Brackish Groundwater in Texas

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Abstract

Access to adequate supplies of fresh water is fast becoming critical in many parts of the world. Texas is in a similar situation. With a population expected to double in the next 50 years, Texas faces a growing demand for fresh water. Fortunately, the State has a large reserve of brackish groundwater that may be available for use after treatment. A 2003 study conducted by LBG-Guyton Associates for the Texas Water Development Board suggests that there is approximately 2.7 billion acre-feet of brackish groundwater in the aquifers of the state. Brackish water is reported in all but four of the 30 major and minor aquifers and in all of the 16 regional water planning areas. The largest amount of brackish water (417 million acre-feet) is present in Region L (South Central Texas region) and the smallest amount (approximately 9 million acre-feet) in Region P (Lavaca region). The Gulf Coast aquifer has the largest amount of brackish water (approximately 522 million acre-feet). Collectively, for all the regional water planning areas, the volume of brackish water in the 1,000 to 3,000 mg/l TDS category is roughly twice as much as the volume in the 3,000 to 10,000 mg/l category. Both the major and minor aquifers have about equal volumes of brackish water (approximately 1.35 billion acre-feet each), but the volume of brackish water in the 1,000 to 3,000 mg/l range in the major aquifers is almost twice as much as that in the 3,000 to 10,000 mg/l TDS category, and a little less than twice as much in the minor aquifers. Sufficient quantities of brackish water are available in aquifers present in the four regional water planning areas that were identified in the 2002 SWP as having the greatest needs. However, what is not known is the availability of the resource at the point of need. We recommend that future studies further quantify local brackish water availability, suggest optimal sites for locating regional treatment facilities based on availability, and provide detailed analysis of the cost-effectiveness of using desalinated water as a future water supply.

Introduction

Fresh water resources on Earth are limited. Over 97 percent of the world's water is sea water with an additional two percent locked up in remote ice caps and glaciers. Saline groundwater and saline inland seas further reduce the amount of usable water. As a result, less than 0.5 percent of the Earth's water resource on land is available for direct human consumption, agriculture, or industrial use. The world's population growth, improved living standards, increased demands from agriculture and industry, and declining quality of existing resources stress this fragile resource.

Texas finds itself in a similar situation. As the State's population grows and water demands rise, access to adequate supplies of fresh water is becoming a critical issue in many areas. Texans,

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though, recognized the importance of planning for the State's future water needs and began state-wide water planning almost 50 years ago (TWDB, 2002). Over this time span Texas adopted seven State Water Plans (SWPs), the most recent of which was the 2002 State Water Plan-Water for Texas; a product of almost three years of planning by the 16 regional water planning groups (RWPGs) and other agencies in the State.

The 2002 SWP projects that by the year 2050 the population of Texas will double and demand for fresh water will increase by about 20 percent (3 million acre-feet). The 2002 SWP further suggests that by 2050 almost 900 water user groups will either need to reduce demand or develop additional water sources beyond those currently available to meet their needs during droughts. The term "needs" as used in the regional water planning process and in our paper refers to a situation where future projected water demand by a water user group is more than current supplies.

The RWPGs anticipate that the number of water user groups that will not be able to meet demands with current supplies (that is, those water user groups that will have needs) will increase from 438 in the year 2000 to 883 in the year 2050. The volume of needs is expected to increase from approximately 2.5 million acre-feet in 2000 to 7.5 million acre-feet in 2050 (TWDB, 2002). To meet these projected needs, the RWPGs are required to develop water management strategies aimed at increasing water supply or maximizing existing supplies. One such water management strategy considered by the RWPGs for the 2002 SWP was desalination of brackish water present in the State's many aquifers.

An assessment of the State's brackish groundwater resources is the focus of this paper. For the purposes of our paper, brackish water is defined as water containing total dissolved solid (TDS) concentrations of between 1,000 and 10,000 milligrams per liter (mg/l). This definition includes slightly saline (1,000 to 3,000 mg/l TDS) and moderately saline (3,000 to 10,000 mg/l TDS) water as defined by the Texas Water Development Board (Ashworth and Hopkins, 1995).

With some exceptions, we have largely limited our discussion to brackish water present in the State's designated major and minor aquifers (Ashworth and Hopkins, 1995). The exceptions are: a) the Hueco-Mesilla Bolson aquifer (a TWDB major aquifer) is treated as two separate aquifers (the Hueco Bolson aquifer and the Mesilla Bolson aquifer), b) the Queen City and Sparta aquifers which are two distinct TWDB minor aquifers are considered as a single aquifer in our study, c) we report on the brackish water resources of the Whitehorse-Artesia formation (not designated as an aquifer by the TWDB), and d) we have not considered the resources of the Brazos River Alluvium aquifer (a TWDB minor aquifer). Brackish water produced during oil and gas operations (produced water) is also not included in our discussion. This type of brackish water is dealt with elsewhere in this volume (Burnett, 2004).

