Goliad County Recharge Evaluation

Preliminary Report December 2018

Submitted by

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Submitted to

Goliad County Groundwater Conservation District

c/o Ms. Heather Sumpter

118 S. Market Street

Goliad, Texas 77963

December 2018

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Objective and Problem Statement

The primary objective this project is to improve the understanding and estimation of recharge values for the Gulf Coast Aquifer in Goliad County. These values feed into the Texas Water Development Board's Gulf Coast Aquifer (GCA) Groundwater Availability Model (GAM) that is used to derive the Modeled Available Groundwater for the Goliad County Groundwater Conservation District (GCGCD) based on the Desired Future Conditions. The District is concerned that the GAM results do not properly describe the past, present, and future recharge conditions in their jurisdiction. District Vice President Art Dohmann contacted Drs. Terry McLendon and Ken Rainwater of Texas Tech University (TTU) to propose tasks associated with this recharge uncertainty for potential funding by the District. Dr. McLendon led the recent ecohydrological modeling of Goliad County sponsored by the Texas State Soil and Water Conservation Board (TSSWCB) and the San Antonio River Authority (SARA). Dr. Rainwater has many years of expertise in field studies of recharge processes, groundwater hydrology, groundwater modeling, and the State's regional water planning and groundwater management processes. He also participates with Dr. McLendon's ecohydrological modeling team. Dr. McLendon retired from TTU in 2017, and his academic position went to Dr. Cade Coldren, a long-time EDYS team member who is now part of this project team. Dr. McLendon remains available for advisory work as needed.

Tasks

After negotiation of scope and budget with the GCGCD, the following tasks were identified for the initial contract. These tasks include establishment of multiple sites for field observation of recharge potential and review of pertinent documents that describe recharge process in Goliad County. The field observations are planned to continue for three to five years, so another proposal will be generated in 2019. The 2018 work can also support future applications of the Goliad County EDYS model to simulate the long-term impacts of historical changes in vegetation distributions on recharge across the County. This report summarizes the findings of these two tasks.

<u>1. Updated approach for local recharge estimates within the District</u>

The TTU team worked with the GCGCD staff to establish field sites that allow observation of soil moisture movement past the root zone toward the groundwater. Two properties were identified, and three observation sites were set up at each property. Data collection began and is planned to continue for several years to allow for variable rainfall conditions. Rainwater and Coldren (2018) previously reported the details of the instrumentation choices and site positions. Table 1 summarizes the details about the soil moisture sensors and weather stations. Appendix A includes excerpts from the Soil Survey Staff (2018) Web Soil Survey for the soil conditions at the two sites. Both sites are dominated by sandy loam and sandy clay loams.

Data collection began on June 28, 2018 at four of the soil moisture sensor sites and both weather stations. Two of the soil moisture sensor sites, L2 and D3, were started on August 23, 2018, due to operator error on June 28 (improper initiation of software data collection process).

Table 1. Installation Details

Land Use	Site	Latitude (DD)	Longitude (DD)	P1 (ft)	P2 (ft)	P3 (ft)	P4 (ft)	P5 (ft)
Culitvated Landgrebe	L1	28.88164	-97.39657	1.0	3.3	4.9	4.9	5.9
	L2	28.88614	-97.39632	1.0	3.3	lost	4.9	5.9
	L3	28.88155	-97.39714	1.0	3.3	4.9	4.9	9.5
	WS	28.88164	-97.39657					
Ranch Dohmann	D1	28.79439	-97.42340	1.0	3.3	4.9	4.9	8.2
	D2	28.79519	-97.42325	1.0	3.3	4.9	4.9	8.2
	D3	28.79480	-97.42204	1.0	3.3	4.9	4.9	8.2
	WS	28.79410	-97.42496					

Fortunately, little precipitation occurred before August 23, so no significant events were missed. Subsequent data downloads were done by both the District staff and the TTU team. The final 2018 downloads were collected on November 20, 2018. All data text files were converted to Excel spreadsheets for analyses and plotting. All Excel files are available upon request, as the tables are too large for inclusion in this report. It should be noted that the actual soil moisture readings were still impacted by the water used in the sensor installation process, and the time required for full equilibration with the surrounding soil was unknown. As water infiltrates to the sensors after more intense storms, the conditions are also changing in the surrounding soil. The true indication of potential recharge will be significant increases in soil moisture content all the way to and past the deepest Probe 5. We hope that our borehole installation process did not encourage short-circuit flow through the backfill soils and bentonite. Multiple years will likely be necessary for observation of multiple such events. No quantitative analyses of these data have been performed at the time of this report, as it is too early for such calculations.

The observations for the Landgrebe location are presented in Figures 1 to 5. Figure 1 provides a bar chart for the weather station data for daily rainfall (blue) and evapotranspiration for a hypothetical reference grass as used in the Penman-Monteith equation (orange, ET Ref) in in/d. Notable rainfall days (> 1 in/d) were noted on July 8 (1.56 in/d), September 15 (4.05 in/d), October 15 (2.97 in/d), and November 9 (1.76 in/d). Figure 2 tracks the cumulative rainfall and ET Ref for the June 28 to November 20, 2018, duration. The total rainfall depth was 23.68 in, while the total ET Ref was 21.21 in. Figures 3 to 5 track the observed soil moisture content at each sensor for sites L1, L2, and L3, respectively. Comparison of Figure 1 with Figures 3, 4, and 5 shows that the more intense rainfall events did show increases in soil moisture content at the probes, especially the largest September event.

The Dohmann location observations are presented in Figures 6 to 10. Figures 6 and 7 provide the daily and cumulative rainfall and ET values, respectively. Notable rainfall days (> 1 in/d) were noted on August 29 (1.61 in/d), September 10 (1.05 in/d), September 15 (2.63 in/d), September 16 (1.17 in/d) September 20 (1.26 in/d), October 15 (4.40 in/d), October 23 (2.20 in/d), and November 9 (3.81 in/d). The total precipitation depth was 28.59 in, while the total ET Ref was 20.80 in. Figures 8 to 10 track the observed soil moisture content at each sensor for sites D1, D2, and D3, respectively. Comparison of Figure 6 with Figures 8, 9, and 10 shows that the more intense rainfall events did show increases in soil moisture content at the probes, especially the largest September and October events.

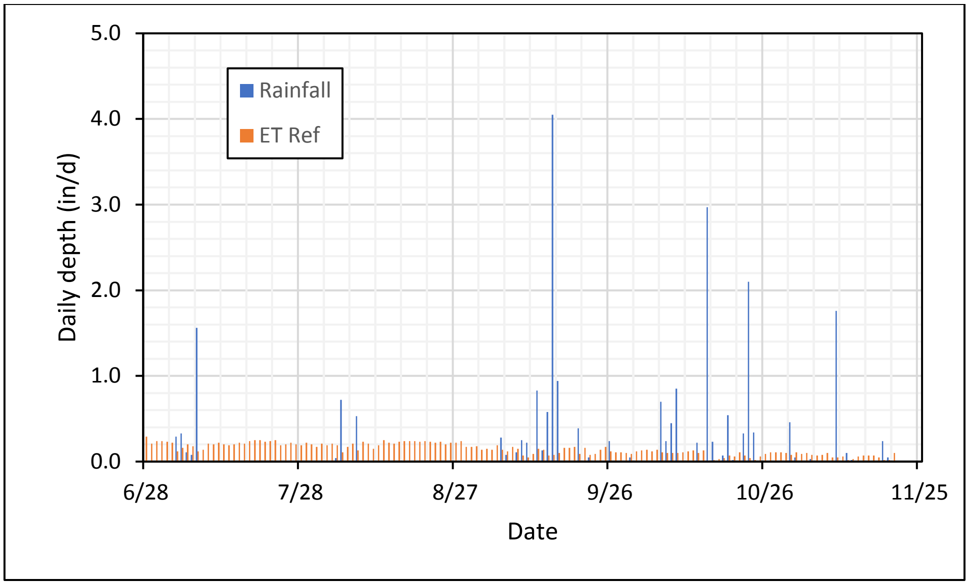


Figure 1. Landgrebe Weather Station Daily Rainfall and ET, 6/28/2018 to 11/20/2018

