Salinity Analysis of 8 Wells in Townships 9 and 10 South, Ranges 94, 95, 96 and 97 West, 6th P.M. in Plateau Field, Piceance Basin, Colorado

Prepared for
COGCC

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All wells:

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Introduction

We were contacted in May 2020 by Craig Burger of COGCC to assist in estimating water salinities in order to map the vertical distribution of fresh water in selected wells located in Townships 9 and 10 South, Ranges 94, 95, 96 and 97 West, 6th P.M. in Parachute Field, Piceance Basin, Colorado. COGCC's goal is to evaluate suitable surface casing setting depths to protect useable fresh water in the Wasatch and Upper Mesa Verde Group. For the purpose of this study, "fresh water" is defined as having a salinity of less than 10,000 ppm.

Similar to the previous studies in Rulison Field, Mamm Creek Field, and Parachute Field, Piceance Basin, Colorado, completed in July 2014, June 2015, and June 2016, respectively, it was decided that a study of eight wells would be used to determine if comparisons between Spontaneous Potential (SP) analysis and traditional Archie analysis could be correlated to help in mapping the fresh water depths. A purchase order for this project was issued in May 2020, when digitizing of eight wells commenced.

It was discovered that one of the selected wells did not have GR or porosity data over the interval of interest, resulting in data that would be unsuitable for Archie analysis. Replacement data was found for this well. Unfortunately, another well was found to have only limited data over the interval of interest, but was not discovered in time to find a replacement. Both an SP analysis as well as a full Archie Analysis was performed on all wells.

This report is a documentation of the results of this study.

Summary

For eight wells selected by COGCC, Digital Formation identified individual sand intervals using gamma ray (GR) logs down to about 500 feet below the top of the WMFK, using the automated identification approach designed in the Mamm Creek project:

Well	Section	Township	Range
05077081330000 Fetters 1-19 *	19	10S	96W
05077082860000 Ducray 3	2	10S	96W
05077083150000 Nichols 1-23-CM	23	10S	97W
05077083200000 Stites 12-3	3	10S	95W
05077083590000 Colo Water 15-2	15	10S	95W
05077084450000 Nichols 1-29	29	10S	95W
05077085190000 Pallaoro 15-2	15	10S	96W
05077085790000 No, 3 Deep Seam 30-4	30	9S	94W

* This well has only limited coverage over the interval of interest

The previously developed approach to automatically calculate salinity from the SP log was made on each of these intervals.

Archie calculations for total porosity and saturation from formation resistivity are calculated for all wells. An automated interpretation of Pickett Plots was used to choose water resistivity (R_W) for each interval. Archie cementation and saturation values of m = n = 1.8 were used for all wells. The values were chosen based on interpretation of the sands and Digital Formation's professional experience in the Piceance Basin.

Using the calculated formation temperature – based on an average annual surface temperature of 50°F, and the log header bottom hole temperature (BHT) – an equivalent salinity is calculated from the R_W value. For many of the sands, there is a scatter of data on the Pickett Plots suggesting either:

1. Small amounts of residual hydrocarbons
2. Variable water salinity – thought to be unlikely

Overall, the data suggests wide variation in R_W, with no consistent depth trend. Water of less than 10,000 ppm is calculated within the Mesa Verde, using m = n = 1.8. There is little correlation between the salinities from Archie analysis and from the SP log.

Data Preparation

Log ASCII Standard (LAS) files were loaded into Digital Formation's ***LESA*** petrophysical software. Curves from logging service companies were renamed for consistency:

Log	Mnemonic	Description
Caliper	DF_CALI	Copy of CALI, or other service company mnemonic
Gamma Ray	DF_GR	Copy of GR or other service company mnemonic
SP	DF_SP	Copy of SP or other service company mnemonic
Density	DF_RHOB	Copy of RhoB, or other service company mnemonic
Neutron	DF_NPHI_L	Copy of NPhi, or other service company mnemonic, converted to limestone matrix
Deep Resistivity	DF_DEEP	Copy of resistivity curve identified as "deep"
Medium Resistivity	DF_MEDIUM	Copy of resistivity curve identified as medium or intermediate
Shallow Resistivity	DF_SHALLOW	Copy of resistivity curve identified as shallow

Programmatic despiking of the porosity logs was performed, to eliminate obvious levels of invalid readings due to bad hole. Whenever the hole is out of gauge, the porosity logs tend to read anomalously high values. The despiking routines identify and eliminate these levels. De-spiked Curves were named adding "DS" – for example:

DF_RHOB_DS

From the data shown on the log header, environmental factors were corrected on the density and GR log curves for hole size, and application of the appropriate tornado chart was used to determine deep resistivity, total resistivity (Rt), and flushed zone resistivity (Rxo). If no match was available, it was assumed that Rt = deep, and Rxo = shallow.

Basic Clean Formation Analysis

Shale Volume

Shale volume (V_{SH}) was determined from the GR log, using the standard non-linear "Stieber" equation:

$$GRI = \frac{GR - GR_{clean}}{GR_{shale} - GR_{clean}}$$

$$V_{SH} = \frac{0.5 \times GRI}{1.5 - GRI}$$

GR_{clean} and GR_{shale} were chosen using interactive graphics.