To be usable, brackish water generally needs to be treated (desalinated). The Texas Commission on Environmental Quality has established a secondary standard of 1,000 mg/l of TDS for public water supply systems (TCEQ, 2004). Without treatment, brackish water can cause scaling and corrosion problems in water wells and piping, and cannot be used in many industrial processes (Warner, 2001). Groundwater with TDS concentrations greater than 3,000 mg/l is not usable for irrigation without dilution or desalination and is not safe for most poultry and livestock watering (Warner, 2001).

Brackish Groundwater in Texas

Texas has long been known to have a large reserve of brackish water in its aquifers (Winslow and Kister, 1956; Core Laboratories, Inc., 1972), but details on its distribution and volume were lacking. In 2001, the TWDB funded a study to assess the availability and distribution of brackish groundwater in the state, and the associated cost of desalination technology and brine disposal. The intent was to make the results available to the RWPGs for use in their assessment of brackish groundwater as a potential water supply source. The study performed by LBG-Guyton Associates was completed in 2003.

Our paper summarizes the main findings and conclusions of LBG-Guyton's 2003 report and makes a preliminary assessment of the potential availability of brackish water in areas identified in the 2002 SWP as having needs. We also extend LBG-Guyton's study by determining the volumes of brackish water in the 1,000 to 3,000 mg/l and 3,000 to 10,000 mg/l TDS ranges for each aquifer and each regional water planning area (RWPA) using information already available in the LBG-Guyton report. (LBG-Guyton (2003) reported a total brackish water volume for each aquifer and each RWPA.) For more information on the methodology employed by LBG-Guyton, the limitations of that study, and detailed distribution of brackish water in the aquifers and RWPAs, the reader is referred to the 2003 LBG-Guyton report.

LBG-Guyton's 2003 study estimates that Texas has almost 2.7 billion acre-feet of brackish groundwater that may be available for use. It must be noted that this estimate likely is conservative because the aquifer boundaries are generally drawn on the basis of a TDS concentration of 3,000 mg/l (or 5,000 mg/l in some aquifers), and more brackish water may be present in the downdip sections of aquifers.

While nearly every geographical region of the state has some brackish water, west Texas, north-central Texas, central Texas, South Texas, and the Gulf Coast regions have the most significant amounts of brackish water (Figure1). Brackish water is reported to be present in every major aquifer and in all but four minor aquifers, and in each of the 16 regional water planning areas in the State (Figure 2). Even in the four minor aquifers where brackish water is reportedly absent, it is likely that brackish water is not being reported because of the absence of wells completed in the saline portions of the aquifer (that is, there is an absence of data points).

The geographical distribution of brackish water varies widely. The largest volume (417 million acre-feet) is present in Region L (South Central Texas region) while the smallest volume (about 8 million acre-feet) is present in Region P (Lavaca region; Figure 2). It must be noted that Region P is the smallest region in terms of areal extent. On a volume per unit area basis, Region A (Panhandle region) has the lowest volume of brackish water (917 acre-feet per square mile) while Region M (the Rio Grande region) has the highest volume (approximately 34,000 acre-feet per square mile). Collectively, for all the regions, the volume of brackish water in the 1,000 to 3,000 mg/l TDS category is roughly twice as much as the volume in the 3,000 to 10,000 mg/l category (Table 1).

Table 1 - Volume of brackish water in the regional water planning areas.

Region	Volume (acre-feet)		
	1,000 to 3,000 mg/l TDS	3,000 to 10,000 mg/l TDS	1,000 to 10,000 mg/l TDS
A	7,883,200	11,216,400	19,099,600
B	5,952,000	8,583,000	14,535,000
C	43,371,200	41,577,700	84,948,900
D	28,866,800	26,916,500	55,783,300
E	121,871,400	3,511,000	125,382,400
F	267,167,600	105,680,700	372,848,300
G	121,988,600	73,551,800	195,540,400
H	122,571,300	73,298,100	195,869,400
I	114,227,300	79,155,200	193,382,500
J	3,201,400	5,436,400	8,637,800
K	101,824,800	100,127,400	201,952,200
L	300,957,900	116,809,300	417,767,200
M	270,765,700	125,303,200	396,068,900
N	200,286,200	132,122,600	332,408,800
O	46,655,400	45,107,400	91,762,800
P	1,364,500	6,461,400	7,825,900
	1,758,955,300	**954,858,100**	**2,713,813,400**

NOTES: TDS = total dissolved solids; volumes have been rounded off to the nearest hundred. Source: Modified from data in LBG-Guyton Associates (2003)

The Gulf Coast aquifer has the largest volume of brackish water (about 522 million acre-feet; Figure 3) among the major aquifers while the Mesilla Bolson aquifer in west Texas has the smallest volume (about 0.5 million acre-feet; Figure 3). Among the minor aquifers, the Queen City and Sparta aquifers contain the largest volume of brackish water (approximately 246 million acre-feet; Figure 4 and Table 2) while the Lipan aquifer is reported to contain approximately 1.3 million acre-feet.