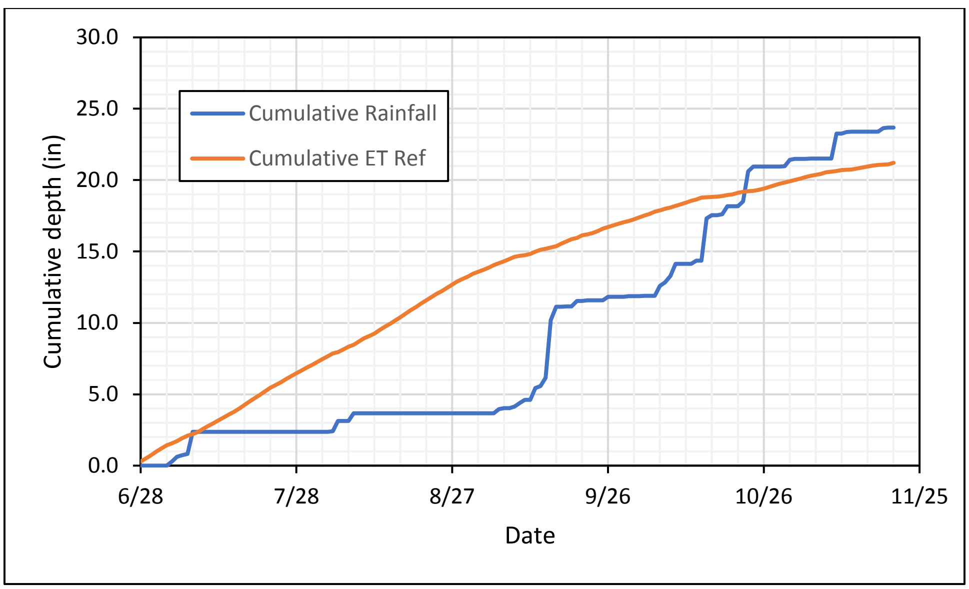


Figure 2. Landgrebe Weather Station Cumulative Rainfall and ET, 6/28/2018 to 11/20/2018

