TOPIC 3/Paper 16

Transboundary Aquifers between Mexico and the United States: The Complete MAP

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Abstract

In 2015, the official number of transboundary aquifers (TBAs) reported between Mexico and the United States of America (U.S.) was 11. However, in 2016, new research indicated that there might be up to 36 aquifers traversing the border between the two countries. In 2018, a more detailed technical study showed that only between Mexico and Texas, there are 33 hydrogeological units (HGUs) identified on the border, of which 15 are considered transboundary aquifers with good to moderate aquifer potential. The most recent study published in 2021 shows that at border-wide scale, there are a total of 72 HGUs from which at least 28 report good aquifer potential and water quality. These 28 HGUs represent 60% of the shareable land between Mexico and the United States. So far there has not been any update on the official numbers of TBAs between the two countries, but groundwater is indeed getting attention and more strategic value as surface water shows its evident exhaustion.

Keywords: Transboundary, Mexico, United States.

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Introduction

In 2015, the International Shared Aquifer Resources Management (ISARM) reported that officially 11 TBAs were traversing the border between Mexico and the U.S. (Rivera et al., 2015). One year later, Sanchez et al. (2016) suggested there might be up to 36 TBAs in the border region. However, this new research only attempted to depict existent aquifers reported on each side of the border without a homogenization effort of criteria used to delineate boundaries among them or to assess its transboundary nature of the different aquifer units across the border. It was not until 2018, when Sanchez et al. (2018) published the first hydrogeological assessment of geological units across the border region between Texas on the U.S. side, and the states of Tamaulipas, Nuevo Leon, Coahuila, and eastern Chihuahua, on the Mexico side. Following the same line of research, in 2021 an additional effort was published to account for the remaining states not covered back in Sanchez et al. (2018). Sanchez & Rodriguez (2021) reported 39 hydrogeological units (HGUs) located between the states of California, Arizona, and New Mexico on the U.S. side, and Baja California, Sonora, and the western part of Chihuahua, on the Mexico side. This latest manuscript is considered the second edition of its predecessor Sanchez et al. (2018), which identified 33 HGUs between the state of Texas in the U.S., and the states of Chihuahua, Coahuila, Nuevo Leon, and Tamaulipas, on the Mexico side. Both publications use the same methodology to assure consistency and coherence among the two assessments, and together comprise the identification, delineation, and classification of all HGUs along the complete border between the two countries. Both studies identify and delineate geological boundaries using surficial geology as the main criterion to perform the geological correlation and structural geology for boundary delineation. Lithological characteristics, hydrogeological features, and topography were used to complement the analysis and strengthen the results.

The combined results of Sanchez et al. (2018) and Sanchez & Rodriguez (2021), as well as Sanchez et al. (2016), are used in this paper as a compilation of findings to offer a synthesized reference of the total number of HGUs in the border between Mexico and the U.S. The complete border area reports 72 HGUs shared between the two countries with an estimate of good aquifer potential and good to moderate water quality in approximately 45% of the land extension covered by the HGUs. As originally reported by Sanchez et al. (2018), the criteria used to define aquifer potential include lithological features, permeability, porosity, hydraulic conductivity, transmissivity, and water yield when available. Water quality parameters are based on the TDS (Total Dissolved Solids) ranges of the Texas Water Development Board (TWDB), as indicated by Sanchez et al. (2018).

What these research findings represent to the current state of knowledge on the border between Mexico and the U.S., is the increasing strategic value of groundwater resources that is shared in the region and that has the potential to become a driver for binational security or an incentive for cooperation. So far, the topic has received limited attention at the binational level and even lesser funding priorities for continued research. Overall, this study reflects two essential realities: half of the border region area has good aquifer conditions, and second, those shared aquifer systems are indiscriminately used by both countries without any legal framework regulating their extraction and management.