Further analysis of the distribution of brackish water in the aquifers indicates that both the major and minor aquifers have about equal volumes of brackish water (approximately 1.35 billion acre-feet each; Table 2). However, within each aquifer category (major and minor), the volume of brackish water in the 1,000 to 3,000 mg/l TDS range in the major aquifers is almost twice as much as that in the 3,000 to 10,000 mg/l TDS category, and a little less than twice as much in the minor aquifers (Table 2).

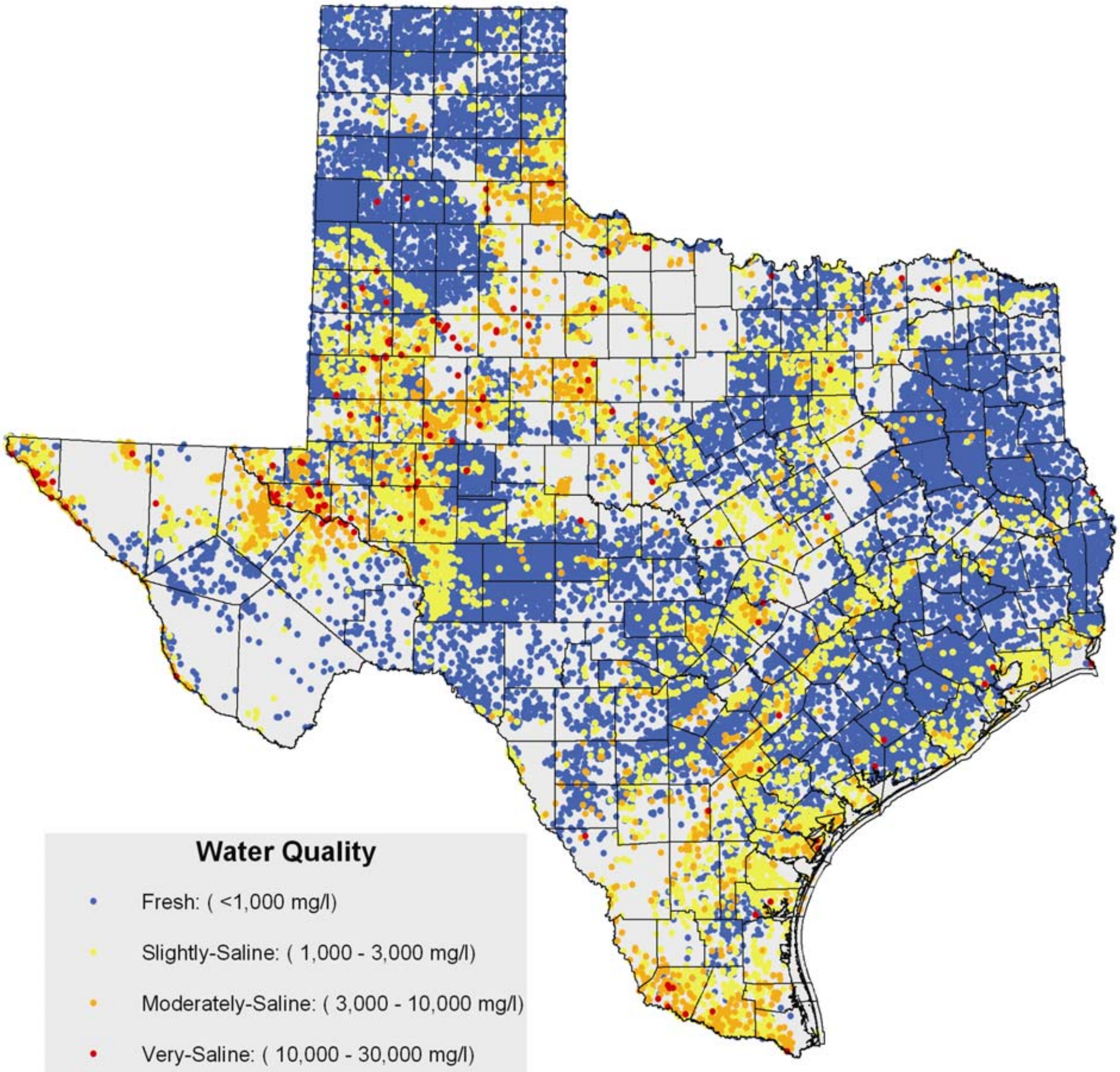

Figure 1 Distribution of brackish groundwater in Texas (modified from LBG-Guyton Associates, 2003)