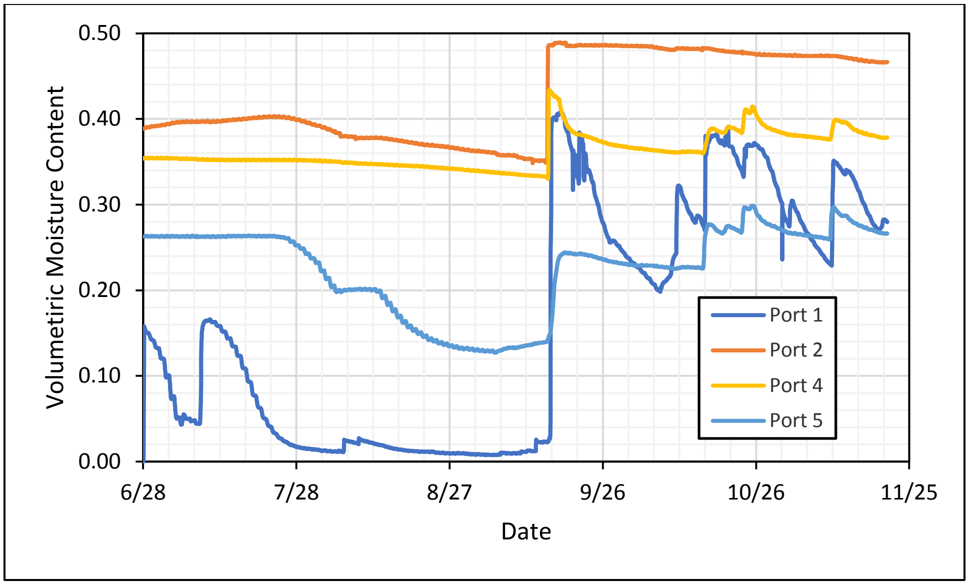


Figure 3. Landgrebe 1, 6/28/2018 to 11/20/2018

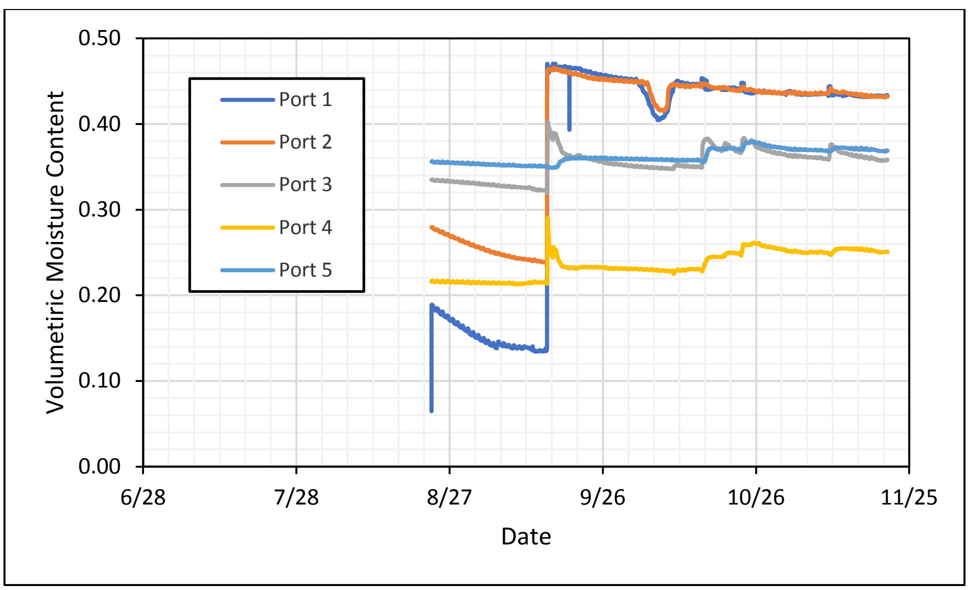


Figure 4. Landgrebe 2, 8/23/2018 to 11/20/2018

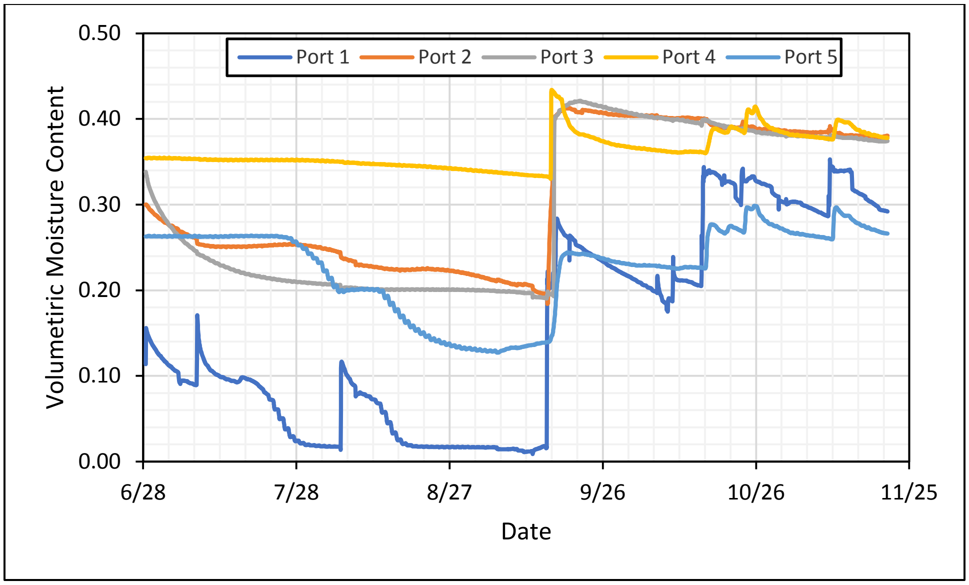


Figure 5. Landgrebe 3, 6/28/2018 to 11/20/2018

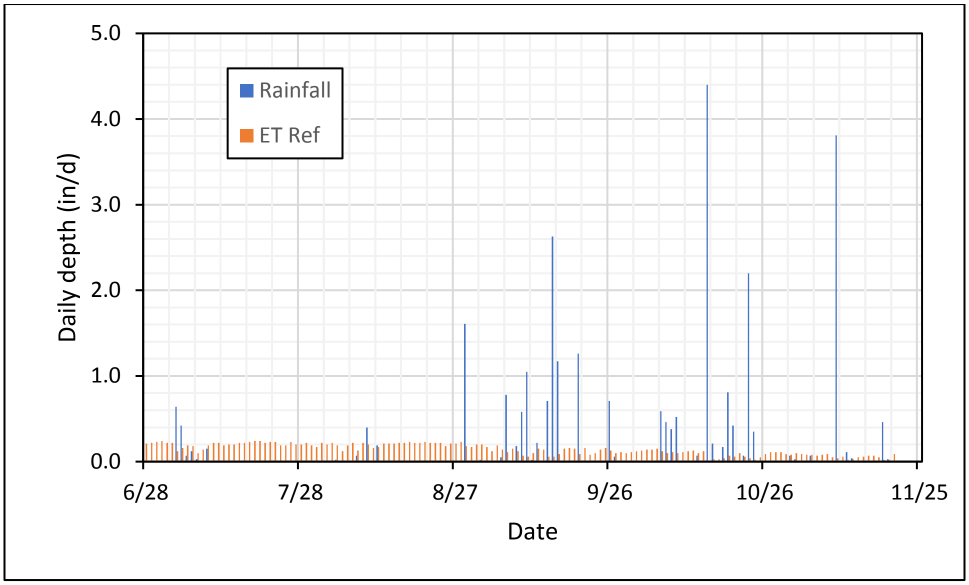


Figure 6. Dohmann Weather Station Daily Rainfall and ET, 6/28/2018 to 11/20/2018

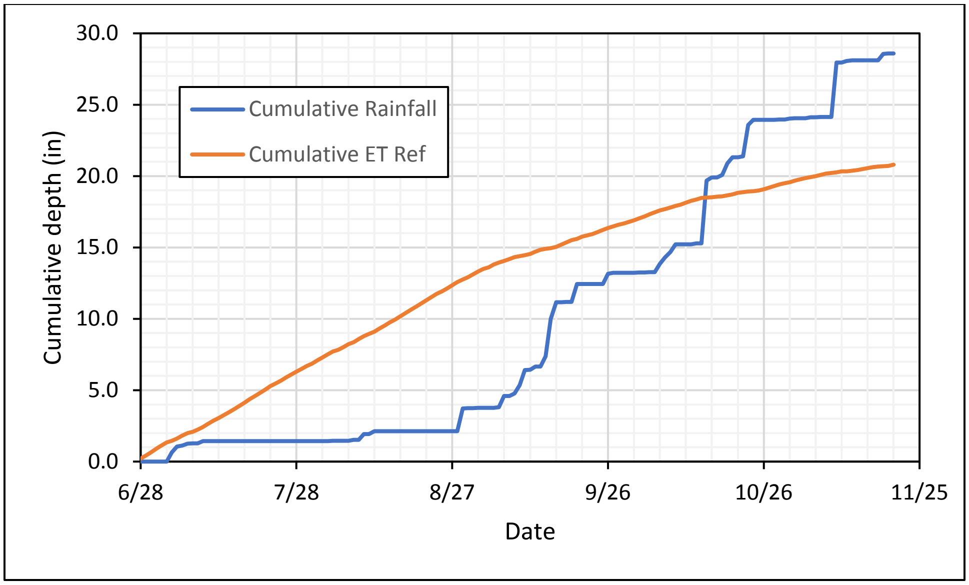


Figure 7. Dohmann Weather Station Cumulative Rainfall and ET, 6/28/2018 to 11/20/2018

