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Existing Opportunities to Adapt the Rio Grande/Bravo Basin Water Resources Allocation Framework

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Abstract: The study of the Rio Grande/Bravo (RGB) Basin water allocation demonstrates how the United States (U.S.) and Mexico have consolidated a transboundary framework based on water sharing. However, the water supply no longer meets the ever-increasing demand for water or the expectations of different stakeholders. This paper explores opportunities for an enhanced management regime that will address past problems and better examine how to balance demands for a precious resource and environmental needs. Based on an overview of the RGB Basin context and the water allocation framework, as well as a discussion on stakeholders' ability to achieve solutions, this paper explores three key questions: (1) Does the current binational water allocation framework meet current and future human and environmental needs? (2) How can the U.S.-Mexico water allocation framework be adapted to balance social and environmental water demands so it can support and preserve the RGB Basin ecosystem? (3) What are the main opportunities to be explored for expanding the U.S.-Mexico water resources allocation framework? The U.S.-Mexico water resources framework is subject to broad interpretation and may be adapted to the circumstances taking the fullest advantage of its flexibility. Policy recommendations highlight the existing flexibility of the binational framework, the potential to move forward with an ad hoc institutional arrangement, and the creation of political will to achieve change through stakeholders recommendations.

Keywords: Rio Grande/Bravo Basin; water allocation framework; stakeholders; adaptation; flexibility; United States; Mexico; political will

1. Introduction

The United States (U.S.) and Mexico share a nearly 3200 km long border that crosses three river basins: the Colorado River (CR), the Tijuana River (TR), and the Rio Grande/Bravo (RGB). This paper focuses on the surface water resources of the RGB (hereinafter the term *water* refers to surface water resources unless otherwise specified). The water of the RGB is allocated within a binational legal framework that allocates water resources, sets extractions and diversions, and sustains political boundaries between the U.S. and Mexico. Allocations to each country are based on an estimate of the basin's hydrology at the time decisions were made. These have remained unchanged despite a substantial increase in municipal, industrial, and agricultural water demands, multiple coexisting water users, and unmet environmental and sustainability needs. Limited water resources in the context of an arid climate and related ecological vulnerabilities invite competition among water uses and users across and along the border, taxing the quality of the river environment and human capacity to solve common problems.

Transboundary water challenges have been successfully addressed on an ad hoc basis in two of the boundary river basins. Binational agreements on the CR and the TR have fostered water management adaptation through ecological restoration, qualitative riparian improvements, and stakeholder involvement. The creation of binational groups of competing stakeholders is one of the key demarches in implementing new legal instruments to solve common river basin issues. But these developments have been slow to emerge in the RGB. The RGB has been managed largely to meet competing binational demands driven by regional economics, with little regard of the river's instream flow. The situation is exacerbated by a lack of environmental conservation and restoration projects and few binational efforts to address these ecological challenges.

This paper answers the following questions: (1) Does the current binational water allocation framework meet present and future human and environmental needs? (2) How can the U.S.-Mexico water allocation framework be adapted to balance social and environmental water demands so it can support and preserve the RGB Basin ecosystem? and, (3) What are the main opportunities to be explored for expanding the U.S.-Mexico water resources allocation framework? Posing these questions directs attention to the existing opportunities to adapt the existing RGB water governance framework in the direction of greater inclusiveness and stakeholder participation in riparian management while strengthening binational cooperation and safeguarding environmental values.

The manuscript is organized into four sections: (i) a general overview of the RGB basin and its challenges; (ii) a description of the RGB water allocation framework and its current social, economic, and environmental limitations; (iii) a review of the opportunities to adapt the present RGB allocative framework to incorporate other beneficial uses and better integrate a wider range of stakeholders' insights; and finally; (iv) an elaboration on the potential to capitalise on the binational water allocation framework's strengths to improve water management in the RGB Basin. An argument is made for the need to strengthen the current RGB water allocation framework's capacity to address ecological needs by means of revitalized and enhanced stakeholder consultation in riparian decision-making.

2. Background Information

2.1. The Rio Grande/Bravo Basin (RGB)

The U.S. and Mexico share a nearly 3200 km long border that crosses the Colorado River (CR), the Tijuana River (TR), and the Rio Grande/Bravo (RGB). The Rio Grande River is longest of these rivers and forms the international boundary for 2034 km (Figure 1).

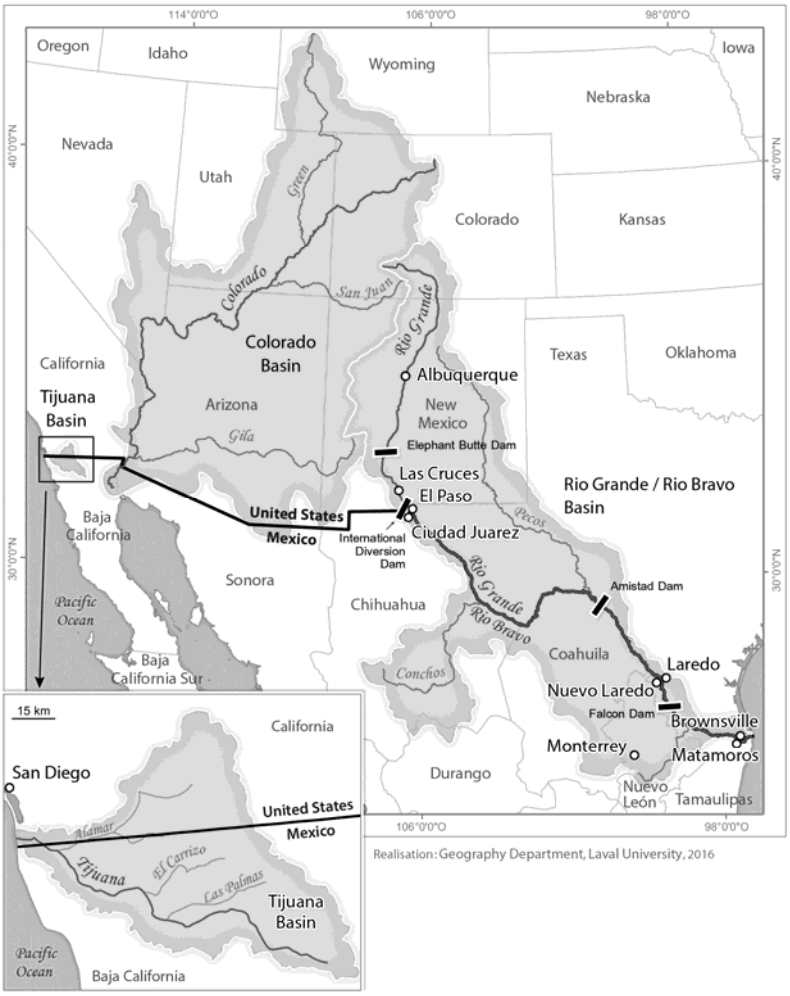


Figure 1. The U.S. and Mexico Transboundary Rivers. Courtesy of the Geography Department, Laval University, 2016.

The Rio Grande, as it is known in the U.S., or the Río Bravo, as it is called in Mexico, is the 20th largest river in the world, with a total length of 3059 km. It carries less water than rivers of similar size because it runs through arid areas for most of its length (the mean flow is 25 m^3/s at Matamoros, 1955–2006 [1]; by comparison, the Danube, River, a river of similar length, has a mean flow of 6486 m^3/s just before the delta [2]). Higher precipitation only characterizes its headwater (>800 mm) and mouth regions (650 mm). The river basin covers an area of 924,300 km^2, divided almost in half between the two countries.

