

UNDERSTANDING RANCHERS' BELIEFS AND BEHAVIORS  
REGARDING DROUGHT AND NATURAL WATER  
STORAGE IN SOUTHWEST MONTANA

by

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DEDICATION

For the citizens of the Red Rock: thank you for inviting me into your homes, feeding me cups and cups of coffee, introducing me to your families and community, and most importantly, sharing your stories. You have taught me so much.

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## GLOSSARY OF ABBREVIATIONS

BLM	Bureau of Land Management
CE	Conservation Easement
CRWFS	California Roundtable on Water and Food Supply
DEQ	Department of Environmental Quality
DNRC	Department of Natural Resources and Conservation
DOC	United States Department of Commerce
DWSAC	Governor's Drought and Water Supply Advisory Committee
EbA	Ecosystem-based Approaches to Adaptation
EPA	Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
FAO	Food and Agriculture Organization of the United Nations
FRIS	Farm and Ranch Irrigation Survey
IPCC	Intergovernmental Panel on Climate Change
IRB	Institutional Review Board
IUCN	International Union for Conservation of Nature
HLPW	High-Level Panel on Water
MCO	Montana Climate Office
MFWP	Montana Department of Fish, Wildlife, and Parks
NASS	National Agricultural Statistics Service
NCEI	National Centers for Environmental Information
NDRP	National Drought Resilience Partnership
NRCS	Natural Resources Conservation Service
PDSI	Palmer Drought Severity Index
RAA	Reasoned Action Approach
SPI	Standardized Precipitation Index
TPB	Theory of Planned Behavior
TRA	Theory of Reasoned Action
UNFCCC	United Nations Framework on Climate Change Convention
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey

## ABSTRACT

Drought has the potential to impact both natural environments and human communities, with specific repercussions for agricultural communities. In the face of changes to the quality, quantity, and timing of water runoff, water storage for drought mitigation is one of the top concerns for many water managers and water users. Due to a growing recognition of negative social and environmental impacts of traditional infrastructure, such as dams, there is a need for alternative forms of water storage. The concept of nature-based solutions, specifically natural water storage systems, has gained traction as a potential strategy to slow spring runoff, store water, and raise water tables, often resulting in an increase in late season streamflows. This research examines the adoption of these new strategies, specifically flood irrigation and beaver mimicry projects in the context of a changing climate in Montana. This thesis uses the theory of planned behavior to better understand findings from twenty-two amenity and traditional ranchers in the Red Rock Watershed/Upper Beaverhead Watershed in southwestern Montana. Results show that ranchers' beliefs toward drought can impact their drought planning responses. In this watershed, it is impractical for ranchers to convert to flood irrigation due its high labor needs and low production outputs. There is potential for beaver mimicry projects to be adopted, but economic and regulatory hurdles must first be addressed. Results suggest that natural water storage practices will be more successful if organizations involved form better relationships with ranchers, remain flexible, and integrate local knowledge into decisions and policies.

## CHAPTER ONE

## INTRODUCTION

Overview of Thesis

*“As the oldtimers say, in Montana, you’re only a week away from a drought.”*

–retired rancher, Red Rock Watershed

The impacts of a changing climate call for innovative strategies to help ecosystems and human communities adapt. Many unanswered questions remain regarding the feasibility of potential adaptation strategies. One key question is the willingness and interest of water users to adopt and implement adaptation strategies. This thesis will first explore the literature on climate change, drought, adaptation, natural water storage, irrigation efficiency, theory of planned behavior, amenity migration, and rancher typology. In many sections, a global and U.S. West overview will be provided before narrowing in on the Montana context. After reviewing the relevant literature, the case study site and methods will be discussed. Results, conclusion, and discussion will then be presented.

## CHAPTER TWO

## LITERATURE REVIEW

Climate Change and Water Resources

Climate change affects the hydrologic cycle, specifically, the quantity and quality of global water resources through precipitation changes and melting snowpack and ice (Intergovernmental Panel on Climate Change [IPCC], 2014). Models indicate there will be less precipitation in the form of snow and snowpack will melt earlier in the spring season (Barnett, Adam, & Lettenmaier, 2005). The effects on water resources will not be spread evenly across the globe, and different regions will experience different issues (IPCC, 2014; Vörösmarty, Green, Salisbury, & Lammers, 2000). Hydrological models indicate that snowmelt-driven systems will experience shifts in timing for peak river flows (Adam, Hamlet, & Lettenmaier, 2009; Arnell & Gosling, 2013). A warming climate is predicted to impact areas of the world with snowmelt-driven watersheds by directly disrupting the timing of runoff and shifting runoff earlier in the season (Adam et al., 2009).

Regional Effects of Climate Change on Water Resources

A warming climate will affect water resources throughout the U.S. West, where the hydrology of many watersheds is driven by snowmelt and snowpack serves as the primary water source (Adam et al., 2009; Environmental Protection Agency [EPA], 2016; Mote, Hamlet, Clark, & Lettenmaier, 2005; Mote, Li, Lettenmaier, Xiao, & Engel, 2018).

Snowpack is stored during the winter as snow and then released as water throughout the spring and summer as it melts (EPA, 2016; Mote et al., 2018). The U.S. West will experience the consequences of temperature changes more than other regions in the country (Adam et al., 2009; Pederson et al., 2011; Pederson et al., 2013). Temperature increases will play a more significant role in influencing snowpack than precipitation in the U.S. West (Adam et al., 2009; Pederson et al., 2011; Pederson et al., 2013). Mote et al. (2018) expanded on their earlier research (Mote et al., 2005) to confirm that snowpack continues to decline across the western U.S., mainly due to increasing temperatures. The loss of snow storage is significant; since 1915 there has been an estimated 21% loss in snowpack (Mote et al., 2018). Changes already occurring across the U.S. West include less precipitation falling as snow, earlier snowmelt, and decreased duration and extent of spring snow cover (Kapnick & Hall, 2012; Mote et al., 2005; Stewart, Cayan, & Dettinger, 2005).

#### Effects on Montana's Water Resources

Montana will be affected as snowmelt and spring runoff shift earlier in the season (Whitlock, Cross, Maxwell, Silverman, & Wade, 2017). Snowmelt-driven hydrologic systems across the state will have to grapple with less water availability during late summer months (Whitlock et al., 2017). In western Montana, most annual precipitation falls as snow (Whitlock et al., 2017). Other areas in the state rely on spring and summer rain for annual precipitation (Whitlock et al., 2017). As a headwaters state, 80% of Montana's water resources come from within the state boundaries (Whitlock et al., 2017). Although climate varies throughout Montana's unique geography, from 1950-2015, the

average annual temperature has increased statewide by 1.5°C (Whitlock et al., 2017). However, annual precipitation has remained relatively stable (Whitlock et al., 2017).

Whitlock et al. (2017) state, “changes in snowpack and runoff timing will likely increase the frequency and duration of drought during late summer and early fall” (p. 123). These changes will also strain water storage and supply throughout Montana (Pederson et al., 2011; Whitlock et al., 2017). Since the 1930s, areas of Montana have experienced declines in snowpack and these declines have become more distinct since the 1980s (Whitlock et al., 2017). From 1951-2010, Montana experienced 12 fewer frost days, 11 more warm days (over 32°C), and gained 12 more growing season days (Whitlock et al., 2017). In the short term, there will be increased temperatures and a longer growing season, but continued warming will result in increased water demands from crops, heat stress on livestock, more invasive species, increased crop pests, and less late season water for irrigation (Whitlock et al., 2017).

### Drought

Drought occurs at local, regional, and global scales and is generally understood as a “temporary dry period” or a water deficit compared to normal conditions (Dai, 2011, p. 45; Sheffield & Wood, 2012). Characteristics of drought include intensity, duration, and spatial extent (Wilhite, 2000). Drought has been described as a recurring extreme climate event, a natural hazard, and a natural disaster (Cook, Seager, Cane & Stahle, 2007; Dai, 2011; IPCC, 2014; Wilhite, 2000). Drought impacts are usually more severe from consecutive rather than individual drought years (Cook et al., 2007). Cook et al. (2007)

elaborate, “one dry year may be accommodated without undue environmental and economic harm providing that it is sufficiently offset by wetter conditions the following year. What really matters is duration because recovery from the cumulative damage of consecutive drought years is more difficult” (p. 95).

Drought affects both human communities and ecosystems (Crausbay & Ramirez et al., 2017; Wilhite, 2000). Drought and climate change share the title “creeping phenomenon” (Wilhite, 2014, p. 5). The creeping phenomenon refers to the difficulty in identifying the gradual manifestation of climate change or drought (Wilhite, 2014).

Increased global drought periods will affect food production systems, migration patterns, water resource availability, and ecosystem functions (IPCC, 2014). Recent droughts around the globe illustrate its consequences on water and water-dependent resources. Australia’s “Millennium” drought lasted from 1995-2009 and pushed the government to provide over \$4 billion in aid to agricultural producers and small businesses (Iceland, 2015). Spain’s 2008 drought forced some cities to ship in water (Iceland, 2015). Many blamed a 2012 drought in India for power outages due to lack of water for hydroelectric dams, and a drought in Brazil resulted in deficient and polluted reservoirs levels (Iceland, 2015).

There is agreement that increasing temperatures will lead to more rapid, intense, and frequent droughts in the U.S. West (Dai, 2011; Strzepek, Yohe, Neumann, & Boehlert, 2010; Whitlock et al., 2017). The U.S. West has experienced more drying in recent decades (Peterson et al., 2013). Droughts across the U.S. West have resulted in various consequences such as decreased electricity generation due to low water levels at

Lake Mead and Lake Powell, and fish kills due to low streamflows in the Upper Klamath River (Strzepek et al., 2010). California's drought (2011-2016) forced restrictions on water use and left agricultural producers in the Central Valley without irrigation water in 2014 (Swain et al., 2014). Overall increased tree mortality and susceptibility to insects has increased across the region as well (Millar & Stephenson, 2015).

### Drought in Montana

Montana, along with North and South Dakota, experienced a drought in 2017. The National Centers for Environmental Information (NCEI), a branch of the National Oceanic and Atmospheric Administration, reported the drought caused \$2.6 billion in impacts to the agricultural industry across the three states (NCEI, 2018). The winter and spring months saw relatively normal precipitation levels and temperatures (Montague, 2017a-d). A Montana Department of Natural Resources and Conservation (DNRC) official stated, "last winter was a really good winter" (Creel, 2018) and another went as far as to say, "drought will not be an issue this year" (DNRC, 2017). However, by June, Governor Bullock of Montana released an executive order, declaring 20 counties and two American Indian Reservations in a drought emergency (Bullock, 2017a). Two additional executive orders, released in July and August, included 31 counties and six American Indian Reservations in a drought emergency (Bullock, 2017b, 2017c). By September, 50% of the state experienced an "extreme drought," and 25% of the state experienced an "exceptional drought" (Tinker, 2017). The level of drought varied throughout the state, with some counties only facing "moderately dry" conditions (Governor's Drought and Water Supply Advisory Committee, [DWSAC], 2017). Other counties, primarily

northeastern and eastern counties, suffered “extremely dry” and “exceptionally dry” conditions (DWSAC, 2017).

As the summer ended, the DNRC stated that parts of Montana had, despite early season fears of flooding, experienced a flash drought (DNRC, 2017; Downey, 2017). A flash drought is characterized by the rapid intensification of drought conditions (Otkin et al., 2017). Flash droughts can trigger different types of drought, such as ecological or agricultural droughts (Otkin et al., 2017). Flash droughts can be especially damaging for agricultural communities as high temperatures, aridity, robust winds, decreasing soil moisture, and low precipitation levels can combine to devastate vegetation production (Otkin et al., 2017).

#### Different Ways of Characterizing Drought

There are four main ways drought is classified: meteorological, hydrological, agricultural, or socioeconomic (Wilhite & Glantz, 1985). Meteorological drought refers to low precipitation and high evapotranspiration which results in a relative lack of water (Vose, Clark, Luce, & Patel-Weynand, 2016). Hydrological drought refers to surface and near-surface water and storage levels such as streamflows, aquifers, reservoirs, or lakes (Vose et al., 2016). Agricultural drought describes insufficient soil moisture which leads to decreased crop productivity and plant growth (Dai, 2011; Vose et al., 2016).

Socioeconomic drought can encompass characteristics of the previously mentioned droughts but refers to the “supply and demand of some economic good” (Wilhite & Glantz, 1985, p. 115). Drought can be defined by its impacts or drivers. Vose et al. (2016)

state, “meteorological and hydrologic[al] droughts relate water availability to a reference condition; agricultural and socioeconomic droughts relate to impacts” (p. 3).

### Drought Characterized by Impacts

Wilhite (2000) and Redmond (2002) see the inclusion of drought impacts as an important consideration when defining drought. Drought impacts affect different sectors of an ecosystem or human community, and impacts are often assessed economically (Vose et al., 2016; Wilhite & Glantz, 1985). These impacts are experienced by various sectors like municipalities, state governments, businesses and industries, households and individuals, and often most significantly, agricultural sectors (Wilhite & Glantz, 1985). Drought can be experienced differently by different people and can be quantified differently depending on the information used (Kohl & Knox, 2016; Redmond, 2002).

### Drought Indicators and Indices

Drought indices, which assess drought severity, exemplify the use of different types of information (Kohl & Knox, 2016; Svoboda & Fuchs, 2016). Svoboda and Fuchs (2016) provide a review of more than 20 drought indices around the world. They classify the indices by the ease of use and index category (e.g., soil moisture, meteorology, hydrology) (Svoboda & Fuchs, 2016). While indicators of drought, like precipitation, streamflow, soil moisture, evapotranspiration, reservoir levels, temperature, vegetation growth, groundwater levels, and snowpack, are universal, drought indices can produce different drought assessments (Svoboda & Fuchs, 2016). Specific indices are designed for specific regions (e.g., the China Z Index versus the Agricultural Reference Index for

Drought used in the southwestern U.S.) or specific information needs (e.g., the Crop Moisture Index versus the Reclamation Drought Index) (Svoboda & Fuchs, 2016). Issues can arise from which indicators an index uses to determine drought (Kohl & Knox, 2016; Svoboda & Fuchs, 2016). Kohl and Knox (2016) looked at the use of the Palmer Drought Severity Index (PDSI) and the Standardized Precipitation Index (SPI) by a county government and state government in Georgia. The PDSI uses monthly precipitation, temperature data, and locally available water content, while the SPI uses historical precipitation records (Svoboda & Fuchs, 2016). The indices provided different drought quantifications for the same area, which resulted in the county and state government implementing different drought policies (Kohl & Knox, 2016). Drought indices are useful and necessary but should not be used to explain all drought broadly (Lloyd-Hughes, 2014).

Mawdsley, Petts, and Walker (1994) give clarity to the different ways different populations define drought: scientists assess drought using indicators that only consider hydrologic or meteorological conditions, water supply administrators consider water supply levels or evaporation in infrastructure like reservoirs, and individuals affected by drought evaluate drought's economic and social impacts to themselves. Redmond (2002) concurs that people have different meanings and different experiences of drought. Furthermore, Wilhite (2000) emphasizes that a universal definition of drought is impractical, as drought varies by region, population, and disciplinary characterization.

### Emerging Drought Frameworks: Drivers and Impacts

Redmond (2002) defines drought as water demand surpassing water supply, where supply refers to the physical system and demand involves physical and human systems. Two emerging drought frameworks include humans as drivers of drought (Crausbay & Ramirez et al., 2017; Van Loon et al., 2016). Van Loon et al. (2016) suggest that drought definitions should include human-induced water shortages. Humans do not passively experience drought but respond to water shortages and cause water shortages (Van Loon et al., 2016). Their drought definition differentiates between “climate-induced drought, human-induced drought, and human-modified drought” (Van Loon et al., 2016, p. 90). This framework evaluates water availability and human water use as interconnected processes (Van Loon et al., 2016).

Crausbay and Ramirez et al. (2017) offer an ecological drought framework to view the human and natural environment together, where nature and people act as drivers of drought and can experience drought impacts (Figure 1). They define ecological drought as “an episodic deficit in water availability that drives ecosystems beyond thresholds of vulnerability, impacts ecosystem services, and triggers feedbacks in natural and/or human systems” (Crausbay & Ramirez et al., 2017, p. 2544). The framework aims to integrate human and natural systems, where the values of each are recognized, and solutions are mutually beneficial, discarding previous drought definitions that followed the “nature versus people misperception” (Crausbay & Ramirez et al., 2017, p. 2547).

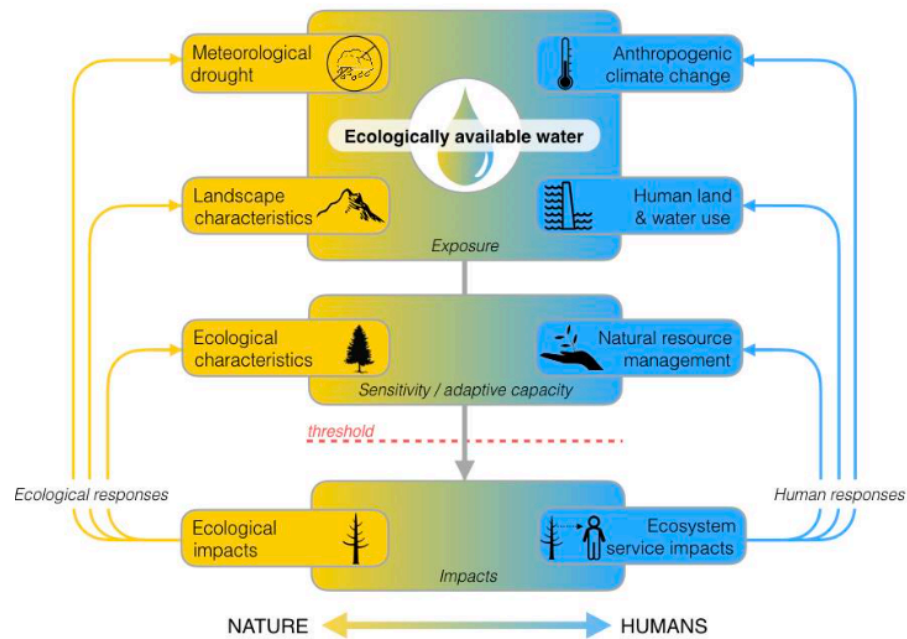


Figure 1. Conceptual Diagram of Ecological Drought. Source: Crausbay and Ramirez et al., 2017, p. 2544.

Since various types of drought (e.g., hydrological and agricultural) can occur at the same time or shift from one drought type to another, the ecological framework can be useful for drought assessment and drought planning since it encompasses factors of different types of drought (Crausbay & Ramirez et al., 2017; Otkin et al., 2017).

### Drought Planning in the U.S.

Drought planning in the U.S. is not as established as other natural hazards planning (McEvoy et al., 2018). The lag in drought planning can be attributed to how drought acts compared to other natural hazards (Wilhite, Hayes, & Knutson, 2005). Drought impacts are nonstructural, cover large geographic areas, and can be less overt on the landscape (Wilhite et al., 2005). Historically, drought plans were largely reactive plans or crisis management approaches, concentrating only on the impacts of drought

(Wilhite, 2014). Wilhite (2014) developed the concept of proactive drought planning in the early 1970s. Proactive drought planning or drought risk management “is focused on identifying where vulnerabilities exist and addresses these risks through systematically implementing mitigation and adaptation measures that will lessen the risk associated with future drought events” (Wilhite, 2014, p. 5).

