Transboundary Groundwater Resources along the Texas-Mexico Border

White Paper Prepared by the Texas Groundwater Protection Committee (TGPC)
Groundwater Issues (GWI) Subcommittee

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Executive Summary

Fifteen transboundary aquifers have been identified between Mexico and Texas (Sanchez et al. 2016), though the mechanisms for hydrogeologic connection across the international boundary, which will be referred to subsequently as transboundary groundwater linkages, are known only for five (Sanchez et al. 2016). The transboundary groundwater resources shared by the two countries are largely uncharacterized due to lack of data, differences in aquifer boundary delineations and methodologies, and the limited cooperation and coordination among federal, state, and local agencies within and between these countries to address groundwater issues from a binational perspective.

From a general perspective, the region of the bolsons (aquifers located southeast of the Conejos-Medanos/Mesilla Bolson, Valle de Juarez/Hueco-Tularosa Bolson Aquifer in northern Chihuahua, in southern New Mexico and western Texas, and between the Serrania del Burro and Allende-Piedras Negras Aquifers in south Texas and northern Coahuila), where Quaternary alluvial deposits are concentrated, appear to be the most important areas for transboundary aquifer development.

Overall, the hydrogeological units along the Texas-Mexico border cover around 182,000 km^2 (approximately 110,000 km^2 on the Texas side and 72,000 km^2 on the Mexico side) (Sanchez et al. 2018). The total area considered to have good aquifer potential (defined as the favorable lithological properties that allow sustained and significant rates of pumpage) as well as good water quality ranges between 50% and 60% (60% of this in Texas). Some 20 to 25% of the hydrogeological units that cross the border area ("border area") are considered to have poor aquifer potential and poor water quality, with the proportion of land being approximately equal on both sides of the border.

In terms of water quality data, some reports are rather general and do not specify the location of the water being tested. If such formations cover a significant area, their water quality parameters might be over- or under-estimated. Also, some reports contradict each other. In those cases, the hydrogeological unit has been identified with two different water quality categories at the same time, again adding uncertainty in terms of the whole unit.

Acronym List

AWRA – American Water Resources Association

CILA – Comisión Internacional del Limites y Agua

CONAGUA – Comisión Nacional del Agua (National Water Commission)

d – day

Fm. – Formation

GCD – Groundwater Conservation District

GWI – Groundwater Issues

IBWC – International Boundary and Water Commission

K – Hydraulic conductivity

km – kilometer

m – meter

mg/L – milligrams per liter

MOU – Memorandum of Understanding

MX – Mexico

n – porosity

NRD – Natural Resource District

ppm – parts per million

Qt – Quaternary

SGA – Sustainable Groundwater Agency

SGMA – Sustainable Groundwater Management Act

T – Transmissivity

TAAP – Transboundary Aquifer Assessment Program

TCEQ – Texas Commission on Environmental Quality

TDS – Total Dissolved Solids

TGPC – Texas Groundwater Protection Committee

TWDB – Texas Water Development Board

TX – Texas

U.S. – United States

USA – United States of America

Introduction

Although there have been some earlier draft definitions (Hayton et al. 2010), a current working definition of Transboundary Groundwater, or Transboundary Aquifers, has been developed from discussions at the American Water Resources Association (AWRA) 2018 Specialty Conference held in Fort Worth, Texas in June 2018, as: *Groundwater systems that cross multiple political, regulatory, management, or operational boundaries*. While this is a vague definition, and in some respects could justify saying "all groundwater is transboundary", it does identify that cooperation between multiple individuals, governmental, and non-governmental entities is needed for the sustainable management and protection of groundwater resources. Without cooperation, or at least communication, between water use entities, the approach taken by individual water users would be to maximize their individual benefit without regard to the long-term sustainability of the groundwater resource. This situation is best known as *The Prisoners Dilemma* (https://en.wikipedia.org/wiki/Prisoner%27s_dilemma), where an attempt by individuals to maximize their own benefit results in a sub-optimal result for the community. Thus, at a minimum, communication between all users of a groundwater resource must occur to help increase the sustainability and overall value of the groundwater that crosses governance or management boundaries. In circumstances where groundwater resources are heavily used, enforceable agreements may need to be developed between groundwater management and governance entities to ensure sustainable use of the resource. Several states have developed, or are developing, mechanisms to facilitate the development of these agreements, including the formation of Groundwater Sustainability Agencies (GSAs) in California which are mandated as part of the Sustainable Groundwater Management Act (SGMA, California Department of Water Resources 2018), the formation of Groundwater Conservation Districts (GCDs) in Texas (TCEQ 2019), and the creation of Natural Resource Districts (NRDs) in Nebraska (Fischer et al. 1970).

Globally, there are 276 rivers and lakes traversing international borders and more than 400 treaties developed since the mid-1800s for these types of water bodies (e.g., the 1944 treaty between Mexico and the U.S. for the Rio Grande and Colorado rivers). In contrast, there are more than 600 aquifers that lie across an international border, but only five treaties and a few recent Memorandums of Understanding (MOUs). The first agreement was between France and Switzerland in 1977 for the Genovese Aquifer (Eckstein 2017) which was renegotiated in 2007. Three agreements were developed between the countries of Chad, Egypt, Libya, and Sudan between 1992 and 2000 to address the use of groundwater from the Nubian Sandstone Aquifer System, which is considered a non-renewable groundwater resource (Eckstein 2017) based on scientific studies led by the International Water Management Institute (2014). Agreements were developed between Brazil, Paraguay, Argentina, and Uruguay in 2010 for the Guarani Aquifer (Eckstein 2017) based on a scientific study led by the World Bank (2006). A formal agreement was developed between Jordan and Saudi Arabia in 2015 for the use of groundwater from the Al-Sag/Al Disi Aquifer (Eckstein 2017). Additional declarations of cooperation or MOUs have been developed for the North-Western Aquifer System between Algeria, Libya, and Tunisia between 2002 and 2008, and the Iullemeden Aquifer System in 2009 between Mali, Niger, and Nigeria which was updated in 2014 to address both the Iullemeden and Taoudeni/Tenezrougt Aquifer Systems with the inclusion of Algeria, Benin, Burkina Faso, and Mauritania in the consultative arrangement (Eckstein 2017).

