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A Case For Cooperation: How A Binational Agreement Between the U.S. and Mexico Can Alleviate the Rapid Drawdown of the Mesilla and the Hueco Aquifer

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A CASE FOR COOPERATION: HOW A BINATIONAL AGREEMENT BETWEEN THE U.S. AND MEXICO CAN ALLEVIATE THE RAPID DRAWDOWN OF THE MESILLA AND THE HUECO AQUIFER

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Dedication

This work is dedicated to my mother Sally. Without her support throughout my life, none of this could have been possible.

A CASE FOR COOPERATION: HOW A BINATIONAL AGREEMENT BETWEEN THE U.S. AND MEXICO CAN STOP THE GROUNDWATER DRAWDOWN OF THE MESILLA AND THE HUECO AQUIFER

by

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CHAPTER 1: WHY ARE WE HERE?

Ask yourself, where does my water come from? It is a question most people are unable to answer. In contrast, most people could quickly find out from the labels on packaging where their bread is made or their smart phone is built. This lack of awareness about where our water originates and how it gets to our homes and businesses is surprising considering how critical water is to living things. Human beings cannot survive for more than a few days without water but we can live for a month without food and at least a few weeks without our cellphones. More troublesome is that many people do not realize that water, which after all does fall from the sky, is not an eternally sustainable resource both as related to surface water and, more importantly, ground water. For a dry desert climate like that shared by Ciudad Juárez and El Paso, even a partial depletion of ground water could have serious economic and social impacts.

This thesis will address the topic of groundwater in the Ciudad Juárez and El Paso region and discuss the current state of ground water usage on the U.S., Mexico border. This will be achieved by delving into the literature that has been written on this subject, discussing the general hydrology of the region, exploring the policies of both nations affected by the area, introduce case studies from similar regions that are concerned about ground water usage and ultimately make policy recommendations that can best be implemented to avoid ground water depletion.

The water for El Paso and Ciudad Juárez comes from the Rio Grande River and two large bolsons (underground aquifers) that lay beneath the city. The bolsons provide roughly 50% of the water used by El Paso (including Fort Bliss) and nearly 100% of the water utilized by Ciudad Juárez. As stated by a report commissioned by the International Boundary Water Commission (IBWC); "forecasts predict the depletion of the recoverable freshwater reserves of these binational shared aquifers by the middle half of the 21st century" (IBWC, 1998: 3). This report, however, was generated in the late 1990's and only took into account increases in human activity and population growth. This report should have taken into account other variables such as climate

change and trends in water use in residential and agricultural applications. Since this aforementioned report was published, the Southwestern United States has gone through a period of unprecedented drought, undoubtedly due to climate change, which shows no signs of reversing. According to Stern "a rise in global temperature will have: severe and widespread impacts, major risks to global food production, and more extreme fluctuations in weather, including droughts, flooding and storms (Stern, 2006: 12) This climate change is having a noticeable effect of snowpack and temperature and it appears that "human activities are a major driver of this rapid change in our climate... particularly patterns of consumption and energy use, driven by consumer demand for higher standards of living" (Stern, 2006: 17). Between the two nations the "per capita water use has reduced by more than 25 percent over the last two decades – yet El Pasoans, on average, continue to use considerably more water than their Juarenze counterparts" (Turner, Hamlyn, Hernandez, 2003: 1). In fact, "the average Juarenzes uses less than 60 percent as much water as the average El Pasoan" (Turner, Hamlyn, Hernandez, 2003: 27).

Due to climate change and over use, "the Rio Grande/Rio Bravo River, on the border of the U.S. and Mexico, often fails to reach the Gulf of Mexico, its strength sapped by dams and irrigation works diverting water to farmers' fields and city water supplies" (World Wildlife Fund, 2007: 1). This dry spell has been titled the forgotten stretch because it is so dry. Without the Rio Bravo's flow coming from its headwaters in Mexico the Rio Grande would stop at this forgotten stretch. Luckily because of the Rio Bravo's flow the river is able to continue on to San Antonio and out into the Gulf of Mexico. Contrasting with this dry river bed, there used to be a strong flow of water through the river, it is clear that this flow is gone because of the humanities use of the existing resources is at an unsustainably high rate and must be managed more efficiently. The best answer to relieve this problem is more rain and higher river flows, but unfortunately the weather is not in our control and the leading trend we are seeing is lower rain falls and a diminished snow pack resulting in lower river flow. "Since the system is largely snow-fed, the effects of climate change on flows may be significant. In 2014, the Natural Resources Conservation Service

estimates that spring runoff in central New Mexico will be just 31 percent of historical average levels" (Center for Water Policy 2013: 2).

A more practical solution lies in how the existing water resources and pumping rates are managed, regulated and controlled. Currently there is very little regulation involving groundwater between the United States and Mexico; both nations' pumping and usage can go on relatively unchecked. This stands in contrast to surface water which has been regulated by water treaties in existence for over a century. These treaties between the United States and Mexico, although controversial and contentious at times, have created a peaceful exchange of resources between the two nations with room for growth. The relative success of surface water treaties contrasted with the uncontrolled usage of groundwater resources points to the inevitable need for a review of the existing policies and how they can be modified or updated to better accommodate these changing times.

Throughout this research thesis, I will conduct a policy analysis that focuses in on the scarcity of treaties and regulations regarding the ground water usage between the United States and Mexico in the Paso del Norte region (Ciudad Juárez and El Paso primarily). I will begin with an overview of the methods used to create this work followed by a review of current literature written on the subject. From this conceptual overview I will discuss aquifer formation and the hydrology of this region and other aquifers around the world, then move into the history of the border between the U.S. and Mexico and its constant focus on water. I will proceed to delve into the current policies that exist for the U.S. Federal Government, the Texas State Government, the New Mexican State Government and the Mexican Government. Moving away from the local perspective I will incorporate three case studies from areas that suffer from similar problems and discuss their methods of learning and adapting to the depleting water resources. The paper will then conclude with practical policy recommendations based on current treaties and minuets that could aid in saving the groundwater of the Rio Grande Basin (RGB).

METHODS:

The research in this paper will follow definitions set up by Blatter, Ingram and Doughman in their paper "Emerging Approaches to Comprehend Changing Global Contexts". These authors specify that their "focus is upon transboundary water, which includes border crossings of several types beyond those of political jurisdiction that the term usually implies" (Blatter, Ingram, Doughman 2001: 4). Having identified their focus, the authors go on to discuss their approach to thinking about transboundary conflicts and cooperation; they state that we must "think thoroughly about the inadequacies of existing approaches (and) propose a complementary usage of approaches combining inductive and deductive or hermeneutical and scientific approaches" (Blatter, Ingram, Doughman 2001: 4).

Similarly the research in this paper follows a comprehensive professional policy analysis format and includes case studies on similar areas of the world that can be compared to the issues faced by the El Paso / Ciudad Juárez region. Policy analysis is a way of tackling real world public problems in a scientific manner with the explicit goal of developing new approaches and recommendations to bring about change and solutions. The professional approach is simply a professional method used to "analyze policy alternatives for solving public problems" (Kraft, Furlong 2015: 3). Public problems as defined by Kraft and Furlong "refer to conditions the public widely perceives to be unacceptable and that therefore require intervention" (Kraft, Furlong 2015; 3). The first step towards achieving an effective policy analysis is the identification of the problem. This process "involves trying to answer the basic questions about the nature of the problem, its extent or magnitude, how it came about, its major causes, and why it is important to consider as a matter of public policy" (Kraft, Furlong 2015:144). To best define the problem of over-use of groundwater resources, I utilize reports from the IBWC, the two municipal water utilities, climate change data, and research from various publications. Though models of the groundwater table and measurements of water held in the bolsons are not 100% accurate and still need further scientific development, other areas of the problem are highly quantifiable and translate directly into water

problems facing the area. This includes the temperatures rising in the region, the reduction of rainfall and snowmelt and the increase in water use and population. However, because of this lack of scientific evidence in the area of groundwater mapping, I rely more heavily on the other components of the problem in order to build a framework outlining why this issue is real and of importance.

As identified by Catherine F. Smith in her book *Writing Public Policy*, "from the perspective of the policy cycle, defining a problem is not solving it. Problem definition comes first in the cycle. Next comes analysis and evaluation of alternatives, whether alternative definitions or alternative solutions" (Smith, 2013: 65). After identifying the problem and its root causes in my thesis, I will present a literature review and begin to analyze and evaluate alternatives by presenting a case for cooperation between the two riparians based on history and a plethora of documents that show a proven record of sharing the water resources of the area. These "documentary information sources and a literature review are used to define the theoretical context of the research object and the general picture of the problem" (Goonetilleke et. al., 2016: 11). The information within these documents will be extrapolated with treaties made between the two countries from their long history of sharing the Rio Grande and other border waters. In addition to treaties, I will use components taken from minutes (or policy amendments to existing treaties) and decisions made by the IBWC which have shown how cooperation can be accomplished when it comes to resource sharing between the U.S. and Mexico. It is important to note that, while many of the treaties and minutes I will examine are in reference to surface water sharing, they still paint an accurate picture of the evolving relations between the two countries. My theory is that if the two nations can agree on surface water, then the link to an agreement on groundwater should be the next logical step. The analysis of this evolution and institutionalization of the commodity reinforce this theory.

After supporting the historical argument that success can be accomplished along the U.S., Mexico border, I will move on to a review of the policies already in place that govern the water of both countries and the state of Texas. By doing so I aim to present a complete picture of the

obstacles and advantages that current law puts in place against a comprehensive groundwater regulation.

I will then proceed with an analysis of case studies. According to Margaret LeCompte and Jean Schensul, “case studies usually focus on detailed examples of cases (which) are examined for similarities and differences, they tend to focus on a population, process, problem, context or phenomenon whose parameters and outcomes are unclear, unknown or unexplored” (LeCompte and Schensul, 2010: 114). Within the case study component of my research I provide analysis of various transnational aquifers, and the conflicts and agreements that allow their users to sustain or deplete the resource. This “case study approach is a methodological technique which aims to understand a case study from field data collection. If a case study is deliberately chosen, there is an interest to generalize the conclusions” (Johansson, 2003: 6). By conducting case studies I illuminate how similar groundwater policy debates have played out which sets the stage for pulling the best policy ideas and lessons learned from these agreements towards the recommendations I will present at the conclusion of the paper.

The case studies I will discuss are the Israel / Palestine Mountain Aquifer, the Guaraní Aquifer, and the Nubian Sandstone Aquifer. These aquifers were chosen because they share some characteristics with the aquifers located on the U.S. Mexico border and present a wide variety of variables from which I can compare them to create a policy recommendation. These are “purposefully or analytically selected case(s). A case may be purposefully selected by virtue of being, for instance, information-rich, critical, revelatory, unique, or extreme” (Johansson, 2000; 14, Stake 1995: 15, Patton 1990: 39). To begin, all of the Aquifers have a political situation wherein there is an asymmetrical power relationship. The more powerful countries in these relationships are; Israel, Brazil, Libya, and Egypt. These shared variable will allow the case studies to shine light upon what a lesser power may need to expect with regard to policy outcomes in dealing with their powerful neighbor. This applies directly to the U.S. and Mexico in that the United States far surpasses Mexico in the nation’s power relationship and has on many occasions used this superior power to broker better deals from negotiations.

The second variable that runs through all of the cases is the creation of agreements while engaged in conflict or lack of conflict over water. This is an important note for comparison because many researchers have claimed that is its conflict over a resource and a critical situation that drives nations towards cooperation and agreements. In the cases that I describe, there are agreements made with both conflict and no conflict transpiring. This ties in with the U.S. and Mexico because, though it can seem like a major crisis in the Mesilla-Hueco aquifer, it is not yet at that critical stage. In addition, from a political point of view, the aquifer is not on many people's issue radars and therefore is not perceived as being a critical issue facing the public.

The third variable that the cases share is that all of them have a solid history of conflict or cooperation between the parties involved in managing the aquifer and all as a result fit into one of the four paradigms of borderland interactions as defined by Oscar Martínez in *The dynamics of border interaction: new approaches to border analysis*. As will become apparent the Guaraní Aquifer and the Nubian Aquifer, countries have all been involved in trade negotiations, regional institutions and have taken part in surface and other resource treaties with neighbors in the past. The Mountain Aquifer case stands as a comparative study in that these two nations have a very long history of conflict and therefore cannot come to a lasting agreement. This characteristic very strongly correlates with the U.S. and Mexico in that the two nations have a very long and in depth history of cooperation together, which I will expand upon in a later chapter.

The fourth variable I investigate in the case studies is the involvement of third party actors on the agreements. As will be seen, in all of the examples used for case studies, an external actor has played a role in creating the agreement between the primary aquifer owners. In many cases this third party actor takes the shape of an international institution and in others it is a separate nation.

The fifth variable I will highlight in some of my cases is the inclusion of more than two state actors in the agreement over the groundwater. In the Israel and Palestine example there are only two actors, like the U.S. and Mexico, however in the other two case studies there are four actors at the negotiating table.

The final variable I extrapolated are the various forms of governments that each aquifer's nations have. The case studies that I will utilize span a wide spectrum of government types from democracies, to autocracies to virtually no government structure at all.

With the inclusion of the Mountain Aquifer, the Guaraní Aquifer and the Nubian Sandstone Aquifer as case studies, I will be better able to propose a viable recommendation to policy makers in the Paso Del Norte region. This use of case studies will strengthen the argument I make because these cases will show how transboundary aquifer management has been effective, and how it has failed between nations that have similar and differing characteristics with the U.S. and Mexico. These characteristics will help to provide real world links to the policies that I am proposing, giving those reading them a perspective on the policies in real world practice.

LITERATURE REVIEW:

Transnational water management is not a new field when it comes to surface water. In fact there have been conflict and cooperation over the world's surface waters for thousands of years. However, "despite the significance of groundwater availability and the necessity of groundwater management, in terms of laws and institutional approaches, management is still in its infancy at the international level" (Barberis, 1991: 169). Kyoko Matsumoto recognizes this lack of research as the consequence of two main factors. "First, groundwater characteristics vary in each aquifer. Groundwater is often deep or unevenly distributed geographically. These uncertainties make groundwater seemingly impossible to regulate, as well as ill defined. The other reason is the transboundary element…in terms of transboundary groundwater, even the delineations of an

aquifer are a challenge (which means that even) the definition of an aquifer cannot provide concrete conclusions about groundwater ownership" (Matsumoto, 2003: 2).

This lack of attention towards groundwater is always changing; first because technology advances in the 20th century began to allow scientists to better understand how underground hydrology works and more recently because of the "vast majority of transnational watercourses coming under growing pressure, it is becoming increasingly important to develop international legal standards, monitoring provisions, compliance mechanisms, and water sharing rules to help moderate competition and conflicting uses, address hydrologic variability and changing basin dynamics and shield environmental sustainability" (Chellaney, 2013: 5621). Specific to the RGB, Mumme states that "since 1973, the public has grown increasingly appreciative of the importance of groundwater in the border region, its economic value, its place in the hydrologic cycle, and the need for managing those resources in a sustainable way" (Mumme, 2003: 343).

Many studies, whose aim is to inform policy makers, take a treaties or law-based approach to the issues of water management and focus on the negotiations between states over transboundary water. An example of this is a study published by the *Colorado Journal of International Environmental Law and Policy* which focused on the creation of a "freshwater dispute database, (where) negotiating notes and published descriptions of treaty negotiations could be collected" (Wolf, 1998: 259). A second study titled: "Conjunctive Groundwater Management as a Response to Socio-ecological Disturbances: a Comparison of 4 Western U.S. States" (Sugg, Ziaja, Schlager, 2015: 1) was designed as a comparative piece for analyzing inter-state groundwater management in the United States. This work analyzed Arizona, California, Nebraska, and Texas and how these states "have responded to disturbances affecting groundwater governance through conjunctive management" (Sugg, Ziaja, Schlager, 2015: 1). The authors go on to explain that "conjunctive management (is the) coordinated use of surface water supplies and storage with groundwater supplies and storage" (Sugg, Ziaja, Schlager, 2015: 3). This research is applicable to the Ciudad Juárez and El Paso area because it lays out a potential framework solution to the problems

experienced in the region specific to groundwater cooperation between multiple stakeholders. Furthermore it does so in landscapes that share similar characteristics to the Paseo del Norte region.

This research also elaborates and discusses how "crafting institutions for groundwater that are consonant with those for surface water is crucial for effective conjunctive management but is a challenge in states where groundwater and surface are subject to separate ownership and regulatory rules" (Sugg, Ziaja, Schlager, 2015: 3). This reasoning shows just how deep the problem is regarding transnational ground waters and how the RGB is ahead in terms of solutions. With long standing institutions in place, the RGB should be able to initiate policy in an efficient and timely manner, assuming these institutions can all get on board with change. Even with the institutions in place, transnational ground water and resource sharing between sovereign nations or states is complicated by the divergence in regulations between ground and surface water as well as the numerous federal and state regulations that are imposed by both stakeholders. Conflict is inevitable and it is easy to see why there are such challenges to solving this problem.

The varying rules and regulations that govern the shared resource complicate matters of creating singular policies for management. It is this "absence of a common frame of reference for the design of management rules concerning the appropriation and use of the resource" (Mumme 2000: 349) that makes regulation so challenging for the RGB. "Mexico's being centralized and directed by federal authorities, and the United States' regime being decentralized and managed under varying state control may significantly impede the achievement of any real comprehensive solution to border groundwater management" (Mumme, 2000: 349). An overarching concept behind so much of this study of varying stakeholders is a theory called the "Tragedy of the Commons" (Hardin, 1968: 3). The primary focus on this subject comes from Eleanor Ostrom's 1990 Nobel Prize winning work titled "Governing the Commons". In this book Ostrom tackles the concept of the tragedy of the commons which, in its classic interpretation "has come to symbolize the degradation of the environment to be expected whenever many individuals use a scarce resource in common" (Ostrom, 1990: 2). This concept, when applied to ground water issues, can be summed up as; "water underlying any parcel of land can be siphoned to a neighbor's

land if the neighbor withdraws water more rapidly than does the owner of parcel A" (Ostrom, 1990: 107). This was found to be the very real case when very strict riparian rights are enforced, ensuring that the groundwater under owned land could only be used by its owner. This example of a groundwater dilemma spurred the institution of numerous and varying laws and precedents in California. As a result of all the conflicting regulations, "two strong pressures encourage pumpers to adopt inefficient strategies. The first is a pumping-cost externality and the second is a strategic externality. Pumping costs increase as the pumping lift increases, because of falling water levels, and therefore each person's withdrawals increase the pumping costs for other. No one bears the full cost of personal actions. Each pumper is consequently led toward overexploitation" (Ostrom 1990: 109). Another example of this phenomenon is illustrated by Fred Pearce in his book *When the Rivers Run Dry* wherein he describes a village in India where "regulation is virtually impossible…nobody knows where the pumps are or who owns them. There is no way anyone can control what happens to them (and) there are no reliable statistics on how much water the farmers pump from beneath the ground" (Pearce, 2006: 36).

Though these stories are grim, Ostrom found that a potential solution to this was not from outside sources, instead solutions began internally through self-enforcement by resource users themselves. When researching the California case, Ostrom states that "elections and public hearings were held at key stages. The solutions to the pumping race however were not imposed on the participants by external authorities. Rather, the participants used public arenas to impose constraints on themselves" (Ostrom, 1990: 110). "The potential for cooperation is greatest where the resource can be converted to a sustainable public good, where the resource takes the form of a common pool, where there are integrated development possibilities, and where no party enjoys asymmetrical control over the resource in question" (Lemarquand, 1977: 46)

Through this work Ostrom uses in-depth empirical cases to prove her points regarding how and why communities of people sharing a resource succeed or fail. Furthermore, the examples are presented through a lens of game theory. This use of game analysis helps the reader to understand easily why the differing actors in each case acted the way they did. Her work goes on to include

examples from an economic stand point as well. She was able to conclude that "when a budget is to be determined in a collective choice arena, the policy space can be thought of as a set of rules concerning who is required, forbidden, or allowed to spend how much money for what purpose during what time frame… In both processes, individuals compare the net flows of expected benefits and costs to be produced by the set of status quo rules, as compared with an altered set of rules. To explain institutional change, it is therefore necessary to examine how those participating in the arenas in which rule changes are proposed will view and weight the net return of staying with the status quo rules versus some type of change" (Ostrom, 1990: 142).