Wilhite et al. (2005) developed a ten-step drought planning approach applicable at local and state levels as well as in other countries. The approach focuses on early drought warnings, evaluating impacts and vulnerability, and developing mitigation and response tools (McEvoy et al., 2018; Wilhite et al., 2005). Since the onset of a drought can be difficult to pinpoint, drought risk information in earlier stages can help decision makers apply site-specific programs and policies (Wilhite et al., 2005). The uniqueness of each drought requires an understanding of which populations or ecosystems are most vulnerable (Wilhite et al., 2005). Finally, this approach utilizes mitigation and response strategies (Wilhite et al., 2005). Mitigation strategies are implemented before a drought occurs to reduce future impacts, and response strategies are reactive strategies implemented during or after a drought (McEvoy et al., 2018; Wilhite et al., 2005).

### Drought Planning in Montana

Drought planning in Montana occurs at the state and watershed level. The Governor’s Drought and Water Supply Advisory Committee (DWSAC) was established in 1991 through Montana Code Annotated 2-15-3308 after several droughts in the 1980s (Missouri Headwaters Basin, 2015). The DWSAC assess water conditions throughout the year to inform drought responses and provide information to officials (Missouri

Headwaters Basin, 2015). The State of Montana published its first drought response plan in 1985 and published its current plan in 1995 (Montana Drought Response Plan, 1995). While the 1995 plan aims to take a proactive approach, it has been criticized for containing mostly reactive responses (Kuglin, 2016; Montana Drought Response Plan, 1995).

The DWSAC is developing a new State Drought and Management Plan, which should be released by 2019 (DNRC, 2016). The new plan aims to better define drought in Montana and emphasizes mitigation strategies (DNRC, 2016; Kuglin, 2016). The DNRC released the Montana Drought Impact Reporter in 2017 (Downey, 2017). This online tool enables citizens to report drought conditions in their area through a questionnaire (Downey, 2017). Questionnaire data is uploaded automatically and displayed in an interactive map (Downey, 2017).

The Montana Climate Office (MCO) provides climate information for the state which includes a drought severity index and precipitation measures (Missouri Headwaters Basin, 2015). The MCO also facilitates The Montana Drought and Climate Project with the University of Montana (MCO, 2018). The project aims to develop new climate information from existing drought forecasts and water availability projections to better assist agricultural producers' decisions (MCO, 2018). One way the project will provide tools to producers is through seasonal newsletters (MCO, 2018). In Montana, state drought planning often coincides with watershed drought planning.

### Watershed Drought Planning in Montana

The National Drought Resilience Partnership (NDRP) was established in 2013 as an effort for more collaboration between federal, state, and local levels (Figure 2) (NDRP, 2016). The Missouri Headwaters Basin in southwest Montana is part of a pilot project with the NDRP and the State of Montana (Montana Drought Demonstration Partners, 2015).



Figure 2. National Drought Resilience Partnership Partners. Source: Schwend, 2016.

The NDRP is “a collaborative of federal and state agencies, non-governmental organizations (NGOs), and watershed stakeholders working together to leverage and deliver technical, human and financial resources to help address drought in the arid West” (Montana Drought Demonstration Partners, 2015, p. 2). The NDRP project aims to provide drought mitigation tools and resources for watersheds, increase local and regional capacity for drought, and implement local drought resilience projects (Montana Drought

Demonstration Partners, 2015). Many watersheds in the Upper Missouri River Basin have drought plans. A recent study by McEvoy et al. (2018) examined if and how these plans assessed ecological drought. They found that the drought plans primarily focus on drought impacts to fisheries (McEvoy et al., 2018). Drought plans from the Jefferson, Big Hole, and Beaverhead basins mainly focused on indicators like streamflows and water temperature to trigger drought mitigation actions or responses (McEvoy et al., 2018). The Beaverhead Plan is a newer plan and was developed as part of the NDRP; it includes additional indicators like U.S. Drought Monitor data and reservoir storage levels (McEvoy et al., 2018).

### Drought Responses

Most drought actions, internationally and within the U.S., are reactive, in the form of emergency response and relief programs (Wilhite, 2014). In the U.S., there are numerous federal drought responses available for agricultural producers (USDA, 2018). The Farm Service Agency provides emergency loans for producers who suffer losses related to crop production or crop quality (USDA, 2018). The Livestock Indemnity Program provides compensation to livestock producers who suffer livestock deaths from natural disasters (USDA, 2018). Additionally, the Livestock Forage Disaster Program provides reimbursement to producers who experience grazing losses on pasture or native land that affect livestock (USDA, 2018).

Drought responses at the agricultural producer level are similar to federal responses in that they typically react to current drought and often do not utilize proactive drought actions (Coppock, 2011; Knutson & Haigh, 2013; Wilmer, York, Kelley, &

Brunson, 2016). Some agricultural producers do not see the need to make drought plans because they do not see drought as a specific circumstance that requires a specific strategy (Wilmer et al., 2016). These agricultural producers either view drought as too severe to plan for and prefer to deal with as it occurs, or see drought as one of many challenges they encounter (Wilmer et al., 2016).

Ranchers, a subset of agricultural producers, have heterogeneous drought beliefs (Wilmer et al., 2016). At the same time, ranchers often use similar indicators to assess if they are in a drought (Coppock, 2011; Svoboda & Fuchs, 2016). These indicators include snowpack levels, low rainfall, and low vegetation growth (Svoboda & Fuchs, 2016). Disagreements exist over whether ranchers can plan for drought, if drought is just another situation to deal with, or if drought is cyclical or due to climate change (Knapp & Fernandez-Gimenez, 2009; Wilmer et al., 2016).

Common reactive drought responses for ranchers include de-stocking, buying feed, receiving federal disaster aid, weaning calves early, selling cattle early, renting pasture, moving livestock to feedlots, diversifying ranch operations, and making off-ranch income (Coppock, 2011; Roche, 2016; Wilmer et al., 2016). Proactive drought responses include storing feed, grass banking, conservative stocking rates, resting pastures, and changing livestock types (Coppock, 2011; Dunn, Smart, & Gates, 2005; Roche, 2016). Regulatory procedures can delay ranchers' drought responses (Dunn et al., 2005). Ranchers' drought responses, whether proactive or reactive, typically center around the ranch operation and often miss an opportunity to reduce drought risk by changing water use during drought (Coppock, 2011; Dunn et al., 2005; Wilmer et al.,

2016). A more in-depth exploration of agricultural water use, specifically irrigation use, can provide insight into water management practices and their connection to drought.

### Irrigation, Efficiency, and Jevons' Paradox

#### Flood Irrigation versus Sprinkler Irrigation

Before reviewing the history of irrigation, it is important to understand the basic characteristics of irrigation systems. The recent conversion in the last 50 or more years from flood irrigation to sprinkler irrigation was done to reduce water consumption and increase efficiency. Consumption can be defined as the amount of water that is consumed or used by plants or crops and transpires so it will not enter the system as a liquid return flow and evaporates into the air (Perry, Steduto, & Karajeh, 2017). Non-consumptive water use is the portion of water that remains liquid and flows to a stream or aquifer with the potential for re-use (Perry et al., 2017). Roberts (2018) defines consumptive use as water used by the crop through evapotranspiration. Burt et al. (1997) define irrigation efficiency as a proportion of water beneficially used by a crop over the consumptive use. Similarly, Roberts (2018) defines irrigation system efficiency as the proportion of water consumed by the crop over the diverted amount.

Flood irrigation is a gravity fed system; water travels to fields in pipes or canals and saturates the soil profile (United States Geological Survey [USGS], 2016a). Flood irrigation is 20-60% efficient (Roberts, 2018; Scanlon, Jolly, Sophocleous, & Zhang, 2007). Sprinkler irrigation is 60-85% efficient and only percolates through a few inches of subsoil (Irmak, Odhiambo, Kranz, & Eisenhauer, 2011; Roberts, 2018). A sprinkler

irrigation system applies water to crops through nozzles, where water is transported by pipes (Ross & Hardy, 1997). Sprinkler systems types include hand moves, wheel moves, and center pivots (Ross & Hardy, 1997; Stubbs, 2016). A hand move system consists of pipes, sprinklers, and risers. The lateral pipes convey water to the vertical risers and sprinklers (Ross & Hardy, 1997). A wheel move system consists of lateral pipes, wheels, and sprinklers (Hill, 2000). The lateral pipes convey water to the attached sprinklers and serve as the axles for the wheels (Hill, 2000). A center pivot system consists of a lateral pipe with sprinklers rotating around a fixed pivot point, usually irrigating a circular field unless attachments are added to the system (Ross & Hardy, 1997).

Sprinkler irrigation increases water efficiency by diverting less water from streams and evenly spreading water on fields, resulting in increased crop production and increased yields (Kendy & Bredehoeft, 2006; Peterson & Ding, 2005). The increase in consumption associated with sprinkler irrigation originates from uniformly irrigated crops consuming more water, expanded land production (land not previously irrigated), evenly distributed water, and changes in crop types (Batchelor et al., 2014; Grafton et al., 2018; Perry et al., 2017; Peterson & Ding, 2005; Roberts, 2018; Scott, Vicuña, Blanco-Gutiérrez, Meza, & Varela-Ortega, 2014). The increased efficiency of irrigation systems, such as sprinkler, can provide fewer return flows, less aquifer recharge, lower water table levels, and can impact downstream users (Essaid & Caldwell, 2017; Kendy & Bredehoeft, 2006; Ward & Pulido-Velazquez, 2008).

### Irrigation and (Re)settlement of the U.S. West

*“The East is a green America, but the American West was a brown land.”*

–Donald Worster, 2003

While recognizing that the area that is now considered the U.S. West has a long history of settlement and occupation predating white settlers, this thesis focuses on the irrigation practices of European settlers. It is helpful to understand the footprint irrigation has had in the U.S. West and how it has evolved. In 1876, John Wesley Powell published “A Report on the Lands of the Arid Region of the United States” (Reisner, 1986). The report criticized the Homestead Act, claiming that much of the United States, especially the lands west of the 100<sup>th</sup> meridian, were not suitable for farming without the development of irrigation (Reisner, 1986). The Homestead Act of 1862 was an initiative to settle land in the western U.S. (Reisner, 1986). It offered 160 acres of land with only a few stipulations: a small registration fee, a requirement to live on the land, build a home, improve the land, and farm on it for five years (Reisner, 1986).

The Homestead Act was drafted with the eastern portion of the United States in mind where rainfall was more abundant (Reisner, 1986). People were encouraged to pack up and move west, many convinced by the “Rain Follows the Plow” theory (Reisner, 1986, p. 35). The theory stated that settlement changed the climate; as people moved west, more rain would follow (deBuys, 2004; Reisner, 1986). With the promise of inexpensive land, many families uprooted their lives and moved west, only to be greeted by less than favorable conditions including high altitudes, persistent winds, poor soils,

unpredictable temperatures, and inconsistent water availability (de Buys, 2004; Reisner, 1986).

After his expedition across the U.S. West, Powell presented his document to Congress in hopes of altering the continued settlement of the region (Reisner, 1986). He maintained that in the U.S. West 160 acres of unirrigated land was too little and 160 acres of irrigated land was too much (Reisner, 1986). He proposed to group farms together and to treat lands as commons (Reisner, 1986). Additionally, Powell suggested the formation of new communities around watershed boundaries (Reisner, 1986). Unfortunately, Congress did not welcome Powell's report (Reisner, 1986; Stegner, 1953). During this time, politicians representing western states wanted to encourage further settlement (Stegner, 1953). They did not want a report showing their states as arid and unable to be farmed without large, expensive irrigation projects (Stegner, 1953). Powell's report was largely ignored (Reisner, 1986). Powell had predicted cycles of drought and the need for federal irrigation projects, both of which are persistent characterizations of the U.S. West today (Reisner, 1986).

The Homestead Act and later the Desert Land Act, encouraged development and settlement of states that were not optimal for farming or ranching (Reisner, 1986). The Desert Land Act of 1877 promoted development of arid and semiarid lands in the U.S. West (Reisner, 1986). In some cases, people would simply pour a bucket of water on the land, pay a witness to say the land was irrigated at a land office, and repeat these steps until they had amassed enough land for a ranch (Reisner, 1986). Despite Montana's aridity, white settlers flocked to this region to homestead and grow crops.

### Irrigation in Montana

In 1842, Jesuit missionaries in Ravalli County, Montana were the first white settlers to use irrigation systems to grow crops (Buck, 1958; Zeisler, 1982). Major John Owen later bought the property and established the earliest water right in the state with a priority date of 1852 (PBS&J, 2009). Not long after, in 1858, the first water rights filings were made in Beaverhead County (DNRC, 2018). The Mammoth Ditch, first used in 1866, is one of the oldest irrigation ditches in the Gallatin Valley (Buck, 1953). The 1953 Water Resources Survey of Gallatin Valley called for the conversion of flood irrigation to sprinkler irrigation (Buck, 1953). Sprinkler irrigation arrived in Montana in the form of hand moves in the early 1940s and wheel moves in the early 1950s (Howard, 1992). Center pivot systems began to appear as early as the 1960s, but it was not until the mid-1990s that the federal government offered subsidies for these systems (Howard, 1992; Stubbs, 2010).

Irrigation Systems and Water Use The National Agricultural Statistics Service (NASS), part of the United States Department of Agriculture (USDA) produces an agriculture census every five years and the Farm and Ranch Irrigation Survey (FRIS). According to the 2013 FRIS, 9,451 farms in Montana irrigated 1,872,268 acres (USDA-NASS, 2014). This does not represent a significant change in irrigated acres in Montana from the 1997 report (USDA-NASS, 2014). In 2013, of the 1,872,268 irrigated acres, 1,144,584 acres were gravity (including flood and furrow) irrigated and 849,332 acres were sprinkler irrigated (USDA-NASS, 2014). Of the 849,332 acres irrigated by sprinkler systems, the most prevalent system was center pivot, which irrigated 595,590 acres

compared to 227,397 acres irrigated by tower sprinklers, permanent sprinklers, wheel moves, and hand move systems combined (Table 1) (USDA-NASS, 2014).

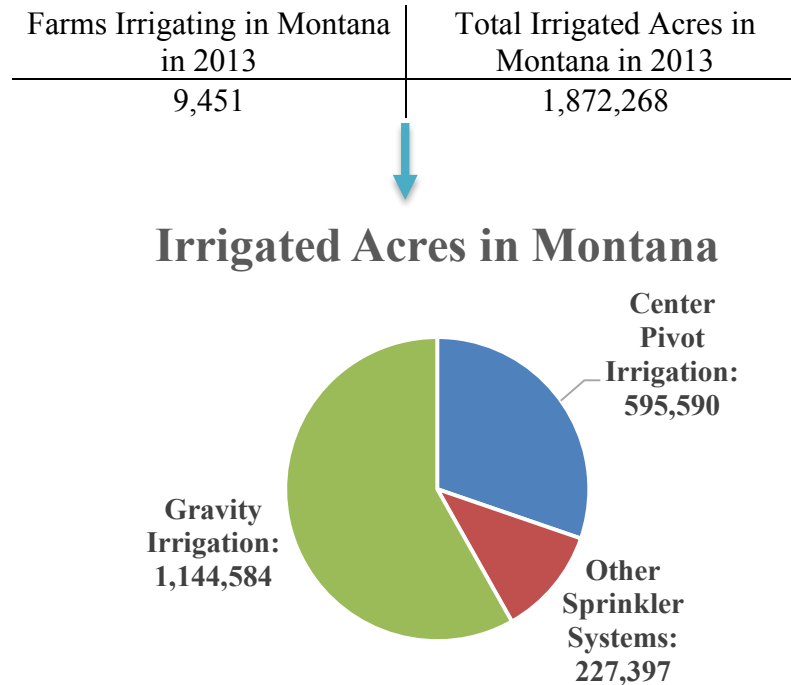


Table 1. Irrigation Systems and Irrigated Acres in Montana in 2013. Data source: United States Department of Agriculture-National Agricultural Statistics Service, 2014.

However, USGS data estimates for 2015 were closer to 2.5 million acres irrigated in Montana, with 9,610 Mgal/d (millions of gallons of water per day) withdrawn from surface water and 205 Mgal/d from groundwater (Dieter et al., 2018). In 2015, irrigation used 9,450 Mgal/d or 98% of water withdrawn in Montana, with 99% of that being surface water withdrawals (Dieter et al., 2018). Currently, in the United States, sprinkler systems represent 58-65% of the irrigation systems while flood irrigation represents 35-42% of irrigation systems (Stubbs, 2016). Agriculture accounts for 80-90% of consumptive water use across western states (USDA-Economic Research Service, 2018).

Changes in irrigation systems have been most evident in the U.S. West, where gravity irrigated acres have decreased 32% from 1984-2013 (Stubbs, 2016; USDA-NASS, 2014). Stubbs (2016) reported that “irrigated land in the West increased by 1.7 million acres during this same time period, while applied irrigation water declined by over 1.37 million acre-feet” (p. 5; see also USDA-NASS, 2014). The Farm Bill program (which includes the Environmental Quality Incentives Program and additional programs) provided \$336 million for sprinkler irrigation from 2009-2014 throughout the U.S. (Stubbs, 2016). From 1995-2017, the State of Montana received \$133 million in Environmental Quality Incentives Program payments, which included \$7 million for groundwater and surface water improvements (Environmental Working Group, 2018).

#### The Environmental Quality Incentives Program

The 1996 Farm Bill established the Environmental Quality Incentives Program (EQIP) (Althoff, 2018; Stubbs, 2010). EQIP is a voluntary program that provides financial assistance to agricultural producers to implement soil and water conservation practices, including more efficient irrigation systems (Althoff, 2018; Stubbs, 2010). The Natural Resources Conservation Service (NRCS) in the U.S. West encourages agricultural producers to utilize EQIP to convert their flood irrigation systems to sprinkler systems (Althoff, 2018; NRCS, 2017). The transition to more efficient irrigation systems is not unique to the U.S. West and has been occurring across the globe.

### Irrigation Efficiency Across the Globe

There has been a continued interest in the relationship between efficiency and natural resource use (Alcott, 2005; York & McGee, 2016). Some people advocate for efficiency policies while others find these policies “simply counter-productive” (Alcott, 2005, p. 19; York & McGee, 2016). In 1865, William Jevons discovered that as coal-powered steam engines became more efficient, the consumption of coal increased (York & McGee, 2016). This discovery contradicted the assumption that as a technology was made more efficient, consumption would decrease (York & McGee, 2016). This phenomenon is known as Jevons’ paradox and is a useful concept when assessing irrigation efficiency (Grafton et al., 2018; Ward & Pulido-Velazquez, 2008; York & McGee, 2016). Recent research highlights the global questions surrounding the consequences of converting to more efficient irrigation systems (Grafton et al., 2018; Perry et al., 2017; Pfeiffer & Lin, 2014; Scott et al., 2014; Ward & Pulido-Velazquez, 2008). The goal of improving the management of a scarce resource is important, especially with regards to agricultural water use as agricultural irrigation accounts for 90% of consumptive water use across the world (Wada, van Beek, & Bierkens, 2012). However, attention must be given to the unintended consequences of technological change.

