

An Assessment of Climate Vulnerability in the Middle San Pedro River

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Tschakert

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1.0 CHAPTER ONE: The Assessment Context -- Diane Austin, Thomas McGuire and Ellen Hansen

1.1 Introduction

Rural communities throughout the Sunbelt of the southwestern United States are experiencing significant changes, and the people who live in them face pressures from a variety of directions--some positive, some negative, some related to environmental conditions, others due to socioeconomic factors. For example, many small towns in the Southwest are struggling to stay afloat as they undergo a transition from dependence on primary industries such as mining or ranching to economies fueled by services and tourism. Likewise, urban growth and economic development are fostering significant changes in land use, community relations, and resource demands. In the southwestern deserts, the emerging economic livelihoods are entwined in complex adaptive relationships with an arid environment characterized by climate-related constraints and essential resource scarcities. The skein of coping mechanisms that once met the past challenges of climate variability may not continue to do so as the underlying socio-economic patterns shift. It is in this context that this assessment of the climate-related vulnerability of human communities within the Middle San Pedro River Valley (MSPRV) takes place.

As a major component of the Climate Assessment Project for the Southwest (CLIMAS), this study is part of a larger effort to assess the vulnerability of natural and human systems to climate variability and change in the southwestern U.S. As importantly, this assessment seeks to fulfill the project's larger mission of working directly with communities to improve their ability to respond adequately and appropriately to climatic events and climate change. Funded by the National Oceanic and Atmospheric Administration (NOAA), CLIMAS is part of a major federal government initiative to develop better quality and more detailed climate assessments at the regional level.

The goal of this study is to demonstrate the utility of a rapid ethnographic approach for (1) conducting a community-level assessment of climate related vulnerability and (2) extending the findings to other assessments. The next two chapters of this report address these purposes. This chapter describes the methodology of rapid ethnographic assessment and introduces the community and the environment in which it is located. The MSPRV, like other regions throughout the southwest, is subject to various influences and pressures, some directly related to climate variability and change and others only indirectly or seemingly unrelated to climate. Through time, the majority of the local population has succeeded in creating buffers against most forms of climate variability. Consequently, climate is but one of many factors of concern to decision makers, policy makers, business owners, residents of and visitors to the MSPRV and generally becomes

a high priority only when residents and leaders are confronted with the immediacy of an event such as a flood or drought. Nonetheless, climate and responses to climate variability influence development in the MSPRV, and shape the constraints and opportunities available to its residents.

1.2 Rapid Ethnographic Methodology in an Integrated Assessment -- Diane Austin

This report is an integrated assessment in two fundamental ways. First, it is designed to integrate natural processes such as rainfall (or lack of) and subsurface flow and availability with socio-economic processes such as population growth, resource use and management, and sectoral shifts in livelihoods. The analyses reported here, while based primarily on ethnographic field data, also include important information taken from past climatic (and paleo-climatic) records, as well as from the surface and groundwater hydrology of the region. Furthermore, it is expected that these interactive processes will define the critical research priorities of common interest for future project involvement. Second, this assessment integrates the academic community with the local population in an explicit outreach partnership. This study has created a set of relationships between the University and the diverse set of stakeholders in the MSPRV, generating opportunities to place the applied research and training resources of the University at the disposal of local inhabitants. If the first sense of an integrated assessment poses the intellectual challenge of interdisciplinary collaboration toward a common, complex research problem, the second sense of the term poses the challenge of directing research toward a social goal consistent with the priorities of local communities. Toward this integrated end, the research team chose to employ qualitative and participatory ethnographic methods to provide the social science data that would complement current understanding of the natural processes in the valley.

The objective of a rapid ethnographic study is to gather information from a wide range of community residents and leaders to generate first a description of the community and then an assessment of the interaction between climate variability and change and the lives and decisions of individuals and groups. The study also examines linkages within the community and with people, places, and institutions beyond its borders. Indeed, one strength of a community ethnographic assessment is the ability to explore the various factors and how they are interrelated, investigating critical connections that may go unnoticed in a statistical analysis of relationships among variables.

The Middle San Pedro River Valley was selected as a case study site because the hydrology and climatology of the San Pedro River has been well studied (Morehouse et al. 1998). In the summer of 1998, two researchers made several visits to the MSPRV to investigate its potential as a case study site. After identifying both issues that are common to southwestern communities and those that are unique to the Middle San Pedro area, researchers *contacted* officials in Benson, the largest city within the MSPRV. Because the integrated assessment establishes a long-term relationship between CLIMAS

and the study community, the interest and cooperation of the community partners is critical to the effort. The coordinator of the CLIMAS core office, along with researchers from the Tree Ring Lab and the Bureau of Applied Research in Anthropology (BARA) of the University of Arizona made a presentation to the Benson City Council, which then voted to support the study. In addition to signaling a willingness to participate in the partnership between the university and the community, this support proved invaluable in soliciting the participation of city and county officials and business leaders.

After study approval was granted, researchers made two additional scoping visits to the MSPRV to identify potential boundaries for the study area (see Figure 2.13), identify the nature and types of residential and commercial establishments within the community, and locate lodging for the study team. Field research was conducted between December 1998 and May 1999. The research team spent a combined total of at least 40 days in the MSPRV, beginning with a concentrated site visit between January 10 and 16 in which seven individuals took part. Following that visit, team members traveled to the MSPRV on eight additional occasions to meet with community members, map the community, and gather documents.

The core methodological approach focused on a series of guided discussions with residents, business owners, city and county officials, ranchers and farmers, commuters, and visitors. Individuals were identified for participation because they represented sectors or occupations that had been previously identified by CLIMAS as potential stakeholders or because other participants recommended them. This method of “snowballing” in the field is especially beneficial for getting to knowledgeable, affected individuals. Nevertheless, to ensure that as many perspectives as possible would be heard; researchers also contacted other local residents to learn about the community history and livelihoods. During each discussion, researchers asked participants to identify documents that provided information relevant to the impacts of climate variability.

A feature of qualitative research is the interweaving of data collection and analysis. Following each visit to the field, researchers converted their notes to electronic format and stored them in a team database. Each researcher therefore had access to the information from all others. After the January site visit, research team members met on several occasions to discuss their findings and plan the visits that would take place over the next six months. As a result of these meetings, researchers identified four areas that were particularly important in the development of the MSPRV and focused their attention on gathering numerical as well as qualitative data to illustrate the patterns of development (see Chapter 2). Two researchers mapped the businesses and industries in Benson to obtain data comparable to that collected in the 1970s by another university researcher (see Section 2.2).

Because the MSPRV case study in part was designed to test assessment methodologies, two areas specific to that charge received attention. First, the case study

was used to explore the potential for quantitative modeling within a community level assessment. Thus, one researcher served as the repository for all information about quantitative data, or the lack of it, within each sector. After evaluating the potential for developing a quantitative model of decision making in the MSPRV and the role of climate variability and change in future scenarios, that individual identified one sector, ranching, that appeared most amenable to the quantification of impacts and developed a Geographic Information Systems (GIS) database (see Section 3.1).

Finally, the effectiveness of a community-based stakeholder assessment of climate information users was compared to the survey approach utilized in the CLIMAS stakeholder assessment cited above. In this process, one researcher compiled data from all others to evaluate the findings in terms of what insights they provide for understanding the experiences, decision-making strategies, and information needs of stakeholders. In contrast to a survey approach, the community-based analysis highlights linkages among sectors and groups (see Section 3.2). The case study of the greater Benson area sets the stage for subsequent studies by illuminating challenges encountered in conducting community climate impact assessments and in documenting the nature of climate vulnerability and response in the community.

Throughout the study, respondents drew on past experiences and their hopes for the future of the community when describing how they perceive climate as an influence on the community and their lives. The population within the study area is influenced by many factors, and this study seeks to situate the natural process of climate variability and perceptions of vulnerability within the growth and development of the MSPRV. An ethnographic study aims to look past regional and national trends and to hear individual and community stories. Yet, in even the smallest of communities, there are many tales to be told. Thus, even at the local level, researchers must look for patterns and generalizations. Nevertheless, it also is possible to highlight some of the idiosyncrasies. What is presented in this report has been selected to illustrate both the common elements and the diversity of perspectives. Information that was shared by many individuals is incorporated throughout the text. Where information was taken from only one or two interviews, interview numbers are cited in parentheses.

1.3 The Middle San Pedro River Valley -- Diane Austin, Thomas McGuire and Ellen Hansen

The target community for this assessment is the Middle San Pedro River Valley (see Figure 2.13), including the city of Benson and the smaller communities of St. David and Pomerene in Cochise County, and J-6 and Mescal in Pima County. The study site is designated the MSPRV based on its location near the center of the river's 140 mile length. In terms of the river's hydrology, the study site is in the Upper San Pedro Basin, which extends from the river's headwaters near Cananea, Sonora, Mexico, to a point 12 miles north of Pomerene called The Narrows. The narrowing of the river divides the Upper

Basin from the Lower Basin, which extends to the San Pedro's confluence with the Gila River near Winkleman (Arizona Department of Water Resources 1997).

Cochise County occupies the southeast corner of Arizona. Within the county, numerous mountain ranges are separated by broad, relatively flat valleys. The San Pedro River begins in Mexico and flows north along the western boundary of the county toward its meeting with the Gila River 120 miles north of the border. The river is lined with open areas, small communities, ghost towns, agricultural fields, and some industrial development. Climate and the San Pedro River have been key features of the history of settlement in the study area, in positive as well as negative ways.

The population of Cochise County is growing, but at a slower rate than ten of Arizona's other 14 counties and the state as a whole (Arizona Department of Economic Security 1998). Most people (70%) in Cochise County live in urban areas, consisting mainly of small cities such as Benson (in 1996 the fourth-largest city in the county). Sierra Vista, south of Benson, is by far the largest city in the county, with a 1998 population of 39,995. With the exception of Sierra Vista and a few of the smaller towns, the cities in Cochise County lost population from 1980 to 1990, but have been growing in the years since (Arizona Department of Commerce 1997:2).

The study area is centered on the small city of Benson. Its permanent population, according to official state figures, was 4,540 in 1998, but its winter population is estimated at double that. About six miles to the southeast is the small town of St. David (population about 2,000), and just north of Benson lies Pomerene (population about 1000). As shown in Figure 2.13, the study area also includes the commercial development at the intersection of Interstate 10 and State Highway 90; the residential areas of J-6 and Mescal in Pima County west of Benson and adjacent to Interstate 10; and Kartchner Caverns State Park to the south of Benson and west of Highway 90. Benson is at about 3600 feet above sea level, St. David is a little over 3700', and Pomerene about 3540'. The study area is surrounded by mountain ranges with elevations nearing 8,000': the Whetstone Mountains to the southwest, the Rincon Mountains in the northwest, the Little Dragoon Mountains and the Dragoons to the northeast and east.

1.3.1 The Physical Setting and Evidence of Change

Change has been occurring rapidly in the MSPRV in recent years, but changes first occurred with human settlements a thousand years ago (Bahre 1991:29) and then increased in speed and intensity after the arrival of European explorers in the 16th century (see below for a brief history of settlement in the MSPRV). The San Pedro River has been critical to the process of exploration and settlement from the beginning of human presence throughout the region. It is described by Hereford (1993:2) as "probably one of the richest wildlife habitats in the Southwest. It is a nesting, migratory, or wintering habitat for 377 bird species and 35 raptor species, as well as an essential habitat for many other

wildlife species, including 82 mammals. An extensive riparian woodland enhances the beauty of the area and provides the lush wildlife habitat.” According to Bahre (1991:4) the river has changed greatly in character since the mid-19th century:

Before 1870, according to historical record, the biological environment of the semiarid basin and range country of southeastern Arizona was comparatively lush. In the 1850s and 1860s, grass was plentiful; the grasslands were open and fairly brush-free; the rivers had perennial flow throughout much of their courses and were in parts unchanneled and lined with *galeria* forests of willows and cottonwoods; marshes (*ciénagas*) and stands of mesquite and sacaton covered large areas of bottomland; wildfires were fairly common; the ponderosa pine and mixed-conifer forests had uneven-aged stands and open understories; malaria was rampant in certain areas; fish were plentiful; and antelope, prairie dog, grizzly bear, otter, beaver, and wolf were abundant.

In the study area today, the San Pedro River is lined with cottonwood, willow, saltcedar (tamarisk, an introduced species), and mesquite trees, which established themselves over the last century as the river’s channel widened and deepened. Other changes include the now intermittent nature of streamflow in the river. Though *ciénagas* were found along tributaries of the San Pedro into the mid-20th century (Dobyns 1981), riparian marshes have been drained or have dried up.

The San Pedro Valley has been the locus of settlement for thousands of years, and understanding the relation between local inhabitants and the river is necessary for apprehending the current status of the river, its environment, and the policies that affect it. As human populations along the river increase, and as climate variation and change determine the timing and availability of water in the river, controversies will occur. In the assessment of vulnerability to climate, existing and future conflicts over water form the context for discussion. For example, the recent publication of the Commission for Environmental Cooperation’s study on the Upper San Pedro River Basin identifies threats to the San Pedro and recommends actions considered necessary to maintain the quality of the riparian habitat, the river’s surface water, and the basin’s groundwater (CEC 1999). Though the most vocal concern about those findings arose from Sierra Vista, people of the MSPRV are also affected by changes in the upstream management of the San Pedro. Similarly, the adjudication of water rights to Native American tribes further downstream may implicate the Middle San Pedro. Arizona is among the states in the U.S. with the largest Native American populations, and has 28 percent of its land in tribal hands. Though Cochise County has no reservation and very few Native Americans in residence, Native American land and water rights claims on the Gila River, of which the San Pedro is a major tributary, remain unsettled. Thus, the complex interplay of legal

claims, historical precedent and environmental values provide the context of debate over land and natural resource use. It is also in the context that the dynamics of climate vulnerability become relevant.

1.3.2 A Brief History of Settlement in the Middle San Pedro River Valley

Like rivers everywhere, the San Pedro draws people to it, shapes their lives, and in turn is impacted by their activities in its valley. The San Pedro River Valley was settled and inhabited by the Sobairpuri tribe of Pima Indians, who were practicing irrigated agriculture when European settlers first came to the area in the 16th century (see Hereford 1993 for a brief overview of the history of the MSPRV and related bibliography). Eventually conflict between the Sobaipuri, the Apaches, and the Spanish forced the abandonment of villages and ranches in the Valley from the 1820s through the 1850s (Hereford 1993:5).

The first recorded visit of Euro-Americans to the Middle San Pedro occurred in 1846 when the Mormon Battalion passed through the area en route to the Mexican-American War. After they returned home with stories of the lushness of the valley in the midst of the desert, and after the Gadsden Purchase brought southern Arizona into the United States in 1853, homesteaders began arriving in the area. St. David, Pomerene, and nearby ranches were settled by colonists of the Church of Jesus Christ of Latter-Day Saints (the Mormons). Some moved south from settlements in northern Arizona and Utah in the 1870s, others moved north to escape the unrest and revolution in Mexico in the early part of the 20th century. Members of the LDS Church were instrumental in the settlement of the area from the mid-19th century and beyond, and remain among its most prominent citizens today (St. David Stake Family History Center 1998).

The town of Benson was founded in 1880 as a stop on the Southern Pacific Railroad at the site chosen for a bridge over the San Pedro River. It quickly became the “Hub City”-- a center of railroad and stage lines east and west, as well as the northern terminus of the railroad from the mining and coastal areas of Sonora, Mexico. Benson served as a center for north-south as well as east-west transportation in the late 19th century, especially for ore shipment as the mining industry developed rapidly in southern Arizona and northern Mexico in the early 20th century. In 1913, though, the railroad companies shifted their main operations to Tucson (see Section 2.4). Subsequent to that change, Benson’s economic base switched to agriculture and ranching, and it renamed itself the “Queen City of the San Pedro.” Later, manufacturing joined agriculture to diversify the city’s economy. According to one Benson historian, the population shifted from a preponderance of single males (railroad workers, miners and cowboys) to more “settled families” involved in agriculture and supporting industries (Tompkins 1998:36). Recent demographic changes have reshaped the population pyramid upwards.

The population of Benson at its founding was about 300 people. It grew to over 1,100 by 1910, and throughout the 20th century has steadily but slowly gained

population, with a few periods of decline. For example, from 1980 to 1990 Benson had a net population loss of 8.73 percent (4,225 to 3,856 residents), but by 1997 had recouped that loss and grown slightly to 3,880 (Cochise College 1998:3). During the depression years of the 1930s Benson also lost population, with the decline of the economic importance of mining, and out-migration of those in search of economic opportunity. During the 1980s, when Benson had a net loss of population, the age cohort over 65 increased by 23 percent (Cochise College 1998:3).

Ranching and farming have been significant influences in the settlement of Arizona, including the MSPRV, where a reliable supply of water and large tracts of level land close to the river attracted early settlers, and continue to draw people to the Valley. The San Pedro is a small river, however, and although irrigated agriculture has been practiced in the area for hundreds of years, it has always been limited in extent and remains so today. Still, though their contribution to the area's economy is relatively small (see Section 2.1), ranches and farms occupy a large geographical area in the valley. Also, as Sheridan et al. (n.d.:1) note, "the livestock industry may be a minor part of modern Arizona's economy, but the industry leaves its ecological, economic, political, and cultural imprint on rural landscapes and rural communities throughout the state."

1.3.3 Current Socioeconomic Profile

From its history as a railroad and then an agricultural center, Benson has reinvented itself various times. Most recently, with the growth of tourism and the number of winter visitors in Benson and St. David, and with the development of Kartchner Caverns, Benson has copyrighted a new name, "Home of Kartchner Caverns." It now promotes itself as an ideal retirement spot and the gateway to many natural wonders and historical sites. St. David and Pomerene, in contrast, have worked to maintain their small town environments and their agricultural and ranching bases.

Despite its history of slow, steady expansion, recent population growth has been more dramatic. In 1998, the permanent population stood at 4,540, nearly a 19 percent increase since 1990 (Arizona Department of Economic Security 1998). While the overall population of Benson dipped in the 1980s, however, the population aged 65 and over increased by 23 percent while the population aged 17 and younger decreased by 16 percent. This demographic change is expected to continue as the area is marketed as an ideal retirement spot. Part of the area's attractiveness to retirees is its mild climate.

Benson's geographical location also constitutes a draw to the older individuals and commuters. Both Sierra Vista (population nearly 40,000 in 1998) and Tucson (greater metropolitan population of 804,200 as of 1997; Arizona Department of Economic Security 1998, Tucson Metropolitan Chamber of Commerce 1997) are less than an hour's drive from Benson, where residents have access to a great variety of services, especially medical, and other urban amenities, including recreation, an international airport, cultural

events and shopping. People of all ages seeking the small town lifestyle thus perceive that they are close enough to the “big city” to take advantage of all it offers, but far enough away that they do not deal with heavy traffic, noise, air pollution, and the other negatives of large urban areas.

The economy of the greater Benson area is concentrated in the retail and service industries, and the top employers are in service and manufacturing (see Section 2.2). In the beginning of 1998, Benson’s unemployment rate just over 7 percent, higher than the 3 percent in Tucson and the state average of 4 percent (Cochise College 1998:6, Arizona Department of Commerce 1998, Greater Tucson Economic Council 1999).

Kartchner Caverns State Park was established in 1988, and development of the caverns for tourism began in 1992 (see Section 2.2). Current estimates are that the cave will open to the public in late 1999 and will draw 150,000 tourists per year. In anticipation of the expected influx of tourists and their dollars, commercial developments are underway at the intersection of the interstate and state highways, and along Highway 90 south of the interstate. To date the development includes hotels, restaurants, and other establishments oriented toward the tourist trade. Although city residents and promoters are well aware that one need not visit the old part of Benson in order to spend time at the caverns, they are also aware that the changes and development along the Kartchner corridor will have an impact on the city. Many are determined that the benefits trickle down to the old city and its businesses, hence the latest incarnation of Benson as the Home of Kartchner Caverns. The city of Benson is also hoping to attract more winter visitors and retirees, and so has enthusiastically received the establishment of new RV parks and services related to this segment of the population.

1.3.4 The Impact of Climate on the Area’s History and Development

The mild climate of the Middle San Pedro River Valley and the existence of a reliable water supply have been key factors in the settlement and development of the study area. Climate variability has been manifest primarily through high summer temperatures, precipitation, and water flow. In the 19th century, the San Pedro River was considered both a blessing and a curse by settlers of the valley. Malaria and other vector-borne diseases were significant health problems for early residents, while the river provided for irrigated agriculture and stock watering. Mild winters provided long growing seasons for a variety of crop types, and canals and diversion dams brought (and still bring) water to agricultural land near the river.

The railroad bridge across the river that established Benson as a town site was regularly washed out in the early 20th century. A history of Pomerene notes that construction of a diversion dam and canal on the San Pedro began in 1908 to provide water to land on the east side of the San Pedro River. The canal was enlarged and extended in 1915, when “excessive rains in January . . . turned lower stretches of the Pomerene-

Benson road into mud holes” (Pomerene Grammar School 1991). Hereford (1993:34) shows average daily discharge of the San Pedro River in the winter of 1914-1915 to have been extremely high at Charleston, about 30 miles south of Pomerene on the river. The steel bridge over the San Pedro washed out twice before 1919, when it was replaced by a concrete bridge. That bridge was destroyed by high waters during a monsoon in 1923, which shows up as a year with only slightly higher-than-average summer precipitation (Hereford 1993:33). The diversion dam was destroyed by summer rains in 1931, and was replaced by a new concrete structure

In more recent times, agriculture plays a less important role in the economy of the Benson area, and fewer people are so directly affected by the variability of climate in the ways farmers and ranchers have always been. Land in the area is still under cultivation, although only 800 acres in the San Pedro River Valley are actually in agricultural production, out of an estimated 6,000 potentially cultivable acres (Dunn 1997:16). A typical description of the area’s climate is that “Benson enjoys a climate that is cooler than communities at lower elevations such as Tucson and Phoenix The average monthly temperature ranges from a low of 29.5 degrees to a high of 95.9 degrees Fahrenheit, testifying to the wonderful weather found in the Benson area” (Cochise College 1998:4). Climate remains directly related to the development of the more recent economically dominant sectors—tourism and services, especially those related to the growing numbers of winter visitors and retirees in Benson and the surrounding area. In turn, many of the jobs being created currently are dependent on those climate-sensitive sectors, and thus the fate of development in the study area remains directly as well as indirectly connected to climate variability both in southeastern Arizona and in other parts of the country (see Chapter 2).

1.3.5 Policy and Development in the MSPRV

In the second half of the 20th century, the regulatory environment in the United States has grown increasingly complex. Controversy swirls through the Middle San Pedro River Valley as competing interests seek to accomplish their goals in the face of legislation, development, and changing environmental conditions.

The policies that affect people who reside, do business, visit, and make decisions in the MSPRV are of various types and are implemented at different scales—local, county, state, national, and international. Agencies and entities at all these levels have diverse pressures acting on them and participate in a complex web of relationships. Government and private interests interact, sometimes at cross purposes, sometimes in harmony. For example, the federal government controls 14 percent of the land in Cochise County, the State of Arizona holds 35 percent, and 41 percent is in private hands. Much of the land administered by the federal and state governments in Cochise County is leased for grazing. The National Forest Service, the Bureau of Land Management, and the State Lands Department administer leased lands, and in some places, including Cochise County,

those lands overlap and jurisdiction is unclear. Section 2.1 describes land use and policies and how they have influenced the development of the study area.

Water policies are also complex and implemented at various scales by different government agencies. Various laws and regulations are in place that seek to control and/or protect surface and groundwater, but in much of Cochise County, even along the San Pedro River, access to groundwater is essentially unregulated (Commission on Environmental Cooperation 1999:99). In 1980, the Arizona Groundwater Management Code, established “active management areas” (AMAs) to control access to groundwater. The AMAs are focused on the large urban areas where most of the state’s population resides and where most problems were encountered regarding groundwater overdraft. Outside the AMAs (including in the study area) access to ground and surface water is controlled under other state codes. Water rights in Arizona have been and continue to be contested, by special interest groups, Native Americans, farmers and ranchers, and various government agencies. Section 2.3 examines water policies and supply in the study area.

In sum, this report addresses and documents the manner in which a local community perceives its vulnerability to climate variability and change. In the process, the research team has sought to identify the types of “climate buffers” that different economic sectors and different livelihoods have established to mitigate the impacts of climate variability. At the same time, the report insists in its focus on the demographic and socio-economic dynamics of the region, assuming that as the character of the valley changes, so do the underlying and perceived vulnerabilities to climate. The following chapters recount how climate variability imposes itself on the lives of community members as they attempt to maintain their economic viability and quality of life.

2.0 CHAPTER TWO: Patterns of Change in the Middle San Pedro River Valley -- Andrew Gardner, Nicholas Benequista, Sarah Stewart, Petra Tschakert, Allison Fish and Diane Austin

2.1 Land Use Change -- Andrew Gardner

2.1.1 Introduction to Climate and Land Use in the Study Area

The arid climate of the Southwest represents one of the primary factors structuring the patterns and combinations of livelihoods that comprise human settlement of the MSPRV. The mosaic of land use in the valley is a reflection of those livelihoods and includes both vestiges of the past and glimpses into the future. Contemporary land use patterns are, in one sense, the result of decades of selection. Those livelihoods able to persevere in the face of the rigorous climate (and a panoply of other factors) comprise the primary land uses now seen in the valley. Those livelihoods unable to persevere in the socioeconomic and climatic context of the valley appear as remnant parcels, elements of the past that are maintained for their symbolic, rather than economic, value. Human society is quick to react but slow to change; untenable ranches pass from owner to owner as each seeks the combination of strategies that might yield a profit, or a commercial district no longer viable lingers for decades as the merchants struggle to make ends meet. Other land uses are speculative. New livelihoods appear and new combinations of livelihoods are attempted, combinations whose long-term viability remains to be seen. Land use, then, can be conceived as a spatial template of livelihood systems, one that stretches into the past and foreshadows the future of land use in the study area.

The history of human habitation in the MSPRV is one of adaptation and change. From the pre-Columbian settlers who arrived by foot to the annual migration of retirees arriving in the caravans of recreational vehicles, the population of the valley has always been enmeshed in a series of interconnected and far-reaching social and economic networks. These networks complicate the analysis of vulnerability to climate variability and climate change, for the social and economic structures observed in the valley are impacted by changes well beyond the study area. For example, increased water usage upriver results in less surface water for users in the MSPRV, a warm autumn in the Midwest keeps the winter people home for an extra month or two¹, or a murder in Tucson sends families packing for the small-town atmosphere of Benson and St. David. To analytically isolate the study area is to ignore the importance of the interconnections that are so integral to the livelihoods of the valley.

In terms of land use, the MSPRV is in the midst of a period of particularly fast-paced change. Several large parcels of land are being converted from grazing to residential use, a process coinciding with the steady growth of the small urban areas in the river valley. This growth in

¹ *Winter people* is the term used by the study respondents to refer to the retirees that migrate to the region during the colder months.

residential land replaces more traditional uses such as ranching and farming. These two land uses, which in the past have occupied the majority of land in the river valley, are of declining economic importance to the inhabitants of the valley. The boom in the residential sector in the MSPRV represents an intensification in terms land use; at the same time, residential land use is less directly vulnerable to climate variability and change than the ranches and farms it replaces. Perhaps because of this shift away from livelihoods vulnerable to climate variability and change, participants in the study reported a low awareness and concern for climate issues. At the same time, nearly all the respondents agreed that the region has the potential for rapid population growth over the next several decades. The expansion of the residential sector in the valley has several long-term implications in the climatic context of the Southwest. The future of the region, and the impact of climate on that future, has much to do with the variables that might (or might not) produce the dramatic population growth predicted by some. These issues are explored below.

2.1.2 Historical and Contextual Factors of Land Use in the MSPRV

2.1.2.1 Early History of Land Use in the Southwest

Humans have occupied the San Pedro river valley for at least 12,000 years (Haury et al. 1953). Written records of human habitation in the valley stretch back only 450 years to the first Spanish visitors to the river valley. Collective knowledge of earlier peoples stems from the work of archaeologists and ethnographers. The picture that emerges from these information sources suggests that even prehistoric Indians were able to mold and change the land to meet their needs through various processes and technologies, including fire, agriculture and irrigation, the harvesting of fuel wood, hunting and gathering (Bahre 1991). The pace of these changes increased with the arrival of the Spaniards. Although few Spanish visited the San Pedro Valley and even fewer settled there, the implements, animals and technologies that arrived through trade and contact impacted the ecology of the valley in significant ways. In particular, the introduction of livestock and plows increased the rate of environmental change throughout the valley (Bahre 1991). Euro-American land claims in the area began in full after the Gadsden Purchase in 1853; however, the Apache, who had arrived in the valley in the late 1600s, controlled much of the region for the latter half of the 19th century. With the military suppression of the Apache people, Euro-Americans moved into the valley in much larger force.

The legacy of the Euro-American settlers is one of environmental change. Those who live in the Southwest are by now quite familiar with the descriptions of the Arizona never seen; early Anglo travelers, as well as the settlers here in 1850s and 1860s, noted the perennial streams, forests of willows and cottonwoods, malarial marshes in the lowlands, grasses as tall as a man on horseback, and abundant wildlife in the streams and beyond, including antelope, grizzly bear, beaver, otter, and jaguar (Bahre 1991). These ecosystems prospered in semiarid climate of the region, a climate that served as both an attraction and a barrier to human settlement. Average rainfall in the San Pedro Valley is between 10 and 15 inches a year, sufficient only for dryland uses such as ranching and mining (Sellers 1974). In terms of land use, rangeland comprised most

of the valley at the turn of the century. The portions of this ranchland forested in oak, juniper and mesquite, as well as the higher pine forests, provided the raw material for a small but significant lumber and fuel wood industry. Because of the climate, farming was limited to irrigated areas, thus concentrated along those lands adjoining the San Pedro River. Other uses, such as mining and residential, were minor.

Though limited in scope, these activities were significant enough to attract a significant Anglo-American population to the San Pedro Valley. Settlement commenced in full in the 1870s because of a series of interrelated events: the Southern Pacific Railroad between Tucson and El Paso was completed, Mormon settlers began arriving in much larger numbers, the Apache peoples were militarily conquered, and several mining districts were established in the valley (Bahre 1991). The newly established railroad, in tandem with a drought in California, pushed the number of cattle in the region to unexpected highs – 217,000 head in Pima and Cochise county in 1891 (Bahre 1991). Over the same period of time, Mormon settlers established a series of irrigation-based farms in the riparian area of the San Pedro valley between Hereford and St. David, while the highlands provided both fuel wood for the mining industry and construction materials for the growing towns and settlements of the valley. Despite the 1891-93 drought, which resulted in the death of 50 to 70 percent of the cattle in the region, and despite the decline and abandonment of several mining towns in the valley, the basic template of rural land use was set at the end of the 19th century, largely dictated by the resources of the valley and the climate in which they exist.

