program became a necessity. Although, if some funding can be retained, some of the more troublesome points along transmission pathways can be more sufficiently monitored and maintained. Aside from the hands-on maintenance required on ditches to begin the growing season, better remote sensing could be employed for better record keeping and allotment. One interviewee pointed to a woeful lack of gauges on irrigation pathways on the West Slope. Perhaps this is due to challenges of difficult terrain, in which case modeling systems may be effective intermediary predictors (Sanadhya, Gironás, & Arabi, 2013).

7. **How would more efficient delivery systems be funded, if deemed beneficial?**

Most of those with whom I spoke who fall under this category manage ditch companies. As these are private companies that are supported by shareholders, infrastructure investments typically must be funded by increasing the dues of the users on

the ditch. However, there are federal, as well as low-interest state subsidies available through EQIP project funding, though it seems that producers are apprehensive to apply for or receive federal funding. Whether it be for sake of ease or a general aversion to federal assistance, the EQIP program has the potential to be more fully utilized in Colorado (Stubbs, Agricultural Conservation: A Guide to Services, 2015).

Others believe that partnerships between municipalities and producers could be beneficial, as municipalities encroach further and further in to what was originally ag water, it would seem to behoove them to assist in irrigation infrastructure improvements. One interviewee relayed to me that ultimately it is the population at large that benefits from ag production, therefore public funding of improvements should be provided through state taxes.

8. **What are some of your primary concerns for the future of irrigated agriculture in your region?**

Climate change arose as a concern frequently. Its impact on the timing and volume of the Spring melt promotes uncertainty as to the usefulness of that water. The feeling is that if there is not enough storage for this water it will flow out of Colorado unused, potentially shortening the growing season, especially in drought years. Fear of climate change also drives the growing contention between ag and cities over supplies. There is a fear amongst ag producers, which is warranted, that if ag and municipalities come into direct competition ag will lose. Ag simply is not as profitable as other commercial and industrial enterprises, not to mention the housing market.

Some fear the disintegration of water law entirely over time, as cities buy up more and more water rights and change its intended use. There is concern in ag that we will be

losing some of the most productive soil by selling off water rights haphazardly. Water managers I spoke with would like to protect the base water supply by creating a more open dialogue between producers and municipalities to avoid, or at least mitigate, the effects that massive buy-and-dry will have on agriculture and the state-at-large. Many producers feel that ag must be made economically viable to remain a fixture in Colorado's landscape. Otherwise, we will be left at the mercy of imports, which make us more vulnerable. As local producers drop out of the race, the lowest bidder will tend to win these contracts. In the case of beef, we will likely be looking to import Brazilian raised beef. Brazilian beef has had several disease scares that make it less attractive to importers (Costa, Bessler, & Rosson, 2011). More importantly, in my mind, is the fact that Brazil has expanded its cattle industry very rapidly in recent years at the expense of the largest rainforest on Earth. It is a discussion for another time, but suffice it to say the destruction of large carbon sinks such as forests to expand one of the most carbon intensive practices on the planet is about the worst thing we could be doing regarding climate change.

Farmers would like to change public perception of themselves to combat what they feel as being misunderstood, at best, or vilified, at worst. For instance, many producers would like to see public perception of Genetically Modified Organism (GMO) crops become more accepting. They point to the lack of any evidence of their destructive nature, and point instead to their increased efficiency, lower pesticide use, and wider profit margins. Producers also feel some contempt from the public who they believe sees them as the primary consumers of water resources, which leads them to the conclusion that they must be operating inefficiently. While there is surely room for improvement,

there was little doubt in my mind after conducting these interviews that ag producers are greatly concerned with efficiency and tend to take all possible steps to reaching peak efficiency in all aspects of their enterprise, particularly in water short systems.

I believe most would prefer an alternative somewhere between buy and dry across the Front Range and the ceasing of all future population growth. However, I imagine both must happen in some capacity to meet somewhere near the middle. There is certainly a growing fear amongst many demographic groups that growth is simply inevitable. As they say, water flows uphill toward money.