The first section of this paper will cover the main findings reported by Sanchez & Rodriguez (2021) and Sanchez et al. (2018) in terms of the

number of HGUs, main aquifer units according to their aquifer potential and water quality, and proportions of the extension of land covered by the HGUs over the complete border region and by state. The second part will present an updated list of transboundary aquifers (Table 1) that has the purpose to substitute the one published by Sanchez et al. (2016) and a corresponding updated map (Figure 1) that shows all the identified HGUs. The last section will address final thoughts on what the binational implications can be with this new knowledge in terms of prioritization and attention to the topic, as well as some binational water security considerations.

The current status

As of today, there is no agreement on the number of transboundary aquifers traversing the border between Mexico and the U.S. The latest official report was published in 2015 where 11 aquifers were recognized by both countries (Rivera et. al 2015). Despite new research findings, no official updates have been published by Mexico or the U.S. since then. Additionally, there is not a recognized common methodology at binational or international levels for identifying or delineating the extension of a transboundary aquifer; even the ISARM report from 2015 has no clear criteria for delineating transboundary aquifer boundaries. Furthermore, there is not a formal legal and policy framework at a binational level to address transboundary groundwater management in the Mexico and the U.S. border region.

This reality, along with increasing drought conditions, uncertain climate conditions, population growth, and surface water exhaustion have defined the future of groundwater resources in the border region: an increasingly strategic non-protected natural resource that has the potential to become a security threat to the border region, and therefore to both countries. The development of institutional capacity in the region to cope with water shortages is as limited as the attention to the current conditions of groundwater use and its extraction. Preparedness and leadership as well as willingness to assess and promote binational cooperation efforts, tend to be limited and isolated, driven mainly by surface water needs and concerns associated with the 1944 Water Treaty (IBWC, 1944).

This paper adds to the current state of knowledge, the first complete map of transboundary aquifers between Mexico and the U.S. using a standardized and consistent methodology. Additionally, this study shows two important findings: half of the area of the border region reports good to moderate aquifer potential which makes it even more valuable and strategic; and second, those shared aquifer systems are indiscriminately used by both countries without any legal framework regulating its extraction and management.

HGUs in the Mexico-U.S. border region

Starting from west to east, results indicate that a total of 39 HGUs have been identified on the border between California, Arizona, and New Mexico on the U.S. side, and Baja California, Sonora, and Chihuahua on the Mexico side. This region accounts for an approximate shareable area of 135,000 km^2 (the extension of the land area covered by the HGUs in Figure 1), with both countries sharing approximately half of the total area (69,000 km^2 in the U.S. and

65,000 km² in Mexico). From the total shareable area, around 40% indicated good to moderate aquifer potential and good water quality, from which 65% is on the U.S. side and 35% on the Mexico side.

According to Sanchez & Rodriguez (2021), from a border-state perspective, the border region between Baja California and California shows a total of five HGUs, but only three (Tijuana-San Diego Aq., Valle de Mexicali -San Luis Rio Colorado/Yuma-Imperial Valley and a significant portion of the Quaternary deposits of Laguna Salada Aq./Coyote Wells Valley) are considered as good to moderate aquifer potential and generally good to moderate water quality. Available data on water quality varies across the Valle de Mexicali-San Luis Rio Colorado/Yuma-Imperial Valley from good to poor water quality (limited information is also significant in this area), particularly in the southern portions where saline intrusion has been reported. In the case of the border between Sonora and Arizona, 26 HGUs have been identified, with at least seven HGUs (Nogales-Rio Santa Cruz Aq./Upper Santa Cruz Basin, Rio San Pedro Aq./Upper San Pedro Basin, Rio Agua Prieta Aq./Douglas Basin, Rio Altar Aq., San Simon Wash, Sonoyta-Puerto Peñasco Aq., and La Abra Plain) reporting generally good to moderate aquifer potential and good to moderate water quality conditions. Variability of water quality data in the Sonoyta-Puerto Peñasco Aq., and San Simon Wash is also significant. There are also four HGUs (Cerro Colorado Numero 3 Valley, Lukeville-Sonoyta Valley, The Great Plain, and Arroyo Seco Aq.) that show good to moderate aquifer potential but poor water quality, with also important data gaps on these HGUs. On the border between Chihuahua and New Mexico, good aquifer potential and good water quality are identified in at least three out of the eight HGUs reported. Those HGUs are identified as: Janos Aq./Playas Basin, Ascension Aq./Hachita-Moscos Basin, and Las Palmas Aq./Mimbres Basin (Sanchez & Rodriguez, 2021). See Table 1.

