Assessing Basin-wide Water Availability to Meet Treaty Obligations:

Rio Conchos, Mexico

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WATER FOR TREATY OBLIGATIONS: RIO CONCHOS, MEXICO

Abstract

The Río Conchos is one of the most important river systems in northern Mexico, and is a key tributary to the transboundary Rio Grande/Rio Bravo. This research evaluates how Mexico can meet specific treaty obligations, despite on stream development, changing aquifer storage, and regional climate change in the Rio Conchos basin. This research performs a thorough an assessment of water resources availability, looks at regional climate trends, and reviews the institutional setting of water resources management in the Rio Conchos to suggest possible management strategies. While this work does not develop a comprehensive water resources management strategy for meeting Mexico's treaty obligations, it finds important conclusions for informing those strategies: 1) regional climate change will impact water resources in the Rio Conchos basin, 2) institutional development is necessary to allow local and regional water-related institutions to better control water use, and 3) a conjunctive management strategy where groundwater abstraction in high recharge areas is used to make up Mexico's deficits is a strategy needing more research. This research contributes to a greater effort looking at sustainable water resources management in the Rio Grande/Rio Bravo basin, and is an initial first step in creating a stakeholder "friendly" basin model of the Rio Grande/Rio Bravo system.

Introduction

The Río Conchos is one of the most important river systems in northern Mexico, and is a key tributary to the transboundary Rio Grande/Rio Bravo. The Rio Conchos has its headwaters high in the Sierra Madre Occidental Mountains, and, eventually, supplies the necessary water for large irrigation districts on the central plains of the Mexican state of Chihuahua (Figure 2). At its confluence with the Rio Grande/Rio Bravo, just above Big Bend National Park on the U.S. side of the Rio Grande/Rio Bravo (Figure 4), the Rio Conchos renews the internationally shared river's stream flow to support downstream communities, agricultural development, and manufacturing.

Under a bi-lateral treaty, Mexico is obligated to leave one third of the Rio Conchos' annual flow, or 350,000 acre-feet, to the U.S, in return for some of the Colorado River's annual stream flow. However, on stream development, regional population growth, industrialization, and global climate change threaten water resources in the Rio Conchos basin, causing "water deficits" that Mexico "owes" the U.S. under the treaty. Disgruntled farmers and downstream waters users on the U.S. side of the river are pressing diplomats in Washington, D.C. and Mexico City to enforce the Treaty of 1944 (Kelly, 2001), causing tension between the two nations. To make matters worse, periodic drought in northwestern Mexico has reduced stream flows, altered groundwater reservoir storage levels through overdraft and compaction, and forced a greater reliance on groundwater in the Rio Conchos basin.

As one of the most important rivers in northern Mexico and part of the major transboundary river system shared by the U.S. and Mexico (Figure 3), meeting Mexico's treaty obligations requires an assessment of the water resources of the Rio Conchos basin. This report presents a water resources assessment of the Rio Conchos basin in ArcGIS, including an assessment of water resources availability and reliability, an overview of regional climate, and a summary of institutional capacity for sustainable water resources management. This research contributes to a greater research effort looking at sustainable water resources management on the Rio Grande/Rio Bravo basin, and is an initial first step in creating a stakeholder "friendly" basin model of the Rio Grande/Rio Bravo system

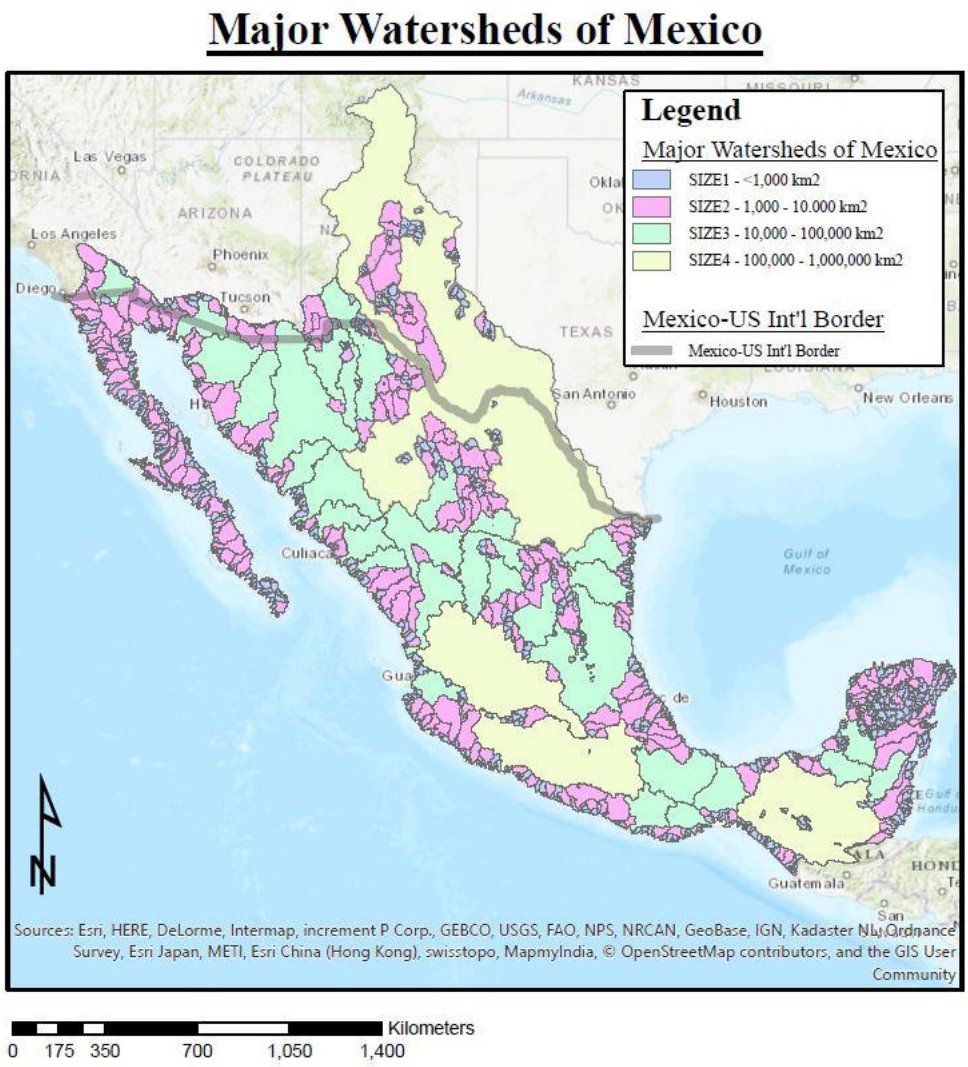

Figure 1. There are several large watersheds across Mexico. The Nature Conservancy (TNC) classifies watersheds in Mexico by areal extent. The Rio Conchos watershed is tributary (part of) the transboundary Rio Grande watershed.

Data Sources

Data collection for this research was challenging and required extensive investigation as, despite bi-national efforts to promote information sharing (Minute 308 of the 1944 Treaty, IBWC, 2017), there remains “no integral database that includes information from both sides of the Rio Grande/Bravo basin” (Patino-Gomez et al. 2004). The primary data sources for this work include the federal water administration of Mexico, or Comision Nacional de Agua (CONAGUA), and non-governmental organizations (NGOs), like the Nature Conservancy and the World Wildlife Foundation (WWF).

Figure 2. There are several major rivers in Mexico. The Rio Conchos is in North Mexico and is a tributary river to the transboundary Rio Grande/Rio Bravo. At its confluence with the Rio Grande/Rio Bravo, the average annual discharge of the Rio Conchos is approximately 24 m^3/s (850 cfs).

This research is an initial first step in creating a stakeholder "friendly" basin model of the Rio Grande/Rio Bravo system. This basin model, developed in a MODFLOW-WEAP-ArcGIS framework, will serve as a data and information repository of the Rio Grande/Rio Bravo basin, including information from the Rio Conchos basin.

