CHAPTER 1: INTRODUCTION

1.1 Research Rationale

It is widely accepted that climate change is occurring this is causing international concern. In addition to an increase in average global temperature, changes in climate variability, including increases in magnitude and frequency of climatic extreme events, are expected to occur (Houghton et al., 2001). However, the effects and impacts of changing climatic conditions will not be felt equally around the world (Rozenweig and Parry, 1994; O'Brien and Leichenko, 2000; Mirza, 2003; Tol et al., 2004).

Climate change and variability will result in challenges for countries, regions, industries, resources, communities and households that are most exposed and/or sensitive and least able to adapt to the changing conditions (Handmer et al., 1999; Smit and Pilifosova, 2003). This notion is captured in the concept of vulnerability. Vulnerability refers to the manner and degree to which a system is susceptible to conditions that affect the well-being of the system.

Climate change is expected to cause increased stress to both natural and human systems such as water resource management, agriculture, forestry, and human health (McCarthy et al., 2001). It is expected that many regions will experience an increasing scarcity of natural resources as a result of changing climatic conditions (McCarthy et al., 2001; Tompkins and Adger, 2004). Water resources are highly sensitive to climate variability and change.

Drylands are often challenged by the demands of existing climate variability and it can be expected that climate change will have further impacts on water resource availability (Frederick and Major, 1997; Miller et al., 1997; Ivey et al., 2004). The Intergovernmental Panel on Climate Change (IPCC) predicts that there will be a decrease in water availability for populations in dryland areas as they are particularly sensitive to climate variations (Frederick and Major, 1997). This could potentially be devastating for the nearly 40% of the world's people who inhabit dryland areas (McCarthy et al., 2001; IISD, 2003). The IPCC estimates that by 2080 nearly 3 billion additional people will experience significant decreases in water resources due to climate change (McCarthy et al., 2001).

An increase in water scarcity for these areas could have serious implications for livelihoods, industry, human health and ecosystem health. Therefore it is important to understand how dryland regions are at risk to climate-related changes and their ability to cope to the changing conditions. The coping ability of a system (community) to deal with changes and risks will be greatly influenced by a number of factors (e.g. infrastructure, economic wealth, kinship, technology) including the effectiveness of institutions (Miller et al., 1997; Ivey et al., 2004). Therefore there is a need to consider the role of institutions in mitigating community vulnerability.

The Elqui River Basin (ERB) is a dryland agricultural region located in North-Central Chile. It has been referred to as is one of the most sensitive areas in South America to water variability (Downing et al., 1994; Kalthoft et al., 2006). The climate is strongly

influenced by El Niño-Southern Oscillation (ENSO) receiving several years of dry conditions (La Niña) followed by a year abundant and intense rainfall (El Niño). The area's economy is heavily based on agriculture. Agricultural products from the region include table grapes for exportation, *pisco* grapes (for Chilean brandy) and smaller amounts of avocado and citrus. The agricultural economy is dependent on water derived mainly from snow and a glacier in the Andes. Andean glaciers have been receding and snow cover is less extensive and more variable (Basso, 1997; Morales-Arnao, 1999; Cepeda et al., 2004). Watersheds in dryland areas, like the ERB are especially sensitive because annual runoff is already highly variable and drought is common (Sauchyn and Skinner, 2001). There is considerable interest for assessing the vulnerability of the semi-arid ERB to climate change.

1.2 Research Aim and Objectives

The aim of this research is to characterize and understand the nature of vulnerability through a case study of a dryland community in the ERB, particularly related to water resources in light of climate change. The research also addresses the role of institutions with respect to mitigating community vulnerability through used adaptive strategies and capacity. The foundation of this study rests on the concept that vulnerability is a function of both exposure-sensitivity and adaptive capacity and will be directed by the following objectives:

1) To understand and document current exposures, i.e., the problematic conditions or stresses related to water resources that people have dealt with and/or are currently dealing with in their lives;

2) To assess the current adaptive capacity and strategies, i.e., the ways in which the community, including institutions, have coped with the current exposures;

3) To identify potential future exposures, i.e., the likelihood of changes in conditions, with a focus of water resources, pertinent to the community in the future;

4) To assess future adaptive capacity and adaptation strategies, i.e., the manner and degree to which the community, including institutions, will be able to adapt to the future exposures.

This study is part of a larger project entitled Institutional Adaptations to Climate Change (IACC). The IACC project is a comparative study between the dryland regions of the South Saskatchewan River Basin, Canada and the Elqui River Basin in Chile. The project is a collaboration of interdisciplinary researchers from Canada and Chile from a variety of disciplines- climatology, hydrology, engineering, ecology, geography, history anthropology and sociology. Rather than developing a set of parallel studies, the project emphasizes permanent integration of research activities that promote collaboration among the members of the research team. This thesis contributes to the IACC project by identifying relevant, problematic, hazardous and/or stressful conditions experienced by a community in the ERB. It also examines the current adaptive strategies and capacity of a

community and institutions including possibilities and constraints with respect to these exposures. This study provides IACC collaborating researchers information with respect to areas of interest that require further investigation (valley hydrology, slope stability), refine climate models and scenarios to reflect the relevant concerns of the ERB and opportunities and constraints to mainstream climate change into the decision-making of institutions.

1.3 Thesis Outline

This thesis consists of seven chapters. Following the introduction, Chapter Two provides the theoretical and conceptual context for the research. The evolution of the concept of the vulnerability and the manner in which it has been assessed is discussed as it has developed through various fields of research. A description of the conceptual model of vulnerability employed to guide the study is provided. The role of institutions in relation to vulnerability in light of climate change and water resources is discussed.

Chapter Three describes the study area. The description begins with a brief summary of Chile's geography, political history and economics. This is followed by an explanation of the institutions involved in the governance of water resources. The chapter concludes with a description of the ERB and the community of Diaguitas.

Research methods are described in Chapter Four. The research approach for the vulnerability assessment is explained. The research design and primary data collection

methods are described in detail. Practical considerations related to the research are addressed, followed by an explanation of data interpretation and analysis.

Chapter Five and Six discuss the results of the community vulnerability assessment as they relate to the research objectives and the conceptual model of vulnerability introduced in Chapter Two. Chapter Five addresses the first two research objectives and reveals the current exposures faced by a dryland community in the ERB and the adaptive capacity and strategies in place by the community and institutions to better cope with these conditions. Chapter Six addresses objectives three and four by discussing the current identified exposures in the context of future climate change and the ability of the community and institutions to adapt to the changing conditions.

Chapter Seven summarizes the major findings of the research objectives. Theoretical and practical contributions are discussed. Opportunities for further research are presented.

CHAPTER 2: CONTEXT FOR RESEARCH

The concept of vulnerability is not new. It is used in a variety of fields and has various definitions. The variations of meaning and use of the term reflect the various epistemological orientations including politically ecology, human ecology, physical science and spatial analysis (Cutter, 1996). Common to all definitions is the notion that vulnerability is susceptibility to harm. The concept of vulnerability has developed in various fields and contexts, including natural hazards (Cutter, 1996; Blaikie et al., 1994; Wisner et al., 2004), food security (Sen, 1981; Hewitt, 1983; Watts and Bohle, 1993) and environmental change (Liverman, 1994). More recently the concept is being employed in the field of climate change as a way to characterize and understand the implications of climate change at the community level (Handmer et al., 1999; Leichenko and O'Brien, 2002; Adger, 2003; Ford and Smit, 2004).

2.1 The Evolution of Vulnerability and Vulnerability Assessment

The conceptualization of vulnerability primarily began with a focus on the biophysical dimension. Vulnerability was determined by the nature of a physical hazard or risk on a system (Brooks, 2003; Ford and Smit, 2004). The concept of vulnerability has evolved from the focus on biophysical hazards to incorporating the human-dimension which helps to characterize the nature of vulnerability. The following section describes how the concept and assessment of vulnerability have evolved through various areas of study.

2.1.1 The Physical Dimension of Vulnerability and Impact Assessments

Interpretations of vulnerability vary among bodies of literature and contexts. Natural hazards are defined as the extreme natural events that pose a threat to people, property and possessions (McGuire et al., 2002). The literature examines how people and societies respond to natural events, what factors influence response choices and how risks are managed (Cutter, 1996; Hewitt, 1997). In natural hazards scholarship, vulnerability has been referred to as the "degree of loss resulting from the occurrence of natural phenomena to a given element or set of elements" (United Nations Disaster Relief Organization, 1982). Attention is focused on the characteristics of the hazard such as magnitude, duration, frequency and rapidity of onset (Burton et al., 1993). From this perspective, vulnerability is explained in terms of physical stimuli and their impacts.

Building on the natural hazards scholarship, research in climate change impact often uses exposure to biophysical conditions to define vulnerability (Liverman, 1994; Smith and Lazo, 2001). In this context vulnerability is concerned with the impacts of a hazard and the resultant damage by a system (Brooks, 2003). Vulnerability is characterized by the distribution of a hazardous condition, the human occupancy of a hazardous zone (unstable slope, seismic zone, coastal area) and the degree of loss (life, property) associated with the occurrence of a particular event (landslide, earthquake, tsunami) (Cutter, 1996). Thus populations are treated as being vulnerable based on their presence in a hazardous location and the nature of the hazardous event (frequency, severity).

Impact assessments have been used in the field of climate change studies. Impact assessments select a particular hazard or environmental stress of concern and seek to identify its most important consequences for a variety of social or ecosystem properties (Clark et al., 2000). Figure 2.1 illustrates this linear relationship.

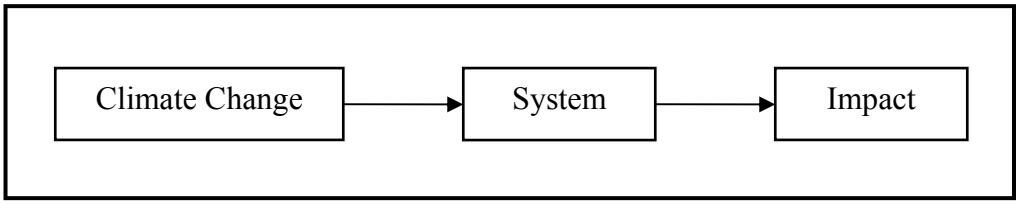

Figure 2.1. Impact Assessment (Kates, 1985).

In the climate change field, these types of assessments have been referred to as the standard approach (Burton et al., 2002), conventional and/or traditional approaches (Carter et al., 1994) with the goal to identify impacts of climate change and the resultant vulnerability of a system. Impact assessments in the climate change field typically relies on scenarios derived from Global Circulation Models (GCM) to identify possible problematic future conditions (Carter et al., 2001). The assessment begins with a stimulus specified by a scenario (e.g. increase/decrease in average temperature/precipitation, sea level rise) and then predicts probable environmental and social implications over a vast area. Although its use has been instrumental in creating awareness of potential impacts of climate change, its focus tends to be on the physical dimension and vulnerability is addressed at the end of the assessment. It is a top-down approach where vulnerability is described as the resulting impact of climate change or as a residual impact following adaptation strategies (Smit and Wandel, 2006). This can be expressed as:

$$I - A = V$$

Where:

I = Impact
A = Adaptation strategy
V = Vulnerability

Most research on climate change impacts in the 1980s and 1990s often linked climate scenarios with biophysical impacts or studying responses of individual systems to selected climatic threats. Few studies captured the dynamism of local vulnerable groups, current exposures to stresses, relationship of various scales and the responses to climate variations and extremes that define future vulnerability to climate change (Downing, 2003). Climate change impact studies assess vulnerability at the end of the analysis which rests on numerous accumulated estimates, uncertainties and assumptions of potential impacts (Kelly and Adger, 2000). Turner et al. (2003: 8074) argue that this approach does not address:

> …the ways in which the systems in question amplify or attenuate the impacts of the hazard, the distinctions among the exposed subsystems and components that lead to significant variations in the consequences of the hazards and the role of political economy, especially social structures and institutions in shaping differential exposure and consequences.

The ability of a population to modify the hazardous event is greatly downplayed as the focus is predominantly on the event and the impacts. These studies underemphasize the processes by which society can increase the possible impacts associated with a hazard or enact adaptations strategies designed to reduce the possible impact (Polsky et al., 2003).

2.1.2 The Human-Dimension of Vulnerability and Vulnerability Assessments

The human-dimension of vulnerability emerged from the recognition that exposure to environmental stress alone was not the only component creating vulnerable conditions (Liverman, 1994). Although hazards, disasters, climate change and variability cause tremendous susceptibility of harm to human communities they are also influenced by the surrounding social conditions. Attention paid to the human-dimension addresses the social attributes of vulnerability. For example, attributes that can increase or decrease a system's vulnerability include marginalization, inequity, presence and strength of institutions, food and resource entitlements, economics and politics (Adger and Kelly, 1999; Adger, 2000; O'Brien and Leichenko, 2000; Pelling 2002).

This conceptual evolution of emphasizing the human dimension in relation to the physical dimension of vulnerability has been well developed in the fields of food security (Sen, 1981; Bohle et al., 1994), political ecology (Blaike and Brookfield, 1987; Bryant and Bailey, 1997; Pelling 1999; Mustafa, 2002; Paulson et al., 2003) and more recently climate change (Handmer et al., 1999; Leichenko and O'Brien, 2002; Adger, 2003; Ford and Smit, 2004). An examination of vulnerability inclusive of the human dimension includes an understanding of the human use of and access to resources, which in turn determines the ability of an individual or society to cope and adapt to change (Wisner et al., 2004). For example, vulnerability has been referred to as "the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard, an extreme natural event, or

process" (Wisner et al., 2004). Sen (1981) defined vulnerability as largely a societal construct, and is a condition that is a result of lack of entitlements, democracy and power.

Downing (2003) acknowledges that Sen's 1981 work marked the end of the single stress-impact, linear-thinking era of vulnerability, specifically in the field of food security. Sen recognized the role of the human dimension of vulnerability in exacerbating or reducing impacts of a hazardous physical event. For example, the occurrence of famine is not simply caused by natural events but also by the social, economic and political conditions that make people susceptible to the event and limit the capacity to cope or deal with it. Thus, the capacity to adapt to hazard stress is rooted in the ability of an individual or community to compete for access to rights, resources and assets (Sen, 1981; Blaikie et al., 1994).

The field of political ecology is particularly adept at integrating elements of society and the environment. There is a growing body of literature on political ecology in relation to vulnerability (Adger, 1999; Blaikie et al., 1994; Pelling, 1999; Mustafa, 2002; Budds, 2004; Mustafa, 2005). Political ecology examines relationships between nature and society. It aims to identify contextual and multi-scalar sources of ecological change. Blaikie and Brookfield (1987: 17) define the field of political ecology as the "combination of concerns of ecology and a broadly defined political economy. Together this encompasses the constantly shifting dialect between society and land-based resources, and also within classes and groups within society itself."

The literature focuses on the social structural constraints and political economic factors that cause differential access to resources and vulnerability to hazards on the part of marginalized groups (Bryant and Bailey, 1997, Mustafa, 2002; Paulson et al., 2003). From this perspective, nature, resource management and environmental issues are inherently politicized and are unable to be understood in isolation from their political, social and economic contexts (Bryant & Bailey, 1997; Escobar, 1999; Castree, 2001; Budds, 2004). Emphasis is therefore placed on variation of scale and plurality of explanation rather than linear-thinking cause and effect (Budd, 2004).

Insights from political ecology have demonstrated that access to resources, livelihoods, the role of institutions and the political and economic systems are key components shaping people's ability to cope with environmental change (Blaikie & Brookfield, 1987; Watts & Bohle, 1993; Bohle et al., 1994; Adger & Kelly, 1999; Mustafa, 2002; Peet & Watts, 2004; Budds, 2004). For example, Mustafa (2002) demonstrated the importance of the unequal distribution of power and wealth as fundamental elements of vulnerability to floods. His study in an arid rural region of Pakistan exemplified how community vulnerability was caused by social conditions rather than natural conditions. The communities identified that the differing access to irrigation water and vulnerability to flood hazard was attributed to social causes (equal distributions of wealth and power) rather than natural causes.

Several studies use the human dimension of vulnerability to understand how communities will adapt to climate change and the associated extremes (Adger, 1999; Adger and Kelly,

1999 and Kelly and Adger, 2000). In these studies, vulnerability is expressed as the exposure to groups or individuals to stress as a result of social and environmental change and is exemplified by the availability of resources, and the entitlement of individuals and groups to utilize the resources (Adger and Kelly, 1999). This point is often demonstrated in the literature through a comparison of developed and developing countries. There is a general agreement that developing countries are deemed to be more vulnerable to climate change compared to developed countries due to the aforementioned characteristics (Downing et al., 1997; McCarthy et al., 2001; Beg et al., 2002; Mizra, 2003; Handmer, 2003). The vulnerability of developing countries is enhanced due to their increased dependency on climate resources compared to industrialized countries (Downing et al., 1997).

In the climate change field, the IPCC Third Assessment Report defines vulnerability as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes" (McCarthy et al., 2001: 89). Vulnerability has been described as an issue of entitlements, where access, availability, and distribution of resources define the level of vulnerability of a social group (Liverman 1994; Adger and Kelly, 1999). Therefore the 'most vulnerable' are those who are most likely to be exposed to perturbation, possess limited capacity for adaptation, and are least resilient to recovery (Bohle et al., 1994). The extent to which individuals, groups or communities are entitled to use resources determines the ability of that population to cope and adapt to stress (Adger and Kelly, 1999). Inequality affects vulnerability by constraining the options of people when faced with changing conditions. Inequity within

a population can increase vulnerability to climate change as climate change can alter communal allocation of resources.

While conventional approaches to climate change impact assessments typically begin with the stimulus as the starting point and identify vulnerability as a residual impact, recent approaches begin with the system (community, region, industry) as the starting point to assess the vulnerability. The focus is to document how a system experiences changing conditions and their ability to accommodate and adapt to such changes (Smit and Wandel, 2006). Clark et al. (2000) referred to these approaches as 'inverse' approaches. From this perspective, vulnerability is seen as a property of a system relative to climatic conditions and vulnerability can be reduced through adaptive measures. Inverse approaches to vulnerability incorporate both the physical and human dimensions of vulnerability (Polsky et al., 2003; Turner et al., 2003; Ford and Smit 2004). These studies characterize the nature of vulnerability of a system to relevant climate-related stresses with respect to the system's ability to deal with the stresses. An important feature of an inverse approach is to the involvement of the population and stakeholders of the system in identifying stresses and adaptive strategies.