Ostrom's research is very relevant to the groundwater situation unfolding in the RGB. Ostrom lays out how the two nations could very easily create a tragedy of the commons by seeing their best option as a race to pump the most water before it runs out or gets too expensive after the other party has drawn the water level lower. The other option, and the one I plan to present in this paper is the aversion of a tragedy of the commons situation by recognizing the need for cooperation in sharing the groundwater resource through agreed upon policy.

To help mitigate the depletion of the water in the RGB that can occur through a tragedy of the commons, there exists multiple water treaties and agreements. As discussed earlier in this paper, many of these treaties deal with surface water and do not delve into the aquifers beneath the ground. That said, it is important to note that these waters are linked hydrologically, the ground waters are "connected to surface water" (Krishna and Salman, 1999: 170) and therefore we as researchers should be able to draw conclusions for more direct groundwater policy based on the surface water treaties. One of the more compelling pieces of research on the updating of treaties examines the "1944 Water Treaty (which) stipulates the allocation of water from the two major rivers, the Rio Grande and Colorado and their tributaries, and extends to the Tijuana River as well" (Mumme, 2003: 346). Mumme argues that "the advances that have been made draw on a mix of agencies and initiatives including the IBWC, Border 2012, and BECC in generating databases and supporting local and regionally based groundwater protection initiatives" (Mumme, 2013: 62). This speaks to the idea that advances made towards groundwater use will need to be collective and

built upon the work already completed in the treaties. Luckily the IBWC has the capability to update the 1944 treaty using what are called "minutes." Unfortunately, to date there still "is no minute specifically addressing groundwater, (though) it has been an issue of concern since as far back as the late 1960's" (Umoff, 2008: 95). I will address the specifics of the minute process and what has occurred in greater detail in the policy section of this paper.

In my exploration of the work completed on transnational groundwater, I appreciated how many of the studies include a discussion of the challenges faced by politicians in the international sphere. Stephen Mumme, in a publication, goes into great detail regarding public support and the "social valuation of water" (Mumme, 2003: 662). So often studies can focus only on the actual policy, the treaty or the end product, and neglect to reinforce the hurdles that must be overcome by the nation and its people before two groups can come to a consensus on how to utilize the resources as well and efficiently as possible.

It is these concepts of border and the roadblocks associated with treaties that add a compelling aspect of reality and impact to a research piece that is mired in theory and fact. A study conducted on the "risks to cooperation along transboundary rivers" (Subramanian, Brown, Wolf, 2014: 1) does a good job at isolating key categories of risk that hinder cooperation and treaties such as "capacity and knowledge; accountability and voice; sovereignty and autonomy; equity and access; and stability and support" (Subramanian, Brown, Wolf, 2014: 1). Furthermore this publication utilizes real world situations and successfully shows how a well tied together research paper that compares relevant case studies can be an effective tool in communicating a message.

CHAPTER 2: THE WATER ARRIVES

At the outset of this paper, the critical question posed was, what is the source of our water? We now recognize that most people cannot adequately answer this question other than to note that water either falls from the sky or bubbles up from the ground. This chapter will help to answer questions about sourcing water in the Rio Grande region by examining how the hydrology of the Rio Grande works, how each aspect of the system is interconnected and therefore impacts the water levels of the groundwater in the RGB. With an increased understanding of the waters, I will conclude by outlining some of the major challenges affecting the water and the region.

According to the U.S. Geological Survey, the Rio Grande flows from "north to south (and is) the fifth longest river in the United States with its headwaters in the mountains of southern Colorado" (Bardolino, James, Cole, 2002: 41). The river begins in Colorado in the "Weminuche Wilderness, San Juan County, Colorado, on the Continental Divide, as a snow-fed mountain stream at an elevation exceeding 14,000 feet above sea level" (Ward, Velazquez, 2008: 2). From this snowy mountain valley, the water collects and begins to form the Rio Grande River Basin which is why "the greatest flows tend to occur in late spring as a result of snowmelt and for shorter periods during the summer in response to rainfall" (Barolino, James, Cole, 2002: 41).

Figure 1: The Rio Grande River Overview (Musser, 2010)

HEADWATERS TO NEW MEXICO

From a geological standpoint "the Middle Rio Grande Basin is one of a series of generally south trending structural basins composing the Rio Grande Rift. The rift is an area of Cenozoic crustal extension originating in central Colorado and extending through New Mexico to Mexico and Texas" (McAda, Barroll, 2002: 5). This rift valley is composed of a high variation of rocks which essentially cradle the river and allow it to flow naturally from North to South.

The river basin follows this rift southward, and along the way collecting more water from streams, runoff and rivers such as the Jémez River, the Santa Fe River, Tijeras Arroyo, Galisteo

Creek and the Rio Puerco as it descends into the high deserts of northern New Mexico. Here it passes through the "area of the Rio Grande Rift between Cochiti and San Acacia, New Mexico" (McAda, Barroll, 2002: 1) which encompasses the city of Albuquerque and down to the Elephant Butte Dam. It is through this region that we encounter what is referred to as the "Middle Rio Grande region, (defined) as the area drained by the stretch of river between Elephant Butte reservoir in southern New Mexico and Fort Quitman, TX"(Hargrove, Borrok, Heyman, Tweedie, Ferregut, 2013: 2). At its highest "the Rio Grande carries an average of about 1,000,000 acre-feet per year of surface water into (this) basin" (S.S. Papadopulos and Associates, Inc., 2000: Ortiz and others, 2001: 125). This may seem like an abundance of surface water, however, "average annual precipitation ranges from about 6 to 16 inches, and the basin wide area-weighted average is about 9.4 inches" (Thorn and others, 1993: 14). This is in competition with an "annual potential evaporation (that ranges) from slightly less than 50 inches to greater than 60 inches, (with) the basin wide area weighted average (at) about 57 inches" (Thorn and others, 1993: 16, 21). It is through this region that we see the first major human competitors to evaporation and users of the surface water as the river passes by major cities and farms in New Mexico.

TEXAS

After passing through New Mexico, the water continues south to the city of El Paso and its geographic conjoined twin, Ciudad Juárez in Mexico. It is here that the river takes a dramatic eastward turn and begins to form the physical border between Texas and Mexico. At this location, the Rio Grande takes on another nickname as it is referred to as "the forgotten reach of the Rio Grande, Fort Quitman to Presidio, Texas" (US Army Corps of Engineers, 2008: 2). This stretch is referred to as the forgotten reach because it is so consistently dry through the year and is at present day "an aggrading reach of stream whose bed is substantially higher than prior to dam construction upstream" (Schmidt et al., 2003: 32). This area in particular has been impacted very hard over the last hundred or so years by human intervention, "the volume of flows through the

Forgotten Reach of the Rio Grande post 1915 is approximately one quarter of the annual volume of flows recorded prior to the construction of Elephant Butte Dam" (Landis, 2001: ii). Even before this construction, this area suffered as a result of the 1906 treaty entitled *The Equitable Distribution of the Waters of the Rio Grande* which routed 60,000 acre feet of water to Mexico directly at the border adding to the low levels that pass through this region. It is these older innovations and agreements combined with the current situation where "surging spring runoffs from snowmelt in the upper Rio Grande Basin, Rio Chama Basin, Sangre De Cristo Mountains Basin, Jémez Basin, and the flash flood swells in summer months have been impounded, impeded, and controlled" (US Army Corps of Engineers, 2008: 9) that has led this area to be barren and therefore "forgotten".

Following the "forgotten" stretch, the Rio Grande is given a rebirth as it merges with the Rio Conchos that flows from south to north out of Mexico from its headwaters in the Sierra Madre Occidental. This is a critical river because it is what makes the Rio Grande (or Rio Bravo as Mexicans refer to it) flow for its duration to the Gulf of Mexico. "Once the waters from the Conchos join the Río Bravo, they are used to meet the same type of water demands in Texas and the more eastern Mexico border states of Coahuila, Nuevo Leon and Tamaulipas" (Kelly, 2001: 3). After being replenished by the Rio Conchos, the Rio Grande continues many hundreds of miles downstream linking with small tributaries and rivers until it reaches the very southeastern tip of Texas and finally meeting with the Gulf of Mexico and finishing its long journey.

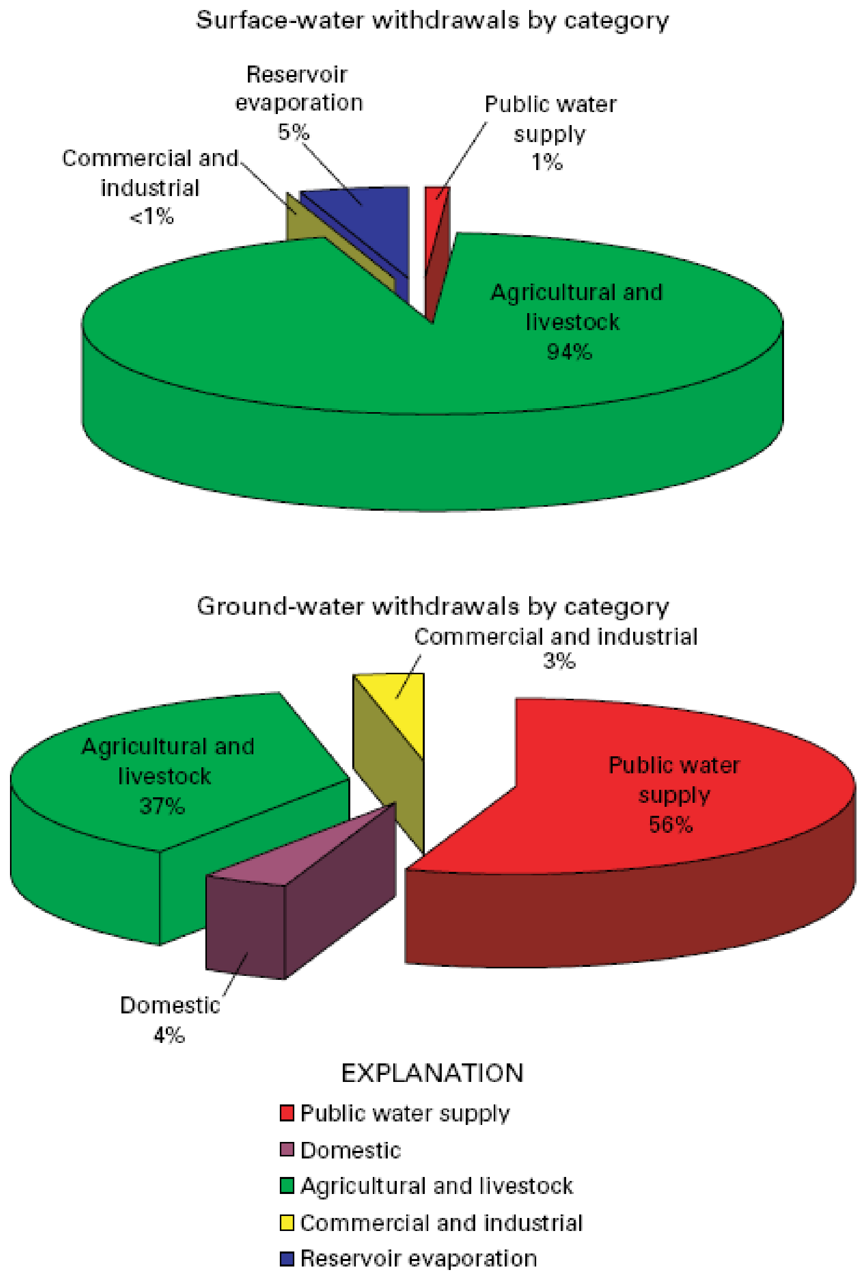

Figure 2: Surface-water withdrawals by category (USGS, 2002: 62)

GROUNDWATER

So far this chapter has covered the flow of the surface water in the Rio Grande Basin. For most of the population living close to the Rio Grande, this is the only water story because it is all most people see. However, unbeknownst to them, there is much more going on in the basin, all this action is simply below what can be seen on the surface. This aquatic activity is underground and is referred to as ground water. The first layer of this groundwater beneath the river bed is called the alluvial aquifer. This type of aquifer is created when "course gravels are deposited in the stream channel, sand and fine gravel form natural levees along river banks, and silt and clay come to rest on the floodplain. The term used for these unconsolidated sediments, include clay, silt, sand and gravel, deposited by flowing rivers is called alluvium" (Fetter, 2001: 598). It is when we take the term alluvium and add the term aquifer to it that we get a clearer picture of the purpose of this layer. MacFarlan describes an alluvial aquifer as "the water bearing alluvium adjacent to the stream and hydraulically connected aquifers in trace deposits and associated alluvial quaternary deposits in paleodrainages" (MacFarlan, 2000: 5). This means that an alluvial aquifer is a basin of water that is closely connected to the surface water that feeds it. The water trapped in this layer is critical for human existence as it is a cheap and readily available source for agriculture and drinking water. The water in the alluvial aquifer tends to be relatively easy to access, being only slightly below the surface and of generally good quality due to its proximity to the moving surface water.

As noted above, this alluvial layer is closely connected to the water system and shares a strong interaction with the surface water. Paradoxically, the alluvial aquifer (groundwater) can actually add to the overall water of the river. In this case the river "receive(s) part of their flow from ground water; this ground water derived component of flow (can) constitute a significant part of the total river flow during dry summer months" (Czarnecki, Hays, McKee, 2002: 4). For this interaction to occur the water level of the river must dip below that of the aquifer's level causing the water from the alluvial system to drain into the surface water river bed, this phenomenon is called recharge. However, when the aquifer is pumped heavily and depleted due to usage, the

reverse interaction can occur: "most rivers now lose water to the aquifer, and minimum observed river flows have decreased, especially during the summer months. Increased pumping from wells induces greater rates of recharge from rivers to the aquifer" (Czarnecki, Hays, McKee, 2002: 4). In this example, the water from the river begins to leave the riverbed and move into the alluvial aquifer as a result of pumping. This type of interaction occurs in the Rio Grande basin as the result of excessive pumping and a long term drought. Knowledge of this phenomenon can be useful however, as humans can purposefully recharge the Rio Grande River bed "due primarily to infiltration of surface water that has been applied to irrigable crops. Recharge (can) also occur to some extent by direct seepage from diversion canals and river channels" (IBWC, 1998: 3). We see this in the RGB as "most canals are unlined, and water from the canals seeps into the ground and recharges ground water. (In this area) an extensive network of drains throughout the inner Rio Grande Valley was constructed by the Middle Rio Grande Conservancy District (MRGCD, an institution created to control flooding, regulate irrigation and overall manage the river system) to lower the water table (the alluvial aquifer) and reclaim crop lands that had become waterlogged from applied irrigation water, canal seepage, and seepage from the Rio Grande" (McAda, Barroll, 2002: 9).

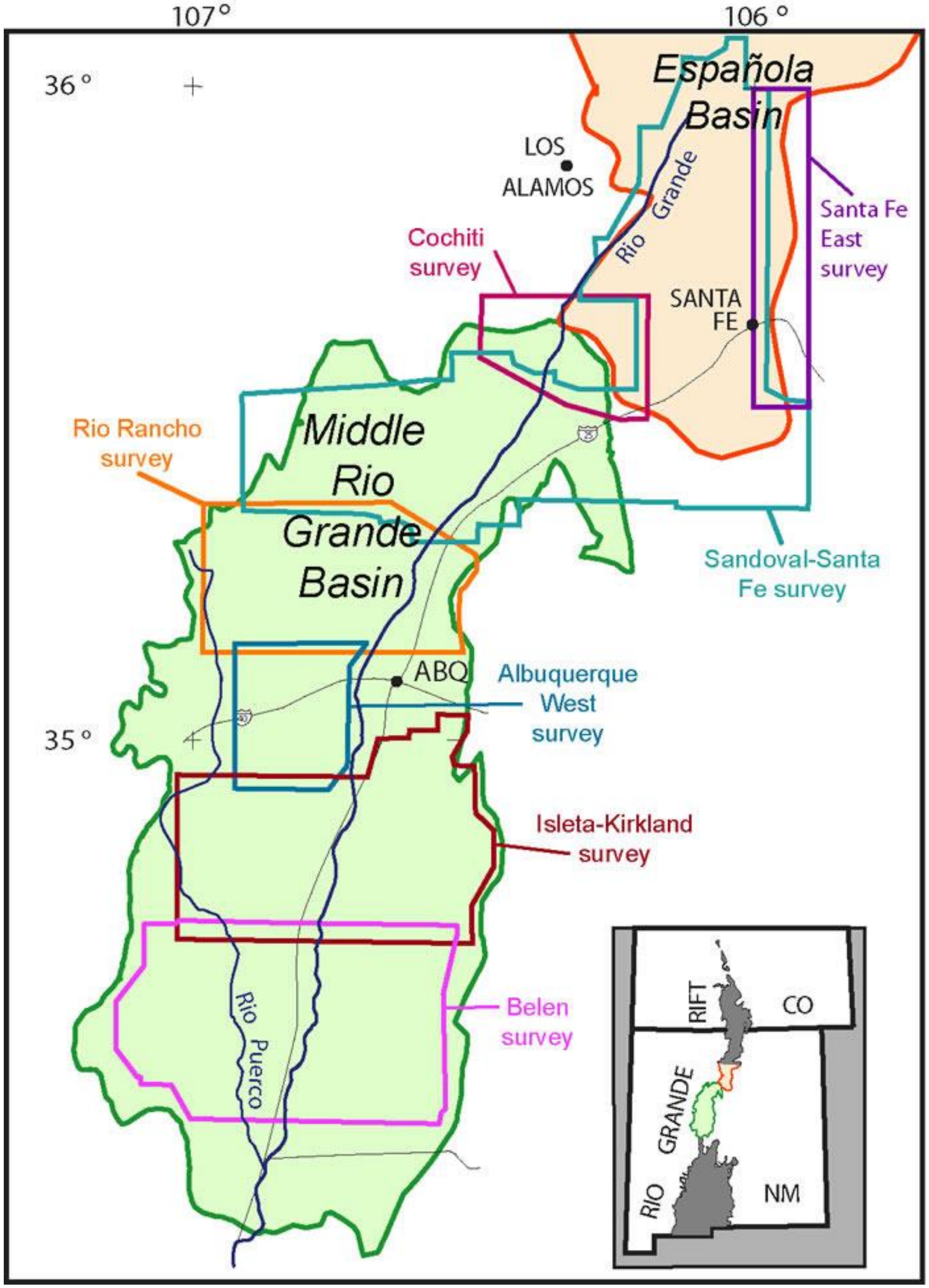

Figure 3: Middle Rio Grande (USGS, 2009: 1)

BOLSON

In addition to the alluvial aquifer, there is another layer where excessive drilling and pumping can have a major effect on water levels. This layer is even deeper into the earth and is where great quantities of water have been captured. Specific to the RGB, this layer is called the Hueco-Mesilla Bolson aquifer which "consists of two bolsons: the Hueco and the Mesilla Bolsons. The Hueco Bolson is in El Paso and Hudspeth Counties, Texas, (and) extends into Mexico south of the Rio Grande, and extends north of El Paso County, Texas into New Mexico" (Mace, Mullican, Angle, 2001: 6). These bolsons are very similar in their geology and location and yet share only small amounts of water. The bolsons also are not completely fresh water and can in fact be very saline depending on where the water sits. The Hueco Bolson is "about 200mi long and 25mi wide. (This) aquifer consists of unconsolidated to slightly consolidated deposits composed of fine to medium grained sand with interbedded lenses of clay, silt, gravel, and caliche. Sediment in the bolson is fluvial, evaporitic, alluvial fan, it is Aeolian in origin and (has) a maximum thickness of 9,000 feet. The bottom part of the Hueco Bolson is primarily clay salt water and silt. Therefore, only the top several hundred feet produce good quality (potable) water" (Sheng, Mace, Fahy, 2001: 6). The Mesilla Bolson (separated by the Franklin Mountain Range to the west of the Hueco Bolson) is very similar to the Hueco in that it "is about 2,000 feet thick and consists of clay, silt, sand, and gravel" (Mace, Mullican, Angle, 2001: 6). It is an extremely old body of water running from central New Mexico to the northern tip of Mexico and into Texas. This bolson is used extensively for water resources all along the agricultural valley of New Mexico, in Las Cruces and in El Paso. Together the groundwater in these aquifers is used "as the primary water supply for urban and industrial water in Ciudad Juárez, El Paso, and Las Cruces. It is also the primary water supply for military bases, and supplements the Rio Grande surface water source for agricultural irrigation" (Hibbs, 1997: 77).

