Phase 2 Subsidence Investigations

Prepared for

Lone Star Groundwater Conservation District

Prepared by

LSGCD Technical Consulting Team

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GEOSCIENTIST SEALS

This report documents the work of the following licensed professional geoscientists.

Michael R. Keester, P.G.

Mr. Keester was primarily responsible for preparing report sections on the Brackish Jasper Aquifer Conceptual Model Review and Phase 3 Drilling and Testing Plan along with the related summary and conclusions. Mr. Keester was also responsible for finalizing the project summary report.

STATE OF TEXAS
MICHAEL R. KEESTER
GEOLOGY
10331
LICENSED
PROFESSIONAL GEOSCIENTIST

05/06/2022

Principal | Hydrogeologist – R. W. Harden & Associates, Inc. (TX Geoscientist Firm License #50033)

Christopher Drabek, P.G.

Mr. Drabek was primarily responsible for preparing the report section on the Gulf Coast Aquifer System Geologic Structure along with the related summary and conclusions. He also provided review and QA/QC of the final report.

STATE OF TEXAS
CHRISTOPHER DRABEK
GEOLOGY
4564
LICENSED
PROFESSIONAL GEOSCIENTIST

05/06/2022

Christopher Drabek

Senior Hydrogeologist – Advanced Groundwater Solutions, LLC (TX Geoscientist Firm License #50639)

Michael Thornhill, P.G.

Mr. Thornhill was primarily responsible for preparing the report sections on Other Considerations related to compaction of subsurface clays and the Summary of Clay Layer Thickness Based on Geophysical Log Analysis. He also provided review and QA/QC of the final report.

Principal – Thornhill Group, Inc. (TX Geoscientist Firm License #50346)

James Beach, P.G.

Mr. Beach was primarily responsible for providing review and QA/QC of the final report.

Principal – Advanced Groundwater Solutions, LLC (TX Geoscientist Firm License #50639)

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INTRODUCTION

Chapter 36 of the Texas Water Code requires Lone Star Groundwater Conservation District (LSGCD) to consider several factors when developing long-term goals and finding the balance between providing fair and impartial access to groundwater production and conservation of groundwater resources. One of LSGCD's considerations is the ability to control subsidence within Montgomery County. In order to thoughtfully consider the ability to control subsidence, the District is developing a robust understanding of the local conditions effect on compaction of the subsurface formations which can cause land surface subsidence.

During Phase 1 of the subsidence investigations, Thornhill and Keester (2020) focused on developing an understanding of existing research. During the initial phase, the focus was not so much on the validity or applicability to Montgomery County; rather, it was on compiling existing studies and determining questions that may need further investigation. In Phase 2 of the District's subsidence investigations, the LSGCD technical consulting team has worked collaboratively to investigate two of the most applicable questions.

One of these questions involved a review of a subsidence study titled: *Subsidence Risk Assessment and Regulatory Considerations for the Brackish Jasper Aquifer* (Kelley and others, 2018). Thornhill and Keester (2020) discussed and summarized this study as part of the Phase I study. However, because information from this study has direct relevance to LSGCD's current and future management of groundwater resources, we conducted a more detailed evaluation of the information provided in the report.

The other question related to the hydrostratigraphy and clay layers within the subsurface units in Montgomery County. To address the question, we conducted an in-depth evaluation of the subsurface geology of Montgomery County. Our work aimed to improve the mapping of the elevation of the top and bottom of the subsurface hydrogeologic formations and to improve the understanding of the thicknesses of sand and clay intervals within the formations in the study area. Our approach for completing the work followed the long-standing approach taken by groundwater professionals of combining an extensive understanding of practical local hydrogeology with geophysical log analysis.

BRACKISH JASPER AQUIFER CONCEPTUAL MODEL REVIEW

Kelley and others' (2018) work focuses on the Jasper Aquifer. As shown on Figure 1, Kelley and others (2018) included all of Brazoria, Fort Bend, Galveston, and Harris counties with portions of the neighboring counties included in the study area. Within Montgomery County, the study area extends to the southern end of Lake Conroe.

Kelley and others (2018) identified their work as an estimate of "the relative risk of subsidence associated with development of brackish groundwater in the Jasper Aquifer of the Gulf Coast Aquifer System within the [Harris-Galveston and Fort Bend Subsidence] Districts." The two objectives of their risk assessment were to:

1. "Assess potential risk of subsidence that may result from development of brackish groundwater resources in the Jasper Aquifer within the [Harris-Galveston and Fort Bend Subsidence] Districts; and
2. Provide the [Harris-Galveston and Fort Bend Subsidence] Districts with guidance regarding the types of activities and data that would benefit the consideration as special provisions to Jasper Aquifer brackish production permits."

To meet the first objective, Kelley and others (2018) developed a numerical model using the MODFLOW code (version not identified). To simulate compaction of the subsurface units, they used the MODFLOW subsidence package developed by Hoffman and others (2003). The development of the numerical model of groundwater flow and use of the MODFLOW subsidence package is common practice for assessing the potential for compaction and is reasonable approach for addressing the first objective. The numerical model is simply a mathematical representation of the conceptual model of the aquifer. The information developed for the conceptual model dictates the development of the numerical model. Therefore, our work focused primarily on the conceptual model described by Kelley and others (2018).

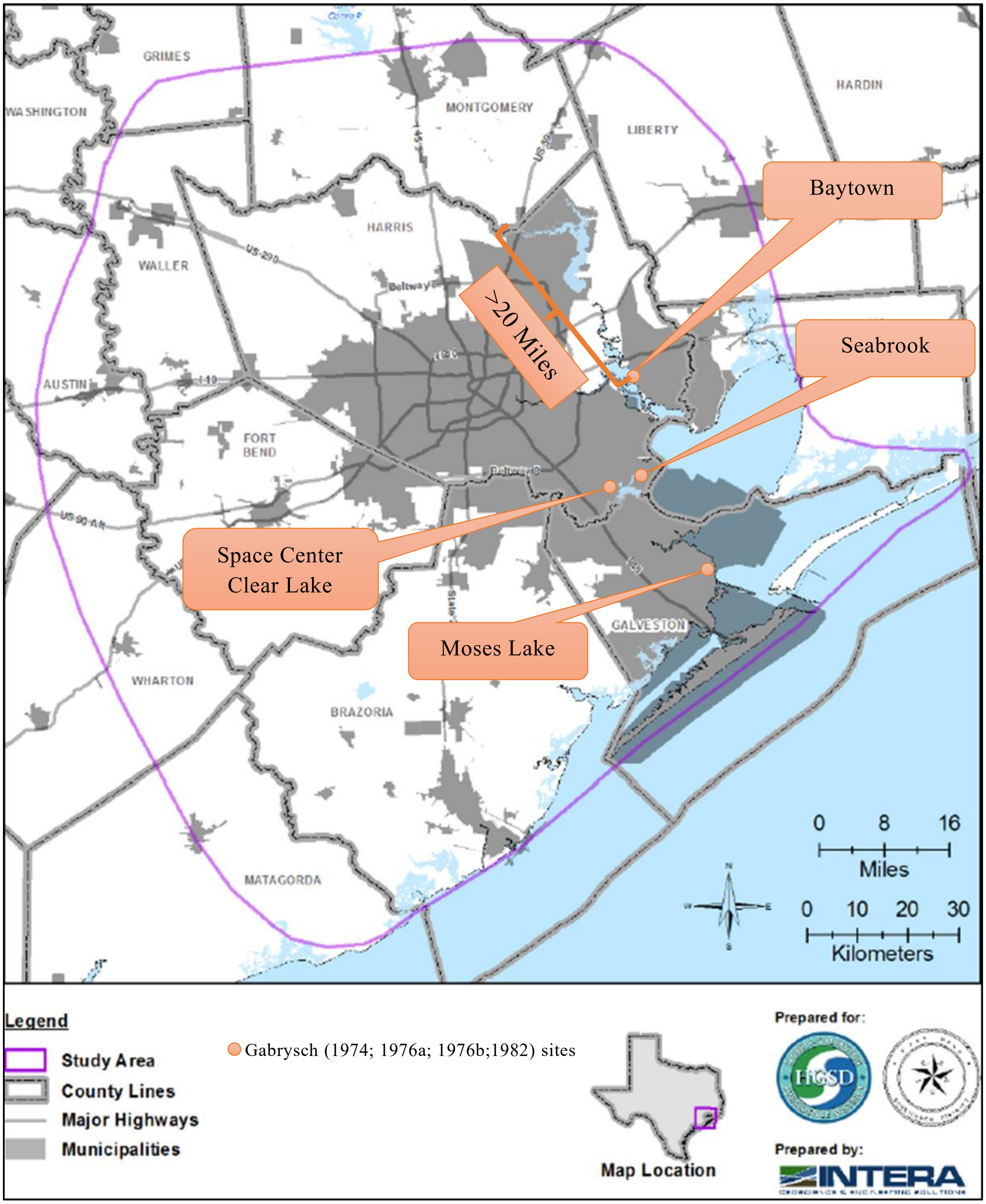

Figure 1. Study area identified by Kelley and others (2018) along with the sites discussed by Gabrysch and Bonnet (1974, 1976a; 1976b) and Gabrysch (1982). Modified from Kelley and others (2018).

Review of Compaction Parameterization

Kelley and others (2018) begin their discussion of the conceptual model with a brief introduction to consolidation theory. Their discussion highlights the mathematics behind the numerical model package used to predict compaction and subsidence. Of particular importance to the equations are the following clay bed properties:

- Geostatic stress (σ), hydrostatic stress (u), and effective stress (σ')
- Thickness
- Specific storage
- Vertical hydraulic conductivity
- Preconsolidation stress

Kelley and others (2018) point out that "none of the physical measurements presented [in their report]… have been collected at depths representative of the brackish Jasper Aquifer in the [Harris-Galveston and Fort Bend Subsidence] Districts.… Properties controlling compaction of the brackish Jasper Aquifer should be considered uncertain." To our knowledge the statement would also have been accurate if it more generally referred to the Jasper Aquifer in the Gulf Coast region.

Much of the analyses discussed by Kelley and others (2018) used data obtained and discussed by Gabrysch and Bonnet (1974; 1976a; 1976b). The locations where these data were collected are shown on Figure 1. As shown on Figure 1, the nearest location is more than 20 miles from Montgomery County. Also, the depth from which the data were collected represents the shallower and younger sediments that make up the Chicot and Evangeline aquifers. As such, we agree with Kelley and others (2018) that the application of results from analyses of these data to the Jasper Aquifer is uncertain.

With regard to the first compaction property listed above, geostatic stress is essentially a combination of the weight of the sediments and fluids above a specified depth in the subsurface. The hydrostatic stress is the pressure within the pore space of the sediments above a specified depth in the subsurface. Effective stress is the difference between the geostatic stress and the hydrostatic stress. Terzaghi (1925) identified this relation which allows effective stress within an aquifer to be expressed as (Leake and Galloway, 2007):

$$\sigma' = \sigma - u \tag{1}$$

Commonly, the geostatic stress is considered to be 1.0 pounds per square inch (psi) per foot (ft) of burial (psi/ft). For fresh water, the hydrostatic stress is 0.433 psi/ft which results in an effective stress gradient of 0.467 psi/ft assuming the geostatic stress gradient of 1.0 psi/ft and a water level equal to the depth of burial. These are the stress values used by Kelley and others (2018). However, Tiab and Donaldson (2016) indicate the geostatic gradient in the Gulf Coast region increases with depth being about 0.85 psi/ft near the surface and increasing to 1.0 psi/ft at about 20,000 feet in depth (see Figure 2). They indicate the reason for the curvature of the trend shown on Figure 2 is due to "sediments being younger and more compressible near the surface but being less compressible and more plastic with depth." For depths up to about 2,000 feet, the geostatic stress gradient presented by Tiab and Donaldson (2016) results in an effective stress gradient of about 0.407 to 0.437 psi/ft.

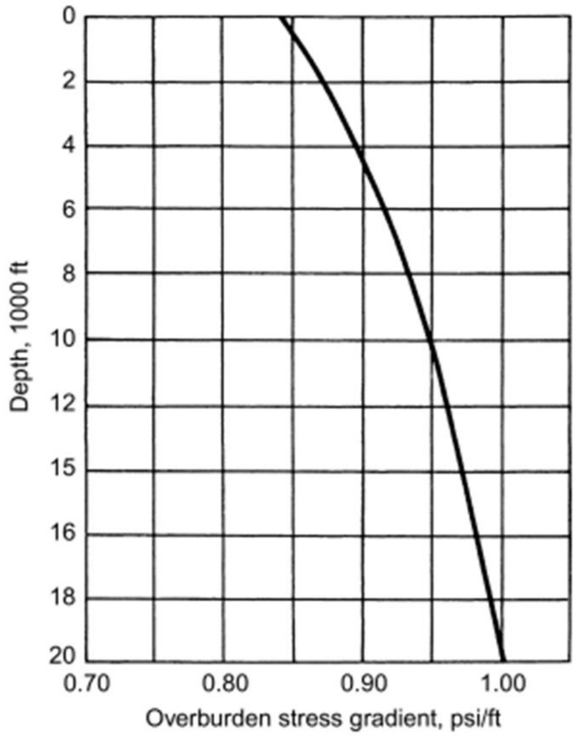

Figure 2. Overburden (geostatic) stress gradient in the Gulf Coast region. Reproduced from Tiab and Donaldson (2016)

The thickness of the clay units also affects compaction of the sediments, particularly the rate of compaction. The local stratigraphy and thickness of clay units is discussed below.

Specific Storage

The specific storage (S_s) of aquifer sediments is the volume of water released from or added to storage in a unit volume of aquifer per unit decline or rise in water level (Bear, 1979). The specific storage value may be further defined as the sum of the elastic (S_{ske}) and inelastic (S_{skv}) components (Hoffman and others, 2003) with the inelastic component being approximately 100 times greater than the elastic component (Leake and Prudic, 1991; Young and others, 2006). Due to the difference between the elastic and inelastic components, we can generally assume (as did Kelley and others (2018)) the inelastic specific storage is essentially equal to the total specific storage. Calculation of the specific storage compents is then as follows:

$$S_{skv} \approx S_s = \rho g(\alpha + n\beta) \tag{2}$$

$$S_{ske} = \frac{S_{skv}}{100} \tag{3}$$

where:

$S_{skv} = inelastic\ specific\ storage\ (m^{-1})$ – multiply by 0.3048 to get per foot (ft^{-1})

$S_{ske} = elastic\ specific\ storage\ (m^{-1})$ – multiply by 0.3048 to get per foot (ft^{-1})

$\rho = density\ of\ water\ \left(\frac{kg}{m^3}\right) \cong 1{,}000\frac{kg}{m^3}\ for\ fresh\ water$

$g = gravity\ \left(\frac{m}{s^2}\right) = 9.80665\frac{m}{s^2}$

$\alpha = sediment\ compressibility\ \left(\frac{m^2}{N}\right)$

$n = porosity$

$\beta = water\ compressibility\ \left(\frac{m^2}{N}\right)$

$Units{:}\ ft = foot;\ m = meter; kg = kilogram; s = second;\ N = Newton = \frac{kg \cdot m}{s^2}$

Kelley and others (2018) state that Gabrysch and Bonnet (1974; 1976a; 1976b) report laboratory measurements of porosity and compressibility for the Baytown, Seabrook, and Moses Lake sites shown on Figure 1. However, these measurements are not actually reported by Gabrysch and Bonnet (1974; 1976a; 1976b); rather, Gabrysch and Bonnet (1974; 1976a; 1976b) report measurements of void ratio at various levels of pressure for clay samples collected at various depths within the Chicot and Evangeline aquifers. While not stated, we assume Kelley and others (2018) calculated porosity and compressibility from reported data using the following equations:

$$n = \frac{e}{1+e} \tag{4}$$

$$\alpha = \frac{\Delta n}{\Delta \sigma_v'} \tag{5}$$

where:

$e = void\ ratio$

$\sigma_v' = applied\ stress$

The Δ in equation 5 represents a change in the value. That is, compressibility is calculated as the change in porosity divided by the change in applied stress to the sample. We performed the same calculations we assume were performed by Kelley and others (2018) to determine porosity and compressibility from the data reported by Gabrysch and Bonnet (1974; 1976a; 1976b). Our results appeared to agree reasonably well with the results presented by Kelley and others (2018).

One of the requirements Kelley and others (2018) applied to their analysis was to only use measurements of the void ratio where the applied stress was greater than the effective depth of burial. Kelley and others (2018) state that they calculated the effective burial depth "by dividing the pressure applied to the core sample by a geostatic gradient of 0.467 pounds per square inch (psi) per foot of burial depth." As noted above, the value of 0.467 psi/ft represent the effective stress gradient assuming a geostatic stress gradient of 1.0 psi/ft. We inquired about the reported value and received an email response from Dr. Steve Young on July 28, 2021 that the sentence should read “net effective stress gradient” rather than “geostatic gradient.” As of December 11, 2021 a corrected report had not been posted to the Harris-Galveston Subsidence District website.

For our evaluation of the data, we used the lower and variable geostatic stress gradient identified by Tiab and Donaldson (2016). To calculate the effective burial depth, we followed the same assumptions as Kelley and others (2018) except that the geostatic stress is lower. The following equation illustrates the calculation:

$$Effective\ burial\ depth = \frac{\sigma_v'}{\sigma - u} \quad (6)$$

Using the lower geostatic gradient allows for additional data points to be included in the calculation of porosity and compressibility. Figure 3 and Figure 4 show porosity and compressibility plotted versus effective burial depth. The calculated values reflect the values determined from the Gabrysch and Bonnet (1974; 1976a; 1976b) data. The modeled value reflects the best fit trend line through the data. We selected a logarithmic trend through the data as it provided the best fit through data representing effective burial depths of less than 5,000 feet. Beyond 5,000 feet of depth, the logarithmic trend is not applicable. The equation shown on the chart represents the modeled values.

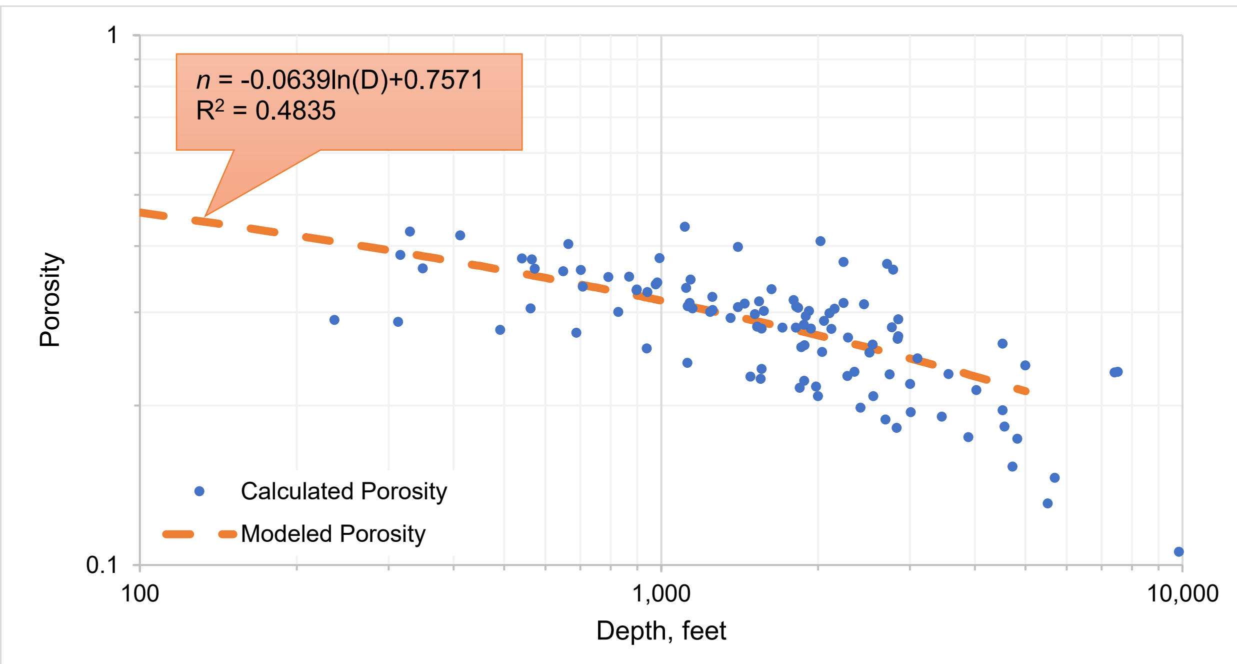

Figure 3. Calculated and modeled porosity with depth based on data reported by Gabrysch and Bonnet (1974; 1976a; 1976b)

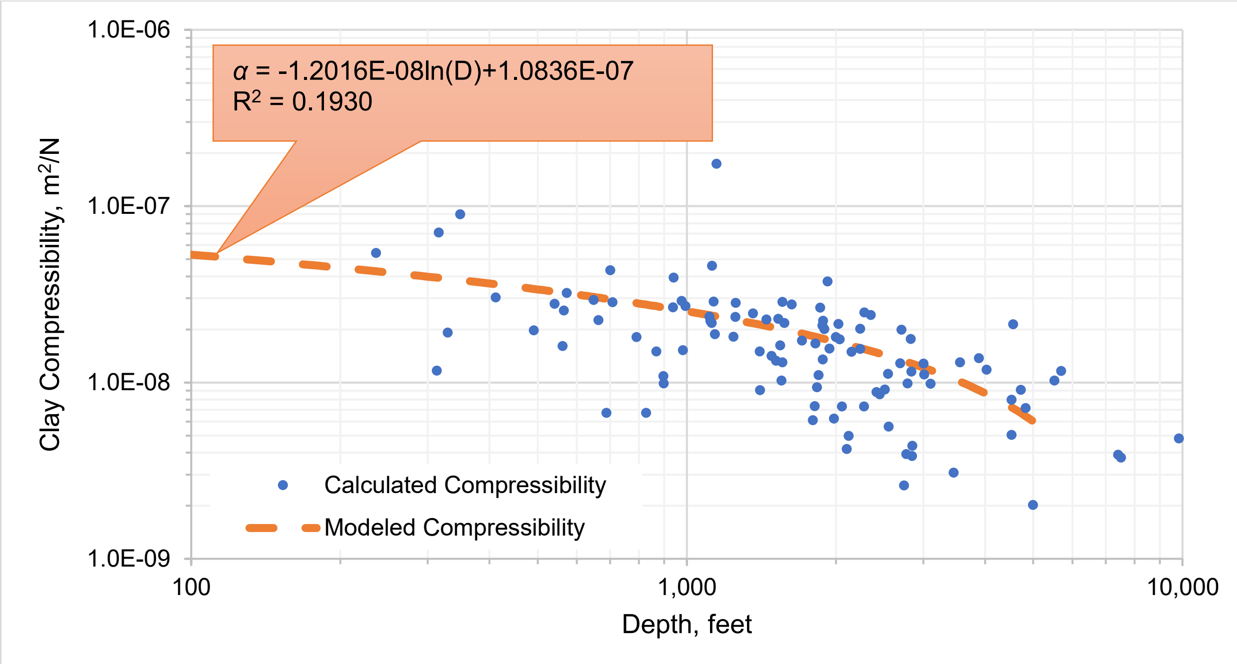

Figure 4. Calculated and modeled clay compressibility with depth based on data reported by Gabrysch and Bonnet (1974; 1976a; 1976b).

Per Equation 2, we also need the compressibility of water to calculate specific storage. Kelley and others (2018) used a constant value of 4.4E-10 m^2/N for the compressibility of water. However, the compressibility of water is not a constant value, and it varies with the temperature of the water. We can estimate the temperature of water at depth based on the average annual air temperature of 20 °C (Long, 2020) and a geothermal gradient of about 9°C per 1,000 feet of depth (Young and others, 2016). We can then use Kell's (1975) equation for the isothermal compressibility of water:

$$\beta = \frac{5.088496\times10^{-10}+6.163813\times10^{-12}t+1.459187\times10^{-14}t^2 +2.008438\times10^{-16}t^3-5.847727\times10^{-19}t^4+4.10411\times10^{-21}t^5}{1+0.01967348t} \quad (7)$$

where

$\beta = isothermal\ compressibility\ (Pa^{-1} \equiv \frac{m^2}{N})$

$t = temperature$ (°C)

Using each of the calculated parameters, we then applied Equation 2 and Equation 3 to calculate the inelastic and elastic specific storage, respectively, for the clay samples.

Figure 5 and Figure 6 illustrate the calculated and modeled clay inelastic and elastic specific storage, respectively. Like the porosity and compressibility values, the specific storage values decrease with depth.

All other factors being equal, lower values of clay specific storage result in less predicted compaction. Overall, our modeled values of clay specific storage based on the Gabrysch and Bonnet (1974; 1976a; 1976b) data are similar in magnitude to the modeled values of Kelley and others (2018). Table 1 provides a comparison of our calculated values and those of Kelley and others (2018).

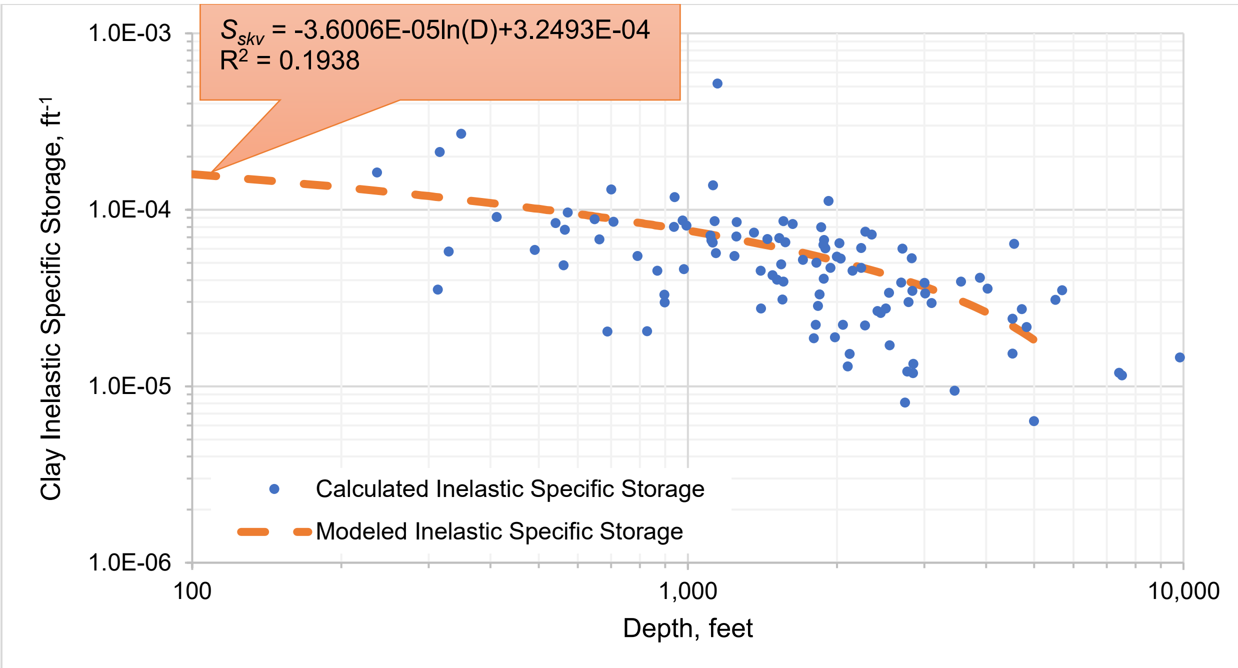

Figure 5. Calculated and modeled clay inelastic specific storage with depth based on data reported by Gabrysch and Bonnet (1974; 1976a; 1976b).

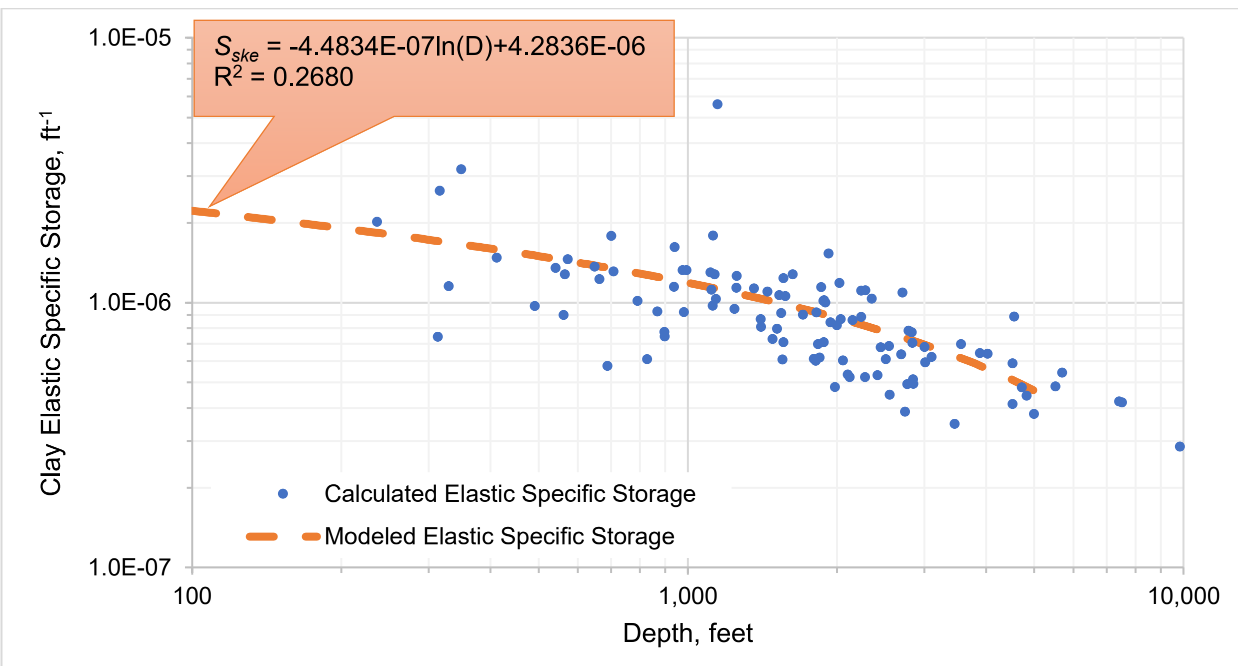

Figure 6. Calculated and modeled clay elastic specific storage with depth based on data reported by Gabrysch and Bonnet (1974; 1976a; 1976b)

Table 1. Comparison of estimated specific storage of clay beds.

Burial Depth (ft)	Clay Inelastic Specific Storage (ft^{-1})			Clay Elastic Specific Storage (ft^{-1})		
	HGSD	LSGCD	Difference	HGSD	LSGCD	Difference
100	3.5E-04	1.6E-04	1.9E-04	4.2E-06	2.2E-06	2.0E-06
250	1.9E-04	1.3E-04	5.9E-05	2.4E-06	1.8E-06	5.7E-07
500	1.1E-04	1.0E-04	1.3E-05	1.6E-06	1.5E-06	8.6E-08
750	8.6E-05	8.7E-05	-7.5E-07	1.3E-06	1.3E-06	-5.4E-08
1,000	7.0E-05	7.6E-05	-6.1E-06	1.1E-06	1.2E-06	-1.1E-07
1,500	5.3E-05	6.2E-05	-8.8E-06	8.7E-07	1.0E-06	-1.3E-07
2,000	4.3E-05	5.1E-05	-8.1E-06	7.5E-07	8.8E-07	-1.2E-07
2,500	3.7E-05	4.3E-05	-6.3E-06	6.7E-07	7.8E-07	-1.0E-07
3,000	3.3E-05	3.7E-05	-4.1E-06	6.2E-07	6.9E-07	-7.7E-08

HGSD = Kelley and others (2018)
LSGCD = This report

The biggest differences are at shallower depths of 500 feet or less. These differences at shallower depths are due to the type of mathematical trend. Using the functions with Microsoft Excel, we applied a logarithmic trend which appears to follow a curved trend in the data whereas Kelley and others (2018) applied a power trend which results in a straight-line on the plots. Also, while both the power and logarithmic trends result in unrealistic porosity values at shallow depths, the logarithmic trend more closely reflects the expected maximum of about 60 percent (Fetter, 1994). For example, the trend line of Kelley and others (2018) results in a clay porosity of 85 percent at a depth of 10 feet while the logarithmic trend we applied results in a clay porosity of 61 percent for the same depth.

Importantly, the values calculated are for samples collected the Chicot and Evangeline aquifers. While our calculated results for specific storage are similar to those of Kelley and others (2018), like those of Kelley and others (2018) they do not represent samples collected from the Jasper Aquifer. While we are able to determine a trendline through the calculated values on

Figure 5 and Figure 6, there is more than an order of magnitude difference in the values for similar depths. This variability should be considered when applying the modeled values to compaction in the Chicot and Evangeline. With the Jasper being an older formation, it is possible the lower bounds of the variability should be considered as a starting point or possibly favored during evaluations using these results.

Vertical Hydraulic Conductivity

The specific storage values of the clay beds control the amount of compaction that can occur under a given amount of stress. However, to determine the rate at which compaction occurs we also need to know the vertical hydraulic conductivity and thickness of the clay beds (discussed below) along with the specific storage.

The thickness and vertical hydraulic conductivity of individual clay beds affects the rate at which compaction may occur. When pumping from the aquifer occurs, water will preferentially move through the coarser-grained sediments (that is, sand) causing a pressure (that is, water level) decline in those layers of coarser-grained sediments. The decrease in pressure within the coarser-grained sediment layers creates a pressure gradient between the coarser-grained sediment layers and the finer-grained (that is, clay) sediment layers. This pressure gradient causes water to move from the finer-grained sediment layers into the coarser-grained sediment layers resulting in a decrease in pressure (and increase in effective stress) within the finer-grained sediment layers.

The decrease in pressure in a finer-grained sediment layer occurs immediately at the interface between that layer and the coarser-grained sediment layer. The decrease in pressure in the finer-grained sediment layer then propagates toward the center of the layer. Assuming consistent hydraulic properties of the layer, as the thickness of the finer-grained sediment layer increases, the time it takes for the pressure decrease to propagate to the center of the layer also increases. The amount of time it takes for full compaction to occur can be expressed as a "time constant" in the compaction calculations (Hoffman and others, 2003). The time constant (τ_0) in Equation 8 represents the amount of time at which about 93 percent of the ultimate clay bed compaction will occur. As illustrated in Figure 7, approximately 50 percent of the compaction occurs relatively rapidly (within about 20 percent of the time constant) and then gradually slows over time.

$$\tau_0 = \frac{\left(\frac{b_0}{2}\right)^2 S_s}{K_v} \tag{8}$$

where:

$b_0 = initial\ thickness\ of\ the\ clay\ bed$

$S_s = specific\ storage\ of\ the\ clay\ bed$

$K_v = vertical\ hydraulic\ conductivity\ of\ the\ clay\ bed$

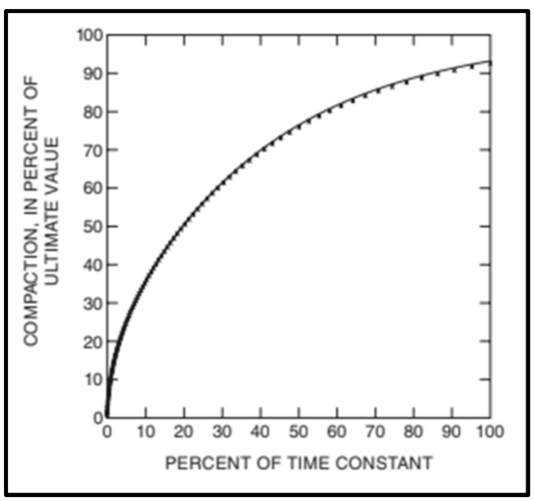

Figure 7. Illustration of compaction as a function of the compaction time constant. Reproduced from Hoffman and others (2003).

Kelley and others (2018) report using vertical hydraulic conductivity values as measured by Gabrysch and Bonnet (1974). However, Gabrysch and Bonnet (1974) only report measured hydraulic conductivity values and do not specify whether those values are horizontal or vertical. Analysis of the data reported by Gabrysch and Bonnet (1974), for samples where the effective stress was greater than the sample depth, provides a range of hydraulic conductivity values from 5.95E-07 to 6.5E-05 feet per day (ft/d). Table 2 provides representative values of the horizontal and vertical hydraulic conductivity of clay.

Table 2. Representative values for horizontal and vertical hydraulic conductivity of clay (Walton, 1987).

Horizontal Hydraulic Conductivity (ft/d)	2.66E-05 – 2.66E-04
Vertical Hydraulic Conductivity (ft/d)	6.52E-09 – 1.33E-07

Comparing the clay hydraulic conductivity results from Gabrysch and Bonnet (1974) to the representative values, the data from Gabrysch and Bonnet (1974) are similar to the representative horizontal hydraulic conductivity values and greater than the representative vertical hydraulic conductivity. While it is possible that the samples from Gabrysch and Bonnet (1974) are outliers to the representative values, we should not assume the values are measurements of the vertical hydraulic conductivity when they were not reported as such.

Kelley and others (2018) developed a model of the vertical hydraulic conductivity with depth based on their analysis of the Gabrysch and Bonnet (1974). To provide a lower bound on their vertical hydraulic conductivity estimates, Kelley and others (2018) also developed a depth dependent model using parameters from PRESS models which are used to simulate one-dimensional compaction in the area. The PRESS vertical hydraulic conductivity values are calibrated model parameters for prediction of compaction within the Chicot and Evangeline aquifers. Figure 8 illustrates the two models developed by Kelley and others (2018) for estimating the vertical hydraulic conductivity of clays within the brackish Jasper Aquifer.

Kelley and others (2018) used the average of the PRESS input model and the core data model to define the vertical hydraulic conductivity of clays in the brackish Jasper Aquifer model. As shown on Figure 8, the use of this average of the two models results in consistently higher vertical hydraulic conductivity values for the clays in the brackish Jasper Aquifer than for clays in the shallower and younger formations. As depth increases the disparity between the models increases with modeled vertical hydraulic conductivity values at a depth of 2,000 feet being an order of magnitude greater for the Jasper than the PRESS models would assume for Chicot and Evangeline. The effect of this difference may be illustrated through a comparison of the representative value for vertical hydraulic conductivity (Table 2) and the model developed by Kelley and others (2018) using the Gabrysch and Bonnet (1974) data.

All other factors being equal, a lower vertical hydraulic conductivity results in a greater time constant. With vertical hydraulic conductivity as the denominator in Equation 8, each decrease in the order of magnitude in the value causes a corresponding increase in the order of magnitude in the time constant. For example, at a depth of 1,000 feet a 10-foot thick clay bed with a specific storage of 7.74E-05 ft^{-1} (sum of LSGCD values in Table 1) the time constant would be 520 days based on Kelley and others (2018) analysis of the Gabrysch and Bonnet (1974) data (K_v = 3.72E-06 ft/d) but would be more than 14,500 days based on the maximum representative value (K_v = 1.33E-07 ft/d).

The approach by Kelley and others (2018) results in vertical hydraulic conductivity values for the clays of the Jasper Aquifer that are higher than those used in modeling of the younger stratigraphic units. Their approach would result in modeled compaction occurring at a much higher rate in the

Jasper than would occur in the Chicot and Evangeline, despite the Jasper being at greater depth than the overlying units. Assuming similar lithologic compositions, it is unlikely that the older and deeper clay units within the Jasper Aquifer would compact at a higher rate than younger and shallower sediments and the conceptualization of this parameter should not be applied within the regional model of the Gulf Coast Aquifer System.

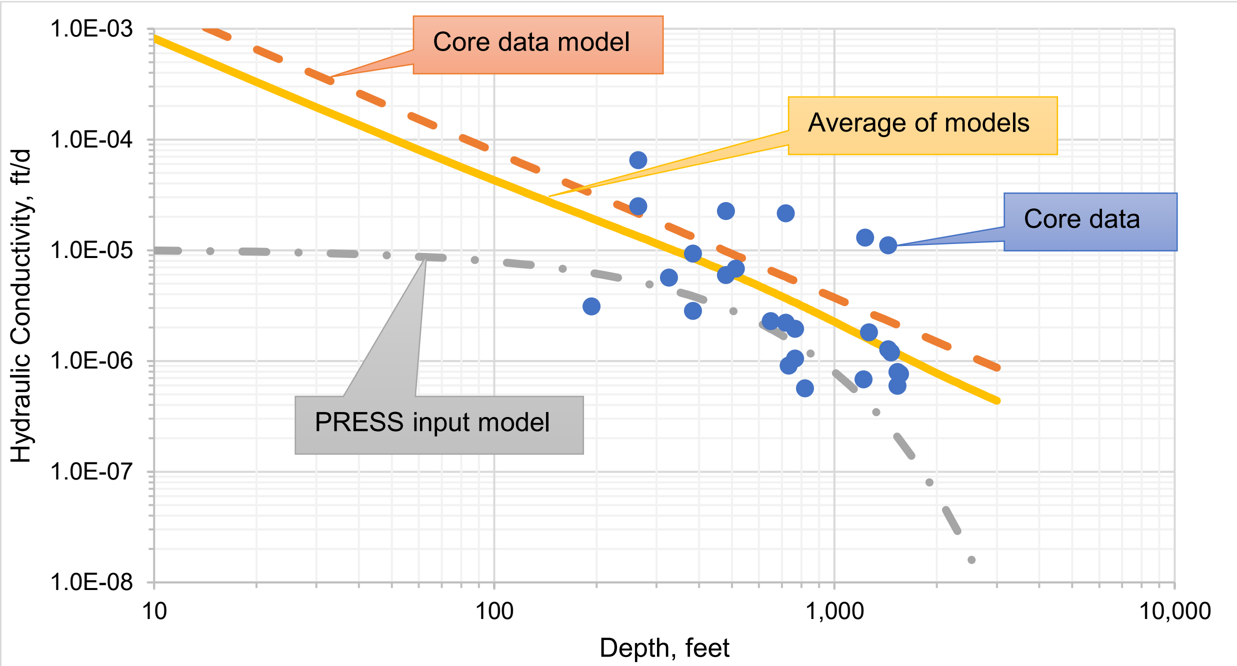

Figure 8. Comparison of the depth dependent vertical hydraulic conductivity models developed by Kelley and others (2018) for the brackish Jasper Aquifer.

Preconsolidation Stress

Irreversible compaction of subsurface sediments begins when sediments are not fully consolidated and the effective stress is greater than the preconsolidation stress (that is, maximum effective stress). Commonly, the preconsolidation stress is synonymous with the preconsolidation head (that is, water level) of the aquifer (Leake and Prudic, 1991; Hoffman and others, 2003). While a single head value is not necessarily sufficient for calculating the effective stress (Leake and Galloway, 2007), for most analyses it provides a reasonable approximation.

Another way to describe the preconsolidation stress is relative to the amount of drawdown that needs to occur before permanent compaction begins. That is, how much do water levels need to decline before the effective stress is greater than the preconsolidation stress? For the Jasper Aquifer, Kelley and others (2018) conceptualized this “drawdown at preconsolidation stress” to be about 75 feet at ground level and decreasing linearly to zero (0) feet at 870 feet below ground level. That is, they conceptualized that compaction would occur immediately with pressure (that is, water level) decline in sediments at depths at or below 870 feet.

For the drawdown at preconsolidation stress, Kelley and others (2018) indicate the value near land surface (75 feet) is consistent with the Houston Area Groundwater Model (Kasmarek, 2013). In that model, Kasmarek (2013) set the preconsolidation head for the clay units as 70 feet below the starting head (that is, water levels) for the model. These starting heads represented his best estimate of water levels in 1890. Within the model, “for changes in head in which head declines below preconsolidation head, an inelastic response is computed, permanent clay compaction is calculated, and the preconsolidation head is reset to the new head value” (Kasmarek, 2013). That is, per Kasmarek (2013) if the simulated water level declines below the 1890 estimated water level minus 70, then compaction occurs and the new water level becomes the preconsolidation head.

Kelley and others (2018) indicate their conceptualization of drawdown at preconsolidation stress is consistent with current PRESS models. As noted above, the PRESS values are calibrated model parameters for prediction of compaction within the Chicot and Evangeline aquifers and we should exercise caution in assuming the values are applicable to the deeper formations. As Kelley and others (2018) state: “the relationship describing drawdown at preconsolidation stress is very uncertain.”

As discussed by Keester and others (2021), the conceptualization of drawdown at preconsolidation stress by Kelley and others (2018) may be inconsistent with observed water-level declines, extensometer measurements, and GPS-modeled vertical displacement at the Lake Houston extensometer site (shown on Figure 9). However, Kelley and others (2018) did not consider these data during their analyses.

The Lake Houston extensometer was completed in 1980 and the reported cumulative compaction within the Chicot and Evangeline aquifers at the end of 2019 was about 7.5 inches. For sediments below the Evangeline, the Lake Houston extensometer and GPS-modeled vertical displacement suggest no measurable compaction occurred. However, during the period of measured compaction in the Chicot and Evangeline aquifers, water levels in the Jasper Aquifer nearly 2,600 feet below ground level have declined by more than 150 feet. Figure 10 illustrates the cumulative compaction of the Chicot and Evangeline aquifers (that is, extensometer data), Jasper Aquifer water level change, and compaction of the formations below the Evangeline (GPS).

One possible reason why no measurable compaction occurred in the units below the Chicot and Evangeline aquifers is that the effective stress in the Jasper at the Lake Houston site has not increased to the point where compaction would occur; that is, the water level is still above the preconsolidation head. If the Jasper water level is above the preconsolidation head despite having declined more than 150 feet since 1980 and the depth of the measurement interval being nearly 2,600 feet below ground level, then the drawdown at preconsolidation stress for the Jasper Aquifer as conceptualized by Kelley and others (2018) must be reconsidered. As indicated above, Kelley and others (2018) conceptualized that any drawdown in the Jasper at depths greater than 870 feet would immediately result in inelastic compaction; however, reported data from the Lake Houston site appear to contradict this conceptualization.

Similarly, Gabrysch (1982) noted that deeper layers of the Evangeline at the Clear Lake site (see Figure 1) were not compacting due to water level declines. In his opinion, “Data from the Clear Lake site, where no appreciable compaction of the lower part of the Evangeline aquifer was occurring even though artesian-head declines were occurring, indicate that compaction of the deeper clay layers needs to be excluded in estimating largescale subsidence.” Like the Lake Houston site, the lack of observed compaction in the deeper intervals may be due to the water levels not yet declining to preconsolidation head but the observations should be considered and addressed as part of the conceptual model.

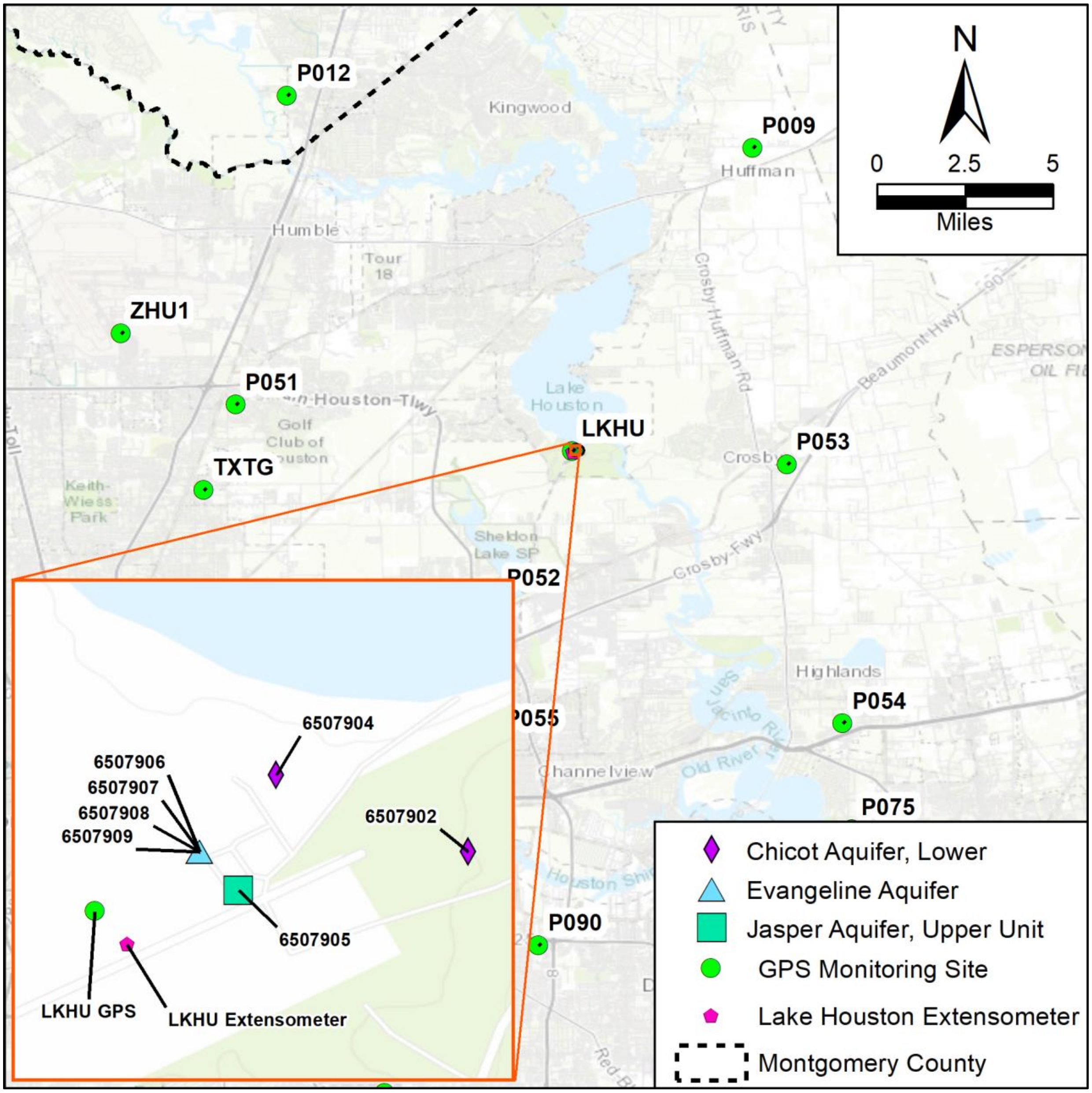

Figure 9. Wells associated with the Lake Houston extensometer site and nearby GPS monitoring sites

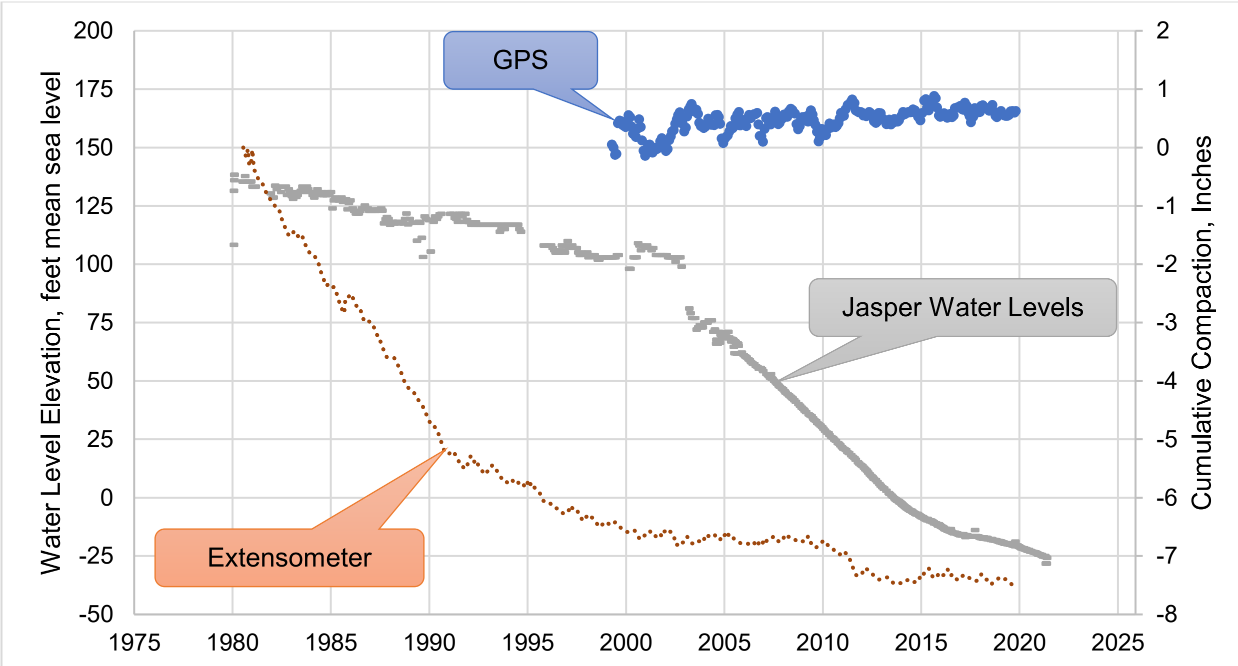

Figure 10. Hydrograph of reported water level measurements from the Lake Houston site Jasper Aquifer monitoring well (TWDB, 2021b), reported cumulative compaction of the Lake Houston extensometer (Ramage and Shah, 2019), and GPS modeled vertical displacement of the subsurface units below the Evangeline Aquifer (https://hgsubsidence.org/GPS/)

Other Considerations

In the conceptual model section of their report, Kelley and others (2018) state that they will review the available data for estimating the properties governing compaction. They identify four properties that are important for their conceptual model of the Jasper Aquifer: specific storage, the thickness of clay beds, the vertical hydraulic conductivity of the clays, and the drawdown at preconsolidation stress. Other interrelated considerations which may influence the conceptualization of compaction and, certainly, the parameterization values and distributions of the factors Kelly and others (2018) identified, derived, or estimated in the Jasper Aquifer include:

- Geometry of geologic units – structural geology maps, model layers, and hydrogeologic cross sections all show that the formations that comprise the Gulf Coast Aquifer System form a "wedge" shape that thickens toward the Gulf of Mexico. Young and others (2012) provide a schematic dip cross section that illustrates older (that is, deeper) beds dipping steeper than the overlying younger beds. Similarly, Popkin (1971) reports that within Montgomery County the Catahoula (which is below the Jasper) dips at 90 feet per mile, while the formations that comprise the Chicot dip at about 10 feet per mile, and intermediate beds dip from between 40 to 85 feet per mile. So far, this study has not discovered any literature that discusses whether variations in geologic dip can affect compaction.