The headwaters of the RGB are located in the U.S. state of Colorado. The river flows south through New Mexico (NM) arriving well south of Albuquerque at two major reservoirs on its course, Elephant Butte (EB) and the Caballo dams. Downstream of these, the flow almost entirely depends on releases from the reservoirs. Starting from the cities of Ciudad Juarez (Chihuahua, Mexico) and El Paso (Texas, USA?) until its mouth, the RGB forms the international border between Texas and the Mexican states of Chihuahua, Coahuila, Nuevo León and Tamaulipas. Due to the semi-arid climate and the extensive withdrawal of water for irrigation, the flow of the river in the section downstream of Ciudad Juarez/El Paso is severely depleted and is aptly called the *Forgotten Reach*. The Rio Conchos, in the Mexican state of Chihuahua, replenishes the RGB which then flows through the ecologically unique, mountainous area of the Big Bend Reach, protected in the form of several national parks. The Pecos River, flowing through the U.S. states of NM and Texas, enters the RGB at the Amistad Reservoir. Downstream in the vicinity of the twin cities of Laredo, Texas and Laredo, Tamaulipas, Falcon Reservoir constitutes

the primary water storage and supply structure on the river's lower reach. The river's flow in these lower parts is continuous thanks to the more humid, subtropical climate, tributaries' inflows, and agricultural return flows to the river. The RGB then joins the Gulf of Mexico [3–5].

The RGB Basin is characterized by a low level of rainfall and a high load of pollutants, leading to a dual dilemma of water scarcity and diminished water quality. These twin problems, exacerbated by population and economic growth, drive competition between different users and degrade the riparian ecosystem [6–11].

2.1.1. Water Scarcity

The RGB is a water scarce basin with an average precipitation greater than 800 mm in less than 5% of the RGB basin's area. While the headwaters are fed by snowmelt from the San Juan mountains in Colorado, most of the basin is located in the Chihuahuan desert, with an average precipitation of less than 500 mm [12]. Scarce precipitation leads to limited water availability. From this limited supply, significant withdrawals for human utilization are made basinwide. Large irrigation withdrawals in Colorado and New Mexico have greatly reduced the streamflow in the RGB mainstem, historically [13], and currently [14]. Historic increased water diversions along the border have also diminished the streamflow in the RGB mainstem, making the RGB basin one of the top 10 rivers at risk in 2007 [15]. The situation is sufficiently critical that some river sections are at times completely dry. No water flows through the Forgotten Reach and the river is barren for the six-month non-irrigation season near Las Cruces in NM.

To date, no binational measures have been taken to sustain instream flows for environmental purposes even though some studies have demonstrated the hydrologic and economic feasibility of doing so in portions of the RGB mainsteam, namely in the Big Bend reach [16–18]. However, a first step towards ensuring a healthy river was taken by the U.S. state of Texas as it adopted environmental flow standards in 2014 [19].

2.1.2. Water Quality

A considerable array of water quality issues are found on the river and in many sections water quality is seriously degraded. Here, we provide a brief overview of these. The greatest and most widespread problems are fecal contamination and high salt levels [20]. Fecal contamination carries pathogens and originates from municipal wastewater discharges as well as livestock and wildlife manure. It is mostly prevalent in and downstream of large urban centers. High salt levels (dissolved solids), including chloride and sulphate, originate principally from irrigation return waters and present challenges for the aquatic life as well as human uses such as municipal supply and crop cultivation [21]. Nutrients originate from fertilizers and wastewater discharges. Higher nutrient levels are found in several sections and cause eutrophication. Ammonia, a potentially toxic nutrient, is also found. High salt, depressed oxygen and high nutrient concentrations may be associated with blooms of toxic golden alga (e.g., *Prymnesium parvum*), leading to extensive fish kills [21]. Additionally, agrochemicals and other industrial organic compounds as well as several metals (e.g., copper, nickel, zinc, mercury, and arsenic) have been detected in surface waters, sediments and in some cases even in edible fish tissue. These compounds and elements are all harmful for aquatic life and human health [22].

The above described problems of water quantity and water quality are inherently linked. On one hand, small volumes of receiving waters impede the river's natural cleaning processes, or recycling of nutrients. On the other hand, if the available water is highly polluted, it is not suitable for municipal or agricultural usage, or only at much higher treatment costs.

2.1.3. Ecosystem Degradation

Channelization and dams coupled with pollution have greatly altered the natural water regime with adverse impacts on the local ecosystems, both riparian and aquatic. Several native species are endangered, such as the silvery minnow (*Hybognathus amarus*) and the southwestern willow flycatcher

(*Empidonax traillii extimus*). At the same time, exotic, invasive species dominate several areas, such as the salt cedar (*Tamarix ramosissima*) or the giant cane (*Arundo donax*) on the banks of the upper stretches to the Big Bend area or the water hyacinth and the hydrilla in waters downstream of the International Amistad Reservoir [21]. With such a degraded environment, the RGB Basin's capacity to provide ecosystem services [23], such as nutrient cycling and sustaining fish stocks, has been greatly compromised.

2.1.4. What Is Fuelling These Problems?

The region has seen a rapid population and economic growth in the past decades [4] (pp. 159–177). Today, 14 million people live in the southwest of the U.S. and the north of Mexico, predominantly in the large, so-called *sister cities*: San Diego–Tijuana; Calexico–Mexicali; Yuma–San Luis; Nogales–Nogales; Naco–Naco; Douglas–Agua Prieta; Columbus–Puerto Palomas; El Paso–Sunland Park–Ciudad Juárez–Ysleta del Sur Pueblo; Presidio–Ojinaga; Del Río–Ciudad Acuña; Eagle Pass–Piedras Negras; Laredo–Nuevo Laredo; McAllen–Reynosa; Weslaco–Rio Bravo; Brownsville–Matamoros [24,25]. In order to supply the needs of this population, the largest quantities of water are allocated to irrigation as the first priority, and to municipal water supply as the second. The number of irrigation and municipal facilities has rapidly increased without real coordination among the users and uses of water [6–10].

Municipal wastewater discharges, irrigation return flows and industrial discharges are the key sources of pollution. Infrastructure development has lagged behind the rapid growth of the region. Adequate treatment of wastewaters to significantly reduce pollution loads is available at some municipalities, while other border settlements lack these facilities [21]. Water scarcity means irrigation water is repeatedly reused, enhancing salt loads, especially in the western part of the basin. This growth is partially driven by more than 3000 assembly plants, so-called *maquiladoras*, that increase the potential for toxic contamination [21]. *Colonias*, impoverished rural border settlements in the U.S., are home to 432,000 people in Texas and NM [26] and represent a special case. With little or no infrastructure, they contribute to water pollution. At the same time, they are highly exposed to water quality issues as they rely on fish and untreated water for human consumption [3,4].

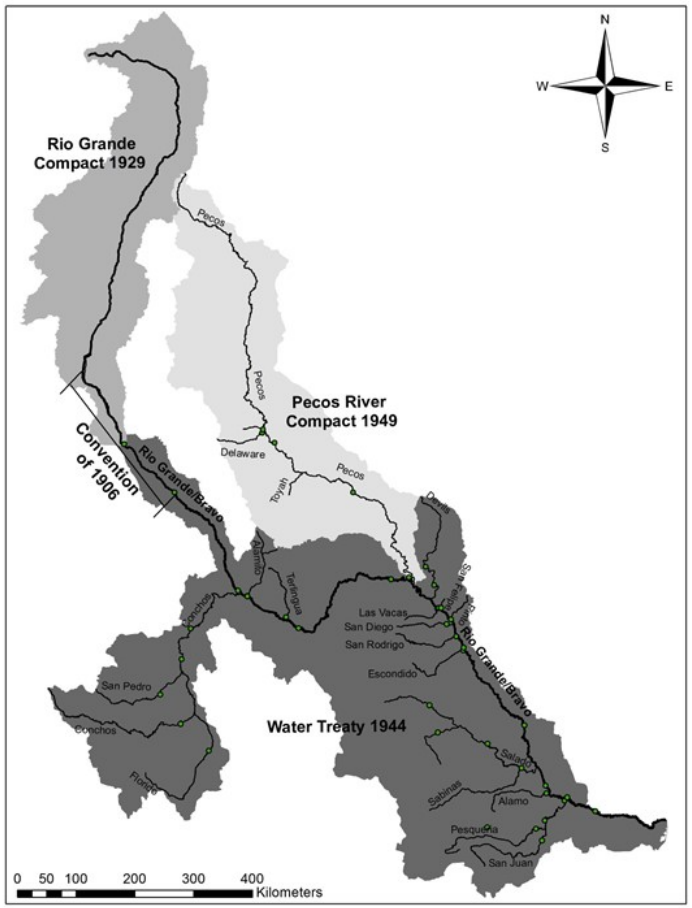
2.2. The Legal Instruments Shaping the Binational Institutional Framework for Water Allocation

The RGB water allocation legal framework is based on *international agreements* between the U.S. and Mexico and *compacts* at the national level among the U.S. riparian states. As an ensemble, these instruments translate into a set of formal rules regulating stakeholder behavior, and facilitating cooperation [27]. In the case of *international agreements*, both federal states have the authority to enter into agreement. *Compacts* are provided for in Article I, section 10, clause 3 of the U.S. Constitution, which establishes the basis for negotiating these interstate agreements: "No state shall, without the consent of Congress [...] enter into any agreement or compact with another state or with a foreign power [...]" [28]. Taking into consideration that the first step for a *compact* is the Congress authorization, a *compact* has been defined in American Western water right law as "an agreement between two or more states dealing with competing demands for a water resource beyond the legal authority of one state alone to solve" [29]. A *compact* may regulate surface and/or groundwater flows. These legal instruments across the U.S. portion of the RGB Basin regulate surface water and provide a framework to manage problems resulting from stakeholder interdependencies [3] (p. 88).