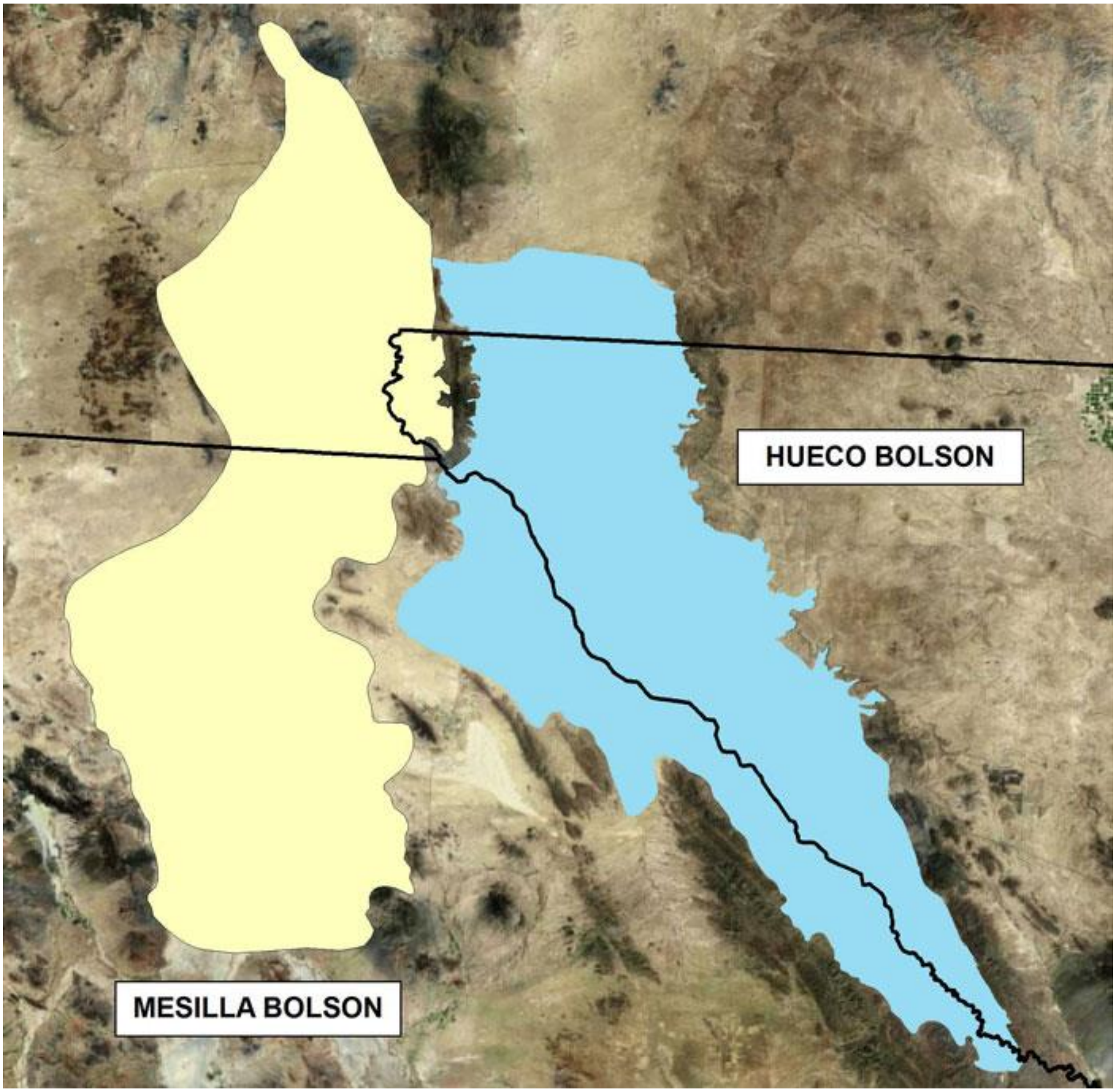

Figure 4: The Hueco and Mesilla Bolsons (El Paso Water Utility, 2009: 1)

These three hydrological features, surface water, alluvial aquifers and bolsons do not just stand alone, they mingle and affect each other. They are recharging and discharging depending on pumping and negative forces. However, where alluvial waters and surface waters differ is that recharge for the bolson groundwater is generally much more difficult and takes a great deal longer. The Rio Grande for example "recharges the underlying aquifers through seepage of riverbed and

canals that divert water for irrigations and deep percolation of irrigation water" (Sheng, 2013: 2). The refilling process can also come from "mountain front recharge (where) the seepage of surface run off after rainfalls (enters) into the aquifer where the bolson laps up against bordering mountains" (Sheng, Mace, Fahy, 2001: 2).

Recharge

The recharge rates for this deep groundwater are very slow due to the difficulty water has penetrating the thick layers of clay and earth between the surface water and the sediments of the Bolson, which can be both a positive and a negative depending on how one looks at the situation. On the negative side, the water in these underground bolsons is can be depleted and if pumped heavily, could disappear of become saline due to its slow recharge. "Mountain-front recharge is, very low; and losing reaches of the Rio Grande channel and associated irrigation-canal systems are the major present sources of groundwater replenishment" (Hawley, Kennedy, Creel, 2001: 92). On the positive side, we can view the groundwater as a hard to penetrate resource that is affected only in a small way by the effects of climate change, pollution and drought.

An excellent metaphor I heard for the conceptualization of this isolation is that of a checking and savings account. Your own accounts represent the two areas of water, the checking account is the surface water and the savings is the groundwater. The checking account is generally where you deposit your pay check, hopefully a regular recurrence. From the checking account, you also withdraw funds when you need them, perhaps at a gas station when you get a sudden urge to purchase a snickers bar or a bottle of water. It is also from this account that you take a small portion and put it into your savings account, where you do your best not to take money out of and over time accumulate as much as possible for long term or emergency needs. Water can be viewed in the same light. Surface water is a relatively easily replenished resource and as such is a useful place from which to pull the resource. It is the primary account where we can feel relatively confident that when we take pieces from it and in due time, the water will be replenished and we

can use more of it. Furthermore, from this account some of the surface water will trickle down and into the groundwater (bolsons) where it will stay for long periods and be protected from the day to day swings of the climate and pollution.

GROUNDWATER DEPLETION

Using this checking and savings account metaphor, it becomes apparent that the Rio Grande has been spending far too frivolously from both the checking accounts and the savings accounts. Due to the impacts of climate change, population growth, low snowfall in the Rockies, and generally severe droughts, this heightened use of groundwater will inevitably create long term emergencies. Water depletion in the region is not just an exclusive problem of the United States, after all water does not follow political boundaries. This is instead an international issue as the boundary for the two great bolsons of the region stretch into Mexico where they are also heavily pumped. In 2001, Washington and Pérez stated that, "the cities of Ciudad Juárez, Mexico, and El Paso, USA, are quickly depleting their fresh groundwater resources. Juárez, it is estimated, will pump the last of its fresh groundwater beneath the city by 2005, and El Paso by 2020 (Washington, Pérez, 2001: 3). Thankfully this prediction for the city of Ciudad Juárez has not come true but there is still great cause for concern. As noted in a report created in 1998 by the International Boundary and Water Commission (IBWC) "Quantities of ground water pumped from the Hueco Bolson from municipal and other sources have increased by a factor of almost 6 since 1950. Recent trends indicate that municipal pumpage in Mexico increased about 12.5% between 1990 and 1994. Municipal and military pumpage in the United States decreased 24.0% during the same time interval. Pumping trends reflect the increased dependence on ground water in Mexico, and partial conversion from ground water to surface-water use in the United States" (IBWC, 1998: 2). It is important to note that this study was conducted in 1998 and has not been replicated in the years since. Also, as it states, the decrease in pumping on the United States side was due to an increase in usage of surface water, a luxury that Mexico does not have (as it is allocated only so much water

from the Rio Grande and can technically only use this water for agricultural purposes). The evidence for concern, however, continues to accumulate. The Texas Water Development Board (TWDB) states that "Several hundred feet of water level decline have occurred, primarily due to municipal pumping in the Hueco Bolson" (TWDB, 2001: 1).

The fact that the water on this boundary is being utilized in different ways and in different amounts that are relatively unregulated only increases the argument that this is a binational problem which will need a binational solution. The decline in freshwater and its continual increase in use should raise more red-flags and get more attention from policy makers. The groundwater that runs beneath this region "is the principal source of water for municipal, domestic, commercial, and industrial uses in the basin" (McAda, Barroll, 2002: 81) and it is not recharging at a rate needed to sustain long term growth in the region. In fact "the problem has intensified as population growth in desert areas has increased and more water is needed to support agriculture and municipalities" (Hargrove, Borrok, Heyman, Tweedie, Ferregut, 2013: 6). The challenges facing this issue are large. Not only is there the physical problem with the water table suffering from "limited surface and groundwater supplies that are becoming increasingly saline (and) increasing water demands from a growing population in the El Paso/Ciudad Juárez area" (Hargrove et. Al., 2013: 2) but also other challenges from a political point of view.

Complicating this problem is the idea that "defining boundaries around water resource domains is "a supremely political act" because they represent different interpretations of key issues such as water quality, water quantity, nature, economics and history" (Jarvis, 2006: 10). This is extremely true between the United States and Mexico where the two nations have well mapped, solid boundaries above ground that include multiple water treaties, yet the two national governments uphold different standards for pollution and the use of the water resources. Transnational waters are an issue due to the vast increase in policies, stakeholders and regulations that come into play when trying to negotiate a deal. Though I will expand on these stake holders in a later chapter, it is still important to note how all of these factors come into play when defining the problem with the Hueco-Mesilla Aquifers. There is not just one issue impacting this region

and its people, there are many simultaneous challenges that need to be considered when updating the policies that regulate the usage of the water.

CHAPTER 3: A BORDER BORN ON WATER

HISTORICAL PERSPECTIVE ON THE U.S. MEXICO BORDER

Over the years, the relationship between the United States and Mexico has gone through significant ups and downs. This history can be compared to an evolution as the relationship between the two nations grew and each entity learned to work with the other. In this chapter I will review the border history of these two nations and how, like a deep river bed, it has been changed, shaped and flourished by the water that flows between its banks. I will illustrate this relationship by utilizing excerpts from the various prominent water treaties that have come to represent the cooperation and conflict that has existed over water in the region. By outlining this historical evolution I will show how initial conflict over water resources has, through the development of joint institutions and policy, grown into a much more developed and cooperative state which I predict will continue into the future.

The history between the United States and Mexico (or at least the region's people) goes back to the late 1700's, when Spain dominated the area. The relationship between Mexico and the United States did not formally begin until the *Treaty of Córdoba* signed in 1825 wherein Mexico gained its independence from Spain and started to function as a sovereign entity. Only 20 years after the signing of this treaty, the United States and Mexico struggled over Texas which ended in the Annexation of the state and a rocky relationship between the nations.

Figure 5: Map outlining the annexation of Texas 1845 (Hanson, 2010)

After this occurrence, we begin to see the first inklings of conflict over the water that flows through the region. In 1846 “U.S. President James Polk offers to purchase New Mexico and California from the Mexican government and seeks to make the Rio Grande River the border between the two countries, which would make Texas part of the United States” (Hanson, 2010: 4). Mexico refused the offer. In retaliation, Polk sent military forces into Mexico. After the United States invaded Mexico City, the Mexican Army surrendered resulting in the Treaty of Guadalupe Hidalgo which was signed in 1848 and outlined the new borders the two countries would adopt. Not coincidentally, the borders drawn after the war were outlined almost entirely by major sources of

water. As stated in Article V of the Treaty of Guadalupe Hidalgo "The Boundary line between the two Republics shall commence in the Gulf of Mexico, three leagues from land, opposite the mouth of the Rio Grande, otherwise called Rio Bravo del Norte, or opposite the mouth of its deepest branch, if it should have more than one branch emptying directly into the sea; from thence, up the middle of that river, following the deepest channel, where it has more than one to the point where it strikes the Southern boundary of New Mexico (Which runs north of the town called Paso) to its western termination; thence, northward, along the western line of New Mexico until it intersects the first branch of the river Gila; (or if it should not intersect any branch of that river, then, to the point on the said line nearest to such branch, and thence in a direct line to the same;) thence down the middle of the said branch and of the said river, until it empties into the Rio Colorado; thence, across the Rio Colorado, following the division line between Upper and Lower California, to the Pacific Ocean" (Treaty of Guadalupe Hidalgo, Article V, 1847:7). Article V defined the first iteration of what is known in modern day as the border between the nations. The language in Article V clearly shows how the U.S. government recognized the critical importance of obtaining the Colorado River and the Rio Grande as they were essential components for westward expansion and the fulfillment of manifest destiny. Following the Treaty of Guadalupe Hidalgo, "President Pierce sent (James) Gadsden to Mexico to negotiate a redefinition of the border. The Mexican regime was urgently in need of money and for $10 million sold the required strip of territory south of the Gila River, in what is now southern New Mexico and Arizona. It was only a mere 30,000 square miles, about the size of Scotland, but it was the country through which the Southern Pacific Railroad would be built" (Cavendish, 2003: 1).

After the border was established and solidified by the Gadsden Purchase in 1853, the two nations realized that defining a border by a river may not be a good idea. Rivers are a dynamic

entity and as such can change and move with time. To contend with this reality, the governments of the two nations convened and created the Convention of 1884. In this treaty, the two governments discussed ways "to avoid difficulties which may arise through the changes of channel to which those rivers are subject through the operation of natural forces" (Convention of 1884, 1884: 2). This treaty goes on to clarify that "the defining line shall forever be that described in the aforesaid treaty and follow the center of the normal channel of the rivers named, notwithstanding any alterations in the banks or in the course of those rivers" (Article 1, 1884: 2).

To manage the large and difficult task of controlling the dialogue between the two nations, it was agreed at the Convention of March 1, 1889 to create a binational governing body to administer any judgments on movements of and developments on the river. This was the document that initiated and gave power to the first iteration of the International Boundary Commission, stating in Article 1 of the convention that "all differences or questions that may arise on that portion of the frontier between the United States of America and the United States of Mexico where the Rio Grande and the Colorado rivers form the boundary line, whether such differences or questions grow out of alterations or changes in the bed of the aforesaid Rio Grande and that of the aforesaid Colorado River, or of works that may be constructed in said rivers, or of any other cause affecting the boundary line, shall be submitted for examination and decision to an International Boundary Commission, which shall have exclusive jurisdiction in the case of said differences or questions" (Article I Water Boundary Convention, 1889: 3).

As the nineteenth century turned into the twentieth, a strong push for the taming of the western waters rose within the United States as farmers in the west saw crops dying out due to droughts and disaster and politicians in Washington saw droves of people mobilizing to move westward. As Marc Risner points out in his book Cadillac Desert, "Even as the victims of the

great white winter and the drought of the 1880's and 1890's were evacuating the arid regions, the trains departing Chicago and St. Louis for points west were full. The pull of the West reached deep into the squalid slums of the eastern cities; it reached back to the ravined, rock strewn farms of New England and down into the boggy, over wet farmlands of the Deep South. No matter what the government did, short of erecting a wall at the hundredth meridian, the settlement of the West was going to continue" (Reisner, 1993: 111). This flow of humanity to the frontier was immense and the government knew it had to find a way to utilize the western waters in an efficient manner that would accommodate this large agricultural influx. President Theodore Roosevelt, passed the bill that would someday change the western landscape and dubbed it the Reclamation Act of 1902. "Under the terms of the Reclamation Act, projects were to be financed by a reclamation fund, which would be filled initially by revenues from sales of federal land in the western states, then paid back gradually through sales of water to farmers" (Reisner, 1993; 113).

CONVENTION BETWEEN THE UNITED STATES AND MEXICO EQUITABLE DISTRIBUTION OF THE WATERS OF THE RIO GRANDE, (CONVENTION OF 1906)

The Reclamation Act was motivation for the government and tax payers to begin building vast water containment and diversion infrastructure with the anticipation of repayment by the future gains of the agriculture industry. It is through this lens that we look at the Convention of 1906 which "provides for the distribution between the United States and Mexico of the waters of the Rio Grande in the international reach of the river between the El Paso-Juárez Valley and Fort Quitman, Texas" (1906 convention, 1907: 1). As the convention states in Article I "after the completion of the proposed storage dam near Engle, New Mexico, and the distributing system auxiliary thereto, and as soon as water shall be available in said system for the purpose, the United States shall deliver to Mexico a total of 60,000 acre-feet of water annually in the bed of the Rio

Grande at the point where the head of the Acequia Madre..” (1906 Convention, Article 1, 1907: 1). The convention goes on to ensure that “delivery shall be made without cost to Mexico, and (that) the United States agrees to pay the whole cost of storing the said quantity of water (Etc.)” (1906 Convention, Article III, 1907: 2). In exchange for this delivery of water, the United States asks that “Mexico waives any and all claims to the waters of the Rio Grande for any purpose whatever between the head of the present Mexican Canal and Fort Quitman, Texas” (1906 Convention, Article IV, 1907: 2). It is because of the Reclamation Act and the United States’ desire to control the flowing waters of the west through large scale programs that this convention and its distribution of water was possible. This also illustrates the beginnings of the taming of the western rivers, no longer would the two countries be pushed around by the ebb and flow of the river. It was also a turning point for the nations in the harnessing of their resources and, as can be seen in the *1906 Convention*, they were just starting to move away from conflict and towards cooperation in order to best distribute the valuable surface water.

RECTIFICATION OF THE RIO GRANDE (CONVENTION OF 1933)

Following these initial agreements, nearly thirty years passed before another convention was written to settle the joint issues faced by the two nations along their river border. Signed into law on November 13, 1933, this agreement is known as the *Rectification of the Rio Grande* and was developed because the “International Boundary Commission (had) been requested by the Foreign Relations Department of its Government to study and develop an international plan for the removal of the flood menace of the Rio Grande from the El Paso-Juárez Valley” (Minute No. 129, 1930: 2). In addition, this agreement highlights some of the natural issues that began to spring up as a result of the construction of the Elephant Butte Dam in 1916. Because of the creation of

the dam, the river itself could no longer flood, leaving the river bed elevated from years of low flows. Because of this, arroyos backed up under strong rains and caused the flooding of low laying areas around them. Before the dam "the action of these (river wide) floods was to scour out the river channel, partly by carrying deposits on through the valley's and partly by making deposits upon the valley floor whenever bank overflow stage was reached" (Minute No. 129, 1930: 22). This agreement highlights the continued mastering of the river and the growing cooperation between the two countries. From a US invasion less than 100 years prior, the United States now was taking care of all costs associated with containment of the river, to shared effort and resolve to fix the flooding problem mutually. This can be seen from Article III wherein it states "In consideration of the difference existing in the benefits derived by each of the contracting countries by the rectification works, the pro-ratable cost of the works will be defrayed by both Governments in the proportion of eighty-eight per cent (88%) by the United States of America and of twelve per cent (12%) by the United Mexican States" (Minute No. 129, 1930: 7). The idea that both countries will hold a stake in the game as part of this treaty is very important. It shows a mutual understanding of a shared problem and a plan set in place to solve it, with both nations contributing their legitimate piece towards resolution. It is also important to note the demographic shifts that have taken place in this border region over the last century. When this treaty was signed into law the Mexican border cities were much smaller in size, since this time populations have boomed dramatically changing the population balance between the two nations.

