Barton Springs Edwards Aquifer CONSERVATION DISTRICT

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Evaluating the Potential Groundwater Availability within a Lower Trinity Aquifer Well Field, Balcones Fault Zone, Hays County, Central Texas

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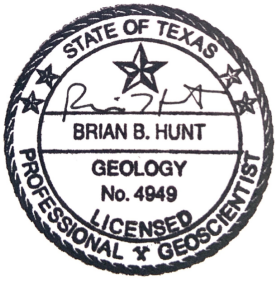

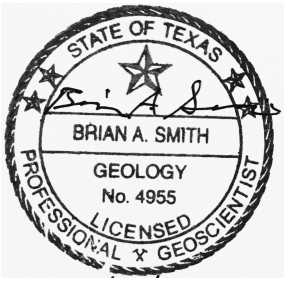

SUMMARY

Groundwater availability from the Edwards and Middle Trinity Aquifers in the study area is generally limited, however, the Lower Trinity Aquifer within the study area is untested because of the aquifer depths, assumed low yields, and poor water quality. This study provides an initial assessment of groundwater availability in a Lower Trinity well field based on aquifer tests, geochemistry, and limited analytical modeling.

The well field contains three wells spaced about 1/3 mile apart that range in total depths from 1,505 to 1,620 ft below ground surface. Depths to static water levels in the wells range from 140 to 150 ft below ground surface. Aquifer testing involved an initial single well test in 2018 followed by a test that pumped the two newer wells drilled in 2019 at 170 gallons per minute (gpm) independently for 96 hrs each, while monitoring the other wells. Maximum drawdown in the pumped wells ranged from 320 to 460 ft. Drawdown in the observation wells (0.2 to 0.4 miles distant) ranged from 8 to 34 ft. To estimate aquifer parameters, continuous water-level data were collected with transducers and fit to Theis and Cooper-Jacob analytical solutions using Aqtesolv software. Results of transmissivity from observation wells averaged about 401 ft^2/day and a storativity of 5.57-E05. These parameters are higher than published median values of Lower Trinity wells in the Hill Country to the west of the study area.

Specific conductance of groundwater was monitored throughout the aquifer test and groundwater samples were analyzed for total dissolved solids (TDS) resulting in values of about 560 mg/L, indicating fresh water. Ion geochemistry indicates a calcium bicarbonate ($Ca\text{-}HCO_3$) water with a tritium value of -0.05 TU, and a carbon-14 value of 0.006 percent modern carbon, PMC, indicating very old water.

Using parameters from the aquifer test and analytical models we forecasted drawdown from the well field with a combined pumping rate of 380 gpm (200 MGY) over a 30-year period. Preliminary analytical model results indicate an estimated drawdown up to about 130 ft at a distance of 2.0 miles from the well field.

Because the results of the aquifer test indicate that the water quality and yield of these wells are high. the Lower Trinity Aquifer may be a direct alternative groundwater supply for the study area. More groundwater studies and modeling are needed to evaluate long-term drawdown effects for the study area. The nearby Lower Trinity Aquifer of western Travis County offers a cautionary example of groundwater mining. In addition, the aquifer may have potential for aquifer storage and recovery (ASR) activities.

This summary was modified from a presentation and published abstract at the 2020 Geological Society of America South-Central Meeting (Camp et al., 2020).

INTRODUCTION

Several potential groundwater resources occur within the jurisdiction of the Barton Springs/Edwards Aquifer Conservation District (BSEACD) and includes the Edwards and Trinity Aquifers. The Edwards Aquifer is well characterized but has very limited and conditional groundwater availability (Hunt et al., 2019). Recent studies have dramatically increased the information on the Middle Trinity Aquifer (Smith et al., 2018), but there is still uncertainty in the availability and an increasing demand on the Middle Trinity Aquifer. However, the Lower Trinity Aquifer has unknown groundwater availability potential as there are generally few wells completed within the Lower Trinity within BSEACD. The owner of the well field referred to as the "Gragg" tract (**Figure 1**) decided to test the groundwater availability potential of the Lower Trinity Aquifer. A single well was drilled (Gragg #1) and a pumping test was performed by Geos Consulting (2018) in early 2018. Results indicated fresh water (542 mg/L TDS) and relatively high well yields (115 gpm). Those results led to the completion of two additional test wells (Gragg #2 and #3) in September and October 2019.

Given the mutual interests of understanding the Lower Trinity Aquifer as a groundwater resource, BSEACD staff assisted in the additional aquifer testing of the Lower Trinity in 2019. An aquifer test was designed (**Appendix D**), and data collected, by BSEACD in cooperation with Bee Cave Drilling and the land owner Bill Walters. This report presents the aquifer test results of the Lower Trinity Aquifer in the Gragg wells 1, 2 and 3. The aquifer tests provide important information about the aquifer, well yields, and water quality and will be critical to inform any future production permit request for the Gragg well field (wells 1-3). The well owner indicated a potential future demand of up to 200,000,000 gallons per year (gpy) from the Gragg well field, which helped guide the design of the test.

Gragg Well Field

The Gragg well field is located on a 325-acre property of historically agricultural land along Old Bliss Spillar Road west of State Highway 45 (**Figure 1**). The well field consist of three Lower Trinity wells: Gragg #1 (SDR 473734; TWDB 58-50-755), Gragg #2 (SDR 527500) and Gragg #3 (SDR 527505) (**Appendix A**). Gragg #1 specific capacity testing was done in 2018. The Gragg #2 and Gragg #3 wells, the focus of this memo, were pumped in 2019 and utilized the adjacent wells as observation wells.

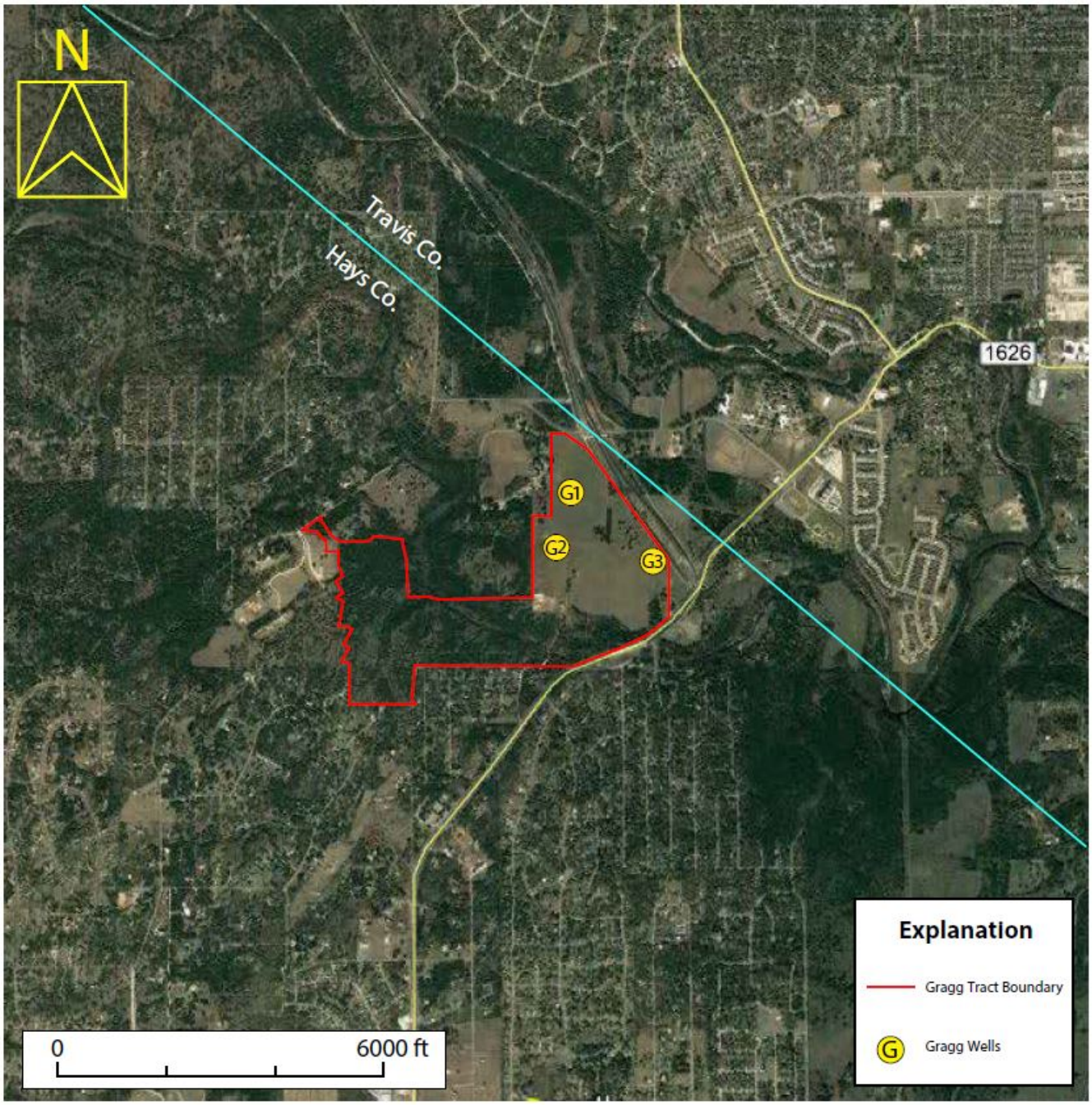

Figure 1. *Site map of Gragg well field in Hays County located at Old Bliss Spillar Rd., Manchaca, TX. The wells are spaced ranging from 0.2 to 0.4 miles apart.*

Hydrogeological setting

The Gragg tract and well field is located within the Balcones Fault Zone and bound by several mapped faults in the area. Bedrock consists of the Georgetown Fm and is overlain by a relatively thick soil (**Figure 2**). The well field area is underlain by the Edwards Aquifer and is considered part of the recharge zone of the Edwards Aquifer.

The target for the production and test wells is the Lower Trinity Aquifer, which is the deepest known aquifer in the area, occurring below the Edwards and Middle Trinity aquifers. The depth to the top of the Lower Trinity Aquifer is about 1,300 ft below surface at the wells (**Figures 3 and 4**). Stratigraphic picks were made from geophysical logs (**Appendix B**) collected at both Gragg #2 and #3 wells after their completion. Stratigraphic contacts are indicated on **Table 1**.

The Lower Trinity Aquifer is estimated to be about 450-500 ft thick in the area and is confined by the overlying Hammett Shale and other geologic units (Hunt et al, 2020). The Hammett is a ubiquitous shale that behaves as a regional aquitard between the overlying Middle Trinity and underlying Lower Trinity Aquifer units. The Lower Trinity Aquifer is composed of the Sligo and Hosston formations. The Hosston (Sycamore Sand equivalent) consists of terrigenous, clastic, fine- to coarse-grained feldspathic sandstone and cobble conglomerate and unconformably overlays the Paleozoic (Ouachita Facies) basement. The Hosston is exposed along the Pedernales and Colorado River valleys in western Travis County. The Sligo Formation is a shallow-water, high-energy carbonate that pinches out to the west prior to reaching the Pedernales River Valley.

Recharge to the Lower Trinity is generally thought to occur from leakage from overlying units through the Hammett Shale and along fractures and faults that breach the shale. Groundwater within the Lower Trinity Aquifer is thought to be within a deeply confined and compartmentalized aquifer system containing very old (1,000s of years) groundwater moving very slowly through a diffuse matrix.

The wells were drilled by Bee Caves Drilling Inc. using air rotary methods and were cemented from the top of the Sligo to the surface using the positive displacement method. Well construction is summarized in **Table 2** and driller's reports are in **Appendix A**. Well schematics for Gragg well #2 is shown in **Figure 4** and wells #1 and #3 are shown in **Appendix C**.

***Table 1**. Stratigraphic contacts of Gragg wells #2 and #3 determined by geophysical logs.*

Geologic Formation	Gragg #2 depth (ft)	Gragg Well #3 depth from surface (ft)	Average Thickness (ft)	Comment
Soil	surface	surface		Soil
Georgetown (Kgt) fm	7	7		partial thickness, eroded (normally 50 ft thick)
Edwards Group (Ked)	20	20	445	
Walnut (Kwal) fm	412	435	41	
Upper Glen Rose (Kgru)	453	476	519	
Lower Glen Rose (Kgrl)	973	993	210	
Hensel (Khe) fm	1183	1202	27	
Cow Creek (Kcc) fm	1212	1226	82	
Hammet (Kha) fm	1291	1310	41	
Sligo (Ksl) fm	1332	1351	85	
Hosston (Kho) fm	1415	1437	274	Minimum thickness; not fully penetrated
Total borehole depth	1700	1700		

***Table 2.** Well information and construction summary. Detailed records within Appendix A.*

Parameter	Gragg #1	Gragg #2	Gragg #3
Tracking number (SDR)	473734	527500	527505
State well number (TWDB)	58-50-755		
Latitude	30.134734°	30.131514°	30.130953°
Longitude	-97.866928°	-97.867811°	-97.861429°
Land surface elevation (ft-msl)	742	732	722
Date completed	1/26/2018	9/25/2019	10/10/2019
Total depth (ft)	1620	1700	1700
Depth of casing (ft)	1434	1350	1355
Diameter of casing (in)	8*	8.625	8.625
Open hole or slotted interval	Slotted 180 ft (1434-1614 ft-bgs)	Open 350 ft (1350-1700 ft-bgs)	Open 345 ft (1355-1700 ft-bgs)
Diameter of open or slotted interval	5.0	7.875	7.875
Water level (ft-bgs)	196 (1/8/2018)	136 (10/18/2019)	132 (10/18/2019)
Reported yield (gpm)	115	170	170
Aquifer test date	2/1/2018	October 18-22, 2019	October 24-28, 2019
Distance to Gragg #3 (ft)	2,215	2,028	0

*telescoping casing (8 in 0-1342 ft, 5 in 1334-1434 ft)

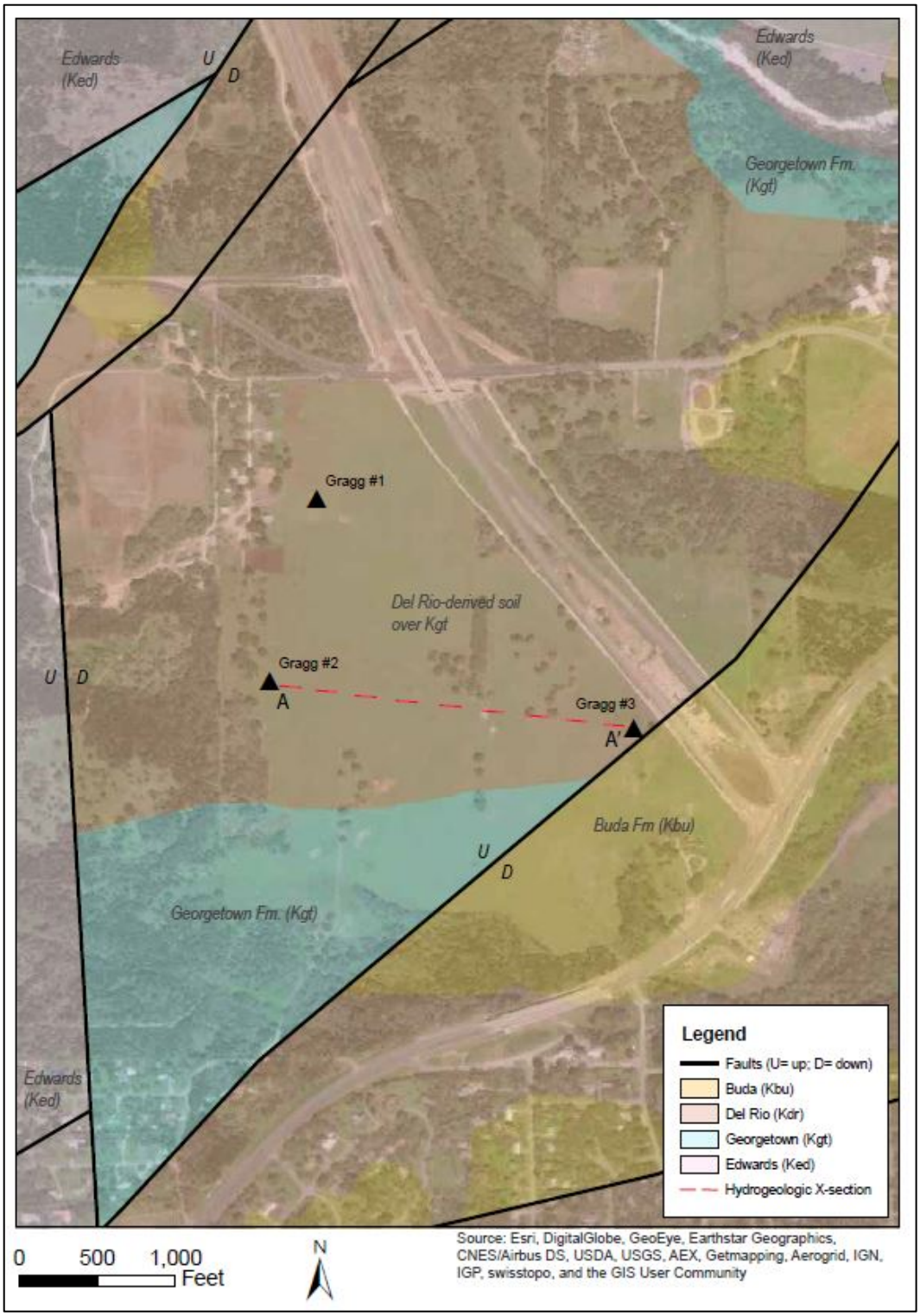

Figure 2. *Geologic map of the well field area (Hauwert, 2008). The well field is on the eastern edge of the Edwards Recharge Zone. Numerous faults are mapped in the area.*

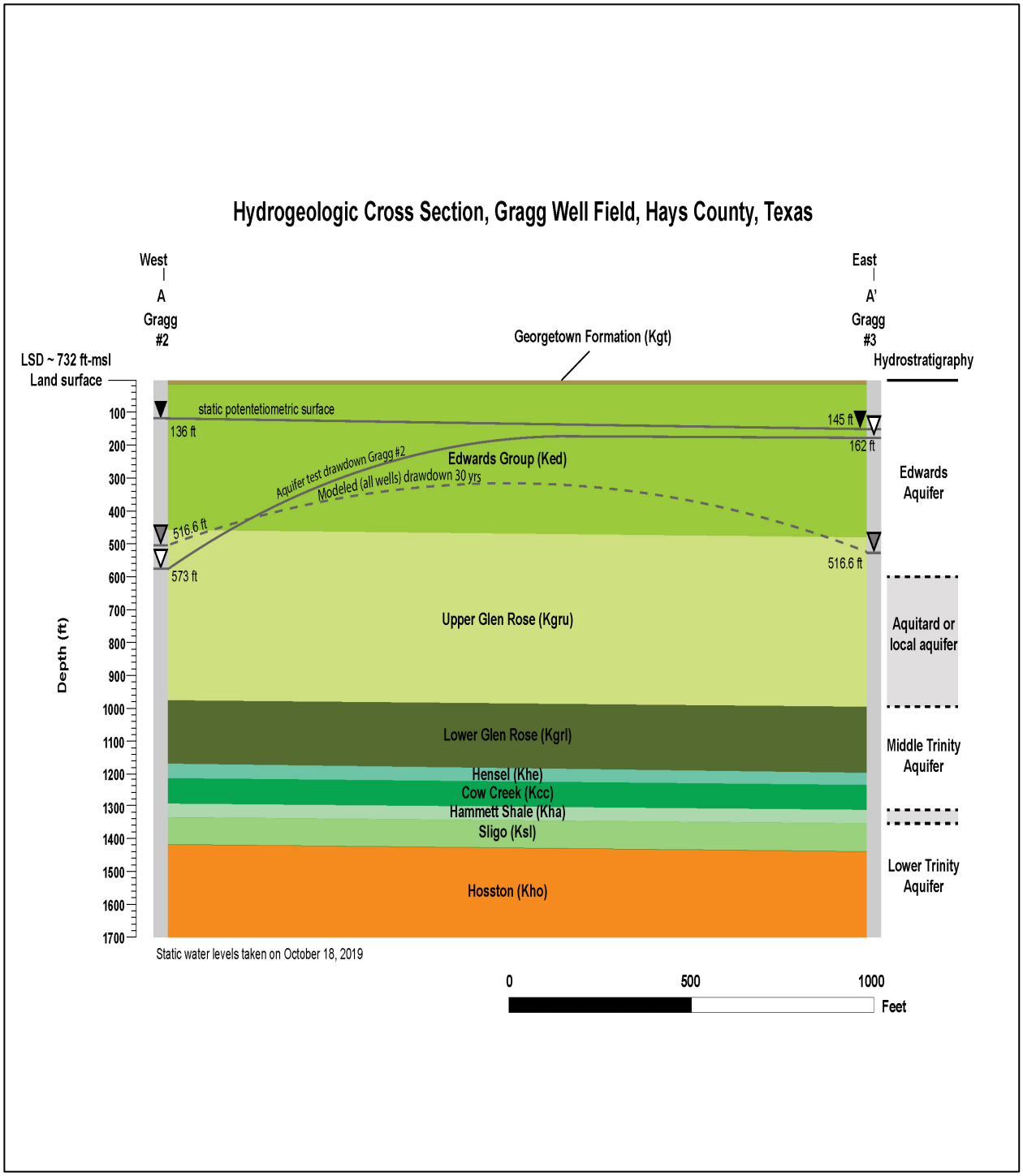

Figure 3. *Geologic and hydrogeologic cross section through study area. Potentiometric surfaces are inferred based upon measured water levels in the wells. Values are shown as depth from surface. Modeled water level (dashed line) is based upon static levels and results from analytical models with parameters derived from the aquifer testing in this report.*

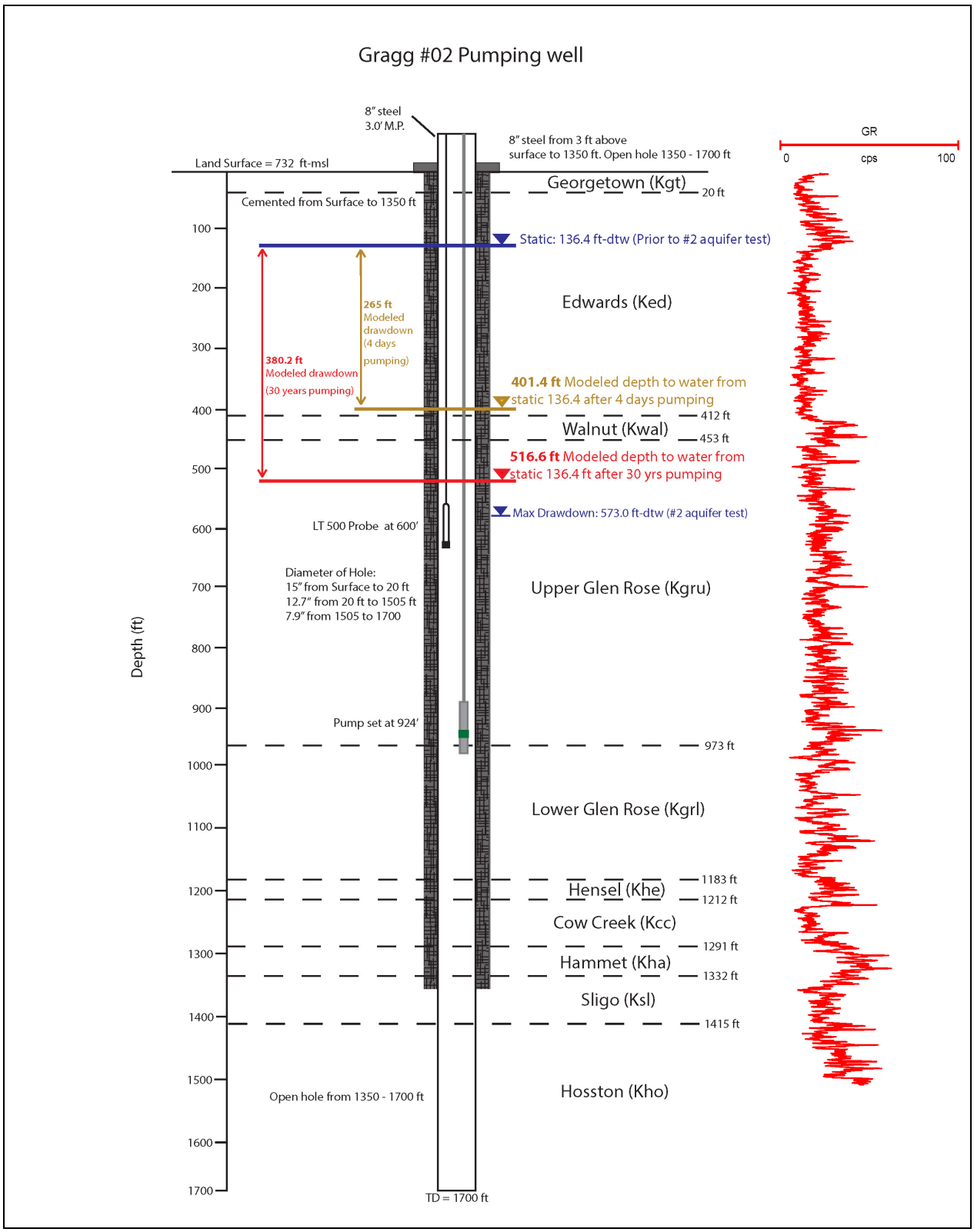

Figure 4. *Schematic of Gragg #2 well construction and stratigraphy with modeled water levels for 4-day and 30-yr pumping scenarios. Stratigraphic picks made from the geophysical log. Actual measured drawdown in well during Gragg #2 aquifer test was 573.0 ft-dtw.*

AQUIFER TEST

In order to achieve the mutual interests of an aquifer test, BSEACD staff helped design the 2019 aquifer test of the Gragg tract well field. A work plan was developed (**Appendix D)** and designed to satisfy the District's guidelines (BSEACD, 2016) for an aquifer test that could support a potential permit request of up to 200 MGY for this well field (Gragg Wells #1-3) in the future. The goal of the test was to produce three times the potential daily volume of about 1.6 million gallons per day, which was estimated to be 96 hrs of pumping at a rate of about 150 gpm for each well. Gragg #1 was not pumped as part of the 2019 aquifer testing but was used as an observation well during the testing and is therefore included as part of the well field.