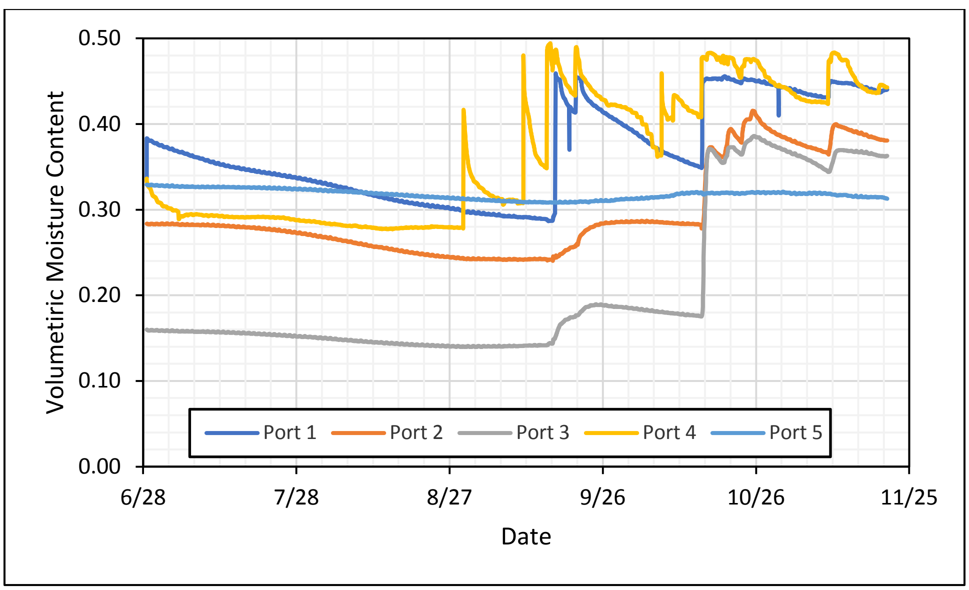


Figure 8. Dohmann 1, 6/28/2018 to 11/20/2018

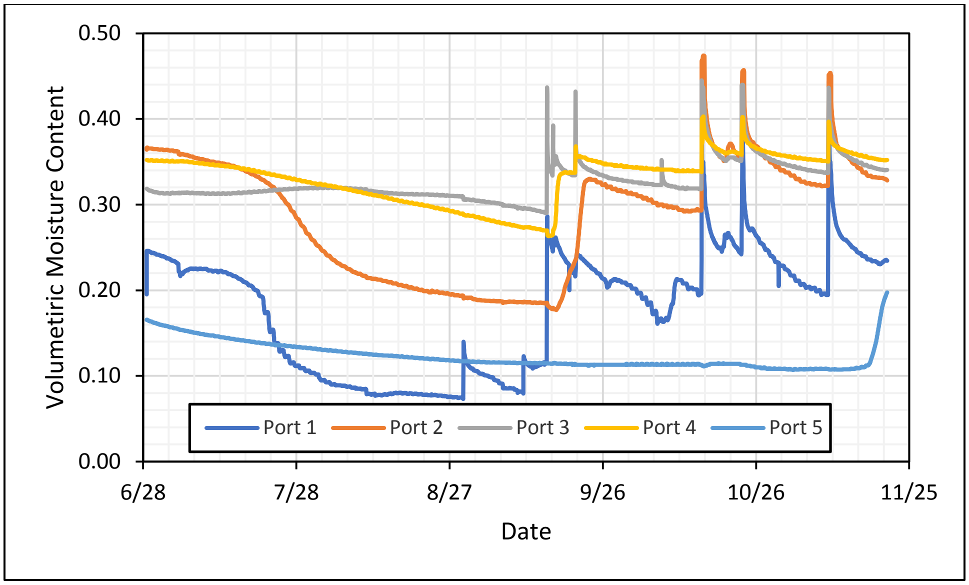


Figure 9. Dohmann 2, 6/28/2018 to 11/20/18

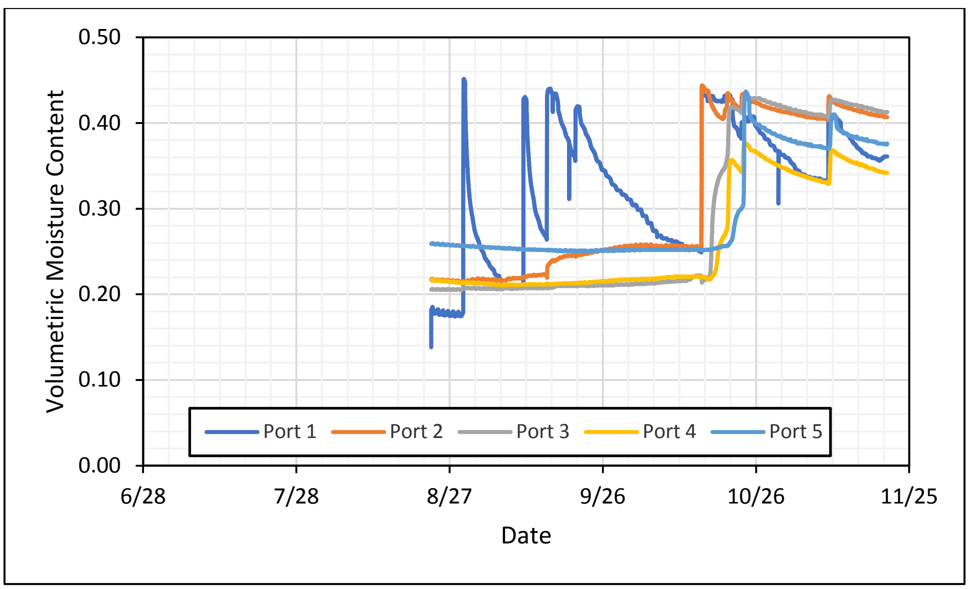


Figure 10. Dohmann 3, 8/23/2018 to 11/20/2018

2. Review of existing information provided by the District

Dr. Rainwater reviewed all documents related to the District's groundwater and recharge conditions as provided by the District. These documents included recent work by Daniel B. Stephens and Associates, the TWDB, and others related to the region's GAM work. Dr. Rainwater explains the previous approaches to recharge simulation used by these parties in this report. He also compares those applications to the water lost to groundwater in the recent Goliad County model presented by Dr. McLendon's team.

Review of Supplied Documents

The following documents were provided electronically by the District staff or obtained by Dr. Rainwater.

- Chowdhury, A., Wade, S., Mace, R., and Ridgeway, C., 2004. Groundwater Availability Model of the Central Gulf Coast Aquifer System: Numerical Simulations through 1999: Model Report, Texas Water Development Board, Austin, TX, 114 p.
- Dale, O., Moulder, E. and Arnow, T., 1957. Ground-water Resources of Goliad County, Bulletin 5711, Texas Board of Water Engineers, Austin, TX, 102 p.
- Donnelly, A., 2018. Memorandum, Daniel B. Stephens & Associates, Austin, TX, 31 p.
- Goliad County Groundwater Conservation District, 2016. Proposed Desired Future Condition, Goliad, TX, 3 p.
- Groundwater Management Area 15, 2018. Proposed Desired Future Conditions, 2 p.
- McLendon, T., Booker, J., Coldren, C., and Pappas, C., 2016. Development of an EDYS Ecological Model for Goliad County, Texas, Final Report, San Antonio River Authority and Texas State Soil and Water Conservation Board, San Antonio, TX., 243 p.
- Muller, D. and Price, R., 1979. Ground-water Availability in Texas: Estimates and Projections Through 2030, Report 238, Texas Department of Water Resources, Austin, TX, 73 p. (cited by others)
- Scanlon, B., Dutton, A., and Sophocleous, M., 2010. Groundwater Recharge in Texas; special report prepared for the Texas Water Development Board, 2010, 84 p. (cited by Donnelly, not available for review, substituted next reference)
- Scanlon, B., Reedy, R., Strassberg, G. Huang, Y., Senay, G. 2011. Estimation of Groundwater Recharge to the Gulf Coast Aquifer in Texas, USA, Final Contract Report, Texas Water Development Board, Austin, TX, 128 p.
- Waterstone Environmental Hydrology and Engineering, Inc., 2003. Groundwater Availability of the Central Gulf Coast Aquifer: Numerical Simulations to 2050, Central Gulf Coast, Texas, Final Report, Texas Water Development Board, Austin, TX, 226 p.

The earliest document was produced by Moulder and Arnow (1957) for the Texas Board of Water Engineers in cooperation with the U.S. Geological Survey and the SARA. This report provided an overview of general groundwater quantity and quality issues in Goliad County. Recharge to the water table was discussed only in a conceptual manner, occurring as a small portion of precipitation on the outcrop areas for the Evangeline and Chicot aquifers, or from streamflow along the river channels in Goliad County. No quantitative values were provided at any locations.

The reports by Chowdhury et al. (2004) and Waterstone (2003) documented two cooperative modeling studies for the Central Gulf Coast (CGC) aquifer GAM for historical calibration through 1999 and predictive simulations through 2050. Both reports referred to previous CGC GAM work by the USGS and others (documents were not provided by the GCGCD) and to the work of Muller and Price (1979) for recharge value assignment as a percentage of annual rainfall varying for different soil types in the outcrop areas. Figures 11 and 12 show the major formation outcrop extents and surface geological materials across the CGC model domain (Waterstone 2003). Note that three surface geological material types were shown in Goliad County: major recharge sand (over most of Evangeline), aquifer recharge zone (over Chicot), and expansive clay and mud (in northernmost Goliad County over Evangeline). Neither report explained the calculations that were done to establish the recharge values, but both cited Muller and Price's (1979) discussion of the groundwater availability in the GCA system. Muller and Price (1979) in turn discussed the important modeling work that was done in the 1970s to understand subsidence problems caused by large groundwater withdrawals in Harris and adjacent counties. Muller and Price (1979) noted that those works concentrated on calibration for those locations, then applied those local parameter values to a larger Gulf Coast model domain. A recharge value of 4 percent of annual average precipitation applied to the aquifer outcrop areas was found through the model calibration process, meaning that this estimated recharge value was subject to uncertainties in the other model parameters such as aquifer hydraulic properties (hydraulic conductivity and storage coefficient) and groundwater withdrawals. Waterstone (2003) refined Muller and Price's (1979) approach to generate distributed recharge rates across the CGC GAM area that allowed for variations in mean annual rainfall depth and surface geological materials (intended to represent the conditions in the unsaturated zone through which percolation can occur). Figure 13 displays the resulting map of the CGC GAM recharge values (Waterstone 2003). The recharge units were not stated by Waterstone (2003), but the small numbers imply the units are ft/d as used in the MODFLOW CGC GAM. For reference, 0.00005, 0.0001, and 0.0005 ft/d as shown for the regions in Goliad County convert to 0.22, 0.44, and 2.2 in/yr. Chowdhury et al. (2004) were unclear about their recharge values for the predevelopment work after presenting a table of widely varying recharge values from previous Gulf Coast modeling studies and only stated that they did not recalibrate recharge. As Chowdhury et al. (2004) and Waterstone (2003) were simultaneous works, it is most likely that Figure 13 described the recharge distribution used by both teams. It should be noted that Chowdhury et al. (2004) recognized that the Gulf Coast model simulations were more sensitive to lower recharge values, which decreased local water table elevations, than higher recharge values, which allowed excess water to leave as spring flow to rivers. Recharge and aquifer hydraulic conductivity also combine to affect water table movement, as lower hydraulic conductivity slows the lateral movement of recharge from the outcrop area, slowing water table decline. They also said the present knowledge of recharge distribution for the CGC GAM was not adequate.