UTILIZATION OF WATERS OF THE COLORADO AND TIJUANA RIVERS AND OF THE RIO GRANDE (TREATY OF 1944):

Following the Convention of 1933, the United States and Mexico signed a treaty titled the *Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande (*Hereafter referred

to as the Treaty of 1944*)*. The catalyst for this treaty was when the agreements already mentioned in this chapter were unable to answer "questions (that) arose as to the location of the boundary and the jurisdiction of lands when the boundary rivers changed their course and transferred land from one side of the river to the other" (IBWC, 2008: 1) as well as ongoing disputes that continuously arose between the two nations over the allocation of the water.

The 1944 Treaty would prove to be a major landmark for the control of the waters that flow between the two nations and laid the framework for many of the systems in place today. In fact, one of the reasons this treaty has stood up so well over time is that it "create(d) a legal regime able to govern all potential uses of the waters of the Colorado and Tijuana Rivers and of the Rio Grande" (Schiff, 2003: 127). This creation of a governing system allowed for some flexibility to adapt and change as climate and the landscape evolved. In addition to this the treaty outlined in Article 4 methods for; "dealing with the allocation of the waters of the Rio Grande; Articles 10 through 15, dealing with the allocation of waters of the Colorado River; and Article 24, containing the enumeration of the IBWC powers and privileges vis a vis the treaty's interpretation and application, as well as the grant of authority to the IBWC to resolve disputes arising under the treaty (Schiff, 2003: 128).

The allocation of the water between the two nations as outlined by the treaty is as follows; "To Mexico: a) all of the waters reaching the main channel of the Rio Grande (Rio Bravo) from the San Juan and Alamo Rivers, including the return flow from the lands irrigated from the latter two rivers. B) One half of the flow in the main channel of the Rio Grande (Rio Bravo) below the lowest major international storage dam … C) Two thirds of the flow reaching the main channel of the Rio Grande (Rio Bravo) from the Conchos, (and all other tributaries of the Rio Grande). To the United States: "(1) an amount equal to all of the waters reaching the main channel of the Rio

Grande from the Pecos and Devils Rivers, Goodenough Spring and Alamito, Terlingua, San Felipe and Pinto Creeks; (2) one-third of the flow reaching the main channel of the (river) from the Conchos, San Diego, San Rodrigo, Escondido, and Salado Rivers and Las Vacas Arroyo … which shall not be less, as an average amount in cycles of five consecutive years, than 350,000 acre-feet annually; and (3) one-half of all other flows occurring in the main channel of the Rio Grande … between Fort Quitman and the lowest major international storage dam*"(*Article 4, 1944: 8). Having outlined the distribution of the water, the treaty goes on to discuss exemptions to the policy. It is important that the treaty goes into exemptions as water is a fluctuating resource and can unpredictably run dry or run high. For example, the treaty states that in the case of "extraordinary drought or serious accident to the hydraulic systems on the measured Mexican tributaries … any deficiencies existing at the end of the aforesaid five year cycle shall be made up in the following five year cycle with water from the said measured tributaries" (Article 4, 1944: 11). Alternatively, the United States voids these water debts when "in at least two of the major international reservoirs, including the highest major reservoir, are filled with waters belonging to the United States, a cycle of five years shall be considered as terminated and all debts fully paid, where upon a new fiver year cycle shall commence" (ibid: 11).

The final component of the Treaty of 1944 is its creation of mechanisms for adaptation and execution between the two nations. To begin, the treaty formally dubbed the governing body of the transnational waters the International Boundary and Water Commission (IBWC). In addition, it extended the existence of this Commission "for the entire period during which the present treaty shall continue in force. Accordingly, the term of the Convention of March 1, 1889 shall be considered to be indefinitely extended" (Article 2, 1944: 5). This is a departure from the earlier

treaties and conventions which only allowed temporary creation of a commission to assist in the implementation and upkeep of the agreement's changes and authority.

The Treaty goes on to assert that "The commission shall in all respects have the status of an international body, and shall consist of a United States Section and a Mexican Section… Wherever there are provisions in this treaty for joint action or joint agreement by the two governments, or for the furnishing of reports, studies or plans to the two Governments or similar provisions … shall be handled by or through the Department of State of the United States and the Ministry of Foreign Relations of Mexico"(Article 2, 1944; 6). This is a high level of power given to a joint institution and it emphasizes the novel thinking and cooperation that the authors of the treaty realized had to occur to jointly control the nations shared resources. Also, by solidifying the IBWC the treaty allows for faster change and flexibility in the study of the river and any policy adjustments that may be needed. The mechanism that was created to ensure flexibility in the treaty is called a "minute", which is essentially a revision of a treaty or any "decisions of the Commission" (Article 25, 1944: 25). "The Minute process has proven useful in situations where the Treaty, as originally written, was silent or vague. The Minute process also gives the Treaty the adaptability it needs, enabling the IBWC to secure long-term compliance through short-term flexibility" (Umoff, 2008: 77).

The treaty of 1944 would become influential in the shaping of the western waters and the joint cooperative nature of their handling. In coming chapters I will refer back to this landmark treaty because over the years it has been amended many times to reflect the current policies that govern the transnational waters.

BOUNDARY SOLUTION OF THE PROBLEM OF THE CHAMIZAL (CONVENTION OF 1963):

New and different disputes arose and needed to be solved. One such major dispute was named the problem of the Chamizal which would be settled through the Chamizal Convention of August 29, 1963, in an agreement called *The Solution to the Problem of the Chamizal*. This agreement "resolved the nearly 100-year-old boundary problem at El Paso, Texas and Juárez, Chihuahua, involving some 600 acres (243 hectares) of territory which were transferred from the south to the north bank of the Rio Grande by movement of the river during the mid-Nineteenth Century" (IBWC, 2008: 1). Article one states that "the Rio Grande shall be relocated into a new channel in accordance with the engineering plan recommended in Minute No. 214 of the IBWC" (Convention of 1963 Article 1, 1963: 3). In addition "the center line of the new river channel shall be the international boundary. The lands that, as a result of the relocation of the river channel, shall be to the north of the center line of the new channel shall be the territory of the United States of America and the lands that shall be to the south of the center line of the new channel shall be the territory of the United Mexican States" (Convention of 1963 Article 2, 1963: 4).

TREATY TO RESOLVE PENDING BOUNDARY DIFFERENCES AND MAINTAIN THE RIO GRANDE AND COLORADO RIVER AS THE INTERNATIONAL BOUNDARY (TREATY OF 1970):

A second territorial agreement followed the Convention of 1963 to settle "all pending boundary differences and provided for maintaining the Rio Grande and the Colorado River as the international boundary" (IBWC, 2008: 1). This would be called the *Treaty to Resolve Pending Boundary Differences and Maintain the Rio Grande and Colorado River as the International Boundary* (hereafter referred to as the Treaty of 1970). This agreement set out to "restore the Rio Grande its character of international boundary in the reaches where that character has been lost, and preserve for the Rio Grande and Colorado River…(to) minimize changes in the

channels of these rivers, and should these changes occur, attempt to resolve the problems arising therefrom promptly and equitably, resolve problems relating to sovereignty over existing or future islands in the Rio Grande, and Finally, considering that it is in the interest of both countries to delimit clearly their maritime boundaries in the Gulf of Mexico and in the Pacific Ocean" (Treaty of 1970, 1970: 3*).* The treaty was to date the final treaty that solidified all major boundary disputes between the two nations. It set a framework for dealing with all future movements of the river and outlined how each side should react in the event of unanticipated movements of the rivers.

ENVIRONMENTAL COOPERATION: AGREEMENT BETWEEN THE UNITED STATES OF AMERICA AND MEXICO. (LA PAZ AGREEMENT, 1983) AND THE BORDER 21 PROGRAM (1994):

I am grouping two agreements into this section because the policies are linked and have had a similar effect on policy. To begin, the La Paz agreement was signed into law by Ronald Reagan and Miguel de la Madrid on August 14, 1983. This agreement was signed into law to "establish the basis for cooperation between the parties for the protection, improvement and conservation of the environment and the problems which affect it, as well as to agree on necessary measures to prevent and control pollution in the border area, and to provide the framework for development of a system of notification for emergency situations" (La Paz Agreement, 1983: 1). The La Paz agreement is very important milestone in the conservation of natural resources and protection of the environment at the border. The Agreement "directly imposed water quality considerations in border water management and intermeshed both quality and quantity concerns with biodiversity protection. It amplified attention to conservation in the border area and technically subjected conservation management to the same monitoring and data sharing obligations as applied to other areas of binational environmental concern" (Mumme, 2015: 23). Unfortunately this agreement can in its application be "interpreted as an arrangement between the

two countries to meet and discuss the important issues" (Staudt, Coronado, 2002: 78). In essence the agreement exists as a standing order for representatives from both nations to discuss problems affecting the environment in the border region but falls short of being a standing policy which outlines "the how to, the when, and the concomitant funding streams needed to address these border problems" (Staudt, Coronado, 2002: 78). Mumme notes that "the Agreement was faulted for not addressing many environmental issues on the border agenda, failing to prioritize solutions, and failing to invest in environmental protection and remediation" (Mumme, 1992: 541).

The Border 21 Program, established in 1994 was built on the back of the La Paz Agreement and was designed in an effort "directed toward conserving natural resources and protecting the environment and the environmental health of the border area communities taking into account the present and future needs of the region" (Border XXI Program, 1994: 3). In this agreement "three new working groups were created to augment the six original work groups that were created by the La Paz Agreement. The new groups are: natural resources, environmental health, and information resources" (Staudt, Coronado, 2002: 86). Unfortunately it seems this agreement, like La Paz, did not have any strategies for effective implementation towards reform and became nothing more than a meeting where the two nations could discuss the issues without creating much or any change. "This (Border 21 Program) is a fine example of symbolic politics at its best that just made both governments and businesses look good" (Staudt, Coronado, 2002: 87).

Though the La Paz Agreement and the Border 21 Program did not produce the outcomes that many environmental activists wished to see it still spurred cross border cooperation and helped gain attention for environmental issues along the U.S. Mexico Border. These types of transnational agreements are important stepping stones that help to lay the framework for further "more

integrated approaches to managing natural resources at the border in the context of a strategic commitment to the border's sustainable development" (Mumme, 2015: 36).

CONCLUSIONS:

It is my belief that treaties such as The Treaty of 1970, with broad and far reaching implications that lay a path for policy that is straightforward and easy to follow, is also the way any developments on groundwater should be managed. As can be noticed through this history of major treaties and agreements there is no reference to groundwater, pumping or the depletion of the resource. There is no mention of what would happen if a drought should cripple the region for two or more five year cycles. It should be noted though that since the creation of the 1944 Treaty there have been extensive minutes written that update and make changes to the agreement. One such minute does reference groundwater but only in a small way, I will discuss this in a subsequent chapter on current policies. What is most important about this historical review is the attention we as researchers should pay to the trend in cooperation. What began as physical conflict between the two nations over water evolved slowly to inequitable one sided treaties, but ultimately on to a future that contained far more equitable division of transnational waters with shared responsibilities enacted through a joint international institution.

This understanding of cooperation and collective movement towards solutions is important, as stated by Ariel Dinar in *Bridges Over Water: Understanding Transboundary Water Conflict, Negotiation and Cooperation*, "while formal agreements cannot in themselves assure cooperative relations among co-riparians in governing shared resources, the institutionalization of cooperation in international water management generally requires some type of formal agreement or set of agreements characterizing the resource, the desirability of cooperation, the aims and

purposes of the agreement, the mechanisms intended to achieve the agreed upon objectives, and measures to insure the parties compliance with whatever agreements the parties strike" (Dinar, 2007: 331).

Dinar's sentiment is correct and can be interpreted that the treaties are a formal recognition of a problem and they lay the groundwork that can lead to a solution. The signed treaties, however, do not mean that the problem is solved. It is only from this starting point that the work begins, and it begins with citizens, organizations, and institutions working hand in hand to alleviate the issues. If anything is to change with regard to groundwater usage, all parties must be on board. Step one will be a comprehensive policy, but this must be followed by widespread action in the community. Only then can history truly be made.

CHAPTER 4: POLICIES REGULATING THE WATER BENEATH EL PASO AND CIUDAD JUÁREZ

A significant roadblock to the creation of an overarching regulatory policy for groundwater in the Paso Del Norte region, and in many transboundary aquifers, is the relative misunderstanding of the nature of groundwater and possibly more important, the varying rules governing the resource on each side of its borders. Cooperation is often hindered when one of the sovereign powers must give up its own policies to successfully accommodate the joint rules that need to be agreed upon in treaties. Interestingly, this bickering over rules stands in stark contrast to the natural order of aquifers. The body of water that lies beneath nations or states does not care which side has national regulation, which side has state regulation or for that matter no regulation at all. This chapter will discuss the current state of the groundwater regulatory policies that impact the Hueco – Mesilla aquifers directly. I will begin with a discussion on U.S. federal policies followed by the policies implemented by the state of Texas and New Mexico then will conclude with the regulations enforced by the Mexican Government in the state of Chihuahua and a discussion on the effects of the North American Free Trade Agreement (NAFTA). Throughout the chapter I will include the various stakeholders, regulatory agencies, and other policy makers involved in the control of the groundwater held in the aquifers.

U.S. FEDERAL WATER POLICY:

The irony of starting this chapter with a section entitled "U.S. Federal Water Policy" is that there is no single U.S. Federal Water Policy, at least not one related to the usage of groundwater (there are U.S. Federal water policies when related to sanitation and pollution). That said, there really is not much federally mandated regulation even on surface waters at least as far as pumping and

ownership goes, "surface water and groundwater rights are seen as primarily state responsibilities, except for federal lands and selected interstate and international waters" (Joshi, 2005: 1). This lack of federal, overarching regulation is due to the difficulties for the "establishment of a single set of legal rules and regulations for common pool resources like groundwater … because of site-specific conditions" (Gould, 1990: 6). The idea of the federal government putting the main regulatory responsibility of water on a state makes sense. Imagine the immense difficulty in trying to make one policy for water rich states like Minnesota and New York and have that very same policy apply to dry states like Texas and New Mexico; it is not feasible.

Where the U.S. Federal Government does step in is with the regulation of the quality of groundwater resources, as mentioned earlier. One of the main regulations on groundwater by the U.S. Government became policy when the "EPA issued the Ground Water Rule (GWR) to improve drinking water quality and provide protection from disease-causing microorganisms. Water systems that have ground water sources may be susceptible to fecal contamination… The GWR applies to public water systems that use ground water as a source of drinking water. The rule also applies to any system that delivers surface and ground water to consumers where the ground water is added to the distribution system without treatment" (Environmental Protection Agency, 2015: 1). Though this is an incredibly important regulation, it does not directly address the pumping of fresh groundwater that is not contaminated.

It is worth noting that although there is little in the way of federal regulation of groundwater usage, states within the territory of the United States can sign treaties amongst themselves. Because of this ability to make interstate agreements the states are authorized to bring disputes over water resources before the Supreme Court of the United States, which has the legal right to settle these arguments and make decisions on behalf of the states. This is currently relevant with

regards to an ongoing dispute between Texas and New Mexico (Texas v. New Mexico No. 220141, 2016). In this dispute, Texas is suing the state of New Mexico because "New Mexico has, contrary to the purpose and intent of the Rio Grande Compact, allowed and authorized Rio Grande Project water intended for use in Texas to be intercepted and used in New Mexico" (Somach et. Al, 2013: 7). This case revolves entirely around the Rio Grande Compact, which was signed in order to "remove all causes of present and future controversy among these states (Colorado, New Mexico, Texas) and between citizens of one of these states and citizens of another state with respect to the use of the waters of the Rio Grande" (Rio Grande Compact, 1938: 1). Essentially this agreement allocated the waters of the Rio Grande as evenly as possibly between the three states that signed the law. Where this agreement becomes complicated is the method for water delivery. Colorado does not have much trouble delivering water to New Mexico as the measurement for quantity delivery is relatively close to the New Mexican border, and therefore not subject to high seepage or evaporation. This is not the case however between New Mexico and Texas. In this case "New Mexico delivers water into Elephant Butte Reservoir – 90 miles north of the border with Texas. From there, water is allocated by the U.S. Bureau of Reclamation to the Rio Grande Project beneficiaries in both southern New Mexico and Texas" (Paskus, 2013: 1). As the water travels the 90 miles south towards Texas allegedly the State of New Mexico has allowed "diversions of surface water and … groundwater pumping downstream of Elephant Butte Dam. Texas alleges that by increasing the amount of groundwater pumping, New Mexico is depleting the amount of surface water available to Rio Grande Project users in Texas" (Paskus, 2013: 1). The paradoxical part of this controversy is that technically those farmers that are operating south of the Elephant Butte Dam are in the Texas water shed and yet they are geographically in the state of New Mexico. Unfortunately, groundwater, and an understanding of how it works, is a modern realization. When

the Rio Grande Compact was enacted the concept of drawing down the river water through ground pumping was nonexistent. Furthermore there would have been drastically fewer wells, farms and people when the compact was signed making the relevance of the agreement's contents questionable in our modern times.

As can be seen from this example, there are instances where the federal government crosses paths with states' water policies and helps to negotiate, though for the most part the states are still left mostly to their own devices to decide how they want to operate with their resources. It is predictable that with climate change, population growth, increased pumping and other modern issues that affect aquifers, the federal government may need to play a stronger role in defining how transboundary water is used and regulated. As discussed earlier, water defies the boundaries set by a government and therefore has a hard time operating on two or more sets of rules for its use.

TEXAS GROUND WATER POLICY:

Texas has a major problem, there just is not enough water to go around. This has been an issue for a very long time and it does not seem to be getting any better. To alleviate the state's deficiency in surface water, the population has turned to groundwater. This groundwater has played a significant role in the state's growth and making Texas a place "where groundwater withdrawals provide over half of the total water used in the state" (Chaudhuri, Ale, 2014: 379). This high use of groundwater does not make Texas a particularly unique case; however, what does set the state apart from the rest is that it has a singularly distinctive policy that governs how groundwater is used by its population.

Texas stands alone among the 50 other states in that it still "adheres to the English common law rule in its traditional form outside of groundwater conservation districts (GCD)" (Caroom, Maxwell, 2013: 41). This rule is fundamentally archaic and is credited as being "traced back many centuries into customs and legal principles of Europe." (Piper, 1960: 2). The rule was widely used in many parts of the United States at one point or another but has been phased out for more modern regulations. As stated in an 1880 legal decision in a discussion on why laws cannot govern groundwater: "The laws of its (ground water) existence and progress … cannot be known or regulated, it rises to great heights, and moves collaterally, by influences beyond our apprehension. These influences are so secret, changeable and uncontrollable, we cannot subject these to the regulations of law, nor build upon them a system of rules, as has been done with streams upon the surface" (Roath v. Dnacoll, 1880: 532). In a second case, *Frazier v. Brown,* the Ohio Supreme Court states that "Because the existence, origin, movement, and course of such waters, and the causes which govern and direct their movements, are so secret, occult, and concealed that an attempt to administer any set of legal rules in respect to them would be involved in hopeless uncertainty, and would, therefore, be practically impossible *(*Frazier v. Brown, 1861: 12).