The RGB legal framework is composed of two federated states' compacts (the Rio Grande Compact (RGC) and the Pecos River Compact (PRC)), and two binational agreements (the 1906 Convention, and the 1944 Water Treaty), which aim to regulate, control, and manage water resources allocation among the signatories. Figure 2 provides a view on the legal instruments regulating water resources in the RGB Basin.

Rio Grande Compact (RGC)
Scale: RGB riparian U.S. states: Colorado, NM, and Texas.
Jurisdiction: Waters of the Rio Grande above Fort Quitman, TX.
Dominant content: Removing all causes of present and future controversy, promotes interstate comity, and effecting an equitable apportionment of waters of the Rio Grande.

Convention of 1906
Scale: Binational.
Jurisdiction: The international reach of the river between the El Paso/Ciudad Juarez Valley, and Fort Quitman, Texas.
Dominant content: Providing for the equitable distribution of the waters of the Rio Grande for irrigation purposes, and removing all causes of controversy between the U.S. and Mexico.



Pecos River Compact (PRC)
Scale: PR riparian U.S. states: NM and Texas.
Jurisdiction: All of the contributing drainage area of the PR and its tributaries above its mouth near Langtry, Texas.
he Pecos Dominant content: Providing for the equitable division and apportionment of the use of the waters of the Pecos River, promoting interstate comity, removing causes of present and future controversies, making secure and protect present development within the states, and facilitating the construction of works for the salvage of water, the more efficient use of water, and the protection of life and property from floods.

1944 Water Treaty
Scale: Binational.
Jurisdiction: Waters of the CR and the TR, and of the Rio Grande (Rio Bravo) from Fort Quitman, Texas, to the Gulf of Mexico.
Dominant content: Fixing and delimiting the rights of the two countries with respect to the waters of the Colorado and Tijuana Rivers, and of the Rio Grande (Rio Bravo) from Fort Quitman, Texas, United States of America, to the Gulf of Mexico, and obtaining the most complete and satisfactory utilization.

Figure 2. Mapping the legal instruments regulating water resources in the RGB Basin [30]. Edited by the first author with information from [31–34].

Each of these legal instruments is discussed here in chronological sequence. The Convention between the United States and Mexico providing for the equitable distribution of the waters of the Rio Grande for irrigation purposes (the 1906 Convention) is an international legal instrument which defines the amount of water to be delivered by the U.S. to Mexico for the primary purpose of irrigation [31]. The 1906 Convention envisions the distribution of surface waters of the RGB basin, within the international segment of the river located between El Paso, Ciudad Juarez and Fort Quitman [3]. The U.S. must deliver a total of 60,000 acre-feet/year (74 million m^3/year) to Mexico at the diversion point called Acequia Madre, located close to Ciudad Juarez, Mexico. However, in case of drought, the amount of 60,000 acre-feet/year can be proportionally reduced according to the specific conditions.

The second instrument is the *Rio Grande Compact (RGC)* [32]. Signed in 1929 and revised in 1939, the Compact provides for the equitable interstate apportionment [35] of the Rio Grande waters—at a level intended to protect water use as it existed from 1928 to 1937—between the U.S. states of Colorado, New Mexico and Texas [36]. The RGC allocates water among the three states after the Mexican 1906 allocation is satisfied. It permits an average normal release from Elephant Butte Reservoir of 790,000 acre-feet/year (974 million m^3/year) for use on lands in New Mexico downstream of Elephant Butte Reservoir and on lands in Texas and to comply with the obligations of the 1906 Convention [37]. This release is primarily for irrigation purposes [38]. The RGC provides for debts and credits to be carried over from year to year until relinquished under the provisions of this agreement for the U.S. states [3] (p. 89).

The third instrument is the Treaty between the United States of America and the United Mexican States relating to the utilization of the waters of the Colorado and Tijuana Rivers, and of the Rio Grande (Rio Bravo) known widely as the 1944 Water Treaty [39]. Signed in 1944, and ratified by each country in 1945, the 1944 Treaty aims "to obtain the most complete and satisfactory utilization of shared waters" [33] based on the equitable distribution between the two countries of the waters of shared river systems. The 1944 Treaty establishes RGB water allocations for the U.S. and Mexico and joint use of its international waters. The Treaty also authorized the construction and operation of two reservoirs, Amistad and Falcon, along the mainstem of the RGB. The Treaty allocates one-third of the water reaching the RGB mainstem from 6 tributaries originating in Mexico to the U.S. and two-thirds to Mexico. The U.S. third shall not be less than 350,000 acre-feet/year (432 million m^3/year), calculated as an average over a treaty cycle of five consecutive years [33]. Under the 1944 Treaty, the International Boundary Commission (IBC), established in 1889 to rectify and maintain the riparian boundary of the Rio Grande and Colorado Rivers [40], became the International Boundary Water Commission (IBWC, hereinafter called the Commission), with specific mandates on shared water resources [41] (pp. 72–75). The Treaty establishes the Commission's authority as an international body and endows it with considerable flexibility in addressing extant and emerging issues through the Minute procedure [33]. The Treaty specifies that if "there are provisions in this Treaty for joint action or joint agreement by the two Governments [. . .] the particular matter in question shall be handled by or through the Department of State of the U.S. and the Ministry of Foreign Relations of Mexico" [33] using the Minute process (presented in Section 2.3) and taking advantage of its role in supporting continuing and emerging issues not explicitly included in the Treaty. This provides for a project or action in the Treaty to be carried out through the foreign ministries—in effect the IBWC—and not some other agency pertaining to the governments.

Finally, the water of the Pecos River, the largest U.S. tributary of the RGB, is allocated between New Mexico and Texas through the *Pecos River Compact* (PRC) signed in 1948 [3]. Its purpose is to promote inter-state collaboration and remove the causes of current and future water resources controversies. Both the RGC and the PRC aim to promote development within the U.S. states and facilitate the construction of infrastructure for the recovery of water, its effective use, and protection against floods [34].

It is important to note that the scope and the jurisdiction of the two binational instruments between the U.S. and Mexico, the 1906 Convention and the 1944 Treaty, do not overlap. This is a relevant aspect, which ensures the accurate implementation of both treaties without conflicts of law. However, as opposed to the 1906 convention that solely addresses water quantity, the 1944 Treaty also addresses transboundary water sanitation problems.

A common feature of the aforementioned agreements is their failure to address environmental objectives associated with joint management of surface and groundwater, and yet this water governance framework has the potential to address inappropriate or uncontrolled water uses, conflicts among water users, and damages to the environment if both countries choose to adapt the treaties and compacts to better address current river basin challenges.

2.3. Enhancing the RGB Water Governance Framework

Legal and binational opportunities exist to adapt the RGB allocation framework and to integrate stakeholders' interests and preferences in decision-making. Principal among these opportunities is the 1944 Water Treaty's provision for treaty development through the IBWC's Minute procedure.