Questions for public:

1. **How concerned are you with ag water efficiency on a scale from 1 to 10?**

Before beginning this section, I feel I should qualify the participants, since the term "public" is rather broad. Most of the folks I interviewed are highly interested and/or actively involved in studying water use and water policy, and may be actively involved in shaping water policy. The public group is no different. Upon further examination of my questions and the interview process, I can see that the efficacy of these ratings questions is perhaps not what it could be if they were approached differently. So, aside from asking for a simple rating, I asked interviewees for their own thoughts on the matter, as well as a rating, and then to qualify that rating. Suffice it to say, the average value, as in other similar questions, presents a null hypothesis and is not necessarily useful as a result.

Regardless of the efficacy here, numerical responses were typically high, ranging from 7 to 10, and averaging in the middle, at 8.5. At the low end, a participant wanted to ensure the message was conveyed that the efficiency which most concerns many farmers is crop per drop. As far as conveyance efficiency is concerned, it was felt that if return

flows are not damaged efficient transmission is fine. Obviously, seepage is less a concern for this individual. Though, I would tend to estimate this school of thought is quite common amongst producers, as well; as is the belief that the rapidly expanding population on the Front Range is woefully unaware and uneducated as to the purpose and use of ag water.

The highest response I received on this question had a considerable amount to say about it. Having conducted his own research on the matter, this participant could provide figures indicating drastic water saving potential by making the West Slope more efficient. The study indicated that upgrading farms who flood irrigate to center-pivot sprinkler systems, in conjunction with financial incentives to leave water in the river, could allow 30-40% of the water drawn to remain in the river. Aside from flood irrigation, a school of thought which promotes waste was shared. I was told that some West Slope irrigators have been running water onto their fields into November, despite it being unnecessary after Labor Day. The fear of "use it or lose it" seems to be playing a role in this activity. This interviewee points to how water is being measured as a leading culprit in waste, saying that the real problem is that we are measuring based on withdraws from the river, essentially ignoring crop consumptive use. The participant believes that further adjudication of consumptive water use rights, diversion rights, as well as a detailed analysis of canal length and the soil substrata below them could also play a key role in conserving water to maintain river baseflows.

2. **How familiar are you with irrigation efficiency upgrades on farms in Colorado?**

Responses here were quite high. I would say that the lowest response was given by a participant who qualified their answer as "proficient, though perhaps not extremely

technical." Others responded quickly, as being very familiar. One went so far as to say that they "[had] better be more up to date than anybody else."

3. **How concerned are you with the future of ag water usage in Colorado?**

Answers varied on this question. One participant was very concerned. Another was concerned primarily by population growth and especially ag transfer. However, one respondent was not particularly concerned because they remain optimistic about the effects that upgrades and innovation can have in closing the gap. It was noted that the Colorado does seem to be heading toward a reduction in irrigated ag, but that more equitable sharing along with innovation and State sponsored irrigation upgrades could significantly dampen the blow to ag while meeting M&I needs.

4. **Are you familiar with Colorado's Water Plan, released in 2015?**

Those I interviewed were probably more familiar with this than most, as they had either consulted on its publication or continue to be involved in its implementation. As I stated previously, the term "public" may be too general a category for the folks I interviewed.

5. **On a scale from 1 to 10, how concerned are you with an expected gap between water supply and demand?**

I received a wide range of responses to this question. Some said that they were very concerned, while others believe that if ag water waste were accounted for, the 2050 gap could be met entirely, eliminating the need for newly Identified Projects and Processes (IPP's). Others are more skeptical, and believe that new storage will be needed to meet ag consumption. These respondents also point out that local agriculture will be needed to support a growing population. There is also concern that as municipalities and

agriculture fight over water, environmental baseflows will suffer thus. Although most responses to this question were very concerned, with numerical responses ranging from 8 to 9, the respondent who believes the issue could be resolved through the elimination of waste gave a response of just 1, and indicated that the risk remains an issue to create a façade of short supply, which will keep the value of water rights high.