The first attempt to develop an approach to comprehensively understand all groundwater resources along a contiguous border between two countries was initiated under the Transboundary Aquifer Assessment Program (TAAP, Public Law 109-448, 2006) whose purpose is to *develop and implement an integrated scientific approach to identify and assess priority transboundary aquifers along the United States-Mexico Border*. This effort included studies of the San Pedro and Santa Cruz aquifers between the states of Arizona and Sonora, and the Hueco Bolson and Mesilla aquifers between the states of Texas, New Mexico, and Chihuahua. It is worth recalling the special case of the Yuma Aquifer which was the first agreement that attempted to regulate groundwater extractions (Minute 242 of the International Boundary and Water Commission/Comisión Nacional de Límites y Aguas (IBWC/CILA) signed in 1973) between the states of Arizona, California, and Sonora. These aquifers were considered the highest priority groundwater resources along the United States-Mexico border due to the large human populations that overlie these basins and the value of the irrigated agricultural production that relies on groundwater provided from these aquifers. However, continuing development of irrigated agriculture and population growth within the Rio Grande / Rio Bravo basin are leading to increased stress on all groundwater resources in the border lands. But, apart from those aquifers referenced above, the rest of the aquifers along the US-Mexico border have remained relatively unexplored as to their transboundary nature. Note that the river that forms the border between Texas and Mexico is called the Rio Grande in the United States (U.S.) and the Rio Bravo del Norte (or simply the Rio Bravo) in Mexico.

The challenge facing the use and management of these relatively unexplored transboundary aquifers between Mexico and Texas is that there are a large number of unknowns, including aquifer conditions and transboundary groundwater linkages. Rapid urbanization, population growth, and climate change predictions envision a more drought-prone border region which will rely more heavily on groundwater resources because surface water resources have already reached their supply limit. According to the World Resources Institute, the Rio Grande / Rio Bravo basin is one of the most water-stressed basins in the world (Maddocks and Reig, 2014), and it supplies water to approximately 90% of the surface water irrigated acreage in Texas. Surface water is an important source of domestic water supply for highly populated cities such as El Paso, Laredo, and McAllen in Texas, and Piedras Negras, Nuevo Laredo, Acuña, Matamoros, and Reynosa in Mexico, although the cities of El Paso and Piedras Negras also depend on groundwater for domestic use. In addition to the large city of Juarez in Mexico, there are also small communities along the border between Chihuahua and Texas and east of the Hueco Bolson that rely on groundwater for domestic use.

Thus, there is a need to expand on previous studies (Sanchez et al. 2016, TWDB 2017) to further understand and classify geologic units along the Texas-Mexico border based on available hydrogeological parameters and water quality data in order to identify those transboundary units that have the potential for significant groundwater development as proposed by Sanchez et al. 2018.

Full Issue Information and Discussion

Aquifer potential is defined as the potential that a geologic formation, a group of formations, or a part of a formation contains sufficient saturated permeable material to yield significant quantities of water for wells and springs (CONAGUA 2006, U. S. Geological Survey, 2016). The criteria used to define aquifer potential includes lithological features, permeability, porosity, hydraulic conductivity, transmissivity, and water yield, when available. Considering the complexity and heterogeneity of the geologic units, as well as the differences in methods used to characterize units on both sides of the border, a combination of criteria were used to classify aquifer potential as ‘good’, ‘moderate’, or ‘poor’ using the following criteria: geological and lithological descriptions of the units; porosity and hydraulic conductivity, when available, or standardized values according to the predominant lithology (Hiscock, 2005); and permeability reports, assessments, and water-yield data from CONAGUA (2006), and technical reports from the Texas Water Development Board (TWDB). Data were collected from federal, state, and local agencies, as well as from technical and scientific reports, private (industry) reports, non-public reports, and field assessments. The common criterion for water quality is Total Dissolved Solids (TDS) which was available for most of the border region.

According to TWDB (TWDB, 2017), TDS criteria to classify groundwater quality are:

- Fresh water with TDS being less than 1,000 mg/L;
- Slightly saline water (called 'brackish water' in many studies) having TDS in the range of 1,000–3,000 mg/L;
- Moderately saline water having TDS in the range of 3,000–10,000 mg/L;
- Very saline water having TDS in the range of 10,000–35,000 mg/L; and,
- Brine having TDS over 35,000 mg/L.

Some reports refer to parts per million (ppm), where 1 ppm is equivalent to 1 mg/L for practical purposes and is the term used in this report. Table 1 shows how the geologic formations and sub-units are classified based on aquifer potential and corresponding water quality. Note that an aquitard is a geologic unit with low permeability.

Table 1. Classification of Formations by Aquifer Potential and Water Quality

Formation Classification			**Water Quality (TDS)**			
			Good (Fresh) <1,000 ppm	Moderate (Slightly saline or brackish) 1,000-3,000 ppm	Poor (Moderately saline to brine) >3,000 ppm	No Info
			1	2	3	4
Aquifer Potential	Good	A	A1	A2	A3	A4
	Moderate	B	B1	B2	B3	B4
	Poor	C	C1	C2	C3	C4
	Aquitard	D	D1	D2	D3	D4
	No Info	E	E1	E2	E3	E4

To identify and geographically characterize the areas of transboundary groundwater between Texas and Mexico, geologic formations and sub-units have been grouped by similar characteristics and defined in Table 2. Five groups were created to identify those geographic areas containing transboundary groundwater with good and moderate potential and to differentiate them from those areas with poor potential according to aquifer properties and water quality. These group definitions ("ID") are also used in Table 3.

- Group 1 (dark green), the most important geologic formations and sub-units in terms of groundwater potential and water quality, corresponds to the A1, A2, B1, and B2 characteristics.
- Group 2 (light green) includes those geologic formations and sub-units that have good to moderate aquifer potential, but poor water quality or limited information on water quality (A3, A4, B3, and B4). This group constitutes a second level of priority, given the good conditions of the aquifer and the potential of those units for future desalination projects.
- Group 3 (orange) includes those geologic formations and sub-units with poor aquifer potential or aquitards, but good to moderate water quality. This group may be considered third in priority given the limited conditions of the aquifer, but still exploitable at the local level for domestic water supply in small communities (C1, C2, D1, and D2).
- Group 4 (light maroon) is the lowest priority group: geologic formations and sub-units with poor aquifer potential or aquitards, low water quality, or limited information on water quality (C3, C4, D3, and D4).
- Group 5 (gray) includes those geologic formations and sub-units with limited information on aquifer potential, no matter their water quality. Their priority is undefined, given the lack of data (E1, E2, E3, and E4).