2.2 A Conceptual Model of Vulnerability

Throughout the literature, definitions and characterizations, vulnerability can be broadly seen as a function of exposure and adaptive capacity. Though authors use different terminology or treat these two ideas in different manners, they are generally common throughout the literature. Vulnerability is also described as a dynamic concept (Hewitt,

1997; Adger, 1999; Adger and Kelly, 1999; Handmer et al., 1999; Leichenko and O'Brien, 2002; Downing, 2003). Vulnerability is a process of continual evolution, as the factors that shape vulnerability are constantly changing (Handmer et al., 1999). Adger and Kelly (1999: 259) emphasize that it is the dynamic aspect of vulnerability that is the most important aspect to capture, rather than any one measure of vulnerability or "any snapshot taken at a particular point in time."

A conceptual model of vulnerability has emerged from the climate change community (Kelly and Adger, 2000; Downing, 2001; Smit and Pilifosova, 2003). Vulnerability here is characterized as a function of the exposure of a system to climate change and its adaptive capacity. A system may be a household, community, industry, an ecosystem, activity, a nation and so on. Generally, a system that is more exposed to a particular climate stimulus will be more vulnerable, and a system that has more adaptive capacity will tend to be less vulnerable due to the ability to cope with the exposure. This idea can be expressed formally as (Smit and Pilifosova, 2003):

$$\mathbf{V}_{ist} = f\ (\mathbf{E}_{ist}, \mathbf{A}_{ist})$$

Where:

V_{ist} = Vulnerability of system *i* to climatic stimulus *s* in time *t*
E_{ist} = Exposure of *i* to *s* in *t*
A_{ist} = Adaptive capacity of *i* to deal with *s* in *t*

The functional relationship between the two components is context specific and dynamic and therefore the details of the relationships expressed above will vary by location,

sector, time and so on. However, it is understood that vulnerability is a positive function of exposure and a negative function of adaptive capacity (Smit and Pilifosova, 2003).

2.2.1 Exposure

Exposure is reflective of both the characteristics of the system and the climate conditions (Downing, 2003; Smit and Pilifosova, 2003; Ford and Smit, 2004). Exposure is a property of the system (not a hazardous event) relative to climatic conditions. Therefore exposure is not limited to the presence of an external stress. Exposure represents the combination of local conditions (sometimes referred to as sensitivity or occupancy characteristics) and external physical stimuli, sometimes referred to as a hazard. Local conditions (e.g., settlement location and types, livelihoods, land-uses, etc.) also reflect the broader social, economic, cultural, political and environmental conditions. Therefore a system's exposure to a physical stimulus only has meaning relative to the sensitivity of the system. For example, a community whose livelihood is highly dependent on water resources is more exposed to drought than a community facing equivalent drought while having livelihoods that do not depend on the availability of water. Within regions, countries and communities, exposures may be similar, but differences in vulnerability may be reflective of differences in their capacity to deal with, manage, or adapt to the exposures (i.e. reducing vulnerability) (Smit and Pilifosova, 2003).

2.2.2 Adaptive Capacity and Adaptation

Adaptive capacity describes a system's potential or ability to adapt to exposure (Wheaton and McIver 1999; Bryant et al. 2000; Smit and Pilifisova 2003; Yohe and Tol 2002;

Füssel and Klein, 2002). The IPCC (McCarthy et al., 2001: 982) defines adaptive capacity as "the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences." Adaptive capacity is context specific and as it varies from country to country from community to community, among social groups and individuals and over time. The scales of adaptive capacity are not independent. For example, the capacity of a household to cope with climate risks will depend to some degree on the adaptive capacity of the community and is reflected by the adaptive capacity of the region (Smit and Pilifosova, 2003; Smit and Wandel, 2006).

Commonly used terms in the literature analogous to adaptive capacity include the following; coping ability, stability, robustness, flexibility and resilience (Stakhiv, 1996; Smithers and Smit, 1997, Adger and Kelly, 1999; Smit et al., 1999; Jones, 2001; Fraser et al. 2003; Tompkins and Adger, 2004). The term 'coping range' is frequently used to reflect a system's adaptive capacity (Rayner and Malone, 1998; de Loë and Kreutzwiser, 2000; Jones, 2001; Smit et al., 2000; Smit and Pilifosova, 2001, 2003). The coping range refers the range of conditions that a system can deal with, accommodate, adapt to and recover from. Most communities and sectors can cope with normal climatic conditions and deviations from the mean to some degree. However, exposures involving extreme events that may lie outside the coping range may exceed the adaptive capacity of the community, which increases vulnerability. Figure 2.2 illustrates the coping range of a system with respect to the variation of a climatic attribute, in this case drought conditions. Drought conditions vary from year to year, yet the system is able cope with a degree of

variation around the mean (indicated by the shaded area). As the mean increases (as is expected with climate change) the entire distribution shifts and the system will experience (and be more vulnerable) to an increase in the frequency and magnitude of events beyond the coping range. To the extent that the system may be able to expand the coping range or enhance its adaptive capacity to deal with these exposures, it will reduce its vulnerability to drought risk.

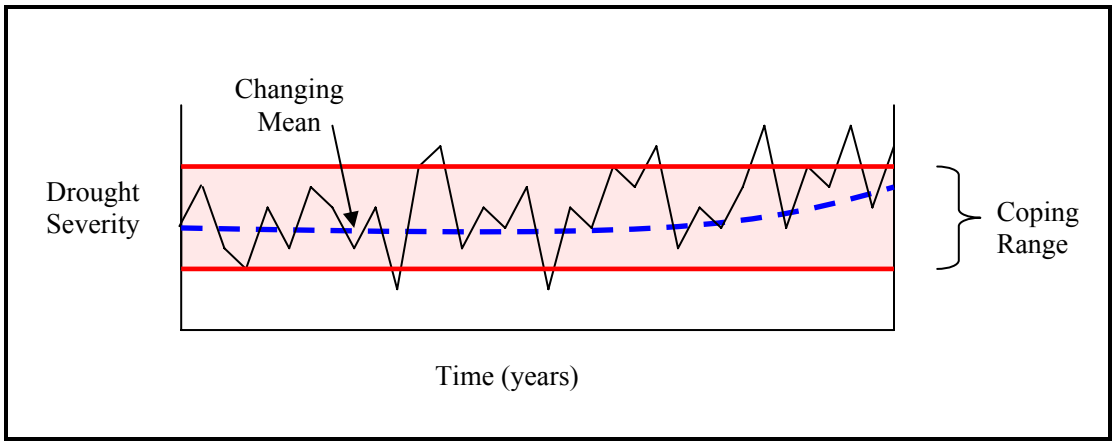

Figure 2.2 Coping range (Hewitt and Burton,1971; Smit et al., 2000; Smit and Pilifosova, 2001, 2003)

It should be noted that this is a coarse and general illustration. A system's coping range is not static as it appears in the figure. Coping ranges are flexible and respond to changes in economic, social, political and institutional conditions over time. For instance, population pressure or resource depletion may gradually reduce a system's coping ability and narrow its coping range, while economic growth or improvements in technology could lead to an increase in adaptive capacity (deVries, 1985; Smit and Pilifosova, 2003).

Since climate change threatens to introduce climatic conditions that fall outside the current coping range, adaptation is required. Adaptation, or adjustments in a system to

better cope with external stress, has the ability to reduce or modify the severity of climate change impacts (Tol et al. 1998). There are many forms of adaptation. Based on their timing, adaptations can be anticipatory or reactive. Depending on their degree of spontaneity they can be autonomous or planned. With respect to spatial scope they can be local to widespread and based on form they can be technological, behavioural, financial, institutional and/or informational (Smithers and Smit, 1997; Smit et al.,1999; 2000; Smit and Pilofosova, 2003).

According to Smit and Pilifosova (2003), often effective adaptations are less related to changes in long-term average temperature or precipitation and more related to frequency and magnitude of extreme events such as droughts or floods. As Handmer (2003) notes, adaptation measures are unlikely to be implemented in response to climate change alone – especially with respect to long term future changes. Adaptive measures to climate change are more likely to occur when they are consistent and/or aligned with existing initiatives and management strategies to reduce vulnerability to a number of exposures (not just climate-related) (Handmer et al., 1999; Huq et al., 2003; Klein and Smith, 2003; Smit and Pilofosova, 2003). This has been referred to as 'mainstreaming' (African Development Bank et al., 2003; Nelson et al., 2002; Rivero Reyes, 2002; Wall et al., 2004; Sutherland et al., 2005; Smit and Wandel, 2006). There is now a strong emphasis on aligning strategies with sustainable development and livelihood initiatives. The goal is to reduce vulnerabilities to current stresses by sustaining and enhancing the livelihoods. This can be addressed through "no regrets" adaptations (Nelson et al., 2002; African Development Bank et al., 2003; IUCN et al., 2004). This refers to actions that

address immediate needs and also contribute to improving the ability to deal with future exposures (IISD, 2003). For example, the Robledo et al. (2004) study documents increasing the resiliency of hillside communities in Bolivia to climate change through the sustainable livelihoods approach. In that case, the community, with assistance from NGOs, reforested the hillsides not only for protection against the unstable slopes (that have the potential to cause future landslides due to climate change) but also because the timber and related non-timber production is a supplementary source of income.

The ability to undertake adaptations (the adaptive capacity) is widely understood to be dependent on or influenced by any of a variety of conditions. These determinants of adaptive capacity include access to financial, technological and information resources, infrastructure, the institutional environment within which adaptations occur, political influence and kinship networks (Watts and Bohle, 1993; Hamdy et al., 1998; Adger, 1999; Handmer et al., 1999; Toth, 1999; Kelly and Adger, 2000; Smit and Pilifosova, 2001; Wisner et al., 2004).

Determinants of adaptive capacity are not independent of each other, nor are they mutually exclusive. Adaptive capacity is generated by a combination of these factors and varies over space and time. For example the presence of a strong kinship network may increase adaptive capacity by allowing greater access to economic resources, increasing managerial ability, and supplying supplementary labour. Similarly, economic resources will facilitate the implementation of a new technology and ensure access to training opportunities. Consequently, the determinants of adaptive capacity will behave

differently under different contexts (e.g. a strong kinship network can be expected to play a much larger role in a subsistence-based agricultural society than in a developed world agribusiness context) (Smit et al., 2005). The determinants of adaptive capacity vary from community to community, due in part to local conditions and exposures and in part due to broader conditions and determinants. The adaptive capacity of a community is a function of local processes and conditions which in turn are influenced by broader socio-economic and political processes and widespread resource availability (Smit et al., 2005).

It is acknowledged in the literature that the adaptive capacity of a community or nation will be greater when institutions and arrangements governing the allocation of power and access to resources assure equitable distribution (Mustafa, 1998; Handmer et al., 1999; Kelly and Adger, 1999, in Smit and Pilifosova, 2001). Therefore, institutions can play a significant role in improving (or hindering) a system's ability to cope or adapt to changing conditions. If institutions fail to plan for changing environmental conditions and risks, vulnerability increases (Adger, 1999; 2000, 2003).

2.3 Vulnerability and Institutions

The term institution has no one agreed upon definition as it is used in a vast array of literature and has taken on a multitude of interpretations. The range of definitions of institutions is so great that O'Riordan and Jordan (1999: 85) note that "the study of institutions will always be frustrated by the absence of agreement on the core topic being studied". The same authors (1999) see the role of institutions as being to hold society together, giving it a sense and purpose and to enable society to adapt.

According to North (1990, 1994), institutions are the rules of the game in a society. They are human-devised constraints that structure human interaction. Institutions are the laws, norms and regulations that influence society (Kemper, 2001). Institutions are identified by their stability and predictable arrangements (Ferrante, 2003; Diaz and Rojas, 2006). Buttel (1997: 40) defines institutions as the "specific or special clusters of norms and relationships that channel behaviour so as to meet some human, physical, psychological, or social need such as consumption, governance and protection, primordial bonding and human meaning, human faith, and socialization and learning". Institutions can be divided into two types, formal and informal. Broadly, formal institutions refer to devised laws and rules, while informal institutions constitute the norms of behaviour, conventions and social capital (North, 1990).

Some definitions not only include the rules or norms to characterize institutions, but also incorporate the organizations that represent and/or govern the rules and/norms. For example, the World Bank characterizes institutions as "the rules, organizations, and social norms that facilitate coordination of human action" (2002: 38). Grindle and Hilderbrand (1995) describe the institutional environment as the informal and formal rules and responsibilities governing organizations and individuals. Organizations can include political, economic, social and educational bodies. They are groups of individuals bound by some common purpose to achieve objectives (North, 1990). According to the Institutional Dimensions of Global Environmental Change (IDGEC) Science Plan, organizations roughly refer to the "players, while institutions constitute the rules of the game that structure their roles and guide their interactions with one another" (IHDP,

2005: 29). In other words, an organization can be a manifestation of a highly formalized institution. Diaz and Rojas (2006) note that for historical reasons some institutions have become highly formalized assuming an organizational representation. For example, in Chile the *Direccion General de Aguas* (DGA) is the organization that oversees and implements the laws and procedures of the Water Code.

Due to the formal network of rules, norms and organizations in place in the ERB to govern water resources, this study focuses on the formal institutions that organize and participate in the governance of water. This includes the rules and norms that define the use and distribution of water resources and the organizations that participate in the formulation and implementation of the rules, strategies and programs of water resource management in the ERB. For the purposes of this study, the term institution refers to the rules and organizations involved in the governance of water resources.

Institutions can affect the social distribution of vulnerability (Naess et al., 2004) and a community's capacity to adapt to water resource variability (Ivey et al., 2004). Institutions can play a significant role in improving, or hindering a system's vulnerability and adaptive capacity by facilitating or constraining adaptation to social and environmental change (Adger, 1998). Institutional constraints and inequalities within society may lead to varying access to resources and vulnerability to climate change (Adger and Kelly, 1999; Smit and Pilifosova, 2001). For example, Kelly and Adger (1999) illustrate in their study of coastal Vietnam that institutional constraints limited entitlements and access to community resources and in turn increased the community's

vulnerability. Khan (2003) identified that the state of degradation and pollution in Pakistan is a result of the institutional failure to incorporate environmental concerns into the development process. Magadza (2000, 2003) illustrates how institutional inefficiencies are resulting in resource inequity in southern Africa. The literature often suggests that developing countries tend to be more vulnerable in large part due to weaker institutions (Smith and Lenhart, 1996; Hamdy et al., 1998; Dinesh, 2003). Developed countries generally have well established institutions that not only facilitate management of contemporary climate-related risks but also help to cope with risks associated with future climate change (Smit and Pilifosova, 2003).

The water sector has a history of adaptation to climatic variation through the institutions which serve to balance the competing needs of resource users and changing conditions (Ivey et al., 2004). Without the capacity to successfully govern its water, society becomes increasingly susceptible to population pressures, industry-driven increases in water demands and to climate change variability. Climate change has the potential to put new demands on existing institutions by either aggravating current water resource problems or by creating new situations and new types of problems. However as Hamdy et al. (1998) discovered, many national and local institutions that are responsible for water governance do not work effectively or efficiently. This is due to several factors, such as; inappropriate policies for water management, unclear definition of the mandates of the institutions, lack of resources, inadequate training and education, lack of participation and lack of commitment from communities.

CHAPTER 3: STUDY AREA

Chile's political and economic history is as variable as its geography. It is necessary to briefly discuss some of the more recent transitions that have occurred in Chile to have a better understanding of the current situations and how and why the country is the way it is today. This is important as it provides some context and insight for analyzing the current conditions in the ERB and water related institutions. The chapter begins with a brief overview of Chile's geography, political history and economy. This is followed by a description of the institutions involved in the water sector. The chapter concludes with a description of the ERB and the community of Diaguitas.

3.1 Chile

Bounded by the Andes to the east and the Pacific Ocean to the west, Chile is one of the most isolated countries in South America and one of the narrowest in the world (Figure 3.1). It is geographically diverse as it extends from north to south 4 279 kilometers through the Atacama Desert in the north, lush rolling farmland of the Central Valley and rocky glacial fields to the south. Altitude ranges from sea-level to 6 880 meters. Chile has a population of 15.8 million and is one of Latin America's most economically developed countries (World Bank, 2004). On the 2005 Human Development Index, Chile ranked thirty-seventh out of one hundred and seventy-countries (UNDP, 2005).

Figure 3.1. Map of Chile (CIA, 2006)

3.1.1 Political History

In 1964 Eduardo Frei (Christian Democrat Party) became president and during his time in power embarked on major liberal reforms including agrarian reform and unionization of agricultural workers. Salvador Allende followed as President in 1970 as a Marxist and member of Chile's Socialist Party, who headed the "Popular Unity". His program included the nationalization of most remaining private industries and banks, advancement

of workers' interests, a foreign policy of "international solidarity" national independence and massive land expropriation. Millions of hectares of land were redistributed to landless agricultural workers as part of the agrarian reform. The Popular Unity program also called for the nationalization of foreign owned copper mines.

By 1972, the economy was in crisis and political polarization and tensions increased. By early 1973, inflation was out of control. On September 11, 1973 a military coup led by General Augusto Pinochet overthrew Allende and took control of the country. Chile was ruled by a military regime until 1990. The military dictatorship abolished civil liberties and the national congress; banned union activities, strikes and collective bargaining; and erased the Allende administration's agrarian and economic reforms. Tens of thousands of Chileans were jailed, tortured, killed and kidnapped. During the sixteen year military dictatorship, Chile moved away from a largely state-controlled economy towards a free-market economy. *Laissez-faire* economic policies were imposed that fostered an increase in domestic and foreign private investment.

In 1988, a plebiscite denied General Pinochet a second eight-year term as president. With an overwhelming majority vote, Chileans elected Patricio Aylwin as president in 1989. With the recent inauguration of Michelle Bachelet, the presidency has been in the hands of the centre-left Coalition of Parties for Democracy since the return to civilian rule in 1990.

