Evaluation of Brackish Groundwater in Kenedy County Groundwater Conservation District

Prepared by

Venkatesh Uddameri, Ph.D., P.E.

Mr. Andy Garza

Prepared for

Kenedy County Groundwater Conservation District

Final Submission: 1/18/2016

Background

Geography and Hydrogeology

The Kenedy County Groundwater Conservation District ("KCGCD" or "the district") is a multi-county groundwater conservation district ("GCD") in South Texas that covers the entire Kenedy County and portions of Brooks, Kleberg, Nueces, Jim Wells, Willacy and Hidalgo counties (see Figure 1).

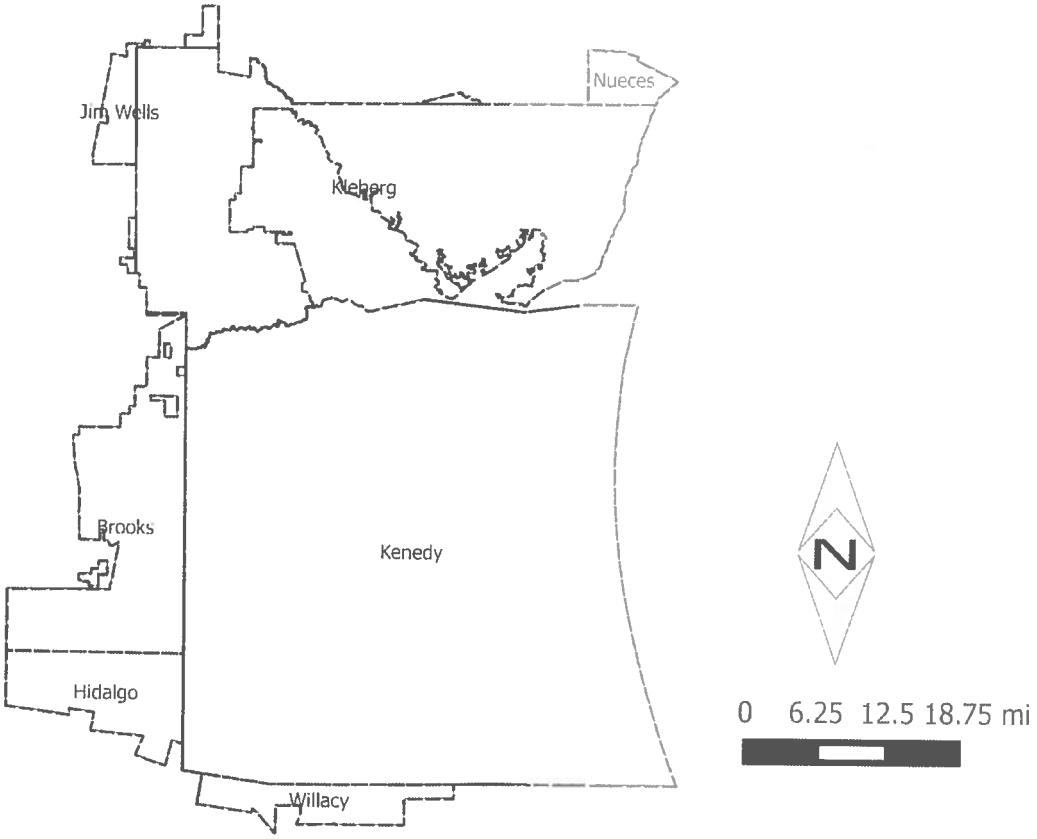

Figure 1: Map of Kenedy County Groundwater Conservation District

Given its location within South Texas, the Kenedy County Groundwater Conservation District experiences erratic rainfall patterns with an annual average precipitation ranging from nearly 25" towards the east to about 12" in the west. There are no major surface water bodies within the district; therefore, groundwater is the primary source used to meet water demands within the district.

The aquifer underlying KCGCD is referred to as the Gulf Coast Aquifer and is a sedimentary formation composed of interbedded layers of sands, silts, and clays. The Gulf Coast Aquifer is further differentiated into four (sub) aquifers, namely – the Chicot Aquifer, the Evangeline Aquifer, the Burkeville Confining Unit, and the Jasper Aquifer.