2.3.1. The Minute Process

The Commission, entrusted with interpreting and applying the suite of boundary and water treaties extant between the two countries, is empowered to reach subsidiary agreements, known as Minutes, that take the form of extensions or extrapolations of the various agreements to which the countries are a party. A Minute technically represents "the written record of meetings, particularly of [. . .] Stakeholders [. . .]" [42]. As such, Minutes are extensions and applications of the treaties and offer the potential for adapting the U.S.-Mexico Water Allocation Framework to changing circumstances. [43]. Under common treaty law, an amendment is a new treaty, and requires ratification [44]. However, Article 25 of the 1944 Treaty provides for this flexible procedure that allows the two countries to adapt their boundary and water treaties to new circumstances [45].

In all, 320 min have been agreed between the U.S. and Mexico subsequent to the signature of the Convention of 1889 (establishing the International Boundary Commission, IBC) and the Convention of 1906 [46]. Of these, 140 have been signed since the 1944 Water Treaty entered into force in November 1945. Of these 140, a total of 71 min concern the RGB Basin.

2.3.2. Practicing the Minute Process

The examples below describe key U.S. and Mexico initiatives to address shared waters challenges through the binational *Minute Process* which enables Treaty adaptation without changing its command structure [41] (pp. 70–98).

2.3.3. Example 1: The Colorado River Salinity Crisis

The Colorado River Salinity Crisis is an example of a treaty dispute that was peacefully and equitably resolved in the interest of both countries (Figure 3). The Treaty says nothing directly about the quality of the water delivered under the Treaty. In the early 1960s, the Colorado River's salinity levels rose dramatically and consequently, the water that Mexico received from the U.S. was not usable for drinking or irrigation [41]. In 1973, after agreeing on recommendations to improve the quality of CR waters going to Mexico, the IBWC recorded Minute 242, which provides a permanent and definitive solution to the CR's international salinity problem.

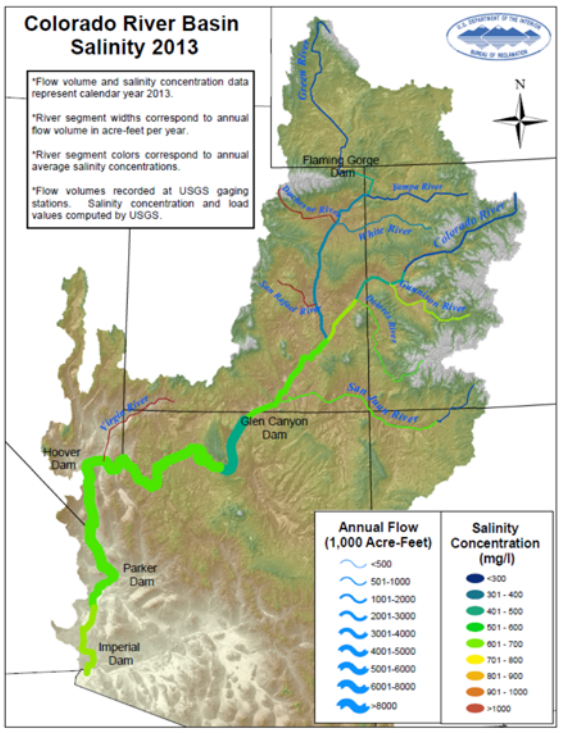


Figure 3. Colorado River Basin Salinity, 2013 [47]. Reproduced with permission from the U.S. Bureau of Reclamation (U.S. BOR).

Minute 242 requires the U.S. to adopt measures to assure that approximately 1,360,000 acre-feet (1.6 million m^3) delivered to Mexico upstream of Morelos Dam, have an annual average salinity of no more than 115 p.p.m. $\pm$ 30 p.p.m. U.S. count (121 p.p.m. $\pm$ 30 p.p.m. Mexican count) over the annual average salinity of CR waters which arrive at Imperial Dam. Minute 242 limits groundwater pumping in each nation's territory within 8 km of the Arizona-Sonora boundary near San Luis to 197.4 million m^3 annually and allows for talks on a comprehensive groundwater treaty. It also stipulates that both countries will consult with each other prior to undertaking any new development on surface or groundwater resources [48]. In a nutshell, Minute 242 centers attention on the need to develop a comprehensive transboundary solution to the emerging groundwater disputes along the border. Four other Minutes also relate to the CR Salinity issue (Minute 218, 241, 248, and 284).

2.3.4. Example 2: Salinity in the Lower Rio Grande

The RGB salinity problem arose from repeated breakdowns of the waterworks associated with the saline water disposal system for controlling the salinity of the LRG. Minutes 223 and 224 identified both U.S. and Mexican causes of the increased Rio Grande salinity [41]. Minute 223 from 1965 acknowledges that the increased levels of salinity of the waters of the LRG should be corrected in order that the waters can be satisfactorily used for domestic and municipal uses and for irrigation. Minute 224 from 1967 demonstrates that the solution to this binational problem required consulting with appropriate U.S. and Mexico agencies in order to make more detailed studies of the costs and benefits of the necessary works for discharging highly saline El Morillo Drain waters to the Gulf of Mexico [49,50].

Over the next 21 years, the canal that carried saline waters to the Gulf of Mexico deteriorated and became heavily silted [41]. Minute 282, from 1990, addressed the need to rehabilitate the saline waters disposal system for solution of the salinity problem in the waters of the LRG. In 2000, Minute 303 called for an annual work plan to ensure operations and maintenance of the joint works for solution of the salinity problem in the LRG [51,52].

2.3.5. Example 3: Border Sanitation

Article 3 of the Treaty requires that the U.S. and Mexico give preferential attention to the solution of all border sanitation problems [33]. The U.S. and Mexico have been working on sanitation issues since 1958. Minute 206 is the first binational agreement to jointly work for the Nogales International Sanitation Project [53]. Since then, fifteen more minutes have addressed the same issue (Minute 216, 220, 222, 227, 240, 261, 264, 270, 273, 274, 276, 279, 283, 288, and 289). The most recent is Minute 299 from 1998. In this agreement, both countries express their support for the Border Environment Cooperation Commission (BECC) as an institutional partner in the development of projects addressing border sanitation problems. Their support is justified since the BECC supports states and localities and other public entities and private investors in technical aspects of the development of border environmental infrastructure [54].

2.3.6. Example 4: Recent Binational Agreements on Water Scarcity in the Colorado River Basin and Environmental Management in the Tijuana River Basin

Three Minutes have been recorded in order to strengthen cooperation and enhance basin water management in the CR Basin. Minute 319, from 2012, refers to the interest of both countries for identifying cooperative opportunities, through coordinated binational work groups, to ensure that the CR system would continue to meet the needs of both nations. Cooperative opportunities concern the development of projects to minimize the impacts of potential CR shortage conditions; generate additional volumes of water using new water sources; conserve water through investments in agriculture and other uses; and envision the possibility for Mexico to use U.S. infrastructure to store water [55]. This Minute covers the activities and projects that have been included in the Minutes 318 and 317.

Minute 320 from 2015, based on Articles 3, 16 and 24 of the 1944 Treaty, aims to establish a framework for binational cooperation on transboundary issues in the Tijuana River Basin. Minute 320 highlights the important joint role played by binational governmental and non-governmental organizations in identifying joint cooperative opportunities on transboundary issues that could benefit both sides of the border [56]. This Minute engages stakeholder participation by the creation of binational multi-stakeholder groups responsible for the development of cooperative actions to address use of surface and groundwater, environmental protection and restoration, and comprehensive and sustainable basin management.

2.4. Binational Ability to Achieve Solutions

The salinity crisis on both the CR and the LRG, as well as border sanitation, environmental protection and restoration, and comprehensive and sustainable basin management are examples of the effectiveness of the *Minute Process* in addressing pressing binational issues. We could say that the 1944 Water Treaty is imperfect owing to its failure to address shared water environmental and sustainable issues; however, the *Minute Process* emphasizes the larger space for both countries to solve issues that were not identified back in the forties, but have manifested over time. In this sense, the *Minute Process* provides a mechanism by which the U.S.–Mexico Water Framework may adapt to emerging needs by means of the IBWC's "rule-making power" [41] (p. 77). The Commission's *Minute Process* enables both governments to establish a common interpretation on the treaty's application to problems where its provisions may be "silent or vague" [41]. In other words, the *Minute Process* builds flexibility into the 1944 Treaty for addressing changing circumstances and supports continuing and emerging issues not explicitly included in the Treaty.