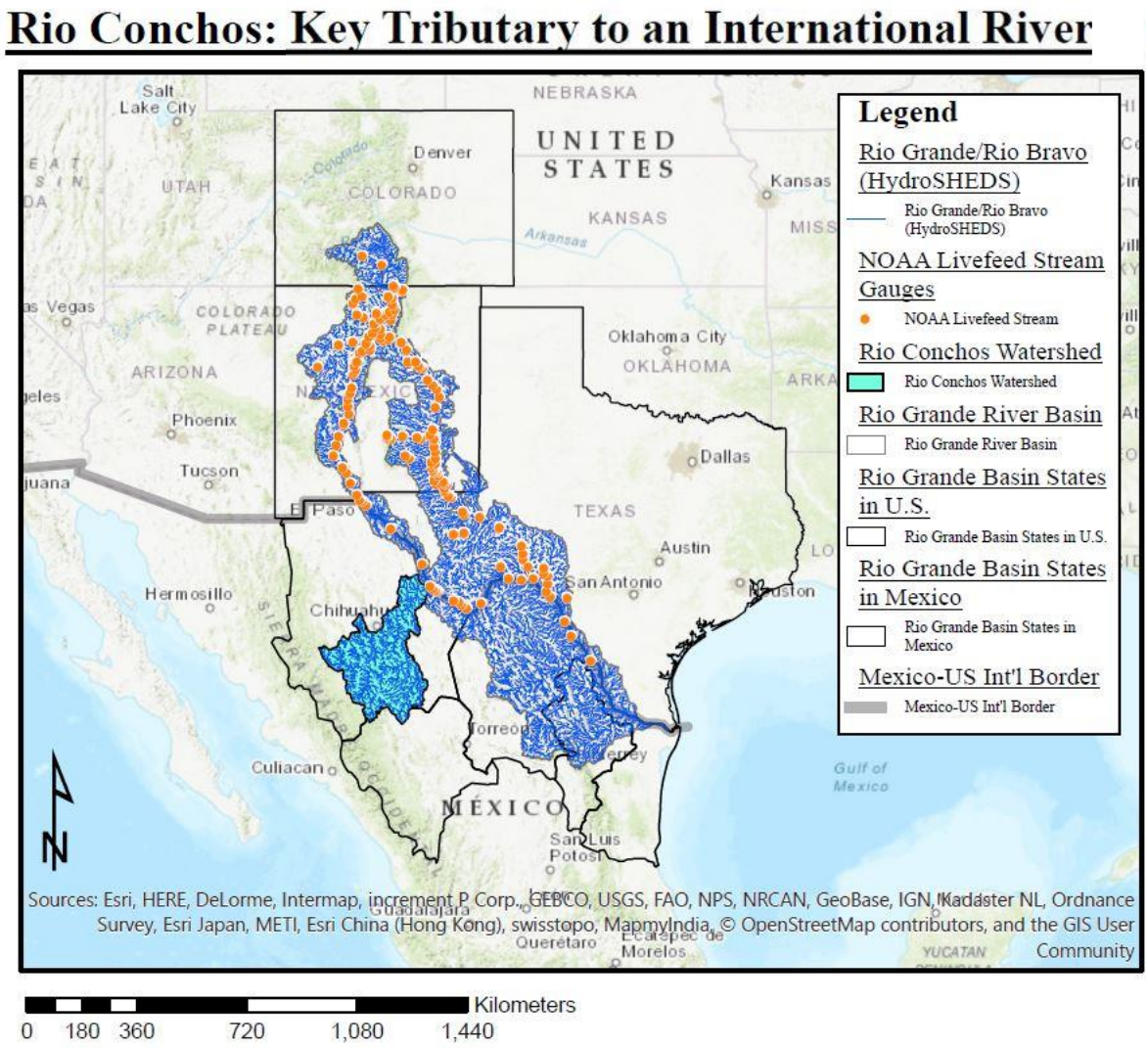

Figure 3. The Rio Conchos is an important tributary river to the transboundary Rio Grande/Rio Bravo. The Rio Grande watershed is approximately 475,000 km^2. Some basin area calculations vary, as many include the isolated, internal drainage basin. Water from the internal drainage basins may contribute to groundwater that interacts with stream flow in the main basin.

The Rio Conchos Basin

The main reach of the Rio Conchos is approximately 560 km and its basin is approximately 68,000 km^2 (Figure 4). The Rio Conchos basin is almost entirely in the Mexican state of Chihuahua, but the basin crosses several municipalities (Figure 4), making political and institutional management of the basin challenging. Above its confluence with the Rio Conchos, the mean annual stream flow in the Rio Grande/Rio Bravo is barely 4 m^3/s (140 cfs). After it gains tributary flows from the Rio Conchos,

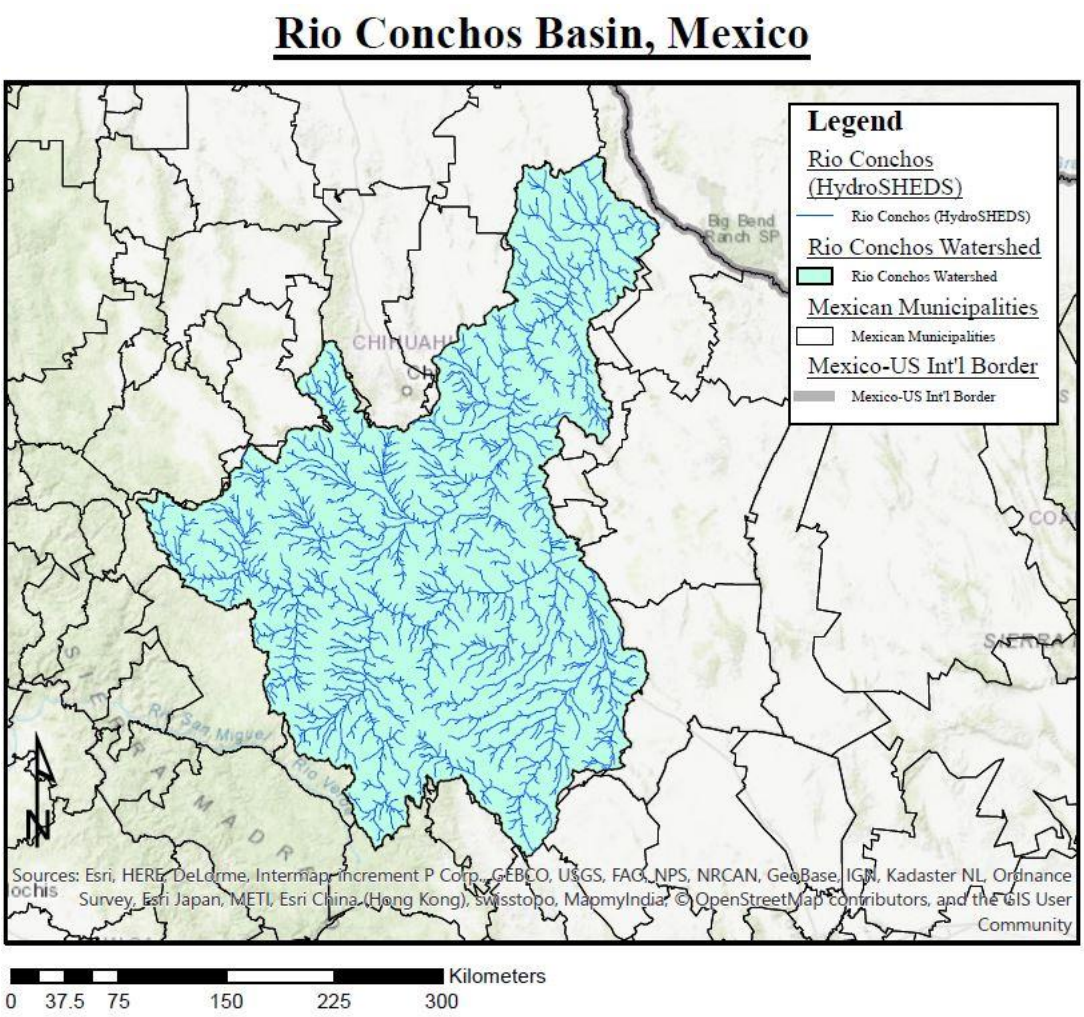

Figure 4. The Rio Conchos Basin is approximately 68,000 km^2 and the main reach of the Rio Conchos is approximately 560 km. The Rio Conchos Basin has both international transboundary importance and domestic transboundary importance, as it crosses several municipal borders.

however, the mean annual stream flow in the Rio Grande/Rio Bravo is 28 m^3/s (990 cfs), making the Rio Conchos a key tributary to the Rio Grande/Rio Bravo (Figure 5 and 6). The Rio Conchos basin makes up 14 percent of the Rio Grande/Rio Bravo basin (Kelly, 2001), but its annual stream flow accounts for more than 50 percent of stream flow in the Lower Rio Grande/Rio Bravo ("lower" is a political subdivision and refers to the section of the Rio Grande/Rio Bravo below El Paso, TX).

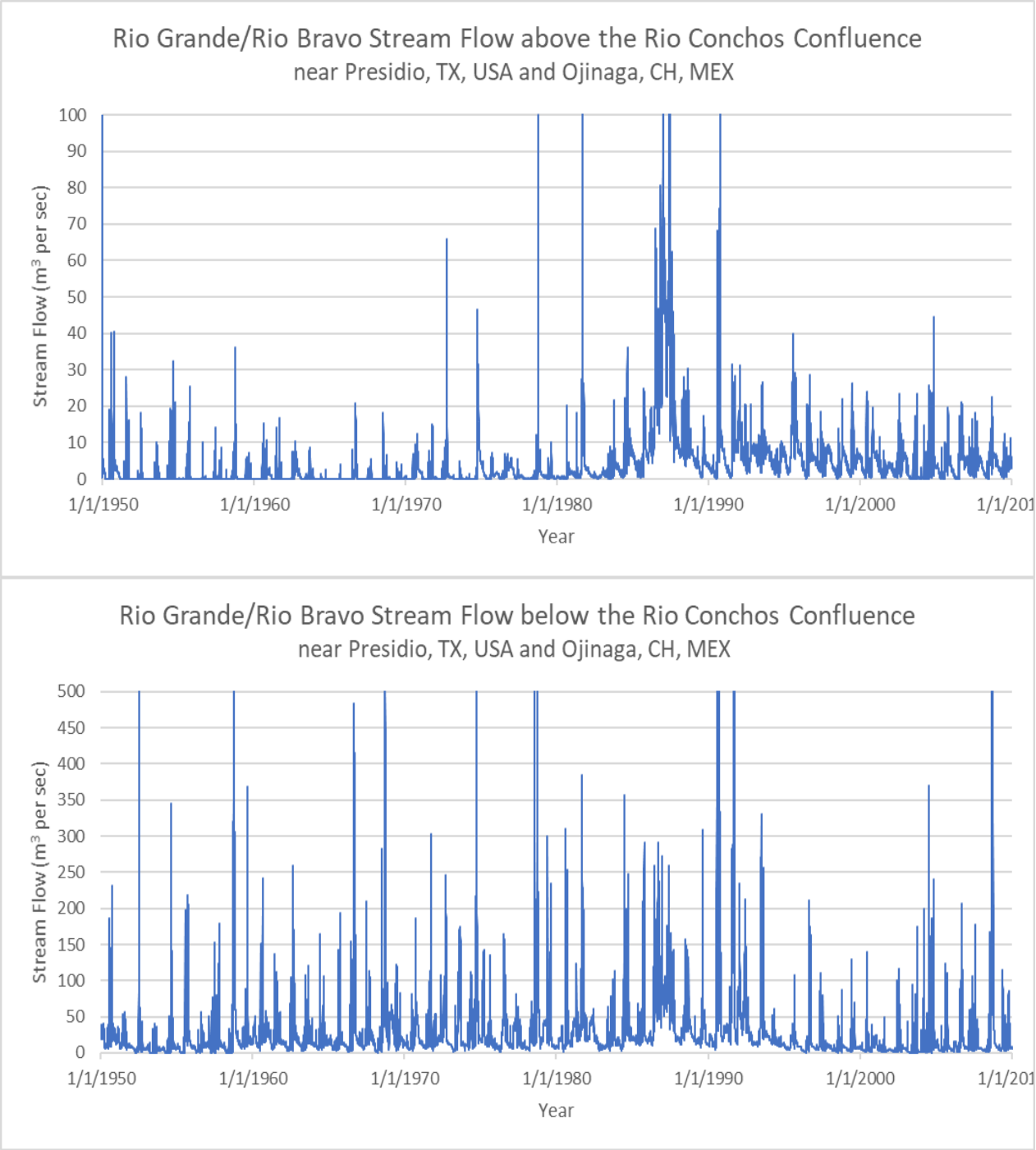

Figure 5. Just above the confluence of the Rio Conchos, the mean annual streamflow of the Rio Grande/Rio Bravo is approximately 4 m^3/s (140 cfs). However, after the confluence, the mean annual stream flow of the Rio Grande/Rio Bravo is more than 28 m^3/s (990 cfs).