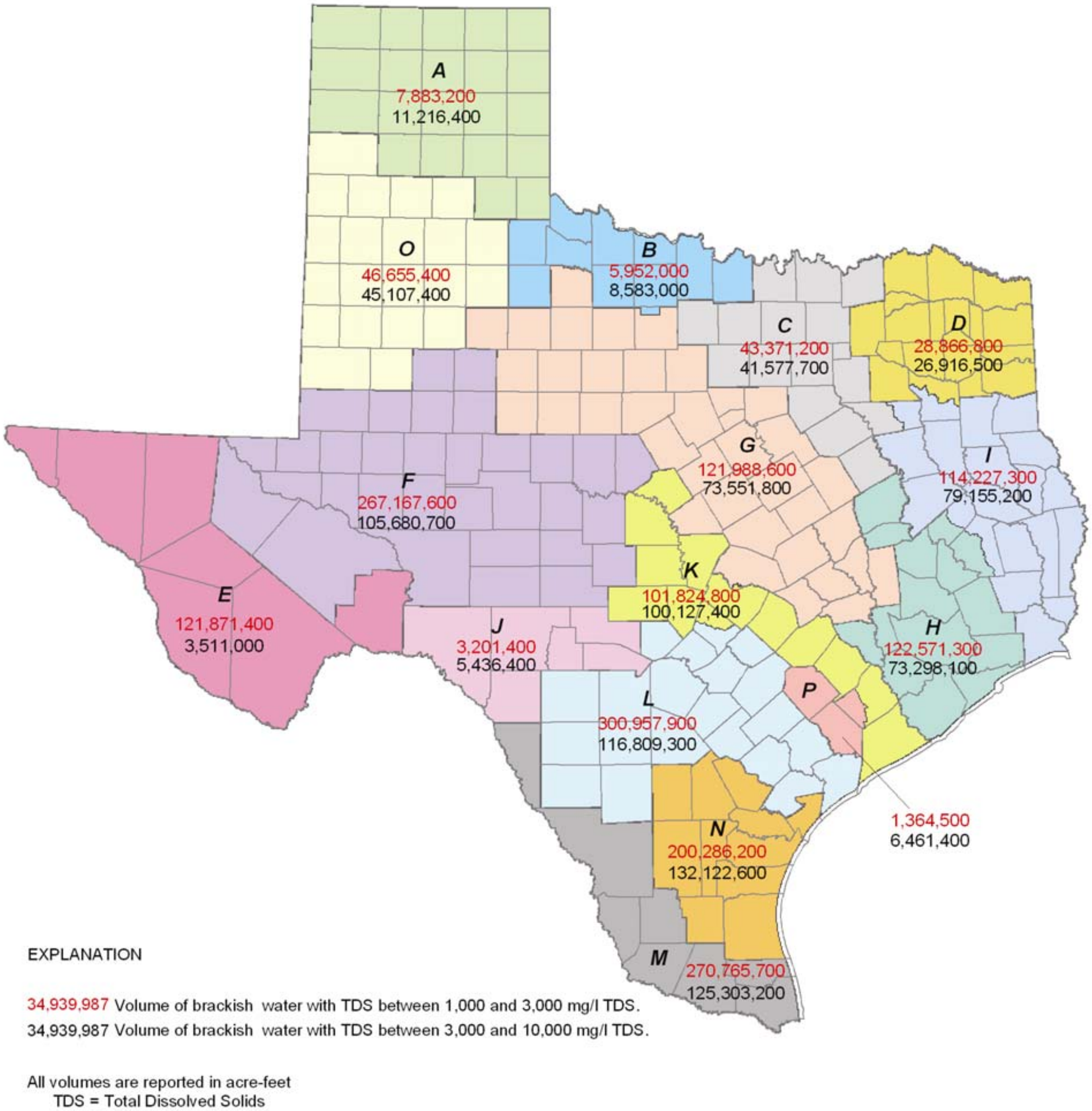

Figure 2 Volumetric estimates of brackish groundwater in the regional water planning areas of Texas (data modified from LBG-Guyton Associates, 2003)