A 2017 report by the Food and Agriculture Organization of the United Nations (FAO) examined case studies from 14 countries and found that “hi-tech” irrigation systems increased acreage and increased water consumption (Perry et al., 2017, p. 2). Grafton et al. (2018) state that increased irrigation efficiency at the farm scale does not

reduce consumption at the watershed scale (Grafton et al., 2018). Grafton et al. (2018) highlight the gaps in regulatory knowledge, even at the highest levels of government. They point to a 2018 United Nations High-Level Panel on Water (HLPW) that advocates to “create incentives for water users, including irrigators, to use water more efficiently” (Grafton et al., 2018; United Nations HLPW, 2018, p. 24). Berbel and Mateos (2014) developed a model to evaluate the conversion to more efficient irrigation in Spain. They concluded that converting to a more efficient system does reduce water use unless more land is then put into production (Berbel & Mateos, 2014). If the potential exists to expand acreage with more efficient systems, then water consumption will increase (Berbel & Mateos, 2014).

Scott et al. (2014) looked at three case studies with similar climate and water resource availability: central Chile, southwestern U.S., and southern Spain. The implementation of more efficient irrigation systems resulted in increased irrigated acres and increased water use, which then resulted in increased production (Scott et al., 2014). At the same time, they found that “water ‘loss’ upstream serves as supply downstream particularly for ecosystems...[and] may also apply to downstream irrigators” (Scott et al., 2014, p. 1346). Ward and Pulido-Velazquez (2008) concluded that Rio Grande Basin irrigation efficiency subsidy programs could hurt water supply as these new irrigation systems result in less water available for downstream or future uses. They state, “although water applied to irrigated lands may fall, overall water depletions increase” (Ward & Pulido-Velazquez, 2008, p. 18219). The potential of increased water

consumption from more efficient irrigation systems calls for a reexamination of less efficient irrigation systems.

### Benefits of Flood Irrigation

This section will provide a more detailed look at the benefits of flood irrigation. Flood irrigation provides incidental recharge to aquifers and groundwater sources (Baker, Everett, Liegel, & Van Kirk, 2014; LaFave, 2010; LaFave & Abdo, 2015). Scanlon et al. (2012) found that flood irrigation from surface water sources causes a net increase in recharge. However, if the irrigation source is groundwater, there is groundwater depletion since that water is only being recycled (Scanlon et al., 2012). Flood irrigation can increase groundwater levels, raise water tables, and increase groundwater returns to streams (Kendy & Bredehoeft, 2006; Scanlon et al., 2007). The conversion of flood irrigation to a more efficient system results in less water available to streams (Batchelor et al., 2014; Helmus et al., 2009; Kendy & Bredehoeft, 2006; Ward, Michelson, & DeMouche, 2007). This can impact downstream agricultural users and aquatic ecosystems (Batchelor et al., 2014; Helmus et al., 2009; Kendy & Bredehoeft, 2006).

Flood irrigation provides groundwater recharge which can lead to cooler downstream temperatures; these cooler temperatures can improve fish habitat (Essaid & Caldwell, 2017). The water lost in transit in ditches or canals increases groundwater levels (Baker et al., 2014; Helmus et al., 2009). Flood irrigation can also supplement streamflows later in the season (Helmus et al., 2009). There are some exceptions where irrigation water moves beyond the root zone and goes into an irrecoverable sink that does not go into groundwater or an aquifer (Batchelor et al., 2014; Linstead, 2018). In this

case, more efficient irrigation systems would make better use of the water available (Batchelor et al., 2014; Linstead, 2018). Irrigation recharge back into the soil provides moisture necessary to grow crops and is a common form of human-caused recharge to groundwater (Lund, Munévar, Taghavi, Hall, & Saracino, 2014). In some areas such as California, soil moisture is seen as a form of “seasonal water storage” (Lund et al., 2014, p. 11).

A 1996 National Research Council report highlighted the difficulties faced by the irrigation community such as its vulnerability to changes in water availability and its reliance in some areas on nonrenewable water supplies (National Research Council, 1996). The issue of vulnerability facing irrigation and agricultural communities extends to other communities, as does the need to build adaptive capacity and promote adaptation strategies.

### Adaptation to Climate Change

Mitigation, which aims to reduce greenhouse gas emissions, had been the prominent international strategy for combating climate change (Biesbroek et al., 2010; Füssel, 2007). The realization that mitigation alone may not be enough to fight climate change has opened the door for other approaches, one of those being adaptation (Biesbroek et al., 2010; Schipper, 2006). Füssel (2007) defines adaptation as moderating “the adverse effects of climate change through a wide range of actions that are targeted at the vulnerable system or population” (p. 162).

While this thesis is more concerned with adaptive capacity and adaptation, the concept of vulnerability is important to keep in mind when assessing populations, whether they are human or ecosystems. Vulnerability “does not fall from the sky,” rather, it is produced by power dynamics on-the-ground and disproportionately affects those who lack access to resources (Ribot, 2010, p. 49). A common framework conceptualizes vulnerability as comprised of sensitivity, exposure, and adaptive capacity (Adger, 2006). Adger (2006) defines adaptive capacity as “the ability of a system to evolve in order to accommodate environmental hazards or policy change and to expand the range of variability with which it can cope” (p. 270). Communities must increase their adaptive capacity to better prepare for the changing effects of climate, like drought or water availability. The development and implementation of adaptation strategies can increase adaptive capacity.

Internationally, adaptation strategies have become part of climate change planning and policy as seen in the Paris Climate Agreement, National Adaptation Plans for countries under the U.N. Framework on Climate Change Convention (UNFCCC), and the IPCC 2014 synthesis report (IPCC, 2014; McGray, 2014; UNFCCC, 2018). Adaptation strategies can broadly include increased education, early warning systems, ecosystem restoration, adequate housing, urban planning, increased social network capacity, reforestation, livelihood diversification, food banks, vaccination programs, new crop varieties, integrated water resource management, economic diversification, technology development, community-based adaptation, and financial incentives (IPCC, 2014). The development of adaptation strategies in the water sector should consider that as the

climate changes, traditional water management plans are likely inadequate given that they rely on models where future conditions remain predictable (Milly et al., 2008). Resource management strategies must present various options for possible future conditions while also adjusting recommendations in response to variability (Grimm et al., 2013).

### Natural Infrastructure or Nature-Based Solutions for Climate Change

One approach to adaptation is the concept of natural infrastructure or nature-based solutions. Natural infrastructure provides benefits that traditional resource management does not (Gartner et al., 2013). The benefits of natural infrastructure include cost-effectiveness, co-benefits, flexibility, and most importantly, helping meet adaptation goals (European Commission, 2015; Gartner et al., 2013).

Natural infrastructure is a network of lands, working landscapes, and other open spaces used strategically in order to benefit from the ecosystem functions associated with that land (Gartner et al., 2013). The International Union for Conservation of Nature (IUCN) defines nature-based solutions as actions that benefit human and natural systems and address societal challenges by providing adaptive strategies of protection, management, and restoration of natural or modified ecosystems (Cohen-Shacham, Walters, Janzen, & Maginnis, 2016). The European Commission (2015) states that nature-based solutions are “inspired by, supported by, or copied from nature” to address societal challenges with benefits for economic, social, and environmental sectors (p. 5).

The term nature-based solution is often used interchangeably with ecosystem-based approaches to adaptation (EbA). EbA focus on reducing climate change impacts by incorporating both hard and soft infrastructure into management, conservation, or

restoration plans (Jones, Hole, & Zavaleta, 2012). Jones et al. (2012) categorize soft approaches as ones that use information, policy, capacity building, and institutional functions to help change behavior. They categorize hard approaches as engineered or infrastructure solutions or other technologies using capital goods (Jones et al., 2012). The term hard approach is synonymous with hard/grey infrastructure, which also refers to human-engineered solutions that involve concrete or steel (Pontee et al., 2016).

Nature-based solutions or EbA fall in the same realm as natural infrastructure. There are varying distinctions of what makes a solution a “nature-based solution,” including the extent of its natural features or what type of approach it employs (e.g., ecological restoration, ecological engineering, forest landscape restoration), but these distinctions are outside the scope of this thesis (Cohen-Shacham et al., 2016; Pontee et al., 2016). Examples of nature-based solutions include mangrove conservation to protect coastlines and provide incomes, riverbank and floodplain restoration to assist with ecological function and flood control, forest restoration for sustainable livelihoods, and wetland and barrier island restoration for storm protection (Cohen-Shacham et al., 2016).

Natural infrastructure also answers Gleick’s call to abandon the state hydraulic paradigm which revolved around the federal creation and maintenance of infrastructure such as reservoirs and dams (Gleick, 2000). The new water paradigm calls for “maintaining ecological health and environmental well-being” (Gleick, 2000, p. 131).

#### Natural Water Storage as a Nature-Based Solution to Climate Change

A specific type of nature-based solution that has been proposed to address drought, especially in the U.S. West, is natural water storage. Reservoir evaporation

remains a concern for western states as scientists and government agencies investigate new solutions to more accurately quantify evaporative losses as most estimates are based on outdated methods (Friedrich et al., 2018; Spears, 2015). Friedrich et al. (2018) emphasize that there are considerable evaporative losses from reservoirs, which can contribute to further stress in a water scarce region. For example, Montana uses 84,000,000 acre-feet of water each year (DNRC, 2015). Water evaporation from reservoirs in the state is 1,002,000 acre-feet each year, which is significant when compared to the 2,414,000 acre-feet used for agricultural irrigation annually (Figure 3) (DNRC, 2015). While reservoirs can mitigate some effects of drought, there is no reservoir system equipped to handle a severe and prolonged drought in Montana (DNRC, 2015).

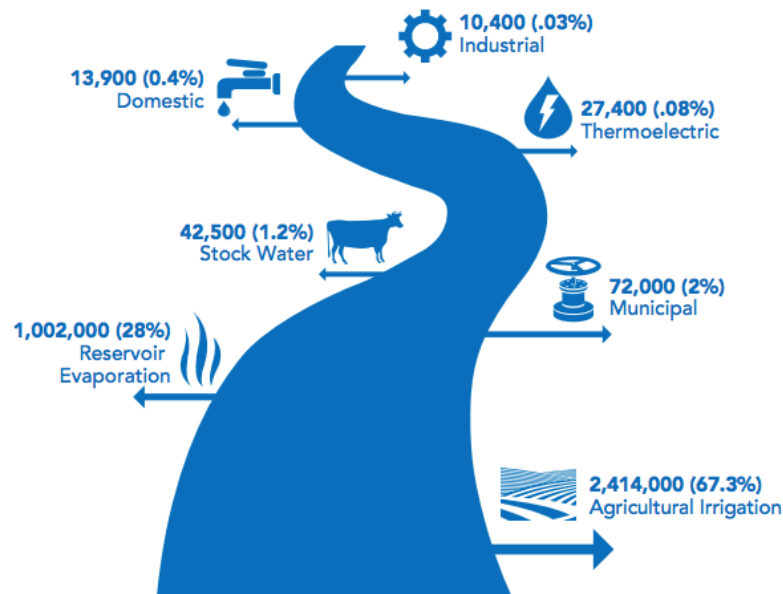


Figure 3. Water Consumption in Montana by Purpose in Annual Acre-Feet. Source: Department of Natural Resources and Conservation: Montana State Water Plan, 2015, p. 35.

The California Roundtable on Water and Food Supply (CRWFS) recommends a broader view of what is considered water storage. CRWFS (2012) suggests “a comprehensive approach to holding back as much water as possible in the landscape for later use while maintaining healthy ecosystems” (p. 2). The recommended approach is best achieved by natural ecosystems (CRWFS, 2012). Natural ecosystems such as riparian areas, wetlands, and floodplains can retain high spring flows and slowly return groundwater back to the system (DNRC, 2015). Groundwater is responsible for the base flows in rivers and streams, which is especially important during drought years (DNRC, 2015). These natural ecosystems can be used to raise the water table in incised streams and provide an alternate water storage method (Hafen & Macfarlane, 2016; Holmes, McEvoy, Dixon, & Payne, 2017; Pollock et al., 2014). Natural water storage can be enhanced by restoring eroded streambanks and incised stream channels, planting riparian vegetation, restoring wetlands, and improving soil health (CRWFS, 2012; Lund, 2014). The two natural water storage practices that will be discussed are beaver mimicry projects and flood irrigation.

Beavers and Beaver Mimicry as Natural Water Storage The ecological services beavers provide on the landscape have been well documented. Pollock, Lewallen, Woodruff, Jordan, and Castro (2015) state “beavers have the ability to improve the water quality of streams by reducing suspended sediments in the water column, moderating stream temperatures, improving nutrient cycling, and removing and storing contaminants” (p. 7). The ponds created by beavers are deeper than the rest of the stream channel (Pollock et al., 2015). Deeper ponds help reduce the flow velocity and spread out

the water's energy, which deposits sediment and elevates the streambed (Figure 4) (Pollock et al., 2015). Beaver pools can increase water quality by filtering out nutrients and toxins, and can trap woody debris used for fish habitat (Pollock et al., 2015). Beaver dams help create riparian and wetland habitat (Pollock et al., 2015). Riparian vegetation lowers water temperatures, which can be important for fish (Pollock et al., 2015).

Beavers provide important hydrologic changes to a stream that prove increasingly significant for drought mitigation. Beavers can convert some intermittent streams back into perennial streams and help some losing streams transform into gaining streams (Majerova, Neilson, Schmadel, Wheaton, & Snow, 2015; Pollock, Heim, & Werner, 2003). Increased groundwater storage and aquifer recharge are the most important benefits beaver projects offer to mitigate the impacts of climate change (Pollock et al., 2003; Pollock et al., 2015; Westbrook, Cooper, & Baker, 2006). Groundwater is released slowly compared to surface water, and groundwater does not suffer evaporative losses like streams, lakes, or reservoirs (Pollock et al., 2015).

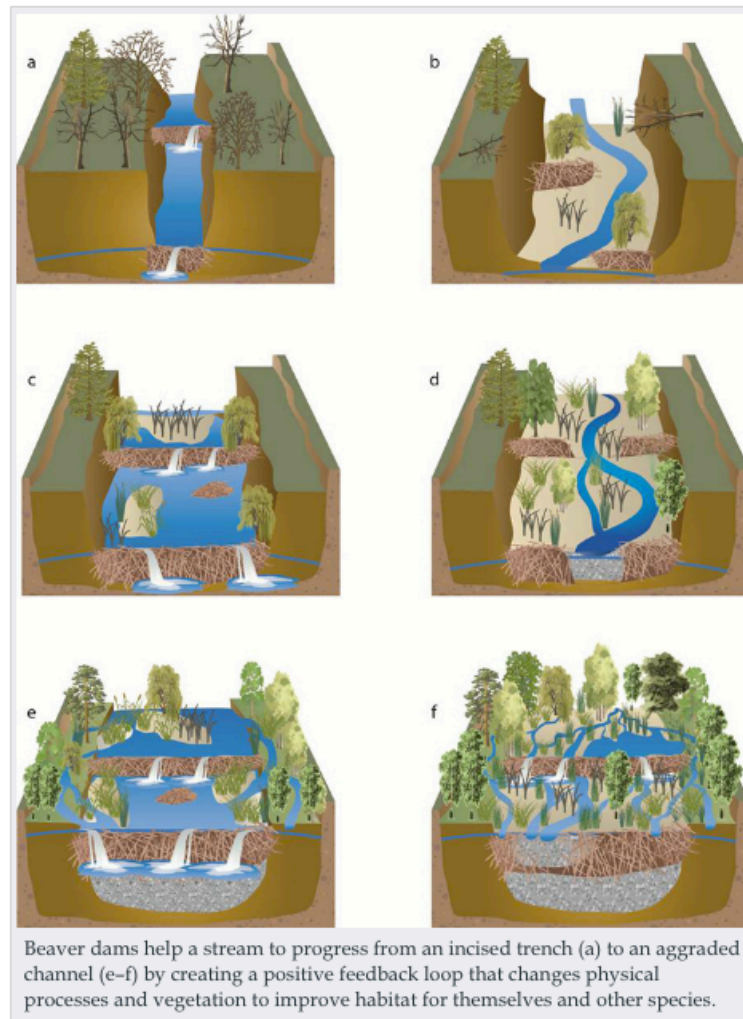


Figure 4. Conceptual Model of Beaver Dam Impacts on Incised Streams. Source: Pollock et al., 2015, p. 12.

Water management plans across the U.S. West have started to include beaver-related restoration projects as options for increasing natural water storage. The Methow Valley Beaver Project relocated nuisance beavers throughout Washington to public land where their dams enhanced salmon runs or recharged groundwater (Goldfarb, 2015). The Lands Council in Washington produced a report exploring beavers as a natural water storage tool in the Columbia River Basin (Walker et al., 2010). The report quantified the

amount of water beaver dams could store and how much suitable habitat existed for beavers (Walker et al., 2010). The Clark Fork and Kootenai River Basin Water Plan (DNRC, 2014) aimed to restore or maintain natural ecosystems to encourage water retention and infiltration (DNRC, 2014). The plan also explored beaver ponds as a possible natural water storage option (DNRC, 2014). A cost-benefit analysis report to improve natural water storage in the Upper Clark Fork River Basin recommended beaver mimicry projects among other passive restoration techniques (Chadwick, Stanley, & Gignoux, 2015).

While the biophysical effects of beaver-related restoration on ecosystems have been studied, the social science component has received less attention. The human dimensions of beaver-related restoration must be studied and included to better understand the benefits and drawbacks of these projects. As is the case for any restoration project, ecosystems cannot be altered without affecting the human community. Beaver-related restoration projects can be more complex than other restoration projects since they take longer to complete and require people to change their thinking when it comes to managing streams and beavers, which can be a slow process (Pollock et al., 2015). Pollock et al. (2015) also recommend a minimum timeframe of five years to gauge the success of a beaver-related restoration project.

From the work that has been done on the relationship between humans and beavers, inconsistency remains regarding the human response to beavers, the impacts of beaver activities, and the presence of beavers on private property (Morzillo & Needham, 2015). Morzillo and Needham (2015) found that landowner responses in Oregon varied

depending on the proximity of beavers to people's homes or their past experiences with beavers.

The Miistakis Institute and the Alberta Riparian Habitat Management Society collaborated on the Putting Beavers to Work for Watershed Resiliency and Restoration Project (Kinas, Duke, & Nisha, 2017). The project provided education through workshops and webinars, focusing on the role of beavers and the ecosystem benefits of beavers in the Alberta watershed (Kinas et al., 2017). The project also included a survey of rural landowners' perceptions and knowledge about beavers (Kinas et al., 2017). The survey found that about half of the landowners were interested in having beavers on their property and the other half were not (Kinas et al., 2017). Nineteen percent of landowners thought beavers were a moderate problem and only 10% thought beavers were an extreme problem (Kinas et al., 2017). Most respondents acknowledged that beavers provide benefits, such as increased riparian vegetation or species diversity, but were concerned with the adverse impacts of beavers like road flooding or damaged culverts (Kinas et al., 2017). Overall, respondents indicated a desire for more information about the benefits of beavers and how to better coexist with them (Kinas et al., 2017).

The studies in Oregon and Alberta serve as a reference point when evaluating landowner responses to beaver mimicry projects. This thesis is interested in landowner perceptions of beaver mimicry projects, which do not specifically aim to reintroduce beavers.