3.1.2 Economy

Since the time of the military government (1973-1990) Chile's economy has been market-oriented and characterized by a high level of foreign trade. The democratic governments that followed the military government have continued with privatization and neo-liberal strategies. Chile's economy has been propelled by the government's limited role in the economy, openness to international trade and investment, and high domestic savings and investment.

During the latter part of the 1980s and beginning of the 1990s, Chile's economy was one of the fastest growing in the world (World Bank, 2004). In the 1990s Chile was the fourth fastest growing economy in the world, surpassed by China, Singapore and Ireland (Embassy of Chile, United States, 2005). Between 1986 and 1997, GDP annual growth was 7.7%, but fell to half of that by 1998. The recession, a product of the global financial crisis was exacerbated by a severe drought in 1999 reducing crop yields and causing hydroelectric shortfalls and rationing. By the turn of the century the economy had begun to recover. The last few years have shown significant economic growth with annual GDP averaging 6.1% (CIA, 2006).

For nearly two decades, exports have been the driving force of the Chilean economy. From 1986 to 2004 they multiplied by eight, escalating from four to 32 billion dollars (Embassy of Chile, United States, 2005). During this time, exports became more diversified in terms of both products and markets. In 2004, exports accounted for about 34% of GDP and consisted mainly of copper, fresh fruit, wood products and fish

(Embassy of Chile, United States, 2005). As of 2004, the United States was the largest national market, taking 14% (CIA, 2006).

Chile's agribusiness has emerged as one of the country's most successful export sectors and a large variety of its products can be found in most countries of the world. Chile's broad diversity in environmental conditions allows for the cultivation of a variety of fruits and vegetables. In the past few decades significant advancements in the fresh fruit industry have occurred. Between 1980 and 2004, the fresh fruit export business grew from US$168 million to US$1.9 billion -an 11-fold expansion over 24 years. In the mid-1960s Chile accounted for 3.5% of all grapes, kiwifruit, apples and pears exported from the Southern Hemisphere. Nowadays the figure stands at 49.9% (ProChile, 2005).

Despite the economic advancements, the World Bank notes that income disparities are particularly strong amongst rural residents, indigenous populations, youth, and female-headed households (2001, 2005). Eighteen percent of the population is classified as below the poverty line (earning less than 3 dollars a day) (World Bank, 2005; CIA, 2006). Chile's poor remain vulnerable to adverse income shocks, such as job loss, costly health events and loss of earnings in old age (World Bank, 2005). Unemployment is a problem for younger and poorer workers. The national unemployment rate is currently 8% (CIA, 2006). However, unemployment among the poorest has been much higher. In 2001, men aged 18-24 had an unemployment rate of 28% (World Bank, 2001).

3.2 Institutions and the Water Sector

This section describes the water sector and relevant institutions in Chile. It begins with an explanation of the water market and water code followed by a description of the main organizations involved in water governance.

3.2.1 Water Market and Water Code

Like most commodities in Chile, water is a market good. In a water rights market, water is reduced to an economic or material good. This notion is clearly illustrated in the fourth principle of the "Dublin Principles" (WMO, 1992):

> Water has an economic value in all its competing uses and should be recognized as an economic good. Within this principle, it is vital to recognize first the basic right of all human beings to have access to clean water and sanitation at an affordable price. Past failure to recognize the economic value of water has led to wasteful and environmentally damaging uses of the resource. Managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources.

Chile regards markets in water rights as an opportunity to optimize the allocation and use of scarce water resources under the assumption that market pricing will force the highest value use of water, private property rights promote individual choice, and that the market is more politically neutral than the state in resource allocation (Haddad, 2000; Budds, 2004).

The Chilean water market was enacted by the military government with the establishment of the 1981 Water Code which favoured strong neoliberal strategies. Since that time Chile has often been regarded as the leading international example of markets in water

rights with strong support from the World Bank in promoting the replication of the Chilean Water Code in neighbouring countries (Bauer, 1997; Trawick, 2003). Examples of water markets are often seen in dryland regions of the world, including the western United States, Spain and Australia.

Under the Constitution, water resources are defined as a 'National Good of Public Use' because they are essential for life, economic development, social objectives and environmental requirements. The state has the responsibility to regulate water use in a manner that meets these objectives (Productivity Commission, 2003). It is the state that grants private water rights for use. Water rights can be granted to individuals and the holders of the water rights have the same legal protection as the owner of any other private good. Once all rights are allocated, future transfers of water rights are to take place through the market. Water rights can be freely bought, sold, traded and inherited and are separate from land rights. Water can be used only if the user owns the corresponding water right (liter/second or proportion of flow). Water rights are allocated with no charge, and in the case of simultaneous requests, water rights are allocated to the highest bid. The role of the State in resolving conflicts is very limited and relies on private negotiations and the civil courts (Brehm and Quiroz, 1995; Productivity Commission, 2003; Budds 2004).

The Water Code is the principal legislation governing water resources management. In 1981, Chile reformed its Water Code. The 1981 Water Code was designed to promote private agricultural development and increased economic efficiency by allocating water

resources to their most economically valuable uses. It was an effort to dismantle the agrarian reform and modernize agriculture to make the rural sector a platform for export-oriented agriculture (Diaz et al., 2005). This was a drastic change from the previous 1967 Water Code which provided the state with a significant amount of authority on water rights. In 2005 the Water Code was once again amended.

Under the 1981 Water Code, water rights were not conditional on the type of use and applicants were not required to indicate how they would use their resources. Also, they could not be penalized for not using the resource. It was this unconditional nature of the water rights that promoted unregulated speculation in water rights, hoarding of rights and concentration of water rights in a few hands by favouring large-scale economic interests (Bauer, 1997; Budds, 2004; Diaz et al., 2005). Therefore the most recent amendments to the Water Code (2005) seek to promote a more rational, efficient and sustainable use of water in the country. Significant amendments include requiring those applying for water rights to justify the amounts of water they are requesting and the DGA (the lead authority of water resources) now has the power to deny requests. Thus more authority is given back to the state. In addition, a tax is now imposed on those that do not use their allocated amount of water. This is to deter the concentration and control of water rights to a few users and not to allow available water to be unexploited (Morales, et al., 2005).

3.2.2 Organizations

Several organizations participate in the governance and use of water resources in Chile. These organization are involved in the formulation, implementation and regulation of the water market, water code and norms with respect to water use. Each has different functions and responsibilities.

The DGA plays the central role in the management and use of water resources. The DGA is a government agency within the Ministry of Public Works. It is in charge of developing water policy, administering the Water Code and providing information for government and private decision-making (Productivity Commission, 2003). Broad responsibilities include water use planning, and the development and exploitation of natural water resources (Brehm and Quiroz, 1995). A key function of the DGA is the responsibility of granting water rights, and it is required to do so if the water is physically and legally available. In general, the DGA will approve new water rights if water is available and the granting of the right does not affect third parties (usually other water users) (Bauer, 1998; Productivity Commission, 2003). When more than one request is received for water rights with respect to the same source of water the DGA performs an auction and the rights are given to the highest bid. In addition, during times of official drought emergencies, the DGA (under the direction of the President of Chile) can limit, redistribute or restrict water use to reduce the damage caused by the drought provided water users are compensated. Minimum ecological flows for a river are determined by the DGA to protect specific endangered flora and fauna (Productivity Commission, 2003). The DGA monitors the activities of the *Junta de Vigilancia* (JDV) and authorizes

and inspects public water works and modifications to natural waterways (Brehm and Quiroz, 1995; Productivity Commission, 2003).

The DGA exercises broad authority over water resource management, while much of the basin-level management and supervision over river flows is under the authority of the JDV. The JDV is a non-profit association that administers and distributes water to owners of water rights of a natural water course of a basin or sections of the basin. Key responsibilities involve maintaining water accounts and distribution of water to water users, reducing the flow in the canals during times of scarcity; monitoring and enforcing the extraction of water and the suitability of water works employed by water users; resolving disputes between water users; and keeping systematic records of the flows in their channels (Productivity Commission, 2003).

JDVs are supervision committees over *asociaciones de canalistas* and *comunidades de aguas.* These three organizations are referred to as Water User Associations (WUA) and only deal with agricultural water issues (Diaz et al., 2005). *Comunidades de aguas* and *asociacion de canalistas* are collections of water users sharing common water resources within a basin. Usually they are group of irrigators sharing a particular canal. They have a President who is elected by the water users and is responsible for maintaining an account of water rights of its members; operating, constructing and repairing infrastructure for the distribution of water; monitoring and enforcing the taking of water from the channel and the collecting of fees (Productivity Commission, 2003). *Asociaciones de canalistas* are generally in charge of administering primary

infrastructure such as dams and main irrigation canals while the *comunidades de aguas* are responsible for secondary infrastructure, such as distribution canals (Brehm and Quiroz, 1995; Productivity Commission, 2003).

The *Direccion de Obras Hidraulicas* (Directorate of Water Works (DOH)) is also a government agency within the Ministry of Public Works. The DOH is responsible for the construction and maintenance of water infrastructure projects, inclusive of irrigation and rainwater drainage structures.

Potable water for household use in rural areas is managed by *Comites de Agua Potable Rurales* (Committees of Rural Potable Water (APR)). APRs are a private, autonomous service providing basic water services to small towns and communities that have a relatively high population density. Responsibilities include the administration, operation and maintenance of the potable water distributions systems and ensuring that the standards of quality and quantity of water are met (Diaz et al., 2005). Under the National Program of Rural Potable Water headed by the DOH, APRs are provided with the basic infrastructure and training to operate the machinery and obtain proper water samples for quality analysis. The DOH sets the price for potable water and the price is negotiated with the local APRs. Payments for water are made at the local APR. In the ERB groundwater is pumped, treated and distributed to homes by APRs. Rural potable water is tested every month by the public health services department and once every two months by the private regional potable water company.

3.3 The Elqui River Basin

Chile is divided into thirteen administrative regions. Each region is headed by an *Intendente* appointed by the President. The ERB (9 657 square kilometers) is located in the northern part of Region Four, south of the Atacama Desert. La Serena is the capital of the region (Figure 3.1). The region covers approximately 5% of Chile's total area and is home to roughly 4% of the national population. Poverty is mainly in the rural sector. Approximately 20% of rural families are classified as poor. In comparison, only 11% of urban families are classified as poor (Cepeda et al., 2004a).

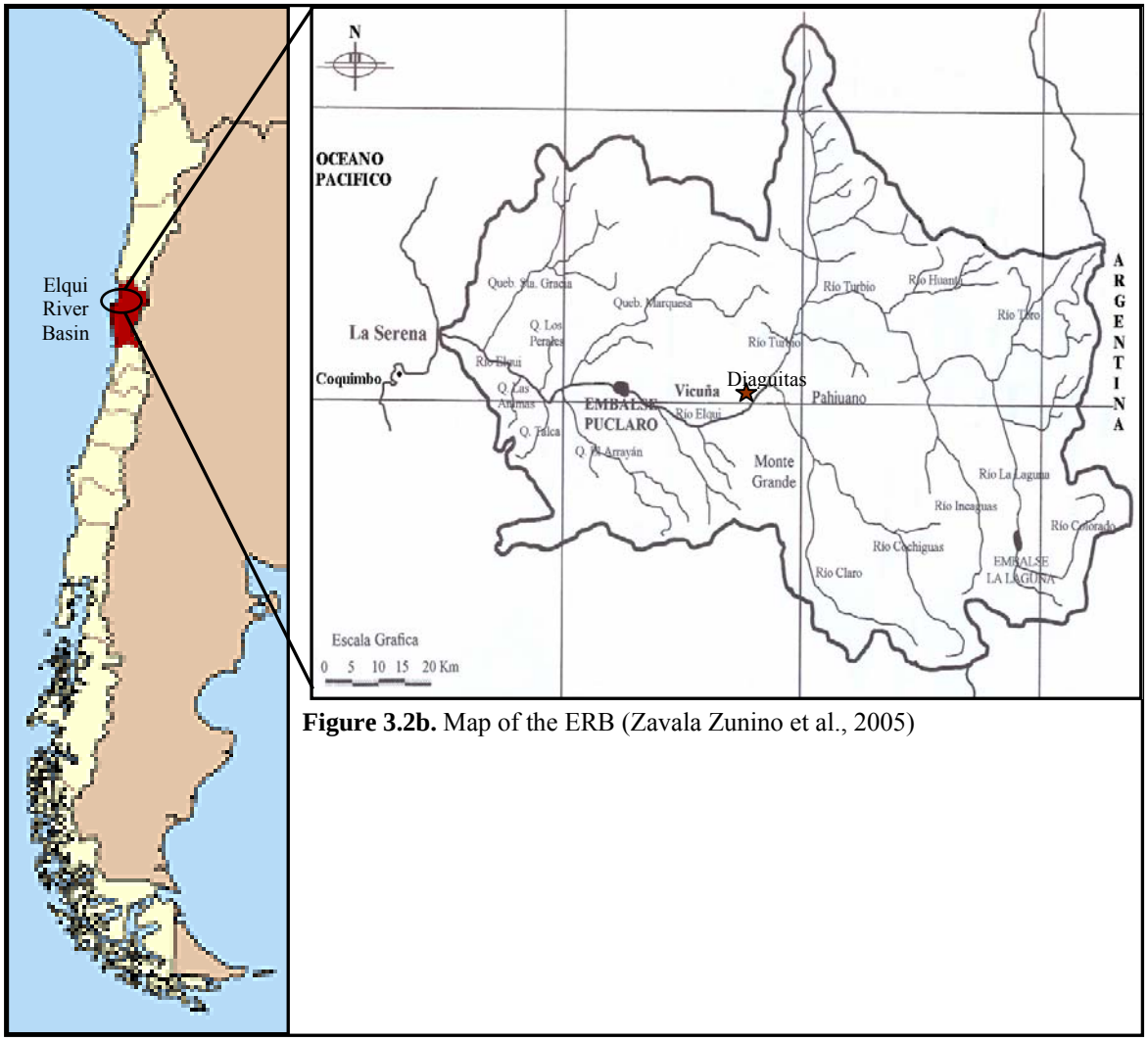

Figure 3.2b. Map of the ERB (Zavala Zunino et al., 2005)

Figure 3.2a. Map of Chile (Zavala Zunino et al., 2005)

The origin of the Elqui River is where the Claro and Turbio rivers converge at 815 m.a.s.l (75 kilometers from La Serena). The source of the Elqui River is predominantly snow-melt, and to a lesser degree, glacier-melt water. El Tapado glacier provides some discharge to the ERB and is located at 5536 m.a.s.l. (Ginot et al., 2006). The average discharge of the Elqui River is 7.1 cubic meters/second with a high seasonal variability (Cepeda et al., 2004b). Snow collects on the Andean tops over the winter season and is gradually released during spring and summer. Average annual discharge can vary between 2.4 cubic meters/second and 33 cubic meters/second. In the past 30 years, river discharge in the ERB has been increasing (see figure 3.3) (Cepeda et al., 2004a; Mall, 2005). The recent increase in river discharge coincides with an increase in snowfall in the high mountains over the past 30 years (Mall, 2005). Figure 3.4 illustrates annual variability and recent increase in discharge for the Turbio, Claro and Elqui rivers.

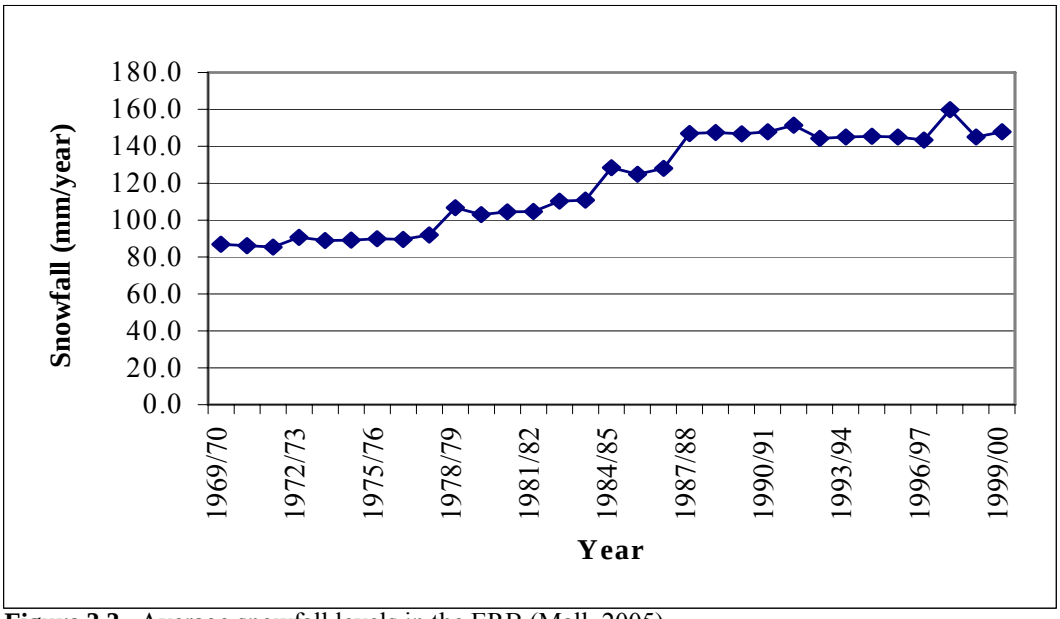

Figure 3.3. Average snowfall levels in the ERB (Mall, 2005).