  Additionally, the sediments in each formation thicken toward the coastline and generally, depending on the distribution of depositional systems, the clay interbeds become more numerous and total clay thickness and percentages increase toward the Gulf of Mexico. As the geologic units thicken, the arrangement and distribution of sand and clay beds vary. Also, the dip, depth and thickness of sands and clays also determine the amount of artesian head reduction that can occur in a particular producing interval. Therefore, updip formations generally have less overall potential for compaction if all other factors are equal.

- Depositional environments and associated sediment characteristics and lithologies – Young and others (2012) provide a thorough discussion of depositional systems and related facies. For example, lithology of geologic units at land surface is a key factor in the resulting topography. Approximately the northwestern half of Montgomery County is characterized by topography with rolling hills and incised drainages, while the southeastern part of the county is generally flat and gently sloping toward the coast. Popkin (1971) reports that land surface elevations range from about 45 feet above mean sea level in southeastern parts of the county to about 440 feet above mean sea level in the northwestern corner. Popkin (1971) also notes that the younger geologic units at land surface form a plain while the older units cropping out farther inland and at higher elevations form cuestas or sand hills. Such features can be important in more precisely delineating depositional distributions and formation characteristics. Also, sediment characteristics such as particle size, roundness, mineral composition, and sorting also factor into compaction characteristics of fine-grained layers. These characteristics vary by deposition setting. Young and others (2012) provided depositional facies definitions and predicted flow characteristics. Reasonable parameterization of models should be based on the most accurate representation of geologic conditions possible. Baker (1979) outlined selected faunal markers for various geologic layers, particularly for the Burkeville Confining System and deeper units. As LSGCD moves into subsequent study phases and collects core samples, such markers should be identified where present in order to accurately determine the geologic layers and aquifer stratigraphy.

- Mineralogy, geochemistry, and diagenesis – the properties of clay, mudstones and shale vary greatly depending on the mineralogy and textural characteristics. With respect to clay deposits, the type of clay mineral can affect the compaction characteristics of the interbeds. For example, montmorillonite retains more water than illite which retains more water than kaolinite (Meade, 1964). Kelley and others (2018) note that clays composed of montmorillonite have the highest compressibility.

  Wilson (1962) referring to a field trip stop south of LaGrange, Texas on Highway 71 notes that "…X-ray analyses show that the Catahoula in Central Texas is a calcium-montmorillonite without illite. The Oakville and Fleming clay is sodium-rich, mixed-layer montmorillonite with illite". Gabrysch and Bonnet (1976a; 1976b) report that samples collected from the sites shown on Figure 1 indicate the clays in the Chicot and Evangeline aquifers are a mix of clay minerals with the Baytown and Johnson Space Center sites being predominantly montmorillonite.

  The ionic composition of interstitial fluids (that is, water) and the clay minerals also play a part in the rate of draining of clay porosity and resulting compaction. The American Geological Institute defines diagenesis as "the process involving physical and chemical changes in sediment after deposition that converts it to consolidated rock; includes compaction, cementation, recrystallization, and perhaps replacement as in the development of dolomite (American Geological Institute, 1976). Such factors can only be assessed by detailed sedimentation and geochemistry models, which are beyond the scope of this study, or on a site-by-site basis by collecting core samples of the formations.

- Thickness and distributions of individual clay interbeds – particularly as related to the sand intervals that form primary producing zones for wells in Montgomery County. Kelley and others (2018) provided a general summary comparing and contrasting thicknesses of individual clay beds in the various layers of the Gulf Coast Aquifer System. In the subsequent section we discuss our data collection and analysis of clay layer distribution within Montgomery County. In particular, we begin an assessment of the vertical and lateral distributions of clay interbeds and the positioning with respect to producing intervals in the Gulf Coast Aquifer System.

- Geologic age of clay layers – Gabrysch (1982) stated, "It is suspected that compressibility of the material is related to the age of sediments and the depth of burial." Similarly, the U.S. Geological Survey did not simulate compaction in the original Northern Gulf Coast groundwater availability model noting that the clay layers in the Jasper and Burkeville "…are geologically older, more deeply buried, and therefore more consolidated relative to the sediments of the Chicot and Evangeline aquifers" (Kasmarek, 2013). Prozorovich (1964) states that geologic age is not a controlling factor with respect to compaction. However, more recently Puttiwongrak and others (2021) concluded that geologic time does affect compaction. As additional information is gathered, particularly subsurface samples, relative importance of various factors can be evaluated.

Along with the parameters discussed by Kelley and others (2018), these additional types of factors must be carefully considered in three-dimensional space when developing concepts and parameters associated with compaction assessments and models. Gabrysch and Bonnet (1976a) note the importance of understanding the variability of distributions and characteristics of clay layers and their properties because the ratio of subsidence to water-level declines "…is not constant in time or uniform in space". Additionally, Gabrysch offers that such variations are "…caused primarily by the difference in total clay thickness, individual clay-bed thickness, and clay characteristics. The depth of the overburden and the amount of load to which the material has been previously subjected must also be considered" (Gabrysch and Bonnet, 1976a).

GULF COAST AQUIFER SYSTEM GEOLOGIC STRUCTURE

Our evaluation of the geologic structure aimed to improve the mapping of the elevation of the top and bottom of the subsurface hydrogeologic formations and to improve the understanding of the thicknesses of sand and clay intervals within the formations within Montgomery County. For decades a common approach was taken by groundwater professionals towards the delineation of water bearing units of the Gulf Coast Aquifer System in Montgomery and surrounding counties (Popkin, 1971; Gabrysch and Bonnet, 1974; 1976a; 1976b; Baker, Jr., 1979; Espey, Huston & Associates, Inc., 1979; Carr and others, 1985; Kasmarek and Robinson, 2004; Kasmarek, 2013). The delineation of the hydrogeologic units in this study continues that approach, combining an extensive understanding of practical local hydrogeology with geophysical log analysis.

Hydrostratigraphy

The Gulf Coast Aquifer System is comprised of, from shallowest (youngest) to deepest (oldest), the Chicot Aquifer, Evangeline Aquifer, Burkeville Confining Unit, the Jasper Aquifer, and the Catahoula Formation. The principal aquifers that provide groundwater in Montgomery County include the Chicot, Evangeline, and Jasper aquifers.

Figure 11 shows the surface geology with the estimated outcrop areas and updip extent of the Chicot, Evangeline, and Jasper aquifers and Burkeville Confining Unit within Montgomery County. The aquifer outcrops shown on Figure 11 were adopted from LBG-Guyton Associates (2016). Montgomery County has a surface area of approximately 1,077 square miles. The Chicot Aquifer outcrop is the largest outcrop in the county and has an estimated area of about 798 square miles. The Evangeline Aquifer is located updip from the Chicot Aquifer outcrop and has an estimated area of about 223 square miles. The outcrop of the Jasper Aquifer can be found in the far northwestern part of Montgomery County and has an estimated area of approximately 24 square miles. The Burkeville Confining Unit is positioned between the outcrops of the Evangeline and Jasper aquifers and has an estimated area of about 32 square miles. The Catahoula Formation outcrop is further north and is not found in Montgomery County.

The geology of the Gulf Coast Aquifer System consists of a complex system of alternating layers of discontinuous sand, silt and clay. The similarities of sediments within each geologic unit can make it difficult to identify the individual geologic units that comprise the hydrogeologic units on geophysical logs. To put the complexity of the Gulf Coast Aquifer System into perspective, it should be noted that site-specific subsurface conditions must be evaluated for each water well that is constructed in the Gulf Coast Aquifer System in the greater Houston area.

Table 3 shows a correlation of the geologic and hydrogeologic units of the Gulf Coast Aquifer System within and near Montgomery County (Popkin, 1971; Young and Draper, 2020). The Chicot Aquifer is composed of the Beaumont, Lissie, and Willis formations. The Beaumont and Lissie formations are of Pleistocene age and the Willis Formation is of Pliocene age. The Goliad Sand and part of the Fleming Group (Upper Lagarto Formation) comprise the Evangeline Aquifer. The Burkeville Confining Unit is made up of the Middle Lagarto Formation and can extend into the upper and lower sections of the Lagarto Formation of the Fleming Group. The Jasper Aquifer also belongs to the Fleming Group and includes the Lower Lagarto and Oakville formations. There is some uncertainty as to which geologic formation(s) would encompass the upper and lower sections of the Jasper Aquifer. The Catahoula Formation is of Oligocene age. The formations generally outcrop in bands that parallel the Gulf Coast and typically increase in depth and thickness to the south and southeast toward the coast.

The updip extent of the Chicot Aquifer generally aligns with the updip extent of the Willis Formation outcrop. The Lissie Formation can be found in the south and southeast parts of Montgomery County. The 2014 Bureau of Economic Geology Digital Geologic Atlas of Texas shows the Willis Formation (landward belt) and the Fleming Formation occurring at land surface in the northwest part of the county. The Evangeline Aquifer, Burkeville Confining Unit, and Jasper Aquifer are estimated to outcrop in the area where these formations outcrop. Note that the Willis Formation (landward belt) shown in the northwest part of Montgomery County on the Bureau of Economic Geology Digital Atlas of Texas is not included in Table 3.

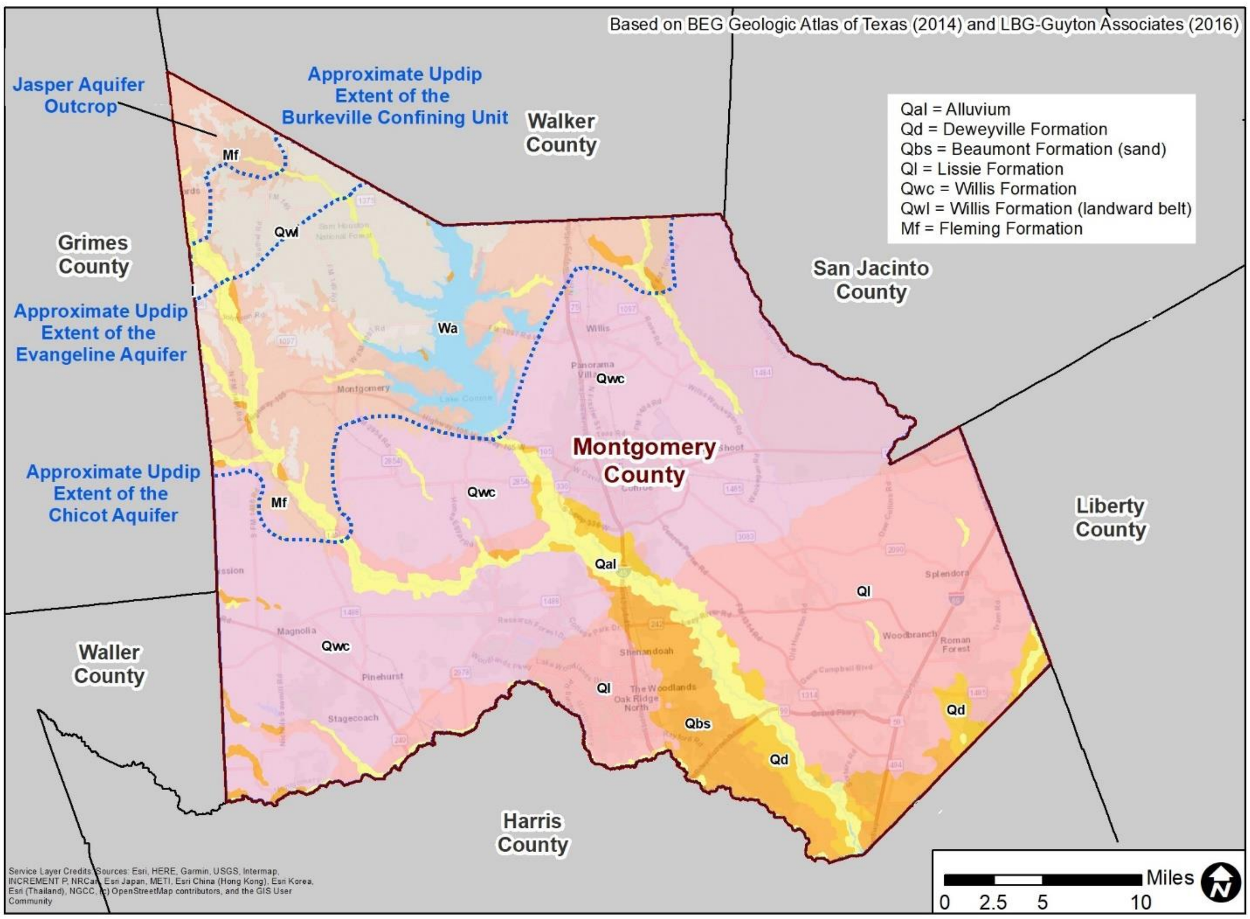

Figure 11. Montgomery County surface geology and approximate aquifer outcrop areas (Bureau of Economic Geology, 2014; LBG-Guyton Associates, 2016).

Table 3. Hydrogeologic and geologic units of the Gulf Coast Aquifer System within and near Montgomery County (Popkin, 1971; Young and Draper, 2020).

<table>
<tr><th>Epoch</th><th>Hydrogeologic Unit</th><th colspan="3">Geologic Unit</th></tr>
<tr><td>Holocene</td><td colspan="4">Alluvium</td></tr>
<tr><td rowspan="2">Pleistocene</td><td rowspan="3">Chicot Aquifer</td><td colspan="3">Beaumont Clay</td></tr>
<tr><td colspan="3">Lissie Formation</td></tr>
<tr><td>Pliocene</td><td colspan="3">Willis Formation</td></tr>
<tr><td rowspan="6">Miocene</td><td rowspan="3">Evangeline Aquifer</td><td colspan="2" rowspan="2">Goliad Sand</td><td>Upper</td></tr>
<tr><td>Lower</td></tr>
<tr><td rowspan="4">Fleming Formation</td><td rowspan="3">Lagarto</td><td>Upper</td></tr>
<tr><td>Burkeville Confining Unit</td><td>Middle</td></tr>
<tr><td>Upper Jasper Aquifer</td><td>Lower</td></tr>
<tr><td>Lower Jasper Aquifer</td><td colspan="2">Oakville</td></tr>
<tr><td>Oligocene</td><td>Catahoula</td><td></td><td colspan="2">Catahoula</td></tr>
</table>

The Chicot and Evangeline aquifers are considered a leaky artesian aquifer system consisting of unconsolidated and discontinuous layers of hydraulically connected sand and clay. The delineation of the Chicot and Evangeline aquifers can be difficult because an areally extensive confining unit does not exist between the two aquifers. Jorgensen (1975) discusses hydraulic conductivity as a basis for separating the Chicot Aquifer and Evangeline Aquifer in the Houston area. Differences in hydraulic conductivity are thought to cause, in part, differences in water level heads or elevations between the two aquifers. The differences in the static water level heads or elevations are noticeable and can be substantial in some areas, with the static water levels or heads in water wells completed in the Chicot Aquifer being shallower versus the static water levels in water wells completed in the Evangeline Aquifer. There also are differences in lithology, permeability and water quality in the Chicot Aquifer and Evangeline Aquifer. Geophysical logs of the test holes for water wells and oil and gas wells also have been used to estimate the resistivity of sand layers, the thicknesses of sand and clay units and help differentiate the contact of the Chicot and Evangeline aquifers in the greater Houston area.

Within the study area, the Burkeville Confining Unit is an aquitard or relatively impermeable layer that is positioned between the Evangeline and Jasper aquifers. The Burkeville Confining Unit can contain fresh to slightly saline water contained in individual sand layers but is considered a confining unit due to its large percentage of silt and clay compared to the Evangeline and Jasper aquifers (Baker, Jr., 1979). The sand layers found in the Burkeville are typically thin and are not considered to be hydraulically connected.

While usually recognized as one hydrogeologic unit, the Jasper Aquifer can be divided into two sections, the Upper Jasper and Lower Jasper. Popkin (1971) had classified the Jasper Aquifer in Montgomery County into two units based on lithology, with the upper portion containing a massive sand layer and the lower part containing mostly interbedded sand and clay. The base of the Lower Jasper Aquifer as discussed by Popkin (1971) extends to a deeper elevation than what is considered the base of the Jasper Aquifer today. Baker, Jr. (1979) classified the Jasper Aquifer as a single hydrogeologic unit and interpreted the base of the Jasper Aquifer at a shallower elevation than Popkin's (1971) base of the Lower Jasper Aquifer. The base of the Jasper Aquifer corresponding to the United States Geological Survey Source Water Assessment Program dataset (Strom and others, 2003) gained acceptance in Montgomery County through a LSGCD Groundwater Panel review during the early 2010's as the Catahoula Formation was being explored as an alternative water resource.

The Catahoula Formation is below the base of the Jasper Aquifer and provides a fresh groundwater supply in the north part of Montgomery County where the formation can contain water with a total dissolved solids concentration of less than 1,000 milligrams per liter. Exploration of the Catahoula Formation as a potential water supply has occurred in a several areas of Montgomery County. Many of these efforts resulted in the completion of large capacity water wells screening the Jasper Aquifer due to the presence of brackish groundwater in the deeper portions of the Catahoula in southern Montgomery County.

Subsurface geologic faults and large oil and gas field locations in the vicinity of Montgomery County are shown on Figure 12. Oil and gas drilling activities are often concentrated at or near subsurface geologic features. Figure 13 shows the locations of oil and gas well and/or test hole locations in and near Montgomery County based on datasets available from the Railroad Commission of Texas (RRC, 2021). It should be noted that this is not a comprehensive location map for all oil and gas wells and/or test holes in this area. The regional dip, subsurface geologic structure, formation thickness and/or groundwater quality may be influenced by geologic structures such as salt domes (TC&B, 2004).

The Conroe Oil Field is the largest oil and gas field in Montgomery County and is located to the southeast of the City of Conroe. Discovered in 1931, the Conroe Oil Field is located over a deep-seated salt dome that occurs at depths of greater than 5,000 feet (TC&B, 2004). Other salt domes in the vicinity of the study area include the Hockley Dome and Humble Dome in Harris County and the North Dayton Dome in Liberty County as shown on Figure 13.

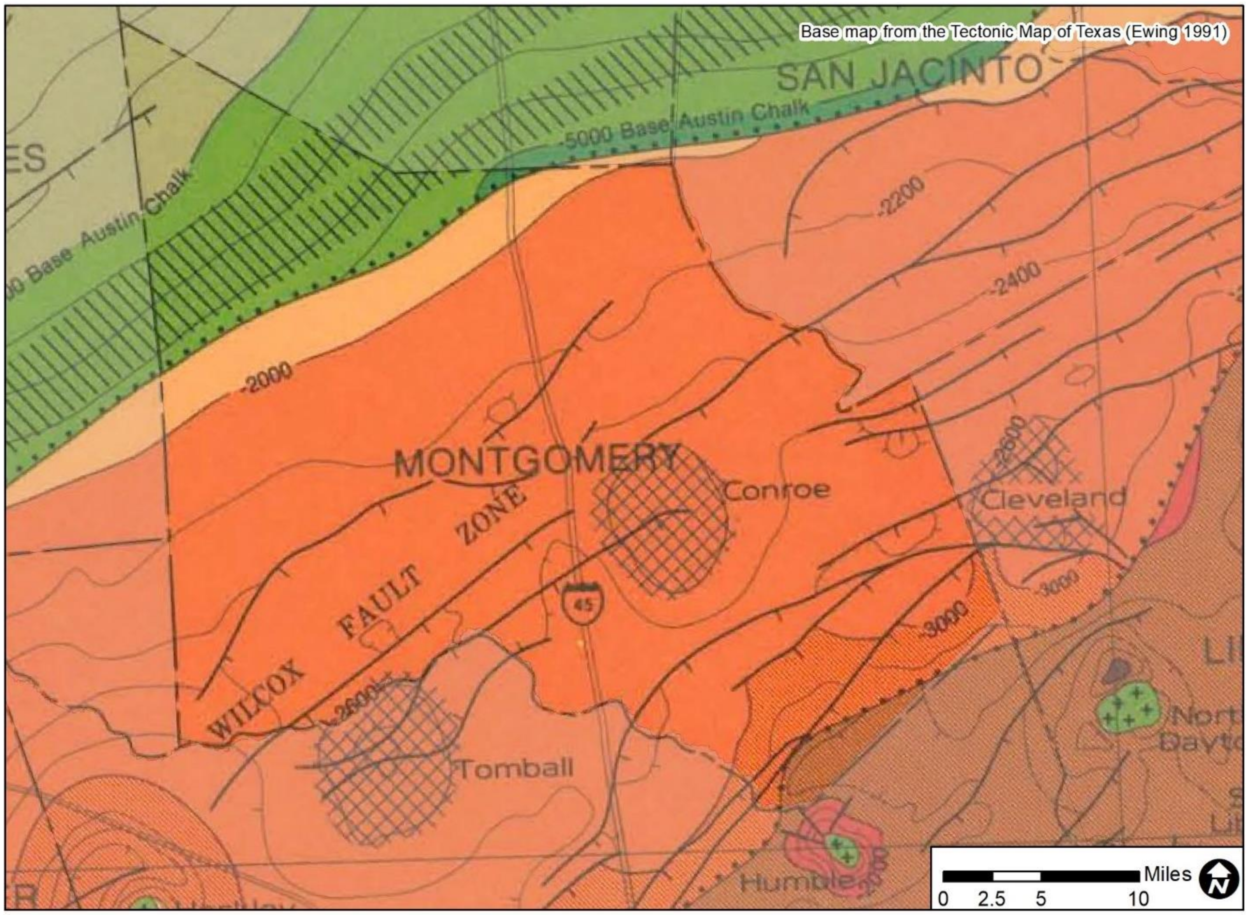

Figure 12. Subsurface faults and large oil and gas fields in the vicinity of Montgomery County (base map from the Tectonic Map of Texas, Ewing, 1991).

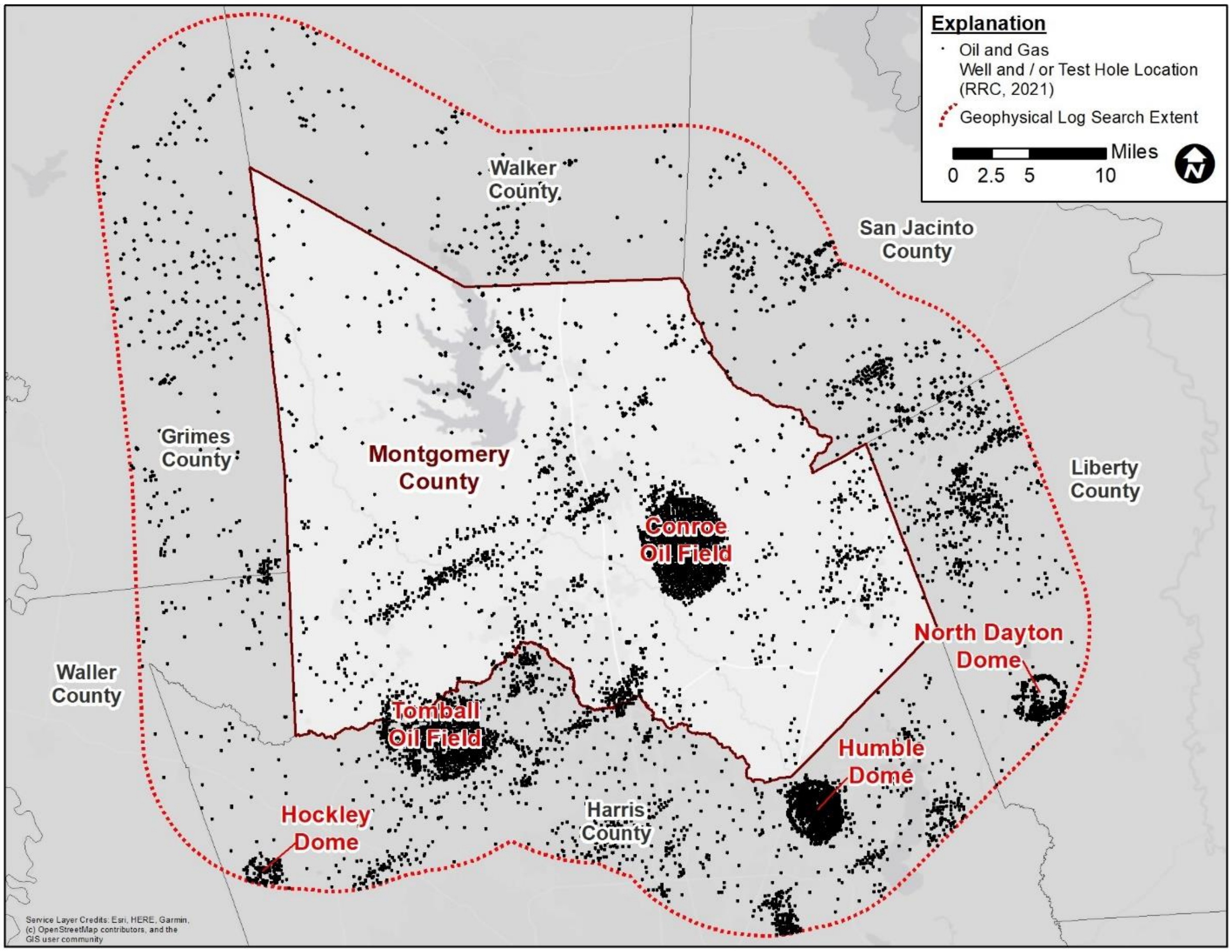

Figure 13. Locations of oil and gas wells or test holes (based on available data from the RRC, 2021).

Geophysical Log Evaluation

One of the goals of the LSGCD Phase 2 Subsidence Study is to improve the mapping and understanding of the subsurface hydrogeologic formations of Montgomery County. Geophysical logs are an important resource that can be utilized to estimate the depths, thicknesses, and composition of the subsurface hydrogeologic units that make up the Gulf Coast Aquifer System.

Geophysical or electric logs are evaluated using the resistivity curves that are shown to the right of the depth scale on the log along with other curves (such as, natural gamma, spontaneous potential, or porosity) when available. As the name implies, these resistivity curves measure the resistivity of the sands, clays, and fluids of the subsurface formations. Clean and coarse sands will have higher resistivity values than fine grained sand, sand intermixed with silt, silt, or clay (lowest resistivity values). Resistivity curves also can provide information on the general mineralization or gross quality of water within subsurface formations. Freshwater sands have higher resistivity values than sands that contain water with more mineralization and higher concentrations of total dissolved solids. The properties of resistivity and conductivity are inverses of each other, so higher resistivity equals lower conductivity. As a result, water that contains more dissolved minerals (that is, higher total dissolved solids concentration) has a higher electrical conductivity and a lower electrical resistivity than water that has relatively low mineralization or total dissolved solids concentration.

Evaluation of spontaneous potential logs can be another way to assess the quality of the water contained within the subsurface formations. The spontaneous potential log is normally shown to the left of the depth scale on a geophysical log. The spontaneous potential curve will show little deflection as the logging tool passes through freshwater sands as freshwater is not highly conductive. The spontaneous potential curve will show more deflection as the logging tool passes through sands that contain water with higher total dissolved solids values.

For this study, the mapping of hydrogeologic units within Montgomery County focused on the Chicot, Evangeline, and Jasper aquifers and the Burkeville Confining Unit. The Jasper Aquifer has been divided into upper and lower units. The delineation of the base and total thickness of the Chicot, Evangeline, Burkeville, and Upper Jasper is based on geophysical log review. The base of the Lower Jasper Aquifer was established for this study using the United States Geological Survey Source Water Assessment Program dataset (Strom and others, 2003).

LSGCD currently permits production from the Chicot and Evangeline aquifers as a single combined aquifer. However, it is important to understand the properties and structure of the individual aquifer units as these two aquifers are often represented as separate layers in groundwater flow models.

Geophysical Log Limitations

Evaluation of geophysical or electric logs to delineate the aquifers of the Gulf Coast Aquifer System is not an exact science. Selections of the top or bottom of a hydrostratigraphic unit is commonly based on experience and professional opinion. As illustrated later in our evaluation, the opinions regarding the top and bottom of hydrogeologic and geologic units can vary between professionals.

The geophysical log datum is a key component for standardizing the depth scale shown on a log. Often the depth shown on geophysical logs is converted to elevation relative to sea level in order to correct for variations in the land surface. The header of the geophysical log may contain the elevation of ground level, Kelly bushing, and drill floor, but often one or more pieces of this information is not available.

Acquiring geophysical logs that start shallow enough to include the base of the Chicot Aquifer was a priority consideration in our geophysical log assembly process. Locating logs that start shallow enough to include the base of Chicot Aquifer was challenging. Often the logs that have a top logged interval showing the base of Chicot Aquifer are relatively older (including from the 1940’s) and can potentially be difficult to interpret due to the image quality of the log.

Geophysical Log Data

We evaluated a total of 146 geophysical logs obtained from public and private sources as part of this study. Most of the geophysical logs reviewed originate from oil and/or gas wells or test holes. The public sources for the geophysical logs include the TWDB Brackish Resources Aquifer Characterization System database (2021a) and the Texas Commission on Environmental Quality Water Well Report Viewer (2021). Geophysical logs also were purchased from a commercial log library in areas where geophysical log coverage was limited or not available from public sources. The search radius for the geophysical logs extends up to 10-miles from Montgomery County in an effort to ensure adequate areal coverage. Figure 14 shows the locations of geophysical logs reviewed as part of this study.

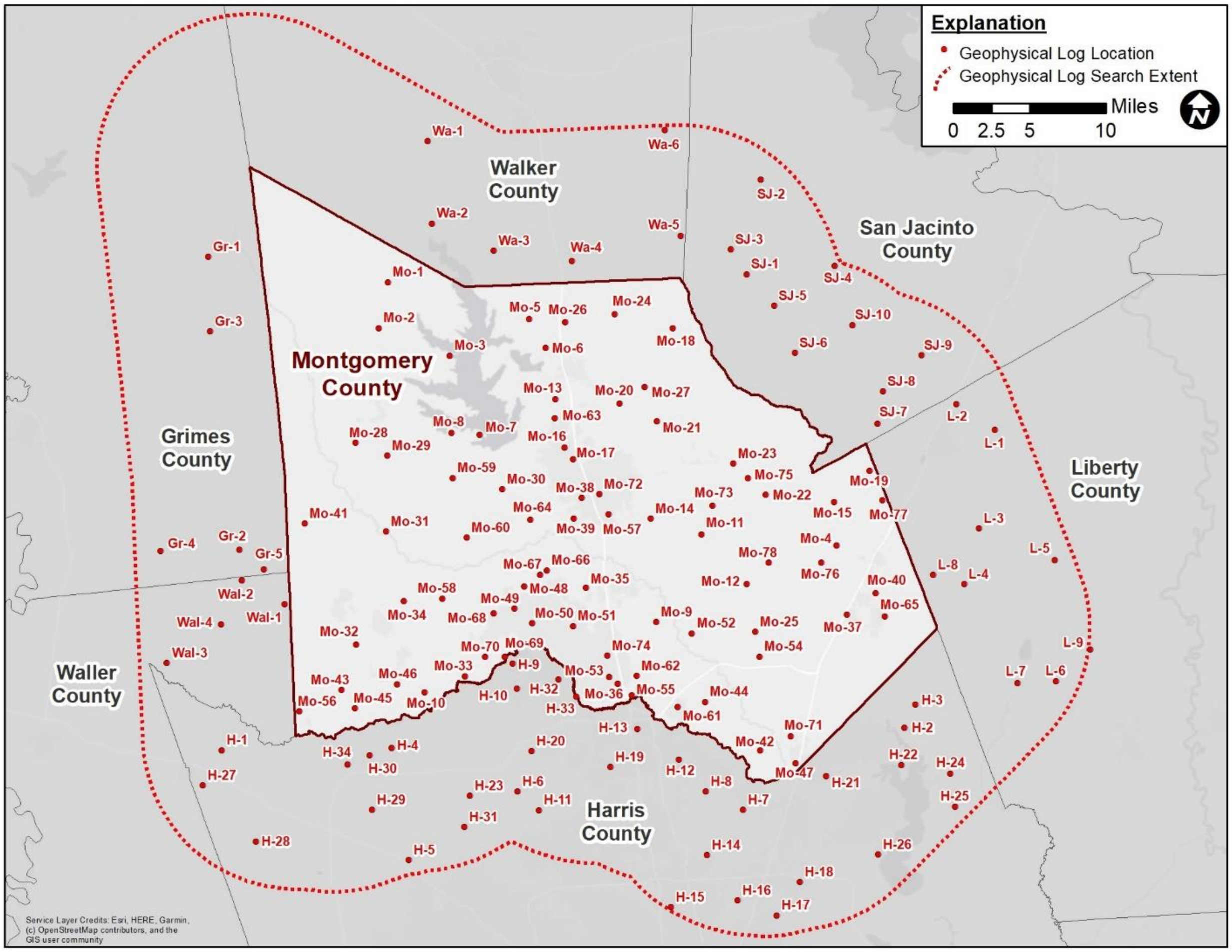

Figure 14. Locations of geophysical logs evaluated for this study.

The datum of the geophysical logs used in this study is based on the land surface elevation. The depth of the hydrogeologic unit selected from the geophysical log has been standardized to account for changes in the land surface elevation by converting the depth of the hydrogeologic unit to elevation relative to sea level. Appendix 1 includes a table that provides geophysical log data utilized in this study including the: Geophysical Log Number, API Number, State Well Number or “Q” Number, well or test hole operator and well ID, latitude and longitude, land surface elevation, and estimated hydrogeologic unit depth and elevation.

Typical Geophysical Logs

We identified 16 typical geophysical logs within Montgomery County and areas to the east and southeast of the county boundary to demonstrate the selection of the base of the hydrogeologic units in this study. Figure 15 shows the location of the geophysical type logs and reduced copies of the geophysical logs are included in Appendix 2. It should be noted that the estimated bases of the hydrogeologic units are shown in depth below land surface on the geophysical logs in Appendix 2.

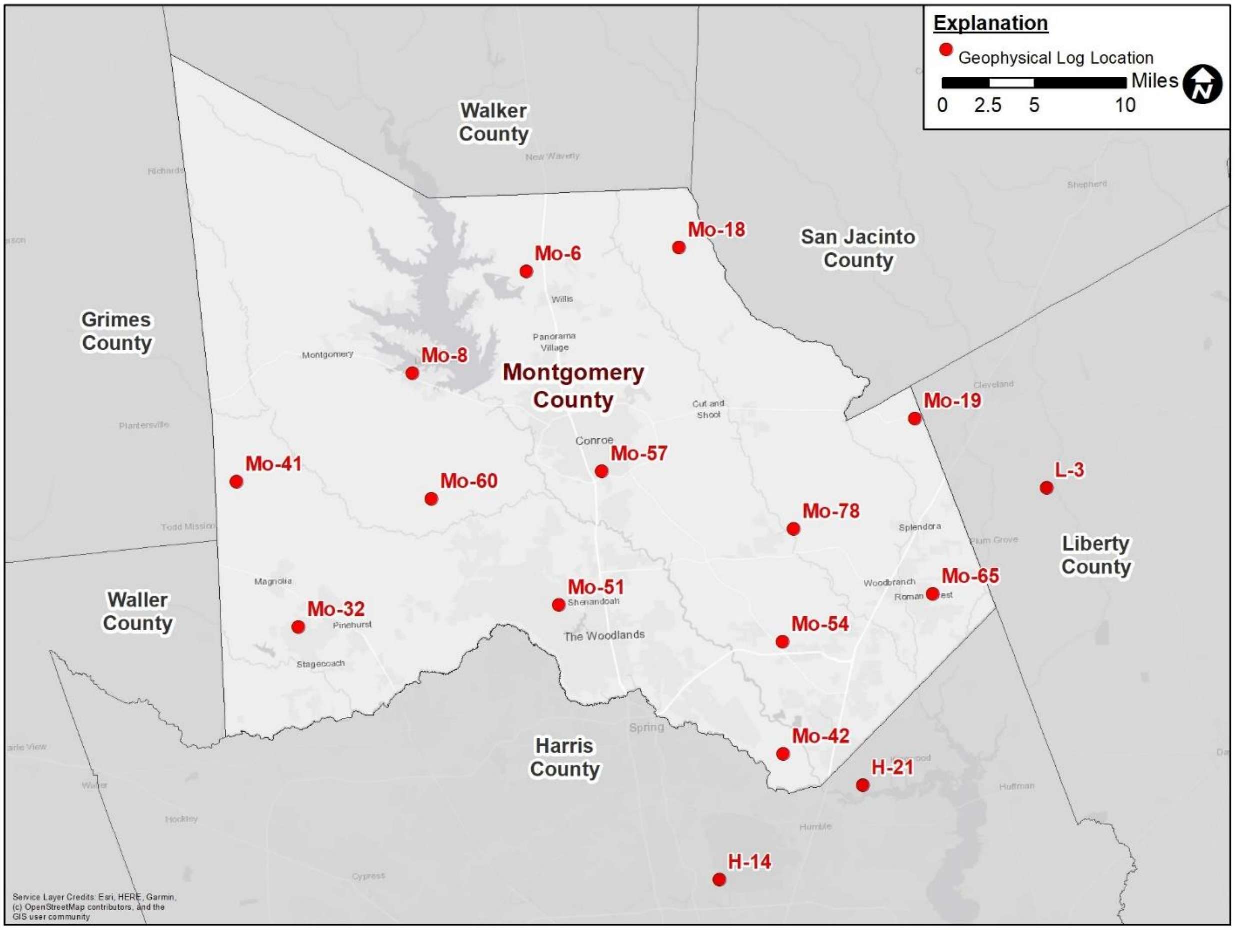

Figure 15. Locations of typical geophysical logs.

The geophysical logs in Appendix 2 show the estimated base of the Chicot, Evangeline, and Upper Jasper aquifers and Burkeville Confining Unit developed for this study, the base of the Jasper Aquifer according to the United States Geological Survey Source Water Assessment Program dataset (Strom and others, 2003), and the base of the Lower Jasper Aquifer identified by Popkin (1971). We also identified the picks by Young and others (2012) and Young and Draper (2020), GULF-2023 dataset, on selected logs

In this study, the base of the Chicot Aquifer is generally estimated to occur at the base of shallow sands which have higher resistivity values and limited clay content. The higher resistivity values of the Chicot Aquifer often coincide with lower total dissolved solids concentrations in water collected and analyzed from water wells completed in the Chicot Aquifer relative to that of the water samples collected from wells completed in the Evangeline Aquifer.

Also, it should be noted that the base of the Lower Jasper as estimated by Popkin (1971) is significantly deeper than the United States Geological Survey Source Water Assessment Program base of Jasper estimate that gained acceptance in the early 2010's. In north Montgomery County, some of the sands that are screened in wells completed in the Catahoula Formation were considered to be part of the Lower Jasper according to the base of Lower Jasper Aquifer estimated by Popkin (1971).

Chicot Aquifer

The Chicot Aquifer is the shallowest hydrogeologic unit of the Gulf Coast Aquifer System occurring in Montgomery County and the aquifer outcrop is present at land surface over approximately 74 percent of the county. A lower amount of groundwater is pumped from the Chicot Aquifer relative to the Evangeline and Jasper aquifers in Montgomery County, with the primary use of the water being for domestic, irrigation (domestic and commercial), and some limited public supply.

Alternating layers of sand, silt, clay, and intermittent gravel comprise the Chicot Aquifer. The transition between the Chicot and Evangeline aquifers is not commonly clear and distinct. Historically, many United States Geological Survey and other scientists, geologists and engineers have used practical hydrogeology concepts, including noticeable differences in lithology, permeability, water levels, and water quality combined with geophysical log interpretation to identify the transition between the Chicot and Evangeline aquifers.

Figure 16 and Figure 17 show the estimated elevation of the base of the Chicot Aquifer and the estimated aquifer thickness, respectively. Evaluation of geophysical logs show that the aquifer is increasing in depth and thickness as the aquifer dips to the southeast towards the Gulf of Mexico. The Chicot Aquifer is estimated to dip at a rate of approximately 15 to 25 feet per mile to the southeast based on the geophysical logs used in this study. The base of the Chicot Aquifer is present at land surface in the outcrop area and is estimated to extend to an elevation of about -375 feet relative to sea level in the southeast part of Montgomery County. The thickness of the Chicot Aquifer increases with distance from the estimated updip extent of the aquifer outcrop to an estimated maximum thickness of approximately 470 feet in the southeast part of the county. The average thickness of the Chicot Aquifer in Montgomery County is estimated to be about 250 feet.

The estimated base of Chicot Aquifer elevation contour map developed for Montgomery County as part of this study is similar to the base of Chicot Aquifer maps shown in Espey, Huston & Associates (1979) and Carr and others (1985). The elevation of the base of the Chicot Aquifer is at or near sea level just to the north of the City of Conroe and the elevation of the base of the Chicot Aquifer is approaching about -400 feet relative to sea level near the Montgomery/Harris County line in the southeast part of Montgomery County in all three studies.

Evangeline Aquifer

The Evangeline Aquifer is positioned below the Chicot Aquifer and above the Burkeville Confining Unit. The aquifer outcrop is present at land surface over approximately 21 percent of Montgomery County. Groundwater pumped from the Evangeline Aquifer is utilized for public supply, commercial, irrigation and industrial uses.

The Evangeline Aquifer is made up of discontinuous layers of alternating sand and clay. Geophysical logs indicate that the Evangeline Aquifer dips at a rate of approximately 40 to 50 feet per mile to the southeast in Montgomery County. Figure 18 shows the estimated base of the Evangeline Aquifer occurring at a depth of about -800 feet relative to sea level in the southwest part of the county and about -1,400 feet relative to sea level in the southeast. Figure 19 shows the estimated thickness of the Evangeline Aquifer which increases with distance from the approximate updip extent in northwest Montgomery County to an estimated maximum thickness of more than 1,000 feet in the southeast part of the county. The average thickness of the Evangeline Aquifer in Montgomery County is about 540 feet.

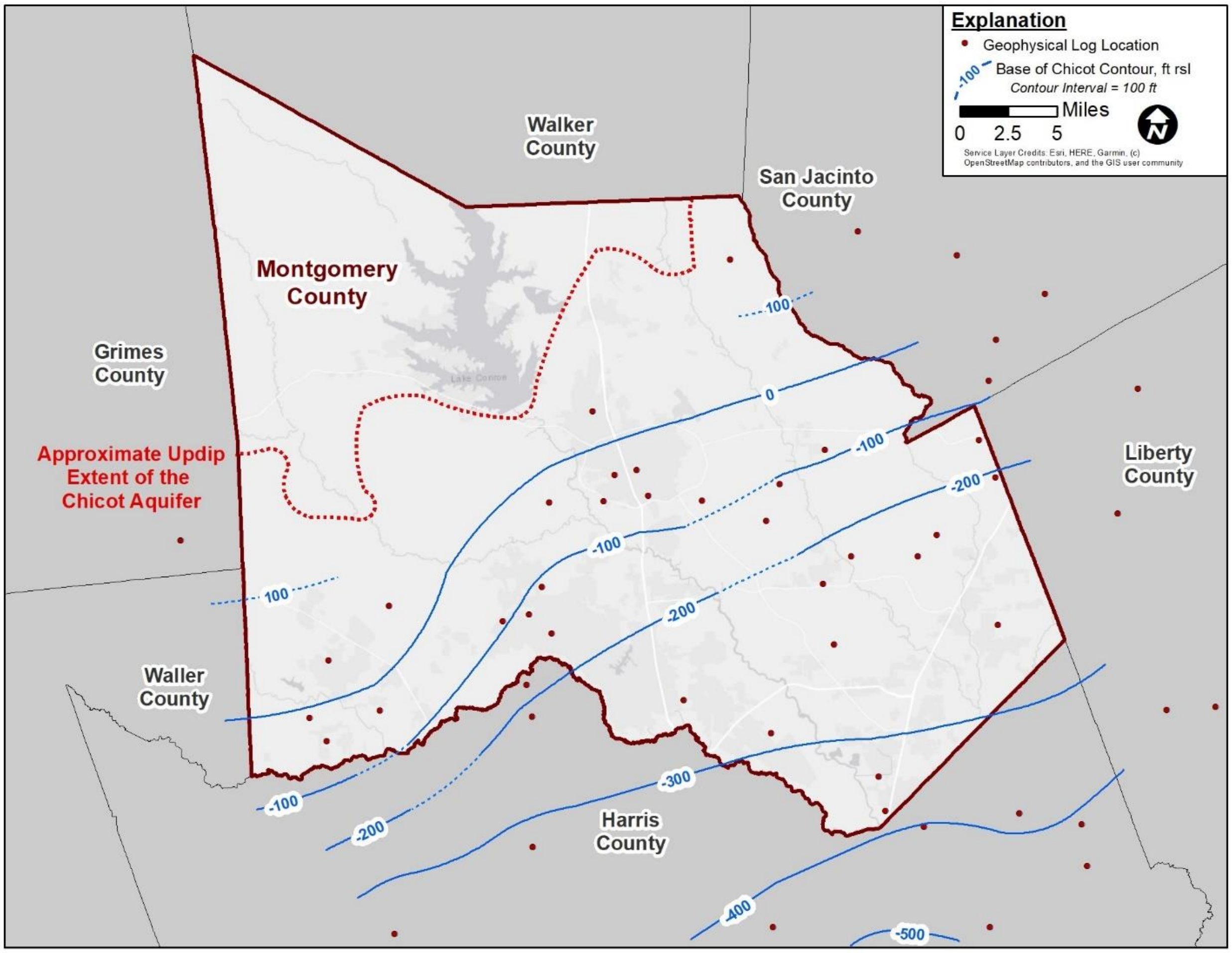

Figure 16. Estimated base of the Chicot Aquifer within Montgomery County.

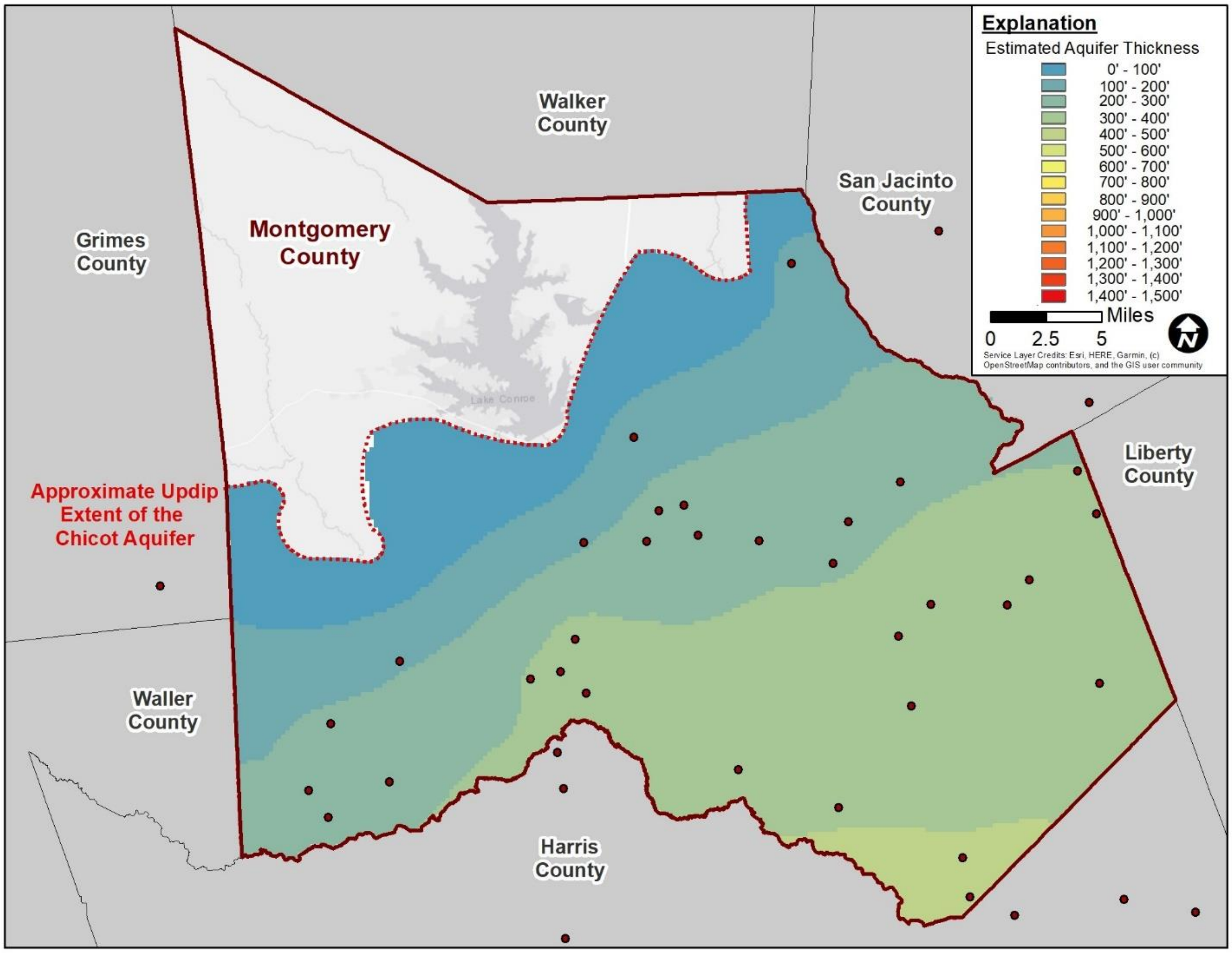

Figure 17. Estimated thickness of the Chicot Aquifer within Montgomery County.

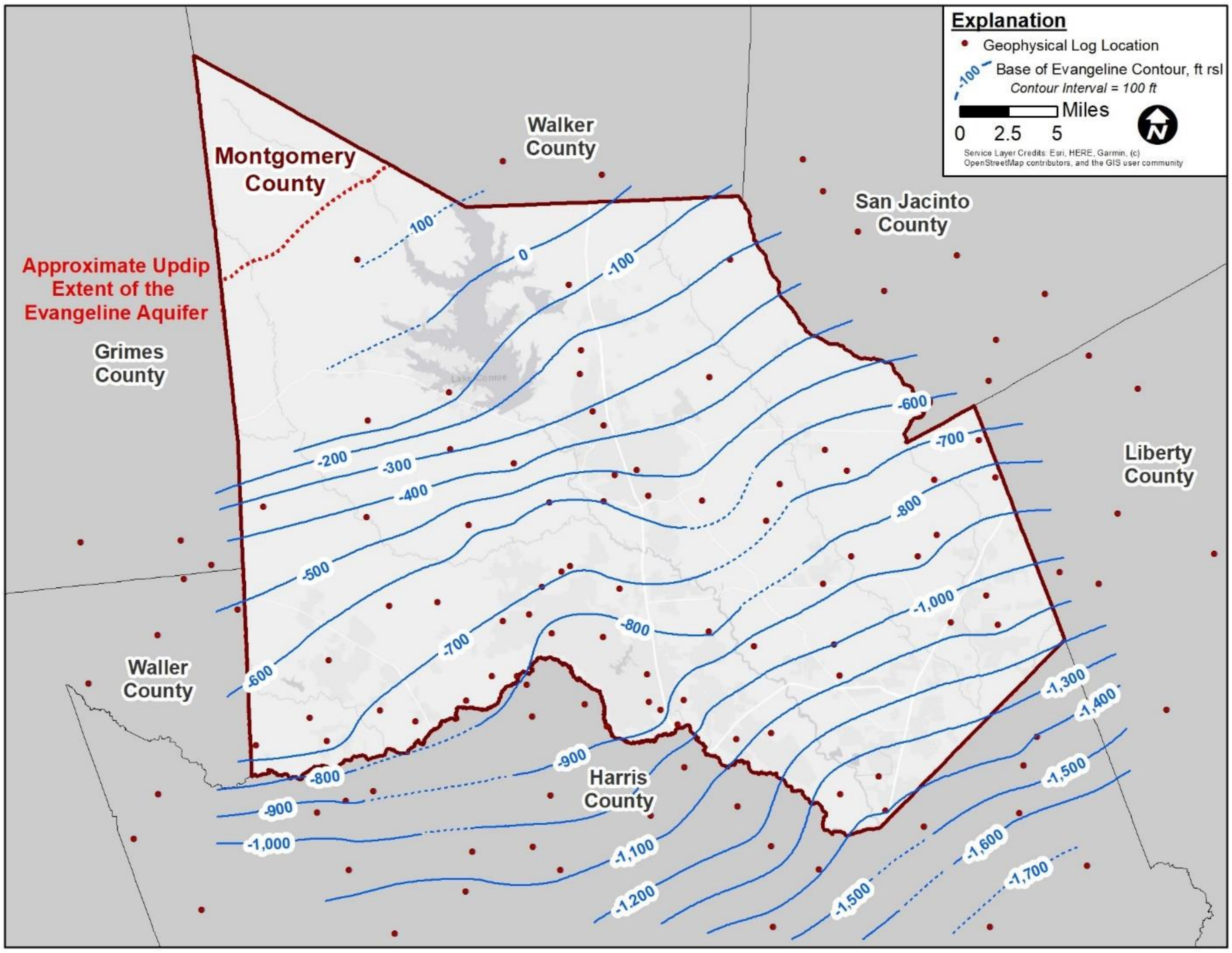

Figure 18. Estimated base of the Evangeline Aquifer within Montgomery County.