Flood Irrigation as Natural Water Storage Flood irrigation is another natural water storage strategy. As discussed in a previous section, flood irrigation (and leakage from flood canals) replenishes groundwater, promotes aquifer storage, boosts soil moisture, and provides later season streamflows (Baker et al., 2014; Helmus et al., 2009; Kendy & Bredehoeft, 2006; Scanlon et al., 2007). Flood irrigation can also be essential to the creation and perpetuation of ephemeral and permanent wetlands (Crifasi, 2005; Peck & Lovvorn, 2001; Peck, McLeod, Hewlett, & Lovvorn, 2004). In many instances, irrigation is the sole cause of wetlands, many of which are habitats for various species, especially birds and waterfowl (Peck & Lovvorn, 2001; Peck et al., 2004; Sueltenfuss, Cooper, Knight & Waskom, 2013). In one study of 74 wetlands, flood irrigation contributed to 65% of inflows into a wetland, compared to 14% from surface stream inflows (Peck & Lovvorn, 2001). Flood irrigation inflows can also expand and support naturally existing wetlands (Crifasi, 2005).

Research on natural water storage practices, like beaver mimicry projects and flood irrigation, demonstrate their potential for use as climate change adaptation strategies, particularly for drought in the U.S. West and Montana. At the same time, public support of these projects will be critical for implementation on private lands. The theory of planned behavior can help understand how beliefs and intentions impact a person's desire to perform a behavior, such as implement a natural water storage project.

### The Theory of Planned Behavior

The theory of planned behavior (TPB) is a prominent theory in social psychology and other social sciences. It is part of the reasoned action approach framework. This framework includes TPB's predecessor, the theory of reasoned action (TRA) and its lesser-known successors, the reasoned action approach (RAA) and the integrated behavior model (IBM) (Ajzen, 2012; Schwarzer, 2014). Martin Fishbein and Icek Ajzen developed the TRA together. As their research paths diverged, Fishbein worked on the IBM and Ajzen worked on the TPB (Fishbein & Ajzen, 2010). However, given the overlap of the IBM and TPB models, they came back together in 2010 to collaborate (Head & Noar, 2014). The RAA was the final product of their partnership (Fishbein & Ajzen, 2010; Head & Noar, 2014).

### The Theory of Reasoned Action

The TRA model was different from earlier social psychology models because beliefs were the basis for attitudes (Ajzen, 2012). Additionally, in the TRA model, beliefs and attitudes were evaluated separately (Ajzen, 2012). Fishbein and Ajzen (1975) used the expectancy-value model to theorize attitude and to explain attitudes and beliefs. They also used the expectancy-value model to develop the TRA and additional models (Fishbein & Ajzen, 1975). In the expectancy-value model, a person's attitude toward a specific object comes from "the subjective values or evaluations of the attributes associated with the object and by the strength of these associations" (Ajzen, 2012, p. 12). The beliefs and subjective values toward an object directly determine attitude (Ajzen,

2012). People can have various beliefs about an object, but the authors propose that there are only so many “readily accessible beliefs” that determine attitude at a specific moment (Ajzen, 2012, p. 18).

In 1975, Fishbein and Ajzen solidified the TRA framework in their book, *Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research* (Fishbein & Ajzen, 1975). The TRA model maintains that people “make systematic use of the information available to them” (Ajzen & Fishbein, 1980, p. 5). Human behavior involves weighing the consequences of actions before deciding to partake or not partake in a certain behavior (Ajzen & Fishbein, 1980). Behavior is not controlled by “unconscious motives or overpowering desires” nor is it “capricious or thoughtless” (Ajzen & Fishbein, 1980, p. 5). In the TRA, behavior is comprised of four components: “action performed, the target at which the action is directed, the context in which it is performed, and time at which it is performed” (Fishbein & Ajzen, 2010, p. 29). Behavior changes if one of those four components is changed (Fishbein & Ajzen, 2010). For example, Fishbein and Ajzen would see buying groceries at a family owned store as a different behavior than buying groceries at a chain supermarket since the context has changed.

The importance of the TRA (and later the TPB) is the applicability to a wide variety of social behaviors (Ajzen & Fishbein, 1980). The authors assert its value in understanding and predicting behaviors such as political, sexual, or consumer behavior (Ajzen & Fishbein, 1980). Furthermore, beyond understanding behavior, the TRA can be used to help influence or change behavior (Ajzen & Fishbein, 1980). In the TRA, certain beliefs affect attitudes and norms which impact intentions which then impact behavior

(Figure 5) (Fishbein & Ajzen, 1975). More specifically, there are two types of beliefs: those relating to attitude (behavioral beliefs) and those relating to subjective norms (normative beliefs) (Fishbein & Ajzen, 1975). Behavioral beliefs revolve around the consequences of a certain behavior (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975). If the behavioral beliefs toward the behavior are positive, the attitude toward the behavior will be positive, or vice versa, which will influence the intention (Fishbein & Ajzen, 1975).

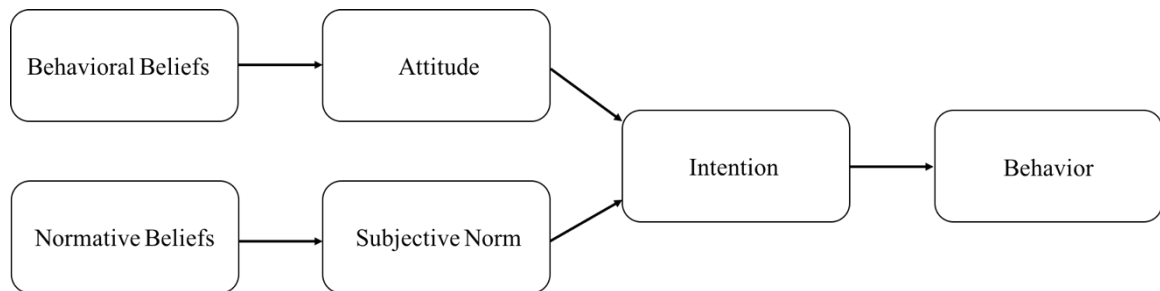


Figure 5. The Theory of Reasoned Action, adapted from Ajzen & Fishbein, 1980, p. 100.

Normative beliefs involve the impact of referents' (i.e., important individuals in a person's life) expectations and actions on a person (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975). A person's normative beliefs are shaped by what referents think he/she should do, what referents are doing themselves, and the perceptions of social pressures associated with a behavior (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975). Both attitudes and subjective norms impact the intention (Ajzen & Fishbein, 1980). Depending on the situation, attitude or subjective norms may be more important (Ajzen & Fishbein, 1980).

According to the TRA, the intention is the direct determinant of behavior (Ajzen & Fishbein, 1980). Intention can be defined as how ready a person is to perform a behavior (Fishbein & Ajzen, 2010). Ajzen and Fishbein (1980) also note that behaviors studied in the TRA are assumed to be under volitional control. The development of the TPB aims to better predict behaviors not completely under volitional control.

### The Theory of Planned Behavior

Formulated by Icek Ajzen in 1985, the original chapter on the TPB in *Action Control: Cognition to Behavior*, has over 20,000 Google Scholar citations and the following paper has over 60,000 citations (Ajzen, 1985, 1991). The TPB is an extension of the TRA and adds control beliefs and perceived behavioral control as factors that influence intention along with subjective norms and attitude (Figure 6) (Ajzen, 1985, 1991, 2002, 2016). Perceived behavioral control is determined by a person's perception of how much control they have over performing that behavior, such as the potential obstacles or pertinent skills they may need to perform that behavior (Table 2) (Ajzen, 2014; Fishbein & Ajzen, 2010). Perceived behavioral control was added as a factor to explain why people may intend to do a behavior but end up not performing that behavior (Ajzen, 1985, 1991, 2002).

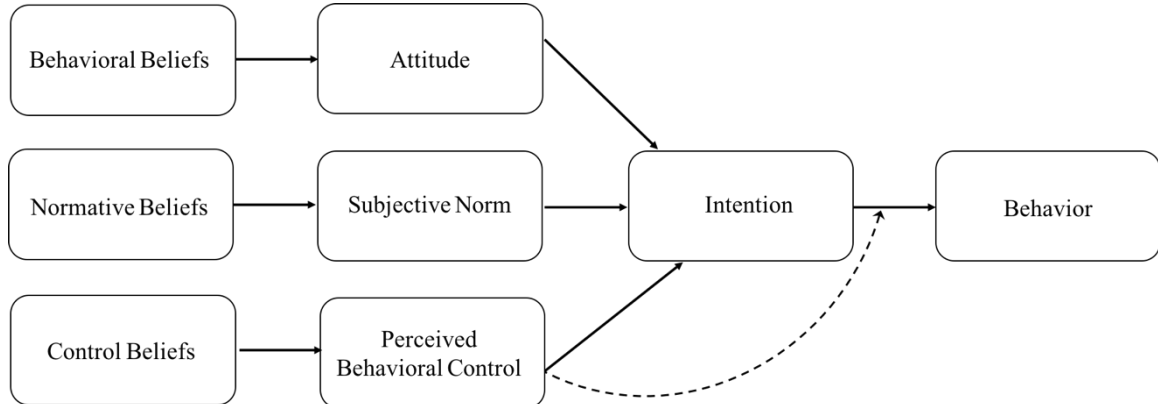


Figure 6. The Theory of Planned Behavior, adapted from Ajzen, 2017.

The TPB still includes behavioral beliefs which produce an attitude, normative beliefs which produce a subjective norm, and adds control beliefs, which produce perceived behavioral control (Ajzen, 1991). The TRA was more successful in predicting the relationship between intention and behavior when a person had complete volitional control over that behavior (Fishbein & Ajzen, 2010). Perceived behavioral control was added to the TPB for situations when people have less volitional control over performing a behavior (Fishbein & Ajzen, 2010). As Fishbein and Ajzen (2010) stated, “intention by itself should permit good prediction” (p. 64). Their research also found that perceived behavioral control can serve as a proxy for actual control since perceptions of control can reflect actual control (Ajzen, 2016; Fishbein & Ajzen, 2010).

Perceived behavioral control differs from an attitude and a subjective norm because it can be used with intention to directly predict behavior (Ajzen, 1991). However, perceived behavioral control alone is not enough to predict behavior (Ajzen, 2012). If the intentions of two people are the same, the person with a higher perceived behavioral control will be more likely to perform that behavior (Ajzen, 1991). In other

words, intentions and perceived behavioral control more accurately predict behavior when perceived behavioral control is high (Ajzen, 1991, 2012). If the perceived behavioral control is realistic, it can help “predict the probability of a successful behavioral attempt” (Ajzen, 1991, p. 185).

<b>Behavioral Beliefs</b>	Concerned with the consequences of a behavior. Directly influences attitude.
<b>Attitude</b>	Directly impacted by positive/negative behavioral belief resulting in a positive/negative attitude toward the behavior.
<b>Normative Beliefs</b>	Perceived expectations by referents to perform the behavior. Directly influences subjective norm.
<b>Subjective norm</b>	Social pressure to perform a behavior. Directly impacted by normative beliefs.
<b>Control beliefs</b>	Includes obstacles or skills that hinder or aid the performance of a behavior.
<b>Perceived behavioral control</b>	Perception of how much control a person has over behavior. With intention, it can predict behavior.
<b>Intention</b>	Indicates how ready a person is to perform a behavior. Influenced by attitude, subjective norm, and perceived behavioral control. Antecedent to behavior.
<b>Behavior</b>	Function of intentions and perceived behavioral control.

Table 2. Table of the Theory of Planned Behavior Terms and Definitions. Source: Ajzen, 2017.

In the TPB, intentions determine behavior. Intentions can change due to how strongly beliefs are held (Ajzen, 1985). Intentions may change if a person obtains new information that makes he/she less willing to perform the behavior or if time passing makes the person less interested in performing the behavior (Ajzen, 1985). For example, a person intends to have a child in five years (Ajzen, 2010). As the time draws closer to conceive a child, the person may have changed his/her mind due to learning new information about childbirth risks, he/she doesn't feel ready, he/she does not have the

previous desire, or he/she may already have one child and not want more children (Ajzen, 2010). Ajzen (2012) states, “this assumption implies, first, a strong relation between intentions and behavior, and second, that changes in intentions are followed by changes in behavior” (p. 19).

### The Reasoned Action Approach

The RAA is a further refinement of the TPB (Fishbein & Ajzen, 2010). The RAA adds background factors such as personality, mood, education, age, gender, and race that impact beliefs (Figure 7) (Fishbein & Ajzen, 2010). These factors indirectly influence intentions and behaviors by first influencing beliefs (Ajzen, 2011). The RAA breaks down subjective norms into injunctive norms and descriptive norms (Fishbein & Ajzen, 2010). Injunctive norms include a person’s perception of performing or not performing a behavior, and descriptive norms include perceptions of other people performing a behavior (Fishbein & Ajzen, 2010; McEachan et al., 2016). The RAA separates attitude into experiential attitude and instrumental attitude (Fishbein & Ajzen, 2010). Experiential attitude is the positive or negative experience with a behavior, and instrumental attitude is the anticipated positive or negative consequences of a behavior (Fishbein & Ajzen, 2010; McEachan et al., 2016). Finally, perceived behavioral control is broken down in capacity and autonomy (Fishbein & Ajzen, 2010; Connor, McEachan, Lawton & Gardner, 2017).

In recent years, researchers have tried to expand the TPB with different sub-factors, resulting in different names for the TPB or inserting new sub-factors in the RAA (McEachan et al., 2016). Fishbein and Ajzen (2010) stated that sub-factors in the RAA vary depending on the population or behavior. Fewer studies have used the RAA than the

TPB (Ajzen, 2012; Conner et al., 2017). Ajzen has incorporated some of the newer clarifications, like injunctive and descriptive norms and background factors to the TPB as well (Ajzen, 2016, 2017). This thesis will use the TPB (Figure 6) and insights from case studies that use the TRA or RAA to assess landowner beliefs, attitudes, perceived behavioral control, and subjective norms toward adaptation strategies.

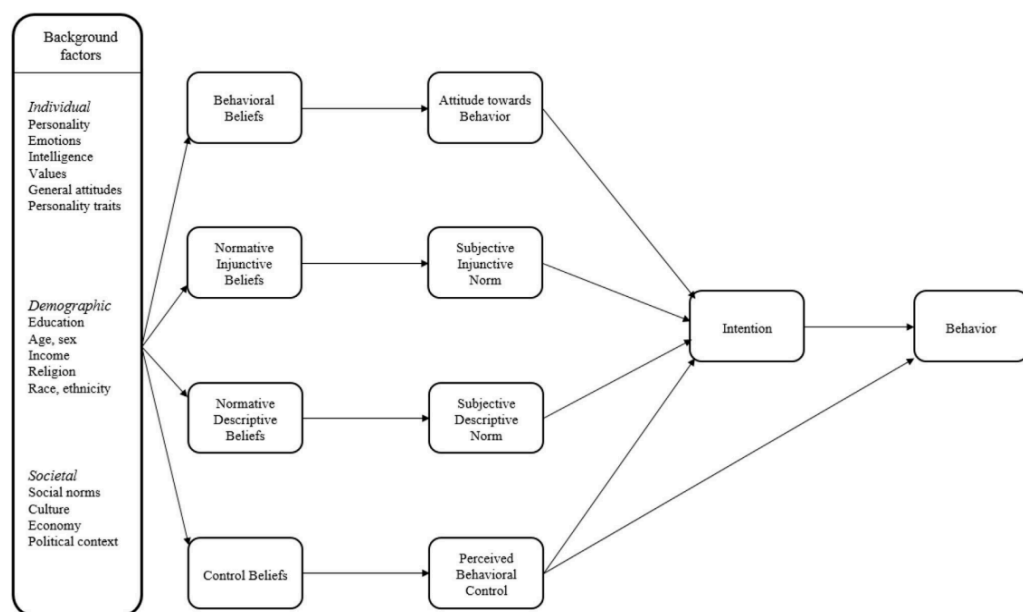


Figure 7. The Reasoned Action Approach. Source: de Leeuw, Valois, Ajzen, and Schmidt, 2015, p. 129.

### Critiques of the Theory of Planned Behavior

Critiques have been made that the TPB is too rational, and does not account for emotions or affect. Ajzen (2010, 2012) and Fishbein (2008) argue that the term reasoned doesn't equate to rational or discount emotions. Fishbein (2008) adds, "these 'higher-order constructs' (e.g., attitudes, norms, intentions) are assumed to follow reasonably from one's beliefs about the world in which one lives. But the beliefs one holds need not be veridical; they may be inaccurate, biased, or even irrational" (p. 2). Ajzen (2011)

maintains that affect and emotion are “background factors that influence behavioral, normative, and control beliefs” with indirect impacts on intentions and behavior (p. 116). Emotions can impact the strength of a belief, such as someone in a positive mood may find a behavior more positive than someone in a negative mood (Ajzen, 2011). Affective states can also “help select the behavioral, normative and control beliefs that are readily accessible in the memory” (Ajzen, 2011, p. 1116). Ajzen argues that studies that used affect to improve behavior prediction did not measure behavior correctly (Ajzen, 2014). These studies measured the anticipated affect of not performing a behavior which provided more information than measurements about performing a behavior (Ajzen, 2014). Ajzen argues that measuring affect related to not performing a behavior is similar to measuring the attitude of the opposite behavior (Ajzen, 2014).

Some studies have found weak links between subjective norms and behavior (Armitage & Connor, 2001). Ajzen counters that these results do not prove that the TPB is inaccurate because the studies did not correctly use the compatibility principle (Ajzen, 2012). The measurement of a general attitude and a specific behavior will have a weak relationship because a general attitude may not have the four specific elements (action, target, context, timeframe) like a specific behavior would, which results in weak compatibility (Ajzen, 2012). The attitude and the behavior must be on the same scale, either broad or specific, to be compatible and provide accurate results from the TPB model (Ajzen, 2012). Others have suggested that RAA framework is outdated (Schwarzer, 2014). Further, its generality is also its weakness, especially when explaining health behaviors (Schwarzer, 2014). There have been suggestions to add moral norms to

complement social norms (Ajzen, 1991). Various studies have included moral norms and resulted in better predictions of intention, so that is a possible direction for future research (Ajzen, 1991). Others have offered suggestions to include past behavior and habit as factors in the TPB but Ajzen (1991) argues that past behavior should be treated as “a reflection of all factors that determine the behavior of interest” (p. 203).

These critiques provide helpful feedback for the use and application of the TPB. The TPB proves useful in this thesis because it ties together the themes of climate change, drought, irrigation efficiency, natural water storage, and rancher typology (to be discussed in a later section) under a larger umbrella of beliefs. The ripple effects of those beliefs give insight into the opportunities and barriers for adopting adaptation strategies.

#### Application of the TPB to Climate Change Beliefs, Perceived Risk, and Adaptation Attitudes

The following case studies provide context into how the TPB has been applied to climate change beliefs, perceived risk, and adaptation attitudes. Mase, Gramig, and Prokopy (2017) conducted a survey that assessed farmers’ beliefs of climate change, their perceived risk from climate or weather, and their attitudes toward adaptation strategies. Mase et al. (2017) found that eight percent of corn farmers in the Midwest believed in anthropogenic climate change compared to Leiserowitz et al.’s (2018) finding that 58% of Americans believe in human-induced climate change. In line with the RAA, Mase et al. (2017) found that for climate change, beliefs do predict adaptation attitudes which predict adaptation behaviors. Additionally, Mase et al. (2017) pointed to the importance

of other research that has shown the importance of social norms for farmers when adopting new conservation practices or technology.