6. **Please rate the efficacy of the following methods for meeting the supply gap, on a scale from 1 to 10:**

   a. **Newly Identified Projects & Processes**

      There was no clear consensus on this. I received a response of 6.5, 10, and 1. The response of 10 believes that new storage will be able to solve water needs. The answer of 1 believes that new IPP's are unnecessary if we were to "lop off the top of the hydrograph." This phrase, which was coined by the participant, refers to the capture of snowmelt that occurs in Spring in volumes greater than current storage capacity can contain.

   b. **Colorado River Development**

      Responses here were quite low, with an average of 2.5. Interviewees felt more skeptical of new projects on the Colorado, saying that there is not enough supply available beyond the IPP's already on the table.

   c. **Conservation/Efficiency Efforts**

      Responses averaged 7.5 in this category, though there was an outlier mentioned, who doubted the effects of in-home efficiency efforts. The respondent believed that efforts focused on outdoor conservation in urban and suburban areas would be far more effective. The highest response held high hopes for municipal efficiency in

conservation, however, and believes that the only aspect realistically viable for expansion in ag is the adaptation of plant physiology to further expand the crop-per-drop. Respondents seemed somewhat hopeful that efficient use would be helpful, but none would go so far as to call it a panacea.

d. Agricultural Transfers

I had responses on both the very low and very high end for both transfers and leasing. I also had a 7 for both categories from one respondent, who believed that both permanent transfers and leasing will likely be widely used in the future, whether it is the best solution or not. It is simply where all the water is.

The very high response cited a sentiment like the response of 7, feeling its inevitability. The very low response fears that this is the wrong path to follow, and that ultimately we will run into food and energy shortages because of it. More importantly, we would essentially be putting farmers and communities out of business for good.

e. Agricultural Leasing

The low response to this category believes that there is typically not enough there to make it worthwhile for the producer, particularly when legal or engineering consultation is required. However, most rated this option highly, especially as an alternative to permanent transfer. Leaving the anomalous low response aside, an average response of 8.25 was attained.

7. **Do you have any personal thoughts on the expected gap and/or how it might be dealt with?**

Many of the thoughts expressed in response to this question were reiterations of prior sentiment. However, there were some more specific thoughts that I will attempt to disseminate here, to some degree. I would prefer to address some of those points later in the conclusion, along with some of the recurring themes I observed. For example, perceptions surrounding buy-and-dry, agricultural waste, and public knowledge regarding water use all could benefit from more concise information. Educated and informed decisions in every aspect of this endeavor will be important in meeting future demands. I believe that continued cooperation and respect for differences of opinion amongst representatives in the water world will be important moving forward. While preparing for the worst we must utilize our best.

I shall attempt now to summarize the thoughts of all the participants of whom I asked this question, in no particular order. Some recurring concerns will be addressed later in the discussion.

One interviewee pointed to conservation programs, and changes to municipal planning to promote water conservation and efficiency as effective methods for meeting future needs. Also of primary concern was the sentiment and hope that the inevitable agricultural water transfers in the future will be the most beneficial and least harmful transactions possible for all involved parties. This individual said that they are observing the posture of other river basin states in the Southwest who are gingerly approaching the issue of water availability. Although they would not care to admit water shortages, to remain economically attractive, there is the potential for Colorado and other basin states

to go water short in the future. It is important that these issues are addressed sooner than later, and that there are contingency plans in place should worse come to worse.

Another interviewee, who acted as a cooperating member in shaping Colorado's Water Plan for 2015 also expressed concern for educated and informed trade-offs in meeting the gap. The flexibility of the water plan was pointed to by the respondent, who feels confident that we will be able to address future needs, but that doing so will likely require a broad portfolio of investments in multiple forms of conservation, efficiency, transfers, and success in IPP's. While the individual believed that storage was important, they did point to the expansion of existing storage being more attractive than creating new buckets. Finally, sustainable consumption should be a priority. Consumption levels should also continue to account for stream health, allowing natural tributaries to support the health of our rivers and streams, which help replenish our over exploited aquifer storage.

Aquifer health was important to many of those with whom I spoke. Withdrawals from deep aquifers are far outpacing inputs in most areas, and Colorado is no exception. This brings me to another point presented to me: Colorado is already over appropriated and water short. How might we address aquifer health considering over consumption? How will transfers affect future water use if total available water falls below historic levels? Will the senior water rights bought by municipalities also push off junior users when they no longer have the resources to irrigate crops? I imagine that determining the answers to these questions is consistently vexing to all those tasked with doing so.