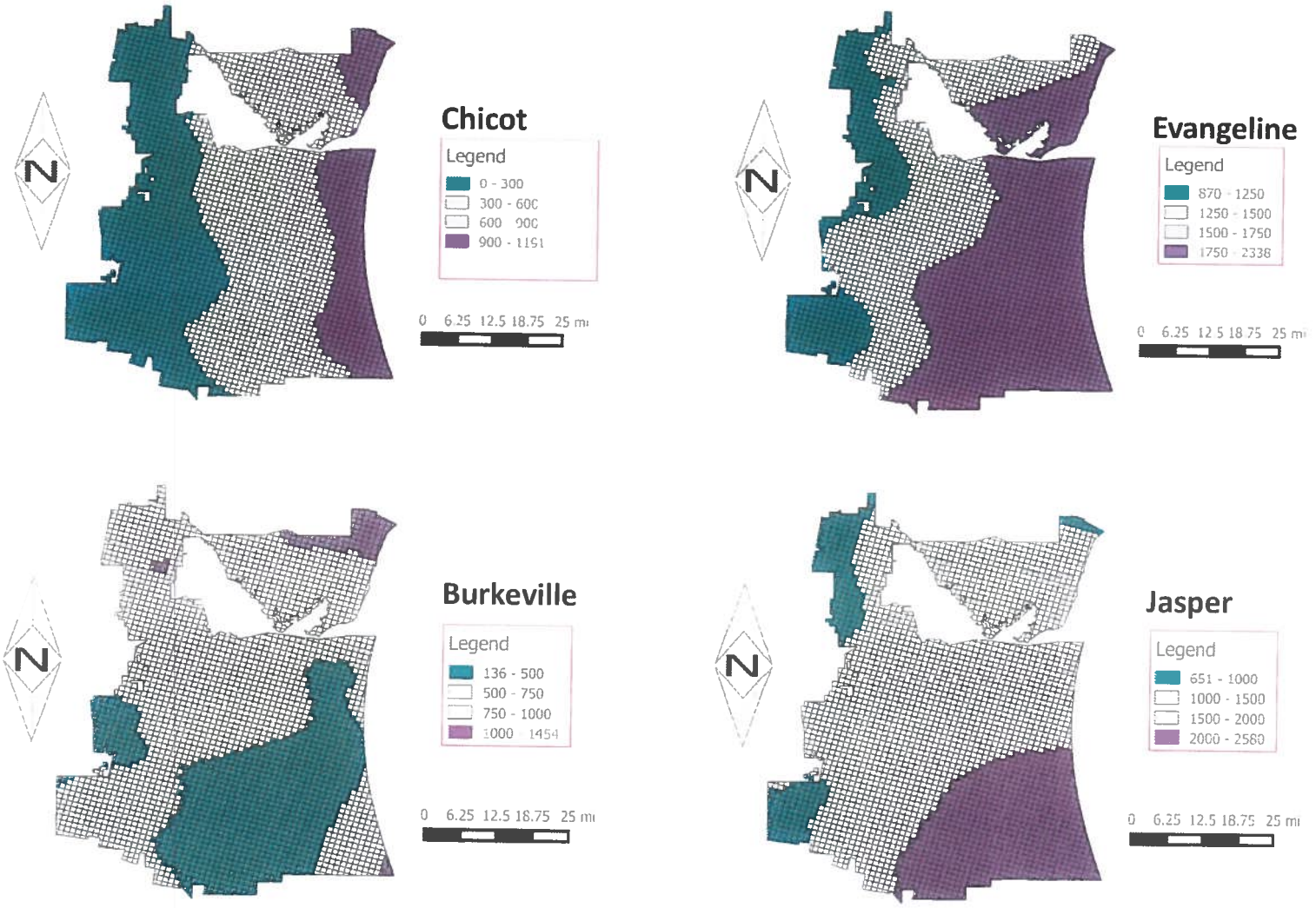

Figure 2: Gulf Coast Aquifer Thicknesses in KCGCD (Thickness is measured in feet)

The Chicot Aquifer includes the youngest deposits and exists under unconfined conditions within the District. While this aquifer is over 1,000 feet thick near the coast, it progressively pinches out along the western section of the district. The Chicot Aquifer and the associated sediments are connected to the nearly 150 mile coastline of the district.

The Evangeline Aquifer lies below the Chicot Aquifer and is widely used for water supply purposes within the district. This aquifer contains sand formations that are locally referred to as the Goliad Sands. Based on existing well data, it is estimated that over 90% of the groundwater production within the district is from the Evangeline Aquifer. The Evangeline Aquifer is also widely used by communities surrounding the Kenedy County Groundwater Conservation District. For example, while not within the district boundaries, the City of Kingsville uses seven wells that tap into the Goliad Sands formation to meet its drinking water needs. The annual production from the City of Kingsville wells is approximately 3,000 acre-ft/year. The drawdowns experienced within the district are affected by this large-scale production given the proximity of these wells to the district boundaries. Furthermore, other cities such as Premont and Falfurrias also have wells that tap into the Evangeline Aquifer.

The Burkeville Confining Unit has a higher percent of silts and clays and behaves as an aquitard regionally. However, this unit can yield low volumes of water locally and is tapped to meet small water uses (domestic and livestock) particularly in the western sections of the district. The Jasper Aquifer is the oldest and deepest unit of the Gulf Coast Aquifer. To the best of the authors' knowledge and based on publicly available information, there is very limited use, if any, within the district. Additional details related to the hydrostratigraphy of the Gulf Coast Aquifer can be found in Baker (1979) and Young et al. (2010).

KCGCD and Groundwater Management Area - 16

The Kenedy County Groundwater Conservation District was created in 2003 by the 78th Texas Legislature under H.B. 3374. It was confirmed by an election held on November 2, 2004. Additional areas abutting the district have subsequently been annexed into the district over time and the current areal extent of the district is depicted in Figure 1. The district has a management plan that is approved by the Texas Water Development Board ("TWDB"). The district is a member of the Groundwater Management Area 16 ("GMA 16") and works closely with other districts and stakeholders in the region to develop suitable desired future conditions ("DFCs"). The proposed DFC for the Kenedy County Groundwater Conservation District and surrounding areas which is currently the subject of notice and public hearing, is summarized below:

Table 1: Proposed DFC for Kenedy County Groundwater Conservation District and other districts and areas in its Vicinity (Data from: Bar-W Groundwater Exploration LLC)

Entity	Drawdown (ft)				Total Gulf Coast Pumping
	Chicot	Evangeline	Burkeville	Jasper	(AFY)
Kenedy County GCD	15	99	21	21	55000
Brush Country GCD	47	76	68	69	14200[1]+5840[2]
Duval County GCD	78	142	95	85	27000
Kleberg County[3]	8	105	11	11	4825
Nueces County[3]	22	39	11	11	10040
Willacy County[3]	28	85	23	23	3200

[1] Brush County GCD excluding City of Alice; [2] City of Alice; [3] Areas not included in Kenedy County GCD

The relatively high drawdowns in the Evangeline aquifer in Table 1 indicate that the stakeholders within GMA-16 concur that a significant portion of the groundwater production corresponding to the DFC is expected to come from the Evangeline Aquifer in the region.