3. Methods

This research employs an interdisciplinary and qualitative approach to problem identification and analysis. Our qualitative approach is composed of various methodological tools, including detailed case-study analysis, collection of documents, and iterative field work and semi-structured interviews.

The 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" [57]. Research on a particular case is highly related to a general principle based on a set of concepts and related facts. In other words, it is by means of an inductive approach that we achieve understanding of a case study from field data collection.

Collection of documents is the most used information-gathering instrument in political science. Employing this technique, the authors have consulted various categories of documents [58] (pp. 90–91) to improve our understanding on transboundary water allocation issues between the U.S. and Mexico. In a qualitative analysis methodology, documentary information sources and literature review are used to define the theoretical context of the research object and the general picture of the problem.

Iterative field work and semi-structured interviews were performed by the first author of the manuscript. Two rounds of field work have been conducted in the RGB area:

(a) The first round is composed of a total of five visits to the field related to our research on governance and sustainable development across the RGB basin [30]. The purposes of the first three visits were to conduct empirical observation of the ground conditions and documentary research, and to participate in water related meetings. A total of 54 interviews were conducted across the RGB during the last two visits (from October 2011 to February 2012) of this first round of field work [30]. Partial key findings and perspectives from stakeholders on water management and governance, and sustainable development can be found in some of our publications [3,30,59–61].

(b) The second round of field work relates to the interviews conducted in the Paso del Norte region to gain information on water resources management and sustainable practices. On this occasion, a total of 23 interviews were conducted between October–November 2015.

In both cases, and taking into account the location of the respondents, interviews were conducted on the basis of their availability, in places that respondents preferred, either their workplace or a public place. In situations where travel was difficult, we conducted interviews by telephone, skype-calls, and electronic mail. Telephone, skype-calls, and face-to-face interviews were recorded with a digital recorder, and transcribed with Nvivo9 and Nvivo10 software. We used NVivo 10 software to analyze and classify the data.

The participation of experts in the interviews was limited to one and a half hours. Key actors in our sample are involved in different sectors: academic, research, water management, irrigation, hydraulic infrastructure, policy and administration, citizen empowerment and natural resources conservation. Above all, they are affiliated with representative organizations addressing a specific problem in the field of water resource management in the RGB Basin. For ethical reasons, we ensure the confidentiality of the interviewees. More specific details on the stakeholders' profile and interview process are provided in the Appendix A (Tables A1–A5).

In short, iterative field work has been conducted to identify a problem and obtain data in order to enable the construction and the development of knowledge from the data acquired in the field. As regards to the interviews, those translate into the dynamic side of the qualitative research as the researcher facilitates the proper expression of the respondent to better capture the way in which they perceive and understand the data that are of research interest [30]. The descriptive, analytical and interpretative aspects of the qualitative methodology derive from the importance of the interview since one "has access to information, that is not found anywhere else, from people that have witnessed events related to the research project" [58] (p. 91). Qualitative data were analyzed using an inductive content analysis approach to better identify the interviewees' perceptions and interests. Content analysis is widely used by political scientists to analyze qualitative data, and aims to describe and interpret in a systematic way the manifested content of the communications with the experts, and to inform, as in our case, subsequent policy recommendations [30].

4. Results

In this section, we elaborate on the potential to capitalise on the binational water allocation framework strengths for enhancing water resources management in the RGB Basin. We argue that the current framework keeps the door open to accommodate a wide range of opportunities for advancing the RGB treaty framework and articulating the interests of stakeholders and water management agencies.

4.1. Fostering Adaptation of the RGB Basin Water Allocation Framework

The purpose of this section is to explore:

(1) The two notions found in the 1944 Water Treaty

   a Feasible use, and
   b Feasible projects.

(2) Further potential for enhanced institutional reach

The Water Treaty provides an *order of preference* for the joint use of international waters. Domestic and municipal uses, and agriculture and stock raising are the preferred water uses, while "any other beneficial uses" are the last in the list of preferred uses [33] (Art. 3). This last category of preferred uses seems to be based on the legal definition which considers the notion of *beneficial use* [62] as the "right to utilize real property, [. . .], and access to it, in any lawful manner to gain a profit, advantage, or enjoyment from it" [63]. In this regard, the Treaty specifies that any other beneficial uses "shall be subject to any sanitary measures or works" [33] (Art. 3). However, this clause doesn't prevent the parties from using water for other beneficial uses such as ecological restoration and conservation. With sufficient political commitment to this core value, the notion of *beneficial use* could potentially expand the RGB waters uses.

4.2. The Concept of Feasible Use as an Institutional Mechanism for Enhancing Water Resources Management in the RGB Basin

To elaborate on the potential for enhanced institutional reach, we need to respond to this question: What would happen if the Commission should be called upon to make provision for *feasible use* of the RGB waters? The notion of *feasible use* may be defined as something that can be done and or successfully dealt with. The term *feasible* is ambiguous and its lack of definition in the 1944 Treaty means its interpretation is largely predicated on the context in which the treaty was accepted and ratified by the parties. In this case, the study of "[t]he 1944 Treaty provides that the jurisdiction of the IBWC extends to the limitrophe parts of the Rio Grande and the Colorado River, the land boundary between the U.S. and Mexico and to works located upon the border" [64]. This establishes the IBWC's authority to determine the feasibility of any project in its jurisdiction. In addition, the contemporary analysis of this term is influenced by the principles of international water law. For any project to be feasible in a transboundary basin, it must be developed in cooperation among the parties, in an equitable and reasonable manner, and taking "all appropriate measures to prevent the causing of significant harm to other watercourse State" [65]. In this case, the principle of cooperation includes notification [66,67] and regular exchange of data and information among riparian countries in order to guarantee the feasibility of a project or use [68].

Article 16 of the 1944 Treaty addressing the management and allocation of Tijuana River water establishes that "in order to improve existing uses and to assure any feasible further development, the Commission [. . .] shall submit to the two Governments [. . .] plans for storage and flood control to promote and develop [. . .] other feasible uses of the waters of this system" [33] (Art. 16). This language is potentially useful in a broader treaty context since the notions of *feasible use* and *feasible project*, though presently specific to the Tijuana River, open a door to the consideration of any *feasible* border project the

two countries, through the Commission, believed to be a mutual and beneficial use within the scope of Art. 3. Art. 3, intended to foster the joint use of international waters, offers an array of opportunities to explore any other waters beneficial uses. Moreover, Art. 24 specifies the Commission as the agency entitled to "settle all differences that may arise between the two Governments with respect to the interpretation or application of this Treaty, subject to the approval of the two Governments" [33]. But what does all this mean? Articles 3 and 24 accommodate the ideas of *feasible uses* and *projects*, and *beneficial uses of water* to be potentially adapted to current needs related to the RGB. The only real constraints on the utilization of this authority are domestic considerations and the political will of the national parties acting under the authority of the Treaty. In the following section, we elaborate on the potential of stakeholders involvement for going through domestic considerations and building political will.

4.3. Enabling Adaptation trough Stakeholders' Insights

All those interviewed in this assessment agreed on the importance of enhanced water resources management to deal with vulnerability in an arid context. Stakeholders' insights have been systematized in six solutions-options reflecting their main visions to solve common problems and foster adaptation in the RGB.

First, interviewees argued that water is a vital resource needed for survival when living in a desert, but its availability hinders its equitable distribution among all users, making environmental sustainability even more challenging. Stakeholders believe that if the river goes dry, it is because all the water in the basin belongs to somebody and is being allocated to someone, but not the environment. They recognized that the environment needs more water, but noted that the current distribution of water in the context of climate change means providing for ecosystems needs is not that simple. Interviewees agreed sustained drought has been the most pressing issue impacting water availability in the river basin and water allocation among uses. Insufficient rain and loss of winter snowpack are identified as key factors affecting water supply within the RGB. On the water quality front, interviewees identified salinity, residual pharmaceuticals in wastewater, high bacterial levels, lack of green corridors, and loss of biodiversity as the most pressing water quality and ecosystem issues. In this context, they pose the question as to whether a new water use, and an adapted allocation system may or may not be sustainable in the RGB Basin.