An aquifer test was conducted for the Gragg #2 and #3 wells over two separate 4-day periods to allow for pumping and recovery. During Gragg #2 pumping, Gragg #1 and #3 were used as observation wells. During Gragg #3 pumping, Gragg #1 and #2 were used as observation wells. Gragg #1 was solely used as an observation well in the 2019 testing. However, information on the Gragg #1 yield, water quality, and drawdown was evaluated from a single-well testing in 2018 (Geos Consulting, 2018). Locations of the pumped and monitored wells are shown in **Figure. 1**. A summary of the aquifer testing information are provided in **Tables 3-5** and hydrographs provided in **Figures 6-8**.

Prior to the start of each 4-day testing period, BSEACD staff installed absolute (non-vented) pressure transducers on a stainless steel cable in each of the observation wells, and a gauged (vented) pressure transducer with vented cable in the pumping well. Water levels in the observation wells taken by the non-vented pressure transducers were confirmed by staff taking periodic manual measurements during the test using an electric measuring tape (E-line). Pumping rates were calculated by reading an inline flowmeter three times and taking the average.

Due to the deeply confined nature and distance from its recharge area, the Lower Trinity Aquifer is less susceptible to surface hydrologic processes during aquifer testing. As such, surface hydrologic conditions, such as rainfall, did not influence the results of any of the testing. Instead, an effort to monitor the static water level over a period of days prior to the testing was done to understand background trends.

Figure 5. *Photographs of Gragg #2 Aquifer Test (taken on 10/18/2019).*

Gragg #1 Test

A single well test was conducted in 2018 on Gragg #1. This was the initial test well of the Lower Trinity in the area. Information on the single-well testing was provided by Geos Consulting (2018) and summarized in **Table 3**.

Table 3. *Aquifer test summary for Gragg #1 on February 2018. Gragg wells #2 and #3 were not yet drilled during the testing.*

	Gragg #1	**Comment**
Pumping start	2/1/2018 10:40	
Pumping stop	2/1/2018 16:10	
Duration (hrs)	5.5	
Pumping rate (gpm)	115	Max 155
Static water level (ft-bgs)	138	
Maximum drawdown (ft)	431	
Specific capacity (gpm/ft)	0.27	
Recovery (hrs to 90%)	1	
Total volume pumped (gal)	~44,550	

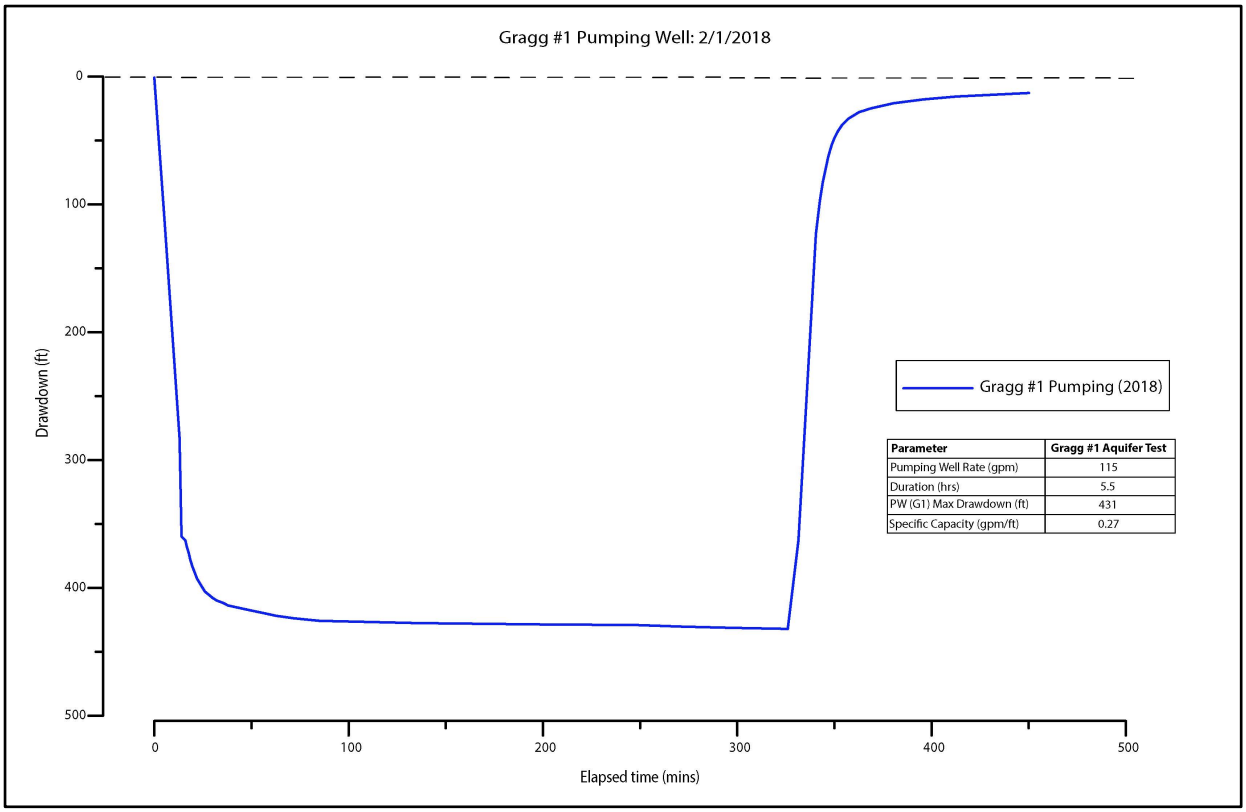

Figure 6. *Hydrograph of the Gragg #1 single-well pumping test from 2018 (data from Geos Consulting, 2018).*

Gragg #2 Test

The Gragg #2 aquifer test data are summarized in **Table 4**. Static background water levels were collected in Gragg wells #1 and #3 with non-vented pressure transducers for 7 days prior to initiating the Gragg #2 aquifer test. Background water-level data show a discernable downward trend prior to the start of Gragg #2 aquifer test. Non-vented pressure transducers in observation wells #1 and #3 were set at 320 ft bgs and 400 ft bgs, respectively, and set to take measurements at 15-minute intervals. In well #2 a 915-ft tremie pipe was installed with the test pump to allow the vented pressure transducer to take measurements at 600 ft bgs at 1-minute intervals. All pressure transducers remained in place throughout the test and until the water level in the pumping well had reached 90% recovery.

Static water level in the Gragg #2 pumping well was 136 ft bgs. Static water levels in Gragg #1 and #3 were 133 ft bgs and 145 ft bgs, respectively. Maximum measured drawdown in the pumping well over 96 hours (5,760 minutes) was a total of 437 ft, and in observation wells #1 and #3 was 34 ft and 17 ft, respectively. The average pumping rate was 168 gpm. Upon turning the well pump off, the water level recovered 418 ft (143.5 bgs) within 1 hour (~90%, **Figure 7**). A total of 915,400 gallons were pumped from Gragg #2.

Table 4. *Aquifer Test Summary for Gragg #2 on October 18-22, 2019*

	Gragg #1	Gragg #2	Gragg #3	Comment
Pumping start	N/A	10/18/2019 10:00	N/A	
Pumping stop	N/A	10/22/2019 10:00	N/A	
Duration (hrs)	N/A	96	N/A	
Pumping rate (gpm)	N/A	168	N/A	Max 178
Static water level (ft-bgs)	133	136	145	
Maximum drawdown (ft)	34	437	17	
Specific capacity (gpm/ft)	N/A	0.38	N/A	
Recovery (hrs to 90%)		1		
Total volume pumped (gal)	N/A	915,400	N/A	

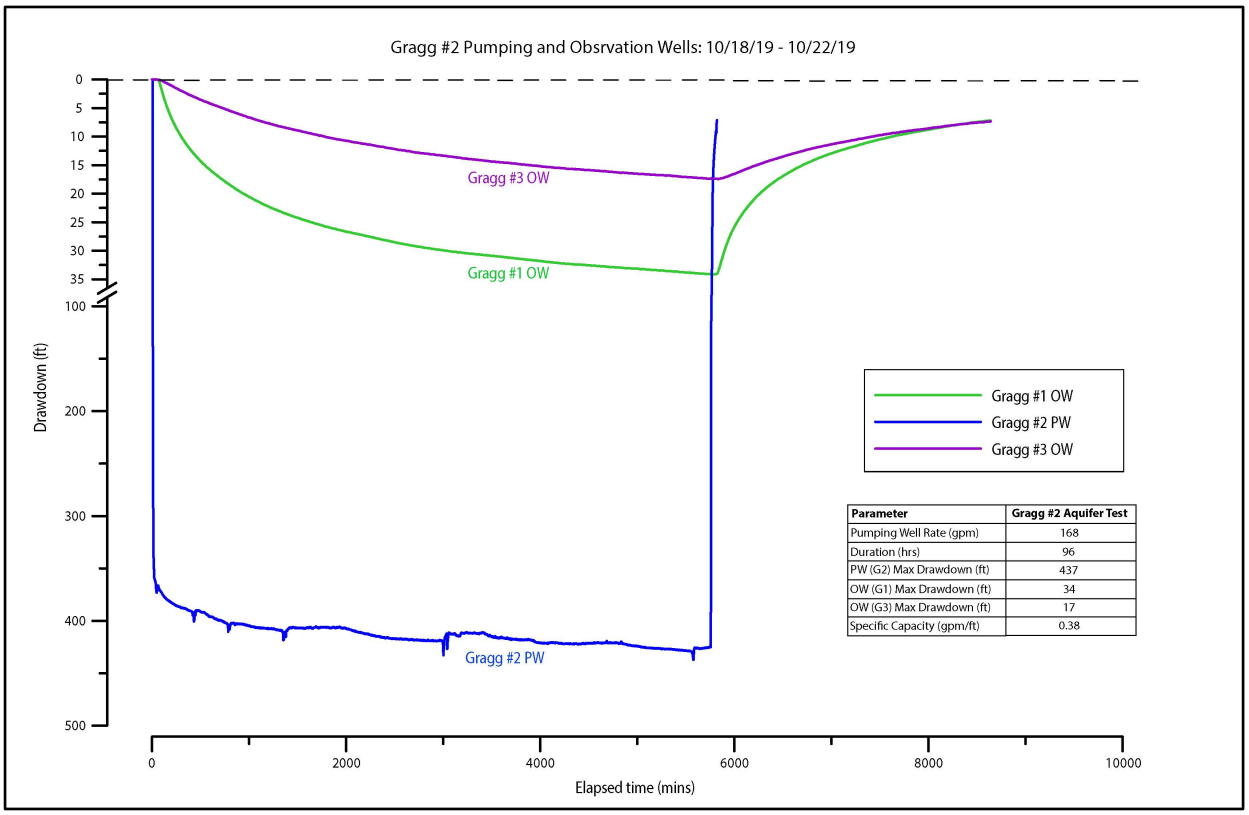

Figure 7*. Hydrograph of Gragg #2 pumping well (blue) and Gragg #1 and #3 observation wells (green and purple, respectively) during pumping and recovery phases of the aquifer test. Note the vertical change in scale.*

Gragg #3 Test

The Gragg #3 aquifer test data are summarized in **Table 5**. Prior to pumping Gragg #3, static background water levels were collected in Gragg wells #1 and #2 during well #3 pump installation. Procedures and setup for the pumping and observation wells in the Gragg #2 aquifer test were applied to Gragg #3.

The static water level in the Gragg #3 pumping well was 141 ft bgs while the static levels in Gragg #1 and #2 were 151 ft bgs and 141 ft bgs, respectively. The maximum measured drawdown in the pumping well

over 93 hours (5,580 minutes) of pumping was 320 ft and in observation wells Gragg #1 and #2 was 8 ft and 9 ft, respectively. The average pumping rate was 175 gpm. Upon turning the well pump off, the water level recovered 320 ft to 141 ft bgs in 1 hour. (~90 %, **Figure 8**). A total of 901,300 gallons were pumped from Gragg #3. Observation wells were still recovering 52 hours after the Gragg #2 test (**Figure 8**) because it represents the combined (slow) recovery from Gragg #2 and #3 pumping.

Table 5. *Aquifer test summary for Gragg #3 on October 24-28, 2019*

	Gragg #1	Gragg #2	Gragg #3	Comment
Test start	N/A	N/A	10/24/2019 16:00	
Test stop	N/A	N/A	10/28/2019 12:00	
Duration (hrs)			93	
Pumping rate (gpm)			175	Max 200
Static water level (ft-bgs)	151	141	141	
Maximum drawdown (ft)	8	9	320	
Specific capacity (gpm/ft)	N/A	N/A	0.54	
Recovery (hrs to 90%)			1	
Total volume pumped (gal)	N/A	N/A	901,300	

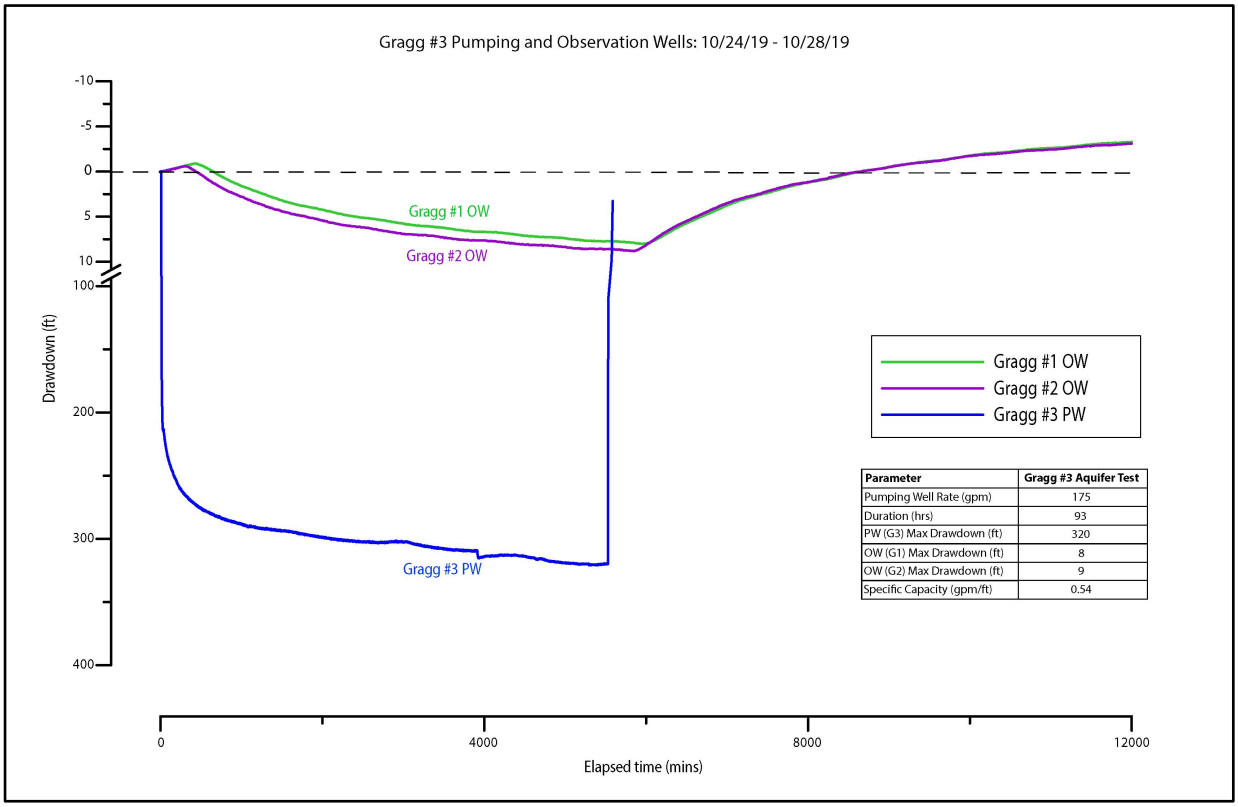

Figure 8. *Hydrograph of Gragg #3 pumping well (blue) and Gragg #1 and #2 observation wells (green and purple, respectively) during pumping and recovery phases of the aquifer test. Note the vertical change in scale. After the test, the recovery of water levels in the observation wells are above the zero line because at the start of Gragg #3 test the water levels had not fully recovered from pumping of Gragg #2. Thus, the water-level recovery is combined from the Gragg #2 and #3 pumping.*

PARAMETER ESTIMATION

Data from the pumping and recovery phases of each aquifer test were analyzed using Aqtesolv software to determine hydraulic properties of the Lower Trinity Aquifer (**Figure 9**). Aqtesolv (Duffield, 2007) is a commercial software package developed for the design and analysis of aquifer-test data. The software provides a model of the theoretical response to pumping for the given input parameters. Aqtesolv is an important tool used by the District to analyze aquifer-test data. The software provides a comprehensive suite of analytical solutions for confined aquifers such as Theis (1963) and Cooper-Jacob (1946).

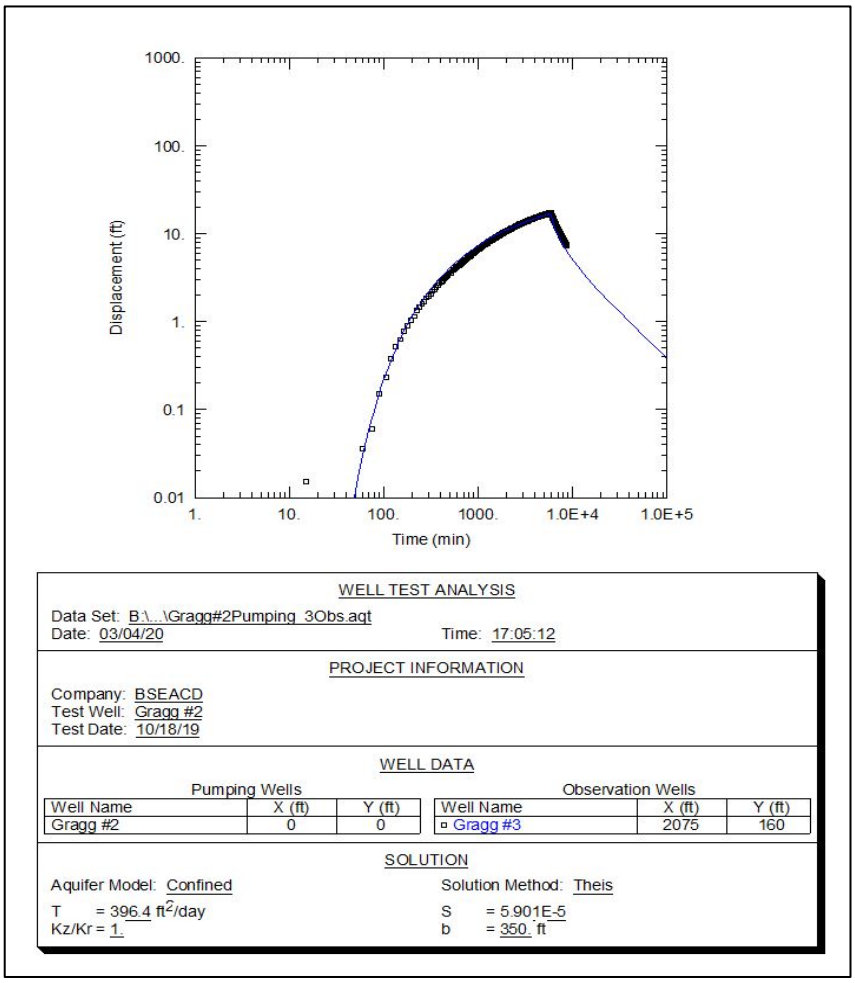

***Figure 9**. Example of results from AqteSolv software analysis of Gragg #3 observation well during Gragg #2 pumping and recovery phases of the aquifer test. There is a very good match of the modeled (solid line) and observed (symbols) data.*

Aqtesolv allows for assigning multiple wells to an X and Y coordinate system, pumping duration, and well construction information (**Table 2**). Detailed pumping times and rates were directly imported into the software. Aquifer-test data were formatted into elapsed time (minutes) and drawdown (ft). The thickness of the aquifer was determined to be about 350 ft from geophysical logs (**Table 1**). The ratio of vertical to horizontal permeability (Kv/Kh) was estimated to be about 0.1. Note that the resulting estimates of the aquifer parameters are generally insensitive to changes in these (thickness, Kv/Kh) parameters.

Analyses of the data included considerations such as: 1) late-time data for a given test are generally more representative; 2) distant observation wells generally provide a better estimate of storativity; 3) drawdown data from pumping wells generally show high levels of head loss; and 4) deviations of the observation data from theoretical (model) type curves can illuminate processes within the aquifer such as boundary conditions. Identification of boundary conditions is critical to the evaluation of the aquifer test (Duffield and Butler, 2015).

The Theis solution fits the observation data better than most other analytical solutions such as straight-line or recovery methods. The use of those straight-line and recovery solutions generally results in elevated aquifer parameters when compared to Theis (**Table 5**). In addition, we determined that the Theis solution fits the data better than other solutions that consider leaky or fractured aquifers. No boundary conditions were observed under the conditions of the test.

Results of transmissivity (T) from pumping and observation wells are summarized in **Table 5**. A summary of the average of the best-fit values using Theis solution is provided in **Table 6**. The average values include a transmissivity value of 401 $ft^{2/}$day and a storativity of 5.57-E05. These parameters are higher than published median values of Lower Trinity wells in the Hill Country to the west of the study area (Hunt et al., 2010; Hunt et al., 2020).

Table 5. *Results of parameter estimation of all wells.*

Well Name	T (ft2/day)	T (gpd/ft2)	S	Analytical Solution
Gragg #2 Pumping Well				
Gragg # 2 Pumping	104.0	778.0	5.34E-05	Cooper-jacob
Gragg # 2 Pumping	100.5	751.8	9.11E-05	Theis
Gragg #1 Obs	266.2	1991.3	3.73E-05	Theis
Gragg #1 Obs	262.6	1964.4	3.84E-05	Cooper-Jacob
Gragg #3 Obs	402.3*	3009.4*	5.97E-05*	Theis
Gragg #3 Obs	403.0*	3014.6*	4.83E-05*	Cooper-Jacob
Gragg #1, 3 Obs	402.1	3007.9	6.07E-05	Theis
Gragg #1, 3 Obs	431.7	3229.3	4.27E-05	Cooper-Jacob
Gragg # 1, 2, 3	402.1	3007.9	6.18E-05	Theis
Gragg # 1, 2, 3	317.0	2371.3	2.34E-05	Cooper-Jacob
Gragg #1, 2	262.6	1964.4	3.84E-05	Theis
Gragg #1, 2	319.7	2391.5	2.35E-05	Cooper-Jacob
Gragg #2, 3	396.4*	2955.2*	5.90E-05*	Theis
Gragg #2, 3	426.7	3191.9	4.63E-05	Cooper-Jacob
Avg	354.3	2650.5	4.5E-05	
Gragg #3 Pumping Well				
Gragg #3 Pumping	100.3	750.3	8.18E-03	Cooper-Jacob
Gragg #1 Obs	475.5	3557.0	6.80E-04	Theis
Gragg #1 Obs	485.6	3632.5	4.75E-04	Cooper- Jacob
Gragg #2 Obs	721.1	5394.2	1.10E-04	Theis
Gragg #2 Obs	487.3	3645.3	1.67E-04	Cooper- Jacob
Gragg # 1, 2, 3	153.3	1146.8	5.12E-05	Theis
Gragg # 1, 2, 3	129.2	966.5	4.59E-04	Cooper-Jacob

Well Name	T (ft2/day)	T (gpd/ft2)	S	Analytical Solution
Gragg #1, 2 Obs	441.6	3303.4	2.55E-04	Theis
Gragg #1, 2 Obs	705.9	5280.5	3.12E-04	Cooper-Jacob
Gragg #2, 3	691.0	5169.0	1.07E-04	Theis
Gragg #2, 3	583.2	4362.6	1.39E-04	Cooper-Jacob
Avg	487.4	3151.0	2.76E-04	
Gragg #1 Pumping (2018 Single Well Test)				
Gragg #1 Pumping	165.7	1239.5	2.99E-15	Theis

*best fit values

Table 6. *Aquifer and Trinity well parameters calculated from data collected during the pumping and recovery phase of the aquifer test. These values were used in analytical modeling forecasts.*

Specific Capacity (gpm ft^{-1})	Storativity (S)	Transmissivity (T) ft^2 /day		
		Theis (1963)	Cooper-Jacob (1946)	Average
0.5	5.57-E05*	399*	403	401

*average of best fit values

DRAWDOWN FORECASTING

This memo documents an aquifer test that could be used as a component of the hydrogeologic report of an application for a pumping permit. District rules require any application for a pumping permit to have an evaluation (hydrogeologic report) of the potential for unreasonable impacts from the proposed pumping (BSEACD, 2016). An important part of that evaluation is using aquifer test data to estimate aquifer parameters to make forecasts of the potential range of drawdown into the future. This report uses those aquifer parameters and the assumed pumping rate to make some estimates of drawdown. For purposes of this evaluation we assume a potential request of about 200 million gallons per year, which is the equivalent to 380 gpm, or about 130 gpm for each of the three wells in the well field. This report does not constitute an evaluation of the potential for unreasonable impacts.