HB 30 Brackish Groundwater Delineation in Texas

The dwindling supplies of freshwater resources associated with unprecedented population growth in many parts of the state has spurred the search for alternative water resources to meet the future demands of the state. There is a growing interest in tapping into the 880 trillion gallons of brackish groundwater estimated to be available in Texas aquifers (LBG Guyton, 2004). House Bill 30 of the 84th Legislature directs the TWDB to work with GCDs and other stakeholders to designate brackish groundwater production zones ("BGPZ" or "zones"). The purpose of the legislation is to encourage meaningful production of brackish groundwater that 1) respects property rights; 2) has minimal impacts on existing fresh groundwater resources and 3) encourages non-potable use of brackish groundwater. HB 30 modifies the Regional Water Planning ("RWP") process and requires submitted plans to identify opportunities for, and the benefits of, developing large-scale desalination facilities for seawater or brackish groundwater that serve local or regional brackish groundwater production zones identified and designated under Section 16.060 (b)(5) of the Texas Water Code.

House Bill 30 requires that the designated zones be in the areas of the state with moderate to high productivity of brackish groundwater that can be used to reduce the use of fresh groundwater. Furthermore, zones are to be delineated such that they are separated by hydrogeologic barriers sufficient to prevent significant impacts to water availability or water quality in any area of the same or other aquifers, subdivisions of aquifers, or geologic strata that have an average total dissolved solids ("TDS") level of 1,000 milligrams per liter ("mg/L") or less at the time of designation of the zones. Also, zones are **not** to be located in aquifers - an aquifer, subdivision of an aquifer, or geologic stratum that: has an average total dissolved solids level of more than 1,000 milligrams per liter; **and** is serving as a significant source of water supply for municipal, domestic, or agricultural purposes at the time of designation of the zones. Other geographically specific restrictions have also been identified in HB 30.

Upon designation of the zones, the TWDB must determine the amount of brackish groundwater that the zone is capable of producing over a 30-year period and a 50-year period without causing a significant impact to water availability or water quality as described by Subsection 16.060 (b)(5)(A) of the Texas Water Code. The TWDB is also mandated to include in the designation description: The amounts of brackish groundwater that the zone is capable of producing during the 30 and 50 year periods and recommendations regarding reasonable monitoring to observe the effects of brackish groundwater production within the zone. The legislation also requires the TWDB to summarize its findings in a biennial progress report on seawater and brackish groundwater desalination activities. The next report is due on Dec. 1, 2016 and will focus on four aquifers – 1) The Gulf Coast, 2) the Carrizo-Wilcox, 3) the Blaine, and 4) the Rustler. Delineation of all aquifers will be completed by Dec. 1, 2022.

A stakeholder meeting was conducted by the TWDB on October 26th, 2015. In this meeting the TWDB shared information and presented their plans to execute the requirements of HB 30. In particular, the TWDB clarified that groundwater with TDS greater than 1,000 mg/L and less than 10,000 mg/L would be classified as brackish for the purposes of HB 30 zone designations. In addition, the TWDB indicated that it is working to better define certain terms in the HB 30 language. More specifically, the TWDB raised questions pertaining to the following clause:

- "the [TWDB] shall identify and designate local or regional brackish groundwater production zones in areas of the state with moderate to high availability and productivity of brackish groundwater that are separated by hydrogeologic barriers sufficient to prevent significant impacts to water availability. or water quality in any area of the same or other aquifers that have an average total dissolved solids level of 1,000 milligrams per liter or less at the time of designation of the zones" [emphasis added]

There is currently discussion on whether the hydrogeologic barriers should be a physical barrier (clay, shale, or fault) or be defined using distances (such that the significant impacts are manageable). Also, the definition of significant impacts is currently being discussed (Mace, 2015). The TWDB indicated that the Gulf Coast Aquifer brackish groundwater production zone delineation will be carried out by an external consultant. As of Jan 6th 2016, it appears that Intera Inc. has been recommended as the consultant for the Gulf Coast Aquifer BGPZ. It is anticipated that the initial report will be completed by August 2016.

Although not in direct response to HB 30, a study has been carried out by TWDB to delineate brackish groundwater resources in the Gulf Coast Aquifer in the Lower Rio Grande Valley, TX with an emphasis on its feasibility for use in municipal desalination efforts (Meyers et al., 2014). The Lower Rio Grande Valley study focuses on parts of Starr, Hidalgo, Willacy and Cameron counties and is wholly included with Region M. However, only a small portion of the Willacy County is included within KCGCD and as such the overlap is extremely minimal.

Goals and Objectives

House Bill 30 represents a seminal policy shift in that it brings water quality considerations into groundwater management and planning. It is imperative that delineation of the BGPZs are based on the best available data and existing science. The legislation also calls for close interaction between GCDs and the TWDB (and its consultants). Given the newness of this policy, it is important that ideas pertaining to its implementation are shared freely among stakeholders. Kenedy County Groundwater Conservation District commissioned this study in the spirit of fostering communications on this important topic with the overarching goal of developing initial ideas and recommendations with regards to BGPZs in the district. In particular, the study reviews and analyzes existing datasets in a stratified manner to highlight significant data gaps and also to qualitatively evaluate potential impacts to existing freshwater resources.