Second, interviewees viewed the RGB Basin as highly managed, highly developed, and over appropriated. Development of water infrastructures and management of water resources have completely changed the hydrological dynamics. Clear examples are the very different rivers above and below EB dam; above the dam, the Middle Rio Grande is still gorgeous, while downstream from EBD, the river is nothing but a modified channel. For them, if the river goes dry it is because of this system of impoundments. Despite this situation, some stakeholders believe that there are not enough reservoirs in the river basin to store water and cope with the quantity issues mentioned above. At the same time, stakeholders highlight the large stock of technical capacities available at the basin scale to solve issues.

Third, those interviewed do not agree on what would constitute sustainable development across the basin, or how sustainability should be promoted on a basin-wide scale [30] (pp. 60–68). Some stakeholders found it difficult to talk about this notion and to consider how to make it operational in the field. Some others avoid using this notion because it is very ambiguous and doesn't have a fixed definition. In fact, they claim that the river basin is so big that it requires separate specific actions to solve one-off problems [30]. That said, these interviewees preferred to focus on a very precise issue in a specific region, e.g., preventing long term declining ground water levels and modifying agricultural production in the New Mexico portion of the LRG. Unsurprisingly, these participants thought that growing cotton and alfalfa and pecans in the RGB is not ecologically-based because of the high consumption of water of these crops. However, drought and over use of groundwater are considered the two major issues defying sustainability in the river basin. Therefore, stakeholder-based

sustainable development in the RGB Basin currently implies a set of ad hoc practical approaches to tackle regional and local issues, while joint binational efforts are necessary to provide a systematic answer to the challenges at the scale of the whole river basin.

Fourth, interviewees placed great weight on the 1944 Water Treaty. The Treaty is generally recognized as an effective instrument for allocating water resources between the U.S. and Mexico and solving binational water-related issues. However, some participants believe it does not apply to any sustainability or environmental concern, maybe because the notion of sustainable development did not exist when water allocation was defined between these two countries. Some others argue that the general level of understanding of water resources is intermediate, and filling these important gaps and uncertainties in knowledge is needed for effective management. Moreover, interviewees pointed out that political will to revisit the 1944 Treaty is non-existent. According to them, the U.S. is not interested in exploring this, and Mexico has never requested to make any changes. In parallel, immigration, drug tracking, and border security have now become interconnected issues that prevent both countries from expanding the binational agreement on water resources allocation to some other areas. In this regard and based on stakeholders views, binational gains in trust, derived from the 1944 Water Treaty, have been very small in the RGB despite the legal opportunities given to move forward on environmental concerns management and water allocation adaptation.

Fifth, and based on findings of our second round of field work, great emphasis is placed on the need to: (a) strengthen communication and articulation among all of stakeholders and related water agencies; (b) provide environmental education; (c) manage surface and groundwater jointly; and (d) renegotiate all water agreements due to imbalances between water supply and demand. In order to achieve these goals, they highlight the challenges and the opportunities related to living in an arid area and desert landscape. The challenges are related to the given environmental conditions. Water in a desert environment is not an abundant available resource. What is abundant is the determination and the capacities that plants, animals, and people living here have deployed to adapt and survive. Development of unique customs, procedures, and technologies has been central in addressing difficulties in this region. Together, they constitute a set of potential opportunities.

Sixth, findings from our second round of field work indicate that the *Minute process* is considered as an existing platform and potential instrument for framing stakeholders' concerns and addressing water quantity and quality issues. A member of the U.S.-Section of the Commission indicates that a Minute is the result of top-down and bottom-up decisions approved by the two governments through the Commission. This respondent highlights that the *Minute process* is a challenging dynamic that could last many months, or years. However, each *Minute* is a unique agreement based on the identification of a problem or a need along the U.S.-Mexico border that is within the authorities of the IBWC. To create a *Minute*, the Commission has to engage in a binational dialogue in order to collaborate in technical or engineering studies, or reviews about the problem or the need. Based on those technical studies or reviews, the Commission elaborates a series of recommendations. The Commission then drafts the recommendation in a *Minute* format. Engineering and diplomatic staffs of the Commission play an important role in the conception of the *Minute*, as they initiate the consulting process with key stakeholders involved in the recommendations that will be proposed. Finally, *Minute* drafts are sent back and forth in English and Spanish to the U.S. and Mexican sections of the Commission after being informed by key stakeholders' comments, and agreed by the parties. The *Minute* is then submitted for approval to the U.S. Department of State and the Mexican Ministry of Foreign Relations. Once the *Minute* is approved, it becomes a binding agreement in the two countries.

5. Discussion

Moving forward on a new RGB Basin institutional arrangement requires stakeholder inclusiveness and binational commitment to advance cooperation through the existing regulatory framework and related institutions, and the creation of new formal platforms for engagement. In this regard, and

before the elaboration of comprehensive policy recommendations, we would like to address the research questions that have driven this manuscript.

First, the current binational water allocation framework for the RGB lacks sufficient initiatives aimed at adapting to meet current and future human and environmental needs; a situation made more acute during shortages. The RGB has to be managed taking into account the inherent conditions of the area, and the changing environment as impacted by present water uses. Water users maximize their allotment, and in doing so, do not provide for the potential use of water for environmental flows. This is due to the perception that water for the environment is not consumed, does not return to its source of supply, and only benefits users like boating, fishing, and hydropower generation sectors that make no consumptive use of the resource [33] (p. 4). If viewed from a more holistic perspective, this is an upstream-downstream cause-and-effect relationship implying that any upstream user rewatering the river will suffer a direct loss of income, while downstream users will benefit. In this case, environmental water uses can be seen as segments of the hydrologic cycle of benefit to downstream users. The question then becomes how to manage for an equitable distribution of benefits across space and sectors, and between upstream and downstream users in different jurisdictions. In this context, it has to be emphasized that there are parts of the basin where environmental restoration is hydrologically [16,17] and economically [18] possible, where the political will to advance environmental values exists, but the policy window that would allow such reform has not been open sufficiently long for reforms to mature as seen in the CR and TR [69].

Second, the U.S.-Mexico water allocation framework can be adapted to balance social and environmental water demands by means of comprehensive water resources management. To support and preserve the RGB Basin ecosystem, its water allocation framework could be adapted if drought events and groundwater challenges are jointly addressed by both Governments and a group of stakeholders. On the one hand, drought projections suggest that at the end of the century, Mexico will experience extreme drought and the U.S. will also experience some severe droughts. Droughts similar in extent to the *Dust Bowl* are very likely to occur [70]. On the other hand, groundwater along the U.S. and Mexico border is both scarce and essential. However, no legal binational agreement addresses allocation of these resources [71]. The challenge related to groundwater is to develop studies on its recharge, watershed mapping, and aquifer formations [72] (pp. 147–157), and on equitable apportionment of shared aquifers [73]. Provided the Transboundary Aquifer Assessment Act is extended beyond 2016, much potential exists for enhanced management of groundwater resources under the terms of the 2006 U.S. Congress bill to foster a better understanding on the U.S.-Mexico transboundary aquifers [74].

Third, the main opportunities to be explored for expanding the U.S.-Mexico water resources allocation framework are related to the *Minute process* and the greater involvement of the river's stakeholders. Up until now, the only formal and binational venue for political dialogue between the U.S. and Mexico on transboundary water issues is represented by the Commission. As has already be recognized in Minute 308 [75], there is presently a vital need for a multi-stakeholder advisory body to the Commission that can both support a binational dialogue on the sustainable development of the river and assist the Commission in developing science-based assessments and policy recommendations. Stakeholders' involvement matters because, as seen in the previous section, it generates ownership, responsibility, and engagement. Stakeholders play a key role in the process leading up to the adoption of new arrangements. Moving forward, there is a need to ensure that they continue to be engaged in both the implementation and monitoring of the water management agenda. Stakeholders' involvement enhances the chances of success of any binational-solving problem effort.

Despite the socio-political challenges along the border, the binational water allocation framework is capable of improvement. Pressing water quantity and quality issues, as well as ecosystem concerns need to be addressed jointly. Making use of all the appropriate capacities and working with stakeholders to strengthen cooperation on sharing the RGB's waters will help build political will among the U.S. and Mexico. Together, formal and binational institutions and arrangements are needed

to achieve change. Stakeholder involvement and interdisciplinary research on water resources are essential to this purpose.