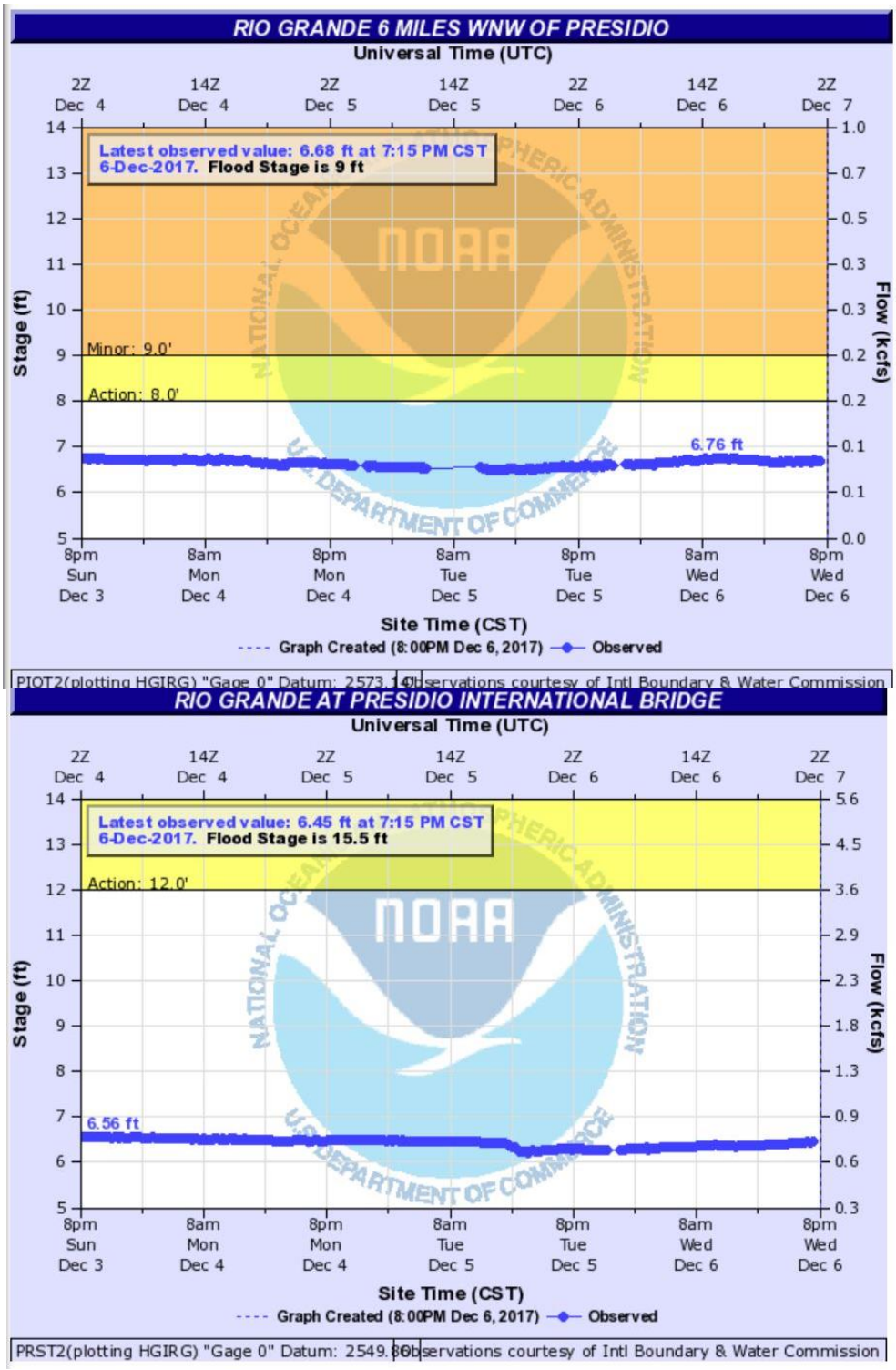

Figure 6. The Rio Conchos is a key tributary to providing necessary water for many down-stream, international uses.

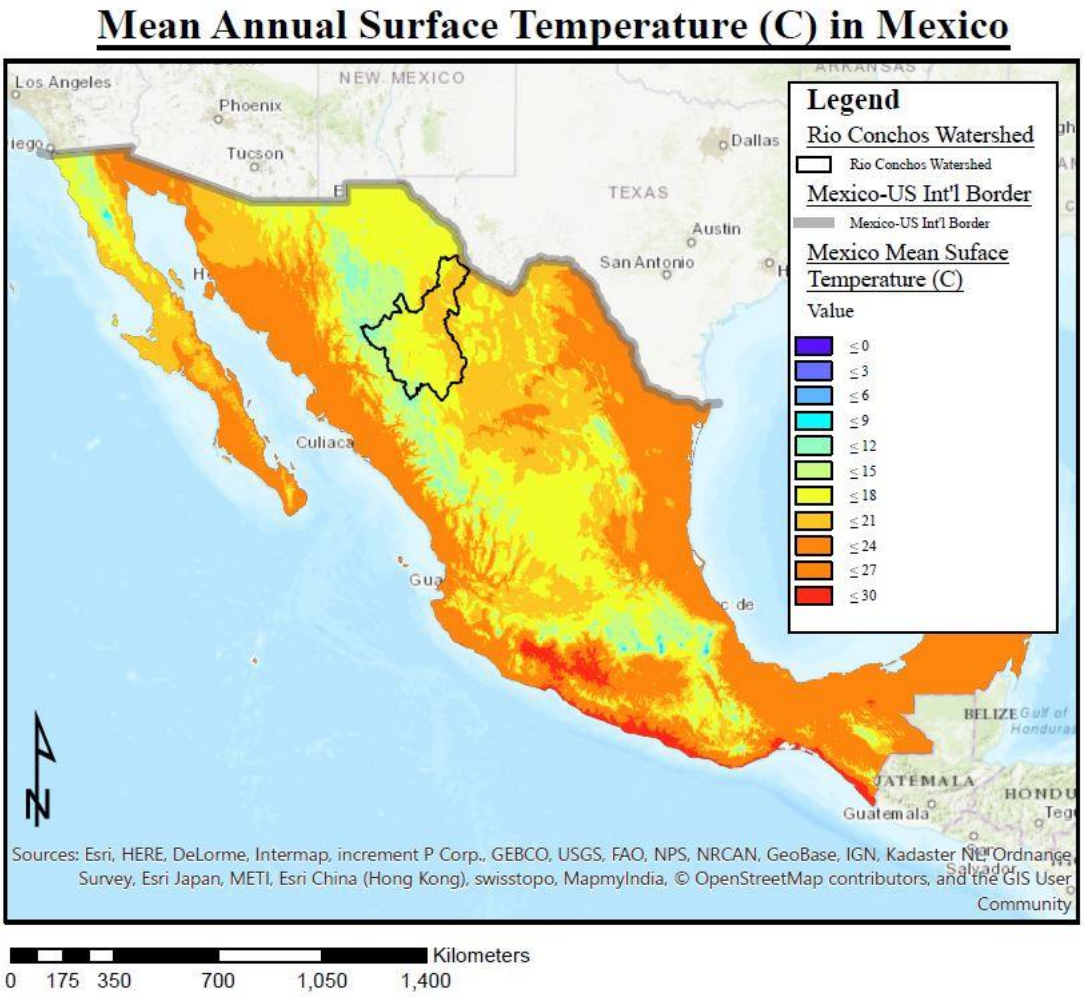

Figure 7. The mean annual surface temperature in the Rio Conchos basin is approximately 18˚C.

Regional Climate of Northern Mexico

Northern Mexico is in the arid, subtropics. The mean annual surface temperature in the Rio Conchos basin is approximately 18˚C (Figure 7), but the region also losses additional moisture as the descending "Hadley" convection cells drops dry air over the region. Similarly, regional precipitation is limited (Figure 8), averaging approximately 550 mm. Most of the basin's precipitation falls at the basin's high elevations (Figure 14), or the Sierra Madre Occidentals, to the southwest. The combination of an arid climate and limited precipitation mean, of course, that water resources in the Rio Conchos basin are under constant stress.