Data Compilation and Analysis

Total Dissolved Solids

Total dissolved solids is a bulk measure of water quality and as the name suggests is the total amount of solids dissolved in a water sample. The dissolved solids are mainly comprised of inorganic salts of calcium,

magnesium, sodium, and potassium and may also include some dissolved organic salts. Total dissolved solids can be directly measured in the lab using standard gravimetric procedures (EPA Method 160.1) and the value is assigned a STORET CODE (70300). As the dissolved solids are primarily comprised of inorganic ions, TDS also correlates strongly with specific conductance ("EC") measured in the units of µmohs/cm @25° C and referred to using a STORET CODE (00095). In a similar fashion, EC can also be measured in the field using calibrated probes and assigned a STORET CODE (00094) when expressed in the standard units of µmohs/cm @25° C. TDS can also be calculated from cation-anion analysis, but this approach is primarily used to check the correctness of the analysis rather than to report a TDS value. It is important to recognize that a proper relationship between EC and TDS needs to be established prior to using EC as a surrogate. Many field probes in the market often come pre-calibrated and directly provide a value of TDS even though they are actually measuring EC. In addition to direct groundwater sampling, TDS can also be inferred from electric-logs, again using empirical correlations.

Mapping Total Dissolved Solids in Kenedy County Groundwater Conservation District

The TWDB groundwater database has the largest collection of publicly available information on TDS measured in groundwater within KCGCD. Direct TDS measurements (STORET CODE 70300) and EC (STORET CODE 00095) were extracted from the TWDB groundwater database. The TDS and EC data were generally co-located; therefore, only TDS measurements were used in this initial analysis because they provide the most direct measurement of dissolved solids. While total dissolved solids have been recorded since 1913, the number of measurements at each well is rather spotty. Eight is the maximum number of annual average measurements (data points), with most wells having 1 – 3 measurements. No visible trends were seen in wells having more than 5 data points. The spatial variability of TDS was far greater than the temporal variability. Therefore, all of the available 234 wells in the TWDB database with at least 1 TDS measurement (and known well depth) were used in this analysis.

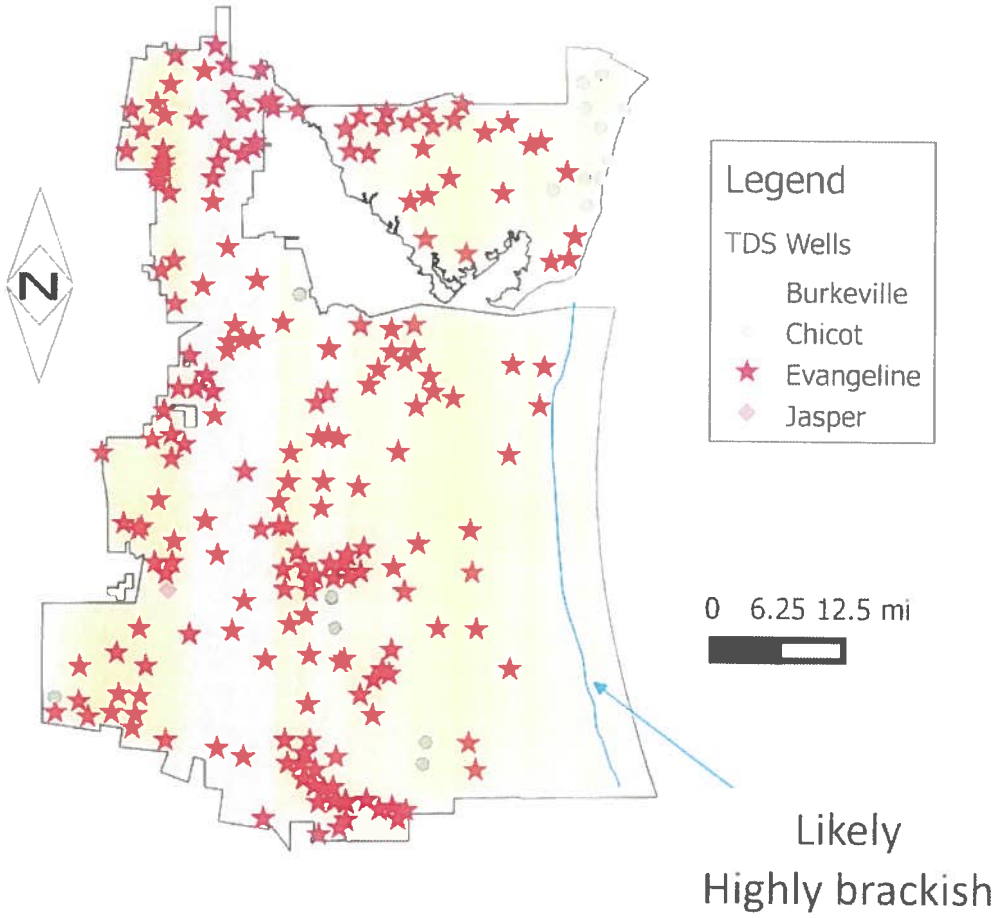

Figure 3: Historical Groundwater Monitoring Well Locations (Data from TWDB)

Well depth information was also extracted from the TWDB groundwater database and used to stratify water quality monitoring wells into different aquifers. Because the well screen information was rather sparse, it was assumed that the wells are mostly screened at the bottom. The aquifer thicknesses were based on stratigraphic information present in the Central and the Southern Gulf Coast GAM models (Waterstone, 2003; Chowdhury and Mace, 2007). The location of wells and the aquifers they tap into are shown in Figure 3. As can be seen, most of the sampled wells are in the Evangeline Aquifer. This aquifer is widely used in the region for meeting all of the water demands. The wells in the Chicot Aquifer are generally localized in the northeastern portion of the district. There is only one observation each in the Jasper Aquifer and Burkeville Confining Unit. Based on information presented in Waterstone (2003), the eastern portion of the district, especially within Kenedy County, probably consists of highly brackish water (3,000 – 10,000 mg/L). This dataset extracted from TWDB groundwater database was used as the basis to analyze potential BGPZs within the district as discussed below.