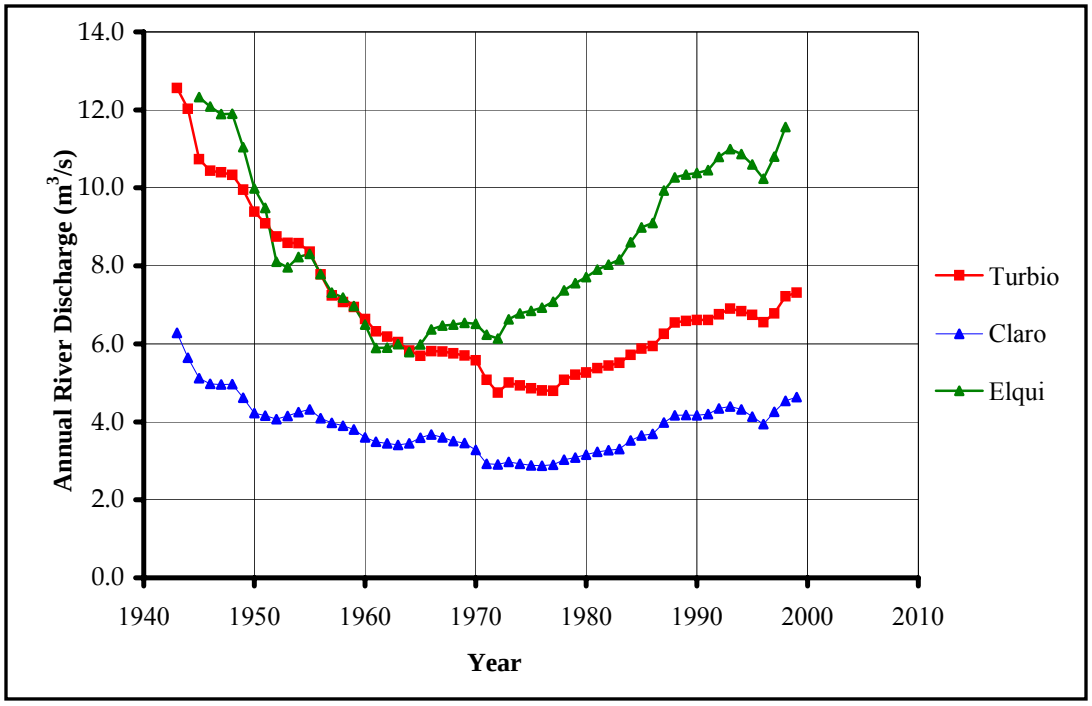

Figure 3.4. Discharge trend for three rivers in the ERB from 1940-1998 (Mall, 2005).

There are two dams in the ERB to regulate the flow of the water. La Laguna dam is located at 3 200 m.a.s.l and has the capacity to hold 40 million cubic meters of water. The much larger Puclaro dam located at 432 m.a.s.l. was completed in 1998 and can hold 200 million cubic meters of water. Diaguitas is situated between the two dams. Therefore, in there ERB there are two instruments regulating surface water resources: physical (dams) and legal (Water Code) mechanisms.

In the ERB, surface water and ground water serve two distinct purposes. Surface water is used mainly for irrigation and to a lesser extent in the mining industry. Groundwater is pumped and treated for potable water used for household purposes, filling swimming pools and preparing fruit for export. The aquifers are recharged by rainfall and to a

lesser extent by infiltration from the canals and river. During dry periods the aquifers supply some water to the river (personal communication, Zavala, H., 2006).

Average annual rainfall in the ERB is very low averaging 100 millimeters/year (Fiebig-Wittmaack and Perez, 2005a). Rainfall is extremely variable from one year to the next. The majority of precipitation falls between May and August leaving the remaining months very dry. Figure 3.5 illustrates the difference in average monthly precipitation between the southern hemisphere summer (dry season) and winter (wet season).

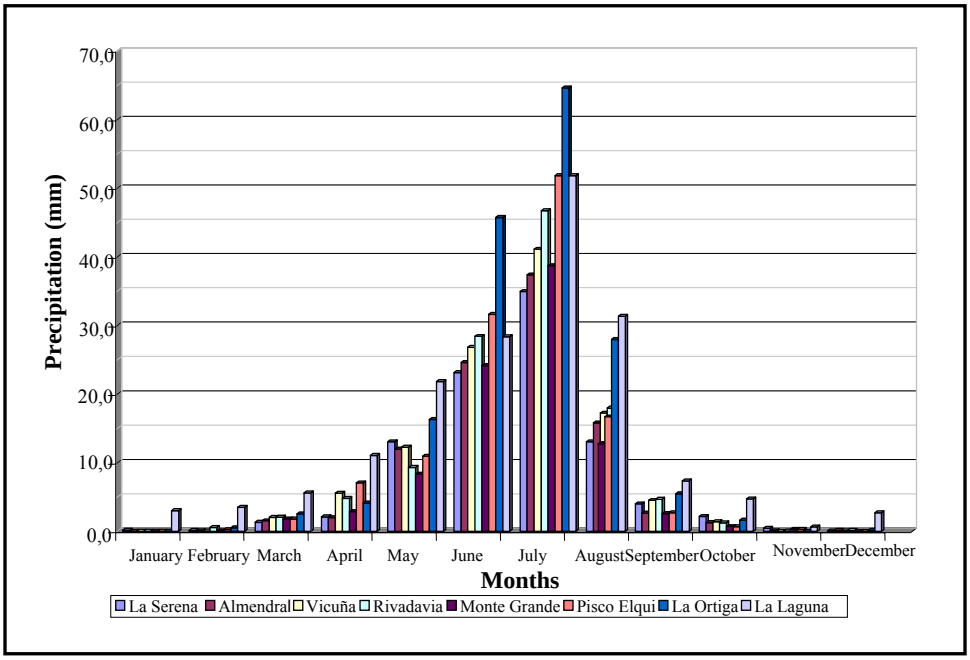

Figure 3.5. Average monthly rainfall for the ERB from 1980-2003. The closest station to Diaguitas is Vicuna. (Fiebig-Wittmaack and Perez, 2005a).

Under ENSO events, the basin is subject to oscillatory periods of drought, brought on by La Niña, and intense, but short, precipitation events instigated by El Niño. El Niño events occur irregularly but typically every three to six years. Although the mean annual

precipitation is low, this value can double or triple during an El Niño year. In the past few El Niño occasions, the volumes in the basin gained destructive power resulting in considerable damage (Cepeda et al., 2004a).

With respect to economic activities, the ERB has mining and agriculture as well as a growing tourism industry. Nearly 43% of the region's dry land is dedicated to commercial agricultural development (Cepeda et al., 2004a). Commercial agriculture production uses extensive drip irrigation systems. These productions are highly dependent on surface water availability. Most agricultural activities in the basin are related to fruit-production, particularly table grapes for exportation. Additional crops include grapes for *pisco* production, citrus fruits and avocados. Large-scale agricultural exportation companies appeared approximately fifteen years ago in the ERB. Sprawling irrigated plantations now cover nearly every accessible valley and are rapidly crawling up the mountainsides (Figure 3.6). Livestock production, mainly goats, is also prevalent in the region (Figure 3.7). Where the land is not covered by crops, the arid mountainsides are dotted with cacti and sparse small bushes.

Figure 3.6. Commercial viticulture in the Elqui Valley

Figure 3.7. Goat herding.

Throughout the ERB are numerous small rural communities and towns connected by a network of mostly paved roads (the roads were paved roughly around the same time as the agricultural companies arrived). The larger towns in the basin are typically the capitals of *comunas,* which are smallest administrative division, headed by an elected mayor. The communities that are scattered throughout the basin are primarily dependent on mining or agricultural industries for employment, and increasingly, tourism. Some of the more rural areas are inhabited by goat herders (see figures 3.6 and 3.7). This study takes a closer look at the community of Diaguitas.

3.4 Diaguitas

Diaguitas is located in the *comuna* of Vicuna. Vicuna is also the name of the nearest town where the municipal government offices, market, hospital, police station, shops and services are located. Diaguitas is a quiet rural community adjacent to the Elqui River at the base of the steep Mamalluca hill (Figures 3.2b and 3.8). The town has a population of approximately 700 residents. Mamalluca is a prominent feature in the community feared by many residents. During the last decade Diaguitas has experienced two mudslides causing extensive damage.

Although Diaguitas is a small community, there is a clear, visible segregation. Older residents live in the older section of the community. This area is characterized by the traditional style homes made of adobe and family *huertos* (large garden/small farm). Younger families that have come to Diaguitas to work, typically live in the *población.*

The *población* is a housing project that was constructed about five years ago. The houses are small, poorly constructed, and very close together (figure 3.9).

Figure 3.8. Mamalluca Hill

Figure 3.9. The población of Diagutias at the base of the Mamalluca Hill.

The dominant source of employment in Diaguitas is within the three commercial agricultural companies. Their vineyards are expanding throughout the community and up the hillside. These companies provide mostly seasonal employment to the residents. Residents (children and students included) agree that there are no other employment opportunities in the community. Prior to the arrival of the companies, people worked and relied on the productivity of their *huertos*. However, small farmers can no longer compete with the low supermarket prices and typically sell their produce from their homes. Those that have maintained their *huertos* are typically retired residents.

The agricultural companies and remaining small farmers in Diaguitas rely on surface water flowing down the Elqui River from the Andes. Water is diverted from the Elqui River into three canals which weave through the community. The canals divide into smaller secondary canals by handmade partitions to divert water to water users (Figure 3.10). Each main canal belongs to a *comunidades de aguas* or *asociacion de canalistas*. Each canal has a schedule with respect to when and how much water is delivered to each water user. The schedule is determined by the amount of water rights a user possesses, and is managed by the canal president. It is the president's responsibility to alternate the partitions to ensure that all water users receive their entitled amount of water at the allotted time.

Figure 3.10. Hand-made water diversion mechanism.

Potable water for household use is managed by the local APR. It began in 1972. Before the APR people drank the water from the canals. The APR board is elected by the community. The Diaguitas APR is recognized by the regional DOH potable water department as a professional and efficient organization with very few problems. Water is pumped from a well, stored in two tanks and distributed to approximately 80% of the community. Those that do not have access to the potable water system typically live high on Mamalluca hill and are unable to be connected to the system. The municipality delivers water to these residents. Residents pay the APR monthly. The largest consumers are the agricultural companies, and camping facilities and residents with pools.

CHAPTER 4: METHODOLOGY

This chapter describes the research approach, design and methods used to assess the vulnerability of Diaguitas, with an emphasis on water resources and institutions, in light of climate change. The research approach used to direct the study is explained below, followed by a description of the processes and methods undertaken prior to and during the field season. The chapter continues with an explanation of practical considerations that were addressed in order for the study to take place. The chapter concludes with a description of the methods used for data interpretation and analysis.

4.1 The Vulnerability Approach

The approach used to guide the study was the 'the vulnerability approach' (Ford and Smit, 2004; Sutherland and Smit, 2005: Smit and Wandel; 2006). What distinguishes the vulnerability approach from previous approaches to vulnerability assessments is that it begins with the system, in this case, the community of Diaguitas (Cutter, 1996; see Polsky et al., 2003, Turner et al., 2003; Downing, 2004; Ford and Smit, 2004). The vulnerability approach examines the conditions that give rise to an individual's and/or community's vulnerability. A crucial aspect of the vulnerability approach is to gather information and understand the nature of the exposures and adaptive capacity (hence vulnerability) from the community. Who and what is vulnerable, why, and to what conditions are not assumed but are developed through the research. The vulnerability approach encourages involvement of various actors from various levels and sectors of society to discuss relevant and immediate issues pertaining to the community. The assessment yields results that are pertinent and relevant to the community.

The conceptual model of vulnerability introduced in Chapter 2 provides the framework that guides the vulnerability approach and parallels the four research objectives. Figure 4.1 outlines the vulnerability approach. The vulnerability approach involves the assessment of current and future exposures and adaptive capacity as they relate to stresses and concerns of the system in question. The vulnerability approach addresses who is vulnerable and how this will change in the future in light of climate change. The approach seeks to understand why and how the community is vulnerable. In what way? What has been done in the past and presently to cope with the problem? The approach also considers how these stresses may change in the future and what capacity exists to deal with the current stress and future changing conditions (Smit and Pilifosova, 2003; Ford and Smit, 2004).

Current vulnerability is addressed through the first two objectives of this thesis: 1) to document current exposures as they relate to water resources and 2) to assess the current adaptive strategies and capacity, highlighting the role of institutions. The identification and documentation of current vulnerability provides the basis for the assessment of future vulnerability which is addressed in the last two objectives: 3) to examine future potential exposures in light of climate change and 4) to assess future adaptive strategies and capacity of the community.

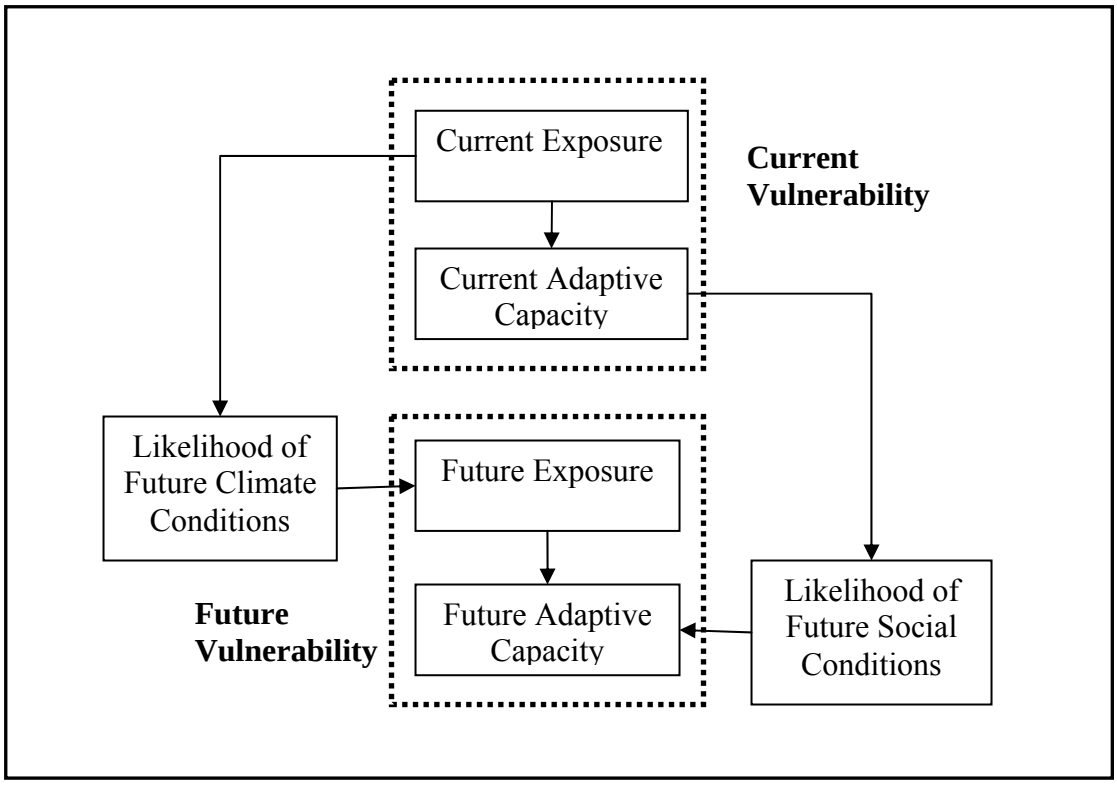

FIGURE 4.1. The Vulnerability Approach. Community, stakeholder and institution involvement throughout the stages (Ford and Smit, 2004; Smit and Wandel, 2006).

The assessment of current vulnerability involves identifying past and current conditions that have been problematic or risky to the community (exposures) and the ability and strategies that have been adopted to cope with these conditions (adaptive capacity). This stage is important because the response to stressful and extreme events can reveal how systems may be vulnerable to future climate perturbations (Hersh and Wernstedt, 2001). This phase of the research produces a summary of stresses and conditions and an inventory of adaptive strategies used by the community and/or institutions and their effectiveness. Conditions that constrain or facilitate adaptive strategies are identified. Although this study has a focus on water resources, it is essential to recognize and understand additional stresses (environmental and social) from local and broader contexts

that challenge community. This allows the researcher to gain further insight into the nature of vulnerability and assist in assessing future vulnerability.

Ethnographic methods (observation, focus groups and interviews) are of central importance in assessing current vulnerability. These methods encourage insight to be gained through the community, institutions and other stakeholders. However, an assessment of current vulnerability also utilizes available information beyond the community to gain an appreciation of the broader features of the community as they relate to vulnerability. Observation and additional sources of information were also sought for the purposes of validation and triangulation, such as researcher collaboration, census data, publications, historical documents, newspapers, government reports and climate and hydrological records.

Examining how climate change will alter the nature of the identified exposures and whether the community and institutions have the capacity and strategies in place to deal with these changes will determine future vulnerability. The gathering of information about future vulnerability involves both climate science assessments and insights from the community and institutions.

Future exposures relate to conditions which are expected to represent risks or opportunities to the community at a later date. These conditions are related to those identified by the community in addition to potential conditions (both physical and socio-economic) that may not yet be realized or problematic to the community. Collaboration

with climate scientists is necessary to estimate the likelihood of changes in current climate-related stresses to the community. Due to the focus of this study, a climatologist and hydrologist from the IACC project were consulted to provide baseline data and insight into the likely future changes in water resources in light of climate change and natural trends. Changes in socio-economic conditions are considered as they can present stresses to the community and influence the sensitivity of the system.

Future adaptive capacity is concerned with the degree and manner to which the community and institutions will be able to cope or accommodate the potential future exposures. The assessment considers if the community and institutions have the resilience, resources and information to deal with expected future exposures. This stage attempts to answer a key question: given the identified adaptive strategies, capacities and constraints, will institutions and the community be able to cope with the potential future exposures? Data sources are a combination of information collected through in-depth field work at the local level and insights from institutions and key informants at local, regional and national scales.

4.2 Community Selection

A community level study is appropriate as it enables an in-depth case study. Case studies, in this case a community, provide a detailed, systematic means that provides an illustrative example of vulnerabilities in the ERB. Case studies provide a means to identify local circumstances and institutional factors that are important in terms of vulnerability within a broader physical, economic, political and social context (O'Brien et

al., 2004). O'Brien et al., (2004) found that case studies enabled researchers to identify state and local-level institutions and policies that influence coping and adaptation strategies used by farmers.

The Chilean IACC research collaborators had selected the community of Diaguitas for the case study in August 2004. Diaguitas was selected because it is a small rural community that is highly dependent on water resources. It is also affected by recurring mudslides instigated by periods of heavy rainfall. A preliminary focus group was conducted by the Chilean researchers in August 2004 to gain an understanding of community history, dynamics and problematic situations that the community has had to deal with. Community leaders, organizations and stakeholders were identified at that time.

4.3 Research Design

The vulnerability assessment was carried out with the collaboration of two IACC Chilean researchers. The work in Diaguitas was assisted by a local researcher with experience in ethnographic research in the ERB. Research associated with the regional and municipal institutions was assisted by another local researcher with knowledge and research experience with many institutions. Additional IACC researchers were used as references and information sources in areas such as climatology, hydrology, sociology and civil engineering.