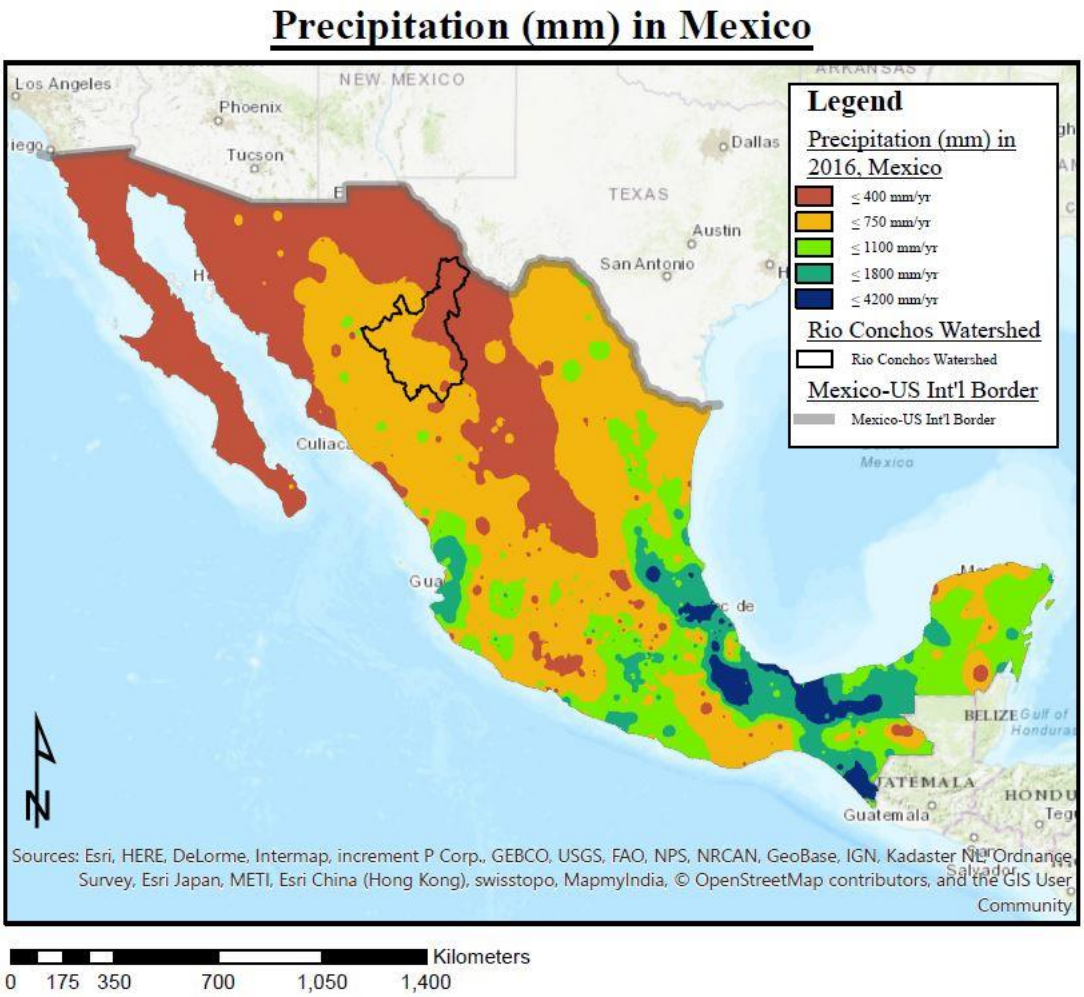

Figure 8. Northern Mexico, where the Rio Conchos basin is located, receives much less mean annual precipitation than Southern Mexico. The mean annual precipitation in the Rio Conchos basin is approximately 550 mm, mostly falling in the basin's higher elevations to the southwest.

Much attention is given to the effect of climate change on water resources, however, estimating the effects of climate change on water resources is challenging. For this research, the difference is mean annual surface temperature from a five-year period in the 1980's to a five-year period in the 2010's is used to illustrate regional climate change in Mexico (Figure 9). In Figure 9, five annual surface temperature rasters were averaged from 1980 to 1985, to "smooth" out any annual variations and to make a representative raster of that decade's mean annual surface temperature in Mexico. This process was repeated for 2010 to 2015. The difference (raster subtraction) in the five-year mean annual surface temperature between the two decades illustrates the magnitude of regional climate change in Mexico,

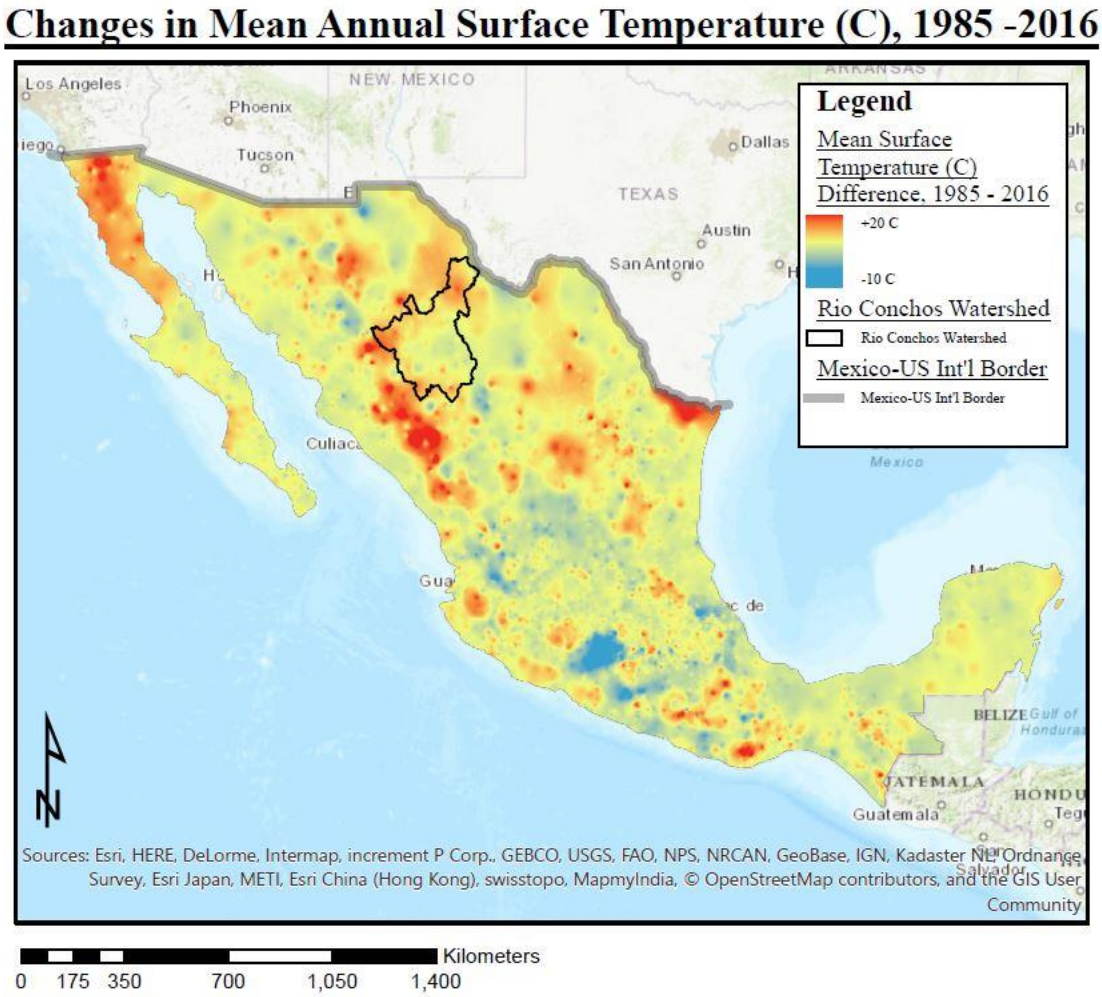

Figure 9. Global Climate Change may affect the availability of water resources in the Rio Conchos basin. Figure 9 was produced by averaging five mean surface temperature rasters from 1980 to 1985 and 2010 to 2015. The difference in mean surface temperature between the two 5-year averaged rasters is shown above. The mean difference in surface temperature across all of Mexico is approximately 2˚C (i.e. 2˚C warmer in 2010's). In the Rio Conchos basin, the mean difference in surface temperature is approximately 2.5 ˚C.

especially the Rio Conchos basin. This process reveals a difference in mean annual surface temperature between the 1980's and the 2010's of 2˚C (i.e. it is, on average, 2˚C warmer). In the Rio Conchos basin, the mean annual surface temperature is 2.5˚C warmer in the 2010's than the 1980's. While the robustness of this method to accurately reflect regional climate change is certainly contestable, it is certain that regional climate change will impact water resources in the Rio Conchos basin.

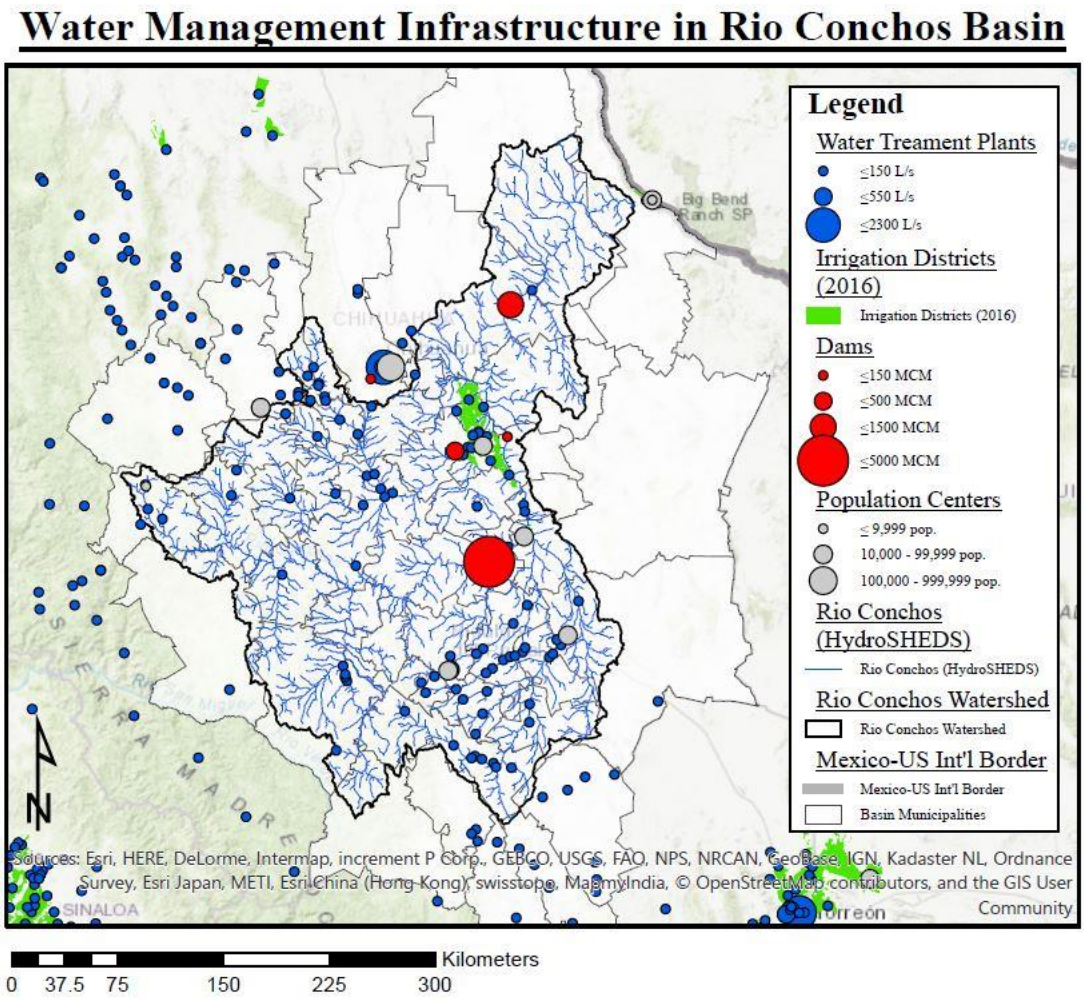

Figure 10. The important, local water management institutions are shown. Water management decisions related to sustainability demand local, stakeholder involvement.