Haigh and Knutson (2013) used a qualitative TPB approach and goal attainment theory in their research on Great Plains ranchers and their drought management strategies. All of the ranchers interviewed used drought management strategies and saw value in preparing for drought (Haigh & Knutson, 2013). Ranchers' beliefs in the importance of drought preparedness often came from experiences with previous droughts (Haigh & Knutson, 2013). The ranchers found value in drought preparedness, but also found it difficult to plan for drought because it wasn't a situation they could control or predict (Haigh & Knutson, 2013). Haigh and Knutson (2013) found that certain drought strategies increased ranchers' perceived behavioral control during drought times. Ranchers' perceived behavioral control increased when their operation had flexibility and maximized pasture health, when they monitored forage and precipitation, and when they had specific decisions to implement on specific dates as drought became evident (Haigh & Knutson, 2013).

There is an unclear relationship between climate change beliefs and risk perceptions to extreme events in the literature (Carlton et al., 2016). Carlton et al. (2016) examined if agricultural advisors (e.g., University Extension staff, government agency employees, for-profit consultants, insurance salespeople) in the Midwest changed their beliefs and attitudes toward climate change adaptation after the 2012 drought. Carlton et al. (2016) saw the RAA as useful since it suggests that more positive adaptation attitudes toward climate change will lead to higher rates of implementation of adaptation strategies

(Carlton et al., 2016; Fishbein & Ajzen, 2010). Their results showed that climate change beliefs and adaptation attitudes did not change considerably after the drought, leading them to conclude that one extreme event is not a catalyst for changing beliefs and attitudes (Carlton et al., 2016). Since adaptation attitudes did not become more positive after the drought, agricultural advisors interviewed in this study would not become more willing to implement adaptation strategies (Carlton et al., 2016).

However, Carlton et al. (2016) suggest that “[agricultural advisors] may be more likely to adapt to the specific risks that they now perceive as more salient or relevant” (p. 223). Agricultural advisors’ risk perceptions did change after the drought, confirming research by Carlton and Jacobson (2013) that people can be “concerned with climate-related hazards even if they are not concerned about climate change specifically” (Carlton et al., 2016, p. 223). At the same time, if respondents didn’t see drought as an effect of climate change, they may not change their beliefs toward climate change (Carlton et al., 2016). Carlton et al. (2016) use Weber’s (2006) concept of “finite pools of worry” to explain drought reactions. According to this concept, individuals focus their worry on events that cause “visceral reactions” (Weber, 2006, p. 104). Therefore, unless a drought causes a significant reaction for those who experienced it, they will remain unconcerned (Carlton et al., 2016; Weber, 2006).

Wheeler, Zuo, and Bjornlund (2013) assessed if and how much climate change beliefs impact the adoption of adaptation strategies for irrigators in Australia. They found that climate change beliefs had a weakly significant influence on adaptation (Wheeler et al., 2013). Specifically, farmers who believed in climate change did not want to increase

farm acreage but did plan to decrease water use or grow different crop varieties (Wheeler et al., 2013). Farmers who believed in climate change planned “accommodating” but not “expansive” adaptation strategies (Wheeler et al., 2013, p. 546). Additionally, farmers who had experienced water shortages were more likely to plan improvements (e.g., irrigation efficiency or selling water) to their irrigation practices (Wheeler et al., 2013). Farmers were more likely to plan future adaptation strategies if they had a known successor to their operation (Wheeler et al., 2013).

Borges and Oude Lansink (2016) used the TPB to study Brazilian farmers’ intentions to use improved natural grasslands. They found that attitude, subjective norms, and perceived behavioral control positively impacted farmers’ intentions to use this strategy (Borges & Oude Lansink, 2016). Contrary to work from Armitage and Conner (2001), who found weak links between subjective norms and behavior, this case study determined subjective norms had more impact on intention than attitude or perceived behavioral control (Borges & Oude Lansink, 2016). Additionally, the study highlighted the importance of social pressure on farmers and that those pressures could persuade farmers with negative attitudes to adopt this strategy (Borges, Oude Lansink, Riberio, & Lutke, 2014; Borges & Oude Lansink, 2016). Positive attitudes also increased intentions to adopt natural grasslands (Borges & Oude Lansink, 2016).

Two companion papers by Artikov et al. (2006) and Hu et al. (2006) used the theory of planned behavior with the theory of derived demand to understand the relationship between farmers and weather forecasts. Hu et al. (2006) found that farmers’ attitudes toward weather forecasts resulted in low usage. Artikov et al. (2006) concluded

that attitudes (followed by social norms) were the most important factor in changing farmers' use of weather forecasts.

### The Theory of Planned Behavior and Ranch Conservation

Willcox, Giuliano, and Monroe (2012) used the TPB to survey cattle ranchers and assess their attitudes, subjective norms, and perceived behavioral control with regards to the implementation of wildlife conservation programs. Ranchers thought wildlife was important and their presence could be helpful on ranches (Willcox et al., 2012). Attitudes and subjective norms were the most important factors in predicting intention (Willcox et al., 2012). It is probable that perceived behavioral control was less important since cattle ranchers had volitional control over the adoption of wildlife conservation programs on their land (Willcox et al., 2012). Factors such as education level, ranch size, or years owning a ranch did not explain intentions to perform the behavior (Willcox et al., 2012).

Brain, Hostetler, and Irani (2014) applied the TPB and the adoption diffusion model to find the main factors that influenced cattle rancher decisions to allow conservation easements (CE) on their property. There were six variables that explained rancher participation in CEs (Brain et al., 2014). The two variables related to TPB included positive attitudes toward CEs and the belief that referents would support their decision (Brain et al., 2014).

Beedell and Rehman (2000) employed the TPB to explain why farmers have different behaviors toward conservation. They surveyed and then interviewed farmers that were members of a Farming and Wildlife Advisory Group (FWAG) and a group of traditional farmers (Beedell & Rehman, 2000). The two groups were asked about six

different conservation practices (Beedell & Rehman, 2000). FWAG farmers saw five of the six practices as beneficial and prioritized conservation beliefs over farm management related beliefs (Beedell & Rehman, 2000). FWAG farmers also saw referents as more important than traditional farmers (Beedell & Rehman, 2000). Both groups of farmers felt they had perceived behavioral control over adopting the conservation practices (Beedell & Rehman, 2000). FWAG farmers used more off-farm information sources and financial assistance than traditional farmers (Beedell & Rehman, 2000).

Sorice, Haider, Conner, and Ditton (2011) used the TRA and the stated-choice model to explain that incentives may not be sufficient for landowners to participate in conservation programs for endangered species on their property. Groups that were unwilling to participate in conservation programs were found to have negative attitudes and experienced social pressure against participating in these programs (Sorice et al., 2011). Sorice et al. (2011) suggested that approaches focused on increasing the adoption of conservation programs should consider local landowners' social norms and incentives.

### Quantitative and Qualitative Applications of the Theory of Planned Behavior

Studies that use the TPB typically use a quantitative approach. The studies in the previous section, apart from Haigh and Knutson (2013), used a quantitative approach. A quantitative approach involves a pilot questionnaire, standard questionnaire, and statistical analysis (Ajzen, 2017). The pilot questionnaire obtains information on referents, salient outcomes, control factors, and background factors (Ajzen, 2017). The results of the pilot questionnaire inform the standard questionnaire, where respondents answer on a 7-point scale (Ajzen, 2017). The pilot questionnaire may ask general

questions while the standard questionnaire is more specific (Ajzen, 2017). Results are analyzed using multiple regression, structural equation modeling, latent class analysis, or another statistical method (Ajzen, 2017).

The TPB framework has also been used qualitatively to understand behavior in a limited setting by using the TPB to inform interview questions (Renzi & Klobas, 2008). One study used qualitative analysis to understand different teaching approaches in a university (Renzi & Klobas, 2008). The study coded interviews for TPB themes like beliefs and attitudes toward the different teaching approaches (Renzi & Klobas, 2008). The results highlighted how different beliefs and attitudes influenced teaching approaches (Renzi & Klobas, 2008). Another study used the TPB qualitatively to understand why people didn't use a pharmacy service despite its convenience (Tan et al., 2015). Interview transcripts were coded for TPB themes like attitude, subjective norms, and perceived behavioral control toward using the pharmacy service (Tan et al., 2015). Additional research has used a qualitative approach to TPB with regards to consumer behavior, adult drinking behavior, health behavior, and compliance behavior (Hanan, 2014; Mortazavi et al., 2017; Silva, Figueiredo, Hogg & Sottomayor, 2014; Zoellner et al., 2012). This thesis will apply a qualitative TPB approach as many of the questions in the interview guide relate to concepts in the TPB like beliefs, attitudes, subjective norms, and perceived behavioral control.

### Research Gaps This Study Fills

In their study of Midwestern corn farmers' climate change beliefs and adaptation attitudes, Mase et al. (2017) recommended more qualitative research "to understand how farmers think about climate change, potential weather-related risks and adaptation strategies" (p. 16). Haigh & Knutson (2013) stated that there has not been expansive research on ranchers' perceived behavioral control with regard to drought preparation behavior. They also suggested that future research should evaluate how having a drought plan could affect perceived behavioral control or behavior during a drought (Haigh & Knutson, 2013). Additionally, they called for research in different areas of the country with different types of producers (Haigh & Knutson, 2013). Carlton et al. (2016) found a weak relationship between risk perception and adaptation attitudes toward climate change, calling for more exploration into the causes of attitude and behavior shifts. This research helps to fill this gap.

### Study Intent

This study aims to add to the literature on attitudes and behaviors toward climate change adaptation and drought. Increased information or even increased exposure to climate change does not necessarily cause people to change their beliefs about its existence or their behaviors toward adapting (Carlton et al., 2016; de Leeuw et al., 2015). People informed from the same sources can reach different decisions and behaviors (Ajzen, Joyce, Sheikh, & Gilbert Cote, 2011). As de Leeuw et al. (2015) state, it is "possible to either challenge beliefs that impede the adoption of the desired behavior,

strengthen those who support it, or facilitate the development of new beliefs that promote the desired behavior” (p. 128).

The intent of this thesis is to use the theory of planned behavior to better understand the barriers and opportunities for ranchers in the Red Rock Watershed in southwestern Montana to adopt natural water storage practices. A better understanding of the local ranching community’s desires and interests can be useful for government agency or nonprofit organization interactions with the community and developing drought or climate change adaptation policy. This thesis will also use rancher typologies to explore if amenity and traditional ranchers have different attitudes and behaviors toward natural water storage.

### Amenity Migration and Rancher Typologies

Agricultural lands face numerous challenges from development, population growth, urbanization, economic growth, land use change, and climate change (FAO, 2107). These challenges are also pertinent to the U.S. West (Travis, 2007). The U.S. West has grown faster than other regions in the country and experienced large amounts of agricultural land conversion (Travis, 2007). Land conversion in the U.S. West can affect hydrologic, ecological, and social systems (Maestas, Knight, & Gilgert, 2001; Van Kirk, 2016). Areas where agricultural lands have been developed can increase consumptive water use and disrupt wildlife and vegetation populations (Maestas et al., 2001; Scott et al., 2001; Van Kirk, 2016). Land conversion to residential or exurban development usually occurs on private lands (Maestas et al., 2001; Scott et al., 2001; Vincent, Hanson,

& Argueta, 2017). Private lands account for a little less than half of the land in the U.S. West and often have more productive soils and greater species diversity (Maestas et al., 2001; Scott et al., 2001; Vincent et al., 2017). Development and in-migration bring new cultural values and changes for rural community dynamics (Glorioso & Moss, 2007). It is important to understand the changes occurring on agricultural lands in the U.S. West and in Montana when evaluating the potential for adaptation strategies.

### Amenity Migration

Much of the U.S. West is experiencing an influx of amenity migration to rural landscapes. Amenity migration involves suburban or urban populations moving seasonally or permanently into historically extractive (e.g., mining, ranching, timber) landscapes (Abrams & Bliss, 2013; Gosnell & Abrams, 2009). New amenity landowners usually bring different environmental views, rural ideals, and land management desires which can have consequences for community dynamics, land use, and policies (Gosnell & Abrams, 2009; Sorice, Kreuter, Wilcox & Fox, 2014). Traditional landowners are equipped with local knowledge and often rely on natural resources for their livelihoods (Sorice et al., 2014). Sorice et al. (2014) found that amenity landowners tend to value conservation and have the financial means to implement such practices, though they may lack the local knowledge to do it. Amenity migrants struggle with their desires for an “authentic” rural landscape that comes from the agriculture production industry while also preferring environmental or conservation improvements (Abrams & Bliss, 2013, p. 851). The economic consequences associated with amenity migration include the commodification of the rural lifestyle, higher land prices as more amenity migrants buy

out ranches or farms, focus on recreation or conservation practices over production, and an inflow of capital that can benefit local economies (Gosnell & Abrams, 2009).

### Rancher Typologies

The literature suggests that values and backgrounds of amenity migrants can be different from more traditional landowners. It can be useful to employ a typology to understand how these value systems and socioeconomic factors influence land management attitudes and behaviors (Emtage, Herbohn, & Harrison, 2006). A landowner typology is a representative description or definition of a typical landowner (Emtage et al., 2006). Emtage et al. (2006) offer that “developing a landowner ‘typology’ is one way of avoiding a blanket approach to landholders, and at the same time recognizing that it impossible to have policies and programs tailored to each individual” (p. 79). Landowner typologies provide a landowner profile and can elucidate the relationships between their attitudes, behaviors, values, and land management practices (Emtage et al., 2006). There have been numerous typologies discussed in the literature to differentiate types of ranchers (Gosnell, Haggerty & Travis, 2006; Gosnell & Travis, 2005; Sorice et al., 2014). These typologies attempt to explain land management changes, the consequences of ownership change, and shifting community dynamics (Gosnell, Haggerty & Travis, 2006; Gosnell & Travis, 2005; Sorice et al., 2014).

Yung, Phear, DuPont, Montag, & Murphy (2015) refer to ranchers as individuals who self-identify as cattle producers. This thesis utilizes this definition and will include bison producers as well. Grigsby (1980) finds ranchers to be a unique subset within the umbrella of agricultural producers. Ranchers see benefits in working with livestock, have

desires to live in the country, and participate in resource stewardship in addition to their economic goals (Rowan, 1994).

Gosnell and Travis (2005) developed a typology for large landowners that included traditional ranchers, part-time ranchers, amenity buyers, investors, corporations, developers, conservation organizations, and others (such as federal agencies). Traditional ranchers were defined as full-time ranchers whose income was generated from their operation (Gosnell & Travis, 2005). Amenity buyers or absentee owners were defined as those who acquired their ranches for recreation or other benefits and usually had a ranch manager for agriculture production management (Gosnell & Travis, 2005). Amenity buyers did not rely on the ranch as a major income source (Gosnell & Travis, 2005). This typology was also used in further work by Gosnell, Haggerty, and Travis (2006) and Travis (2007).

Sorice et al. (2014) presented three landowner groups consisting of agricultural producers, multiple-use landowners, and lifestyle-oriented landowners. Agricultural producers used the land for ranching and derived their income from their operation (Sorice et al., 2014). Multiple-use landowners did not rely on profit as much agricultural producers and had varied uses for the land such as agriculture, lifestyle, wildlife programs, or financial assets (Sorice et al., 2014). Lifestyle-oriented landowners owned the land mostly for the lifestyle and then for financial investment (Sorice et al., 2014).

Other studies such as Coppock and Birkenfield (1999) offered five types of landowners differentiated by socioeconomic factors: large-scale operators, private hobbyists, public hobbyists, private ranchers, and public ranchers. Gentner and Tanaka

(2002) looked at landowners with federal grazing permits and identified groups such as small hobbyists, retired hobbyists, working hobbyists, trophy ranchers, dependent family ranchers, diversified family ranchers, corporate ranchers, and sheep herder ranchers.

This thesis used an amenity and traditional rancher typology to understand the differences in beliefs and behaviors between these groups. The rationale for the typology will be discussed in the methods section.

### Connection to Other Ranch Case Studies

The Red Rock Watershed in southwestern Montana provides an exciting case study due to amenity migration influences as well as its geography as a headwaters basin to the Missouri River. Other case studies on ranch communities have collected information about ranchers' relationships with government agencies, ranchers' adoption rates of new practices, or ranchers' values. Sayre (2004) points to decades of studies that conclude that profit is not the primary motivation for western ranchers. Further research shows that ranchers do not agree with the public perception of them as solely profit driven landowners who don't properly manage the land and resources (Haggerty, Auger, & Epstein, 2018). Ranchers across the U.S. West emphasize the need for flexibility in their operations, whether it be during drought periods or from government agencies (Dunn et al., 2005; Haigh & Knutson, 2013; Kennedy & Brunson, 2007; Roche, 2016; Roche et al., 2015; Sayre, Carlisle, Huntsinger, Fisher, & Shattuck, 2012; Wilmer et al., 2016). In some instances, the government was seen as a barrier to management and flexibility rather than a partner (Brain et al., 2014; Monroe, Bowers, Hermansen, 2003; Roche et al., 2015). There has also been an interest in utilizing ranchers' local knowledge

to complement scientific knowledge (Knapp & Fernandez-Gimenez, 2009; Roche et al., 2015).

## CHAPTER THREE

## CASE STUDY AND METHODS

Case Study Site: The Red Rock WatershedPhysical Attributes

The Red Rock Watershed is a 1,580 square-mile snowmelt-driven watershed located in the headwaters of the Upper Beaverhead Watershed in southwestern Montana (Figure 8). The Red Rock River flows into the Beaverhead River, which then joins the Big Hole River and flows into the Jefferson River. The Jefferson River is one of the main tributaries to the Missouri River. The Red Rock River flows west from the Upper and Lower Red Rock Lakes before reaching the Lima Reservoir (Montana Department of Fish, Wildlife, and Parks [MFWP], n.d.). The Lima Reservoir was built in 1902 for irrigation water storage and holds 6,800 acres (MFWP, n.d.). After the Lima Dam, the Red Rock River travels 57 miles through agricultural and rangelands before emptying into the 4,900 acre Clark Canyon Reservoir (MFWP, n.d.). In 1964, the Bureau of Reclamation built the reservoir for irrigation storage and flood management (MFWP, n.d.). The reservoir is now a popular recreation area (MFWP, n.d.). The confluence of the Red Rock River and Horse Prairie Creek used to be the start of the Beaverhead River, but since the construction of the Clark Canyon Dam, the Beaverhead River now begins at the outlet of the dam (Montana Department of Environmental Quality [DEQ], 2014). Parts of the Beaverhead River are periodically and/or chronically dewatered (Montana DEQ, 2014). A dewatered stream is one that does not have sufficient streamflow to support fish

habitat (Montana DEQ, 2014). Despite dewatering on the Beaverhead River, it is a blue ribbon trout stream most known for brown trout, as well as rainbow trout, brook trout, westslope cutthroat trout, and Arctic grayling (Carparelli, 2016).