Data were collected in Diaguitas and the ERB over a period of three and a half months in the summer of 2005. This entailed gathering primary data (interviews, focus groups, and observations) from the community and municipal and regional institutions in addition to secondary sources and collaborating with Chilean researchers. As the researcher was not from Chile, it was essential to thoroughly review documentation with respect to the physical, political and socio-economic characteristics of Chile and the ERB and water resource institutions in Chile prior to beginning fieldwork.

The researcher lived in Diaguitas for the duration of the field season. The practice of staying in the community during the research period is an essential part of ethnographic research (Babbie, 2002). Staying in the community not only helps to build familiarity and rapport but can change outsider attitudes and perceptions, improve linguistic ability, facilitate informal discussion, and demonstrate a commitment to community life (Pretty, 1995). It enabled the researcher to take advantage of the unexpected, for example, conversations with neighbours, attending community events and meetings, and setting up or conducting impromptu interviews. Relationships and trust were established making interviewees more comfortable in an interview setting. Many interviews occurred over *onces* (afternoon tea) with neighbours.

4.4 Interview Guide

Prior to the beginning of the field season, IACC researchers (Canadian and Chilean) involved in community vulnerability assessments took part in a workshop to discuss the concept of vulnerability and training on the vulnerability approach. The training was

essential for all team members to have consistent understanding of the research approach and the type of insight to be gathered in order to characterize the nature of vulnerability and identify how institutions mediate vulnerability. During this training session, a general interview guide was developed (see Appendix A).

The purpose of the guide was to provide the researchers with a similar framework and checklist of topics to ensure that relevant issues were covered. The guide was structured to mirror the four research objectives and was composed of open-ended questions. A guide was used rather than a survey to avoid bias in prompting and allow respondents to elaborate on their experiences and concerns. The interviewer was free to further explore, probe and ask additional questions when needed. This would take place after respondents had identified unprompted, key exposures and adaptive strategies. Furthermore, many relevant questions may only become obvious as the interviewing process continues. A guide allowed for flexibility as it is likely that new issues which had not been considered at the outset will be entered into the research checklist. The checklist was a list of topics, exposures, adaptive strategies that had come up in previous interviews, observations or secondary sources. The checklist was consulted when a respondent had not identified topics during the open-ended questioning.

4.5 Sampling Strategy

Participants for interviews and focus groups were purposefully selected as the intent was to gain specific insights with respect to their experiences and knowledge as it relates to the research (Hay, 2000). The sample selection aimed to include all social and economic

groupings in the community. Community residents were selected to capture a range of livelihoods, employment, location of dwelling, age, sex, institutional affiliation and knowledge related to the study. These groups were identified by the researchers prior to and throughout the research. In addition to reflecting the community's profile, the sample selection attempted to capture interests and perspectives beyond the settlement itself (e.g. agri-business, local business, neighbouring settlements, community groups and municipal/regional institutions). In Vicuna and La Serena interviews were conducted with institutions related to water resources, the environment and social wellbeing.

Sampling strategies employed were opportunistic (taking advantage of the unexpected) and chain/snowball sampling (interviewee identification comes from previous interviews and/or recommendations) (Hay, 2000).

4.6 Primary Data Collection Methods

4.6.1 Interviews

In total, forty-eight interviews were conducted. Interviews were in-depth and semi-structured directed by the interview guide. Interviews flowed like a conversation and were carefully guided to address particular topics related to this project. A Chilean collaborating researcher would lead the interview while the other researcher(s) would take notes, make observations and pose questions as needed. After an interview the researchers would de-brief to discuss relevant topics such as identified exposures and adaptive strategies. During the first week of field work, pilot interviews were conducted and when necessary, adjustments were made to the interview guide.

In-depth, semi-structured interviews were used because they are considered an excellent method for gaining access to information about events, opinions and experiences (Hay, 2000). This technique allows for respondents to discuss, unprompted, the problematic conditions faced by the community and/or personally through their experience and how they coped with the situation. It allows for the respondent to voice their opinion on the effectiveness of coping strategies and possible future conditions. The semi-structured format allowed for a number of predetermined issues to be discussed and for control over the interview, while encouraging digression for increased detail (Berg, 1995). As interviewees were purposefully selected, some topics/issues were emphasized and elaborated based on the knowledge and experiences of the interviewee.

Twenty-six in-depth interviews were conducted in Diaguitas including four interviews that were carried out in a neighbouring community that shares many resources including employment and irrigation canals. The sample included men and women; small farmers, commercial agricultural companies; employees of the companies; goat herders; retired residents; small business owners (store, camping); long-time, part-time and newly arrived residents; leaders of community clubs and members of local water-related institutions. Table 4.1 exemplifies a small sample range. Most respondents possessed overlapping characteristics. For example, one respondent is a temporary employee for an agriculture company, maintains a small farm, lives in the *población* and is the President of a canal. Interviews lasted about an hour. The interviews delivered personal insights into the sensitivities and stresses faced by the individuals and the community and how they have coped with these situations from various perspectives. Figure 4.2 is a picture of an

interview with a manager of an agricultural company and Figure 4.3 is taken from a transect walk of the community with a President of a canal.

Livelihood	Male	Female
Small Farmer	6*	-
Large Farm Employee	2	3
Large Farm Manager	2	-
Professional	2	1
Small Business Owner	-	2
Goat Herder	2	-
Retired	-	6

Table 4.1. Sample summary in Diaguitas.
*All small farmers were also retired.

Figure 4.2. Manager of commercial agriculture company demonstrating the irrigation system of the vineyard

Figure 4.3. President of a canal in Diaguitas demonstrating how the water level is regulated in the canal.

Twenty two interviews were carried out with representatives of key municipal and regional institutions. Four interviews were conducted in Vicuna and eighteen interviews in La Serena. The interview guide was tailored more towards the interests, responsibilities, roles and expertise of the institutions (e.g. potable water issues, irrigation water issues, public works projects).

4.6.2 Focus Groups

Three focus groups were conducted. Each focus group consisted of between six and twelve participants. Focus groups were used because they generate unprompted, unbiased discussion on many ideas, issues and topics (Stewart and Shamasani, 1990). The group atmosphere and open-ended questions encouraged a chain-reaction effect and

encouraged participants to draw from and respond to each other (Stewart and Shamasani, 1990). The focus groups allowed for a broad characterization of the problematic conditions facing the community and the ways that the community has dealt with the issues.

The first focus group was a clay-modeling activity (Figure 4.4). The participants were asked to make a miniature model of Diaguitas. The aims were to 1) familiarize the researchers with the community (location of canals, mudslides, wells, roads, vineyards) and residents; 2) create an informal setting to promote free-flowing conversion between participants and 3) gain insights into the problematic conditions facing the community. For example, during this activity the participants illustrated in the model where the mudslides tend or originate from, its path and damage to the community. The second focus group was conducted with the Club de Adultos Mayor (elders club) to achieve insight into how the community has changed. The third focus group took place with students. The purpose was to develop an understanding of their awareness of water resources and their perspective of the exposures and adaptations in the community. These insights are important because these participants are the future of Diaguitas and the ERB.

Figure 4.4. Clay modeling exercise.

4.6.3 Observation

Participant observation was used to see and experience ordinary and unusual events, to listen and partake in casual conversation, and to learn about everyday activities as they happened (Neuman, 2004). Observation was also a tool used to ground-truth statements given by respondents and to witness occurrences in an effort to understand peoples' everyday experiences. The advantage of this technique is that it allowed the researcher to appreciate events and problems holistically and to recognize the various stakeholders, challenges, social interactions, rituals and customs.

The researcher observed a community meeting held with the mayor and members of the municipality. This activity showcased issues of concern and how the municipality responds to the concerns. A transect walk of the community was guided by a local

resident. Observations were made with respect to the damages of the most recent mudslide and how the canal system functions. The researcher also attended a national conference that discussed the amendments made to the Water Code.

4.7 Practical Considerations

It was important for the researcher(s) to slowly be introduced into the community and to develop a rapport with residents before conducting any interviews or focus groups. It was beneficial that the IACC research collaborators assisting with the fieldwork were local to the ERB and had experience working in communities and with water governance institutions. In addition the researcher had an intermediate level of comprehension in the local language.

In many cases, a natural mistrust of researchers exists, and this can be compounded if researchers are working with communities who have been extensively studied with little perception of change resulting from their participation in researchers (Wallerstein, 1999). The ERB is a heavily researched area and residents have become wary of researchers. Mistrust of researchers is increased if there is any potential that the researcher is seen as a government informant. To help overcome this, the researchers made two preliminary visits (three including the initial focus group in August 2004). These visits were important to make and maintain contacts with the community and to familiarize the researchers to the community (and vice versa). Living in the community also helped build trust and acceptance.

Language can be a barrier to effective research (Patton, 1990). A translator was hired to help improve communication and to serve as a cultural guide by providing background information and context. The translator had worked in the ERB and was knowledgeable about the ERB and local colloquialisms. At first the translator orally translated the interviews from the recordings to the researcher following the interview. This process allowed for a relatively quick turn around time and the researcher was able to clarify unknown terms and background information. Eventually translation was completed by the translator from Spanish transcripts.

Although the researcher(s) attempted to include all social and economic groupings of the community, it was difficult to arrange interviews with some members of the community. Interviews with workers of the agricultural companies were difficult to contact because they worked long days, six days a week. Often they would not be interested in participating in an interview on their day off. It was common for men to be drunk or hung-over on their day off and not willing to participate in the study. Therefore there were slightly more interviews conducted with retired residents.

4.8 Data Interpretation and Analysis

Information gained through ethnographic methods, research collaboration, documents (newspapers, publications, climate and hydrological records, etc) provided sufficient information for a comprehensive data interpretation and analysis.

Recorded interviews and notes from unrecorded and recorded interviews, focus groups and meetings were translated (if necessary) and transcribed electronically. Field notes and relevant documents were recorded in electronic form (if not already). The electronic documents were analyzed with latent content analysis, a method used to systematically identify key themes in the data, in this case with respect to exposures facing the community and adaptations measures untaken.

To aid in the analysis, the electronic documents were imported into QSR NVivo, a computer software program used to organize and code text. Documents were searched for recurring themes relevant to the research objectives. A coding system was developed to extract the pertinent information from the text to make the data set more manageable. A coding hierarchy, or 'coding tree', was used to further dissect the data. For example, a 'node' was labeled 'Exposure' and beneath was various sub-nodes such as 'Exposure-Environment', 'Exposure-Water', 'Exposure-Employment' etc.

To achieve further insight into future vulnerability this involved reviewing documents, climate scenarios and collaborating with physical scientists to ascertain the likelihood of changes in conditions relevant to current stresses and risks faced by the community. Future adaptive capacity was interpreted by referring to the current constraints of adaptation, capacity and possible opportunities that are not addressed.

CHAPTER 5: CURRENT VULNERABILITY

This chapter discusses the current vulnerability of the community of Diaguitas with respect to water-related conditions. For the most part the exposures are related to water resources. However the community also had strong concerns with respect to problematic conditions incurred by the arrival of the agricultural companies. The adaptations undertaken by the community and institutions to cope with the identified conditions are described. This includes the conditions and processes that facilitate or influence adaptive capacity and strategies. The chapter concludes with a discussion and summary of the current vulnerability of the community.

5.1 Current Exposures

The following section describes the problematic conditions that were identified by the community. Exposures related to water resources are emphasized. However, these exposures were not the main concerns of the community. Several prominent exposures were identified relating to employment, influx of migrant workers and pesticide use by the agricultural companies. These are briefly discussed as they add to the understanding of the nature of the community's vulnerability, affect the livelihoods of the community and have the potential to be exacerbated in the future in light of climate change. In general, the exposures faced by Diaguitas stem from three main factors: global climatic phenomenon (ENSO), international demand (fruit, wine) and national economic strategies (export-oriented, neoliberalism). Figure 5.1 illustrates the forces and processes related to the exposure of Diaguitas.

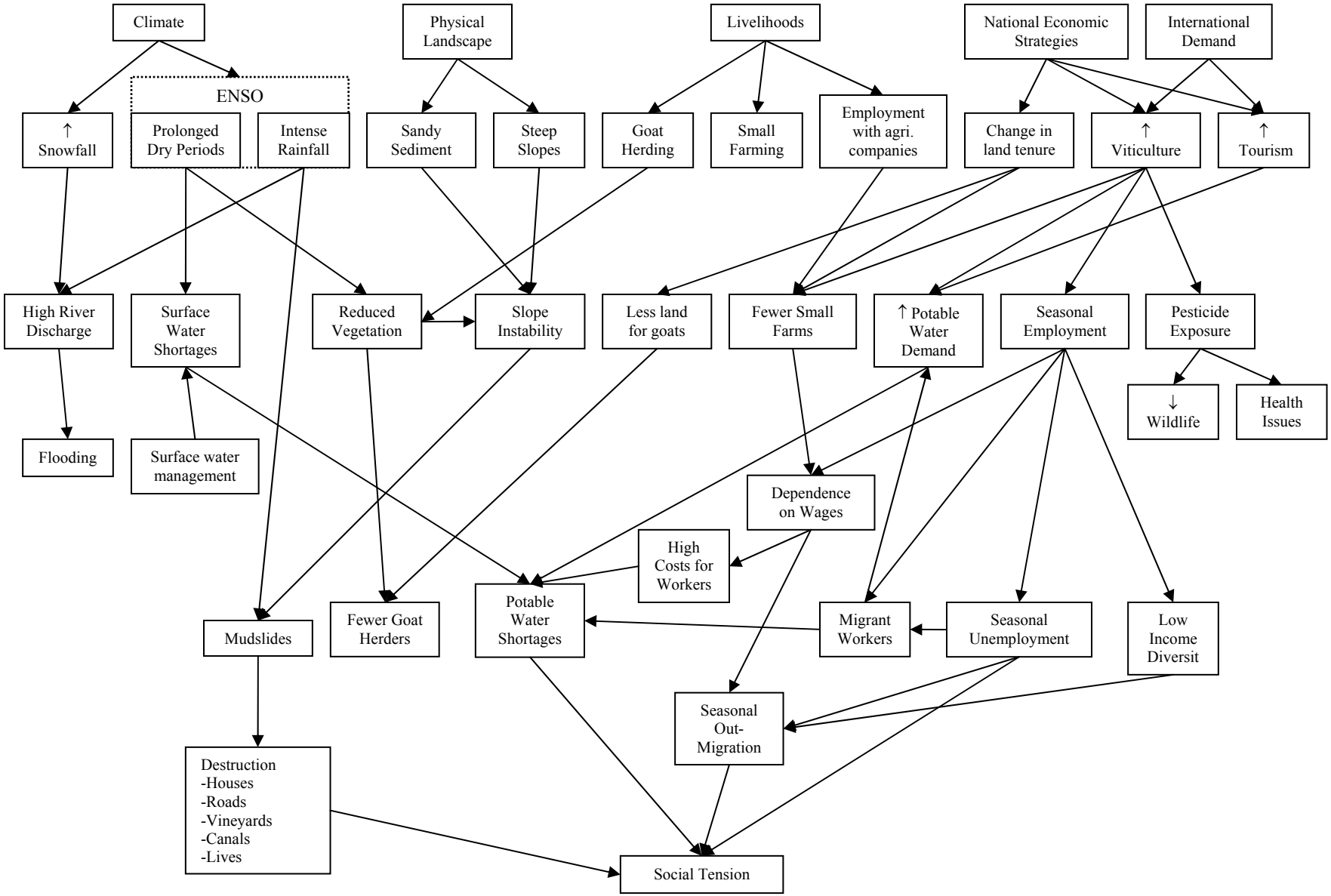

Figure 5.1. Forces and processes related to the vulnerability of Diaguitas.

5.1.1 Intense Rainfall

Abundance and intensity of rainfall was a dominant concern for the community. Respondents identified intense rainfall episodes as a hazard to the community. These types of rainfalls, or '*lluvias locas'* (crazy rains), as referred to by the community occur every few years caused by the El Niño. Rainfall can double or triple the annual average amount during an El Niño year. During these years, precipitation causes an immediate increase in river flows, very little superficial drainage, temporary lagoons and erosion of land (Cepeda et al., 2004). The heavy rains have initiated mudslides, broken canals, caused river swells and blocked roads- sometimes making areas of the community inaccessible.

Members of the community feel that the rains have become much more intense. They agreed that before rainfall was more moderate, it would rain for days but with less intensity. However, there is very little recorded data available to verify these observations. According to a climate specialist, there is not enough data to indicate a change in intensity (M. Fiebig-Wittmaack, 2005, personal communication). A major feature of this region is the high variability of rainfall. Overall there is an average annual decrease in precipitation for the area. Precipitation has decreased by 50% in the past 100 years (Folland and Karl, 2001; Cepeda et al., 2004; Kalthoff et al., 2006). Vicuna is the closest meteorological station to Diaguitas, and Rivadavia and Montegrande are north of Diaguitas. Figure 5.2 illustrates the average annual decrease in precipitation for the ERB (La Florida is the name of the meteorological station in La Serena).