Results and Discussion

Jasper and Burkeville Confining Formation

The available TDS data for wells in the Jasper and Burkeville formation are summarized in Table 2.

Table 2: Available Water Quality Information in Burkeville Confining Unit and Jasper Aquifer (Data from TWDB, 2015)

TWDB Well ID	Latitude	Longitude	TDS (mg/L)	Elev LSD (ft above MSL)	Well depth (ft)	Aquifer
8708101	26.97000	-98.0872	1646.75	120	1600	Burkeville
8708901	26.88778	-98.0403	2457	63	2312	Jasper
8818502	26.66722	-97.8247	NA	31	2150	Burkeville

The limited measurements available indicate that the TDS value in these formations is greater than 1,000 mg/L and less than 3,000 mg/L. Being older formations, the pore water in these units has had a long time to interact with the surrounding aquifer matrix and achieve near equilibrium conditions. As a result, brackish levels are to be expected in these stratigraphic units. Also, the hydrogeologic properties of these units have not been studied within the district. While these aquifers have considerable thickness, their ability to store and conduct water needs to be better assessed. It is also possible that water quality in these units could be greater than the 1,000 mg/L – 10,000 mg/L limits selected by the TWDB for initial mapping of the brackish groundwater resources.

Despite the above mentioned data limitations, the Burkeville Confining Unit and the Jasper Aquifer underlying the KCGCD can potentially be delineated as BGPZs. While interconnectivity exists among different stratigraphic units of the Gulf Coast Aquifer, these units (Burkeville and Jasper) can be viewed as hydrogeologically distinct from the shallower more productive formations in that they appear to exert limited influence on those formations. In particular, using the Burkeville as a confining unit (and not a BGPZ) would further support the designation of the Jasper Aquifer as a BGPZ as the pumping effects within the Jasper will have a minimal effect on the upper shallower formations that have been tapped for large-scale use in the area. Dewatering of clays however is a potential concern when developing these formations and limit the amount of water that can be productively extracted. This issue is of greater importance in the Burkeville Confining Unit and as such, it is perhaps better to use this unit as a confining layer and not be designated as BGPZ.

Chicot Aquifer

The Chicot Aquifer and the associated younger sediments are in direct connection with the coast of the Gulf of Mexico and are likely to contain brackish water near the coast. The aquifer is not used widely in the district, primarily due to poor water quality. The TDS data from the TWDB corresponding to the Chicot Aquifer is depicted in Figure 4. As can be seen, the water quality generally deteriorates with depth. However, anomalous behavior can be noted near the coast due to mixing of coastal waters and recharge from rainwater containing significant amounts of marine aerosols as well as likely contamination from past oil and gas activities. Measurement in two wells exceeded 20,000 mg/L (and are not shown in Figure 4 because the focus is on the 1,000 mg/L – 10,000 mg/L range). Given its limited use, the Chicot Aquifer also has the potential to be designated as a BGPZ. The relatively large thicknesses of the aquifer along the coast could potentially serve as a hydrogeologic barrier that is protective of the deeper Evangeline

Aquifer, especially if brackish groundwater production wells are placed as partially penetrating wells. However, the productivity will likely be limited by aquifer heterogeneity and presence of interbedded tight clays.

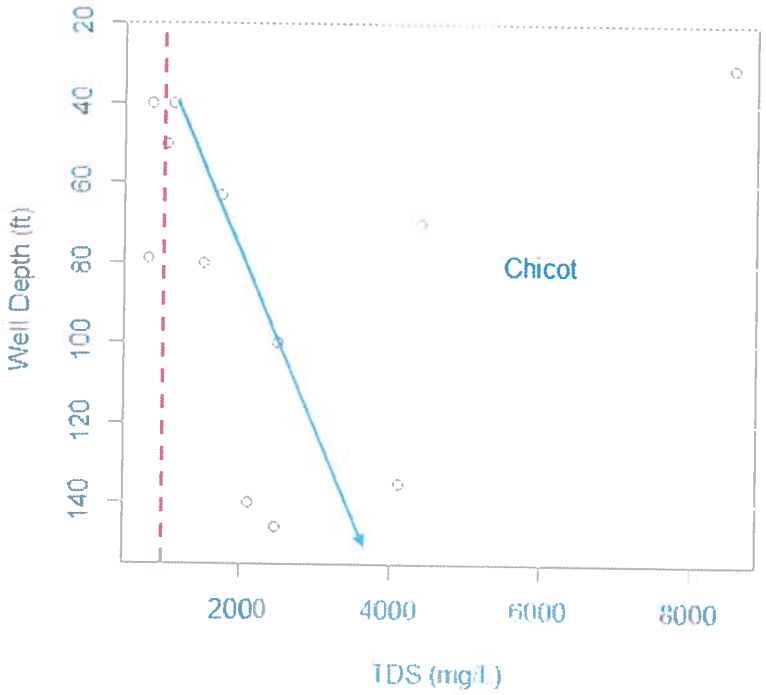

Figure 4: Depth TDS Relationship in Chicot Aquifer

A preliminary TDS contour plot for the Chicot Aquifer within KCGCD is depicted in Figure 5 and was delineated using an inverse distance weighting approach (power = 2). Caution should be exercised when interpreting the map as it has been constructed using very limited and highly clustered data. The map nonetheless gives an initial impression of the water quality and indicates that the aquifer is practically unusable in the western sections due to extremely high TDS values. Again the region along the coast (perhaps east of Hwy 77) could be designated as a BGPZ. The extent of impact of the BGPZ would depend upon its location and whether it is mostly drawing water from the coastal body or from the hinterland locations.