The mystery of the movement of groundwater at the time of the creation of the doctrine led lawmakers to conclude that it would be impossible to regulate and therefore should not waste their time doing so. As a result "the groundwater in the State (Texas) belongs to the landowner" (Joshi, 2005: 63). Essentially, "the rule of capture combined two ideas: first, the idea that groundwater is reduced to individual ownership once pumped out of the ground and physically controlled, or captured, on the surface; and second, the related idea that the new owner could not be held liable to neighbors for injury resulting from this withdrawal" (Bray, 2015: 1283). This odd and old fashioned rule seems out of place in a state where groundwater is such a vital resource. Some

researchers conclude that in addition to a culture of resistance to regulation there is a strong link in the state between regulation of gas and oil and groundwater. In the case *Edwards Aquifer v. Day*, "the court analogized groundwater to oil and gas, reasoning that the two were similar enough that the oil and gas ownership in place rule should apply to groundwater as well." (Welles, 2013: 484). This is inherently a problem because the resources, though they seem similar are not at all the same. After all, oil does not fall from the sky, is not imperative for immediate life and does not have surface flows like water does. Regardless of these known differences and the modern scientific understandings of groundwater that took away its near mystical qualities, the Texas Supreme Court has been "unwilling to abandon the absolute ownership doctrine, largely out of concerns about stability and proper deference to the legislature" (Wells, 2013: 490). Because of their resistance, the Texas Supreme Court has given the legislature the ability to control laws that pertain to the regulation of groundwater resources. This governing body, the legislature, has modified the original law on occasion usually after severe droughts. In 1917 the legislature created an amendment to the Texas Constitution that gave the "right to pass any laws dealing with such topics (Groundwater)" (Davidhizar, Robertson, Sullivan, 2014: 93). In addition, the amendment created conservation reclamation districts to address localized issues involving groundwater. Since this amendment, there have been numerous challenges to the rule of capture policy however none have yet to do away with the doctrine. In 1997 the state of Texas ratified *Senate Bill 1* which "established groundwater conservation districts as the state's preferred method of managing groundwater resources. The established districts regulate pumping from wells through district level rules and procedures" (Ibid, 2014: 94). Regardless of *Senate Bill 1's* passage, opponents still argued that the "rule was primarily established (as referred to earlier) because there was no way to monitor movements, or know about this secret occult (referring to the unknowns of groundwater

science). There was also fear of interfering with the expanding railroads and other economic developments which had a great need for water. However, with modern technology and high demands on limited water supplies, the rule of capture, as argued, should be done away with" (Ibid, 2014: 94).

The State of Texas is on course to continue to follow a rule of capture policy with smaller groundwater conservation districts empowered to make localized decisions on use of ground water resources. This begs the question; what are groundwater conservation districts? According to *Tex. Water code, 36.0015* "Groundwater conservation districts are to provide for the conservation, preservation, protection, recharging, and prevention of waste of groundwater and groundwater reservoirs or their subdivisions and are to control subsidence" (Tex. Water code, 36.0015, 2005: 1). These groundwater districts are led by a board of directors and "financed by user fees, the sale of bonds, and local property taxes" (Davidhizar, Robertson, Sullivan, 2014: 99). The GCDs have pros and cons, on one hand the GCDs can adapt to the particular needs of the community due to the varying local rules, climates, aquifers and environmental factors, while on the other this variation leads some communities to take issue as they see their regulations as unfair as compared to another GCD.

In the end, the overarching rule of common law that Texas subscribes to brings up the very likely possibility of a tragedy of the commons. "Common law fails to provide adequate guidance for merging the divergent legal regimes governing groundwater and surface water, leading to uncertainty that undermines conjunctive management efforts" (Wells, 2013: 505). As a guiding principal it is no surprise that many of the other 49 other states have drifted away from this doctrine and moved closer to reasonable use doctrine, and correlative rights doctrine with many adopting the groundwater as property of the state. The rule of capture that Texas follows simply leaves too

much room for greedy behavior by those connected to the same resource but governed perhaps by different or no rules at all. With this in mind I will now move east across the state border to discuss the other U.S. governing force presiding over the aquifers, New Mexico.

NEW MEXICO POLICY

New Mexico's policy towards groundwater is quite different from Texas and actually lines up much closer with Mexico's water regulations (perhaps due to the strong linkages in their histories and cultures). The New Mexican water conservation and regulation policies are progressive for the Western United States and have become a model for conjunctive management in the region. The laws governing groundwater in New Mexico are based on an early acceptance and appreciation for the resource, starting over a century ago and have evolved to promote "the orderly development and optimum utilization of a diminishing groundwater resource" (Brockman, Brockman, 2009: 1).

In New Mexico all the water (surface and ground) is owned and regulated by the state "and allocated for beneficial use with the prior appropriation doctrine" (Galano, Edwards, 2003: 21). This essentially means that the State Engineer and the Division of Water Resources is "charged with administering the state's water resources (and has the) authority over the supervision, measurement, appropriation, and distribution of all surface and groundwater in New Mexico, including streams and rivers that cross state boundaries" (NM Office of the State Engineer, 2016: 1). This regulation gives the state the authority to step in when regulation is needed and to arbitrate all water disputes that arise within the territory as well as administer water rights. This level of regulation prevents any land owner in the state from digging a well and pumping with no supervision or regard for the aquifer and surface water around them. In fact, "a permit from State Engineer's Office is required to drill a well and to use the water" (Galano, Edwards, 2003: 22). These regulations are the result of some early awareness of the interconnectivity between surface and ground waters in the state, in "the 1920s, combined with already noticeable effects of groundwater development on hydrologically connected streams and other groundwater rights in

parts of the State led to the introduction of New Mexico's first groundwater code in 1927" (Brockman, Brockman, 2009: 2). This early awareness of the need for groundwater regulation set the foundation for the policies that still govern the resource to this day which led to the declaration by the State Engineer in 2005 that "all groundwater within the State of New Mexico is now within a declared basin and subject to regulation" (Brockman, Brockman, 2009: 2).

Though the State has taken control of all groundwater basins there are still ways for those with water rights in place before this declaration to maintain these water rights, these are referred to as "Mendenhall Rights". "First and appropriator must legally commence drilling a well prior to declaration of the basin. Second, an appropriator must proceed diligently to develop the water pursuant to a plan. Third, the appropriator must apply the water to beneficial use" (State v. Mendenhall, 1961: 5). It is important to note that even though these historical water rights are still regulated and monitored by the state to ensure that the users have a plan in place and that the water is pumped for beneficial use. This regulation enforced by the State also includes the impairment of other wells. In the State of New Mexico, well permits will not be granted if other water rights are impaired. This impairment includes "the drawdown that would result from granting the application, the age of the well, and whether there is saturated thickness to deepen a well" (Mathers v. Texaco, 1966: 2).

As mentioned earlier, New Mexico recognizes the hydrological connection between ground and surface water. This recognition is extremely important in New Mexico water law and has "has served as a precedent to other western states" (Brockman, Brockman, 2009: 5). This is so important because it allows for the administration of ground and surface water as one resource and because it allows the state to regulate those groundwater users who impact the surface water users.

Laws like those set by New Mexico are scientifically sound and recognize the importance of sustainability over water resources. It is no surprise that the water laws of New Mexico serve as an example for many western states as it is regulations like theirs that help all the water users in the state manage their ground and surface waters responsibly and with an eye toward the future.

As we will see in the following section on Mexico water laws, they too have the capacity to regulate their groundwater like New Mexico.

MEXICO WATER POLICY:

Simply by crossing the Rio Grande into Mexico one will enter an entirely new world of dealing with water resources. Mexico differs greatly from the United States in the way that it deals with its water resource management.

"In Mexico, water is considered a strategic and essential element of national security. In order to control water scarcity occurring in the country, the National Water Commission is carrying out a plan at different levels. At a national level, major policies and strategies associated with water management and conservation are proposed; at regional level, implementation is defined in more detail, considering the characteristics of each particular zone in the country. At a local level, policies and strategies are applied so as to have a favorable impact on social well-being, economic development and environmental conservation" (Facchini, 2009: 15).

The waters of Mexico are both federally owned and decentralized (controlled by local areas). Water is viewed as an essential resource for the nation and should therefore be available to all people. Throughout the 20th century the government of Mexico experimented with control of the water by initiating different plans to regulate the resource. In "1992, Mexico adopted the Law of the Nation's Waters (Ley de Aguas Nacionales, LAN), which together with its regulations, contained specific provisions for the role of Comisión Nacional del Agua (CONAGUA), the structure and functioning of river basin councils, public participation in water management, etc" (Scott, Banister, 2008: 68). This, along with earlier plans and laws was all part of the decentralization of the nation's water rights to autonomous agencies. In addition, the LAN also

implemented the framework for the more localized river basin councils. These policy shifts are pushing Mexican water regulation towards a more regional management system (similar to the United States) with its water policy. This makes perfect sense from what was has been discussed during the chapter in that Mexico is taking steps to empower regional institutions with more authority to make their own decisions. This movement is evident and as the years have passed since 1992 we can see an increase in the authorities of the local governments, "an important test-case for CONAGUA came with the 29 April 2004 passage of reforms to the Law of the Nation's Waters, which stipulated that the 13 decentralized CONAGUA regions would become basin organizations, or more specifically, serve as the technical arm of more broad-based basin councils that incorporate civil society interests including the private sector, citizens' groups, etc." (Scott, Banister, 2008: 71).

Mexico has seen improvements in its water management systems as a result of these legislative actions, however there are still major roadblocks to overcome. For example the river basin councils that were created by the 1992 and 2004 law "were not given the necessary powers and regulatory functions to carry out their duties. In absence of subordinate regulation, these institutions were left with no updated roles and attributions, and very limited technical, capacity and financial resources" (OECD, 2013: 56). In addition to these problems, the decentralization of the water management systems has created a fractured system where contradictory policies on "water pollution regulations can hinder integrated water policy. The Ministry of Agriculture is in charge of regulating and inspecting the use of fertilizers in irrigation areas, while CONAGUA is responsible for overseeing the water quality norms and standards" (OECD, 2013: 57). These complicated relationships extend throughout all levels of water management. Because of the differences in regulation over the same body of water, confusion can ensue on enforcement and

responsibilities leaving many laws and policies unfulfilled and many regulations unenforced. For example these challenges extend to the Comisión Internacional de Límites y Aguas (CILA) counterpart of the IBWC, because of the "mismatch at the sub-national level that often obstructs water policies and complicates the relationships between elected representatives, local authorities, water agencies, resource managers and end users…Management failures, such as a lack of co-operation, participation and transparency, are often rooted in the hydro-administrative mismatch" (OECD, 2013: 58). This organization has a tough job as it is constantly dealing with disorganization with water regulation within its own nation as well as trying to balance agreements with the United States at the border.

With regards to groundwater and the longevity of aquifers I am convinced even through these hurtles that regional agreements and localized control of these resources is the right path for the Mexico to take. If the local water management institutions can become more focused on their specific resources and have the financial and educational support from the federal government as well as shared information then there will be success for water sustainability in Mexico.

NAFTA

The passage of The North American Free Trade Agreement (NAFTA) in 1994 was a golden opportunity to make a transboundary groundwater agreement; unfortunately, this did not occur. In fact, NAFTA and its sub treaty the North American Agreement on Environmental Cooperation (NAAEC) had very little direct effect on the aquifers that lay between the U.S. and Mexico. The primary reason for this is because the NAAEC "requires only that countries enforce their own domestic laws and attempt to moderate industrial activities that might transcend their borders. Consistent with sovereignty, the NAAEC allows each country to reject the deal if it threatens their national security interests (Article 42). In addition, the NAAEC establishes very limited enforcement powers over transborder environmental problems and ultimately relies on

national compliance" (Douglas, 1996: 357). Though many researchers are critical of these treaties, there are positives that came from their creation. For one "the two governments have agreed to develop joint environmental initiatives, including the development and funding of projects and enforcement through a Border Environmental Cooperation Commission (BECC)" (Douglas, 1996: 358). In addition there was an increase in "support for local and regional watershed planning through the Border 2012 Program and enhanced authority at the BECC and NABD to help fund projects that may incorporate a component safeguarding groundwater resources" (Mumme, 2013: 57). As I will discuss in my policy recommendations, there is a strong benefit towards cooperation by simply having gone through the process of putting agreements in place. These incremental bi and tri national agreements give policy makers and researchers a familiarity with the cooperative process with the other nations and a comfort with working together.

In conclusion, it can be seen from all of these examples of policy and regulation that there is a serious uphill battle to be fought when it comes to any single, shared regulation controlling a transboundary aquifer, like the Hueco-Mesilla. The fact that this body of water sits beneath these three very different regulatory bodies makes even the idea of controlling its pumping a difficult thought to conceptualize. Though it is difficult however does not make it impossible, with the current policies in place, and with the minute process as a tool, I believe there is a clear path towards regulation of the joint groundwater resources.

CHAPTER 5: THE CASE STUDIES

As mentioned earlier in this thesis, the following case studies were chosen because they illustrate examples of nations that can help us draw lessons that can be applied to the situation that the U.S. and Mexico are facing with the sharing of the Hueco-Mesilla Aquifer. These cases are not mirror images with the Hueco-Mesilla case but they do share common traits and a wide array of variables that allow for their comparison and therefore permit us to draw conclusions based on how their transboundary groundwater is being handled. Within the three cases I have identified six variables that will help us to create a framework for developing a relevant policy. The six variables are asymmetry in the power relationship between the states, conflict or cooperation present at the time of the agreement, a history of interaction, the involvement of third party actors, involvement of more than two nations in the agreement, and the types of governments in power.

The first variable I will analyze between the three case studies and the U.S. and Mexico relationship is asymmetry of power. In the U.S. and Mexico case, the power is held by the United States as the U.S. is a much larger and wealthier nation. In all three case studies, there exists an imbalance of power between the riparians that control the aquifers. In the case of the Mountain Aquifer, this power is held by Israel, in the case of the Guaraní Aquifer it is held by Brazil, in the case of the Nubian Sandstone Aquifer it is held by both Libya and Egypt. This commonality is important to highlight because the power dynamic between riparians, or any negotiators, plays a very important role when all parties come together to discuss agreements. The asymmetrical power held by the dominant nation will give their negotiators an upper hand and can result in the exploitation of the less powerful country. However, even in asymmetrical relationships, the interaction between the nations should be beneficial and will result in "a higher flow of economic and human resources across the border (and) the creation of a mutually beneficial economic

system" (Martínez, 1994: 4). Also, while there may be a large asymmetry a degree of interdependence (mutual reliance) should form between the nations. As Martínez states, "the prevalent pattern in binational regions throughout the world has been one of asymmetrical interdependence…in the case of two substantially unequal economies, the productive capacity of the wealthier countries is often matched with the raw materials and cheap labour in the poorer nation to create complementarity which, while asymmetrical in nature, none the less yields proportional benefits to each side" (Martínez, 1994: 5). Specifically related to the case of the U.S. and Mexico there exists a strong interdependence leading me to believe that cooperation is an inevitability.

The second comparative element found in these cases is the creation of agreements while engaged in conflict or lack of conflict over water. For the majority of the cases excluding Israel and Palestine including the case of the U.S. and Mexico, there is not currently a major ongoing conflict over groundwater. As is often discussed by some researchers, conflict as a result of water scarcity is what drives agreements and discussions on resources. In two of the cases I discuss, the Guaraní and the Nubian cases, I will show that agreements can be made with no conflict present. The countries came to an aquifer management agreement as a preventative measure to ensure that such a conflict does not arise in the future and that the water resources can be maintained. The outlier among this group is the Mountain Aquifer case which highlights the allocation of an aquifer shared between Israel and Palestine. There is no doubt that there is conflict in this case and that conflict is driving any agreements made. In this situation the Palestinian People are driven to agreement with their Israeli neighbors due to the Israeli strategy of cutting the Palestinian people off from their water sources "this process included the settlement movement, the construction of Israeli-only roads, the establishment of checkpoints, the creation of nature reserves that prevented

Palestinian construction, and the demolition of houses when people defied these regulations" (Jones, 2012: 85). It seems that with proper cooperative management there would be enough groundwater to go around for both communities that use the mountain aquifer; however because of the existing territorial conflict between the two nations the Palestinian people end up lacking water to give to their families and to irrigate their crops. This case will be used to demonstrate actions that should not be used in the US and Mexico situation.

The third correlation identified in these cases is a history of past conflicts or cooperation between the riparians. As will be seen, all of the cases present a history of interaction over goods and resources. None of the cases remain neutral or non-responsive to their neighbors and all fall into a model of "borderland interaction" (Martínez, 1994: 1). These models are various paradigms that can categorize the relationships between border nations in easy to package definitions. The four models are "alienated borderlands, co-existent borderlands, interdependent borderlands, and integrated borderlands" (Martínez, 1994: 1). This variable of relationships is used to illustrate the potential for cooperation or disagreement over aquifers. The case of the Mountain Aquifer highlights an alienated borderland where "international strife leads to militarization and the establishment of rigid controls over cross border traffic" (Martínez, 1994: 2). The case of the Guaraní Aquifer presents a group of countries which have formed into a regional institution with one another and represent a coexistent paradigm. These nations are "structurally bonded to each other (and have a) mutually beneficial economic system" (Martínez, 1994: 4). In the case of the Nubian Sandstone Aquifer we see a conglomerate of countries that have signed long lasting treaties with their neighbors over other water sources and goods and exhibit signs of representing two border paradigms, co-existent and interdependent borderlands. This case falls into the co-existent category because of the high degree of "unfavorable internal conditions in one or both countries

(that) preclude binational cooperation" and falls into the interdependent borderlands paradigm because many of the countries on the aquifer are "symbiotically linked with the border region of an adjoining country" (Martínez, 1994: 4).

It will be presented through this variable of interaction, that a history of cooperation over resources even if there has been a history of conflict at times leaves the nations well practiced in the art of negotiation with those that share their resource. The U.S. and Mexico, has a co-existent paradigm and as "conditions in the USA-Mexico borderlands constitute a good example of strong asymmetrical interdependence" (Martínez, 1994: 5). As has been seen, these two nations have a very extensive history of conflict, resolution and, in more modern times, successful cooperation with each other which should lead to successful cooperation over groundwater.

In addition to a history of interaction is the variable of third party influence. In all of the case studies presented, a third party influence tends to play a role in facilitating agreements made between the nations. In the case of Israel and Palestine, the United States and the U.N. play an essential role in creating the Oslo Accords as well as hosting numerous "talks" and summits intended to facilitate peace and understanding between the two nations. In the case of the Guaraní Aquifer, the World Bank as well as the international institution, Mercado Común del Sur (MERCOSUR), played pivotal roles in the development of a regional agreement on the transnational groundwater. Lastly, in the Nubian Sandstone Aquifer, the World Bank (African Development Bank) aided in the creation of the Joint Authority of the Nubian Sandstone Aquifer System and helped to research and map the aquifer.

The fifth variable that must be examined is the inclusion of two cases where there is more than a single pair of actors in the agreement itself. The two cases included are the Nubian Sandstone Aquifer which includes four nations, Chad, Sudan, Libya, and Egypt and the Guaraní

Aquifer which includes Brazil, Paraguay, Argentina, and Uruguay. This inclusion of more actors plays a role in making the agreements more complicated. The agreements become more complicated because in order to formulate an overarching management policy, all four nations need to agree on regulations as opposed to just two nations.

The final variable is the type of government in the countries. This variable is interesting to explore, especially in the context of these case studies, because the forms of government vary across a wide spectrum. In the Israel – Palestine case, Israel exists as a democracy whereas Palestine exists as a provincial self-government. It is worth noting here that Israel exists as a democracy within its own borders to those who subscribe to its faith and Palestine's government has limited sovereign powers even within its own territory. The Guaraní Aquifer's countries all have a variation on democratic republics, though corruption is known to be pervasive in the region. Lastly, the countries that surround the Nubian Sandstone Aquifer have all undergone major shifts in their governments over the last few years, some of these shifts leading us to question whether there is still a functioning government. Libya, for example, was ruled by an authoritarian dictator for over forty years and has since fallen into a provisional government with loose control over the nation. Egypt has undergone a political revolution of its own resulting in a semi presidential republic. However this is questionable following a coup by Abdel Fattah el-Sisi resulting in his becoming president of the nation with strong executive powers. Chad has a mostly farcical government led by a dictatorship for the last twenty five years, and ranks near the top of the lists in terms of failed status and corruption in the world. The nation "has long suffered from its landlocked position, inadequate infrastructure, weak governance, and political instability" (Coleman, 2016: 40). As a government Chad has a score of 4 out of 10 on the Political Risk Index (a system that rates governments on political stability, corruption, conflict and other risk

indicators). This rating can be compared with Sudan at a 3.5 and Libya with a 2. Sudan's government falls in line with Chad, being led by an authoritarian dictator with near universal control over the population and the military. The variable of type of government is important to recognize as states that lean more towards authoritarianism do not need to ask permission of any legislative body that represents the people. They can simply enact law and sign agreements. In those states that are more democratic, the processes for creating law and policy will be slower and involve more negotiation.