A simple estimate of drawdown from parameters in **Table 6** is presented in **Figure 10**. Results presented show an approximation of drawdown after 4 days of pumping from a hypothetical well in the well field at a rate of 380 gpm. Drawdown is estimated to be a total of 265 ft in the pumping well with drawdown decreasing to 0 ft at a distance of 8,930 ft from the well (**Figure 10**). Using the same parameters when time is increased to 30 years, a total estimated drawdown of 380 ft within the pumping well decreases to about 112 ft at a distance of 10,000 ft radial from the pumping well (**Figure 10**).

Aqtesolv allows a more sophisticated forward modeling and geographic drawdown estimation using all three wells and the parameters in **Table 6**. **Figure 11** presents a 30-year average drawdown. All three wells

collectively pumping at 380 gpm resulted in a combined drawdown of about 140 ft at a radial distance of about 10,000 ft from the well field.

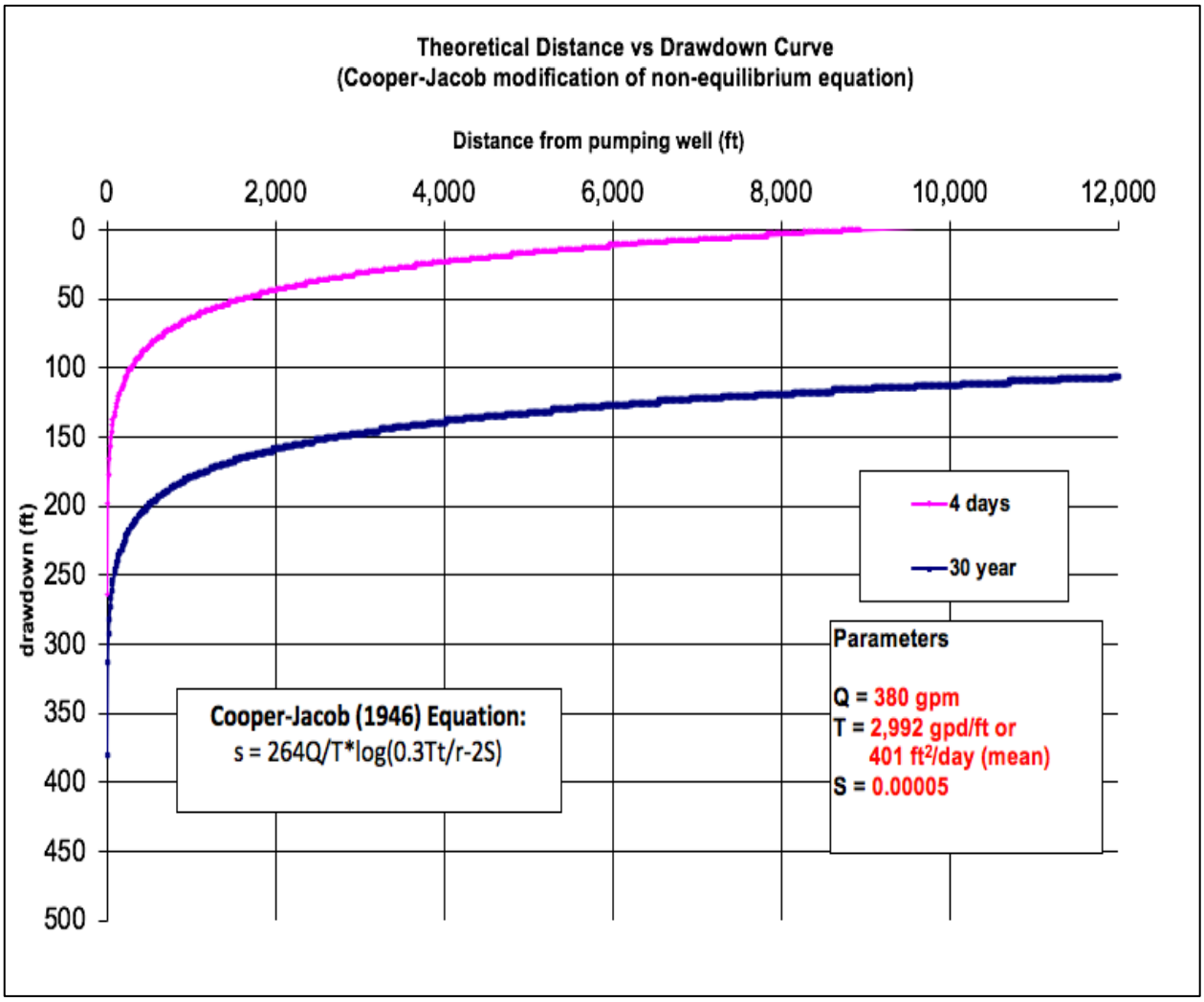

Figure 10. *Four-day and thirty-year theoretical drawdown versus distance of the Lower Trinity well modeled using (Cooper and Jacob, 1946).*

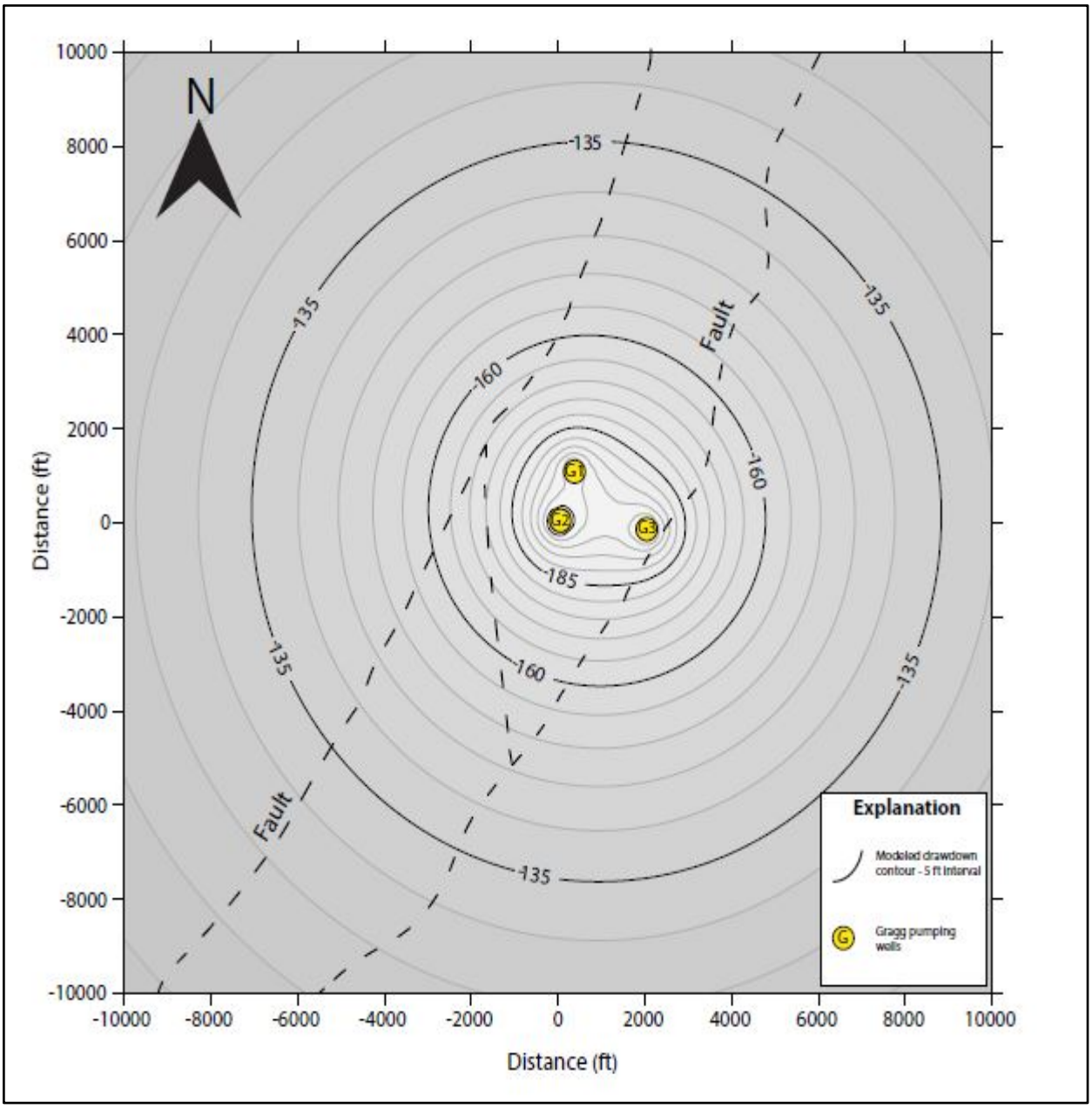

Figure 11. *Map of combined drawdown from pumping 200 MGD (380 gpm) after 30 years using Aqtesolv and the Theis solution.*

Water Quality

Physicochemical data of the groundwater produced from Gragg #2 and #3 was measured throughout both tests with a Horiba water-quality instrument. Temperature, pH, conductivity, and dissolved oxygen values did not vary greatly between probe readings (**Table 7**). Water samples were collected at the termination of pumping for Gragg #1 (8/28/2019), Gragg #2 (10/22/19), and Gragg #3 (10/28/19) and submitted for laboratory analyses at LCRA Environmental Laboratory Services (**Table 8**; **Appendix E**). Ion geochemistry indicates Ca-HCO_3 water with relatively low TDS (542-568 mg/L) and sulfate (161-169 mg/L). All other water-quality parameters analyzed were within ranges characteristic of the Lower Trinity Aquifer. These results indicate that the water in the Lower Trinity Aquifer likely meets the TCEQ's primary and secondary public drinking water standards. Isotope data was collected from Gragg #1 at the end of its single pumping test. Isotope results indicate very low tritium (-0.05 TU) and carbon-14 (0.006 PMC), indicating very old (pre-modern) water (**Appendix F**).

Table 7. *Physicochemical well-water data monitored during pumping of both Lower Trinity wells with a Horiba water-quality probe. Values did not vary greatly between readings and were found to be within ranges characteristic of the Lower Trinity Aquifer.*

Event	Temp (°C)	pH	Conductivity (µs/cm)	DO (mg/L)
Gragg #2	29.61	7.49	908	5.38
Gragg #3	30.09	7.29	906	6.45

Table 8. *Gragg #1-3 Lower Trinity groundwater sample results processed by LCRA Environmental Laboratory Services.*

	Gragg #1	Gragg #2	Gragg #3
Parameter	**Result**	**Result**	**Result**
Hardness (mg/L)	196	184	162
Calcium Total (mg/L)	78.3	73.8	65.0
Iron Total (mg/L)	0.431	0.497	0.217
Sodium Total (mg/L)	32.5	43.5	76.0
Aluminum Total (mg/L)	0.0099	1.06	<0.0050
Arsenic Total (mg/L)	<0.0010	<0.0010	<0.0010
Copper Total (mg/L)	0.0017	<0.0010	0.0017
Lead Total (mg/L)	0.0007	0.0022	<0.0010
Manganese Total (mg/L)	0.0044	0.0066	0.00519
Zinc Total (mg/L)	0.327	0.352	0.399
Chloride (mg/L)	19	32.8	45.9
Fluoride (mg/L)	1.85	1.67	1.80
Alkalinity (mg/L)	254	259	249

	Gragg #1	Gragg #2	Gragg #3
Nitrate/Nitrite (mg/L)	<0.020	<0.010	<0.010
Sulfate (mg/L)	162	161	169
TDS (mg/L)	542	559	568
Total Coliform	N/A	Absent	Absent
Ecoli	N/A	Absent	Absent
Isotopes			
Sr 87/86 (Ratio)	0.708372	N/A	N/A
Deut./O18 (VSMOW)	-24.6	N/A	N/A
Tritium (TU)	-0.05	N/A	N/A
Carbon-14 (Y-BP)	41100	N/A	N/A

CONCLUSIONS

Because the results of the aquifer test indicate that the water quality and yield of these wells are high the Lower Trinity Aquifer may be a direct alternative groundwater supply for the study area. At this time there are no large permitted Lower Trinity wells in the BSEACD.

However, further evaluation of the Lower Trinity is needed to determine how long-term pumping from the Lower Trinity could affect water levels (storage) over time and space. The nearby Lower Trinity Aquifer of western Travis County offers a cautionary example of groundwater mining (Hunt et al., 2020).

In addition, the Lower Trinity Aquifer could be a good candidate for ASR. However, more study is needed to evaluate its ASR potential.

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APPENDIX A: State well reports

STATE OF TEXAS WELL REPORT for Tracking #473734

Owner:	**Gragg Tract, LP**	Owner Well #:	**1**
Address:	**1010 W. Martin Luther King Jr. Blvd. Austin, TX 78701**	Grid #:	**58-50-7**
		Latitude:	**30° 08' 05.03" N**
Well Location:	**Old Bliss Spillar Rd. Manchaca, TX 78652**	Longitude:	**097° 52' 00.85" W**
Well County:	**Hays**	Elevation:	**742 ft. above sea level**
Type of Work:	**New Well**	Proposed Use:	**Public Supply**

Drilling Start Date: **10/30/2017** Drilling End Date: **1/26/2018** **Plans Approved by TCEQ - NO**

Borehole:

Diameter (in.)	*Top Depth (ft.)*	*Bottom Depth (ft.)*
13.5	**0**	**1400**
8	**1400**	**1620**

Drilling Method: **Air Rotary**

Borehole Completion: **Perforated or Slotted**

Annular Seal Data:

Top Depth (ft.)	*Bottom Depth (ft.)*	*Description (number of sacks & material)*
0	**1342**	**Cement 1175 Bags/Sacks**

Seal Method: **Positive Displacement**

Sealed By: **Driller**

Distance to Property Line (ft.): **No Data**

Distance to Septic Field or other concentrated contamination (ft.): **none**

Distance to Septic Tank (ft.): **none**

Method of Verification: **No Data**

Surface Completion: **Surface Slab Installed** **Surface Completion by Driller**

Water Level: **196 ft.** below land surface on **2018-01-08**

Packers: **No Data**

Type of Pump: **No Data**

Well Tests: **Pump** **Yield: 115 GPM with 427 ft. drawdown after 5.5 hours**

Water Quality:

Strata Depth (ft.)	Water Type
1434 - 1620	Trinity

Chemical Analysis Made: **Yes**

Did the driller knowingly penetrate any strata which contained injurious constituents?: **No**

Certification Data: The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the report(s) being returned for completion and resubmittal.

Company Information: **Bee Cave Drilling, Inc.**

185 Angel Fire Dr.
Dripping Springs, TX 78620

Driller Name: **Jim Blair** License Number: **54416**

Comments: **From Geologging:**
Georgetown Edwards 50' - 100'
Edwards 100' - 430'
Walnut Edwards 430' - 460'
Upper Glenrose 460' - 480'
Middle Glenrose 480' - 1020'
Cow Creek/Hensel 1020' - 1315'
Hammett 1315' - 1360'
Lower Trinity 1360' - 1620'

Lithology:
DESCRIPTION & COLOR OF FORMATION MATERIAL

Top (ft.)	Bottom (ft.)	Description
0	2	topsoil
2	12	caliche
12	32	tan & white broken limestone
32	390	Edwards Limestone w/ voids (lost returns)
390	1085	no returns
1085	1090	gray limestone
1090	1130	gray sandstone
1130	1165	gray limestone
1165	1200	gray sandstone
1200	1270	brown & gray limestone
1270	1350	gray limestone
1350	1620	gray sandstone & limestone

Casing:
BLANK PIPE & WELL SCREEN DATA

Dia (in.)	Type	Material	Sch./Gage	Top (ft.)	Bottom (ft.)
8	Blank	New Steel	sch. 40	0	1342
5	Blank	New Plastic (PVC)	sch. 80	1334	1434
5	Perforated or Slotted	New Plastic (PVC)	sch. 80	1434	1614

STATE OF TEXAS WELL REPORT for Tracking #527500

Owner:	**Gragg Tract LP #2**	Owner Well #:	**2**
Address:	**1010 W. Martin Luther King Jr. Blvd. Austin, TX 78701**	Grid #:	**58-50-7**
		Latitude:	**30° 07' 53.46" N**
Well Location:	**Old Bliss Spillar Rd. Manchaca, TX 78652**	Longitude:	**097° 52' 04.03" W**
Well County:	**Hays**	Elevation:	**732 ft. above sea level**
Type of Work:	**New Well**	Proposed Use:	**Public Supply**

Drilling Start Date: **8/22/2019** Drilling End Date: **9/25/2019** **Plans Approved by TCEQ - NO**

Borehole:

Diameter (in.)	*Top Depth (ft.)*	*Bottom Depth (ft.)*
15	**0**	**20**
12.75	**20**	**1505**
7.875	**1505**	**1700**

Drilling Method: **Air Rotary**

Borehole Completion: **Open Hole**

Annular Seal Data:

Top Depth (ft.)	*Bottom Depth (ft.)*	*Description (number of sacks & material)*
0	**1350**	**Cement 1148 Bags/Sacks**

Seal Method: **Positive Displacement**

Sealed By: **Driller**

Distance to Property Line (ft.): **220**

Distance to Septic Field or other concentrated contamination (ft.): **none**

Distance to Septic Tank (ft.): **none**

Method of Verification: **No Data**

Surface Completion: **Surface Slab Installed** **Surface Completion by Driller**

Water Level: **136 ft.** below land surface on **2019-10-18**

Packers: **No Data**

Type of Pump: **No Data**

Well Tests: **Pump** **Yield: 170 GPM with 425 ft. drawdown after 96 hours**

Water Quality:	Strata Depth (ft.)	Water Type
	No Data	No Data

Chemical Analysis Made: **Yes**

Did the driller knowingly penetrate any strata which contained injurious constituents?: **No**

Certification Data: The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the report(s) being returned for completion and resubmittal.

Company Information: **Bee Cave Drilling, Inc.**

185 Angel Fire Dr.
Dripping Springs, TX 78620

Driller Name: **Jim Blair** License Number: **54416**

Comments: **Cementing by CUDD Pumping Services using Type H Cement per BSEACD**

Lithology:
DESCRIPTION & COLOR OF FORMATION MATERIAL

Top (ft.)	Bottom (ft.)	Description
0	2	topsoil
2	20	tan limestone
20	45	white limestone
45	80	tan limestone
80	140	lost returns
140	280	tan sandstone
280	300	gravel
300	340	tan sandstone & gravel
340	1700	lost returns

Casing:
BLANK PIPE & WELL SCREEN DATA

Dia (in.)	Type	Material	Sch./Gage	Top (ft.)	Bottom (ft.)
8.625	Blank	New Steel	sch. 40	0	1350

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking Number on your written request.

Texas Department of Licensing and Regulation
P.O. Box 12157
Austin, TX 78711
(512) 334-5540

STATE OF TEXAS WELL REPORT for Tracking #527505

Owner:	**Gragg Tract LP #3**	Owner Well #:	**3**
Address:	**1010 W. MLK Jr. Blvd. Austin, TX 78701**	Grid #:	**58-50-7**
		Latitude:	**30° 07' 51.92" N**
Well Location:	**Old Bliss Spillar Rd. Manchaca, TX 78652**	Longitude:	**097° 51' 41.78" W**
Well County:	**Hays**	Elevation:	**722 ft. above sea level**
Type of Work:	**New Well**	Proposed Use:	**Public Supply**

Drilling Start Date: **9/5/2019** Drilling End Date: **10/10/2019** **Plans Approved by TCEQ - NO**

Borehole:

Diameter (in.)	*Top Depth (ft.)*	*Bottom Depth (ft.)*
15	**0**	**19**
12.75	**19**	**1385**
7.875	**1385**	**1700**

Drilling Method: **Air Rotary**

Borehole Completion: **Open Hole**

Annular Seal Data:

Top Depth (ft.)	*Bottom Depth (ft.)*	*Description (number of sacks & material)*
0	**1355**	**Cement 1195 Bags/Sacks**

Seal Method: **Positive Displacement**

Sealed By: **Driller**

Distance to Property Line (ft.): **150**

Distance to Septic Field or other concentrated contamination (ft.): **none**

Distance to Septic Tank (ft.): **none**

Method of Verification: **No Data**

Surface Completion: **Surface Slab Installed** **Surface Completion by Driller**

Water Level: **132 ft.** below land surface on **2019-10-18**

Packers: **No Data**

Type of Pump: **No Data**

Well Tests: **Pump** **Yield: 170 GPM with 450 ft. drawdown after 96 hours**

Water Quality:	Strata Depth (ft.)	Water Type
	No Data	No Data

Chemical Analysis Made: **Yes**

Did the driller knowingly penetrate any strata which contained injurious constituents?: **No**

Certification Data: The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the report(s) being returned for completion and resubmittal.

Company Information: **Bee Cave Drilling, Inc.**

185 Angel Fire Dr.
Dripping Springs, TX 78620

Driller Name: **Jim Blair** License Number: **54416**

Comments: **Cementing by CUDD Pumping Services using Type H Cement per BSEACD**

Lithology:
DESCRIPTION & COLOR OF FORMATION MATERIAL

Top (ft.)	Bottom (ft.)	Description
0	5	topsoil
5	140	tan limestone
140	290	tan limestone & gravel
290	1700	lost returns
1300	1350	Hammett
1350	1425	Sligo
1425	1700	Hosston

Casing:
BLANK PIPE & WELL SCREEN DATA

Dia (in.)	Type	Material	Sch./Gage	Top (ft.)	Bottom (ft.)
8.625	Blank	New Steel	sch. 40	0	1355

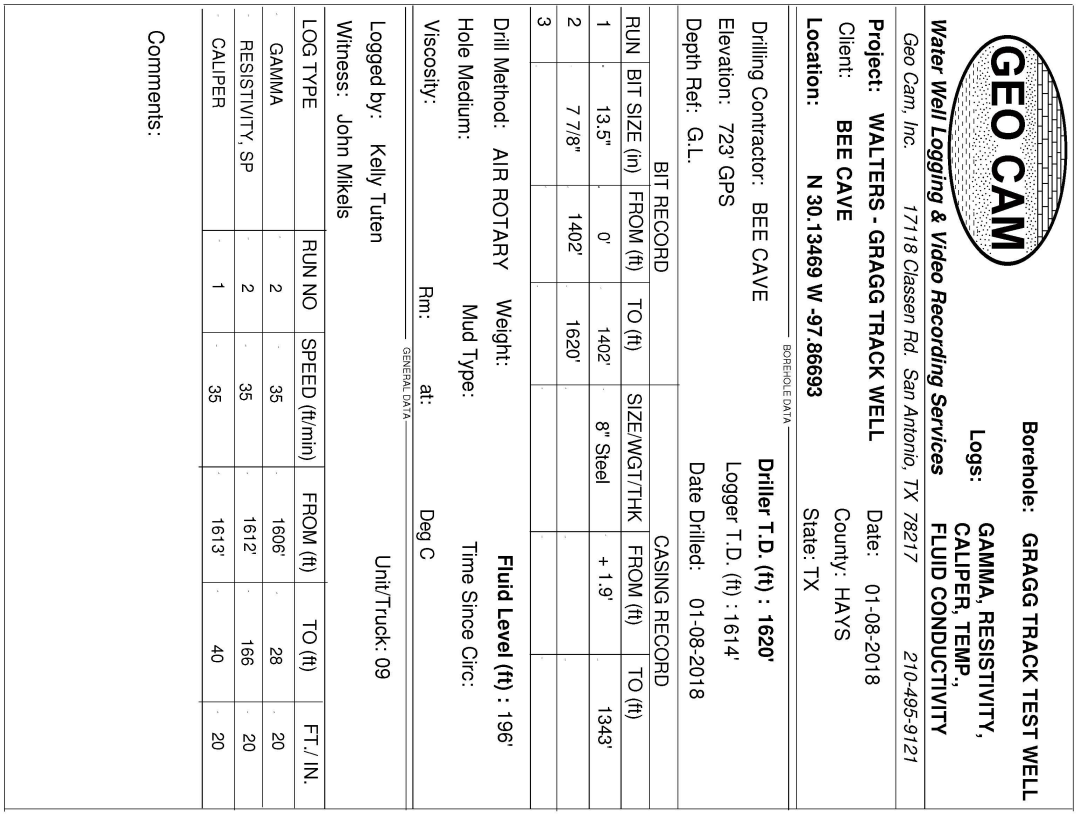
IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking Number on your written request.