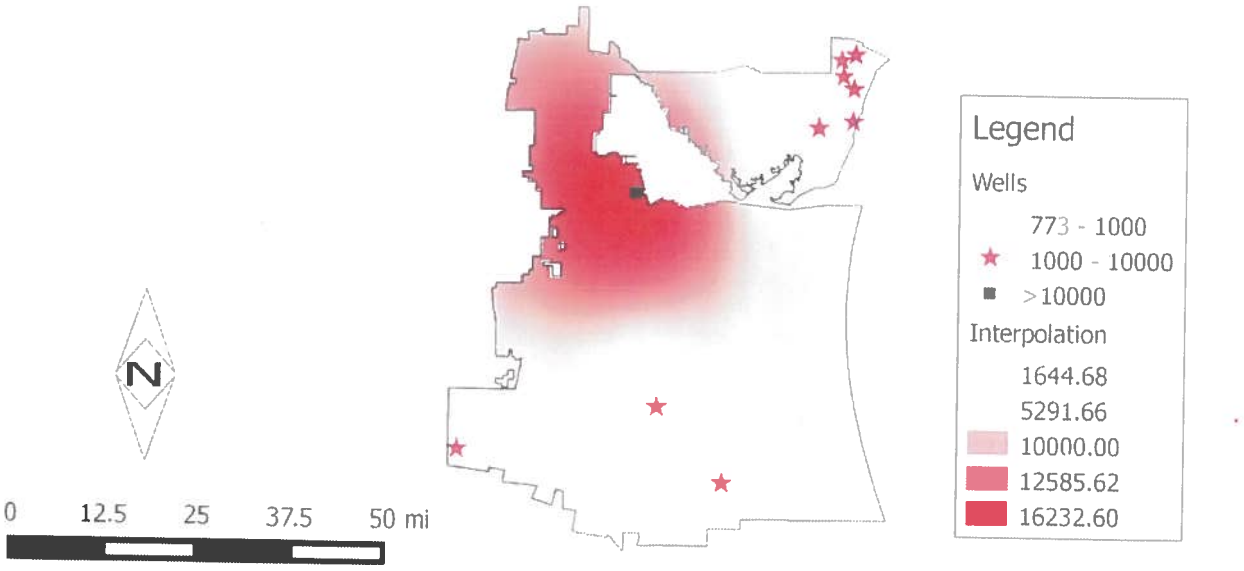

Figure 5: Measured and Interpolated TDS Concentrations in the Chicot Aquifer

Evangeline Aquifer

The Evangeline is the most prolific and widely used aquifer in KCGCD and its neighboring areas. As a result, there is more water quality data available for this aquifer. As can be seen from Figures 6 and 7, there are a considerable number of wells where the TDS value is less than 1,000 mg/L within the district. Furthermore, the range of variability of TDS is low compared to other aquifers within the district. Fresh (or at least slightly brackish) water is generally available in the Evangeline throughout the district. While water quality generally deteriorates with depth, the aquifer exhibits a high degree of heterogeneity with regard to TDS. Based on the interpolated map shown in Figure 7, intermingled fresh and brackish groundwater can be found in most parts of the district. While zones of brackish groundwater can be seen in the southeastern and northeastern corners of the district, the observed data indicate the presence of a large number of wells with slightly brackish groundwater (1,000 – 3,000 mg/L) in these areas. Given the lack of other water resources within the district, the water in the Evangeline Aquifer is the only consistently available water and is used for various purposes, primarily domestic and livestock uses.