Following the geography to the east, and according to Sanchez et al. (2018), there are 14 (from a total of 33) HGUs identified between Chihuahua, Coahuila, Nuevo Leon, and Tamaulipas on the Mexico side, and Texas in the U.S. side, which report good to moderate aquifer potential and good to moderate water quality (see Table 1). The HGUs classified as good to moderate aquifers are the Edwards Aquifer system (predominantly the Upper Salmon Peak, Edwards Fm., Devils River Limestone), Santa Fe del Pino, Serrania de Burro, Presa la Amistad Aquifers, and the bolsons of Valle de Juarez, Mesilla, Red Light Draw, Green River Valley, Presidio, and Redford. Additionally, the Allende-Piedras Negras Aquifer, Austin Fm., the Carrizo Fm/Carrizo Sand, and part of the Carrizo-Wilcox Aquifer are also in this category, as well as the BRB/Gulf Coast (mainly the Catahoula Fm/Catahoula Fm., Reynosa Fm./Goliad Fm. and Lissie Fm.). From a border-wide perspective, the areas of the bolsons southeast of the Hueco-Tularosa Bolson Aquifer in northern Chihuahua and southwestern Texas, and between the Serrania del Burro and Allende-Piedras Negras Aquifers in southern Texas and northern Coahuila, where the Quaternary and Alluvium deposits are concentrated, appear to be the most important for transboundary aquifer potential. Table 1 shows the compilation of Sanchez et al. (2018) and Sanchez & Rodriguez (2021), which lists the total of HGUs in the border region with good to moderate aquifer potential and good to moderate water quality. They are listed by state on each side of the border. Table 1 only includes the HGUs with good to moderate aquifer potential and water quality for prioritization purposes, therefore they are referred to as transboundary aquifers.

Border-wide, the total number of HGUs between Mexico and the U.S. is 72, covering approximate 315,000 km^2 (180,000 km^2 on the U.S. and 135,000 km^2 on the Mexico side). The total HGUs considered to have good to moderate aquifer potential and good to moderate water quality at a border-wide scale is 28 (referred to as TBAs), which covers an area that ranges between 50 to 55% (of which an approximate 60% is on the U.S. side and the rest in the Mexico side). See Figure 1.

If we compare the original 36 aquifers initially reported by Sanchez et al. (2016) and those HGUs categorized as aquifers according to Sanchez et al. (2018) and Sanchez & Rodriguez (2021), results indicate a more mature analysis and assessment of transboundary aquifers across the region. The 28 transboundary aquifer systems (including the 11 officially reported by ISARM in 2015) have been geologically correlated using the same methods and have been categorized using the same criteria. This contribution by itself, represents the first assessment of this scale between the two countries and the first step towards a more border-wide assessment of transboundary aquifer systems and, at the same time, represents the path towards the refinement of physical features and differences across them. It constitutes a well based platform from which future research can build upon at local, regional, or border-wide scale. This methodology can potentially be replicated at other transboundary aquifers in other world regions and adapted according to data availability. Geological and main hydrological features would be a minimum data required to perform a similar analysis.