Table 2. Formations Classified into Five Color-Coded Groups According to Aquifer Potential and Water Quality

Formation Classification			**Water Quality**			
			Good	Moderate	Poor	No Info
			1	2	3	4
Aquifer Potential	Good	A	A1	A2	A3	A4
	Moderate	B	B1	B2	B3	B4
	Poor	C	C1	C2	C3	C4
	Aquitard	D	D1	D2	D3	D4
	No Info	E	E1	E2	E3	E4

The classifications in Table 3 show the predominant conditions according to available data in terms of aquifer potential and water quality parameters for all geologic formations and sub-units along the Texas – Mexico border. As shown in Table 3, from the total of 53 boundary and transboundary formations, 15 geologic formations and sub-units are considered to have good to moderate aquifer potential and good to moderate water quality, and four formations have good aquifer potential but limited information on water quality (Upper West Nueces Formation (Fm.), Santa Elena Fm./Santa Elena Limestone, Austin Fm./Austin Chalk, and Ojinaga Fm.). It is fair to say that approximately 35% of the areal extent of the identified geological formations and sub-units have good aquifer potential, with at least 28% of good to moderate water quality. The predominant geologic formations under this classification are the Edwards Fm., Upper Salmon Peak and Aurora Fm./Glen Rose Fm., and all parts of the Edwards Aquifer as referred by Sanchez et al. 2018. Likewise, good aquifer potential is also prominent in the Quaternary alluvial deposits of Santa Fe del Pino, Serrania del Burro and Presa la Amistad Aquifers, and the Quaternary conglomerate deposits of the bolsons of Valle de Juarez, Mesilla, Red Light Draw, Green River Valley, Presidio, and Redford. The Carrizo Fm./Carrizo Sand, part of the Carrizo-Wilcox Aquifer, is also in this category. Moderate water quality conditions, but with less than 1,000 ppm TDS, were found in Oakville-Lagarto Fm./Fleming Fm., Reynosa Fm./Goliad Fm., and Wilcox Fm./Indio Fm. An estimated 17 geologic formations and sub-units (32%) have been identified as having poor aquifer potential or aquitards with poor to moderate water quality. The predominant geologic formations and sub-units in this category are the Yegua Fm. (part of the Yegua-Jackson Aquifer); Santa Elena Fm./Santa Elena Limestone (part of the Cretaceous-Terlingua Aquifer); Upson Fm./Upson Clay; Aguja Fm.; Escondido Fm.; Midway Fm./Kincaid Fm.; Bigford Fm.; Palma Real-Guayabal Fm./Laredo Fm.; Frio Fm. and the Lower Catahoula Fm. (both parts of the Catahoula Confining System); and the Beaumont Fm. (part of the Gulf Coast Aquifer). The rest of the geologic formations and sub-units (5) are considered aquitards with limited data on water quality, or aquitards with good to moderate water quality (3). There are also six boundary and transboundary geologic formations and sub-units that have no reported data on either aquifer potential or water quality: San Carlos Fm./San Carlos Sandstone, Chisos Fm. (USA), Cox Sandstone (USA), La Pena Fm./Yucca Fm., Picacho Fm., and Benevides Fm. Caution should be taken in estimates of percentages, considering that these are based on the type of geologic formation or sub-unit and not on geographical extent.

Table 3. Classification of Geological Formations and Sub-Units at the Border between Texas and Mexico according to Aquifer Potential and Water Quality (T=Transmissivity m^2/d, K=Hydraulic conductivity m/d, n=porosity, Fm. = Formation, TX = Texas, MX = Mexico, Qt = Quaternary, USA = United States of America)

BOUNDARY FORMATIONS	TRANSBOUNDARY FORMATIONS AND/OR SUB-UNIT	AQUIFER NAME	AQUIFER POTENTIAL	HYDRO-GEOLOGIC FEATURES	WATER QUALITY	TDS (ppm)	ID
Loma de Plata Fm./Espy Limestone	Loma de Plata Fm./Espy Limestone		Aquitard		Unknown		D4
Aurora Fm./Glen Rose Fm.	Aurora Fm./Glen Rose Fm.	Edwards	Good Aquifer		Slightly saline	1000 to > 3000	A3
Edwards Fm.	Edwards Fm.	Edwards	Good Aquifer	T=0.15-25,100 K=0.0009-221	Fresh	< 1000	A1
West Nueces Fm.	Upper West Nueces Fm.	Edwards	Good Aquifer		Unknown		A4
West Nueces Fm.	Lower West Nueces Fm.	Edwards	Aquitard		Unknown		D4
McKnight Fm.	McKnight Fm.	Edwards	Aquitard		Unknown		D4
Salmon Peak Fm./Salmon Peak Limestone.	Lower Salmon Peak	Edwards	Poor Aquifer		Unknown		C4
Salmon Peak Fm./Salmon Peak Limestone.	Upper Salmon Peak	Edwards	Good Aquifer		Fresh to Slightly saline		A1-A3
Devils River Limestone (USA)		Edwards	Good Aquifer	n=0.033% to 0.15%	Fresh to Slightly saline		A1-A3
Santa Elena Fm./Santa Elena Limestone	Santa Elena Fm./Santa Elena Limestone	Edwards	Moderate Aquifer		Unknown		B4
Santa Elena Fm./Santa Elena Limestone	Santa Elena Fm./Santa Elena Limestone	Cretaceous -Terlingua	Poor Aquifer		Slightly saline	1130–1303	C2
Pen Fm.	Pen Fm.	Cretaceous -Terlingua	Moderate Aquifer		Slightly saline	2173	B2
Javelina Fm. (USA)		Cretaceous -Terlingua	Poor Aquifer		Moderately saline		C3
Aguja Fm.	Aguja Fm.	Cretaceous -Terlingua	Poor Aquifer		Moderately saline and hard	5287	C3
Kiamichi Fm.			Poor Aquifer		Slightly saline to Moderately saline		C2
Cox Sandstone (USA)			Unknown		Unknown		E4
La Pena Fm./Yucca Formation			Unknown		Unknown		E4
Benevides Fm.			Unknown		Unknown		E4
Boquillas Fm.	Boquillas Fm.		Poor Aquifer		Fresh to Slightly saline		C1-C2
Eagle Ford Fm./Eagle Ford Group	Eagle Ford Fm./Eagle Ford Group		Aquitard		Unknown		D4