In summary, the case studies will provide an in-depth look at how nations with similar and differing characteristics have dealt with cooperation and dysfunction over their own transboundary aquifers. This will help provide us with a framework on which to build a solid policy recommendation based upon practices that work or do not work.

CASE STUDY ONE: THE MOUNTAIN AQUIFER

The first case study I will examine is one that centers on a conflict zone in the Middle East. This regional hot spot is the area occupied by Israel and Palestine as well as a very large freshwater aquifer known as the Mountain Aquifer. This chapter will examine how the conflict over this water resource began, how the two states have historically managed their disagreements over this essential resource, why the aquifer is a viable case study, and how the United States and Mexico can take lessons learned from this area and apply them to the Hueco-Mesilla aquifer.

The Aquifer

"The mountain aquifer covers the central area of the occupied territories on both sides of what are called in Israel the Judaean and Samarian Mountain range and extends generally from the Jezreal Valley in the north to the Beersheba Valley in the South and from the foothills of the Judean Mountains near the Mediterranean in the West to the Jordan River in the East" (Shuval, 2000: 35). The aquifer is split into three distinct regions which begin in the heart of the West Bank and, through gravity, flow out in all directions from the mountain tops. The "upper cretaceous aquifers are often referred to as the Mountain Aquifer. Groundwater recharged along the high ridges of the anticlinorial axis diverge into three directions along the structural slopes: to the west (so called Western Basin Aquifer) towards the Coastal Plain, to the east (so called Eastern Basin) towards the Jordan–Dead Sea trough, and to the north (so called Northeastern Basin) draining towards the Valley of Jezreel" (Mimi, Aliewi, 2005: 88). This flow is a problem because the high mountainous area where the waters begin is essentially surrounded by the West Bank territory and populated heavily by Palestinians. Because of this, "the control and allocation of water has evolved into an issue of "high politics, and it has been explicitly made a part of the ongoing peace negotiations"

(Gleick, 1994: 8). The water itself flows down the mountains and therefore collects at the base making "the most appropriate place to tap the aquifer over the deeper confined artesian areas on the foot hills and lower slopes of the mountains towards the Mediterranean Sea, the major portion of which is within Israel" (Shuval, 2000: 37). Hence we have a dilemma (a transboundary aquifer situation) whereby the prime area for water extraction lies within the Israeli territory while "the major portion of the recharge area of the Western Mountain Aquifer is in the Occupied Territories. Almost all of the recharge area of the North Eastern and Eastern Aquifers lie within the West Bank area" (Gvirtzman, 1994: 211).

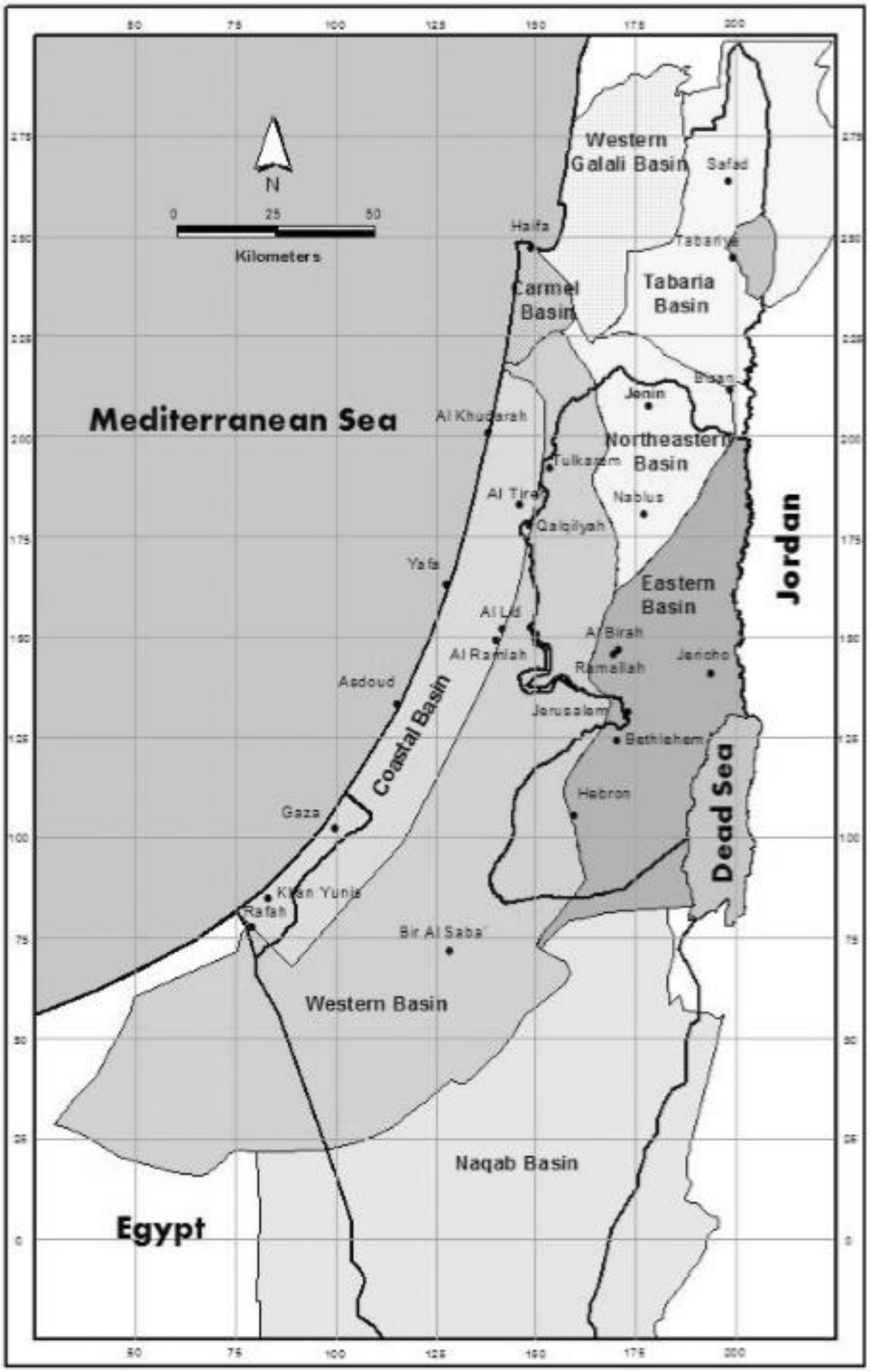

Figure 6: The Mountain Aquifer (Mimi, Aliewi, 2015: 87)

Conflict Between the Nations

Naturally this sharing of such a strategic resource causes a problem as either side with the right pumping power could cut off the others water supply. The Palestinians could rapidly extract water from the source of the aquifer and decrease supply to the reservoir and the Israelis could increase pumping and decrease the water that sits at the higher elevations. This is an obvious problem for two groups who have been at odds since the Zionist militias began to run Palestinians off of their land after "the UN proposed a partition plan in 1947 that would give the new state of Israel 56 percent of the land and Palestine 43 percent" (Jones, 2012: 75). This conflict over resources will create several issues for the two sides working out a compromise with one another. The problem is only intensified because of a hardline political stance that many Israeli law makers take where they want to continue to construct walls and settlements that degrade the land rights of the Palestinian people. These two nations, will need to find a way to cooperate over the aquifer if they wish to abide by humanitarian and environmental standards to maintain people's crops and daily water intake. "Unless both sides cooperate and jointly manage their shared water they both stand to lose, in terms of the long-term viability of their water systems. In other words, the only real choice both sides face is between a lose–lose situation if they do not cooperate, and a potential win–win situation if they do" (Mimi, Aliewi, 2005: 88).

Historically the aquifer remained little used as a source for groundwater, though in more modern history, "major portions of the groundwater of the mountain aquifer have been utilized by early Jewish farmers who settled in Palestine during the period of Turkish rule before 1918 and then under the British Mandate going back some 60 – 80 years. (Blass, 1960: 44) This mandate essentially granted all of the waters of the Yarkon River to the Jewish state which led to "the intensive exploitation of this aquifer initiated by the early Jewish farmers some 80 years ago,

starting in the 1920's, included pumping from the Yarkon River to irrigate extensive orange groves in the area between Tel Aviv and Petach Tikva and by numerous drilled wells in the Hadera area" (Blass, 1960: 45). Consistently and on many fronts the Israeli state very aggressively began to develop the water systems throughout the last century for extraction and efficient use of the aquifer. "This initiative was part of the state-building development ethos espoused by the Zionist movement from the outset" (DeShalit, 1995: 73).

In contrast, the Palestinians farmers were generally too poor to build up any impactful water extraction facilities or shape the broad water resources of the area. Due to this low use, the Palestinian state has very little historic precedent to claim water rights to the area though they have inhabited the space. This serves as the main basis for Israel's claim over the control of the waters of the aquifer.

Israeli Claims

The Israeli government legitimizes this claim based upon "the principal of international *Law of Prior Use* of the Mountain Aquifer" (Shuval, 2000: 42). The law of prior use is a form of common law that grants those who were using the resource first the right to continue exploiting it at their leisure. The application of this law as it relates to the Mountain Aquifer and Israel's use of the water is not firm. The Arab population was on the land before the Israelis and technically using the resource, just not in any large way. In addition, this type of common law can easily set up a situation for a tragedy of the commons where both parties on their respective sides of the border make a grab to maximize their use of the aquifers and deplete the resource as a result. The Israeli government also claims their aggressive intervention into the aquifer is based on fears that "once given independence, the Palestinians will drill many new wells in the aquifer and increase

the pumping rates in an unsupervised and uncontrolled manner which will result in seriously lowering the water table and depriving Israel of water resources essential for its survival." (Shuval, 200: 42). The Israeli state also fears that due to poor monitoring and control of local communities, the aquifer will become polluted and contaminated for the downstream users.

Palestine's Claims

The Palestinian people, though they do not have the historical water extraction infrastructure like the Israelis do, still have many claims to water rights within the Mountain Aquifer. They too, articulate their water rights through right of capture, quite literally like the State of Texas, in that they claim that they should have the right to the water because they occupy the space, and occupied this space longer than the Israelis. In addition to this claim, the Palestinians assert that the Israeli establishment has effectively cut off their water supplies and used methods of pumping and storing as tools to assert their domination over the Palestinian people. This is not a hyperbolic assertion by any means because "when Israel occupied the West Bank in 1967, it seized the western bank of the Jordan River as a military buffer zone and prevented Palestinian use of its waters for agriculture. As the water was not to be used in the occupied territory, Israel's increased diversion of waters in the northern Jordan basin from 1967 onward enabled it to absorb for internal Israeli purposes much of the riparian allotment contemplated for the West Bank under the US inspired Johnston plan of the mid-1950s" (El-Hindi, 2000: 124). This leads into the final claim made by the Palestinian people, that this dominance exhibited by Israel is simply a method for controlling the Palestinian State. Essentially, the Israeli government has found ways to cut off the water and sell or provide water back to the Palestinians at a high cost (or not at all). "Even when Israeli authorities supply alternative water to the communities that lost

their original wells or springs, through the Israeli Mekorot Water Company, the cost to the villagers is significantly increased, while this is viewed as a method of Israeli control and domination over the Palestinian residents" (Shuval, 2000: 41). These claims, which are generally substantiated, go against well-established rules recognized by the United Nations called the *Helsinki Rules.* Though it would be difficult to call these guidelines *laws,* they do serve as a standard for a nation to follow regarding sharing waters. One such rule outlined by the document is that "shared water should be used in an equitable and reasonable manner with attention to sustainable exploitation and the interests of the parties" (London, International Law Association, 1967: 1). The claims made by the Palestinians line up directly with what the *Helsinki Rules* dictate making it clear that the Israelis are violating international rules should the claims be true.

Oslo Accord Impacts

To alleviate some of the issues contended by the two nations, the 1993 Oslo Accords were signed by both nations to help increase cooperation "and were hailed at the time as recognizing the Palestinian right to some of the land in the West Bank and as establishing Palestinian control and administration" (Jones, 2012: 85). In this agreement "Israel accepted the Palestine Liberation Organization (PLO) as the representative of the Palestinians, and the PLO renounced terrorism and recognized Israel's right to exist in peace. Both sides agreed that a Palestinian Authority (PA) would be established and assume governing responsibilities in the West Bank and Gaza Strip over a five-year period" (U.S. Dept. State, 2016: 2). Article 40 within the Oslo Accords II, written one year later, was the outline of how to best utilize the water resources shared by the states. The agreement "was the first document to be explicit about Palestinian water rights in the West Bank,

but it did not define them. Oslo II did establish a framework for the management of shared water resources, including establishment of a Joint Water Committee (JWC) and a Palestinian Water Authority; quantitative allocation of water between Israel and Palestine; and mutual obligations to treat or reuse wastewater" (Brooks, Trottier, 2014: 107). The Oslo Accords unfortunately did not hold up well and, in the long run, proved to be more destructive to peace negotiations than beneficial. Regardless of the Accord's ability to maintain order, the creation of the Joint Water Committee should have been a promising step towards prosperous regulation of the water resources. As can be seen by the International Boundary Water Commission that regulates the waters of the U.S., Mexico border, this type of institution can be very beneficial towards cooperation. However, the institution created by the Oslo Accords serves as more of an extension of the asymmetrical power relationship between the two countries and tends to only empower and embolden Israeli rights over the water. In the past and "throughout the period when the JWC did meet (1996-2010), its structure effectively coerced Palestinian members to approve Israeli settlement water projects. Implicit legitimization of what the PA perceives as illegal occupation in the West Bank" (Selby, 2013: 6). As the institution stands, the "mechanisms for integrated project planning and execution require serious reevaluation regarding their effectiveness in equitably fulfilling the sides' separate and shared water needs. In many examples, the outcomes of joint management prove at best superficial cooperation, at worst detrimental to building trust and a functional groundwork necessary for a permanent peace" (Garvett, 2015: 2).

Summation of the case

The U.S., Mexico shared aquifers and the Israeli, Palestinian shared aquifers have similarities. Aside from climate and water scarcity, the largest comparison is the asymmetry of

power that exists between the participants. The U.S. and Israel tower over Mexico and Palestine in terms of national power and this gives them strong upper hands when they arrive at the negotiating table. In the case of Israel, “The transboundary water situation is unique because one party occupies the other, creating an imbalance in the joint management process over the Mountain Aquifer and limiting potential for mutually beneficial projects and equitable divisions of supplies” (Garvett, 2015: 15). It appears that the focal point for the Israeli, Palestinian water situation is a lack of trust and respect which negatively impacts any level of cooperation. Limited trust is understandable considering the history between Israel and the Arab populations. However it seems that there are opportunities to develop cooperation and increase their abilities to trust one another that go unused. The two populations seem to be stuck in an ever failing iteration of a prisoner’s dilemma, wherein they are unable to look out for the other and as a result will continue to find mutual long term failure. “In the absence of joint management there is risk of high social and economic costs and loss of resources and benefits. On the other hand, joint management should lead to identification of mutual opportunities for development and investments for socio-economic development with poverty alleviation, based on efficient and equitable utilization of shared water” (Mimi, Aliewi, 2005: 88).

The important point as it relates to the U.S. and Mexico is not so much what the Palestinian and Israelis do well, but where they fail and it is clear that they fail at building trust. It is therefore imperative when making policy recommendations that the buildup of trust is part of the process. The US and Mexico certainly have a better relationship than do the Israeli’s and the Palestinians, however there is still some distrust and, when it comes to resource sharing, it is easy to anticipate a greater distrust emerging. Learning from the Mountain Aquifer case, I believe that the optimal method to build trust between the U.S. and Mexico is to ensure transparency for both governments

and communities through regular reporting and research on aquifers and pumping on both sides of the border. In addition, it is essential that the current joint institution (The IBWC) remains strong and fair, giving each riparian an equal voice and vote in what occurs on the border. Lastly, both nations should encourage local level cooperation with trade groups, community activists, and environmentalists on both sides of the border to encourage joint projects and public relation campaigns around the cities. With this accomplished, and with an awareness and understanding of the trap of an asymmetrical power relationship (dominance is not the answer, if one loses, both lose.), trust can be built and an effective cooperative joint management can exist.

CASE STUDY 2: THE GUARANI AQUIFER

This case study as well as the earlier case study of the Israeli Mountain aquifer are presented mainly to highlight asymmetrical power relationships and past cooperation or conflict when dealing with transnational underground aquifer disputes. The case of the Guaraní Aquifer has an obvious asymmetrical power relationship wherein Brazil is, with is large geographic size, population and economy, the dominant power in the region. In addition the Guaraní has a long history of countries working together and cooperating on regional programs and trade agreements creating a situation where there is a third party influence on the agreement process. This case also presents the first of two cases where there are four state actors involved in the creation of a groundwater management plan. This is facilitated and made possible by the success of the major regional institution, Mercado Común del Sur (MERCOSUR) as well as other influential joint projects and cooperative agreements shared by the nations involved with the Guaraní Aquifer System Project.

The Aquifer

"The Guaraní Aquifer System (GAS) is a transboundary aquifer shared by four Latin American countries: Argentina, Brazil, Paraguay and Uruguay" (Sindico, 2011: 256). The GAS is one of the largest freshwater aquifers in the world and is estimated to contain "30,000 km of water, which amounts to 100 years of continuing flow from the Parana River (The Parana River is second only to the Amazon in length, in South America)" (Sindico, 2011: 256), or enough fresh water to "quench the thirst of the global population for the next 2,000 years at current levels of consumption" (Sindico, Hawkins, 2015: 320).

The aquifer is wide spread and flows according to “three main hydrogeological domains delimited by two geological structures … the Ponta Grossa Arch, which forces groundwater to flow from east to west in Sao Paulo State – Brazil (and) the Asuncion-Rio Grande Arch, which divides the portion south of the Ponta Grossa Arch into two semi-independent sedimentary basins” (The World Bank, 2009: 4). The aquifer has a high recharge rate, thanks to its permeability, and is refilled through surface water intrusion from streams and rivers and by moist soil that conducts water from the humid air and deposits it into the aquifer. This top layer permeability, though good for recharge, makes the aquifer susceptible to intrusion by human activity and pollution on the surface which has increased dramatically over the last 30 years. The human activities that could harm the groundwater include; “1) urbanization and the disposal of domestic urban wastewaters, 2) industrial premises, and their potentially inadequate storage and handling of hazardous chemicals, and disposal of liquid and solid effluents, and 3) the intensification of agricultural crop cultivation and forestry” (The World Bank, 2009: 9). The most significant of these three pollution behaviors is the increasing agricultural activities. The first, and most obvious, agricultural reason is the potential for pesticides and other harmful chemicals used in modern day farming to leech into the aquifer. The second, and less noticeable, reason is deforestation, deforestation negatively impacts the aquifer recharge that feeds the GAS. When forests are replaced by crops and pasture, the soil becomes degraded and no longer able to absorb the moisture from the air and deposit it into the aquifer, thereby cutting off a major source of recharge.