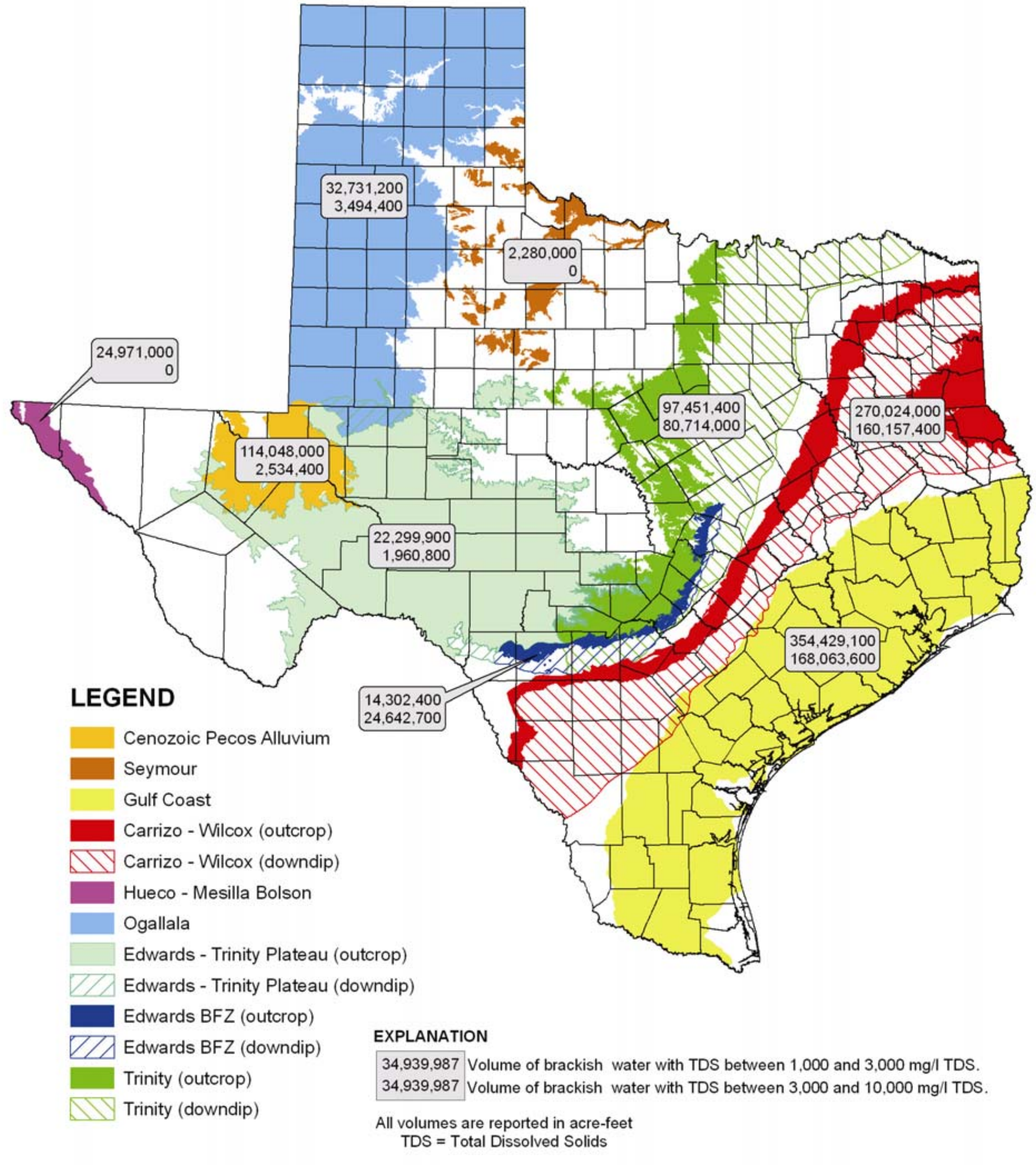

Figure 3 Volumetric estimates of brackish groundwater in the major aquifers of Texas (data modified from LBG-Guyton Associates, 2003)