Shale Responses

Shale responses of porosity logs were determined using interactive porosity cross plots.

Porosity

Total porosity (Phi_X) was determined using a density/neutron cross plot porosity on all but one well. The final well used a density porosity. Effective porosity (Phi_E) was determined using the equation:

$$Phi_E = Phi_X - (V_{SH} \times Phi_{shale})$$

Water Saturation

The Archie parameters, water resistivity (R_W) and cementation exponent (*m*), were determined automatically from porosity/resistivity (Pickett) cross plots. The apparent R_W (R_{Wa}) assuming 100% water saturation was calculated at each depth.

$$R_{Wa} = Phi^m \times R_t$$

The minimum value of this calculation over each interval is used as R_W. Saturation exponent (*n*) was assumed equal to m, consistent with industry practice in the Piceance Basin.

Water saturation (S_W) was calculated using the Archie Model:

$$S_W^n = \sqrt{\frac{a \times R_W}{\varphi^m \times R_t}}$$

Permeability

Permeability was determined using a modified Timur equation:

$$k = \frac{62500 \times {Phi_E}^6}{{S_{Wi}}^2}$$

S_{Wi} is the lower of log-calculated S_W or theoretical S_{Wi} from a Buckles equation:

$$Phi_E \times S_{Wi} = Constant$$

A constant of 0.05 was used. This value is suitable for most reservoirs in the Piceance Basin.

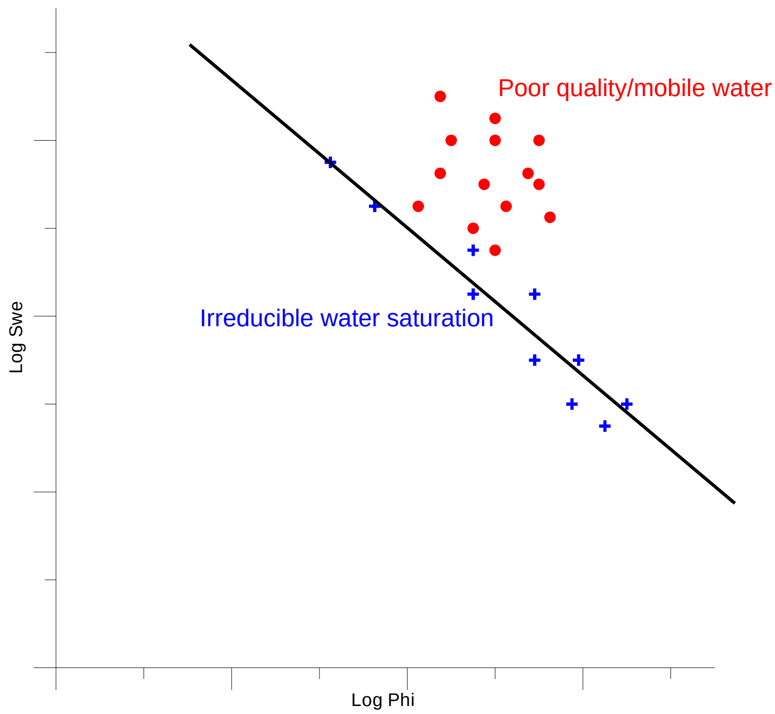
Effective Porosity and Effective Water Saturation

Effective water saturation (S_{WE}) was calculated using Dewan's equation:

$$S_{WB} = V_{SH} \times \frac{Phi_{SH}}{Phi_X} = \text{Bound Water Saturation}$$

$$S_{WE} = \frac{(S_W - S_{WB})}{(1 - S_{WB})}$$

From log/log cross plots of S_{WE} vs. Phi_E, by petrophysical zone, levels interpreted to be at irreducible water saturation (S_{Wi}) were identified. Points with $S_{WE} > S_{Wi}$ contain potential mobile water (or belong to a poorer reservoir quality rock with higher values of S_{Wi}). Poorer reservoir qualities indicate high values of irreducible water saturation, and consequent low permeability.



Analysis of many reservoirs, including tight gas sands, suggests relations exist between porosity and irreducible water saturations.

$$Phi^Q \times Swi = \text{Constant}$$

In literature, it is normally assumed that the exponent Q is equal to 1.0. Digital Formation's work, in a very extensive data base of all types of reservoirs, suggests that Q often diverges from (and is usually larger than) unity. A log/log cross plot of porosity vs. water saturation can be interpreted to distinguish rocks at irreducible saturation from others where $S_w > S_{wi}$. The inequality may be due to one of two possibilities:

1. Poorer rock quality than the choice made by the interpreter
2. Presence of mobile water

Values of Q and the constant have been selected for each sand identified, accounting for these factors.