Donnelly (2018) reviewed the recharge descriptions for the Goliad County area in multiple documents with greater focus on the more recent CGC GAM work. Figure 14 was provided as the distribution of recharge values for Goliad County in the current CGC GAM applied for GMA 15 simulations. The orange cells over the Evangeline outcrop have recharge rates from 0 to 0.25 in/yr, while the green cells over the Chicot outcrop have recharge rates of 0.75 to 1.0 in/yr. He also referred to a TWDB recharge study by Scanlon et al. (2010) submitted as a special report but not readily available on the TWDB website. A related report for the Gulf Coast region by Scanlon (2011) was found, so that document was substituted for this discussion.

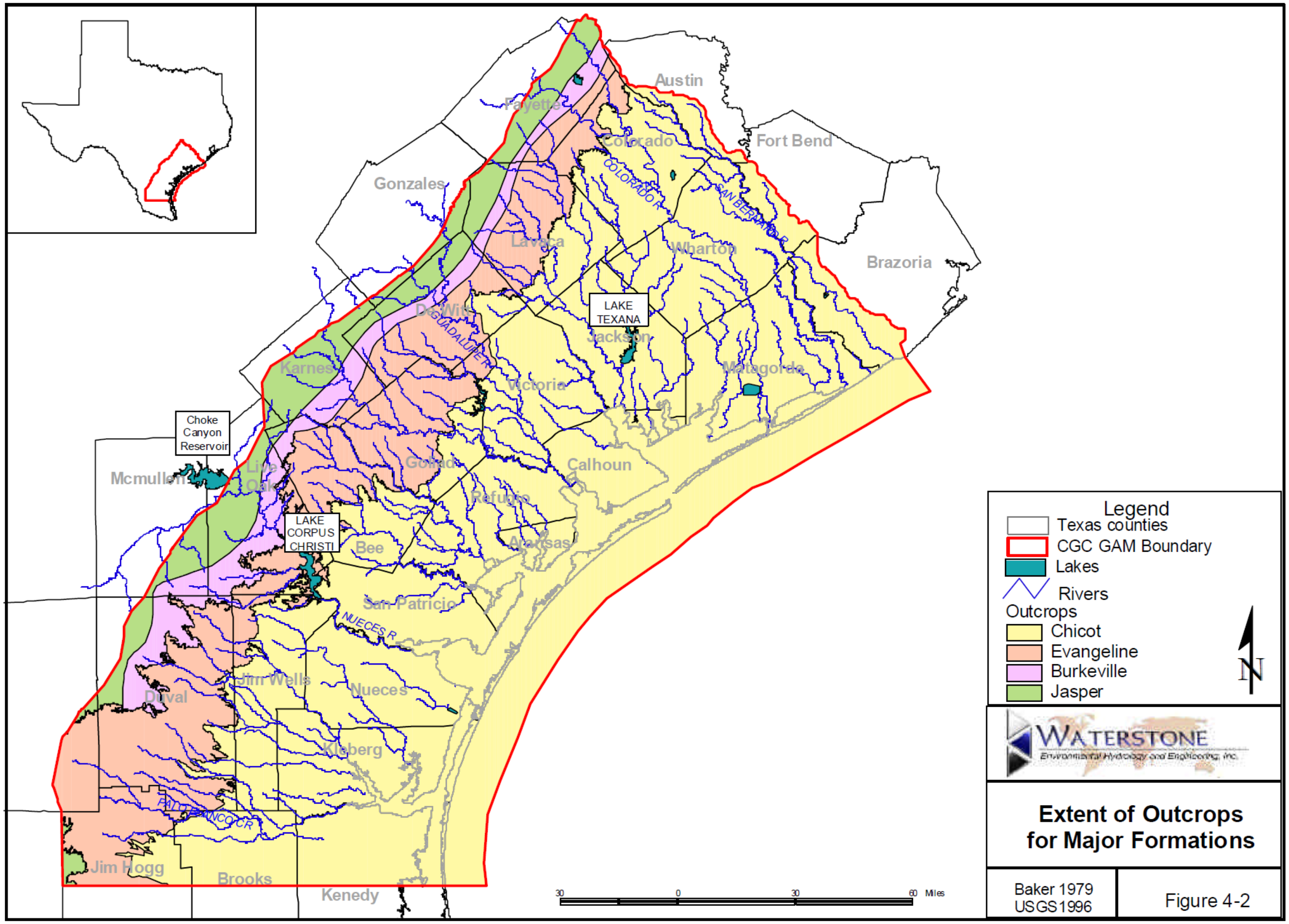


Figure 11. Extent of Outcrops of Major Formations in CGC GAM (Waterstone 2003)

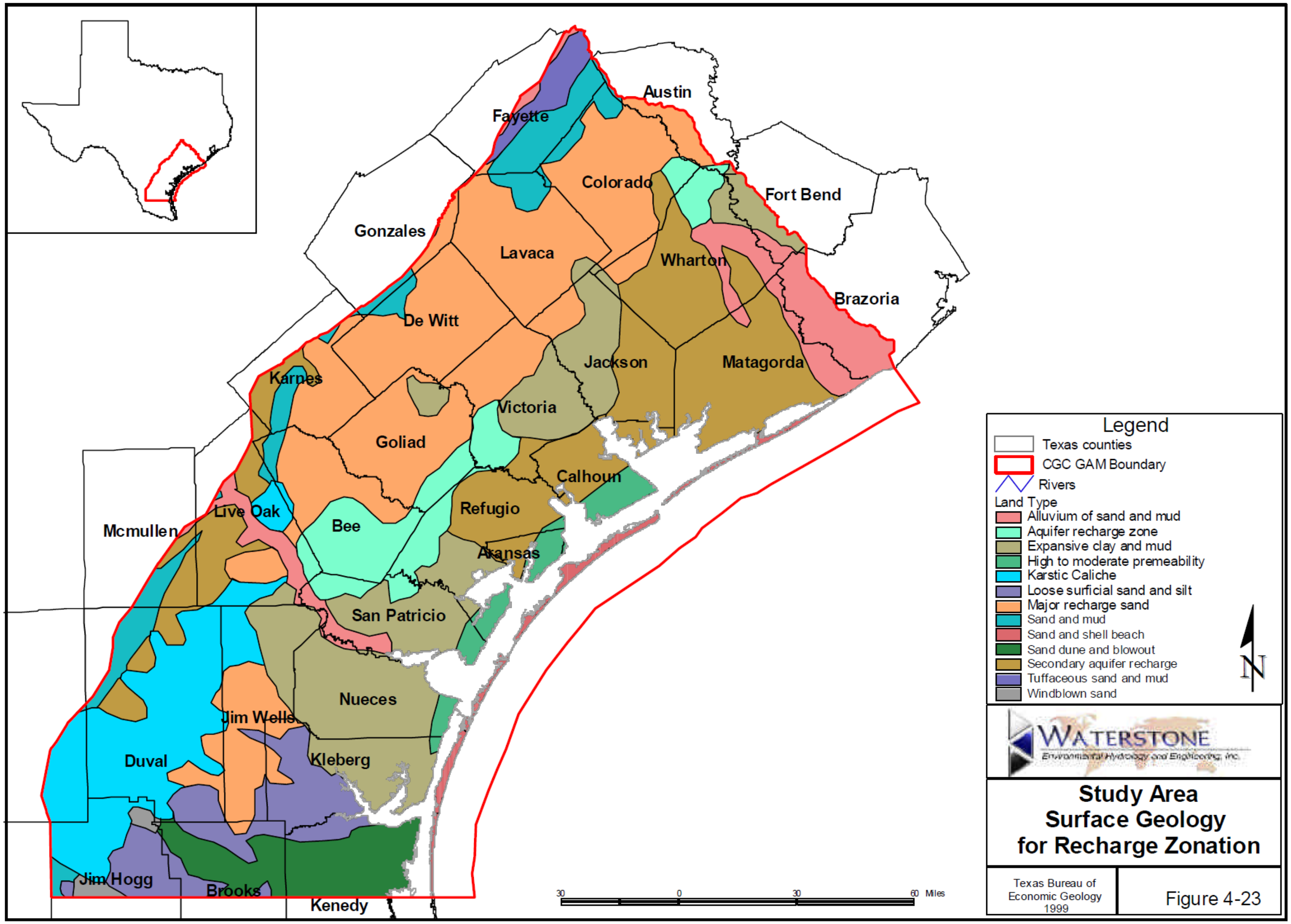


Figure 12. Surface Geological Materials in CGC GAM Area (Waterstone 2003)