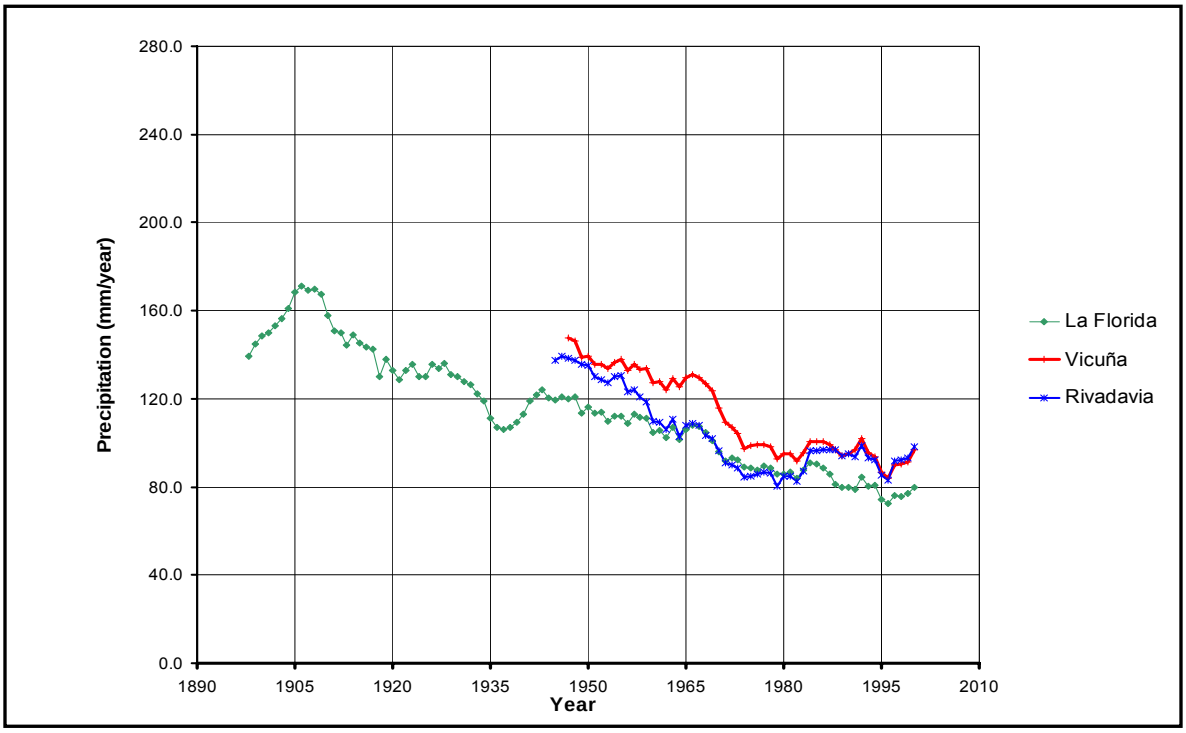

Figure 5.2. Average annual precipitation trend over the past 100 years (Mall, 2005).

5.1.2 Mudslides

Mudslides were identified as being a serious risk to the community. During the last decade Diaguitas has experienced two mudslides (1997and 2004). Mudslides were initiated by the *lluvias locas* during El Niño episodes when abundant rains are prevalent after a prolonged dry period. In 2004, more than 100mm of rain fell in six hours to cause the mudslide.

Mudslides in Diaguitas are not only a product of periods of intense rainfall. Diaguitas was settled at the base of Mamalluca. The soil is sandy and dry. The physical landscape and steep, unstable slopes of Mamalluca make Diaguitas more prone to mudslides. In

addition, the human impact and modifications of the slopes likely cause the area to be more susceptible to mudslides.

Goat herders take their herds to graze on the available vegetation (small bushes and cacti). Though there are currently fewer goat herders than in the past, this practice was identified by some respondents as causing erosion and degradation to the slopes. However, with respect to exacerbating slope instability, commercial agriculture was a more prominent issue than goat herding. Mudslides have been more frequent since the arrival of the agricultural companies and the planting of monoculture commercial vineyards on the slopes. Locals and some respondents from the DOH blame the agricultural companies for changes in land-use and the natural landscape. This occurred by major movement of land for flattening areas for vineyards and removing native vegetation. An engineer of the DOH explained that although vegetation has the ability to stabilize slopes, in this case it is causing instability (personal communication, Valenzuela, J., 2005). The roots of the vines are not very deep as they are fed by drip irrigation and there is no canopy during the rainy season to protect the soil from the impact of the rain. The removal of natural slope vegetation and modification to the slope and land-use tends to accelerate or increase slope failures (Gray and Sotir, 1996). In addition, agricultural soils tend to be more compacted and there is a decline in organic matter resulting from reliance on chemical fertilizers which also adds to their susceptibility to mudslides (Goudie, 2001).

The expansion of commercial vineyards and land use change has occurred rapidly. One resident remarked that "since I came here 5 years ago 100% has been planted above what existed before". Older residents of the community agreed that previously there were multiple creeks for water to run down the slopes during periods of intense rainfall. Water would not accumulate and the energy of the water would be dispersed. Now, there are only one or two creeks where all the water is forced to descend, increasing the force of the flow and moving more debris. It is perceived that when the land was covered by natural vegetation and the slope and land was unmodified by humans, the energy of the mudslides was dissipated and less of a threat.

The mudslides are very destructive and threaten lives of the residents. The mudslides caused damage to homes, canals and vineyards as water, mud, rocks and debris descend down the hill towards the community. Figures 5.3 and 5.4 show damages from the 2004 mudslides. Roads and paths were blocked making it difficult to help other residents in more isolated parts of the community. Respondents recalled furniture, beds and kitchen appliances being carried by the water and mud through the community. It is easy to become trapped in the descending water and debris. Several residents were sent to the hospital with hypothermia and injuries and luckily there have not been any casualties. Locals remember the mudslide events vividly. One elderly woman was extremely emotional and cried when she recalled the event. Respondents said that before when it rained, people were happy. Nowadays, people have fear of the rain. The mudslide of 2004 was the largest and most destructive that anyone could remember. Even a year after the mudslide, there was still evidence of the mudslide. Some residents were left

homeless and forced to relocate with family or find a new home, typically in the *población*. Debris is still in piles, damaged vineyards have not been replaced, damaged homes are abandoned and the path of the mudslide is still visible. Although the mudslides cause extensive damage to the community and threaten lives, locals have accepted that mudslides are part of living in Diaguitas.

Figure 5.3. Damaged vegetation from mudslide (Zavala, H., 2004).

Figure 5.4. Mud flowed through the school (Zavala, H., 2004).

5.1.3 Access to Potable Water

Diaguitas has a local APR, a well and two storage tanks to provide and distribute water to the community. Respondents mentioned that there is a lack of accessibility to potable water for some residents and at some times of the year. During the summer months, potable water resources are in high demand and are stressed in several ways. More wealth among some members of the community and attempts to promote tourism have led to more swimming pools. Pools are filled using potable water. Seasonally higher population caused by migrant workers, tourists and seasonal residents all increase potable water consumption. There is a much higher demand for potable water by the packing departments of the agricultural companies. The companies use significantly more water

during the summer months to prepare and clean the grapes for exportation. In addition there are more employees using the washroom facilities increasing the use of water.

During times of higher demand in the summer, the potable water supply is frequently shut off by the APR for the entire community. This is compounded by less supply in the dry summer months when aquifer recharge is slower (Zavala, H, 2006, personal communication). This has been most problematic for the packing departments who require potable water to prepare the fruit for exportation. The department has to close down until the water turns back on. There is no warning by the APR if and when they will be turning off the supply. Locals have become accustomed to the APR shutting off the water and prepare accordingly (discussed further in this chapter).

Nearly the entire community is connected to the potable water system. However, there are several houses located on Mamalluca hill that are not connected to the potable water system. These homes are situated above the storage tank. Thus it is not possible to pump water to these houses (Figure 5.5). These residents have constructed their own shelters and have chosen to live apart from the community and not be connected to the electricity or water systems. These households rely on the municipality to deliver water to the houses.

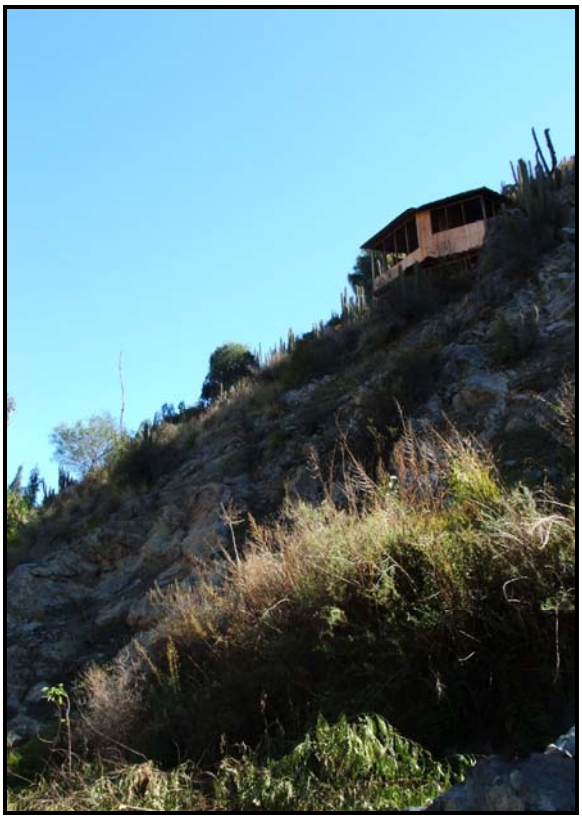

Figure 5.5. House on Mamalluca not connected to potable water system.

There are also households that can not afford potable water year round. For seasonal workers and pensioners it is difficult for them to pay their water bill every month. A water bill can amount to approximately 25% of a seasonal worker's salary at times. Water is shut off by the APR if a resident fails to pay their bill.

5.1.4 Surface Water Shortages

Surface water shortages were not perceived equally as a significant concern by all members of the community. The goat herders, a minority in the community, are greatly affected by surface water shortages. During prolonged dry periods the goat herders face problems as there is insufficient moisture for vegetation growth. As a result, the goats have nothing to feed on during these periods. Goat herders are forced to migrate to areas

with more vegetation. This can be very costly because often the herder will rent a truck to move the herd.

The agricultural companies were not very concerned, as they have only been operating in Diaguitas for approximately 15 years and have yet to be heavily affected by surface water scarcity. The companies use highly efficient drip-irrigation systems and do not require large amounts of water to maintain their crops. They also have storage ponds and cement-lined secondary canals minimizing water loss through seepage (Figures 5.6 and 5.7).

The majority of Diaguitas residents are employed by the companies and no longer rely directly on their own agricultural production and irrigation system. Therefore their livelihoods do not feel the affects of surface water shortages as strongly as a small farmer in the community. During times of water scarcity small farmers only irrigate to keep the plants alive, but not to produce any crops to sell.

Elderly respondents agreed that periods of surface water shortages have become more prevalent. However younger residents may not perceive this because they do not directly rely on water resources to maintain their livelihoods. The community has experienced some very dry conditions. Between 1915 and 2003 there have been 16 years of drought conditions (30-60mm of precipitation) and 11 years of extreme drought conditions in the ERB (less than 30 mm) (Fiebig-Wittmaack and Perez, 2005b).

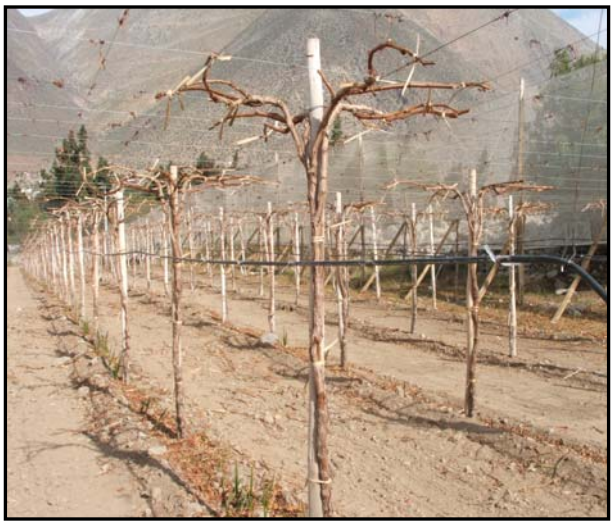

Figure 5.6. Drip irrigation system used the commercial vineyards.

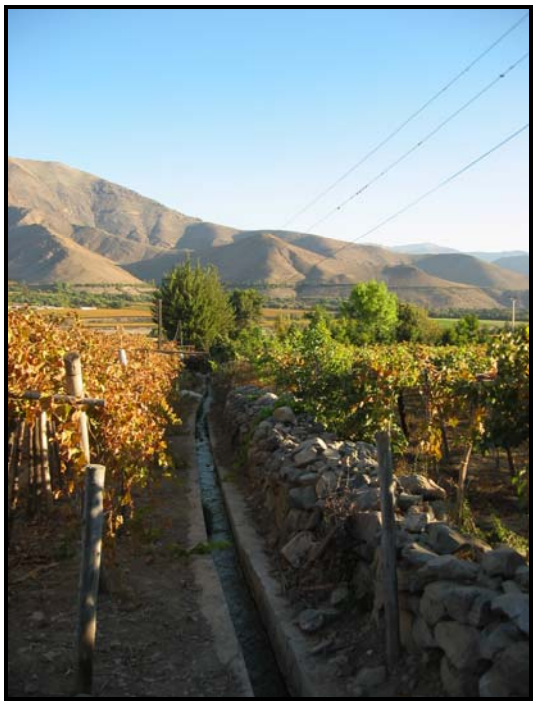

Figure 5.7. Cement lined canal in a commercial vineyard to minimize water loss.

5.1.5 Surface Water Management

Surface water management was identified by the agricultural companies and to a lesser degree, small farmers, as being problematic. It was a concern because water users do not always receive their entitled water amounts (based on how many water rights they own) on the appointed day or time. As one small farmer mentioned "sometimes there is water [in Canal Diaguitas] on your day, and sometimes it is late". This can result in some water users receiving more, or less than their prearranged amounts and water going unexploited.

As discussed in Chapter 3, the water distribution schedule is conditional on how many water rights each user has and is administered by the JDV and either a *comunidad de*

agua or *asociacion de canalistas*. The canals are diverted to different water users by the President of the particular canal. This is an unpaid position, elected by the water users of the canal and is accountable to the Junta de Vigilancia de Rio Elqui.

According to an agricultural company, the schedule is not always adhered to, which could threaten their production. The agricultural companies are unsatisfied with the management and would prefer a more professional and reliable distribution system. They complained that it can be difficult to locate the president of the canal to change the gates to receive their water. However, small farmers were not as bothered by the informal nature of management, most likely because their livelihoods do not rely on production from their small farms. Furthermore, some users take more water (intentionally and unintentionally) than their allotted amounts. The researcher observed non-water rights owners using water from a canal to water plants in the *población*. This leads to irrigators at the end of the canal not always receiving their full amount of water. Although a water user at the end of the canal may be paying for several hours of water to run through their property, the volume of water at times can much lower in the canal due to previous users taking more than their entitled amount. There is no monitoring of how much users take as it passes through their property. There is a camping facility at the end of one of the canals and the owner was unsatisfied with this situation because she is not receiving her entitled amount of water that she requires to maintain the facility and plants. Indeed there is concern from a few groups in the community that the regulation of water distribution in the community is ineffective and as some water users are not receiving their allocating portions.

5.1.6 Additional Community Exposures

While water-related exposures were identified, the majority of respondents were most pre-occupied with problematic conditions and changes due to the arrival of the agricultural companies. Many of these exposures are relevant with respect to potential future vulnerability in light of climate change. In addition, they are important to include as strategies to decrease vulnerability consequently need to be rooted in an understanding of how people currently sustain their livelihoods (occupancy characteristics) (Scoones, 1998). Some of the raised concerns with respect to the community's social dynamics and identity are discussed as these situations have the potential to hinder the community's adaptive capacity.

Ideal climate and international demand for grapes and other fruits, combined with Chile's export-oriented economic strategies has brought multi-national agricultural firms, such as Del Monte to Diaguitas. The arrival of the companies has created many employment opportunities; however they have also brought several changes and problems to the community. As one Diaguitas resident exclaimed, "then arrived the hand of the rich man and everything changed."

Residents have become less dependent on their own agricultural production and dependency on employment (wage labour) has increased. As one regional institution representative admitted, "the small farmer really doesn't have a possibility". This is true for many residents in Diaguitas. Small farmers do not have the ability to compete with the low super market prices. Since more people are now working in the commercial

vineyards they no longer have time to grow their own crops. Even those that have some land often do not grow anything because it is associated with poverty. Nearly the entire community is now dependent on an agricultural company to maintain their livelihood. Residents (students included) agree that there are no other employment opportunities; there are no other industries or services in the community or near by. Furthermore, education levels are very low among the adults and most young adults have only ever worked in grapes and agriculture. As one resident proclaimed, "the one that does not work in grape production is lost".

Diaguitas has experienced a steady seasonal influx of migrant workers. Some workers chose to settle permanently while others are working on a contract for an out-sourcing company. Some of the agricultural companies use out-sourcing companies to find workers that will work for less money from outside the community. This migration has created a social tension and community segregation between the original residents and the newcomers. The newcomers to the community are blamed for bringing problems such as dirtiness, drugs, robberies and alcoholism to the community. Residents complain that Diaguitas is much dirtier and garbage is piling up along the river bank. There is a strong concern that the community's identity will be lost. "We have been invaded by the people that have arrived" one resident said. Another resident believed that, "it is them that ought to adapt to the customs of the people of Diaguitas".

The increase in population has put a strain on the sewage system in the *población*. It has been difficult to collect the fee from the residents to have the septic tank emptied. The

septic tank that the *población* uses requires to be emptied every six to eight months. Each household is required to pay a monthly fee of $500 pesos (about one Canadian dollar). However, many residents do not pay. Residents that do not pay tend to be temporary workers and they say that they do not have extra money to pay when they are not working. The problem appears to be that there is no organization or person in charge of the sewage system. There is no accountability for residents to pay the fee. When it is not emptied the septic tank overflows and contaminates the *población*. There are concerns that the sewage will contaminate the drinking water.

Positions are typically seasonal, leaving locals jobless for several months of the year. Seasonal workers have relatively low incomes and consequently have problems with respect to paying bills, including potable water and sewage removal. Nowadays both men and women both work in the grape industry. Seasonal work as led to men leaving the community for months at a time to work in other regions or *comunas*.

A dominant and consistent concern of the respondents was the use of pesticides and chemicals by the agricultural companies. Locals blame pesticides for the disappearance of birds and fish in the area. Many complained that it can be difficult to breathe and children have been sick after pesticides have been applied. Respondents are fearful the toxins may contaminate the drinking water.

5.2 Current Adaptation Strategies

"*Here in Chile we adapt to everything*" – Resident of Diaguitas

This section presents the adaptations undertaken by the community and institutions to moderate the exposures identified by the community. Of the problematic conditions indicated during the fieldwork, several adaptation strategies are currently in place, varying in effectiveness. In general, the adaptations are reactionary. They tend not to address the source of the problem but rather provide 'band-aid' solutions. Therefore, some of the adaptations are potentially less capable of eliminating harm or coping with the problematic conditions. Table 5.1 summarizes the current adaptation strategies by the community and institutions.