Dramatic changes in the flora and fauna, water resources, and even topography accompanied the century of Anglo settlement. Many of the animals described by the early visitors and settlers are now rare or gone altogether. The marshes of the valley were drained. The juniper and oak forests of the upper portions of the watershed were in many places cleared, first to serve the mining industry, later to serve the fuel wood demands of the valley residents (McCool 1973). The water table was increasingly pumped to meet the demands of the growing agricultural, industrial, and residential livelihoods in the valley. Overgrazing at the turn of the century resulted in the loss of native grass cover, changes in vegetation, increasing erosion, and severe arroyo cutting in portions of the valley.² Today, as travelers, visitors, and residents crest the final hill on the interstate between Tucson and Benson, or as they drive through the cottonwoods of the St.

² C. H. Bayless, owner of a large ranch near Oracle, describes the range conditions of the San Pedro valley in a response to a questionnaire mailed by D. A. Griffiths of the Arizona Experiment Station at the turn of the century (1901): “The present unproductive conditions are due entirely to overstocking. The laws of nature have not changed. Under similar conditions, vegetation would flourish on our ranges today as it did fifteen years ago. We are still receiving our average amount of rainfall and sunshine necessary to plant growth. Droughts are not more frequent now than in the past, but mother earth has been stripped of all grass covering. The very roots have been trampled out by the hungry herds constantly wandering to and fro in search of enough food. The bare surface of the ground affords no resistance to the rain that falls upon it and the precious water rushes away in destructive volumes, bearing with it all the lighter and richer particles of the soil. That the sand and rocks left behind are able to support even the scantiest growth of plant life is a remarkable tribute to our marvelous climate. Vegetation does not thrive as it once did, not because of drought, but because the seed is gone, the roots are gone, and the soil is gone. This is all the direct result of overstocking and cannot be prevented on our open range where the land is not subject to private control.” In (Bahre 1991).

David basin, they are presented with valley much different from that to which the early Anglo settlers arrived.

It would be misleading to discuss these changes solely in terms of climate. Most of the changes described above can be attributed to the interplay between the climate of the region and human decisions about the land and its resources. As a concept, land use resides at the nexus between climate and livelihood systems – climate structures land use, which in turn shapes the livelihood systems by which the citizens of the valley survive and, sometimes, prosper. The climate of the region figures prominently in some decisions; in others, it functions as a subtext to other factors. In the last century of habitation, climate has occasionally dealt a severe blow to the inhabitants of the valley; the ranchers of the region are no strangers to drought, and many of the elders in the valley can recollect several great floods of the past fifty years. At the same time, from the earliest Anglo-American wagon master to the owner of today’s luxurious recreational vehicle, climate—despite its variability—has always been one of the most decisive drawing points to the region.

To understand the implications of climate change and climate variability in the Middle San Pedro Valley, one must consider the historical processes through which climate shaped the livelihoods in the region, survey the contemporary spectrum of land use in the greater Benson area, and extrapolate the potential land use outcomes in the region, all in the hope of producing a better understanding of the changing vulnerability of livelihood systems to climate variability and change. This section begins with a more detailed overview of land use in the region, as well as a discussion of the policies related to land and natural resource management. Next, a set of case studies is presented to better illustrate processes of land use change and the role of climate variability. Finally, a discussion of the impediments to land use change, as well as the forces driving growth, will provide the basis for assessing the future of the region.

2.1.2.2 Overview of Contemporary Land Use in the Middle San Pedro River Valley

For dearth of data, quantitative assessments of land use change at a sub-regional level are difficult to make. At the regional scale, however, the federal government maintains fairly accurate data, and more land use detail is available via tenure category. This section of the chapter first reviews quantitative land use and land tenure data for the Southwest region. Then the case yields a more qualitative and specific perspective on land use change in the Middle San Pedro River Valley. The Economic Research Service (ERS), within the U. S. Department of Agriculture, collects land use data at a regional level. The ERS utilizes five land use categories, three of which are further subdivided (see Figure 2.1).

Grassland Pasture/Range	Forest-Use Land	Cropland	Special Uses	Misc. Other Land
(no subdivisions)	forestland, grazed	cropland used for crops	urban land	(no subdivisions)
	forestland, not grazed	cropland idled	transportation land	
		cropland used for pasture	recreation/wildlife areas	
			national defense areas	
			misc. farmland uses	

Figure 2.1: Land Use Categories Employed by the Economic Research Service

In the Southwest, the amount of land in the two primary land use categories – grassland/pasture and forest-use land – has decreased in the last fifty years. In Arizona, over 3 million acres of land shifted out of rangeland between

1945 and 1992; over the same period, nearly 4 million acres shifted out of forest use (Gardner 1999). Conversely, the quantity of urban land, as well as land reserved for recreation and wildlife, has increased substantially over the same period. In Arizona, the quantity of land characterized as

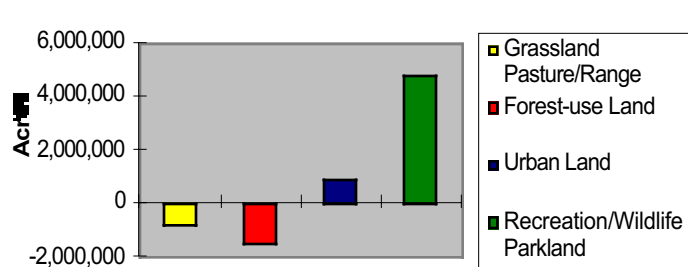


Figure 2.2: Selected Land Use Change in Arizona, 1969-1992

urban increased from 44,000 acres in 1945 to 1,371,000 acres in 1992 (USDA 1997). Over the same period, the quantity of land set aside for recreation and wildlife increased from 1,455,000 acres to 8,431,000 acres (USDA 1997). Much of this change has occurred in the last three decades (see Figure 2.2). These shifts in land use represent large-scale shifts in livelihood.

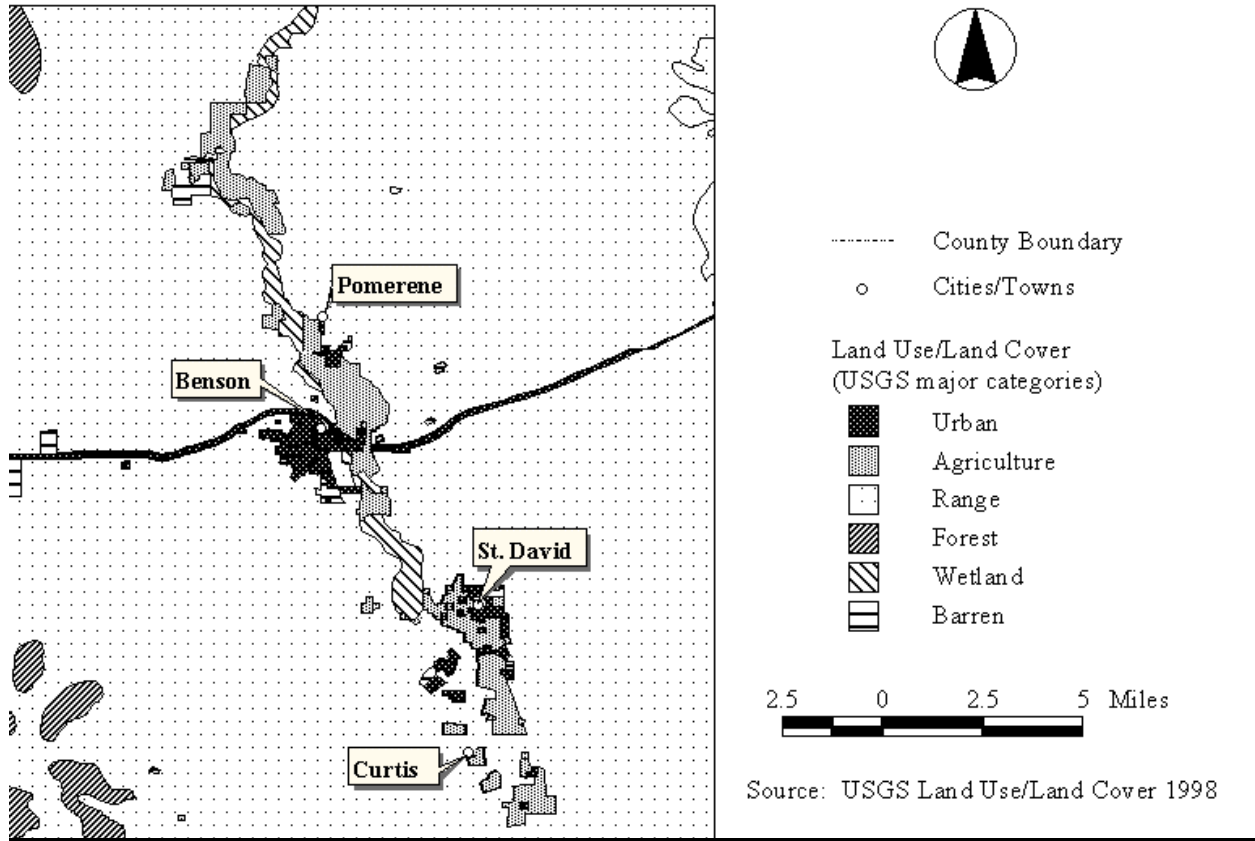
While the causes of land change throughout the Southwest certainly obtain in the case of the Middle San Pedro River Valley, land tenure patterns for the study area are somewhat atypical. For example, Cochise County and the Middle San Pedro river valley display many of the same patterns in land use change. The urban edges of Benson and St. David continue to expand, and significant portions of land south of the study area have been set aside as recreation and wildlife habitat (see Figure 2.3). Despite these similarities, there are several noteworthy differences between Cochise County and other regions of the Southwest, particularly in terms of land tenure. First, Cochise County contains the highest proportion of private land in the state of Arizona. Large reserves of private land hold particular implications in the process of land use change – the degree of centralized control over changing land use on private land is less than on public land. As a result, the region is ripe for development. Second, there are no Native American reservations in the study area or in the county. In the political context of many Southwestern counties, Native American groups have emerged as key players in the control of land and water resources.³ Finally, it is noteworthy that no U.S. Forest Service land appears in the study area. Many of the

³ Although there are no Native American reservations in the study area or in Cochise County, the St. David irrigation district is currently engaged in a legal battle with the Gila River Indians over water rights to the San Pedro.

rural livelihoods in the Southwest are dependent on public land, and the individual federal and state agencies manage holdings with different goals in mind. While the Forest Service is a major force in other regions of the Southwest, it has little involvement in the Middle San Pedro study area.

Figure 2.3: Middle San Pedro River Valley Land Use/Land Cover

Middle San Pedro River Valley Land Use/Land Cover

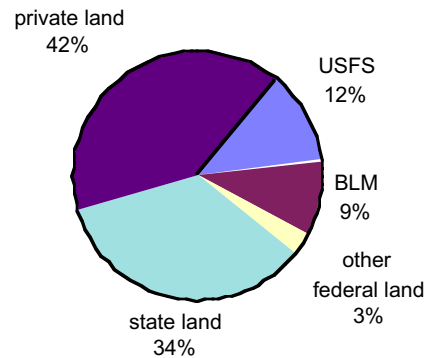


2.1.2.3 Policy Environment of the MSPRV

The policy environment in which the livelihoods of the study area exist is multifaceted. One important policy aspect of the region is the reliance of livelihoods on public land. As noted earlier in the chapter, Cochise County contains a higher proportion of private to public land than any other Arizona counties. Nonetheless, a majority of the land in the county is still publicly managed (see Figure 2.4). The major land-managing agencies have traditionally favored ranching-related uses of the land and resources in the Southwest,

Figure 2.4: Land Tenure in Cochise County, 1997

Land Tenure in Cochise County, 1997



thereby granting key land and water rights to politically powerful ranchers.⁴ Today, ranchers in the region tend to be less influential; and many struggle to make ends meet, even with the benefits provided by federal and state agencies. Several ranchers in the area, while benefiting from the remnant policies that favored large-scale operations, now treat their ranches more as an investment strategy for holding potentially valuable land. These changes coincide with a broader shift in the agendas of the Federal and State agencies managing land in the West. As cities in the western United States continue to grow, the Bureau of Land Management (BLM), the United States Forest Service (USFS), and other land managing agencies continue to modify land management and use policies to meet the needs of the changing demographics. In particular, urban populations are widely perceived as lobbying for increases in the amount of land dedicated to recreational use and reserved for wildlife. Federal and state agencies, and the policies by which they manage land resources in the MSPRV, are another example of the expansive social, economic and political networks in which the livelihoods of the study area are enmeshed.

Despite the prominent role of public lands in economically buffering the traditional livelihoods of the region, study respondents registered a broad disapproval of the federal and state agencies and their management policies. Some of this distrust can be traced to the noted frontier mentality pervasive throughout the West. Particularly older generations disagree not only with the way public lands are managed but also with the notion that the federal government should have a role at all. It is certainly true that public lands have at times been poorly managed; in the study area, however, the poor attitude toward public land management agencies appears to

⁴ Ranches typically consist of a combination of *deeded* and *leased* land. Deeded land is privately owned, while leased land belongs to the Forest Service, Bureau of Land Management, or the State of Arizona. Ranchers hold, buy and sell these state and federal leases through a variety of means. As portions of the MSPRV are converted to residential use, the quantity of deeded land on a ranch becomes increasingly important, as only this land can be developed.

have much more to do with a lack of communication and participation between the agencies and the local population.

Zoning policy provides a mechanism for local control of land use. Zoning is one of the primary policy mechanisms by which the city and the county guide and control growth. County planners manage all unincorporated land in the San Pedro Valley (including St. David), while incorporated areas (such as Benson) retain control of the regions within their legal boundaries. City zoning regulations are similar but not identical to those of the county. Several study participants noted that the county zoning regulations are not stringently enforced. For both the city and the county, land transactions which divide the original parcel into four or more plots smaller than 36 acres require city or county approval and must follow subdivision regulations. Transactions involving fewer or larger plots require only the approval of the Subdivision Committee. Of these non-subdivision sales, the committee usually requires that the owner plan easements for access. For those sales that must meet the subdivision regulations, the plan must include not only access easements but also telephone, water, electricity and other infrastructural components. Landowners often seek to avoid the expenses involved in meeting these regulations by selling off large, 36-acre parcels (as in the Dragoon Mountain Estates described below).

2.1.3 Case Studies

Quantitative data for land use change in the study area paint only a general picture. The four case studies that follow stem from a series of ethnographic interviews conducted over several months; together, they illuminate some of the micro-processes driving land use change in the middle San Pedro river valley. The first case study explores the history of the San Pedro Ranch which, through various ownerships, has been ranched since the late 1800s. The second case study describes the trajectory of the portion of the Little Boquillas Ranch in the middle San Pedro river valley which, after passing through a series of corporate owners, is now slated for large-scale residential development. The third case study examines the Nature Conservancy and Bureau of Land Management holdings just south of the study area. The final case study looks at the steady fragmentation of ownership of land in and around Benson and St. David, a process held to be indicative of the growing residential land use in the valley. These case studies reinforce the long history of regional, national, and international linkages in both social and economic sectors, as well as the role of technological and infrastructural advances as a driving force behind land use change.

2.1.3.1 Over 120 Years of Ranching: Case Study One

Ranchers in the MSPRV operate in a precarious physical, political, and economic climate. When faced with prolonged drought, unstable and often low cattle prices, rising feed prices, political pressure from environmental groups, and development incentives from the real estate market, many consider leaving the cattle business. Yet there are other ranchers determined to preserve their way of life that have found a way to survive on the land. The ZR Hereford Ranch, which now occupies the land previously run by the San Pedro Ranch, is a case in point.

Located roughly 10 miles north and east of Benson, The ZR Hereford encompasses 30 sections⁵ of diverse country ranging from desert scrub at 3000 ft. elevation to sparse oak woodland at 6000 ft. The ranch is largely comprised of leased land -- 29.5 sections are publicly owned with the largest portions leased from the Arizona State Land Department (ASLD), while the remaining half section of deeded land consists of parcels scattered throughout the leased land. At the secretary and treasurer of the ZR family corporation, 76 year-old Peggy Monzingo has been in ranching most of her life. After starting out in 1942 on a ranch near Mt. Wrightson, she headed to New Mexico in 1960 in search of more deeded land and less government interference. In New Mexico, she and her late husband endured three catastrophic droughts. They then returned the ZR to Arizona in 1984, where together with her son and daughter-in-law, they manage the daily affairs of the ranch.

The Monzingos, like some of the other ranchers in the valley, are adamantly opposed to the idea of selling out the deeded portion of the ranch. Ranching as a livelihood holds symbolic importance to the Monzingo family. They see themselves as an important part of the American food chain, they like the isolation, and they love animals. Though times have been difficult (with below average rainfall over the past 7 years), the ZR Hereford has persevered using a variety of strategies. Peggy attributes the ranch's relative security to the diversity of the forage base and a good partnership with the ASLD. When grasses become sparse, the cattle can rely on a variety of browse species if adequate mineral supplement is provided. Pasture rotation has made a significant difference in the forage base of the ranch.

As the operator of the ZR Hereford ranch, Peggy Monzingo has coped with economic and climatic variation through diversification. Six years ago, when Peggy had to give up horseback riding, she created a bed and breakfast to supplement the ranch's income. Since then the ZR Hereford has received a regular stream of visitors who come to escape the Midwest and East Coast chill, relax with good home-cooked meals, and experience the day-to-day operations of a working ranch. Receipts from the BandB and a few catering contracts on the side help bolster the ranch's income and cover daily household expenses. The ranch also does all of its own welding, farrier, and other ranch chores, as well as some for neighbors. Peggy's son is continuing to raise his own ranch horses and now pursues a secondary income source as a hunting guide. Secondary sources of income, Peggy notes, are a key buffer in bad years; without them, ranches such as the ZR would go out of business. Marketing strategies such as backgrounding calves for sale⁶, herd bull selection, and the close monitoring of market trends are all part of economic survival as well.

Staying in business also means employing sound range management principles. The Monzingos recognize that the resource base is their most important asset, and that without productive range, there is no cattle business. Though the ZR Hereford is permitted to run 280

⁵ A section of public land is one square mile, or 640 acres

⁶ This procedure is called "backgrounding." The ranchers wean calves early, vaccinate them, and then teach them to eat grain from troughs. By assuring that calves will adapt to the feedlot environment, the Monzingos are able to sell the calves at an extra premium.

cattle, the ranch has remained stocked at an average of 230 head for the past few years. The ranch works to distribute the herd evenly across the range. Eight pastures have been established through the installation of fencing and development of seventeen water sources. The watering points benefit wildlife while allowing cattle to access distant pastures. Environmentally sustainable grazing strategies are an absolute necessity for the long-term maintenance of the ranching livelihood. The Monzingos, like other ranchers in the region, have adopted new methods and technologies as a means of preserving and enhancing the sustainability of the ranching system.

With the current drought now seven years old, the ZR Hereford is bracing itself for a potential culling of nearly half the herd. Climate events—particularly drought—have always been part of the ranching scenario in the Southwest. In the current context, ranching is only marginally profitable; during drought years, just getting by is difficult. New technologies and new management systems have allowed ranchers like the Monzingos to better make use of the ranch resources while also reinforcing the sustainability of the livelihood. At the same time, economic diversification has become a necessity for ranches like the ZR Hereford. This diversification, however, does not signal a departure from the ranching livelihood, but instead represents a means for sustaining a livelihood that is of symbolic as well as economic significance to the inhabitants of the Southwest.

2.1.3.2 The Future is a Golf Course: Case Studies Two and Three

Two ranches in the greater Benson area are being converted to residential use. Both ranches were once part of the Little Boquillas Ranch, the largest one in the valley. Horse Ranch, commonly referred to as the Dragoon Ranch, is the eastern half of the former Little Boquillas Ranch, established in 1878. The original ranch served the booming town of Tombstone which, at the time, prospered from its rich copper and silver mining industry. The ranch also provided a place for wealthy townspeople to keep their horses. J. H. Shultz, one of the original owners, purchased full control of the ranch from his two brothers in 1882 and then collaborated with Charlie Helm. Charlie had overgrazed his ranch at South Pass, Arizona, and was in need of decent pasture for his herd. Sadly, Charlie was shot and killed in an altercation that same year, and Shultz sold Horse Ranch to Bothin Tweed and Company, which was owned by the nephew of Tammany Hall's Boss Tweed. The landscape of the ranch was permanently changed in this period. Tweed was able to secure the sole fuel wood contract with the County Courthouse; woodchoppers cleared vast forests of oak and juniper, none of which have grown back. Tweed eventually went broke and the ranch passed through the hands of two other owners before it was sold to the Kern County Land Company, under whose ownership the ranch was called the Little Boquillas Ranch.

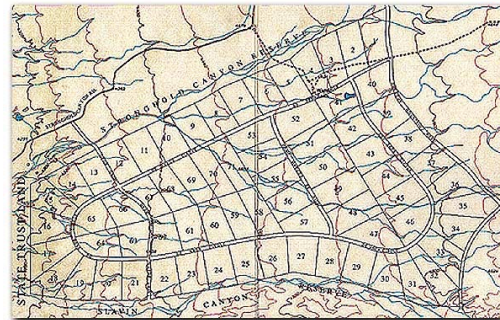
The Kern County Land Co., based in Bakersfield, California, purchased large portions of the valley in the early part of the 20th century. Prior to 1936, the company relied on vineyards, farming, land leasing, and ranching as sources of income. Including leased land, the company's operation covered over 2 million acres in California, Arizona and New Mexico. The sale of cattle

remained the primary source of income until 1936 when oil was discovered on the California holdings. The capital generated from oil fueled the company’s expansion into manufacturing, additional oil and gas holdings, mining, and real estate. In 1967, stockholders approved a merger with Tenneco, Inc.⁷ Unlike the Kern County Land Company; Tenneco was not specifically interested in ranching as an industry. One study participant noted that Tenneco was interested in obtaining the Australian gas holdings of the Kern County Land Co., and the San Pedro tracts were incidental to this goal. Through the 1980s, the conglomerate drifted into disfavor on Wall Street, eventually resulting in a share-price collapse and restructuring. It was during this period that Tenneco put its San Pedro Valley landholdings on the auction block. The Horse Ranch was sold to the Tucson-based Empirita Ranch Limited Partnership in 1992 as part of a much larger deal involving three ranches and riparian sections sold to the BLM. At the time of the sale, Horse Ranch comprised 52,272 acres, including 14,039 acres leased from the state and 11,380 acres leased from the Coronado National Forest District (Heltsley 1993).

Ernie Graves, one of the partners involved in the Emprita Ranch Limited Partnership in Pima County, purchased the ranch as part of three-ranch deal. He “papered it out,” i.e.; he prepared a development plan for the ranch, and then sold the property to a Phoenix-based developer. The ranch was subdivided into 36-acre parcels, thereby avoiding the expense incurred by the county zoning regulations. According to several of the study participants, the demand for these parcels has come from Californians and Europeans.

The other half of the former Little Boquillas Ranch became known as the Whetstone Ranch and Tenneco Ranch. This 15,677-acre parcel abuts the Whetstone Mountains and the town of Benson.⁸ Like Horse Ranch, the Whetstone Parcel passed to Tenneco as part of the larger deal. Tenneco then sold the Whetstone Ranch as part of the land package to a pair of Tucson-based developers, including the aforementioned Ernie Graves and his partner, Neil Simonsen. Simonsen is a co-founder of Fairfield Communities and part of the development team that built the Green Valley retirement community in southern Arizona.

Figure 2.5: Whetstone Ranch Development Plan



Source: <http://www.arizonaland.com/escalantemap.htm>

Unlike Horse Ranch across the valley, the owners of the Whetstone Ranch pursued a much more intensive development plan. Initial blueprints for the property included several golf courses, new commercial districts, and homes for between 2,500 and 7,000 new residents (see

⁷ Tenneco is a \$9 billion, low profile Fortune 500 conglomerate currently engaged in shipbuilding, energy, and packaging. Prior to restructuring, the company also engaged in chemical production, agriculture and insurance.

⁸ At the time of purchase, the Whetstone Ranch included 15,677 acres of deeded land. Another 11,396 acres were leased from the state.

Figure 2.5). The intensive development plans included lots much smaller than the 36-acre threshold below which subdivision costs are incurred.⁹ Furthermore, the city annexed the parcel, quickly doubling the size of Benson. The annexation served several purposes—the Whetstone parcel included most of the land around Highway 80, the primary approach to the soon-to-open Kartchner Caverns State Park. A new commercial district had already been established at the junction of Interstate 10 and Highway 80. The city planners (and many of the participants in this study) noted that much of the land along the corridor to the caverns would probably emerge as a commercial district and be further augmented by such additions as Cochise College. Several participants went so far as to suggest that the Kartchner Caverns Corridor might become the new commercial center of Benson and thereby eclipse the old downtown. By annexing this portion of land, the City of Benson ensured access to the potentially lucrative tax base of a new and large commercial district. While the Whetstone Annex remains the focus of the Benson development plan, the owners of other parcels adjoining the annexation are also planning for residential and commercial use. The Sands Ranch, which stretches north to the Kartchner Caverns State Park, recently ceded a square mile to development and annexation, and the owners have plans to put another square mile into real estate development as well.

The forces pushing these ranchlands toward conversion are many. The development plans for the Whetstone Annex are aimed at the national retirement community. The hot, arid climate of the region remains one of the primary draws at a national level; at the same time, the microclimate of the greater Benson/St. David area is a regional draw for many vacationers and retirees.¹⁰ The high proportion of deeded land to leased land provides a land base for speculators and developers. Increases in the interstate speed limit make travel to and from Tucson much easier, so retirees have access to the amenities of the big city—such as shopping and health services. Finally, the proximity of the Whetstone location to nature preserves, the mountains, and the future state park is often cited as an important factor in the proposed development.

Despite all these factors, the plans for Whetstone remain on the drawing board, as the owners of the property await capital investment to fund the first phase of large-scale conversion. Some of the peripheral development is already underway as motels and fast food chains have made their appearance at the junction of Interstate 10 and Highway 80. Unlike the development at Horse Ranch, the owners of the Whetstone tract seek the higher profits of a master-planned subdivision (as opposed to a 36 acre plot sell-off such as that of Horse Ranch). Because such subdivisions by law require water and electricity to each plot, they are also capital intensive. The regions near Phoenix and Tucson contain many examples of both successful and failed subdivisions of this type. While the fate of the Whetstone Annex remains in question, many similar projects in the region are moving forward under the assumption of its success.

As one of the study participants noted, “The only way to make a small fortune at ranching is to begin with a large one.” In the contemporary Southwest, ranching is widely perceived as a

⁹ See the brief explanation of county and city zoning policy, section 2.2.2.3: Policy Environment of the MSPRV

¹⁰ As many of our participants pointed out, Benson is, “five degrees cooler” than Tucson.

marginal livelihood. Ranchowners can expect small profits (at best) and difficult times; several dry years in a row can put a ranch out of business. The history of these two ranches reveals the results of that vulnerability to climate variability—the frequent shifts in ownership are emblematic of the vulnerability of ranching relative to urban development. These histories clearly document the movement away from more vulnerable land uses, such as ranching, to more intense, better-buffered forms of land use. There are more people on these parcels than ever before, but they are individually and collectively less vulnerable to climate variability.

Another insight that emerges from these land use and tenure histories is the global context of local vulnerability. Even the first settlers were enmeshed in religious, economic, and political networks that stretched well beyond the valley confines. The railroad established a mainline for trade networks stretching both east and west; investment flowed in from New York and other eastern metropolises. Drought, overgrazing, and other factors might destroy a particular ranch, but there were always new owners in line. The corporations that purchased much of the valley in the early part of the 20th Century were able to weather droughts because of their diversified holdings and financial backing. For land speculators and developers now holding the properties, ranching is secondary to the sale and development of the parcels. Large-scale development of the type described above is, ironically, partially dependent on the perceived poor climate of other regions of the United States. Local droughts are of concern only in the case that they might prevent the delivery of sufficient groundwater to the golf courses and residences of the planned communities. This scenario, despite whatever underlying reality it might reflect, has yet to occur in any similar communities in the Southwest (see section 2.3).

2.1.3.3 The Greenest Grass is Off Limits: Case Study Four

Over the past decade, much of the San Pedro riparian area has shifted from traditional ranching uses and now comes under the protection of the San Pedro Riparian Conservation Area (SPRCA). The catalyst for these land exchanges is the Nature Conservancy, a non-governmental organization that seeks to preserve land through purchases and transfers. In cooperation with the BLM, the Nature Conservancy attempts to purchase private land within the existing boundaries of the SPRCA, and then transfers the parcels to the BLM for stewardship. The stated ideology behind the Nature Conservancy's role is to surmount the lethargy of the federal land purchase system and thereby increase the amount of protected land.

In 1988, the BLM eliminated grazing, shut down irrigation wells, and closed existing mines within the conservation area. Through this process, the BLM sought to improve the ecological condition of the river within the conservation boundaries. Figure 2.6, a pair of “before and after” slides, attest to the impacts of this effort on the riparian area. The SPRCA roughly abuts the MSPRV study area near St. David and is the only portion of the study area where conservation agencies are active. At the current time, the riparian stretch between St. David and Pomerene is not part of the Nature Conservancy's future plans, since by their estimation; this strip of riparian land is already damaged beyond repair. The Conservancy's focus on the upper and lower

stretches of the San Pedro is part of a calculated strategy to return significant, viable portions of the river to their natural condition.

Figure 2.6: The San Pedro River, several years before and several years after the formation of the SPRCA



The solidification of the SPRCA land holdings in the region, in conjunction with the activity of non-profit conservation agencies, presents several problems for local, small-scale landowners. Proximity to a preserved or public land is a strong selling point for planned residential development, and real estate agents openly advertise this feature as a special enticement.¹¹ At the same time, conservation purchases can potentially raise the assessed value of nearby parcels, which is set according to the sale value of comparable parcels. Thus, the increased land acquisitions by the Nature Conservancy along the San Pedro raises the overall value of land. Rising land values tend to benefit speculators and to encourage land sales. At the same time, through increased taxes, the rising land values discourage the more conservative, marginal and climate-vulnerable land uses in the valley. Furthermore, the conversion of private land to public holdings removes the parcels from the county tax rolls, reducing access to tax revenues. These issues were of great concern to many of the study participants.

2.1.3.4 Homes by the Truckload

Visitors to the Benson area are quick to notice the prevalence of manufactured homes. One-bedroom models retail for \$25,000, while the more popular three to four bedroom “double-wide” models begin at \$45,000. Many of the homes are built in the Phoenix area and the industry as a whole supplies a lucrative and growing market. There are eight to ten dealers in Sierra Vista, countless more in Tucson. A single dealer has worked Benson for the last three years, but has now been joined by a local competitor. The owner of the older business reports sales of

¹¹ “Stronghold Canyon & Slavin Canyon Reserves: These riparian water courses channel the rains from the high mountains through the Ranch to the San Pedro River Riparian Preserve below. They are graced with a wide variety of tree and plant life including oak, willow, mesquite and walnut trees. They will forever be preserved in their natural state as equestrian and wildlife conservation easements. Ownership of any of the properties bordering these preserves affords their owners the opportunity for frequent sightings of area wildlife such as deer, fox, coatimundi and javalina.” From a description of the Escalante Subdivision of the Dagoon Mountain Ranch, at <http://www.arizonaland.com/escalantemap.html>

approximately thirty units per year, which accounts for only a small portion of total sales as many customers and developers purchase in Sierra Vista, Tucson, or Phoenix. Only one out of five new homes in Benson is “stick built;” the other four are manufactured. A purchased manufactured home can be skirted and put on blocks in half a day by a team of two laborers. The same team might spend two days on homes that require foundations.