Texas Department of Licensing and Regulation
P.O. Box 12157
Austin, TX 78711
(512) 334-5540

APPENDIX B: Geophysical Logs (Wells 1, 2, & 3 respectively)



GEO CAM

Water Well Logging & Video Recording Services

Geo Cam, Inc. 17118 Classen Rd. San Antonio, TX 78217 210-495-9121

Borehole: GRAGG TRACK TEST WELL

Logs: GAMMA, RESISTIVITY, CALIPER, TEMP., FLUID CONDUCTIVITY

Project: WALTERS - GRAGG TRACK WELL Date: 01-08-2018

Client: **BEE CAVE** County: HAYS

Location: N 30.13469 W -97.86693 State: TX

BOREHOLE DATA

Drilling Contractor: BEE CAVE **Driller T.D. (ft) : 1620'**

Elevation: 723' GPS Logger T.D. (ft) : 1614'

Depth Ref: G.L. Date Drilled: 01-08-2018

BIT RECORD					CASING RECORD		
RUN	BIT SIZE (in)	FROM (ft)	TO (ft)	SIZE/WGT/THK	FROM (ft)	TO (ft)
1	13.5"	0'	1402'	8" Steel	+ 1.9'	1343'
2	7 7/8"	1402'	1620'			
3						

GENERAL DATA

Drill Method: AIR ROTARY Weight: **Fluid Level (ft) : 196'**

Hole Medium: Mud Type: Time Since Circ:

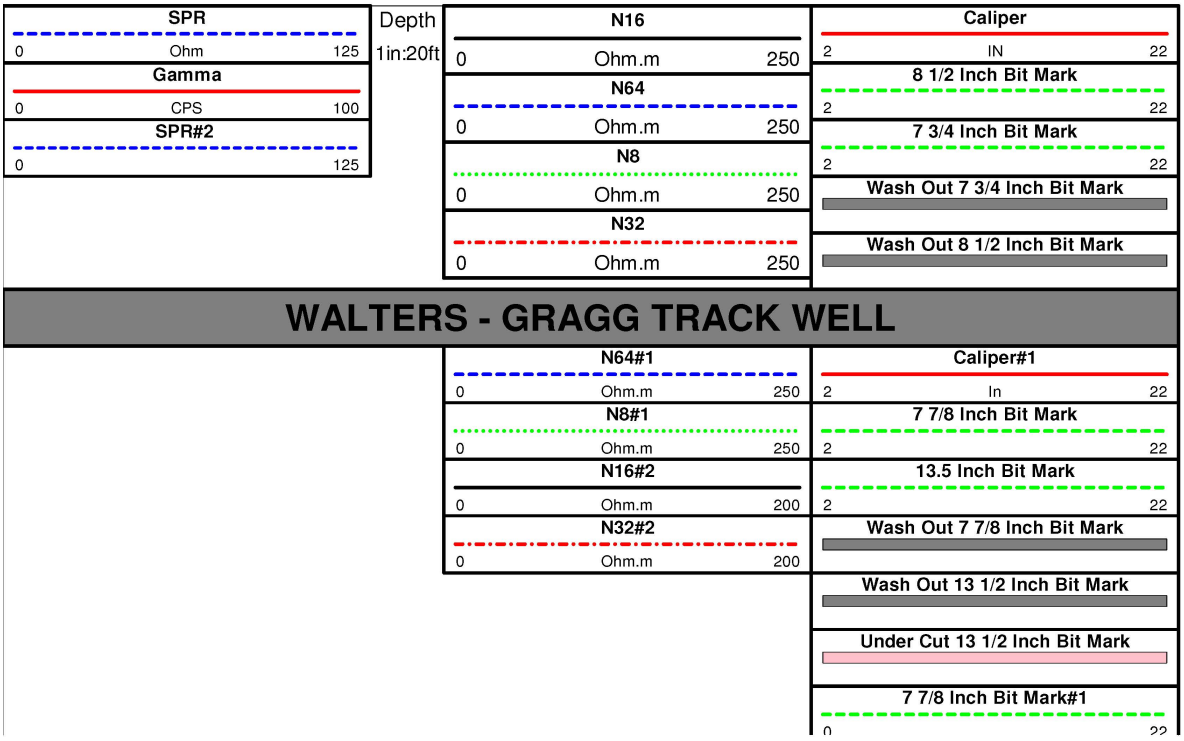
Viscosity: Rm: at: Deg C

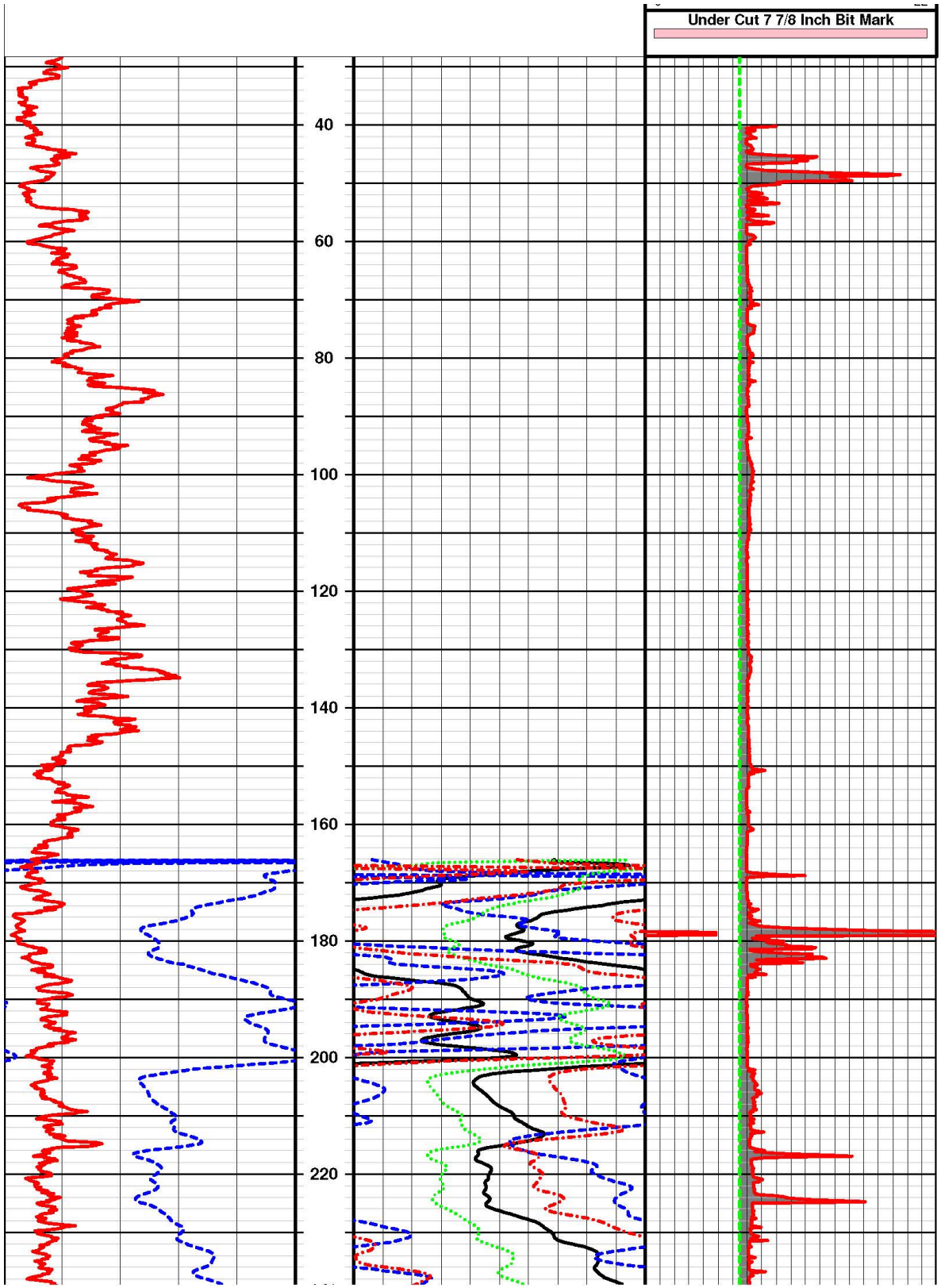
Logged by: Kelly Tuten Unit/Truck: 09

Witness: John Mikels

LOG TYPE	RUN NO	SPEED (ft/min)	FROM (ft)	TO (ft)	FT./ IN.
GAMMA	2	35	1606'	28	20
RESISTIVITY, SP	2	35	1612'	166	20
CALIPER	1	35	1613'	40	20

Comments:




Under Cut 7 7/8 Inch Bit Mark
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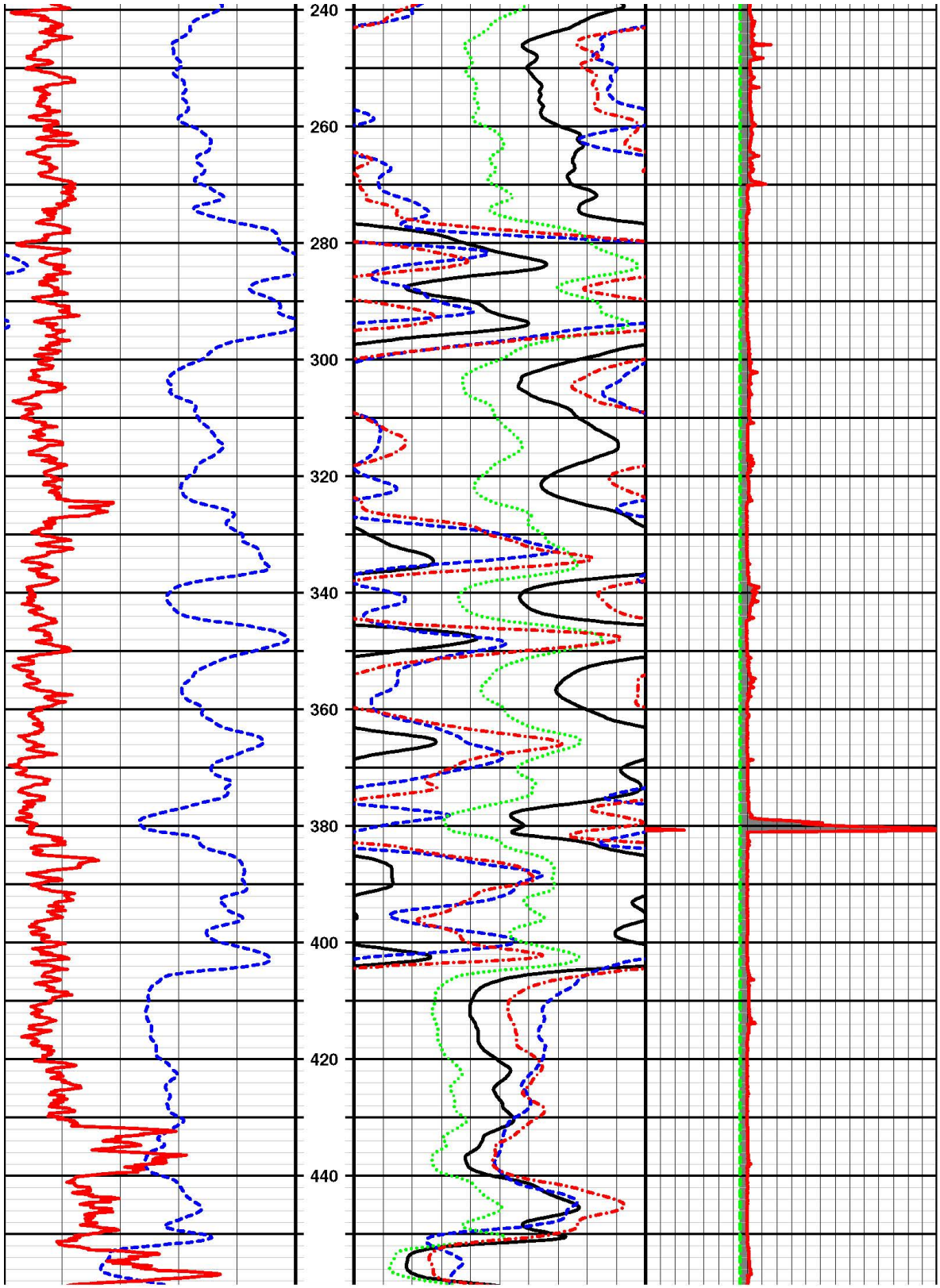
60
80
100
120
140
160
180
200
220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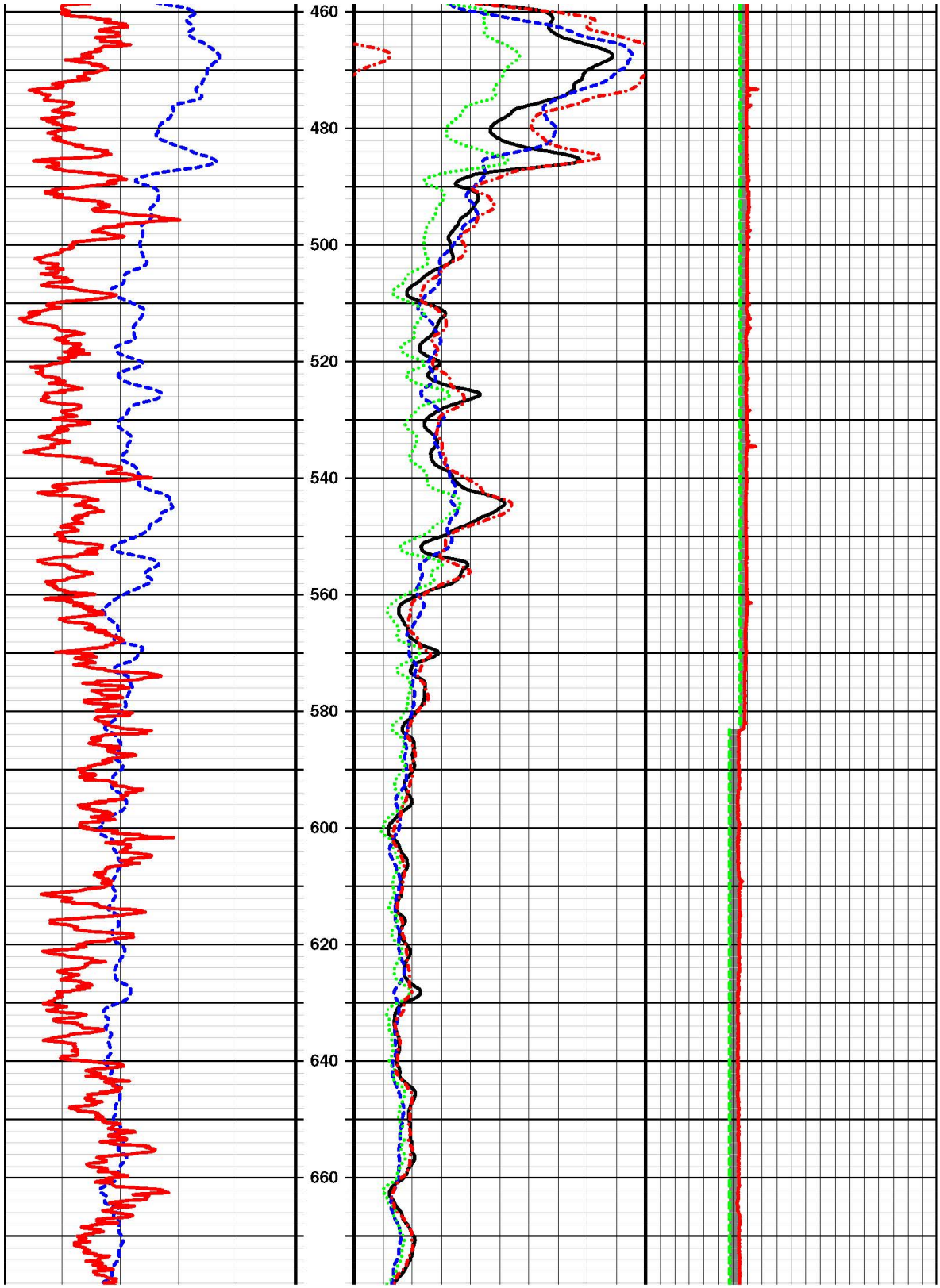
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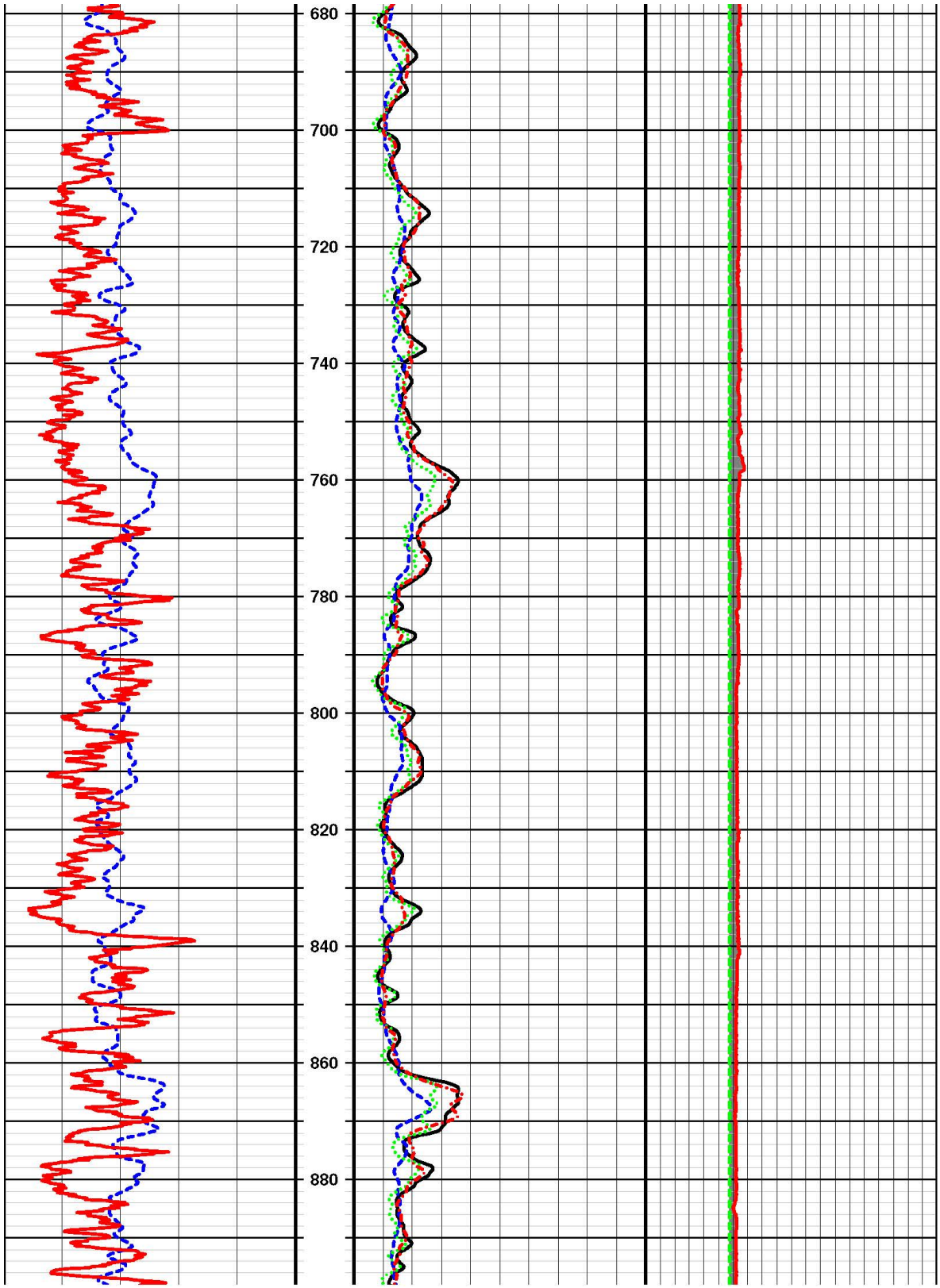
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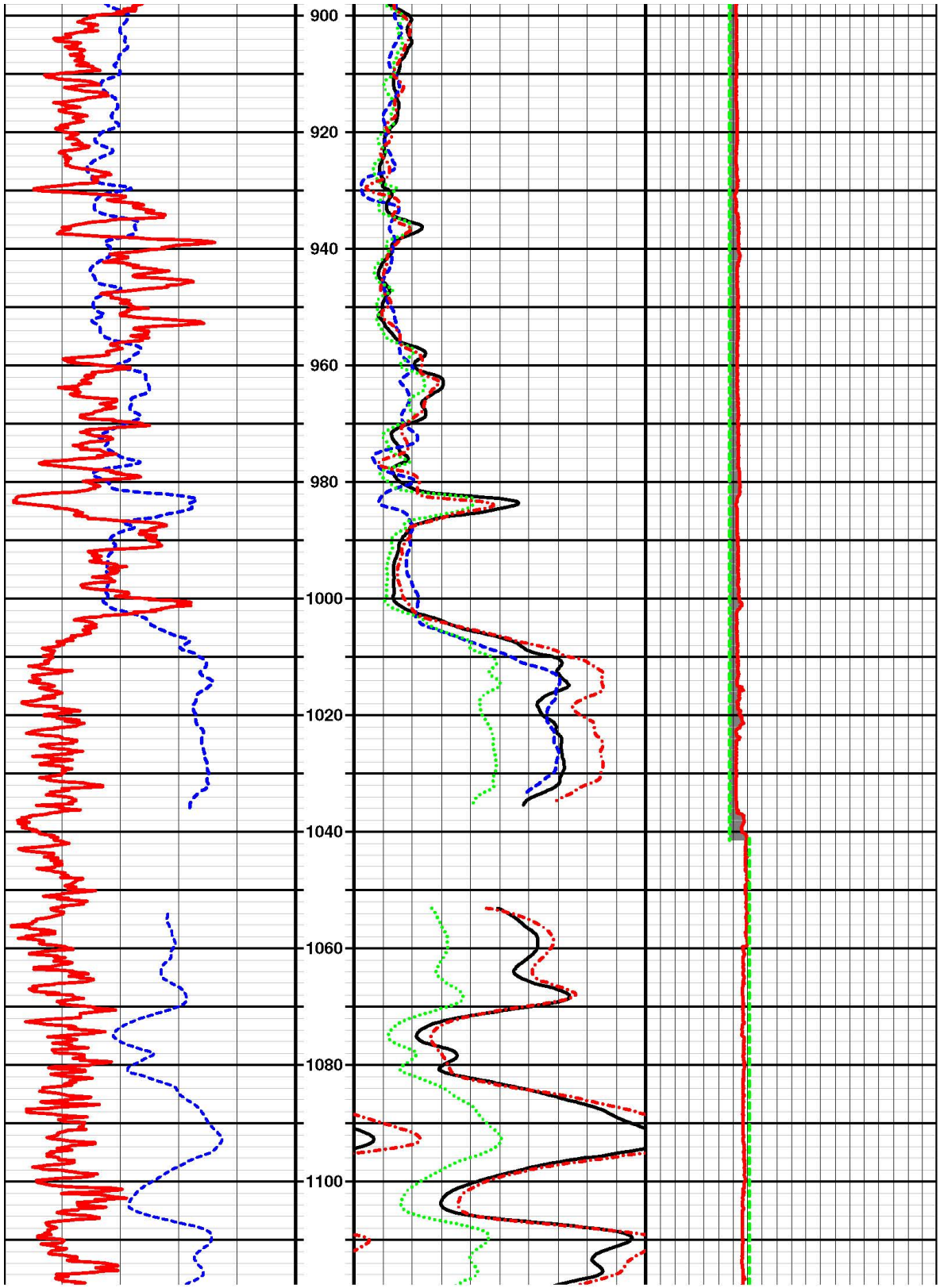
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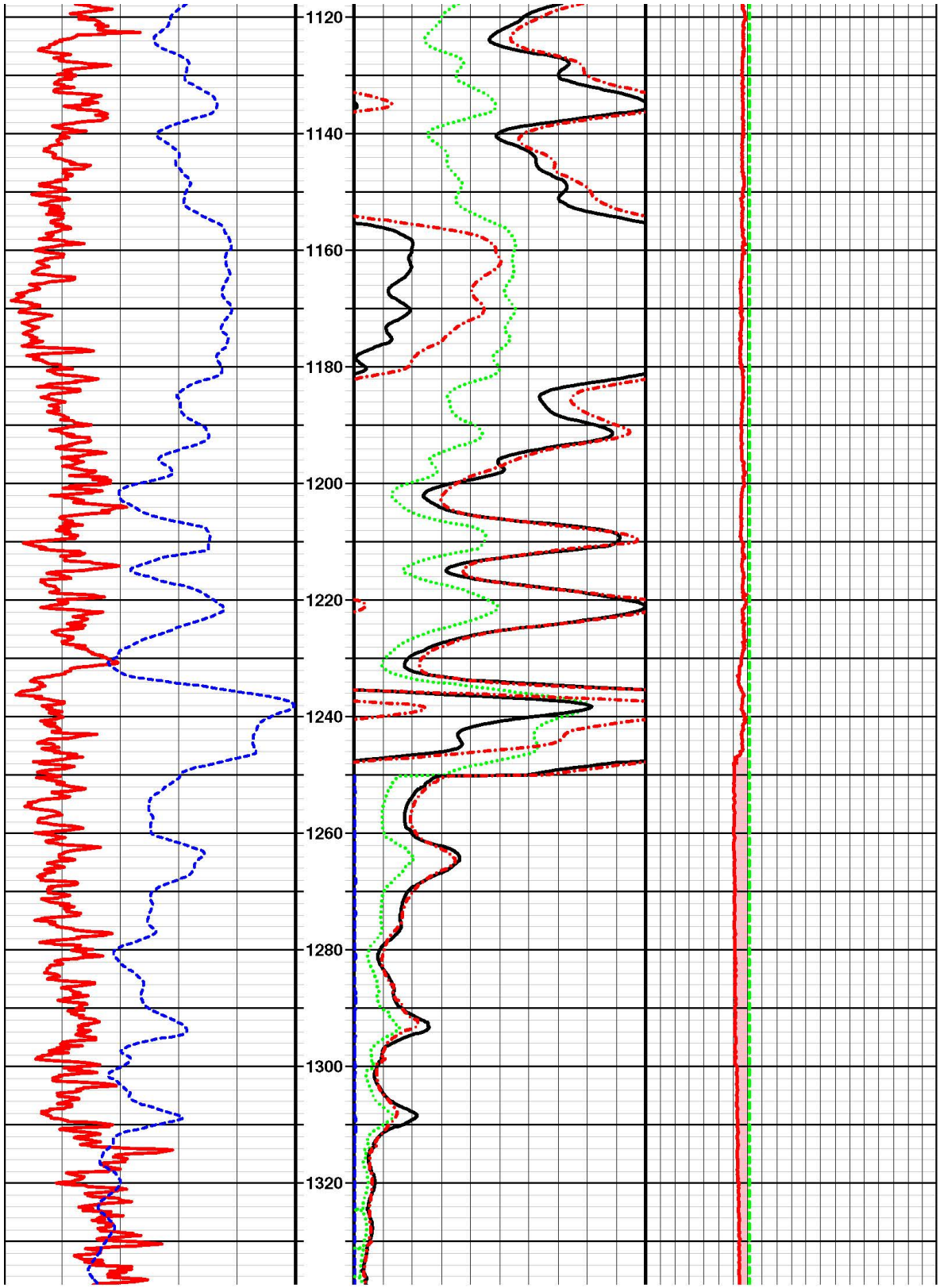
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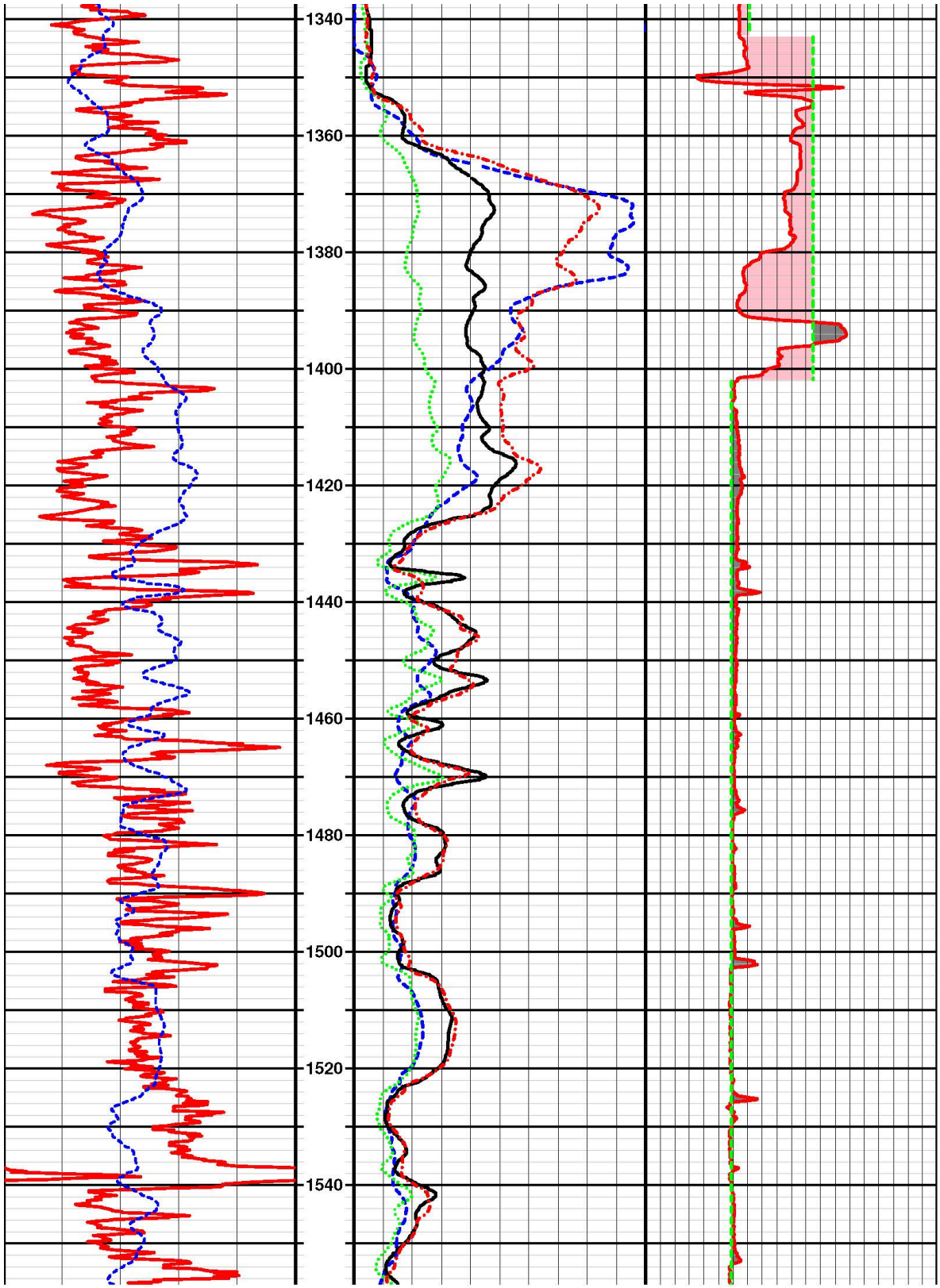
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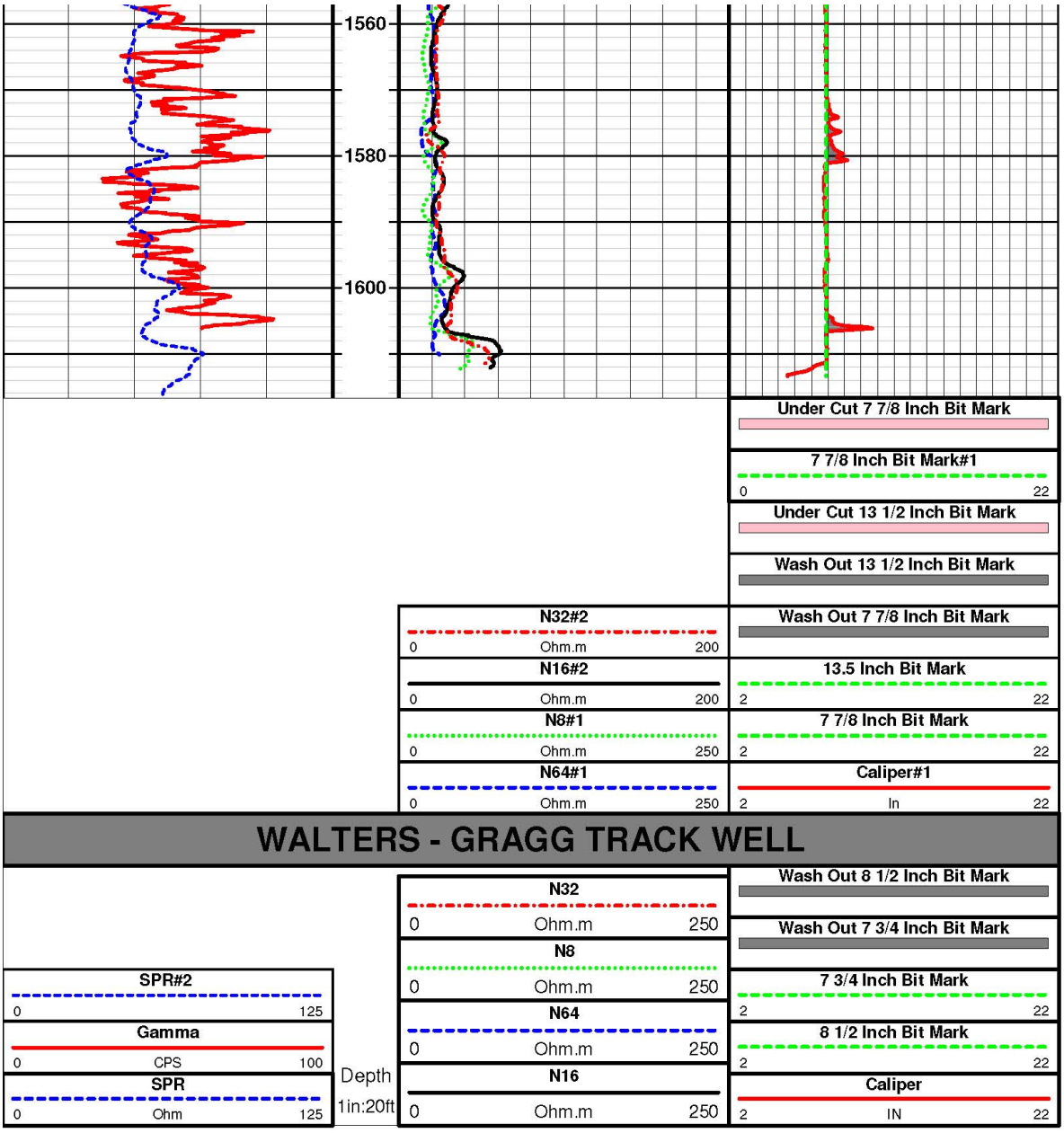
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1580
1600
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N32#2
0
Ohm.m
200
Wash Out 7 7/8 Inch Bit Mark
N16#2
0
Ohm.m
200
13.5 Inch Bit Mark
2
22
N8#1
0
Ohm.m
250
7 7/8 Inch Bit Mark
2
22
N64#1
0
Ohm.m
250
Caliper#1
2
In
22
WALTERS - GRAGG TRACK WELL
N32
0
Ohm.m
250
Wash Out 8 1/2 Inch Bit Mark
Wash Out 7 3/4 Inch Bit Mark
SPR#2
0
125
N8
0
Ohm.m
250
7 3/4 Inch Bit Mark
2
22
Gamma
0
CPS
100
N64
0
Ohm.m
250
8 1/2 Inch Bit Mark
2
22
SPR
0
Ohm
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Depth
1in:20ft
N16
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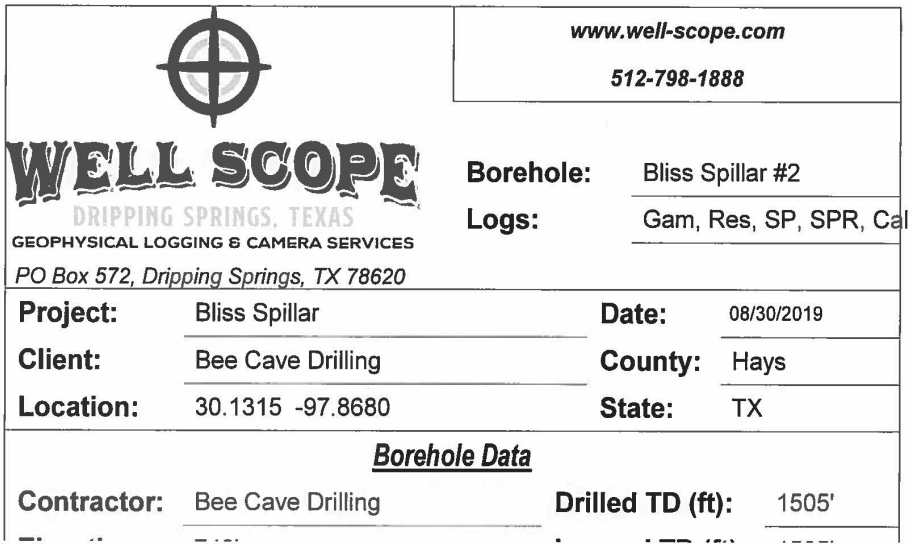
Ohm.m
250
Caliper
2
IN
22