BOUNDARY FORMATIONS	TRANSBOUNDARY FORMATIONS AND/OR SUB-UNIT	AQUIFER NAME	AQUIFER POTENTIAL	HYDRO-GEOLOGIC FEATURES	WATER QUALITY	TDS (ppm)	ID
Upson Fm./Upson Clay	Upson Fm./Upson Clay		Aquitard		Slightly saline	1000–2500	D2
Austin Fm./Austin Chalk	Austin Fm./Austin Chalk		Good Aquifer		Unknown		A4-D4
Buda-Del Rio Fm./Buda Limestone-Del Rio Clay	Buda-Del Rio Fm./Buda Limestone-Del Rio Clay		Poor Aquifer		Fresh to Slightly saline		C1-C3
Ojinaga Fm.	Ojinaga Fm.		Good Aquifer		Unknown		A4
Picacho Fm.			Unknown		Unknown		E4
San Carlos Fm./San Carlos Sandstone			Unknown		Unknown		E4
San Miguel Fm.	San Miguel Fm.		Poor Aquifer		Unknown		C4
Olmos Fm.	Olmos Fm.		Aquitard		Unknown		D4
Escondido Fm.	Escondido Fm.		Poor Aquifer		Slightly saline	1000–2500	C2
Chisos Fm. (USA)			Unknown		Unknown		E4
Midway Fm./Kincaid Fm.	Midway Fm./Kincaid Fm.		Aquitard		Unknown		D3
Wilcox Fm./Indio Fm.	Wilcox Fm./Indio Fm.	Carrizo-Wilcox	Moderate Aquifer		Fresh to Slightly saline	1000–3000 (TX)	B1-B2
Carrizo Fm./Carrizo Sand	Carrizo Fm./Carrizo Sand		Good Aquifer		Fresh to Slightly saline (TX) / Moderately saline (MX)	1000–3000 (TX), 482–9334 (MX)	A1-A3
Bigford Fm.	Bigford Fm.		Poor Aquifer		Slightly saline		C3
El Pico Clay Fm.	El Pico Clay Fm.		Poor Aquifer-Aquitard		Unknown		C3-D3
Palma Real-Guayabal Fm./Laredo Fm.	Palma Real-Guayabal Fm./Laredo Fm.	Palma Real-Guayabal Fm./ Laredo Fm.	Poor Aquifer		Moderately saline		C3
Yegua Fm.	Yegua Fm.	Yegua-Jackson	Poor Aquifer		Unknown		D3
Jackson Fm./Jackson Group	Jackson Fm./Jackson Group		Moderate Aquifer	T=7.8 K=0.4	Moderately saline	> 3000	C3
Vicksburg Fm.	Vicksburg Fm.	Catahoula Confining System	Poor Aquifer	n=5%	Unknown		C4
Frio Fm.	Frio Fm.		Aquitard		Moderately saline	>3000	D3
Catahoula Fm./Catahoula Fm. and Catahoula-Vicksburg Fm. Undivided	Lower Catahoula Formation		Aquitard	T=4.5 K=0.2	Slightly saline to Moderately saline	>3000	D2
	Upper Catahoula Formation	Gulf Coast/Bajo Rio Bravo	Moderate Aquifer		Slightly saline	>1000	B2
Oakville-Lagarto Fm./Flemming Fm.	Oakville-Lagarto Fm./Flemming Fm.		Moderate Aquifer	T=9.3 K=1	Slightly saline	>1000	B1-B2
Reynosa Fm/ Goliad Fm.	Reynosa Fm/ Goliad Fm.		Moderate Aquifer	T=22 K=1.5	Slightly saline	>1000	B1-B2

BOUNDARY FORMATIONS	**TRANSBOUNDARY FORMATIONS AND/OR SUB-UNIT**	**AQUIFER NAME**	**AQUIFER POTENTIAL**	**HYDRO-GEOLOGIC FEATURES**	**WATER QUALITY**	**TDS (ppm)**	**ID**
Lissie Formation (USA)			Good Aquifer	T=46.3 K=8.5	Fresh to Moderately saline	800–5000	A2
Beaumont Fm.	Beaumont Fm.		Poor Aquifer		Slightly saline	> 2000	C2
Quaternary Deposits	Qt Lacustrine		Aquitard		Moderately saline		D3
	Qt Alluvium		Moderate Aquifer		Slightly saline		B2
	Qt Alluvium	Santa Fe del Pino	Regular Aquifer	$T=0.77 \times 10^{-3}$ to 0.01×10^{-3}	Slightly saline		B2
	Qt Conglomerates		Good Aquifer		Fresh to Slightly saline	400–1500	A1-A2
	Qt Alluvium	Serrania del Burro	Good Aquifer		Fresh to Slightly saline		A1-A2
	Qt Colluvium		Unknown				E4
Qt to Tertiary clay and mud (USA)			Poor Aquifer		Slightly saline	>1000	C2-C3
Quaternary Deposits	Qt Alluvium	Presa la Amistad	Good Aquifer		Fresh to Slightly saline		A1-A2
Uvalde Gravel (USA)			Good Aquifer		Fresh to Slightly saline	<1000-3000	A1-A2
Uvalde Gravel (USA)		Allende-Piedras Negras	Good Aquifer		Fresh to Slightly saline	<1000-3000	A1-A2
Quaternary Deposits			Good Aquifer	T=0.0005 to 0.005	Fresh to Slightly saline	<1000-3000	A1-A2
Qt Conglomerates	Qt Conglomerates		Good Aquifer		Fresh to Slightly saline	400-1500	A1-A2
Quaternary Deposits	Quaternary Deposits	Bolsons: Valle de Juarez, Hueco-Tularosa, Mesilla Aquifer, Conejos-Medanos, Red Light Draw, Green River Valley, Presidio, Redford	Good Aquifer	$T=2 \times 10^{-3}$ $K=8.69 \times 10^{-6}$ n=9%	Fresh to Slightly saline	400-1500	A1-A2
Qt Conglomerates	Qt Conglomerates		Good Aquifer		Fresh to Slightly saline	400-1500	A1-A2
Qt to Tertiary clay and mud (USA)			Poor Aquifer		Slightly saline	>1000	C2-C3
Neogene Conglomerate (MX)			Moderate Aquifer		Fresh	710	B1
Tertiary Igneous Rocks		Tertiary Igneous Rocks	Poor Aquifer / Aquitard		Fresh to Slightly saline	870–3013	C1-D1
Tertiary Basalts		Tertiary Basalts	Poor Aquifer		Fresh	354	C1