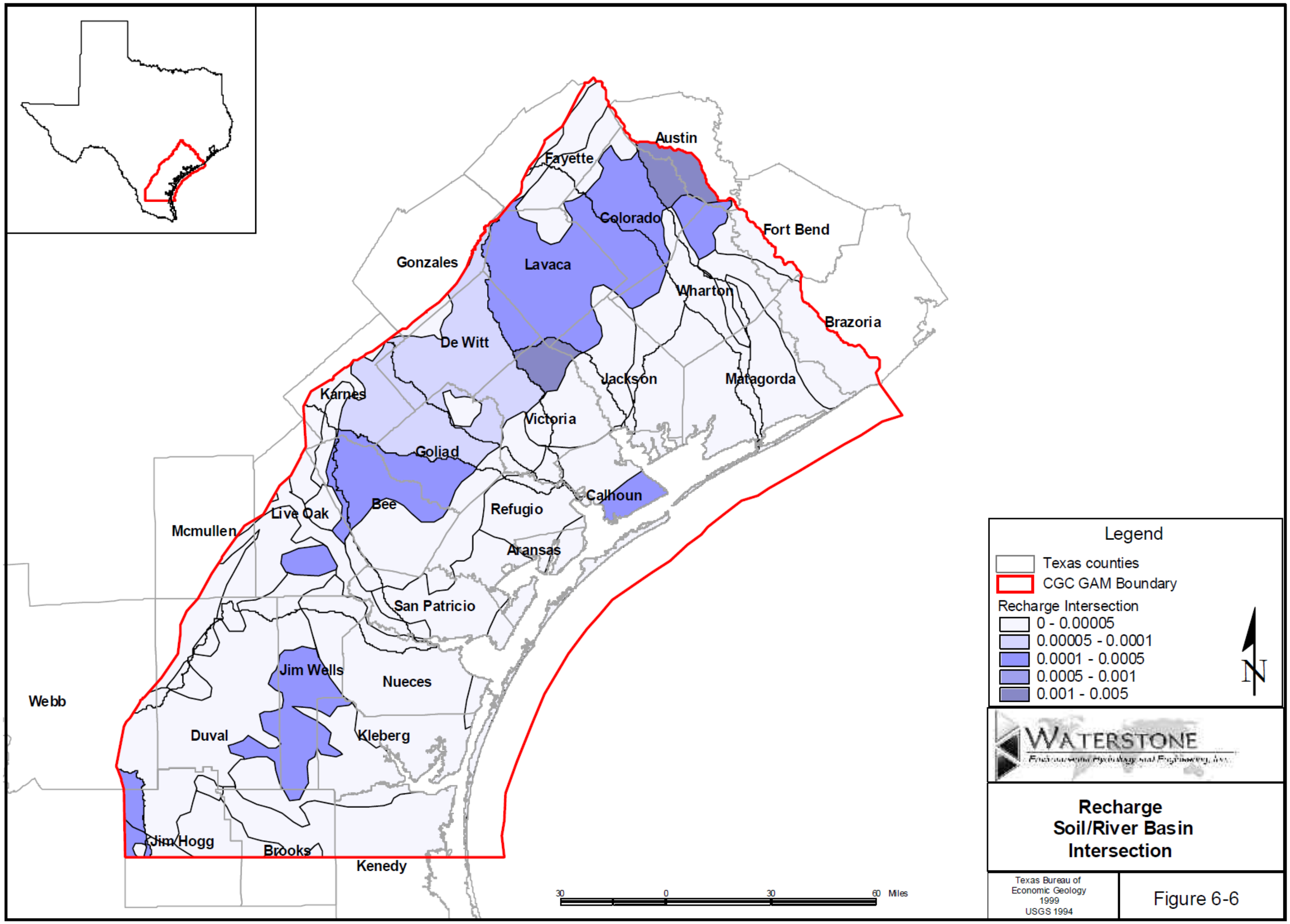


Figure 13. Recharge Distribution in CGC GAM (Waterstone 2003)

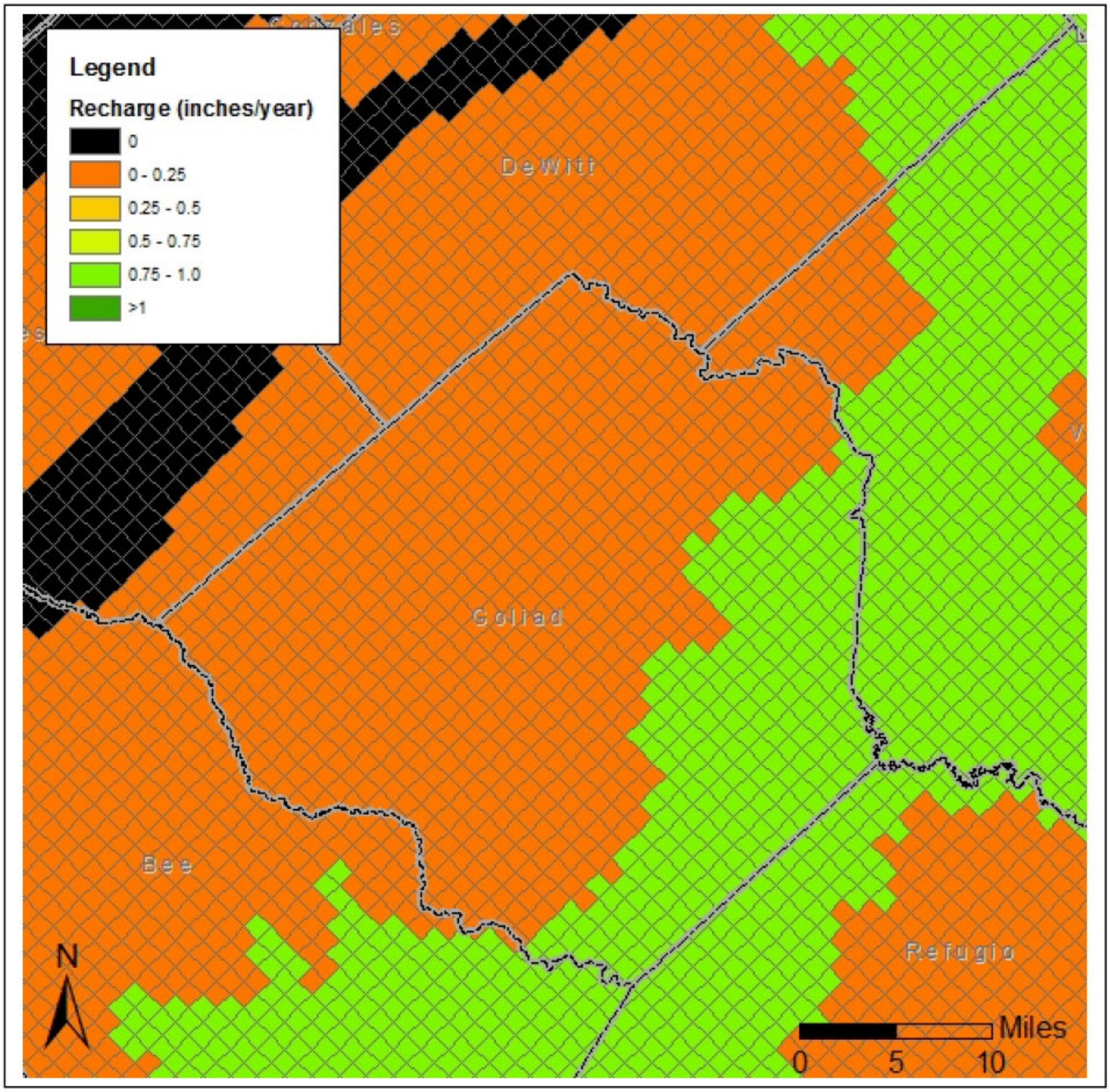


Figure 14. Distribution of Recharge Rates for GMA 15 Predictive Simulations (Donnelly 2018)