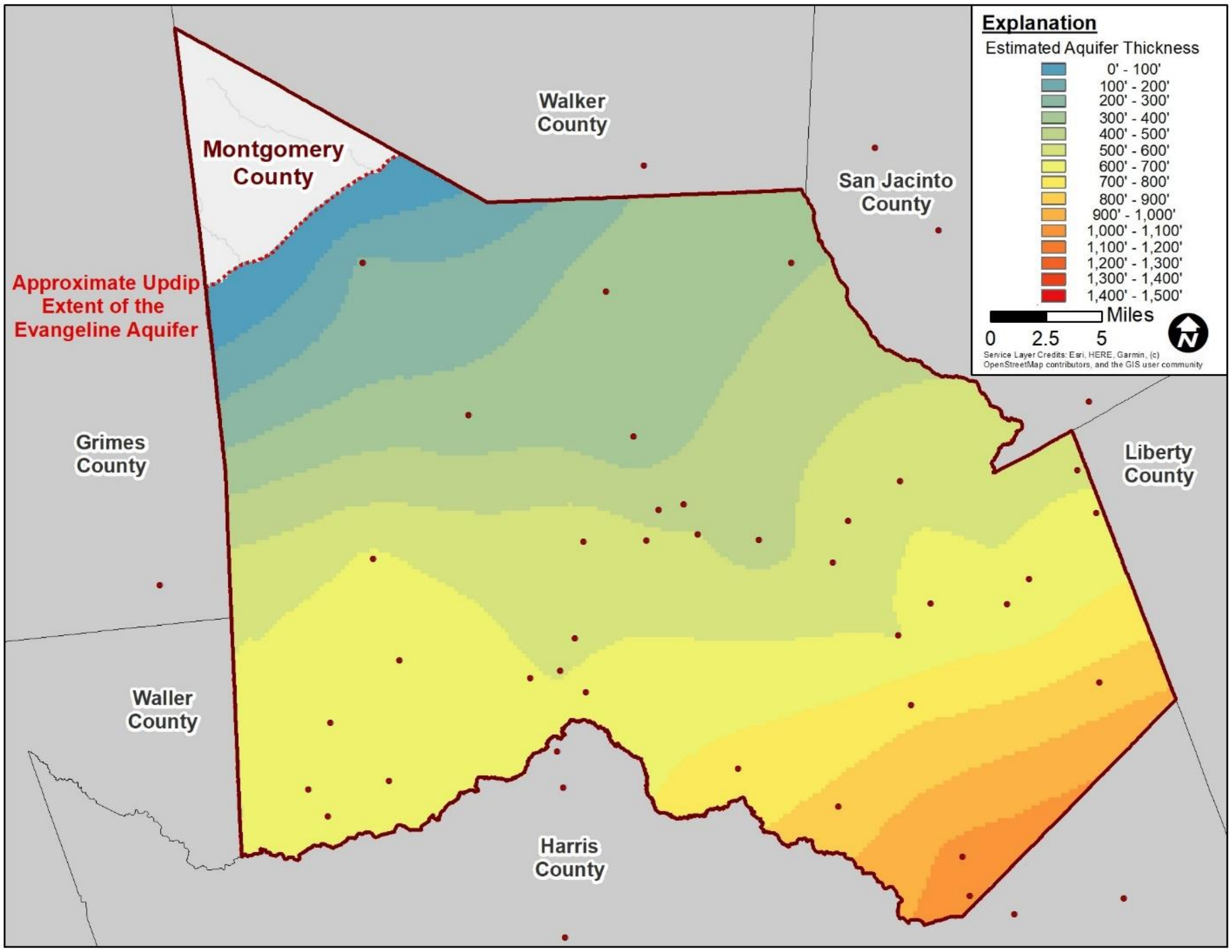

Figure 19. Estimated thickness of the Evangeline Aquifer within Montgomery County.

Burkeville Confining Unit

The Burkeville Confining Unit is vertically positioned between the Evangeline and Jasper aquifers, and the outcrop is estimated to be present at land surface over approximately three percent of Montgomery County. The high percentage of clay content in the Burkeville Confining Unit limits movement of groundwater between the Jasper and Evangeline aquifers. Limited sands occur in the Burkeville and are thought to not be hydraulically connected. In some areas completion of smaller volume domestic wells is possible in the Burkeville Confining Unit; however, the sands of the Burkeville Confining Unit might not be capable of fully supporting a moderate to large capacity water well. In some areas large capacity wells have been constructed with screen set opposite sands in the Burkeville, but the percentage of total well screen in the Burkeville is very small compared to the entire screen interval of the well, which probably is primarily in the shallower Evangeline Aquifer or the upper part of the Jasper Aquifer.

The estimated base of the Burkeville Confining is shown on Figure 20. The elevation of the base of the formation is estimated to occur at a depth of about -1,100 feet relative to sea level in the southwest part of the county and about -1,870 feet relative to sea level in the southeast part of the county. The estimated dip of the base of the Burkeville Confining Unit (equivalent to the top of the Jasper Aquifer) is generally to the southeast at a rate of approximately 40 to 50 feet per mile. The estimated thickness of the Burkeville Confining Unit is shown on Figure 21 and generally increases with distance from the approximate updip extent located in far northwest Montgomery County to an estimated maximum thickness of about 480 feet in the southeast part of the county. The Burkeville Confining Unit thickness is estimated to range from about 200 to 300 feet in a large part of Montgomery County, with an average thickness of the formation estimated to be approximately 240 feet.

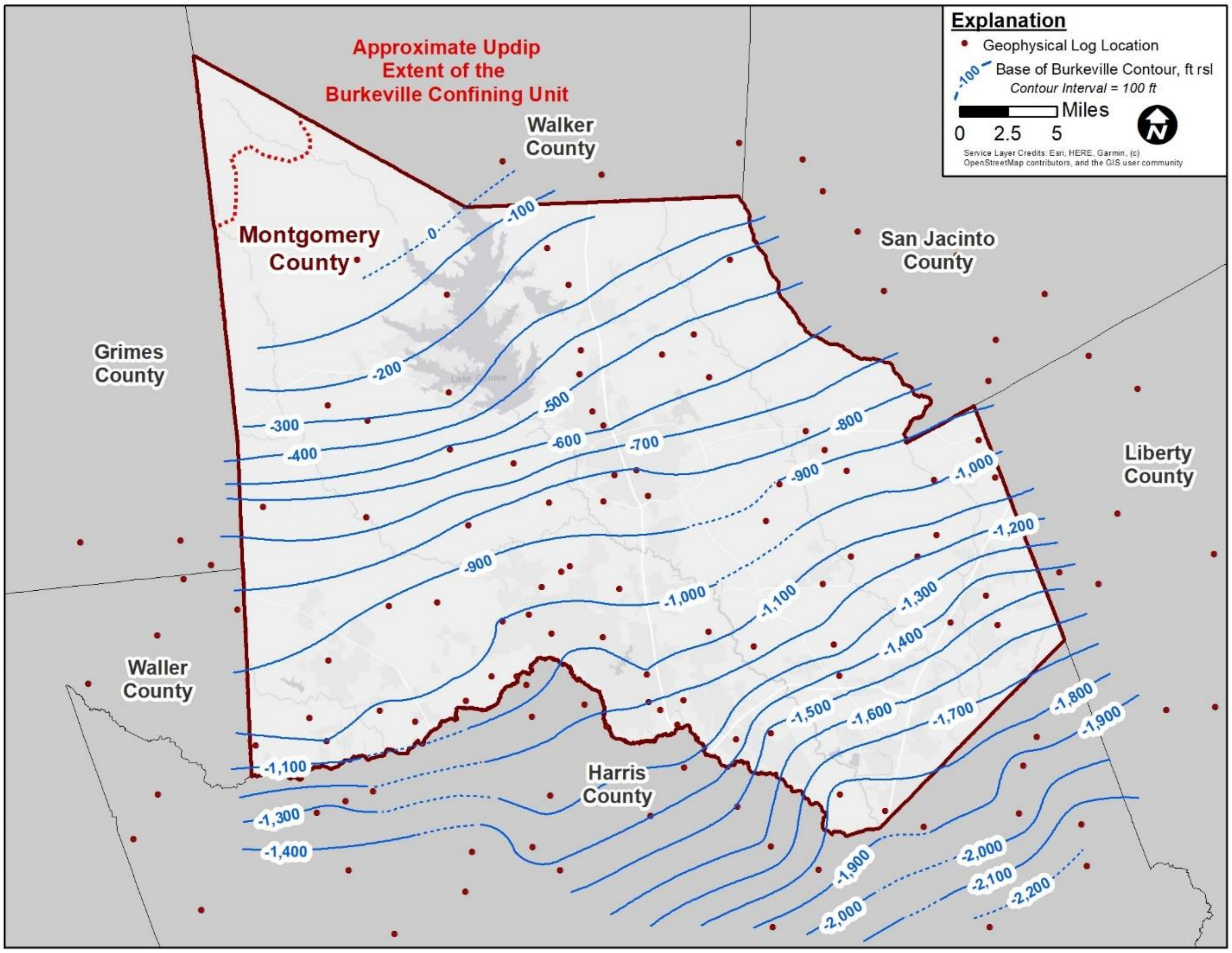

Figure 20. Estimated base of the Burkeville Confining Unit within Montgomery County.

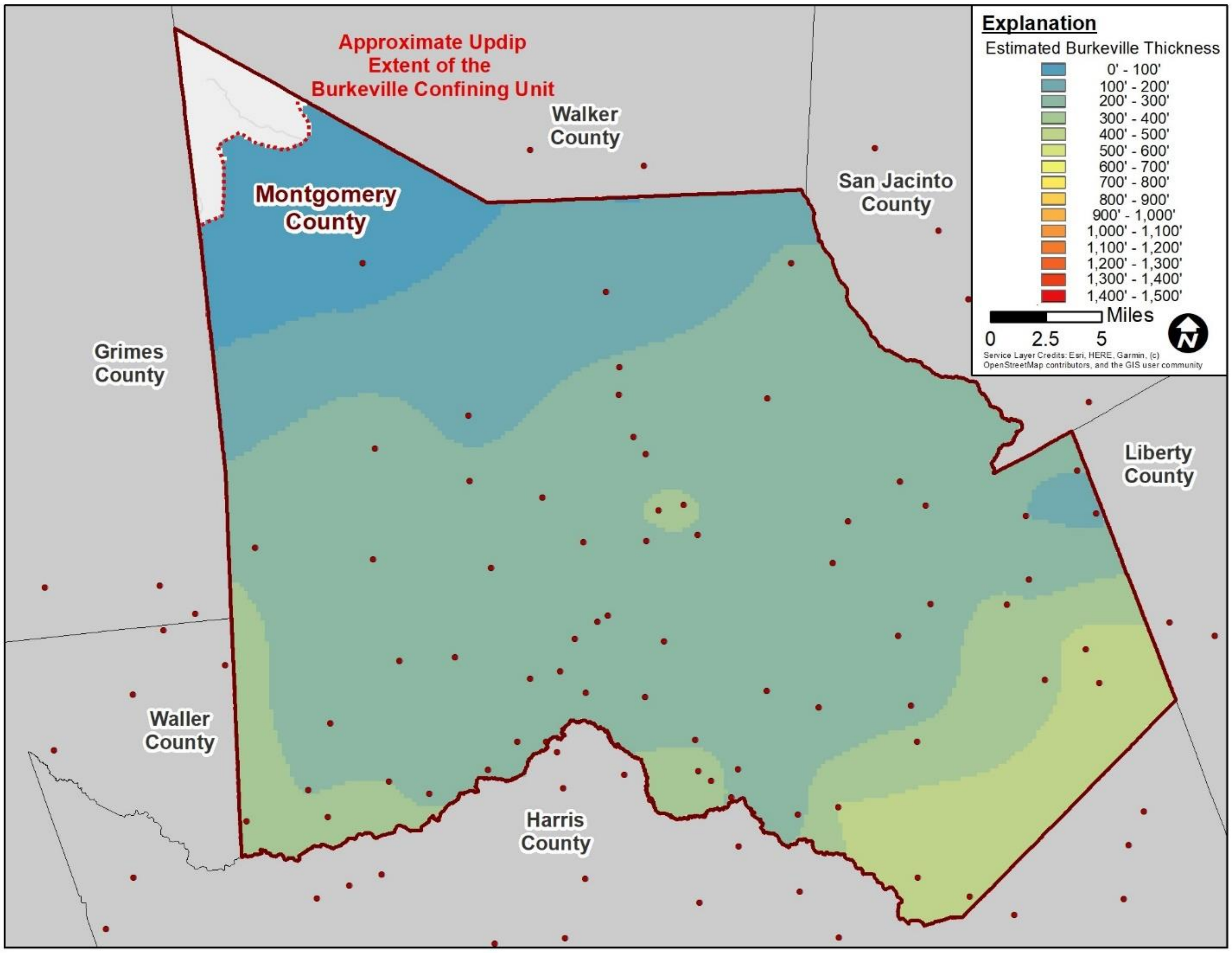

Figure 21. Estimated thickness of the Burkeville Confining Unit within Montgomery County.

Jasper Aquifer

The Jasper Aquifer is a significant source of groundwater production in Montgomery County. It is positioned between the overlying Burkeville Confining Unit and the underlying Catahoula Formation. Groundwater produced from the Jasper Aquifer is used for public, industrial, and other water supply, but also can be used for domestic purposes in the shallower, updip part of the formation. The Jasper Aquifer outcrop is present at land surface in approximately two percent of Montgomery County, the smallest of any hydrogeologic unit in the county.

As the focus of this study is on the principal hydrogeologic units from which groundwater is produced in Montgomery County, we separated the Jasper Aquifer into upper and lower units based on lithology. The Upper Jasper Aquifer contains more sand than the Lower Jasper and is the section of the aquifer screened in moderate to large capacity public supply and industrial wells throughout Montgomery County and in parts of north and northwest Harris County. The thicker sands that comprise the Upper Jasper Aquifer can contain brackish groundwater in downdip areas of the formation located in southeast Montgomery County. The Lower Jasper is made up of mostly interbedded sand and clay and the water contained within the sands can often be of brackish water quality. At the time of this study there has been no development of the brackish groundwater resources available from the Jasper Aquifer in Montgomery County. The United States Geological Survey Source Water Assessment Program dataset corresponding to the base of the Jasper Aquifer (Strom and others, 2003) was used as the base of the Lower Jasper in this study.

Upper Jasper Aquifer

The base of the Upper Jasper Aquifer is estimated to dip at a rate of approximately 50 to 60 feet per mile to the southeast. Figure 22 shows the estimated elevation of the base of the Upper Jasper Aquifer, with the elevation of the base of the Upper Jasper Aquifer occurring at a depth of about -1,500 feet relative to sea level in the southwest and about -2,350 feet relative to sea level in the southeast part of the county. Figure 23 illustrates the estimated thickness of the Upper Jasper Aquifer which increases with distance from the approximate updip extent in far northwest Montgomery County. The maximum estimated thickness is about 570 feet in the southeast part of the county. The average thickness of the Upper Jasper Aquifer is estimated to be about 390 feet in Montgomery County.

Lower Jasper Aquifer

The base of the Lower Jasper Aquifer was generated from the base of the Jasper Aquifer in the United States Geological Survey Source Water Assessment Program dataset (Strom and others, 2003) and can be seen on Figure 24. Strom and others (2003) indicate that the Source Water Assessment Program base of the Jasper Aquifer was created using well data from cross sections included in Baker, Jr. (1979; 1986). The cross sections included in Baker, Jr. (1979; 1986) have limited geophysical log data within Montgomery County. The estimated dip of the base of the Lower Jasper Aquifer is approximately 50 to 60 feet per mile to the southeast. The elevation of the base of the Lower Jasper Aquifer is estimated to occur at a depth of about -2,000 feet relative to sea level in the southwest part of the county and about -2,900 feet relative to sea level in the southeast part.

Figure 25 shows the approximate thickness of the Lower Jasper Aquifer based on the estimated base of the Upper Jasper (as defined in this study) and the base of the Jasper Aquifer as defined by the

United States Geological Survey Source Water Assessment Program dataset (Strom and others, 2003). The estimated thickness of the Lower Jasper Aquifer in Montgomery County ranges from approximately 100 feet in the northwest part of the county to approximately 900 feet in the east part of the county, with an average thickness of about 500 feet.

Combined Jasper Aquifer

Figure 26 shows the estimated thickness of the Jasper Aquifer (combined upper and lower units) based on the difference between base of the Burkeville Confining Unit as delineated in this study and the base of the Jasper Aquifer depicted by the United States Geological Survey Source Water Assessment Program dataset. This thickness using the base of the Jasper Aquifer as defined by the United States Geological Survey Source Water Assessment Program dataset provides a general estimate of the total thickness of the Jasper Aquifer using the surface that was recognized as the base of the Jasper by LSGCD in the early 2010's. The total thickness of the Jasper Aquifer is estimated to range from about 150 feet in the outcrop area in the northwest part of Montgomery County to an estimated maximum thickness of approximately 1,280 feet in the east part of the county. The estimated average thickness of the Jasper Aquifer (combined upper and lower units) is approximately 890 feet.

The estimated thickness of the Jasper Aquifer (combined upper and lower units) based on Popkin (1971) is substantially greater than the estimated thickness using the United States Geological Survey Source Water Assessment Program dataset. An estimated thickness for the total Jasper Aquifer based on Popkin (1971) was developed using data assembled for the 2004 LSGCD Groundwater Resources Management Information Report for Montgomery County (TC&B, 2004). Estimated total Jasper Aquifer thicknesses based on the Popkin (1971) methodology range from approximately 1,490 feet to approximately 3,040 feet in Montgomery County, with an average thickness of about 2,100 feet.

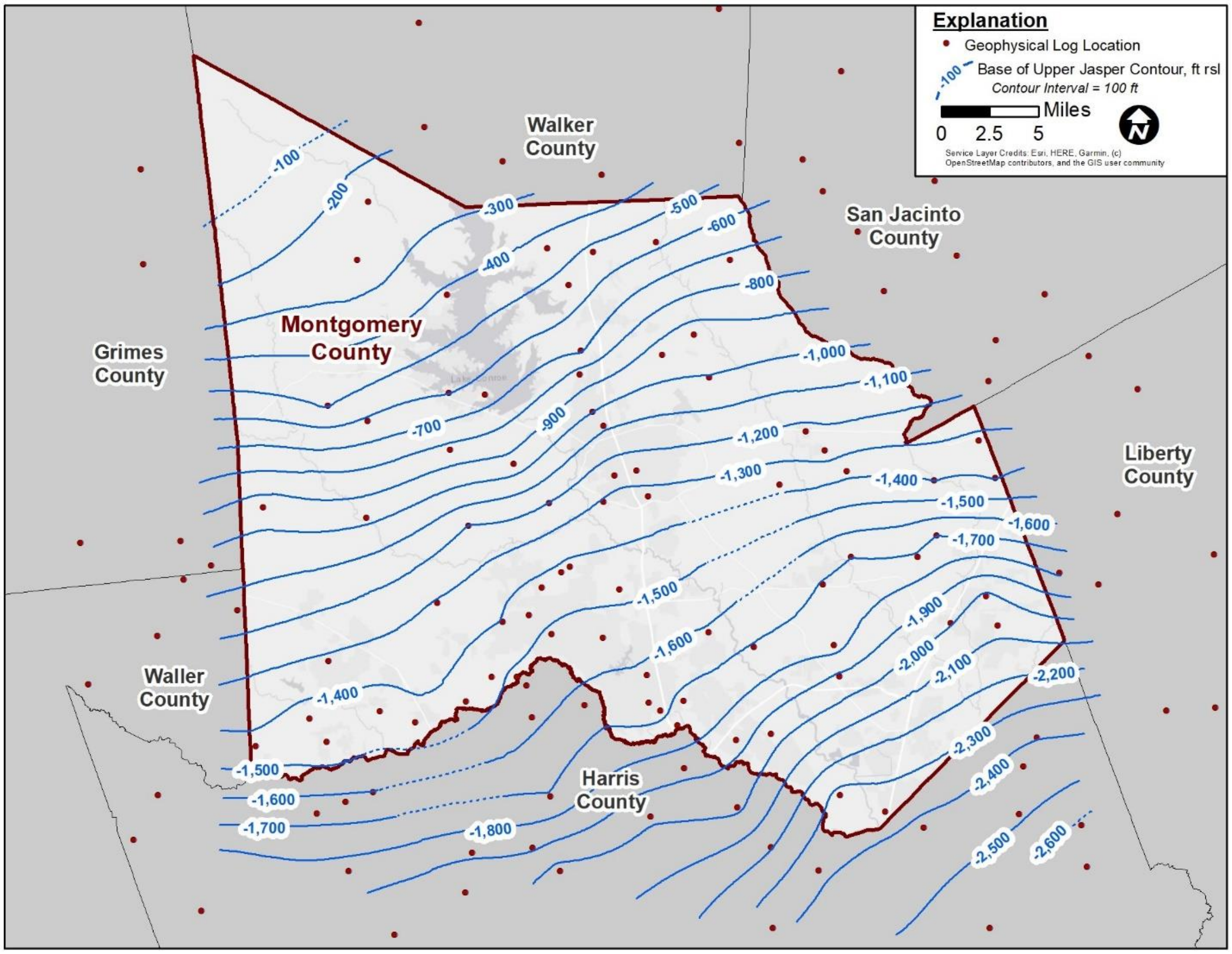

Figure 22. Estimated base of the Upper Jasper Aquifer within Montgomery County.

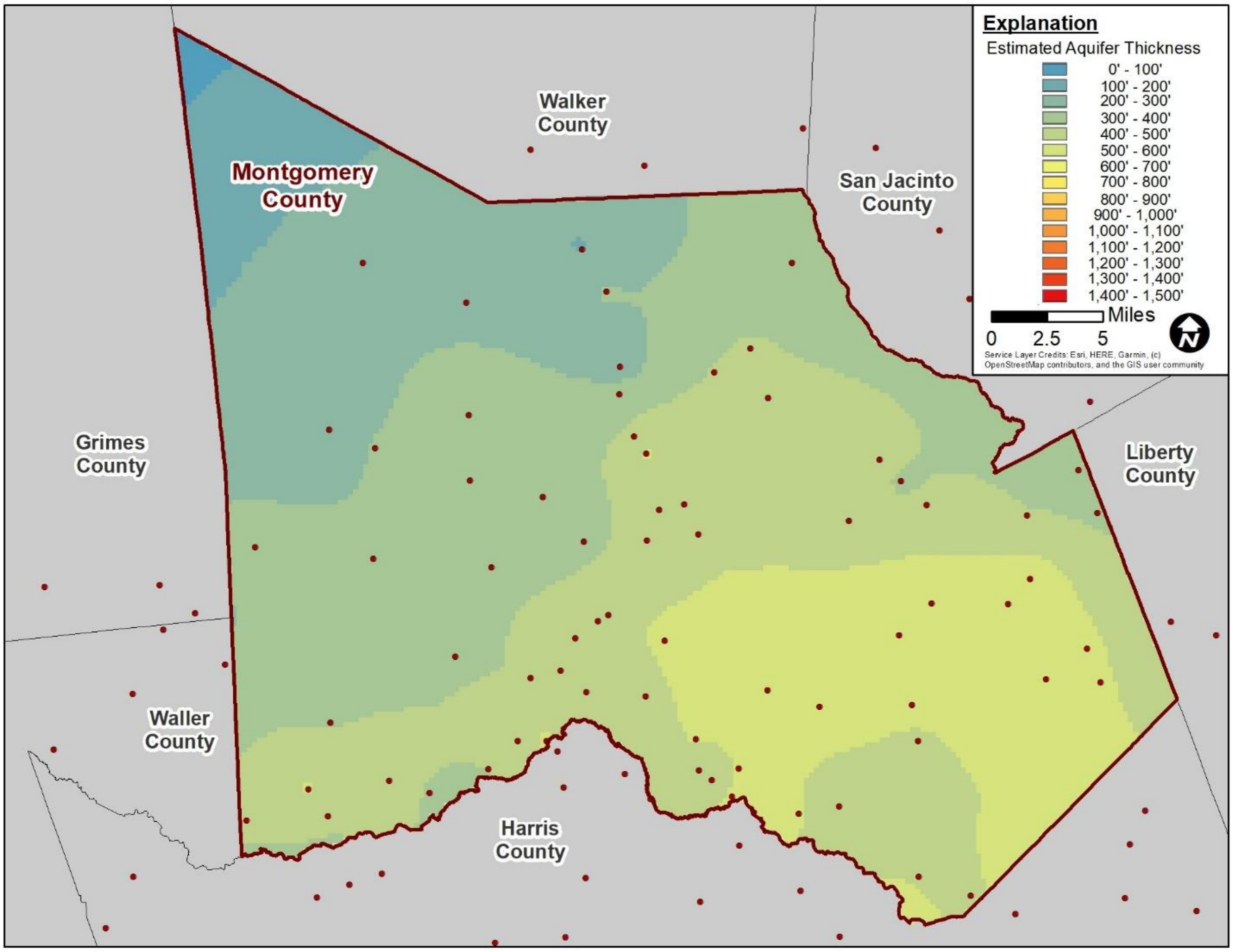

Figure 23. Estimated thickness of the Upper Jasper Aquifer within Montgomery County.

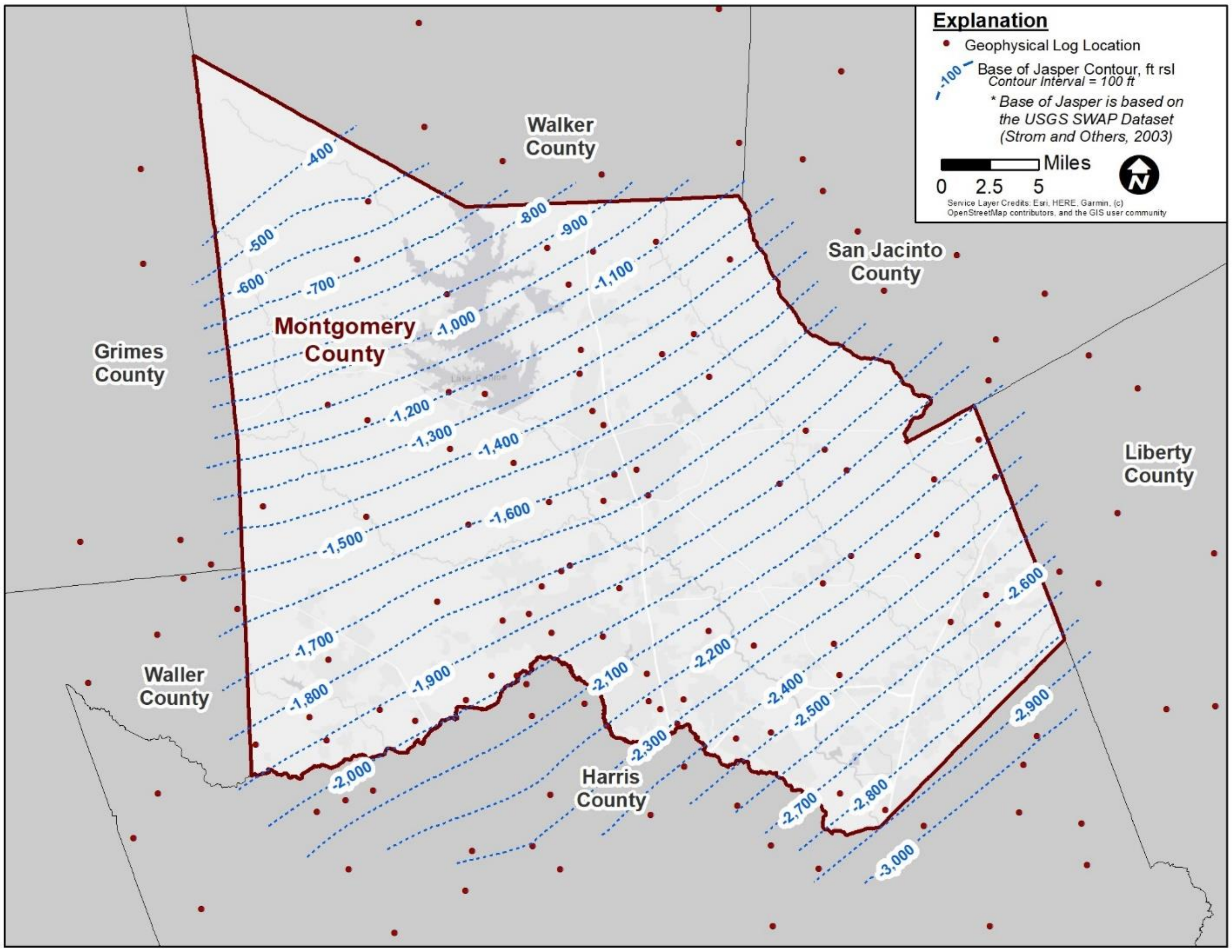

Figure 24. Estimated base of the Lower Jasper Aquifer within Montgomery County based on the United States Geological Survey Source Water Assessment Program dataset (Strom and others, 2003).

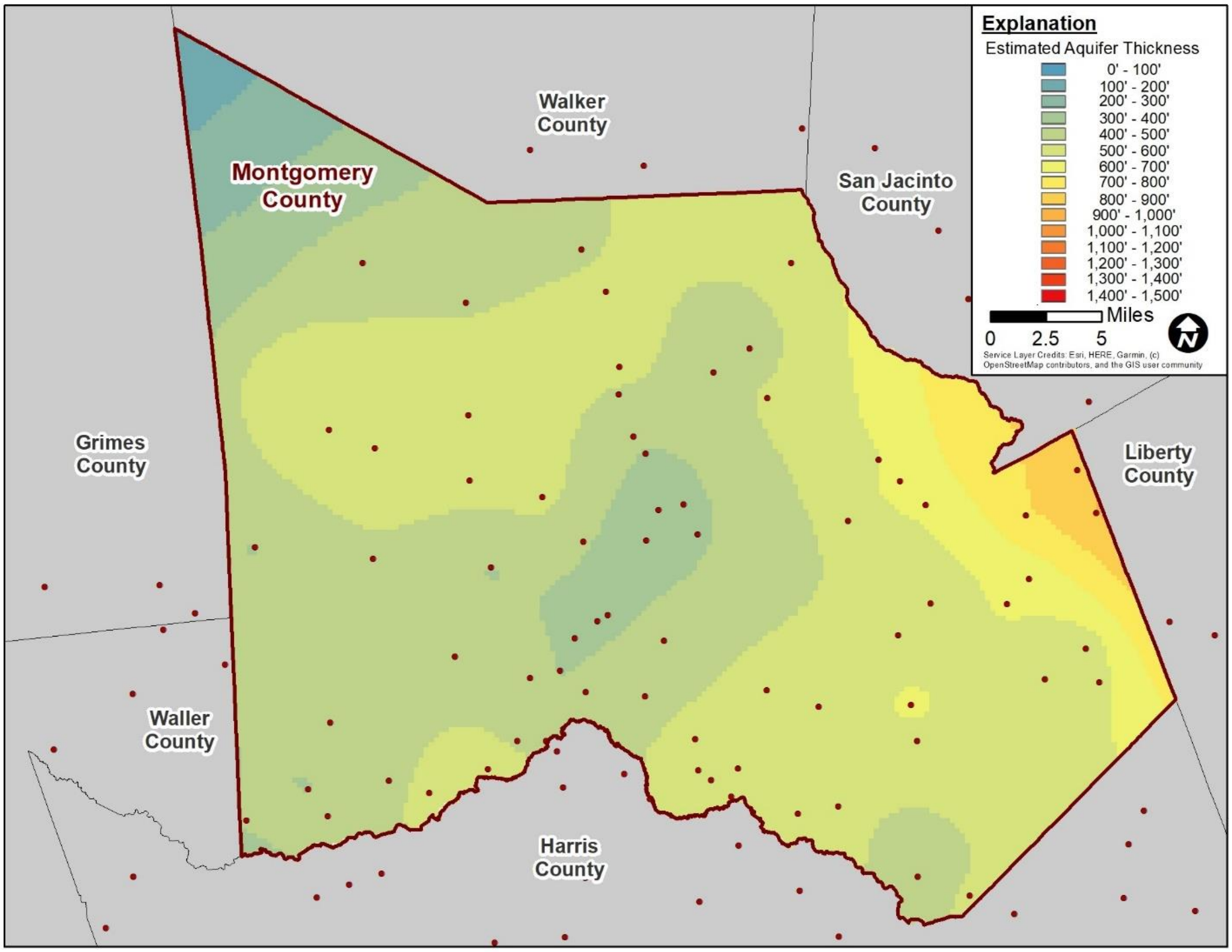

Figure 25. Estimated thickness of the Lower Jasper Aquifer within Montgomery County as the difference between the base of the Upper Jasper as defined as part of this study and the base of the Jasper Aquifer as defined by the United States Geological Survey Source Water Assessment Program dataset.

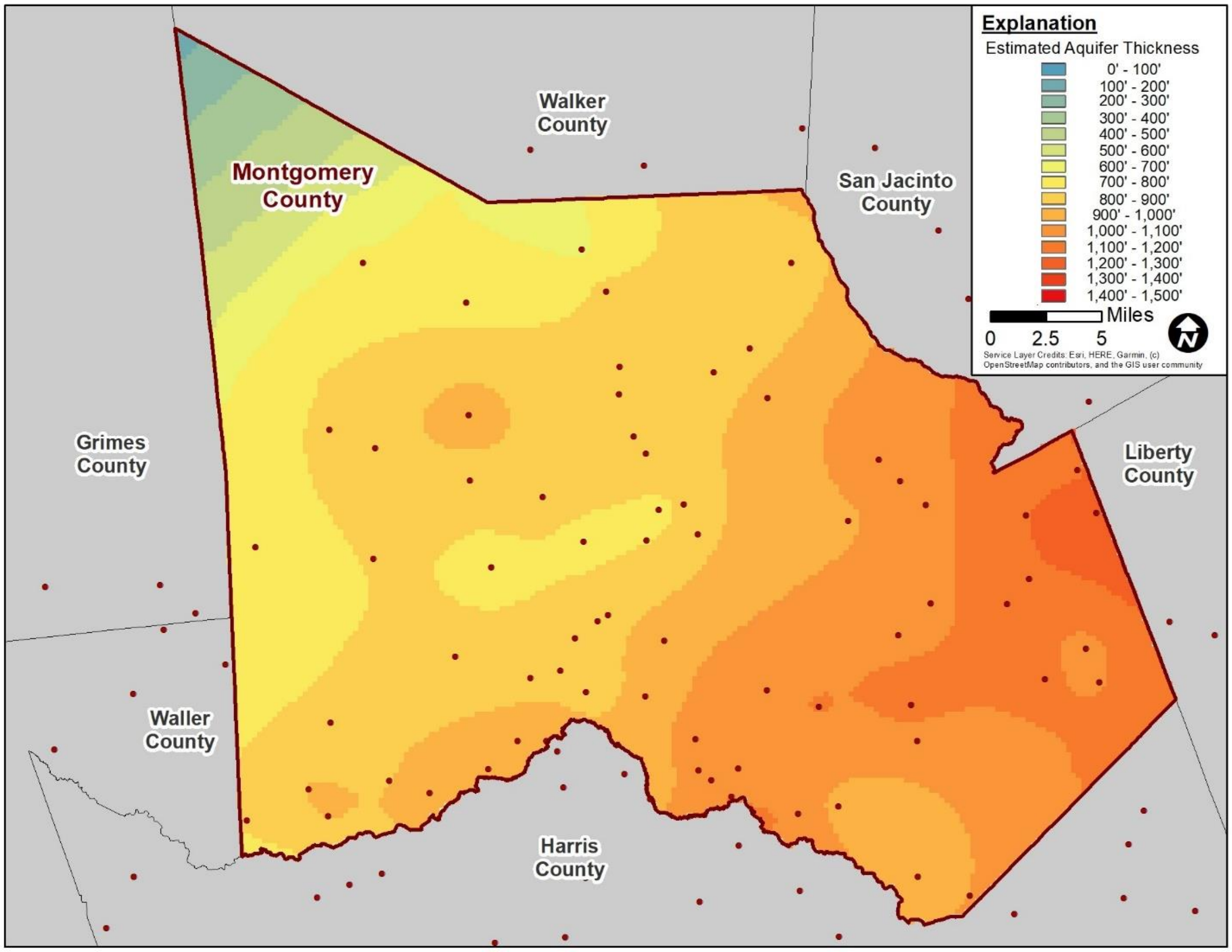

Figure 26. Estimated total thickness of the Jasper Aquifer within Montgomery County as the difference between the base of the Burkeville Confining Unit as defined in this study and the base of the Jasper Aquifer as defined by the United States Geological Survey Source Water Assessment Program dataset.

GULF-2023 Groundwater Flow Model

In an effort to improve future groundwater availability models of the Gulf Coast Aquifer System, additional stratigraphic and lithologic data beyond the existing Chicot, Evangeline, and Jasper aquifers and Burkeville Confining Unit data was developed by Young and others (2012). A lithostratigraphic approach, as defined by Young and others (2012), involves interpolating formation lithologies from geophysical logs and correlating the lithologies between additional geophysical logs (Young and other, 2012). To update the hydrostratigraphic framework of the Gulf Coast Aquifer System, Young and others (2012) utilized a chronostratigraphic approach and sequence stratigraphy to identify clay-dominated flooding surfaces of the same age and subsequently subdivide the Chicot, Evangeline, and Jasper aquifers and Burkeville Confining Unit into sub-aquifer layers.

As a result of the work performed, Young and others (2012) subdivided the Chicot, Evangeline, and Jasper aquifers and the Burkeville Confining Unit of the Gulf Coast Aquifer System into 10 subunits as follows:

- Chicot Aquifer: 1) Beaumont Clay; 2) Lissie Formation; 3) Willis Formation;
- Evangeline Aquifer: 4) Upper Goliad; 5) Lower Goliad; 6) Upper Lagarto;
- Burkeville Confining Unit: 7) Middle Lagarto;
- Jasper Aquifer: 8) Lower Lagarto; 9) Oakville Formation; and 10) Catahoula Formation

Young and Draper (2020) updated the extent of the Burkeville Confining Unit and the base of the Chicot Aquifer to support the development of the GULF-2023 groundwater model. The GULF-2023 groundwater model is a six-layer groundwater flow model that is currently being developed by the United States Geological Survey for the Harris-Galveston Subsidence District. The following layers are assigned to the GULF-2023 model: Layer 1 – Alluvium and Beaumont Clay; Layer 2 – Chicot Aquifer; Layer 3 – Evangeline Aquifer; Layer 4 – Burkeville Confining Unit; Layer 5 – Jasper Aquifer; and Layer 6 – Catahoula Formation.

Young and Draper (2020) updated the subdivided formations defined by Young and others (2012) by adjusting the base of the Chicot Aquifer (top of the Evangeline Aquifer), the top of the Burkeville Confining Unit (base of the Evangeline Aquifer), and the base of the Burkeville Confining Unit (top of Jasper Aquifer) to support the GULF-2023 model. Regarding the updated Burkeville Confining Unit utilized in the GULF-2023 model, Young and Draper (2020) state:

> "Because the Burkeville unit defined by Baker (1979) is a lithostratigraphic unit that is not bounded by isochronous boundaries and exists across the Upper, Middle and Lower Lagarto formations, it cannot be accurately represented by any single chronostratigraphic formation defined by Young and others (2010, 2012). To create a "lithostratigraphic-based" Burkeville Unit from the clays and sand sequences generated by Young and others (2010, 2012), we correlated the sand and clay sequences in the Upper, Middle and Lower Lagarto Formations based on a lithostratigraphic approach. This approach provides a practical integration of the lithostratigraphic and chronostratigraphic approaches to represent the conceptualization by Baker (1979) of the Burkeville Confining Unit."

Young and Draper (2020) indicated that the Willis Formation (base of Chicot Aquifer) was primarily updated to incorporate additional geophysical logs into the analysis, increasing the number of logs used to estimate the base of the Willis Formation from 290 logs to 650 logs with stratigraphic picks. Young and Draper (2020) state:

> "At each geophysical log, the location of the base of the Willis was selected to represent a transition from the sand-rich basal Chicot Aquifer (Willis Formation) to the sand-poor top of the Evangeline. In most of the logs, the adjustment to the previous picks by Young and others (2010, 2012) was less than 100 feet."

GULF-2023 Hydrogeologic Surface Comparison

The base of the geologic units (with hydrogeologic equivalents) developed by Young and others (2012) and the updated picks of the hydrogeologic units based on Young and Draper (2020) are shown on the typical geophysical log examples included in Appendix 2, where available. Hydrogeologic picks approximated from Young and Draper (2020) are noted as the 'Gulf 2023 Dataset' and the geologic formation picks approximated from Young and others (2012) labeled 2012 and include the hydrogeologic unit where applicable.

The picks shown on the geophysical logs in Appendix 2 were based on common API numbers for geophysical logs used in this study and the referenced reports. The appendices included with Young and others (2012) and Young and Draper (2020) provide the geophysical log API number, datum, and the estimated elevation of the hydrogeologic/geologic unit. The geophysical log datum and hydrogeologic/geologic unit elevation were used to convert the elevation of the base of the hydrogeologic/geologic unit to depth below land surface for a cleaner presentation of the picks on the geophysical logs.

Based on a limited number of geophysical logs common between this study and Young and others (2012), the base of the hydrogeologic units selected by Young and others (2012) appears to be generally deeper in the subsurface in the southeast part of Montgomery County relative to this study. The Burkeville Confining Unit/Middle Lagarto as defined in Young and others (2012) include sand intervals that are considered to be part of the Upper Jasper Aquifer in this study. It should be noted that a number of high-capacity water wells in Montgomery County that screen sands of the Upper Jasper Aquifer would have been included as part of the Burkeville Confining Unit based on the chronostratigraphic formation picks of Young and others (2012).

Modifications to the Young and others (2012) dataset by Young and Draper (2020) to support the GULF-2023 model included adjustments to the top and bottom of the Burkeville Confining Unit and the base of the Chicot Aquifer. Young and Draper (2020) used a lithostratigraphic based approach to adjust the Burkeville Confining Unit elevations, which yielded formation picks that are generally similar to the picks defined in this study for most parts of Montgomery County.

A chronostratigraphic approach was utilized by Young and Draper (2020) to update the base of Chicot Aquifer in support of the GULF-2023 model. The base of the Chicot Aquifer as defined by Young and Draper (2020) is generally deeper than the base of Chicot Aquifer defined in this study and previous work by others and becomes increasingly deeper in the southeast part of Montgomery County. The depth of the estimated base of Chicot Aquifer (Young and Draper, 2020) exhibits larger increases in depth in parts of Liberty and Harris counties based on geophysical logs reviewed within the search area of this study.

The estimated depth of the base of the Chicot Aquifer as defined by Young and Draper (2020) can be significantly deeper in parts of northeast and east Harris County than defined in previous work. The estimated base of the Chicot Aquifer developed by Young and Draper (2020) can reach depths that are approximately twice as much as previous depth estimates in areas of Harris County.

GULF-2023 Observation Well Designations

The differences between the estimated aquifer elevations developed in support of the GULF-2023 model by Young and Draper (2020) and work performed by others can be illustrated by plotting the observation wells used in the development of the United States Geological Survey 2021 Water-Level Altitude Map Series and highlighting the observation wells that will receive new aquifer designations based on the GULF-2023 model.

In May 2021, LSGCD received provisional water level data in tabular form that was collected and provided by the United States Geological Survey (USGS, 2021b). The provisional table included a column that displayed the newly assigned aquifer designation based on the GULF-2023 model surfaces generated from the Young and Draper (2020) dataset. Original aquifer designations available from the United States Geological Survey National Water Information System Web Interface Groundwater Levels for Texas (2021a) were compared to the newly assigned aquifer designations.

Figure 27 shows the United States Geological Survey observation well locations that have an updated aquifer designation based on the GULF-2023 model surfaces that were developed using data from Young and Draper (2020). Based on the provisional data provided by the United States Geological Survey in May 2021, it is estimated that approximately 36 percent (165 out of 458) of the water wells included in the United States Geological Survey observation program experienced a change in aquifer designation in Montgomery and Harris counties.

Prior to the adoption of the new approach taken in the delineation of the hydrogeologic units for the GULF-2023 model, a large number of the wells in the United States Geological Survey observation program had been developed and evaluated over several decades by experienced local United States Geological Survey technical staff. In addition, previous United States Geological Survey aquifer data and designations have been reviewed and generally accepted by groundwater engineers, hydrogeologists, and consultants with decades of local experience in the greater Houston area, based on assessment of site-specific geophysical logs, well material setting sheets and construction data, and well pumping test data. Reassignment of the observation wells may affect conceptual understanding of groundwater flow in the Gulf Coast Aquifer System and ultimately how that flow is simulated in the GULF-2023 model.

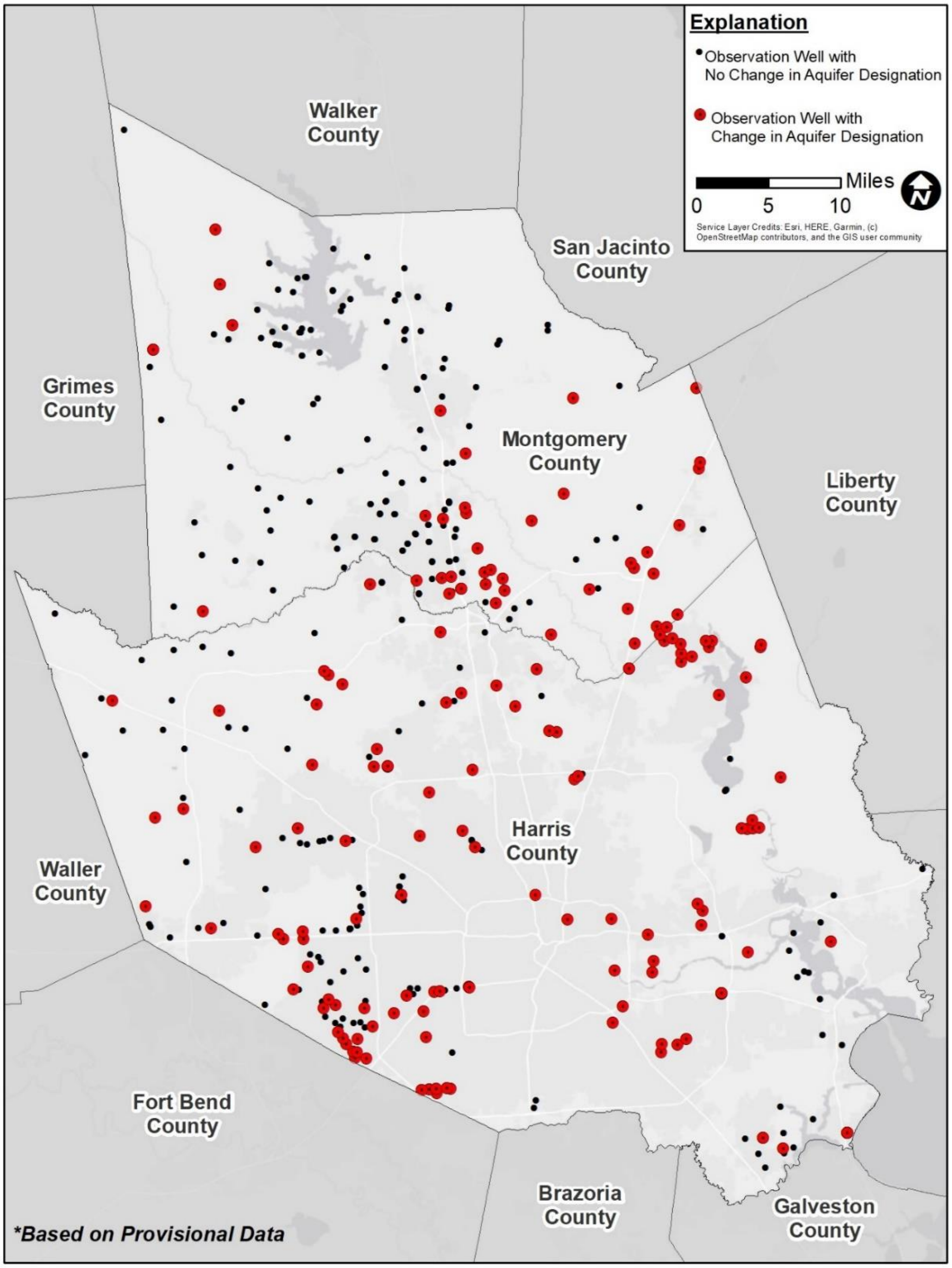

Figure 27. United States Geological Survey observation wells assigned a new aquifer designation based on the GULF-2023 groundwater flow model (based on provisional data provided by the United States Geological Survey in May 2021).

Summary of Clay Layer Thickness Based on Geophysical Log Analysis

It has long been understood that most compaction in sediments occurs in layers dominated by clay. Therefore, the thickness of clay layers within aquifers is one key in understanding the amount of subsidence that may occur in areas of groundwater withdrawal. The United States Geological Survey has produced maps showing cumulative clay thickness for the Chicot, Evangeline, and Jasper aquifers across the Houston Area including the entirety of Montgomery County (Kasmarek and Robinson, 2004). Similarly, LSGCD published maps showing the clay thickness for the geologic units that comprise the Chicot, Evangeline, and Jasper aquifers, and the Burkeville Confining Unit, all based on GIS operations utilizing datasets by Young and others (2012) (see Thornhill and Keester (2020)).

The United States Geological Survey conducted some of the definitive work relating to the depth of burial and the compressibility of clay layers in the Chicot and Evangeline aquifers in selected areas of southern Harris County and Galveston County, noting, “The time lag between loading and ultimate consolidation is dependent upon the thickness and permeability of the clay bed” (Gabrysch and Bonnet, 1976a). Similarly, Kelley and others (2018) noted the relationship between the fluid-pressure reductions in groundwater producing zones (that is, sands), the thickness of individual clay beds (sometimes called interbeds), the vertical hydraulic conductivity of the clay layers, and the time it takes for compaction to occur. Figure 28, reproduced from Kelley and others (2018) illustrates the relationship of the positioning and thickness of clay interbeds and the compaction of a clay layer between aquifer sand zones.

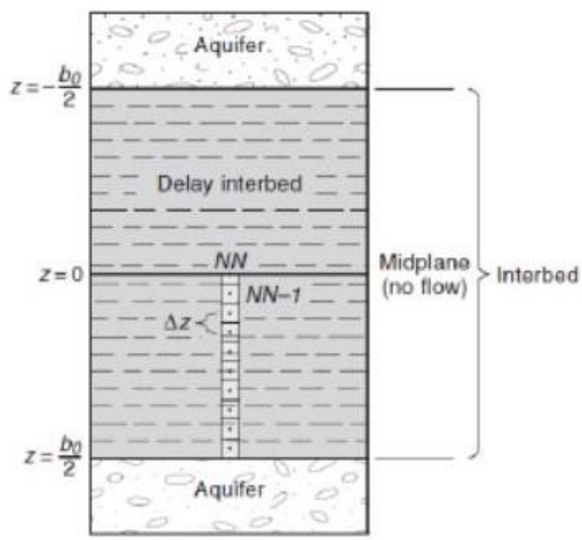

Figure 28. Illustration of the relationship between the aquifer sands and clay interbeds (reproduced from Kelley and others, 2018).