WELL SCOPE
DRIPPING SPRINGS, TEXAS
GEOPHYSICAL LOGGING & CAMERA SERVICES
PO Box 572, Dripping Springs, TX 78620

www.well-scope.com
512-798-1888

Borehole:	Bliss Spillar #2
Logs:	Gam, Res, SP, SPR, Cal

Project:	Bliss Spillar	**Date:**	08/30/2019
Client:	Bee Cave Drilling	**County:**	Hays
Location:	30.1315 -97.8680	**State:**	TX

Borehole Data

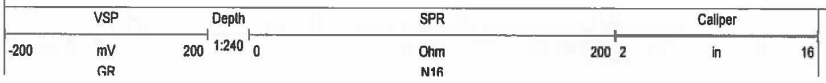
Contractor:	Bee Cave Drilling	**Drilled TD (ft):**	1505'

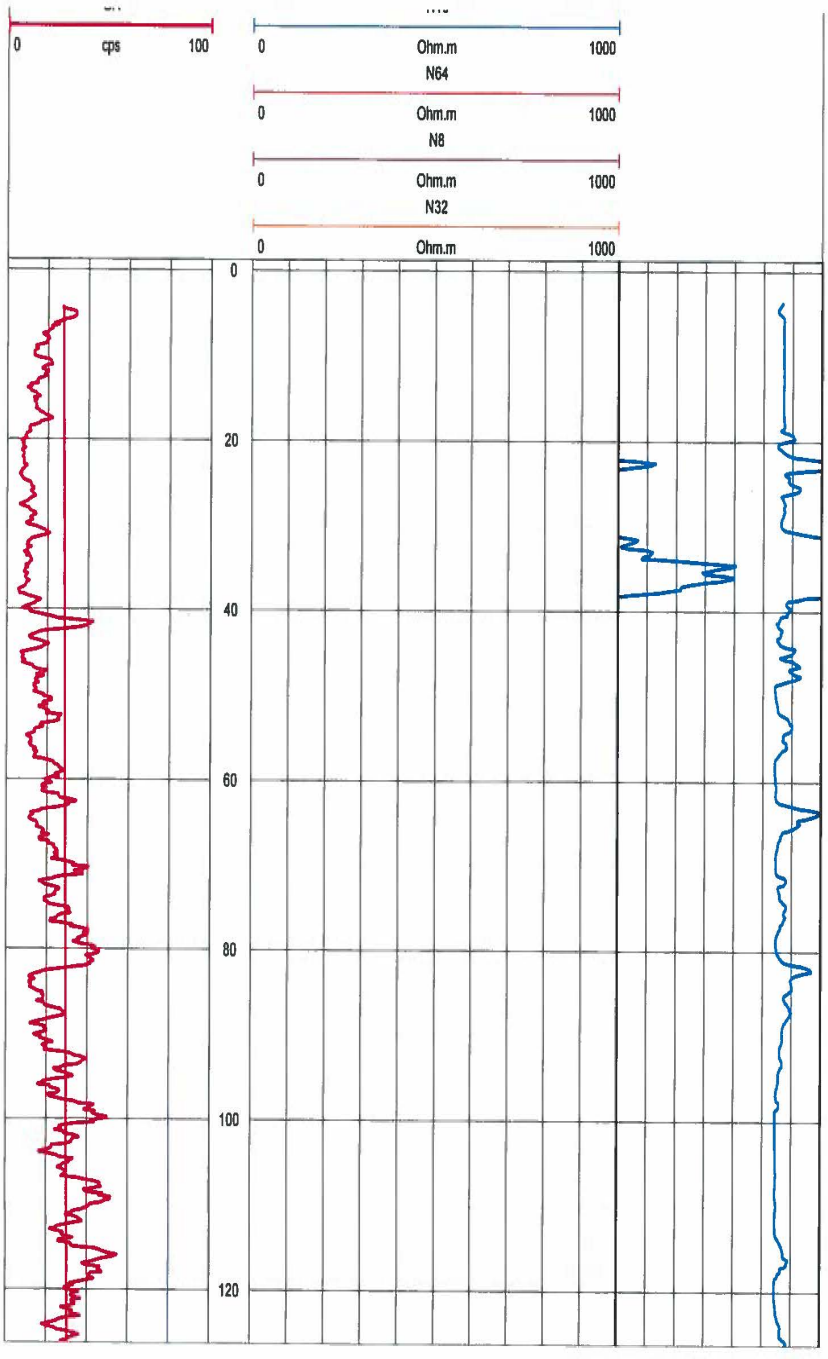
Elevation:	742'			**Logged TD (ft):**	1505'	
Depth Ref:	Ground Level			**Date Drilled:**	08/30/2019	
BIT RECORD				CASING RECORD		
RUN	BIT SIZE (in)	FROM (ft)	TO (ft)	SIZE/WGT/THK	FROM (ft)	TO (ft)
1	15"	0	20	14" steel	+1	19'
2	12 5/8"	20	1505'			
Drill Method:	Air Rotary		**Weight:**		**Fluid Lvl (ft):**	130'
Hole Medium:	Rock/clay		**Mud Type:**	foam	**Circ Time:**	1hr
Viscosity:			**Rm:**		**at (Deg F):**	

General Data

Logged By:	Chase Crane		**Unit/Truck:**	1	
Witness:	Mike Scott				
LOG TYPE	RUN	SPEED (ft/min)	FROM (ft)	TO (ft)	FT/IN
CALIPER	2	20	1500'	5	ft
GAMMA	1	30	1505'	3'	ft
RESISTIVITY/SP/SPR	1	30	1500'	130'	ft
VIDEO					

COMMENTS:

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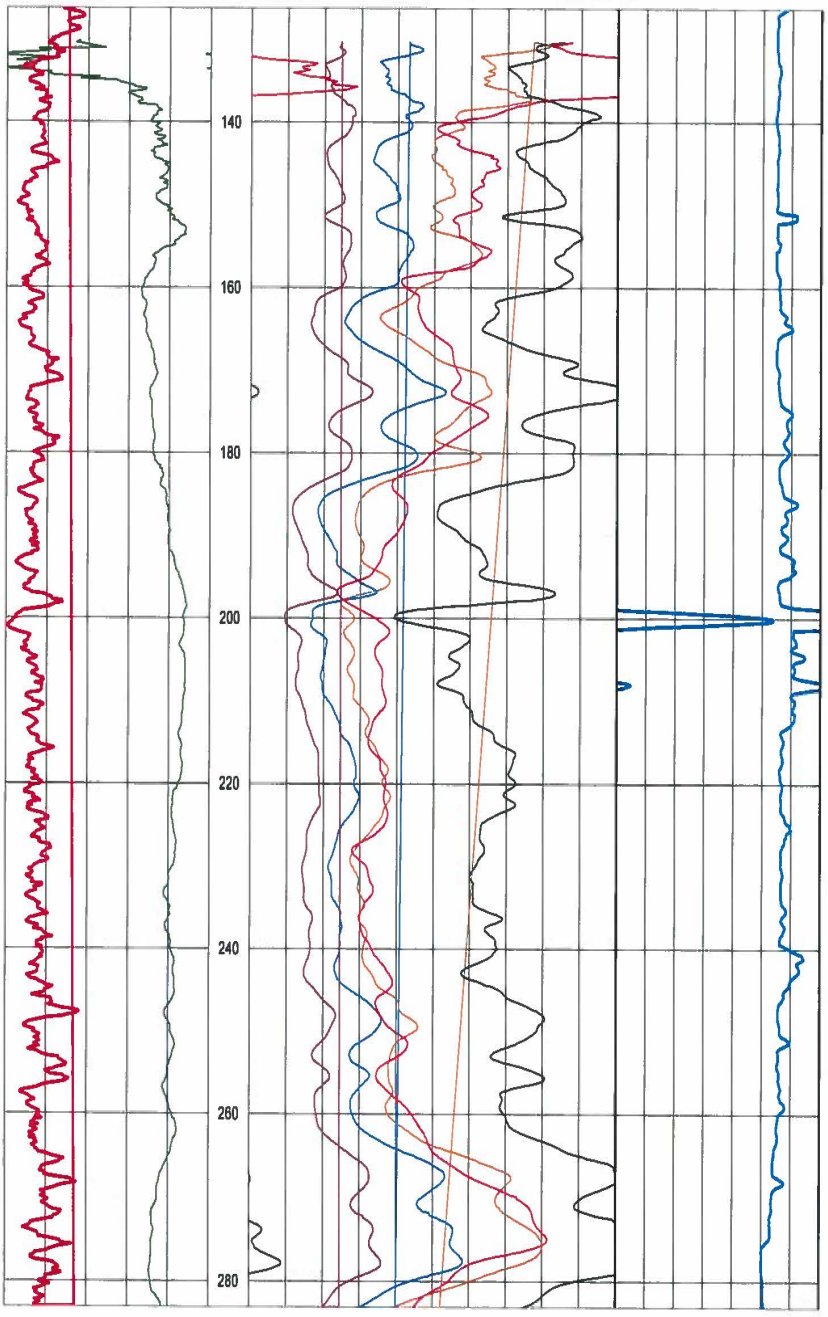
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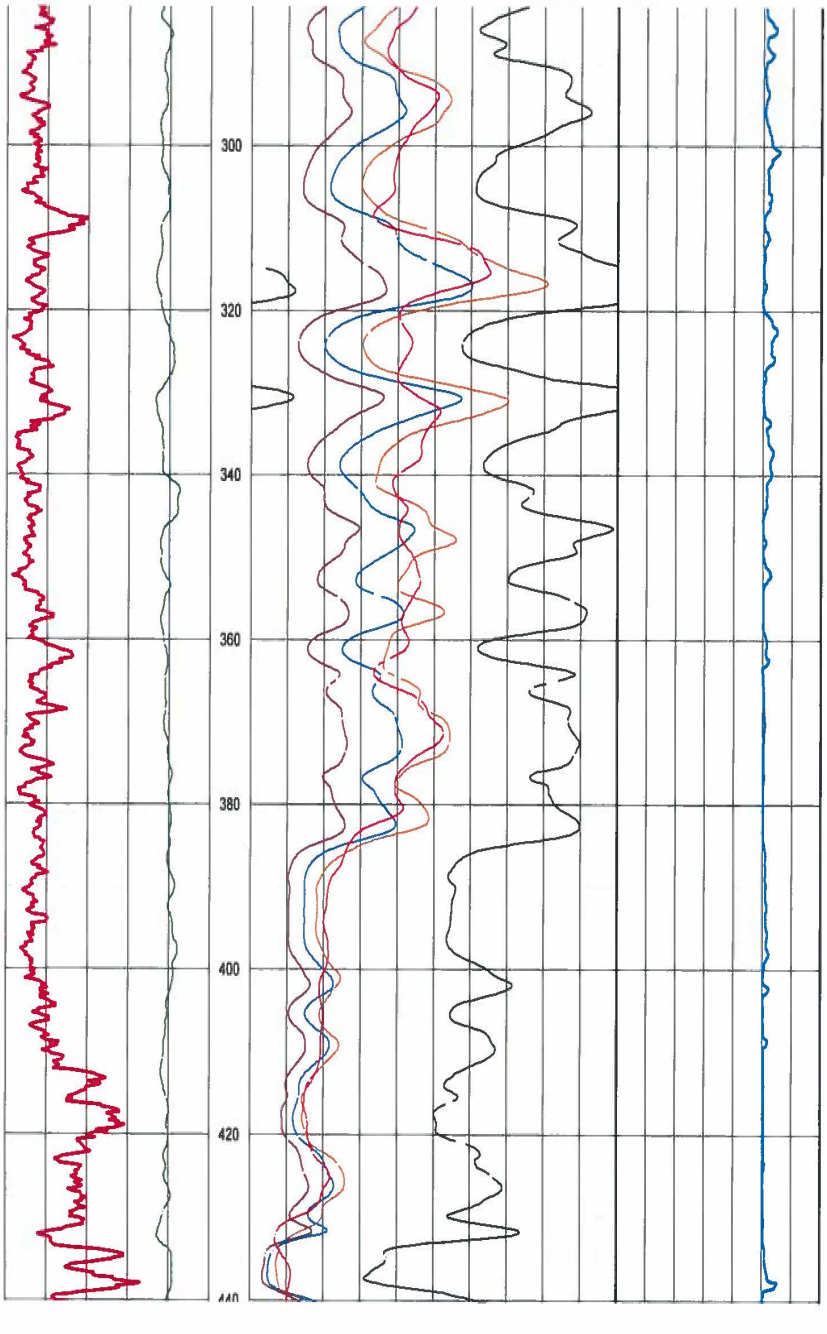
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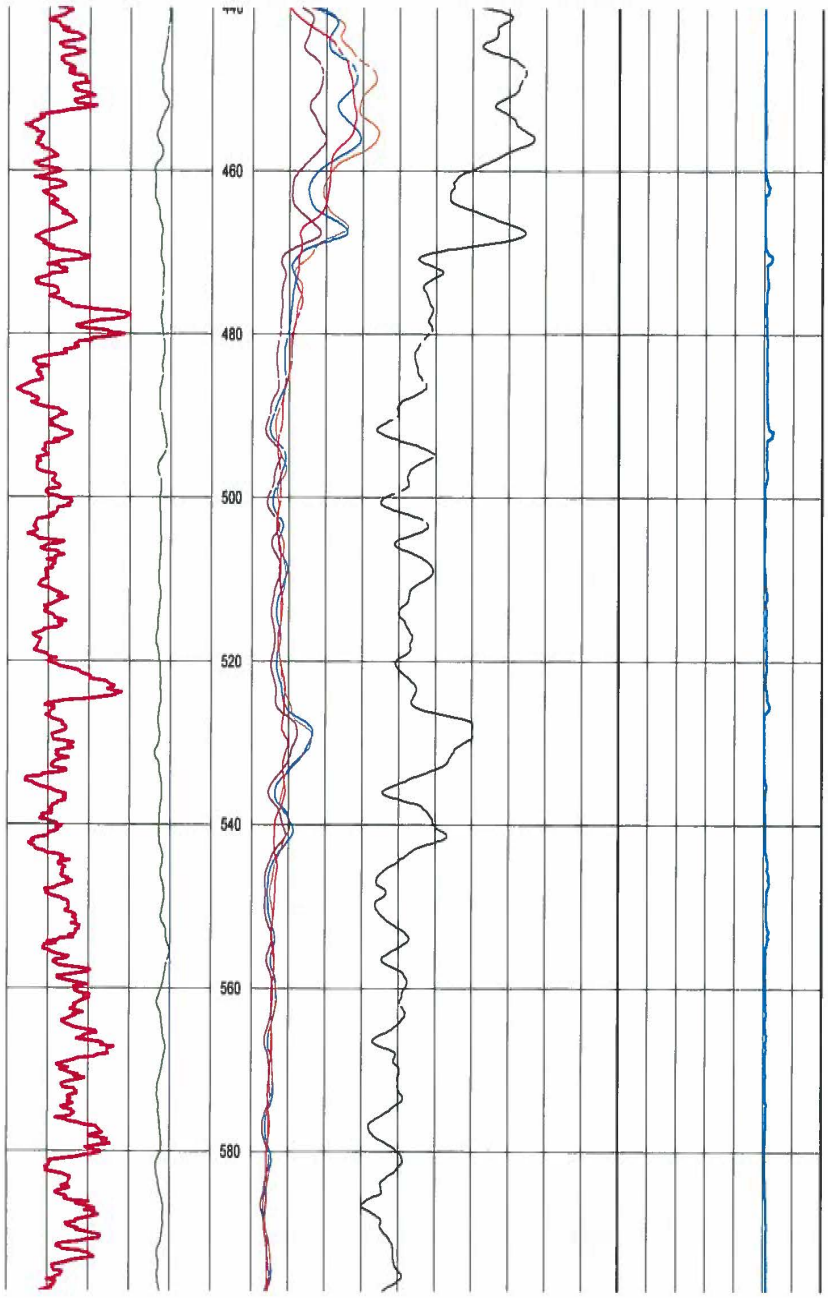
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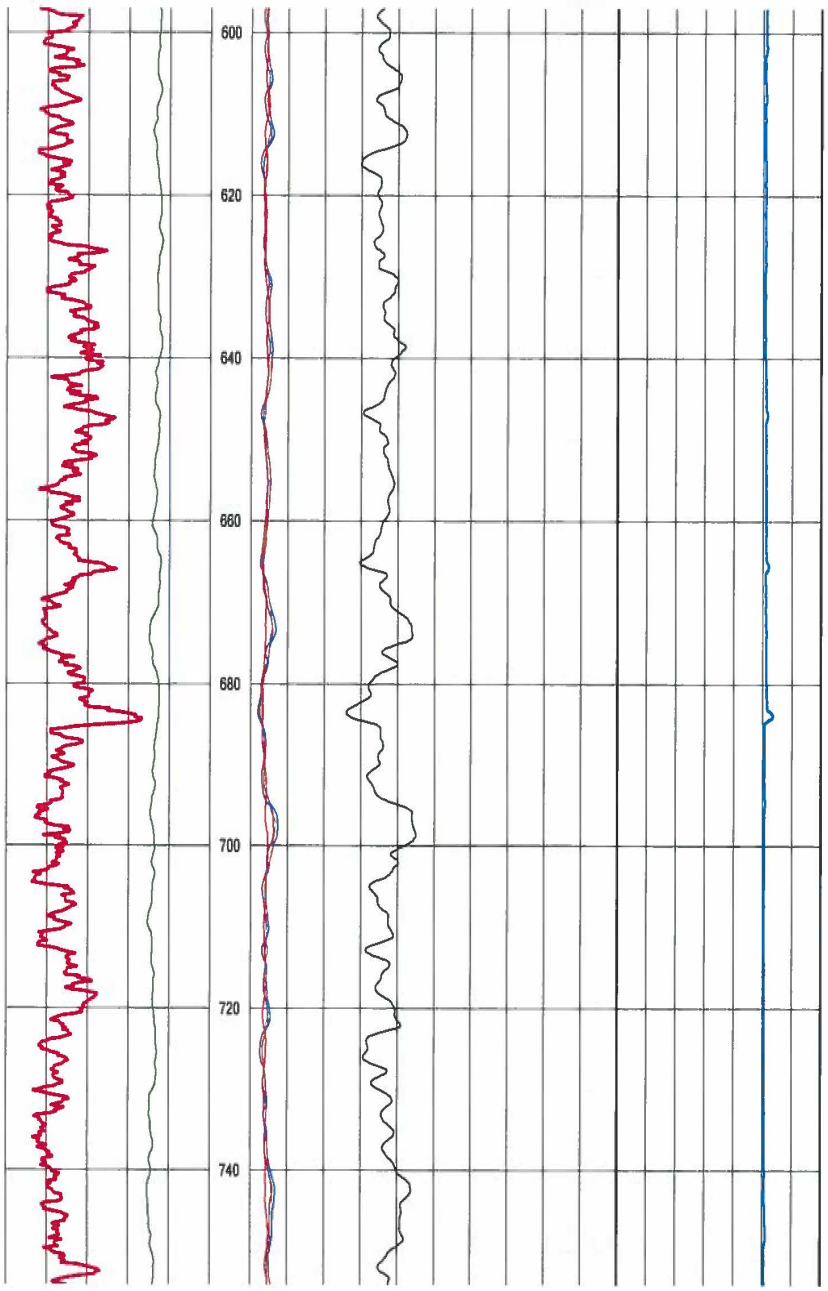
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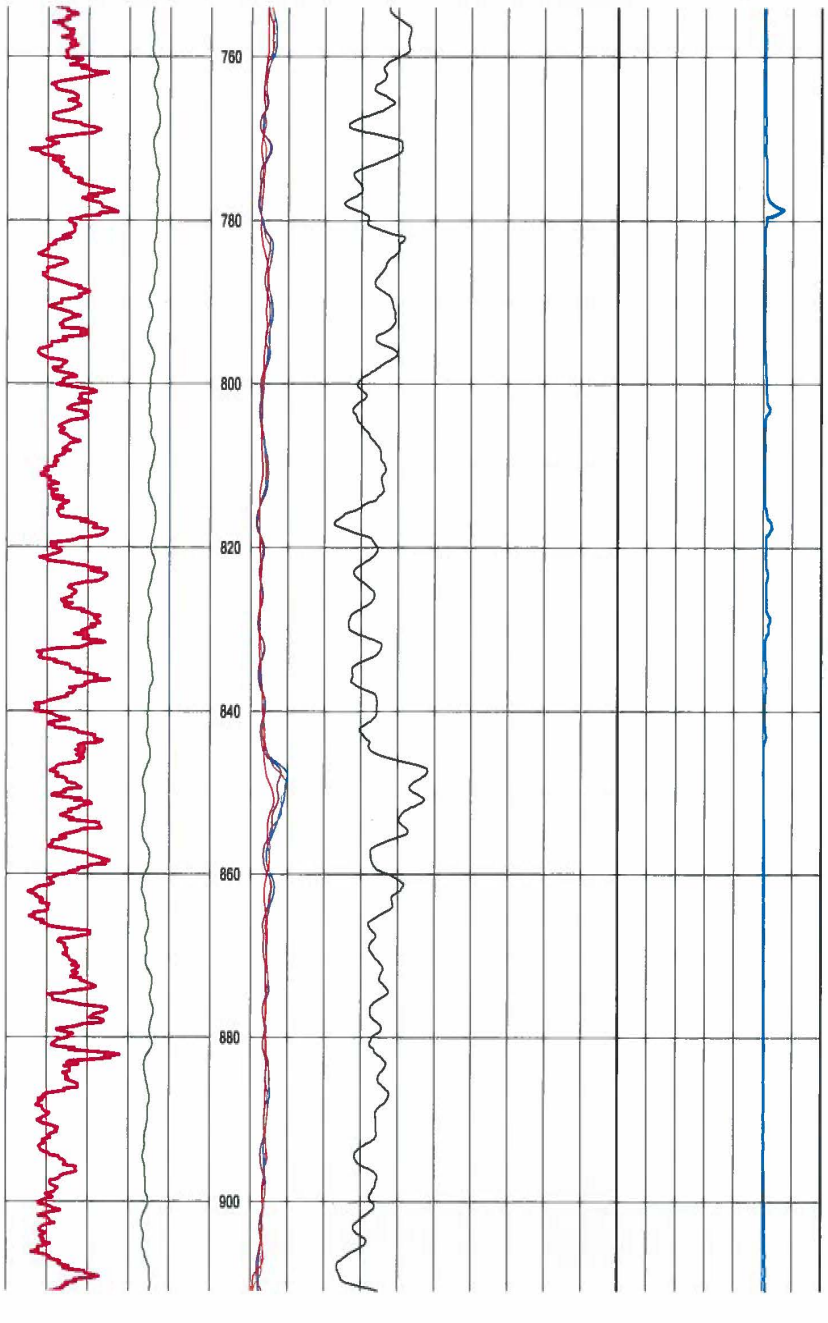
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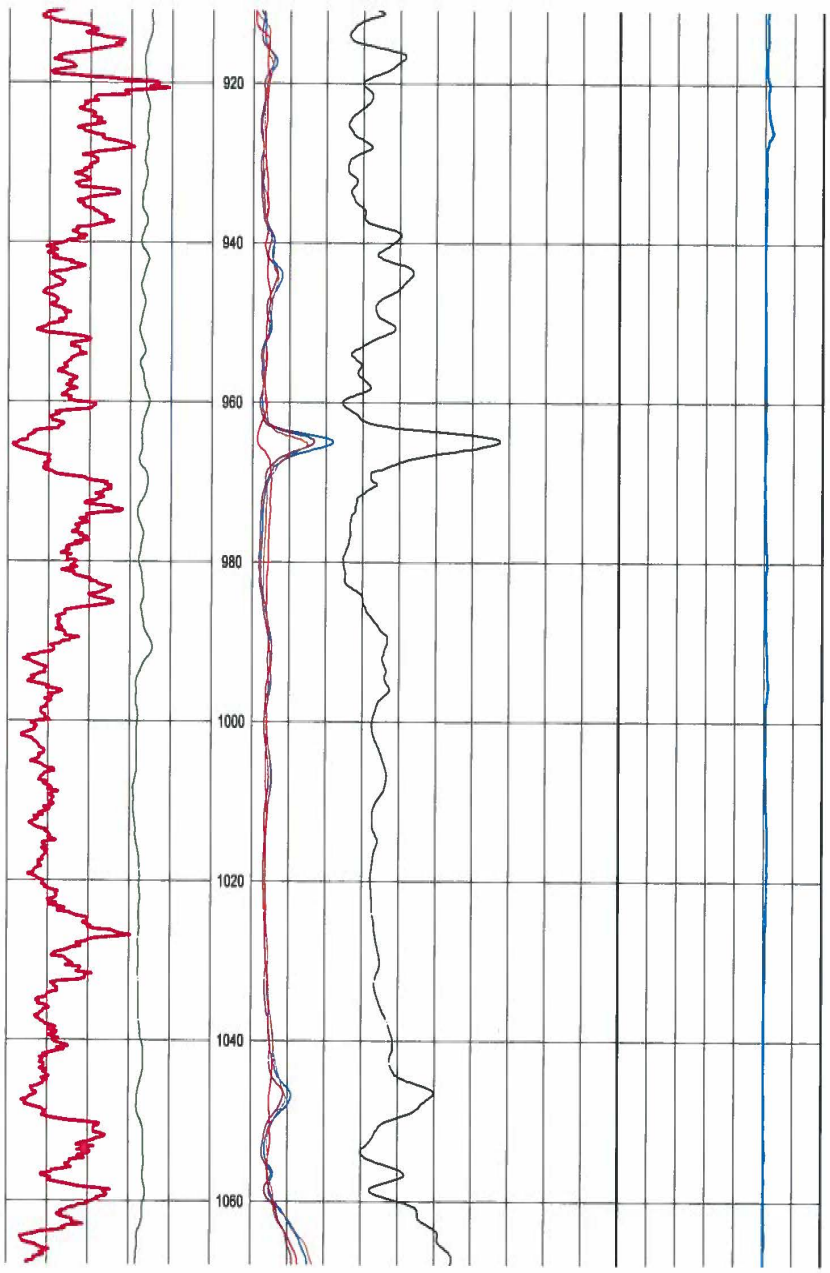
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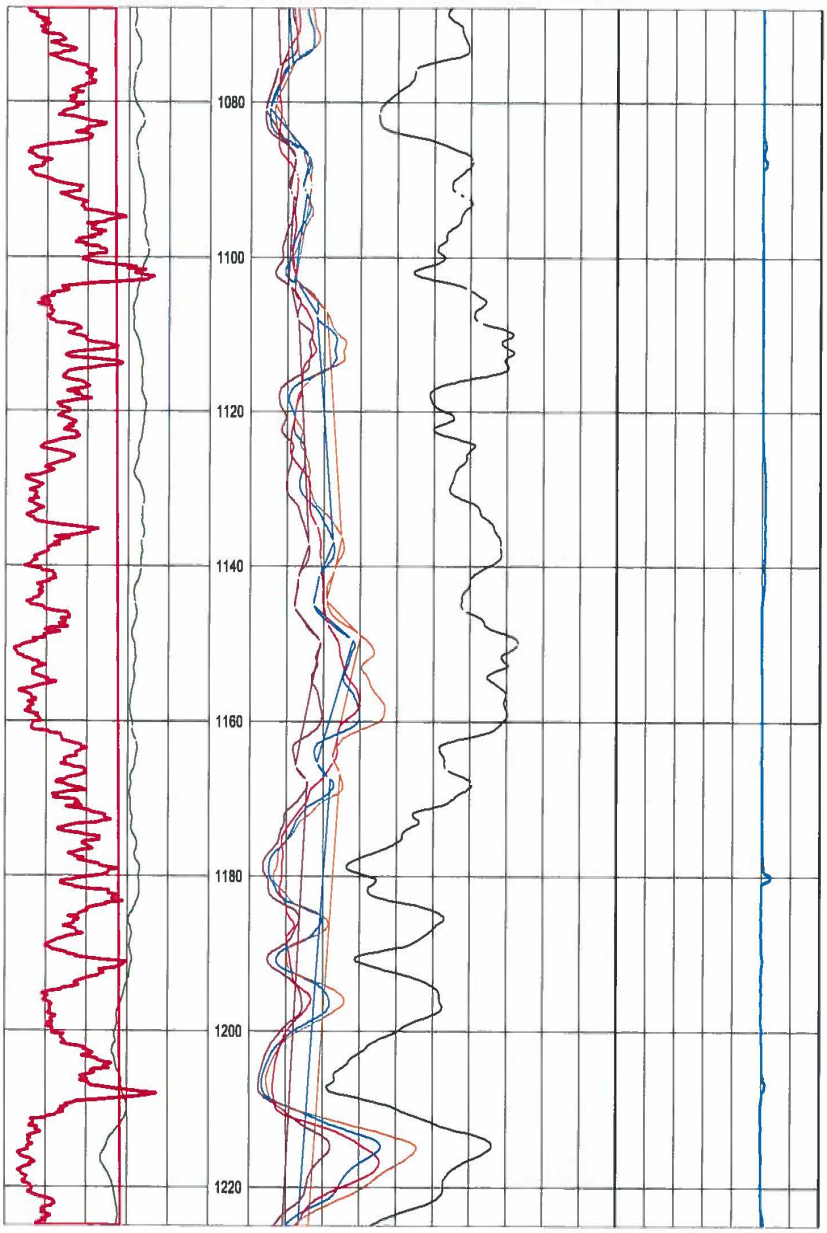
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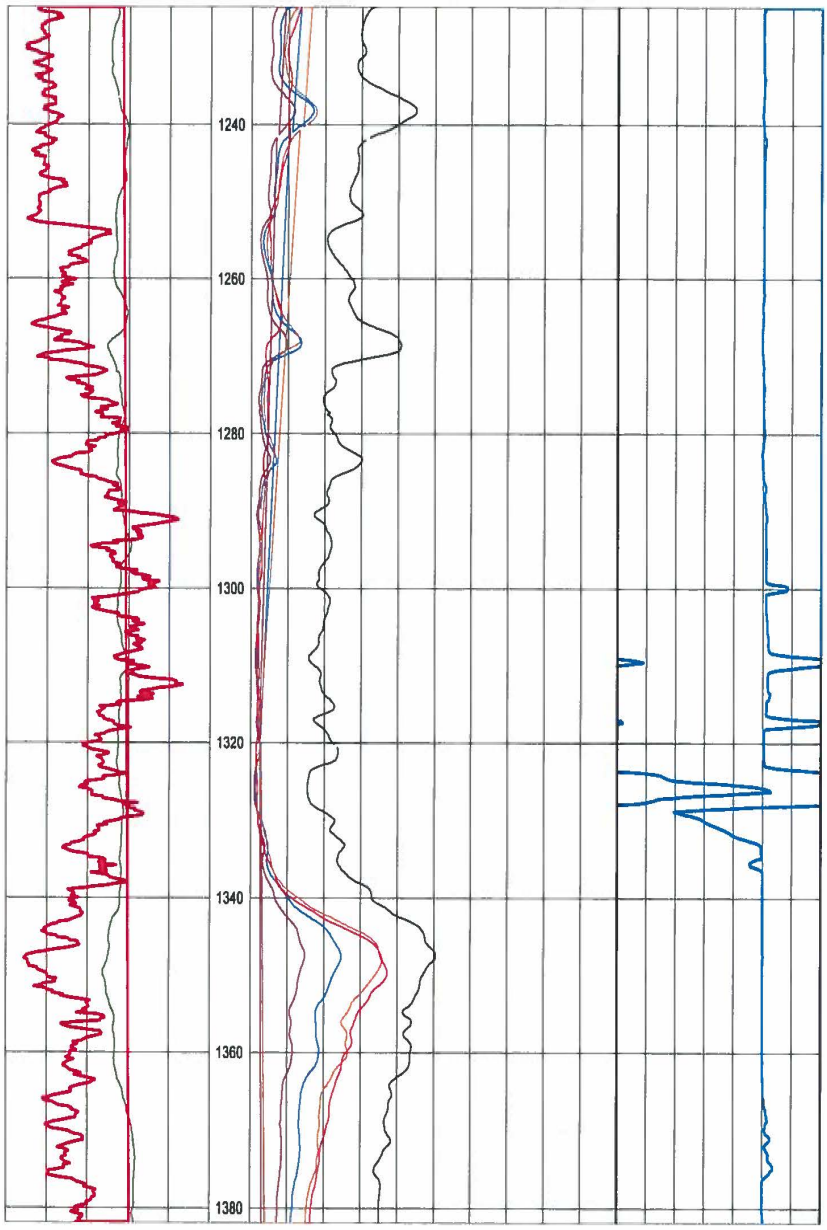
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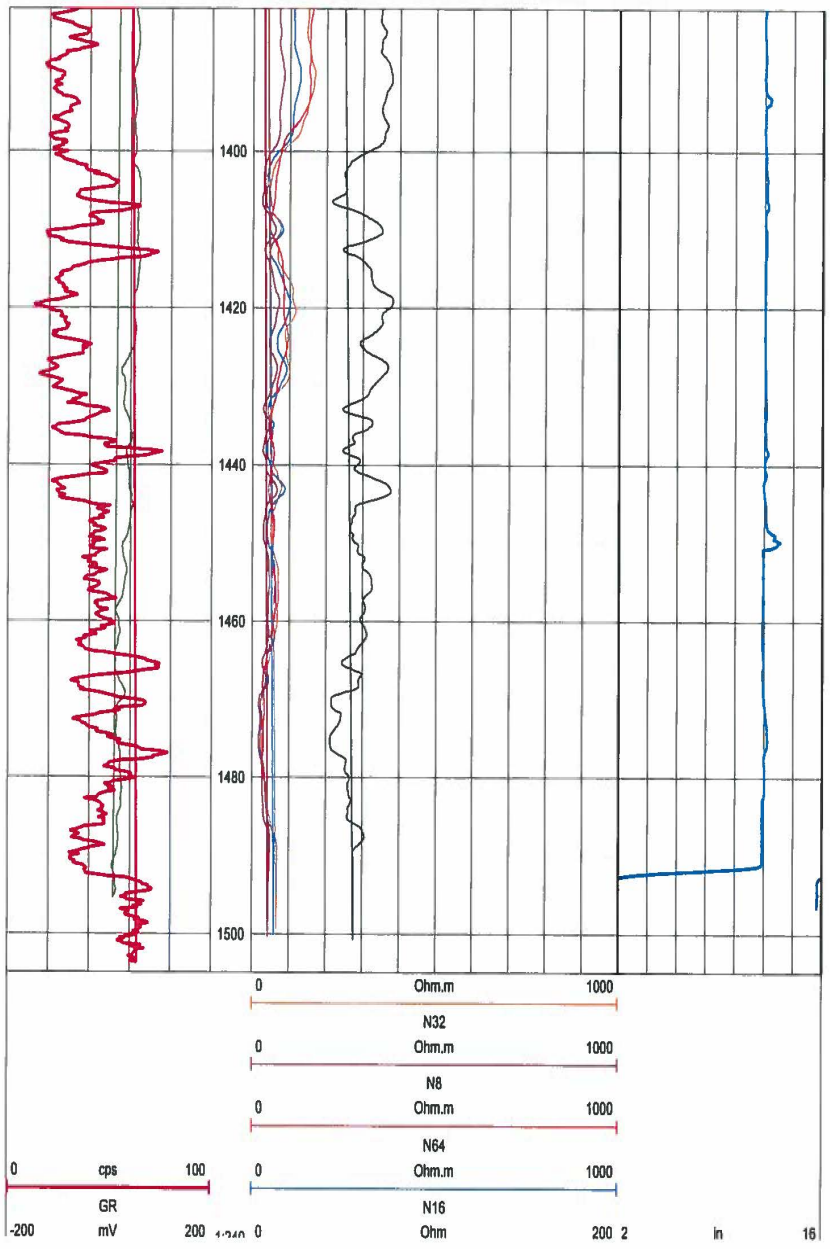
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-200
mV
200
1:240
0
Ohm
200
2
in
16

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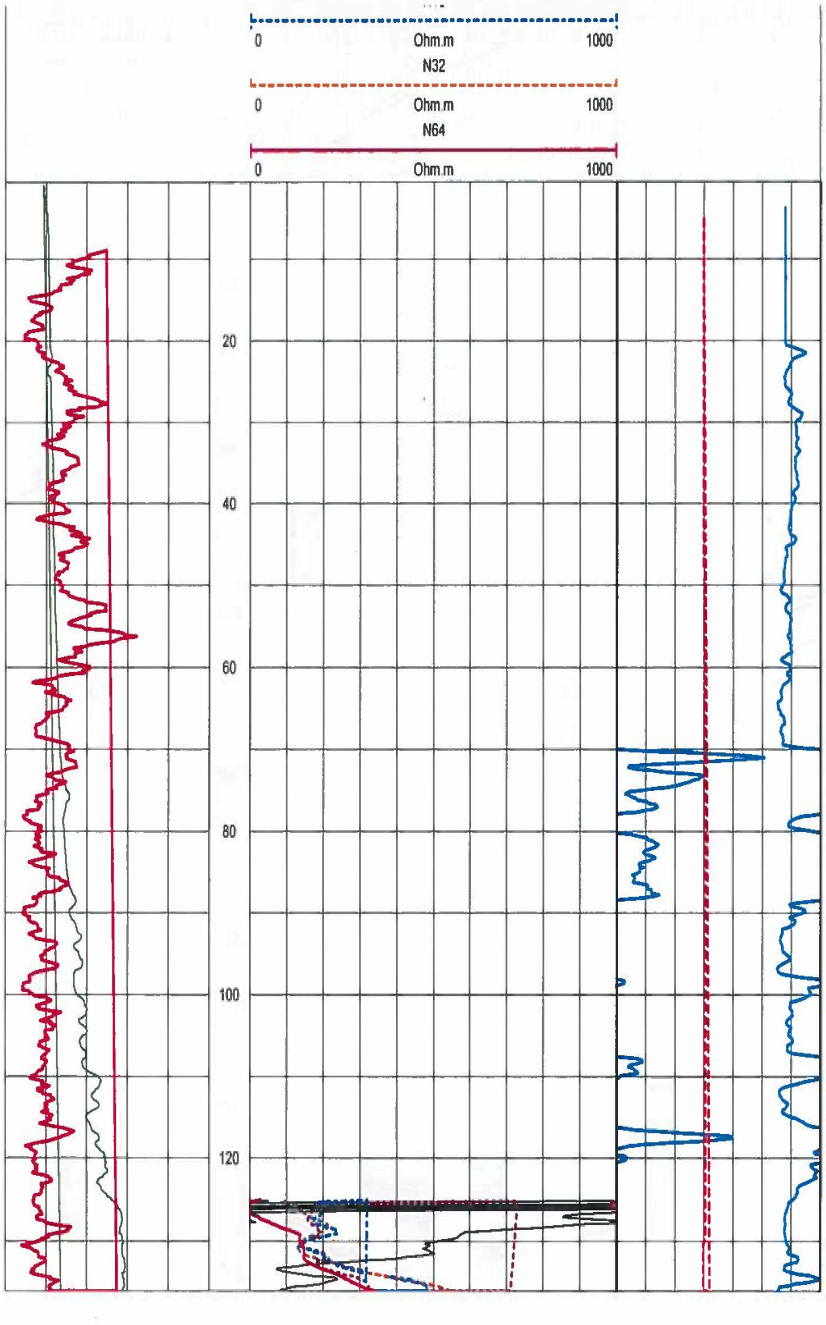
512-798-1888

Borehole:	Bliss Spillar #3
Logs:	Gam, Res, SP, SPR

Project:	Bliss Spillar	**Date:**	09/11/2019
Client:	Bee Cave Drilling	**County:**	Hays
Location:	30.1310 -97.8615	**State:**	TX