Figures 1, 2, and 3 map the hydrogeological units, colored by group (ID). Figure 1 shows the western region of Texas, bordering the state of Chihuahua. The most important hydrogeological units in the region are the bolsons, which are classified as good potential transboundary aquifers. However, except for the cities of El Paso-Juarez and Presidio-Ojinaga, which are the most important urban centers in the region, and small towns that use groundwater for irrigation and livestock in the border area (Guadalupe and Sierra Blanca in Chihuahua, and Valentine, Fort Davis, and Van Horn in Texas), not much research or groundwater development is reported in this region. Given the low surface water availability in this border area, there is a high dependency on groundwater, which has had impacts on the sensitive ecosystem of the Chihuahuan desert (Sanchez et al., 2016). More research and data collection on aquifer properties and water quality on both sides of the border in this region is of high priority for both countries.

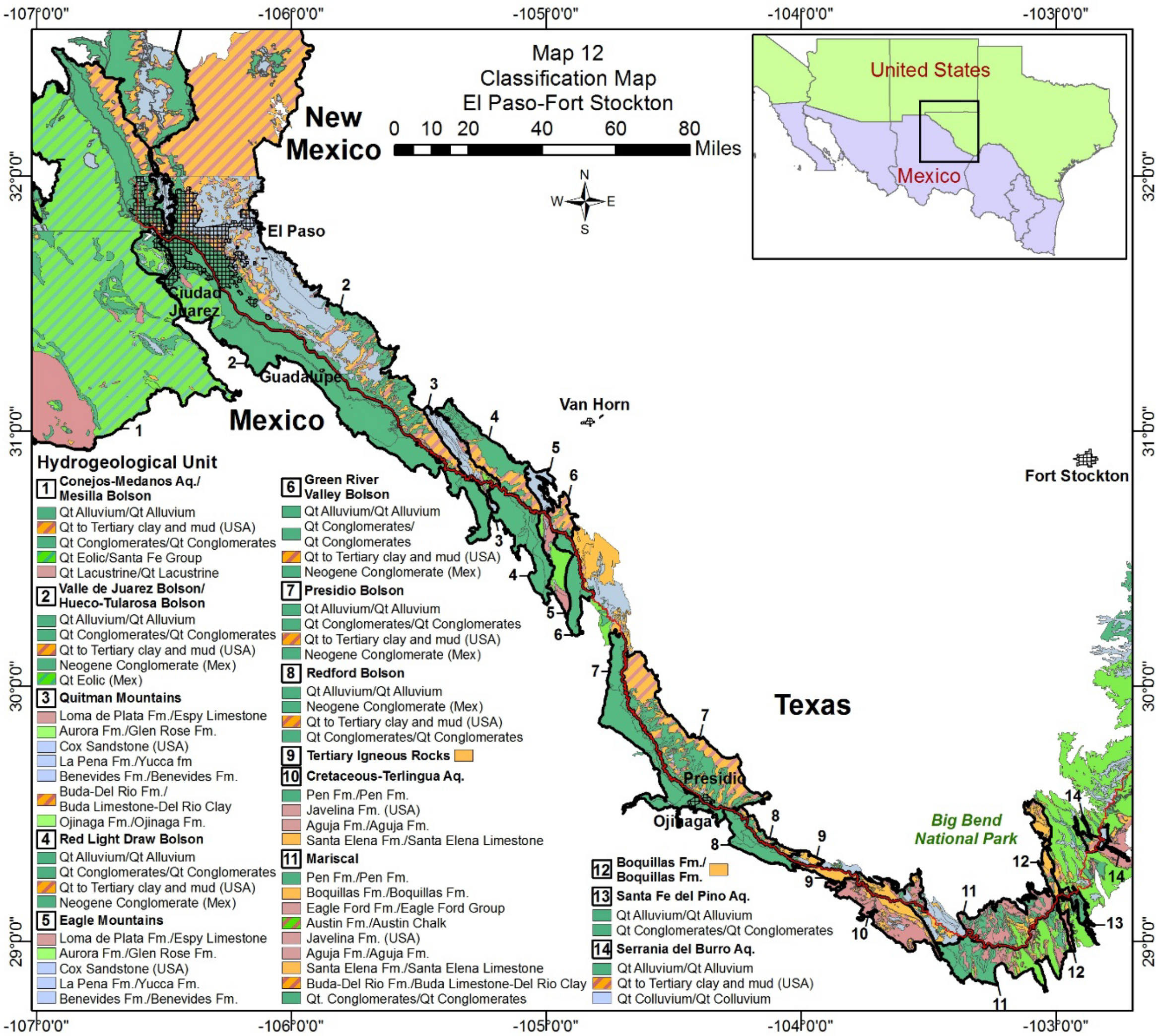

Figure 1. Map of Transboundary Aquifers between Mexico and Texas extending from the El Paso area to the Big Bend region. Source: Sanchez et al. 2018. Transboundary Aquifers between Mexico and Texas: Identification and Categorization. Journal of Hydrology, Regional Studies. Special Edition on Transboundary Aquifers. https://doi.org/10.1016/j.ejrh.2018.04.004)

The Big Bend region does not represent an important source of groundwater development given the complexity of the formations that surround the transboundary area and the mixture of formations, some classified as good aquifers and others as aquitards. The fact that this region is a national park (Big Bend) on the U.S. side and a protected natural area (Maderas del Carmen) on the Mexico side makes significant groundwater development in this region unlikely. However, two small transboundary aquifers consisting of Quaternary alluvial deposits have been detected on the eastern side of the Big Bend region (Santa Fe del Pino and Serrania del Burro), which should be noted for future research and water needs in the area. Generally, 60–65% of the land in this area is estimated to have good aquifer potential and good water quality.