Institutional Setting of the Rio Conchos Basin

Implementing sustainable water resources management requires a consideration of local and regional water-using and water management institutions. As illustrated in Figures 11 and 13, the primary anthropogenic biome in the Rio Conchos basin is sparsely populated rangeland. However, a few population centers exist within the basin and within the basin's region of influence (in this case, a 20 km buffer is defined as the basin's "region of influence", to capture the effect of regional economies and their effect on the basin). Chihuahua, Mexico is the largest city in the basin's region of influence, with a population of more than 800,000. The basin's population centers are projected to require more water for domestic use as population growth continues (Kelly, 2001). As institutions, the basin's population centers

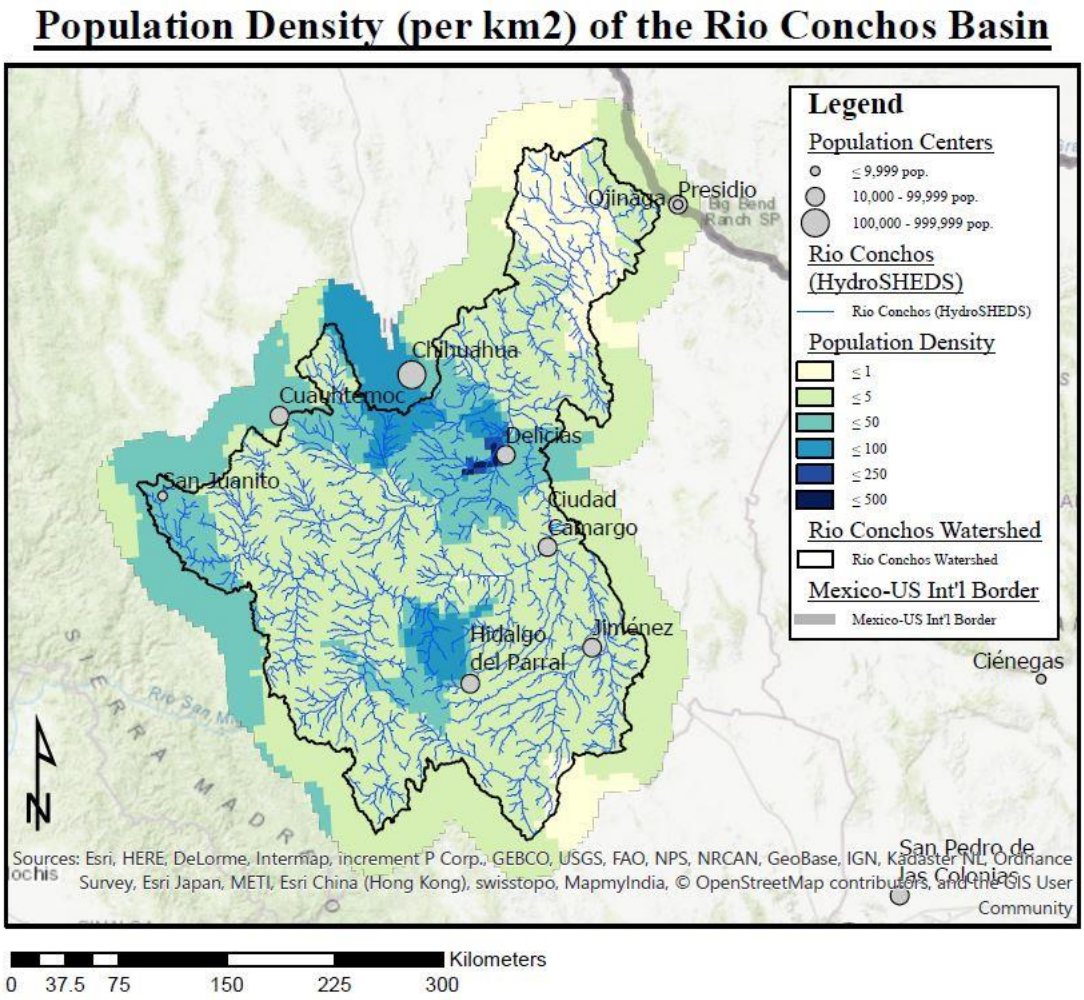

Figure 11. Aside from the basin's few population centers, the basin is predominantly rural, with population density evenly distributed to serve the region's ranching and agricultural industries.

will play a significant role in sustainable water resources management in the basin and meeting Mexico's treaty obligations.

Other significant, water-related institutions in the Rio Conchos basin include water treatment facilities, dams, and irrigated agriculture (Figure 10). The region has several low-capacity water treatment facilities. Sustainable water resources management may require more treatment capacity be installed to meet growing water demands across the basin. Similarly, the basin has a few large dams, including the Rio Conchos basin's largest dam, La Boquilla. Mexico's federal water authority, CONAGUA, is currently planning to construct more dams on the Rio Conchos, potentially limiting Mexico's ability to

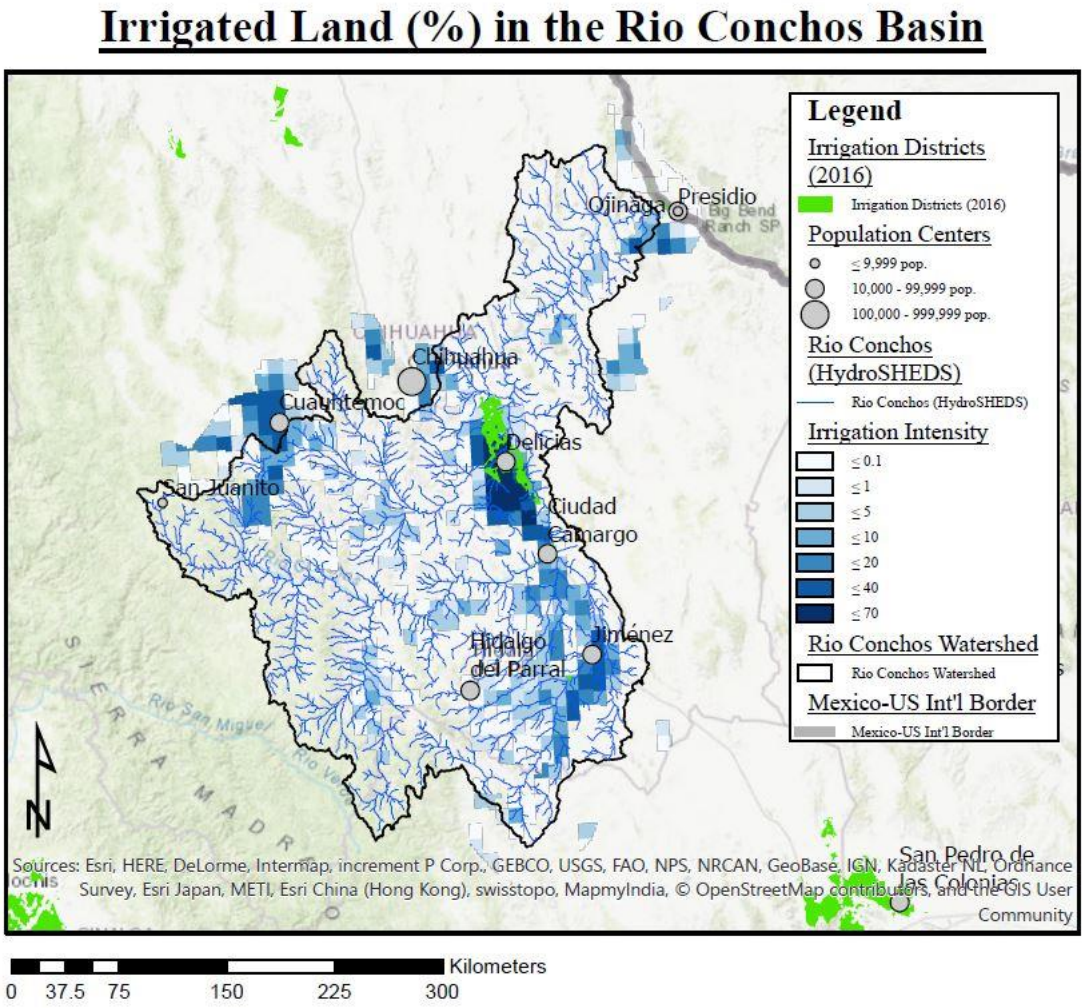

Figure 12. Irrigated agriculture is a key water management institution in the Rio Conchos basin. There is only one organized irrigation district (Distrito de Riego "005"), meaning water management decisions are less centralized.

meet treaty obligations as water evaporates from stagnant reservoirs. Finally, irrigated agriculture is the basin's most important water-using institution, as 90 percent of water use in the Rio Conchos basin is for irrigated agriculture (Kelly, 2001). There is only one established irrigation district (Distrito de Riego "005") in the Rio Conchos basin. Sustainable water resources management in the Rio Conchos basin that allows Mexico to meet its treaty obligations requires water-using organizations, like irrigation districts, have the institutional capacity to limit their members (i.e. individual irrigators) water use to meet these goals. Figure 12 shows there are several highly irrigated regions in the basin that lack the institutional capacity to limit their use, potentially stressing water resources as their use goes unchecked.