Kelley and others (2018) provided a summary of individual clay-bed thicknesses for selected logs across much of the Houston area including the southern part of Montgomery County from about Lake Conroe to the southern county border. For this study, we focused on log analysis to determine clay-bed thicknesses and distributions relative to producing intervals (that is, sands) across all of Montgomery County. While total clay thickness is important, understanding the vertical and horizontal distributions of clay layers relative to sand zones that are typically screened in water wells within Montgomery County and the region also affects the understanding of potential compaction. The relationships between the thicknesses of clay layers and the positioning with respect to well-screen intervals can impact the total amount and rate of compaction. Therefore, the work included:

- Analyzing the geophysical logs and making picks categorized as sand, silty or clayey sand, silty or sandy clay and clay. For this evaluation, the zones were simplified as either being "clay" or "sand" based on the predominant geophysical signature;
- Evaluating the clay layers for the Chicot, Evangeline, and Jasper aquifers, as well as for the Burkeville Confining Unit, with respect to total clay thickness, and average clay-layer thickness; and,
- Selecting potential high production sand intervals and evaluating the clay layers within the interval that would likely be screened in a well, and determining the number of clay interbeds, the total clay thickness, the minimum and maximum clay-bed thicknesses, and average interbed thickness.

Due to the age of the logs available, the clay picks were primarily based on induction (that is, resistivity) log signatures, although spontaneous potential curves were also assessed. Because of the log resolution, some thicker sequences of clays are likely comprised of multiple layers of thinner beds which cannot be distinguished based on log interpretation alone.

Figure 29 is a histogram illustrating the clay-bed thickness distribution by hydrologic unit in Montgomery County. The histogram shows that most clay layers are less than 50 feet thick. 58 percent of the clay beds within the Chicot Aquifer are less than 30 feet thick with 89 percent being less than 50 feet thick. For the Evangeline, the percentage of clay beds less than 30 feet thick reduces to 55 percent with 73 percent of the clay beds being less than 50 feet thick. There is an even greater percentage of the clay beds in the Burkeville being greater than 50 feet thick with only 42 percent being less than the 50-foot thickness. In the Upper Jasper, the clay bed thicknesses are similar to the Chicot with about 59 percent being less than 30 feet and 77 percent being less than 50 feet in thickness.

Figure 30 is a violin plot illustrating the distribution of clay thicknesses in the hydrostratigraphic units of the Gulf Coast Aquifer System. The width of the violin plot indicates the relative number of clay beds with a particular thickness and the dots represent the actual clay thickness value. Like the histogram suggests, the width of the violin plots in Figure 30 for the Chicot, Evangeline, and Upper Jasper indicates most of the clay beds are less than 20 feet thick in these aquifers. There are fewer clay bed thickness values for the Chicot and Burkeville than for the Evangeline and Upper Jasper. For Chicot, the fewer clay beds is due to fewer logs of the Chicot interval while for the Burkeville the fewer clay beds is due to the beds generally being thicker.

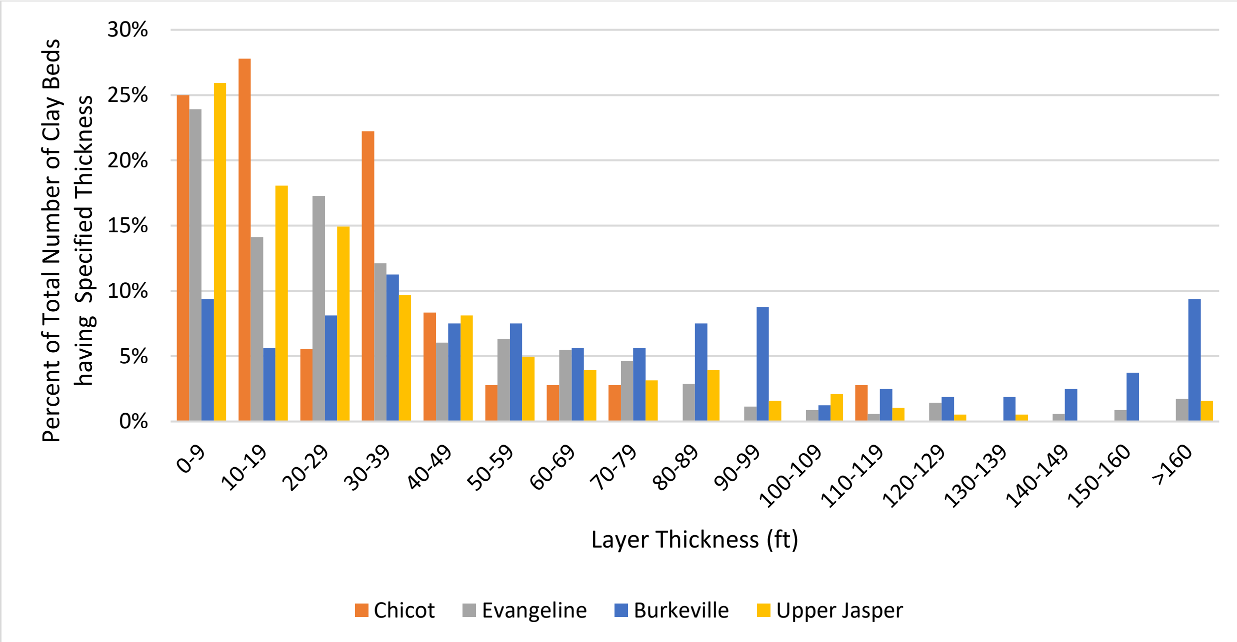

Figure 29. Histogram illustrating the percentage of clay bed thicknesses by hydrogeologic unit in Montgomery County.

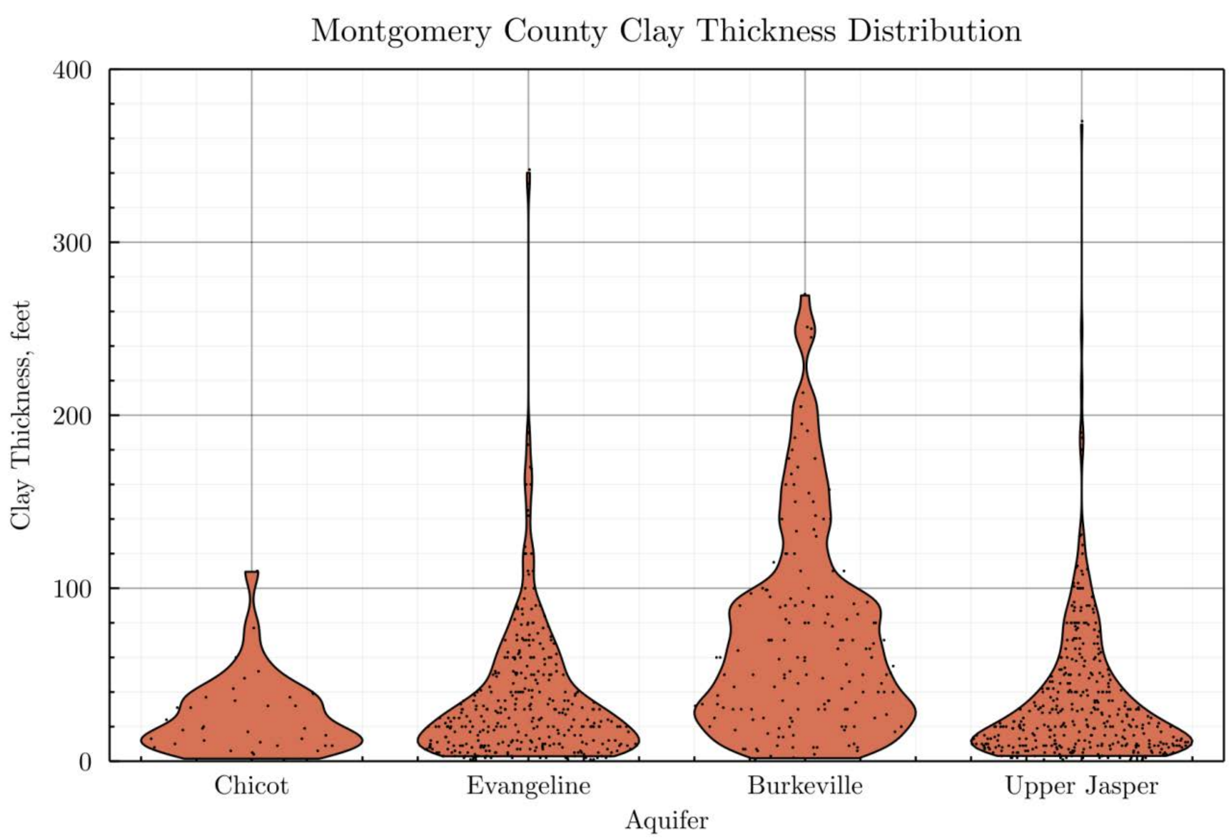

Figure 30. Violin plot illustrating the distribution of clay bed thickness by hydrogeologic unit in Montgomery County.

Appendix 3 provides summary tables characterizing sand and clay layers for 60 log sites in Montgomery County. For the identified sites, we used the hydrostratigraphic picks with our sand and clay determinations to calculate the net sand and net clay percentages. Using our professional judgement and experience, we also identified the likely producing interval (that is, where a well is more likely to be screened) within each hydrostratigraphic unit to determine the percentage of sand and clay associated with the producing interval. Appendix 4 provides maps illustrating the percent clay calculations at each evaluated site.

Visual comparison of our calculations with cumulative clay thicknesses presented by Kasmarek and Robinson (2004) suggest the total clay thickness for the Chicot and Evangeline aquifers are similar. However, since Jasper production within Montgomery and northern Harris counties is almost exclusively limited to the Upper Jasper Aquifer, the total clay thickness likely affected by depressurization is thinner than the reported clay thickness of the entire Jasper. Comparing original GAM cumulative clay thickness for the Jasper Aquifer as presented by Kasmarek and Robinson (2004) with Upper Jasper clay-interbed thicknesses suggests that the GAM Jasper clay thicknesses are 2.3 to 4.9 times thicker than the clay interbeds within likely targeted fresh and brackish groundwater zones in the Upper Jasper.

The distribution and thickness of clay layers is critical to understanding the hydraulics, mechanics, magnitude, and timing of compaction and resulting subsidence. Understanding these distributions as related to zones targeted for large-capacity pumping should also be a consideration for future studies and modeling efforts. The information compiled from the log analyses identifying clay and sand layers will be critical in planning subsequent work including planning drilling, logging, and coring efforts.

PHASE 3 DRILLING AND TESTING PLAN

Much of the work by Kelley and others (2018) was based on data collected approximately 50 years ago. Since the work by Gabrysch and Bonnet (1974; 1976a; 1976b), drilling and testing specifically for subsidence investigations has not occurred. As a next step in the District's subsidence investigations, we have developed a drilling and testing plan designed specifically to obtain site-specific data related to the potential compaction of the subsurface geologic units.

Proposed Test Drilling Locations

A first step for the test drilling program is to secure site for conducting the operations. For possible locations we considered several factors, including:

- Areas of observed or projected water level decline in the aquifers
- Areas with anticipated growth or increase in groundwater demand
- Locations with potential collaborators or interested parties
- Locations near existing GPS monitoring sites
- Locations that are accessible for drilling equipment
- Locations with limited geophysical data

Considering these factors, we identified six locations for conducting drilling and testing. These proposed locations are spread across the county and will provide site-specific data that does not place a greater weight on any particular area. Figure 31 illustrates the locations of the proposed drilling locations across the county. Appendix 5 includes a map for each proposed location with notes regarding the proposed site. Our recommended priority of drilling and testing is:

1. Lone Star Groundwater Conservation District
2. Woodlands Area
3. Magnolia Area
4. Southeast Area
5. Splendora Area
6. Montgomery Area

As one may expect, clay bed thicknesses within the hydrostratigraphic units are not uniform across the county. For each of the proposed drilling and testing sites, we associated geophysical log locations to the site based on proximity to the site; that is, if a log location was closer to the LSGCD location than to any other, then it was assigned to the LSGCD location. We then prepared a violin plot for the subset of clay thicknesses associated with the proposed drilling and testing location. These plots are included with the proposed test drilling location maps in Appendix 5.

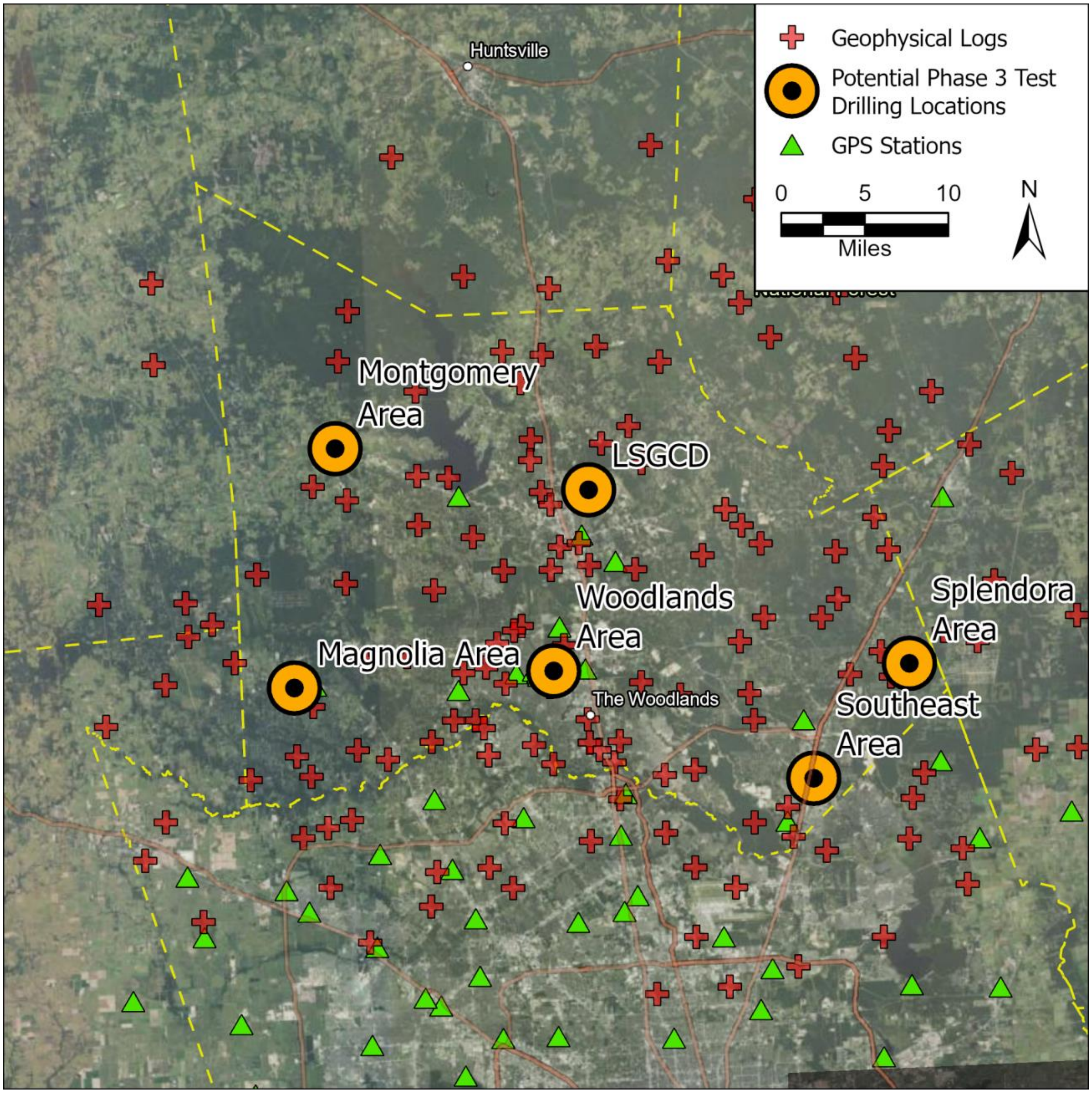

Figure 31. Proposed drilling and testing locations.

Proposed Data Collection

Proposed test drilling operations will involve drilling a test hole followed by coring selected intervals of the subsurface materials. During drilling of the test hole, a geoscientist will analyze and describe drill cuttings of the subsurface formations collected by the drilling contractor. Following completion of the test hole, a geophysical logging contractor will obtain a geophysical log of the open hole. Following are the geophysical logs we recommend obtaining for the initial test hole:

- Triple Combo (Resistivity, Natural Gamma, and Neutron/Density porosity)
    - Lithology
    - Water quality
    - Porosity
- Micro-normal/micro-inverse resistivity
    - Relative permeability (qualitative)
    - Water quality
- Spectral Gamma
    - Lithology
    - Clay mineral composition
- Magnetic Resonance
    - Permeability (quantitative)
    - Porosity
    - Movable water

The triple combo geophysical log is standard in the industry for obtaining site-specific depths of the subsurface lithologic materials. The addition micro resistivity provides additional information for the investigator to infer the relative permeability of the subsurface materials and for estimating the dissolved solids concentration of the formation water. With these logs alone we are able to delineate the general subsurface lithology, determine the aquifer intervals, and calculate the net sand and clay as we have done in this Phase 2 Subsidence Investigation. However, there are additional geophysical logs that will provide meaningful insight into the subsurface characteristics.

The spectral gamma log provides an in-situ analysis of the type of clays in the subsurface through measurements of the thorium, uranium, and potassium content. Data from the spectral gamma log will provide insight into the clay composition. Figure 32 illustrates how the type of clay may be determined based on the ratio of thorium and potassium in the mineral. As discussed previously, Kelley and others (2018) note that clays composed of montmorillonite have the highest compressibility (see Other Considerations section). Obtaining the spectral gamma log will improve our understanding of the subsurface clay mineralogy and where compaction may more likely occur due to that mineralogy.

The magnetic resonance logging tool creates a magnetic field that changes the orientation of water molecules within the pore space of the subsurface lithology. The tool then measures the magnetic resonance as the molecules then reorient to their original positions. Processing of the collected measurements then provides information on the porosity and permeability of the formation on a continuous basis. Subsequently, we can estimate the transmissivity of specific subsurface intervals using the thickness of the interval. Figure 33 illustrates the permeability and volumetric water content that can be derived from the magnetic resonance logging data.

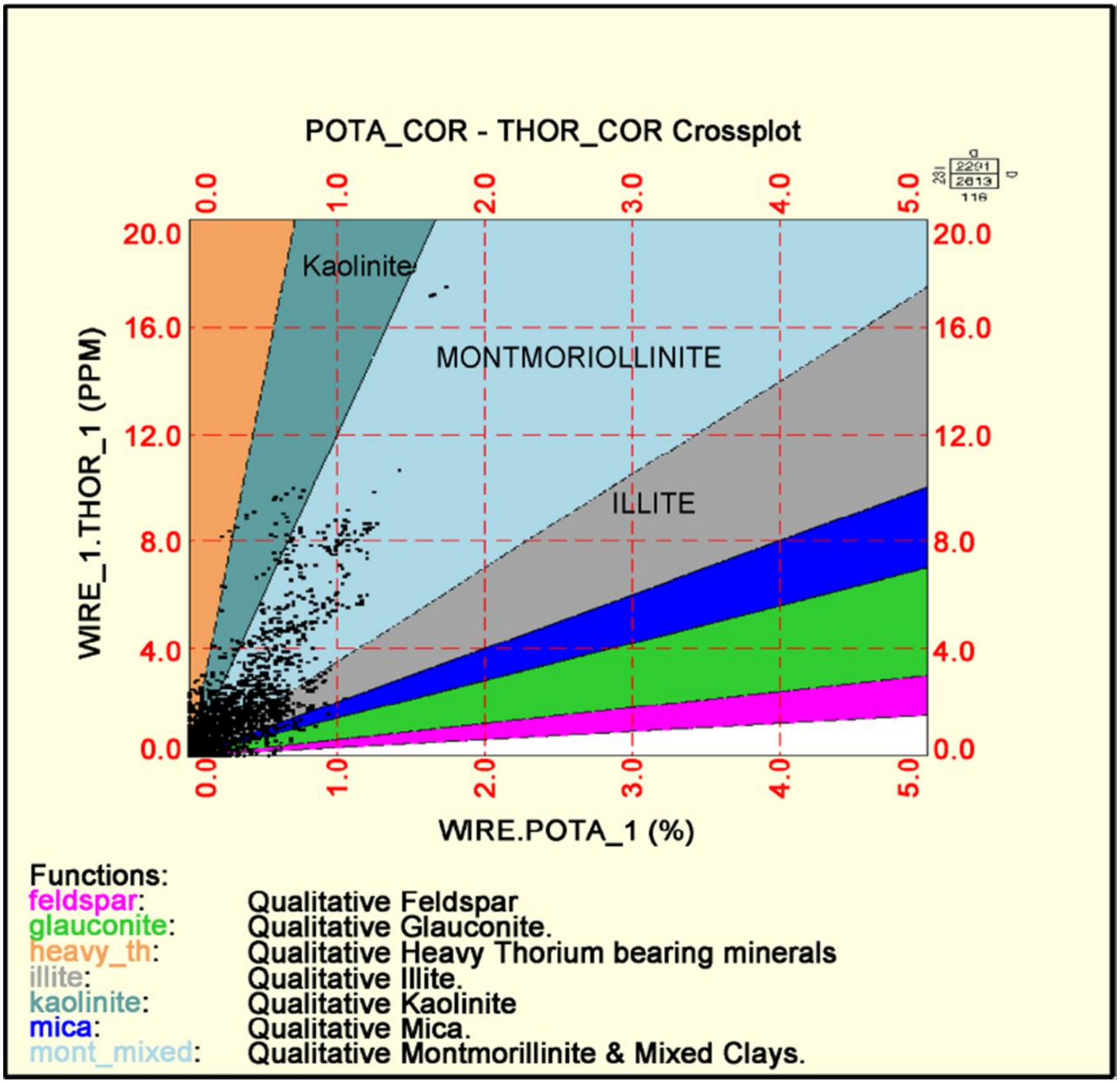

Figure 32. Cross plot illustrating clay type determination from spectral gamma ray tool measurements (Arbab and others, 2017).

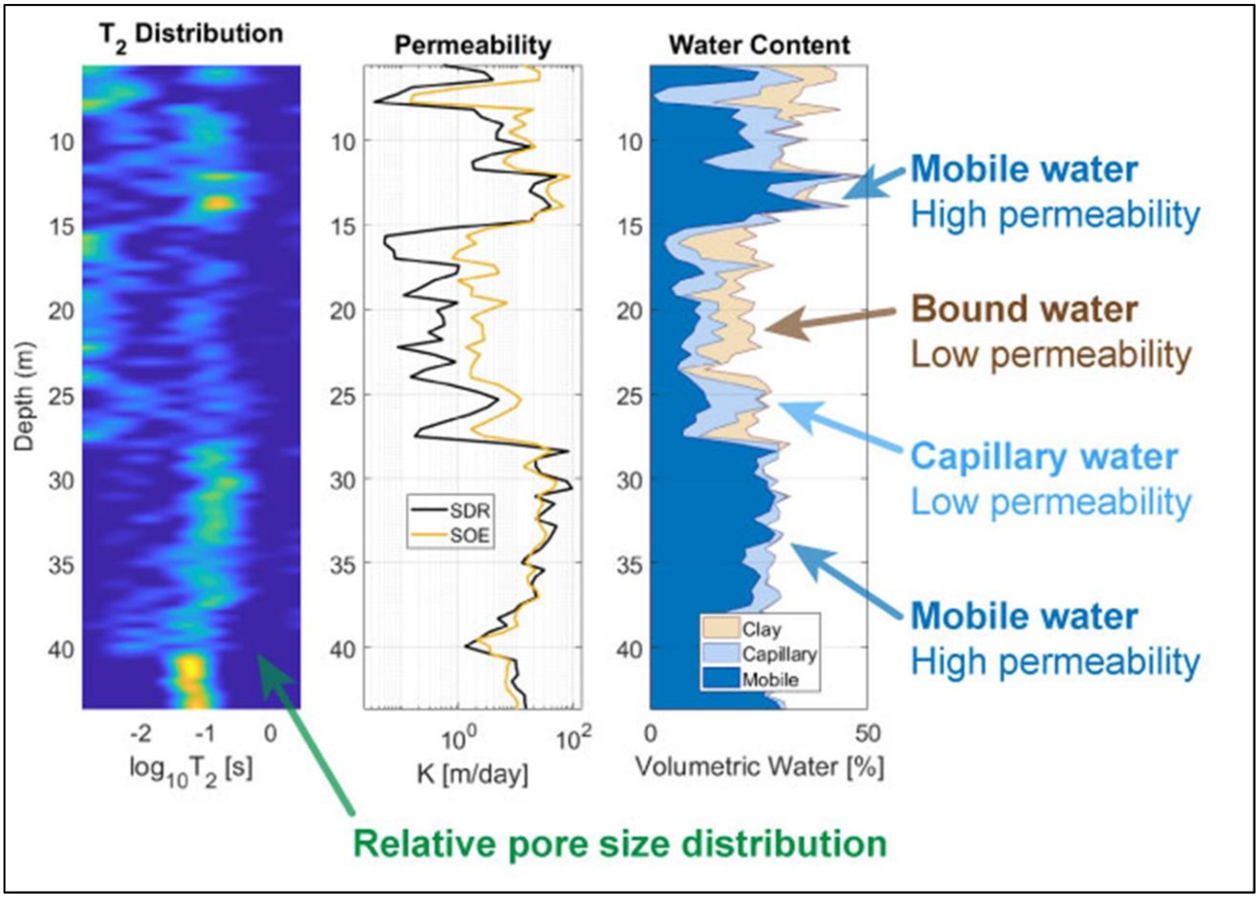

Figure 33. Illustration of measurements and results from a magnetic resonance log (Vista Clara, Inc., 2022).

In addition to the geophysical logs, we recommend collection of percussion sidewall cores for analysis of depth-specific porosity and mineralogy (Figure 34 illustrates clay mineral identification of a core sample using x-ray diffraction). Sampling depths for these cores will be selected by the onsite professional geoscientist based on the geophysical logging. Following collection, the cores will be submitted to lab for analysis and the results can be used to inform or calibrate the magnetic resonance logging data. In addition, the porosity data collected will aid in our understanding of the specific storage values of the subsurface materials (see the section on Specific Storage for a discussion of the calculation of specific storage values from porosity).

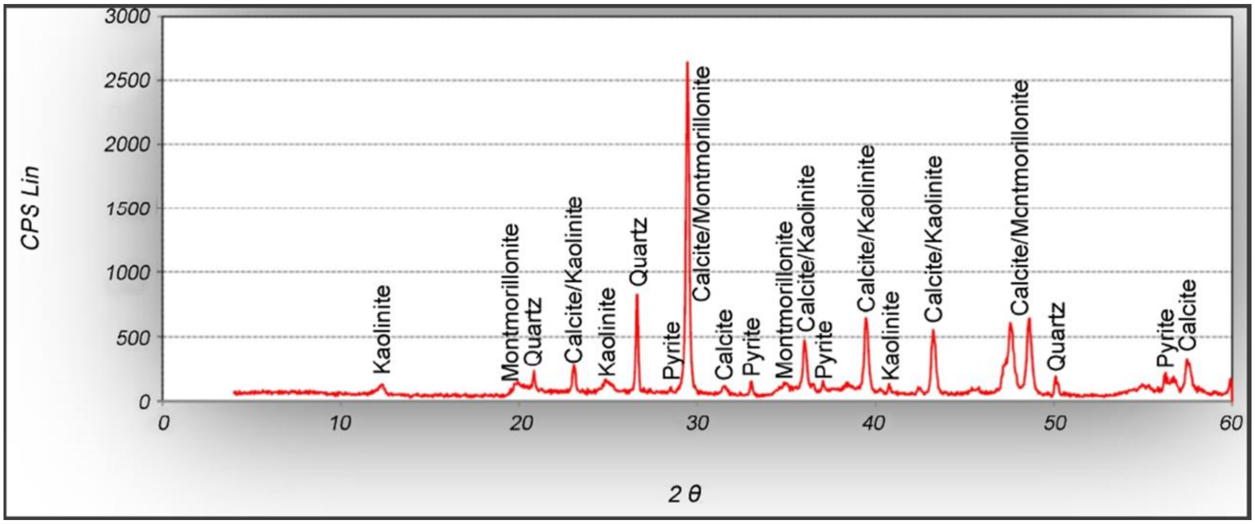

Figure 34. Illustration of clay mineral identification using x-ray diffraction (Arbab and others, 2017).

Once the geophysical logs and samples are collected, we recommend completion of a dedicated water-level monitoring well at the location. The completion interval for the dedicated monitoring well could be determined based on the site-specific conditions, stakeholder interest, and input from the property owner. Once the monitoring well is complete, the drilling contractor would move the rig a short distance (30 to 50 feet) from the test hole to collect cores of selected subsurface clay intervals. Following collection of the core samples, a second dedicated water-level monitoring well could be installed to monitor a different sub-surface interval than that of the well completed at the test hole site.

We anticipate coring of up to ten subsurface intervals to collect samples for laboratory analysis. Similar to the sidewall cores, the laboratory would analyze the porosity and mineralogy of the core sample. In addition, the lab would perform oedometer testing to measure the change in void ratio with pressure which would provide a direct comparison to the data reported by Gabrysch and Bonnet (1974; 1976a; 1976b). Finally, the lab will analyze the core for permeability in the vertical direction.

As discussed in the section reviewing the brackish Jasper Aquifer conceptual model, the porosity of the sediments relates to the specific storage (inelastic and elastic) and the amount of compaction that can occur. The vertical permeability (and related hydraulic conductivity) affects the rate of the compaction. While the lab analyses will provide data for only a specific site at specific depths, much like the work of Gabrysch and Bonnet (1974; 1976a; 1976b), the results will inform our understanding of the Gulf Coast Aquifer System characteristics throughout Montgomery County and nearby areas.

Researchers, consultants, regulatory entities, and others have referred to the work by Gabrysch and Bonnet (1974; 1976a; 1976b) for nearly 50 years when discussing the factors affecting compaction and subsidence in the Gulf Coast Aquifer System. Their work has been interpreted and applied to inform the understanding of compaction throughout the Gulf Coast Region despite being limited to a relatively small area. Adding to the body of knowledge by developing physical data related to clay compaction in an updip area of the Gulf Coast Aquifer System, and particularly in the Jasper Aquifer, will provide benefit to the scientific community for years to come and will enhance the data-driven management of groundwater resources by Lone Star Groundwater Conservation District.

SUMMARY AND CONCLUSIONS

Our work during the Phase 2 subsidence investigations focused primarily on two of the most applicable questions from the Phase 1 work. We focused on these questions as they were identified as providing the highest level of support to the data-driven management of groundwater resources by Lone Star Groundwater Conservation District. In addition, the work conducted during this Phase 2 forms a basis for the potential Phase 3 drilling and testing program.

Brackish Jasper Aquifer Conceptual Model

One of the questions under investigation related to the brackish Jasper Aquifer conceptual model develop by Kelley and others (2018). During Harris-Galveston Subsidence District Regulatory Plan Update meetings, United States Geological Survey staff appeared to suggest that they would use this conceptual model as the basis for simulating compaction of the Jasper Aquifer in the GULF-2023 model. Since the conceptual model dictates or guides the subsequent development of a numerical model, it follows that any issues or potential flaws with the conceptual model are also issues or potential flaws with the numerical model. Our review of Kelley and others (2018) revealed questions with their conceptualization of compaction in the Jasper Aquifer.

- Our calculated estimates of inelastic and elastic specific storage of clay samples from Gabrysch and Bonnet (1974; 1976a; 1976b) are similar to those of Kelley and others (2018).
    - Data reported by Gabrysch and Bonnet (1974; 1976a; 1976b) are used to calculate the coefficients needed to determine the inelastic and elastic specific storage of the clay samples. These coefficients (namely, porosity and compressibility) are not reported by Gabrysch and Bonnet (1974; 1976a; 1976b) as stated by Kelley and others (2018).
    - Our evaluation of the porosity and compressibility values results in trend (that is, model) that differs increasing for depths below about 500 feet.
    - Kelley and others (2018) trend through porosity values calculated from the Gabrysch and Bonnet (1974; 1976a; 1976b) data results in unrealistic porosity values for shallow depths.
    - The constant geostatic stress gradient used by Kelley and others (2018) to determine effective burial depth from applied pressure may be too high for the Gulf Coast Region.
- Gabrysch and Bonnet (1974) report laboratory measured hydraulic conductivity for four clay samples, but they do not indicate if it is horizontal or vertical hydraulic conductivity.
    - Kelley and others (2018) state the hydraulic conductivity data from Gabrysch and Bonnet (1974) is a measure of the vertical component.
    - The hydraulic conductivity values from Gabrysch and Bonnet (1974) are consistent with representative values of the horizontal hydraulic conductivity of clays.
    - The minimum hydraulic conductivity values from Gabrysch and Bonnet (1974) are about four times greater than the maximum representative value of the vertical hydraulic conductivity of clays.
    - High values for the vertical hydraulic conductivity of the clay result in a shorter time constant for compaction. That is, compaction occurs at a faster rate.

- Kelley and others (2018) conceptualization of drawdown at preconsolidation stress does not appear to be consistent with observed changes in water level and compaction.
    - Observations by Gabrysch (1982) indicated that water-level declines in the deep Evangeline Aquifer did not result in appreciable compaction.
    - Observations at the Lake Houston extensometer site indicate there is no discernable compaction of units below the Evangeline Aquifer despite about 150 feet of water level decline in the Jasper Aquifer.
    - Preconsolidation head may be below observed water-level declines in the Jasper or the drawdown at preconsolidation stress is greater than conceptualized by Kelley and others (2018).
- Along with burial depth, the age and mineralogy of the sediments may affect the compressibility of the clay layers.
    - It is suspected that younger and shallower materials will compact more easily (Gabrysch, 1982).
    - Kelley and others (2018) note that clays composed of montmorillonite have the highest compressibility
    - Chemical reactions within older sediments may allow for increased cementation of the grains.
    - Burial depth increases the effective stress on the sediment grains which increases compaction of the units.

With regard to the application of the work by Kelley and others (2018) to the Jasper Aquifer in Montgomery County it is important to remember that the data they used are from more than 20 miles away and are not from the Jasper Aquifer. The data used by Kelley and others (2018) are from younger sediments of the Chicot and Evangeline aquifers. Regarding their analyses, Kelley and others (2018) state that "properties controlling compaction of the brackish Jasper Aquifer should be considered uncertain."

We recommend users of the Kelley and others (2018) conceptual model of compaction in the Jasper Aquifer carefully consider the conclusions listed above. Revisions to the conceptual model based on our observations may result in less predicted compaction in Jasper Aquifer or a slower rate of compaction. While the sediments that make up the formations of the Jasper Aquifer may compact with declining water levels, it is important to appropriately conceptualize the compaction based on the observed data. While the compaction results from a numerical model will remain uncertain, we may reduce the uncertainty through consideration of the available observations.

Hydrostratigraphy

For decades a common approach was taken by groundwater professionals towards the delineation of water bearing units of the Gulf Coast Aquifer System in Montgomery and surrounding counties. This common approach was practical and reflected the consensus and understanding of the aquifers and groundwater flow through the system. Recently, other approaches to delineating the hydrostratigraphic units have been applied; however, practical application of the results from the approach within the GULF-2023 model were unsuccessful and required revision to allow implementation within the numerical model. For our evaluation of the local hydrostratigraphy, we applied the common approach and practical understanding of the hydrostratigraphic units of the Gulf Coast Aquifer System to develop the structural and clay thickness dataset for Montgomery County. The following provides a summary of our evaluations focused on the subsurface conditions beneath Montgomery County.

- The geology of the Gulf Coast Aquifer System is made up of a complex system of alternating layers of discontinuous sand, silt, and clay that increase with depth and thickness toward the Gulf of Mexico.
    - It can be difficult to identify the individual geologic units on geophysical logs due to the similarities of sediments within each geologic unit.
    - Historically, the sub-aquifers of the Gulf Coast Aquifer System in Montgomery County and the greater Houston area have been classified by hydrogeologic units and include from shallowest (younger) to deepest (older) the Chicot Aquifer, Evangeline Aquifer, Burkeville Confining Unit, Jasper Aquifer and the Catahoula Formation.
    - Our evaluation focused on the Chicot, Evangeline, and Jasper aquifers which are the principal aquifers for groundwater production in Montgomery County. The Catahoula was not discussed at length in this report.
- In this study the Jasper Aquifer was divided into two units based on lithology, the Upper Jasper and the Lower Jasper.
    - The upper part of the Jasper Aquifer can have relatively thick sand beds that typically contain freshwater and are capable of supporting moderate to large capacity water wells in most parts of Montgomery County.
    - The lower part of the Jasper Aquifer contains mostly interbedded sand and clay and the sands contain water with likely brackish quality.
    - At the time of this study, no wells have been completed in the brackish portion of the Jasper Aquifer.
    - It is our understanding that all registered and permitted wells with the LSGCD that are designated as the Jasper Aquifer are completed in the sands that comprise the upper part of the aquifer.
- We evaluated geophysical logs to improve the understanding of the depth, thickness, and composition of the principal aquifers within Montgomery County.
    - Elevation estimates relative to sea level were developed and mapped for the base of the Chicot, Evangeline and Upper Jasper aquifers and the Burkeville Confining Unit.
    - We applied the United States Geological Survey Source Water Assessment Program dataset (Strom and others, 2003) as the base of the Lower Jasper.

  - The base of aquifer and confining unit surfaces developed as part of this study provide a reference for the approximation of the tops and bottoms of the hydrogeologic units in Montgomery County. Site specific conditions may vary from the surfaces developed using the evaluated geophysical logs.
- Young and Draper (2020) used an approach combining the chronostratigraphic and lithostratigraphic methodology to update the hydrogeologic units in support of the development of the GULF-2023 groundwater flow model.
  - The approach resulted in a generally deeper base of the Chicot Aquifer in Montgomery and surrounding counties compared to the base of Chicot Aquifer as defined in this study and previous work (Popkin, 1971; Gabrysch and Bonnet, 1974; 1976a; 1976b; Baker, Jr., 1979; Espey, Huston & Associates, Inc., 1979; Carr and others, 1985; Kasmarek and Robinson, 2004; Kasmarek, 2013).
  - The lithostratigraphic based approach to adjust the Burkeville Confining Unit elevations yielded formation picks that are generally similar to the picks defined in this study for most parts of Montgomery County.
  - While the GULF-2023 model will have hydrogeologic surfaces that are delineated differently, the hydrogeologic and subsidence parameters assigned to each model layer will likely influence the performance of the model and its ability to simulate observed aquifer conditions as much or more than the hydrogeologic surfaces developed for the model.
- Jasper production within Montgomery and northern Harris counties is almost exclusively limited to the Upper Jasper Aquifer
  - The clay layers likely affected by depressurization and potential compaction are likely much thinner than the cumulative clay thickness of the entire Jasper.
  - Comparing cumulative thickness for the Jasper Aquifer as presented by Kasmarek and Robinson (2004) with clay-interbed thicknesses from our evaluations indicates that the cumulative clay thicknesses for the Jasper are up to five times thicker than the clay interbeds within likely targeted production zones in the Upper Jasper.
- The distribution and thickness of clay layers is critical to understanding the hydraulics, mechanics, magnitude, and timing of compaction and resulting subsidence. Understanding these distributions as related to zones targeted for large-capacity pumping should be a consideration for all future studies and model parameterization. The information compiled from the log analyses and identifying clay and sand layers will be critical in planning subsequent work including planning of drilling, logging, and coring efforts.

Phase 3 Drilling and Testing

Researchers, consultants, regulatory entities, and others have referred to the work by Gabrysch and Bonnet (1974; 1976a; 1976b) for nearly 50 years when discussing the factors affecting compaction and subsidence in the Gulf Coast Aquifer System. Their work has been interpreted and applied to inform the understanding of compaction throughout the Gulf Coast Region despite being limited to a relatively small area. Adding to the body of knowledge by developing physical data related to clay compaction in an updip area of the Gulf Coast Aquifer System, and particularly in the Jasper Aquifer, will provide benefit to the scientific community for years to come and will enhance the data-driven management of groundwater resources by Lone Star Groundwater Conservation District.

To obtain this data, we recommend conducting a drilling and testing program designed to collect data that are directly applicable to understanding the subsurface compaction characteristics. We anticipate the program would involve:

1. Drilling a test hole to obtain lithologic samples and geophysical logs then completing a water-level monitoring well
2. Adjacent to the test hole, drilling to collect core samples of selected clay layers then completing a second water-level monitoring well

One immediate benefit of the program would be dedicated water-level monitoring wells (screened at different intervals) for potential collection of continuous data. Lab analysis of core samples collected from each hole would provide mineralogical, compressibility, porosity, and permeability data. These collected data would then inform the conceptual understanding of potential compaction within the groundwater production intervals and guide management of the resources by the District.

To begin collection of the data, we recommend drilling and testing at six locations spread across Montgomery County. We recommend the first location be at the Lone Star Groundwater Conservation District property if space is available. This location could provide the District with the demonstration of on-site data collection and could be used for long-term educational opportunities. For all six of the proposed locations, our recommended priority for drilling and testing locations is:

1. Lone Star Groundwater Conservation District
2. Woodlands Area
3. Magnolia Area
4. Southeast Area
5. Splendora Area
6. Montgomery Area

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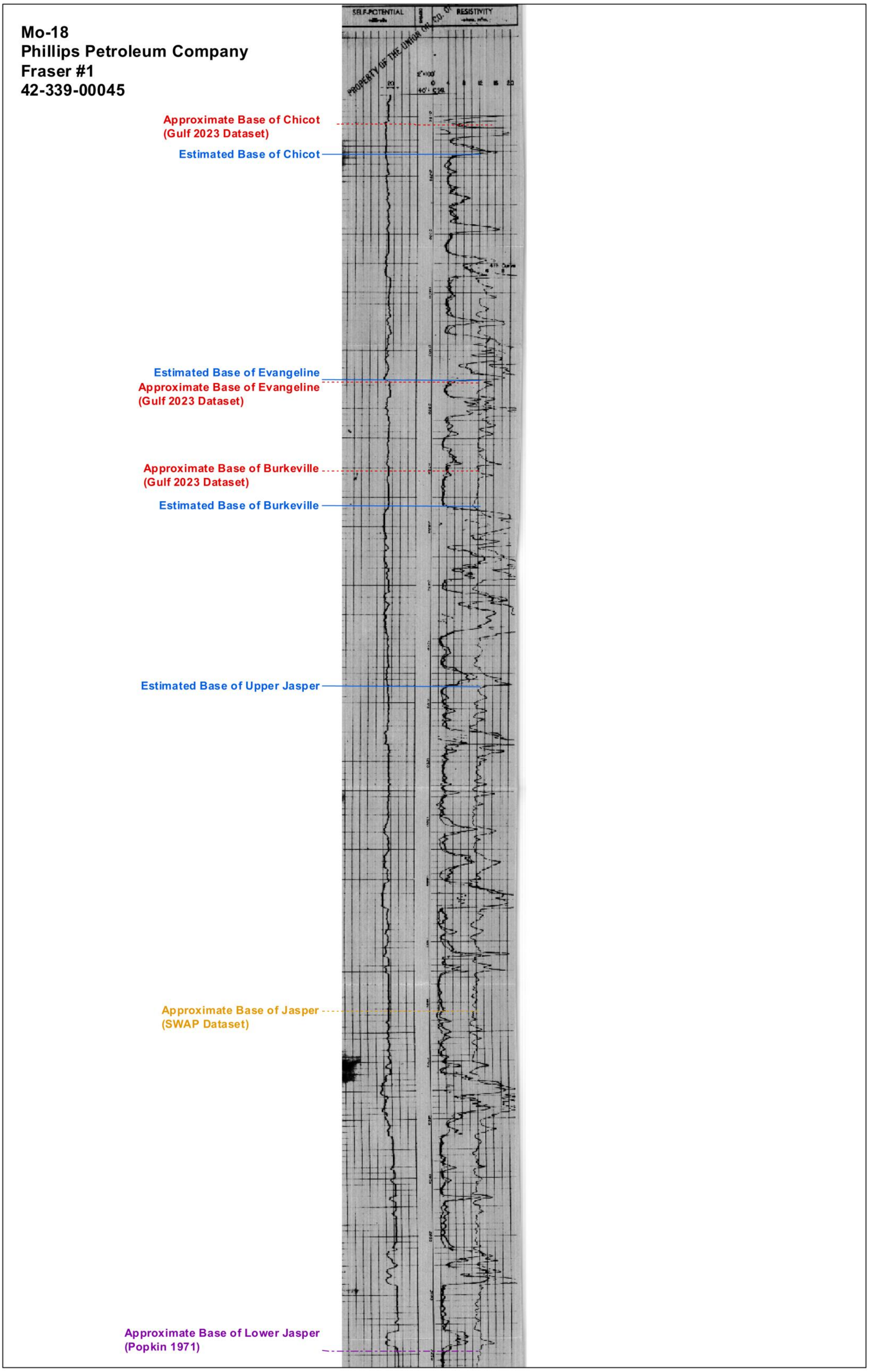
APPENDIX 1 – GEOPHYSICAL LOG DATA

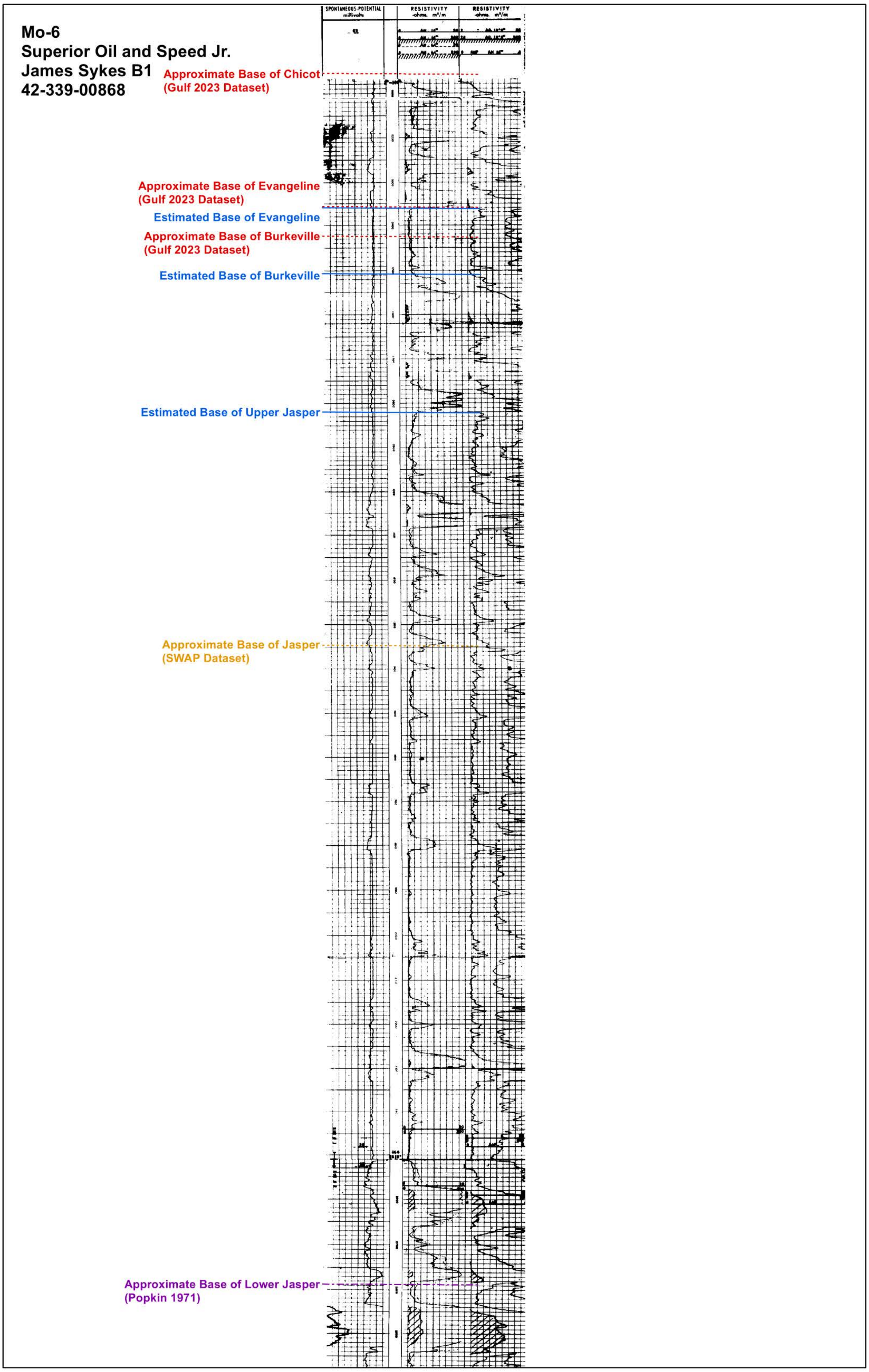
Geophysical Log Number	API Number, State Well Number and / or Q Number	Company	Well	Latitude	Longitude	Land Surface Elevation (feet)	Base of Chicot Depth (feet, bls)	Base of Evangeline Depth (feet, bls)	Base of Burkeville Depth (feet, bls)	Base of Upper Jasper Depth (feet, bls)	Base of Chicot Elevation (feet, rsl)	Base of Evangeline Elevation (feet, rsl)	Base of Burkeville Elevation (feet, rsl)	Base of Upper Jasper Elevation (feet, rsl)	SWAP Base of Jasper Elevation (feet, rsl)
Mo-1	4233901886	THE PURE OIL CO. & W.T. MORAN CORP.	CENTRAL COAL & COKE 3	30.5159	-95.6830	191	--	--	--	445	--	--	--	-254	-507
Mo-2	4233900966	RED BANK OIL CO.	CENTRAL COAL & COKE	30.4727	-95.6947	334	--	220	280	550	--	114	54	-216	-665
Mo-3	Q-41 / 6036403	STRUM & WOMACK	FOSTER #2	30.4441	-95.6180	191	--	--	335	610	--	66	-144	-419	-905
Mo-4	4233901799	E.L. KURTH TRUSTEE	SOUTHLAND PAPER MILLS 4	30.2492	-95.2027	123	390	1,005	1,260	1,825	-267	-882	-1,137	-1,702	-2,320
Mo-5	Q-197 / 6036304	C.W. CHICK HANSLIP	CRAWFORD #1	30.4756	-95.5294	290	--	--	538	730	--	--	-248	-440	-927
Mo-6	4233900868	SUPERIOR OIL CO AND CARLTON L. SPEED JR.	JAMES SYKES B 1	30.4477	-95.5122	284	--	360	510	820	--	-76	-226	-536	-1,059
Mo-7	4233900980 / 6044101	T. J. WOOD	FULTZ #1	30.3682	-95.5885	210	--	--	--	860	--	--	--	-650	-1,249
Mo-8	4233900979 / 6043304	F. A. CALLERY	WEISINGER 1	30.3707	-95.6197	264	--	330	500	860	--	-66	-236	-596	-1,197
Mo-9	4233930630	CYPRESS ENERGY DEV.	HARPER B. / 1	30.1842	-95.4035	117	--	910	1,190	1,730	--	-793	-1,073	-1,613	-2,149
Mo-10	4233901142	STABLE OIL CO.	JOLKE #1	30.1260	-95.6601	167	--	900	1,190	1,580	--	-733	-1,023	-1,413	-1,970
Mo-11	4233930951	WHITING PETROLEUM CORPORATION	RHODES, W.S. 1801A	30.2653	-95.3500	159	280	810	1,090	--	-121	-651	-931	--	-1,969
Mo-12	4233901930	HUMBLE OIL AND REFINING CO	KATHRYN M. HINES 1	30.2161	-95.3030	124	400	995	1,280	1,835	-276	-871	-1,156	-1,711	-2,224
Mo-13	4233900901	SUNRAY - MIDCONTINENNT OIL CO.	MARGARET SYKES #1	30.3985	-95.5042	339	--	580	790	1,025	126	-241	-451	-686	-1,253
Mo-14	Q-152	HUMBLE OIL REFINING CO.	SO TEX DEV CO 80-A	30.2822	-95.4048	210	290	745	--	--	-80	-535	--	--	-1,810
Mo-15	4233900032	J. A. GRAY	FOSTER LBR. CO. #1	30.2905	-95.2032	123	--	910	1,110	1,520	-135	-787	-987	-1,397	-2,185
Mo-16	4233900097	OHIO OIL CO.	ANDERSON #1	30.3525	-95.4961	203	180	510	780	1,200	23	-307	-577	-997	-1,428
Mo-17	4233900101	COX & CAL-MON OIL CO.	FOSTER #2	30.3413	-95.4872	235	--	600	810	1,320	-5	-365	-575	-1,085	-1,478
Mo-18	4233900045	PHILLIPS PETR. CO.	FRASER #1	30.4613	-95.3718	345	165	550	765	1,070	180	-205	-420	-725	-1,269
Mo-19	4233900013	AMERADA PETR. CO.	FOSTER LUMBER CO. #1	30.3187	-95.1627	155	305	950	1,150	1,480	-150	-795	-995	-1,325	-2,180
Mo-20	4233900082 / 6037803	MORRIS K. WOMACK	HUNT #1	30.3925	-95.4337	265	--	--	815	1,220	87	--	-550	-955	-1,386
Mo-21	4233900079	MORRIS K. WOMACK ETAL	HUTCHINGS SEALY NBT #1	30.3742	-95.3940	253	--	585	825	1,250	--	-332	-572	-997	-1,520
Mo-22	4233900504	CURTIS HANKAMER	FORMAN #1	30.3001	-95.2780	165	--	830	1,100	1,540	-110	-665	-935	-1,375	-1,997
Mo-23	4233900502	W. F. NEWTON	MARSH - RICE UNIVERSITY #1	30.3310	-95.3120	208	--	--	962	1,440	-64	-652	-754	-1,232	-1,826
Mo-24	4233900056	MCCRAY G. / 1	COPANO TRANS	30.4768	-95.4349	272	--	--	--	850	--	--	--	-578	-1,087
Mo-25	4233901713	STANDARD OIL OF TEXAS	DOROTHY ANDERSON 1	30.1707	-95.2957	120	350	1,120	1,360	1,880	-230	-1,000	-1,240	-1,760	-2,388
Mo-26	4233900059	SPILLER J.B. / 1	KINSALA & NEWTON	30.4715	-95.4897	330	--	--	--	860	--	--	--	-530	-1,009
Mo-27	4233900066	ROSE K.G. / 1	THE MORAN CORP.	30.4067	-95.4056	244	--	--	780	1,200	--	--	-536	-956	-1,388
Mo-28	Q-44 / 6043101	O. C. GARVEY AND TODD	MARTIN #1	30.3649	-95.7250	261	--	--	535	760	--	--	-274	-499	-1,094
Mo-29	4233900993	F. A. CALLERY	MARY LENA CASTLE #1	30.3519	-95.6911	393	--	425	700	1,010	--	-32	-307	-617	-1,185
Mo-30	Q-362	FISH OIL AND GAS CO.	BERKLEY & HOGG #1	30.3158	-95.5663	231	--	600	850	1,170	--	-369	-619	-939	-1,476
Mo-31	4233930484	SOUTHLAND ROYALTY COMPANY	GEORGE MITCHELL #1	30.2799	-95.6954	183	--	620	840	1,160	--	-437	-657	-977	-1,463
Mo-32	4233901881	HUMBLE OIL & REFINING CO.	J. W. LEWIS ET AL #1	30.1743	-95.7328	261	220	920	1,190	1,580	41	-659	-929	-1,319	-1,753
Mo-33	4233901102	MITCHELL & MITCHELL	NEIDRAL #1	30.1399	-95.6155	149	--	900	1,180	1,580	--	-751	-1,031	-1,431	-1,982
Mo-34	4233901046	THE GRAY WOLFE CO	PAN-AM 3	30.2131	-95.6788	249	190	885	1,180	--	59	-636	-931	--	-1,712
Mo-35	Q-222 / 6053105	BASSETT S. WINMILL	F.M. YOST ETAL	30.2190	-95.4792	185	--	890	1,140	1,650	--	-705	-955	-1,465	-1,916
Mo-36	4233901420	COFFEE C W	LATZER-LAYTON UNIT 1	30.1271	-95.4482	134	--	1,020	1,370	1,820	--	-886	-1,236	-1,686	-2,251
Mo-37	4233901846	F. S. CROCKETT	BUCK WILLIAMS #1	30.1834	-95.1941	107	--	1,180	1,538	2,100	-333	-1,073	-1,431	-1,993	-2,553
Mo-38	4233900162	HUMBLE OIL AND REFINING CO	O. C. COX 1	30.3043	-95.4794	179	220	690	1,025	1,450	-41	-511	-846	-1,271	-1,607
Mo-39	4233900199	HUMBLE OIL AND RRG. CO	B. D. GRIFFIN B-1	30.2848	-95.4895	160	240	760	1,020	1,470	-80	-600	-860	-1,310	-1,655
Mo-40	4233930558	INDEPENDENT EXPL.	MCCLAIN / 1	30.2021	-95.1622	105	--	1,140	1,600	2,130	--	-1,035	-1,495	-2,025	-2,559
Mo-41	4233930072	GLENN H. MCCARTHY	SAUNDERS GREGG ET AL 1	30.2906	-95.7842	318	--	670	940	1,275	--	-352	-622	-957	-1,352
Mo-42	4233901732	W. O. HEINZE	BENDER #1	30.0586	-95.2960	78	--	1,450	1,920	2,415	-372	-1,372	-1,842	-2,337	-2,748
Mo-43	4233901014	STANOLIND OIL AND GAS CO	H. C. NICHOLS 1	30.1317	-95.7511	229	240	880	1,170	1,680	-11	-651	-941	-1,451	-1,846
Mo-44	4233901739	MOBIL OIL COMPANY	BENDER ESTATE FARM 1	30.1065	-95.3535	100	390	1,220	1,630	2,060	-290	-1,120	-1,530	-1,960	-2,486
Mo-45	4233930521	ALLIED PRODUCTION CORP.	JOHN BIRCH	30.1137	-95.7374	219	230	880	1,220	1,640	-11	-661	-1,001	-1,421	-1,909
Mo-46	4233901079	COAST CO	PITTS AND LYLES 1	30.1351	-95.6901	216	240	930	1,230	1,685	-24	-714	-1,014	-1,469	-1,910
Mo-47	4233901728	D B OIL COMPANY	CLEVELAND W D / 1	30.0448	-95.2575	104	460	1,500	1,970	2,450	-356	-1,396	-1,866	-2,346	-2,868
Mo-48	4233901109	MOBIL OIL CORPORATION	INA ARCENAUX 1	30.2228	-95.5462	194	340	900	1,170	1,630	-146	-706	-976	-1,436	-1,824
Mo-49	4233930003	THE MORAN CORPATION COLUMBIA DRILLING CO.	M AND M MINERALS 1	30.2024	-95.5583	187	320	895	1,190	1,670	-133	-708	-1,003	-1,483	-1,876
Mo-50	4233901954	CYPRUS OIL COMPANY	CHASE MANHATTAN 4	30.1877	-95.5394	173	325	1,015	1,260	1,680	-152	-842	-1,087	-1,507	-1,943
Mo-51	4233901879	ASSOCIATED OIL AND GAS COMPANY	BLANCHE FOLEY EST 1	30.1835	-95.4949	165	--	1,035	1,250	1,730	-145	-870	-1,085	-1,565	-2,012
Mo-52	4233901721	WHIFFEN ESTATES INC.	C. A. WHITE #1	30.1719	-95.3650	100	--	1,035	1,250	1,810	--	-935	-1,150	-1,710	-2,256
Mo-53	4233901779	WILEY CORP.	WILEY #1	30.1337	-95.4575	121	--	930	1,320	1,750	--	-809	-1,199	-1,629	-2,216
Mo-54	4233901718	HUMBLE OIL & REFINING CO.	W. M. WICKIZER	30.1471	-95.2921	120	--	1,200	1,550	2,040	-311	-1,080	-1,430	-1,920	-2,474
Mo-55	4233901743	CORLEY & GEISELMAN	HARVEY P. / 1	30.1156	-95.4337	105	--	1,020	1,310	1,820	--	-915	-1,205	-1,715	-2,309
Mo-56	4.2339E+13	FLEMMING #1	DAVID B. MACDANIEL	30.1128	-95.7983	243	--	890	1,265	1,670	--	-647	-1,022	-1,427	-1,841
Mo-57	4233900202	HUMBLE OIL AND REFINING	GRAND LAKE GAS UNIT 2 WELL 1	30.2875	-95.4508	169	220	720	1,010	1,495	-51	-551	-841	-1,326	-1,706