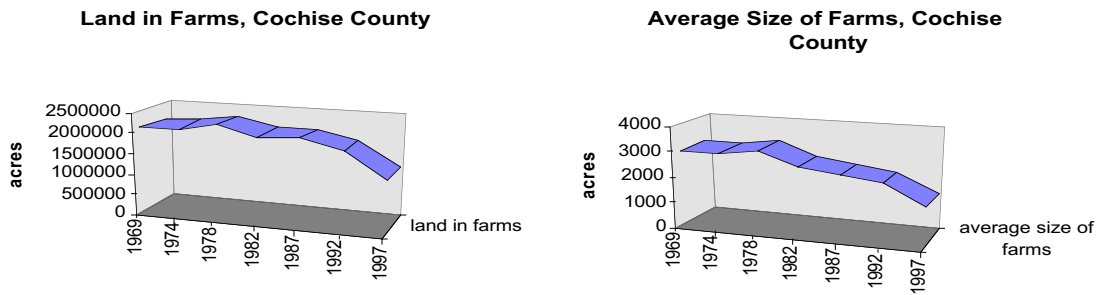
Manufactured homes are the overwhelming choice for the population feeding the residential growth in the Middle San Pedro River Valley. Many of the purchasers are retirees who, after several seasons of traveling back and forth between summer and winter locales via recreational vehicle, often decide to purchase a manufactured home to save on transportation costs.¹² Some of these homes are located on the same lots previously occupied by their recreational vehicles, while others purchase available parcels in and around St. David and Benson. In addition to the retirees, many of the new homes are sold to the growing bedroom community now established in the study area. This demographic subgroup live and work in the larger metropolitan areas—typically Tucson or Sierra Vista—but make their home in the Benson/St. David area. While the declining employment prospects in the area are certainly a factor in the growing commuter population, the change in speed limit is perhaps the most important factor. By raising the interstate speed limit to 75 mph in 1995, Arizona legislators opened up many peripheral communities to urbanization. The city of Benson is just over 40 miles from the industrial area on the southeast side of Tucson; the commute from Benson is shorter in time than that of many other Tucson suburbanites (to the northwest, for example). Similar changes in highway speed limits have also made the commute to Sierra Vista, the other major center of employment in the region, much shorter.

The Little Boquillas case study explored the large-scale development of two ranches in the area; some of this development, should it reach fruition, will rely on manufactured homes. At the same time, there has been an increasing fragmentation of land parcels in and around Benson and St. David as the population of the region expands. The demographic forces feeding this process are threefold: organic growth, expansion of the commuter population, and retirees purchasing land and houses outside the RV parks. The latter groups cite climate, freedom from traffic problems, and the “small-town” lifestyle as the major draws of the Middle San Pedro River Valley.¹³ As newcomers to the area arrive, and as the families of the region grow, larger parcels become fragmented. In terms of land use, the impacts of demographic change can be seen in the farmland data available for the San Pedro River Valley. Both the number of farms and the size of farms in the county have been steadily decreasing (see Figure 2.7).

¹² The costs of traveling by recreational vehicle are surprisingly high. Gas costs are exorbitant, with the larger RVs often getting 4 to 8 miles to the gallon, and parking fees at favored campgrounds begin at \$20 a night. The impact of the *winter people* on the socioeconomic landscape of the valley is dealt with explicitly in section 2.2.

¹³ The “small-town” lifestyle appeared again and again in the team interviews. The notion is connected to the perception that the crime rate of Tucson has escalated to a point where the schools are no longer safe for children, drive-by shootings are a constant threat, and so on. While the Tucson Police Department actually records a significant decrease in the crime rate over the last five years, the profile of these crimes in the public consciousness seems to have increased.

Figure 2.7: Agricultural Land in Cochise County



The fragmentation of farms and other parcels in the region is symptomatic of a steady rate of land use change that is difficult to quantify. Unlike the large development plans underway on the Horse and Whetstone Ranches, records are not kept for the infill growth, or for land conversion in the more remote parts of the county. Yet, this growth is readily perceptible in many regions of the study area. Several participants pointed to the increasing parcelization of the land between Benson and St. David. This rapid transformation has sometimes created a tense relationship between the two communities, as the possibility of annexation looms and the cities grow together. Residents decry the “wildcat” growth of the Mescal and J6 along the western edge of the county, both of which are expanding at an unprecedented and uncontrolled rate.

The process of parcelization in the study area is also symptomatic of a shift in livelihood. As one of the respondents noted, farming has long been a secondary source of income for the landowners in the region. The proliferation of manufactured homes, as an emblem of the growing importance of residential land use, is but a feature of the proliferation of “hobby farms” and “ranchettes” in the region. The symbolic values associated with ranching and farming, both pillars of rural life in the Southwest, seem the only support and last bastion of hope for these declining livelihoods.

2.1.4 Land Use in Perspective

It was the original intent of this study to map the changes in land use through time as a means of documenting the impacts and direction of important socio-economic processes within the context of climate variability. Unfortunately, a quantitative analysis of land use change throughout the MSPRV is constrained by the lack of consistent spatial data. The data sets currently maintained by the USDA and the landholding federal agencies are not consistent in terms of unit, nor do they have a historical series. At the state level, several urban counties have generated detailed GIS sets, but Cochise County and other rural counties in the Southwest have neither the funds nor the infrastructure to assemble such data. Until federal and state agencies harmonize the existing data resources and formalize a regimen for collecting future data, it is not possible to provide a comprehensive, quantitative and spatial analysis of land use change in the study area.

Nonetheless, the combination of regional and county quantitative data with the qualitative stakeholder interviews in the area does suggest a current period of rapid land use change along the San Pedro. Ranching and farming, the principal livelihoods of the region during much of this century, have in part given way to residential growth. Some of this residential growth is yet to be actualized, some of it is underway. Speculative plans for large residential communities are now the center of focus for many of formal and informal leaders of the study area, and many perceive residential growth and the tourism industry as the foundation for economic success. This process represents a move from land uses that are less intensive but more vulnerable to climate variability and change to uses that are more intensive but less vulnerable. Several factors underpin this process and have enabled change to proceed.

The first important factor to consider in the process of intensification in the region is technological change. Advances in the ability to withdraw water from the aquifer have allowed farming and ranching to continue and, in some cases, to prosper where climate would dictate otherwise. Improvements in the regional and national transportation infrastructure made possible the seasonal migration of northerners to the warmer climate of the Southwest, as well as the daily commute to and from Tucson and Sierra Vista. Moreover, new materials have produced inexpensive and semi-portable homes. These technological advances have increased the mobility of many of the valley's inhabitants, buffering against the inherent risk of the local microclimate. Technological advances have also provided unfettered access to local resources, particularly water, making them seem abundant rather than scarce.

Technology has also spurred economic diversification in the region. As the case studies reveal, the livelihoods of the region have been part of a global context since their inception, but recent technological improvements have pushed economic diversification to new plateaus. The seasonal retirement contingent now comprises nearly half of Benson's population; in spatial terms, the foundation of their livelihoods are scattered across the continent, and surely reach into every branch of our nation's economy. Among the winter visitors are retired teachers, farmers, insurance salesmen, car dealers, factory workers, real estate agents, and so on. Similarly, part of the working population in Benson is employed in Tucson and Sierra Vista, again diversifying the economic base by distributing it spatially. The economy of the study area, via a series of technological innovations, has become increasingly connected to a wider global economic structure; and this process has reduced vulnerability to climate variability, at least over the short run.

Technological change and increasing economic diversification, as the dominant processes underlying the shift in both livelihood and climate vulnerability in the study area, have been accompanied by the growth of the social networks in which livelihoods are embedded. The substance of these networks is the relations between people. Many of the inhabitants of the MSRPV can rely on friends, relatives, and coworkers locally or in other cities and states. Furthermore, the seasonal population is often *members* of communities in other parts of North

America. These social networks help mitigate the impact of localized climate variability and change.

Decreasing vulnerability to climate variability and change in the context of population density increases is directly the result of the ability to intensify access to groundwater. The valley water table acts to mitigate, even eliminate, the effects of drought; and, as land use shifts from ranching and farming to residential, the land and its people are decreasingly reliant on rainfall. Much like Tucson, Phoenix, and Sierra Vista, the water table provides a vast, mitigating buffer against climate variability and change. With residential growth as the intended foundation of the MSPRV's economic future, it is likely that groundwater supplies will at some point in time make climate variability a more pressing concern.

Finally, the case studies described above suggest the mercurial nature of residential growth and development. While the deserts of the Southwest contain several grand, successful residential schemes (Green Valley, Arizona, for example), there are notable failures as well (Sunsites, Arizona, for example). The steady infill growth in the MSPRV is predictable via standard demographic models; the rapid growth of planned communities, however, is much more difficult to analyze. The success of the developments planned for Whetstone depends on a myriad of factors: development-side financing, the national economy, advertising, word of mouth, the perception of the planned community, and so on. Attempts to model growth in the valley must grapple with the inherent unpredictability of residential growth in this form. It is entirely possible that the population of the MSPRV might double over the next ten years; at the same time, the grand development schemes might fail, resulting in slow, continued growth of the population. These difficulties in predicting population growth create further problems for predicting water use, future electrical demand, and a variety of other socio-economic factors. Several of the study respondents said as much: it is clear that the region will continue to grow, but no one knows just how much.

2.1.5 Conclusion

The result is a system of complex vulnerability to climate variability and change. Overall, the livelihoods represented in the valley are less vulnerable to climate variability and change than in previous decades. Remnant land uses, such as farming and ranching, continue to this day more or less as viable enterprises. The climate vulnerability of these activities is now mitigated by the context in which they are now pursued, as many ranchers and farmers have additional sources of income. The inhabitants of the study area recognize these factors and clearly noted on many occasions that climate rarely figured prominently in their decision processes. The region is perceived by many of the participants as one on the cusp of rapid and vast residential growth. In places, this process is underway.

2.2 Commercial Business and Industry -- Nicholas Benequista and Sarah Stewart

2.2.1 Introduction

While shifting land use patterns transform the rural landscape of the Middle San Pedro River Valley; the urban landscape is also changing, driven by global and local forces. This section examines the economic restructuring and community development occurring in the urban areas of the region and highlights the role of climate variability and change in this process. Since Benson has been the urban center of the region and much of the anticipated socio-economic change is expected to occur there, the discussion will focus on that community.

While agriculture, ranching, mining and other natural resource-based industries are still significant in terms of land use, they have become less important as economic livelihoods over the past 30 years (Galston 1995). In the place of these traditionally rural activities, manufacturing and the service activities have become increasingly important for small towns. Benson is one such community that seeks to transform itself, in part, by developing these two sectors. Like many communities across the U.S. that have undergone this change, Benson faces new challenges and a shifting set of vulnerabilities.

During the 1960s and 70s the Southern Black Belt South was transformed into the Sun Belt South by the growth of industries attracted by factors such as cheap land, low-cost labor, relatively tolerant regulations, and weak or non-existent unions (Gaventa 1990). Large government investment in transportation, mostly highways, facilitated this transformation (see Section 2.4). Over the last two decades, however, the rural Southwest experienced a different urbanization and industrialization process. Here rural areas were intricately tied to mining, and the rural to urban shift occurred in the context of boom-bust cycles (e.g., Guilford 1989, Ringholz 1989). With the worldwide crisis in mining, many communities in the Southwest have sought to stimulate declining economies by importing people and public dollars, exploiting a competitive advantage in the “quality of life” amenities that rural towns can offer. Consequently, the economic shift has been toward a service structure for retirees and tourists complemented by small light industries. This section examines the role of climate variability and change in this economic transformation. While the report of the International Panel on Climate Change states that the “sensitivity of industry and energy to climate change is widely believed to be low in relation to that of natural ecosystems and agriculture” (IPCC 1996: 370), the arid Southwest presents a unique set of climate challenges.

The MSPRV provides an opportunity to investigate the effects of climate on the siting and survival of two industrial plants; one established in connection with the historical mining interests of the area and the other because of a sustained labor supply. In both case studies, however, industries that are potentially sensitive to climate in their productive operations have developed buffers against extreme climate events. Labor availability, public environmental values, and transportation have been more salient factors in the establishment of industry in the valley.

The MSPRV also illustrates the transition to a service economy dependent on tourism. The warm average winter temperatures and the cooler summer temperatures (relative to Tucson) of the Benson area constitute a principal feature that draws tourists to the valley. The climate “reputation” of MSPRV is a highly positive one that ignores the extreme events that can occur in an arid environment. In fact, several climate variability studies have explored the potential effects of climate on the natural attractiveness of communities to the tourist flow (Brotton et al. 1997; Rothman and Herbert 1997; Zinyowera 1995). These assessments have examined the direct effects of climate change and variability on physical systems and, subsequently, the indirect impacts upon the social systems. These studies suggest that social systems are often affected by climate before significant changes occur in the physical systems. This examination of tourism in the MSPRV demonstrates the importance of perceptions of climate and highlights the problem of scale in addressing the socio-economic impacts of climate.

2.2.2 Overview of Business and Industry in the MSPRV

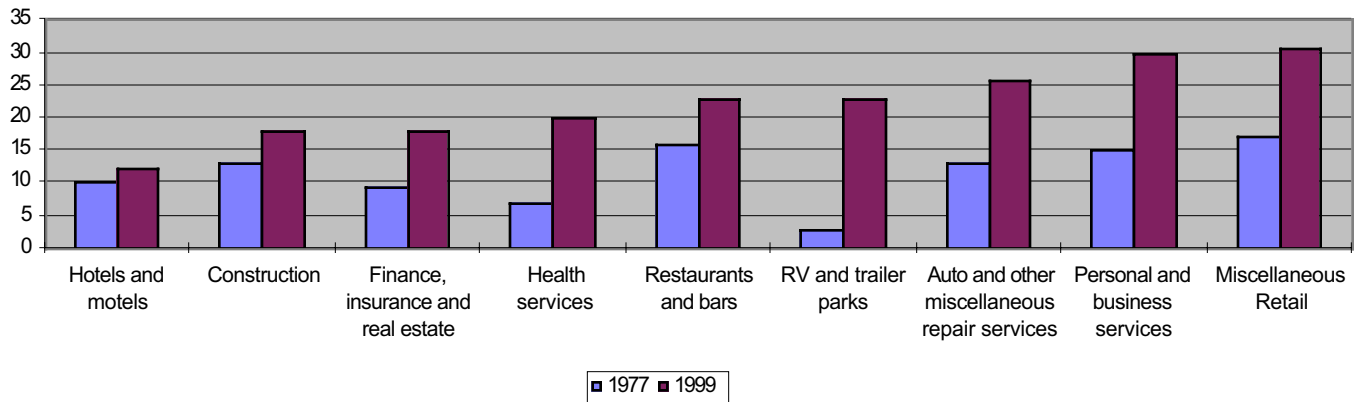
In the early 1900s, Benson was a flourishing railroad center, and several businesses opened in the area including the Yellowstone Mining District, the Carr and Company barley crushing mill, and a smelter (Tompkins 1998). The growth was stifled, however, when the El Paso and Southern Pacific Railroads merged in 1910 and shifted their operations to the roundhouse and shops in Tucson. Still today, city leaders speculate that Benson would have become a major population center of Southern Arizona had the railroad companies decided differently. Nevertheless, as history would have it, Benson was limited to one railway and the aforementioned companies eventually shut down. Agriculture and ranching largely supported the area in the next 30 years, and one company, Apache Powder, opened in 1922, provided a stable base of employment for the communities of St. David and Benson.

Commercial business was later bolstered in the 1930s by the construction of Highway 80, linking Benson’s Fourth Street to Douglas. Motels, restaurants, auto shops, and other traveler related services opened along the section of the highway passing through downtown Benson. The completion in 1974 of Interstate 10, which passes Benson to the north, removed the flow of traffic from the commercial center of Benson, but also increased the overall volume of traffic, so that the city remains dependent on travelers for much of its revenue. Figure 2.8 shows the number of businesses in various SIC categories in 1977 and 1999. According to community leaders, the growth indicated in the graph occurred almost exclusively in the last three years.

Partially fostered by the announced opening of the Kartchner Caverns State Park (now postponed until November 1999), several hotels, fast-food restaurants and RV parks have recently opened in Benson. A majority of the new hotels and restaurants have opened at the junction of I-10 and the newly expanded Highway 90 which leads to the state park entrance. RV parks are also in the plans for that area, but new parks are opening throughout the MSPRV. In many ways, Benson exemplifies rural trends at state and national levels. The decline of agriculture, the struggle to maintain industry, and a growing tourist/visitor based economy are features common to many of America’s small towns. Benson is adjacent to a large metropolitan

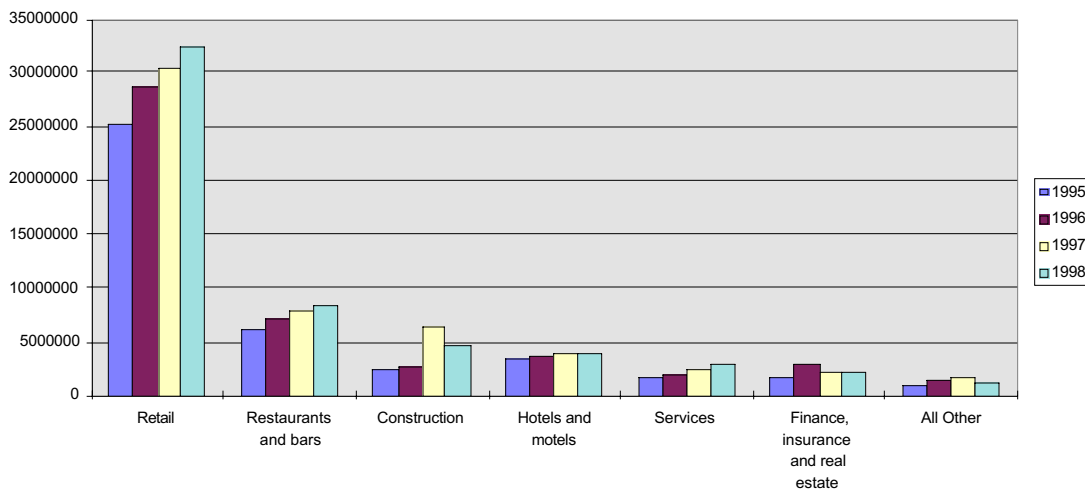
area, has historical and natural attractions, and has a moderate climate relative to other settlements in the area. Ex-urbanite commuters, travelers, and winter visitors are now the largest markets for local merchants and the taxable sales figures for retail and restaurants and bars reflect this growth (Figure 2.9).

Figure 2.8: Number of Businesses in Selected SIC Categories 1977 and 1999



Source: Gibson, 1977

Figure 2.9: Taxable Sales for the City of Benson 1995 – 1998



Source: City of Benson

Currently, the major categories of businesses in Benson are retail, RV parks, restaurants and bars, and personal and business services. There are 70 retail stores in the Benson city limits - mostly concentrated along Fourth Street and Ocotillo Avenue - that provide over fifty percent of the City's taxable sales revenue (see Figure 2.9). Many of these shops are minimarts and gift shops that depend on winter visitors and travelers to support their businesses. The category of fastest growth in the last 20 years has been RV and trailer parks, increasing from 3 in 1977 to 23

in 1999 (see Figure 2.8). The impact of growth in this area, however, is not accurately captured in the taxable sales figures for lodging establishments since park visitors are not charged a Bed Tax unless they stay longer than 30 days, and even if they do stay for an extended period, the tax is only a nominal fee (see Figure 2.9). Nonetheless, RV parks are an extremely significant component of the changing Benson economy and identity. Restaurants and bars contribute the second largest portion of taxable sales revenue. Though only seven more eating and drinking establishments are open now than in 1977, several more restaurants, mostly fast food, are under construction on Highway 90.

2.2.3 Climate and Industry: Two Case Studies

This section examines how climate operates as only one of many factors influencing the decision of industry to locate in Benson and affecting the success of those industries. Two case studies demonstrate that climate's impact on industry in Benson has been negligible relative to other factors. Especially in recent years, climate has been irrelevant compared to the importance of public perception of industry, labor supply, and transportation. There are only two major industrial companies in Benson. The first opened in Benson 77 years ago in part because of the arid climate, but this factor has decline in significance relative to other factors, such as safety and pollution. The second company opened only five years, and in this case, only the business climate was a consideration. Each company is described in the following case studies.

2.2.3.1 Case Study I: Apache Nitrogen

Apache Nitrogen has a long history in the Benson area. It was originally named Apache Powder Company and was constructed in 1922 by a conglomeration of mining companies that wanted a less expensive supply of dynamite. The location of Apache was chosen for its proximity to the mining industry and the railroads, and the climate and geography of the area. The conditions were thought to be ideal for the dynamite industry; the dry climate was considered best for making explosives and the hills served as barriers in case of accidental explosions. Apache was the second largest explosive manufacturer in existence for some time, until the development of ammonia caused a decline in popularity of dynamite and, in response, Apache began to produce ammonium nitrate and ammonium nitrate fuel oil, changing its name to Apache Nitrogen in 1981.

Currently Apache produces industrial chemicals, explosives, and nitrogen-based fertilizer products; it is now considering an expansion that would shift sixty percent of the production to agricultural products and add 50 new jobs. Apache is a privately owned company with annual sales around \$40 million and employs about 110 people. About 70 members of the labor force live in the Benson and St. David area. Apache has not had any trouble finding employees for entry-level positions in the area, but the company does recruit on a national level for professionals such as chemical engineers. Apache attracts professional employees by selling the warm Arizona climate and the friendly image of a small company.

Environmental Issues

Since the shift from nitroglycerin to ammonia based products, the risks associated with the plant are no longer explosions but emissions. In the 1970's, the Arizona Department of Health and Safety found what they determined to be high levels of nitrate and ammonia in water samples taken near the plant. The problem largely originated prior to 1971 when the wastewater from Apache was routinely dumped into the San Pedro River. In order to deal with this, Apache built unlined evaporation ponds that leaked almost as much water as they evaporated. In 1986 the Environmental Protection Agency proposed that Apache be included on the National Priorities List, a list of sites intended to aid in the cleanup of contaminated (Superfund) sites as established by the Comprehensive Emergency Response, Compensation and Liability Act (CERCLA). It was officially added to the list in 1990, and the EPA made demands of Apache that included waste removal, facility upgrades, training and record keeping, aquifer protection, air compliance, storm water runoff, backflow prevention, and underground storage tank upgrades.

Between 1993 and 1996 Apache failed to report three releases, two of nitric acid and one of anhydrous ammonia. These were cited as a violation of the Emergency Planning and Right to Know Act which requires notification of the National Response Center, the state emergency response commission and the local emergency planning committee when certain releases are exceeded. The company settled the violations in August 1998 by paying \$17,000 in fines and contributing \$71,000 toward projects that improve local emergency response agencies and provide an on site weather station. Apache also had to pay for the drilling of eight wells and for bottled water for the residents of the contaminated area.

In order to treat its wastewater more effectively, Apache built a brine contractor with Hargis and Associates, a Tucson consulting firm. The brine contractor is a \$5 million chemical treatment plant that allows Apache to reuse all of its wastewater, can be fueled by natural gas at the site, and reduces Apache's need for groundwater. The water goes back into Apache once it is distilled and the impurities are used as a fertilizer ingredient. This project won an award from the National Groundwater Association. The biological process pumps contaminated water from a shallow aquifer through five shallow ponds that treat the water using cattails and other aquatic plants. The bacteria combine with organic carbon from dead plant materials, liberating the oxygen from the nitrate that is then released into the atmosphere as nitrogen gas which is harmless. Each pond progressively cleanses the water so that by the fifth pond it meets drinking water standards and is released into a dry wash where it seeps into the shallow aquifer and makes its way to the San Pedro River. The plan is designed to be effective for twenty-five years.

Despite the success of its groundwater treatment project, Apache has suffered from negative public perception. Efforts to expand production have been met with some objection by the public. Under new leadership, the company has adopted an open-door policy; holding open house and inviting members of the community to visit the plant and learn more about its operations. These efforts are recent and the impact yet unknown. What is clear, though, is that

the MSPRV has not escaped the increasing concern about industrial facilities and will carefully assess attempts to locate new industries in the region.

Climate Issues

Though climate initially played a role in the decision of locating Apache, the significance of climate has since changed with its operations. When Apache was first in operation, it was thought that the hot, dry climate was ideal for the production of dynamite. Today the mild climate is still important for Apache's operations, but for entirely different reasons. The plant runs more efficiently in cooler weather, which means that in the winter the company produces 15 to 20 more tons a day of ammonium nitrate than in the summer. When the weather is cooler it is easier to maintain control parameters and to keep the pressure tables in line. However, freezing causes problems for the water lines and instrumentation. Mild conditions are therefore ideal and easier on the end product as well. When there are extreme highs or lows during the day, it causes ammonium nitrate to break down. The mild climate is also beneficial for transportation that is crucial to the manufacturing process. Everyday, raw materials are shipped in by rail and because of the plant's location, climate related transportation delays are extremely rare. Apache ships its finished product by highway and by rail.

Outside temperature affects Apache in a number of ways. Apache's plants require cooling towers, which function more efficiently in cool weather. High temperatures diminish the ability of the towers to cool the water they contain, which in turn slows production. Furthermore, air is one of the raw materials needed in the chemical process that produces ammonia-based products. High temperatures decrease air density that reduces the rate of this process. Climate also determines how nitrates interact with the ecology of an area. Geology and rainfall are important for determining the susceptibility of an aquifer to contamination because denitrification occurs in wet, warm soils where oxygen is present

Apache Nitrogen maintains an on-site weather station that records temperature, wind direction, and barometric pressure. The weather station is part of the 1998 EPA Supplementary Environmental Project (SEP) that has served as a partial alternative to fines in the settlement of Apache's environmental enforcement case. Apache furnishes the information collected by the station to Cochise County and to the National Weather Service. For its own purpose, Apache uses the weather and climate information retrospectively to understand problems with production and to formulate emergency response strategies. Emergency response plans are devised based on the most probable prevailing conditions during an ammonium release. For example, wind conditions determine how far and in what direction a release will travel. Windsocks are placed around the plant and workers are trained to react to them. Weather and climate information also dictates immediate response to emergency at the plant site. Also, if a relief valve goes off during production, employees look at the climate data to find out why this occurred. On a hot day ammonia in a gaseous form will expand and increase the pressure that releases the valve. According to one source from Apache, "hot days bring a little more concern around the plant." Hot days are also a factor in terms of emergency response. In case of a severe

emergency rescue, workers are provided suits that cover them from head to toe for protection. In hot weather, the temperature inside the suits can reach 130 degrees, so rescue workers can only operate for twenty minutes at a time.

2.2.3.2 Case Study II: AACCO Casting Products, Inc.

The foundry produces alloy, brass and bronze castings for other industries and has additionally expanded into Southwestern art castings, though a majority of their business is industrial casting. As one example, AACCO produces a casting that is used as a part of an assembly line at a company in Tucson that produces commercial glass, refrigerator and freezer doors. Castings are produced in a labor-intensive process by creating sand molds in which molten metal is poured. Operations currently require two furnaces and thirty full-time employees.

Though AACCO has been manufacturing castings for 45 years, the company only recently moved its operations to Benson from California in 1994. The company was formerly struggling with the high taxes and wages of California that often kept profits below five percent. After deciding to relocate “anywhere out of California”, AACCO selected Benson as a candidate because of the poor economic situation and high unemployment, conditions which translate in industrial terms as “business friendly.” After visiting Benson, company officials were enticed by the safety and serenity of the small town, the promises of an unlimited labor supply, and the assurance that the operations of their plant would not bother the community.

Labor Issues

In AACCO’s first three years in Benson, employment turnover was a major impediment to operations. According to the current president, Bill Ritter, AACCO hired and fired hundreds of chronically unemployed people from the MSPRV in its first years, often for problems related to substance abuse. One employee speculates that the high employee turnover is the cause of AACCO’s reputation as a “sweatshop”, which has further contributed to the difficulty of finding workers. Largely due to these labor problems, AACCO was unable to make a profit in its first three years.

Unable to find labor locally, AACCO began drawing workers from the twin city, Douglas-Agua Prieta, along the U.S.-Mexico border. At one time, 90% of the company’s new employee base came from this area. Unable to recognize false work visas, AACCO inadvertently hired several Mexican Nationals without proper authorization. Citizens in Benson, possibly disgruntled by AACCO’s hiring practices, suspected AACCO’s indiscretion and reported the company to the International Naturalization Service. The company was raided twice and lost a significant portion of their workforce, but has since successfully guarded against hiring undocumented workers.

Recently, AACCO has recruited labor from across the Southwest, in particular from its former California location. Potential employees are invited to conduct an interview and to visit

Benson. Of those selected, several have declined the position because of Benson's "hot climate." Those that did elect to relocate to Benson did so for quality of life reasons. The quality of the schools, the safety of the community, and inexpensive real estate appeal to many of the workers coming from dense, urban areas. Significantly, many of the Tucson commuters currently residing in the MSPRV cite the same reasons for their relocation. Only four of AACCO's current employees are from the local area. Having succeeded in establishing a stable labor force, improved management, and a diversified product line, AACCO began turning a profit in 1997 and does not plan to leave Benson.

Public Perception

AACCO also contends with a negative public perception of their operations. When the facility in Benson first opened, the company still operated the facility in Torrance. The costs associated with maintaining two plants forced them to open the Benson facility before the ventilation system was operational. As a result, the working environment was extremely dusty for the first month. While the ventilation system was soon completed, the community had already developed a negative opinion of the foundry working conditions. Coupled with the high turnover rates, many locals became unwilling to work for the company, and AACCO was forced to turn to a local pool of chronically unemployed labor, creating the problems cited above.

Citizens have also filed complaints about air contamination after witnessing the steam released in the casting process. Since the casting process does produce lead dust as a by-product, the state performs periodic inspections and imposes fines for unsatisfactory conditions or excessive releases. Faulty complaints can result in a higher frequency of inspections that ultimately costs the company money. AACCO has not, however, been significantly impacted by the enforcement of environmental regulations.

Climate Issues

As mentioned previously, Benson's climate was considered to be too hot by many of the potential employees AACCO tried to attract. This is one of the few cases in which Benson's climate has not been considered positive feature of the region. Nonetheless, AACCO had little trouble encouraging people to relocate to Benson. In effect, climate has had minimal impact on AACCO's operations. The cooling towers that lower temperatures in the core of the furnaces and the evaporative coolers for the facility operate more efficiently in a dry climate. Current water rates make the costs associated with the towers and coolers negligible, and even if water rates rise, the cooling towers only lose 15-20 gallons per day through evaporation, and the facility's coolers will always be a less expensive alternative to air conditioning. Only an extreme shift towards high humidity, significantly reducing the capacity of the coolers, would cause the company to consider replacing their current system with air conditioning.