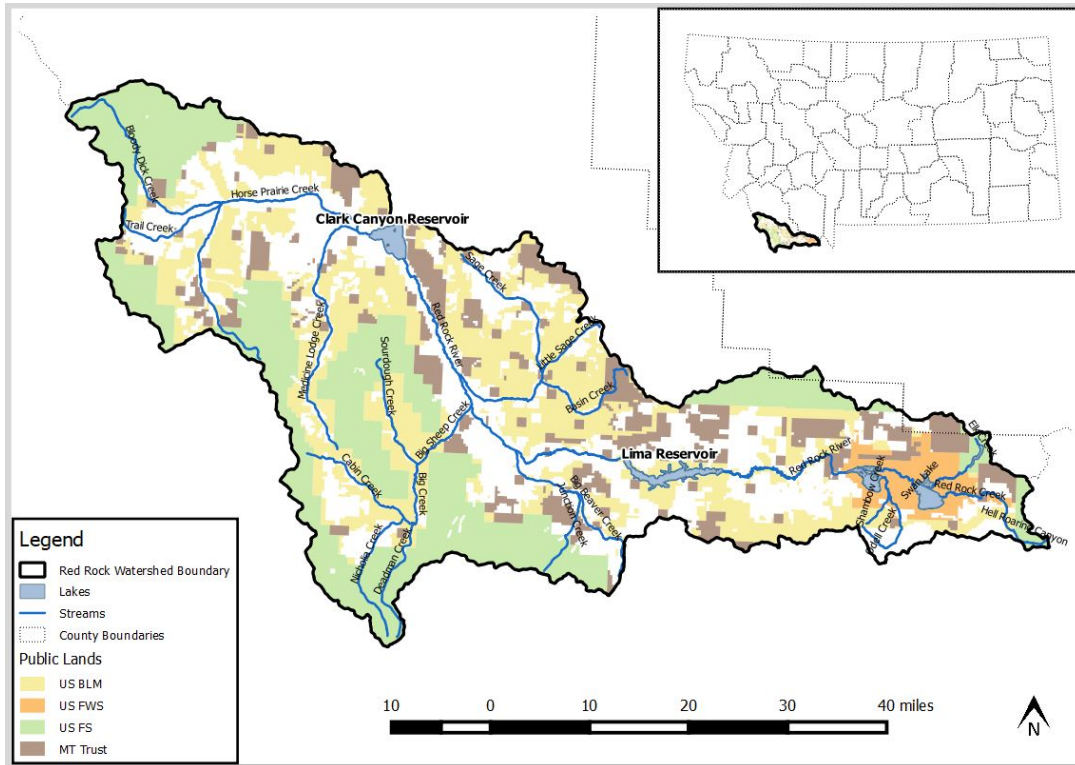


Figure 8. Map of the Red Rock Watershed.

The Red Rock Watershed falls mostly within Beaverhead County, with a small area overlapping into Madison County. The average annual precipitation in Beaverhead County varies dramatically due to topography and elevation with areas receiving 6-12 inches, 12-14 inches, 14-16 inches, or 16-22 inches (NRCS, n.d.; PRISM Climate Group, 2012). Of the 56 counties in Montana, Beaverhead County is one of the top five water withdrawers for irrigation, withdrawing between 400-832 million gallons per day (USGS,

2015). Flood irrigation is still dominant in Beaverhead County although sprinkler irrigation has been implemented in the past decades (Figure 9) (Uthman & Beck, 1998).

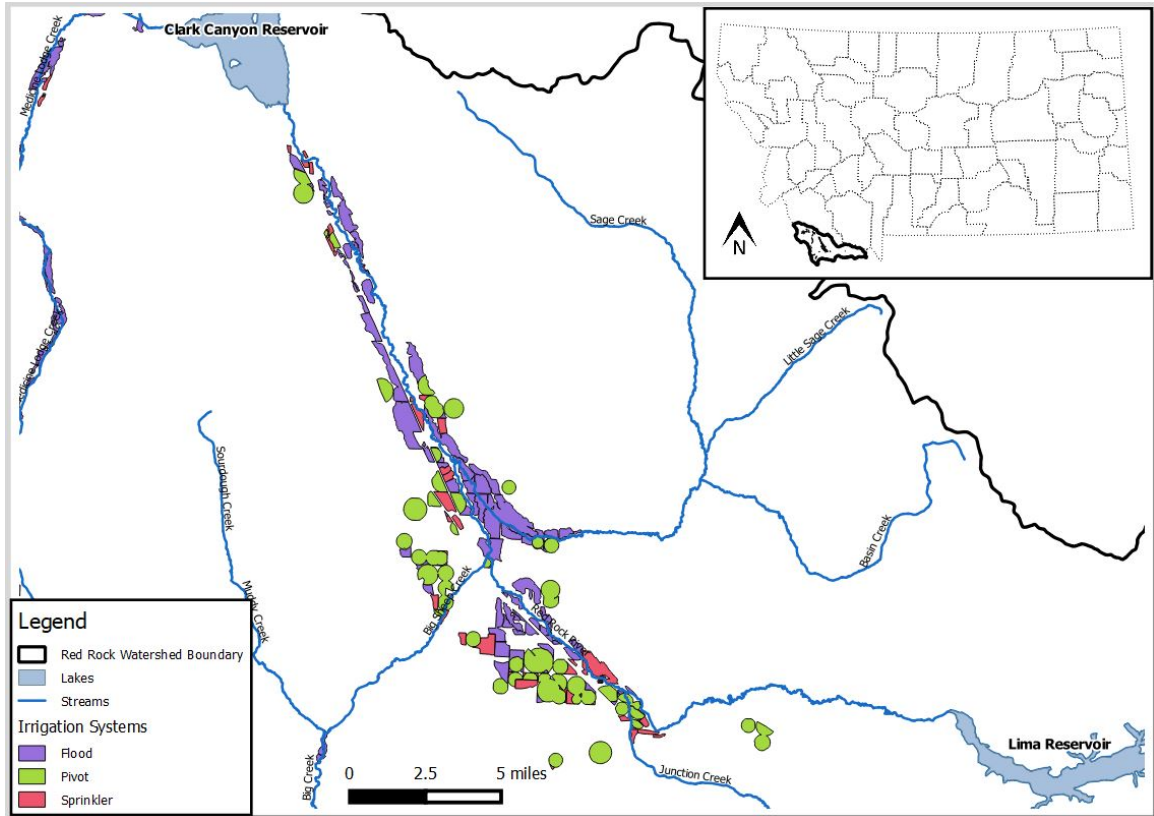


Figure 9. Map of Irrigation Systems in the Red Rock Watershed.

### Social Demographics

Lewis and Clark met the Shoshone American Indians on their land—in what is now Beaverhead County—in 1805 (National Park Service [NPS], 2015). It was with the guidance of Sacagawea that Lewis and Clark were able to determine their location (NPS, 2015). Sacagawea recognized the Beaverhead Rock formation and realized she was close to her homeland (NPS, 2015). Explorers and trappers explored the Beaverhead Valley in the following years (Nicholas, 1990). By the early 1860s, there was a growing population

due to gold and silver mining and agriculture (Nicholas, 1990). In 1865, Beaverhead County became one of nine original counties before Montana was granted statehood in 1889 (Briggeman, 2012). The city of Dillon was established in 1880 and named after the Union Pacific Railroad President Sidney Dillon (Britannica Academic, 2011). Dillon's proximity to gold mines gave it an opportunity to flourish as a railroad town, transporting goods to surrounding boomtowns (Britannica Academic, 2011). Dillon's central location allowed it to usurp the county seat from the contending city of Bannack, and it remains the seat today (Britannica Academic, 2011). As gold mining fizzled out in the area, Dillon survived due to talc mining, the railroad, and agriculture (Britannica Academic, 2011).

There are 3.5 million acres in Beaverhead County, of which, 59% is federal land, 10% is state land, and 31% is private land (USGS, 2016b). Public lands include the Big Hole National Battlefield, Beaverhead Deerlodge National Forest, and Red Rock Lakes National Wildlife Refuge along with large amounts of Bureau of Land Management (BLM), United States Forest Service (USFS), and state land. While the county is one of the largest in area in Montana, it has a population of only 9,434 residents (U.S. Census, 2016; USGS, 2016b). The majority of residents are Caucasian and politically conservative (DOC, 2017b; Leip, 2016). More than 90% of residents have a high school education and 30% hold a Bachelor's degree (DOC, 2017b). Roughly 70% percent of residents work within the county in management, professional, service, or sales professions (DOC, 2017b; Leip, 2016). Agriculture makes up 10% of total employment in the county (DOC, 2017b).

Certain data, such as population changes, migration, residential development, non-labor income, and travel and tourism employment, can be used to assess amenity migration in a region (Hansen et al., 2005; Loeffler & Steinicke, 2007; Shumway & Otterstrom, 2001). From 1990-2016, Beaverhead County experienced an 11% population increase while the U.S. experienced a 29% population increase (DOC, 2017a). While there was not a significant population increase in the county during those years, net migration accounted for 39% of the population change from 2000-2017 (DOC, 2014). Available data for 2000-2010 also shows that the county had an increase in residential development of 60%, compared to the overall U.S. increase of 12% (DOC, 2017a; Theobald, 2013). In 2016, second homes made up 15% of the homes in the county, compared to the U.S. average of second homes of four percent (DOC, 2017a; Theobald, 2013). Changes such as population, in-migration, and residential development suggest an amenity migration influence in the county.

Of the 3.5 million acres in Beaverhead County, 1.4 million acres are farmland (i.e., agricultural production and livestock operations) (USDA-NASS, 2014). The average farm size is 3,211 acres (USDA-NASS, 2014). Ranchers usually rotate their livestock between private pasture land during the winter and spring and public grazing allotments during the summer and fall (Carparelli, 2016). Beef cattle operations are the main type of farm activity within Beaverhead County, and the county often has the largest quantity of beef cows, making it the top producer of beef within the state (USDA-NASS, 2018). Feed crops like alfalfa and hay make up 80% of the 131,000 harvested acres in the county and the remaining 20% of crops are spring wheat, barley, and seed potatoes (Carparelli,

2016; USDA-NASS, 2014). From 1995-2017, agricultural producers in Beaverhead County received over \$32 million in federal government subsidies for commodity, disaster, crop insurance, and conservation (e.g., conservation reserve program, EQIP, agricultural conservation program) (Environmental Working Group, 2018).

### Methods

Qualitative data, such as interviews, can fill knowledge gaps and gather information on opinions or experiences (Hay, 2005). Sayre (2004) sees qualitative research as a way to uncover “historical, political, and economic factors” that quantitative research has missed (p. 668). He calls for future case studies to examine interactions among ranchers and to utilize their local knowledge to inform research needs (Sayre, 2004). Kennedy and Brunson (2007) echo the benefits of using qualitative research methods to interview ranchers and study ranching communities. Qualitative methods evaluate rancher decision-making and behavior in a context-specific manner (Kennedy & Brunson, 2007). It should be noted that interview results should not be used to extrapolate for the whole public (Hay, 2005). For example, results from rancher beliefs in one watershed should not be assumed to be the same for all surrounding watersheds (Hay, 2005).

This research utilized a key informant to begin the interviewee selection process. Key informants may act as gatekeepers or provide access to a community the researcher would not otherwise have (McKenna & Main, 2013). The key informant provided a list of 36 ranch and ranch owner names, which included a main point of contact and an

associated phone number. In most cases, the main point of contact was the male owner of the ranch or the male ranch manager. In a few instances, a husband and wife were listed. It should be recognized that the key informant may have had an implicit bias regarding which ranchers were put on the list due to the key informant's previous interactions or experiences with those ranchers. Each contact that the informant gave was who the researcher ended up speaking with if an interview was conducted.

Each individual or ranch name on the list was contacted a minimum of four times via phone and voicemails were left if no one answered. The researcher introduced herself and explained to potential interviewees that she was a graduate student at Montana State University and would like to visit (a preferred local term over a formal "interview") with them about their water and land management practices. Many landowners were often hesitant to speak with the researcher, stating that they were extremely busy or that they did not want to talk about water rights. The basin is currently going through re-adjudication and water rights are a sensitive topic for many people. Landowners were assured that they would not be asked to give details or information on their water rights and could answer questions to their comfort level.

Interviews began based on the contacts from the key informant's list but were expanded through a snowball sampling technique as interviewees provided suggestions for landowners to visit with next. Snowball sampling refers to an interviewee informally recruiting the next person to be interviewed if they fit the criteria (Hay, 2005). There was significant overlap between the contacts on the key informant list and the snowball sampling recommendations. However, snowball sampling recommendations often

included an alternate number or the permission of the interviewee to use his name when reaching out to a new contact, which often helped secure an interview. Fifteen interviews were conducted from the contacts on the key informant list. Four interviews were conducted from snowball sampling. Midway through the interviewing process, another key informant shared a list of 30 ranches in the area based on water usage. Ten of the ranches were already on the initial list. Many of the additional phone numbers were disconnected or did not correspond to a current landowner living in the area. However, all phone numbers were called at least twice and did result in three additional interviews.

In total, 23 semi-structured interviews were conducted with landowners within the Red Rock Watershed from late August 2017 to mid-February 2018. Of those 23 interviews, one interview with the water commissioner was not included in the set of transcripts coded because he was not a rancher. However, his insight did inform this case study. Interviews were conducted until saturation, or no new information, was reached (Hay, 2005).

In a semi-structured interview context, an interview guide is used as the broad framework for asking questions, which allows some flexibility (Hay, 2005). A semi-structured interview allows an interviewer to follow up on an answer the interviewee gave that is of interest or is particularly revealing and was not in the interview guide (Hay, 2005). Semi-structured interviews do require the interviewer to guide the interviewee back to the interview guide if they veer off topic too much, in contrast to an unstructured interview (Hay, 2005).

The interview guide used in this research (Appendix A) remained the same throughout the interview process, while details such as interview location, interview length, and people present did vary by interview. Eighteen interviews took place on ranchers' properties, ranging from visiting in a living room to balancing on the back of a flatbed truck, but were commonly conducted inside a home or ranch headquarters. Two interviews were conducted in Bozeman as the rancher passed through town and two interviews were conducted in Dillon as the rancher had time to meet between errands. Interviews ranged from 30 minutes to 1.5 hours with an average interview lasting around 55 minutes.

A representative from the Beaverhead Conservation District accompanied the researcher on 14 of the 23 interviews. The Conservation District was writing a new watershed management plan, and the representative asked questions regarding ranchers' main use of the land and water, their concerns about water quality and quantity, what they valued most about the land, and if they wanted any technical assistance or education. These questions were a good introduction and set the stage for the researcher's more in-depth questions which were always asked afterward.

Interviews began with a brief restatement of the project goals followed by obtaining the interviewee's informed consent with a signed Montana State University (MSU) Institutional Review Board (IRB) form. Interviewees gave verbal approval for the interview to be recorded and were reminded their interviews would be kept confidential. The interview process and guide were approved through the MSU IRB. The researcher asked a series of questions related to drought and two natural water storages practices,

specifically flood irrigation and beaver mimicry. Examples of drought questions included asking the interviewee to describe drought in their watershed, what they see as the causes and impacts of drought, what type of responses (proactive or reactive) they take to deal with drought, any regulatory barriers they run into when they are dealing with drought, and any innovative strategies they had used or heard about using when in a drought.

Next, interviewees were given a brief description of natural water storage and asked if they were familiar with the concept. They were then told that flood irrigation and stream restoration, particularly beaver mimicry projects, are considered by some people to be natural water storage practices. The interviewees were given handouts that had pictures of flood irrigation, sprinkler irrigation, and beaver mimicry to help familiarize them with these practices (Appendix B). The interviewees were asked to describe the type of irrigation system they had (flood or sprinkler), what they saw as the advantages and disadvantages to each system, if they would switch back to flood irrigation, and what the practical and regulatory barriers would be to switching back. For stream restoration, the interviewees were asked if they had ever implemented this practice on their property, if they saw stream restoration as being helpful in mitigating water shortage or drought, and what they saw as the practical and regulatory barriers for implementing these practices.

After the data collection process, the data entry and analysis processes began. Audio recordings of the twenty-two interviews were transcribed. The transcripts of the interviews were coded for themes using NVivo software (version 12). One interview was not recorded (and another half of an interview was inaudible due to background noise)

but notes were taken and the notes were coded. The first round of coding took a deductive approach focusing on themes expected to be present in the interviews. The second round of coding used an inductive approach, searching for themes that emerged from the interviews.

All the ranchers ran cattle operations, except one who had bison. All ranch operations were at least 1,000 deeded acres. Some ranches were only 1,000 or 2,000 acres; others were as large as 46,000-300,000 acres. Ranchers had permits to graze on BLM, USFS, or state land. Of the interviewees, 14 were classified as traditional ranchers and eight were classified as amenity ranch managers. The researcher classified ranchers as “traditional” if they said their main source of income was from the ranch, that they ran the ranch with their family, if they spoke of their parents, grandparents, or previous generations establishing the ranch, and/or they compared their livelihoods, incomes, or values to those of amenity ranches. Absentee owners whose main source of income did not include the ranch were classified as “amenity” ranchers. Amenity ranchers employed a ranch manager to direct day-to-day operations, and some compared their ranch to traditional ranches. The interviewer spoke with traditional amenity ranch managers, as the amenity owners were unavailable. The amenity ranch managers’ answers were understood to be the views and goals of the amenity ranch. This is a more simplified typology than other studies have used. It was chosen because ranch income, off-ranch work, or specific lifestyle values were not explicitly asked about during the interview process making it difficult to separate ranchers into more detailed categories.

Furthermore, this study was focused on differences among specific beliefs and behaviors (e.g., government trust and climate change beliefs) between the different ranchers.

All of the ranches except one had a stream running through their property, and all of the ranches used water for irrigation or stock water. Fourteen ranchers used a mix of flood and sprinkler irrigation on their fields<sup>1</sup>. Most mixed systems were center pivot except for one which was a hand move and one which was only identified as sprinkler. Five ranchers used only flood irrigation on their operations and two used only center pivot irrigation. One amenity ranch did not irrigate the ranch within the case study watershed but irrigated ranches outside the watershed.

There was not a great range of diversity in terms of rancher demographics. All of the ranchers who were interviewed were male. Nine ranchers were born in the area and five ranchers had been there ranching for 20 years or more. There were five ranchers that lived and ranched in the area for over 10 years and three ranchers that had lived and ranched in the area for five years or less. Only three of the ranchers interviewed were retired.

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<sup>1</sup> Ranchers that had both flood irrigation and sprinkler irrigation used the systems on different areas of land on their property.

## CHAPTER FOUR

## RESULTS

Results

The results are organized in the categories of drought definitions, drought planning and drought responses, barriers and opportunities of flood irrigation, opportunities and barriers of beaver mimicry projects, differences between amenity and traditional ranchers, and views toward government agencies, nonprofit organizations, and resource management entities. These categories allow for deeper exploration into the beliefs and behaviors of individuals in this community.

Drought Definitions

Ranchers provided their views on the definitions, causes, and impacts of drought in their watershed. Ranchers defined drought largely by its indicators. The most common ways ranchers defined drought were a lack of water, a lack of “timely rain,”<sup>2</sup> dry, lack of snowpack, and lack of moisture. A lack of water was the most common way to define drought. In some instances, it was specified as lack of irrigation water while others referred to a lack of water or a water shortage as affecting plant and animal health. One rancher succinctly defined drought as: “The simple answer is when we don't have any water.” Another rancher added to this definition, specifying a lack of water affects plants

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<sup>2</sup> Ranchers used this term differently but it usually referred to the best time of year for rainfall.

and cattle: “I guess to me it would be a water shortage that affects the health of the plants. And dries up traditional places where cattle can drink from live water. That would be *my* definition anyway.”

Ranchers used indicators such as “timely rain,” moisture<sup>3</sup>, and snowpack to define drought and to explain what caused drought. Often, ranchers used past years as a reference for current conditions. This is in line with Vose et al. (2016), who state that meteorological drought relates to a reference condition.