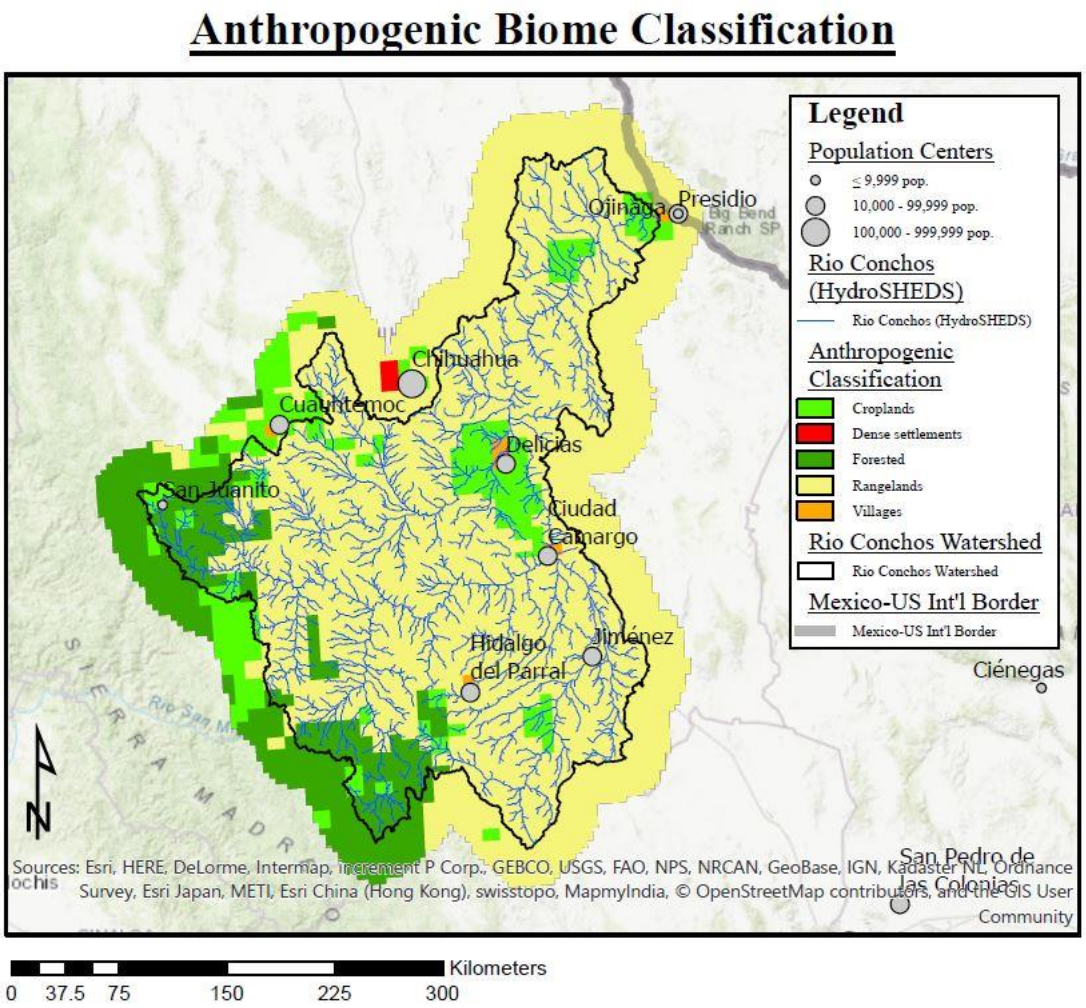

Figure 13. Anthropogenic land use in the Rio Conchos basin is predominantly for animal husbandry and rangeland. The upper (southwest) contributory areas to the basin are less developed forest. The largest settlement in the basin's area of influence is Chihuahua, Mexico (population ~800,000).

Water Resources of the Rio Conchos Basin

A thorough water resources assessment requires not only an assessment of surface water availability (see Figures 4 and 5 for a discussion of surface water availability), but also groundwater. Similarly, it is also important to consider current trends in regional water demand and use sources to evaluate what resources are most important and what resources are most likely to support sustainable water resources management to meet Mexico's treaty obligations.

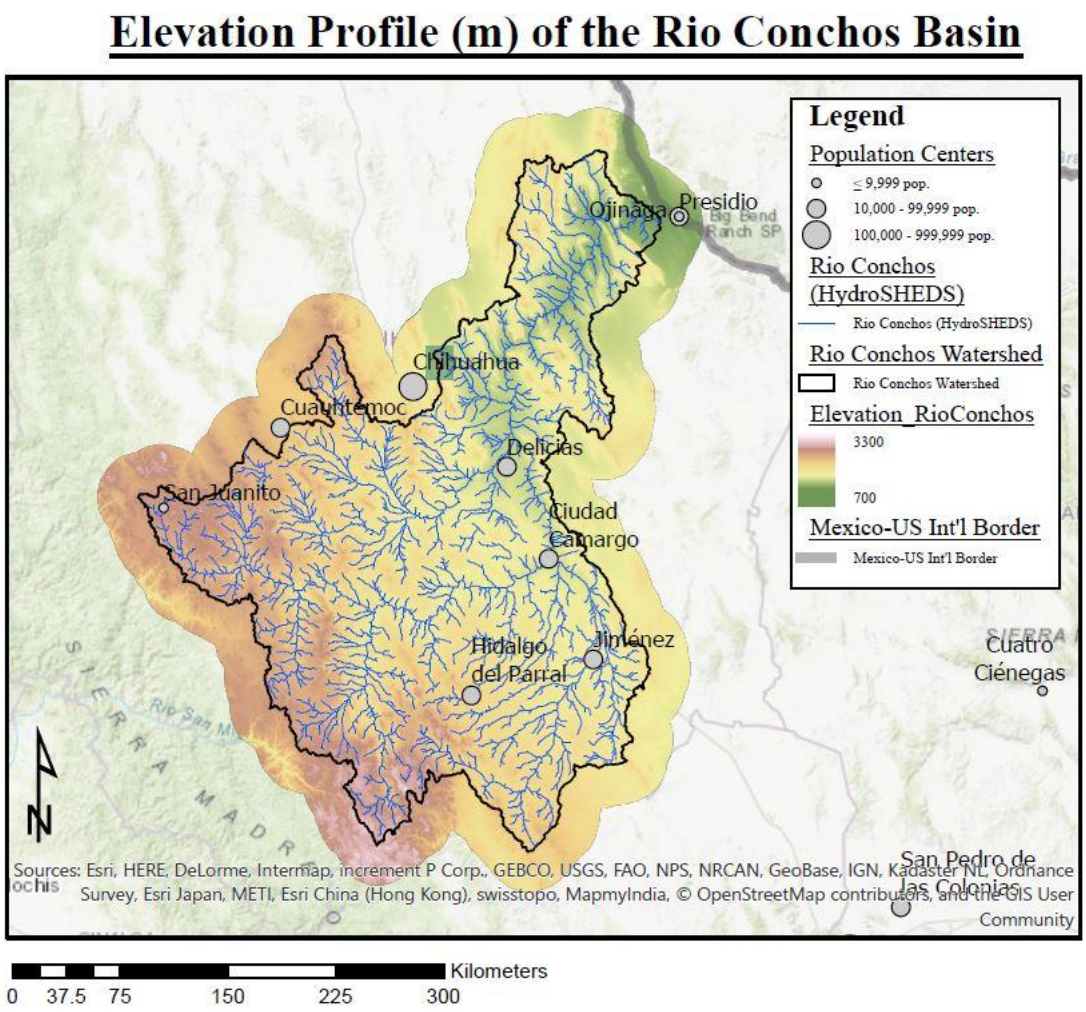

Figure 14. The Rio Conchos is a north-easterly flowing river. The primary contributory areas are in the basin's southwest mountains (Sierra Madre Occidentals).

Water rights in Mexico, under a system that lacks clear continuity, are renewed every five years. Water rights are based on estimated watershed availability, and in times of drought, are limited *pro rata* (Kelly, 2001). As illustrated in Figure 17, CONAGUA estimates there is "no available" surface water for new allocations throughout the entire Rio Conchos Basin. This lack of available surface water resources, however, does not mean surface water is the primary source of consumptive water use throughout the Rio Conchos Basin. CONAGUA estimates the primary consumptive source by each municipality in Mexico (Figure 16), as well as the consumptive use intensity in each municipality (Figure 15). In this case, consumptive use is used as a close estimate of water demand, as any "non-consumptive" use will return to

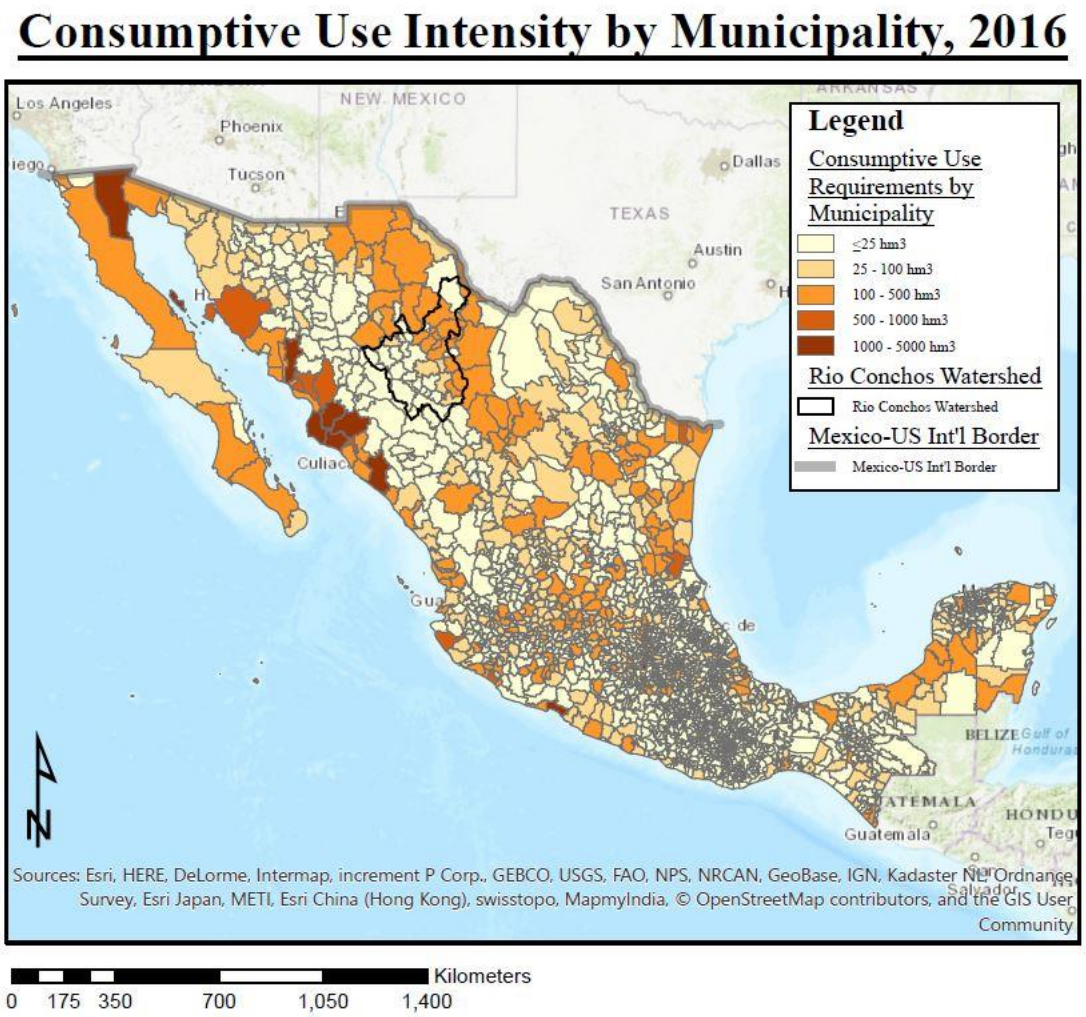

Figure 15. The primary consumptive use in the Rio Conchos basin is for irrigated agriculture.

the Rio Conchos for downstream use and meeting treaty obligations. Figure 16 shows surface and groundwater resources are of equal importance in the Rio Conchos basin, meaning both resources will be part of a sustainable water resources management plan to meet Mexico's treaty obligations.