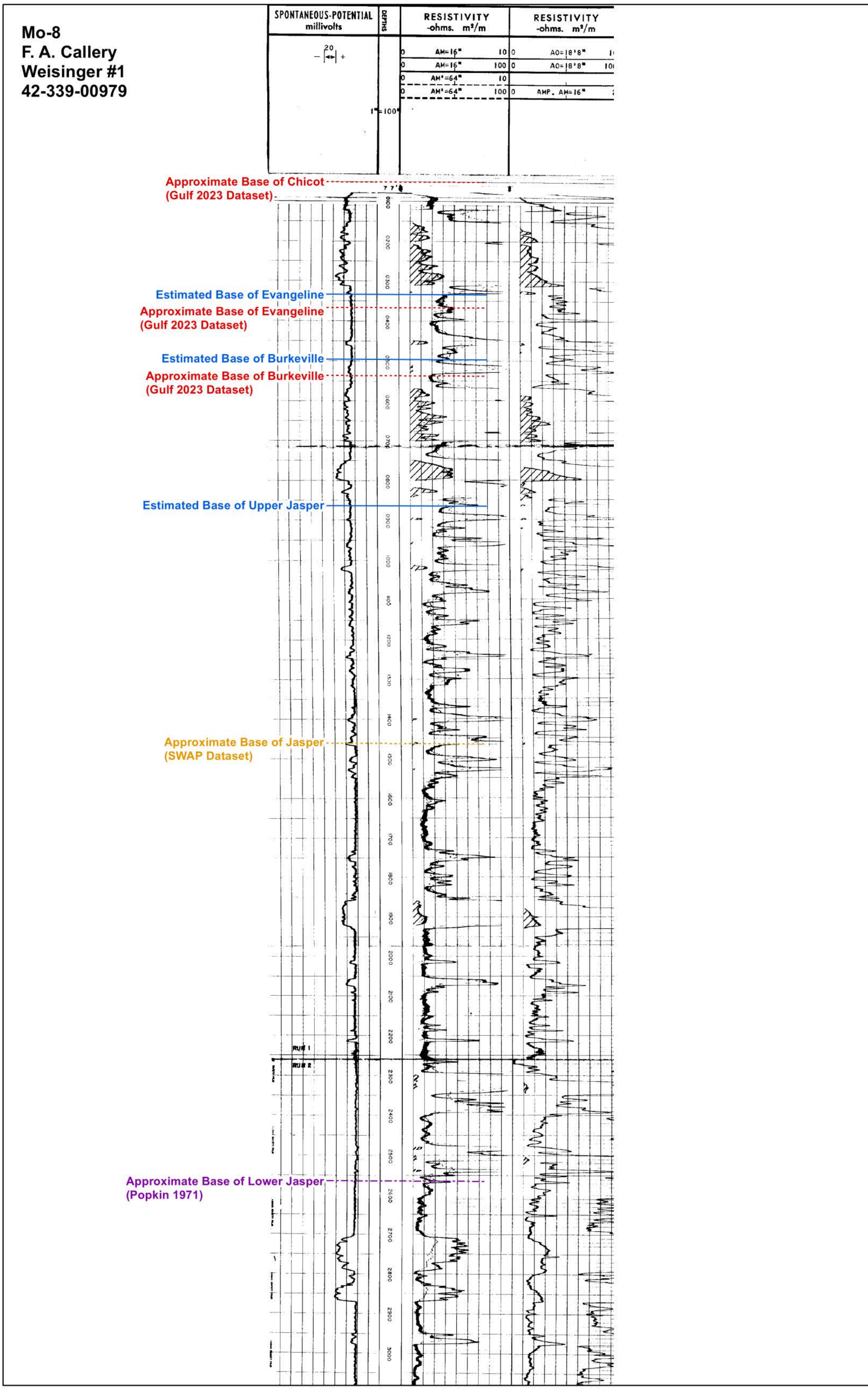
Geophysical Log Number	API Number, State Well Number and / or Q Number	Company	Well	Latitude	Longitude	Land Surface Elevation (feet)	Base of Chicot Depth (feet, bls)	Base of Evangeline Depth (feet, bls)	Base of Burkeville Depth (feet, bls)	Base of Upper Jasper Depth (feet, bls)	Base of Chicot Elevation (feet, rsl)	Base of Evangeline Elevation (feet, rsl)	Base of Burkeville Elevation (feet, rsl)	Base of Upper Jasper Elevation (feet, rsl)	SWAP Base of Jasper Elevation (feet, rsl)
Mo-58	4233901039	ACCO-ROBERTS & MURPHY COMPANY	M ROBERTS ESTATE / 1	30.2143	-95.6370	220	--	840	1,140	1,530	--	-620	-920	-1,310	-1,764
Mo-59	4233901887	SOCONY MOBIL OIL COMPANY	SEALY-SMITH FOUNDATION / 1	30.3282	-95.6204	227	--	530	750	1,060	--	-303	-523	-833	-1,365
Mo-60	4233930199	LADD PET. CORP.	SEALY & SMITH FDTN. / 2	30.2711	-95.6073	195	--	780	1,030	1,400	--	-585	-835	-1,205	-1,600
Mo-61	4233901734	JACK W. FRAZIER	BENDER #1	30.1029	-95.3838	104	--	1,180	1,450	1,960	-282	-1,076	-1,346	-1,856	-2,439
Mo-62	4233930730	FIRST MATAGORDA CORP	BENDER ESTATES A-2	30.1339	-95.4274	112	360	1,095	1,340	1,850	-248	-983	-1,228	-1,738	-2,267
Mo-63	4233900902	B. B. BURKE	FERGERSON #1	30.3805	-95.5057	307	--	550	790	1,150	100	-243	-483	-843	-1,315
Mo-64	4233900934	HUMBLE O&R CO.	HUMBLE O&R CO.	30.2857	-95.5367	167	190	775	1,010	1,370	-23	-608	-843	-1,203	-1,613
Mo-65	4233901849	ATLANTIC REFINING COMPANY	FOSTER LBR. CO 1	30.1799	-95.1533	105	340	1,180	1,660	2,180	-235	-1,075	-1,555	-2,075	-2,650
Mo-66	4233901113	DAVID L. GORDON	MCMAHAN H.M. / 1	30.2372	-95.5209	182	--	880	1,120	1,610	--	-698	-938	-1,428	-1,802
Mo-67	4233901105	D.L. GORDON TRUST	D.L. GORDON TRUST	30.2334	-95.5288	190	--	880	1,130	1,610	--	-690	-940	-1,420	-1,808
Mo-68	4233930494	AIKMAN PETROLEUM INC	AIKMAN PETROLEUM INC	30.1983	-95.5812	216	310	930	1,220	1,620	-94	-714	-1,004	-1,404	-1,864
Mo-69	4233930097	BINTLIFF DAVID C	BINTLIFF DAVID C	30.1569	-95.5709	160	--	915	1,160	1,680	--	-755	-1,000	-1,520	-1,991
Mo-70	4233901101	SIMONTON & TALLEY	SIMONTON & TALLEY	30.1575	-95.5924	162	--	910	1,180	1,640	--	-748	-1,018	-1,478	-1,963
Mo-71	6062604	LAYNE TEXAS COMPANY	KINGWOOD PLACE #1	30.0706	-95.2620	85	410	1,450	--	--	-325	-1,365	--	--	-2,779
Mo-72	4233900154	HUMBLE OIL AND REFINING COMPANY	CONROE TOWNSITE OIL UNIT 97 1	30.3070	-95.4602	209	218	695	1,010	1,470	-9	-486	-801	-1,261	-1,629
Mo-73	4233900742 / 6046504	HUMBLE OIL & REFINING CO.	MARY A. EMORY #5	30.2921	-95.3369	164	275	855	1,080	1,540	-111	-691	-916	-1,376	-1,903
Mo-74	4233901423	C.W. COFFEY ETAL	BALDWIN BROS #1	30.1540	-95.4586	145	--	980	1,250	1,760	-250	-835	-1,105	-1,615	-2,156
Mo-75	4233901872	TEXACO INCOROATED	B.D. GRIFFIN 1	30.3165	-95.2964	194	280	870	1,070	1,440	-86	-676	-876	-1,246	-1,907
Mo-76	4233901801	E. L. KURTH AND S. W. HENDERSON JR.	SOUTHLAND PAPER MILLS 8	30.2336	-95.2202	119	390	990	1,315	1,830	-271	-871	-1,196	-1,711	-2,333
Mo-77	4233900019	AMERADA PETROLEUM CORPORATION	H. A. GODEJOHN 1	30.2901	-95.1502	155	360	995	1,170	1,550	-205	-840	-1,015	-1,395	-2,297
Mo-78	4233901604 / 6054302	ATLANTIC REFG. CO	SO. TEX. DEVELOPMENT 1	30.2358	-95.2777	130	340	990	1,260	1,830	-210	-860	-1,130	-1,700	-2,207
Wa-1	Q-50	M. H. MARR AND THE MORAN CORRPORATION	KATIE WARD NO 1	30.6477	-95.6329	345	--	--	--	190	--	--	--	155	-122
Wa-2	4247130016	MORAN CORPORATION, THE	CENTRAL COAL AND COKE 9	30.5698	-95.6318	211	--	--	--	390	--	--	--	-179	-394
Wa-3	4247130010	THE MORAN CORP.	CENTRAL COAL & COKE A-2	30.5419	-95.5653	352	--	220	322	564	--	132	30	-212	-617
Wa-4	4247100046	R.W. RAMEY AND TEXMO OIL CO.	TOMY KMEICIK 1	30.5287	-95.4799	349	--	300	370	630	--	49	-21	-281	-818
Wa-5	4247130232 / Q-91	GETTY OIL CO	T.W. KEELAND 1	30.5484	-95.3592	353	--	--	325	770	--	--	28	-417	-990
Wa-6	4247130011	PLACID OIL COMPANY	GIBBS BROS. #2	30.6492	-95.3718	340	--	--	--	240	--	--	--	100	-623
Gr-1	4218530369	ARCO EXPLORATION	CHARLIE ASHORN 1	30.5465	-95.8792	359	--	--	--	190	--	--	--	169	8
Gr-2	4218530009	LONE STAR PRODUCING CO	GOFORTH 1	30.2681	-95.8569	317	120	700	975	1,260	197	-383	-658	-943	-1,392
Gr-3	4218530028	VICTORY PETROLEUM CO.	WILLIAM BLEVINS #1	30.4756	-95.8801	375	--	--	--	370	--	--	-999	5	-317
Gr-4	4218500117	ATLANTIC REFINING CO	E. R. SANDERS 1	30.2695	-95.9437	324	--	610	860	1,040	--	-286	-536	-716	-1,162
Gr-5	4218530056	CHARLES B. MARINO	COWAN-ZOLLMAN 1-6	30.2488	-95.8310	306	--	730	1,090	1,350	--	-424	-784	-1,044	-1,467
SJ-1	4240700031	MIDLAND PRODUCTION CORP AND WOLF'S HEAD	HILL ESTATE 1	30.5096	-95.2884	376	--	535	750	1,010	--	-159	-374	-634	-1,283
SJ-2	4240730059	GLEN ROSE CORP	CENTRAL COAL AND COKE C-1	30.5985	-95.2685	312	--	--	--	830	--	--	--	-518	-1,010
SJ-3	4240730086	HOUSTON PETROLEUM CO	BROWDER-SCOTT UNIT 1	30.5338	-95.3049	273	--	350	455	820	--	-77	-182	-547	-1,160
SJ-4	4240730453	HOUSTON PETROLEUM COMPANY	U.S.A. 1	30.5140	-95.1913	254	--	--	--	865	--	--	--	-611	-1,483
SJ-5	4240730017	CONTINENTAL OIL CO	GIBBS BROTHERS AND COMPANY 1	30.4784	-95.2597	266	95	545	715	995	171	-279	-449	-729	-1,461
SJ-6	4240730018	CONTINENTAL OIL COMPANY	DRUCILLA MAYS, ET AL #1	30.4331	-95.2394	235	--	600	800	1,090	--	-365	-565	-855	-1,665
SJ-7	4240700271	ATLANTIC REFINING CO	R. L. WHITE 1	30.3626	-95.1519	180	255	750	1,010	1,370	-75	-570	-830	-1,190	-2,066
SJ-8	4240700214	AMERADA PETR. CORP AND MID-STATES OIL CORP.	CENTRAL COAL COKE CORP 1	30.3930	-95.1444	151	175	670	900	1,180	-24	-519	-749	-1,029	-1,988
SJ-9	4240700246 / Q-8	MAGNOLIA PETROLEUM COMPANY	HINCHLIFF-SIMS #1	30.4257	-95.1002	187	200	630	900	1,160	-13	-443	-713	-973	-1,962
SJ-10	4240700156 / Q-130	AMERADA PET. CO	FOSTER LBR. CO A-1	30.4572	-95.1749	253	210	560	770	1,012	43	-307	-517	-759	-1,780
L-1	42229105456	WILSON - BROACH CO.	C. M. HIGHTOWER #1	30.3517	-95.0232	156	315	840	1,185	1,460	-159	-684	-1,029	-1,304	-2,349
L-2	4229100008	MILES PRODUCTION CO	HINCHLIFF MRS M P / 1	30.3780	-95.0643	214	--	810	1,030	1,360	--	-596	-816	-1,146	-2,183
L-3	4229105018	HUMBLE OIL AND REFINING COMPANY	B. E. QUINN B-1	30.2592	-95.0455	123	370	1,040	1,310	1,680	-247	-917	-1,187	-1,557	-2,622
L-4	4229131549	GUARDIAN OIL COMPANY	FRIENDSWOOD 1	30.2073	-95.0648	130	--	1,200	1,650	1,970	--	-1,070	-1,520	-1,840	-2,754
L-5	4229102431	ACORN OIL CO.	C.C. BERRY 1	30.2259	-94.9641	115	--	1,260	1,710	2,025	0	-1,145	-1,595	-1,910	-2,909
L-6	4229102483	THE TEXAS CO.	R.B. BALDWIN C-4	30.1114	-94.9689	82	450	--	2,040	2,490	-368	--	-1,958	-2,408	-3,279
L-7	4229132387	ANSCHUTZ EXPLORATION CORPORATION	STORSSER FARMS INC. #1	30.1110	-95.0113	80	420	1,640	2,065	2,510	-340	-1,560	-1,985	-2,430	-3,185
L-8	4229130349	ANDERSON T G	BALDWIN EST / 1	30.2175	-95.0983	89	--	1,120	1,510	1,875	--	-1,031	-1,421	-1,786	-2,647
L-9	4229105450	CENTAUR PETR CORP	M R SCOTT ETAL 1 / 1	30.1399	-94.9297	97	--	1,755	2,400	2,590	--	-1,658	-2,303	-2,493	-3,284
Wal-1	4247330066	STARR OIL & GAS CO.	WILLIAM M. RICE INSTITUTE	30.2147	-95.8099	280	--	790	1,110	1,420	--	-510	-830	-1,140	-1,569
Wal-2	4247330379	HIGH CHAPPARAL OIL COMPANY	COWAN-ZOLLMAN-HIGH CHAPPAR	30.2390	-95.8554	290	--	740	1,080	1,330	--	-450	-790	-1,040	-1,473
Wal-3	4247300029	C. W. WEAVER	STEGER #1	30.1635	-95.9410	300	--	910	1,100	1,480	--	-610	-800	-1,180	-1,522
Wal-4	4247300037	STARR OIL & GAS COMPANY	WILLIAM M. RICE INSTITUTE / 1	30.1977	-95.8802	283	--	785	1,140	1,460	--	-502	-857	-1,177	-1,523
H-1	4220107892	AL A. BROWN	W. P. THOMPSON #1	30.0789	-95.8848	245	--	1,010	1,360	1,800	9	-765	-1,115	-1,555	-1,816
H-2	4220101024	J. M. FLAITZ & R. B. MITCHELL	HAMILTON ESTATE / 1	30.0740	-95.1367	59	--	1,480	2,020	2,510	--	-1,421	-1,961	-2,451	-3,027

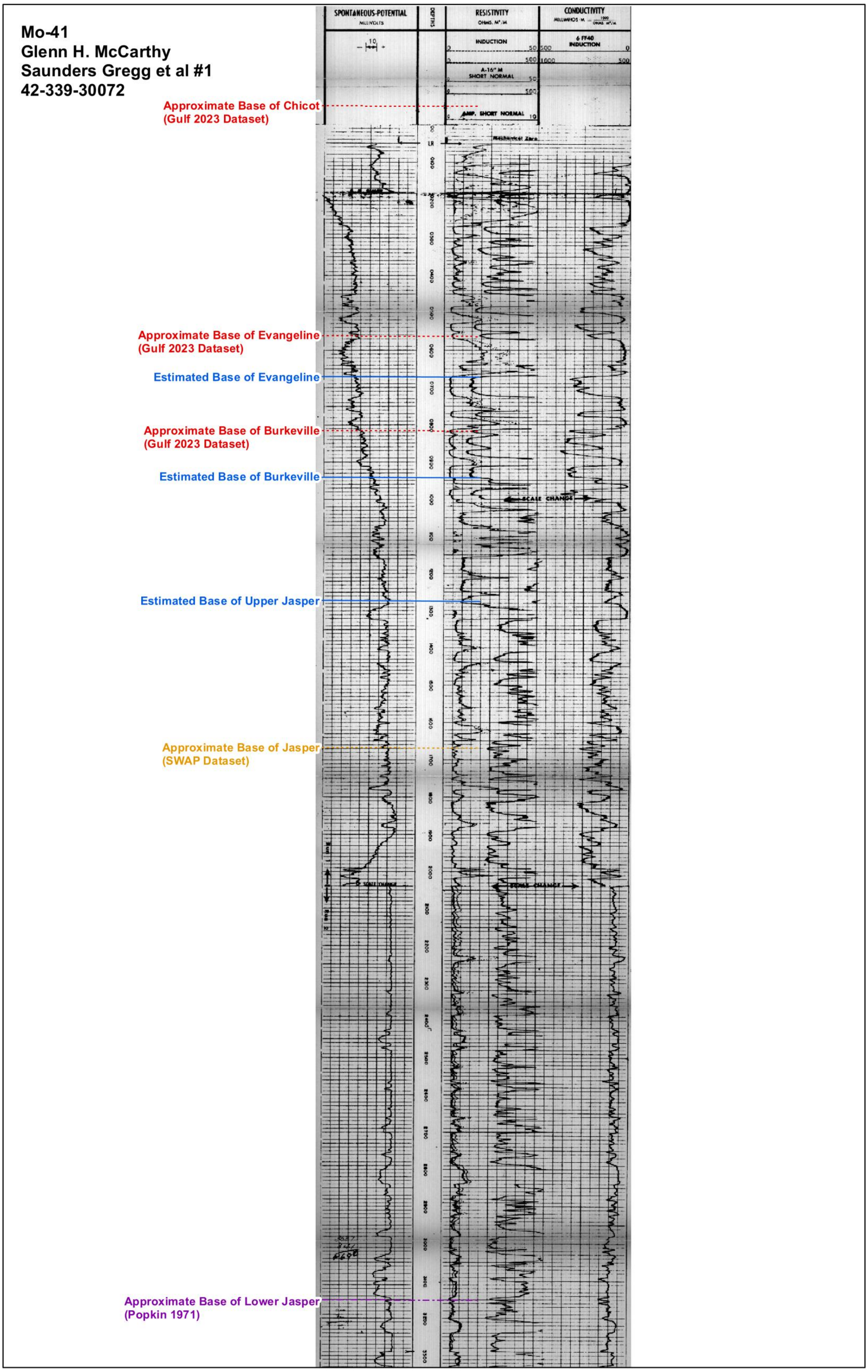
Geophysical Log Number	API Number, State Well Number and / or Q Number	Company	Well	Latitude	Longitude	Land Surface Elevation (feet)	Base of Chicot Depth (feet, bls)	Base of Evangeline Depth (feet, bls)	Base of Burkeville Depth (feet, bls)	Base of Upper Jasper Depth (feet, bls)	Base of Chicot Elevation (feet, rsl)	Base of Evangeline Elevation (feet, rsl)	Base of Burkeville Elevation (feet, rsl)	Base of Upper Jasper Elevation (feet, rsl)	SWAP Base of Jasper Elevation (feet, rsl)
H-3	4220101022	S. & H. OIL & ROYALITY	W. M. ALLAUN	30.0953	-95.1241	105	--	1,510	1,950	2,500	-391	-1,405	-1,845	-2,395	-2,988
H-4	Q-222 / 6059503	THE TEXAS COMPANY	J.E. WILSON #1	30.0749	-95.6986	206	--	1,090	1,420	1,810	--	-884	-1,214	-1,604	-2,061
H-5	4220132375	CARNEGIE FINANCIAL CORP	J A KITZMANN 1A	29.9681	-95.6851	147	550	1,360	1,760	2,150	-403	-1,213	-1,613	-2,003	-2,375
H-6	4220100858	SLICK OIL CORPORATION	PAUL H. JACKSON 1	30.0288	-95.5628	143	480	1,190	1,485	2,030	-337	-1,047	-1,342	-1,887	-2,306
H-7	4220101017	STARR OIL & GAS COMPANY	LEANDER WALKER / 1	30.0030	-95.3174	91	--	1,480	1,920	2,470	--	-1,389	-1,829	-2,379	-2,878
H-8	4220101014	ALLDAY & TAYLOR	#1 DULANEY	30.0217	-95.3572	74	--	1,310	1,690	2,270	-426	-1,236	-1,616	-2,196	-2,740
H-9	4220100717	SOUTHERN UNION GAS COMPANY	WM. HOLDREITH 1	30.1500	-95.5629	135	310	990	1,190	1,645	-175	-855	-1,055	-1,510	-2,018
H-10	4220100794	R.W. RAMEY	W.T. JONES #2	30.1263	-95.5593	166	390	992	1,315	1,740	-224	-826	-1,149	-1,574	-2,083
H-11	4220100882	R. D. SIMONTON	HIEDAN 1	30.0104	-95.5402	130	--	1,212	1,565	2,170	-510	-1,082	-1,435	-2,040	-2,413
H-12	4220100964	FALCON SEABOARD DRILLING COMPANY	HUGO LEMM / 1	30.0529	-95.3851	104	--	1,230	1,608	2,080	--	-1,126	-1,504	-1,976	-2,589
H-13	4220131542	HAMMAN OIL & REFINING COMPANY	R. D. SMITH / 1	30.0836	-95.4293	117	--	1,200	1,430	1,990	--	-1,083	-1,313	-1,873	-2,412
H-14	4220102972	UNION PRODUCING COMPANY	DEUTSER 1	29.9615	-95.3589	70	500	1,510	2,000	2,450	-430	-1,440	-1,930	-2,380	-2,918
H-15	4220102680	TEXAS STATE DRILLING COMPANY	FLEMING 1	29.9134	-95.4005	57	510	1,690	2,150	2,340	-453	-1,633	-2,093	-2,283	-2,973
H-16	4220103001	J. BRIAN EBY	CLAUD B. HAMILL 1	29.9171	-95.3277	66	570	1,680	2,190	2,510	-504	-1,614	-2,124	-2,444	-3,116
H-17	4220132052	MARSHALL, A.B.	MARSHALL, A.B. FEE 25	29.9015	-95.2854	70	600	1,760	2,290	2,575	-530	-1,690	-2,220	-2,505	-3,254
H-18	4220102983	MCDANNALD OIL CO.	MCDANNALD FEE 1	29.9321	-95.2583	70	610	1,740	2,260	2,585	-540	-1,670	-2,190	-2,515	-3,216
H-19	4220100991	SOHIO PETROLEUM COMPANY	H. KOTHMAN / 1	30.0484	-95.4604	110	--	1,145	1,510	2,095	--	-1,035	-1,400	-1,985	-2,453
H-20	4220132489	DAN A. HUGHES COMPANY	WRIGHTSTONE UNIT / 1	30.0668	-95.5458	149	--	1,090	1,415	1,855	--	-941	-1,266	-1,706	-2,234
H-21	4220107603	HUMBLE OIL AND REFINING COMPANY	FOSTER LUMBER CO 2	30.0315	-95.2249	70	475	1,540	1,950	2,500	-405	-1,470	-1,880	-2,430	-2,978
H-22	4220101032	HUMBLE OIL AND REFINING COMPANY	FOSTER LUMBER COMPANY 1	30.0388	-95.1419	52	410	1,645	1,965	2,535	-358	-1,593	-1,913	-2,483	-3,127
H-23	4220100709	GORDON STREET INC	FINGER / 1	30.0269	-95.6154	148	--	1,200	1,690	2,030	--	-1,052	-1,542	-1,882	-2,281
H-24	4220101065	PLACID OIL COMPANY	MRS. D.F. SMITH 1	30.0284	-95.0890	80	500	--	2,260	2,700	-420	--	-2,180	-2,620	-3,269
H-25	4220132265	ARKLA EXPLORATION CO	THARP ESTATE 2	29.9972	-95.0856	67	500	1,800	2,310	2,715	-433	-1,733	-2,243	-2,648	-3,368
H-26	4220102720	CHARLES B. WRIGHTSMAN	HARRIS COUNTY LAND AND IMPRO	29.9548	-95.1717	59	550	1,855	2,310	2,620	-491	-1,796	-2,251	-2,561	-3,321
H-27	4220131572	DURANGO EXPLORATION	RAINES 1	30.0463	-95.9069	247	--	1,260	1,530	1,950	--	-1,013	-1,283	-1,703	-1,861
H-28	4220104295	J. F. CORLEY	WARREN RANCH / 1	29.9914	-95.8508	201	--	1,450	1,865	2,275	--	-1,249	-1,664	-2,074	-2,076
H-29	4220100476	CARNES W. WEAVER	KITZMANN / 1	30.0169	-95.7225	169	--	1,210	1,600	2,010	--	-1,041	-1,431	-1,841	-2,186
H-30	4220100090	M. E. ANDREWS & KIRBY SOUTHWORTH DRILLING	A. A. FROENAIEN #1	30.0686	-95.7228	211	--	1,100	1,490	1,840	-89	-889	-1,279	-1,629	-2,048
H-31	4220103517	M. P. S. PRODUCTION COMPANY	JOYCE BURG / 1	29.9972	-95.6226	143	--	1,270	1,765	2,140	-308	-1,127	-1,622	-1,997	-2,368
H-32	4220100809	RAMEY & MOSBACHER	PEDEN ET AL #1	30.1336	-95.5133	128	--	982	1,310	1,770	-252	-854	-1,182	-1,642	-2,128
H-33	422010078	HARRELL OIL COMPANY	HILDERBRANDT G. / 1	30.1164	-95.4948	112	--	990	1,340	1,815	--	-878	-1,228	-1,703	-2,203
H-34	4220130640	MCCORMICK OIL & GAS CORP.	GERALD O. NICHOLS ET AL / 1	30.0608	-95.7479	216	--	1,200	1,550	1,880	--	-984	-1,334	-1,664	-2,036

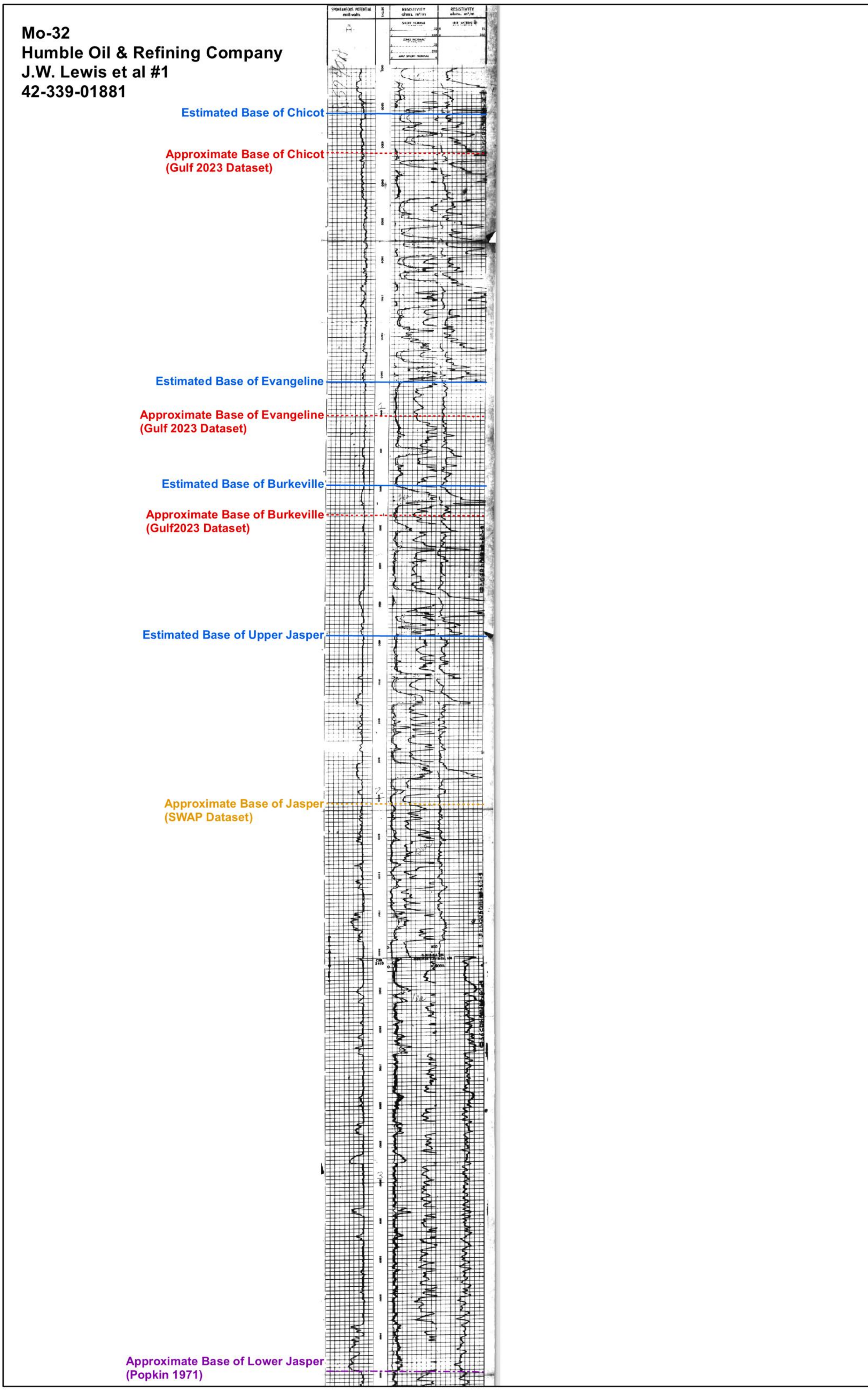
APPENDIX 2 – TYPICAL GEOPHYSICAL LOGS

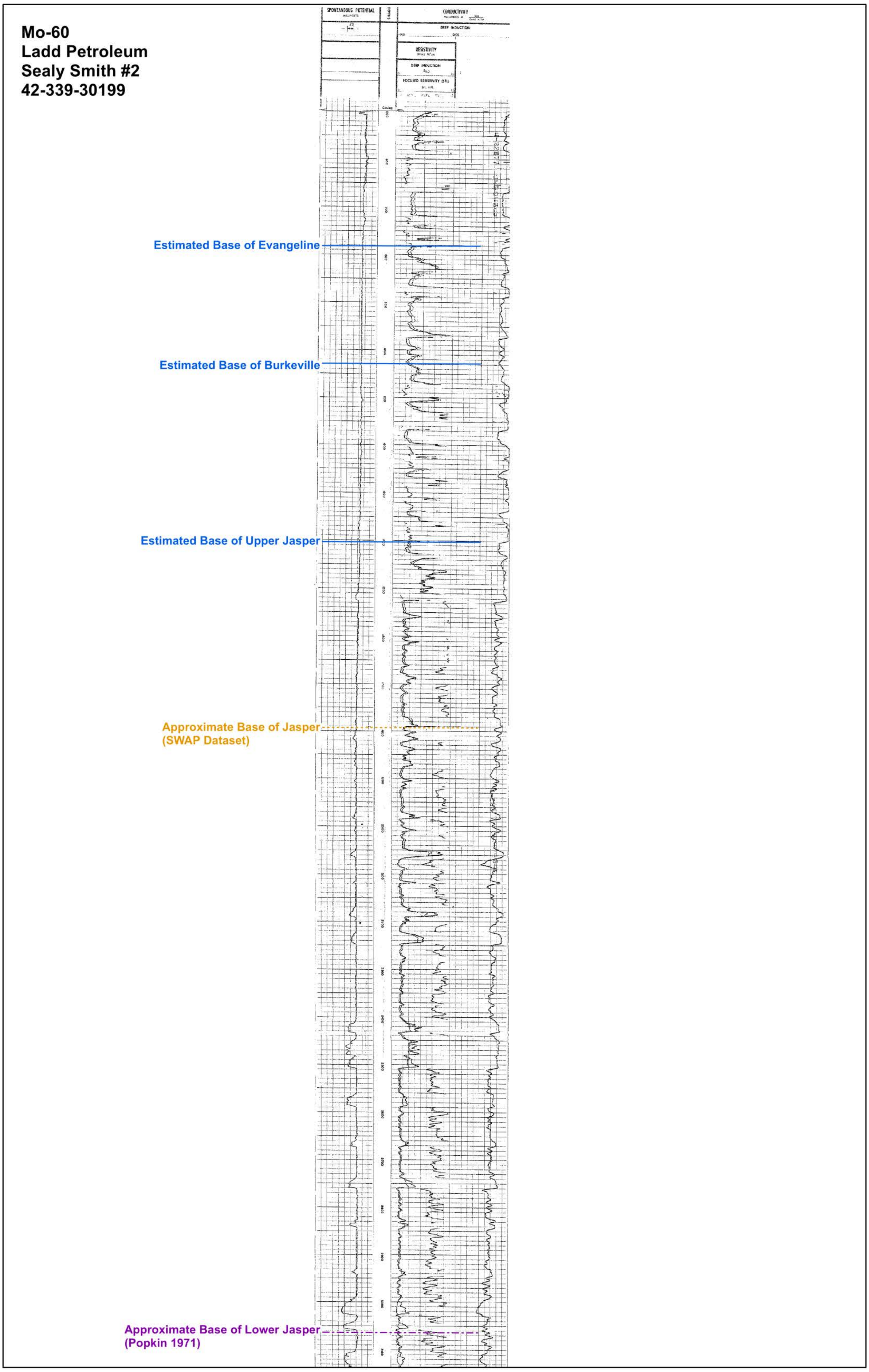

Mo-18
Phillips Petroleum Company
Fraser #1
42-339-00045
SELF-POTENTIAL
RESISTIVITY
Approximate Base of Chicot
(Gulf 2023 Dataset)
Estimated Base of Chicot
Estimated Base of Evangeline
Approximate Base of Evangeline
(Gulf 2023 Dataset)
Approximate Base of Burkeville
(Gulf 2023 Dataset)
Estimated Base of Burkeville
Estimated Base of Upper Jasper
Approximate Base of Jasper
(SWAP Dataset)
Approximate Base of Lower Jasper
(Popkin 1971)

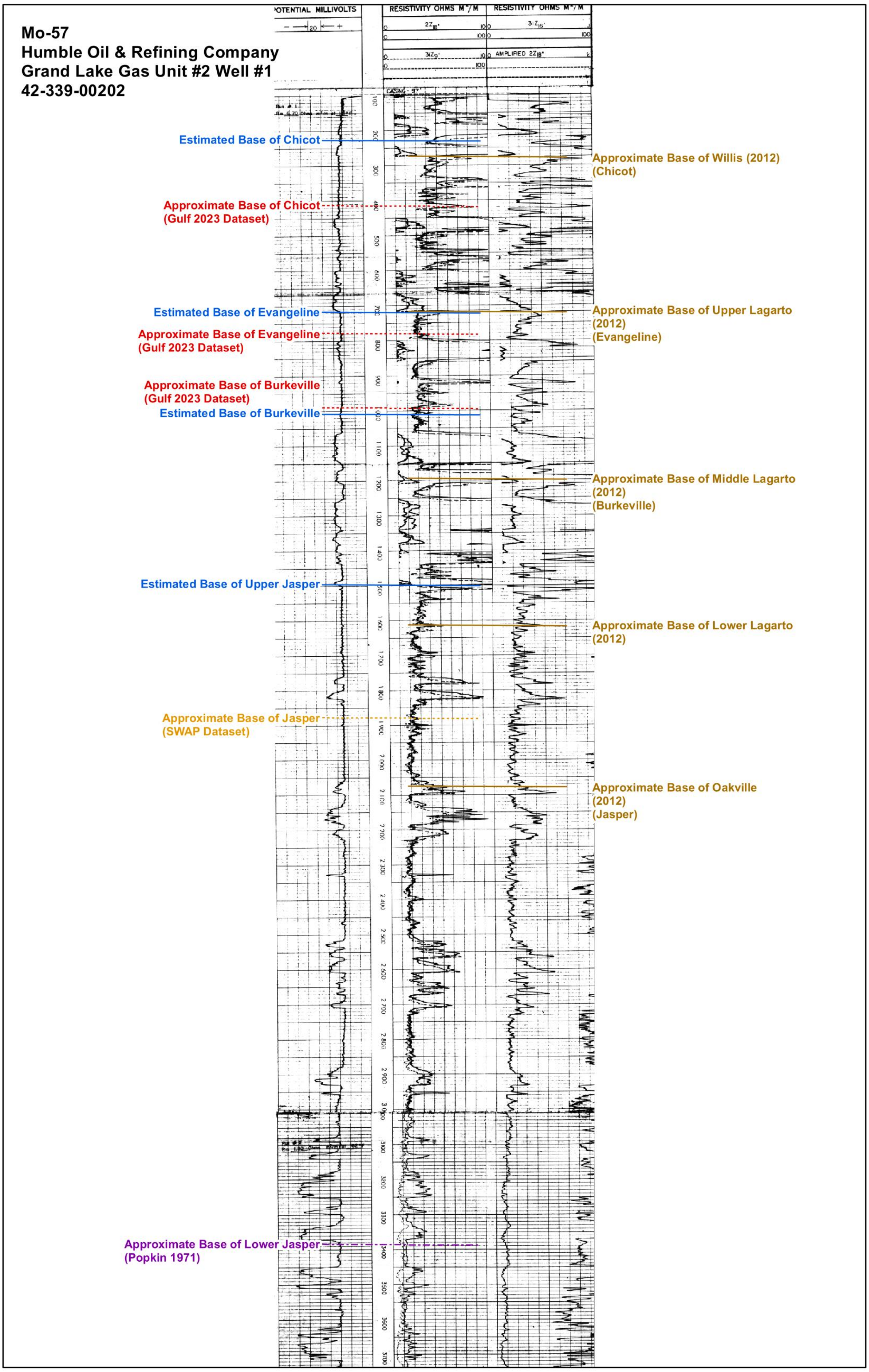

Mo-6
Superior Oil and Speed Jr.
James Sykes B1
42-339-00868
Approximate Base of Chicot
(Gulf 2023 Dataset)
Approximate Base of Evangeline
(Gulf 2023 Dataset)
Estimated Base of Evangeline
Approximate Base of Burkeville
(Gulf 2023 Dataset)
Estimated Base of Burkeville
Estimated Base of Upper Jasper
Approximate Base of Jasper
(SWAP Dataset)
Approximate Base of Lower Jasper
(Popkin 1971)
SPONTANEOUS-POTENTIAL
millivolts
RESISTIVITY
RESISTIVITY

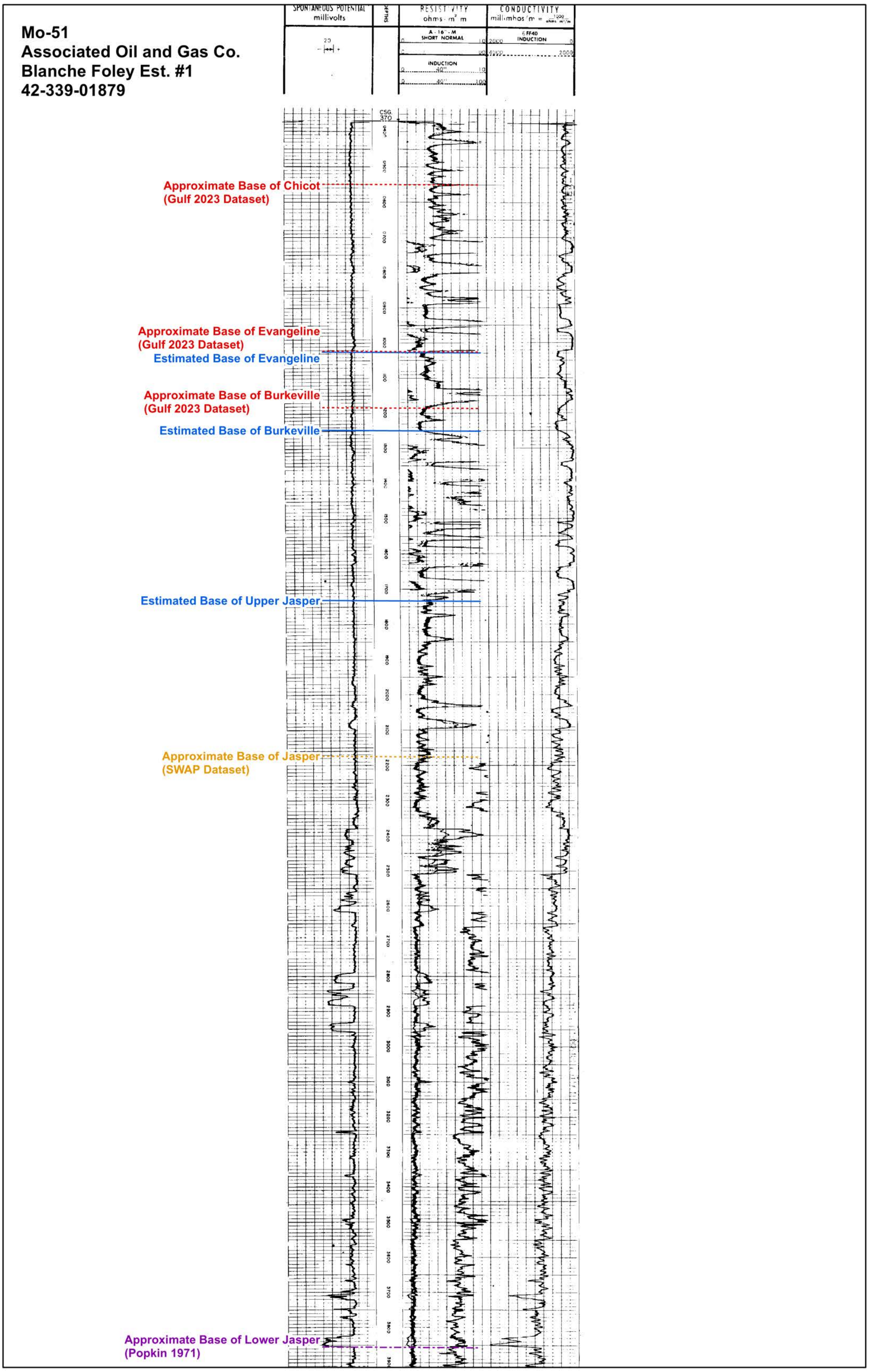

Mo-8
F. A. Callery
Weisinger #1
42-339-00979
SPONTANEOUS-POTENTIAL
millivolts
DEPTHS
RESISTIVITY
-ohms. m²/m
RESISTIVITY
-ohms. m²/m
Approximate Base of Chicot
(Gulf 2023 Dataset)
Estimated Base of Evangeline
Approximate Base of Evangeline
(Gulf 2023 Dataset)
Estimated Base of Burkeville
Approximate Base of Burkeville
(Gulf 2023 Dataset)
Estimated Base of Upper Jasper
Approximate Base of Jasper
(SWAP Dataset)
Approximate Base of Lower Jasper
(Popkin 1971)
RUN 1
RUN 2