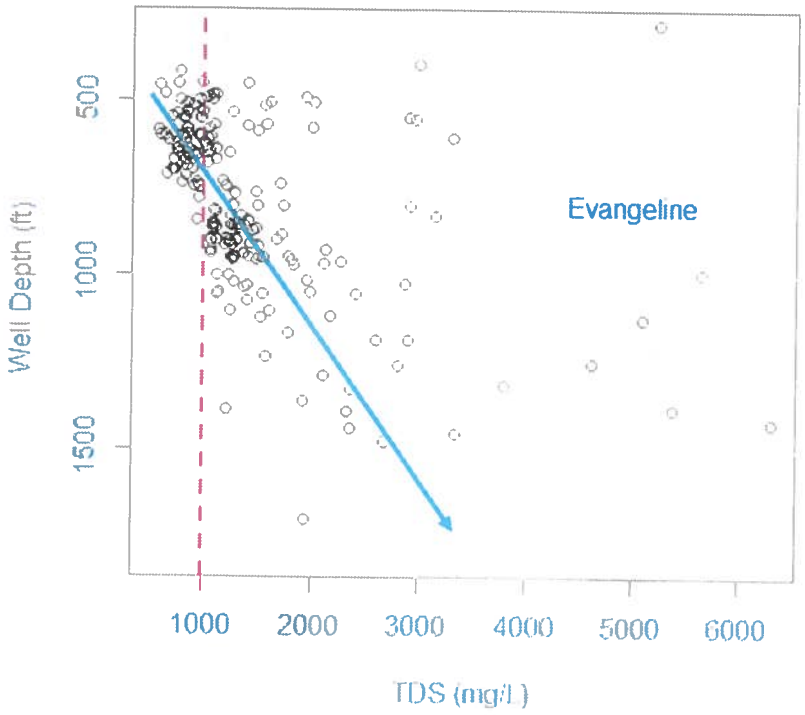

Figure 6: Depth TDS Relationship in the Evangeline Aquifer

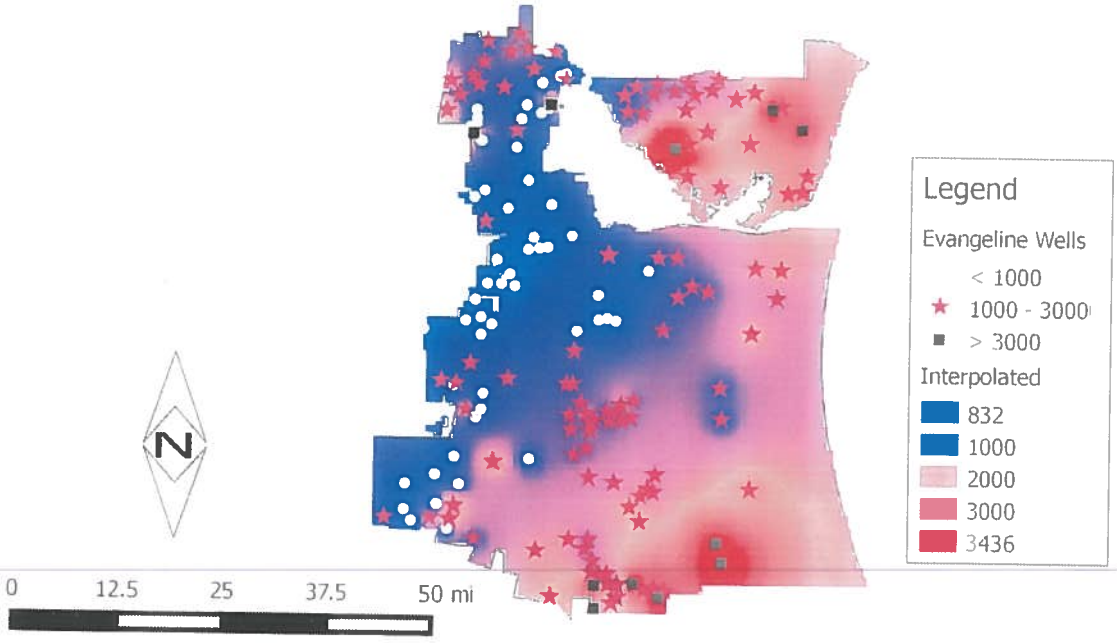

Figure 7: Measured and Interpolated TDS Concentrations in the Evangeline Aquifer

Summaries of water quality testing data collected by King Ranch as part of their annual monitoring efforts was made available to obtain additional insights with regard to water quality in the region, and particularly the Evangeline Aquifer. These data were collected by King Ranch field personnel and analyzed using Test America Laboratories in Corpus Christi, Texas. The results presented in Figure 8 corroborate the general trends seen in Figure 7 (better quality along the western sections and poorer quality in the north).

Division	# wells tested	# wells >1000 TDS	% >1000 TDS	> 900 TDS
Santa Gertrudis (2014)	139	48	35%	20
Laureles (2015)	106	101	95%	2
Norias (2012)	140	133	95%	1
Encino (2013)	68	34	50%	10
Total All	453	316	70%	33

Figure 8: Summary of Wells exceeding 1000 mg/L TDS in Various Divisions of King Ranch (Data Courtesy: King Ranch, Inc.; Note: the entire King Ranch is included within KCGCD).

The summary results also point out the heterogeneity in the aquifer, with some wells having TDS values less than 1,000 mg/L while others exceed it (within a small region of interest).

The KCGCD has initiated a groundwater monitoring program where TDS has been inferred at 21 wells using a field probe. The data from this monitoring endeavor is depicted in Figure 9. Again, this sampling also confirms the general trends seen in Figure 7.

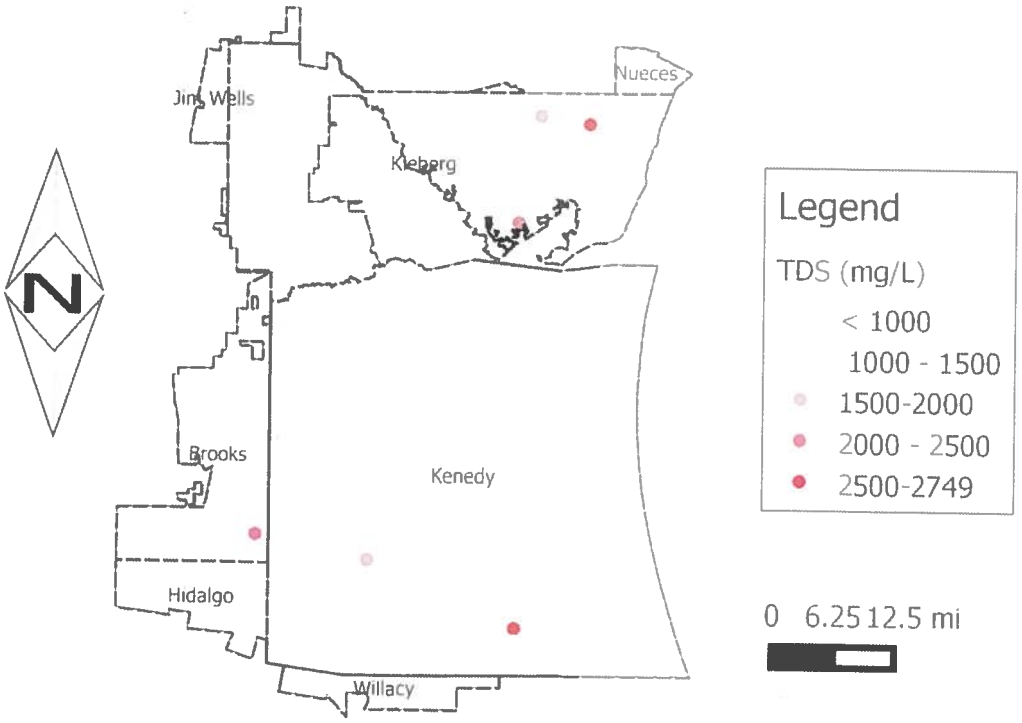

Figure 9: Total Dissolved Solids (TDS) measured as part of KCGCD Groundwater Monitoring Program (Data Courtesy: Mr. Andy Garza, General Manager KCGCD and collected using a field probe (Hanna Inc.))