6. Policy Recommendations

Bearing in mind the aforementioned conclusions, two main arguments guide our policy recommendations for advancing policy adaptation within the RGB Basin: (1) The 1944 Water Treaty is subject to interpretation and application; and (2) the *Minute Process* is the binational mechanism allowing flexibility to the Treaty by enabling a common interpretation on a boundary issue. Noting the successes in the CR and the TR from ad hoc approaches to specific issues, we draft here four ad hoc policy recommendations directly informed by stakeholders' insights; however, further discussion on these recommendations will be continued in another paper.

First, the distribution of water in the context of sustained drought can be mitigated by a mechanism allowing the movement of water from one use to another on a temporary-reciprocity basis. Moving water from one use to another as well as an ad hoc sustainable water management plan taking into consideration population growth, economic and hydraulic developments, and water availability in a sustained drought context, could help to accomplish long-term benefits of conserving water quality and, more importantly, equitable water distribution for current and prospective water uses [76] (p. 6). Equitable water distribution for environmental purposes suggests that "wherever possible, the various water uses be compared by the benefit each use produces". One procedure for measuring benefits and costs reflects the idea that the benefit from making an increment of water available for a particular use is measured by society's willingness to pay for the additional allocation of water. [However], it is unreasonable to believe that transboundary water between the U.S. and Mexico will ever be allocated without controversy based on a nominal price. In fact, no society has ever implemented in practice within its borders the principle of "optimal allocation" of water using one explicit operational objective. Therefore, the term [equitable] distribution of water implies "*whatever system a society accepts as a principle for allocating water*" [76] (p. 20) over a period of time, or during times of drought and water abundance.

Second, despite high hydrological development in the RGB, there is a considerable potential of existing technical human resources to solve water quantity and quality issues in the basin. How to fully exploit this potential? Communication and collaboration—inter and intra agencies—can be broadened through proactive dissemination of the results and achievements of each agency to catalyze further interest across the basin, its jurisdictions, the myriad of agencies, and the multitude of water users. This should be a cross-cutting responsibility of each of the water related agencies in the RGB Basin to bridge activities and responsiveness articulation gaps. Regular communication and intermediary milestones events between agencies and those responsible are paramount for building agency/responsible engagement and assisting in the satisfactory resolution of punctual issues.

Third, there is no agreement on what sustainable development means at the basin scale. In this case, we recommend to put in practice sustainable solutions to solve punctual issues in a specific area. For this purpose, it is crucial to forge common understandings on key issues that require formulating and implementing ad hoc strategies. Local and/or regional stakeholders can assist water related agencies by facilitating the identification of issues and providing practical solutions insights. Sustainable initiatives based on "combining the exploitation of resources with the protection of the environment without compromising the ability of future generations to meet their own needs" [76] (p. 9), must be sensitive to and serve the specific context, and interested and affected stakeholders must be involved in the coframing of these initiatives. Engagement, communication, and collaboration are of particular importance to tackle regional and local issues, especially in situations where there is a broad range of problems to solve but none of them can be considered more important than the other. In this case, an ad hoc sustainable development strategy responds to a specific context, constraints, desired goals and effects. It will certainly differ across the river basin and between stakeholders.

Fourth, the 1944 Water Treaty is the cornerstone for managing shared waters crossing the U.S.-Mexico border. Its importance is due to fixing the distribution of water resources and establishing the *Minute process* as the binational mechanism allowing for flexibility to address new circumstances. New circumstances can be then addressed through the *Minute process* which means that the Treaty itself is updated to meet current needs and emerging issues on an ad hoc basis. Related to water distribution system in the context of sustained drought, high hydrological development, and unconsented sustainable development, all water agreements, but specially the 1944 Water Treaty, can be amended if the involved parties agree, for example, on reallocating water from one use to another on a temporary-reciprocity basis as mentioned above, and ensuring that "all stakeholders have a channel to express their preferences" [76] (p. 14) and willingness to move forward.

Continuing this line of thought but from a more comprehensive approach, we further urge the Commission to make provision for *feasibility reforms* and specifying *beneficial uses* of international waters for ecological purposes in order to enhance RGB Basin sustainability. The U.S. and Mexico should recognize that allocating water for environmental flows is of binational interest. This is an essential precondition for developing environmental protection and restoration projects along the RGB, and one that can be achieved through the *Minute Process*.

Practicing the *Minute Process*, we suggest that the Commission study, investigate, and evaluate the potential of water flows required to maintain the components, functions, processes, and resilience of aquatic ecosystems which provide goods and services to people [77]. Then, we suggest that the Commission submit to the two governments for their approval recommendations to improve the RGB flows and storage for the environment and irrigation purposes taking into consideration water availability, water ecosystem needs, floodplains and wetlands management, and balanced use of groundwater. The creation of an exploratory *Task Force* or an inclusive process to obtain recommendations from stakeholders, such as in the Tijuana River Basin, the Lower Colorado River, and the Colorado River Delta (Minutes 317–320), is crucial.

In this case, we propose that the *RGB Basin Task Force* (1) take into consideration the valuable stakeholders insights presented here; (2) consider the prospects for establishing the International Advisory Council to address the potentiality of environmental flows for water quality, ecological preservation, and sustainable practices across the river basin; and (3) explore sustainable water use and allocation by creating a mechanism for collaboratively working and funding sustainable water preservation and conservation issues. We further suggest that the successful efforts to advance this type of advisory mechanism in the Tijuana and Colorado Basins should inform the IBWC's effort to develop similar advisory bodies and sustainability mechanisms for the RGB.

Importantly, there is nothing in the 1944 Water Treaty that would appear to prevent execution of this recommendation. There are challenges between the current RGB Basin management and the regulatory binational water allocation framework, and much can be done with communication, institutional structure, inclusiveness and participation of all stakeholders. Minute 308 from 2002, based on cooperation on drought management, sustainable management of the basin, and the adoption of an International Advisory Council, represents the first stone of this project and a declaration of good intentions towards the RGB sustainability [75]. Hence, the binational *Minute Process* highlights the potential to move forward with an ad hoc institutional arrangement and materializes the key instrument for framing our recommendations. Stakeholders are therefore called upon to coordinate their actions with the aim of dealing with challenges posed by water uses and the preservation of the environment in the RGB.

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Author Contributions: Luzma Fabiola Nava wrote the paper, contributed to the geographical discussion of the case study, the political analysis of water distribution legal instruments, the legal and institutional analysis of the water distribution framework between the U.S. and Mexico, reviewed the background on transboundary water resources between the U.S. and Mexico, the policies recommendations design, and coordinated the scoping document. Christopher Brown contributed to the geographical discussion of the case study, the political analysis of water distribution legal instruments, and discussed the paper with respect to its improvement. Katalin Demeter contributed to the analysis of qualitative data, commented on the scoping document, made suggestions for its improvement, and played an important part in revising the manuscript according to the reviewers' comments. Frédéric Lasserre contributed to the geographical discussion of the case study, the political analysis of water distribution legal instruments, and discussed the paper with respect to its improvement. Maria Milanés-Murcia contributed with the legal and institutional analysis of the water distribution framework between the U.S. and Mexico, commented on the scoping document, and made suggestions for its improvement. Stephen Mumme contributed to the geographical discussion of the case study, the political analysis of water distribution legal instruments, the legal and institutional analysis of the water distribution framework between the U.S. and Mexico, the policies recommendation design, and played an important role in addressing the scope of the document. Samuel Sandoval-Solis contributed to the analysis of quantitative data, the institutional analysis of the water distribution framework between the U.S. and Mexico, and commented on the scoping document and made suggestions for its improvement.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

BECC	Border Environment Cooperation Commission
CONAGUA	Comisión Nacional del Agua
CONAPO	Consejo Nacional de Población
CR	Colorado River
CRC	Colorado River Compact
EB	Elephant Butte
EDF	Environmental Defense Fund
IBC	International Boundary Commission
IBWC	International Boundary Water Commission
LRG	Lower Rio Grande
MX	Mexico
NM	New Mexico
NMOSEL	New Mexico Office of the State Engineer
NMWRRI	New Mexico Water Resources Research Institute
PR	Pecos River
PRC	Pecos River Compact
RGB	Rio Grande/Bravo
RGC	Rio Grande Compact
TCEQ	Texas Commission on Environmental Quality
TR	Tijuana River
U.S.	United States
USBOR	U.S. Bureau of Reclamation
USCB	U.S. Census Bureau
USIBWC	U.S. International Boundary Water Commission
WB	World Bank
WWF	World Wildlife Fund

Appendix

Specific details of the interview process.