While other opinions expressed hope for greater conservation and efficiency projects in meeting demands, others are more skeptical. Even though Colorado's system of prior appropriation was devised in part for the purposes of avoiding speculation (CRS § 37- 92-103(3)), it seems quite difficult to me to extricate the two. As water becomes more scarce, its value is driven up. Private interests, who are for all intents and purposes speculating that there will be greater future demand, and the municipalities which need water to sustain their growing economies seem to be trending toward outpricing producers. It seems only inevitable at this point that ag production will be pushed out of the Front Range, at least in some considerable capacity.

This has lead one interviewee to believe that there is little desire by the Colorado government and private interests to limit growth and consumption, for if you reduce either, the value of the water right falls. This participant pointed to the Front Range Water Council's push to keep the West slope from conducting a "West Slope Water Risk" study to determine the likelihood of a Lake Powell compact call. For, if the risk is discovered to be high, those on the Front Range will be less likely to obtain new water through trans-basin diversions already in place. All most of us can do is hope that this race to the bottom ends early, through reasoned communications between all involved parties, from the producer to the public, the scholar to the student, and the environmentalist to the industrialist.

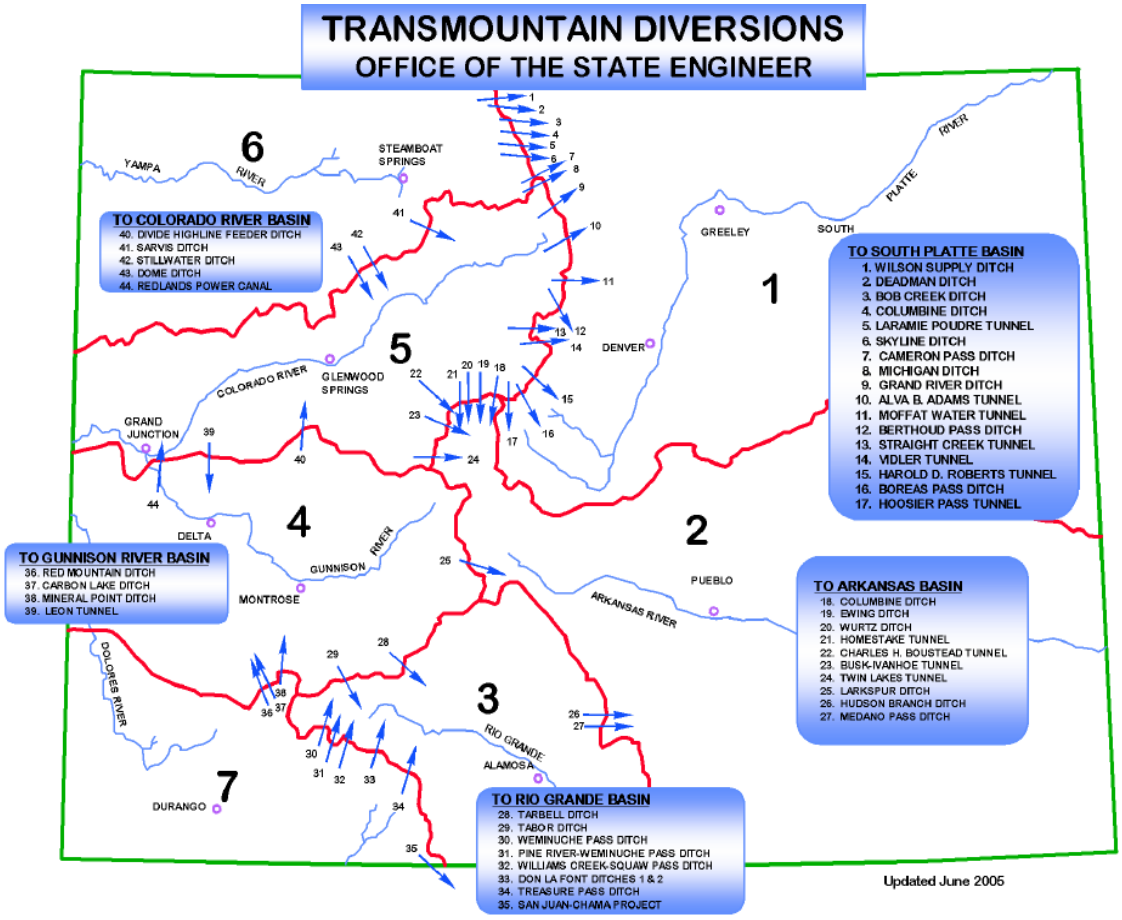


Figure 10. Trans-basin diversions occur between the boundaries of river basins. In Colorado, there are already several in place, seen here (Wolfe, 2016).

Final Thoughts

There are many complexities surrounding the issue of water use. In Colorado, the law is designed to protect water rights, and it does a fine job. However, I believe there is still room for beneficial changes that could allow for greater flexibility. For instance, the practice of water leasing could be adapted for tentative leases of conserved water at rates agreed upon by participants of a conceived program, assuming of course that the transfer will not harm another's water right or raise the threat of a compact call on the river basin. Current ATM's in Colorado now allow for a water right to be leased for three out of ten years, transferring the use right for other purposes; primarily this means transferring water out of ag for M&I uses. Traditionally, an intent to change the use of a water right requires processing through water court. This is not to say that Colorado water courts are inefficient, but these courts do see many cases in a year, and if the process could be streamlined there is no doubt that enacting the change of use on a water right would be significantly expedited.