Binational security considerations

Results of the three publications referenced above (Sanchez et al., 2016, Sanchez et al., 2018, and Sanchez & Rodriguez, 2021) can be summarized in three main points: first, there are 72 HGUs crossing the border between the U.S. and Mexico, from which at least 28 have good to moderate aquifer potential. Second, the area covered by these 28 HGUs (transboundary aquifers) represents approximately 60% of the shareable land between the two countries. Third, these findings represent the most current state of knowledge on the number, delineation, and categorization of all transboundary aquifers in the border region. Although only 11 have been officially recognized by both countries, as mentioned before.

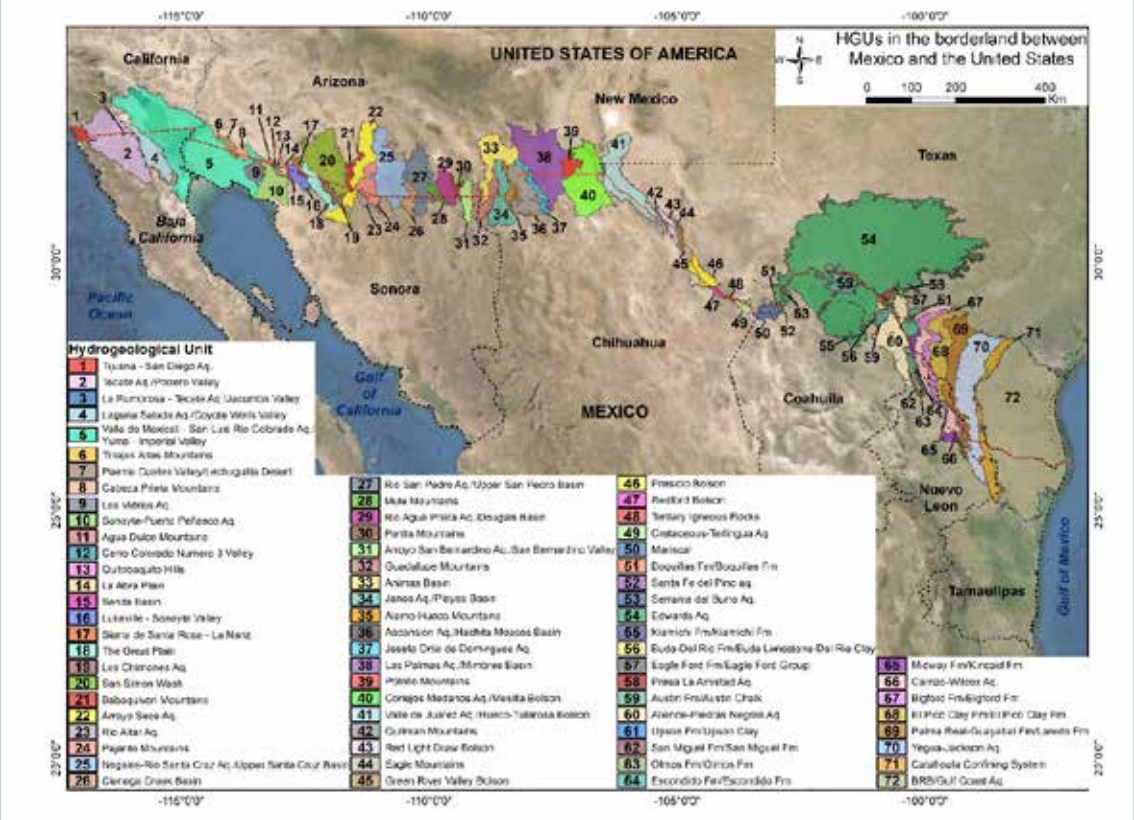
Now, in terms of the implications of this new information to the current legal or policy frameworks in the area, there are several considerations worth mentioning. First, groundwater is rapidly becoming a strategic resource worldwide as surface water becomes scarcer; the Colorado River and Rio Grande binational basins are not the exception. However, the lack of a legal framework that regulates the management of transboundary groundwater resources promotes the unsustainable use and exploitation of the resource. Second, as surface water becomes scarcer in the border, the production of data related to 'new sources' of water such as transboundary aquifers, can potentially speed up the eventual acknowledgment of the strategic value of groundwater at a binational scale.