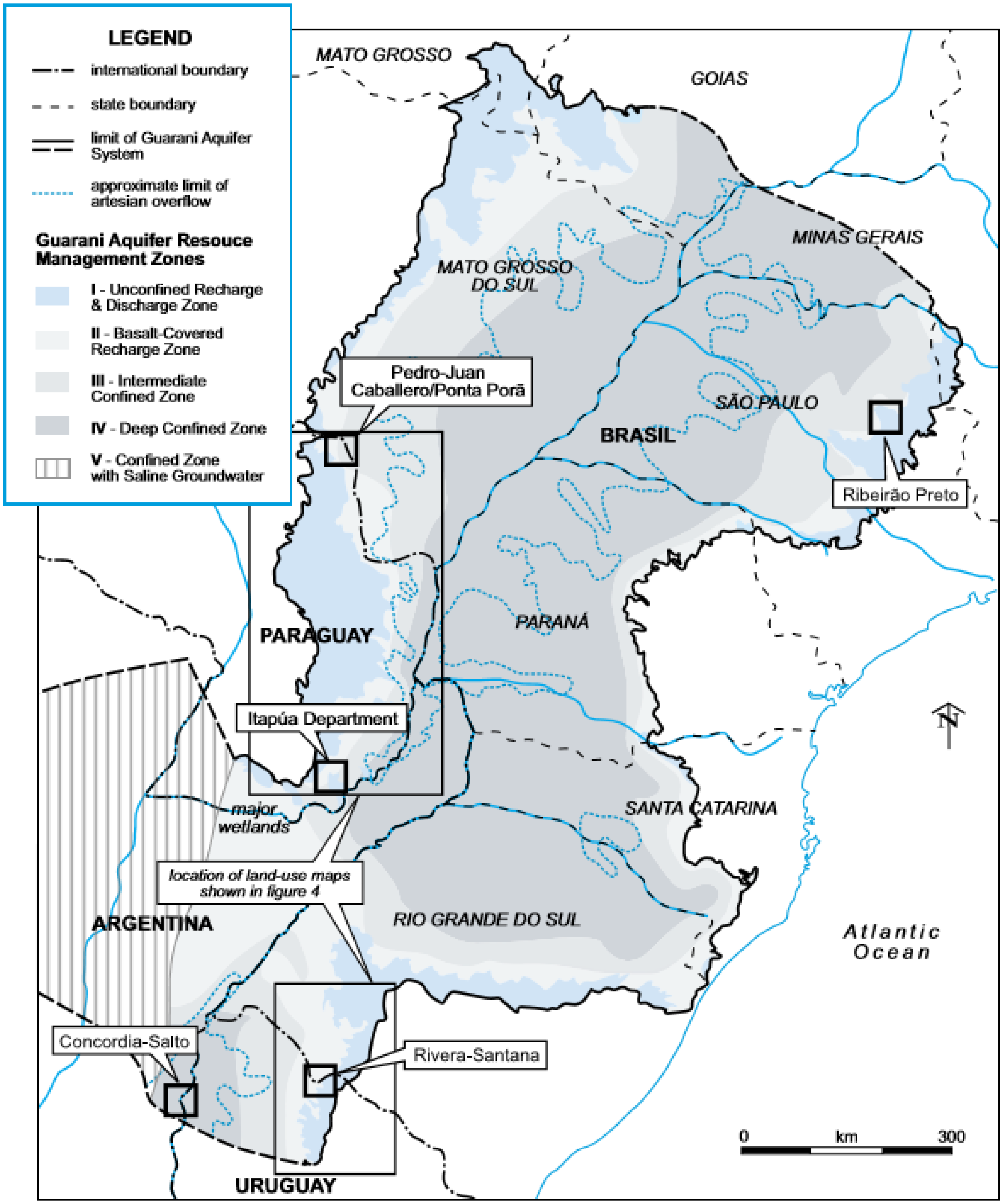

Figure 7: General delineation of resource management zones for the Guaraní Aquifer System (World Bank, 2009)

An Agreement on the Resource

With an increase in pumping due to population growth, the impact of human pollution and the obvious fear of contamination, the four nations agreed to begin work on a cooperative program to protect the aquifer and the water resources. The four riparians of the aquifer recognized the "economic and social importance of the Guaraní aquifer (which) has spurred concern over the pollution and over exploitation of its groundwater, especially in the context of growing demand for freshwater resources in all four states… (in addition) the potential for future problems in these areas has led to immediate action and cooperation among the four states to develop an aquifer management strategy" (Newton, 2004: 1). As a result of these concerns, the nations embarked on the Guaraní Aquifer System Process (GASP). This process for cooperation was progressive and, through the course of its life, has incrementally led to greater protections for the aquifer, greater opportunities for joint projects on sustainability and the creation of "The Agreement on the Guaraní Aquifer". The GASP can be separated into three sequential processes.

"The first one took place in the nineteen nineties and was related to epistemic community studies. Since the year 2000, the control of cooperation has transcended from the epistemic community to international organizations and the States" (Vilar, 2016: 12). In these studies, scientists from all four nations began to discover the full extent and importance of the aquifer, and named it the Guaraní Aquifer after the Guaraní people who live throughout the area covered by this resource. Until this cooperative branding or naming, the "Guaraní aquifer was known by the names of the (individual) national geological formations: Pirambóia / Botucatu in Brazil; Misiones in Paraguay; Tacuarembó in Argentina; and Buena Vista/Tacuarembó in Uruguay" (Borghetti, Borghetti, Rosa Filho, 2011: 5). Simply by changing the name to an accepted nomenclature utilized by the four countries, the researchers were able to bridge the initial reluctance to accept

that the aquifer was shared and were able to start national dialogues about its use and protection. In addition to raising awareness and studying the aquifer, the researchers took the initiative to involve international institutions and the funding that comes with them.

This brings us to the second stage of the GASP where "international organizations and states were to play a major role" (Vilar, 2016: 13). The most notable and engaged of these organizations was the MERCOSUR and the World Bank which provided funding and support for research. MERCOSUR serves as a unifying customs and trading organization of South America and it took a strong stance in the organization and development of the aquifer and its four nation use. As awareness grew within the organization and the region, the "MERCOSUR Parliament proposed: (i) the formation of a commission to study, analyze and compare each country's water-resource legislation; (ii) an agreement for the common management of the GAS and a transitional project assuring the continuity of the GAS Project structure; and, (iii) the establishment of a regional Research and Development Institute for the Guaraní aquifer and other aquifers shared by the states" (Villar, Ribeiro, 2011: 3). Supported by this background, all four nations were able to draft individual laws regarding groundwater use, representing a significant step forward in regulation. Brazil and Uruguay even went so far as to create groundwater specific programs such as the National Program for Groundwater, which serves to bridge a policy gap between the state and national regulations by involving all parties and emphasizing that "the need for integrated management of this resource (groundwater) and the fact that the aquifers are almost always external to the boundaries of river basins, States and countries, require coordination between all the mechanisms involved" (Ministerio do Meio Ambiente, 2016: 1).

With the strength of these individual nation's groundwater programs and the large amount of data collected through them, the third stage of the GASP was primed for execution. This third

and final stage was the signing of the *Agreement on the Guaraní Aquifer*. This pact represents a large step towards cooperation in transboundary aquifers because it "reaffirmed the applicability of international water law principles to aquifers and was the first agreement for transboundary groundwater developed under the influence of the UNGA Resolution" (Sindico, 2015: 5). Furthermore, it represents how profound cooperation over resources can be achieved as a preventative measure and not only during times of crisis. "Thus the fact that GAS States mobilized interests and resources without having a conflict and exclusively for an aquifer has turned it into a unique experience" (Villar, Ribeiro, 2011: 1). The agreement strongly emphasizes reasonable water use, the collection and sharing of information and general cooperation among the nations.

> "The Parties shall proceed to adequately exchange technical information about studies, activities and works that contemplate the sustainable utilization of the Guaraní Aquifer System water resources" (Agreement on the Guaraní Aquifer, Article 8, 2013: 3).

> "The Parties shall establish cooperation programs with the purpose of extending the technical and scientific knowledge on the Guaraní Aquifer System" (Agreement on the Guaraní Aquifer, Article 12, 2013: 4).

It also is written in a way that leaves issues flexible and helps to facilitate cooperation that are not actual laws and policy which helps maintain individual states sovereignty and makes the agreement more appealing for signature. Real progress for individual issues is achieved in Article 15 when the agreement discusses the creation of an independent commission that can establish regulations and monitor the nations.

> "It is established under the Treaty of the Plata River Basin, and in accordance with Article VI of such Treaty, a Commission be comprised by the four parties, which shall coordinate the cooperation among such parties for complying with the principals and objectives of this agreement. The Commission shall elaborate its own regulations" (Agreement on the Guaraní Aquifer, Article 15, 2013: 4).

Sadly, to date, few of the provisions have been fully enacted by the nations. The agreement has, however, built a strong foundation for cooperation and joint management of the aquifer. In

addition, it has led to the creation of a joint groundwater institution, the Regional Center for Groundwater Management for Latin American and the Caribbean (CeReGAS), which will hopefully lead to a jumpstart in the implementation of the agreement.

Summation of the Case

The Guaraní Aquifer case study demonstrates that the process towards collaboration and the creation of a resource management agreement is a long one but also one that is possible without conflict or crisis. In this case, the asymmetric relationship did not play a strong role in influencing the outcome for the creation of the regional agreement. That said, Brazil remains the most consumptive of the four nations and has continued to balk at fulfilling its obligations under the *Agreement on the Guaraní Aquifer*. In addition to its large scale consumption, Brazil also struggles with issues of water pollution around its urban areas, a common problem among the large developing nations of the world. Based on this case study, it appears important for the most powerful nation in the group to take the lead on the agreement. It seems that if Brazil drove the momentum of the agreement, the smaller countries would continue to grow more involved in the process. In the case of the U.S. and Mexico, it is essential that the United States, as the more powerful country, takes the lead to begin development and implementation of any transnational agreement. This must be accomplished while maintaining sovereignty and while finding common ground in the regulation that will benefit both countries.

As it relates to Guaraní, it also appears that prior regional agreements and institutions have a positive effect on the ability of nations to cooperate towards creating transnational groundwater policies. "These four states have a history of collaboration (for example, the Intergovernmental Committee for the La Plata river basin and the MERCOSUR trade mechanism) rather than conflict

in recent decades" (Newton, 2004: 2). As Newton highlights, the nations have been largely influential with one another for the past thirty years especially with the creation of MERCOSUR. Through this institution the nations have grown accustomed to cooperation with one another which played well when the group decided to create a governing policy on the Guaraní Aquifer. In a similar way, the U.S. and Mexico, as discussed in a previous chapter, have a long history of interaction and cooperation. With the North American Free Trade Agreement, the Border Environmental Cooperation Commission (BECC), North American Agreement on Environmental Coopeartion (NAAEC), North American Development Bank (NADBANK) and the International Boundary Water Commission serving as regional treaties and institutions it is logical that a pact similar to the *Agreement on the Guaraní Aquifer* can take place successfully.

CASE STUDY 3: THE NUBIAN SANDSTONE AQUIFER

The Aquifer

The Nubian Sandstone Aquifer sits in the Sahara Desert, under North East Africa, and is shared by four nations; Egypt, Libya, Chad and Sudan. With a land area of roughly "2.2 million km2" (Bakhbakhi, 2006: 74) and with enough capacity to hold up to "500,000km^3 (of water), of which the recoverable resource is thought to be in the region of 15,000km^3" (Regional Strategic Action Program for the Nubian Aquifer System (RSAP), 2013: ix), the aquifer system is considered one of, if not the largest, groundwater reservoirs on earth. Technically the aquifer can be broken up into two distinct but still hydrologically connected portions, the "Nubian Sandstone Aquifer (NSA) underlies the Post Nubian Aquifer (PNA) and whereas the NSA covers the whole area of the Nubian Sandstone Aquifer System (NSAS), the PNA is located only in the north" (Alker, 2008: 239). For the purposes of this case study, we will refer to the entirety of the aquifer as the Nubian Sandstone Aquifer System (NSAS). The aquifer system can be visualized as stretching all the way to the Mediterranean Sea in the North and is "bounded in the east by the impervious mountain ranges of the Red Sea and Northwards by the Suez Canal…the western boundary is a groundwater divide extending from the Tibesti Mountains in the south and Northwards along the 19 degree meridian" (Bakhbakhi, 2006: 75). Some of the water that sits in the NSAS is, "according to recent radiocarbon dating, more than a million years old. Most of it (however) comes from a more recent wet era when the Sahara was a crocodile-infested swamp" (Pearce, 2008: 45). Approximately seven thousand years ago, the desert formed on top of the land and trapped the water beneath it. In fact, the desert did such a good job trapping the water that the "recharge rate is very low and the contained water is fossil water (therefore making the) NSAS a

non-renewable groundwater resource" (Alker, 2008: 241). This said, there is some speculation that there is a small degree of recharge occurring as inflow due to seepage from the Nile but this research is still inconclusive. Though there is very little water that is able to penetrate into the aquifer, there still exists some natural discharge as a result of evaporation in areas of the aquifer thanks to the incredibly arid climate all around the groundwater. The implication of all of this is that "because water stored in the NSAS is regarded as non-renewable, its extraction will inevitably lead to its eventual depletion" (Alker, 2008: 242).

Depletion of the Aquifer

The depletion of the Nubian Sandstone Aquifer System is becoming clearer but remains little known. Some researchers believe that because of the immense size of the aquifer that even at current pace "it appears that the present extraction represents only some .01% of the estimated total recoverable freshwater volume stored in the NSAS" (Salem, Pallas 2002: 20). What this means is that because of the large quantity of water in the aquifer system, drinkable water will be available for hundreds, if not thousands of years, with the current rate of pumping. This outlook may be overly optimistic as many other researchers have discussed how the exploitation of the aquifer is leading to massive declines in water levels. Bakhbakhi discusses how "in the past 40 years over 40 billion m^3 of water has been extracted from the system in Libya and Egypt. This has produced a maximum drawdown of about 60m" (Bakhbakhi, 2006: 79). This is a rather bleak estimate although others have also noticed physical drawdowns occurring around the region in more recent years. For example, some lakes in Libya "linked to Kufra Basin Oases have begun drying up because of groundwater pumping. (In addition) scientists hypothesize that Egyptian

extraction will soon begin lowering the Sudanese water table" (Maxwell, 2011: 383). In the case of the NSAS, there exists many different pockets of depth, which can lead to transboundary issues. For example, the water in Chad sits high to the surface and is very susceptible to the overall drawdown in water levels causing "a migration of the rural population" (Alker, 2008: 250).

One of the most pressing issues facing the NSAS is the growing populations and rapid expansion of Libya and Egypt over the last few decades. In addition to this expansion is the increase in groundwater use (from the NSAS) by both countries for urban and agricultural consumption. Egypt, as an example, still remains incredibly dependent on the waters of the Nile River to sustain its population however the nation is showing an ever increasing interest in the ground waters of the NSAS. "In 2003, 4200 hectares were already under irrigation, it is planned to increase in this area, and is projected by 2010 that the groundwater extraction will have risen to 1,700 million m^3 from the NSA" (Food and Agriculture Organization of the United Nations (FAO), 2016: 3).

Nothing epitomizes growth and extraction better than the Great Man Made River Project (GMMRP) of Libya. This project was set up by the often eccentric Colonel Muammar al-Qaddafi as an attempt to bring the waters via pump from the NSAS to the people of Libya during a time when "new industrialization put stress on Libya's minimal freshwater resources. As water levels dropped in the small coastal aquifers near Libya's population centers on the Mediterranean coast, salt water began to flow in from the Mediterranean" (Maxwell, 2011: 380) thereby creating the need for another water supply at the coast. In an attempt to fulfill this need, Colonel Qaddafi embarked upon a huge pumping apparatus which was "designed to transport eventually 2.3 BCM of fossil water from the south of Libya to the north" (Alker, 2008: 246). The project's "first phase of the GMMRP opened in 1991, carrying 600,000 acre-feet of fossil water each year from well

fields around the oases of Sarir and Tarirbu" (Pearce, 2008: 47). From this starting point, the project progressed through three of its phases (out of a projected 5 total) and was halted by the civil unrest that gripped the country in 2011. Even if the project had gone absolutely according to plan, "the total amount of water available for all uses will be approximately 6.5 BCM and will thus barely cover 50% of total water requirements" (Alker, 2008: 246).

Chad and Sudan are far less developed than Libya and Egypt and therefore are not using as much groundwater as their northern partners. Groundwater requires a much more costly and technologically savvy method to procure so because of "severe technical and economic constraints in Chad, no major irrigation projects are planned" (Council of Ministers (HCNE) et. al., 2003: 15). Sudan's use is not much different than Chad as they primarily utilize waters from the Nile. The aquifer is still used almost exclusively by "nomadic and semi nomadic herders for extensive animal production" (Alker, 2008: 249). Regardless of the direct use of the NSA, Chad and Sudan still see the effects of the depletion of the aquifer in the lowering of their oasis levels and in the groundwater that they are using "there is a marked reduction (over 60m) in the North Continental Terminal and the West Pleistocene and in the static level in the north in the Nubian Sandstone (HCNE et. al., 2013: 213).

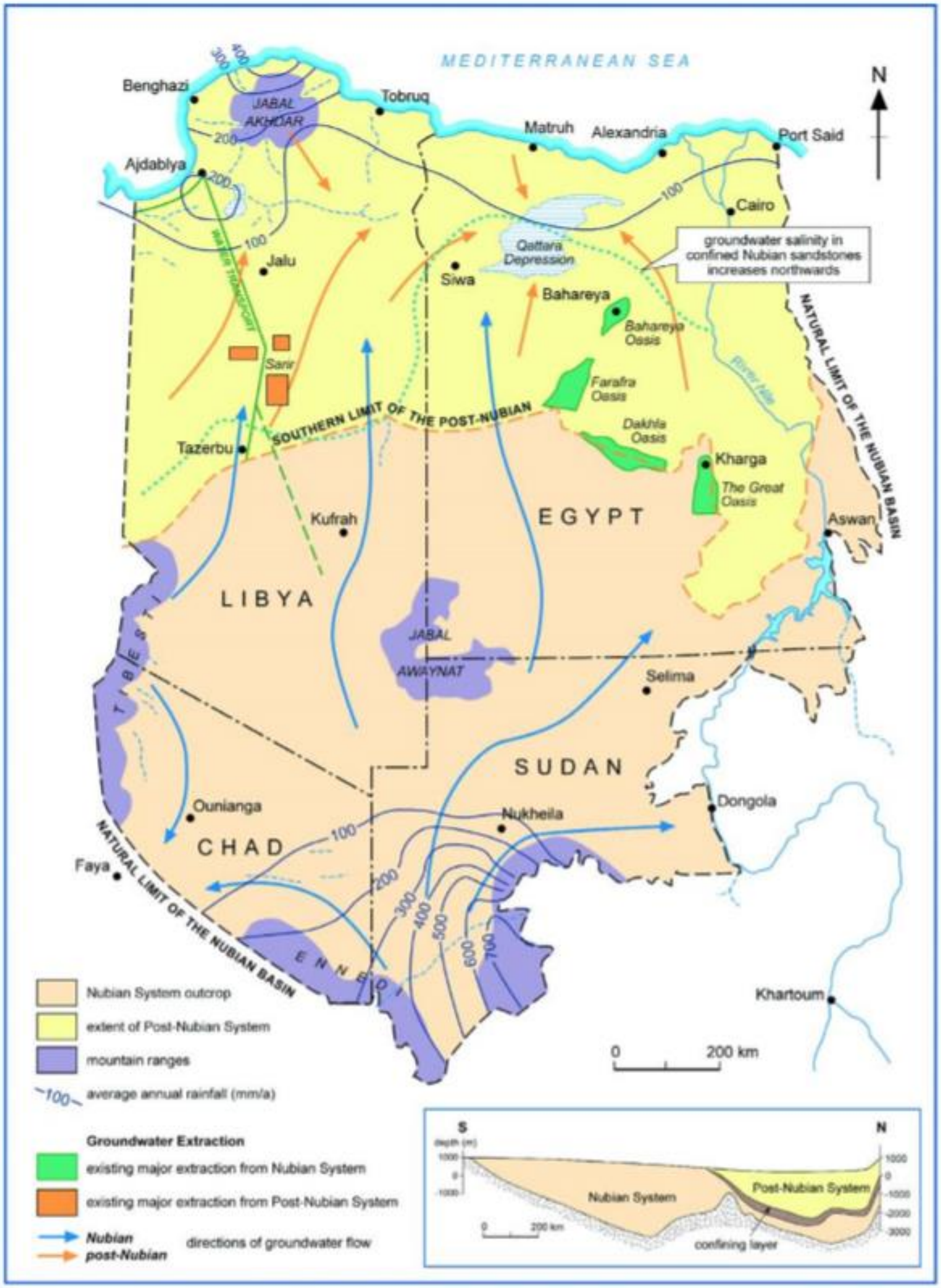

Figure 8: The flow of the NSAS (Council of Ministers (HCNE) et. al., 2003)

Transboundary Issues and Cooperation

The Nubian Sandstone Aquifer case is different than the previous two cases in that it involves four nations, Libya, Egypt, Chad, and Sudan. This adds a new layer of complexity to achieving cooperation between the water users. Though there are more actors involved in this case, asymmetry between the users remains important as seen between Libya and Egypt (the stronger), compared with Chad and Sudan (the weaker). Like all the transboundary aquifers explored in this thesis, the NSAS exhibits an "asymmetric use pattern (where) two riparian countries, namely Egypt and Libya, are apparently exploiting the aquifer more intensively than the southern riparians Sudan and Chad" (Alker, 2008: 249). As has been discussed, this high exploitation will inevitably have a negative effect on the two lesser users and on Libya and Egypt as well when groundwater levels begin to slowly sink lower. This is especially true in the southern part of Egypt and Northern areas of Sudan where "based on planned extraction rates, it is estimated that water levels will eventually sink below economically viable groundwater depths" (Sefelnasr, Gossel, Wycisk, 2007: 170). In addition to the declining water levels experienced around the region, the increase in pumping by Egypt and Libya is predicted to greatly "threaten water quality due to the intrusion of salt water in the deeper, confined part of the NSAS (Salem, Pallas, 2002: 10). This increase in salinity is a threat to all the users of the aquifer and will have a non-reversible impact on the water for all time, thereby harming any future development of the aquifer.