Automatic Sand Interval Identification

The procedure for identifying sands has been partially automated by looking at sand and non-sand interval thicknesses. Sands are identified as have a 70 API reading or less, and being at least 5 ft. thick, with the possibility of small non-sand streaks within them of no more than 2.5 ft. The 70 API cutoff had to be manually adjusted well-by-well to accurately model the data in a reasonable manner. Additionally a cutoff is used to eliminate any intervals that only barely meet these requirements based on the original GR cutoff. This automatic identification was then manually reviewed to:

1. Remove intervals that still did not appear to be sufficient sand intervals
2. Merge nearby intervals that appear to be part of the same sand body
3. Extend or reduce intervals as appropriate

Salinity from SP Analysis

As developed previously on the Mamm Creek project, this process has also been automated. The average value of Ri/Rm is determined over the interval for input to the Schlumberger SP-5 chart (2009), which is used to correct the SP for the effects of invasion and bed thickness. For this calculation, R_i was assumed to be equal to the deep resistivity, and mud resistivity (R_m) was read from the log header and temperature corrected to depth. Using the sand thickness and this average Ri/Rm, a corrected SP is calculated.

The minimum value of this corrected SP over the interval is used as the SP Clean value. Since the intervals are defined as the sands, an expanded interval of +/- 5 ft. is used to determine the maximum SP value, which is used as the shale base line. Using these values and the R_{mf} from the log header, temperature corrected to depth, an R_{Weq} value is calculated using the Schlumberger transform:

$$R_{Weq} = 0.85 \times R_{mf} \times 10^{\frac{SP}{60.5+0.133\times Temp}}.$$

This R_{Weq} was then corrected using Schlumberger SP-2 (2009) to get R_W, and R_W was then converted to salinity using Schlumberger Gen-9.

A plot showing the Salinity vs Depth is provided for each well. This plot also includes the salinity from Archie analysis.

Anomalous Wells

There is one well where the SP analysis results were not consistent with the other seven wells:

05077081330000 Fetters 1-19

It was noted that this well is the only well drilled with KCL mud, and the Rm and Rmf values were considerably lower than the others. Assuming this difference resulted in a reversed SP deflection, the model was rerun with this assumption, and the results are much more in line with the other seven wells. Unfortunately, this is also the well for which most of the logged interval is below the bottom of the desired interval of interest.

Another well is calculating consistently much higher salinities from the Archie analysis than the other seven:

05077083150000 Nichols 1-23-CM

This could be driven by potential hydrocarbon saturation over the interval, which could be problematic with the automatic approach for picking Rw in this analysis.

Comments on the Major Intervals

There is reasonably good agreement between the SP analysis and the Rw analysis in the Ohio Creek and WMFk intervals. However, in the Wasatch and WSTC G there is more separation. In these intervals, the Archie Rw is calculating higher salinities than the SP analysis. A possible reason for this separation may be due to the presence of hydrocarbons, or due to vertical migration of mud filrate. In most wells, the Archie analysis and SP analysis are in closer agreement and generally have salinities below 10,000 ppm in the Ohio Creek and WMFk. There are several points in two wells where the Rw from SP is much higher than the Rw from Archie:

05077083590000 Colo Water 15-2

05077085790000 No, 3 Deep Seam 30-4

It is possible these differences are caused by streaming potential on the SP, which can cause anomalously high salinities.

It is noted that in general, where the mobile water analysis sees more water, the agreement between the two models is better. The middle of the WSTC G shows the lowest mobile water, and thus the greatest difference between the models.

Tabulations

05077081330000 Fetters 1-19

Top F	Bottom F	Thickness F	Temp DEGF	SP mv	Rmf ohmm	Rweq ohmm	Rw ohmm	TDS ppm	Archie Rw ohmm	Archie TDS ppm
1294	1312	18	74.2	2	0.244	0.225	0.227	27,676	3.711	1,413
1408.5	1444.5	36	76.5	12	0.238	0.296	0.311	18,569	3.674	1,388
1459	1489	30	77.4	20	0.235	0.379	0.430	12,800	4.049	1,245
1614.5	1619	4.5	80.1	111	0.228	7.040	729.507	7	0.835	6,083
1703	1777	74	82.4	41	0.222	0.716	1.213	4,012	1.324	3,667
1853.5	1868	14.5	84.6	16	0.217	0.308	0.337	15,276	1.231	3,853
2139.5	2147	7.5	89.9	6	0.205	0.210	0.219	23,470	0.553	8,406
2238	2244.5	6.5	91.7	10	0.201	0.232	0.245	20,146	0.423	10,982
2302.5	2313	10.5	92.9	9	0.199	0.227	0.240	20,327	0.565	7,938
2327	2332	5	93.3	16	0.198	0.283	0.313	15,020	0.282	16,835
2438.5	2445	6.5	95.4	19	0.194	0.299	0.339	13,432	3.563	1,164
2450	2458.5	8.5	95.6	12	0.193	0.240	0.258	18,197	0.815	5,251
2476	2481.5	5.5	96.1	18	0.192	0.290	0.326	13,900	3.242	1,272
2490	2580.5	90.5	97.2	13	0.190	0.241	0.260	17,706	0.249	18,610
2748.5	2774	25.5	101.4	5	0.183	0.183	0.193	23,782	0.335	12,802
2793.5	2800	6.5	102.0	5	0.182	0.182	0.192	23,767	0.466	8,879