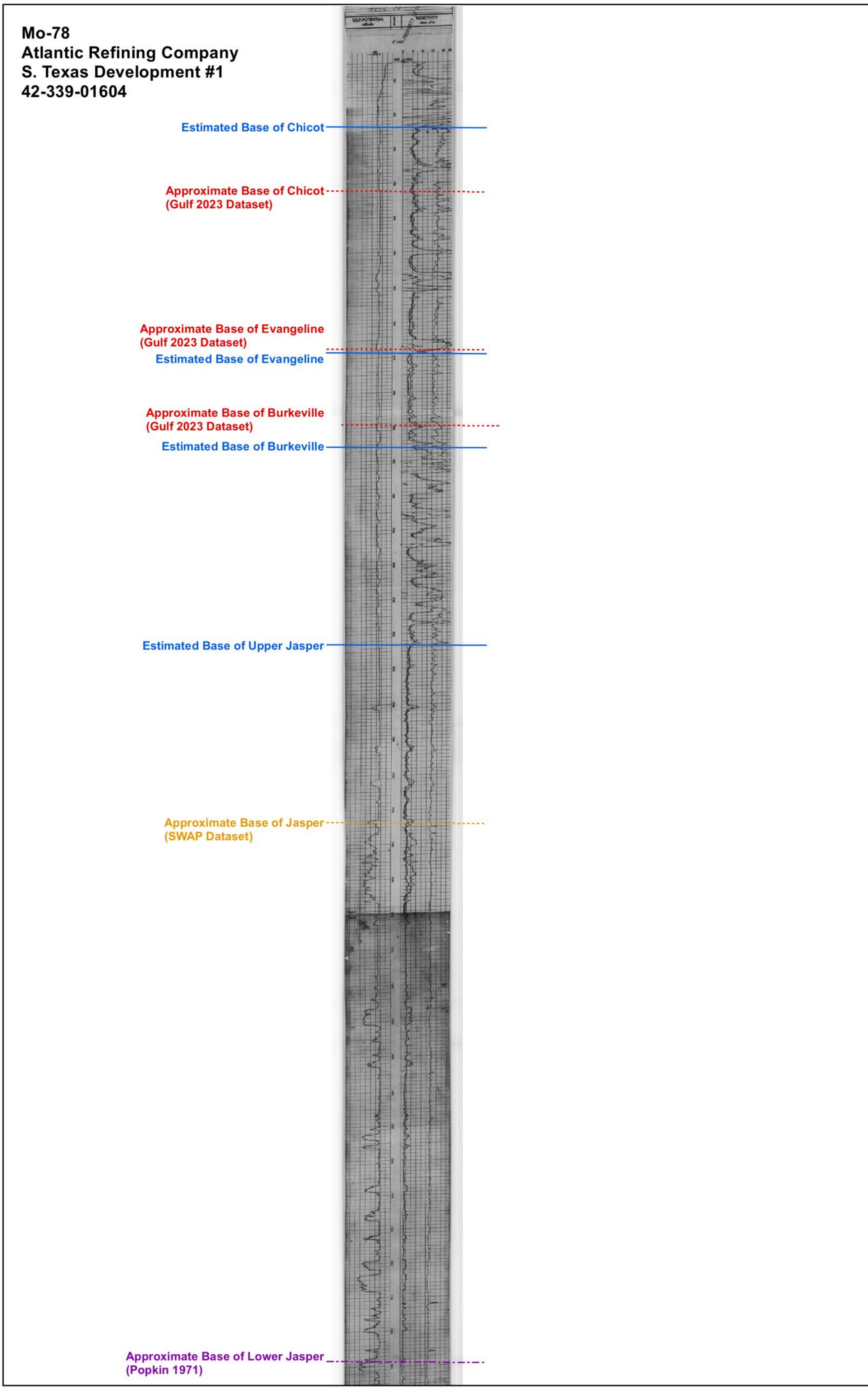

Mo-41
Glenn H. McCarthy
Saunders Gregg et al #1
42-339-30072
Approximate Base of Chicot
(Gulf 2023 Dataset)
Approximate Base of Evangeline
(Gulf 2023 Dataset)
Estimated Base of Evangeline
Approximate Base of Burkeville
(Gulf 2023 Dataset)
Estimated Base of Burkeville
Estimated Base of Upper Jasper
Approximate Base of Jasper
(SWAP Dataset)
Approximate Base of Lower Jasper
(Popkin 1971)
SPONTANEOUS-POTENTIAL
DEPTHS
RESISTIVITY
CONDUCTIVITY
INDUCTION
SHORT NORMAL
SCALE CHANGE

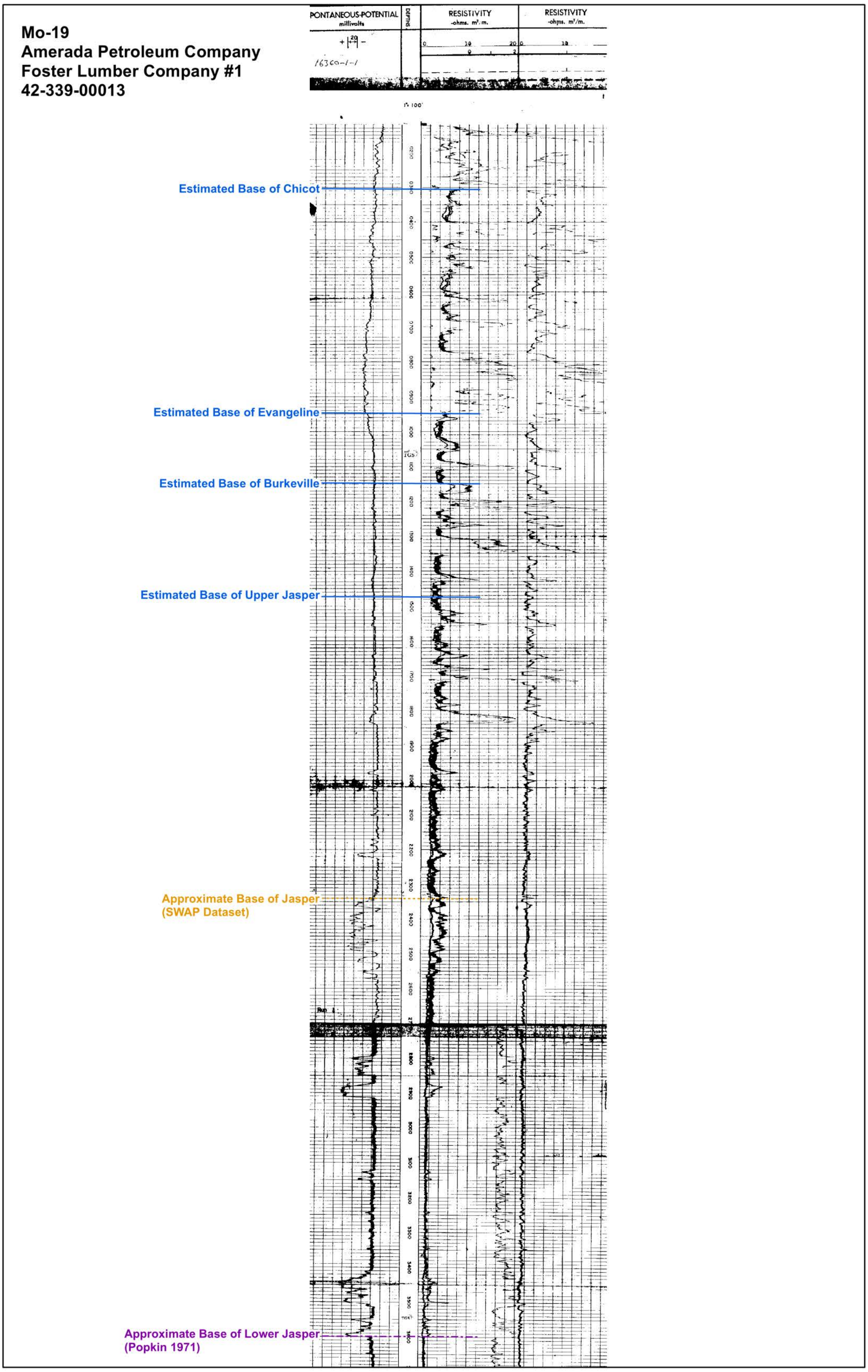

Mo-32
Humble Oil & Refining Company
J.W. Lewis et al #1
42-339-01881
Estimated Base of Chicot
Approximate Base of Chicot
(Gulf 2023 Dataset)
Estimated Base of Evangeline
Approximate Base of Evangeline
(Gulf 2023 Dataset)
Estimated Base of Burkeville
Approximate Base of Burkeville
(Gulf2023 Dataset)
Estimated Base of Upper Jasper
Approximate Base of Jasper
(SWAP Dataset)
Approximate Base of Lower Jasper
(Popkin 1971)

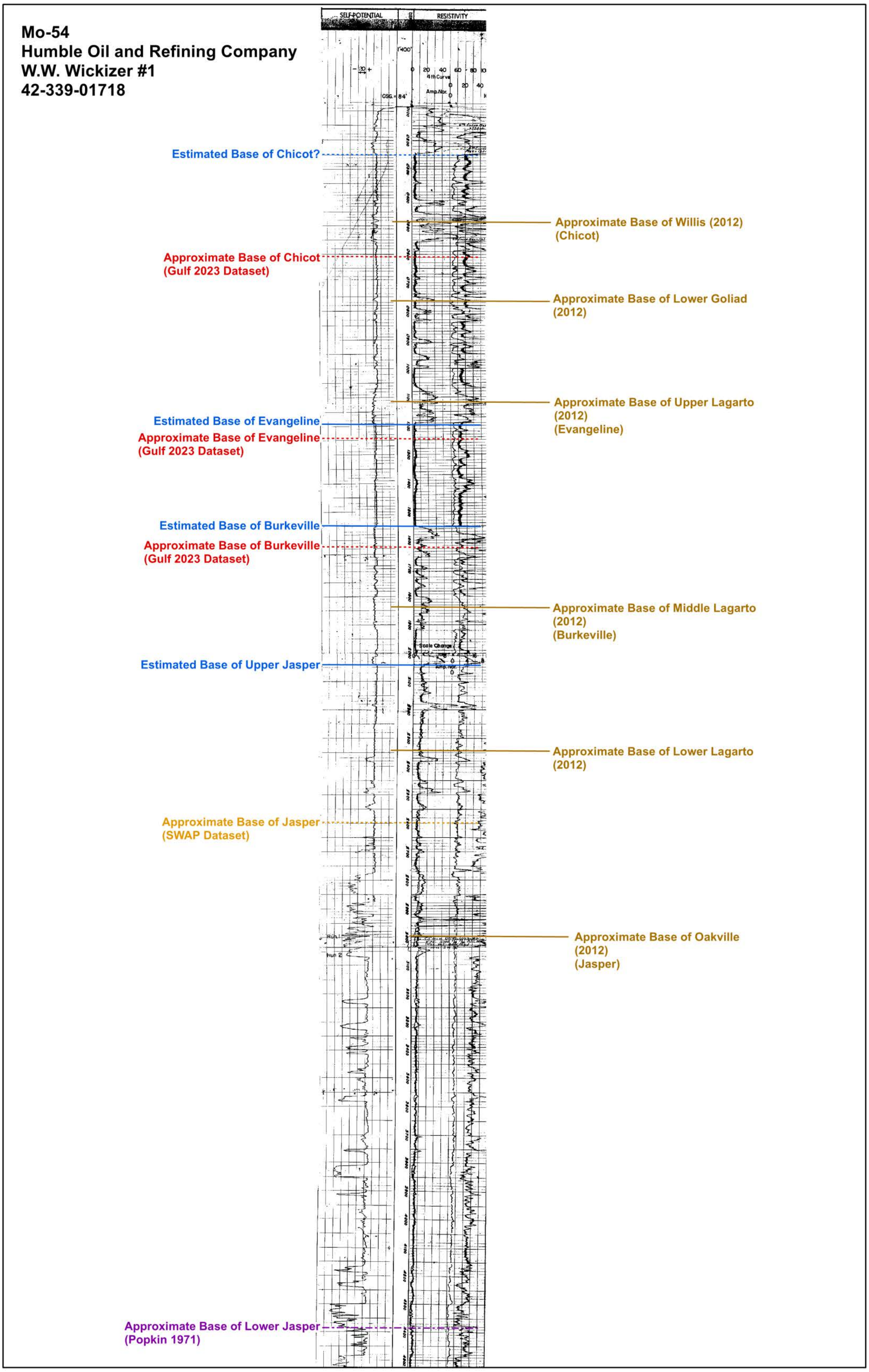

Mo-60
Ladd Petroleum
Sealy Smith #2
42-339-30199
Estimated Base of Evangeline
Estimated Base of Burkeville
Estimated Base of Upper Jasper
Approximate Base of Jasper
(SWAP Dataset)
Approximate Base of Lower Jasper
(Popkin 1971)
SPONTANEOUS POTENTIAL
CONDUCTIVITY
DEEP INDUCTION
RESISTIVITY
FOCUSED RESISTIVITY

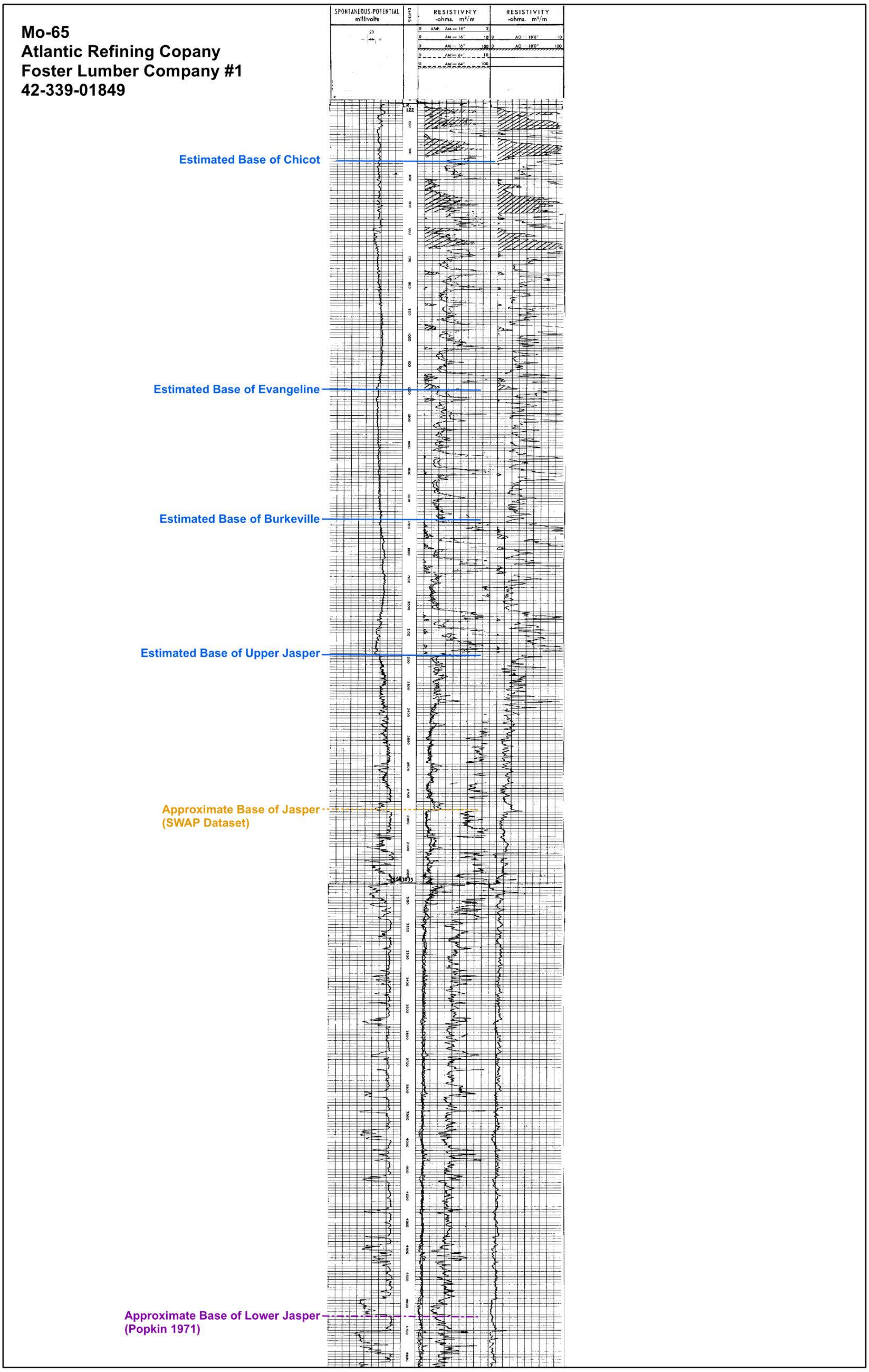

Mo-57
Humble Oil & Refining Company
Grand Lake Gas Unit #2 Well #1
42-339-00202
POTENTIAL MILLIVOLTS
RESISTIVITY OHMS M²/M
RESISTIVITY OHMS M²/M
Estimated Base of Chicot
Approximate Base of Willis (2012) (Chicot)
Approximate Base of Chicot (Gulf 2023 Dataset)
Estimated Base of Evangeline
Approximate Base of Upper Lagarto (2012) (Evangeline)
Approximate Base of Evangeline (Gulf 2023 Dataset)
Approximate Base of Burkeville (Gulf 2023 Dataset)
Estimated Base of Burkeville
Approximate Base of Middle Lagarto (2012) (Burkeville)
Estimated Base of Upper Jasper
Approximate Base of Lower Lagarto (2012)
Approximate Base of Jasper (SWAP Dataset)
Approximate Base of Oakville (2012) (Jasper)
Approximate Base of Lower Jasper (Popkin 1971)

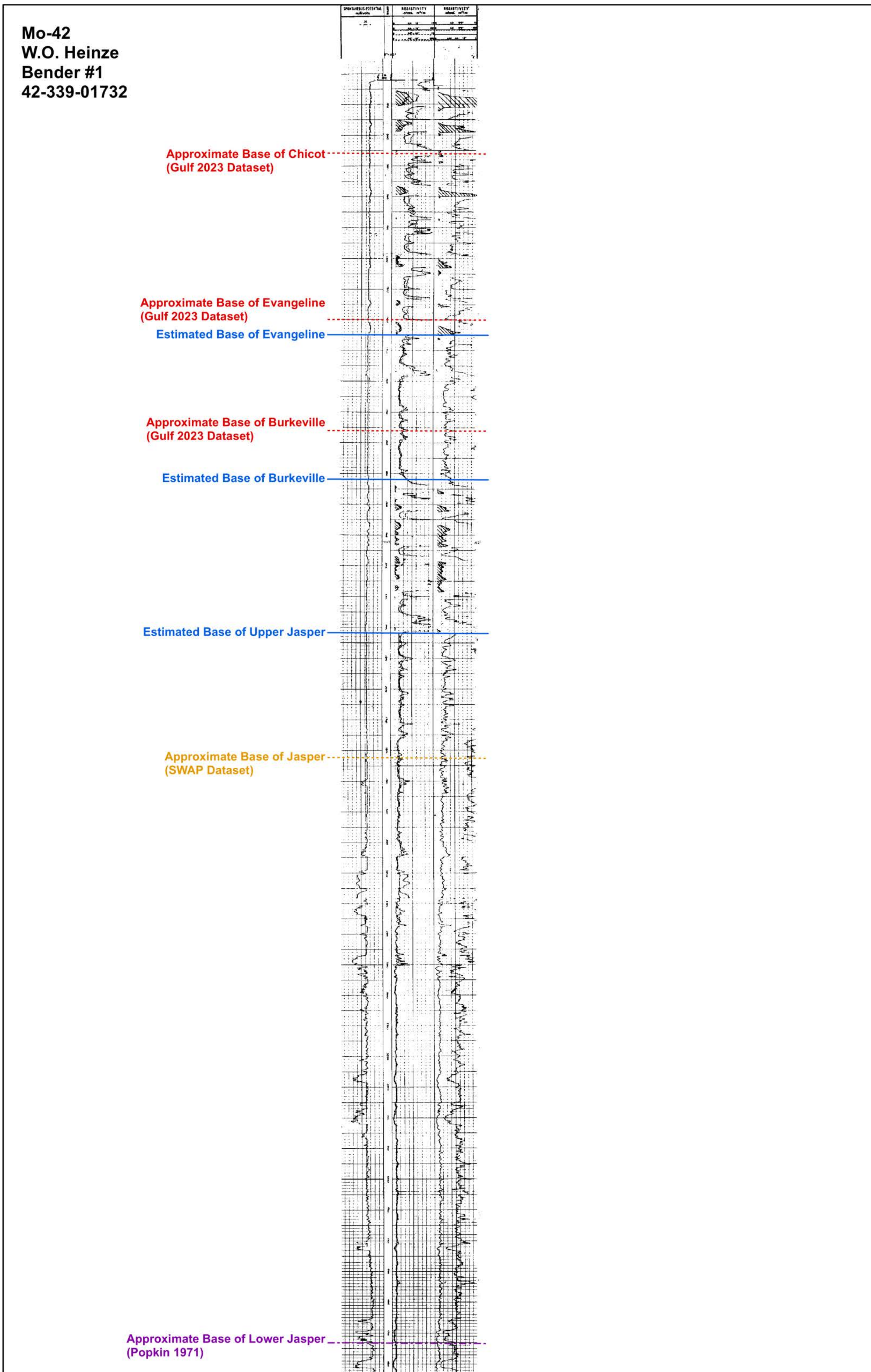

Mo-51
Associated Oil and Gas Co.
Blanche Foley Est. #1
42-339-01879
SPONTANEOUS POTENTIAL
millivolts
RESISTIVITY
ohms · m²/m
CONDUCTIVITY
SHORT NORMAL
INDUCTION
Approximate Base of Chicot
(Gulf 2023 Dataset)
Approximate Base of Evangeline
(Gulf 2023 Dataset)
Estimated Base of Evangeline
Approximate Base of Burkeville
(Gulf 2023 Dataset)
Estimated Base of Burkeville
Estimated Base of Upper Jasper
Approximate Base of Jasper
(SWAP Dataset)
Approximate Base of Lower Jasper
(Popkin 1971)

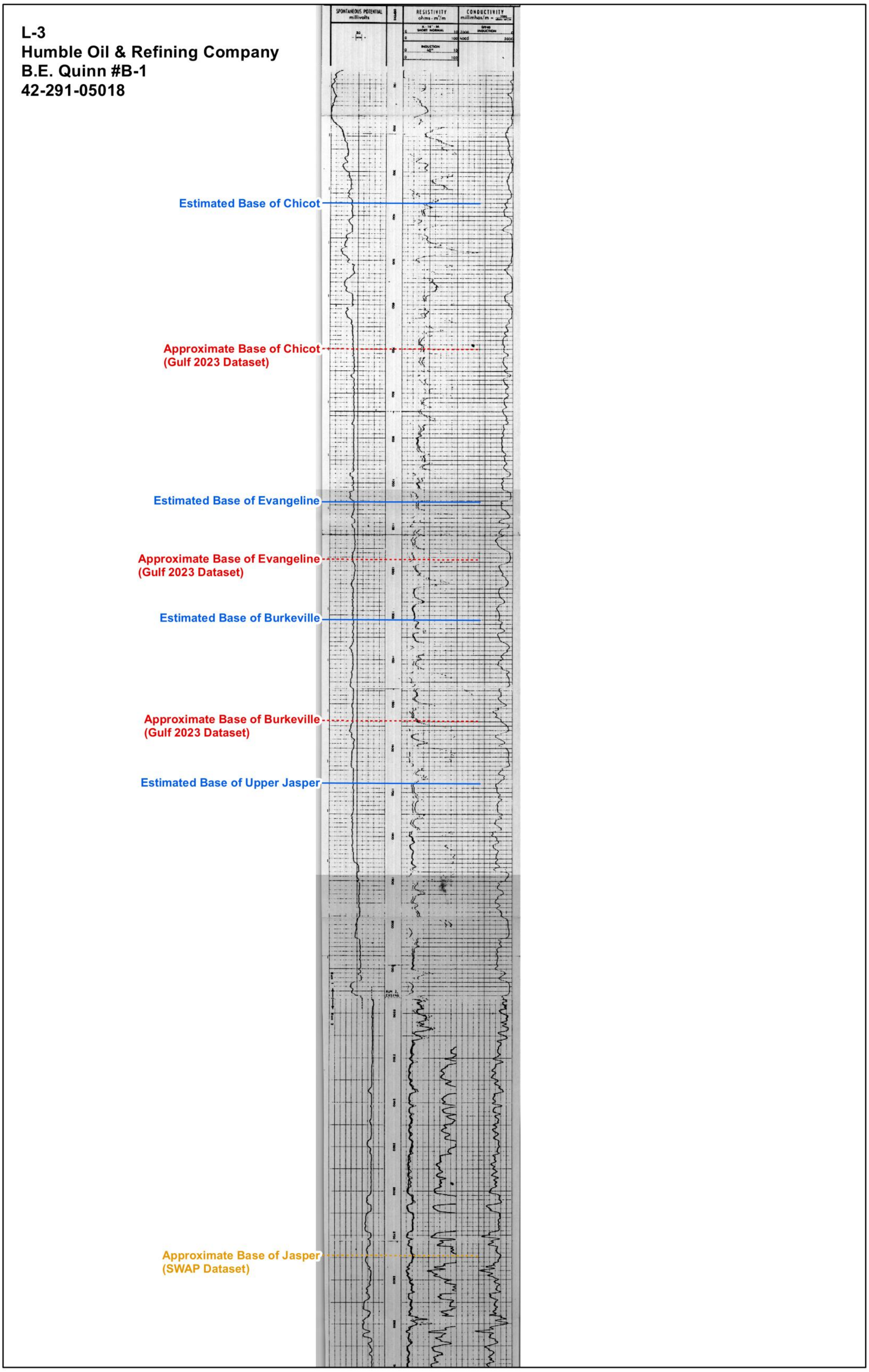

Mo-78
Atlantic Refining Company
S. Texas Development #1
42-339-01604
Estimated Base of Chicot
Approximate Base of Chicot
(Gulf 2023 Dataset)
Approximate Base of Evangeline
(Gulf 2023 Dataset)
Estimated Base of Evangeline
Approximate Base of Burkeville
(Gulf 2023 Dataset)
Estimated Base of Burkeville
Estimated Base of Upper Jasper
Approximate Base of Jasper
(SWAP Dataset)
Approximate Base of Lower Jasper
(Popkin 1971)

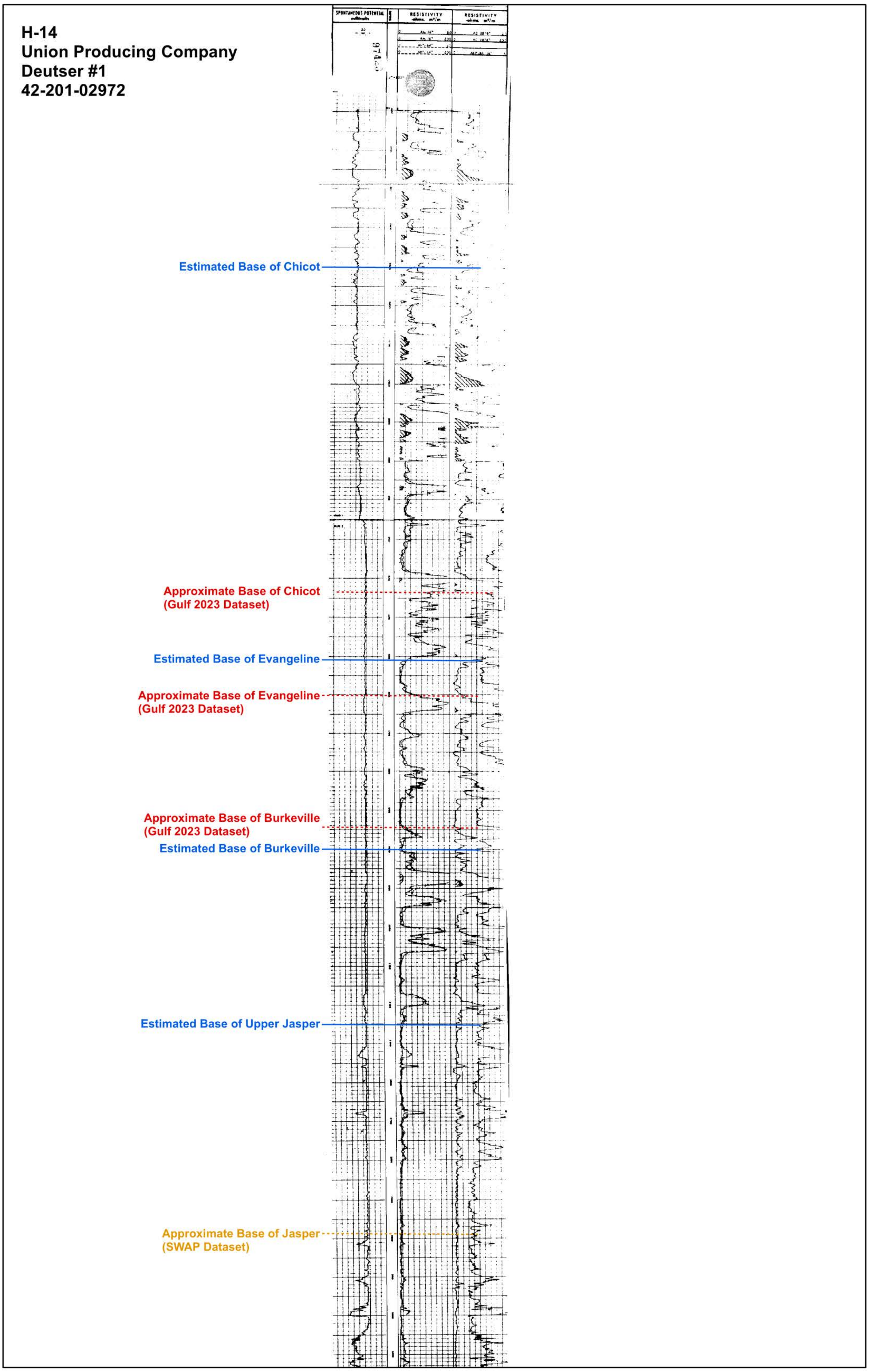

Mo-19
Amerada Petroleum Company
Foster Lumber Company #1
42-339-00013
SPONTANEOUS-POTENTIAL millivolts
DEPTHS
RESISTIVITY -ohms. m²/m.
RESISTIVITY -ohms. m²/m.
Estimated Base of Chicot
Estimated Base of Evangeline
Estimated Base of Burkeville
Estimated Base of Upper Jasper
Approximate Base of Jasper (SWAP Dataset)
Approximate Base of Lower Jasper (Popkin 1971)

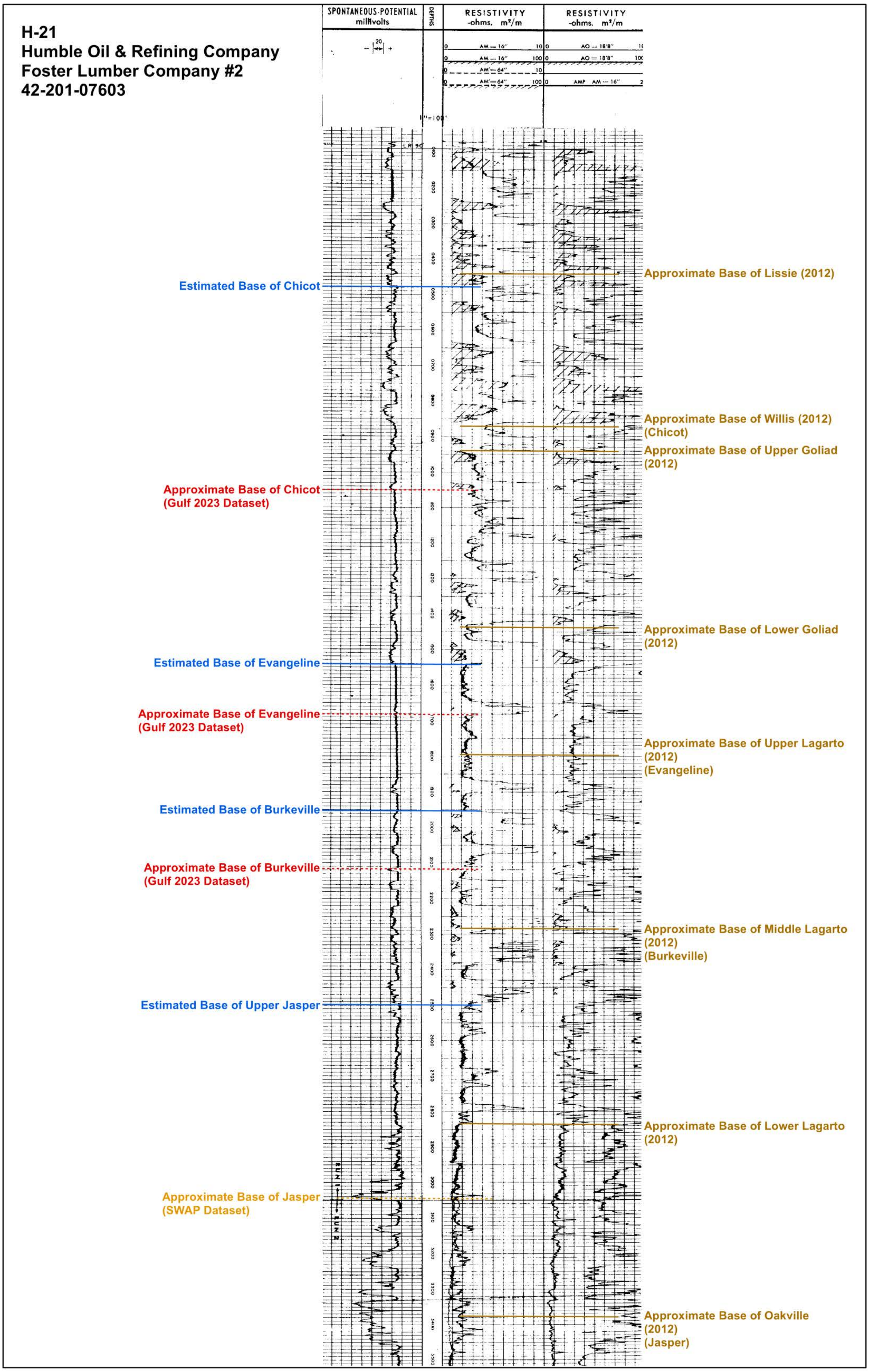

Mo-54
Humble Oil and Refining Company
W.W. Wickizer #1
42-339-01718
SELF-POTENTIAL
RESISTIVITY
Estimated Base of Chicot?
Approximate Base of Willis (2012)
(Chicot)
Approximate Base of Chicot
(Gulf 2023 Dataset)
Approximate Base of Lower Goliad
(2012)
Approximate Base of Upper Lagarto
(2012)
(Evangeline)
Estimated Base of Evangeline
Approximate Base of Evangeline
(Gulf 2023 Dataset)
Estimated Base of Burkeville
Approximate Base of Burkeville
(Gulf 2023 Dataset)
Approximate Base of Middle Lagarto
(2012)
(Burkeville)
Estimated Base of Upper Jasper
Approximate Base of Lower Lagarto
(2012)
Approximate Base of Jasper
(SWAP Dataset)
Approximate Base of Oakville
(2012)
(Jasper)
Approximate Base of Lower Jasper
(Popkin 1971)


Mo-65
Atlantic Refining Copany
Foster Lumber Company #1
42-339-01849
SPONTANEOUS-POTENTIAL millivolts
RESISTIVITY -ohms. m²/m
RESISTIVITY -ohms. m²/m
Estimated Base of Chicot
Estimated Base of Evangeline
Estimated Base of Burkeville
Estimated Base of Upper Jasper
Approximate Base of Jasper (SWAP Dataset)
Approximate Base of Lower Jasper (Popkin 1971)


Mo-42
W.O. Heinze
Bender #1
42-339-01732
Approximate Base of Chicot
(Gulf 2023 Dataset)
Approximate Base of Evangeline
(Gulf 2023 Dataset)
Estimated Base of Evangeline
Approximate Base of Burkeville
(Gulf 2023 Dataset)
Estimated Base of Burkeville
Estimated Base of Upper Jasper
Approximate Base of Jasper
(SWAP Dataset)
Approximate Base of Lower Jasper
(Popkin 1971)


L-3
Humble Oil & Refining Company
B.E. Quinn #B-1
42-291-05018
Estimated Base of Chicot
Approximate Base of Chicot
(Gulf 2023 Dataset)
Estimated Base of Evangeline
Approximate Base of Evangeline
(Gulf 2023 Dataset)
Estimated Base of Burkeville
Approximate Base of Burkeville
(Gulf 2023 Dataset)
Estimated Base of Upper Jasper
Approximate Base of Jasper
(SWAP Dataset)
SPONTANEOUS POTENTIAL
millivolts
RESISTIVITY
ohms · m²/m
CONDUCTIVITY
millimhos/m


H-14
Union Producing Company
Deutser #1
42-201-02972
Estimated Base of Chicot
Approximate Base of Chicot
(Gulf 2023 Dataset)
Estimated Base of Evangeline
Approximate Base of Evangeline
(Gulf 2023 Dataset)
Approximate Base of Burkeville
(Gulf 2023 Dataset)
Estimated Base of Burkeville
Estimated Base of Upper Jasper
Approximate Base of Jasper
(SWAP Dataset)


H-21
Humble Oil & Refining Company
Foster Lumber Company #2
42-201-07603
SPONTANEOUS-POTENTIAL
millivolts
DEPTHS
RESISTIVITY
-ohms. m²/m
RESISTIVITY
-ohms. m²/m
Approximate Base of Lissie (2012)
Estimated Base of Chicot
Approximate Base of Willis (2012)
(Chicot)
Approximate Base of Upper Goliad
(2012)
Approximate Base of Chicot
(Gulf 2023 Dataset)
Approximate Base of Lower Goliad
(2012)
Estimated Base of Evangeline
Approximate Base of Evangeline
(Gulf 2023 Dataset)
Approximate Base of Upper Lagarto
(2012)
(Evangeline)
Estimated Base of Burkeville
Approximate Base of Burkeville
(Gulf 2023 Dataset)
Approximate Base of Middle Lagarto
(2012)
(Burkeville)
Estimated Base of Upper Jasper
Approximate Base of Lower Lagarto
(2012)
Approximate Base of Jasper
(SWAP Dataset)
Approximate Base of Oakville
(2012)
(Jasper)

APPENDIX 3 – CLAY LAYERS SUMMARY

Appendix
Clay Layers Summary
Geophysical Log: Mo-4

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	390	1005	1260	1826
Total Clay Thickness (ft)	50	379	235	339
Total Sand Thickness (ft)	340	626	1025	1487
Percent Clay	13%	38%	19%	19%
Percent Sand	87%	62%	81%	81%
	Potential High Producing Interval			
Number of Producing	1	1	N/A	1
Producing Interval Thickness	390	1005	N/A	1801
Net Clay Thickness (ft)	50	379	N/A	214
Net Sand Thickness (ft)	340	626	N/A	200
Percent Clay	13%	38%	N/A	12%
Percent Sand	87%	62%	N/A	11%
	Clay Interbed Characteristics			
Number of Clay Intereds	1	6	N/A	6
Minimum Thickness (ft)	19	3	N/A	4
Maximum Thickness (ft)	33	90	N/A	50
Average Thickness (ft)	25	32	N/A	21

Appendix
Clay Layers Summary
Geophysical Log: Mo-5

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	UTD	UTD	192
Total Clay Thickness (ft)	UTD	UTD	UTD	74
Total Sand Thickness (ft)	UTD	UTD	UTD	118
Percent Clay	UTD	UTD	UTD	39%
Percent Sand	UTD	UTD	UTD	61%
	Potential High Producing Interval			
Number of Producing Interval	UTD	UTD	UTD	1
Producing Interval Thickness (	UTD	UTD	UTD	152
Net Clay Thickness (ft)	UTD	UTD	UTD	34
Net Sand Thickness (ft)	UTD	UTD	UTD	118
Percent Clay	UTD	UTD	UTD	22%
Percent Sand	UTD	UTD	UTD	78%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	UTD	UTD	4
Minimum Thickness (ft)	UTD	UTD	UTD	2
Maximum Thickness (ft)	UTD	UTD	UTD	14
Average Thickness (ft)	UTD	UTD	UTD	9

Appendix
Clay Layers Summary
Geophysical Log: Mo-6

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	UTD	150	310
Total Clay Thickness (ft)	UTD	UTD	150	92
Total Sand Thickness (ft)	UTD	UTD	0	218
Percent Clay	UTD	UTD	100%	30%
Percent Sand	UTD	UTD	0%	70%
	Potential High Producing Interval			
Number of Producing Interval	UTD	UTD	N/A	1
Producing Interval Thickness (	UTD	UTD	N/A	305
Net Clay Thickness (ft)	UTD	UTD	N/A	87
Net Sand Thickness (ft)	UTD	UTD	N/A	218
Percent Clay	UTD	UTD	N/A	29%
Percent Sand	UTD	UTD	N/A	71%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	UTD	N/A	3
Minimum Thickness (ft)	UTD	UTD	N/A	10
Maximum Thickness (ft)	UTD	UTD	N/A	50
Average Thickness (ft)	UTD	UTD	N/A	29

Appendix
Clay Layers Summary
Geophysical Log: Mo-8

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	UTD	170	360
Total Clay Thickness (ft)	UTD	UTD	160	130
Total Sand Thickness (ft)	UTD	UTD	10	230
Percent Clay	UTD	UTD	94%	36%
Percent Sand	UTD	UTD	6%	64%
	Potential High Producing Interval			
Number of Producing Interval	UTD	UTD	N/A	1
Producing Interval Thickness (	UTD	UTD	N/A	335
Net Clay Thickness (ft)	UTD	UTD	N/A	125
Net Sand Thickness (ft)	UTD	UTD	N/A	210
Percent Clay	UTD	UTD	N/A	37%
Percent Sand	UTD	UTD	N/A	63%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	UTD	N/A	3
Minimum Thickness (ft)	UTD	UTD	N/A	20
Maximum Thickness (ft)	UTD	UTD	N/A	55
Average Thickness (ft)	UTD	UTD	N/A	42

Appendix
Clay Layers Summary
Geophysical Log: Mo-9

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	270	279	535
Total Clay Thickness (ft)	UTD	139	179	281
Total Sand Thickness (ft)	UTD	131	100	254
Percent Clay	UTD	51%	64%	53%
Percent Sand	UTD	49%	36%	47%
	Potential High Producing Interval			
Number of Producing Intervals	UTD	1	1	1
Producing Interval Thickness	UTD	270	120	535
Net Clay Thickness (ft)	UTD	139	60	281
Net Sand Thickness (ft)	UTD	131	60	254
Percent Clay	UTD	51%	50%	53%
Percent Sand	UTD	49%	50%	47%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	5	3	12
Minimum Thickness (ft)	UTD	8	9	3
Maximum Thickness (ft)	UTD	41	90	100
Average Thickness (ft)	UTD	28	45	20

Appendix
Clay Layers Summary
Geophysical Log: Mo-10

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	332	287	390
Total Clay Thickness (ft)	UTD	95	195	298
Total Sand Thickness (ft)	UTD	237	92	92
Percent Clay	UTD	29%	68%	76%
Percent Sand	UTD	71%	32%	24%
	Potential High Producing Interval			
Number of Producing Intervals	UTD	1	1	1
Producing Interval Thickness	UTD	332	247	338
Net Clay Thickness (ft)	UTD	95	155	168
Net Sand Thickness (ft)	UTD	237	92	170
Percent Clay	UTD	29%	63%	50%
Percent Sand	UTD	71%	37%	50%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	4	6	7
Minimum Thickness (ft)	UTD	18	7	7
Maximum Thickness (ft)	UTD	30	70	70
Average Thickness (ft)	UTD	24	28	33

Appendix
Clay Layers Summary
Geophysical Log: Mo-12

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	160	715	285	555
Total Clay Thickness (ft)	70	420	245	350
Total Sand Thickness (ft)	90	295	40	205
Percent Clay	44%	59%	86%	63%
Percent Sand	56%	41%	14%	37%
	Potential High Producing Interval			
Number of Producing Intervals	1	1	N/A	1
Producing Interval Thickness	160	715	N/A	253
Net Clay Thickness (ft)	70	420	N/A	53
Net Sand Thickness (ft)	90	295	N/A	200
Percent Clay	44%	59%	N/A	21%
Percent Sand	56%	41%	N/A	79%
	Clay Interbed Characteristics			
Number of Clay Intereds	4	11	5	9
Minimum Thickness (ft)	9	4	20	8
Maximum Thickness (ft)	41	60	65	100
Average Thickness (ft)	23	35	35	31

Appendix
Clay Layers Summary
Geophysical Log: Mo-13

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	UTD	210	235
Total Clay Thickness (ft)	UTD	UTD	210	77
Total Sand Thickness (ft)	UTD	UTD	0	158
Percent Clay	UTD	UTD	100%	33%
Percent Sand	UTD	UTD	0%	67%
	Potential High Producing Interval			
Number of Producing Interval	UTD	UTD	N/A	1
Producing Interval Thickness (	UTD	UTD	N/A	227
Net Clay Thickness (ft)	UTD	UTD	N/A	69
Net Sand Thickness (ft)	UTD	UTD	N/A	158
Percent Clay	UTD	UTD	N/A	30%
Percent Sand	UTD	UTD	N/A	70%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	UTD	N/A	6
Minimum Thickness (ft)	UTD	UTD	N/A	5
Maximum Thickness (ft)	UTD	UTD	N/A	20
Average Thickness (ft)	UTD	UTD	N/A	12

Appendix
Clay Layers Summary
Geophysical Log: Mo-16

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	330	270	420
Total Clay Thickness (ft)	UTD	240	208	308
Total Sand Thickness (ft)	UTD	90	62	112
Percent Clay	UTD	73%	77%	73%
Percent Sand	UTD	27%	23%	27%
	Potential High Producing Interval			
Number of Producing Interval	UTD	1	N/A	1
Producing Interval Thickness (	UTD	108	N/A	168
Net Clay Thickness (ft)	UTD	29	N/A	83
Net Sand Thickness (ft)	UTD	79	N/A	85
Percent Clay	UTD	27%	N/A	49%
Percent Sand	UTD	73%	N/A	51%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	4	N/A	3
Minimum Thickness (ft)	UTD	2	N/A	10
Maximum Thickness (ft)	UTD	14	N/A	55
Average Thickness (ft)	UTD	7	N/A	28

Appendix
Clay Layers Summary
Geophysical Log: Mo-17

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	UTD	210	510
Total Clay Thickness (ft)	UTD	UTD	189	184
Total Sand Thickness (ft)	UTD	UTD	21	326
Percent Clay	UTD	UTD	90%	36%
Percent Sand	UTD	UTD	10%	64%
	Potential High Producing Interval			
Number of Producing Interval	UTD	UTD	N/A	1
Producing Interval Thickness (	UTD	UTD	N/A	492
Net Clay Thickness (ft)	UTD	UTD	N/A	166
Net Sand Thickness (ft)	UTD	UTD	N/A	326
Percent Clay	UTD	UTD	N/A	34%
Percent Sand	UTD	UTD	N/A	66%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	UTD	N/A	5
Minimum Thickness (ft)	UTD	UTD	N/A	10
Maximum Thickness (ft)	UTD	UTD	N/A	52
Average Thickness (ft)	UTD	UTD	N/A	33

Appendix
Clay Layers Summary
Geophysical Log: Mo-18

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	385	215	305
Total Clay Thickness (ft)	UTD	300	185	163
Total Sand Thickness (ft)	UTD	85	30	142
Percent Clay	UTD	78%	86%	53%
Percent Sand	UTD	22%	14%	47%
	Potential High Producing Interval			
Number of Producing Interval	UTD	1	N/A	1
Producing Interval Thickness (	UTD	265	N/A	213
Net Clay Thickness (ft)	UTD	180	N/A	71
Net Sand Thickness (ft)	UTD	85	N/A	142
Percent Clay	UTD	68%	N/A	33%
Percent Sand	UTD	32%	N/A	67%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	8	N/A	4
Minimum Thickness (ft)	UTD	3	N/A	8
Maximum Thickness (ft)	UTD	70	N/A	42
Average Thickness (ft)	UTD	23	N/A	18

Appendix
Clay Layers Summary
Geophysical Log: Mo-19

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	146	614	270	329
Total Clay Thickness (ft)	43	360	188	175
Total Sand Thickness (ft)	103	254	82	154
Percent Clay	29%	59%	70%	53%
Percent Sand	71%	41%	30%	47%
	Potential High Producing Interval			
Number of Producing Intervals	1	1	N/A	1
Producing Interval Thickness	146	514	N/A	201
Net Clay Thickness (ft)	43	260	N/A	47
Net Sand Thickness (ft)	103	254	N/A	154
Percent Clay	29%	51%	N/A	23%
Percent Sand	71%	49%	N/A	77%
	Clay Interbed Characteristics			
Number of Clay Intereds	2	8	N/A	7
Minimum Thickness (ft)	19	3	N/A	5
Maximum Thickness (ft)	24	68	N/A	50
Average Thickness (ft)	23	35	N/A	25

Appendix
Clay Layers Summary
Geophysical Log: Mo-20

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	UTD	UTD	405
Total Clay Thickness (ft)	UTD	UTD	UTD	90
Total Sand Thickness (ft)	UTD	UTD	UTD	315
Percent Clay	UTD	UTD	UTD	22%
Percent Sand	UTD	UTD	UTD	78%
	Potential High Producing Interval			
Number of Producing Interval	UTD	UTD	UTD	1
Producing Interval Thickness (	UTD	UTD	UTD	400
Net Clay Thickness (ft)	UTD	UTD	UTD	87
Net Sand Thickness (ft)	UTD	UTD	UTD	313
Percent Clay	UTD	UTD	UTD	22%
Percent Sand	UTD	UTD	UTD	78%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	UTD	UTD	2
Minimum Thickness (ft)	UTD	UTD	UTD	34
Maximum Thickness (ft)	UTD	UTD	UTD	53
Average Thickness (ft)	UTD	UTD	UTD	44

Appendix
Clay Layers Summary
Geophysical Log: Mo-21

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	UTD	240	425
Total Clay Thickness (ft)	UTD	UTD	222	217
Total Sand Thickness (ft)	UTD	UTD	18	208
Percent Clay	UTD	UTD	93%	51%
Percent Sand	UTD	UTD	7%	49%
	Potential High Producing Interval			
Number of Producing Interval	UTD	UTD	N/A	1
Producing Interval Thickness (	UTD	UTD	N/A	420
Net Clay Thickness (ft)	UTD	UTD	N/A	212
Net Sand Thickness (ft)	UTD	UTD	N/A	208
Percent Clay	UTD	UTD	N/A	50%
Percent Sand	UTD	UTD	N/A	50%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	UTD	N/A	7
Minimum Thickness (ft)	UTD	UTD	N/A	5
Maximum Thickness (ft)	UTD	UTD	N/A	71
Average Thickness (ft)	UTD	UTD	N/A	31

Appendix
Clay Layers Summary
Geophysical Log: Mo-22

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	258	272	440
Total Clay Thickness (ft)	UTD	169	230	284
Total Sand Thickness (ft)	UTD	89	42	156
Percent Clay	UTD	66%	85%	65%
Percent Sand	UTD	34%	15%	35%
	Potential High Producing Interval			
Number of Producing Intervals	UTD	1	1	1
Producing Interval Thickness	UTD	258	192	440
Net Clay Thickness (ft)	UTD	169	150	284
Net Sand Thickness (ft)	UTD	89	42	156
Percent Clay	UTD	66%	78%	65%
Percent Sand	UTD	34%	22%	35%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	5	4	6
Minimum Thickness (ft)	UTD	9	10	20
Maximum Thickness (ft)	UTD	100	82	54
Average Thickness (ft)	UTD	56	38	36

Appendix
Clay Layers Summary
Geophysical Log: Mo-23

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	UTD	110	478
Total Clay Thickness (ft)	UTD	UTD	110	202
Total Sand Thickness (ft)	UTD	UTD	0	276
Percent Clay	UTD	UTD	100%	42%
Percent Sand	UTD	UTD	0%	58%
	Potential High Producing Interval			
Number of Producing Interval	UTD	1	N/A	1
Producing Interval Thickness (	UTD	204	N/A	458
Net Clay Thickness (ft)	UTD	59	N/A	182
Net Sand Thickness (ft)	UTD	145	N/A	276
Percent Clay	UTD	29%	N/A	40%
Percent Sand	UTD	71%	N/A	60%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	3	N/A	6
Minimum Thickness (ft)	UTD	9	N/A	6
Maximum Thickness (ft)	UTD	38	N/A	63
Average Thickness (ft)	UTD	20	N/A	30

Appendix
Clay Layers Summary
Geophysical Log: Mo-25

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	230	713	240	542
Total Clay Thickness (ft)	29	443	200	319
Total Sand Thickness (ft)	201	270	40	223
Percent Clay	13%	62%	83%	59%
Percent Sand	87%	38%	17%	41%
	Potential High Producing Interval			
Number of Producing Intervals	1	1	1	1
Producing Interval Thickness	230	713	112	542
Net Clay Thickness (ft)	29	443	83	319
Net Sand Thickness (ft)	201	270	29	223
Percent Clay	13%	62%	74%	59%
Percent Sand	87%	38%	26%	41%
	Clay Interbed Characteristics			
Number of Clay Intereds	4	16	5	14
Minimum Thickness (ft)	5	3	10	1
Maximum Thickness (ft)	9	40	80	70
Average Thickness (ft)	7	20	25	28

Appendix
Clay Layers Summary
Geophysical Log: Mo-29

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	UTD	275	310
Total Clay Thickness (ft)	UTD	UTD	246	121
Total Sand Thickness (ft)	UTD	UTD	29	189
Percent Clay	UTD	UTD	89%	39%
Percent Sand	UTD	UTD	11%	61%
	Potential High Producing Interval			
Number of Producing Interval	UTD	UTD	N/A	1
Producing Interval Thickness (	UTD	UTD	N/A	260
Net Clay Thickness (ft)	UTD	UTD	N/A	71
Net Sand Thickness (ft)	UTD	UTD	N/A	189
Percent Clay	UTD	UTD	N/A	27%
Percent Sand	UTD	UTD	N/A	73%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	UTD	N/A	4
Minimum Thickness (ft)	UTD	UTD	N/A	15
Maximum Thickness (ft)	UTD	UTD	N/A	21
Average Thickness (ft)	UTD	UTD	N/A	18