Borehole Data

Contractor:	Bee Cave Drilling	**Drilled TD (ft):**	1535'
Elevation:	711'	**Logged TD (ft):**	1531'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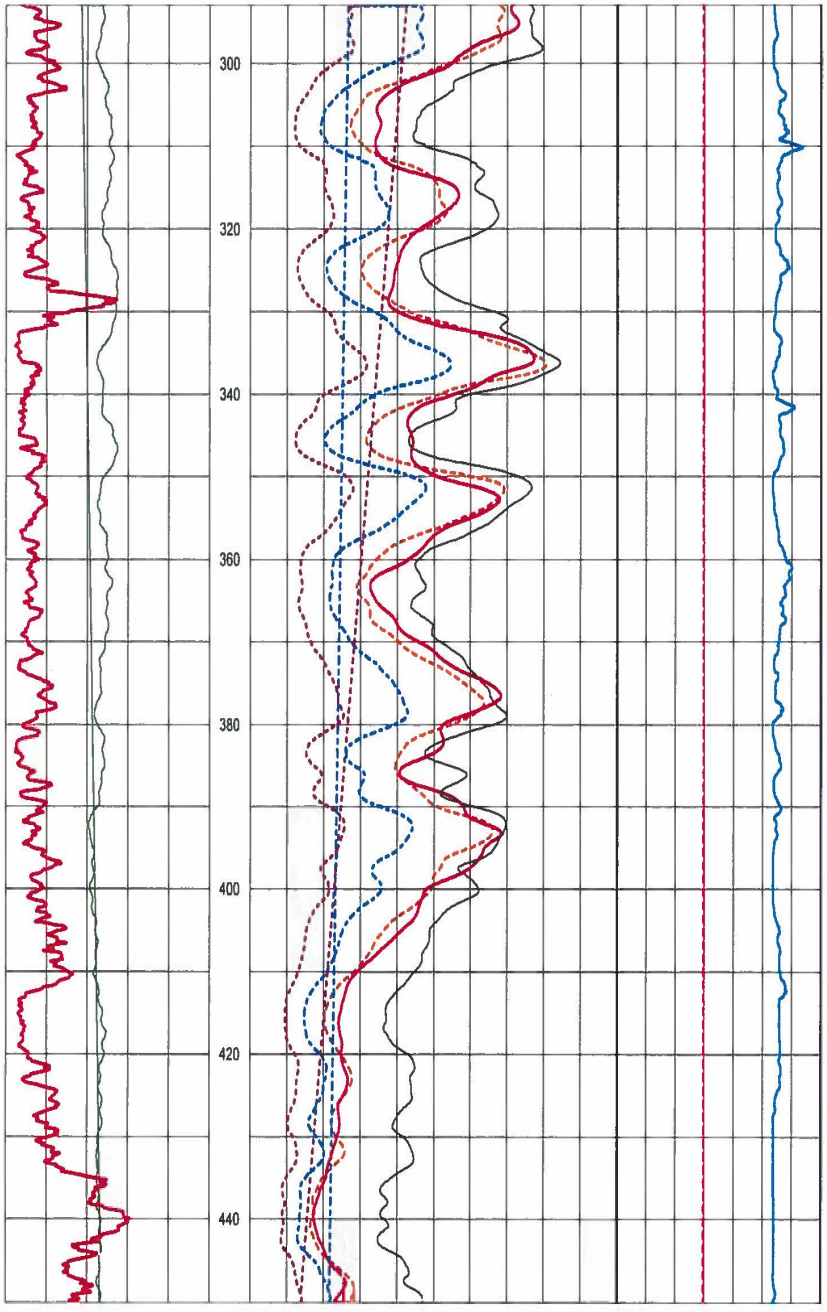
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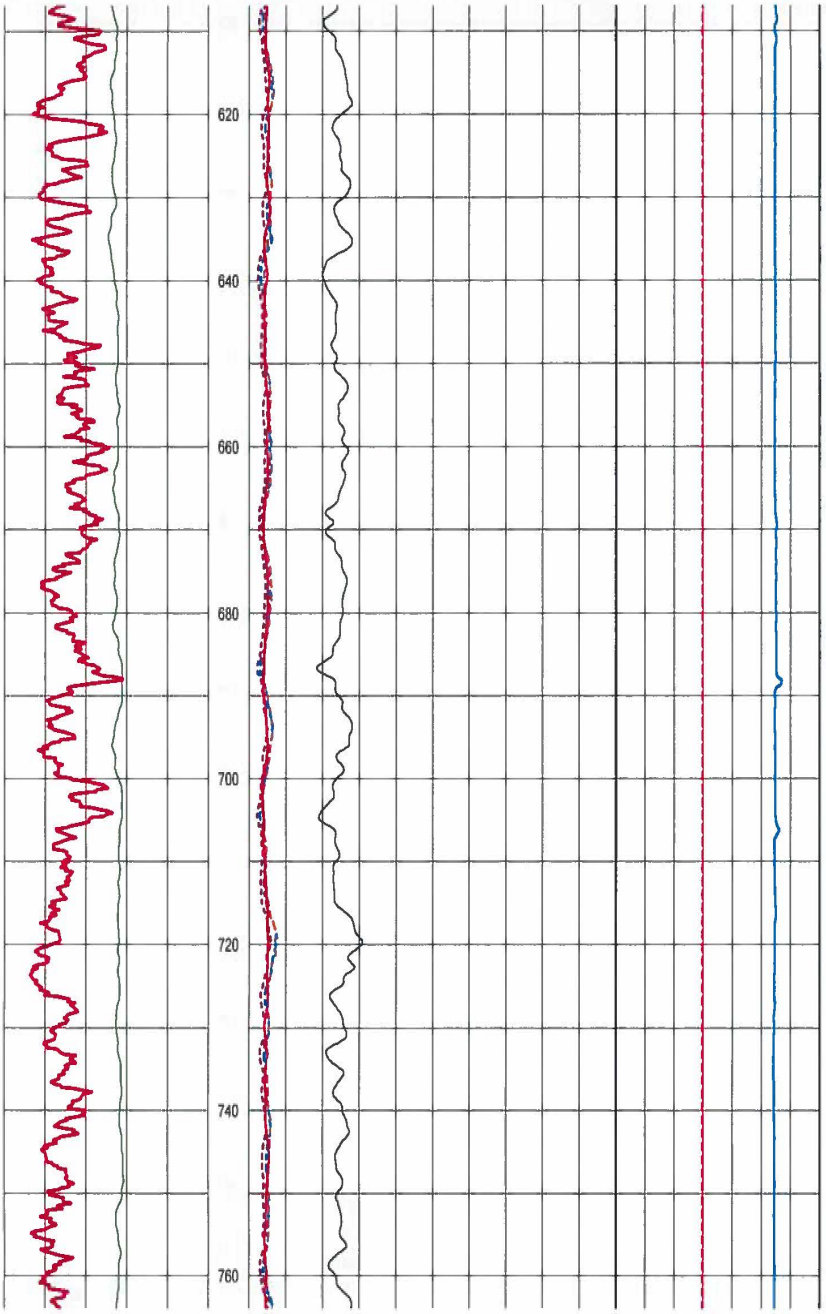
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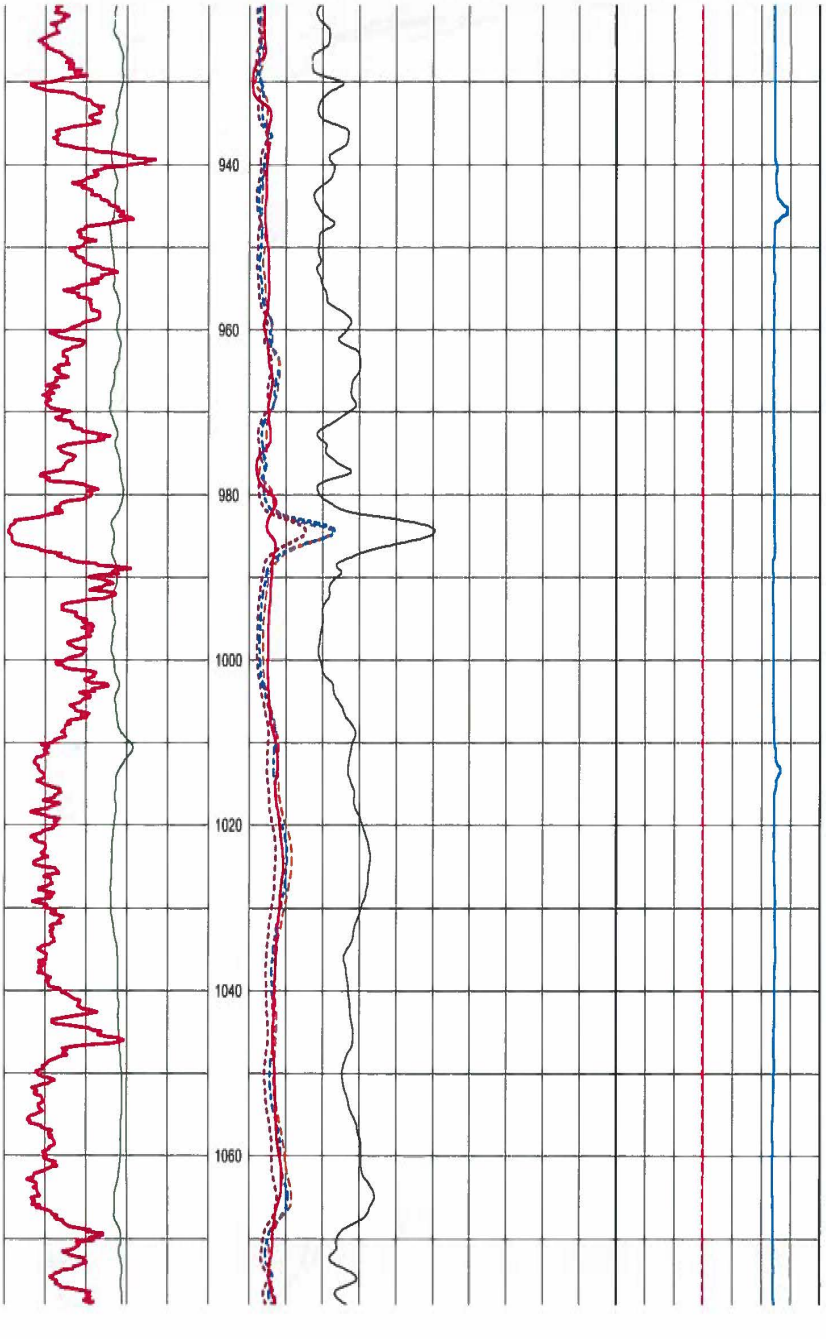
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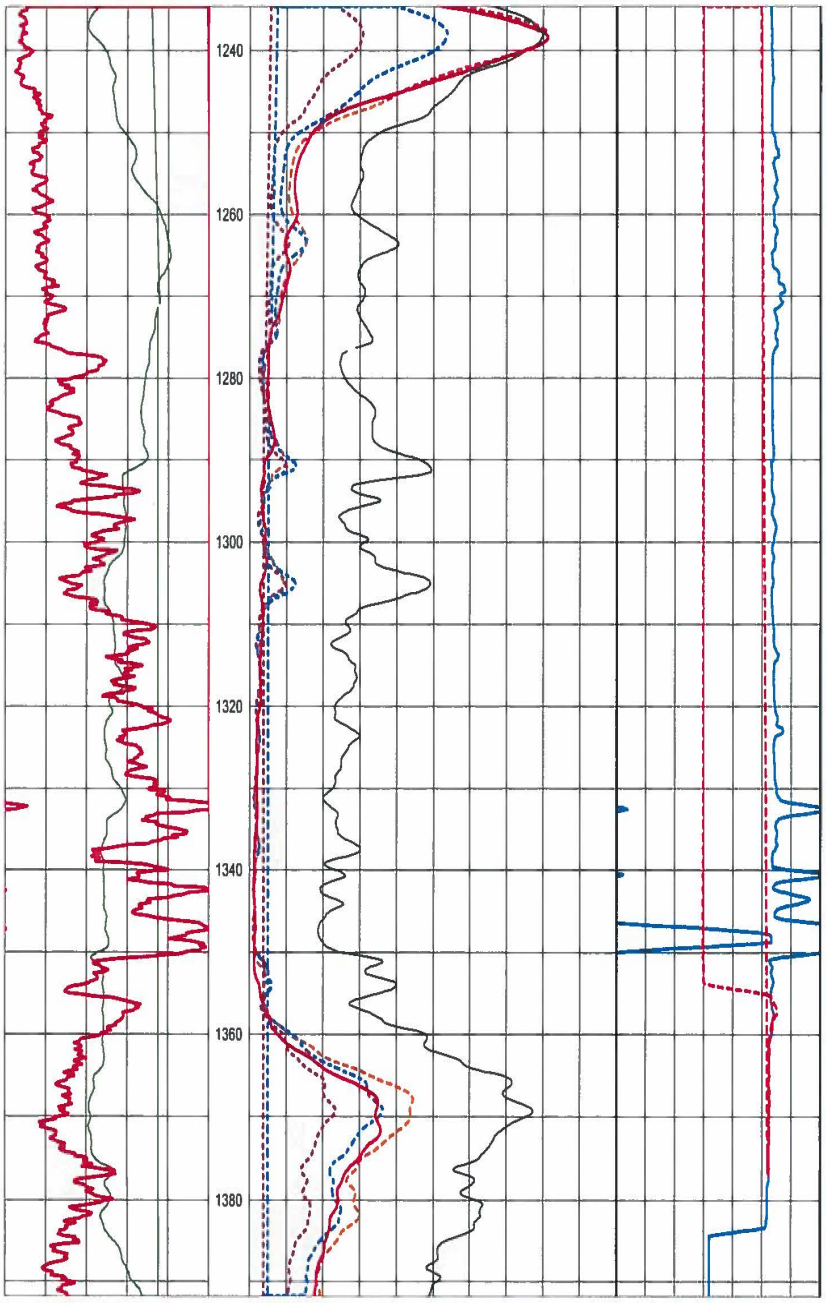
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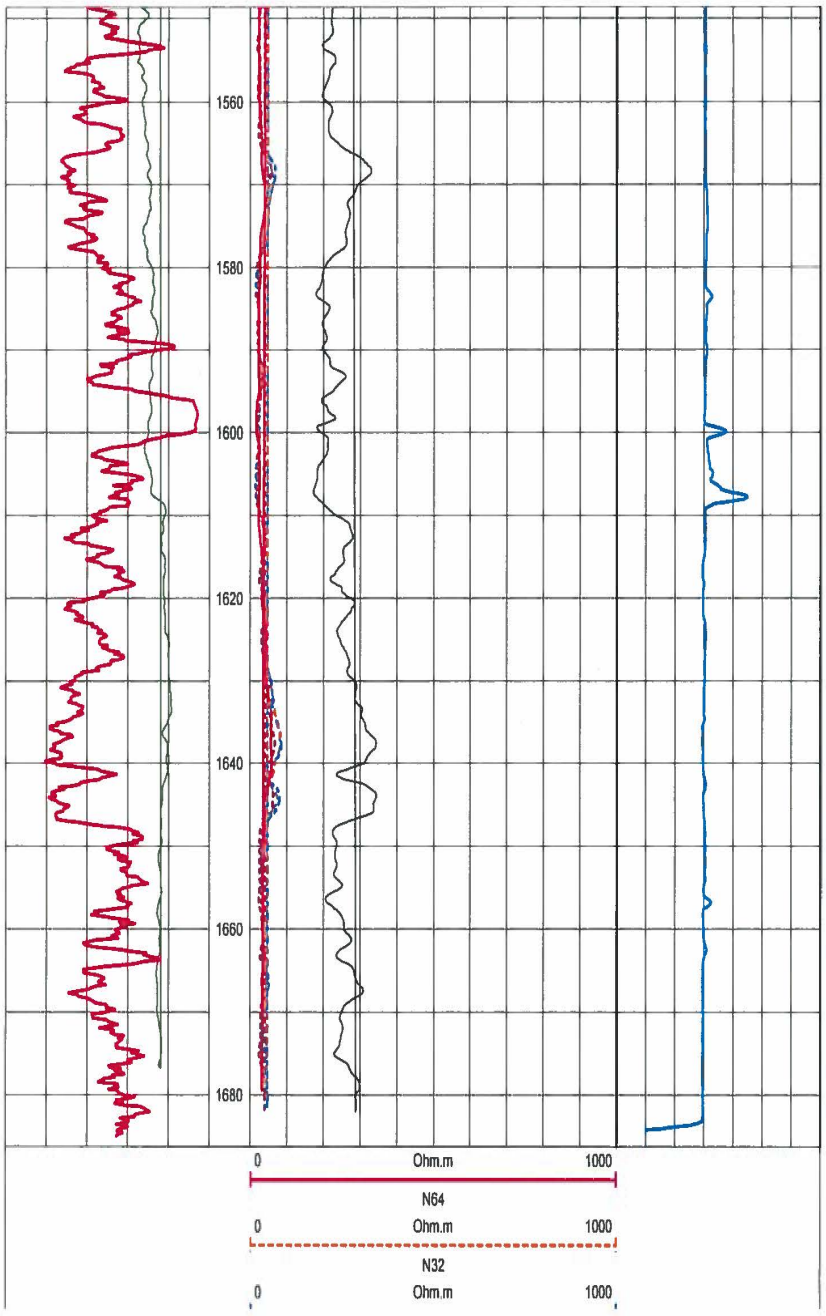
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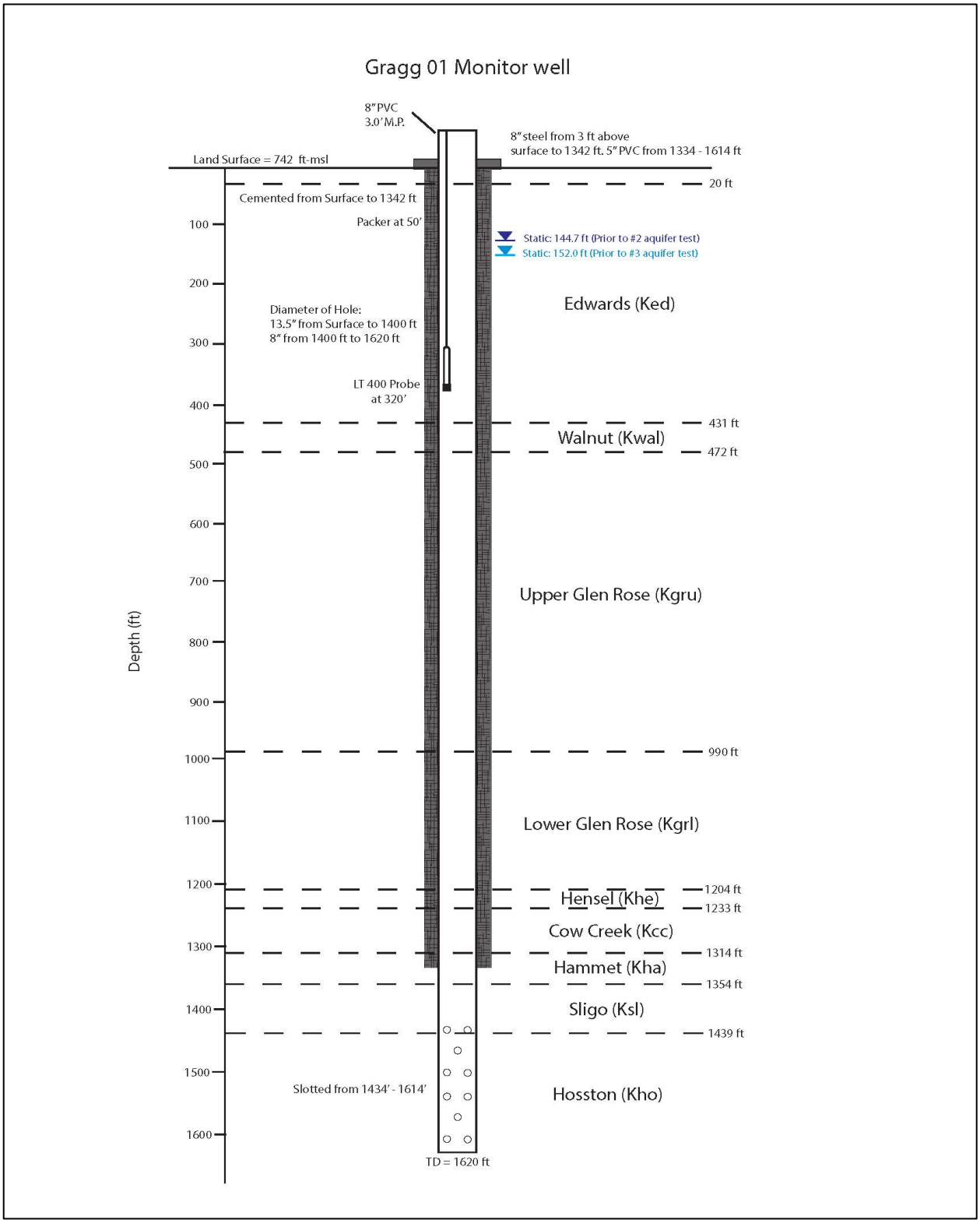
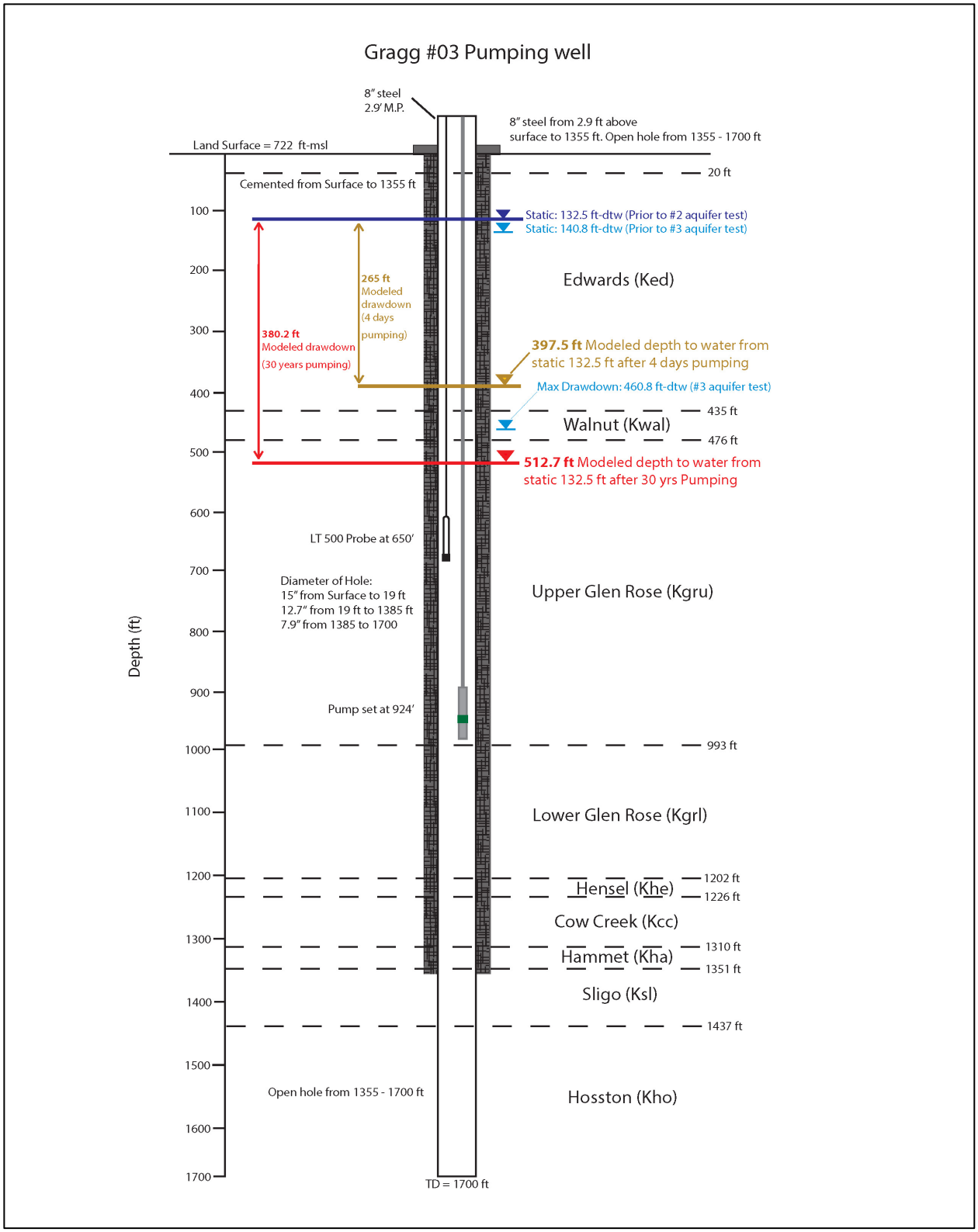
APPENDIX C: Well Schematics (Wells #1 and #3)



Schematic of Gragg #1 Lower Trinity Well construction and stratigraphy. Stratigraphic picks made from a geophysical log. Gragg #1 was used only as an observation well. Static water level is shown in ft-dtw.



Schematic of Gragg #3 well construction and stratigraphy with modeled water levels for 4-day and 30-yr pumping scenarios. Stratigraphic picks made from a geophysical log. Actual measured drawdown in well during #3 aquifer test was 460.8 ft-dtw.

APPENDIX D: Aquifer Test Work Plan

Barton Springs
Edwards Aquifer
CONSERVATION DISTRICT

Proposed Work Plan for the Lower Trinity Aquifer Gragg Well Field, Hays County, Texas

October 8, 2019

The District proposes to support the collection of data from an aquifer test for the Lower Trinity Aquifer. The Lower Trinity Aquifer is presently an underutilized groundwater resource and may be an alternative water supply for the area. In addition, the Lower Trinity may be a good candidate for future Aquifer Storage and Recovery projects. The Aquifer Science Team views this testing as an important evaluation and characterization study. Few Lower Trinity Aquifer wells exist within the BSEACD and very little is known about the hydraulic properties of the aquifer. Leveraging the "well testing" that was planned as part of the drilling of the test wells, we suggest that the well owner (Bill Walters) and the District would both gain valuable information from a prolonged aquifer test following the District's Aquifer Test guidelines.

Aquifer Science staff propose to collect aquifer test data (continuous water levels), periodic water quality samples, and periodic pumping rate measurements during testing. This workplan would satisfy the District's Aquifer Test guidelines for a given volume tested.

Figure 1. *Location of wells. Gragg #1 has a state well number 58-50-755.*

Pumping Duration and Pumping Rate

This testing assumes that two wells, Gragg #2 and Gragg #3, will be pumped sequentially (not simultaneously). This test could be conducted to inform or support future production permit requests for this well field. The District issues permits for an annual volume that is based on nonspeculative demand estimates and aquifer testing evaluations. The well owner has indicated a potential future demand of 200 MGY from the Gragg well field, which is the assumed testing target for this test.