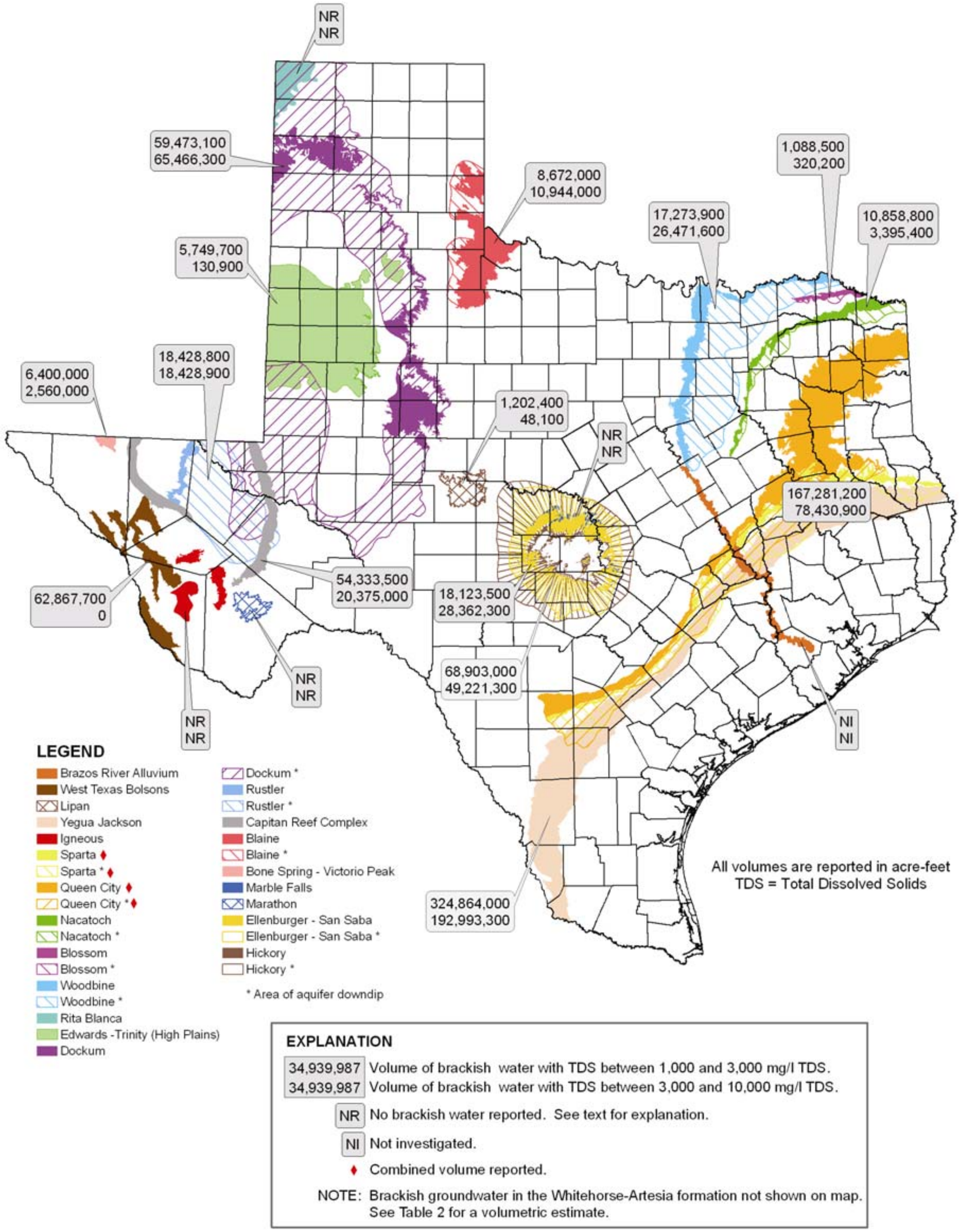

Figure 4 Volumetric estimates of brackish groundwater in the minor aquifers of Texas (data modified from LBG-Guyton Associates, 2003)

Table 2 -Brackish groundwater in the major and minor aquifers of Texas.

Major Aquifer	Volume (acre-feet)		
	1,000 to 3,000 mg/l TDS	3,000 to 10,000 mg/l TDS	1,000 to 10,000 mg/l TDS
Carrizo-Wilcox	270,024,000	160,157,400	430,181,400
Cenozoic-Pecos Alluvium	114,048,000	2,534,400	116,582,400
Edwards-Balcones Fault Zone	14,302,400	24,642,700	38,945,100
Edwards-Trinity (Plateau)	22,299,900	1,960,800	24,260,700
Gulf Coast	354,429,100	168,063,600	522,492,700
Hueco-Bolson[1]	24,490,900	0	24,490,900
Mesilla-Bolson[1]	480,100	0	480,100
Ogallala	32,731,200	3,494,400	36,225,600
Seymour	2,280,000	0	2,280,000
Trinity	97,451,400	80,714,000	178,165,400
	932,537,000	**441,567,300**	**1,374,104,300**
Minor Aquifer	Volume (acre-feet)		
Blaine	8,672,000	10,944,000	19,616,000
Blossom	1,088,500	320,200	1,408,700
Bone Spring-Victorio Peak	6,400,000	2,560,000	8,960,000
Capitan Reef	54,333,500	20,375,000	74,708,500
Dockum	59,473,100	65,466,300	124,939,400
Edwards-Trinity (High Plains)	5,749,700	130,900	5,880,600
Ellenburger-San Saba	18,123,500	28,362,300	46,485,800
Hickory	68,903,000	49,221,300	118,124,300
Lipan	1,202,400	48,100	1,250,500
Nacatoch	10,858,800	3,395,400	14,254,200
Queen City and Sparta[2]	167,281,200	78,430,900	245,712,100
Rustler	18,428,800	18,428,900	36,857,700
West Texas Bolson	62,867,700	0	62,867,700
Whitehorse-Artesia[3]	898,200	16,142,600	17,040,800
Woodbine	17,273,900	26,471,600	43,745,500
Yegua-Jackson	324,864,000	192,993,300	517,857,300
	826,418,300	**513,290,800**	**1,339,709,100**

Source: Modified from data in LBG-Guyton Associates (2003)

NOTES:
TDS = total dissolved solids
Volumes have been rounded off to the nearest hundred
[1] Designated as one aquifer by TWDB
[2] Designated as two separate aquifers by TWDB