2.2.4 Climate, Commercial Businesses and a Mobile Market

According to owners and managers of businesses in the MSPRV (e.g. restaurateurs, shopkeepers) who participated in this study, climate is not a major factor considered in their decision-making. Climate does, however, influence the decisions made by the markets served by Benson businesses - commuters, travelers, and seasonal residents. These groups are affected by climate in subtle and complex ways that raise considerable issues regarding (1) the perception of climate and climate information, and (2) differences between the scale of climate variability and its socio-economic impacts.

Commercial businesses in Benson are affected by regional and national perspectives of the local climate. These perceptions are predominantly influenced by climate information circulated by popular informal sources. Due to the bias of climate information systems toward larger cities, these sources often erroneously characterize the climate of small towns in terms of their larger neighbors, neglecting the subtle yet important differences in microclimate which influence demographic changes and therefore impact local economies. Benson's moderate climate is one of its principal amenities, but potential visitors may never be aware of this unless climate information systems report data at a higher resolution.

Variation in Benson's temperature, however, may not be the most significant climatic factor affecting local business. Rather, Benson has its climate ear attuned to climate variations in other (tourist sending) regions of the country. Local climatic variation in the MSPRV is less likely to channel tourist flows than is the severity of northern winters.

Taxable sales and figures for the number of businesses in various categories (Figures 2.8 and 2.9) indicate that RV parks, retail stores, and restaurants and bars are the sectors of greatest significance to the Benson economy. The following sections explore the issues facing each of these interrelated sectors and the potential impacts of climate on Benson's commercial business. Particularly salient are the potential effects of the proposed Kartchner Caverns State Park.

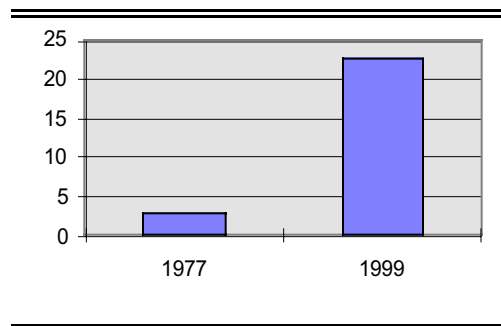
2.2.4.1 RV Parks

The term "recreational vehicle" is a bit of a misnomer, since RVs are not merely a source of recreation. Indeed, RVs reflect a lifestyle. They have been said to embody the ideals of a generation, perhaps representative of a particular group (Counts and Counts 1996). The RVer touts both freedom and community, independence and interdependence. According to Dorothy and David Counts, "RVers have fashioned communities that give them a sense of belonging and mutual interdependence while building their lives on mobility and independence - values they equate with freedom" (Counts and Counts 1996). The origin of this spirit can be traced back to the rhetoric of western expansion that first encouraged Anglo settlers to cross the prairies 150 years ago.

The recreational vehicle followed closely behind the invention of the car. By the 1930s, camper trailers were furnished with most of the luxuries of the home. By the end of WWII, full-time trailer living gained social acceptance and trailer parks became a common site. The “home on wheels” divided into two separate lineages in the 1960s with the advent of modular homes that attach to foundations. These occasionally mobile homes were akin but distinct from the nomadic trailers that would evolve into the RV and fifth wheel. Another significant development was the beginning of RV clubs and organizations, the institutions that turned a lot of like-minded individuals into a socially cohesive group and, in fact, function to disseminate climate information.

In the past 20 years, the majority of new businesses in Benson have been RV and trailer parks. Some Bensonites believe that this emerging industry could provide the boon the city has been awaiting; others, however, see no benefit from this migratory community. Figure 2.10 demonstrates the rapid growth in the number of such businesses in the last 20 years. Most of this growth, however, has been concentrated in the last 5 years. There are now approximately 1,647 RV spaces in the Benson city limits and an additional 500 lots in the surrounding areas.

Figure 2.10: Number of RV and Trailer Parks in Benson 1977 and 1999

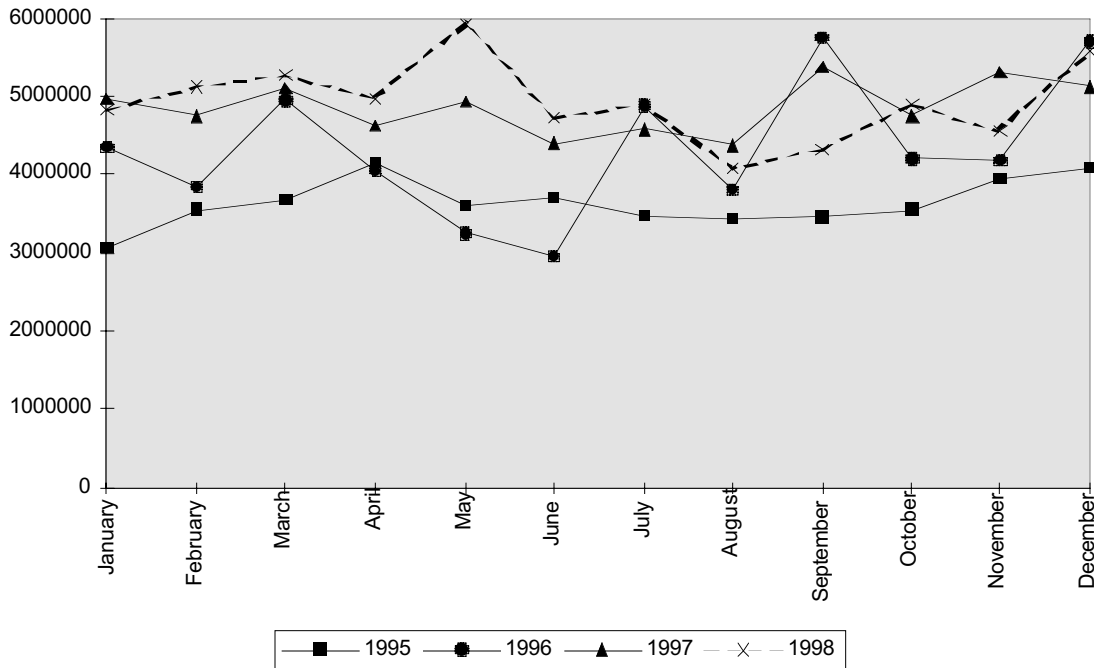


Source: Gibson, 1977

Most RVers hail from colder regions of the country. Some RVers vary their routes every year depending on climate and other factors, but most follow a standard travel schedule determined by the changing seasons. In one scenario, an RVing couple will leave their base location (where they may or may not have a permanent home) in early October and begin a slow trek southwest. After stopping briefly at several sites, they eventually arrive at their favorite winter town, where they may rent or own a space at a private park or belong to a co-op. Once in the community, the couple may fly home for holidays or take short trips in the local area. In early April, the couple leaves for home, possibly taking an alternative route. Under this scenario, Benson may be either one of the sites en route or the final destination itself.

The yearly schedule is, however, prone to disruptions and delays that are often linked to climatic variations. The El Niño event of 1998 provides an example. Many Benson residents speculate that the unseasonably warm winter temperatures in the Midwest created by the El Niño event resulted in a significant delay in the schedule of winter visitors. RV park owners

Figure 2.11: Taxable Sales for the City of Benson by Month 1995 - 1998



Source: City of Benson

corroborated the suspicions by noting that occupancy rates were lower than average (or than expected) for October and November. Figure 2.11 charts the taxable sales for the City of Benson from 1995 - 1998 and shows the decline in sales in the month of November associated with El Niño.

2.2.4.2 Kartchner Caverns

Though climate may have an impact on businesses in Benson as explained above, factors other than climate also play a large role. For example, the opening of Kartchner Caverns State Park has been a salient topic in the Benson community since 1988 when Arizona Legislature first approved the creation of the park. The caverns were surveyed and studied until 1992, at which time park development began in preparation for opening the site to the public. The grand opening was initially planned for late 1993, but cavern planners quickly postponed the date as they realized the careful and arduous preparation required to preserve the caverns' delicate ecosystem. This was, however, only the first in a series of delays and postponements that have pushed the opening of the park to November 1999.

In the interim, a struggle developed between Benson and its neighbor, Sierra Vista, 50 miles to the south. The caverns are located six miles from the economic center of Benson on Highway 90 between Benson and Sierra Vista. Each Chamber of Commerce waged a media war in attempt to

associate the caverns with their respective town until Benson unequivocally settled the debate by annexing the strip of land from I-10 to the Whetstone Mountains.

Although Benson has earned the right to claim Kartchner as a local park, community members remain concerned about drawing visitors to the established business center of Benson. The most visible growth in Benson has occurred at the junction of Highway 90 and I-10, and merchants fear that travelers will exit on Highway 90 en route to Kartchner without passing through the Fourth Avenue business strip in Benson. Visitors may indeed just gas up and eat along Highway 90 before traveling on to Sierra Vista and other Cochise County destinations.

The sectors that are likely to be impacted by the increased tourism are retail, restaurants and bars, hotels and motels, and services. The City of Benson reported the combined taxable sales for these sectors as \$47,468,321, the majority of which is in retail (see Figure 2.9). In an attempt to draw a greater number of visitors into the city, the City of Benson organized the Main Street Project, which seeks to beautify the central business strip Fourth Avenue (Highway 80). Benson residents are further divided on their support of this project.

The Cochise College Center for Economic Research assembled a brief Economic Impact Statement of Kartchner Caverns State Park based on figures provided by the Arizona State Parks. The report estimates that in the initial years, 150,000 will visit the park annually. The Center predicts that, in the first five years, fifty percent of these visitors will be from within Cochise County or a neighboring county and an additional twenty-five percent will arrive from within a day's travel. Only twenty-five percent will stay overnight in lodging in Cochise County. The report estimates that an average traveling party consisting of 2.5 people will spend approximately \$70 per day on a trip consisting of 2.5 days in Cochise County. Based on this scenario, Kartchner Caverns State Park would annually generate \$4,424,000 in direct spending and \$7,080,000 when considering economic multiplier effects. The impact of climate variability on the flow of visitors to Kartchner Caverns is not yet understood, although one might anticipate that a particularly wet season would reduce this tourist traffic in ways that might not affect the RVer community.

2.2.5 Conclusions

In conclusion, commercial business and industry in the MSPRV are not directly vulnerable to climatic variability. In the case of the two industrial companies located near Benson, public perception and labor supply have overshadowed climate as factors of concern. Commercial business in Benson, driven by an emerging tourist economy, is sensitive to climatic fluctuations, but often beyond a regional scale. Business success will depend, above all, on the ability to adapt to the changes related to Kartchner Caverns and the overall expansion of the tourist and retirement communities. The shift away from industry to efforts to attract retirees and tourists and create planned residential development has set the MSPRV on a specific trajectory that will become increasingly fixed and irrevocable. The dependence of this new economy on the climate

and socioeconomic conditions outside the Southwest extend the social and economic networks upon which Benson residents are dependent.

While climate plays a minor role in determining the course of the Benson economy, it may, however, become increasingly significant as growth and development place increased demands on the natural resource base of the area. Commercial business and industry may never be directly affected by climate, but the mining of groundwater that could potentially result from increased water use and a concomitant drop in precipitation would certainly have consequences for the entire Benson community. Similarly, an increase in the vulnerability of the energy sector could have a significant impact on the ability of industry to operate in the area.

2.3 Climate Impacts on Water and Electricity -- Petra Tschakert

2.3.1 Introduction

The economy and the livelihoods of the Middle San Pedro River Valley, including the various land use patterns, businesses, and industries outlined in the previous sections, rely to a great degree on the availability and reliability of the region's primary infrastructure, mainly for water and energy sources. This section of the report outlines some of the key features of the water and electricity providers in the MSPRV and their sensitivity to climatic variation and changes.

According to a general framework developed by the Intergovernmental Panel on Climate Change (1996:327, 471, 367), it can be assumed that both hydrologic (water) and energy systems are likely to be impacted by climate variability and change. While natural ecosystems, including hydrologic systems, are expected to be more sensitive to climatic changes than the energy sector, the latter is presumed to show a greater degree of adaptability to changes in temperature, precipitation, and humidity (IPCC 1996: 370).

In terms of hydrologic regimes and water related infrastructure, the IPCC (1996:327) asserts that the drier the climate of a region, the greater sensitivity to climatic changes. The arid and semi-arid river basins in the western part of the United States, where water is already limited during part or all of the year, are expected to be particularly sensitive. Total surface water use already exceeds average streamflow (Smith and Tirpak 1990:287). Also, the Southwest depends largely on non-renewable groundwater resources. For example, Smith and Tirpak (1990: 290) report that groundwater overdraft in the Colorado Basin amounts to 48 %, the highest in the entire Southwest. These two indicators can be considered a "warning lamp for vulnerability" (Waggoner 1990:14). Climate variability and change are expected to exacerbate this situation.

Since the MSPRV is part of the semi-arid Southwest, it can be hypothesized that both short-term and long-term climatic variability and changes as well as extreme climate events such as severe droughts and floods will affect both water supply and demand. This is primarily due to the fact that the amount of groundwater and surface water available is directly related to temperature and precipitation. Moreover, it can be expected that competition and conflict over water resources among various users will increase when climatic variability becomes more pronounced (Smith and Tirpak 1990:281).

Overall, it can be hypothesized that sectors and population that depend primarily on surface water from the San Pedro River might be more vulnerable to climatic variability and extreme climate events because both lack and overabundance (floods) of surface water are experienced immediately. Declines in the groundwater table, on the other hand, might not be perceived as an immediate threat. Nevertheless, in the long run, non-renewable groundwater reserves are as sensitive to climate change and variability as surface water supplies.

Those water management entities, both residential/commercial and agricultural, with the least amount of flexibility with regard to meeting water needs are the most vulnerable to the effects of climate variability and change on water supply and demand (Schwarz and Dillard 1990:365). Possible indicators for high flexibility among residential/commercial water providers are the existence of contingency plans, the usage of climatic and hydrologic information, conservation measures, as well as the integration of population growth rates and changes in per-capita use in current and future water budgets. Also, residential/commercial water management entities might increase flexibility through the purchase of water rights outside their municipalities to ensure adequate water supplies for growing populations (Smith and Tirpak 1990:300; Stern and Easterling 1999:49).

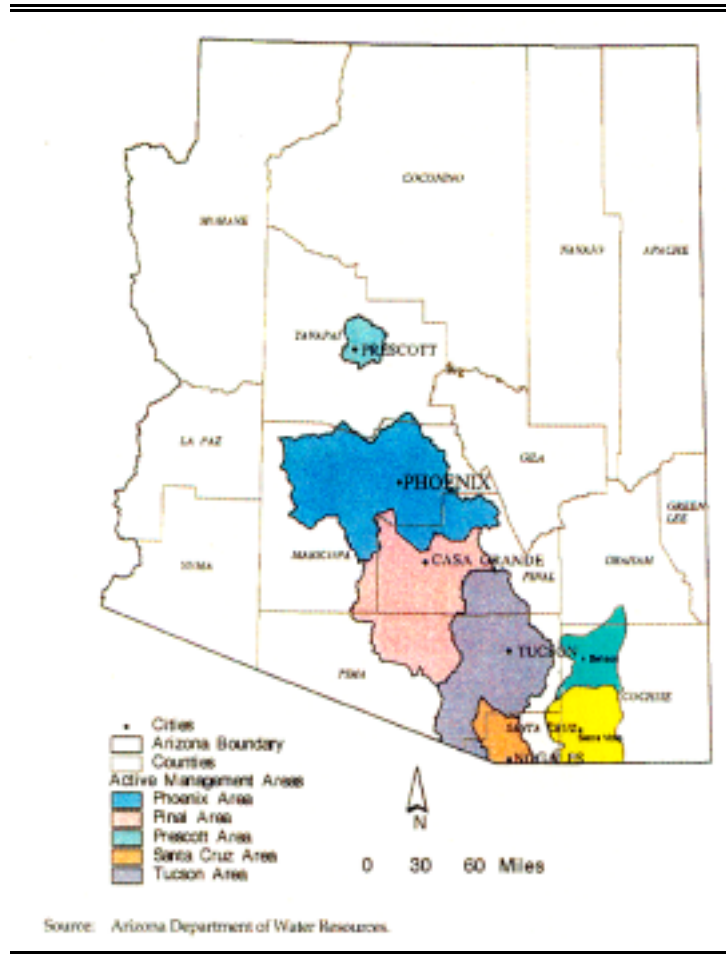
The flexibility of agricultural water providers in the Middle San Pedro River Valley to adapt to climatic variability and change will depend on the availability of alternative sources of water available in addition to surface water, their adaptation to electricity price fluctuations that affect irrigation pumping, and their competitiveness with other users such as riparian ecosystems and Gila Indian claims.

As for the energy sector, the emphasis in the MSPRV is on electricity generation, transmission, and distribution. In contrast to the hydrologic system, the energy sector can be expected to be most sensitive to temperature extremes over daily and seasonal cycles (IPCC 1996: 371). In terms of energy demand, it is assumed that space heating and air conditioning in residential and commercial buildings as well as irrigation pumping will be most affected by changes in temperature (IPCC 1996:376). According to Smith and Tirpak (1990:579), the largest increase in US electricity demand due to climate variability and change can be expected for the Southeast and Southwest where costs for air conditioning exceed space heating. Temperature-sensitive summer loads, such as air conditioning, could significantly increase peak loads in the MSPRV. Furthermore, growing populations, increasing wealth, and diversification of electronic technology within the household and the commercial sector are expected to drive energy demands.

Since electricity providers have to be constantly prepared for peak capacity needs - in the winter for heating and in the summer for cooling - the sensitivity of these providers will depend on their financial and technical ability to adapt to increased peakings related to climate variability including extreme events. Conservation measures and load management programs that improve efficiency or alter the patterns of customer uses are expected to play a significant role (Smith and Tirpak 1990:592). Another factor relevant to the study area is the susceptibility of electricity transmissions to extreme weather events such as storms (IPCC 1996:382). Overall, it can be expected that new technological improvements and new capacity requirements among electricity providers in the MSPRV will impact their flexibility to efficiently adapt to climate variability and change.

Despite a general focus on sensitivity of utility providers to climatic variability, it should be emphasized that this type of sensitivity constitutes only one component of a complex set of

Figure 2.12: Arizona Active Management Areas and Subwatersheds in the Upper San Pedro River



sensitivities, including socio-cultural, ecological, economic, political, and institutional factors (Schwarz and Dillard 1990:341-342; Smith and Tirpak, 1990). Evaluating providers’ management strategies to climatic variation without taking into consideration those other components could be misleading.

2.3.2 Availability of Resources

2.3.2.1 Water

In order to assess water supply for the MSPRV, the Benson subwatershed was selected as the basic unit of analysis. According to Maddock (1998:I-1), the Middle San Pedro River is defined as that portion of the river north of Fairbank up to the USGS stream gauge just south of Redington. The Benson subwatershed has its southern boundary also near Fairbank, but its northern limit is defined around the Narrows, 23 miles south of the Redington gauge (see Fig 2.13).



Figure 2.13 Map of the MSPRV

The baseline supply figures for the Benson subwatershed were derived from the *Hydrographic Survey Report for the San Pedro River Watershed* (HSR), published in 1991 by the Arizona Department of Water Resources. The Sierra Vista subwatershed, extending from the US/Mexico border up to Fairbank, as well as the neighboring Active Management Areas (AMAs)¹⁴ of Tucson and Santa Cruz are included for reasons of comparison (see Table 2.1). Data for the Sierra Vista Subwatershed also are derived from the HSR while those for the AMA are based on figures of the ADWR management plans of 1995. For the purpose of this comparison, some of the categories had to be redefined.

2.3.2.2 Surface Water

As shown in Table 2.1, 56% of the water supply in the Benson subwatershed is surface water. This exceeds the statewide percentage of 47% which includes water from the Central Arizona Project (ADWR 1994:16). The surface water supply in Sierra Vista subwatershed, in contrast, accounts for only 4% of the total supply due to the high amount of outflow. The main source of surface water in the Benson and Sierra Vista Subwatershed is the San Pedro River. Its headwaters are in northern Sonora, Mexico and its confluence is with the Gila River, 150 miles north at Winkelman, Arizona.

Table 2.1: Water Supply in the Benson Subwatershed and Neighboring Areas

Water Supply (acre-feet/year)	Benson Subwatershed 1990	Sierra Vista Subwatershed 1990	Tucson AMA 1995	Santa Cruz AMA 1995
Surface Water Inflow + Tributaries	51,000	40,720		
Surface Water Outflow	25,500	39,200		
Total Surface Water (Inflow-Outflow)	25,500 (56%)	1,520 (6%)	0	1,000
Natural Groundwater Recharge	11,760	16,860	60,800	24,650
Incidental Groundwater Recharge	7,675	2,591	82,300	16,425
Intentional Recharge	0	0	0	0
Total Groundwater	19,435 (43%)	19,451 (79%)	143,100	41,075
CAP	0	0	100	0
Effluent	600	3,600	10,300	50
Total Renewable Supply	45,415 (100%)	24,571	153,500	42,125

As with other dryland rivers, the San Pedro has only a couple of perennial reaches where surface water is available all year round. However, those perennial reaches are outside the Benson subwatershed. Most of the stream reaches within the subwatershed are intermittent (flow in response to precipitation and base flow) or ephemeral (flow only during storm events).

¹⁴ Active Management Areas (AMAs) are areas in Arizona where groundwater depletion has been identified as most severe. There are five AMAs: Prescott, Phoenix, Pinal, Tucson, and Santa Cruz. These areas are subject to regulation pursuant to the Groundwater Management Code, created by the State Legislature in 1980. The primary goal is to achieve safe-yield by the year 2025. Safe-yield implies that no more groundwater is withdrawn than can be annually replaced (ADWR 1994:35).

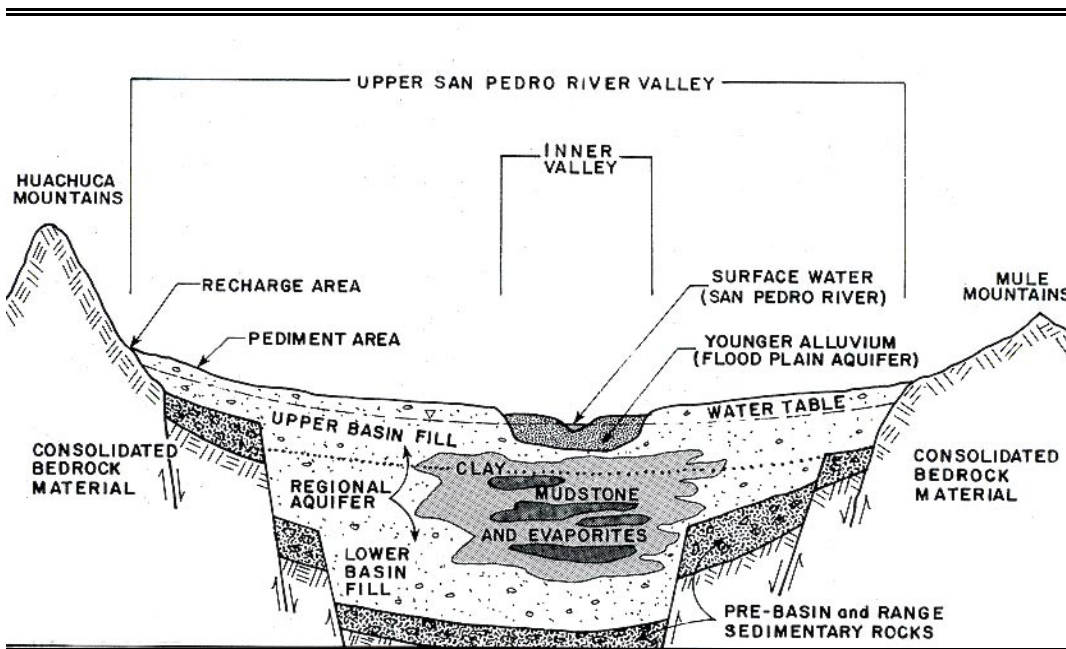
2.3.2.3 Groundwater

From a hydrogeological standpoint, the MSPRV represents a typical valley of the Basin and Range Province that covers most of the Southern and Western Arizona. In this geological province, linear mountain ranges, trending north-south or northwest-southeast, alternate with basins of various widths. While the mountain ranges are remnants of faulted blocks, the basins represent areas that dropped down along vertical faults. Since their formation, these basins have accumulated eroded gravel and sand from the surrounding mountain fronts (Chronic 1998:53).

The MSPRV has a wide valley floor with two main sediment layers and an underlying area of consolidated rock like that which joins the surrounding mountains. The two sediment layers are the primary sources of groundwater and make up (1) the regional and (2) the floodplain aquifer (see Figure 2.14).

- (1) The regional aquifer, the largest source of groundwater, is found within the older alluvium (upper and lower basin fill) with an average thickness of several hundred to over 1,000 feet. According to the HSR, 27.2 million acre-feet of recoverable groundwater are stored in the Benson subwatershed. Well depths are between 200 and 1200 feet and well yields are 1,000gallons/minute on average. Many of these wells tap artesian flows.
- (2) The floodplain aquifer is located in the younger alluvium that overlays the older alluvium along the stream course. While average floodplain well yields are

Figure 2.14: Generalized Cross Section of the Upper San Pedro River Valley



Source: Lacher, 1994

generally higher than in the regional aquifer (up to 2,700gallons/minute), the overall amount of recoverable groundwater stored in the flood plain alluvium in the Benson subwatershed is limited to 0.124 million acre-feet. Well depths are usually between 40 and 150 feet.

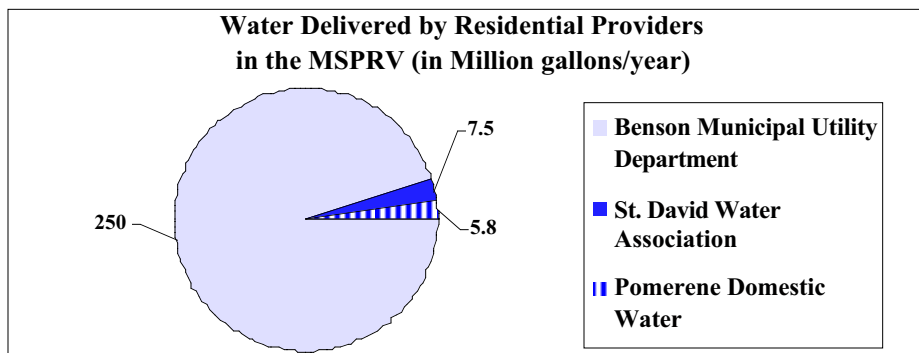
2.3.3 Water Providers

Water is removed from the San Pedro River and the two aquifers for various purposes. While many farmers and ranchers have private wells or diversion canals to take advantage of available water, the majority of human populations of the MSPRV rely on water providers for their water demands. This section distinguishes between residential and irrigation water providers identified in the study area.

2.3.3.1 Residential Water Providers

There are three main residential water providers located within the study area. The largest provider is the Benson Municipal Utility Department, regulated by the City Council. The two other providers, St. David Water Association and Pomerene Domestic Water, are non-municipal providers, and are regulated by the Arizona Corporation Commission¹⁵. In addition, there are two irrigation water providers, the Pomerene Water User Association and the St. David Irrigation District. The following information regarding the history and infrastructure of residential water providers was obtained through several interviews with employees from each water provider. Annual water volumes provided by the three water providers are shown in Figure 2.16.

Figure 2.15: Water Delivered by Residential Providers in the MSPRV



Benson Municipal Water, a subunit of the Benson Municipal Utility Department, owns eight wells, four of which are located in the valley and four

on the mesa. All eight of these wells rely on groundwater from the regional aquifer with depths ranging from 400 to 1150 feet. The average depth to the water table is 250 feet. The service area is approximately 35 square miles large, serving 2,500 people with potable groundwater for municipal/residential purposes. Approximately 250 million gallons of groundwater are delivered annually (100,000 gallons/user). The storage capacity in tanks totals 2.6 million gallons.

¹⁵ The fact of having multiple and distinct regulative structures governing water providers in the MSPRV could complicate policy implementation under conditions of climatic extremes.

According to the operations manager, four out of the total of eight wells were constructed during the last ten years as a direct result of development and increased demand. Except for two wells, which became operational only in 1997 and 1998 and do not yet operate at full capacity, the total amount of water produced per year per well ranges between 30 and 69 million gallons. Citing an almost unlimited groundwater supply in the area, this manager declared that Benson Municipal Utility Department expects to have the capacity to satisfy all the demands related to current and future development along the Kartchner Corridor on Highway 90.

The St. David Water Association, established in 1968, currently operates three wells, also pumping potable groundwater from the regional aquifer, with well depths between 300 and 600 feet. The average depth to the water table in the St. David area is much smaller, averaging 28 feet. With a population of approximately 2,000, St. David's service area is 7 square miles. Altogether, 7.5 million gallons/year are provided to 390 customers, with 96% going to the municipal/residential sector and 4% to the industrial sector. The current storage capacity amounts to 150,000 gallons. According to the CLIMAS water provider survey¹⁶, filled out by the operation's manager, the St. David Water Association plans an additional well and a new reservoir for this current year. The primary reason for expansion is population growth in the community.

Pomerene Domestic Water, established in 1948, maintains four wells with an average depth of 800 to 1000 feet, which hit the water table at around 240 feet. Again, the primary source of groundwater pumped is the regional aquifer and the water is 100% potable. About 300 customers are hooked up to the system within a service area of roughly 4.5 square miles. These customers include the municipal/residential sector, the church, and the school. The one available storage tank holds 250,000 gallons of water. As in the case of the two other providers, expansions (additional wells, reservoirs, pumps, and pipes) are planned for the near future, again in anticipation of population growth.

2.3.3.2 Irrigation Water Providers

Two irrigation water providers, the Pomerene Water User Association and the St. David Irrigation District, distribute San Pedro River water to individual irrigators, normally from November to May. According to the HSR (1991:319-351), the Pomerene Association diverts 1,526 acre-feet/year of surface water and delivers it to 41 landowners, all members of the association (see Figure 2.16). Nevertheless, the majority of the irrigation water (5,399 af/year) has to be pumped from the groundwater. The amount of surface water delivered through the St. David Irrigation District is much higher (4,179 af/year). In addition to the ditch, the irrigation district also maintains two wells that are able to supply additional 10.5 cfs directly into the ditch system. The overall amount of groundwater pumped for irrigation purposes is 4,451 af/year. The primary crops are alfalfa and pasture related crops.