Figure 2 shows the area covered by the Edwards Aquifer and adjacent hydrogeological units. According to the classification in Table 3, apart from a portion of the border region between Texas and Coahuila (above the Austin Chalk and a small portion to the west), the rest of the hydrogeological unit has 80–85% good to moderate aquifer potential, with both good and poor water quality areas. Given the areal extent of the Edwards Aquifer (approximately 35,000 km^2 on each side of the border) and its potentially good water quality conditions, this region is considered high priority for future research. The Mexico side is considered an ecological priority for the state of Coahuila because it hosts the headwaters (in the Serrania del Burro Mountains) of all the perennial rivers in the state, which are interconnected with the Five Springs Region (Region de los Cinco Manantiales) and provide water for the cities of Ocampo, Muzquiz, and Cuatrocienegas (the last one outside the limits of the Edwards Aquifer). There is high dependency on the Presa la Amistad Aquifer in the cities of Del Rio/Acuña (bordering the Edwards Aquifer) and on the Allende Piedras Negras Aquifer in the bordering cities of Piedras Negras/Eagle Pass (Sanchez et al., 2016). San Felipe Springs is the sole water source for Del Rio, Texas. There are reports of high transmissivity along the border area, as well as groundwater confinement that increases water yield in the area of the Amistad Aquifer close to Acuña (George et al., 2011). Other communities in Uvalde, Kinney, Edwards, and Val Verde Counties in Texas also rely on groundwater from the Edwards Aquifer (Boghici, 2002).

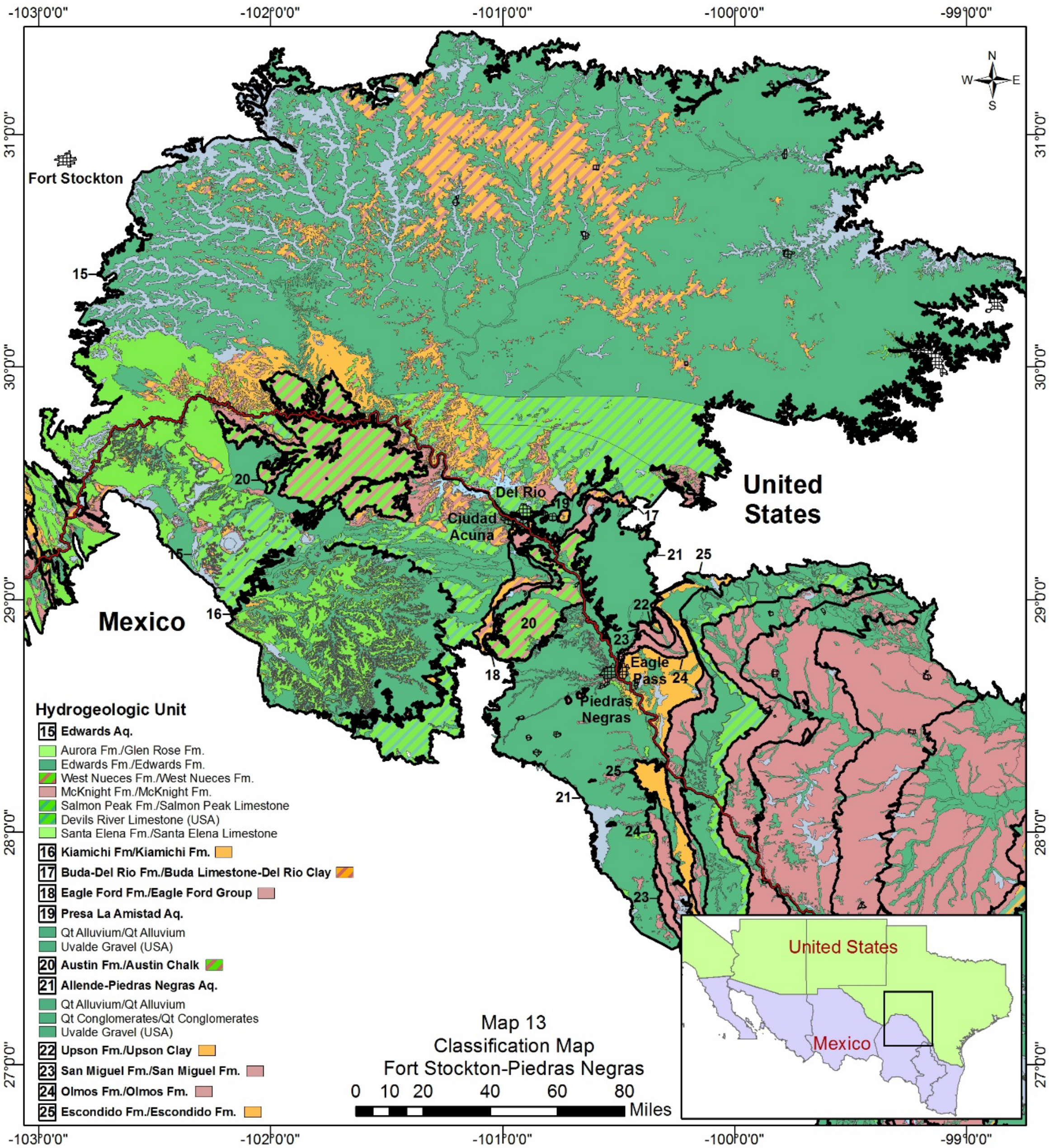

Figure 2. Map of Transboundary Aquifers between Mexico and Texas extending from the Big Bend region to Piedras Negras. Source: Sanchez, R., Rodriguez, L., Tortajada, C. (2018). Transboundary Aquifers between Mexico and Texas: Identification and Categorization. Journal of Hydrology, Regional Studies. Special Edition on Transboundary Aquifers. https://doi.org/10.1016/j.ejrh.2018.04.004)