[3] Not a TWDB-designated aquifer

Water Needs in Texas

As noted earlier, in the regional water planning process, when current water supply is less than the future projected demand, there is a need. The RWPGs were tasked with identifying future needs by comparing current supplies with projected demands. The 2002 SWP projects that the volume of needs will increase from approximately 2.4 million acre-feet in the year 2000 to 7.5 million acre-feet in the year 2050. Irrigation and municipal needs account for more than 75 percent of all projected needs in the 50-year planning period. In the year 2000, the largest volume of needs (approximately 652,000 acre-feet) was in Region M (Rio Grande region) followed by Region L (South-Central Texas region). By the year 2050, the largest volume of needs is projected to shift to the more populous areas in Region C and Region H which are anticipated to have needs of approximately 1.2 and 1.4 million acre-feet, respectively. Region C is also projected to have the largest number of water user groups with identified needs in the year 2050.

Where needs exist, the RWPGs were further required to develop water management strategies to meet the projected needs. One of the water management strategies identified by the RWPGs was desalination of brackish groundwater. In the 2002 SWP, desalination was recommended as a water management strategy by only three RWPGs and constituted only about 2.5 percent, by volume, of all water management strategies. In Region E (Far West Texas region) and Region N (Coastal Bend region), desalination of brackish groundwater is expected to provide approximately 67,000 acre-feet of water per year while in Region B desalination of brackish water is expected to provide about 29,000 acre-feet of the region's projected needs.

Water Needs and Brackish Groundwater Availability

In addition to making a volumetric assessment of the brackish groundwater resources of the state, LBG-Guyton (2003) also developed qualitative or semi-quantitative measures and a ranking scheme (low, moderate, high) of availability, productivity and source water production costs for the different aquifers present in the 16 RWPAs. Availability is defined as a general measure of the amount of brackish water in an aquifer, and productivity is defined as a measure of the production capacity of an aquifer (LBG-Guyton, 2003). Productivity measures the ease of producing water from an aquifer for municipal or industrial purposes taking into consideration the transmissivity of the aquifer and the production capacity of a typical well. Source water production cost is an indication of the relative cost that would be incurred to produce the brackish water. It does not, however, include costs associated with treatment of the water.

A detailed discussion of availability, productivity, and production costs for each aquifer in each RWPA is beyond the scope of this paper. Here, we discuss these parameters in the context of regions that were identified in the 2002 SWP as having the most needs in the 2000 to 2050 planning period (Regions M, L, C, and H) and those that have already identified desalination of brackish groundwater as a water management strategy (Regions E, N and B). For this analysis, we include only those aquifers that were identified in the 2003 LBG-Guyton report as having moderate to high availability, moderate to high productivity, and low to moderate production costs. These are optimal aquifer characteristics and we do not mean to imply that aquifers with less-than-optimal characteristics are unsuitable for use. Ultimately, local, site-specific conditions will dictate the need for and feasibility of using brackish water from an aquifer to meet an RWPG's specific need.

Regions M and L were identified in the 2002 SWP as having the greatest needs in the year 2000. While neither region listed desalination of brackish groundwater as a water management strategy, a few of the aquifers appear to be potentially favorable sources. The Gulf Coast and Yegua-Jackson aquifers in Region M each contain almost 140 million acre-feet of brackish water with more than 75 percent of this volume in the 1,000 to 3,000 mg/l TDS category. Much of the brackish water is in Cameron, Hidalgo, Starr, and Zapata counties. The Queen City and Sparta aquifers are another potential source with about 90 million acre-feet of brackish water (about equal amounts of the two brackish water categories). The three aquifers in Region M are considered to have moderate to high availability, low to moderate productivity, and moderate to high production costs.

In Region L, the Carrizo-Wilcox and Yegua-Jackson aquifers each contain approximately 125 million acre-feet of brackish water with about 73 percent of this volume in the 1,000 to 3,000 mg/l TDS category. The production cost for these two aquifers is considered to be moderate to high, and availability is considered to be moderate to high. The productivity of the Carrizo-Wilcox aquifer is high, but is low in the Yegua-Jackson aquifer because much of the brackish water occurs at depth in the down-dip portions of the aquifer where transmissivities are low. The Queen City and Sparta aquifers, and the Gulf Coast aquifer, also contain fair amounts of brackish water; approximately 75 million and 45 million acre-feet, respectively. Productivity of the Queen City and Sparta aquifers is expected to be low because the brackish water is present in deeper, down-dip portions of the aquifers. The Gulf Coast aquifer might offer the most favorable conditions; moderate availability, high productivity, and low production costs. Much of this water is at the southern end of the RWPA in Karnes and Goliad counties.