Because of this decline in water levels, and increase in salinity the NSAS is ripe for cooperation in the face of mounting environmental and extraction pressures. To begin, it is important to note that all four nations have a national level authority that focuses on groundwater within their territories. The importance of this, especially with regard to Libya and Egypt, is that there is a strong presence for monitoring, engineering and researching water levels and flows

within the NSAS. Unfortunately for the southern riparians, due to the extreme poverty and conflict within their nations, the water authorities are not well put together and wildly underfunded. In the case of Chad, there was at least the development of "Integrated Plan for Water Development Management" (HCNE et. al., 2003: 11). This helped give the nation a track to follow towards further betterment of their water systems. Though Sudan and Chad lack outstanding water institutions, they still have them and they are utilized to help create bonds between the four countries. It is likely that because of these institutions and a strong desire for cooperation, that the four countries embarked on a joint commission to help regulate and study the aquifer.

The Joint Authority for the Study and Development of the Nubian Sandstone Aquifer

This authority "was created by Libya and Egypt in 1982, and Sudan and Chad became members at a later point in time" (Alker, 2008: 259). The institution that exists is in place to conduct studies and collect data to manage the ground water in a scientific manner, study the environmental impact created by human intervention, spread information to the populations and prepare plans and policies for the use of the water resources. Much of the mission of this authority is to conduct research and share information with the regional partners that control the aquifer. This may not seem like a tremendously important step but as can be seen in so many examples, the first step to true cooperation and development is accurate and bountiful scientific information regarding the resources. From the foundation laid by this sharing of information, the joint authority has been able to sign a number of agreements. "The first governs the supervision and exchange of groundwater information concerning the NSAS (a formal recognition of the ability to share), and a second agreement (that) governs continuous monitoring of the aquifer and data sharing by

updating the regional information system" (Abu-Zeid s. a., 2014: 2, 8). Historically, the authority maintained its focus on research and information. In 2013, however, the four nations, through their joint authority were able to sign an agreement to "manage the shared aquifer in a sustainable and equitable way for the benefit of the NSAS countries on the basis of joint regional planning in order to minimize negative effects within and between countries, anticipating the challenges including increasing population, needs of agricultural expansion and climate change" (Regional Strategic Action Programme for the Nubian Aquifer System (RSAP), 2013: xii). This agreement and the creation of the joint authority was made easier as a result of a long history of treaties signed between these nations regarding water rights. For example, The Nile Waters Agreement was signed between Sudan and Egypt in an effort to regulate the usage of the Nile River and its basin. This agreement was updated many times over the years and led to the creation of the Nile Basin Initiative (NBI) whose stated objective is to "achieve sustainable socio-economic development through the equitable utilization of and benefit from the common Nile Basin water resources" (FAO, 2016: 1). It is this experience with "a strategic program containing a number of joint projects" (Grossmann, 2006: 207) that we can assume helped guide the creation for an agreement that manages the groundwater of the NSA.

This agreement is profound as it is the first of its kind in Africa and was acted upon in anticipation of crisis not as the result of crisis. As the agreement states, "It is still early enough in the development of the NSAS that priority threats have not yet, according to national reports, resulted in ecosystem impairment, providing the Nubian countries the unique opportunity to prevent rather than mitigate resource impairment" (RSAP, 2013: xi). This agreement should be the model as more and more transboundary aquifers need mutual management by the involved nations. The agreement is also based on extensive aquifer research which included "numerical models

(created) to understand the behavior of the NSAS (which) have been produced since the 1970s and fall into the general categories of local models to predict the effects of pumping wells and regional models to characterize the larger scale behavior of the aquifer" (RSAP, 2013: 8). The agreement goes into a very specific set of rules and guidelines based on a "strategy for protecting the water resources and ecosystem of the NSAS" (RSAP, 2013: 20). Some examples of these rules and guidelines include; "anticipatory action, preventative action, environmental and health considerations, sustainable agriculture, the polluter pays principle, the use of economic instruments for sustainable development, and accessibility of information" (RSAP, 2013: 21). This agreement is striking in that it covers so many aspects of proper basin management which includes investment, monitoring, and climate change. The document focuses specifically on the ability "to enhance the NSAS resilience to adapt to climate change impacts" (RSAP, 2013: 27). While this agreement falls into the category of raising awareness through education and research focused on climactic warming patterns, it is an enlightened step in the right direction when creating a joint agreement on groundwater management.

Like the NSAS the U.S. and Mexico have a large water source and a long history of treaties and agreements on water already in place. The U.S. and Mexico have all of the proper tools in place to create a robust groundwater agreement in the Hueco-Mesilla aquifer. It seems logical that the U.S. and Mexico, with the IBWC leadership, could emulate parts of the RSAP with the creation of a binational water agreement and find success.

CONCLUSION:

This thesis includes a review of aspects of the Mesilla-Hueco Aquifer, discussion of the relationship between the US and Mexico, and a comparison with other nation's handling of their water resources and aquifers. With this information it is apparent that cooperation between these two stakeholders can be achieved and policy recommendations can be developed for successful resource management.

In chapter one I discussed the methods behind my study through an exploration of both what it means to conduct a policy review as well as the finer details of how case studies operate to include variables found in the cases used in this paper. In addition, I have explored previous literature written on this subject to include transnational water management strategies, conjunctive groundwater management, policy and laws regarding groundwater, the tragedy of the commons, and border studies issues.

Chapter two explored the hydrology of the aquifer starting at the headwaters of the Rio Grande in Colorado and eventually working its way through New Mexico, past the Elephant Butte Dam, into Texas and out to the Gulf of Mexico. In addition to the surface water I discussed groundwater recharges, and how aquifers form in layers and concluded with a detailed description of how the two cities are over utilizing their resources and drawing the water level downward.

Following hydrology, chapter three presented a historical perspective which reviewed the many agreements, disagreements and treaties that have led the two border nations to where they are today. This chapter progressed through time from Mexican independence, to the Mexican American War, to the creation of the border based on the Rio Grande's flow, to the Treaty of 1944, the La Paz Agreement and finally to modern day minutes made by the IBWC and the CILA. With this historical background, I aimed to demonstrate two nations that have undergone considerable

changes through time and have adapted and learned to work with one another to create an effective borderland relationship.

Chapter four introduced the groundwater policies of the stakeholders of the Mesilla-Hueco aquifer. This included U.S. Federal, Mexican Federal, New Mexico and Texas water policy. In addition, I included a section on the North American Free Trade Agreement's impact on joint environmental regulations between the two countries.

Lastly, chapter five presented the Mountain Aquifer, the Guaraní Aquifer, and the Nubian Sandstone Aquifer as three case studies from which I could build a framework of understanding based on the variables of the cases. The variables I chose to use were an asymmetrical power relationship, conflict or lack of conflict over groundwater resources, borderland interactions, third party influence, number of state actors and the types of government.

There is no straightforward answer to the problem of cooperation over transboundary groundwater management on the U.S. Mexico border. As I have explored in the preceding pages, the issue is complex and dynamic and unfortunately does not have one magic bullet solution. It can be seen from the previous case studies that each situation is unique and requires a solution that must take into account the political atmosphere of the countries that control the resource, the nation's past interactions, the ecosystems, power relative to one another and the aquifer itself. In many cases, the solutions found cannot be nationwide but instead must remain only aquifer wide because of the differences between each situation. The major reoccurring theme in all cases is that solutions are not found without cooperation.

It is therefore my conclusion that the United States and Mexico are in a position where a binational agreement on the management of groundwater in the Mesilla-Hueco Aquifer is within reach. I have made this conclusion by analyzing the causes for cooperation, other cases where

success and failure over aquifers were found, and the policies of and cooperative history between the U.S. and Mexico. The two countries have a long history of cooperation over water disputes. It is these types of agreements that help to create a foundation for which future negotiations can be built. It is these arrangements that provide "municipal leaders invaluable experience in local binational resource management and improves the climate for considering similar ventures…They provide needed experience and nurture mutual trust in cooperative management approaches" (Mumme, 2000: 343).

In addition to a history of cooperation there is reason to believe that, though there exists an asymmetrical power relationship between the two nations, this imbalance should be less relevant in the context of groundwater as there is no upstream or downstream riparian relationship. "While both countries have access to the resource, neither can effectively deny the other access. Moreover both sides recognize that the current race to deplete the resource harms everyone's interest in sustaining a reliable source of urban water beyond the near future" (Mumme, 2000: 352). Because of this fact, the U.S. has something to gain by coming to the bargaining table. Unlike in other surface water (and some groundwater) situations where the upstream, more powerful riparian stands to gain very little by negotiating water agreements with those downstream, in the Mesilla-Hueco aquifer all Mexico needs is a small entrance point in their territory and they have access to a vast quantity of the water.

Lastly, I am confident that cooperation on groundwater is feasible because of the long standing institutions that exist between the two nations. The IBWC has been managing the shared water resources between the two nation's borders for many years and has all of the necessary committees and tools in place to successfully implement a binational agreement. In addition to this joint commission, with the signing of NAFTA the two counties developed other institutions

like the U.S. Border Environment Cooperation Commission, the North American Development Bank and the Commission on Environmental Cooperation who have a vested stake in protecting groundwater in the region.

Though I am confident that an agreement between the two nations is feasible and within reach I also find myself questioning why, if all of these factors have been in place for so many years, has one not yet been reached? My answer to this question is that the major roadblock impeding cooperation is the policy differences exhibited by the parties involved, i.e. Mexico who treats groundwater as a state owned resource and Texas who views groundwater as rule of capture. Because of these differing policies, the institutions, most notably the IBWC have been ineffective in pushing through or acknowledging any form of significant groundwater agreement. It is because of these hand tying policies that "The architects of the IBWC's mandate (minute 242) deliberately avoided making any reference to transboundary groundwater, regarding this and other matters as ancillary to the agreement" (Utton, 1991: 477).

It may be possible for New Mexico as a State to create an agreement with Mexico, to regulate the shared aquifer that sits on their border because of their closely related water laws. This has not happened to date because the area where New Mexico and Mexico share an aquifer is very sparsely populated and the rate of pumping on both sides is relatively insignificant. With population increases however, this will most likely change, requiring these two entitites to work out an agreement over the water. Should this take place it may serve as a precedent, which could propel Texas towards an adjustment of its current water laws to accommodate legislation that can foster a binational agreement of their own.

However, even if this does occur the creation of an agreement that holds all parties accountable between the U.S. and Mexico is an uphill battle. This is why my policy

recommendation proposes an initial campaign that involves the community and the people who utilize the aquifer's waters to sustain their lives. This involvement and understanding is the only way to rally support for such an agreement before getting tied up in the bureaucracy and politics of the institutions and the governments.

A WAY FORWARD

The solution that I envision for the management of the aquifer, is not one that will happen easily or quickly, it will require commitment by all stakeholders and a great deal of work to make a viable resolution to the problem. This agreement will need to be flexible and adaptable to allow for climate and population changes, should the agreement have specific allocations between the two countries this will leave "little flexibility for changing flow conditions…this characteristic is especially problematic in the context of climate change" (Cooley, Gleick, 2011: 713). From the research presented in this thesis it seems the most effective strategy for aquifer management is a four phase approach described below.

The first phase of the proposal would be to inform the public that utilize the aquifer about the dire need to support research and regulation of its waters. By doing this there would be an increase in community outreach on both sides of the border to raise awareness of the issues that face the aquifer and to encourage sustainable water use practices by the population. By taking this step, the community can become aware of the aquifers existence and the issues it faces and can become grassroots agents of change. The outreach program for this would need to be far reaching and easy to digest for the community. It should target environmental groups, activists and politicians and also groups and individuals who may not have such a direct link such as schools, community organizers and church groups. By working with these groups and making them aware

of the risks associated with a heavy drawdown in the aquifer, the water utilities and the institutions on the border and the politicians in Austin would be far more empowered to initiate a binational agreement or modify archaic groundwater laws.

The second phase is to increase awareness and scientific knowledge of the aquifer through research. As could be seen in the Nubian Sandstone Aquifer System, it was information and a strong understanding of the aquifer and its future that laid the foundation for action. At this point, there is still insufficient and outdated data regarding the water in the bolson. Also, it has been nearly twenty years since a comprehensive survey was completed on the aquifer in 1998. There was an attempt to map all of the shared aquifers between the United States and Mexico in 2008 but due to the recession of 2008 the initial budget of 50 million dollars was reduced to 1.5 million dollars (Center for Water Policy 2013: 4). With the reduced budget the groups involved in mapping the aquifers had to reduce their initial plans from 14 aquifers to 1. This reduction of funding shows the immense need for lobbying by the people and by the state to get funding. 50 million dollars is not a particularly large sum for the United States, especially compared with the estimated 9 billion that is spent securing the border each year. Because of this lapse in relevant information, the data that was gathered may not have utilized the most up to date technology and modern understanding of groundwater, thereby potentially rending it deficient. My proposal would call upon the IBWC and the people of El Paso acquire funding to reopen and expand research on the aquifer to create a reoccurring scientific study that will retrieve data which will include quantity of water, quality of the water, rate of drawdown, modeling and rates of recharge. In addition, both riparians should continue to have a free flow of information regarding pumping rates and any research conducted by the water utilities on either side of the border. If this is

accomplished, both nations can have a more complete picture based on current data to create goals and metrics so they can cooperate on a way ahead.

The third phase of the proposal is likely the most difficult to achieve. At this juncture the modification of Texas groundwater law would be an ideal stepping stone towards effective management of state groundwater resources and towards creating an agreement with Mexico. This amendment to policy would need to begin with the Groundwater Conservation Districts (GCD), by utilizing these already existing authorities any adaptations to groundwater management will be easier to implement. The first recommendation would be to "support the creation of additional districts or expansion of existing districts by annexing areas with similar aquifer conditions"(Joshi, 2005: 100) By taking this step, aquifers could be managed according to their site specific requirements which would allow for the most efficient and appropriate forms of conservation and use. This merging and reshaping of GCD to fit specific aquifers would allow regulators a way to address specific problems of the site by setting well limitations and modifying rules to account for recharge rates. In addition, I believe the legislature should outline and encourage these GCD to regulate their territories using a combination of reasonable use methods and correlative rights methods. By doing this the GCDs will be able to "establish spacing limits and production limits based on acreage or tract size" and "establish a certain quantity of water that can be withdrawn per acre of land owned, leased, or irrigated" (Joshi, 2005: 101). Lastly, Texas must consolidate its regulatory institutions. At the current time Texas has upwards of 20 organizations that regulate water which creates a weak and fragmented system. Consolidation would help these organizations gain a stronger voice in the state capital and enable them to be more effective in their efforts to manage water systems. By taking these steps, GCDs could, without affecting other Texas water users, autonomously have the authority to adjust and accommodate for any new regulation

imposed by the IBWC through a binational agreement on withdrawals from the Mesilla-Hueco aquifer.

The fourth and final phase would be to enact a formal minute in the IBWC. With community support I believe the IBWC could pass a minute that would focus specifically on groundwater. The specific details of this minute are out of the scope of this thesis but I would recommend that the policy "should support those prescriptive solutions that balance values and emphasize equity as well as place protection of environmental values on the docket along with human health and material well-being" (Mumme, 2000: 362). In addition, the authors who pen the agreement would do well to adapt pieces from other agreements such as the Regional Strategic Action Programme for the Nubian Sandstone Aquifer, The Helsinki Rules, and the Bellagio Draft Treaty. All of these already existing agreements have outlined methods to improve the output of the aquifer while balancing the needs of humanity and growth. The Bellagio Draft Treaty states that it

"Provides mechanisms for the international aquifers in critical areas to be managed by mutual agreement rather than continuing to be subjected to unilateral leaking. The treaty addresses contamination, depletion, drought and transboundary transfers as well as withdrawal and recharge issues. The fundamental goal is to achieve joint optimum utilization and avoidance or resolution of disputes over shared ground waters in a time of ever increasing pressures upon this priceless resource" (Hayton, Utton, 1989: 1). With documents in existence like the Bellagio Draft Treaty, there is no reason to reinvent the wheel. Instead an existing comprehensive and effective agreement can be adopted and tweaked to suit the needs of the aquifer based on these effective strategies. In addition, by utilizing portions of established agreements the minute will not seem so radical, which should make it easier to get ratified.

There is not a doubt in my mind that humanity can find a solution to the depletion of the Hueco-Mesilla Aquifer. However, this solution will not come without cooperation between the U.S. and Mexico. As has been seen in the last 20 years, when a more conservative government takes power in the United States the issues of the environment takes a back seat to a more militaristic and profit focus on the border. When 9/11 occurred much of the progress made towards cooperation over environmental through agreements like La Paz or the Border 21 Program slipped away or became much more difficult to sustain. With the incoming administration of the United States less interested in environmental issues and more interested in renegotiating NAFTA, dividing the two nations and building up protections on the border it is more important than ever for local communities to rise up and speak out about the issues that they and their environment face. Though I have argued in this paper and still believe that the two nations can come to an agreement over this shared resource without a crisis, perhaps this is exactly what is needed in order to get lawmakers in both capitals to wake up to the reality that something must be done. Much like the severe droughts in California that became front page news and enabled law makers and environmental activists to make positive changes, it is the responsibility of the people in this region to let their governments know that this is already a crisis and that inaction cannot be tolerated any longer. From a citizen of the U.S. opting for a lawn and not xeriscaping, to a citizen of Mexico taking a prolonged shower, from institutional inability to an ignorance of the situation below their feet, and from a community to a community everyone must play a role in being a part of the solution. It can never be forgotten that a border is a manmade creation. No amount of barbed wire fencing, nor number of agents, nor length or height of wall can keep the environment at bay. In the end it is cooperation that will save us, for water and thirst have no borders.

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