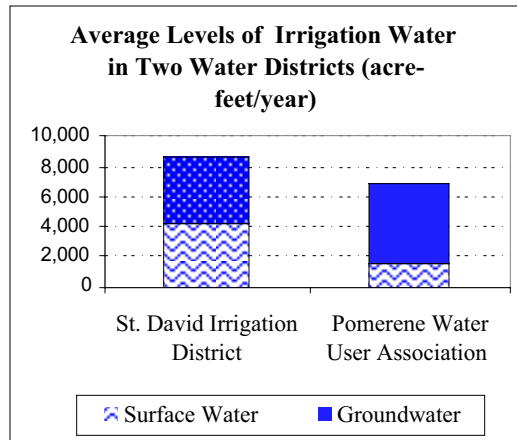
¹⁶ The CLIMAS water provider survey is a research tool used for an urban water study in southern Arizona. CLIMAS stands for the Climate Assessment Project for the Southwest, located at the Institute for the Study of Planet Earth/University of Arizona.

However, it should be noted that the above numbers on surface water supply represent rough averages. During the times of the interviews (January and March), the riverbed was totally dry and there was no surface water available for irrigation farmers. According to different study participants, the irrigation canals have been dry for 4 to 5 years due to lack of rainfall. In the past, residents anticipated the winter rains to start in October. Now, it is seen to be a question of whether they will come at all. Informants in St. David explained that, historically, the water in the river usually started running on November 5 in their area. Over the last three years, however, the water began to flow later and later. In 1998, the San Pedro started running only in January. This year, the change was even more dramatic. At the time of the interviews, there had been no water in the river at all.

2.3.3.3 Wastewater Treatment Facilities

The only wastewater treatment facility within the study is located in Benson, and it is operated by the Benson Municipal Utility Management, regulated by the City Council. All zones outside the municipal service area rely on septic tanks. At the present time, the Benson treatment plant operates four disposal ponds of which three are in regular use. According to the operations manager, the fourth pond was built to address sewage back-flow problems resulting from heavy rainfalls in February 1992.

Figure 2.16 Average Levels of Irrigation Water in Two Water Districts



A new treatment facility is planned. It is expected to accommodate increasing sewage due to population growth, tourism, and economic development. Since the existing facility has almost reached its capacity, the city of Benson is concerned that the State of Arizona might impose strict fines as well a moratorium on all development in the case of a spill-over. Currently, the treated water is used for irrigation purposes on 70 acres around the plant. The land belongs to the City of Benson. However, it is used by farmers who lease the land in exchange for the crops produced (primarily alfalfa).

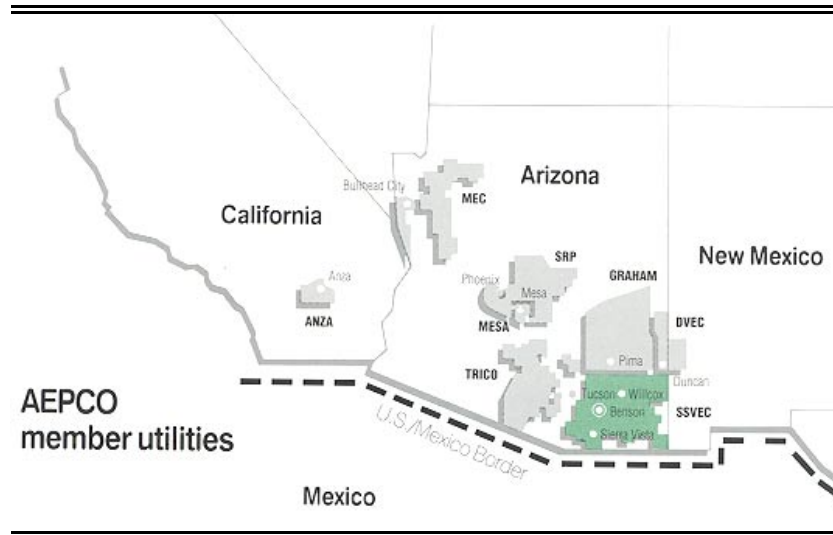
2.3.4 Electricity

Although water resources, their availability and reliability have always been critical for both the people and the economy, they are not the only factor influencing development in the MSPRV. Another key feature that has to be taken into account is energy and its various sources. Water and energy, especially electricity, are closely interdependent, a fact made abundantly clear during the late 1970s and early 1980s when many irrigation farmers went out of business because of significant increases in pumping costs. The following section describes the main electricity provider in the MSPRV, its history, and its importance for the region.

2.3.4.1 Electricity Providers

Sulphur Springs Valley Electric Cooperative (SSVEC) is the only electricity provider in the Middle San Pedro Valley. SSVEC was incorporated in 1938 as a non-profit electric cooperative. Today it is the largest electric cooperative in Arizona, with more than 3,500 miles of line and 38,000 customers (SSVEC 1998:1). Its service area of 6,400 square miles covers most of Cochise County, except for the area around Willcox and the eastern part of the Chiricahua Mountains. It also includes some parts of Graham, Pima, and Santa Cruz counties (see Figure 2.17). SSVEC is part-owner of Arizona Electric Power Cooperative (AEPCO), which has its headquarters in Benson.

Figure 2.17: Location of AEPCO Member Utilities, Including SSVEC



All of the electric power distributed by SSVEC is purchased from AEPCO. AEPCO generates two thirds to three quarters of its energy in its Apache Generating Station, south of Benson. Roughly one half of this energy is generated from coal and the other half from natural gas. Both fuel sources must be imported from outside the region. In addition, the portion of electricity that is not produced locally is bought from outside. According to one of the planning and design supervisors of SSVEC, AEPCO would have the infrastructure and the resources to generate

100% of its own electricity if it wanted to do so. However, economically it makes more sense to buy some electricity wherever it is cheapest.

AEPCO also produces power for four other electric cooperatives in Arizona (TRICO, MEC, DVEC, Graham) and one in California (ANZA) as well as power for the city of Mesa and SPR in Tempe (SSVEC 1998:2). Moreover, AEPCO is responsible for all the transmission for the various cooperatives.

The challenge of any electricity provider is to have the capacity to supply energy during times of maximum demand (i.e., the system peak) even if this peak occurs only once a year. In 1997, the peak occurred in July, amounting to over 90,000kw in only single hour (SSVEC 1997:6). This is almost twice as much as hourly average based on one year's supply. Assuming that increased climate variability will result in more extreme events, electricity providers may have to adapt to more pronounced peaks in the future.

2.3.5 Access to Resources

2.3.5.1 Water Rights

According to Arizona law, groundwater and surface water are allocated as separate and discrete resources. This has enormous implications for the Middle San Pedro. The surface water law relies on the prior appropriation system for surface water rights adopted in 1864 and on the State Water Code from 1919. Prior appropriation can be described simply as “first in time, first in use”. Since 1919, water rights applications have to be filed with a state administrative agency, presently the Arizona Department of Water Resources (Lacher 1994:online). According to the 1919 Code, surface water is defined as “the waters of all sources, flowing in streams, canyons, ravines, natural channels, or in definite underground channels, whether perennial or intermittent, flood or waste or surplus water, and of lakes, ponds, and springs on the surface.” (Tellmann 1994:29). Surface water belongs to the public and is subject to appropriation and beneficial use. Most important, water appropriations are considered rights to use water, not to own it. Beneficial use generally implies the diversion of water away from the stream. However, in-stream water rights along the San Pedro River are also considered beneficial. Beneficial use is based on the “use it or lose it” principle. This implies that the water has to be used at least once within five years, otherwise the beneficial use right becomes invalid.

A critical issue is the appropriation of subflow, which, according to the Arizona Supreme Court, is defined as “those waters which slowly find their way through the sand and gravel constituting the bed of the stream, or the lands under or immediately adjacent to the stream, and are themselves a part of the surface stream” (Lacher 1994:online). In the Middle San Pedro valley, the issue of subflow also directs the classification of wells into three different zones. The main purpose of this classification is to identify all well users who, potentially, might diminish streamflow. In times of water shortage, it can be assumed that certain wells might lose their priority rights in favor of surface water rights. In a community vulnerability assessment, it is

appropriate to identify these wells and their owners because they are very likely to represent one of the main groups at risk.

In terms of groundwater use, the beneficial use rule applies in the Middle San Pedro. Compared to the Active Management Areas (AMAs) around Tucson and Nogales along the Santa Cruz and the Irrigation Non-Expansion Areas (INAs) such as the Douglas INA, the subwatersheds in the San Pedro basin are only partially subject to the Arizona Groundwater Management Code of 1980. So far, no areas have been designated as Active Management Areas. However, considerable groundwater overdraft has been recorded in the Sierra Vista/Fort Huachuca area (Putman et al. 1988:97). A future AMA designation is possible (Lord et al. 1991:20-21).

Groundwater rights go with land ownership. Thus, anyone can pump water from below his or her property as long as it is considered as reasonable and beneficial for that property. It should be noted that “reasonable” is an ambiguous term, especially because it is not measured objectively in relation to the needs of other users in the area. Moreover, since the prior appropriation doctrine applies only to surface water use and not to groundwater use, senior surface water users could be impacted by more recent groundwater extraction without any legal recourse (Liverman et al. 1997:6). This becomes extremely critical given the increased groundwater pumping to the west side of Benson which is related to the recent development described in the sections 2.1 and 2.2. As a result, water that otherwise would reach the San Pedro might be intercepted. In other words, farmers who rely exclusively on surface water flow in the river would not be able to claim their senior water rights and, therefore, could become increasingly vulnerable. It should be noted, however, that the majority of the farmers have the flexibility to switch to private wells and pump groundwater to cover surface water losses. The only restrictions that apply to groundwater use in the San Pedro are the requirement of a well registration with ADWR and certain well construction standards (Lacher 1994).

Another critical aspect of water rights in the Middle San Pedro is the Gila River Adjudication. The purpose of this adjudication is to consolidate various water rights, including prior appropriation on Indian lands, into one comprehensive framework. So far, no conclusion on this general adjudication has been reached. However, as stated by Conde et al. (1997:28), a shift in water rights could result in a very different allocation pattern along the San Pedro, which flows into the Gila River. Several thousand claimants (more than 8,000 just in the San Pedro basin) and 12 Indian Reservations are hoping for a new assignment of surface water flows. This adjudication could dramatically increase competition among existing users. At the same time, it could also increase vulnerability. Although 180,000 acre-feet of water might be delivered to the Gila River Indian Community in form of CAP water (Arizona Republic, April 15, 1999), several farmers in the Middle San Pedro consider their livelihoods at risk because of these Indian settlements.

Finally, the federal government can limit the extraction of groundwater to protect surface water supply in specifically assigned areas. Federal reserved water rights fall under this category. These rights apply for parcels of federal land on which the availability of surface water is

necessary to fulfill the purpose for which this piece of land has been set aside (Tellmann 1994:20). Lands that were part of the federal domain from the beginning, such as BLM lands, do not fall under these federal reserved water rights. For the Middle San Pedro, federal rights currently apply only for the portion of the San Pedro River National Conservation Area (SPRNCA) between Fairbank and south of Curtis, primarily to protect the riparian habitat.

Concerns among farmers that this conservation area might be expanded to the north are probably unfounded. One member of the Nature Conservancy made it very clear that his organization had no interest in the portion of the river between St. David and Pomerene. The native riparian vegetation along this reach is considered practically destroyed, without any hope of regrowth. As a result, it seems highly unlikely that any claims for such in-stream rights would be filed.

In any case, it is deceptive to assume that federal reserved water rights provide a guarantee of sustained flow in the river. As in the case of surface water dependent farmers, groundwater near the river can be pumped without regard to the effect on previously-established surface water rights. This situation is due to the inability of either the juridical or the political process to appropriately resolve the problems inherent in treating surface water and groundwater as legally separate and distinct sources.

2.3.5.2 Private Wells

Although the Arizona Department of Water Resources provides highly detailed data regarding watershed file report numbers, land owners, types of water diversion, water uses, and reservoir types (HSR, 1991), it is basically impossible to ascertain the total number of private well owners in the MSPRV. Since the number of wells per land owner varies between zero and more than five, the total number of land owners or lessees/allottees in the subwatershed (541 with watershed file report numbers and 16 with no applicable filing) does not allow any reliable estimate of existing private wells. A more user-friendly format would enhance understanding of the sensitivity of private well owners to climatic variation.

2.3.5.3 Water Pricing Policies and Conservation Measures

Water prices in the Middle San Pedro valley are comparatively lower than in most urban centers of Arizona (see Figure 2.18). While an average monthly water bill within the lowest residential user category for a typical winter month in Sierra Vista might range between \$19 and \$29, people in Benson pay only around \$12 (Figure 2.19). Bills in Tucson might range from \$20 to \$23 for the same month and same user category. In the peak of the summer time, residential users within the lowest user rate pay on average \$20 per month compared to \$32-50 in surrounding locations (Figure 2.20). In terms of water prices for commercial users, the rate offered in Benson is also very attractive: for one inch meters and an average amount of 10 units (7,480 gallons) per month, local businesses in Benson pay around \$8.50. This is slightly higher than the rate at Bella

Vista/Sierra Vista (\$8.29) but clearly below the rates of Pueblo del Sol/Sierra Vista and Tucson Water (\$17.2 and \$14 respectively).

Figure 2.18: Average Water Bills in Selected Communities

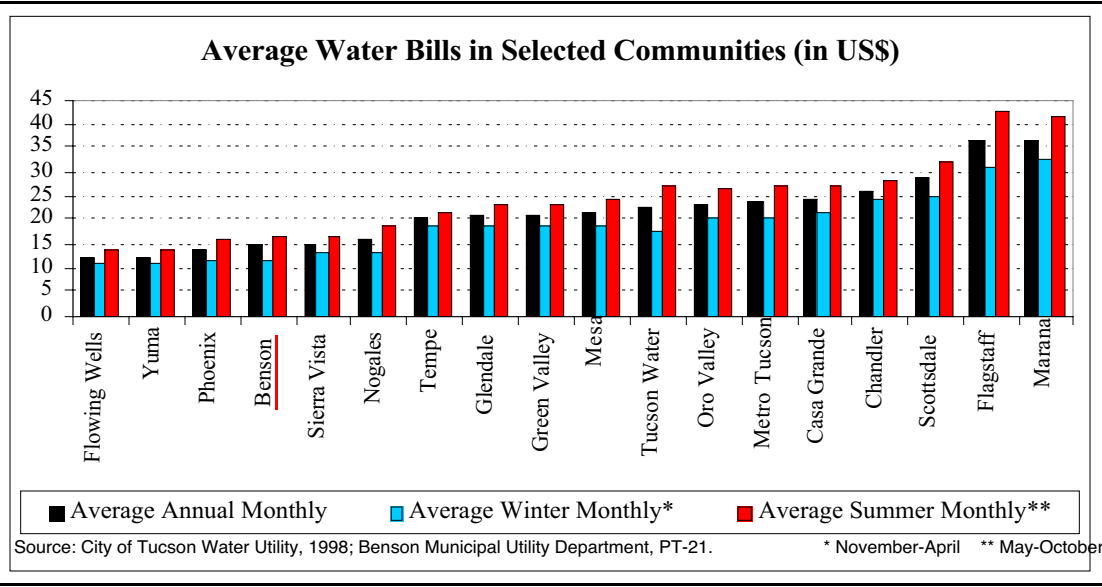
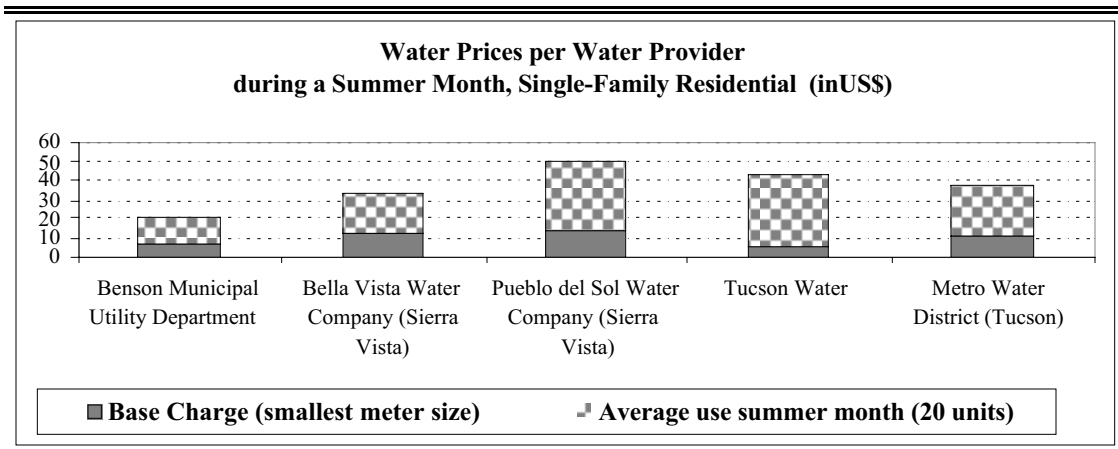
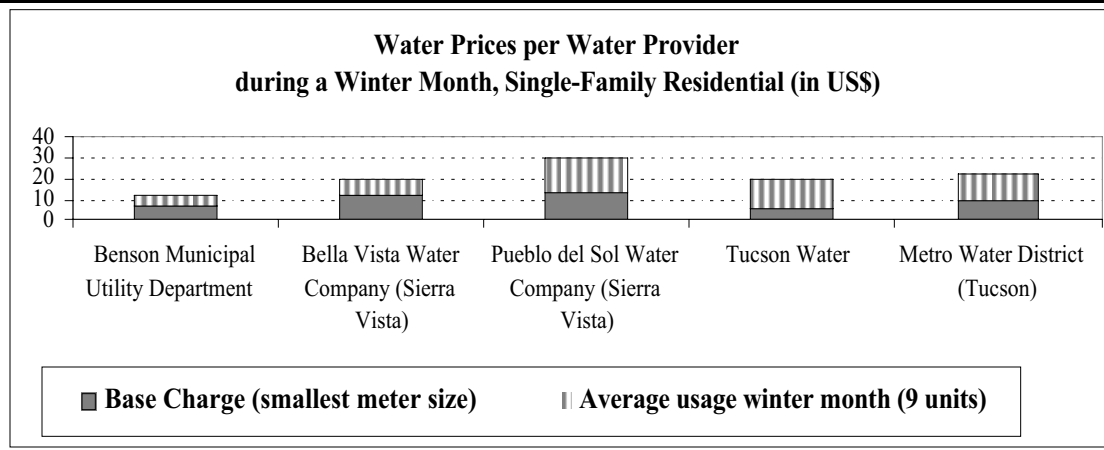


Figure 2.19: Water Prices per Water Provider during a Summer Month



Source: City of Tucson Water Utility, 1998; Benson Municipal Utility Department

Figure 2.20: Water Prices per Water Provider during a Winter Month

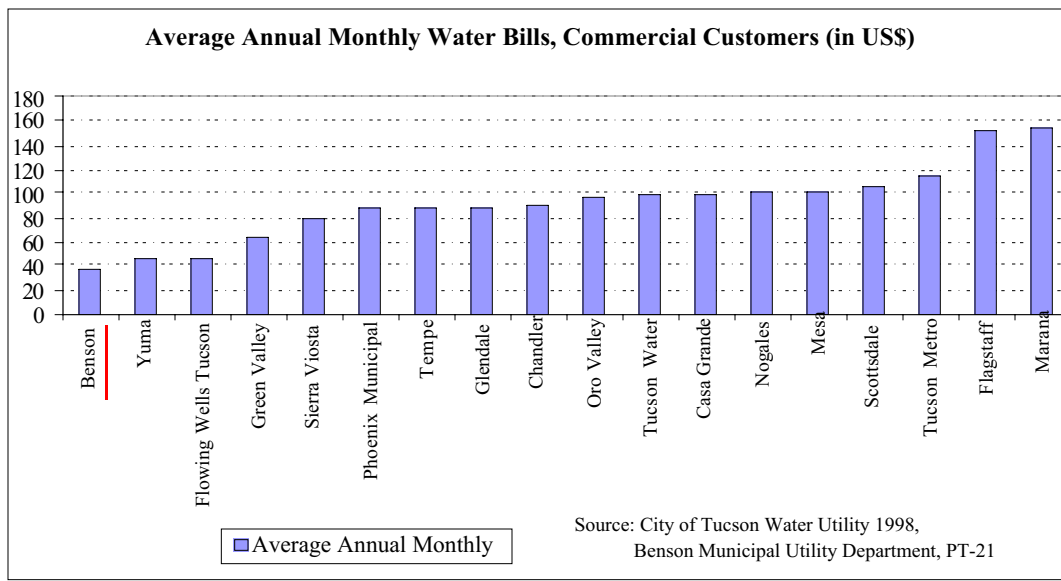


Source: City of Tucson Water Utility, 1998; Benson Municipal Utility Department

An average annual water bill for commercial customers in Benson is low compared to other communities (see Figure 2.21). However, this might be due to the fact that the majority of commercial businesses in Benson are relatively small. According to an employee at Benson Municipal Utility Department 80% of all commercial users rely on the smallest meter size of 1/2 inch.

The pricing scheme used by the Benson Municipal Utility Department is set by the City Council. For residential water use, this scheme is based on an inverted rate structure: the more water one uses, the more expensive it gets (refer to Appendix 2). According to the accountant of

Figure 2.21: Average Annual Monthly Water Bills, Commercial Customers



Source: City of Tucson Water Utility 1998, Benson Municipal Utility Department, PT-21

the Benson Municipal Utility Department, residential customers would use approximately 9 units during a winter month and up to 20 units during the hotter summer months. Unlike water prices for residential consumption, commercial water prices are based on a flat rate, of 85 cents per unit. Water prices have not changed since 1990/91. However, the rates are expected to rise in the very near future, primarily because of development and infrastructure expansion in the area.

In contrast to municipal water providers, the Arizona Corporation Commission regulates the prices for non-municipal providers such as Pomerene Domestic Water and St. David Water. According to the president of board of directors of the Pomerene water provider, current monthly water bills are approximately \$28. This monthly amount is clearly higher than the average in Benson. It includes a very recent rise in water prices to pay for a new well needed to accommodate the recent population growth in the community. As explained above, the rates in Benson are expected to rise soon as well.

Unlike conservation programs of large urban water providers, such as Tucson Water's "Beat the Peak", none of the three water providers has ever felt the need to implement any type of conservation program. According to the operations manager, the Benson area is privileged due to the overall quantity of groundwater available in the basin and the reliable infrastructure set up by the city to satisfy all demands, even in times of climatic stress. It was explained that a hypothetical 100 feet drop in the water table of the regional aquifer under drought conditions would not have any impact on the municipal wells. Also, measures like "Beat the Peak" and xeriscaping are designed primarily to cut down on water for outdoor residential and commercial irrigation. Since outdoor irrigation plays only a relatively minor role in the Benson area, it might be argued that local water managers have not considered it a worthwhile strategy to implement in their area. Water-saving measures that are more oriented toward indoor use, such as low-flow toilets or faucets, have not been encouraged either .

All in all, given the overall scarcity of water resources in a semi-arid region, including limited renewable groundwater reservoirs as well as the sensitivity of surface water flows to variation in temperature and precipitation, the absence of conservation measures is unexpected. It can be deduced that, without any previous experience in conservation measures, water providers in the Middle San Pedro River Valley might be ill-prepared to cope with severe and extended climatic extremes.

2.3.5.4 Electricity Pricing Policies, Conservation, and Deregulation

Electricity prices are set by the SSVEC, the only electricity provider in the area. The board of directors, elected by the members of this private corporation, establishes pricing policy, although each decision has to be filed with and approved by the Arizona Corporation Commission. There is a general trend toward lower prices, essentially because of decreasing interest rates and anticipated competition. Currently, residential and commercial users pay on average 10 cents/kwh while irrigators and industrial users pay only 8 cents/kwh. It should be noted, however, that these numbers represent only the basic rates. As explained by one of the planning

and design supervisors, SSVEC offers a variety of additional rates depending on the time of use, load factors, quantity of use, etc. As in the case of irrigation users, rates are especially low when users allow SSVEC to shut off the electricity at their relays during peak times. As outlined in a section below, this arrangement represents an integral part of SSVEC's conservation measures.

One of the major goals of a non-profit cooperative such as SSVEC is to maintain costs as low as possible. Costs are directly related to the electric load bought from AEPCO, so the goal is to keep the load from fluctuating too widely. As explained by the SSVEC demand monitoring manager, electric loads are most sensitive to temperature changes, especially on an hourly and daily basis. Usually, loads reach their maximum either in the wintertime because of space heating or in the summer months due to increased use of air conditioning and/or irrigation pumping. Consequently, the primary objective of SSVEC's conservation measures is to beat these demand peaks.

AEPCO's major conservation strategy is voltage reduction. As soon as hourly demand rates come close to a certain threshold value, monitored directly at SSVEC and supported by an emergency management system based at AEPCO, the voltage at critical substations is reduced. An automatic voltage alarm, installed at each substation, kicks in as soon as the voltage comes close to that limit, to prevent users from experiencing any negative impact. This type of load reduction is performed automatically via the computer.

In addition, during truly critical times, SSVEC has the option, through AEPCO, to cut off irrigation farmers who are connected to a specific relay. These are farmers who have agreed on this specific conservation measure in return for a special discount rate. Finally, SSVEC also has the possibility to use back-up generators that belong to a nearby greenhouse operation involved in tomato production. As in the case of the irrigation farmers, special pricing arrangements exist between SSVEC and the owners of the vegetable operation. All three conservation measures, voltage reduction, cut-off of irrigation users, and the use of back-up generators, can help SSVEC, saving up to \$140,000 per month during times of increased demand.

Both pricing policies and conservation measures as they are currently employed by SSVEC might undergo some significant changes as soon as the retail Electric Competition Rule ("deregulation"), passed by the Arizona Corporation Commission in 1996, takes effect. According to the revised ACC timetable (SSVEC 1998:3), any business/industry with a peak load minimum of 1MW can choose its power supplier in 1999. The same rule will apply to all additional customers starting January 2001.

One of the main goals of this retail rule is to replace the old monopoly with a competitive market structure. This new structure will include decisions regarding electricity prices, technical innovations, alternative ways of generating electricity, conservation policies and more (ACC at <http://www.cc.state.az.us/utility/electric/hmpage>). It should be noted, however, that these modifications are not expected to take place over night. As explained by one of the SSVEC employees, deregulation is considered a slow process, which seems to be substantiated by the

fact that the competition thus far has been very slow to materialize. Nonetheless, both SSVEC and AEPCO have started to prepare for potential changes. Examples of how deregulation might affect conservation measures, as well as weather/climate forecasting techniques, were discussed during the interviews and are described in the stakeholder section (see Section 3.2).

2.3.6 Water and Electricity Demand

2.3.6.1 Demand Numbers for the Water Sector

Unfortunately, there are no available data concerning water demand changes in the Benson subwatershed over time. Unlike in the greater Sierra Vista area, where intensive research and monitoring has been undertaken since the 1970s, primarily because of concerns of groundwater depletion, reliable data for the greater Benson area have been gathered only since the early 1990s. The most encompassing data source on water demand in the study area is the Hydrographic Survey Report, produced by the Arizona Department for Water resources in 1991.

The Data for Cochise County reveal an overall decrease of water demand from the 1970s to the early 1990s, followed by a considerable increase (ADWR 1991). These changes are primarily related to changes in agricultural acreage. It should be noted, however, that the county's overall trends vary widely by subregion, and these differences are compared in Figure 2.22. Comparison of the Figures 2.22 demonstrates the high proportion of water use in the Benson subwatershed (91%) still concentrated in agriculture, a level similar to the Willcox Playa Basin. In contrast, in the upstream Sierra Vista subwatershed the majority (56%) of available water is used for municipal purposes and only 41% for irrigated agriculture. This difference is explained by the fact that most of the agricultural land has been retired and transformed into the San Pedro River National Recreation Area by the BLM. Compared to Cochise County and the state of Arizona, the Benson subwatershed shows a significantly higher allocation of water to agriculture, while at the same time, Benson municipal water use is considerably lower than state and county averages. Table 2.2, while not entirely consistent with the percentages in Figures 2.22, presents annual water use in acre-feet and demonstrates the relatively high level of water consumed by the riparian vegetation areas.

The likely focus of future trade-offs between water users will involve town and country, i.e., water for agriculture shifting to municipal use. With regard to current municipal demand, the Benson Municipal Utility Department serves 2,500 customers, the St. David Water Association serves 390, and Pomerene Domestic Water serves 300 customers. All three water providers declared that the major user sector is municipal/residential (96-100% of all customers). Based on more detailed information provided by the accountant of Benson Municipal Utility Department (the number of residential and commercial customers for 1998) it becomes obvious that the vast majority of residential and commercial customers are small users (Table 2.3). Unfortunately, customer records are only kept for three years, making comparisons over the last 10 to 20 years impossible.

Figures 2.22: Water Use by Sectors for the State, Counties, and Subwatersheds

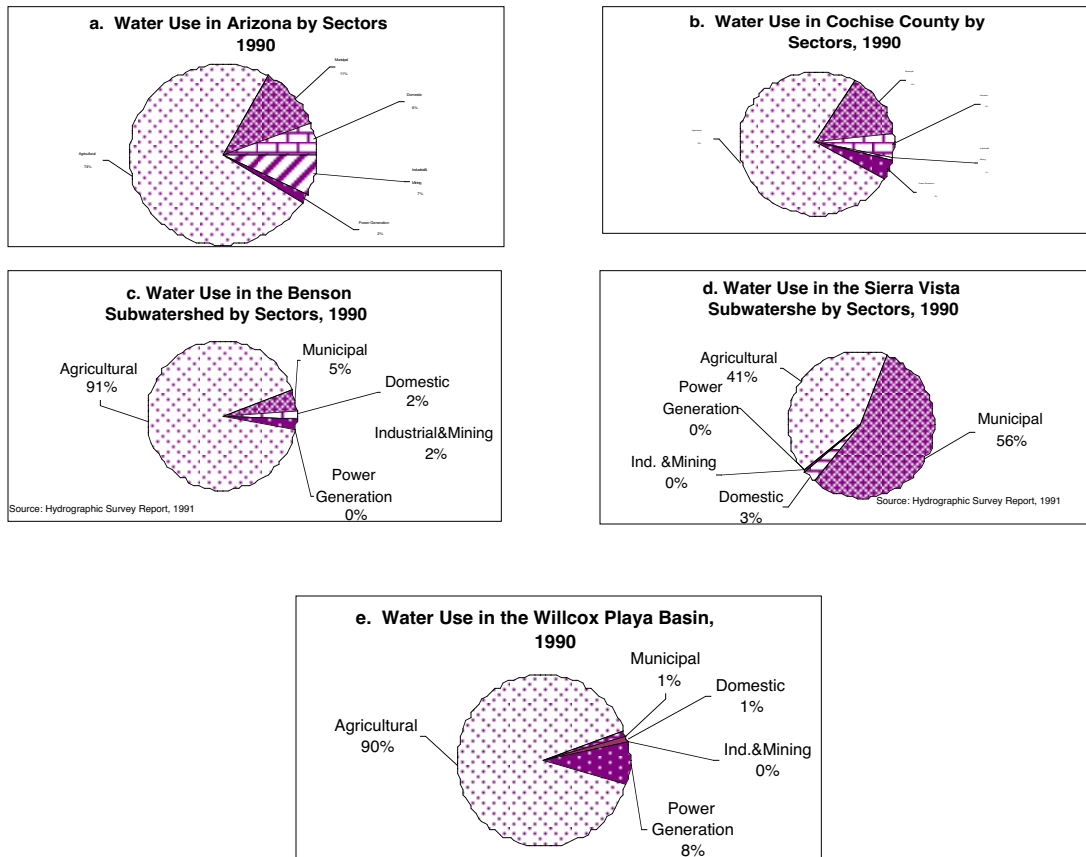


Table 2.2. Water Demand per User Category, 1990

Demand (acre-feet/year)	Benson Subwatershed	Sierra Vista Sub-watershed	Tucson AMA	Phoenix AMA	Santa Cruz AMA
Municipal	1,425 (3%)	11,003 (30%)	155,500	870,269	6,925
Agricultural	21,569 (50%)	6,157 (17%)	98,000	1,301,433	12,450
Industrial	542 (1%)	227 (1%)	72,582	83,088	2,119
Riparian Vegetation	17,690 (41%)	14,450 (39%)	3,700	48,000	16,775
Other	2,269 (5%)	5,124 (14%)	-	-	-
Total	43,495	36,961	329,782	2,302,790	38,269

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National Recreation Area by the BLM. Compared to Cochise County and the state of Arizona, the Benson subwatershed shows a significantly higher allocation of water to agriculture, while at the same time, Benson municipal water use is considerably lower than state and county averages. Table 2.2, while not entirely consistent with the percentages in Figures 2.22, presents annual water use in acre-feet and demonstrates the relatively high level of water consumed by the riparian vegetation areas.