Appendix
Clay Layers Summary
Geophysical Log: Mo-30

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	UTD	250	320
Total Clay Thickness (ft)	UTD	UTD	250	153
Total Sand Thickness (ft)	UTD	UTD	0	167
Percent Clay	UTD	UTD	100%	48%
Percent Sand	UTD	UTD	0%	52%
	Potential High Producing Interval			
Number of Producing Interval	UTD	UTD	N/A	1
Producing Interval Thickness (	UTD	UTD	N/A	300
Net Clay Thickness (ft)	UTD	UTD	N/A	133
Net Sand Thickness (ft)	UTD	UTD	N/A	167
Percent Clay	UTD	UTD	N/A	44%
Percent Sand	UTD	UTD	N/A	56%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	UTD	N/A	4
Minimum Thickness (ft)	UTD	UTD	N/A	7
Maximum Thickness (ft)	UTD	UTD	N/A	68
Average Thickness (ft)	UTD	UTD	N/A	33

Appendix
Clay Layers Summary
Geophysical Log: Mo-32

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	700	270	390
Total Clay Thickness (ft)	UTD	366	250	276
Total Sand Thickness (ft)	UTD	334	20	114
Percent Clay	UTD	52%	93%	71%
Percent Sand	UTD	48%	7%	29%
	Potential High Producing Interval			
Number of Producing Interval	UTD	1	N/A	1
Producing Interval Thickness (	UTD	608	N/A	373
Net Clay Thickness (ft)	UTD	302	N/A	259
Net Sand Thickness (ft)	UTD	306	N/A	114
Percent Clay	UTD	50%	N/A	69%
Percent Sand	UTD	50%	N/A	31%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	10	N/A	5
Minimum Thickness (ft)	UTD	8	N/A	7
Maximum Thickness (ft)	UTD	90	N/A	120
Average Thickness (ft)	UTD	30	N/A	52

Appendix
Clay Layers Summary
Geophysical Log: Mo-33

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	UTD	280	400
Total Clay Thickness (ft)	UTD	UTD	210	276
Total Sand Thickness (ft)	UTD	UTD	70	124
Percent Clay	UTD	UTD	75%	69%
Percent Sand	UTD	UTD	25%	31%
	Potential High Producing Interval			
Number of Producing Interval	UTD	1	1	1
Producing Interval Thickness (	UTD	380	115	340
Net Clay Thickness (ft)	UTD	163	45	216
Net Sand Thickness (ft)	UTD	217	70	124
Percent Clay	UTD	43%	39%	64%
Percent Sand	UTD	57%	61%	36%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	5	2	2
Minimum Thickness (ft)	UTD	14	10	60
Maximum Thickness (ft)	UTD	52	35	216
Average Thickness (ft)	UTD	33	23	138

Appendix
Clay Layers Summary
Geophysical Log: Mo-35

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	UTD	250	510
Total Clay Thickness (ft)	UTD	UTD	235	207
Total Sand Thickness (ft)	UTD	UTD	15	303
Percent Clay	UTD	UTD	94%	41%
Percent Sand	UTD	UTD	6%	59%
	Potential High Producing Interval			
Number of Producing Interval	UTD	UTD	N/A	1
Producing Interval Thickness (	UTD	UTD	N/A	482
Net Clay Thickness (ft)	UTD	UTD	N/A	179
Net Sand Thickness (ft)	UTD	UTD	N/A	303
Percent Clay	UTD	UTD	N/A	37%
Percent Sand	UTD	UTD	N/A	63%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	UTD	N/A	8
Minimum Thickness (ft)	UTD	UTD	N/A	5
Maximum Thickness (ft)	UTD	UTD	N/A	46
Average Thickness (ft)	UTD	UTD	N/A	23

Appendix
Clay Layers Summary
Geophysical Log: Mo-36

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	UTD	350	450
Total Clay Thickness (ft)	UTD	UTD	321	331
Total Sand Thickness (ft)	UTD	UTD	29	119
Percent Clay	UTD	UTD	92%	74%
Percent Sand	UTD	UTD	8%	26%
	Potential High Producing Interval			
Number of Producing Interval	UTD	1	N/A	1
Producing Interval Thickness (	UTD	290	N/A	350
Net Clay Thickness (ft)	UTD	118	N/A	231
Net Sand Thickness (ft)	UTD	172	N/A	119
Percent Clay	UTD	41%	N/A	66%
Percent Sand	UTD	59%	N/A	34%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	3	N/A	6
Minimum Thickness (ft)	UTD	20	N/A	10
Maximum Thickness (ft)	UTD	60	N/A	68
Average Thickness (ft)	UTD	39	N/A	39

Appendix
Clay Layers Summary
Geophysical Log: Mo-37

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	457	358	562
Total Clay Thickness (ft)	UTD	16	179	220
Total Sand Thickness (ft)	UTD	441	179	342
Percent Clay	UTD	4%	50%	39%
Percent Sand	UTD	96%	50%	61%
	Potential High Producing Interval			
Number of Producing Intervals	UTD	2	1	2
Producing Interval Thickness	UTD	377	70	150
Net Clay Thickness (ft)	UTD	14	0	4
Net Sand Thickness (ft)	UTD	363	70	146
Percent Clay	UTD	4%	0%	3%
Percent Sand	UTD	96%	100%	97%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	3	4	6
Minimum Thickness (ft)	UTD	2	17	2
Maximum Thickness (ft)	UTD	12	99	87
Average Thickness (ft)	UTD	5	45	37

Appendix
Clay Layers Summary
Geophysical Log: Mo-38

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	470	335	425
Total Clay Thickness (ft)	UTD	317	313	193
Total Sand Thickness (ft)	UTD	153	22	232
Percent Clay	UTD	67%	93%	45%
Percent Sand	UTD	33%	7%	55%
	Potential High Producing Interval			
Number of Producing Interval	UTD	1	N/A	1
Producing Interval Thickness (	UTD	215	N/A	410
Net Clay Thickness (ft)	UTD	99	N/A	178
Net Sand Thickness (ft)	UTD	116	N/A	232
Percent Clay	UTD	46%	N/A	43%
Percent Sand	UTD	54%	N/A	57%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	4	N/A	7
Minimum Thickness (ft)	UTD	8	N/A	11
Maximum Thickness (ft)	UTD	45	N/A	45
Average Thickness (ft)	UTD	25	N/A	25

Appendix
Clay Layers Summary
Geophysical Log: Mo-39

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	520	260	450
Total Clay Thickness (ft)	UTD	295	248	246
Total Sand Thickness (ft)	UTD	225	12	204
Percent Clay	UTD	57%	95%	55%
Percent Sand	UTD	43%	5%	45%
	Potential High Producing Interval			
Number of Producing Interval	UTD	1	N/A	1
Producing Interval Thickness (	UTD	278	N/A	300
Net Clay Thickness (ft)	UTD	72	N/A	125
Net Sand Thickness (ft)	UTD	206	N/A	175
Percent Clay	UTD	26%	N/A	42%
Percent Sand	UTD	74%	N/A	58%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	6	N/A	6
Minimum Thickness (ft)	UTD	5	N/A	5
Maximum Thickness (ft)	UTD	24	N/A	60
Average Thickness (ft)	UTD	12	N/A	20

Appendix
Clay Layers Summary
Geophysical Log: Mo-40

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	610	460	530
Total Clay Thickness (ft)	UTD	195	248	132
Total Sand Thickness (ft)	UTD	415	212	398
Percent Clay	UTD	32%	54%	25%
Percent Sand	UTD	68%	46%	75%
	Potential High Producing Interval			
Number of Producing Intervals	UTD	2	1	2
Producing Interval Thickness	UTD	350	320	280
Net Clay Thickness (ft)	UTD	70	220	88
Net Sand Thickness (ft)	UTD	280	100	192
Percent Clay	UTD	20%	69%	31%
Percent Sand	UTD	80%	31%	69%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	7	7	5
Minimum Thickness (ft)	UTD	5	8	2
Maximum Thickness (ft)	UTD	50	80	48
Average Thickness (ft)	UTD	28	35	22

Appendix
Clay Layers Summary
Geophysical Log: Mo-42

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	828	470	495
Total Clay Thickness (ft)	UTD	204	289	68
Total Sand Thickness (ft)	UTD	624	181	427
Percent Clay	UTD	25%	61%	14%
Percent Sand	UTD	75%	39%	86%
	Potential High Producing Interval			
Number of Producing Intervals	UTD	1	1	1
Producing Interval Thickness	UTD	828	50	495
Net Clay Thickness (ft)	UTD	204	0	68
Net Sand Thickness (ft)	UTD	624	50	427
Percent Clay	UTD	25%	0%	14%
Percent Sand	UTD	75%	100%	86%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	9	6	3
Minimum Thickness (ft)	UTD	12	4	13
Maximum Thickness (ft)	UTD	35	95	42
Average Thickness (ft)	UTD	23	48	23

Appendix
Clay Layers Summary
Geophysical Log: Mo-43

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	650	290	510
Total Clay Thickness (ft)	UTD	317	179	338
Total Sand Thickness (ft)	UTD	333	111	172
Percent Clay	UTD	49%	62%	66%
Percent Sand	UTD	51%	38%	34%
	Potential High Producing Interval			
Number of Producing Interval	UTD	1	1	1
Producing Interval Thickness (	UTD	580	182	480
Net Clay Thickness (ft)	UTD	247	74	308
Net Sand Thickness (ft)	UTD	333	108	172
Percent Clay	UTD	43%	41%	64%
Percent Sand	UTD	57%	59%	36%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	5	3	8
Minimum Thickness (ft)	UTD	35	14	10
Maximum Thickness (ft)	UTD	71	40	80
Average Thickness (ft)	UTD	49	25	39

Appendix
Clay Layers Summary
Geophysical Log: Mo-44

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	290	830	410	430
Total Clay Thickness (ft)	18	133	191	176
Total Sand Thickness (ft)	272	697	219	254
Percent Clay	6%	16%	47%	41%
Percent Sand	94%	84%	53%	59%
	Potential High Producing Interval			
Number of Producing Intervals	1	1	N/A	1
Producing Interval Thickness	290	830	N/A	300
Net Clay Thickness (ft)	18	133	N/A	66
Net Sand Thickness (ft)	272	697	N/A	234
Percent Clay	6%	16%	N/A	22%
Percent Sand	94%	84%	N/A	78%
	Clay Interbed Characteristics			
Number of Clay Intereds	3	6	5	2
Minimum Thickness (ft)	1	2	2	4
Maximum Thickness (ft)	9	39	50	110
Average Thickness (ft)	6	11	32	44

Appendix
Clay Layers Summary
Geophysical Log: Mo-45

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	650	340	420
Total Clay Thickness (ft)	UTD	420	192	225
Total Sand Thickness (ft)	UTD	230	148	195
Percent Clay	UTD	65%	56%	54%
Percent Sand	UTD	35%	44%	46%
	Potential High Producing Interval			
Number of Producing Interval	UTD	1	1	1
Producing Interval Thickness (	UTD	275	248	420
Net Clay Thickness (ft)	UTD	135	100	225
Net Sand Thickness (ft)	UTD	140	148	195
Percent Clay	UTD	49%	40%	54%
Percent Sand	UTD	51%	60%	46%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	4	4	6
Minimum Thickness (ft)	UTD	20	18	12
Maximum Thickness (ft)	UTD	145	35	90
Average Thickness (ft)	UTD	71	25	38

Appendix
Clay Layers Summary
Geophysical Log: Mo-46

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	690	300	455
Total Clay Thickness (ft)	UTD	418	233	374
Total Sand Thickness (ft)	UTD	272	67	81
Percent Clay	UTD	61%	78%	82%
Percent Sand	UTD	39%	22%	18%
	Potential High Producing Interval			
Number of Producing Interval	UTD	1	N/A	1
Producing Interval Thickness (	UTD	390	N/A	392
Net Clay Thickness (ft)	UTD	191	N/A	311
Net Sand Thickness (ft)	UTD	199	N/A	81
Percent Clay	UTD	49%	N/A	79%
Percent Sand	UTD	51%	N/A	21%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	6	N/A	5
Minimum Thickness (ft)	UTD	10	N/A	8
Maximum Thickness (ft)	UTD	67	N/A	190
Average Thickness (ft)	UTD	32	N/A	62

Appendix
Clay Layers Summary
Geophysical Log: Mo-47

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	1040	470	480
Total Clay Thickness (ft)	UTD	650	56	162
Total Sand Thickness (ft)	UTD	390	414	318
Percent Clay	UTD	63%	12%	34%
Percent Sand	UTD	38%	88%	66%
	Potential High Producing Interval			
Number of Producing Interval	UTD	1	N/A	1
Producing Interval Thickness (	UTD	400	N/A	480
Net Clay Thickness (ft)	UTD	180	N/A	162
Net Sand Thickness (ft)	UTD	220	N/A	318
Percent Clay	UTD	45%	N/A	34%
Percent Sand	UTD	55%	N/A	66%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	8	N/A	8
Minimum Thickness (ft)	UTD	5	N/A	5
Maximum Thickness (ft)	UTD	110	N/A	55
Average Thickness (ft)	UTD	23	N/A	20

Appendix
Clay Layers Summary
Geophysical Log: Mo-48

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	560	270	460
Total Clay Thickness (ft)	UTD	325	197	331
Total Sand Thickness (ft)	UTD	235	73	129
Percent Clay	UTD	58%	73%	72%
Percent Sand	UTD	42%	27%	28%
	Potential High Producing Interval			
Number of Producing Interval	UTD	1	N/A	1
Producing Interval Thickness (	UTD	500	N/A	362
Net Clay Thickness (ft)	UTD	265	N/A	233
Net Sand Thickness (ft)	UTD	235	N/A	129
Percent Clay	UTD	53%	N/A	64%
Percent Sand	UTD	47%	N/A	36%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	8	N/A	7
Minimum Thickness (ft)	UTD	20	N/A	10
Maximum Thickness (ft)	UTD	62	N/A	45
Average Thickness (ft)	UTD	33	N/A	33

Appendix
Clay Layers Summary
Geophysical Log: Mo-49

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	230	575	293	480
Total Clay Thickness (ft)	70	447	259	349
Total Sand Thickness (ft)	160	128	34	131
Percent Clay	30%	78%	88%	73%
Percent Sand	70%	22%	12%	27%
	Potential High Producing Interval			
Number of Producing Intervals	1	1	1	1
Producing Interval Thickness	230	575	98	480
Net Clay Thickness (ft)	70	447	27	349
Net Sand Thickness (ft)	160	128	71	131
Percent Clay	30%	78%	28%	73%
Percent Sand	70%	22%	72%	27%
	Clay Interbed Characteristics			
Number of Clay Intereds	2	12	8	11
Minimum Thickness (ft)	8	5	6	3
Maximum Thickness (ft)	52	80	31	30
Average Thickness (ft)	35	25	19	17

Appendix
Clay Layers Summary
Geophysical Log: Mo-50

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	690	245	420
Total Clay Thickness (ft)	UTD	438	162	231
Total Sand Thickness (ft)	UTD	252	83	189
Percent Clay	UTD	63%	66%	55%
Percent Sand	UTD	37%	34%	45%
	Potential High Producing Interval			
Number of Producing Interval	UTD	1	N/A	1
Producing Interval Thickness (	UTD	367	N/A	320
Net Clay Thickness (ft)	UTD	135	N/A	131
Net Sand Thickness (ft)	UTD	232	N/A	189
Percent Clay	UTD	37%	N/A	41%
Percent Sand	UTD	63%	N/A	59%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	8	N/A	5
Minimum Thickness (ft)	UTD	8	N/A	10
Maximum Thickness (ft)	UTD	223	N/A	68
Average Thickness (ft)	UTD	55	N/A	26

Appendix
Clay Layers Summary
Geophysical Log: Mo-51

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	UTD	233	475
Total Clay Thickness (ft)	UTD	UTD	185	128
Total Sand Thickness (ft)	UTD	UTD	48	347
Percent Clay	UTD	UTD	79%	27%
Percent Sand	UTD	UTD	21%	73%
	Potential High Producing Interval			
Number of Producing Interval	UTD	1	N/A	1
Producing Interval Thickness (	UTD	312	N/A	475
Net Clay Thickness (ft)	UTD	143	N/A	128
Net Sand Thickness (ft)	UTD	169	N/A	347
Percent Clay	UTD	46%	N/A	27%
Percent Sand	UTD	54%	N/A	73%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	4	N/A	9
Minimum Thickness (ft)	UTD	10	N/A	3
Maximum Thickness (ft)	UTD	68	N/A	30
Average Thickness (ft)	UTD	36	N/A	14

Appendix
Clay Layers Summary
Geophysical Log: Mo-52

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	545	215	560
Total Clay Thickness (ft)	UTD	334	165	311
Total Sand Thickness (ft)	UTD	211	50	249
Percent Clay	UTD	61%	77%	56%
Percent Sand	UTD	39%	23%	44%
	Potential High Producing Interval			
Number of Producing Intervals	UTD	1	1	6
Producing Interval Thickness	UTD	545	230	456
Net Clay Thickness (ft)	UTD	334	36	207
Net Sand Thickness (ft)	UTD	211	194	249
Percent Clay	UTD	61%	16%	45%
Percent Sand	UTD	39%	84%	55%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	5	3	7
Minimum Thickness (ft)	UTD	13	30	10
Maximum Thickness (ft)	UTD	142	85	175
Average Thickness (ft)	UTD	67	55	50

Appendix
Clay Layers Summary
Geophysical Log: Mo-53

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	UTD	390	430
Total Clay Thickness (ft)	UTD	UTD	369	254
Total Sand Thickness (ft)	UTD	UTD	21	176
Percent Clay	UTD	UTD	95%	59%
Percent Sand	UTD	UTD	5%	41%
	Potential High Producing Interval			
Number of Producing Interval	UTD	1	N/A	1
Producing Interval Thickness (	UTD	150	N/A	307
Net Clay Thickness (ft)	UTD	38	N/A	141
Net Sand Thickness (ft)	UTD	112	N/A	166
Percent Clay	UTD	25%	N/A	46%
Percent Sand	UTD	75%	N/A	54%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	2	N/A	3
Minimum Thickness (ft)	UTD	18	N/A	45
Maximum Thickness (ft)	UTD	20	N/A	52
Average Thickness (ft)	UTD	19	N/A	48

Appendix
Clay Layers Summary
Geophysical Log: Mo-55

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	590	290	510
Total Clay Thickness (ft)	UTD	330	210	389
Total Sand Thickness (ft)	UTD	260	80	121
Percent Clay	UTD	56%	72%	76%
Percent Sand	UTD	44%	28%	24%
	Potential High Producing Interval			
Number of Producing Intervals	UTD	1	1	2
Producing Interval Thickness	UTD	590	100	280
Net Clay Thickness (ft)	UTD	330	28	88
Net Sand Thickness (ft)	UTD	260	72	192
Percent Clay	UTD	56%	28%	31%
Percent Sand	UTD	44%	72%	69%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	7	3	8
Minimum Thickness (ft)	UTD	10	30	9
Maximum Thickness (ft)	UTD	90	70	160
Average Thickness (ft)	UTD	47	42	39

Appendix
Clay Layers Summary
Geophysical Log: Mo-56

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	UTD	375	405
Total Clay Thickness (ft)	UTD			
Total Sand Thickness (ft)	UTD			
Percent Clay	UTD			
Percent Sand	UTD			
	Potential High Producing Interval			
Number of Producing Interv	UTD	1		1
Producing Interval Thicknes	UTD	70		252
Net Clay Thickness (ft)	UTD	18		169
Net Sand Thickness (ft)	UTD	52		83
Percent Clay	UTD	26%		67%
Percent Sand	UTD	74%		33%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	1		2
Minimum Thickness (ft)	UTD	18		46
Maximum Thickness (ft)	UTD	18		123
Average Thickness (ft)	UTD	18		85

Appendix
Clay Layers Summary
Geophysical Log: Mo-57

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	117	500	290	860
Total Clay Thickness (ft)	71	284	210	545
Total Sand Thickness (ft)	46	216	80	315
Percent Clay	61%	57%	72%	63%
Percent Sand	39%	43%	28%	37%
	Potential High Producing Interval			
Number of Producing Intervals	1	1	1	1
Producing Interval Thickness	117	500	200	860
Net Clay Thickness (ft)	71	284	54	545
Net Sand Thickness (ft)	46	216	146	315
Percent Clay	61%	57%	27%	63%
Percent Sand	39%	43%	73%	37%
	Clay Interbed Characteristics			
Number of Clay Intereds	5	10	4	11
Minimum Thickness (ft)	19	3	20	3
Maximum Thickness (ft)	30	50	50	110
Average Thickness (ft)	24	24	30	36

Appendix
Clay Layers Summary
Geophysical Log: Mo-60

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	UTD	250	370
Total Clay Thickness (ft)	UTD	UTD	240	153
Total Sand Thickness (ft)	UTD	UTD	10	217
Percent Clay	UTD	UTD	96%	41%
Percent Sand	UTD	UTD	4%	59%
	Potential High Producing Interval			
Number of Producing Interval	UTD	1	N/A	1
Producing Interval Thickness (	UTD	198	N/A	330
Net Clay Thickness (ft)	UTD	64	N/A	108
Net Sand Thickness (ft)	UTD	134	N/A	212
Percent Clay	UTD	32%	N/A	33%
Percent Sand	UTD	68%	N/A	64%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	3	N/A	8
Minimum Thickness (ft)	UTD	8	N/A	2
Maximum Thickness (ft)	UTD	48	N/A	30
Average Thickness (ft)	UTD	21	N/A	14

Appendix
Clay Layers Summary
Geophysical Log: Mo-61

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	UTD	270	510
Total Clay Thickness (ft)	UTD	UTD	270	326
Total Sand Thickness (ft)	UTD	UTD	0	184
Percent Clay	UTD	UTD	100%	64%
Percent Sand	UTD	UTD	0%	36%
	Potential High Producing Interval			
Number of Producing Interval	UTD	1	N/A	1
Producing Interval Thickness (	UTD	448	N/A	440
Net Clay Thickness (ft)	UTD	265	N/A	256
Net Sand Thickness (ft)	UTD	183	N/A	184
Percent Clay	UTD	59%	N/A	58%
Percent Sand	UTD	41%	N/A	42%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	3	N/A	3
Minimum Thickness (ft)	UTD	30	N/A	25
Maximum Thickness (ft)	UTD	200	N/A	175
Average Thickness (ft)	UTD	88	N/A	85

Appendix
Clay Layers Summary
Geophysical Log: Mo-62

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	256	753	245	510
Total Clay Thickness (ft)	173	390	205	310
Total Sand Thickness (ft)	83	363	40	200
Percent Clay	68%	52%	84%	61%
Percent Sand	32%	48%	16%	39%
	Potential High Producing Interval			
Number of Producing Intervals	2	1	N/A	1
Producing Interval Thickness	156	753	N/A	510
Net Clay Thickness (ft)	55	390	N/A	310
Net Sand Thickness (ft)	101	363	N/A	200
Percent Clay	35%	52%	N/A	61%
Percent Sand	65%	48%	N/A	39%
	Clay Interbed Characteristics			
Number of Clay Intereds	5	18	6	10
Minimum Thickness (ft)	10	2	10	7
Maximum Thickness (ft)	32	35	65	50
Average Thickness (ft)	22	20	21	24

Appendix
Clay Layers Summary
Geophysical Log: Mo-63

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	50	240	360
Total Clay Thickness (ft)	UTD	8	187	192
Total Sand Thickness (ft)	UTD	42	53	168
Percent Clay	UTD	16%	78%	53%
Percent Sand	UTD	84%	22%	47%
	Potential High Producing Interval			
Number of Producing Intervals	UTD	1	1	2
Producing Interval Thickness	UTD	50	88	360
Net Clay Thickness (ft)	UTD	8	23	192
Net Sand Thickness (ft)	UTD	42	65	168
Percent Clay	UTD	16%	26%	53%
Percent Sand	UTD	84%	74%	47%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	3	7	7
Minimum Thickness (ft)	UTD	8	7	7
Maximum Thickness (ft)	UTD	8	70	42
Average Thickness (ft)	UTD	8	37	24

Appendix
Clay Layers Summary
Geophysical Log: Mo-64

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	90	585	235	320
Total Clay Thickness (ft)	15	274	228	86
Total Sand Thickness (ft)	75	311	7	234
Percent Clay	17%	47%	97%	27%
Percent Sand	83%	53%	3%	73%
	Potential High Producing Interval			
Number of Producing Intervals	1	1	N/A	1
Producing Interval Thickness	90	585	N/A	320
Net Clay Thickness (ft)	15	274	N/A	86
Net Sand Thickness (ft)	75	311	N/A	234
Percent Clay	17%	47%	N/A	27%
Percent Sand	83%	53%	N/A	73%
	Clay Interbed Characteristics			
Number of Clay Intereds	2	11	3	10
Minimum Thickness (ft)	15	1	34	2
Maximum Thickness (ft)	15	100	60	41
Average Thickness (ft)	15	25	45	17

Appendix
Clay Layers Summary
Geophysical Log: Mo-65

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	210	840	480	520
Total Clay Thickness (ft)	20	490	420	291
Total Sand Thickness (ft)	190	350	60	229
Percent Clay	10%	58%	88%	56%
Percent Sand	90%	42%	13%	44%
	Potential High Producing Interval			
Number of Producing Intervals	1	1	N/A	2
Producing Interval Thickness	210	840	N/A	378
Net Clay Thickness (ft)	20	490	N/A	149
Net Sand Thickness (ft)	190	350	N/A	200
Percent Clay	10%	58%	N/A	39%
Percent Sand	90%	42%	N/A	53%
	Clay Interbed Characteristics			
Number of Clay Intereds	1	9	6	9
Minimum Thickness (ft)	20	30	20	2
Maximum Thickness (ft)	20	80	90	130
Average Thickness (ft)	20	49	47	32

Appendix
Clay Layers Summary
Geophysical Log: Mo-66

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	270	240	487
Total Clay Thickness (ft)	UTD	91	210	246
Total Sand Thickness (ft)	UTD	179	30	241
Percent Clay	UTD	34%	88%	51%
Percent Sand	UTD	66%	13%	49%
	Potential High Producing Interval			
Number of Producing Intervals	UTD	1	N/A	1
Producing Interval Thickness	UTD	270	N/A	487
Net Clay Thickness (ft)	UTD	91	N/A	246
Net Sand Thickness (ft)	UTD	179	N/A	241
Percent Clay	UTD	34%	N/A	51%
Percent Sand	UTD	66%	N/A	49%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	5	N/A	13
Minimum Thickness (ft)	UTD	2	N/A	2
Maximum Thickness (ft)	UTD	40	N/A	30
Average Thickness (ft)	UTD	18	N/A	15

Appendix
Clay Layers Summary
Geophysical Log: Mo-67

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	250	250	480
Total Clay Thickness (ft)	UTD	74	210	267
Total Sand Thickness (ft)	UTD	176	40	213
Percent Clay	UTD	30%	84%	56%
Percent Sand	UTD	70%	16%	44%
	Potential High Producing Interval			
Number of Producing Intervals	UTD	1	N/A	1
Producing Interval Thickness	UTD	250	N/A	480
Net Clay Thickness (ft)	UTD	74	N/A	267
Net Sand Thickness (ft)	UTD	176	N/A	213
Percent Clay	UTD	30%	N/A	56%
Percent Sand	UTD	70%	N/A	44%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	4	N/A	12
Minimum Thickness (ft)	UTD	1	N/A	1
Maximum Thickness (ft)	UTD	40	N/A	40
Average Thickness (ft)	UTD	25	N/A	18

Appendix
Clay Layers Summary
Geophysical Log: Mo-68

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	180	620	290	400
Total Clay Thickness (ft)	10	338	260	241
Total Sand Thickness (ft)	170	282	30	159
Percent Clay	6%	55%	90%	60%
Percent Sand	94%	45%	10%	40%
	Potential High Producing Interval			
Number of Producing Intervals	1	1	1	1
Producing Interval Thickness	180	620	26	400
Net Clay Thickness (ft)	10	338	26	241
Net Sand Thickness (ft)	170	282	0	159
Percent Clay	6%	55%	N/A	60%
Percent Sand	94%	45%	N/A	40%
	Clay Interbed Characteristics			
Number of Clay Intereds	3	16	7	8
Minimum Thickness (ft)	4	1	7	6
Maximum Thickness (ft)	6	60	40	70
Average Thickness (ft)	5	17	22	27

Appendix
Clay Layers Summary
Geophysical Log: Mo-69

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	285	245	520
Total Clay Thickness (ft)	UTD	57	245	221
Total Sand Thickness (ft)	UTD	228	0	299
Percent Clay	UTD	20%	100%	43%
Percent Sand	UTD	80%	0%	58%
	Potential High Producing Interval			
Number of Producing Intervals	UTD	1	N/A	1
Producing Interval Thickness	UTD	285	N/A	520
Net Clay Thickness (ft)	UTD	57	N/A	221
Net Sand Thickness (ft)	UTD	228	N/A	299
Percent Clay	UTD	20%	N/A	43%
Percent Sand	UTD	80%	N/A	58%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	5	N/A	12
Minimum Thickness (ft)	UTD	8	N/A	5
Maximum Thickness (ft)	UTD	20	N/A	50
Average Thickness (ft)	UTD	14	N/A	22

Appendix
Clay Layers Summary
Geophysical Log: Mo-70

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	450	270	459
Total Clay Thickness (ft)	UTD	210	230	207
Total Sand Thickness (ft)	UTD	240	40	252
Percent Clay	UTD	47%	85%	45%
Percent Sand	UTD	53%	15%	55%
	Potential High Producing Interval			
Number of Producing Intervals	UTD	1	1	1
Producing Interval Thickness	UTD	450	270	459
Net Clay Thickness (ft)	UTD	210	230	207
Net Sand Thickness (ft)	UTD	240	40	252
Percent Clay	UTD	47%	85%	45%
Percent Sand	UTD	53%	15%	55%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	6	4	8
Minimum Thickness (ft)	UTD	4	20	5
Maximum Thickness (ft)	UTD	110	70	50
Average Thickness (ft)	UTD	35	46	23

Appendix
Clay Layers Summary
Geophysical Log: Mo-72

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	477	315	460
Total Clay Thickness (ft)	UTD	277	236	155
Total Sand Thickness (ft)	UTD	200	79	305
Percent Clay	UTD	58%	75%	34%
Percent Sand	UTD	42%	25%	66%
	Potential High Producing Interval			
Number of Producing Interval	UTD	1	N/A	1
Producing Interval Thickness (	UTD	115	N/A	350
Net Clay Thickness (ft)	UTD	16	N/A	90
Net Sand Thickness (ft)	UTD	99	N/A	260
Percent Clay	UTD	14%	N/A	26%
Percent Sand	UTD	86%	N/A	74%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	4	N/A	5
Minimum Thickness (ft)	UTD	2	N/A	3
Maximum Thickness (ft)	UTD	8	N/A	40
Average Thickness (ft)	UTD	4	N/A	18

Appendix
Clay Layers Summary
Geophysical Log: Mo-73

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	175	580	227	218
Total Clay Thickness (ft)	0	436	113	100
Total Sand Thickness (ft)	175	144	114	118
Percent Clay	0%	75%	50%	46%
Percent Sand	100%	25%	50%	54%
	Potential High Producing Interval			
Number of Producing Intervals	1	1	1	2
Producing Interval Thickness	175	230	139	62
Net Clay Thickness (ft)	0	86	25	18
Net Sand Thickness (ft)	175	144	114	44
Percent Clay	0%	37%	18%	29%
Percent Sand	100%	63%	82%	71%
	Clay Interbed Characteristics			
Number of Clay Intereds	0	8	4	11
Minimum Thickness (ft)	0	8	1	2
Maximum Thickness (ft)	0	96	50	65
Average Thickness (ft)	0	36	28	16

Appendix
Clay Layers Summary
Geophysical Log: Mo-74

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	UTD	270	510
Total Clay Thickness (ft)	UTD	UTD	241	218
Total Sand Thickness (ft)	UTD	UTD	29	292
Percent Clay	UTD	UTD	89%	43%
Percent Sand	UTD	UTD	11%	57%
	Potential High Producing Interval			
Number of Producing Interval	UTD	1	N/A	1
Producing Interval Thickness (	UTD	356	N/A	505
Net Clay Thickness (ft)	UTD	121	N/A	213
Net Sand Thickness (ft)	UTD	235	N/A	292
Percent Clay	UTD	34%	N/A	42%
Percent Sand	UTD	66%	N/A	58%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	5	N/A	7
Minimum Thickness (ft)	UTD	7	N/A	8
Maximum Thickness (ft)	UTD	58	N/A	73
Average Thickness (ft)	UTD	26	N/A	22

Appendix
Clay Layers Summary
Geophysical Log: Mo-75

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	590	200	370
Total Clay Thickness (ft)	UTD			
Total Sand Thickness (ft)	UTD			
Percent Clay	UTD			
Percent Sand	UTD			
	Potential High Producing Interval			
Number of Producing Interv	UTD	1		1
Producing Interval Thicknes	UTD	390		340
Net Clay Thickness (ft)	UTD	106		75
Net Sand Thickness (ft)	UTD	284		265
Percent Clay	UTD	27%		22%
Percent Sand	UTD	73%		78%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	5		3
Minimum Thickness (ft)	UTD	13		10
Maximum Thickness (ft)	UTD	32		40
Average Thickness (ft)	UTD	21		25

Appendix
Clay Layers Summary
Geophysical Log: Mo-76

	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	290	600	325	515
Total Clay Thickness (ft)	35	292	258	325
Total Sand Thickness (ft)	255	308	67	190
Percent Clay	12%	49%	79%	63%
Percent Sand	88%	51%	21%	37%
	Potential High Producing Interval			
Number of Producing Intervals	1	1	2	1
Producing Interval Thickness	290	600	152	515
Net Clay Thickness (ft)	35	292	85	325
Net Sand Thickness (ft)	255	308	67	190
Percent Clay	12%	49%	56%	63%
Percent Sand	88%	51%	44%	37%
	Clay Interbed Characteristics			
Number of Clay Intereds	1	7	8	11
Minimum Thickness (ft)	35	6	6	1
Maximum Thickness (ft)	35	83	50	30
Average Thickness (ft)	35	37	18	14

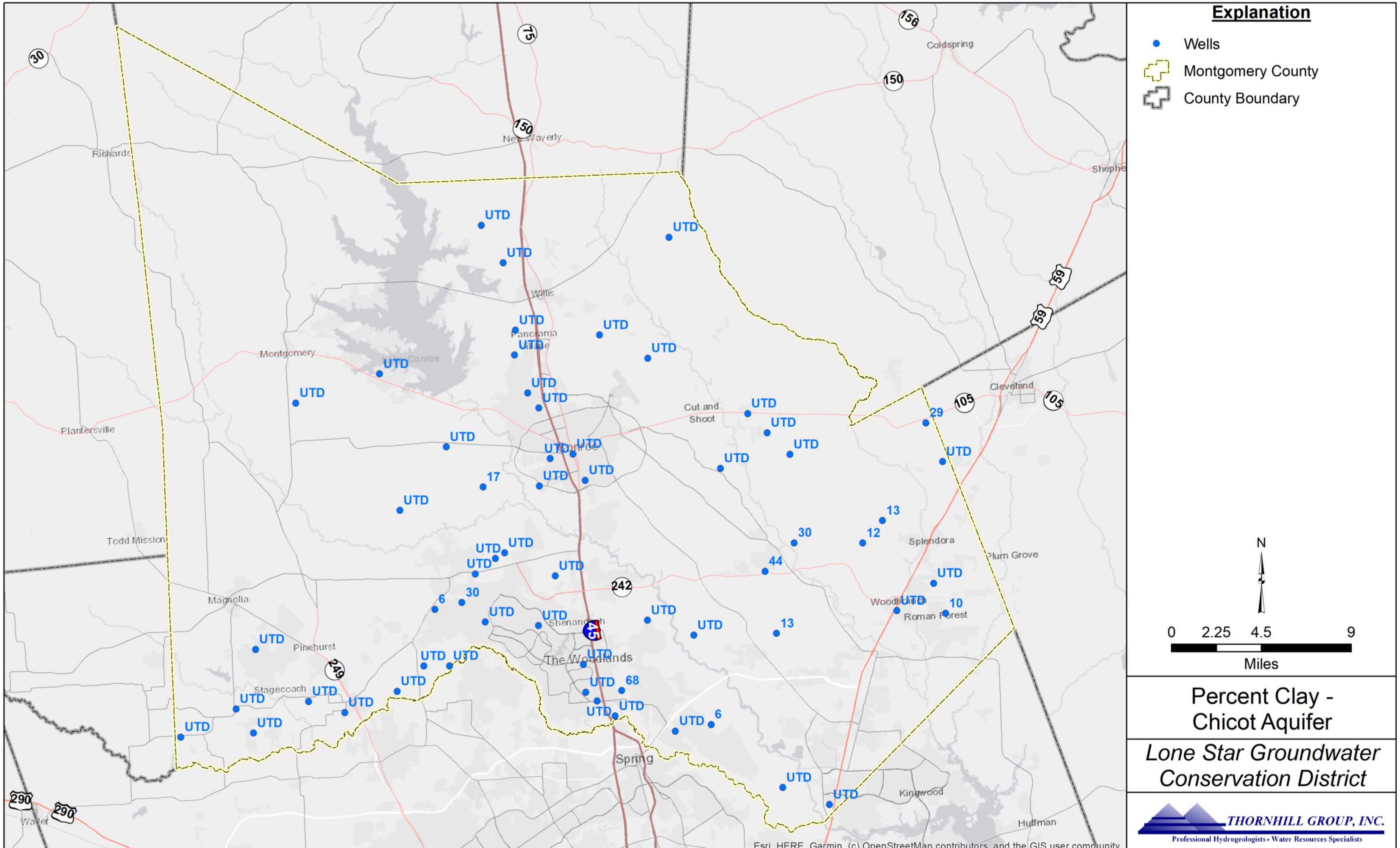
Appendix
Clay Layers Summary
Geophysical Log: Mo-77

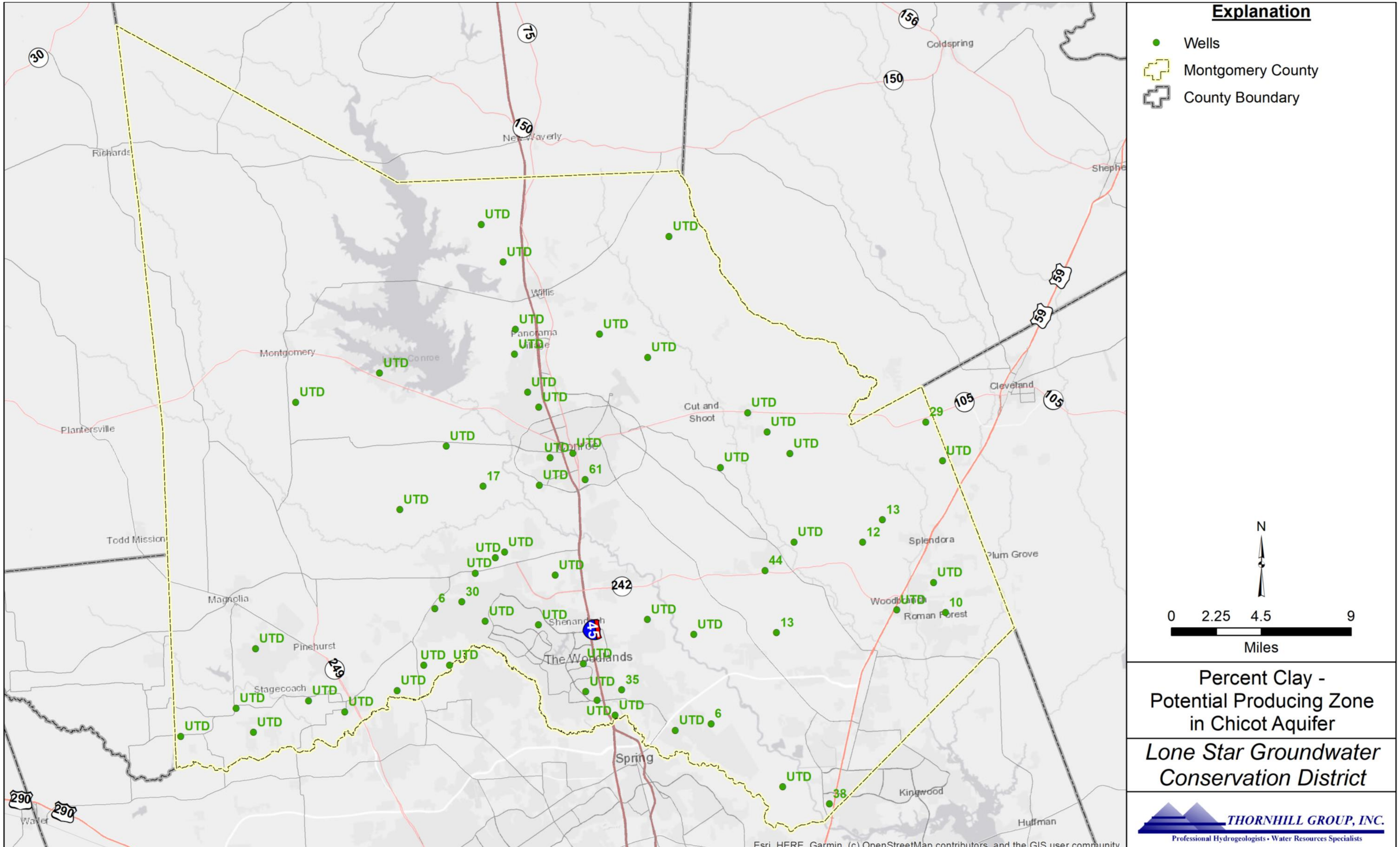
	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	UTD	635	175	380
Total Clay Thickness (ft)	UTD			
Total Sand Thickness (ft)	UTD			
Percent Clay	UTD			
Percent Sand	UTD			
	Potential High Producing Interval			
Number of Producing	UTD	1		1
Producing Interval Thickness	UTD	310		228
Net Clay Thickness (ft)	UTD	177		130
Net Sand Thickness (ft)	UTD	133		100
Percent Clay	UTD	57%		57%
Percent Sand	UTD	43%		44%
	Clay Interbed Characteristics			
Number of Clay Intereds	UTD	6		4
Minimum Thickness (ft)	UTD	8		15
Maximum Thickness (ft)	UTD	67		70
Average Thickness (ft)	UTD	30		33

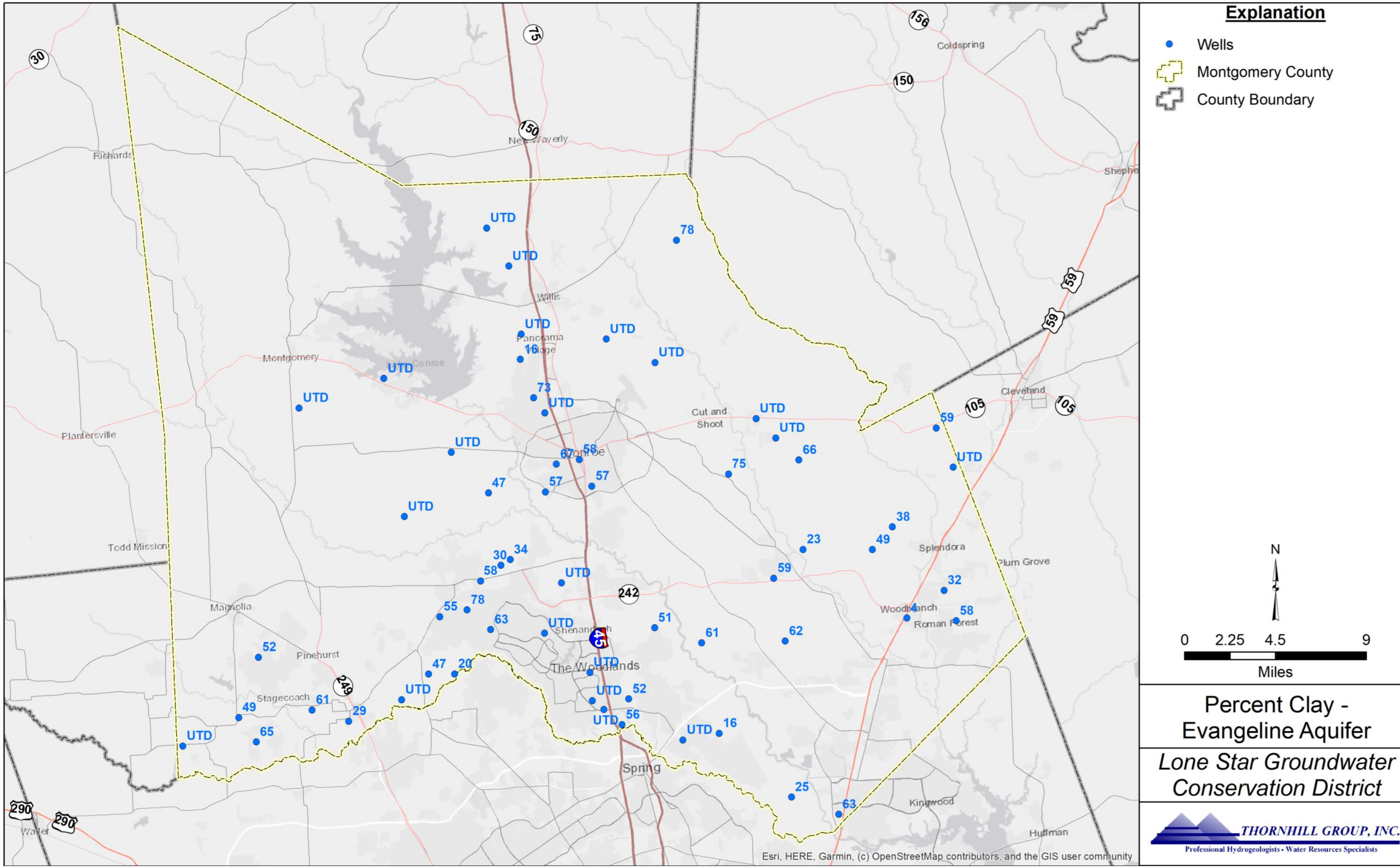
Appendix
Clay Layers Summary
Geophysical Log: Mo-78

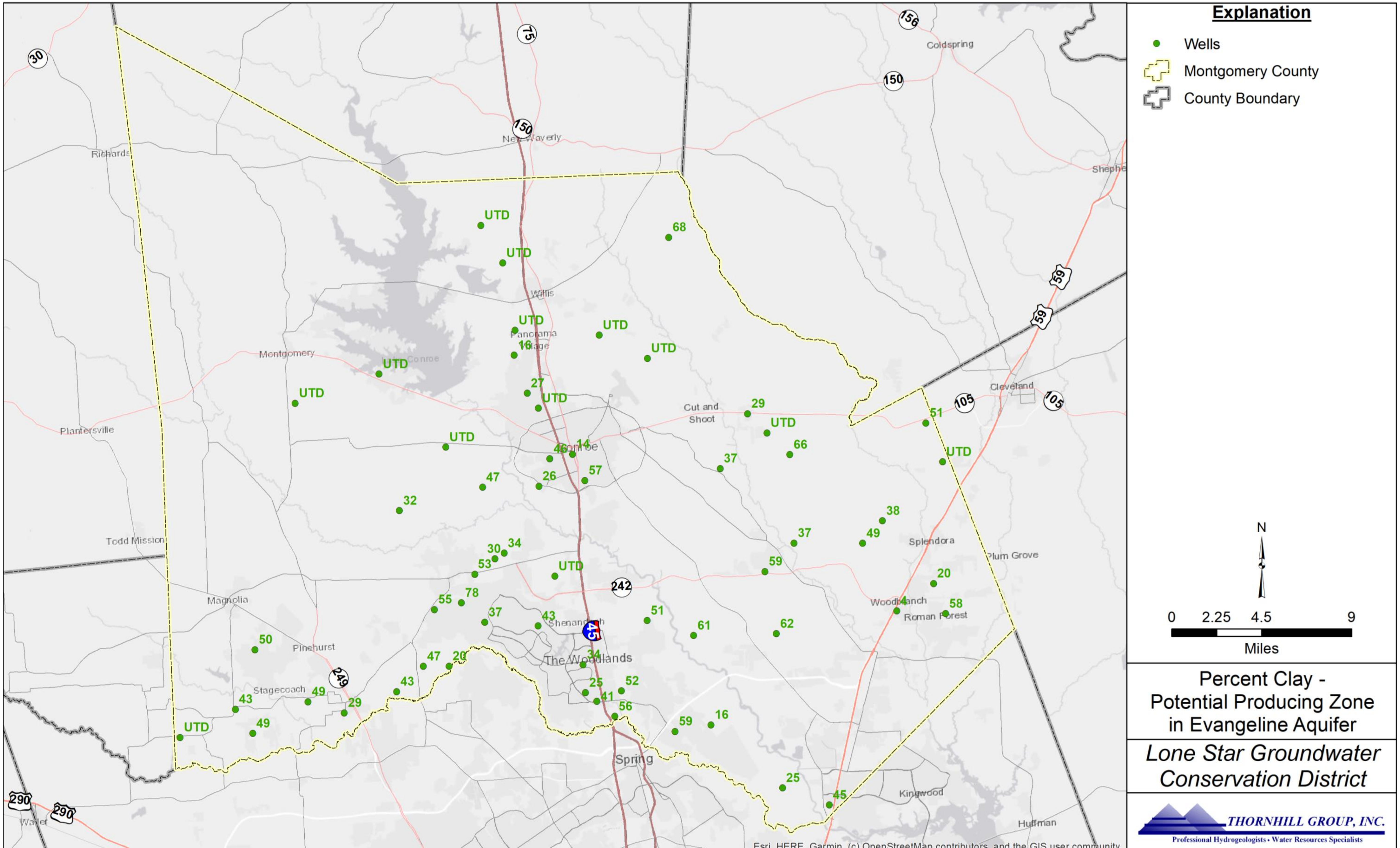
	Chicot Aquifer	Evangeline Aquifer	Burkeville Confining Layer	Upper Jasper Aquifer
	Total Aquifer Interval			
Total Interval Thickness (ft)	142	730	240	570
Total Clay Thickness (ft)	42	171	126	318
Total Sand Thickness (ft)	100	559	114	252
Percent Clay	30%	23%	53%	56%
Percent Sand	70%	77%	47%	44%
	Potential High Producing Interval			
Number of Producing	1	1	N/A	1
Producing Interval Thickness	96	190	N/A	500
Net Clay Thickness (ft)	0	71	N/A	170
Net Sand Thickness (ft)	96	119	N/A	330
Percent Clay	0%	37%	N/A	34%
Percent Sand	100%	63%	N/A	66%
	Clay Interbed Characteristics			
Number of Clay Intereds	1	10	N/A	10
Minimum Thickness (ft)	42	1	N/A	1
Maximum Thickness (ft)	42	63	N/A	35
Average Thickness (ft)	42	17	N/A	12

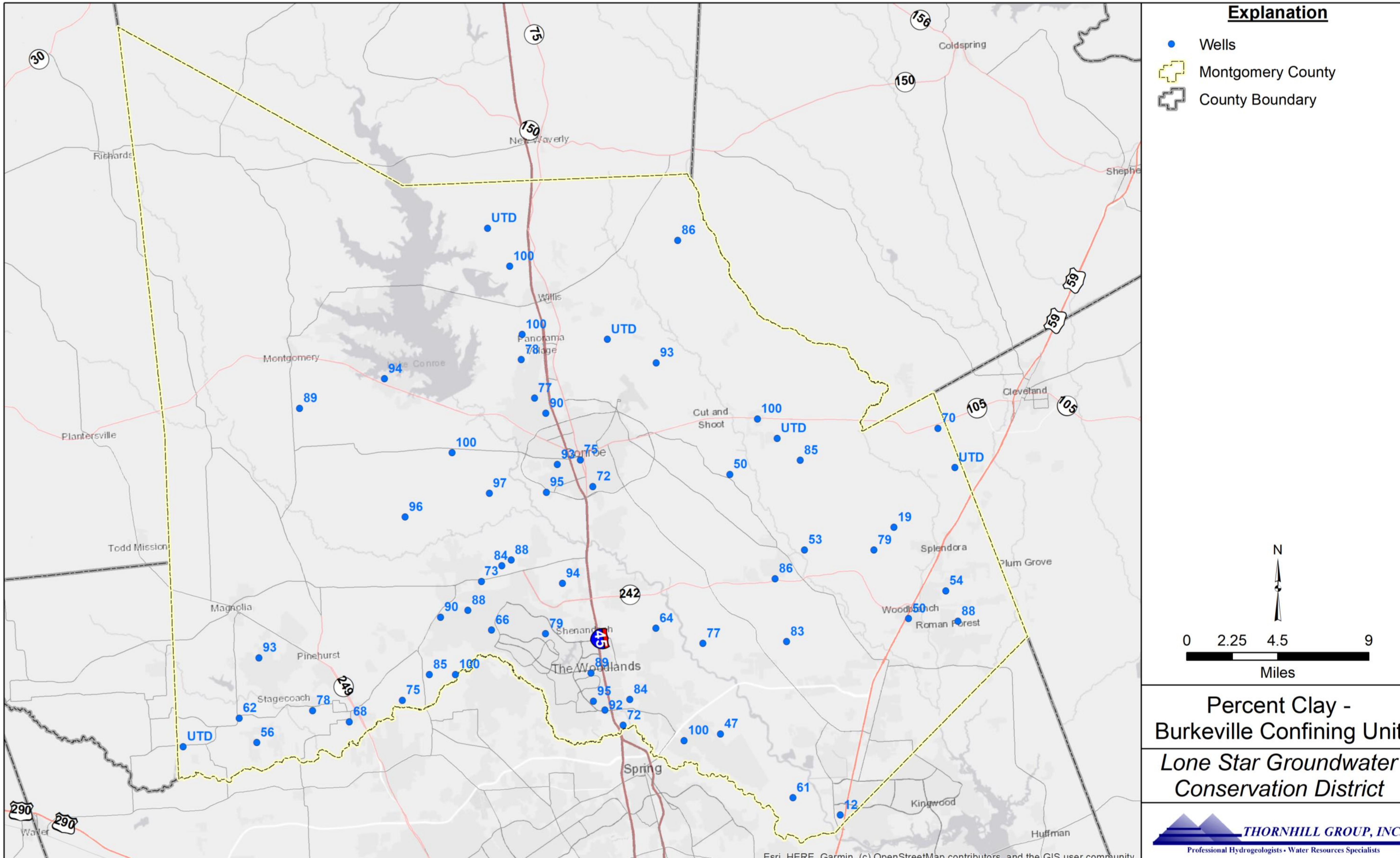
APPENDIX 4 – PERCENT CLAY MAPS


Explanation
Wells
Montgomery County
County Boundary
N
0 2.25 4.5 9
Miles
Percent Clay -
Chicot Aquifer
Lone Star Groundwater
Conservation District
THORNHILL GROUP, INC.
Professional Hydrogeologists • Water Resources Specialists
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community