Scanlon et al. (2011) considered multiple methods for regional recharge distributions, including water table variations, fractions of annual precipitation, and the chloride mass balance (CMB) approach. They reviewed previous works that included recharge rate estimates, such as predevelopment recharge rates of 0.14 in/yr in the Chicot outcrop and 0.41 in/yr in the Evangeline outcrop. This document emphasized the CMB approach through comparison of chloride content in rainfall to [1] chloride concentration in the residual water in the unsaturated zone as found in samples collected from boreholes and [2] chloride concentration in shallow groundwater. The effective recharge rate can be found by Equation 1:

$$R_{CMB}=\frac{P\,Cl_p}{Cl_{UZ}}=\frac{P\,Cl_p}{Cl_{GW}} \qquad [1]$$

where R_{CMB} = recharge rate (in/yr) from CMB, P = precipitation rate (in/yr), Cl_P = chloride concentration (mg/L) in precipitation, Cl_{UZ} = chloride concentration (mg/L) in the unsaturated zone in the borehole samples, and Cl_{GW} = chloride concentration (mg/L) in the groundwater. The first CMB approach is primarily limited by the number, depth, and spatial distribution of borehole locations. Table 2 provides the results for the three boreholes in Goliad County. Figure 15 displays the spatial distribution of CMB recharge rates based on the second method. The three ranges of CMB recharge rate in Goliad County (roughly outlined with red polygon) are less than 0.1 to 0.25, 0.25 to 0.5, and 0.5 to 1 in/yr. It is interesting to note the differences in Figures 14 and 15, as well as the highest recharge rate zone in the county in Figure 15 is positioned similarly to the expansive clay and mud zone in Figures 12 and 13. There is no direct way to verify which distribution of recharge values is more correct.

Table 2. Recharge Estimates from CMB Boreholes in Goliad County (Scanlon et al. 2011)

Borehole	Setting (Outcrop)	Depth (ft)	P (in/yr)	Cl_P (mg/L)	R_{CMB} (in/yr)	% of Pr
Gol 10-1	South (Chicot)	36.5	36.6	1.74	0.03	0.1
Gol 10-2	North (Evangeline)	21.0	35.4	1.30	0.36	1.0
Gol 10-3	Central (Evangeline)	15.5	34.8	1.46	2.00	5.7

Each of the recharge estimation processes mentioned so far has excluded consideration of land use, vegetation types, and vegetation distributions on the infiltration of water into and through the unsaturated zone. McLendon et al. (2016) assembled an ecohydrological EDYS model of Goliad County for the SARA and TSSWCB's Water Supply Enhancement Program. The purpose of that model was to characterize the movement of water through the county's subwatersheds based on soils, slopes, land use, vegetation, and seasonal rainfall and plant growth cycles with a spatially discrete grid-cell-based model domain. While this EDYS model did not simulate groundwater movement directly, the water balance by cell and subwatershed does calculate a net soil storage value for each time step based on

$$\text{Net Soil Storage} = \text{Rainfall} + \text{Groundwater Use} - \text{Evapotranspiration} - \text{Runoff} \qquad [2]$$

where Groundwater Use is the groundwater used by transpiration by vegetation with roots deep enough to consume groundwater. Each value in Equation 2 is expressed a depth of water per time step, assumed to occur over the grid cell area. Table 3 summarizes the major water balance components for nine simulated scenarios with the Goliad EDYS model. The baseline group considered the current distribution of land use and vegetation, while the brush control group simulated removal of 100 percent or 50 percent of the oak woody vegetation. The cultivation group considered different levels of cultivated land. Precipitation (PPT) conditions for the scenarios were established by extracting 25-consecutive year periods that were closest to the average annual precipitation value (Ave) for the complete period of record, wettest (Wet), and driest (Dry). For seven of the nine scenarios simulated, the net soil storage value was negative, indicating overall loss of water from the subsurface and thus little to no available water for deep recharge. Consideration of these land use and vegetation impacts on current recharge leads to the conclusion that over time little to no water is likely available to reach the water table. Full details of the results are available in McLendon et al. (2016) report.

As the GCGCD considers continuation of this recharge study, the Board and District should be encouraged that the current field work is collecting useful data for actual observation of infiltration of

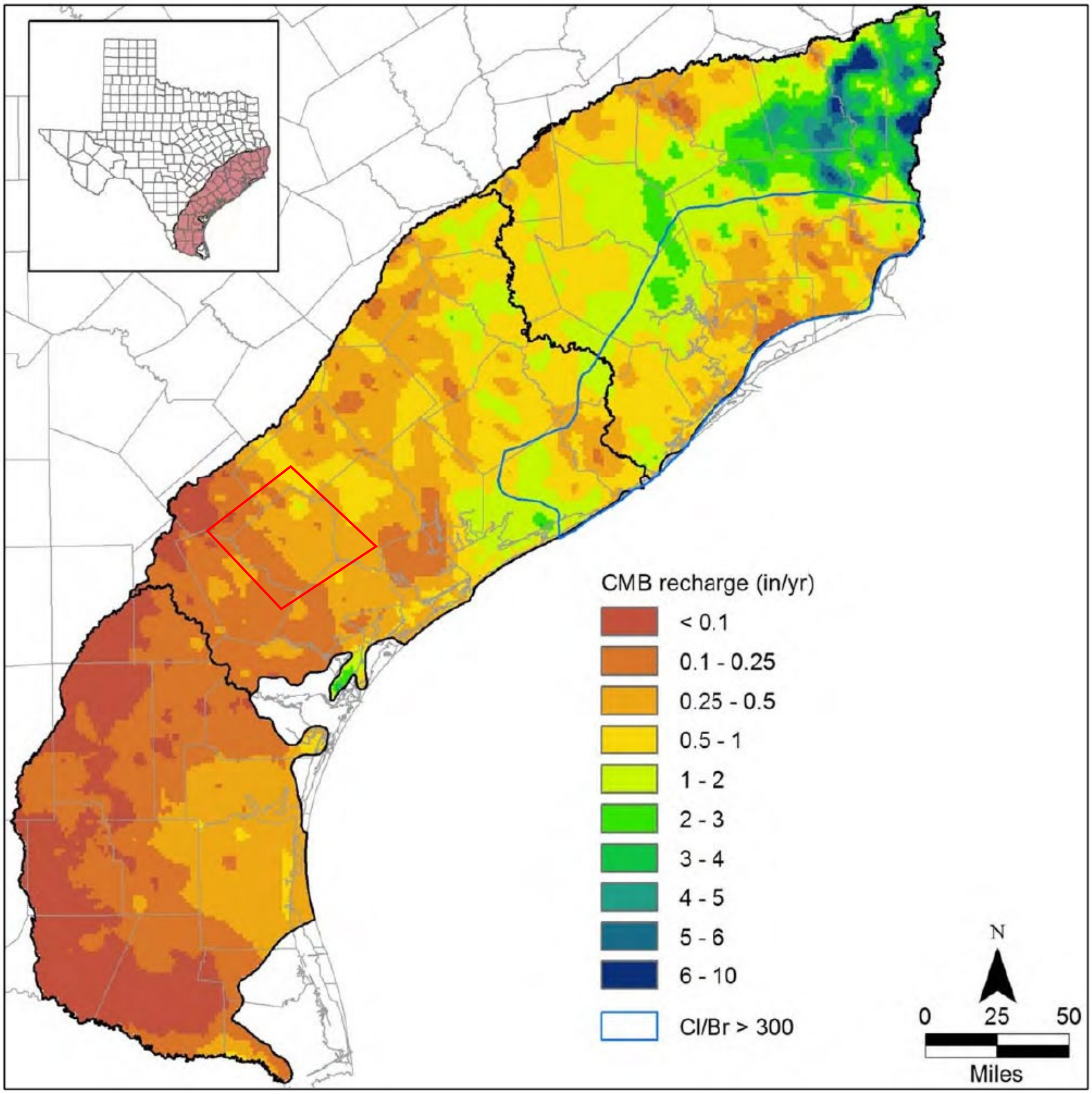


Figure 15. Distribution CMB Recharge Rates Based on Cl_P and Cl_{GW} (Scanlon et al. 2011)

water into the subsurface. The regional approaches are unable to represent all the watershed characteristics that affect the fates of precipitation. The uncertainties in all the methods discussed in this review can only be reduced through “ground-truth” local-scale observations. The EDYS model of Goliad County will be useful for demonstrating the impacts of historical and future local land use and vegetation changes on runoff and net soil storage.