05077082860000 Ducray 3

Top F	Bottom F	Thickness F	Temp DEGF	SP mv	Rmf ohmm	Rweq ohmm	Rw ohmm	TDS ppm	Archie Rw ohmm	Archie TDS ppm
306.5	315.5	9	55.7	1	3.322	2.930	22.525	299	5.250	1,294
320	342	22	56.1	-6	3.303	2.277	11.387	590	2.077	3,306
588.5	597	8.5	60.9	-19	3.069	1.388	3.693	1,705	0.309	23,764
1342.5	1351	8.5	74.7	-17	2.548	1.227	3.310	1,578	0.666	8,266
1378	1459.5	81.5	76.0	-10	2.507	1.538	5.636	907	1.313	3,993
1551.5	1580.5	29	78.7	-18	2.428	1.163	3.079	1,617	2.507	1,993
1662.5	1677.5	15	80.6	-13	2.375	1.316	4.145	1,171	3.222	1,511

05077083150000 Nichols 1-23-CM

Top F	Bottom F	Thickness F	Temp DEGF	SP mv	Rmf ohmm	Rweq ohmm	Rw ohmm	TDS ppm	Archie Rw ohmm	Archie TDS ppm
190	234	44	53.5	-8	2.237	1.449	3.711	1,908	0.037	279,803
262.5	284.5	22	54.5	-11	2.201	1.273	2.845	2,460	0.051	250,156
291	380	89	55.5	-10	2.165	1.330	3.158	2,174	0.126	80,977
422	457	35	57.2	-17	2.107	0.996	1.792	3,779	0.175	50,930
490	523.5	33.5	58.3	-17	2.071	0.996	1.811	3,673	0.131	72,362
673	708	35	61.3	-17	1.980	0.938	1.663	3,828	0.121	75,683
739	760	21	62.3	-19	1.952	0.875	1.472	4,279	0.116	78,441
982	1030	48	66.5	-15	1.840	0.961	1.832	3,212	1.481	3,999
1110	1182	72	68.8	-7	1.784	1.185	2.874	1,966	6.985	801
1223.5	1242	18.5	70.2	-2	1.751	1.390	4.146	1,330	11.835	463
1368	1385.5	17.5	72.6	-3	1.699	1.310	3.733	1,435	13.076	406
1400	1483	83	73.6	-5	1.677	1.195	3.084	1,718	12.241	428
1505	1513.5	8.5	74.7	-3	1.654	1.257	3.492	1,494	14.485	357
1546	1590	44	75.7	-5	1.634	1.173	3.031	1,704	10.667	479
1611	1628.5	17.5	76.5	-4	1.618	1.211	3.284	1,555	9.628	526
1785	1806	21	79.4	-3	1.564	1.198	3.312	1,489	5.797	846
1831	1839	8	80.1	-12	1.552	0.887	1.783	2,774	7.028	692
1908	1916	8	81.3	-9	1.530	0.969	2.155	2,254	1.524	3,211
1969.5	1996.5	27	82.5	-13	1.510	0.837	1.626	2,964	3.166	1,504
2018	2042.5	24.5	83.3	-13	1.497	0.827	1.600	2,986	2.320	2,044
2054.5	2069	14.5	83.8	-12	1.488	0.860	1.737	2,730	3.149	1,491
2120.5	2128.5	8	84.8	-12	1.472	0.846	1.696	2,766	1.666	2,816
2199	2233	34	86.3	-21	1.448	0.633	1.004	4,668	1.176	3,962
2244	2255.5	11.5	86.9	-12	1.439	0.827	1.653	2,776	1.387	3,323
2377.5	2404.5	27	89.2	-24	1.405	0.549	0.804	5,697	1.290	3,490
2660.5	2678	17.5	93.8	-32	1.341	0.420	0.541	8,242	0.451	10,007
2716.5	2725	8.5	94.6	-3	1.330	1.016	2.719	1,543	1.659	2,551
2733.5	2738	4.5	94.8	-7	1.326	0.915	2.181	1,925	14.227	291
2770	2800	30	95.7	-24	1.316	0.531	0.795	5,388	0.338	13,448