If this were a pumping permit request, the aquifer test would be designed to pump a minimum of three times the daily equivalent of the requested annual permitted volume. Given the target volume of 200 MGY and an assumed pumping rate of 150 gpm, each pumping well would need to be pumped for 96 hours (4 days) (**Table 1**).

Table 1. Illustration showing how the duration of an aquifer test is determined from the requested permit amount and the pumping rate capacity of the pump.

	Annual volume (gal)	Gal/d	Target Test Volume (3x Gal/d)
Target volume	200,000,000	547,945	1,643,836

Aquifer Test

well	Estimated GPM	Pumping Time (hrs)	Test Volume/well (gallons)
Gragg 1			-
Gragg 2	150	96	864,000
Gragg 3	150	96	864,000
		Test target volume	**1,728,000 gallons**

***Assume 2 wells to be tested.**

****estimated pumping rate of 150 gpm**

The test will be a constant-rate test, which we assume to be pumped at a rate of about 150 gallons per minute based on communications with Kevin Langford of Bee Caves Drilling. Staff from the driller or Walters will be responsible for maintaining the pumping rate and duration within each well. In addition, recovery of the pumping well should reach 90% prior to removing the pump and starting the next testing phase (this is likely to be 4 to 6 hours based on Gragg #1).

The pumping rate will need to be measured periodically throughout the test, especially if a change in pumping rate is noted or the pump is adjusted. Measurements need to be made with a calibrated meter provided by the driller. The District may also make periodic flow measurements at the outflow to verify pumping rates.

The driller or Walters staff will also be responsible for containing or redirecting produced waters towards a beneficial purpose where possible (i.e. irrigating pastures, trees, landscapes).

Water-Level Data

Prior to the start of the test, District staff will install absolute (non-vented) pressure transducers in each of the two observation wells. A gauged (vented) pressure transducer with vented cable will be used in the pumping well. We assume a 1 inch tremie pipe will be installed in the pumping well to an adequate depth. District staff will collect data from the transducers periodically. The sample rate will be set at 1 minute for the pumping well, with observation wells set at a sample rate of a maximum of 15 minutes. Periodic manual measurements will be made throughout the testing.

After the aquifer testing, we would like to leave a pressure transducer within the Gragg #1 well to continue collecting water-level data. District staff would download the data quarterly.

Collecting the long-term data would not change the use or limit the well owner's future options for the well.

Water Quality

District staff will make periodic field measurements of temperature, conductivity, and pH during the test. At the start and end of pumping for each pumped well a sample will be collected and submitted to the lab for analysis of TDS. Other samples may be collected at differing time periods.

Communication and Access

District staff will need access to the site during normal working hours; overnight measurements will not be needed. District and driller or Walters staff will need to communicate actions and different activities such as start and stop of pumping, or other changes.

Data Delivery and Analyses

The data collected by the District will be in electronic form and will be provided to the well owner. The District will also analyze the data to calculate aquifer parameters and will document the results in a technical memorandum, which will also be made available to the well owner.

This aquifer-test data collection is a significant portion of the effort and expense required to perform an aquifer test that supports a production permit application. If this proposed test is conducted at a high rate of pumping for a sufficient period of time (**Table 1**), a later aquifer test will not be required for the permit application for this well field. If a permit application is made later, these data and results could be submitted as part of an overall hydrogeologic report submitted by a qualified geoscientist or engineer. The hydrogeologic report would need to follow the guidelines described in the District's Aquifer Test Guidelines.

Brian A. Smith, Ph.D., P.G.

Brian B. Hunt, P.G.

Vanessa Escobar

APPENDIX E: Water quality lab results (Wells #2 and #3)

Environmental Laboratory Services
The Solution Lab

LCRA Environmental Laboratory Services
3505 Montopolis Drive
Austin, TX 78744
Phone: (512) 730-6022
Fax: (512) 730-6021

December 4, 2019

Justin Camp
BSEACD
1124 Regal Row
Austin, TX 78748
jcamp@bseacd.org

RE: Final Analytical Report Q1973176

Attn: Justin Camp

Enclosed are the analytical results for sample(s) received by LCRA Environmental Laboratory Services. Results reported herein conform to the most current NELAP standards, where applicable, unless otherwise narrated in the body of the report. This final report provides results related only to the sample(s) as received for the above referenced work order.

Thank you for selecting ELS for your analytical needs. If you have any questions regarding this report, please contact us at (512) 730-6022. We look forward to assisting you again.

Authorized for release by:

Dale Jurecka
Account Manager
dale.jurecka@lcra.org

NELAP ACCREDITED TNI LABORATORY

Enclosures:

Environmental Laboratory Services
The Solution Lab

LCRA Environmental Laboratory Services
3505 Montopolis Drive
Austin, TX 78744
Phone: (512) 730-6022
Fax: (512) 730-6021

Analytical Results

Lab ID: Q1973176001 Date Received: 10/22/2019 16:09 Matrix: Drinking Water
Sample ID: GRAGG 2 Date Collected: 10/22/2019 09:57 Sample Type: SAMPLE
Project ID: NEW WELL BSEACD

Parameter	Results	Units	MRL	LOD		DF	Prepared	By	Analyzed	By	Qual
ALKALINITY (SM2320B, Alkalinity)											
Phenolphthalein Alkalinity	0.00	mg/L	0.00	0.00		1			10/25/19 00:00	ML	*
Hydroxide Alkalinity	0.00	mg/L	0.00	0.00		1			10/25/19 00:00	ML	*
Bicarbonate Alkalinity	259	mg/L	0.00	0.00		1			10/25/19 00:00	ML	*
Carbonate Alkalinity	0.00	mg/L	0.00	0.00		1			10/25/19 00:00	ML	*
Total Alkalinity (CaCO3)	259	mg/L	20.0	20.0		1			10/25/19 00:00	ML	*
INORGANICS (E200.7 Prep/E200.7 Metals, Trace Elements)											
Calcium Total	73.8	mg/L	0.200	0.0700		1	10/24/19 11:08	ME	10/28/19 14:09	FM	*
Iron Total	0.497	mg/L	0.0500	0.0200		1	10/24/19 11:08	ME	10/28/19 14:09	FM	
Sodium Total	43.5	mg/L	0.200	0.0700		1	10/24/19 11:08	ME	10/28/19 14:09	FM	
INORGANICS (E200.8, ICP-MS Prep/E200.8, ICP-MS)											
Aluminum Total	1.06	mg/L	0.0500	0.0200		10	10/24/19 11:17	ME	10/25/19 10:12	FO	
Arsenic Total	<0.00100	mg/L	0.00100	0.0004	0.01	1	10/24/19 11:17	ME	10/25/19 09:27	FO	
Copper Total	<0.00100	mg/L	0.00100	0.0004	1	1	10/24/19 11:17	ME	10/25/19 09:27	FO	
Lead Total	0.00216	mg/L	0.00100	0.0004	0.015	1	10/24/19 11:17	ME	10/25/19 09:27	FO	
Manganese Total	0.00657	mg/L	0.00100	0.0004		1	10/24/19 11:17	ME	10/25/19 09:27	FO	
Zinc Total	0.352	mg/L	0.00500	0.0020		1	10/24/19 11:17	ME	10/25/19 09:27	FO	
INORGANICS (E2340B, Hardness Calc.)											
Hardness, Calcium	184	mg/L				1			10/28/19 15:26	CW	
INORGANICS (E300.0, Anions)											
Chloride	32.8	mg/L	1.00	0.500		1			10/23/19 09:51	ML	
Fluoride	1.67	mg/L	0.0100	0.0050	4	1			10/23/19 09:51	ML	
Nitrite (as N)	<0.0100	mg/L	0.0100	0.0050	1	1			10/23/19 09:51	ML	
Nitrate (as N)	<0.0100	mg/L	0.0100	0.0050	10	1			10/23/19 09:51	ML	
Sulfate	161	mg/L	5.00	2.50		5			10/23/19 11:11	ML	
TOTAL DISSOLVED SOLIDS (SM2540C, TDS)											
Total Dissolved Solids(TDS)	559	mg/L	25.0	10.0		10			10/25/19 11:01	ERR	
Total Coliform by Colilert (SM9223, IDEXX)											
Residual Chlorine	<0.5	mg/L				1			10/22/19 16:29	PJO	*
Total Coliform	Absent	P/A	1.00	1.00		1			10/22/19 16:29	PJO	
Ecoli	Absent	P/A	1.00	1.00		1			10/22/19 16:29	PJO	
pH (SM4500-H+B, pH @ 25ºC)											
pH	7.90	pH	0.00	0.00		1			10/25/19 08:04	ML	*
Temperature	20.8	C				1			10/25/19 08:04	ML	*

Environmental Laboratory Services
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Austin, TX 78744
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Fax: (512) 730-6021

December 4, 2019

DANA WILSON
BARTON SPRINGS - EDWARD AQUIFER CONSERVATION DISTRICT
1124 REGAL ROW
AUSTIN, TX 78748

RE: Final Analytical Report Q1974421

Attn: DANA WILSON

Enclosed are the analytical results for sample(s) received by LCRA Environmental Laboratory Services. Results reported herein conform to the most current NELAP standards, where applicable, unless otherwise narrated in the body of the report. This final report provides results related only to the sample(s) as received for the above referenced work order.

Thank you for selecting ELS for your analytical needs. If you have any questions regarding this report, please contact us at (512) 730-6022. We look forward to assisting you again.

Authorized for release by:

Dale Jurecka
Account Manager
dale.jurecka@lcra.org

NELAP ACCREDITED TNI LABORATORY

Enclosures:

Environmental Laboratory Services
The Solution Lab

LCRA Environmental Laboratory Services
3505 Montopolis Drive
Austin, TX 78744
Phone: (512) 730-6022
Fax: (512) 730-6021

Analytical Results

Lab ID: Q1974421001 Date Received: 10/30/2019 12:15 Matrix: Drinking Water
Sample ID: Gragg 3 Date Collected: 10/28/2019 11:55 Sample Type: SAMPLE
Project ID: NEW WELL BSEACD

Parameter	Results	Units	MRL	LOD		DF	Prepared	By	Analyzed	By	Qual
ALKALINITY (SM2320B, Alkalinity)											
Phenolphthalein Alkalinity	0.00	mg/L	0.00	0.00		1			11/01/19 00:00	ME	*
Hydroxide Alkalinity	0.00	mg/L	0.00	0.00		1			11/01/19 00:00	ME	*
Bicarbonate Alkalinity	249	mg/L	0.00	0.00		1			11/01/19 00:00	ME	*
Carbonate Alkalinity	0.00	mg/L	0.00	0.00		1			11/01/19 00:00	ME	*
Total Alkalinity (CaCO3)	249	mg/L	20.0	20.0		1			11/01/19 00:00	ME	*
INORGANICS (E200.7 Prep/E200.7 Metals, Trace Elements)											
Calcium Total	65.0	mg/L	0.200	0.0700		1	11/04/19 14:48	ME	11/05/19 15:12	FM	*
Iron Total	0.217	mg/L	0.0500	0.0200		1	11/04/19 14:48	ME	11/05/19 15:12	FM	
Sodium Total	76.0	mg/L	0.200	0.0700		1	11/04/19 14:48	ME	11/05/19 15:12	FM	
INORGANICS (E200.8, ICP-MS Prep/E200.8, ICP-MS)											
Aluminum Total	<0.00500	mg/L	0.00500	0.0020		1	11/04/19 14:44	ME	11/07/19 11:13	FO	
Arsenic Total	<0.00100	mg/L	0.00100	0.0004	0.01	1	11/04/19 14:44	ME	11/07/19 11:13	FO	
Copper Total	0.00169	mg/L	0.00100	0.0004	1	1	11/04/19 14:44	ME	11/07/19 11:13	FO	
Lead Total	<0.00100	mg/L	0.00100	0.0004	0.015	1	11/04/19 14:44	ME	11/07/19 11:13	FO	
Manganese Total	0.00519	mg/L	0.00100	0.0004		1	11/04/19 14:44	ME	11/07/19 11:13	FO	
Zinc Total	0.399	mg/L	0.00500	0.0020		1	11/04/19 14:44	ME	11/07/19 11:13	FO	
INORGANICS (E2340B, Hardness Calc.)											
Hardness, Calcium	162	mg/L				1			11/06/19 09:09	CW	
INORGANICS (E300.0, Anions)											
Chloride	45.9	mg/L	1.00	0.500		1			10/31/19 06:43	ML	*
Fluoride	1.80	mg/L	0.0100	0.0050	4	1			10/31/19 06:43	ML	*
Nitrite (as N)	<0.0100	mg/L	0.0100	0.0050	1	1			10/31/19 06:43	ML	*
Nitrate (as N)	<0.0100	mg/L	0.0100	0.0050	10	1			10/31/19 06:43	ML	*
Sulfate	169	mg/L	5.00	2.50		5			10/31/19 16:27	FO	
TOTAL DISSOLVED SOLIDS (SM2540C, TDS)											
Total Dissolved Solids(TDS)	568	mg/L	25.0	10.0		10			11/04/19 13:57	ERR	
pH (SM4500-H+B, pH @ 25ºC)											
pH	7.99	pH	0.00	0.00		1			11/07/19 08:32	ME	*
Temperature	21.0	C				1			11/07/19 08:32	ME	*

Sample Comments

Sample Type: SAMPLE

- General Comments for METHOD SM4500-H+B, pH - Defined as a field parameter, measurement must be taken within 15 minutes of collection. Results are provided for information purposes only.

APPENDIX F: Water quality lab results & Isotope Geochemistry Results (Well #1)

Email information for report date:
2/28/18 17:11

B003298

Bee Cave Drilling

Attn: Bee Cave Drilling

185 Angel Fire Drive
Dripping Springs, TX 78620

Happy New Year!

We at ATL appreciate your business and thank you for allowing us to partner in servicing your environmental needs.

Call or email us today at samplingbryan@aqua-techlabs.com for more information or to set up an event.

Sincerely,
June M. Brien
Executive Technical Director

CORPORATE OFFICE
635 Phil Gramm Boulevard
Bryan, TX 77807
Phone: (979) 778-3707
Fax: (979) 778-3193

AQUA-TECH LABORATORIES, INC.

AUSTIN OFFICE
7500 Hwy 71 W, Suite 105
Austin, TX 78735
Phone: (512) 301-9559
Fax: (512) 301-9552

The analyses summarized in this report were performed by Aqua-Tech Laboratories, Inc. unless otherwise noted. Aqua-Tech Laboratories, Inc. holds accreditation from the State of Texas in accordance with TNI and/or through the TCEQ Drinking Water Commercial Laboratory Approval Program.

The following abbreviations indicate certification status:

NEL	TNI accredited parameter.
ANR	Accreditation not required by the State of Texas.
DWP	Accreditation through the TCEQ Drinking Water Commercial Laboratory Approval Program.
INF	Aqua-Tech Laboratories, Inc. is not accredited for this parameter. It is reported on an informational basis only.

Subcontracted data summarized in this report is indicated by "Sub" in the Lab column.

TCEQ DW Lab ID TX 239

General Definitions:

NR	Not Reported.
RPD	Relative Percent Difference.
% R	Percent Recovery.
dry	Results with the "dry" unit designation are reported on a "dry weight" basis.
SQL	The Sample Quantitation Limit is the value below which the parameter cannot reliably be detected. The SQL includes all sample preparations, dilutions and / or concentrations.
Adj MDL	The Adjusted Method Detection Limit is the MDL value adjusted for any sample dilutions or concentrations.
MDL	The Method Detection Limit is the lowest theoretical value that is statistically different from zero for a specific method, taking into account all preparation steps and instrument settings.

All samples are reported on an "as received" basis unless the designation "dry" is added to the reported unit.

Copies of Aqua-Tech Laboratories, Inc. procedures and individual sampling plans are available upon request. Note that samples are collected by Aqua-Tech Laboratories, Inc. personnel unless otherwise noted in the "Sample Collected" field of this report as "Client" or "CLT".

Samples included in this report were received in acceptable condition according to Aqua-Tech Laboratories, Inc. procedures and 40 CFR, Chapter I, Subchapter D, Part 136.3, TABLE II. - *Required containers, preservation techniques, and holding times*, unless otherwise noted in this report.

Record Retention:

All reports, raw data, and associated quality control data are kept on file for 10 years before being destroyed. Any client that would like copies of records must contact Aqua-Tech Laboratories, Inc. no later than six months prior to the scheduled disposal. An administrative fee for retrieval and distribution will apply.

This report was approved by:

June M. Brien, Technical Director

corp@aqua-techlabs.com www.aqua-techlabs.com

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Fax: (512) 301-9552

Analytical Report

Bee Cave Drilling

Report Printed: 2/28/18 17:11

B003298

Gragg Tract Pump Test 1

Collected: 02/01/18 12:30 by CLIENT
Received: 02/01/18 13:11 by Suzanne Rudd

Type: Grab
Matrix: Drinking Water
C-O-C #: 284494

Lab ID# B003298-01	Result	Units	Notes	MDL	Adj MDL	SQL	Lab	Analyzed	Method	Batch	
General Chemistry											
Total Dissolved Solids	**642**	mg/L		25.0	50.00	50.0	Bryan	02/07/18 16:32 BLR	SM2540 C 2011	M084200	NEL
Nitrate as N (NO3N)	**<0.0500**	mg/L			0.02	0.0500	Austin	02/06/18 13:10 MBA	SM4500-NO3-F 2011	[CALC]	NEL
Nitrite as N	**<0.01**	mg/L	J (0.001)	0.001	0.00	0.01	Austin	02/02/18 07:55 MBA	SM4500 NO2- B 2000	M084064	NEL
Nitrate/Nitrite as N	**<0.05**	mg/L		0.02	0.02	0.05	Bryan	02/06/18 13:10 MRB	SM4500-NO3-F 2011	M084124	INF
Total Alkalinity as CaCO3 (pH4.5)	**264**	mg/L		4.00	16.00	16.0	Bryan	02/06/18 14:34 MCP	SM2320 B 2011	M084154	DHP
Fluoride	**1.85**	mg/L		0.02	0.02	0.10	Bryan	02/09/18 12:18 MCP	SM4500-F C 2011	M084282	NEL
pH, Lab	**7.3**	S.U.	Hold-03			N/A	Austin	02/05/18 12:04 KT	SM4500-H+ B 2000	M084102	DHP
Temperature @ pH Analysis	**18.5**	Deg. C				N/A	Austin	02/05/18 12:04 KT	SM2550 B 2000	M084102	ANR
Metals (Total)											
Aluminum	**8.85**	ug/L		0.299	0.31	1.03	Bryan	02/09/18 15:52 PNS	EPA 200.8 R5.4	M084118	NEL
Arsenic	**0.714**	ug/L		0.032	0.03	0.515	Bryan	02/09/18 15:52 PNS	EPA 200.8 R5.4	M084118	NEL
Calcium	**78.3**	mg/L		0.023	0.23	1.02	Bryan	02/14/18 17:12 PNS	EPA 200.7 R4.4	M084229	DHP
Copper	**1.87**	ug/L		0.029	0.03	0.515	Bryan	02/09/18 15:52 PNS	EPA 200.8 R5.4	M084118	NEL
Iron	**0.431**	mg/L		0.002	0.00	0.102	Bryan	02/13/18 17:19 PNS	EPA 200.7 R4.4	M084121	NEL
Lead	**0.786**	ug/L		0.005	0.01	0.515	Bryan	02/09/18 15:52 PNS	EPA 200.8 R5.4	M084118	NEL
Manganese	**4.39**	ug/L		0.108	0.11	0.515	Bryan	02/09/18 15:52 PNS	EPA 200.8 R5.4	M084118	NEL
Sodium	**32.6**	mg/L		0.011	0.11	1.02	Bryan	02/08/18 21:19 PNS	EPA 200.7 R4.4	M084229	NEL
Zinc	**327**	ug/L	MS-01	0.379	0.39	4.12	Bryan	02/09/18 15:52 PNS	EPA 200.8 R5.4	M084118	NEL
Drinking Water Metals (Total)											
Calcium Hardness as CaCO3	**196**	mg/L			0.59	2.55	Bryan	02/14/18 17:12 PNS	EPA 200.7 R4.4	[CALC]	ANR
General Chemistry											
Sulfate as SO4	**182**	mg/L		0.01		3	Sub	02/02/18 14:41 ANA	EPA 300.0	SUB	NEL
Chloride	**19**	mg/L		0.02		3	Sub	02/02/18 14:41 ANA	EPA 300.0	SUB	NEL

Explanation of Notes

A-01	Optional LCSD was outside expected range, causing RPD to be greater than expected. Results accepted on one required passing LCS and sample matrix RPD.
A-01a	Optional LCSD was outside expected range. Results accepted on one required passing LCS.
Hold-03	This parameter was outside of EPA holding at the time the sample was received in the laboratory.
J	Analyte detected below the SQL but above the MDL.
MS-01	The spike recovery was outside acceptance limits for the MS and/or MSD. The batch was accepted based on acceptable LCS and/or LCSD recovery.

Environmental Laboratory Services
The Solution Lab

LCRA Environmental Laboratory Services
3505 Montopolis Drive
Austin, TX 78744
Phone: (512) 730-6022
Fax: (512) 730-6021

BETA Beta Analytic
TESTING LABORATORY

Beta Analytic Inc
4985 SW 74 Court
Miami, Florida 33155
Tel: 305-667-5167
Fax: 305-663-0964
info@betalabservices.com

ISO/IEC 17025:2005-Accredited Testing Laboratory

Dale Jurecka — Report Date: 9/23/2019

LCRA-Environmental Laboratory Services (EL-101) — Material Received: 9/9/2019

Sample Data	pMC	$F^{14}C$	d13C o/oo	d18O o/oo	dD o/oo
Beta - 536533	< 0.44 pMC	< 0.0044	-0.50	-4.64	-24.46
Q1960710001					
AMS-Standard delivery					**68-08-206**

MATERIAL/PRETREATMENT: (water DIC) acidify-gas strip

COMMENTS: The equivalent "Apparent" radiocarbon age to the reported pMC/fMDN values is ~ > 43500 BP BP (not adjusted for any hydro-geochemical effects on meteoric water 14CO2). Given the complex nature of groundwater DIC14 chemistry, duplicate measurements within 1-2 pMC are reasonable for a single water sample. For very low DIC concentration waters (< 20 mg/L HCO3) DIC14 and waters with complex organic chemistry, results can vary significantly outside of this expectation.

Beta - 536534	0.60 +/- 0.04 pMC	0.0060 +/- 0.0004	-4.80	-4.58	-24.36
Q1960710002					
AMS-Standard delivery					**58-50-755**

MATERIAL/PRETREATMENT: (water DIC) acidify-gas strip

COMMENTS: The equivalent "Apparent" radiocarbon age to the reported pMC/fMDN values is ~ 41100 BP (not adjusted for any hydro-geochemical effects on meteoric water 14CO2). Given the complex nature of groundwater DIC14 chemistry, duplicate measurements within 1-2 pMC are reasonable for a single water sample. For very low DIC concentration waters (< 20 mg/L HCO3) DIC14 and waters with complex organic chemistry, results can vary significantly outside of this expectation.

```
Client: LCRA ENVIRONMENTAL LAB SERVICES              Purchase Order: Q1960711
Recvd : 19/09/05                          Contact: Dale Jurecka, 512/356-6022
Job#  : 3839                                   3505 Montopolis Dr (f)-6021
Final : 19/11/20          envlab@lcra.org                Austin, TX 78744

Cust  LABEL INFO                JOB.SX  REFDATE QUANT  ELYS     TU      eTU
-------------------------------------------------------------------------------
Q1960711001                    3839.01  190828  1000    275     0.03    0.09 68-08-206
Q1960711002                    3839.02  190828  1000    275    -0.05    0.09 58-50-755
Q1960711003                    3839.03  190828  1000    275    -0.05    0.09 68-08-205
Q1960711004                    3839.04  190829  1000    275     1.46    0.09 57-40-304
-------------------------------------------------------------------------------
```

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 732787 Job #: 42696 IS-64056 Co. Job#:
Sample Name: Q1960713002 Co. Lab#:
Company: LCRA Environmental Lab Services
API/Well:
Container: Plastic Bottle
Field/Site Name: 45324066 **58-50-755**
Location:
Formation/Depth:
Sampling Point:
Date Sampled: 8/28/2019 14:10 Date Received: 9/04/2019 Date Reported: 9/13/2019

δD of water	----------	-24.6 ‰ relative to VSMOW
δ^{18}O of water	----------	-4.44 ‰ relative to VSMOW
Tritium content of water	----------	na
δ^{13}C of DIC	----------	na
^{14}C content of DIC	----------	na
δ^{15}N of nitrate	----------	na
δ^{18}O of nitrate	----------	na
δ^{34}S of sulfate	----------	na
δ^{18}O of sulfate	----------	na
Vacuum Distilled? *	----------	No

Remarks:

nd = not detected. na = not analyzed.
*Indicates if vacuum distillation was utilized for hydrogen and oxygen isotopic analysis of water

MIT Isotope Laboratory

Massachusetts Institute of Technology

Date: 10/14/2019

Analysts: Ryan Frazer and Jahan Ramezani

Sample #	Sample Type	$^{87}Sr/^{86}Sr$ (1)	% std err (2)	2σ std err	
Q1960712001	water	0.707606	0.00074	1.05E-05	**68-08-206**
Q1960712002	water	0.708372	0.00088	1.25E-05	**58-50-755**
Q1960712003	water	0.707904	0.00071	1.01E-05	**68-08-205**
Q1960712004	water	0.709376	0.00092	1.30E-05	**57-40-304**

(1) Corrected for mass-dependant fractionation.

(2) Within-run internal precision of measured ratio.

Long term reproducibility of NBS-987 Sr standard at MIT: 0.7102379 ± 0.0000109 (2σ s.e.).