Figure 3 shows the classification of hydrogeological units from the Allende Piedras Negras Aquifer to the Gulf Coast. In this figure, it can be seen that, apart from the Carrizo-Wilcox Aquifer and bordering sections of the Gulf Coast Aquifer which are considered to have good aquifer potential and good water quality on both sides of the border, the rest of the region falls into the poor category for both aquifer potential and water quality. This region is known for higher salinity (TDS 1,000–3,000 mg/L) and referred to as a “bad water zone” (Sanchez et al., 2016); reliance on groundwater in this region is limited. In the Carrizo-Wilcox Aquifer, over-pumping of groundwater has been reported around the Texas cities of Crystal City and Cotulla. In the Gulf Coast Aquifer, good transboundary conditions that extend to the state of Tamaulipas are significant, and groundwater supply is reported to be significant in the bordering cities of McAllen/Reynosa, Brownsville/Matamoros, and the surrounding area. Extensive irrigation districts on both sides of the border depend on groundwater for economic development.

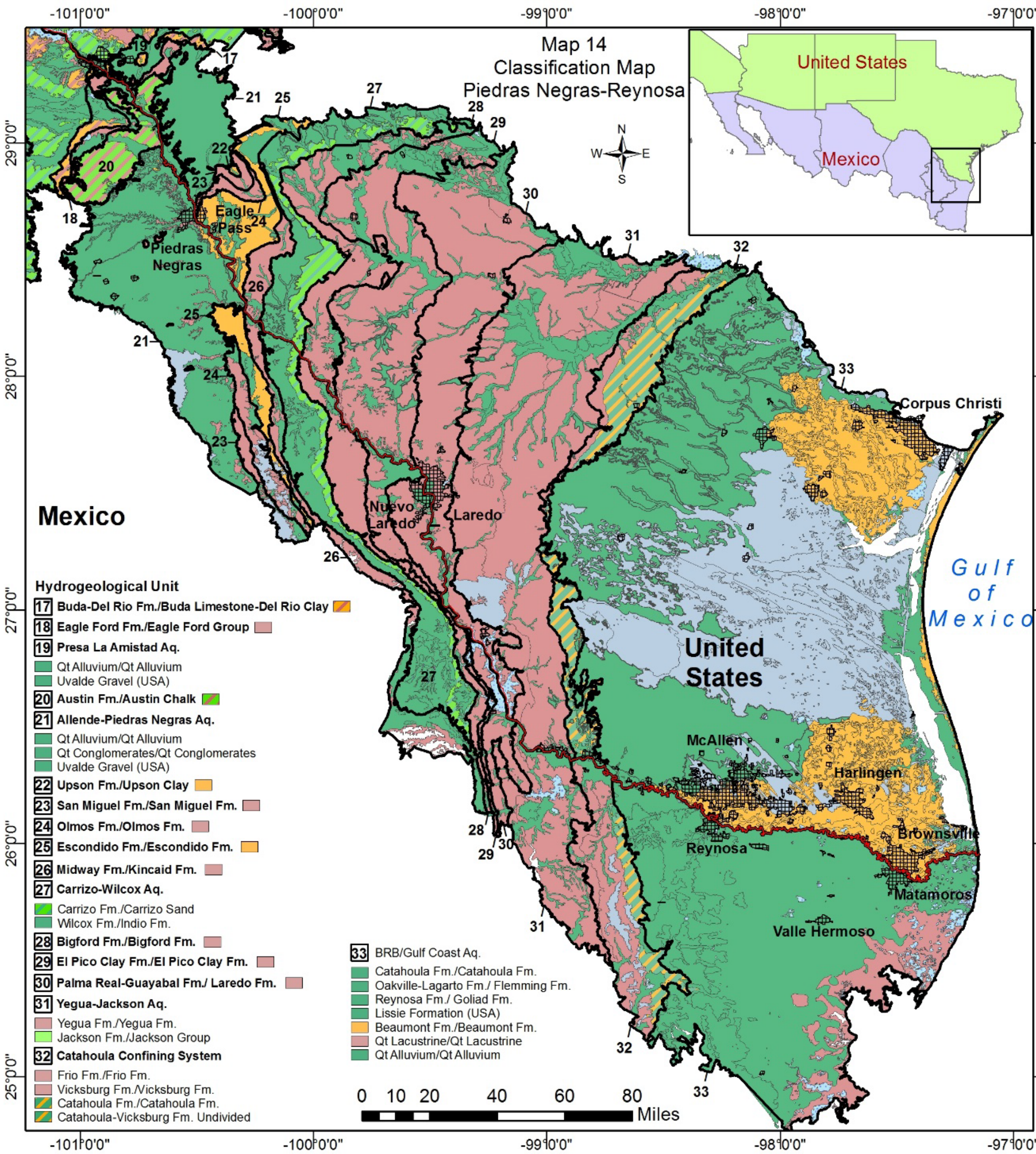

Figure 3. Map of Transboundary Aquifers between Mexico and Texas extending from Piedras Negras to Reynosa. Source: Sanchez, R., Rodriguez, L., Tortajada, C. (2018). Transboundary Aquifers between Mexico and Texas: Identification and Categorization. Journal of Hydrology, Regional Studies. Special Edition on Transboundary Aquifers. https://doi.org/10.1016/j.ejrh.2018.04.004)

Likewise, because of the location of the Amistad and Falcon international dams in this region, as well as the groundwater – surface water interactions that contribute to the Rio Grande / Rio Bravo flow and its tributaries, a portion of the groundwater on the Mexico side is considered to be committed to fulfill Mexico's water obligations under the 1944 treaty, adding pressure on groundwater resources in this region (CONAGUA, 2015). According to this classification, it is estimated that around 30–35% of the bordering land in this region has good aquifer potential.