Table 3. Effects of Moisture Regime, Brush Control, and Cultivation on Average Annual Water Balance Components (ac-ft) for 25-year Simulations with Goliad County EDYS Model (McLendon et al. 2016)

Groups	Scenario	Rainfall	Groundwater Use	Runoff	ET	Net Soil Storage
Moisture Regime	Baseline, Ave PPT	1,487,218	172,320	19,094	1,726,256	-75,902
	Baseline, Dry PPT	1,364,762	166,383	15,900	1,604,361	-88,116
	Baseline, Wet PPT	1,723,842	155,747	34,477	1,855,027	-9,915
Brush Control	100% Oak, Ave PPT	1,487,218	131,096	19,101	1,641,010	-41,797
	50% Oak, Ave PPT	1,487,218	121,510	19,121	1,620,939	-31,332
	50% Oak, Dry PPT	1,365,762	118,991	15,923	1,507,877	-39,047
	50% Oak, Wet PPT	1,723,842	111,476	34,498	1,759,930	+40,890
Cultivation	6.5% of County Area	1,487,218	157,674	18,897	1,675,645	-49,650
	21% of County Area	1,487,218	125,343	18,281	1,561,468	+32,812

References

Rainwater, K. and Coldren, C., 2018. Site Installations for Goliad County Groundwater Conservation District Recharge Study, Report to Goliad County Groundwater Conservation District, Goliad, TX, 8 p.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture, 2018. Web Soil Survey, available online at the following link: https://websoilsurvey.sc.egov.usda.gov/. Accessed December 2018.

Appendix A. Excerpted Soil Reports for the Two Locations (Soil Survey Staff 2018)

Soil Map—Goliad County, Texas
(Landgrebe soils map)

Map Scale: 1:2,050 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0 30 60 120 180

Feet: 0 50 100 200 300

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 14N WGS84

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Goliad County, Texas
Survey Area Data: Version 25, Sep 14, 2018

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

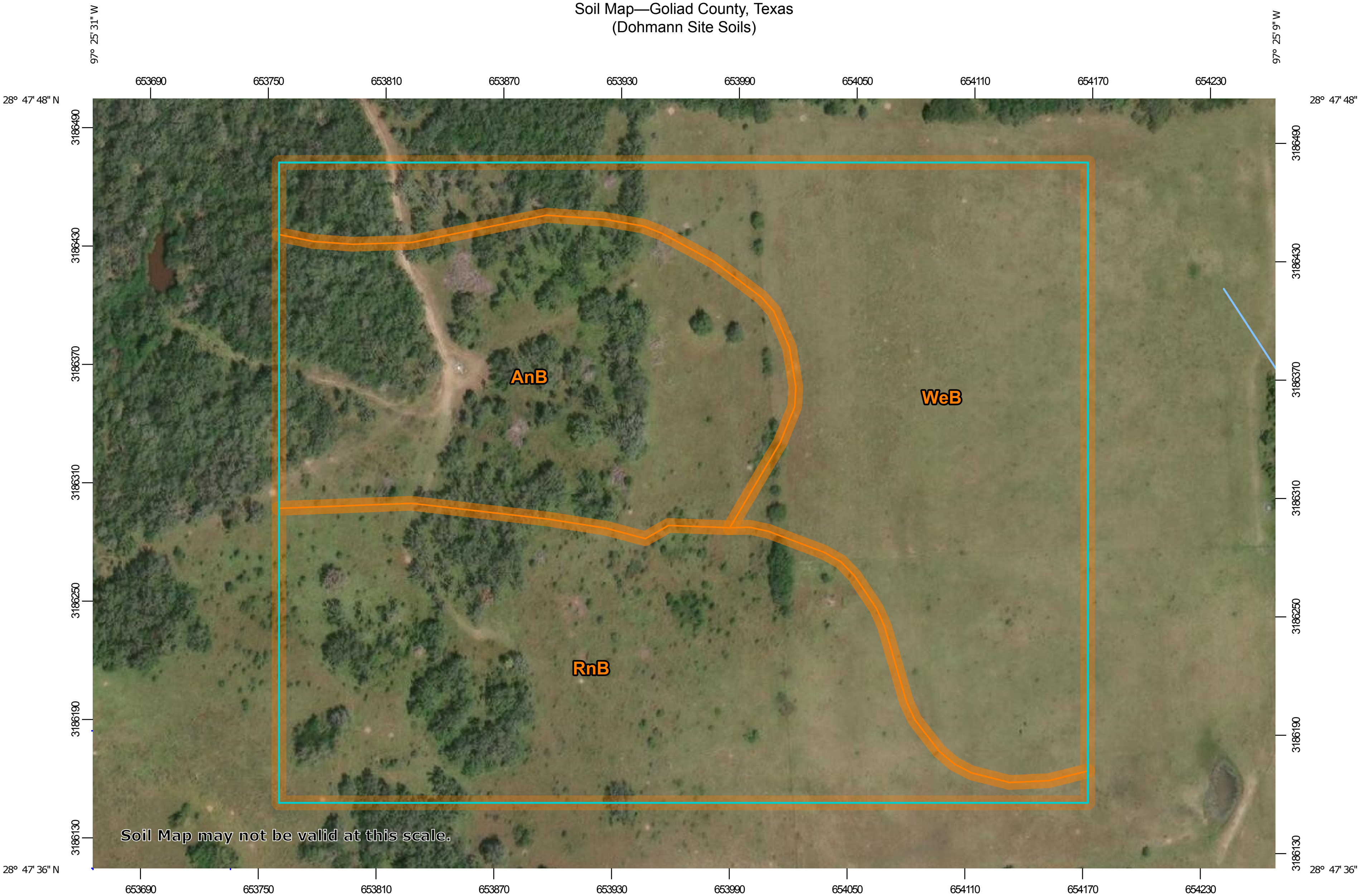
Date(s) aerial images were photographed: May 28, 2010—Oct 17, 2017

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

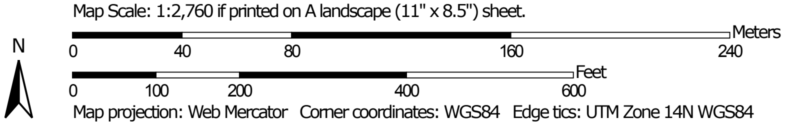
Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
AnA	Ander fine sandy loam, 0 to 1 percent slopes	2.1	10.7%
CrB	Clareville sandy clay loam, 1 to 3 percent slopes, rarely flooded	2.4	11.9%
PtC	Pernitas sandy clay loam, 2 to 5 percent slopes	15.4	77.4%
Totals for Area of Interest		**19.8**	**100.0%**

Soil Map—Goliad County, Texas
(Dohmann Site Soils)



Map Scale: 1:2,760 if printed on A landscape (11" x 8.5") sheet.



Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 14N WGS84

MAP LEGEND

Area of Interest (AOI)
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Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Goliad County, Texas
Survey Area Data: Version 25, Sep 14, 2018

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: May 28, 2010—Oct 17, 2017

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
AnB	Ander fine sandy loam, 1 to 3 percent slopes	8.8	26.6%
RnB	Raisin fine sandy loam, 1 to 3 percent slopes	11.4	34.2%
WeB	Weesatche sandy clay loam, 1 to 3 percent slopes	13.0	39.1%
Totals for Area of Interest		**33.2**	**100.0%**