Not surprisingly, the areas where groundwater is the primary source of consumptive use water are the heavily irrigated regions. A more interesting observation is that groundwater resources (measured as sub-aquifers by CONAGUA) are generally "under-exploited" in the Rio Conchos basin (Figure 18), meaning groundwater may be a potential source for meeting Mexico's treaty obligations. A conjunctive management strategy, whereby groundwater abstractions from areas of high annual recharge (Figure 19)

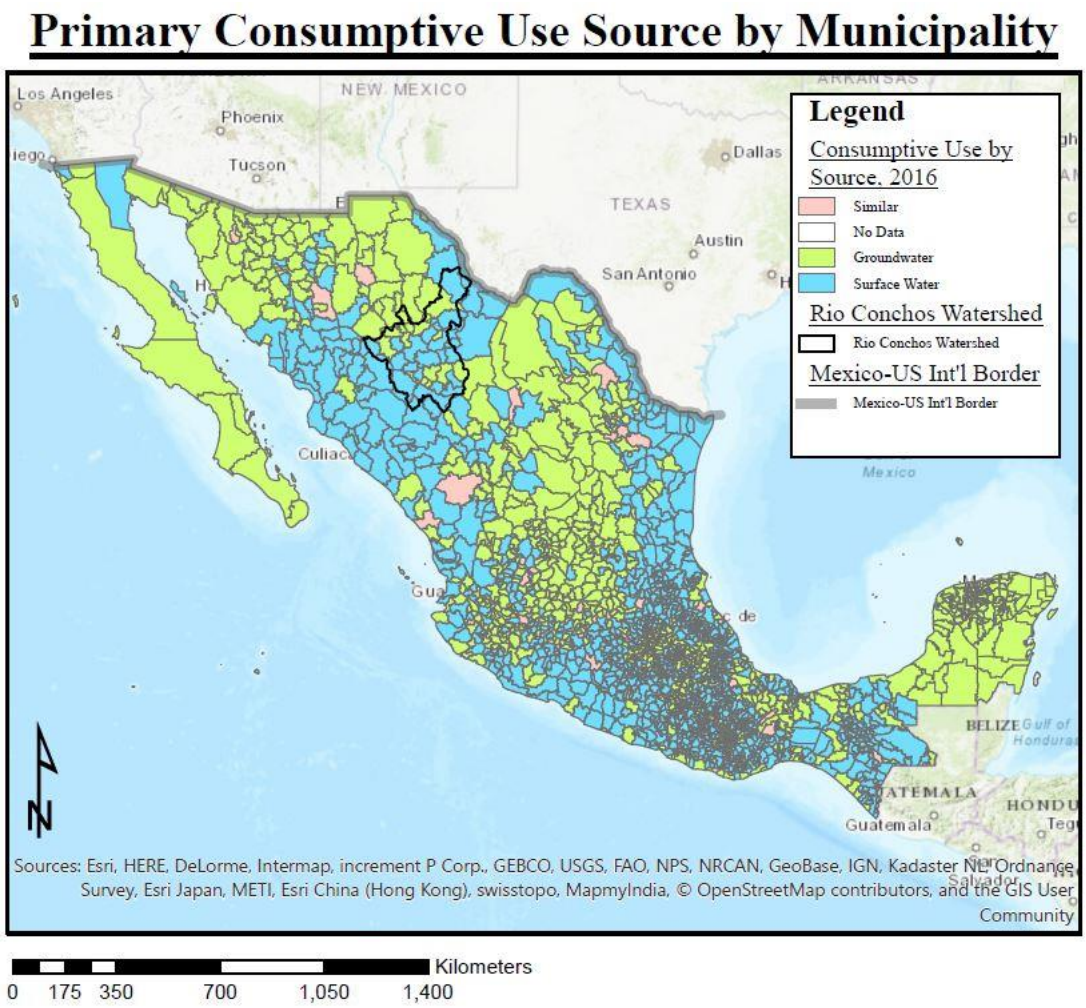

Figure 16. Both surface and groundwater are used for consumptive uses in the Rio Conchos basin, so a sustainable water management strategy must consider both surface and groundwater resources.

make up surface water supplies to meet Mexico's treaty obligations is a possibility. However, a "nearest neighbor" approximation of different groundwater contaminants measured by CONAGUA's extensive groundwater monitoring network (Figure 20) suggests making up surface water supplies with groundwater may be complicated by water quality issues. In the Rio Conchos basin, there are groundwater quality issues related to coliform contaminants (from the region's agriculture and animal husbandry industries) and naturally occurring geological contaminants, like alkalinity.

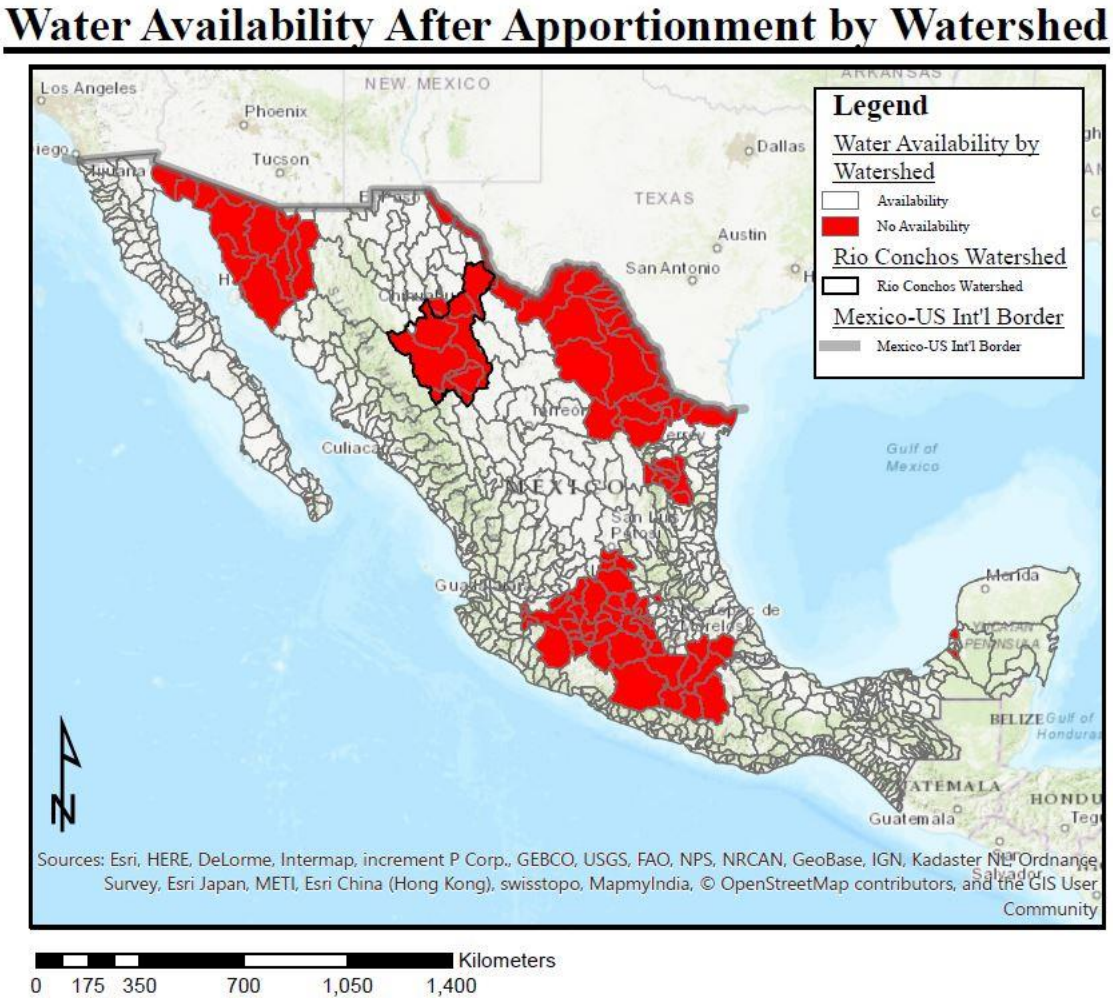

Figure 17. There is no "available" water in the Rio Conchos sub-watersheds. Mexico's federal water administration, CONAGUA, allocates surface water resources every five years.

Conclusions

By no means is this work thorough enough to propose fully developed water management strategies for meeting Mexico's treaty obligations. However, this research, though a water resources assessment, reveals notable conclusions: 1) regional climate change will impact water resources in the Rio Conchos basin, 2) local and regional water-related institutions require institutional development to allow better control over water use, and 3) abstraction of groundwater in high recharge areas may be used to supplement surface water supplies to meet Mexico's treaty obligations (i.e. conjunctive management).