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Table 2.3. Residential and Commercial Water Use, Benson Municipal Utility Department

Residential Sector 1998				Commercial Sector 1998			
Meter Size	Number of Customers	Average Usage Bill/ Customer	Average Total Monthly Bill/ Customer	Meter Size	Number of Customers	Average Usage Bill/ Customer	Average Monthly Bill/ Customer
5/8"	1,233	\$8.84	\$14.50	—	187	\$12.95	\$20.33
1"	7	\$8.58	\$20.00	1"	17	\$37.21	\$46.69
1.5"	1	\$47.77	\$61.27	1.5"	9	\$86.96	\$105.36
2"	2	\$338.50	\$366.52	2"	20	\$91.57	\$119.02
				4"	2	\$82.62	\$190.62
	Total : 1,243				Total: 235		

The average amount of water consumed per day and per person reported during the interviews is roughly 150-200 gpcd (gallons per capita per day) in the study area. This corresponds with the 168 gpcd noted in Braun, Maddock and Lord. (1991:3-31). This average amount can be compared to 150 gpcd in the Sierra Vista area (Bella Vista Water Company), 172 gpcd in Tucson AMA, 172 gpcd in the Santa Cruz AMA, and 238 gpcd in the Phoenix AMA. High amounts of per-capita use, as in the Phoenix AMA, are related to outdoor water use during the summer months. In the Benson subwatershed, outdoor water use for irrigating lawns is relatively limited, accounting for approximately 60-70 gpcd out of the total amount compared a maximum of 189 gpcd in Tucson (Woodard and Horn 1988:20).

It is important to note, however, that the amount of water used varies considerably between seasons. The highest usage occurs during the months of May and June (176-229 gpcd), probably to increased outdoor usage. The lowest usage occurs between November and February (91-120

gpcd). Because the data available included only the years 1995-1998, long-term comparisons of water use per capita and the detection of possible changes in user behavior are not possible.

In the case of agricultural demand, irrigation water comes from either groundwater or surface water sources. As stated above, the San Pedro has been dry for 4-5 years and, therefore, no surface water was available. As explained by two farmers in the Pomerene area, most people were able to supplement the necessary water through their wells, except for 3 or 4 families who do not own a private well. Due to the lack of rain, these families have not been able to farm for a couple of years.

As expected, that sectors and/or groups of people who rely primarily on surface water for either domestic or economic activities and who do not have the option of switching to an alternative source of water exhibit the greatest vulnerability to the effects of climate variability. Also, farmers with the option to switch to personal wells faced increasing electricity costs for the amount of supplemental water that must be pumped from the aquifer. Also, water requirements for various crops increase during the hottest and driest periods of the year. For crops irrigated during this periods, the electricity costs are even higher, thereby putting additional economic pressure on farmers.

Unfortunately, no conclusive notion could be obtained from the interviews in terms of the extent of water table fluctuations during times of drought. Additional data are required to determine the relation between drops in the groundwater table, increased pumping costs, and vulnerability among irrigation farmers.

2.3.6.2 Demand Numbers for Electricity Sector

Sulphur Springs Valley Electric Cooperative served 38,696 customers in 1997, including 538 new connections (SSVEC 1997:6). These customers are spread over the entire service area of SSVEC (approximately 6,400 square miles), including most parts of Cochise County except for the Douglas area and the east side of the Huachuca Mountains. Thus, based on available data, it was not possible to obtain energy use only for the study area. During 1997, over 459 million kwh were sold, which represents an increase of 2.4% compared to 1996 (SSVEC 1997:6).

The SSVEC differentiates its customers as residential, irrigation, small commercial, large commercial/industrial, and highway lighting. During the late 1970s and early 1980s, farmers were the main users of electricity. Due to the energy crisis and the related price increases for pumping water, however, two thirds of these irrigation farmers dropped out of business. Today, electricity use for irrigation is ranked fourth in terms of total energy use per sector while businesses and residential areas have become the major consumers. Although their use per customer is relatively low, the total use in the residential and small commercial sector clearly exceeds the other user categories (see Table 2.4).

Unfortunately, SSVEC was not able to provide detailed demand numbers over time. Most of the data are considered confidential because of expected increases in competition due to deregulation. Nevertheless, baseline data from 1996 provide some overview of the demand situation within the SSVEC service area. Averages and ranges for 1996 are depicted in Table 2.4.

Table 2.4. Electricity Use within the SSVEC Service Area, 1996

Customer Sector	Number of Customers	Range of Use per customer (in kwh/month)	Average Use per customer (in kwh/month, rounded)	Total Use per Sector (in kwh/year)
Residential	29,478	300-1,000	610	213,800,000
Irrigation (including water companies)	392	5,000-20,000	7,200	33,000,000
Small Commercial (small to medium sized shops, domestic wells, pump-back systems)	6,403	500-3,000	1,750	134,463,000
Large Commercial/Industrial (large agricultural processors, silos, military, industries)	33	3,500-100,000 or more	2,000,000	66,000,000
Highway Lighting	n.a.	n.a.	50,000	n.a.

It should be noted that these annual numbers mask the fact that there are two clear peaks in energy during per year, one in the summer due to air conditioning and increased crop requirements, the other in the winter due to space heating. On average, the low usage months of March/April and October/November usually show three quarters of the mean monthly use.

Irrigators in the Benson area generally rank at the lower end of monthly usage, (around 5,000 kwh), while farmers in the Wilcox basin use around 10,000 kwh or more on average. According to a supervisor at SSVEC, this difference can be attributed to a water table that is relatively close to the surface and crops water needs (alfalfa and pasture in the Benson area versus cotton and corn in the Willcox Basin). Out of an annual total of 20 to 30 million kwh delivered to water pumps in the entire service area, the pumps in the San Pedro River valley account for only about 10% of the total energy demand.

According to the utility company, it can be expected that the energy use by the residential sector will increase during the next 10 to 20 years. Although use rates per customer will decrease due to more energy efficiency in residential areas, increases in the overall number of customers will outnumber these potential gains. An overall increase in energy demand among residential users in and around Benson might also be explained by predicted changes in price structures, including cheaper electricity for urban than for rural areas.

2.3.7 Conclusion

The analysis of water and energy use in the MSPRV reveals differences in sensitivity to climatic variability. Under current conditions, residential/commercial water providers seem to be least sensitive while irrigation providers, depending on the availability of surface water in the San Pedro River, could be considered most affected by climatic variations. Electricity providers appear best equipped to respond to meteorological and short-term climatic changes.

Despite a general assumption that water providers in the Southwest might be severely impacted by both climate variability and extreme events, the residential/commercial water providers in the Middle San Pedro River Valley are not concerned, at least not under current socio-economic, political/institutional, and hydrologic conditions. The current infrastructure, primarily the wells and reservoirs, is considered a reliable buffer against any foreseeable shifts in climate conditions. The overall perception of unlimited groundwater reserves can also be used to explain the lack of any preventive measures, contingency plans, conservation measures, and the use of climate information and forecasts.

Although the increasing extraction of groundwater from the regional aquifer in the Benson subwatershed cannot be considered sustainable in the long run, it does not represent an immediate concern to the water managers. This clearly contrasts with the situation of municipal and private water providers in the Sierra Vista area, 25 miles upstream from Benson. Decades of groundwater pumping for military and residential purposes have caused the development of a cone of depression, intercepting underground streams that eventually would reach the San Pedro. As a result, the water sector in Sierra Vista has been strongly encouraged to implement conservation measures to reduce the pressure on the aquifer. The anticipated development in the greater Benson area might require a similar step in the future.

The lack of rainfall experienced in the area since 1994 has resulted in a complete standstill of all diversion operations. Although floods were not perceived as a present threat, they could easily damage or destroy the ditches in the irrigation systems. Further investigation would be necessary to assess the impact of the San Pedro National Riparian Conservation Area as possible buffer against floods further downstream.

High vulnerability of irrigation providers results in equally high vulnerability of individual farmers who depend on the delivery of surface water. In contrast to residential/commercial water consumers, farmers in the MSPRV are directly affected by climate variability, although they represent a small portion of valley residents, especially since the decline in farming suffered during the 1970's. As shown above, irrigators who do not have access to alternative sources of water are most sensitive to climatic variations. In the case of farmers who do have the possibility to switch to private wells, energy costs will determine whether or not groundwater is a feasible alternative.

Compared to the water sector, the electricity sector is more sensitive to meteorological rather than climatic variations. Since hourly and daily temperatures drive demand in the most direct way, either through air conditioning or space heating, they represent the most important variable for both the monitoring/regulating operations and the long-term forecasts.

Overall, SSVEC and AEPCO, the major electricity provider and generator in the MSPRV respectively, are well equipped to meet peak demands. The challenge is not to provide the entire amount required during such peak times, but to provide this quantity at a reasonable cost. As a non-profit electric cooperative, SSVEC seeks to minimize its expenditures by predicting hourly and daily demands as precisely as possible. The lack of real time data at a local scale complicates this attempt (see Section 3.2). In an economic sense, it could be argued that this insufficiency of adequate data makes the electricity sector in the study area more sensitive than in areas where such information exists on site.

In summary, under the current conditions, the utility sector in the MSPRV seems to be less sensitive to climatic variation than expected. Both water and electricity providers have developed relatively efficient adaptive strategies that allow them to cope with meteorological and climatic variability. Nevertheless, economic, ecological, political, and institutional factors might change considerably in the near future. Such changes could impact the operational setting of the various utility providers and, subsequently, their sensitivity to climatic variability.

For instance, deregulation in the electricity sector is expected to result not only in increased competition but also in growing needs for meteorological information and forecasts. Providers who do not have the financial or technical capacity to adapt to this new situation are expected to be less competitive and, therefore, more vulnerable.

As for the water providers, economic and policy-related changes seem to be most likely to occur in the near future. Increased numbers of tourists and part time residents in the MSPRV are expected to considerably augment overall water demand. At the same time, the adjudication of the Gila River or the Endangered Species Act might put substantial restrictions on groundwater pumping. Combined with severe climate conditions, water providers, who, at present time, are insensitive to climatic variations, might become more vulnerable, too. Overall, it remains to be tested whether or not the current adaptive mechanisms employed in the utility sector will still be appropriate to probable future scenarios.

2.4 Transportation: Linking it All Together -- Allison Fish and Diane Austin

2.4.1 Introduction

The transportation sector is a significant and growing contributor to air pollution, specifically carbon dioxide emissions; and much attention has been focused on the relationships among transportation, energy use, and climate change (e.g., IEA 1997). Transportation activity and associated energy consumption are growing very rapidly throughout the world with air and highway modes of transportation growing at the fastest rates. The interconnections between transportation and land use are significant. These relationships have long been recognized and continue to receive attention (e.g., Taaffe, Garner, and Yeates 1963, Mowbray 1968, Rose 1990, Skinner 1996). Likewise, as noted elsewhere (e.g., IPCC 1995), interaction among industrial sectors, transportation, and other economic sectors are significant in trying to understand the history of a region. For these reasons, transportation is considered here in its relationship to the factors identified in the preceding three chapters: land use changes, water and energy, and commercial/industrial activity.

Research addressing the interactions among transportation needs, infrastructure, and climate has been erratic at best. For example, according to the IPCC (1995) report: “Changes in the nature and location of agricultural production, in the rates of population growth in different regions, and in the volume and types of fossil fuel used, and in tourism and recreational travel can have profound effects on the performance of existing transportation facilities and on requirements to construct new ones” (380). However, this report concludes, “Climate induced changes...that would affect infrastructure demands have been acknowledged but not quantified” (374), and “The question of the impacts of climate change on regional transportation systems via the redistribution of population and economic activities has been neglected” (394). Although the ethnographic methodology employed for this case study does not allow quantification of such impacts, it does allow the exploration of the issues that link transportation, human settlement and economic activities, with climate variation and change.

Climate variability and change can affect such transportation related factors as: (1) transportation infrastructure and operations; (2) the redistribution of population and economic activities; and (3) energy use. The interrelationship of climate, transportation, and energy is complex and requires analysis beyond the community and regional level. A case study would offer little to enrich that discussion, so, this chapter will focus on the first two effects and their linkages.

Overall, the climate sensitivity of the transportation sector has been found to be low relative to other activities such as agriculture and natural ecosystems (IPCC 1995). In the IPCC summary of research linking climate and transportation, coastal regions and regions with permafrost were identified as locations where the transportation infrastructure is particularly sensitive to climate change. The only noted potential impact of high temperatures, such as the climate conditions experienced in the Middle San Pedro River Valley (MSPRV), is increased pavement buckling

under long periods of intense heat (Black 1990). Similarly, researchers have observed that transportation operations may be slowed by fog, rain, snow, and ice and that changes in the frequency and intensity of extreme weather events may affect the safety and reliability of transportation.

What climate researchers have generally overlooked, however, is that transportation related impacts are caused not only by local climatic conditions, such as precipitation and changes in temperature, but also by regional, national, and international policies and climatic conditions that influence the movement of people and goods. In the Middle San Pedro River Valley, climate variability plays a minor role in infrastructure maintenance and transportation operations, and significant alterations due to climate changes are unlikely. Yet, the region is highly vulnerable to transportation-related impacts triggered by the movement of people and goods directly attributed to regional, national, and international conditions and policies. The ability of the local, regional, national, and international infrastructure to facilitate human response to climatic conditions and climate-driven policies beyond the local area is the locus of the most significant connection between transportation and climate change and variability. The preceding chapters have discussed how regional climate, such as differences in temperature extremes between Tucson and the MSPRV, have played a role in land use changes in (1) the residential sector as city dwellers have moved to the MSPRV to escape extreme heat in the summer (along with city problems such as traffic congestion and crime) but continue to commute to Tucson and (2) the seasonal increase in the commercial sector as winter visitors have flocked to the MSPRV and other southwestern sites to escape extreme cold in the winter (this includes the establishment of the recreational vehicle (RV) industry). These and other climate-transportation links will receive further attention in this section. The following describes the transportation infrastructure of the MSPRV, discusses its relationship to the area's development and climate, relates population to transportation, and examines transportation issues in the MSPRV compared to similar southwestern communities.

2.4.2 Development of Transportation Infrastructure in the MSPRV

In addition to the area's moderate climate, the transportation of people and goods through southeastern Arizona has played a major role in the development of the MSPRV and is still considered a key asset for MSPRV communities. For example, the *1998 Benson Prospectus* boasts, "(t)he city offers an attractive climate, excellent access to major transportation routes, and a variety of cultural and recreational opportunities" (Cochise College 1998:12)



The first large scale transportation of Euro-Americans through the study area was the movement of soldiers of the Mormon Battalion through the MSPRV during the U.S.-Mexico

War. Between July and October of 1846, Mormon soldiers from Council Bluffs, Utah en route to Santa Fe, New Mexico passed through the MSPRV and identified the present day location of St. David as an attractive future home site because of the presence of surface water and a climate conducive to farming (<http://www.mormonbattalion.com/history/brief.html>). Thirty-four years after this event, the town of Benson was established with the arrival of the Southern Pacific Railroad. Within the first half year of railroad service the town of Benson grew exponentially to include four stores, numerous small shops, a hotel, several saloons, and a population of more than 300 individuals (Tompkins 1998). Additionally, the appearance of the railroad became a key factor in the decision to locate Apache Powder Company just south of the town in an area protected from extreme heat and flooding (see Section 2.2). As these examples and previous sections illustrate, both residential settlement and commercial activity in the MSPRV have depended on the interaction between transportation and climate since the first Euro-American presence in the area. Therefore, information about the development of transportation infrastructure connecting the MSPRV to the outside world is central to understanding the area both at present and in the future as well as individual and community vulnerability to climate variability and change.

Currently, transportation infrastructure in the MSPRV is limited primarily to highways as rail is unimportant to industry. The nearest airport is 45 miles away in Tucson and MSPRV users must travel there by highway. There are no major transportation facilities, as recognized by the United States Department of Transportation, along navigable waterways in the state Arizona (see Appendix B). Local transportation is accomplished by four lane, two lane, and unpaved roads to which the most significant climate-related impact is short term flooding. Local rail transportation is limited to the Tourist Train that serves a tourist/recreational purpose. No public transportation or mass transit, such as bus or train service, is available within the Valley. As in other small communities, automotive transportation infrastructure linking the MSPRV to the outside world overwhelms other local features (see Appendix B), and that is the focus of the remaining sections of this chapter.

2.4.2.1 Railroads

Though unpaved trails and paths were established in the MSPRV long before the coming of significant numbers of Euro-Americans, the first significant financially backed transportation infrastructure development was the establishment of the Southern Pacific Railroad linking San Diego, California to El Paso, Texas. In 1880, the railroad crossed the MSPRV and the town site of Benson was established where the tracks crossed the San Pedro River. Two years later, in 1882, the New Mexico and Arizona Railroad joined Benson to Nogales, Arizona, and, in 1894, the Arizona and Southeastern Railroad expanded into Benson to connect with the Southern Pacific. At that time, Benson became the only Arizona location to be served by three major railroads (Tompkins 1998).

The railroad was of great importance primarily because it facilitated the intra- and inter-state transport of people, products to and from nearby mines, and agricultural products. The first

recorded climate-related impact to the MSPRV railroad infrastructure was the 1896 flood that knocked the Wells Fargo depot off its foundation. Unfortunately, the railroad boom in Benson ended in 1913 when the El Paso and Southwestern Railroad merged with the Southern Pacific and shifted the company's economic activity away from the Benson roundhouse and into Tucson. After this time, railroad activity became limited to the passage of freight and an occasional passenger train en route from Los Angeles to San Antonio (Tompkins 1998, www.Amtrak.com 1998).

The major commodities shipped out of Arizona by rail are copper, silver, gold, and zinc, and coal is the leading product shipped into the state. Historically, the rural Arizona economy has depended heavily upon the mining industry which, though playing a smaller role at present, is still active in southeastern Arizona, specifically the MSPRV. In fact, the Southern Pacific Railroad chose the Benson site to cross the San Pedro River and as a junction point because of the easy access to the mines which lie to the south of the town. In the late 1800's and early 1900's copper and silver ore were brought into Benson via wagons and then shipped out on the railroad. Presently the mineral industry still plays an important part in Arizona's economy. Figures from the 1993 US DOT survey show that almost one and three quarter million tons, approximately thirty percent of the state total, of metallic ores are shipped out of Arizona via rail. In addition to this more than ten million pounds of coal, 53 percent of total state coal consumption, is imported by rail (Bureau of Transportation Statistics, USDOT 1993; anon n.d.).

2.4.2.2 Paved Roads and Highways

Though it is impossible to trace the origins of the first roads in the MSPRV, development of the highways has been chronicled. United States Highways 80 and 86 were both constructed in the early 1930's as two-lane highways in the first years of the Arizona state highway system. According to Arizona Department of Transportation (ADOT) representatives, these two roadways formed part of the state's primary southward extension and eastward route into New Mexico. By 1954, the two-lane state highway 86 between Benson and Willcox had been widened to three lanes in the uphill stretches to accommodate slow climbing vehicles (Arizona State Highway Department 1954: 97). As part of the interstate development stemming from the Highway Act of 1956, a portion of Highway 80 was rerouted around Benson to complete Interstate 10 in 1974 (Department of Commerce 1965, Department of Transportation 1972). Once Interstate 10 (I-10) was completed Highways 80 and 86 became more or less obsolete. I-10 now plays a major role not only in local travel patterns, but is now the primary route of importance in national east-west travel from California to Florida.

Though caught up in the interstate building boom, Arizona leaders ignored the question of how interstate development would determine transportation patterns far into the future. For example, in January 1972, the Senate Transportation Committee voted down a Senate resolution calling for a moratorium on the construction of freeways in urban areas within Arizona until possible impacts on mass transit and land use were investigated ("Moratorium. . .," *Arizona Daily Star*, January 19, 1972). Such lack of foresight has in part contributed to an enormous

highway construction and maintenance need throughout the state, which has been estimated in the hundreds of millions of dollars. In the 1999 legislative session a bill, Senate Bill 1201, passed both houses and was signed into law by the governor. This bill will require the Arizona State Treasurer to create Board Funding Obligations (BFO) totaling four hundred million dollars. The BFO shall be backed by state treasury funds and sold through private and public sales. The monies generated from the BFO process are to be used by ADOT towards highway repair and construction, with exactly 25 percent of total revenues directed towards projects in rural Arizona

The most immediate impact of the 1974 infrastructure improvements for the MSPRV was to alter the patterns of visitor traffic through the area. The completion of I-10 around Benson was designed to reduce traffic congestion and take the 10,000 or so vehicles out of the downtown area, and some Benson residents feared that it would negatively affect motels, restaurants, and service stations serving the tourist and commercial traffic through the area. At the time of construction, improved travel between the MSPRV and Tucson was not identified as a significant outcome of the new project. During the completion of construction on I-10 near Benson, the city built its new hospital to take advantage of an exit planned at Ocotillo Street. However, the Arizona Highway Commission deleted this exit from its plans. This move caused a backlash from local public officials and citizens and exacerbated concerns that the completion of the I-10 upgrade would signal the demise of the city. According to State Representative Hank Benn (D-Benson), "Ninety-five per cent of the business in Benson, Tombstone, Douglas and other areas which this interchange would give access to is tourism" (Cavanaugh 1972)/ The interchange, including a reintegrated exit at Ocotillo Road in Benson, was completed in 1974 (*Arizona Daily Star*, June 7, 1974).

Though the development of I-10 reduced the flow of traffic through downtown Benson it has probably contributed to the increase in one segment of MSPRV visitors: the RVers. Though experiencing a steady rise over time, RV use began to boom in the mid 1990s and at present shows no signs of tapering off (see Section 2.2). A Benson RV park developer noted that the industry expects one half million first time RVers to take to US highways in 1999 alone. Safe and reliable transportation infrastructure is certainly key to this group. Yet, it is the national highway network, as well as the local highway conditions, that has made it possible for the RV lifestyle to prosper.

Another major change in transportation patterns which is linked to infrastructure improvements, but in recent years has depended more on policy decisions, is the rise in highway and interstate speed limits.

Twenty years ago highways were so designated and constructed that safe speeds ranged from 20 to 45 miles per hour. With the advancement of the automobile age, the incorporation of additional safety features in the design and manufacture of motor vehicles, and to meet the time-saving and safety demands of the motorist, highways have constantly been improved in design and construction to

a point where highway design speeds in Arizona now range up to 80 miles per hour, although actual operating speeds are much lower (Arizona State Highway Department 1954: 63).

In 1954, the State of Arizona had a 50 mph speed limit for night driving and a “reasonable and prudent limit for daytime operation.” On most open highways, however, the daytime speed limit had been set for 60 mph (Arizona State Highway Department 1954: 67). According to data collected that year from the observation station located on Highway 80 nine miles east of Tucson, most travelers between Tucson and Benson rode at 60 mph during the day and 55 mph at night.

In 1997, the speed limit was raised to 75 miles per hour on interstates within Arizona (ADOT 1999). Unlike infrastructure improvements that affected Valley visitors, the most dramatic impacts of rising speed limits have been on the transportation patterns of area residents. Coupled with increasing traffic problems within Tucson (see PAG 1998), the effect of the increased speed limit was to reduce the effective distance of the MSPRV from Tucson and make it possible for more people to move into the Valley and continue to work in Tucson. Like people throughout the Southwest, study participants within the MSPRV talk of the distance to Tucson in terms of minutes and hours - not miles. Indeed, a key factor heard time and again to explain migration to the Valley from Tucson is that driving across Tucson to work takes longer than driving from the MSPRV to the city. The combination of improved highways, increased vehicle fuel efficiency and improved handling, and increased speed limit brings the MSPRV within the reach of Tucson.

2.4.2.3 Factors for the Future

Cochise County is expected to grow in population from an estimated 109,930 in 2000 to 123,583 in 2011. Transportation infrastructure will be a major factor in the direction of that growth. SR90 is the main link between the center of Cochise County and the major metropolitan areas of Tucson and Phoenix. Driven primarily by expansion of Fort Huachuca, Kartchner Caverns, and increased trade with Mexico resulting from North American Free Trade Agreement (NAFTA), growth along SR90 is expected to increase by more than eighty percent in the next 20 years (ADOT). In addition, approximately 728 hectares of the Whetstone Ranch, a planned community, borders the highway, so development there also will affect and be affected by travel along SR-90 (Highway 90).

The recent and rapid growth in traffic along the SR-90 is indicative of the rapid population growth and an increase in tourism that is expected to continue into the future. Consequently, the highway has been classified “Category B” by ADOT, a classification applied to communities exhibiting urban-style growth and a community attitude “in support of such growth” (ADOT). ADOT already has begun constructing additional lanes to the existing highway to create a four lane highway, which in some stretches may be increased to five lanes. An estimated \$43,796,000

will be spent on this construction project. The impact that such outward signs of Cochise County growth will have on the MSPRV is uncertain.

Though continued highway improvement along I-10 will mean that the established patterns of commuting and travel remain, improvements along SR-90, however, may dramatically change the existing travel patterns of many stakeholders. According to statistics kept at the Benson Chamber of Commerce, nearly eighty percent of the tourist traffic into the MSPRV comes from the west. It is possible that the improvements to Highway 90 may funnel the bulk of both tourist and future residential traffic away from the MSPRV and toward Sierra Vista. It is also possible, however, that the Highway 90 changes may, however, capture RVers that to date do not stop in the MSPRV. Although some community leaders in Benson are working to link the SR-90 development with the present downtown area, others express a willingness to let the development bypass the community. The expansion of SR-90 without complementary improvements in roads that lead into Benson and St. David is likely to restrict the impacts of the expansion, both positive and negative, to the area directly along the highway. One result, though, may be increased interaction between the MSPRV and Sierra Vista. Following existing patterns, the MSPRV will likely be the recipient of change instigated by outside forces, such as Tucson and Sierra Vista, instead of the initiating such changes.

Another factor likely to impact transportation in the MSPRV is a change in gasoline prices at the pump. With continued low gasoline prices, the patterns of travel will remain the same. If gas prices were to be raised significantly, both commuters and RVers might reduce the total number of miles they are willing to drive, and these reductions may mean fewer people in the MSPRV. However, it has also been noted elsewhere that small changes in gas prices (such as an increase in gas taxes that have been proposed to combat the creation of greenhouse gases) will have little affect on the miles driven by rural individuals (MacDonald 1999 and Douglas 1999).

A final transportation-related factor that requires mention is the potential impact of Tucson's urban transportation infrastructure on the MSPRV. Tucson's steadily worsening traffic congestion has been attributed to rapid growth in the metropolitan area combined with an increase in the daily vehicle miles traveled per person (PAG 1998). In April 1996, Pima County's share of gas tax revenues increased, putting money into road projects (Brooks 1996). Yet, though Tucson's problems have been identified and transportation plans developed, serious efforts to manage land use and transportation have been lacking. Development continues on all sides of Tucson, including the southeastern side nearest to the MSPRV. The Pima Association of Governments' proposed five year Transportation Improvement Program for 2000-2004 was out for public review during this case study. Among the roadway capacity improvements slated for completion by the year 2020 is the widening of Houghton Road to I-10. The increased ease of getting out of Tucson and heading east combined with the location of a proposed new shopping area at the Houghton-I-10 intersection, will facilitate commuting to Tucson for work and shopping.

2.4.3 Climate-Related Impacts on Transportation in the Middle San Pedro River Valley

Three potential areas of impact of climate on transportation were identified in the introduction to this chapter: (1) , infrastructure and operations; (2) movement of commodities and people; and (3) energy. The nature and extent of these impacts within the MSPRV are discussed in this section.

2.4.3.1 Infrastructure and Operations

In general, potential climate impacts on transportation infrastructure are of concern because railroads and highways have a very long lifespan and major changes in either their location or construction do not come quickly, easily, or at a small cost. Neither the users nor those responsible for maintenance of the rails and roads have many short term alternatives in transportation. Delaying travel, rerouting people and goods, changing to another mode of transportation, and planning for longer travel periods are all limited options in the MSPRV.

Although compared to other places in the U.S. the MSPRV has a warm, dry climate, climate variability does affect both infrastructure and operations. Even before the completion of the interstate, highway maintenance work in Arizona was comprised mainly of routine repairs, plowing snow, sanding slippery pavement, removing slides and patrolling the sections during stormy weather (Arizona State Highway Department 1954: 116). In the winter, commercial truck drivers argue they select I-10 over other highway routes to avoid snow and ice along I-40 (DA-15). Yet, the very absence of major periods of rain, snow, and ice make these factors treacherous for unsuspecting or unskilled drivers when they occur. For example, between 1989 and 1992, 13 percent of the accidents along SR-90 were caused by “unusual conditions such as water, ice, snow, or sand on the roadway” (BRW 1996:23).

The two principal problems for highway infrastructure in the MSPRV are flooding and buckling due to heat. The potential for 25, 50, and 100 year floods is the major factor in determining the construction of drainage and bridges along a roadway. For example, a major negative impact of the construction along SR-90 is the potential for exacerbated flooding due to highly sodic soils (a non-saline, clay-like soil) along the highway and the lack of well-defined channels to carry runoff through the Whetstone area. Maintenance costs and durability are dependent on weather events. Though such cataclysmic weather events as those cited above are rare, ADOT does require that contractors take such environmental stresses into account when designing road improvements and projects. These requirements vary depending upon project location and should be included in the plan that is submitted to the state as a bid for the transportation project (MacDonald 1999).