Table A1. Distribution of the interviews and the way they were conducted.

Where	Interviews by Telephone and Electronic Mail	Interviews in Person	Total
First round of field work related to governance and sustainable development across the RGB basin			
Rio Grande Basin section	9	31	40
Rio Bravo Basin section	11	3	14
Total	20	34	54
Second round of field work related to water resources management and sustainable practices in the Paso del Norte region			
Paso del Norte Region	10	13	23 *

Notes: Work conducted in the field by the first author; * As of 27 April 2016.

Details on the first round of field work related to governance and sustainable development across the RGB basin.

Table A2. A total of 54 Respondents in the Rio Grande/Rio Bravo Basin sections.

	# of Participants	Affiliation	Scale	Sector *
A total of 40 Respondents in the Rio Grande Basin section	3	U.S. International Boundary & Water Commission (USIBWC)	Binational	WM, HI, PA
	1	U.S. Army Corps of Engineers (USACE)	Federal	WM, HI, PA
	2	U.S. Bureau of Reclamation (USBOR)	Federal	WM, HI, PA
	2	U.S. Environmental Protection Agency (USEPA)	Federal	WM, PA
	1	U.S. Fish & Wildlife Service (USFWS)	Federal	NRC
	3	Local stakeholder, Albuquerque, NM	Local-NM	CE, NRC
	1	Colorado Division of Water Resources Division 3	Regional/Closed Basin	WM, IRR, HI
	1	El Paso del Norte Watershed Council	Regional/LRGB	RE, CE, NRC
	1	Rio Grande International Study Center (RGISC)	Regional/LRGB	CE, NRC
	1	MRGCD Board of Directors Position No. 4, Bernalillo County, Albuquerque, NM	Regional/MRGB	WM, IRR, NRC
	1	Rio Grande Return, Santa Fé, NM	Regional/MRGB	CE, NRC
	1	Santa Fe Watershed Association, Santa Fe, NM	Regional/MRGB	PA, CE, NRC
	1	Rio Grande Advisory Council (RAC)	RGB Basin	RE, CE
	1	Audubon New Mexico, Las Cruces, NM	State-NM	RE, CE
	1	New Mexico State University (NMSU) & El Paso del Norte Watershed Council	State-NM	AC, RE, CE
	1	Middle Rio Grande Endangered Species Collaborative Program, the U.S. Fish and Wildlife Service	State-NM	RE, NRC
	1	New Mexico Department of Agriculture & El Paso del Norte Watershed Council	State-NM	NRC, AC, RE, CE
	1	New Mexico Environment Department	State-NM	NRC, WM, PA
	2	New Mexico Interstate Stream Commission	State-NM	WM, PA, IRR
	3	New Mexico State University (NMSU)	State-NM	AC, RE
	1	New Mexico Office of the State Engineer	State-NM	WM, PA, IRR
	1	The Water-Culture Institute	State-NM	RE, CE
	1	El Paso County Water Improvement District No. 1	State-TX	WM, IRR, HI
	1	Rio Grande Council of Governments , El Paso, TX	State-TX	PA, RE, CE
	1	Texas Commission on Environmental Quality, Austin, TX	State-TX	WM, HI, PA
	2	The University of Texas at Austin	State-TX	AC, RE
	4	University of Texas at El Paso (UTEP)	State-TX	AC, RE
A total of 14 Respondents in the Rio Bravo Basin section	2	MEX—International Boundary & Water Commission	Binational	WM, HI, PA
	2	Instituto Mexicano de Tecnología del Agua (IMTA)	Federal	AC, RE, PA
	1	Comisión Nacional del Agua (CONAGUA)	Federal	WM, IRR, HI, PA, NRC
	1	Dirección del Medio Ambiente y Cambio Climático, Nuevo Laredo	Local-Tamaulipas	WM, PA, CE, NRC
	1	El Colegio de la Frontera Norte	Regional	AC, RE
	1	Organismo de Cuenca Río Bravo, CONAGUA	Regional/Rio Bravo Basin	WM, IRR, CE
	1	Distrito de Riego 009 Valle de Juárez	Regional/Rio Bravo Basin	WM, IRR, HI
	1	Centro Internacional de Estudios del Río Bravo (CIER)	Regional/Rio Bravo Basin	CE, NRC
	1	Universidad Autónoma de Ciudad Juárez (UACJ)	State	AC, RE
	2	Instituto Tecnológico y de Estudios Superiores de Monterrey (ITESM, Centro del Agua para América Latina y el Caribe, Cátedra de Investigación Servicios de la naturaleza: valoración económica y ecológica como factor clave para el desarrollo sostenible)	State	AC, RE
	1	Distritos y Unidades de Riego para el Desarrollo Rural de la Comisión Estatal del Agua de Tamaulipas (CEAT)	State	WM, IRR, HI

Notes: * Legend: Academic (AC); Research (RE); Water management (WM); Irrigation (IRR); Hydraulic infrastructure (HI); Policy and administration (PA); Citizen Empowerment (CE); Natural resources conservation (NRC). Work conducted in the field by the first author [30].

Table A3. Semi-structured interviews. The above list of topics is only indicative.

Nature of the study	The research goal is to study the Governance of the Watershed of the Rio Grande according to the principles of Sustainable Development
Semi-structured interviews related themes	Ecology and environment
	Hydraulic Planning
	Citizen Participation
	Sustainable Development

Note: Work conducted in the field by the first author [31].

Details on the second round of field work related to water resources management and sustainable practices in the Paso del Norte region.

Table A4. A total of 23 Respondents in the Paso del Norte region.

	# of Participants	Affiliation	Scale	Sector *
A total of 23 Respondents in the Paso del Norte Region	3	U.S. International Boundary & Water Commission (USIBWC)	Binational	WM, HI, PA
	1	World Wild Fund for Nature	Binational	CE, NRC
	2	U.S. Bureau of Reclamation (USBOR)	Federal	WM, HI, PA
	1	U.S. Fish & Wildlife Service (USFWS)	Federal	PA, NRC
	3	City of Las Cruces	Municipal	WM, PA, CE, NRC
	1	El Paso del Norte Watershed Council	Regional/LRGB	RE, CE, NRC
	2	The University of Texas at Austin	Regional	AC, RE
	1	The Water-Culture Institute	Regional	PA, CE, NRC
	1	Southwest Environmental Center (SWEC)	Regional-NM	CE, NRC
	1	Dona Ana Mutual Domestic Water Consumers Association	Regional-NM	WM, CE
	1	Hunt Institute	Regional- & TX	RE, PA
	1	The University of California, Davis	Regional	AC, RE
	1	Oklahoma University	Regional	AC, RE
	2	Universidad Autónoma de Ciudad Juárez (UACJ)	Regional	AC, RE
	1	New Mexico State University (NMSU)	State-NM	AC, RE
	1	Dixie Ranch	State-NM	WM, IRR

Notes: * Legend: Academic (AC); Research (RE); Water management (WM); Irrigation (IRR); Hydraulic infrastructure (HI); Policy and administration (PA); Citizen Empowerment (CE); Natural resources conservation (NRC). Work conducted in the field by the first author.

Table A5. Semi-structured interviews. The above list of topics is only indicative.

Nature of the study	To gather information on water resources management and sustainable practices in order to assess water governance performance and build qualitative indicators, which may serve as the basis to define priorities and guide implementation of recommendations on the water sector.
Semi-structured interviews related themes	Water allocation roles and responsibilities
	Issues and Challenges for Water Governance
	Multi-level interactions across boundaries and sectors, and roles and responsibilities
	Societal, environmental and basin challenges and issues
	Open Section to give a written or oral answer.

Note: Work conducted in the field by the first author.

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