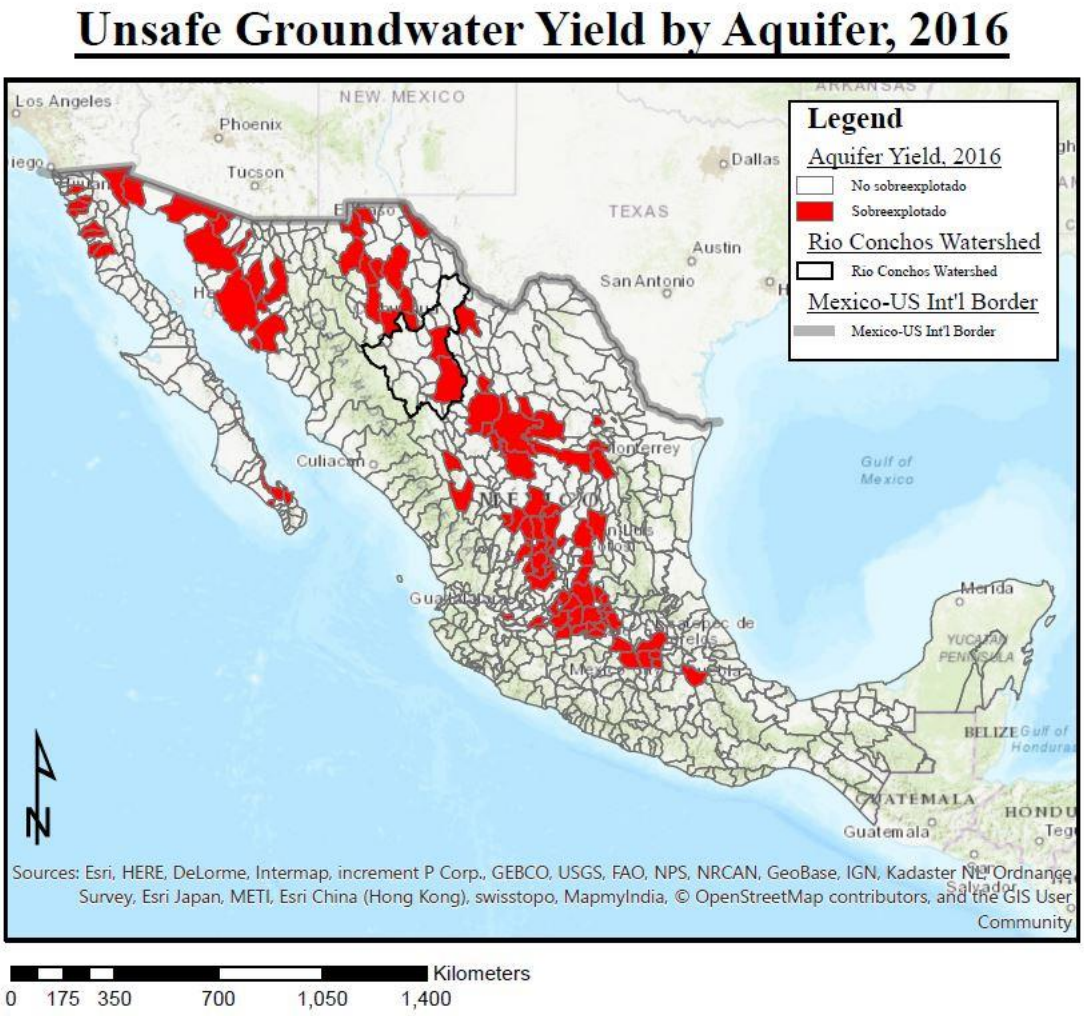

Figure 18. Mexico's federal water administration, CONAGUA, does not regulate groundwater as much as surface water, but CONAGUA recognizes several sub-aquifers are overexploited (i.e. abstraction is more than recharge). Many of the Rio Concho basin's sub-aquifers are overexploited, because of irrigated agriculture.

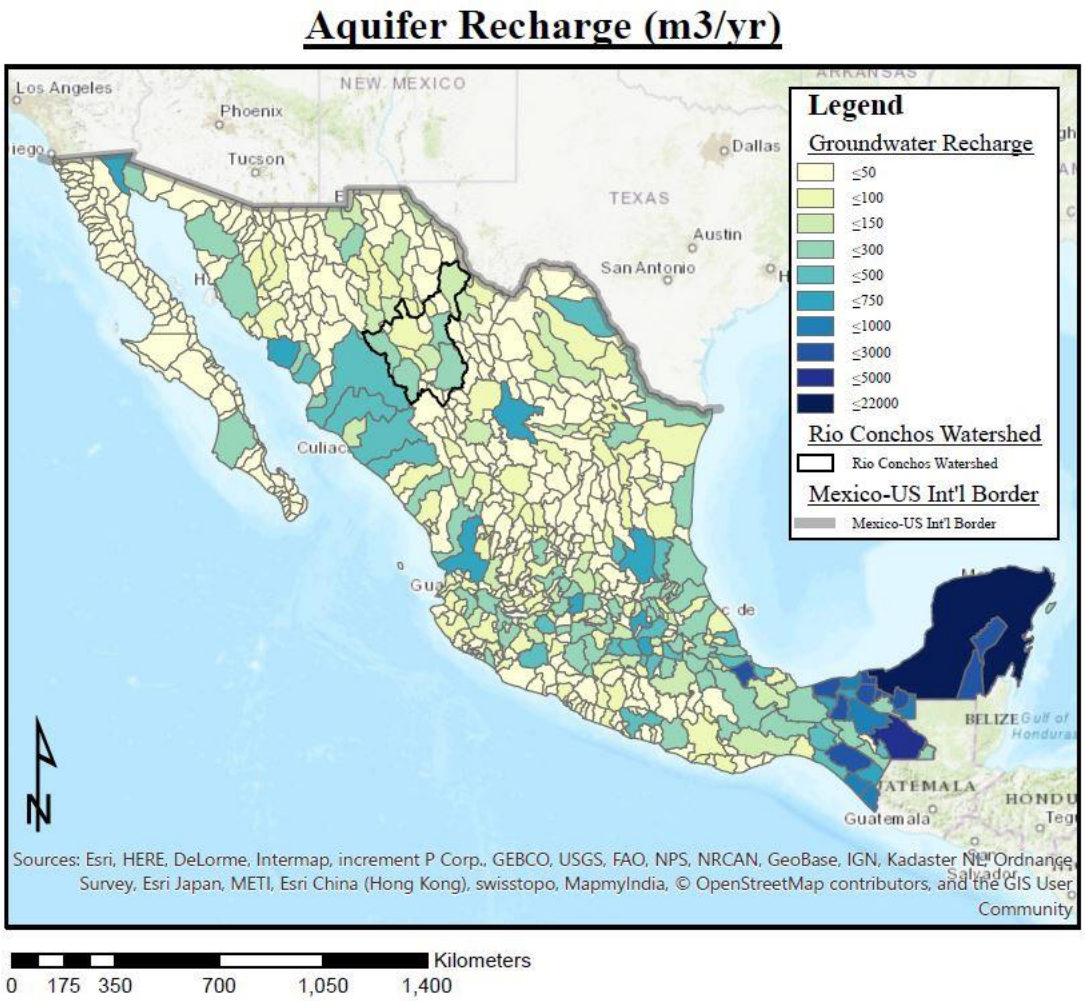

Figure 19. Mexico's federal water administration, CONAGUA, estimates recharge to sub-aquifers. Groundwater recharge to the Rio Conchos basin's key aquifers is higher in the Sierra Madre Occidentals.

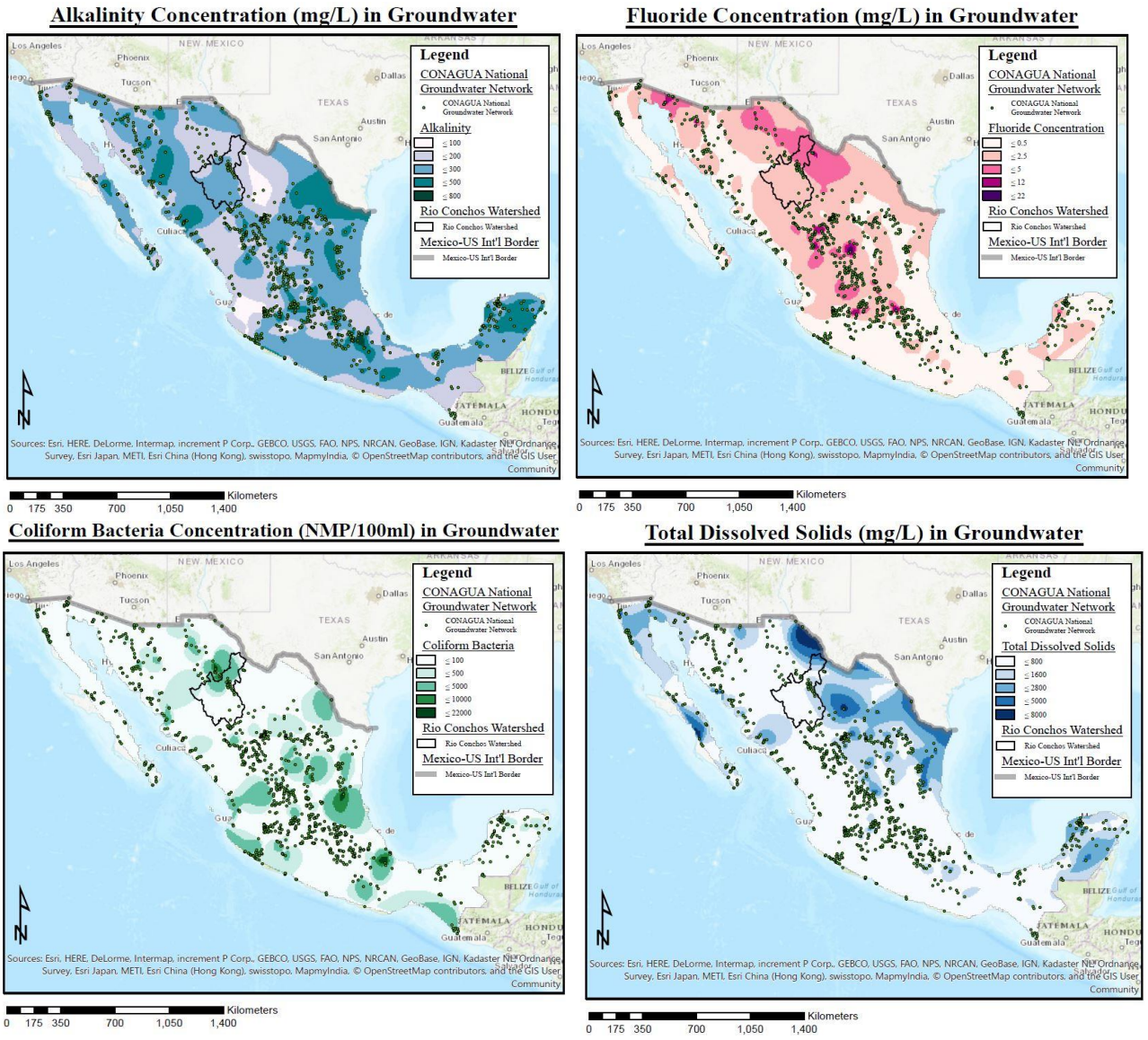

Figure 20. Groundwater resources in the Rio Conchos basin may suffer from water quality issues related to regional geology and agricultural runoff.

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