05077083200000 Stites 12-3

Top F	Bottom F	Thickness F	Temp DEGF	SP mv	Rmf ohmm	Rweq ohmm	Rw ohmm	TDS ppm	Archie Rw ohmm	Archie TDS ppm
314.5	327.5	13	56.3	-12	6.049	3.466	37.297	179	0.812	8,777
358.5	367.5	9	57.2	-11	5.970	3.485	38.504	171	0.783	8,999
485	511.5	26.5	59.8	-15	5.730	2.899	23.440	269	0.772	8,750
531.5	550.5	19	60.7	-15	5.659	2.911	24.066	259	0.724	9,242
608.5	623.5	15	62.2	-36	5.537	1.391	3.770	1,638	0.615	10,769
633.5	650.5	17	62.7	-35	5.496	1.449	4.157	1,472	0.582	11,348
679.5	732.5	53	64.0	-26	5.398	1.945	8.538	699	0.960	6,520
919.5	930	10.5	68.3	-7	5.087	3.377	42.821	131	0.642	9,389
962.5	972	9.5	69.1	-2	5.031	3.948	71.328	78	1.163	4,952
1039	1055.5	16.5	70.7	-4	4.928	3.632	56.226	96	0.701	8,258
1207.5	1238.5	31	74.2	-2	4.717	3.721	64.863	80	0.497	11,398
1412	1434.5	22.5	78.1	-2	4.497	3.553	60.236	82	0.511	10,516
1515.5	1525	9.5	80.0	-2	4.397	3.476	58.151	83	0.419	12,718
1540.5	1553.5	13	80.6	-35	4.371	1.202	3.377	1,441	0.511	10,194
1684.5	1691.5	7	83.4	-10	4.236	2.580	24.739	189	0.294	18,088
1836.5	1871	34.5	86.6	-38	4.087	1.038	2.621	1,740	0.705	6,734
1939	1971.5	32.5	88.6	-53	4.001	0.638	1.036	4,405	0.561	8,387
2049.5	2059	9.5	90.6	-58	3.921	0.533	0.773	5,847	1.033	4,327
2085.5	2097	11.5	91.3	-32	3.892	1.197	3.775	1,145	1.522	2,880
2245	2255	10	94.5	-35	3.771	1.051	2.917	1,439	1.018	4,219
2441	2453	12	98.4	-17	3.631	1.790	11.144	359	1.568	2,603
2557	2572.5	15.5	100.7	-23	3.553	1.472	6.913	568	5.110	770
2710	2750	40	103.9	-29	3.448	1.176	4.172	916	2.764	1,388
2768.5	2794.5	26	105.0	-33	3.417	1.039	3.177	1,195	2.116	1,803
2817.5	2822.5	5	105.7	-29	3.393	1.163	4.144	908	1.055	3,646
2830.5	2858	27.5	106.2	-30	3.379	1.146	4.027	930	2.508	1,501
2876	2917	41	107.2	-23	3.348	1.398	6.588	562	4.894	757
2953.5	2978.5	25	108.6	-26	3.309	1.277	5.354	684	1.392	2,673
3011.5	3033.5	22	109.7	-29	3.277	1.145	4.178	869	1.908	1,919
3045	3051	6	110.2	-31	3.263	1.068	3.573	1,013	3.652	991
3079	3100	21	111.0	-10	3.240	2.055	19.617	182	4.908	731

05077083590000 Colo Water 15-2

Top F	Bottom F	Thickness F	Temp DEGF	SP mv	Rmf ohmm	Rweq ohmm	Rw ohmm	TDS ppm	Archie Rw ohmm	Archie TDS ppm
300	320.5	20.5	54.9	-56	4.069	0.518	0.589	12,738	0.378	20,923
690	711	21	61.1	-18	3.697	1.694	5.852	1,066	0.949	6,884
726	736	10	61.6	-14	3.671	1.932	8.123	761	1.017	6,352
782	808.5	26.5	62.6	-20	3.617	1.592	5.154	1,185	1.981	3,133
863.5	894.5	31	64.0	-28	3.549	1.175	2.677	2,259	1.017	6,134
902	922	20	64.5	-38	3.523	0.841	1.398	4,368	0.655	9,707
981	1000	19	65.7	-51	3.462	0.543	0.676	9,204	0.902	6,782
1013.5	1026	12.5	66.2	-63	3.440	0.356	0.376	17,409	1.359	4,389
1048.5	1056	7.5	66.7	-34	3.416	0.933	1.733	3,391	0.996	6,022
1100	1115	15	67.6	-40	3.376	0.759	1.192	4,933	0.468	13,356
1125.5	1131	5.5	67.9	-14	3.361	1.782	7.250	780	0.388	16,367
1204	1220.5	16.5	69.3	-12	3.302	1.887	8.527	651	0.353	17,836
1387	1393	6	72.1	-7	3.183	2.172	12.816	417	0.485	12,049
1665	1675	10	76.5	-9	3.013	1.890	9.476	534	0.369	15,344
1835	1852.5	17.5	79.3	-27	2.917	1.046	2.468	2,010	0.358	15,283
1910	1937.5	27.5	80.6	-35	2.874	0.781	1.403	3,528	0.398	13,382
1955.5	1961	5.5	81.1	-27	2.856	1.016	2.370	2,051	0.512	10,100
2106.5	2122.5	16	83.6	-36	2.778	0.740	1.303	3,675	0.545	9,159
2139	2159.5	20.5	84.2	-67	2.761	0.276	0.294	17,920	0.827	5,856
2179.5	2244.5	65	85.2	-69	2.731	0.254	0.267	19,721	0.586	8,323
2875.5	2883.5	8	95.8	-31	2.448	0.785	1.615	2,590	2.650	1,566
2917	2950.5	33.5	96.6	-90	2.428	0.122	0.130	40,407	0.919	4,587
2978	3000	22	97.5	-45	2.408	0.506	0.741	5,687	1.429	2,887