Similarly, ranchers explained the causes of recent droughts as less moisture, less rain, or less snowpack than previous years, taking a historical approach in line with the Standardized Precipitation Index, which uses historical precipitation data. One older rancher, whose grandfather homesteaded their ranch, provided insight into the necessity of rainfall in the area: “It's gotta be rain. My dad always said the oldtimers used to bet on rain 28 days in June and they'd win their money. But nowadays, if you bet on two days you'd have more chance.”

A different rancher summarized similar ranchers' statements about lack of moisture and snowpack. He said:

We don't get moisture in the winter time. It appears to me that we don't get as much snow as we used to. Whether that's accurate or just my ignorant perception of...why things [are] different this year than they were last year. Did it really not snow as much or did it snow more? I don't know. The reality of it to me seems like we don't get the snowpack. And if we don't have snowpack it makes a tough summer.

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<sup>3</sup> Ranchers did not specifically define moisture. Some referred to moisture from precipitation or snowpack, while others referred to soil moisture.

Ranchers also named cyclical factors and “Mother Nature” as the causes of drought. These causes of drought differ from research that finds climate change leads to more drought periods (Dai, 2011; IPCC, 2014; Whitlock et al., 2017). Cyclical factors and “Mother Nature” as causes of drought had similar meanings to ranchers, in that the watershed had gone through wet and dry periods throughout history. Most ranchers did not connect changing amounts of rain, snowpack, or moisture with climate change. One rancher reiterated multiple times during the visit: “It’s just ‘Mother Nature.’ You’ve got your droughts and you’ve got your wet years and you’ve got your winters. That’s the way it is.” Another rancher confirmed the previous response by adding: “I think it’s a cyclical thing and a totally random thing. The more you try to guess what it’s going to be in a given year the more wrong you tend to be.”

Contrary to the abundance of scientific literature on climate change, only two ranchers, one amenity ranch manager and one traditional rancher, saw climate change as the cause of drought. The traditional rancher expressed his views on the changing climate in the area as: “Mostly due to some climate change. I think we’ve had some climate change. That’s just my personal opinion. I think there has been some climate change in the last 20, 25 years.”

Ranchers typically defined drought using a meteorological classification, where a lack of precipitation leads to a lack of water. They identified the impacts of drought in an agricultural drought sense, relating the decreased plant growth to impacts on their operations. Decreased agricultural production was the main impact of drought. Decreased grass and forage production were the direct impacts and decreased cattle production was

an indirect impact from reduced grass and forage. One rancher summarized the impacts to his operation as: “Decreased production in grass and forages. That translates into decreases in animal production.” Another rancher linked his drought definition (i.e., lack of water) with the impacts he experienced. He said: “When we’re into those extreme dry years, of course, we see less production. In this country, your production is pretty much tied to how much water you put on it, to a point.”

Two ranchers noted that drought impacts are usually felt more intensely during the second year of a drought. One rancher emphasized that drought doesn’t just happen as an isolated event, but can have lasting consequences. He said:

Usually we can get by the first year pretty good. It’s the second year that animal health and reproduction is poor. Plant health is poor. Recruitment of new young plants is poor. It isn’t just one year and you’re out. You’ve got to watch it for a couple of years.

A different rancher related the impacts of consecutive drought years back to production.

He said:

If you have a drought two years in a row, then you see a real severe decline in the amount of production. You can get by with one year, it seems, with lower water, less water, less rainfall and it doesn't impact the production as much as if you get into your second dry year, then you have a tremendous decrease in production.

None of the ranchers saw humans as drivers of drought. Only one rancher mentioned the impacts of drought on people. He said: “Some of the drought years put a lot of stress on people, it's a human thing too. It's not just climate.”

### Drought Planning and Drought Responses

None of the traditional ranchers had formal drought plans in place. Five amenity ranch managers had formal proactive drought plans in place. One amenity ranch manager saw proactive drought plans as essential in the livestock business, stating: “As a rancher we always have drought management plans. We have to have that.” Another amenity ranch manager discussed the indicators he used in his drought plan that governed how he changed his management strategy. He said: “We have a drought plan where if by whatever date it is, June or April, we have different dates of the year where if we don't have so much moisture by then, we'll cut the numbers [of cattle] back.”

Ranchers who did not have formal drought plans employed proactive and reactive strategies depending on the circumstance. The most common reactive drought responses were: selling cattle early at lighter weights, buying hay, moving or shipping cattle, destocking or changing cattle numbers on the pasture, and using less water or shutting off water early. Sixty-three percent of ranchers sold cattle early as their main reactive response. Many of these ranchers saw the impact of less hay production to be the force behind their response to sell cattle. One rancher said: “We're unable to produce the amount of hay we needed to produce. We had cattle, we had to sell light calves early that year, so it's drastic when you're in this business.” Another rancher talked about buying more hay in hopes of avoiding his “worst case scenario” of selling cattle: “[I] usually wind up having to buy more hay. I can usually get by with just that.” Ranchers did not mention federal government assistance as part of their reactive responses or as a possibility to be used for proactive responses even though many in the area had received

some type of crop, livestock, or commodity federal assistance in the past 20 years (Environmental Working Group, 2018).

Ranchers mentioned fewer proactive responses to drought compared to reactive responses. This is not surprising as many state and federal drought responses for agriculture in Montana are still reactive (Kuglin, 2016; Wilhite, 2014). The most common proactive responses were: having a grazing plan, changing grazing management, storing hay, or developing springs and wells. Storing hay as a response was also found in other studies, but additional proactive responses like resting pasture or changing livestock types were not mentioned in the Red Rock Watershed (Coppock, 2011; Dunn et al., 2005; Roche, 2016). One rancher explained his proactive response, which included storing hay and changing his grazing management. He said: “Basically, preparation for drought is just a cushion of maintaining a little extra hay, maintaining a little extra pasture, and being able to not run at your maximum amount every year.”

For some ranchers, their proactive strategies developed after experiencing drought in the area for many years and deciding to get ahead of the next drought. For others, their proactive responses were a product of their grazing management goals. For instance, a few amenity ranch managers talked about their grazing plan as a way to increase production but also take better care of the land, which would hopefully cushion them when drought did hit. One amenity ranch manager explained his use of rest rotation pastures:

Pretty much everything is rest rotation pastures here. We always rest a pasture every year. That helps for nutrient load, from grass production, from drought. So, we're always going in on fresh pasture the next year. That

always helps us. So even in a drought you have a little time to take to make a good decision.

Another amenity ranch manager used intensive grazing and not growing hay as part of his proactive drought strategy. He said:

For instance, how we graze on this [ranch], we don't hay much anymore. We're just doing intensive grazing for the most part. Yeah, we have cattle there for short periods, like 24 hours, and move them. If we can leave some canopy, that's the biggest thing we see. We just don't get the water back. We don't let things get dry again.

In the context of the theory of planned behavior (TPB), it makes sense that most ranchers in the Red Rock do not have proactive drought plans in place. Ranchers described the causes of drought as physical indicators like low snowpack or lack of “timely rains,” or as environmental phenomena like cycles or “Mother Nature.” Ranchers also said how hard it was to prepare for a drought or predict that a drought was coming. The difficulty to prepare due to lack of control or prediction matches results put forth by Haigh & Knutson (2013). Said best by one rancher: “We can’t ever predict. I look at the weather and I don’t go more than three days out. I’ve been looking at it the last couple days and three days out they’ve already changed it.” If ranchers believed that they did not have much control over causing a drought or preparing for a drought, it would impact their level of perceived behavioral control. Ranchers felt they had less perceived behavioral control over proactively planning for a drought, either due to inaccurate weather forecasts as the previous rancher mentioned or that proactively planning didn’t change the limited options a rancher had once a drought occurred. The limited options available to ranchers may be why they preferred a crisis management or reactive

approach that focused on the economic impacts of drought, which was the main impact they described. As one rancher said:

For one thing, it's really hard to prepare for a drought it seems like. Because when we get into a drought, you just don't have a lot of options. Everything is dry. There is no feed. There is no place that you can move the cows to. There is no place that you can go to get the water to turn the pivot on. You just sort of have to respond to it based on what the economic factors are.

### Opportunities and Barriers for Flood Irrigation

One of the behaviors of interest in this study was the conversion of sprinkler irrigation back to flood irrigation. According to the TPB, attitudes, subjective norms, and perceived behavioral control will influence a person's intention to perform a certain behavior (Ajzen, 1991). In the case of flood irrigation, ranchers had positive and negative attitudes toward flood irrigation, felt some perceived behavioral control over converting back to it, and saw subjective norms playing a small role in their decision.

The positive attitudes toward flood irrigation came from its ability to replenish aquifers and groundwater. One rancher talked about the benefits of flood irrigation by explaining a sprinkler system: "The problem is with a sprinkler, as you know, we don't replenish the water table with it or recharge the aquifer." Another rancher added that flood irrigation provided streamflows. He said: "I think the biggest thing is the more ground you can flood irrigate, the better it returns to the streams."

Ranchers had negative attitudes toward flood irrigation due to the lack of labor availability. Labor availability included people willing to or possessing the expertise to flood irrigate. One rancher talked about labor in terms of willingness. He said: "The big problem you have with flood irrigation is the labor involved. You've got a lot of ditch

maintenance, headgates, ditches, diversions in the river.” Another rancher talked about labor in terms of expertise: “My biggest concern would be labor today. Because I’ve tried to find somebody that has a little bit of experience to help with some flood irrigating on our 800 acres that we still flood. It’s tough.”

Ranchers discussed their lack of perceived behavioral control with regards to production, in that sprinkler irrigation was more productive. Ranchers used “production” in two ways. One type of production referred to irrigating and using land to grow crops that was not previously irrigated under flood irrigation. The other type of production referred to the productive capacity of the land in terms of crops per acre increasing under sprinkler irrigation. One rancher explained the desire to use sprinkler in order to use all of the available land:

There's pivots in this valley that have taken less productive ground and made it more productive by putting a pivot on it. Because maybe you couldn't get at the top of the circle or top of the pivot, you couldn't get that water up there, now you can with a pivot system.

Another rancher explained the increased production in specific terms for his operation:

You figure under sprinkler, you should get a good three tons to the acre out of a hay crop. Well at \$100 bucks a ton, that adds up. You take a thousand acres out of production and put it into 300 [acres] or 400 [acres] of flood, it's going to be huge.

Interestingly, over half of the ranchers believed that the efficiency gains of sprinkler irrigation resulted in less water use. Many of the same people commented on the increased production they received from sprinkler irrigation either by crop per acre or putting more acres into production. Their belief that sprinkler irrigation does not increase consumption is contrasted with results put forth by Berbel and Mateos (2014), Perry et al.

(2014), and Scott et al. (2014). One rancher concisely described sprinkler irrigation efficiency, specifically center pivots. He said: “The pivots, I think, do an amazing job of more efficiently spreading water.”

Perceived behavioral control of converting to flood irrigation can also be viewed through the regulatory barrier of water rights. Ranchers expressed divergent views on how much of an obstacle water rights would be if someone wanted to convert back to flood irrigation. Some ranchers thought that those that currently used sprinkler systems would need more water to adequately convert back to flood irrigation. These ranchers thought that if someone’s sprinkler system had been in place for many years (as most had) their water rights could have been re-adjudicated resulting in that person having rights to less water since sprinkler is more efficient. One rancher’s response encompasses many of these ranchers’ views. He said:

When you move from one system to another, in particular from flood irrigation to a pivot, you quote unquote use water more efficiently. For example, let's say to flood irrigate it took, it took 200 inches to irrigate 100 acres. With a pivot, it might only take 50 inches of water to irrigate. Then the DNRC will take that extra 150 inches because you're not using it. There's no beneficial use.

Other ranchers reasoned that as long as a person had a water right, changing it back to flood irrigation would not matter. As one rancher said: “State wise, the NRCS water rights might look at you kind of funny. But I don’t know that they could do anything or would object because it is your water.”

Ranchers agreed that sprinkler irrigation was more efficient and did not feel that sprinkler irrigation had the potential to increase water consumption. One rancher

reiterated that there was more water available in the watershed once someone converted to sprinkler:

Say you've had a flood system and you've got water rights to...well what do they figure, an inch to the acre, I think. So, if you've got 400 inch water rights that you're going to irrigate, well, let's just say it's 300 acres, like in our case over there. You've got 300 inches of water to irrigate that, according to the law. Then you put that into sprinkler irrigation, like that pivot over there, I think it's 172 miners' inches of water on 300 acres. Somebody is going to come along and want that water that you're not using.

The attitudes toward flood irrigation such as the frustration with finding labor and the perceived behavioral control factors such as agricultural production and water rights resulted in none of the interviewees proposing an incentive or a situation where a rancher would convert back to flood irrigation in earnest. A few ranchers mentioned that if significant funding were available or someone wanted to convert as an environmental gesture, it might be an option, but they did not see that realistically happening. One rancher talked about converting to flood irrigation for the environment but did not have much hope it would actually happen. He said: "That's about the only thing I can think of is that you get yourself a little 'atta boy' for trying to get the aquifer back up." Another rancher confirmed that converting back to flood irrigation was not going to happen. He said: "You can keep the flood irrigation you have but I don't think you can go back to it."

Ranchers saw converting back to flood irrigation as improbable. If there was a slight chance that they or another rancher in the basin did convert back to flood irrigation, subjective norms played a small role. Subjective norms include social pressures, what referents think a person should do, and what referents are doing themselves (Ajzen & Fishbein, 1980). Ranchers discussed the barriers of labor and production outcomes to

flood irrigation more than subjective norms. Subjective norms played less of a role in influencing ranchers' views about flood irrigation than other studies like Borges and Oude Lansink (2016) or Willcox et al. (2012). The subjective norms mentioned were property rights, usually water rights, and increased water availability. Property rights helped in creating subjective norms for ranchers because many of them commented that their neighbors were free to do what they wanted on their own private property up until it affected their own water rights. One rancher discussed what would happen if his neighbor converted to flood irrigation. He said: "As long as it didn't affect my irrigation at all, whatever they did above me... I wouldn't have a problem at all. It's their private property. But if it affects my irrigation or my water rights or something like that...and I don't see anybody doing that."

Ranchers thought if someone switched to flood irrigation their neighbors, especially their downstream neighbors, would be pleased since more water would return to the streams or aquifers. One rancher talked about the benefits for a downstream neighbor and for springs in the basin. He said:

I would think if you were a neighbor downstream, it would probably be beneficial if somebody upstream went back to flooding. You could potentially get some sub water [groundwater] out of it. If there are springs on their property, it might increase those springs. I would think [that] would be beneficial.

### Barriers and Opportunities for Beaver Mimicry Projects

Similar to converting to flood irrigation, ranchers' concerns about implementing beaver mimicry projects centered on attitudes and perceived behavioral control; subjective norms were less influential. Many ranchers were not familiar with beaver

mimicry projects before the interview. Ranchers beliefs and attitudes toward beaver mimicry projects were a mixed bag. It is also likely that ranchers' previous experiences with beavers or similar projects influenced their attitudes toward beaver mimicry projects.

The interviewer reiterated that these projects did not entail reintroducing or relocating beavers to private property. However, some ranchers spoke of letting beavers build on their property in the right locations while others spoke of their dislike for them. One rancher said: "Honestly, if [beavers] build in the wrong spot, they're kind of a pest." Another rancher voiced his skepticism for beaver mimicry projects through his experience with other restoration projects. He said: "But for a rancher that say, is just flood irrigating his pastures, to spend the money it takes for restoration. You'll never recoup it. We figure it takes about \$1,000 per mile to do [stream restoration]. So that's a huge expense."

Some ranchers did express a negative attitude toward the behavior itself. They believed that the impracticality of beaver mimicry projects on their property outweighed the potential incentives, such as financial assistance or additional water storage. One rancher said: "From an operational standpoint, [beaver mimicry projects] don't make sense. Maybe from an environmental standpoint, it does." A different rancher took a stronger stance, questioning how much water beaver mimicry projects could store. He said: "I can't believe that would do much good. [Beaver mimicry projects] wouldn't store enough water... I think it's just a fantasy."

More than half the ranchers interviewed cited cost and permitting as the biggest barriers for implementing beaver mimicry projects. In terms of perceived behavioral control, ranchers were split on the degree to which permitting was a barrier. Some ranchers saw permitting as a regulatory step, which was easily obtained at the Conservation District office. One rancher said: “If it’s just a 310 [permit] that we get in here at Beaverhead County, that’s not too unreasonable.” Another rancher viewed obtaining a permit as much more of a burden. He said:

I wanted to do a few things [in the river] and they make you jump through a lot of hoops. So, I just finally, I threw up my hands and said I'm done doing the 404 and 310 permit. It just wasn't worth it. I thought it would have benefitted things, but they put up a lot of...they had their own idea of what I needed to do.

Another rancher added his dislike of the permitting process. He said: “Christ...you just look at this Red Rock [River] and you've got to get a 310 permit.”

The majority of ranchers recommended financial help, whether through grants or cost share programs, as the main incentive to implement beaver mimicry practices. One rancher stated: “Funding, that motivates. If you want to get something done... offer [ranchers] some money. That’s what it boils down to.” Another rancher echoed the sentiment, he said: “If there was a way to subsidize the cost of the actual construction then I think people would be more on board with it.” Other incentives such as technical assistance, added land value, or trained crews were only mentioned a handful of times.

Water rights were the only subjective norm mentioned when ranchers discussed beaver mimicry projects. Subjective norms provided mixed results, but were mentioned by over half of the ranchers. Ranchers again echoed that they would not interfere with

their neighbor's water rights, and people were free to implement practices as long as it didn't affect their own water rights. Some ranchers thought that if a basin was adjudicated and one person put in a beaver mimicry project, the water used in a beaver project would just be part of that person's existing water rights. One rancher said: "If you're doing stream restoration, it wouldn't be a problem for anyone that was in an adjudicated area. Because they're going to get their water from the water commissioner, no matter what." Another rancher saw neighbor relations as more contested, in that people would not allow him to implement these strategies because it may negatively affect them. He said:

Anything like [beaver mimicry projects], yeah those are great ideas and they're cool but you won't get them to work up here because people fight it. Any kind of change is perceived as a negative use on the water. They would rather see it run by than let me have it. That's the reality.

#### Differences between Amenity and Traditional Ranchers

The results show that there are differences in amenity and traditional ranch operations. However, these differences do not fall neatly into one category or the other, and are often ranch dependent. Traditional and amenity ranches employ different management strategies or have different goals for the land. Only amenity ranches had proactive drought plans in place. Amenity ranch management goals usually stemmed from the desires of the owner, which varied from wanting to see more elk on their property to reintroducing bison on the landscape to providing recreation for anglers and friends to managing the land as an investment. These goals are in line with other amenity migration research (Gosnell & Abrams, 2009; Sorice et al., 2014). One amenity ranch

manager described one of the goals of the ranch: “[For] the owner of the ranch, one of their visions and dreams is to move some elk on the place.” A different amenity ranch manager stated that the recreation value of the ranch drove many stream restoration projects. He said: “The primary reason for a [stream restoration project] was fishing but that’s how we got [it] sold to the owner.”