Region C is one of the regions projected to experience large needs in the year 2050. The Trinity aquifer in the region contains approximately 60 million acre-feet of brackish water (equal amounts of 1,000 to 3,000 mg/l and 3,000 mg/l to 10,000 mg/l TDS). While availability for the aquifer is moderate, its productivity is considered to be low because the water is mainly present in the deeper portions of the aquifer. Consequently, the production costs are ranked as moderate to high. The Woodbine aquifer in this region contains lesser volumes of brackish water (about 22 million acre-feet). Its availability is considered to be high, productivity is considered to be low to moderate, and production costs are moderate to high because of the tighter and deeper nature of the aquifer.

The 2002 SWP projects that in the year 2050, Region H will experience needs of about 1.2 million acre-feet annually. The Gulf Coast and Yegua-Jackson aquifers in this region contain the largest volume of brackish water (approximately 85 million and 70 million acre-feet, respectively). Relatively smaller amounts are present in the Carrizo-Wilcox (23 million acre-feet) and Queen City and Sparta (14 million acre-feet) aquifers. Of the two aquifers with the largest volume of brackish water, the Gulf Coast aquifer might be the most favorable source of water. Availability from and productivity of this aquifer are considered to be high, and the production costs are considered to be low to moderate. The Yegua-Jackson aquifer, on the other hand, has moderate availability, low productivity (because of deeper depths), and moderate production costs. The Carrizo-Wilcox and Queen City and Sparta aquifers have moderate to high production costs because brackish water is present at depths of 3,000 to 6,000 feet below ground surface.   In certain areas of Region H (for example, in the Harris-Galveston and Fort Bend subsidence districts) increased use of groundwater is being curtailed because of ground subsidence problems. In such areas, use of brackish groundwater may not be a viable option.

Region E (Far West Texas region) is one of the three regions that recommended using desalination of brackish groundwater to meet needs. Brackish groundwater conditions in the region are favorable. Virtually all the aquifers in the region, except the Rustler aquifer, are reported to have high availability, moderate to high productivity, and low to moderate production costs. Additionally, much of the brackish water in these aquifers is in the 1,000 to 3,000 mg/l TDS range making the resource more amenable for desalination than higher TDS brackish water. The City of El Paso in conjunction with the US Army has started constructing a desalination plant on Fort Bliss to supply water to El Paso and the military base. This facility is expected to start operations in 2006 and will provide about 27.5 mgd of water per year.

The largest volume of brackish groundwater in Region N is present in the Gulf Coast aquifer (approximately 180 million acre-feet) followed by the Yegua-Jackson and the Carrizo-Wilcox aquifers (approximately 70 million acre-feet each). The Queen City and Sparta aquifers in the region contain about 10.5 million acre-feet of brackish water. Of the five aquifers, the Gulf Coast has the most favorable characteristics. It has moderate availability, moderate to high productivity, and low production costs. Furthermore, brackish water in this aquifer is present throughout the region. Availability from the Carrizo-Wilcox, Yegua-Jackson, and the Queen City and Sparta aquifers is low, and production costs moderate to high.

Desalination of brackish groundwater is one of the water management strategies recommended by Region B to meet its water needs. Brackish water in the region is present in the Blaine and Seymour aquifers, and in the Whitehorse-Artesia formation. The largest volume is present in the Blaine aquifer (11.5 million acre-feet with equal amounts of 1,000 to 3,000 mg/l and 3,000 to 10,000 TDS). The Seymour aquifer has a relatively small volume (192,000 acre-feet) and the Whitehorse-Artesia formation contains an unknown amount. The Seymour aquifer might offer the most favorable conditions: moderate availability and productivity, and low production costs. The Blaine aquifer has high availability and moderate to low productivity, but production costs can be high because of the disconnected nature of the aquifer and the unpredictability of finding sufficiently productive areas within it.

Our preliminary assessment indicates that the aquifers in regions M, L, C, H, E, N, and B have sufficient quantities of brackish water available to meet the needs identified in these regions. However, this does not necessarily mean that the water will always be available where a local need exists. More site-specific studies will be needed to make such determinations.

Conclusions

Texas has a large amount of brackish water in its aquifers (approximately 2.7 billion acre-feet). This resource is available in all 16 RWPAs and is present in all major and almost all minor aquifers of the state. Our initial assessment of brackish groundwater as a potential source of water supply in regions that have been identified in the 2002 SWP as having current needs, or are projected to have needs in the future, suggests that there is a sufficient quantity of this resource of suitable chemical quality to meet these needs. However, what is not known is the availability of the resource at the point of need. This level of detail was beyond the scope of our study and will require further investigations.

We recommend that future studies further quantify local brackish water availability, suggest optimal sites for locating regional treatment facilities based on availability, and provide detailed analysis of the cost-effectiveness of using desalinated water as a future water supply. The 2003 LBG-Guyton report laid the foundation for brackish groundwater studies in Texas, and it is now up to us to build on it.

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