05077084450000 Nichols 1-29

Top F	Bottom F	Thickness F	Temp DEGF	SP mv	Rmf ohmm	Rweq ohmm	Rw ohmm	TDS ppm	Archie Rw ohmm	Archie TDS ppm
350	398	48	56.6	-17	3.456	1.632	5.053	1,325	0.237	35,228
406.5	417	10.5	57.3	-13	3.419	1.876	7.108	929	0.783	8,991
427.5	433	5.5	57.6	-12	3.402	1.951	7.862	835	0.594	12,046
475.5	493.5	18	58.6	-5	3.352	2.394	13.520	477	1.498	4,447
515	580.5	65.5	59.7	-26	3.296	1.183	2.592	2,487	0.760	8,919
629	650.5	21.5	61.3	-17	3.217	1.528	4.611	1,352	0.606	11,079
655	669	14	61.7	-15	3.198	1.631	5.392	1,148	1.264	5,055
691	726	35	62.6	-12	3.160	1.806	6.960	877	0.560	11,854
740.5	773	32.5	63.4	-8	3.122	2.035	9.498	633	0.488	13,609
809.5	838	28.5	64.6	-2	3.070	2.416	15.231	387	0.415	15,984
857	872	15	65.3	-1	3.039	2.473	16.412	356	0.503	12,773
1037	1049.5	12.5	68.5	-3	2.911	2.275	13.742	407	0.510	11,998
1071	1096.5	25.5	69.2	-3	2.884	2.205	12.762	435	0.420	14,713
1164	1180.5	16.5	70.8	-1	2.825	2.315	14.919	364	0.465	12,842
1294	1305.5	11.5	73.0	-2	2.745	2.193	13.337	396	0.491	11,721
1341	1358.5	17.5	73.9	-2	2.715	2.160	12.965	403	0.359	16,353
1383	1394	11	74.6	-2	2.692	2.162	13.145	394	0.328	17,927
1429	1440	11	75.4	-3	2.665	2.073	11.885	431	0.382	14,990
1488.5	1495.5	7	76.4	-1	2.633	2.164	13.543	374	0.350	16,288
1523.5	1576.5	53	77.5	-15	2.601	1.371	4.387	1,147	0.325	17,477
1581.5	1649.5	68	78.6	-32	2.565	0.782	1.382	3,667	1.134	4,498
1746.5	1753	6.5	81.0	-8	2.496	1.621	6.838	704	0.756	6,677
2153	2186.5	33.5	88.5	-9	2.301	1.454	5.759	771	5.864	757
2323	2374.5	51.5	91.6	-26	2.227	0.833	1.751	2,488	1.914	2,272
2388.5	2400	11.5	92.4	-11	2.208	1.340	4.966	858	3.436	1,245
2407.5	2456.5	49	93.1	-15	2.194	1.143	3.466	1,225	2.809	1,516
2462	2508	46	94.0	-9	2.173	1.392	5.546	756	3.451	1,219
2568.5	2592	23.5	95.7	-9	2.137	1.355	5.305	777	2.382	1,745