Even when pockets of brackish groundwater have been identified within the Evangeline Aquifer, delineating a BGPZ within the Evangeline Aquifer is problematic. The aquifer exhibits high transmissivity and a fairly low storage coefficient (Chowdhury et al., 2004). As a result, pumping within the aquifer results in a rather large cone of depression. For example, the groundwater production by the City of Kingsville has resulted in a significant drawdown and a large cone of depression extending several miles. Given the high heterogeneity and lack of physical barriers, delineation of any BGPZs within the Evangeline Aquifer formation will likely cause freshwater migration into these brackish zones. The Evangeline Aquifer is also the sole source of water within the district and is used extensively by the City of Kingsville and other entities in the vicinity of the district. Given this significant use and other factors discussed above, it is recommended that BGPZs not be delineated within the Evangeline Aquifer within the district.

Summary and Recommendations

The overall goal of this study was to perform a preliminary assessment of groundwater quality within the Kenedy County Groundwater Conservation District and use existing data to evaluate the delineation of potential BGPZs. While TDS data have been collected over a long period of time, there are very limited data at any given well. The available TDS data from the Texas Water Development Board were stratified according to the aquifer. There are only two data points within the Burkeville Confining Unit and the

Jasper Aquifer. These existing data and the characteristics of these units indicate that they can be delineated as BGPZs. In particular, the Burkeville Confining unit can provide the necessary hydrogeological barrier that will minimize the effects on the overlying formations due to pumping of brackish groundwater from the Jasper Aquifer. The Chicot Aquifer exists as an unconfined formation within the district. The aquifer has sufficient thickness along the coast but thins out westward. This aquifer is also interconnected with the Gulf of Mexico. Based on this initial analysis, a BGPZ can be envisioned along the coast in the Chicot Aquifer. The quality of the water and the aquifer geology are perhaps not conducive for a BGPZ in the western sections of the Chicot Aquifer.

The Evangeline Aquifer is the most prolific aquifer within the district and in the surrounding areas. It is estimated that over 90% of the wells in the district tap into this aquifer. The Evangeline Aquifer has relatively good water quality and is important due to the lack of other water sources (particularly surface water sources) in the region. The City of Kingsville, located just outside the district boundary, is a major user of water from the Evangeline Aquifer. While pockets of brackish groundwater can be identified within the Evangeline Aquifer, considerable heterogeneity with closely spaced wells exhibiting significant water quality variations is also evident from the available data. The aquifer has high transmissivity but relatively low storage. Historical production by the City of Kingsville indicates the likely behavior of the aquifer, especially creation of a large cone of depression around the pumping zone. This aquifer behavior coupled with connectivity between fresh and brackish water zones and the significance of the aquifer to meeting the water demands in the region indicate that BGPZs should not be delineated within this aquifer within the district.

References

Baker, E.T., Jr., 1979, Stratigraphic and Hydrogeologic Framework of part of the Coastal Plain of Texas, Texas Department of Water Resources Report 236, 43 pp.

Barr-W Groundwater Exploration Inc., 2015, Draft DFC Explanatory Report, Submitted to Groundwater Management Area 16, 5 pp (excluding appendices).

Chowdhury, A., and R.E. Mace, 2007, Groundwater Resource Evaluation and Availability Model of the Gulf Coast Aquifer in the Lower Rio Grande Valley of Texas, Texas Water Development Board, Report 368, 120 pp.

Chowdhury, A.H., Wade, S., Mace, R.E. and Ridgeway, C., 2004, Groundwater Availability Model of the Central Gulf Coast Aquifer System: Numerical Simulations through 1999, Texas Water Development Board, 114 pp.

Mace, R. E., 2015, House Bill 30 Stakeholder Meeting Presentation, Available online: https://www.twdb.texas.gov/innovativewater/bracs/doc/2015_10_26_HB30_Stakeholder_1_Mtg.pdf (Accessed on: 12/1/2015).

Meyer, J.E., Croskrey, A.,Wise, M. R., and Kalaswad, S. 2014, Brackish Groundwater in the Gulf Coast Aquifer, Lower Rio Grande Valley, Texas, Report 383, Texas Water Development Board, 181 pp.

TWDB, 2015, Groundwater Database Reports; Available online: http://www.twdb.texas.gov/groundwater/data/gwdbrpt.asp, (Accessed on 12/1/2015).

Waterstone Inc., 2003, Excerpts from the Groundwater Availability Model of the Central Gulf Coast Aquifer System: Numerical simulations through 2050 Central Gulf Coast Texas, Texas Water Development Board, 158 pp.

Young S. C., Knox, P. R., Baker, E., Hamlin, S., Galloway, B. Deeds, N, 2010, Hydrostratigraphy of the Gulf Coast Aquifer from the Brazos River to the Rio Grande, Texas Water Development Board, 213 pp.