2.4.3.2 Movement of Commodities and People

Since the closure of the railroad depot in 1913, the transportation of commodities has been of minimal importance in the MSPRV's economy. With the exception of the tourist train, no aspect of the transportation industry originates in or has significant activity in the MSPRV. The minor position of the railroads in the MSPRV economy and the minimal impact of highway trucking mean that the direct impacts of climate on the transportation of goods are minimal. The movement of commodities into and through the MSPRV is very limited, and, with the exception of the fuel going to Apache Nitrogen and the ammonium nitrate going away from the plant, only merchandise for area businesses stops in the Valley. The impact of disruptions in the flow of such goods are difficult to measure and beyond the scope of this study.

The movement of people, however, is a major force in how the MSPRV has been and will be shaped. This redistribution of the population will remain tied to climate as long as the MSPRV climate remains milder than that of Tucson in the summer and than other parts of the U.S. in the winter. Indeed, it is the relative climate of the MSPRV when compared to these other locales that is of significance. Conditions affecting highways far from MSPRV, such as snowstorms that closed highways in the Midwest in 1998, directly impact the arrival of winter visitors.

2.4.4 Vulnerability and its Relationship to Transportation and Other Factors

Vulnerability in relation to transportation occurs primarily at a community rather than individual level. For example, the routing of commuters and tourists away from the MSPRV and toward other parts of Cochise County would impact the entire community. Nevertheless, because transportation infrastructure is not equally accessible to all people and organizations, vulnerability to infrastructure impacts are not evenly distributed. This section examines first residential and then commercial issues related to vulnerability.

2.4.4.1 Residential Sector

The individuals who use the highways connecting the MSPRV to surrounding communities and are most likely to be impacted by increased costs of transportation are of middle and lower middle incomes. While there are poor in the MSPRV and surrounding communities, the absence of any regional public transportation network and their lack of resources to leave their home communities on a regular basis limit their vulnerability to highway impacts. Conversely, vulnerability to rising transportation costs is reduced with increasing income.

2.4.4.2 Commercial Sector

The MSPRV's commercial sector is dominated by retail and is unlikely to change in the near future (see Section 2.2). Though the initial siting of Apache Nitrogen was influenced by available transportation and the MSPRV has adequate highway and rail infrastructure, the area has no specific transportation advantages that make it more attractive than other southern Arizona

communities. If energy and transportation costs rise, the present appeal of the MSPRV's moderate climate and lack of congestion may decrease in relation to the benefits of proximity to Tucson and Phoenix.

Of the area's existing industries, Apache Nitrogen Products requires continued access to rail, but its vulnerability to climate related changes in transportation infrastructure are minimal. The sector most vulnerable to the interplay of climate and transportation is the emerging RV sector. Of special significance in the vulnerability of this sector is the power of climate information in areas outside the MSPRV and the perceived and real differences in climate between the MSPRV and other potential destinations for RVers. Additionally, if energy costs rise, the sustainability of the RV lifestyle will be at risk for all but the wealthy. Given changing preferences with regard to leisure activities, the future of the RV industry may be independent of changes in climate and energy costs.

2.4.5 Conclusion: The Middle San Pedro River Valley in a Southwestern Context

Although the MSPRV, like all communities, has its unique local history and flavor, its transportation concerns and the impacts of climate variability on transportation infrastructure and operations and on the redistribution of its population are widespread in the Southwest. The link between the MSPRV and urban centers, especially Tucson, is a pattern repeating itself throughout the southwest. The rapid growth of the nearby urban area is expected to continue (see Table 2.5).

Table 2.5. Population of Selected Areas in Southeastern Arizona

Community	1950	1960	1970	1980	1990	1997	2020 estimate
Benson							4,499+
Tucson*				330,537	405,390	452,836	589,899+
Cochise County	31,488	55,039					149,990+
Pima County	141,216	265,660					1,206,244+

Source: U.S. Bureau of the Census

**Report to Pima County Board of Supervisors on Urban Growth and Development in Eastern Pima County* +”July 1, 1997 to July 1, 2050 Arizona Subcounty Population Projections for Counties, Places and Reservations,” Arizona Department of Economic Security, Research Administration, Population Studies Unit

The interstate highway construction within the MSPRV in the 1970s stemmed from the 1956 Highway Act which irrevocably committed land and resources to support automobile travel across the U.S. Arizona received large sums of federal money from the Highway Act because the formula for distribution of those funds, whose base match was one dollar federal funds for each dollar of state funds, increased the federal ratio by one tenth of the percentage of federal lands. The result was that as of January 1966 the ratio was 94.4 percent federal and 5.6 percent state funds (Betz and Matthias 1968). (In 1954, ratio was 72.37 federal to 27.63 state.) Consequently, over \$1 billion was spent on the initial development of Arizona's interstate highway system.

Transportation-related growth like that of the MSPRV is common. Building highways in urban areas improves accessibility to suburban and exurban locations, facilitating the development of housing and employment at the urban fringe and encouraging the expansion of metropolitan areas. Interstate highways have been shown to bias transportation investments, improve automobile travel times and costs, disadvantage transit operations, and facilitate suburbanization (PBQandD and Pucher 1998). In a national study, following interstate highway construction, population and retail growth were found to occur immediately in adjacent nonmetropolitan counties compared with similar counties without interstate highways (Rehmann and Isserman 1994). Whether interstate highways caused new development or were built in the path of new development is an open question, though Rehmann and Isserman's time series matched pair study provides evidence that interstates directed development (PBQandD and Pucher 1998).

Similarly, the travel patterns of MSPRV residents and visitors reflect state and national trends. Throughout Arizona, out-of-state drivers make up almost half of the users of Arizona highways. In 1954, for example, out-of-state motor vehicle owners using Arizona's highways drove about 40 percent of the total vehicle mileage (Arizona State Highway Department 1954). The work-related transportation patterns of MSPRV residents are not unusual either. In the 1990 United States Nationwide Personal Transportation Study, for example, the dominant trend in modes of transportation used for trips to work both nationally and for Pima and Cochise Counties was a *decline* in all alternatives except that of driving alone (FHA 1993).

3.0 CHAPTER THREE: Moving Beyond the Ethnographic Case Study -- Patrick Barabe, Nicholas Benequista, Diane Austin, and Tim Finan

This chapter explores the use of data collected during the ethnographic case study to extend knowledge of climate variability and vulnerability in the Middle San Pedro River Valley. Section 3.1 examines current land and resource use in the Middle San Pedro Valley and the potential for extending the climate assessment via qualitative and quantitative modeling. It discusses availability of data and of the parameters upon which a model or other quantitative examination might be built. It extends the discussion to issues common throughout Arizona and the Southwest and their relevance to the pursuits of integrated assessment. Section 3.2 describes the results of a community-based stakeholder analysis and compares it to alternate approaches. Section 3.3 concludes the report with a summary and discussion of issues raised by the use of ethnographic methodology in an integrated climate assessment.

3.1 Modeling and Cartographic Analysis -- Patrick Barabe

3.1.1 Introduction

In considering models of human activity, and the degree to which they may be either quantifiable or qualitative in nature, it is necessary to acknowledge that technology, ideology, and social networks are as much elements of human environments as the physical environments, including climate, which they inhabit. Thus, a broad definition of environment should be considered when assessing human activities. This may include, as mandated in New Zealand's 1991 Natural Resources Management Act for instance, social, cultural, and amenity factors (Taylor, Goodrich, and Bryan 1998). Further, inventiveness and innovation are primary qualities of the human ability to adapt to the broad range of environments, both physical and social, which people encounter, while conversely, the impacts of human activities on geophysical systems is the topic of a broad range of contemporary discourses, from popular to academic to political.

Efforts to capture human-environment interactions in a modeling framework must be informed by the particular nature of such relationships. Though this may appear obvious, the intricacy of such a task cannot be overemphasized. The complexity of developing a research methodology is complicated by the dynamic qualities of human and environmental systems. Johnson (1991:46) suggests that in considering climate relationships to agricultural production, for instance, it is necessary to assume an evolution of institutions, policies, and agreements governing trade, linkages to non-agricultural sectors, and the use of the natural resource base. This may also be said of modeling other economic relationships to the physical landscape, as well as of socio-

environmental relationships in general. Taplin (1998:236) cites several observations from researchers who have made attempts at integrated climate assessment:

- Integrated assessment models focus on the organization of vast quantities of technical information across disciplines;
- Integrated assessments of climate impacts are in their infancy and no one model can yet be recommended for general use;
- The significant complexities and uncertainties associated with the operation of the climate system, and how it impacts - and is impacted by - human activities, make it impossible to know exactly what to focus on and what methodology to employ.

The MSPRV Case Study has been undertaken in part to (1) develop a methodology by which to systematically examine community-climate relationships; (2) to consider qualitative assessments as they relate to potential quantitative methods, and (3) to define data needs, availability, and suitability with regard to promoting greater understanding of human vulnerability to climate in the Southwest in general. The first part of this report described the results of the application of an ethnographic methodology for community research on climate vulnerability. The remaining two objectives are then discussed.

3.1.2 Examining Climate-Community Relationships

Quantitative assessments rely on both numeric data and appropriate algorithms. In other words, as a system of numeric equations, both the variables (the data) and the parameters (the relationships among them) must be known. An evaluation of the climate data available for integrated spatial modeling in the MSPRV reveals several limitations that have been noted elsewhere:

- Climatic actuality is poorly represented by statistical averages based on course networks of weather stations (Tuan 1973);
- Apparent, though not necessarily actual, long-term climate may be influenced by factors such as urbanization, reclamation of desert for vegetated residential use, or the relocation of an existing weather station (Tuan 1973);
- Because precipitation in the Southwest generally occurs in local storms which are irregularly scattered in both space and time, a denser network of long term weather stations would significantly improve our understanding of the region's climate (Barry and Chorley 1998).

In addition, the most current climate data and spatial models exist at resolutions that, for broad regional analysis, may indicate clear regional trends, but which would introduce significant errors if incorporated quantitatively at a community level analysis. The

Parameter-elevation Regressions on Independent Slopes Model (PRISM), for instance, currently being developed and refined by the Oregon Climate Service and the U.S. Department of Agriculture, provides spatial precipitation and temperature data for the continental U.S. in raster and vector formats. These data represent annual and monthly averages for the period of 1961 to 1991.

However, as indicated by the metadata for the published PRISM data, grid cells exits at four kilometer resolution and care should be taken in estimating precipitation values at any single point on the map. Precipitation estimated for each grid cell is an average over the entire area of that cell; thus, point precipitation can be estimated at a spatial precision no better than half the resolution of a cell, i.e. two kilometers (Daly and Taylor 1998). Thus, while the overall distribution over broadly-defined regions may be accurate, the utility of such data for studying a region the size of the Middle San Pedro River Valley is limited by the precision of the resolution. Figures 3.1a and 3.1b demonstrate raster precipitation data at two such scales.

Figure 3.1a. PRISM Raster Precipitation Map - Arizona and New Mexico

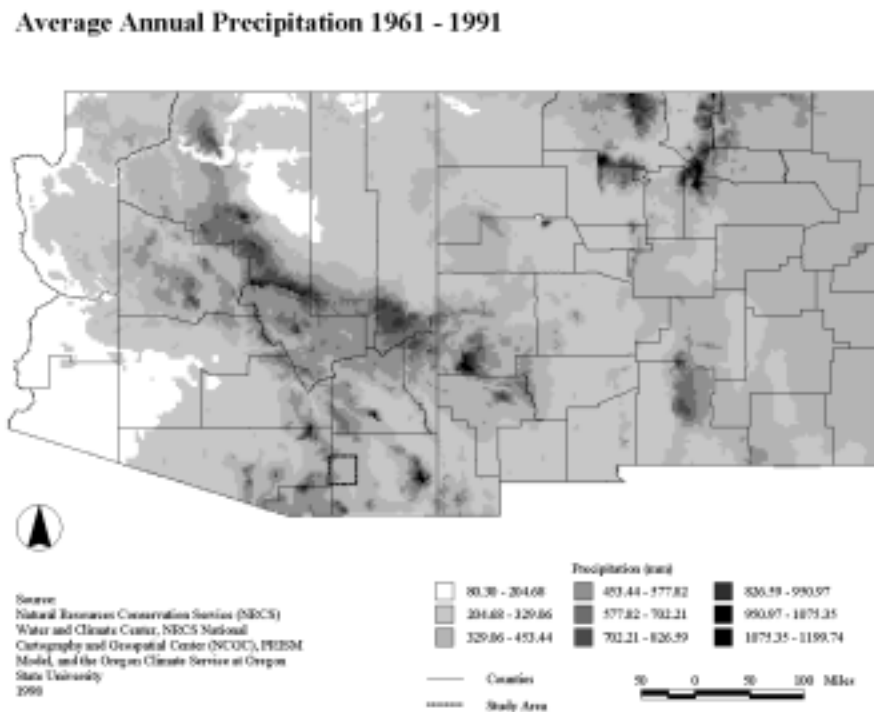
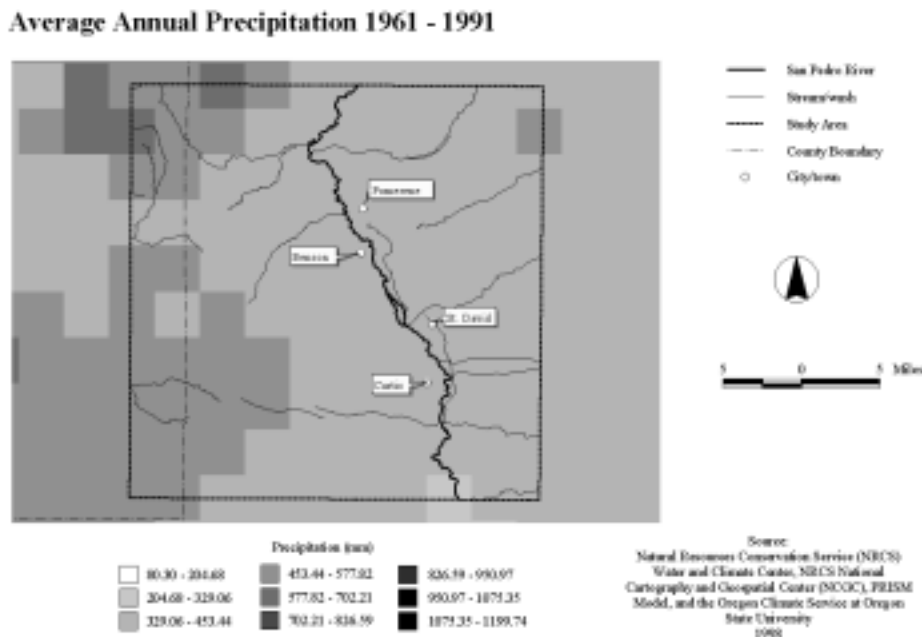


Figure 3.1b. PRISM Raster Precipitation Map - MSPRV Study Area



Other limitations, too, can be recognized in the effort to incorporate climate data of this kind into a community level analysis. The temporal nature of available spatial data, such as the 30 year mean, is not compatible with an examination of short-term vulnerability to climate extremes. For instance, as discussed in the utilities section of the previous chapter (Section 2.3), electricity providers must prepare for seasonal and even daily fluctuations in temperature, and sensitivity to climate is most likely to manifest itself as an inability to respond to unforeseen temperature extremes at periods of peak use. In contrast, surface and ground water availability involve a complex system of stream flow infiltration to and augmentation from groundwater, floodplain and regional aquifers, evaporation and evapotranspiration, and human water use behaviors which comprise much broader spatial and temporal scales (Lacher 1995).

Clearly, available data present particular limitations to large-scale analysis of local distributions in climate. With regard to the MSPRV study, research tends to indicate limited human vulnerability to climate, which suggests that a direct relationship between climate and communities in the MSPRV does not exist in an easily quantifiable correlation. More specifically, community members themselves have identified few scenarios in which anything but short-term fluctuations in weather events may influence decision-making. While this may indicate the development of social buffers to climate variability, it should be noted that in all likelihood such buffers represent regional

phenomena among communities whose historical development has occurred in arid sub-regions of the Southwest. However, as variations in physical environments are spatially distributed, so too may be social, economic, and institutional characteristics of communities across the region. Hence, if a climate relationship were hypothesized in this broader sense, it may, then, be desirable to perform a characterization of sub-regions of the Southwest based on several criteria:

- Prevailing precipitation and temperature characteristics, which may be suitably obtained from PRISM data sets, given the broad spatial nature of the query;
- Sources of water;
- Tenure of adjacent lands;
- Use characteristics of adjacent lands;
- Predominant vegetation regimes;
- Community-level economic compositions, which may be deduced from census and other labor and employment statistics¹⁷;
- Driving distance to metropolitan areas; and
- Other criteria as they may be identified.

3.1.3 Models and Paradigms of Land Use

Even with a resolution to the problems of representing climate data at the community level, other issues challenge the development of quantitative models. The significance of land use decisions in the determination of vulnerability to climate variability and change (see Section 2.1) require the incorporation of data and decision rules (both ideologies and practices) regarding land use. Early contributions to agricultural economics, particularly the rent theories of David Ricardo and Johann von Thünen¹⁸, exemplify early models of productivity that, despite a history of academic critique, offer insights into southwestern perspectives on land use. They also persist as elements of a paradigm of progress which, sometimes embedded institutionally in policy and sometimes apparent in land-use and resource-consumption behaviors, affect human decision-making. For instance, regarding the use of State School and Trust lands, the Arizona State Constitution states that said lands shall not be sold or leased, in whole or in part, except to the highest and best bidder at a public auction (*Article 10, Section 3*). While legislation of this kind only places constraints on the use of State lands, it does reflect a dominant mindset reflecting the value of land itself: the best use of land is that which most improves its financial value.

¹⁷ Research of this kind is currently being conducted by Dr. Gordon Mulligan, of The University of Arizona's Department of Geography and Regional Development.

¹⁸ Rent theory aimed at determining means of maximizing agricultural output while minimizing inputs, given the relative productivity of particular parcels of land.

Trends in urban expansion in Arizona may represent new attitudes in land use or recent policy agendas, or they may simply reflect the demand for and utilization of technologies (air conditioning, transportation, telecommunications) that allow conceptual ideals of land to be distilled, with greater economic efficiency, into financial gain. Conversely, it may be hypothesized that use of such innovations has influenced the value of land. For instance, air conditioning and the automobile may be viewed as innovations that have allowed the Southwest's hot, arid regions to be perceived more inhabitable by a greater number of people. In-migration, in turn, created a market for improved land such that a portion of the region's economic activity, perhaps a significantly large proportion in metropolitan areas, became directly related to land development. Land, then, rather than remaining a factor of production in more traditional rent theories, may be considered an actual commodity when coupled with improvements, be they residentially or commercially oriented. A third condition of land use change was discussed in Section 2.1 in the previous chapter: proximity to conserved land in the MSPRV is often a selling point for private land holdings, while subsequent increases in assessed value and taxes can discourage marginal or vulnerable uses.

While the specifics of such hypotheses would require further inquiry to validate, the phenomena of land use practices are clearly parts of a complex, dynamic system of which climate may be merely a marginal factor.

3.1.4 Community Analysis - The Middle San Pedro River Valley

Though climate and land use are critical elements of any model, they are not sufficient for assessing potential vulnerability to climate variability and change. Considerations of importance in establishing a modeling framework of human-environment interactions in the MSPRV would include, but are not necessarily limited to:

1. Human impacts on physical environment in MSPRV
 - Water Use
 - Ranching
 - Development
2. Physical and/or resource constraints on human activity
 - Water Supply
 - Rain-fed pasture
 - Availability of land for agriculture, grazing, or urban uses
3. Human constraints on human activity
 - Institutional constraints
 - State land law
 - ADEQ Nonattainment Areas

- Arizona Groundwater Code
- Riparian area protection
- Markets
- Competitive land uses
- Infrastructure
- Land tenure

Given the current state of both data and knowledge to be incorporated into the establishment of parameters in any quantitative model of the MSPRV, further attempts to create such a model would be difficult to achieve, and, even if successful, unrepresentative of the greater Southwest. However, the availability of data and decision rules at a subregional, sector level may make modeling of sector-specific vulnerabilities possible. The following section examines one sector, ranching, where perceived vulnerabilities to climate variability and change are high.

3.1.5 Sectoral Analysis - Ranching

Given the historical predominance of ranching in proximity to the MSPRV, and in consideration of the direct interaction between ranching and the physical environment, a thorough understanding of the relationship between ranching and climate may be desirable. While such an understanding may be greatly enhanced by a spatial model, the particular difficulties of developing such a model should be explored. Therefore, as part of the MSPRV assessment project, efforts were made to gather data and determine the feasibility of developing a quantitative model of vulnerability in the ranching sector. This section reports on the methods and results of this effort.

After an initial survey of land management agencies and the data they collected and controlled, the question of primary importance in this pursuit became, what, in the Southwest, is a ranch? While it is known that ranches are comprised of varying combinations of private, State, Bureau of Land Management (BLM), and U.S. Forest Service (USFS) lands, exactly which lands, and in what proportions, make up individual ranches in the region as a whole remains unknown. Data maintained by these agencies may be useful in determining tenure relationships within ranches - and different environmental qualities of differently tenured lands - but not without difficulty¹⁹.

The pursuit to identify individual ranches in Cochise County began with the accumulation of ranching and leased-land digital map layers (also known as coverages) provided by the Arizona State Lands Department, the BLM, and the USFS. Using Geographic Information Systems (GIS) software in an initial examination of these layers,

¹⁹ It should be noted that the following discussion refers to ranching map layers for Cochise County, Arizona. Similar issues for other regions of Arizona and New Mexico are likely but should not be assumed.

a complex assortment of data reporting and management procedures was revealed, the meaning of which was not immediately apparent. Determining the nature of the ranching layers was particularly difficult given the poor documentation provided with most of the data. Overlaying the coverages with that of land ownership²⁰, maintained by State Lands, provided some clues. From this examination, the nature of the three agencies' ranch layers was deduced:

- Ranching polygons maintained by the BLM represent ranches that contain some portion of BLM-owned land;
- Lease polygons maintained by the State represent State lands allotted to ranching leases (regardless of the status of the lease), State lands allotted to other leases, and private lands associated with State leases;
- USFS polygons represent USFS ranching allotments where they occur on USFS-owned lands, and in some cases, private lands that are bounded on all sides by USFS allotments.

By calculating the spatial identity of the three ranching layers and the ownership layer, tenure categories were determined for ranching lands: privately-owned, State-owned, BLM-owned, and USFS-owned (see Figure 3.2). From the associated tabular data for the input layers, it may be possible to determine individual ranch boundaries. However, due to different data maintenance standards of the various source agencies (including data entry standards, allotment naming discrepancies, and other data-related inconsistencies) and the number of records involved (over 6,500 polygon records resulted from the identity operation for Cochise County alone), this task is difficult and time-consuming to accomplish.

At present, environmental characteristics of ranch lands by tenure can be queried for a range of statistical values (see Table 3.1 and Figure 3.3). As might be expected, Forest Service ranch lands clearly occur in areas of higher elevation and precipitation than do other categories. Given that forested lands in the Southwest tend to occur in terrain of higher elevation and precipitation, this would support a hypothesis that ranchers who use USFS lands may have different advantages, employ different decision-making strategies, and are subject to different institutional constraints than do ranchers utilizing other lands.

Given a more thorough understanding of these issues, as well as the development of a spatial database of individual ranches, it may be possible to model levels or types of vulnerability consistent with the goals of integrated assessment. Such a vulnerability index may be based on:

- Tenure compositions;

²⁰ The State Lands land ownership coverage identifies individual public agents. Private lands are designated only as private.

- Landscape characteristics, such as terrain, access to water sources, and soil and vegetation regimes;
- Climate characteristics, such as precipitation and temperature;
- Management strategies, such as season-of-use constraints;
- Fluctuations in the beef market.

The non-parametric qualities of most of these data, and the resolution limits of climate data, introduce a hurdle that may be difficult to overcome in examining ranching and other human-environment interactions. If a model can be developed using the aforementioned criteria as principal components, questions will be raised for further qualitative research:

- Role of seasonal use patterns of differently tenured lands *within* a ranch;
- Role of seasonal decision-making used to minimize vulnerability;
- Differences in management practices between family and corporate proprietors.

It should be noted that these issues introduce temporal variables for which GIS applications may not be well suited.

Figure 3.2 Tenure of Ranch Lands in Cochise County

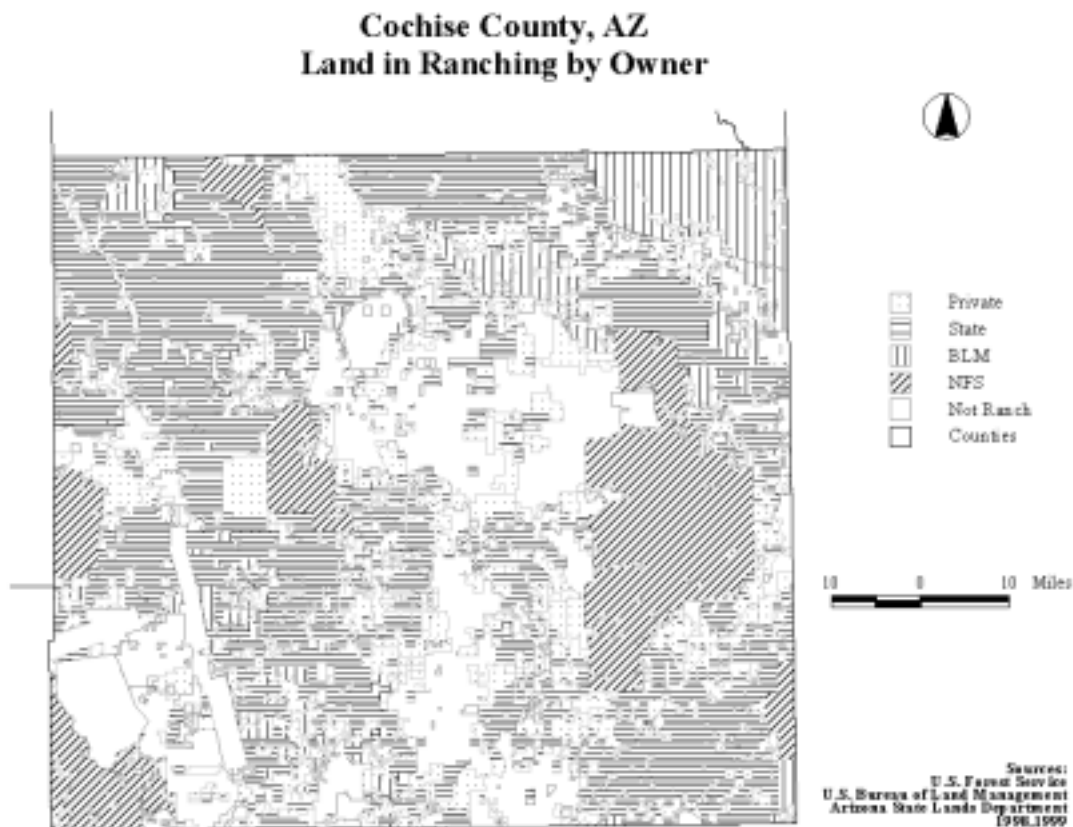


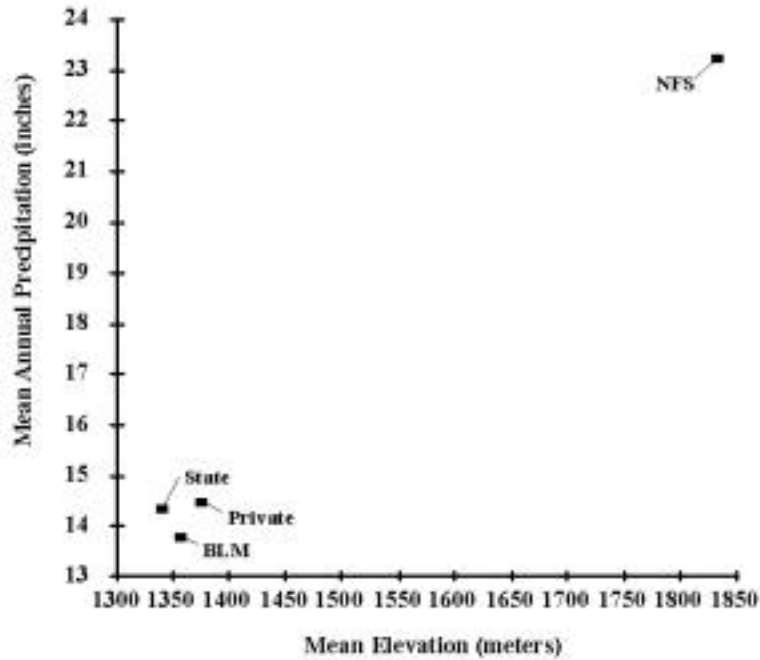
Table 3.1 Tenure Characteristics of Ranching, Cochise County, AZ

Owner	Acres	Minimum Elevation (m)	Maximum Elevation (m)	Mean Elevation (m)	Minimum Precipitation (inches)	Maximum Precipitation (inches)	Mean Precipitation (inches)
Private	944,876	914	2573	1376	9	37	14.5
State of Arizona	1,1331,866	914	2316	1341.4	9	25	14.4
Bureau of Land Management	325,517	1036	2377	1357	9	25	13.8
U.S. Forest Service	486,612	1218	2986	1833	13	45	23.2

Sources: PRISM; US Geological Survey; BLM; USFS; Arizona State Lands Dept.

Figure 3.3 Basic Environmental Qualities of Ranch Lands in Cochise County, AZ

Environment of Ranching by Ownership in Cochise County, AZ



3.1.6 Conclusion

This section has been intended to discuss the potential of quantitative research in augmenting ethnographic methods of examining community-level relationships to climate. In addition, it has attempted to profile needs, suitability, and availability of data necessary to quantify such relationships. In particular, available climate data such as the PRISM models are unavailable at spatial and temporal resolutions that are adequate to elucidate climate relationships within local regions such as the Middle San Pedro River Valley. Similarly, the wealth of data necessary to represent a community as a complete system in relation to climate fluctuations is likely to be both laborious to acquire and, even if relationships can be estimated, difficult to extend as representative of broad geographic regions. Despite these limitations, it may be possible to characterize subregions of the Southwest, or to demonstrate types or degrees of vulnerability within particular sectors. However, because human-environment interactions are complex, and because available data are subject to a variety of limitations including standards of collection and management, level of aggregation, and spatial and temporal precision, it is difficult to suggest that the task of performing a quantitative assessment of community-level climate sensitivity is anything less than formidable.

3.2 Stakeholder Analysis Within a Community Context -- Nicholas Benequista and Diane Austin

3.2.1 Stakeholders and the CLIMAS Core Office

The term *stakeholder* has been the subject of much discussion and debate across disciplines in recent years. Fields such as environmental management, international development, and business management have developed unique definitions and theories surrounding this topic (Mitchell 1997, Peelle 1995, Phillips 1997). Most of these definitions roughly encompass the same space: the term stakeholder refers to persons or groups of persons that *can affect* the outcome of a project or policy or that *are affected* by a project or policy. In the scope of a typical project, stakeholders usually represent groups, organizations, or institutions comprised of persons with some shared ideology or concern. For the purposes of this study, a *stakeholder* represents any person, group, or organization that might contribute to or benefit from Climate Assessment of the Southwest (CLIMAS) research initiatives and the CLIMAS climate information system²¹.