05077085190000 Pallaoro 15-2

Top F	Bottom F	Thickness F	Temp DEGF	SP mv	Rmf ohmm	Rweq ohmm	Rw ohmm	TDS ppm	Archie Rw ohmm	Archie TDS ppm
160	187	27	53.1	-136	3.248	0.027	0.059	222,626	0.150	67,541
261	277	16	54.8	-3	3.159	2.424	13.163	520	0.823	8,887
307	328	21	55.6	-7	3.115	2.120	9.412	719	1.144	6,184
345.5	390	44.5	56.5	-4	3.071	2.302	11.804	565	0.723	9,915
416	427.5	11.5	57.5	-9	3.025	1.912	7.466	882	1.075	6,397
475	499.5	24.5	58.7	-13	2.971	1.645	5.283	1,227	1.211	5,545
516.5	523.5	7	59.2	-11	2.945	1.704	5.785	1,110	1.525	4,322
586.5	600.5	14	60.5	-7	2.888	1.962	8.307	756	1.804	3,561
937	957	20	66.8	-2	2.642	2.073	10.469	547	8.665	662
1076.5	1084.5	8	69.2	-6	2.559	1.790	7.457	746	4.146	1,348
1120	1138	18	70.1	-4	2.530	1.863	8.343	659	4.251	1,300
1175	1202.5	27.5	71.1	-5	2.496	1.796	7.720	702	6.176	879
1238	1271.5	33.5	72.3	-5	2.459	1.761	7.476	714	7.059	757
1306.5	1331	24.5	73.4	-2	2.424	1.913	9.356	562	6.795	775
1397.5	1411	13.5	75.0	-4	2.379	1.757	7.702	671	5.041	1,028
1470.5	1524	53.5	76.6	-10	2.332	1.410	4.633	1,097	9.632	525
1551	1590.5	39.5	77.9	-18	2.296	1.079	2.598	1,940	15.261	326
1696.5	1714.5	18	80.3	-11	2.233	1.351	4.381	1,111	5.574	871
1776.5	1791.5	15	81.7	-12	2.197	1.280	3.941	1,217	9.656	493
1813	1832.5	19.5	82.4	-10	2.180	1.358	4.545	1,045	4.507	1,054
1967.5	1992	24.5	85.2	-4	2.114	1.572	6.684	687	0.435	11,463
2032	2044	12	86.2	-16	2.091	1.054	2.699	1,697	1.455	3,185
2220.5	2248	27.5	89.7	-31	2.015	0.639	1.048	4,303	0.372	12,931
2373	2381	8	92.2	-29	1.964	0.665	1.149	3,809	0.429	10,752
2436	2444.5	8.5	93.4	-33	1.941	0.589	0.932	4,673	0.434	10,475
2505.5	2516	10.5	94.6	-20	1.917	0.862	1.928	2,187	0.415	10,864
2564.5	2577	12.5	95.7	-22	1.898	0.812	1.728	2,420	0.505	8,693
2650.5	2659	8.5	97.2	-20	1.870	0.855	1.941	2,117	17.281	234
2793	2803.5	10.5	99.7	-12	1.825	1.068	3.196	1,247	13.139	301
2821	2896	75	100.8	-22	1.807	0.767	1.612	2,471	0.273	16,143
2909	2918.5	9.5	101.8	-13	1.791	1.007	2.866	1,365	0.394	10,679
3141	3172	31	106.1	-20	1.723	0.796	1.818	2,082	0.374	10,814
3273.5	3294.5	21	108.4	-22	1.689	0.726	1.544	2,410	0.434	9,031
3333	3358.5	25.5	109.5	-18	1.673	0.807	1.928	1,904	0.228	18,099
3421	3440	19	111.0	-3	1.651	1.271	5.435	660	0.051	117,566

05077085790000 No, 3 Deep Seam 30-4

Top F	Bottom F	Thickness F	Temp DEGF	SP mv	Rmf ohmm	Rweq ohmm	Rw ohmm	TDS ppm	Archie Rw ohmm	Archie TDS ppm
240	292	52	54.3	-55	2.398	0.312	0.305	27,211	0.577	13,188
1082.5	1095.5	13	67.4	-4	1.972	1.482	4.638	1,233	0.266	25,405
1124.5	1133	8.5	68.1	-8	1.956	1.286	3.402	1,672	0.729	8,216
1203.5	1208.5	5	69.3	-12	1.924	1.089	2.420	2,325	0.456	13,416
1331	1347	16	71.5	-34	1.871	0.521	0.659	8,724	1.210	4,605
1394	1409	15	72.5	-25	1.848	0.686	1.039	5,325	1.008	5,497
1453	1464	11	73.4	-36	1.827	0.473	0.576	9,825	0.815	6,791
1562.5	1585.5	23	75.2	-95	1.785	0.069	0.087	91,812	0.615	8,937
1670.5	1691	20.5	76.9	-40	1.749	0.405	0.471	11,667	0.557	9,717
2152	2157.5	5.5	84.5	-3	1.603	1.222	3.660	1,270	0.442	11,354
2206	2213.5	7.5	85.4	-3	1.588	1.222	3.696	1,245	0.196	28,213
2218	2227	9	85.6	-2	1.585	1.283	4.143	1,107	0.259	20,304
2267	2273	6	86.4	-3	1.572	1.220	3.725	1,223	0.387	12,857
2304.5	2312	7.5	87.0	-2	1.561	1.263	4.056	1,114	0.242	21,651
2503.5	2510	6.5	90.2	-5	1.510	1.107	3.128	1,401	0.352	13,673
2591.5	2609	17.5	91.7	-39	1.487	0.373	0.450	10,277	0.429	10,825
2628	2639	11	92.2	-38	1.479	0.376	0.457	10,038	0.377	12,376
2677.5	2697	19.5	93.1	-39	1.466	0.363	0.436	10,463	0.471	9,623
2724.5	2735	10.5	93.7	-5	1.456	1.045	2.861	1,478	0.501	8,946
2770	2788.5	18.5	94.5	-23	1.445	0.600	0.971	4,427	0.394	11,503
2829.5	2836.5	7	95.4	-59	1.433	0.191	0.200	24,432	0.638	6,799
2841.5	2862	20.5	95.7	-85	1.429	0.083	0.096	59,909	0.826	5,176
2922	2927.5	5.5	96.9	-31	1.412	0.460	0.633	6,757	0.548	7,874
2935.5	2945.5	10	97.1	-28	1.409	0.503	0.733	5,776	0.337	13,281
2971.5	2976.5	5	97.7	-4	1.402	1.036	2.924	1,391	0.282	16,055
3039.5	3062	22.5	98.9	-37	1.386	0.370	0.461	9,265	0.329	13,367
3072	3103	31	99.5	-32	1.378	0.427	0.572	7,321	0.372	11,621
3139	3178.5	39.5	100.6	-66	1.363	0.148	0.155	31,110	0.415	10,206
3223	3279.5	56.5	102.1	-64	1.345	0.157	0.164	28,525	0.492	8,382
3296	3305.5	9.5	102.9	-38	1.335	0.344	0.422	9,790	0.523	7,786
3593	3598.5	5.5	107.6	-33	1.280	0.393	0.525	7,414	0.476	8,225