Perhaps if more accurate recording of canal flow rates and usage statistics were available, we may be able to make the judgement calls of when and where water is transferred at the level of the regional district engineer, or if there is some question the case may be raised to the level of the State engineer for review. It is possible that with quality data and greater legal flexibility, the variety of ATM's may expand, perhaps to the extent of allowing for periods of transfer as short as a single growing season. Others involved more heavily in the legal side of water court are a bit more cynical of this possibility after participating in the process for years, to little effect. As one respondent put it, "I've stopped going to meetings run by water lawyers trying to reform Colorado water law. Been there. Done that" (Ransford, The South Platte Basin, n.d.). The individual notes that they are a citizen volunteer, who made the preceding comment based on

experiences trying to improve access to rivers in the 1996 Colorado Stream Safety Act, working closely with Senator Gail Schwartz to pass a bill in the 2012, 2013, and 2014 sessions that would permit irrigators to protect diversion savings resulting from increased irrigation efficiency as an instream flow. These legislative attempts failed, leading the individual and others to believe that the capability of ATM's to close the supply gap is quite limited. Though several participants did seem receptive to the concept and efficacy of ATM's.

Similar alternatives such as water banking are also a possibility, though previous attempts to promote them have proven difficult. Mutual ditch cooperatives may be able to fill this role, however. Through Colorado Revised Statutes Title 37 (C.R.S. § 37-92-308(4)(a)), the State engineer is granted authority to approve a plan, contract, or change on Arkansas river basin water, provided the case has been filed with a water court. Thought the permit for said plan may be extended After passing in to law, the city of Aurora used this method to arrange a two-year water leasing-fallowing arrangement with 160 farmers on the Highline Canal. Even through this expedited process it took about 18 months for the plan to be approved by the State engineer (Schempp, 2009). Similar plans have been proposed in the Arkansas River basin, such as the recently approved "Super Ditch." The Super Ditch is a conglomeration of six farms with five owners who entered in to an agreement to transfer approximately 311 shares of agricultural water, generating an estimated 470af of consumable water (based on average supply) from the Catlin Canal for use within Otero County for M&I uses (Browning, 2015). The project shows promise, but as I was told by a principal promoter of the plan, greater participation by shareholders on the canal is needed to enhance its spatial and temporal usefulness.