Exposures	Institutions	Community
Intense Rainfall	▪ The Municipal Emergency Committee distributes a bulletin and broadcasts radio announcements reminding residents how to prepare for the winter/rain season.	▪ Residents reinforce their doors, roofs and windows. ▪ Residents buy extra food and batteries.
Mudslides	▪ The DOH constructed two artificial channels for debris/water to descend away from the community. ▪ The DOH constructed pool-like structures to collect debris/water that descends down the hills. ▪ 'Shacks' were provided by the government to those that lost their homes.	▪ Members of the community attempted to form a 'Community Emergency Committee' after the 1997 mudslide. It no longer exists. ▪ The majority of residents identified a strong spontaneous solidarity to help each other in times of emergency.
Slope Instability	▪ Nothing	▪ Nothing

Surface Water Shortages	▪ The Junta de Vigilancia and/or the president of the canal are able to diminish the intake of the canals. ▪ In drought emergencies the DGA is able to reduce all water use and seize water rights under orders of the President of Chile. ▪ Public funds are available by application to improve irrigation efficiency.	▪Goat herders migrate to areas with more vegetation. ▪ An agricultural company has water rights on two canals, one for daily and the other for emergency. ▪ Agricultural companies in the ERB use highly efficient irrigation systems.
Potable Water Accessibility	▪ The APR does not shut off residents' water right away, as there are months when people are jobless and unable to pay their bill. The APR gives these residents a few extra months to pay their bill. ▪ Subsidies are available from the government to single mothers to pay for potable water. ▪ Nothing has been done to address high summer demand.	▪ Residents keep barrels full of water for times when water is shut off. ▪ Couples may not marry in order to receive the subsidies from the government.
Surface Water Management	▪ Nothing	▪ An agricultural company sends an employee to check that canals are flowing on schedule.
Seasonal Employment	▪ Nothing	▪ Men will leave the community to find work. ▪ Women are working for wages outside of the home.
Pesticide Use	▪ Nothing	▪ An agreement was made between the school and surrounding agricultural company not to apply chemicals during the school day.
Sewage System in the Población	▪ Nothing	▪ The población has started an 'Improvement Committee' to deal with the problem. They are in negotiations with the Municipality and the APR to find an institution to take responsibility for the service and enforce payments.

Table 5.1. Summary of community and institution adaptations

Intense Rain and Mudslides

At the regional level, there are several adaptations taking place to help Diaguitas prepare for and cope with intense rainfall and mudslides. For example, the director of the regional emergency office (OREMI) found that using the internet has helped with quicker communication between other institutions at the regional and national level. He receives information and alerts daily with respect to potential risky situations in the region from the national emergency office. He is also able to check weather and seismologic activity daily on the internet and send out a warning to potentially risky areas. He believes that this technology has minimized the time taken to identify a potential hazard and relay this information to the people at risk. Therefore people may have more time to prepare for the event. In the extreme event of housing being destroyed, the region and municipality have provided shacks to those in need.

The DOH constructed several structures to lessen the impact of the heavy rains and potential mudslides. Pool-like structures were constructed to collect descending debris. They have been effective by retaining water and debris but locals were concerned because they were almost full. The pools have to be emptied or new ones created or the community could be in danger. Currently no one is taking responsibility for the structures. Two artificial channels were also constructed to divert water and debris away from the community and school and down to the river (Figure 5.9). Parts of the channels are lined with cement, but for the most part they are simply dug into the sandy soil. These structures were deemed to be a waste of money and time by residents and some employees of the DOH. Respondents agreed that they are not large enough support the

large flows and the walls of the channels will be destroyed. These channels were built after the 2004 mudslide and have not yet been tested.

Figure 5.9. A channel constructed by the DOH to divert water and debris.

Prior to the beginning of the winter/rainy season, the Municipal Emergency Committee distributes bulletins to households and conducts radio announcements to disseminate information on preparing for heavy rains. The director of the committee thought that twenty years ago people were not prepared for the rainy season, but since they have started to educate people on how to prepare for the hazardous conditions there has been less damage. The bulletin and announcements remind residents to reinforce their roofs, windows and doors; remove debris from the yard; clean the canals; have a supply of food, water, batteries, a first aid kit and flashlight. It also encourages people to be supportive and to help neighbours.

At the community level, Diaguitas created a Community Emergency Committee in 1997. This was in response to a catastrophic year. In 1997 the ERB experienced a prolonged period of surface water shortage, an earthquake, and heavy rains followed by a mudslide. Diaguitas wanted to be better organized and prepared to respond to future emergencies. The committee no longer exists. Past members indicated that due to a lack of resources (money, equipment) the committee could not function properly. Although there may not be an organized committee to help during emergencies, residents report a strong commitment to helping each other in times of need. Some residents identified strong solidarity and spontaneous reaction in times of emergency. After the events of 1997 many residents that lived up higher on hill, a very risky area, moved down to the *población*.

At the household level, when residents know there is the possibility of rain, they prepare their homes. Residents reinforce their homes (windows, roofs and doors) to better withstand the heavy precipitation and potential associated impacts. They also buy extra food and batteries before the rains begin. The canals are closed by the canal presidents to avoid overflowing and breaking the walls of the canals.

Surface Water Shortages

Living in the ERB Diaguitas has always had to cope with surface water shortages and there are several adaptations used to deal with this condition. For example, in times of water scarcity goat herders will migrate to the coast where there is generally more moisture and precipitation to support vegetation. However, this is costly for herders

because often they have to rent a truck to transport their herd. If the herders do not migrate they risk losing many goats and their milk production will be very low.

The agricultural companies in the ERB use highly efficient irrigation systems to increase their coping ability during times of water scarcity. Companies use drip irrigation systems which are approximately 80-90% efficient while traditional furrow irrigation is only 45%. The large scale operations in addition to a few small farmers use reservoirs to store water to use at a later time. One agricultural company has water rights on two canals, one of which is primarily kept for emergency use.

There are public funds available for farmers to apply for to improve the efficiency of their irrigation system. Improvements could include cementing a portion of the canal, covering the canal, making a small reservoir and/or upgrading from furrow irrigation. Farmers must apply for these funds. If selected and when the project is completed and inspected, the farmer will be refunded for 75% of the incurred costs. The public sector institutions interviewed realized that small farmers require assistance in order to optimize their irrigation systems as banks will not assist them as they are seen as too 'risky'. However, it is very difficult for small farmers to access these funds. Farmers must travel to La Serena to apply, pay a non-refundable application fee and complete a computerized application form. This is beyond the capacity of many, if not most small farmers, as it requires time, money and skills that many do not have. Consequently no farmer in the community has taken advantage of this program and made improvements.

During times of water shortages, it is up to the discretion of the JDV or the President of the canal to lower the main canal gate and reduce the intake into the canal. This forces farmers to use less water. In the case of small farmers they will only irrigate their plants to keep them alive. This is often not enough to produce any fruit. During official drought emergencies, the DGA has the authority to call for a reduction in all private water use and seize water rights with compensation to water-rights holders (Hearne and Easter, 1997). Official drought zones are declared by the President of Chile.

Access to Potable Water

Lack of access to potable water is due to non-payment of bills in some cases, and insufficient supply in others. In the case of non-payment, the APR is sympathetic and lenient to those who can not always make their payments. The APR often gives households several months to pay their bill before shutting the water off. The government also provides subsidies to single mothers to help pay for potable water. As the government provides additional subsidies to single mothers it has led to some couples not marrying in order to be eligible for these funds. One retired woman that was interviewed opened a small store and French fry stand to help pay for her family's bills. As a pensioner with a large family she finds it difficult to pay the water bill every month.

In the case of lack of potable water due to insufficient supply, the community has become accustomed to this situation, especially in the summer. Community members adapt by keeping barrels full of water. The companies have not been able to adapt to this problem. Often the packing department is forced to close down until the water is turned back on.

Surface Water Management

The only groups in the community taking adaptive measures towards surface water management for the purpose of irrigation are the agricultural companies. To ensure that water is flowing in the appropriate canal at the correct time, an agricultural company sends a paid employee to check the canal gate. If is the water is not flowing correctly the employee must locate the president of the canal to switch the gate.

Additional Community Exposures

Some adaptation measures have been put in place to deal with the additional stresses faced by the community. All of these adaptations have been done by the community. For example, there has been an agreement made between the agricultural company that surrounds the school and the school with respect to when to spray pesticides. The company has agreed not to spray chemicals during the school day and some chemicals they will only apply on Saturdays so the smell has dissipated by Monday.

A man from the *población* has started a *Comité de Adelanto* (improvement committee). These committees are typical in rural communities to help organize and initiate projects that will improve the community. He began a *Comité de Adelanto* in the *población* because they are dealing with different situations and conditions than the rest of Diaguitas, like the septic tank and sewage problem. The committee has been in negotiations with the APR and the municipality to have one of these institutions take responsibility for the service and enforce payments. To date there has been advancements.

To compensate for the lack of full-time employment, some men leave the community for months at a time to work in other regions. Women are working for the companies to supplement the household income. Children are left alone or sometimes they also work for the companies. There have been a few attempts by individuals or small groups of original or permanent residents in the community to promote tourism and to diversify the community's economy and employment. For example, one woman started a small museum. One couple rents rooms to visitors. There is one small campground and community members have painted traditional symbols in the community. However, very few visitors have come to Diaguitas regardless of these efforts.

5.3 Summary and Discussion of Current Vulnerability

Residents of Diaguitas identified several exposures related to water resources that stress the community. A dominant concern and risk to the community was rainfall abundance and intensity as this tends to trigger mudslides. Mudslides are also instigated by the steep and unstable slopes of Mamalluca. Both the community and institutions have found ways to better cope with these conditions such as public education and the construction of physical structures. Surface water shortages were found to be problematic for some sectors of the community. Goat herders are particularly affected by prolonged dry periods, while the majority of locals, who no longer directly rely on their own agricultural production, are not significantly affected. The agricultural companies use highly efficient irrigation and water storage systems and have yet to be affected. One company also purchased extra water rights in case of extremely dry conditions. Potable water access has been problematic for the community and the companies during the summer months.

This is due to a combination of high demand and slower recharge and supply of the aquifer. Again, there have been adaptations to help cope with lack of accessibility by the community and institutions. Surface water management was problematic for the companies and for very few residents. The water distribution schedule is often not adhered to, regulated or supervised. This does not affect the majority of community members as they no longer rely on their own agricultural production to sustain their livelihood. In general, the adaptations to the exposures were reactionary and spontaneous and do not address the cause of the stress. For example, with respect to mudslides, time and money perhaps would be better spent assessing slope stability.

The water related exposures were important to the community, but they had additional, non-water related stresses. Main concerns were with respect to the exposures incurred by the arrival of the agricultural companies. Residents were very concerned about the chemicals used by the companies. They see a decrease in fish and birds in the community. Children are coming home with headaches. Sometimes residents find it difficult to breathe. Community members are also concerned about the changes that have occurred to their livelihoods since the arrival of the agricultural companies. The community now is dependent on a single industry for low-wage seasonal employment. The social tensions that have been created since the arrival of the companies with the influx of migrant workers have begun to deteriorate the kinship that the community once remembers. It is the social tension that has caused segregation within the community. This has become a hindrance in the community's ability to organize, for example, to promote addition industries in the community, or adapt to certain exposures. This is

currently problematic and is likely to be a challenge to adapt and take advantage of opportunities in the future. Although these exposures are not directly related to current water related stresses, they are relevant with respect to understanding the current occupance characteristics and sensitivities of the community and the future vulnerability of the community.

The community could not identify many adaptive strategies that were implemented by an institution. In fact, many community members were not familiar with the Water Code, the water market or municipal and regional organizations within the water sector. Many community members were unaware of the public funds available to improve their irrigation systems. Distrust exists between the community and the municipality. Community members complain that the municipality holds community meetings with the residents to listen to their concerns; however no action to resolve the problems in the community is ever initiated.

CHAPTER 6: FUTURE VULNERABILITY AND CLIMATE CHANGE

The community of Diaguitas identified several exposures related to water resources that are problematic. In the future, under climate change, these conditions are likely to be exacerbated. This chapter exmaines the current identified exposures by the community in light of climate change. The capacity of the community and institutions to deal with these new conditions is discussed. Future adaptive capacity of the community and institutions is discussed with respect to the identified constraints of current adaptation in addition to information gathered on potential changes in society.

6.1 Future Exposure and Climate Change

This section examines potential future changes in conditions identified by the community as problematic. Predicted future climatic conditions that were not identified as currently challenging, but which have the potential to be problematic in the future, are discussed. Potential non-climate related changes are briefly addressed, such as the fruit market. The information used to examine future exposures were gathered through documents and scenarios prepared by the climate science community and personal communication and documents prepared by IACC physical scientists. Table 6.1 provides a summary of future climatic conditions.

El Niño	The frequency of El Niño is likely to increase as a result of climate change (IPCC, 2001). Since the mid-1970s, the El Niño phenomenon has been more frequent and more persistent (Francis and Hengeveld, 1998).
Rainfall	A decrease in average precipitation is predicted. In the past 100years precipitation has decrease by 50% (Cepeda et al, 2004).
Drought Conditions	Climate change may result in more frequent and prolonged droughts (Downing, 1992; IPCC, 2001; Cepeda et al., 2004).
Mudslides	An increase in El Niño combined with increase land use and the physical landscape has the potential to cause more mudslides
Temperature	Climate predictions (2XCO2) indicate that the north-central area of Chile can expect an increase in temperature (IPCC, 2001), approximately 2-3 degrees during the second decade of the 21st century (Cepeda et al., 2004). Higher temperatures, hence higher crop evaporative demand, mean that the general tendency would be towards an increase in irrigation demands (IPCC, 2001).
River Discharge	Andean glaciers are predicted to recede (IPCC, 2001; personal communication Melitta Fiebig, 2005). Increase in the short/medium term due to increased snowfall, the melting of snow and glacier reserves as a consequence of the rising temperature (Cepeda et al., 2004). In the long-term, as the reserves diminish and volume of melt decreases, flows will no longer be supported and will decline to below present levels (IPCC, 2001).

Table 6.1. Summary of potential future climatic conditions.

Conditions leading to mudslides may worsen in the future. Global climate change may result in more frequent and prolonged periods of drought for the ERB (Downing, 1992; IPCC, 2001; Cepeda et al., 2004). This can be attributed to the likely increase in frequency of El Niño as a consequence of climate change (IPCC, 2001). Since the mid-1970s, El Niño has become both more frequent and more persistent (Francis and Hengeveld, 1998).

Although El Niño brings periods of abundant and intense rainfall, average precipitation has decreased in the Elqui River Basin by approximately 50% over the past 100 years (refer to figure 5.2) (Holland and Karl, 2001; Cepeda et al., 2004). Figure 5.2 illustrates the strong variability of rainfall and decrease in precipitation over the past century. This trend is expected to continue. Scenarios with a doubling of carbon dioxide concentration in the atmosphere relative to 1990 levels indicate a 20% to 25% rainfall decrease in the fourth region (Downing, 1992; CONAMA, 1999; Cepeda et al., 2004). As goat herders are currently affected by surface water scarcity, a further reduction in average precipitation may force the remaining goat herders to ultimately migrate out of the region or to stop herding.

Neither community residents nor representatives of water related institutions seemed concerned about the possibility of decreased river discharge in the future. The ERB is fed by snowmelt and some glacier melt from El Tapado glacier, in the Chilean Andes. El Tapado glacier only provides a net annual discharge of 0.034 cubic meters per second (Ginot et al., 2006; personal communication, Zavala, H., 2006). This is a nominal amount compared to the average annual discharge of the Elqui River, approximately 7 cubic meters per second. Under climate change it is predicted that glaciers in this region will decrease (IPCC, 2001; personal communication, Fiebig, M., 2005). However a recent study suggests that although Andean glaciers are typically receding, El Tapado is not (Ginot et al., 2006).

In general, glaciers in South America have receded dramatically in the past decades and many of them have disappeared (IPCC, 2001). In the Peruvian Andes, 18 glaciers have shown a reduction of more than 20% since 1968. Significant reductions have also occurred in Southern Chile and Argentina (IPCC, 2001). Therefore, although there is significant glacier recession in South America, the ERB has not yet been affected. However, as temperatures rise in the region, El Tapado may begin to recede. A warming of 2°C to 3°C is expected by the second decade of the 21st century (Downing., 1992; Cepeda et al., 2004).

A rise in temperature may generate complex changes in the water cycle. Warming in the high mountains could lead to the disappearance of a significant amount of snow and glacier recession. Increased temperatures also mean that less precipitation may fall as snow. Loss of snow and the recession of El Tapado will impact runoff and water supply. From the present to medium term, river discharge is expected to increase (IPCC, 2001; Cepeda et al., 2004). Currently, snowfall in the high mountains is increasing (refer to figure 3.3), sustaining higher discharge levels in the ERB. If temperatures rise, as is predicated, precipitation will fall as liquid rather than solid, accumulated snow will melt and El Tapado will begin to recede. As surface water resources increase, this could foster further agricultural expansion. However, in the long term, depletion of these reserves coupled with drought could result in an overall reduction of the Elqui's flow to the point where current and future production needs cannot be met. Figure 6.1 illustrates some of the potential effects in the medium term as a result of an expected increase in temperature.