Table 1.
Transboundary Aquifer (TBA) Systems between Mexico and the U.S.

STATES (MX/U.S.)	TBAs
Baja California/ California	Tijuana-San Diego Aq.
	*Valle de Mexicali-San Luis Rio Colorado/Yuma-Imperial Valley. Laguna Salada Aq./Coyote Wells Valley (Quaternary deposits predominantly)
Sonora/ Arizona	Nogales-Rio Santa Cruz Aq./Upper Santa Cruz Basin
	Rio San Pedro Aq./Upper San Pedro Basin
	Rio Agua Prieta Aq./Douglas Basin
	Rio Altar Aq.
	La Abra Plain
	*San Simon Wash
	*Sonoyta-Puerto Peñasco Aq.
Chihuahua/New Mexico	Janos Aq./Playas Basin
	Acension Aq./Hachita-Moscos Basin
	Las Palmas Aq./Mimbres Basin
	Potrillo Mountains
Chihuahua/ New Mexico/ Texas	Conejos-Medanos Aq./Mesilla Bolson
Chihuahua/Texas	Valle de Juarez Bolson/Hueco-Tularosa Bolson
	Red Light Draw Bolson
	Green River Valley Bolson
	Presidio Bolson
	Redford Bolson
Coahuila/ Texas	Santa Fe del Pino Aq.
	Serrania del Burro Aq.
	*Edwards Aq. system (predominantly Edwards Fm., Upper Salmon Peak Fm., Devils River Limestone)
	Presa La Amistad Aq.
	*Austin Fm./Austin Chalk
	Allende-Piedras Negras Aq.
Nuevo Leon-Tamaulipas/Texas	Carrizo-Wilcox Aq.
Tamaulipas/Texas	BRB/Gulf Coast Aq. (predominantly Catahoula Fm., Reynosa Fm, Lissie Fm.)
TOTAL	28

(good to moderate aquifer potential and good to regular water quality only).
*Indicates high variability of water quality across the aquifer.

Figure 1.
HGUs in the borderland between Mexico and the United States of America



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Third, Mexico and the U.S. share a water security threat in the border region. Although the sharing concept of a natural resource might sound contradicting to the international principles of sovereignty and self-determination, the conceptualization of a security threat to a border region linked by a natural resource, is really where the pandora box is located. Under the current paradigms of international relations, national security approaches and even water security approaches fail to address the underlying nature of transboundary waters, and more clearly the nature of groundwater resources: the security concern is not conceived nor visualized as a shared threat.

In contrast, the binational water security threat approach is based on recognizing an undisputable sharing condition, into which the security threat operates, but at the same time, the opportunity for cooperation and peace building arises. This recognition can allow for the development of alternative perspectives and strategies to build attention from and prioritization to areas, scopes and issues that might transcend the water topic. This could sound unrealistic in a world ruled by borders and power asymmetries, and we might not be mature enough to invoke it, but at least it offers a potential vision of how nature actually sees and understands water and provides alternative perspectives on the strategic value of our shared waters.

On the optimistic side, this new knowledge along with the recent global trend that focuses on the topic of transboundary aquifers as drivers for peace and cooperation across nations (Walschot and Ribeiro, 2021), can have the potential to elevate the binational conversation into a more formal discussion over shared management of transboundary aquifers.

A more modest expectation is to obtain official recognition by both countries for the existence of at least 28 transboundary aquifers systems in the border region. Additionally, it can help identify priority areas of attention in the short and long term. At the very least, this new research can support the development of subsequent research for more refined case-by-case aquifer conditions and, therefore, more precise local aquifer analysis and assessment approaches.

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