Explanation
Wells
Montgomery County
County Boundary
N
0 2.25 4.5 9
Miles
Percent Clay -
Potential Producing Zone
in Chicot Aquifer
Lone Star Groundwater
Conservation District
THORNHILL GROUP, INC.
Professional Hydrogeologists • Water Resources Specialists
Richards
New Waverly
Coldspring
Shepherd
Willis
Panorama Village
Montgomery
Conroe
Plantersville
Cut and Shoot
Cleveland
Todd Mission
Magnolia
Pinehurst
Stagecoach
Shenandoah
The Woodlands
Splendora
Plum Grove
Woodbranch
Roman Forest
Spring
Kingwood
Huffman
Waller
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community


Explanation
Wells
Montgomery County
County Boundary
N
0 2.25 4.5 9
Miles
Percent Clay - Evangeline Aquifer
Lone Star Groundwater Conservation District
THORNHILL GROUP, INC.
Professional Hydrogeologists • Water Resources Specialists
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Coldspring
New Waverly
Richards
Willis
Panorama Village
Montgomery
Conroe
Plantersville
Cut and Shoot
Cleveland
Splendora
Plum Grove
Todd Mission
Magnolia
Pinehurst
Stagecoach
The Woodlands
Shenandoah
Woodbranch
Roman Forest
Spring
Kingwood
Humble
Waller
Shepherd

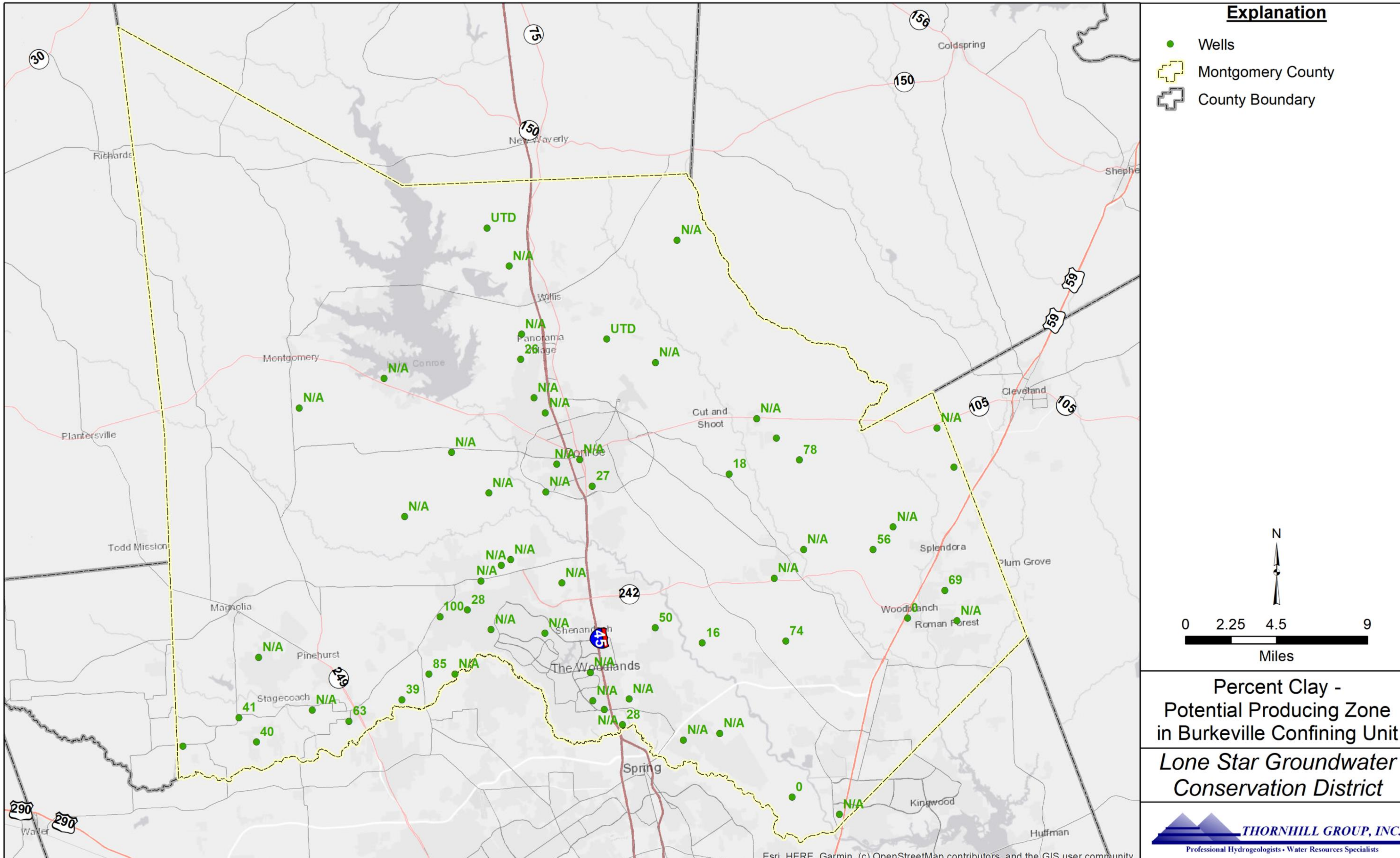

Explanation
Wells
Montgomery County
County Boundary
N
0 2.25 4.5 9
Miles
Percent Clay -
Potential Producing Zone
in Evangeline Aquifer
Lone Star Groundwater
Conservation District
THORNHILL GROUP, INC.
Professional Hydrogeologists • Water Resources Specialists
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

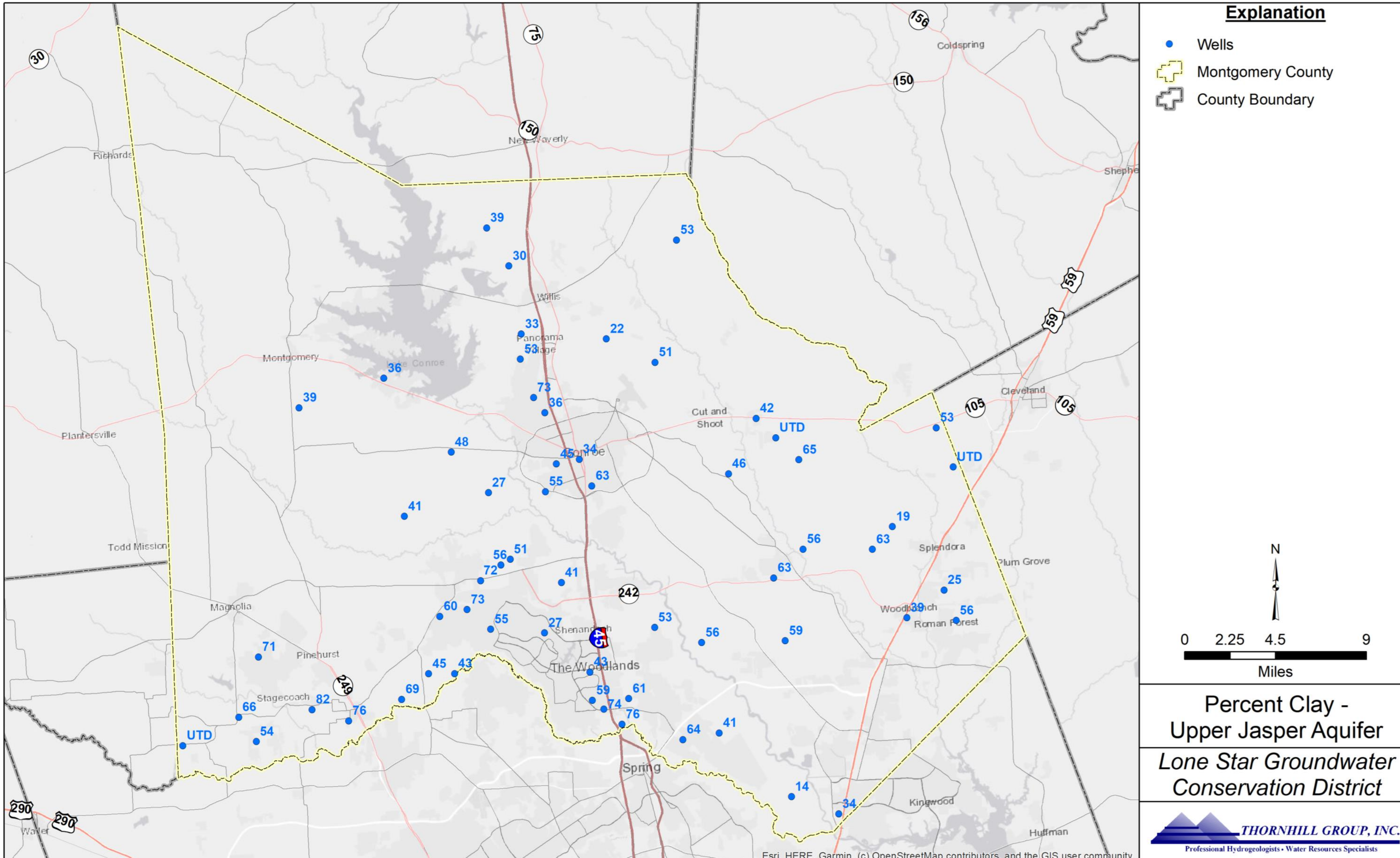


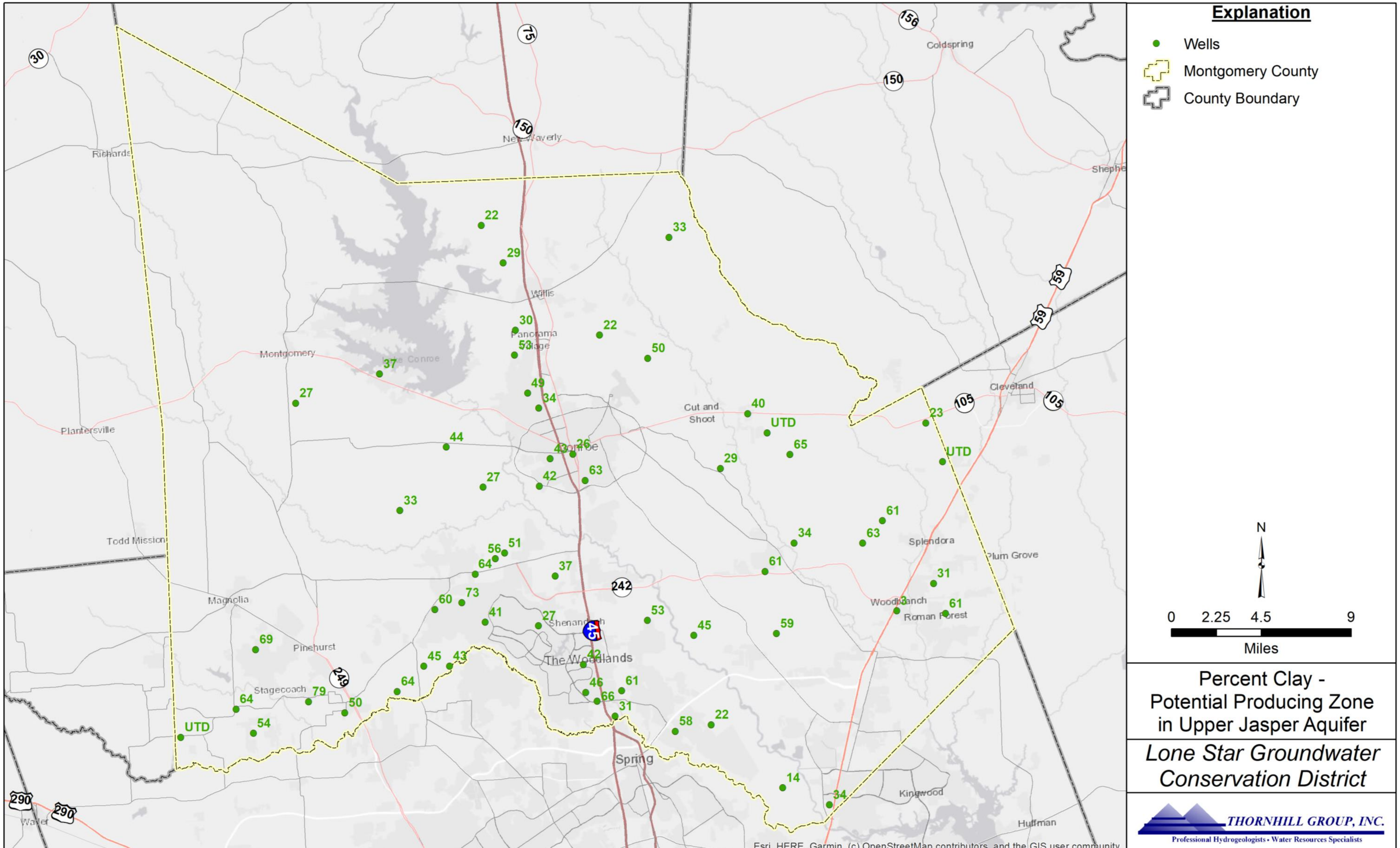
Percent Clay -
Burkeville Confining Unit

Lone Star Groundwater Conservation District

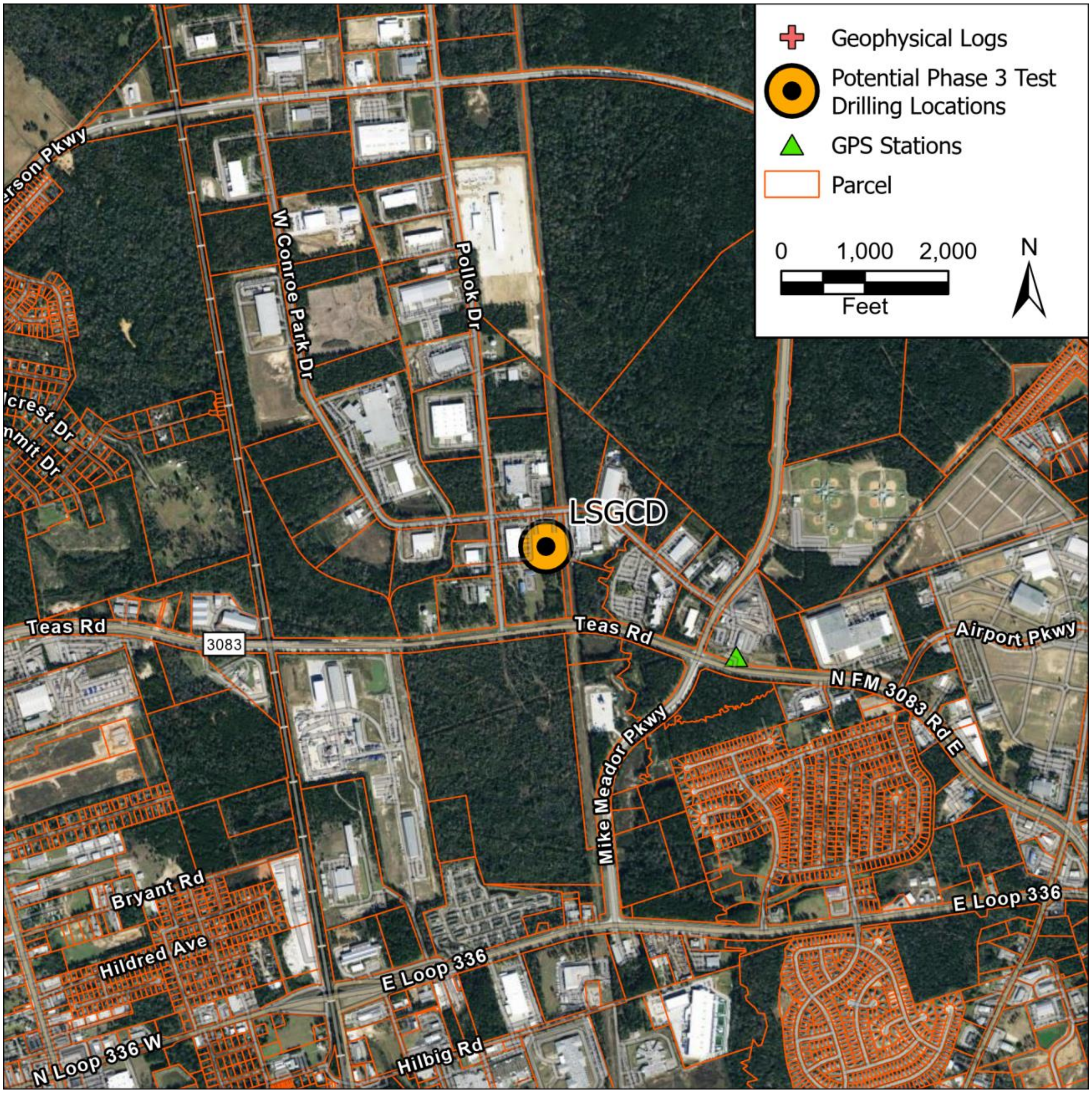
THORNHILL GROUP, INC.
Professional Hydrogeologists • Water Resources Specialists


Explanation
Wells
Montgomery County
County Boundary
N
0 2.25 4.5 9
Miles
Percent Clay -
Potential Producing Zone
in Burkeville Confining Unit
Lone Star Groundwater
Conservation District
THORNHILL GROUP, INC.
Professional Hydrogeologists • Water Resources Specialists
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Coldspring
Richards
Willis
Montgomery
Conroe
Plantersville
Cut and Shoot
Cleveland
Todd Mission
Magnolia
Pinehurst
Stagecoach
Splendora
Plum Grove
Roman Forest
The Woodlands
Spring
Kingwood
Huffman

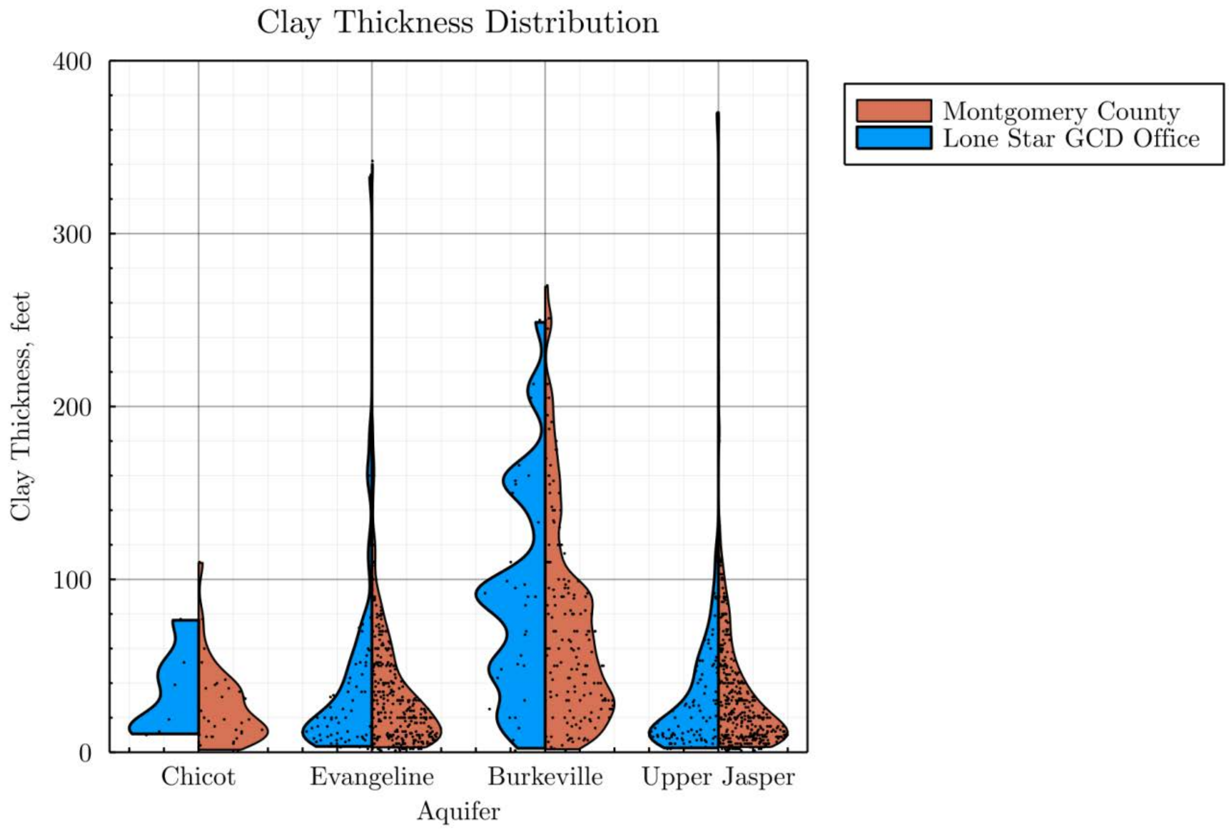

Explanation
Wells
Montgomery County
County Boundary
N
0 2.25 4.5 9
Miles
Percent Clay -
Upper Jasper Aquifer
Lone Star Groundwater
Conservation District
THORNHILL GROUP, INC.
Professional Hydrogeologists • Water Resources Specialists
Coldspring
New Waverly
Richards
Willis
Panorama Village
Montgomery
Lake Conroe
Plantersville
Cut and Shoot
Cleveland
Shepherd
Conroe
Todd Mission
Magnolia
Pinehurst
Stagecoach
Shenandoah
The Woodlands
Splendora
Plum Grove
Woodbranch
Roman Forest
Spring
Kingwood
Huffman
Waller
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

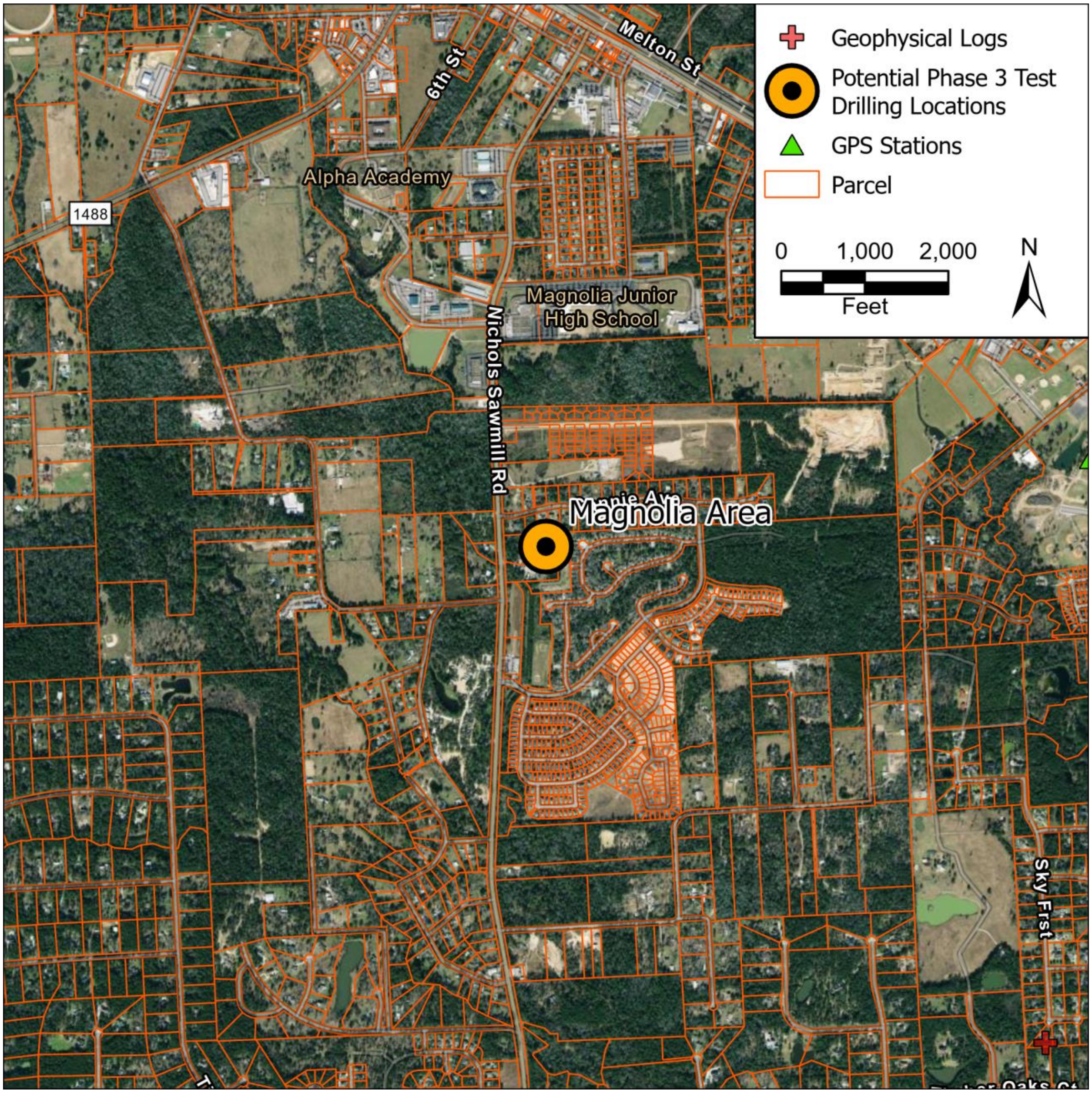

Explanation
Wells
Montgomery County
County Boundary
N
0 2.25 4.5 9
Miles
Percent Clay -
Potential Producing Zone
in Upper Jasper Aquifer
Lone Star Groundwater
Conservation District
THORNHILL GROUP, INC.
Professional Hydrogeologists • Water Resources Specialists
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Coldspring
New Waverly
Richards
Willis
Montgomery
Plantersville
Todd Mission
Magnolia
Pinehurst
Stagecoach
Cut and Shoot
Cleveland
Splendora
Plum Grove
Roman Forest
The Woodlands
Spring
Kingwood
Huffman
UTD

APPENDIX 5 – PROPOSED TEST DRILLING LOCATIONS

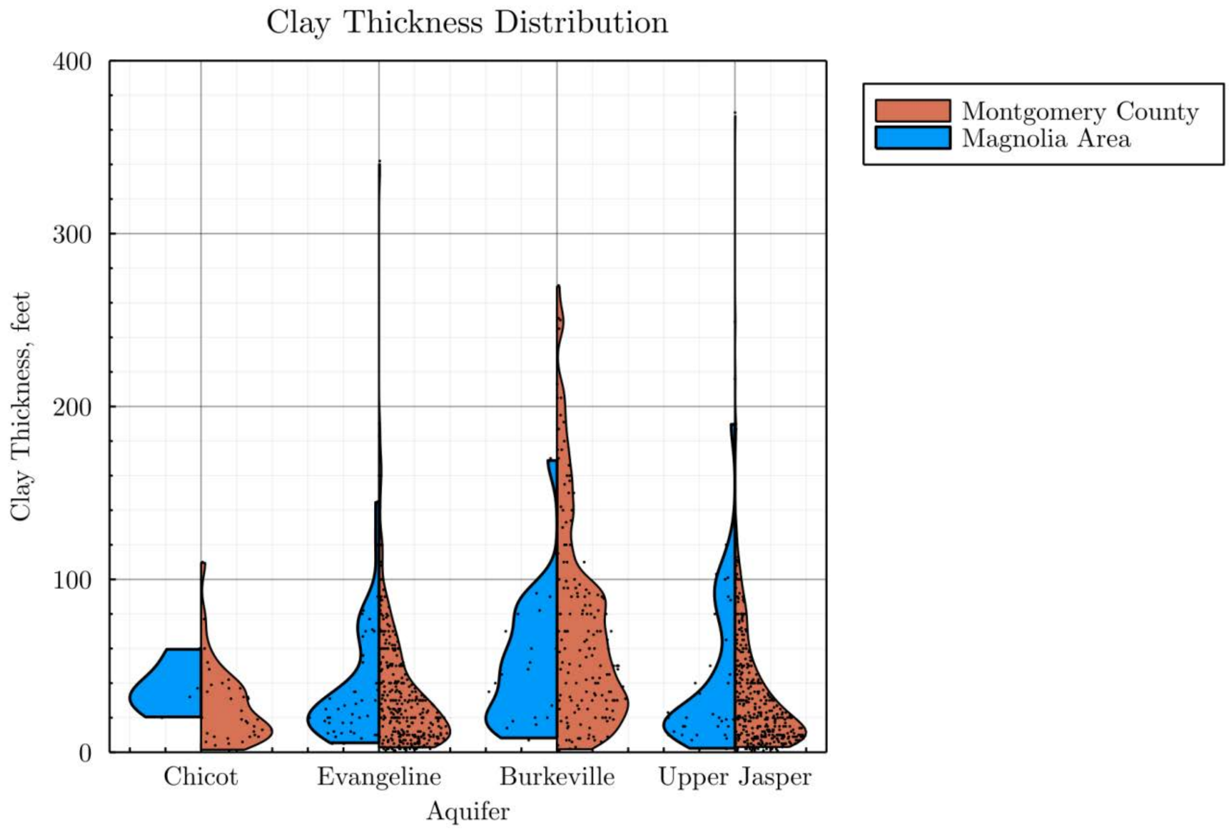


- Site Info:
    - Property ID: 373396
    - Owner: Lone Star Groundwater
- At District office
- Educational tool
- Central part of the District
- Near existing GPS site (TXCN)

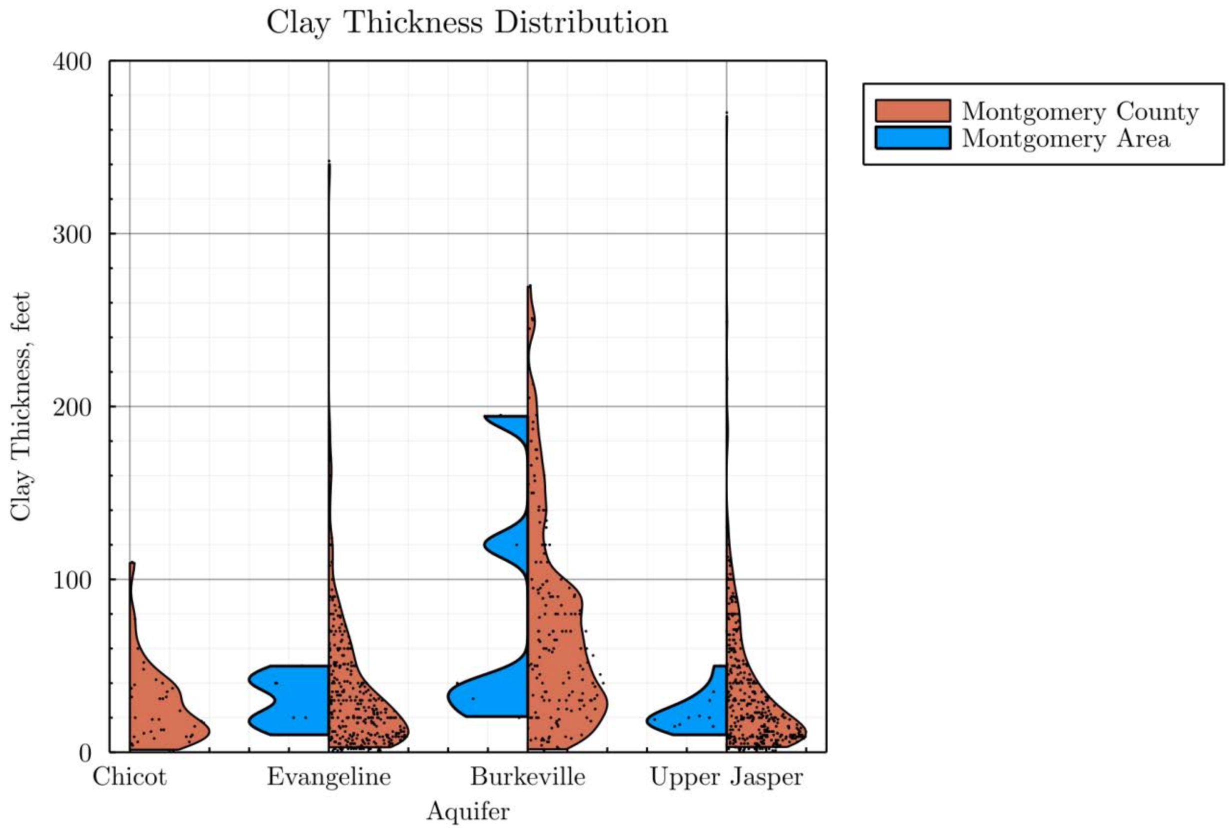

Clay Thickness Distribution
Montgomery County
Lone Star GCD Office
Clay Thickness, feet
400
300
200
100
0
Chicot
Evangeline
Burkeville
Upper Jasper
Aquifer

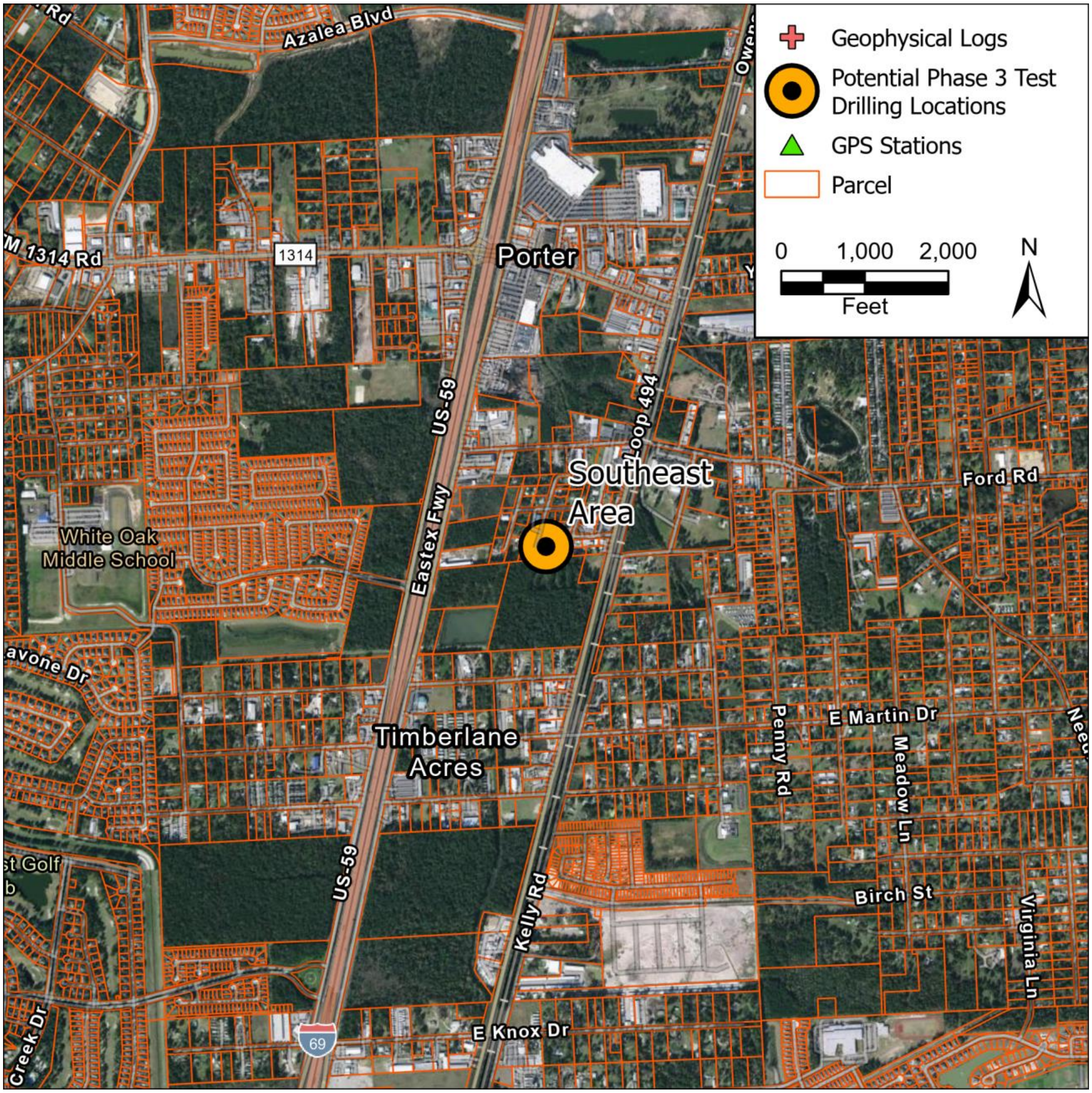


- Site Info:
  - Property ID: 283366
  - Owner: City of Magnolia
- Southwest corner of the District
- Near areas of projected growth or increase in GW demand
- Relatively sparse geophysical data

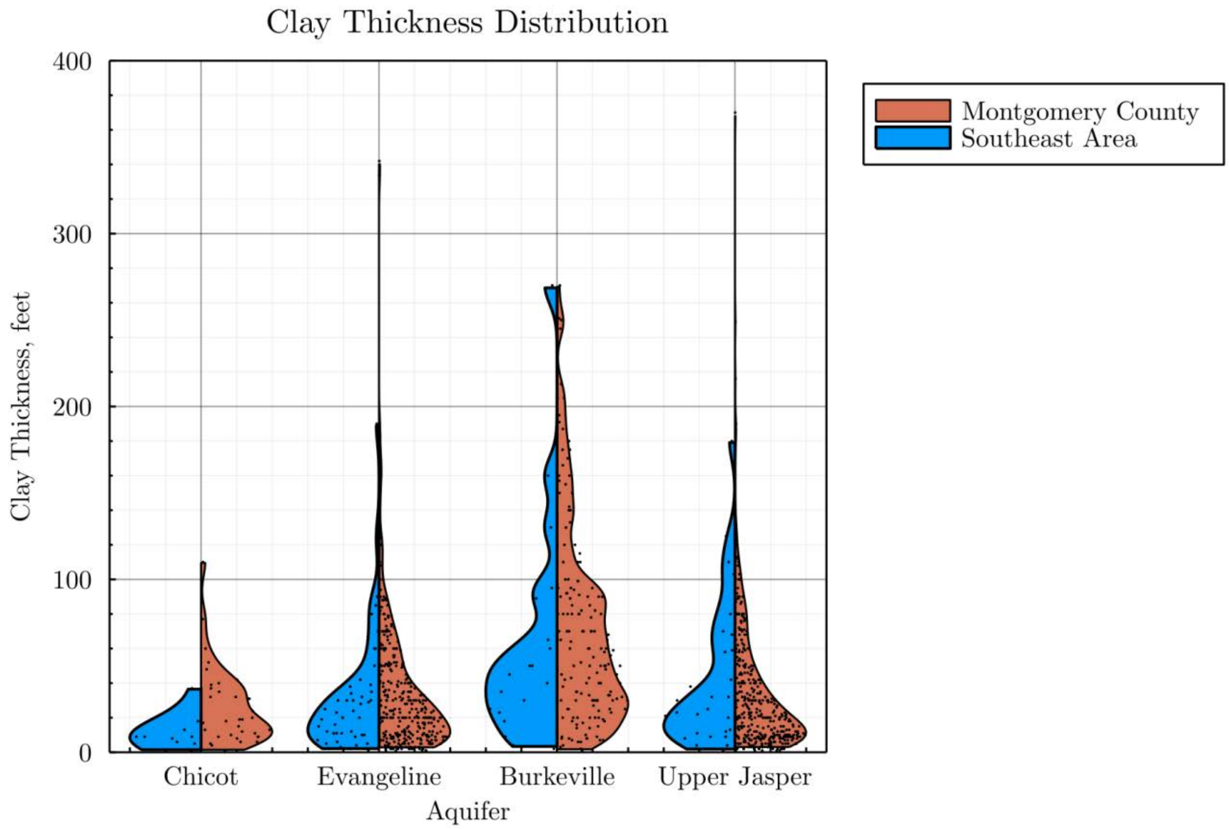

Clay Thickness Distribution
Clay Thickness, feet
0
100
200
300
400
Chicot
Evangeline
Burkeville
Upper Jasper
Aquifer
Montgomery County
Magnolia Area

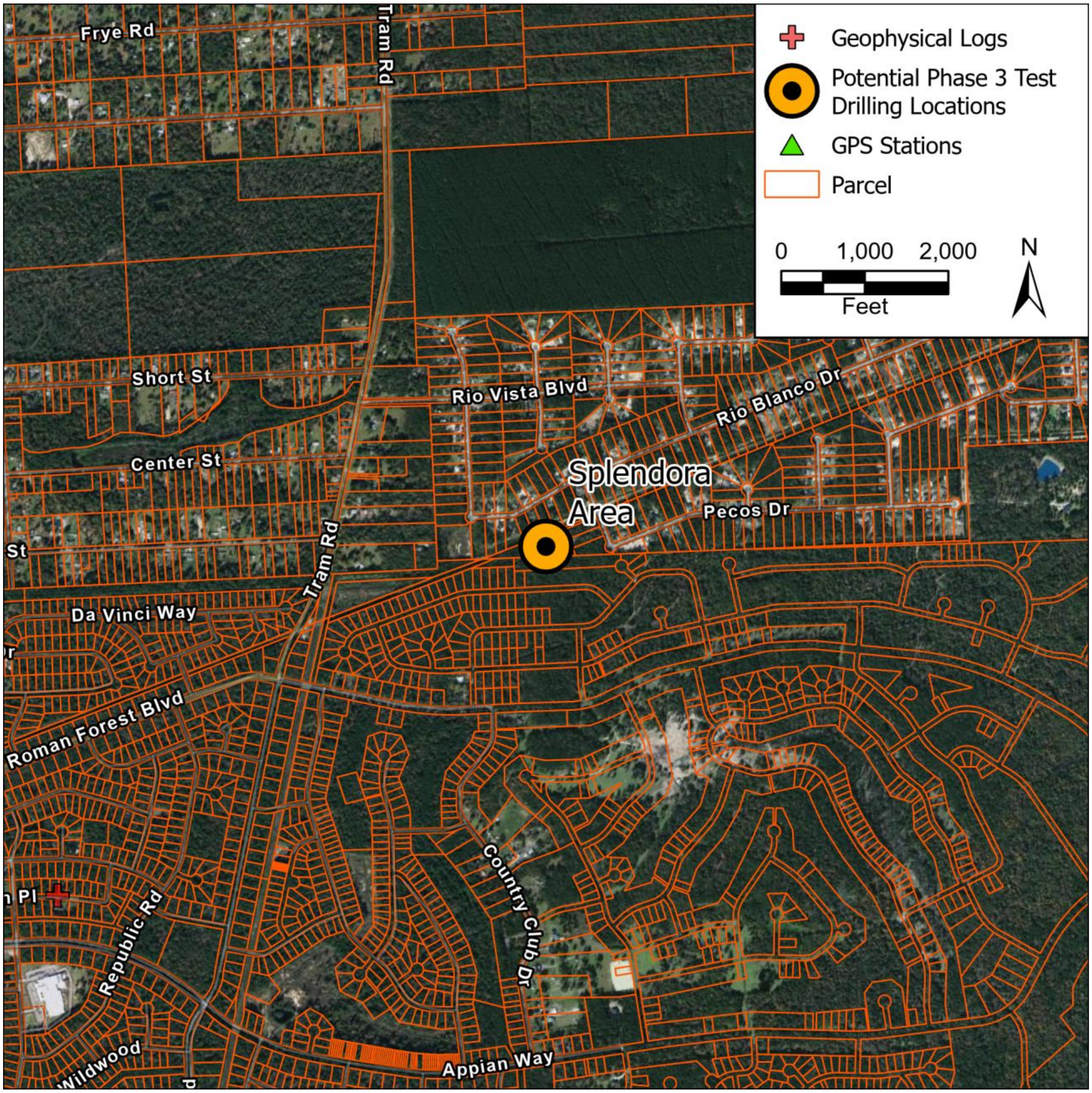
- Site Info:
    - Property ID: 124049
    - Owner: City of Montgomery
- Relatively sparse geophysical data
- Northwest area monitoring
- Possible growth area
- Shallowest Jasper of the six possible locations


Clay Thickness Distribution
Clay Thickness, feet
400
300
200
100
0
Chicot
Evangeline
Burkeville
Upper Jasper
Aquifer
Montgomery County
Montgomery Area

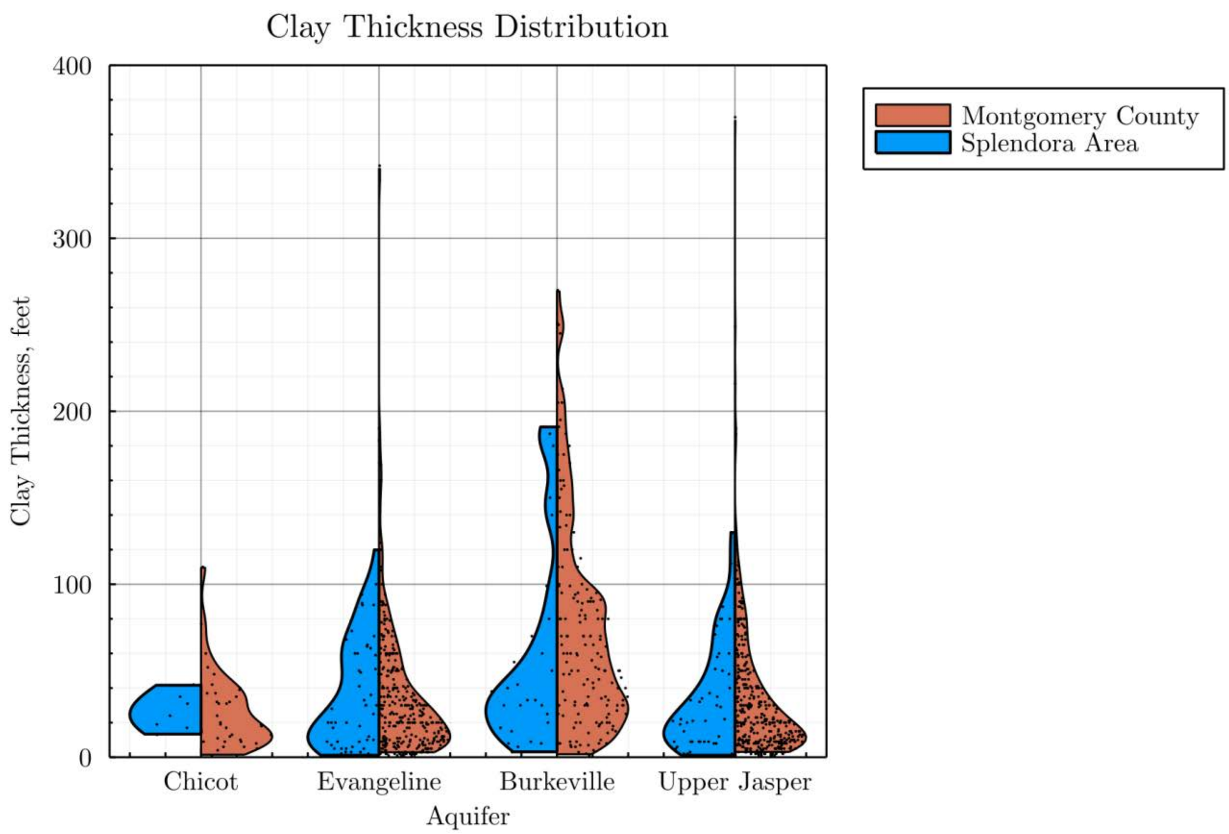


- Site Info:
    - Property ID: 49361
    - Owner: Porter Special Utility District
- Identified water level declines in special project
- Near growth areas
- Relatively close to the Lake Houston Site
- Deepest Jasper of the six possible locations

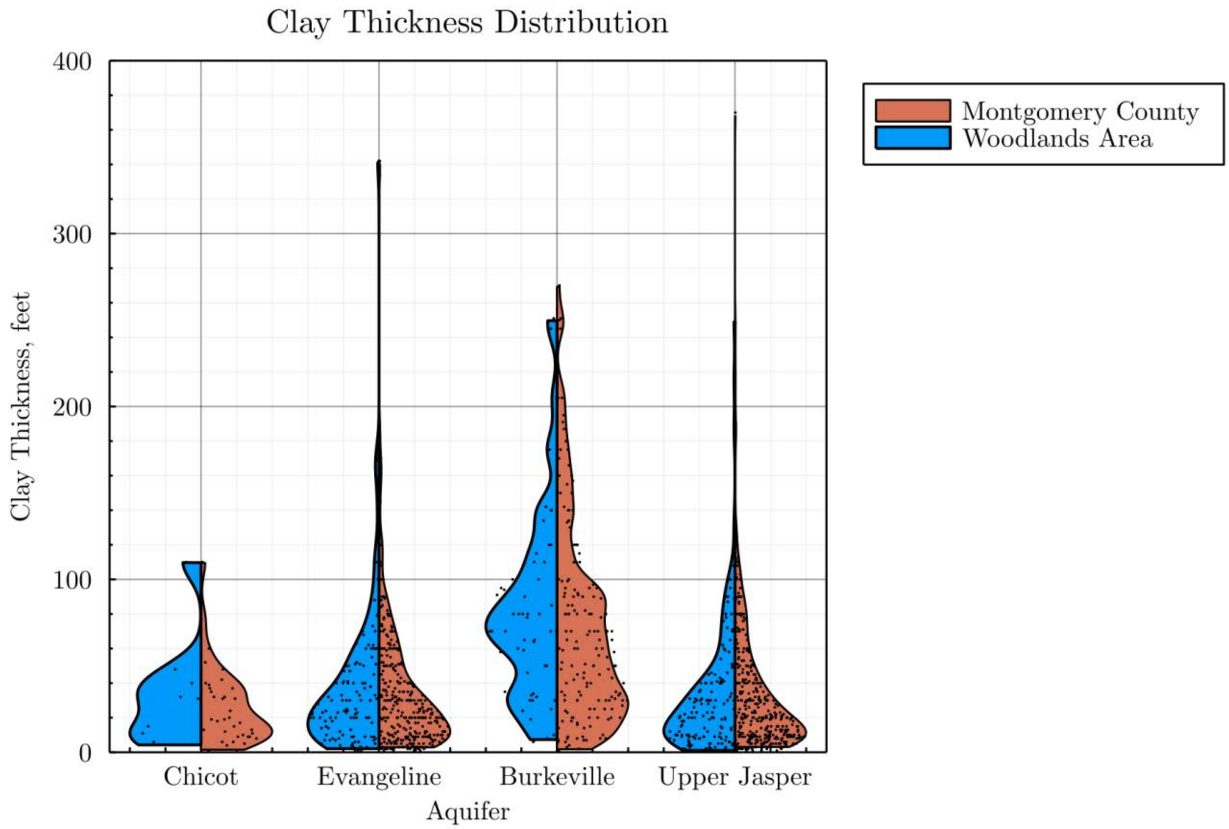

Clay Thickness Distribution
Montgomery County
Southeast Area
Clay Thickness, feet
400
300
200
100
0
Chicot
Evangeline
Burkeville
Upper Jasper
Aquifer



- Site Info:
  - Property ID: 152063
  - Owner: Southern Oaks Water System, Inc.
- Possible area of future growth
- Sporadic historical water level data, but generally slower declines than central and southern MoCo
- Near log Mo-4; New site won't add much more info regarding structure


Clay Thickness Distribution
400
300
200
100
0
Clay Thickness, feet
Chicot
Evangeline
Burkeville
Upper Jasper
Aquifer
Montgomery County
Splendora Area

- Site Info:
  - Property ID: 210035
  - Owner: San Jac River Authority
  - Same property as PA13
- Area of high interest
- Along growth corridor
- Near SJRA well field


Clay Thickness Distribution
Clay Thickness, feet
400
300
200
100
0
Chicot
Evangeline
Burkeville
Upper Jasper
Aquifer
Montgomery County
Woodlands Area