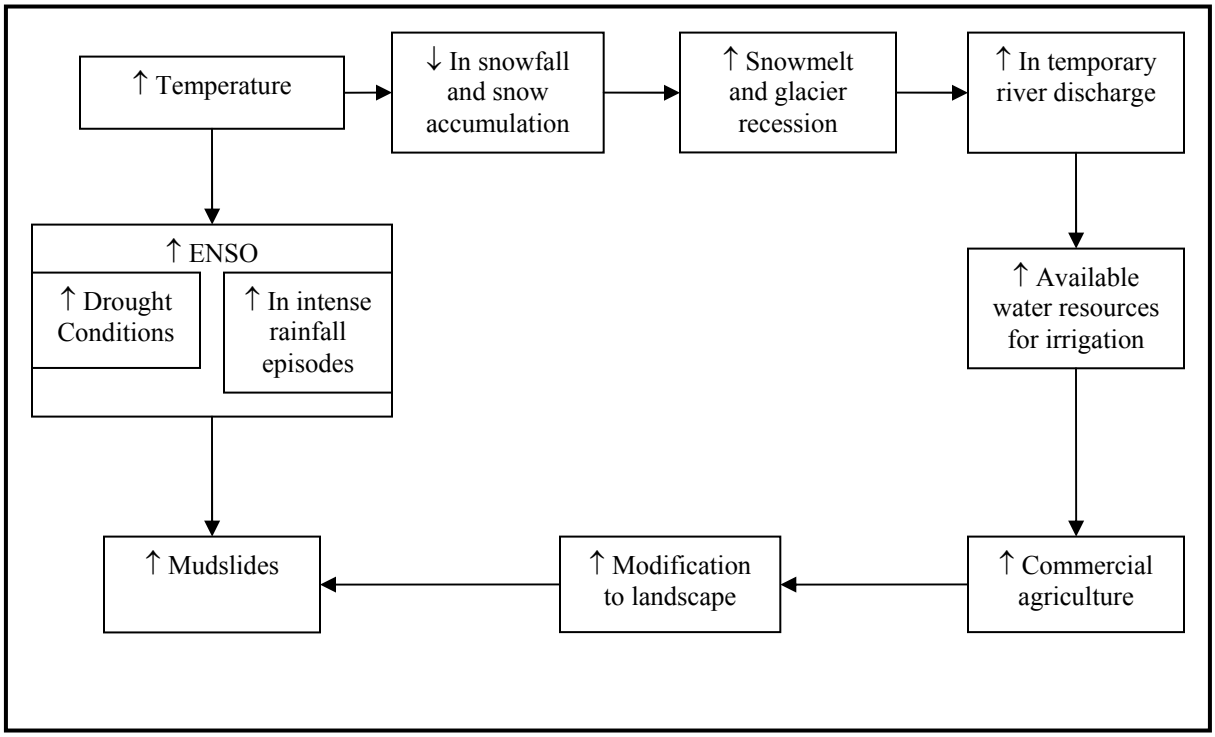

Figure 6.1. Mid-term possibilities in Diaguitas as a result of climate change.

Fieldwork did not indicate that temperature was a concern for agricultural companies, institutions or community members. However, Downing (1992) notes that 7% more irrigation water would be required for each degree of temperature increase. If temperatures rise to their predicted values, this could mean an increase of 14%-21% in surface water required for irrigation. One agricultural company mentioned that if their irrigation supply was reduced by 20% they would only be able to keep the vines alive, but not produce grapes. Downing (1992) noted that grapes can expect a decrease in yield due to an increase in temperature. However, the increase in river discharge, hence available water for irrigation in the medium term could lessen the effects of higher temperatures on the crops.

Currently, there is no indication that the export table grape industry is slowing down. As the field season was coming to an end, more land was being prepared for vineyards (Figure 6.3). Intensified land-use change combined with the potential increase of El Niño suggests that mudslides may be even more likely. Given the current production with future expansion, surface water reserves may not be able to adequately supply the industry. Similarly, higher seasonal population to meet labour demands places increasingly higher pressure on potable water supplies. Potential tourism may also strain the current potable water system. Currently there is very little research and information with respect to the groundwater system and the interaction between groundwater and surface, precipitation and groundwater recharge in the ERB. There are no studies with respect to the alterations in the groundwater system in light of climate change. However, given a further decrease in precipitation, it is reasonable to say that there would be less aquifer recharge, thus less supply.

Figure 6.2. Land being leveled for commercial vineyards in Diaguitas.

Climate change, particularly if it includes increased drought risk, significantly accelerates the point at which economic expansion in this area becomes constrained by water resources (Downing, 1992). Agricultural companies come to the valley because of favourable production climate but are reliant on surface water for irrigation. Agriculture is a sector that is very susceptible to climate change. Countries, regions, communities with a large portion of the economy in agriculture face a larger exposure to climate change (IPCC, 2001). If future water shortages threaten the viability of the main employers in the ERB, livelihoods are at risk. In addition, settlements with little economic diversification and thus a high percentage of incomes deriving from climate-sensitive primary resource industry such as agriculture, are more vulnerable than more diversified settlements (IPCC, 2001). Fluctuations in international market demand or national economic strategies could also cause agriculture production to seize. This is compounded by the possibility of agricultural companies using non-local labour in the future. A representative of the main employers in Diaguitas indicated that next season his will be using an outsourcing company to hire new employees rather than hiring locals in order to find more productive employees for less money. The combination of the possible future climate, hydrologic and employment changes create a vulnerable situation for the people of Diaguitas.

6.2 Future Adaptive Capacity

How people have adapted in the past and their current ability to cope will be reflected in their potential to cope in the future. This applies to both the community and institutions. Several factors were identified that are currently constraining the adaptive capacity of

Diaguitas and institutions. If not addressed will most likely carry into to future. Currently the community and institutions are adapting to some exposures of the community. However, under climate change these exposures are likely to be intensified.

Respondents in the community and municipal and regional institutions shared a similar attitude with respect to the future. As one respondent mentioned "it is part of our culture not to worry when things are fine". There appeared to be a collective lack of awareness and concern for possible future hazards and conditions. For example, most respondents did not consider that the river level could or would ever change. They recognize that the river level fluctuates throughout the year. However, most did not believe that the average river flow could diminish because the mountains will always provide water. In addition, some community members believe that a severe drought would not occur again. Some believed that another mudslide would not be possible. It was very common for community residents and many of the institutions to only have short-term plans and live day to day. They often did not concern themselves with what could happen in the future, even if they had experienced a similar problematic condition in the past. This is especially apparent with respect to their physical environment. As previously mentioned, the majority of members of the community no longer directly rely on the physical environment to maintain their livelihoods. These respondents were most concerned with social conditions, such as employment and crime in the community. There was little concern about changes in the climate and water resources and the potential implication for the future.

Adaptive strategies in the community and institutions are formulated within the confines of available information and resources. At the community level respondents were unfamiliar with the predictions and scenarios of global climate change. Most of the respondents (community and institutions) were not familiar with the term climate change. At the regional institutional and large-scale agricultural level, few respondents acknowledged climate change as a risk or concern to resources and/or industry to take into consideration. For example, the JDV stated that they do not take future climate variability and/or change into their plans. A representative of the regional emergency department (OREMI) had never heard of climate change and an agricultural company mentioned that they do not take any precautions with respect to future climate conditions.

A lack of dissemination of information, planning and awareness of future conditions pertinent and potentially hazardous to the economy and livelihoods of the valley was identified. If this persists, industry and institutions run the risk of not implementing anticipatory adaptations and/or reacting too late. Currently institutions plan predominantly for the short-term and implement mostly reactionary measures that do not address the source of the problem. For example, the DOH constructed artificial channels to deter water and debris to descend down to the community. This adaptation occurred after the second major mudslide in the last 10 years. Employees of the DOH and the community agree that the channels are too small. Perhaps there is an opportunity here to address the cause of the mudslides, study the slope's instability, in order to prevent further mudslides.

Nearly all institutions identified and complained of a lack of human and financial resources as a major constraint on their capacity. A representative of the DOH went as far as saying that "there is no institutional capacity". Another representative from the DOH said that there was not money available for preventative projects. Employees admitted that tasks (e.g., checking water and land rights) are often not completed due to lack of resources. There is also minimal communication horizontally and vertically within and between the various institutions at the various administrative levels (this was often referred to 'Chilean bureaucracy'). For example, an employee the representative of OREMI mentioned that there should be a person in charge of emergencies at the municipal level. In fact, that position has existed for many years. Another notable trend is the very high turnover rate (a few years) of employees at the municipal and regional institutions. This has the potential to affect decision-making and capacity due to lack of knowledge and experience in the position.

In the community of Diaguitas, organization, participation, motivation and leadership is minimal. Few people see the need, importance or power of community organization. Factors that may contribute to this are the dismantlement of community organizations during the coup and distrust amongst community members and the speculation that when people participate they have an alternative motive (e.g., stealing money). Furthermore, existing kinship ties are weakening with an influx of migrant workers. The social tension and community segregation was identified as a key constraint on community cohesion. If the community had greater kinship and less social tension, the community could possibly create opportunities to expand economic activities by pooling resources. This would

allow a coordinated approach for applying for funds to make improvements to the canals (increase efficiency of irrigation), maintain the sewage system (currently there is no one in charge of the sewage system) and make improvements to the community to make it more attractive for tourism. Tourism strategies could be developed and marketed. Already, ideas to promote more rural tourism including horseback riding have been circulating amongst some residents. Strategies such as this would serve to diversify the economic base and provide more secure livelihoods in order to better respond to changes outside their control.

CHAPTER 7: CONCLUSION

This chapter provides a summary of the research and discusses the theoretical and practical contributions, and future research opportunities.

7.1 Summary of Research

The research aimed to understand the nature of vulnerability in the dryland community of Diaguitas, situated in the ERB of Chile. This was achieved by using the vulnerability approach which seeks to characterize the current relevant problematic conditions faced by the community (exposures) with respect to water resources; the ability to adapt to such conditions with an interest in the role of institutions; and how these conditions may change in the future in light of climate change. The summary of the research is divided into the four research objectives.

Objective 1: To understand and document current exposures, i.e., the problematic conditions or stresses related to water resources that people have dealt with and/or are currently dealing with in their lives.

The current community level vulnerabilities in Diaguitas are a reflection of multiple influences and forces. Physical environment, international demand and national economic strategies play a large role with respect to the current situations in Diaguitas and the ERB.

Diaguitas has experienced two mudslides in the last decade. The mudslides are caused by a combination of conditions, such as; prolonged dry periods followed by intense

rainfall, slope instability and possibly the change in land-use by the increase in commercial vineyards. Throughout the community there is a lack of accessibility to potable water at some times of the year. This is due to a combination of seasonal insufficient potable water to supply the higher seasonal population. Potable water is frequently shut off by the APR during these times due to high demand in the summer months and slower recharge. In addition, there are households that can not afford potable water year round. For seasonal workers and pensioners it is difficult for them to pay their water bill every month, resulting in their water being shut off periodically. Surface water shortages and prolonged dry periods were not identified as an exposure by the majority of the community. However, goat herders, the minority and most impoverished group in the community, are particularly affected. Insufficient vegetation growth forces goat herders to migrate which can be very expensive. Surface water management was also recognized as a concern by another minority in the community- the agricultural companies. At times insufficient water is distributed to some users, the water distribution schedule is not adhered to and/or water is taken by non-users.

Even though this dryland community has been challenged by mudslides, climate variability and water resource availability, the community (agri-business included) was more pre-occupied by exposures affecting their daily lives. These exposures were related to employment, health and social relations within the community. Due to the employment opportunities with the agricultural companies, nearly all residents fully depend on the companies for employment to maintain their livelihoods. There are no other opportunities in the community. Residents are dependent on a single industry. As

the positions are temporary and relatively low paying, residents often have difficulty paying their potable water and sewage removal bills. This results in water being turned off and at times the sewage system overflows. Employment opportunities have attracted workers to the community. This has created a tension and physical segregation between the original residents and the new residents. Some see an increase in crime, drug and alcohol use. These two groups do not communicate nor attend community meetings and events together.

Objective 2: To assess the current adaptive strategies and capacities, i.e., the ways in which the community, including institutions, have coped with the current exposures.

Although it is a dryland area, few exposures were identified and few adaptive strategies in place to deal with them. For the most part, the adaptations are reactionary and typically often do not deal with the source of the problem. However with conditions that the community has become accustomed to, such as potable water being turned off or mudslides, residents prepare for these situations in advance. Other than the construction of structures to protect the community from mudslides, it was difficult for community members to identify adaptive strategies that were implemented by an institution. Perhaps this is due to several degrees of separation between individuals in a community and the regional (to a lesser degree municipal) institutions that have been involved in adaptive strategies. In addition, as the majority of residents no longer directly depend on surface water, the role of water-related institutions is negligible. There is very little involvement and interaction between the community and institutions.

However, with respect to the agri-businesses in the community, the role of institutions had greater importance. For example, one company bought extra water rights from a second canal in case of emergencies, another company sends an employee to make sure that water is flowing the in the canals and in the case of potable water shortages, production ceases.

Objective 3: To identify potential future exposures, i.e., the likelihood of changes in conditions, with a focus of water resources, pertinent to the community in the future.

Although more research needs to occur in this region with respect to potential changes in the ERB in light of climate change, several trends were identified. An increase in frequency of El Niño could instigate more mudslides due to the impact of the intense and abundant rainfall following the prolonged dry periods of La Niña. If land use change also continues, mudslides could also be intensified. An increase in temperature will have several impacts on the water cycle. In the short to medium term river discharge is likely to increase, however has snow levels and the glacier melt and resources diminish, river discharge could decrease. How the commercial agricultural sector and water institutions deal with the short, medium and long-term changes in water resources is speculative.

Objective 4: To assess future adaptive capacity and adaptation strategies, i.e., the manner and degree to which the community, including institutions, will be able to adapt to the future exposures.

There are current constraints to adaptation at the community and institutional levels that could impede the capacity of Diaguitas and institutions to respond to future exposures in light of climate change. The main constraints include; a lack of awareness and/or

concern for the future, short-term planning, reactive responses and adaptive strategies rather than anticipatory and dealing with the cause of the exposures, limited information and lack of information sharing and lack of financial and human resources. For example, although this is a dryland area with an economy nearly completely dependent on agriculture, the agri-businesses and institutions did not consider climate change as a current or future concern.

7.2 Research Contributions

This research provides both practical and conceptual contributions. A practical contribution is the application of the vulnerability approach as a framework to carry out a vulnerability assessment. This approach is relatively new in the field of climate change. In addition, the study provides an example of how to use the approach and the benefits of the approach in a community-level case study. The participatory nature of the approach allows researchers to identify the relevant concerns of the community and how they have dealt with the past and present conditions. As the respondents share their experiences and the researcher lives within the community and observes, the researcher can better understand the nature of the vulnerabilities of the community, embedded within a larger context, and relate those conditions to future changes in climate, environment, policy, market, etc. This study provides an example and insights into the application of the vulnerability for future studies.

A conceptual contribution is the advancement of the conceptualization and contextualization of vulnerability. Conceptually, this study emphasizes that vulnerability

is a function of both exposure to problematic or hazardous events and the ability to adapt to such conditions. It illustrated various adaptive strategies undertaken by various cohorts of the community. In addition, the role of institutions with respect to vulnerability and a determinant of adaptive capacity are emphasized.

This research provides documentation of the nature of vulnerability to climate stresses in a dryland community, illustrating a variety of exposures and adaptive strategies and capacity. This is important as people in semi-arid regions currently exhibit vulnerability to the consequences and challenges of existing climate variation which are only expected to be intensified (Ribot et al., 1996). However it is important to note that this study showed that this community in particular was pre-occupied with non-water related stresses that have created vulnerable daily conditions for the community. This study demonstrates that assuming a dryland area's vulnerabilities will be limited to water-related conditions is premature as this was not the case in Diaguitas.

Furthermore, this study provides baseline information with respect to the current exposures and adaptive capacity for further studies to take place or to be used in management and/or policy decision making.

7.3 Research Opportunities

Climate change will not occur in isolation of other social, economic and political changes in the community, ERB, region, country and internationally. It is important that climate change is addressed in future decision and policy making. There is an opportunity to

mainstream what has been learned about the vulnerability of Diaguitas and the ERB, the role of institutions and the effects of climate change into decision and policy making. However, for this to occur there is a need for further investigation into the implications of climate change on water resources in the ERB.

Currently there is very little data available with respect to the hydrology and climate of the ERB. There is a need for further research to take place with respect to the implications on water resources in dryland mountain regions caused by climate change. Further research also is required on the groundwater system in the ERB.

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APPENDIX A – INTERVIEW GUIDE

General Information

This part of the interview serves two purposes: it situates the person being interviewed in the larger picture with personal details (occupation, family and community status) which will allow for more appropriate questions later, and it aims to create a rapport, to allow the respondent to become comfortable.

- How long have you lived in Diaguitas/the ERB? Where else have you lived? Why did you come to Diaguitas/the ERB?
- What do you do for a living? Who lives in your household? What do they do for a living? Is _____ the only source of income for the household?
- Are you a member of local organization? Why/why not? Which ones? In what capacity?
- Do you grow any crops? Which canal do you use?

Exposures and Adaptive Capacity and Strategies

The purpose of this part of the interview is to document, from the respondent's point of view, conditions that are important to people, and why, and how those are dealt with (why, why not, how effective). Based on insights from general information questions about the respondent's life in the community, he/she is asked (open-ended) about what factors/conditions/changes affect his/her life and what stresses affect his/her livelihood and the community. While there are general questions, the interviewer strives to turn this into a conversation while following-up new topics as they arise. How, why, when etc. are key questions here.

- How would you describe Diaguitas? (people, environment)
- Have you noticed any changes in the community (for example: residents, employment, organizations, weather, environment, water)? When did they take place? Are they good or bad from the community? In what way?

- What are some problems/challenges that you/your family/the community have had to deal with in the past? Presently? Why are they a problem, when, in what why, what causes them? Are there areas of the community that are difficult/risky to live? Why?
- How have you/the community dealt with these problems? Was/is it effective? Why or why not? Do you receive assistance from anyone? Who (community members, community organization, municipality or region)? In what way? Is it helpful? Have things changed over time? Do you think that this situation could be handled better? How?

If the respondent did not mention water-related issues, potential probing questions could include:

- What canal are you a member of? Are you a member of the APR? What do you use the water for? Do you have the water you need to do everything you're currently doing? [if no] Why not? Is this/has this always been the case? When/why did things change?

For example, if "too little water" emerges as an exposure for a particular respondent, a follow-up could include:

- What do you mean by too little water (management or natural)? Does this occur often? When? What do you do in times of water shortage? Are there programs you can use?

Future Vulnerability

- What main challenges do you anticipate for your livelihood/the community in the future? Why these? How would these affect you? What might be done about them?
- What are your hopes for your children?
- How would you and the community be affected if:
    - The river level (available irrigation water) became 10%, 25%, 50% less than today?
    - The *lluvias locas* became more frequent?
    - There was less average annual rainfall?
    - An agricultural company left or required less employees?
- How would you deal with this change?