My brief foray in to this field left me reeling. There are many options available with potential to help meet the gap. One estimate I received calculates that the water savings potential

if Colorado's producers all switched to center-pivot sprinklers, the efficiency change alone would be enough to meet Colorado's future needs for some time to come. If presented as a State income tax, the upgrading and/or retrofitting of irrigation systems to center-pivot would cost individual taxpayers just $22 per resident per year, spread over twenty years, which could be cut in half were all the improvements augmented by federal EQIP funding through the National Resources Conservation Service (NRCS) (Ransford, Colorado's Grand Bargain, n.d.). EQIP funds have the potential to be further employed in Colorado, and likely will be in the future. Across the country EQIP funding obligations for irrigation practices reached $5.7 billion from 2004-10 (Schaible & Aillery, 2012).

Through the course of gathering interviews, I noticed several recurring themes in the responses. From these themes, I noticed several areas that I believe address the core values of efficiency, speak of the ethos of ag producers and public interests, as well as create pathways to understanding between and within these demographics. I arrived at several of these conceptual areas myself, either because I felt the concept would be efficacious, because it has previously demonstrated value, or because it was suggested by participants to positive effect.

Colorado's Water Plan expects to acquire 50,000af of new ag water resources by means of ATM's in the near future. While I cannot presume to know how best to approach this topic after just dipping my toe in over the course of this research, I tend to agree with similar research conducted that recommends greater collaboration between irrigation companies and water providers, increased communication between shareholders of ditch companies to discuss options for water use such as leasing arrangements and storage considerations, as well as education and outreach to not only ag producers, but also to the public (The Poudre Water Sharing Working Group, 2015). As more and more producers adopt conservationist techniques, I believe that fears

of implementing local projects and cooperatives will subside, promoting a model of open communication and collaboration amongst producers, as well as State and public interests. Thus, I feel that education and outreach programs should be the foundation on which future collaboration is built. Through effective cooperative leasing arrangements such as the Superditch and others, willing participants support mutually beneficial arrangements to provide water for M&I.

I feel that municipalities could also show greater interest in where water comes from and how it is used; an issue which seems to me a constant thorn in the side of conservation. However, it cannot be expected that individuals bear the brunt of the cost in the implementation of efficiency upgrades on their appliances. Some components, such as more efficient, late-model water heaters can be quite expensive. While there are programs in place to assist with low-cost upgrades, these more expensive implements should be factored into the cost of future residential expansions, and much of these expansions should occur in urban centers. Building up more than out allows for the use centralized utilities, which can be more easily managed and assure greater, and more efficient coverage.

One of the most important concepts that education and outreach can inform people of are some of the simpler low to no-risk efficiency options. This is important in not only retrofitting homes with things like high efficiency showerheads and low-flow toilets, but in creating public understanding of how ag water is used. It also serves to promote transparency between the public and the water world, which is primarily concerned with agriculture. I believe that through a reasoned, informed approach, that involves the public as well as ag in the discussion, some of the misunderstanding, or even mistrust between demographic groups may alleviated. If the public

were aware of just how precious this under-valued resource truly is, its use as a commodity would not be taken for granted, as I believe it so often is.

My final talking point relates to how future growth will be funded. Colorado's Water Plan expects to raise an additional $100 million annually to fund all the concepts it lays forth. Additional water storage to the tune of 400,000af will not be cheap in and of itself, but that is just a small portion of future expenditures. The Plan suggests the use of tax funds already in place which provide loans to innovators who wish to undertake new water projects. The Water Project Loan Program, as it is monikered, has an annual purse of approximately $50 million. The CWCB is exploring options to create a repayment guarantee fund to secure financing for multi-partner, multi-purpose water projects. As the repayment fund is paid off, the dividends could be used to green bonds. The CWCB estimates that in doing so, an initial investment of $50 million could be leveraged into half a billion dollars for regional projects (Colorado Water Conservation Board, 2015).

There is no doubt that the water and the money are there to bridge the gap (Payne, Smith, & Landry, 2014), it is simply a matter of determining the best course of action; though the term simple would certainly be an understatement. As I discovered, the multitude of factors and numerous actors involved make this a daunting task. It is my hope that continued interest in this topic will promote further exploration, ultimately leading to specific solutions to meet the water needs for all Coloradans, and the millions of Americans who depend on the "headwaters of the West."

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