The CLIMAS Core Office has an integral role in maintaining stakeholder involvement and is the central component of a climate information system. The office serves as a stable link to stakeholders by organizing periodic forums for stakeholder discussion and by offering workshops and training sessions tailored to the particular needs of stakeholder groups. The office also collects climate research and forecasts from national, state and university organizations and disseminates that information (or provides a referral) via a clearinghouse and web site. These interactions with the Core Office allow stakeholders to guide the direction of future research and the management of the climate information system.

In order to identify stakeholders and initiate the involvement process, CLIMAS researchers conducted a Pilot Stakeholder Assessment (Benequista et al. 1999). Interviews were conducted throughout Southeastern Arizona (in the southern Deserts Ecozone) in towns of varying size and land ownership characteristics and of different dominant economic sectors. The team completed 72 interviews with emergency managers, utility managers, water providers, public officials, land managers, and miscellaneous private stakeholders (ranchers, farmers, industrial managers). The Pilot Stakeholder Assessment effectively characterized the perspective of these stakeholder groups, identified their information needs, and initiated a relationship between stakeholders and CLIMAS researchers. The Pilot Assessment also established a methodology for conducting climate information stakeholder research and, in conclusion, recommended areas for further, more in-depth research.

²¹ This document reports on the integrated case study performed for the Climate Assessment Project for the Southwest (CLIMAS) by a research team from the University of Arizona's Bureau of Applied Research in Anthropology (BARA) and the Institute for the Study of Planet Earth (ISPE). CLIMAS was established with funding from the National Oceanic and Atmospheric Administration. The Project unites several departments at the University of Arizona in the mission to improve the ability of people and organizations within the southwest to respond effectively to climatic events and changes.

Because participants were limited to potential stakeholders, the Pilot Assessment was unable to explore the interaction between stakeholders and the larger community; a critical link for understanding how information dissemination can mitigate or exacerbate vulnerability at a community level. As an alternative to the focus on stakeholders as separate entities, the Middle San Pedro River Valley (MSPRV) case study provides an opportunity to explore the dynamic links among stakeholders. With only one exception, the MSPRV study identified the same stakeholders and similar informational needs reported in the Pilot Assessment, but the MSPRV study also raised new issues that have not yet been addressed by other climate assessments.

The unit of vulnerability in the MSPRV is not the individual or the economic sector, but the community. By focusing on isolated stakeholders, key elements of a community are excluded from study which are essential for understanding how climate information can be useful. The MSPRV study demonstrates how inquiries into the utility of climate information systems can incorporate the general concerns of each economic sector and go even further, beyond stakeholders, to conceptualize climate in a community development context.

This section begins by outlining the informational needs of MSPRV stakeholders and identifying areas in which more or improved climate information would be beneficial, then explains how the coping strategies, cultural traits, and specific situations of each stakeholder influence his or her use of climate information. The next section focuses on the community, elucidating the issues of potential concern to policy makers that relate to climate information. The chapter concludes with recommendations for information dissemination and for evaluating stakeholder involvement in this CLIMAS research initiative.

3.2.2 Information Needs of Stakeholders in the Middle San Pedro River Valley

Climate information products can be improved by developing a consumer voice and by capturing the perspectives of stakeholders that will bring scientific outputs and user needs closer together (Stern 1999). This section outlines the information needs of stakeholders and identifies areas where more or improved climate information could benefit stakeholders. Climate information systems may not satisfy the needs of stakeholders for a number of reasons. Stakeholders may not be familiar with available information, the data may not exist, or if the data do exist, the accuracy or resolution may not be suitable for the needs of the user.

Stakeholders may describe their information needs in as many as three dimensions; topic, space, and time. A stakeholder might identify a topic such as rainfall about which data are scarce, or they may identify an information gap because the data in existence lack the needed temporal context or spatial frequency (e.g., not enough rain gauges).

The MSPRV study identified six stakeholder groups that identified climate information needs: (1) water providers; (2) electricity providers; (3) RV park owners; (4) ranchers; (5) farmers; and (6) industry and emergency management representatives. As mentioned previously the information needs identified by these groups did not diverge greatly from those identified by

the same groups in the Pilot Stakeholder Assessment. There is, however, one exception. The Pilot Assessment concluded that electricity providers in small towns, as subsidiaries of larger companies, lack the decision-making capacity to utilize climate information systems. In contrast, the MSPRV study showed that stakeholders in this group not only have the capacity to use climate information but also may have a significant need for it. Five of the stakeholder groups are described in this section. These stakeholders were selected to illustrate different patterns of interdependencies between the community and the stakeholders. For example, some stakeholders are critical to community well-being because they provide essential services, others provide jobs, and others could cause tremendous harm. Farmers are not well represented in the study area, so they have not been singled out in the following sections.

3.2.2.1 Water Providers

Water providers form a readily identifiable group of climate stakeholders. Depending on their responsibilities, whether to residential, industry, and or agricultural customers, they potentially affect all community members. Although their interests and those of their clients may not always coincide (e.g., in rate setting), their business is the acquisition and distribution of stable and secure sources of water, and in that respect they represent the community's needs.

Responses to Climatic Variability

None of the three water providers who participated in the study perceived the effects of climate variability and change on their operations as particularly stressing. However, where a connection to climate was established, it involved precipitation rather than temperature. This represents exactly the opposite concerns expressed by the electricity providers of the area (see Section 3.2.2.2).

The operations manager of Benson Municipal Utility Department, for instance, declared that wet winters kill the treatment plant. As explained in the discussion, the treated water from the plant is usually used to irrigate some surrounding fields. During times of high winter rainfall, the soil is easily saturated and there is no additional outlet for treated water. In February 1992, rainfall was so intense that it caused the storage ponds of the treatment plant to overflow, resulting in sewage flowing back into some households. Consequently, the city was forced to build an additional storage pond to prevent similar occurrences in the future. To date, flooding related to events of high rainfall has not caused any problems to water providers, which can be explained by the significant depth of their wells. As described by one member of the board of directors of the Pomerene Water Association, only shallower, domestic wells had been affected in the past. In terms of infrastructure damage, no incidence was reported.

Drought periods seem to have little impact on water providers in the Middle San Pedro. There seems to exist no history of running short of water. Due to a firm belief in the availability and reliability of groundwater resources, one operation manager declared that not even a drought over five consecutive years could threaten the water supply and delivery. However, it can be

assumed that the city would have to increase its water rates in order to account for higher pumping costs. In other words, increased operation costs due to climatic factors would simply be passed on to the customers. At this point, it remains unclear how this transfer of costs would occur and which individuals/sectors would be the most vulnerable. The only other issue referred to with respect to the impact of changes/variability in precipitation were variations in the amount of water delivered to private households. During dry periods people in St. David would use additional residential water for their drip irrigation systems, especially to water fruit trees.

Use of and Further Need for Climate Information

Participants reported knowledge and acceptance of only a few sources of climate information and forecasting that has assisted or could assist water providers in preparing for harmful events. For instance, the 1998 El Niño forecasts, broadcast by local news (radio and TV) and weather stations, clearly influenced the city's utility department's decision making by leading them to empty the sewage ponds of the treatment facility prior to the anticipated heavy rainfall. Moreover, the crop cycles for the surrounding alfalfa fields were scheduled more efficiently in order to lessen the burden on the storage ponds. However, the forecasts, designed for the entire Southwest, were not seen to apply to the Benson area. The Middle San Pedro received distinctly less precipitation during this last El Niño than the Tucson or Phoenix area. Thus, issues of scale must be taken very seriously if climate information and forecasts are to be made locally relevant. In addition to local news and weather stations, one participant in St. David mentioned a radio station located in the Gulf of Mexico. This station provides five-day forecasts that are apparently more accurate and useful than those received from Tucson. As explained by the participant, this is due to the fact that the area around St. David has a very different climate than the Tucson area. On average, the St. David area is about 10 degrees cooler (the elevation there is 3,680 feet compared to Tucson's 2,500).

3.2.2.2 Electricity Providers

Like water providers, electricity providers serve all sectors of the community, residential, business and industry, and agriculture. In the MSPRV, electricity is provided by private utilities that combine their own generation with the purchase of electricity from the regional grid (see Section 2.3).

Responses to Climatic Variability

Compared to the water providers, the electricity providers in the Middle San Pedro area were distinctly more preoccupied by the impact of weather on their operations. As explained by representatives of the SSVEC and AEPSCO, their main areas of concern are short-term changes in temperature, winds, and humidity.

As described above in Section 2.3, electricity providers have to be prepared for peak demands, in the wintertime due to space heating and in the summer time due to air conditioning.

Abrupt changes in temperature, both cold and hot, can dramatically increase hourly demands. Thus, real time temperature data, especially at the lowest possible time unit (hourly basis) are crucial in forecasting such drastic rises in demand and in making it possible to take all the necessary steps to reduce the forecasted loads. According to one demand monitoring manager, SSVEC is able to save up to \$140,000/month due to an efficient temperature monitoring system and the timely usage of various conservation measures.

Another highly useful technical device for responding to climatic events is the lightning detection system at AEPCO. This system allows operators to identify, characterize, and locate lightning strikes for the entire county. Lightning strikes that are critical for the region are monitored in detail. A large monitoring screen, displaying all transmission line structures, the substations, and possible system breakers, allows to immediately identify interrupted lines and to check for impacts on the system.

Use of Weather/Climate Information and Further Information Needs

When considering weather/climate information already in use by the electricity providers in the Middle San Pedro, a distinction has to be made between data used for daily and long-term forecasts. For the daily demand monitoring, the pre-scheduling of electricity load, and potential load reductions, daily minimum and maximum temperature are obtained, primarily through the Tucson Airport. According to the operation manager at SSVEC, general weather trends are followed through the National Weather Service Tucson, Channel 13, and to some extent the Weather Channel, although it was considered not very reliable. For long-term forecasts in electricity demand, monthly degree heating and cooling days, based on 10-15 years of record, represent the most important type of data. Degree heating and cooling days, obtained through NOAA, are used as the main predictor for the number of heating and cooling days which must be provided; however, this information has shown to be misleading in terms of forecasting daily peaks.

Although temperature constitutes the main factor in electricity forecasting, AEPCO and SSVEC also integrate other parameters into their models. According to planning engineers at SSVEC and AEPCO, five scenarios are designed for all customer categories and cooperatives (see Table 3.2).

Data are obtained through NOAA reports, the Weather Channel, the fire station, and local weather watchers in and around Sierra Vista. The latter two are particularly important because they provide real time data on precipitation and temperature. According to the same participants, unfortunately, those manually derived data are not always accurate and sometimes incomplete.

Table 3.2. Forecasting Scenarios, AEPCO and SSVEC

Scenario	Description
Baseline	Average temperature and economic conditions
Severe Weather	High summer temperatures with load peaking in the summer (AC) or very low winter temperatures with load peaking in the winter (space heating)
Mild Weather	Milder than long-term averages
Low economic/ low population growth	Lack of growth or growth rate 0.5-1%
High economic/ high population growth	Growth rate 5-6%

In terms of weather/climate information needs, emphasis was put on more timely and more precise real time temperature data. Instead of relying on six to eight month old NOAA reports or the local weather watchers, both AEPCO and SSVEC expressed the need for having their own weather-monitoring infrastructure. This would allow them to obtain accurate hourly temperature data, the precondition for accurate load forecasting. Also, closer cooperation with Apache Nitrogen (Section 2.2.2), which has been collecting climate and weather information since 1923 (Western Regional Climate Center), might facilitate this undertaking.

According to one AEPCO employee, this detailed electricity demand forecasting will become even more important as soon as deregulation (the Retail Electric Competition Rule) starts to be fully operational. Due to the fact that miscalculations of the actual but unknown demand will result in penalties, competing providers will have to secure supply in the most precise way. Real time forecasts, preferably on an hourly basis, are anticipated to play a crucial role in electricity providers abilities to estimate demand, avoid penalties, and, most important, maintain both liability coverage and economic viability. Since a competitive environment is expected to result in a decreased willingness to share information, the need for on-site weather and climate information is perceived to be fundamental.

These findings clearly demonstrate the specific needs of electricity providers and the relationship between information resources and effectiveness. The higher their technical and financial ability, the better their chances to respond to increased peakings related to climatic variability, including extreme events, in a timely and efficient manner.

3.2.2.3 RV Park Owners

This study has described the growing importance of the recreational vehicle (RV) sector of the tourist economy of the MSPRV (see Section 2.2). Although many RV park owners talked about

the relationship between their business and the climate of other parts of the U.S. and Canada, only one individual articulated how she could use climate information in her business decisions. This section is intended to describe existing and potential relationships between RV park owners and climate information providers.

Responses to Climatic Variability

Several RV parks in the MSPRV are affiliated with national franchises, and many owners communicate among themselves. One chain even seeks to control the flow of RVers, frequently in response to climate events. For example, due to storms heading for Florida, organizers were identifying parks in other parts of the U.S. that could accommodate RVers leaving that area. Through communication with other parks, RV park owners also have identified how national forecasts of weather in the Southwest affect the flow of visitors. When a majority of park guests are from outside the state, national news coverage, which influences the decisions of those guests, can impact business in the MSPRV. Precipitation forecasts related to the 1998 El Niño event demonstrate the connection between business in the MSPRV and forecasts reported elsewhere. Occupancy rates at several parks were lower than expected during the 1998-99 winter season because national weather broadcasts reported that El Niño was causing higher-than-average precipitation throughout the Southwest. In reality, the Middle San Pedro Valley was not experiencing those trends. One RV Park owner heard similar complaints from several other members of the Campground Association that the erroneous weather reports were discouraging potential customers from visiting the area.

In response to these reports, compiled from information on surrounding areas but reported for the entire region, one RV park owner began a letter-writing campaign to a weather reporter. On one occasion when the reporter issued a forecast for heavy rain in the area, the RV park owner held a weenie-roasting competition in the backyard, took photos of the event, made a T-shirt from the photos, and mailed it to the reporter. While such efforts illustrated the problem, they could not address its source. The following section offers suggestions to that effect.

Use of Weather/Climate Information and Further Information Needs

The RV park owner who currently uses information in planning for visitor influxes relies on the Farmer's Almanac to inform her business budget. However, her greatest difficulty comes from those outside the area who receive inaccurate information about the MSPRV. Efforts to improve weather reporting require the localization and use of weather information stations, such as those at the Apache Nitrogen plant (see Section 2.2). The RV park owner believes that, although weather information can be obtained from the Internet, a toll-free number with the information would increase the accessibility of the service.

As described previously in Section 2.2, RVers maintain highly integrated information systems that quickly disseminate information. Given the mobility of the group, information can cause drastic shifts in seasonal demographics of small communities like those of the MSPRV. Special

stakeholder groups, such as the RV park owners, illustrate the potential for using existing networks to broadcast information. For example, forecast information, such as predictions that El Niño would not result in high precipitation in the Benson area, could have been circulated among the owners of the other 540 campgrounds in the campground franchise via the Internet. Those owners then could have informed campers of the moderate weather expected in Benson. The community assessment approach is critical for identifying such specialized stakeholder groups and their networks.

3.2.2.4 Ranchers

Ranching continues to be important to the MSPRV, for symbolic as much as economic reasons (see Section 2.1). Ranging from small operations with few cattle and simple technologies to large spreads with hundreds of thousands of cattle and very sophisticated technologies, ranches and their information needs are difficult to characterize. Within this group as others, researchers cannot ignore issues of equity in the privileging of one group over another via the provision of information.

Responses to Climatic Variability

Ranchers are highly dependent on rainfall. As one rancher said, "If you don't have rain you don't have anything. Everything a rancher does depends on rain." The amount of forage available for their herd is directly affected by the amount and intensity of rainfall. Drought is, therefore, the largest concern for ranchers. Range management can mitigate the effects of drought, but these measures are generally *ex post*, crisis response strategies. The most common adaptive strategies employed by ranchers during a drought are moving the herd, selling cattle, providing supplemental feed, hauling water, and selling deeded land. Most of these strategies, of course, require land or capital. The ability of a ranch to survive a prolonged drought will depend in part but not solely on the presence of these factors. When asked if she knows any ranchers that were forced to sell out completely by the current drought, one rancher responded, "With politics as they are, the government and the environmentalists, they are destroying the local industries. Drought will just finish them off." The rise in property value and tax caused by land speculation and efforts by the Nature Conservancy and BLM to retire riparian land represent real threats to ranchers. Some are giving in and selling off their deeded land, others claim they will never sell (see Section 2.1). Furthermore, the increased globalization of the cattle market has steadily lowered the price per pound of beef, diminishing the ability of ranchers to make a living.

Ranchers have generally adopted adaptive strategies without serious consideration of climate forecasts. Most ranchers in the MSPRV believe that the area has been in a drought since 1992; some argue that precipitation in the area has been below average since 1979. Many of the ranchers who participated in the study wistfully reminisced about a time when the grass was taller, the river ran perennially, and their water tanks and wells were full. Thus, ranchers operate their ranges under the assumption of continued drought. Indeed, the respondents agreed that the local climate has changed, though they do not attribute the change to global warming.

Use of Weather/Climate Information and Further Information Needs

The discussions in the MSPRV corroborated the findings of the Pilot Stakeholder Assessment concerning rancher use of climate information. First of all, ranchers are impacted by a number of factors as well as climate, including the markets, property taxes, and feed prices, government policy, and environmental regulations. In general, they do not rely heavily on climate information for their decision-making, preferring recently to operate under the assumption that drought conditions will continue. But the ranching community is also critical of the usefulness of current information sources, and they cite the lack of relevant spatial and temporal scale as one of the major deficiencies of current climate forecasts. Microclimates are highly variable in the Southwest. One ranch alone may include different micro-climates which the prediction services do not differentiate. In addition to improved spatial resolution, ranchers from both studies would like to see information with a longer prediction horizon. In the MSPRV, two or three months without rain may not affect the condition of the herd, but six months or longer without rain is considered a drought. Ranchers need long-term forecasts in order to modify their operations in advance. Even if they know that one good rain will fall, that may still mean that tougher times lie ahead. Many found the El Niño forecasts useful and would be happy to see more such forecasts in the future, if they are perceived as reliable.

Ranchers typically distrust current information sources and seldom make important range management decisions based on this information. When ranchers do consult climate information, it is generally from ranch community radio broadcasts, the National Weather Service, TV reports, and professional livestock publications. Most commonly, ranchers collect their own climate data, using numerous rain gauges across their land. Furthermore, ranchers feel that they have an understanding of the local climate from working so closely with the land. Despite skepticism, ranchers in the MSPRV would like to see historical trends in precipitation broken down by season and by month. Most requested seasonal and annual forecasts but also demanded a probability greater than 50 percent. They require that information to be as specific as possible. Most ranchers want to know if it will rain on their property. Also, forecasts for winter rains in the Midwest grain areas would be useful for predicting cattle prices. Several ranchers also suggested that they would attend workshops on the current state of forecast capability, arguing that they would like access to training on satellite imagery interpretation. Clearly, building rancher capacity to collect and interpret his or her own information is a desirable goal of the project.

3.2.2.5 Industry and Emergency Management

As the largest industry in the study area, Apache Nitrogen is the focus of this section. It provides jobs for many local residents. In addition, the potentially harmful impacts of an air or water release at the plant mean that its concerns are those of the entire community. Because many of the facility's climate and weather information needs stem from requirements for preparing to respond to emergencies, the two are discussed together.

Responses to Climate Variability

The case study of Apache Nitrogen in Section 2.2 describes the relationship of the plant to climate and weather. Although information that would help the plant operate more efficiently would be valuable to owners, of greater significance to the community is information that could be used to improve emergency response planning. Apache Nitrogen processes several materials identified as hazardous by the U.S. Environmental Protection Agency. As required by the Comprehensive Emergency Response, Compensation, and Liability Act (CERCLA), the company must develop, in cooperation with a Local Emergency Planning Committee, emergency response plans to be used in the event of a toxic release. Those plans presently are developed using annual scenarios of most probable weather and wind patterns. Due to the seasonal climate fluctuations in the MSPRV, models that provided seasonal scenarios could be incorporated into the planning efforts. MSPRV emergency response personnel also must respond to other climate-related emergencies, of which flooding is a primary problem. Although there was no official preparedness for the last El Niño event (1998), past floods have wreaked havoc on the farmers along the river.

3.2.3 Moving Beyond the Stakeholders and Disseminating Information

The community level assessment demonstrates the value of getting beyond treating stakeholders as isolated entities and makes it possible to view climate information and impacts in a community development context. While there is still a role for addressing sector-specific needs, it is equally important to go beyond the individual sector representatives to make a useful assessment at the community level. As illustrated in the sections above, the climate vulnerabilities and information needs vary across sectors. Decisions about the allocation of scarce resources are best made by community leaders who can weigh the interests and concerns of the entire community and identify local priorities. The next step for the MSPRV integrated assessment is to return to the community and seek direction for researchers and the CLIMAS Core Office (see Section 3.3).

In addition to the community decision makers, a receptive audience to climate information can be found in the schools. School officials and community leaders expressed an interest in finding ways to bring locally relevant climate education into the schools, especially as part of new initiatives such as the integrated mathematics curriculum. Following models developed elsewhere for environmental education (e.g., the Global Rivers Environmental Education Network), researchers can work with school students to establish monitoring stations and collect and analyze data that will allow community residents to assess their vulnerability to climate changes. For example, indicators such as depth to water, vegetation patterns, river flow, and weather from local stations will assess the physical and natural conditions while devices such as business and tourist surveys can assess socioeconomic circumstances.

Finally, with the MSPRV as the target for community assessment, it is necessary to monitor the relationship between the community and the CLIMAS project. A mechanism is needed for organizing stakeholders and gathering and reporting feedback on how information provided to the stakeholders and community officials has and has not been useful. One approach would be to identify a climate event, exchange information, and evaluate its impacts. After the event, the group could reflect on the event, the role of information in the decisions made by stakeholders, and the ability of stakeholders and community leaders to reduce and respond to vulnerabilities.

3.3 Conclusions: Buffering of Climate Vulnerability in Southwestern Communities -- Tim Finan

This study has sought to tease out the vulnerability of a local community in Southwestern Arizona to climate variability and climate change. To do so, the research team reviewed the history of the settlement of the Middle San Pedro River Valley, then traced the social dynamics that have led to the current situation. Thus, this integrated assessment reveals both the cross-sectoral patterns of climate vulnerability and the *changing* level of vulnerability through time. Benson and the areas surrounding it clearly demonstrate a cumulative process of *buffering* against the vagaries of a desert environment. Whereas the early settlers were forced to confront such climate-based crises such as crop loss due to flood or drought, loss of cattle, malaria, etc., the livelihood systems of today's residents have undergone an adaptation that, in essence, buffers them against most climate extremes. Such buffering has been more successful in some sectors than in others. This report highlights the disadvantaged position of ranchers and some farmers relative to urban dwellers. It is likely that these stakeholders and those that appreciate them as they pass through the MSPRV on their migratory routes are also affected by severe climate events. But for most of the residents of the valley, sensitivity to climate is subtle, and climate variability is more annoying than endangering.

The MSPRV is typical of an arid environment with clear seasonal climatic variations. Rainfall is always low (10-15 inches) and distributed bimodally across the average year. Temperatures are elevated in the summer and moderate in the winter. Drought of more or less severity is a regular occurrence, the length and strength of seasons may vary, floods occasionally sweep through the river, and temperatures may reach extreme highs and lows. Climate change and increasing climate variability have been gradual processes and people have adapted their lives to accommodate climate factors. Residents of Southeastern Arizona and other arid regions rely on applications of advancing technologies to maintain their homes, businesses, educational and recreational opportunities. The population of the desert Southwest has grown with the availability of electric pumps, air conditioners, rapid automobile transport, and other kinds of technological advances that make living in the area more comfortable and convenient. As a result, this and other communities are not immediately vulnerable to continued variability to a significant degree, as long as changes continue to happen gradually, giving people and communities time to build the necessary buffers.

This report further documents the movement of people and livelihoods away from the more climate vulnerable sectors of the economy. Thus, ranches are rapidly becoming "ranchettes" and farms are becoming "horse properties" as former livelihoods shift to quality-of-life residence preferences. But most strikingly, small communities like Benson and its environs have opened their arms to the outside, welcoming tourists, retirees, and the disenchanting from neighboring Tucson. The improvements in transportation infrastructure have facilitated this transformation to a service economy, and many Bensonites flush at the development perspectives for their region. The opening of the Kartchner Caverns State Park, the increasing presence of the RVer community, and the expanding conversion of desert to real estate are all causes for optimism

among the economic development segments of the community. In this context, the research team examined the hypothesis that this social dynamic throughout the valley might ultimately increase the vulnerability of the region to climate variability and change. Based on current knowledge of the hydrology of the Benson subwatershed, there will be an increase in recharge deficit of the fossil water aquifer (as opposed to the alluvial aquifer of the river valley), but the point at which wells go dry or pumping costs get too high lies well into the future. Less understood is how upstream urban growth in Sierra Vista, where aquifer depletion is a matter of actual concern, will affect MSPRV residents in the future. Nonetheless for the time being and into the near foreseeable future, Benson and the valley will embrace the expansion of the tourism/retirement sector.

It was not possible here to determine if there is a true vulnerability based on the underlying scarcity of the resource base, other than in the ranching sector. In other words, for lack of better physical information, the report cannot conclude that there is a discrepancy between the actual vulnerability and the perceived vulnerability. Clearly, city planners and utility managers, as well as the real estate and business communities, do not perceive climate to be a matter of concern. In fact, climate is low on the list of priorities considered important by decision makers at all levels, from individuals and households to local government agencies to international treaty negotiators. The point here is that people adapt. As development proceeds, people make concessions to factors related to climate variability, but not necessarily because they are concerned about climate. Wells, air conditioners, evaporative coolers, space heaters, and other technologies have buffered climate impacts to the extent that climate variability has become as routine and mundane as the street vegetation.

From a purely local perspective, the MSPRV appears content, even braced for its growth trajectory. Benson, however, is part of a wider system in which increasing use of the aquifer might bring competing demands and value systems into confrontation, particularly in the event of severe climate variability. Again, at the complex technical level, understanding is not yet sufficient to explore specific scenarios. However, there is likely a relationship between growth in Sierra Vista, the fragility of the riparian areas, growth in Benson, and factors such as unsettled Indian claims. In the context of the entire valley, possible constraints on the natural system might emerge, but these are not amenable to prediction at the current time.

The insights from this study suggest that an enhanced climate forecasting system could contribute to the existing protection of climate vulnerability buffers, as an aid to mitigate the impacts of the most severe climatic extremes (prolonged drought, torrential rains and flooding, etc.). Again, seasonal forecasts based on El Niño or La Niña events (or influenced by other climatic phenomena) have the highest potential for the most vulnerable sectors (i.e., ranching) if the quality of the information is accurate enough to inform decision-making. For example, prior knowledge of an extended drought could allow ranchers and farmers to develop coping mechanisms that serve to reduce or minimize the economic consequences. These conditions (of accuracy) require that climate forecasting information be made available to and digestible by the target community. The research team has already contacted stakeholders in the region in order to

determine climate information needs, and the CLIMAS project office is now in a position to promote basic local understanding of climate variability throughout the valley, particularly if this climate information has a long historical context.

The research team realizes that this community assessment did not answer all the relevant climate questions, and as the previous chapters suggest, Benson does not represent the case of all Southwestern communities. However, the process of building buffers against climate vulnerability is theoretically and practically interesting, particularly when the roles of the private and public sectors are differentiated. In a follow-up activity, a limited number of oral histories will be elicited to capture the evolution of this buffering in the context of record climate extremes. Also, contacts with community representatives will be reinitiated to allow discussion of this report and suggestions for greater integration of Benson and the CLIMAS office. In the final accounting, climate is one dynamic reality, and the socio-economic transformation of the valley is another, and all will benefit from understanding the relationship between the two.

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APPENDIX A: Water Rates per Selected Water Providers

Rate <i>Water Provider</i>	Benson Municipal Utility Department	Bella Vista Water Company (Sierra Vista)	Pueblo del Sol Water Company (Sierra Vista)	Tucson Water	Metro Water District (Tucson)
Minimum Charge/Base Rate (Meter Size)	<p>Residential</p> <p>0.625" = \$6.25 1" = \$11.50 1.5" = \$18.50 2" = \$28.00 4" = \$108.00</p> <p>Commercial</p> <p>0.75" = \$8.00 1" = \$11.00 1.5" = \$18.50 2" = \$28.00 4" = \$108.00</p>	<p>Residential (incl. 0-1.34 units)</p> <p>0.625" = \$11.90 0.75" = \$17.00 1" = \$18.70</p> <p>Commercial (incl. 0-1.34 units)</p> <p>0.625" = \$14.90 0.75" = \$17.80 1" = \$19.50 1.5" = \$23.75 2" = \$28.85 3" = \$81.50 4" = \$115.50 6" = \$871.65</p>	<p>Residential + Commercial (incl. 0-1.34 units)</p> <p>0.625" = \$13.45 0.75" = \$20.20 1" = \$24.25 1.5" = \$53.80 2" = \$95.30 3" = \$215.20 4" = \$382.00 5" = \$850.00</p>	<p>Residential + Commercial (incl. 0-3 units)</p> <p>0.75" = \$5.30 1" = \$6.40 1.5" = \$9.50 2" = \$14.00 2.5" = \$20.00 3" = \$25.00 4" = \$42.00 6" = \$82.00 8" = \$123.00 10" = \$185.00</p>	<p>Residential (incl. 0-2.7 units)</p> <p>0.625" = \$10.22</p>
Commodity Charge (1 unit = 100 cubic feet = 748 gallons)	<p>Residential</p> <p>Units 0-5: \$0.55 6-10: \$0.65 11-15: \$0.70 16-20: \$0.75 21-30: \$0.90 31-50: \$1.00 >50: \$1.10</p> <p>Commercial</p> <p>\$0.85/unit</p>	<p>Residential + Commercial (units are rounded)</p> <p>Units 1-7: \$0.67 >7: \$1.20</p>	<p>Residential + Commercial (units are rounded)</p> <p>Units 1-13: \$1.72 14 -40: \$2.09 >40: \$2.32</p>	<p>Residential</p> <p>Units: 0-3: \$0 4-15: \$1.62 16-30: \$2.61 >30: \$3.29</p> <p>Submetered Mobile Home Parks/Commercial</p> <p>Units: 0-3: \$0 >3: \$1.35/1.40</p> <p>Summer Surcharge Tier 1: \$0.95</p> <p>Summer Surcharge Tier 2: \$0.25</p>	<p>Residential (units are rounded)</p> <p>Base rate: \$1.38/unit</p> <p>Summer rate: >20: \$1.84</p> <p>High user rate: >33: \$2.32</p>

Appendix B: United States Department of Transportation, Map of Major Transportation Routes in Arizona