This white paper was prepared for the TGPC GWI Subcommittee whose members include, but are not limited to:

- Texas Commission of Environmental Quality (TCEQ);
- Texas Water Development Board (TWDB);
- Railroad Commission of Texas (RRC);
- Texas Department of State Health Services (DSHS);
- Texas Department of Agriculture (TDA);
- Texas State Soil and Water Conservation Board (TSSWCB);
- Texas Alliance of Groundwater Districts (TAGD);
- Texas A&M AgriLife Research (AgriLife Research);
- Bureau of Economic Geology of The University of Texas at Austin (UTBEG);
- Texas Department of Licensing and Regulation (TDLR);
- Texas Parks and Wildlife Department (TPWD);
- Texas Tech University (TTU);
- Texas A&M AgriLife Extension Service (AgriLife Extension); and,
- United States Geological Survey (USGS).

The primary goals of the TGPC GWI Subcommittee are to:

- Facilitate interagency communication for assessment programs addressing groundwater contamination;
- Coordinate and assist member agencies with monitoring programs for:
  - Ambient groundwater conditions;
  - Pesticides; and,
  - Emerging contaminants or constituents of concern;
- Review published data reports and evaluate data independent of reports to assist in the determination of the effectiveness of existing regulatory programs;
- Review published data reports and evaluate data independent of reports for potential contaminants not addressed by existing regulatory programs; and,

- Develop recommendations for consideration by the TGPC to address potential groundwater contamination identified through monitoring and data review.

Conclusion

From the total of 53 boundary and transboundary formations identified between Mexico and Texas, there are 15 geologic formations and sub-units considered to have good to moderate aquifer potential and good to moderate water quality. Approximately 35% of the areal extent of the identified geologic formations and sub-units have good aquifer potential, with at least 28% of good to moderate water quality. The predominant geologic formations and sub-units under this classification are the Edwards Fm., Upper Salmon Peak and Aurora Fm./Glen Rose Fm. (part of the Edwards Aquifer), the Quaternary alluvial deposits of Santa Fe del Pino, Serrania del Burro and Presa la Amistad Aquifers, and the Quaternary conglomerate deposits of the bolsons of Valle de Juarez, Mesilla, Red Light Draw, Green River Valley, Presidio, and Redford. The Carrizo Fm./Carrizo Sand part of the Carrizo-Wilcox Aquifer is also in this category. On the other hand, an estimated 17 geologic formations and sub-units (32%) have been identified as poor aquifers or aquitards with poor to moderate water quality. The predominant geologic formations and sub-units in this category are the Yegua Fm. (part of the Yegua-Jackson Aquifer); Santa Elena Fm./Santa Elena Limestone; Upson Fm./Upson Clay; Aguja Fm.; Escondido Fm.; Midway Fm./Kincaid Fm.; Bigford Fm.; Palma Real-Guayabal Fm./Laredo Fm.; Frio Fm. and the Lower Catahoula Fm. (both parts of the Catahoula Confining System); and the Beaumont Fm. (part of the Gulf Coast Aquifer).

Overall, the area covered by the identified hydrogeological units in the border region between Texas and Mexico is around 182,000 km^2 (approximately 110,000 km^2 on the Texas side and 72,000 km^2 on the Mexico side). The total area considered to have good aquifer potential as well as good water quality ranges between 50% and 60% (60% of this in Texas). Approximately 20% to 25% of the border area is considered to have poor aquifer potential and poor water quality. From a general perspective, the region of the bolsons (aquifers located southeast of the Valle de Juarez/Hueco-Tularosa Bolson Aquifer in northern Chihuahua, southern New Mexico, and western Texas, and between the Serrania del Burro and Allende-Piedras Negras Aquifers in south Texas and northern Coahuila), where Quaternary alluvial deposits are concentrated, appear to be the most important areas for transboundary aquifer development.

As there are only a few assessments of this kind within this region (Sanchez 2016 and TWDB 2017 are the only publications found), further study is needed to understand the physical aspects of these aquifers, as well as the approaches used to manage groundwater pumpage in these transboundary areas that can focus attention on preventing the degradation of the aquifers and ensure sustainable use of groundwater resources within the border region between Mexico and the United States.

Recommendations and Continuing Research Needs

The growing tendency in the Rio Grande / Rio Bravo basin is to rely more on groundwater than surface water, and there are a number of additional concerns (e.g., water security, current conditions of the shared groundwater resources, and limited knowledge and data availability). These recommendations are based on water security concerns as well as to inform users of the current conditions of the shared groundwater resources and to explore the potential vulnerabilities that may arise if the current condition of limited research, knowledge, and data availability in the border region between Texas and northeastern Mexico continues.

- Provide funding for research in areas that have been classified as good to moderate aquifer potential which includes the border region of the Edwards Aquifer, the Green River Valley Bolson, Presidio Bolson, Redford Bolson, Presa la Amistad, Santa Fe del Pino Aquifer, Serrania del Burro Aquifer, Allende-Piedras Negras Aquifer, and the border region of the Gulf Coast/Bajo Rio Bravo transboundary aquifer.
    - Conduct studies focused on the level of groundwater connectivity (geologic and geochemistry assessments) on those priority aquifers that have a high vulnerability to contamination and high groundwater dependency, in order to evaluate the amount and condition of groundwater flow between the hydrogeological units in Texas and Mexico.
    - Conduct water quality monitoring of priority transboundary areas that have limited research and are considered to have good aquifer potential and good water quality.
- Evaluate the possibility of creating transboundary working groups under the legal framework of Groundwater Conservation Districts (GCDs) for the Texas border counties in order to identify common threats and vulnerabilities across the border related to groundwater use from a regional perspective. This will increase the knowledge base and awareness of a common pool of groundwater resources on both sides of the border.
- Determine the geographical extent of vulnerability from each side of the border where water quality and the likelihood of impact (e.g., from pumping or pollution) changes

for each of the Texas-Mexico transboundary aquifers. For example, human activity 100 km from the border over a large transboundary sandstone aquifer would likely have no significant impact in the neighboring country for many years (if any). However, human activity 100 km from the border over a large transboundary karst aquifer could result in a significant impact in the neighboring country at some more imminent time in the future.

The above recommendations represent the opinion of the TGPC GWI Subcommittee and do not necessarily reflect the views and policies of each participating organization. The USGS may have contributed scientific information, only.

For more information about this white paper, please contact the TGPC (https://tgpc.texas.gov/contact-us/).

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