Traditional ranchers spoke of their goals as primarily economic, such as growing grass and raising cattle. They did also have an interest in protecting the water and the land. One traditional rancher said: “Probably the biggest thing is we make our living, this ranch we operate under, is our only income. So, we’re going to protect our land, the resources we have, to continue this whole environment we live in.” Another traditional rancher went further, voicing his frustration that people assumed that the economic goals of ranchers don’t coincide with resource management goals. This feeling echoes findings by Haggerty et al. (2018) where ranchers did not agree with the public perception of them as degrading the resource. He said:

Ranchers have become somewhat offended by the fact that people say, ‘well, you’re not taking care of the resource.’ That’s not true. Ranchers take care of the resource better than anybody else could because they’re the most concerned about making a living on it.

Some traditional and amenity ranch managers pointed out the uneven financial resources available to amenity ranches that made it easier for them to implement new strategies. One traditional rancher spoke of the ability for amenity ranches to put in stream restoration projects due to their wealth, and remarked that it was impractical for a traditional owner. He added: “A cattleman can’t do [stream restoration projects].” An

amenity ranch manager agreed with that sentiment as he discussed one of his restoration projects. He said:

Not everybody and not every year are you able to financially do these [stream restoration projects]. That project took a couple years to pay for. We were in a different situation at the time than the average rancher. Fully aware of that. The family operation would have probably waited until there was a program to help them with that.

Views toward Government Agencies, Nonprofit Organizations, and Resource Management Entities

The results also suggest the approach taken by government agencies, nonprofits, or other resource management entities should be reexamined and adjusted when engaging with the Red Rock community. Various instances exemplified the wariness ranchers had toward the researcher based on her background or biases. The response put forth by ranchers was one of confusion and disbelief when asked if they or their neighbors would switch back to the flood irrigation. Their responses seemed to indicate that only someone unfamiliar with the area or life as a rancher would propose that as a solution. One rancher said simply: “I’ve just never really thought of [converting back to flood irrigation] as a possibility that people would consider... I’d never thought of someone actually doing that.” Another rancher provided a persuasive analogy of what converting to flood irrigation meant for ranchers in the basin. He said:

[A] new pivot costs \$70,000. Who's going to, why would he do that? It's like getting a brand new car. You've got a \$70,000 Mercedes and you're going to say you're getting rid of that and I'm going to give you a dang old Impala. Plus, you're going to have to take more time to work on it and it's not going to be as easy to manage. And that's what you're asking these guys.

Ranchers expressed mixed feelings toward working with government agencies, nonprofits, and other resource management entities. Ranchers did not usually differentiate between the state and federal government when discussing partnerships and associated issues with them. Often, ranchers mentioned the “government” in general to encompass agencies they routinely interacted with, like the BLM, USFS, NRCS, or the Conservation District. Other ranchers discussed specific government agencies or nonprofit organizations by name.

Some amenity ranch managers believed they were more willing to work with the government or other organizations than traditional ranchers. However, over half of all the interviewees said they had good relationships with government agencies, nonprofits, and other resource management entities. One rancher talked about how his ranch partner gets along with government agencies. He said: “The family gets along pretty well with all our agencies. I would like to think that we have a good relationship with them because it seems like, whatever [the other ranch owner] says, [agencies are] fine with it.”

There was not a consensus on the elements of a good partnership, however, flexibility, trust, and being local were each mentioned at least four times. One rancher talked about the NRCS and local Conservation District. He said: “Both of those groups have good relationships and have people on the ground. Like I said, you’ve got our local people on the advisory boards and everything. I think it’s a good level of trust already built there and established.” Other research has found that the elements of trust and flexibility are factors for a good relationship between ranchers and government agencies (Brain et al., 2014; Kennedy & Brunson, 2007; Wilmer et al., 2016).

Half of the ranchers recommended the NRCS as the entity they would prefer to work with or receive technical assistance from for natural water storage projects. One rancher elaborated on his trust in the NRCS. He said: “I would say the NRCS, people have good faith in them. They can get their hands on good technical papers. So that is where [the information about natural water storage projects] would have to come from.”

Even if amenity or traditional ranchers thought government agencies were their partners, many expressed a spectrum of dissatisfaction, which did not fit neatly into a few themes. Dissatisfaction was conveyed by disagreement with grazing plans (especially government agencies wanting fewer cattle on the land), assertions that the government wastes money, the complaint that strings are attached to government funding, and the frustration with inconsistent and frequently changed government policies and personnel. Ranchers also were dissatisfied with the lack of monitoring or on-the-ground experience of agency personnel, the lack of concrete decisions or answers from agencies, and the feeling that agency policies were politically motivated. One rancher commented on the strings attached to government funding. He said: “You got some ranchers who don’t want any help from the damn government. I don’t know how you’d get around that.” Another rancher said he didn’t want the government on his property due to past encounters. He said: “I don’t want anybody from the government on my ground that doesn’t have to be there. Because my experience with the government is not good.” Another rancher felt that government policies hindered his ability to make a living as a rancher. He said:

I do not begrudge government people. I like most of the ones I know and they work hard. In terms of the policies that they enforce, [those] could be very deleterious to our ability to make a living here which is, I think, the reason they're there.

Finally, a different rancher compared the government (in general) as a barrier as large as the weather for ranchers. He said:

The point is, is that if you're from the government, that's not good. People ask me what are your biggest difficulties as a rancher and I say the weather and the government. That's it. Now I can't do anything about the weather but boy the government gives me a lot of grief.

This suggests that ranchers' relationships with state and federal government agencies, nonprofit organizations, and other resource management entities are more complicated than simply liking or disliking them. It seems that many attitudes toward government agencies stem from prior experiences with them. At the same time, ranchers were not insulated from working with government agencies since they lease land from the BLM, USFS, or the state. Other government agencies adjudicate ranchers' water rights and regulate their irrigation. Many ranchers who criticized agencies also talked of their working relationships with them. It seems ranchers may feel they have little control over interacting with the government when it comes to land leases or water rights, but they do have control over voluntary behaviors such as converting back to flood irrigation or implementing beaver mimicry practices on their own land.

## CHAPTER FIVE

## CONCLUSION AND DISCUSSION

Conclusion

This thesis has examined the barriers and opportunities of implementing natural water storage practices as a drought adaptation strategy in southwest Montana. Flood irrigation and beaver mimicry practices were the two natural water storage practices discussed. Ranchers' attitudes and perceived behavioral control were more influential toward determining their desire to implement natural water storage practices than subjective norms. Flood irrigation, though inefficient in using water, provides benefits for the surrounding ecosystems and human communities. Flood irrigation saturates the soil profile and water returns to groundwater or aquifers, often coming out as later season streamflows. Flood irrigation also creates and sustains wetland habitat. Beaver mimicry practices slow down water through the creation of pools, spread water out over the floodplains, and reconnect incised streams with floodplains. While flood irrigation and beaver mimicry have the potential to function as natural water storage practices, the degree to which landowners would be interested in adopting these practices is uncertain.

The case study of the Red Rock Watershed demonstrated that amenity and traditional ranchers acknowledge the natural water storage benefits of flood irrigation. However, the barriers associated with flood irrigation, such as cost and loss of production, do not make flood irrigation a practical strategy. Ranchers could be offered incentives to keep existing flood irrigation, but it is unlikely that they will convert from a

more efficient system back to flood irrigation. Ranchers expressed that the main barriers to beaver mimicry practices were financial. Many ranchers explained that using their limited time to implement or maintain beaver mimicry projects would take away from running their ranch. Additionally, not all ranchers were convinced of the potential benefits of beaver mimicry (i.e., increased water storage). Ranchers were concerned with the disadvantages of beaver mimicry practices, like unclear water rights implications or disruptions to their operation from flooding or beavers themselves. Most ranchers recommended financial assistance as the primary incentive to encourage the implementation of beaver mimicry practices.

To ensure the success of beaver mimicry practices or other natural water storage strategies, it is also imperative for government agencies, nonprofit organizations, and other resource management entities to improve their relationships and communication approaches with the community.

Ranchers who felt little perceived behavioral control over natural water storage practices could benefit from having a plan (Gärling & Fujii, 2002; Kidwell & Jewell, 2010). Plans can increase perceived behavioral control which can increase the likelihood of performing a behavior (Gärling & Fujii, 2002; Kidwell & Jewell, 2010).

Mase et al. (2017) suggest that improving weather forecasts and other tools that address specific risks for ranchers can be more useful than broadly discussing the impacts of climate change. This strategy can be especially useful for ranchers in the Red Rock Watershed since many of them defined drought as part of an environmental cycle or “Mother Nature,” usually driven by changes in snowpack, rainfall, or moisture. At the

same time, ranchers are a diverse group, so outreach strategies will be more effective when they consider the differing perspectives ranchers have toward drought or climate change (Arbuckle, Tyndall, Morton, & Hobbs, 2017). Numerous case studies highlight the need for ranchers to have flexibility in their operations, whether in their management practices or with institutions they work with (Brain et al., 2014; Dunn et al., 2005; Haigh & Knutson, 2013; Kennedy & Brunson, 2007; Roche, 2016; Roche et al., 2015; Sayre et al., 2012; Wilmer et al., 2016).

Carlton et al. (2016) explain that adaptation attitudes are also diverse and will not necessarily change because someone feels more at risk due to extreme events. Policies that only focus on increasing risk perceptions can fall short in convincing people to adopt adaptation strategies (Carlton et al., 2016). Most ranchers in the Red Rock Watershed did not see drought as an effect of climate change, which can make them less inclined to adopt adaptation strategies (Carlton et al., 2016). Government agencies, nonprofits, and other resource management entities interested in helping ranchers implement adaptation strategies should remain flexible and incorporate local rancher knowledge (Knapp & Fernandez-Gimenez, 2009).

Ranchers have unique knowledge that comes from lived experience and familiarity with an area that can complement scientific knowledge (Knapp & Fernandez-Gimenez, 2009). The integration of ranchers' knowledge can help make interactions and policy decisions more collaborative. Ranchers in the Red Rock Watershed expressed a desire for their needs and goals to be of equal importance when making policy decisions. While many of them did not have an interest in working with the government, one

individual was mentioned by every single rancher and many government officials as an innovator and wealth of knowledge. This individual could work as an intermediary between the community and government agencies, nonprofits, or resource management entities.

There is no one size fits all solution to mitigate the effects of drought and climate change. However, further research on natural infrastructure and natural water storage, which aim to ensure the health of both ecosystems and human communities is important.

### Discussion

This project allowed the researcher to become fully immersed in topics related to climate change, drought, adaptation, natural infrastructure, natural water storage, amenity migration, and rancher typologies. The researcher also acquired valuable knowledge and experience during project design, data collection, and data analysis periods. Additionally, the researcher gained pertinent insight from other individuals, either through conversations, conferences, or informal meetings that provided added value to the project. There is anecdotal evidence of a rancher in Montana that uses flood and sprinkler irrigation as a dual system on the same piece of land. Meshing the two different infrastructures (i.e., flood irrigation canals with pivot wheels) has been mentioned as a challenge. However, this strategy could prove beneficial in some areas, depending on soil type and topography, and is worthy of further investigation. Another suggestion included using a sprinkler or center pivot system all year, but in the spring, running the sprinkler at flood irrigation flows in order to saturate the soil profile. In summer and fall months, the

sprinkler would be used at normal water pressure. In 1988, the Ruby River Plan was developed to prevent the dewatering of the river (Ruby Valley Conservation District, 1988). In this plan, the Water Users Association and the DNRC collaborate to begin irrigation earlier in the season if it is a low water year (Ruby Valley Conservation District, 1988). The DNRC provides the Association with data on snowpack and water conditions in March and based on those conditions, the groups decide whether to begin irrigating earlier (Ruby Valley Conservation District, 1988). Further research could illuminate if this plan was feasible for other watersheds.

Montana and many other western states still receive EQIP funding for converting from flood to sprinkler irrigation. At a conference, one attendee mentioned that sprinkler companies are well versed in filling out the paperwork for EQIP. Sprinkler companies assist interested ranchers with their EQIP paperwork because, in return, ranchers will purchase a sprinkler system from them. More research into this topic would be helpful to see how invested sprinkler companies are in EQIP funding and if an option exists for other entities to help ranchers fill out paperwork for flood irrigation or natural water storage. Finally, the question of water rights remains unclear for converting back to flood irrigation or beaver mimicry practices. In some basins, like the Ruby River, irrigators operate on a “hand-shake” agreement in order to coordinate water use (Kirk Engineering & Natural Resources, 2014). For the Ruby River, this arrangement works well but more research is needed to explore if it can be replicated in other basins.

In an ideal world, this project would be expanded to other basins to collect more insight from amenity and traditional ranchers. If this project expanded, it would be

helpful for the interview guide to include questions about where on their property ranchers would allow beaver mimicry projects or flood irrigation. The interviewer should ask ranchers if they would be willing to experiment with a dual or hybrid irrigation system. In a hybrid system, ranchers would flood irrigate early in the spring and then sprinkler irrigate the same piece of land later in the summer. Alternatively, ranchers could be asked if they would be willing to use sprinkler systems to apply water at flood irrigation rates early in the season and then switch to sprinkler irrigation rates later in the season. The interviewer should also ask ranchers what the factors for a collaborative relationship with government agencies and other entities would be. Ranchers should also specify their views toward state versus federal government agencies. These more detailed questions would allow the interview responses to provide more action items for government agencies, nonprofits, and other resource management entities interested in working with ranchers and making policy decisions.

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APPENDICES

APPENDIX A

INTERVIEW GUIDE

## Red Rock Watershed Interview Guide

### Introduction

- How do you define drought, especially in the context of the upper Beaverhead Watershed/Red Rock Watershed? (be open to this definition also being “water shortage” driven by human water use, not just lack of precipitation)
- What are the causes of drought or water shortages in the upper Beaverhead Watershed?
- What are the main impacts of drought or water shortages to you and your community? (prompt: what do you worry about? What outcomes or impacts are you trying to avoid during times of water shortage/drought?)
- There is often a distinction made between actions taken to prepare for drought/water shortages (i.e., things you do before drought happens) and actions taken to respond to drought/water shortages (i.e., actions taken once a drought begins to cope with its impacts)
  - What actions have you taken/would you take to prepare for drought or water shortage?
  - What actions have you taken/would you take to respond for drought or water shortage?
- Are you aware of any other strategies that landowners can take to manage water for drought/water shortages?
- Are there any regulatory barriers that prevent you from managing for drought or water shortage? (Prompt: water laws such as first in time, first in right; use it or lose it, inability to lease water on a temporary basis, etc.)

**Natural Water Storage Practices:** I am going to show you two examples of natural water storage practices and I would like to hear your thoughts on each them.

- There’s a lot of talk among academics, NGO’s – and even the Army Corps of Engineers about a concept called “natural water storage” – this refers to practices that help to slow water run-off and increase water infiltration to recharge aquifers and “soak the sponge”.
  - Have you heard of the term “natural water storage” or the concept of “soaking the sponge”?

**Flood Irrigation** (or combination of flood and sprinkler irrigation):

- Are you aware of any changes in streamflows or water use associated with the conversion to sprinkler/pivot irrigation in your watershed (or other watersheds)?
- Do you currently use flood or sprinkler/pivot irrigation or both?
  - If currently flood irrigating, ask: Do you consider switching to sprinkler/pivot irrigation?
- What are the advantages and disadvantages of flood irrigation?
- What are the advantages and disadvantages of sprinkler/pivot irrigation?
- What would be the practical barriers to either adopting a dual irrigation system or maintaining flood irrigation? (prompt: how would it affect your daily farm/ranch/property operations?)

- If you decided to adopt a mixed irrigation system or maintain (or reconvert to) flood irrigation, can you walk me through what regulatory steps you think you would have to go through to get it done?
  - Do these steps/process make you less interested in doing these practices?
  - Are there things that would incentivize you to adopt these practices? (e.g., cost-share, grants, other funding, trained crews coming to your property to implement project, or environmental benefits, drought mitigation benefits or water availability benefits?)
- How do you think your neighbors would react to your implementing this practice (i.e., dual irrigation system and/or maintaining/re-converting to flood irrigation)?
- Who would you trust to provide this information to you?

**Stream Restoration/Beaver Mimicry:** Some restoration practitioners and landowners have observed that reconnecting incised streams with their floodplains can result in increased water storage in the floodplain – which, in some cases, provides return flows to the river. This is sometimes called “beaver mimicry” because it mimics what a beaver dam does.

- Have you heard of this type of practice before?
- Do you think this type of practice could be used to help mitigate drought/water shortages? Why or why not?
- Have you ever done any stream restoration/beaver mimicry on your property? Why? What were the results? (or why not?)
- Are there any practical barriers to implementing a stream restoration project on your property? (prompt: how would it affect your daily farm/ranch/property operations?)
- If you decided to implement a stream restoration/beaver mimicry project on your property, can you walk me through what regulatory steps you think you would have to go through to get it done?
  - Do these steps/process make you less interested in doing these practices?
  - Are there things that would incentivize you to adopt these practices? (e.g., cost-share, grants, other funding, trained crews coming to your property to implement project, or environmental benefits, drought mitigation benefits or water availability benefits?)
- How do you think your neighbors would react to your implementing this practice (i.e., stream restoration/beaver mimicry)?
- Would you be interested in further information or discussion on stream restoration/beaver mimicry?
- Who would you trust to provide this information to you?

### **Final Questions**

- Is there an amount of flooding on your property or change in streamflow that you would find acceptable if it meant there was later season stream flows? What would this look like? And what would your concerns be?

- Besides these two practices (Flood irrigation, Stream restoration), can you think of any other “nature-based strategies” or other innovative strategies for dealing with drought/water shortage?
- Can you point me in the direction of someone who closely aligns with your views on this topic and someone who disagrees with you?

APPENDIX B

VISUAL HANDOUT

**Visual Handout**

Flood irrigation and sprinkler irrigation



Source: Vanuga, 2002.



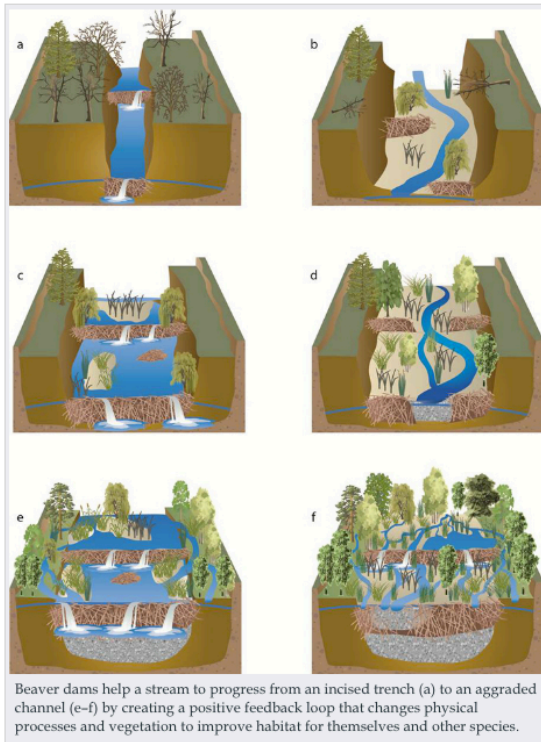
Stream restoration and beaver mimicry



**LONG CREEK, CENTENNIAL VALLEY, MT  
INCISED CHANNEL RESTORATION PILOT PROJECT:  
Demonstration of Hardened Riffle Construction  
J-Bar-L Ranch 2014**



Source: Montana Department of Fish, Wildlife, and Parks, 2014.



Source: Pollock et al., 2015.