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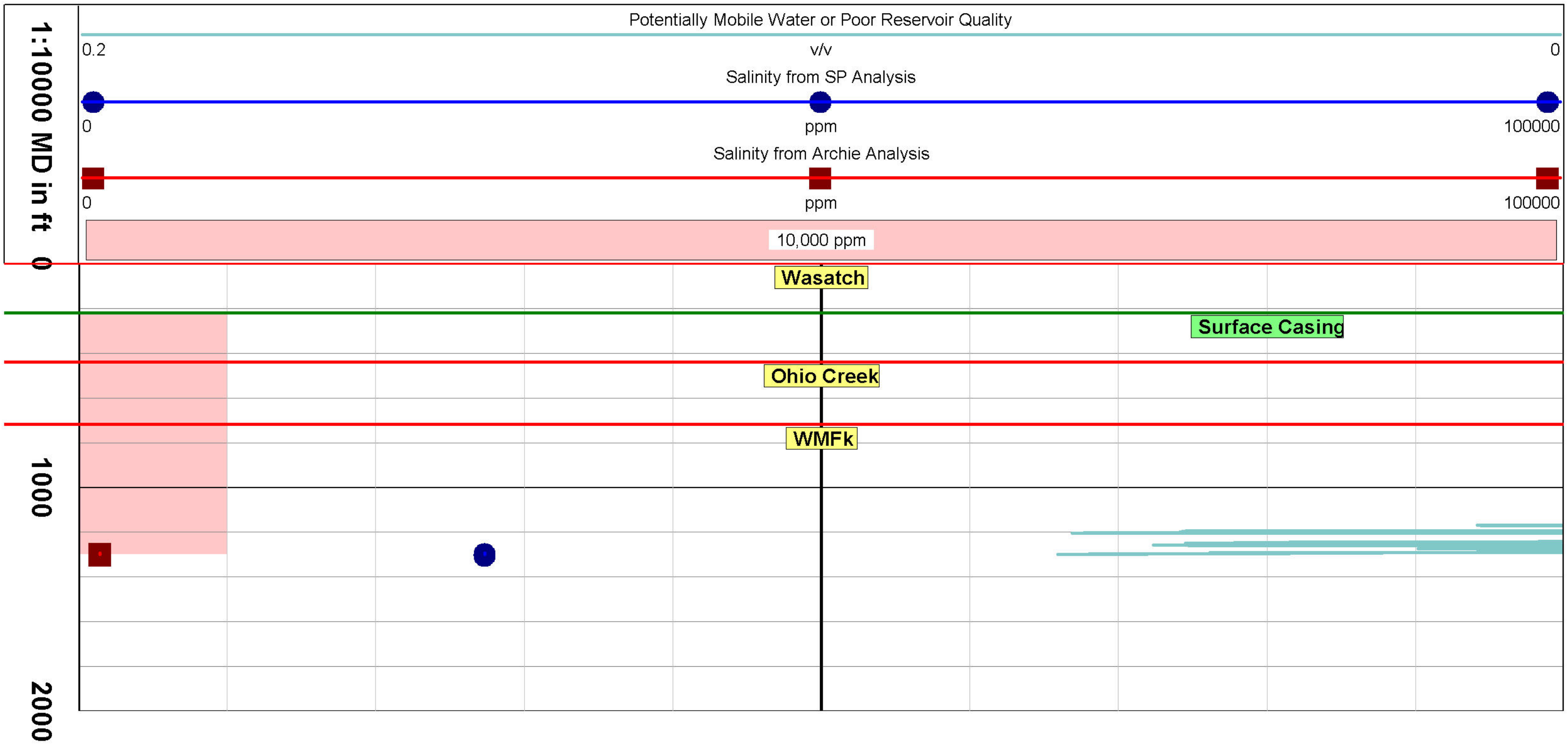
File: 05077081330000 Fetters 1-19.lbs		Well Name:	Fetters 1-19
Plot: Salinity by Depth			
Gross Interval: 220 to 2800 by 0.5 F			
Ranges: User Ranges 220-1300			
Time: 11:10 AM	Date: Mon, Jun 15, 2020		
Section: SECTION	Township: TOWNSHIP	API #:	05077081330000
Location: LOCATION	Range: RANGE	UWI:	05077081330000
Comments: N/A			



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File: 05077081330000 Fetters 1-19.lbs   Well Name: Fetters 1-19

Plot: SP Shift Deflection

Gross Interval: 220 to 2800 by 0.5 F

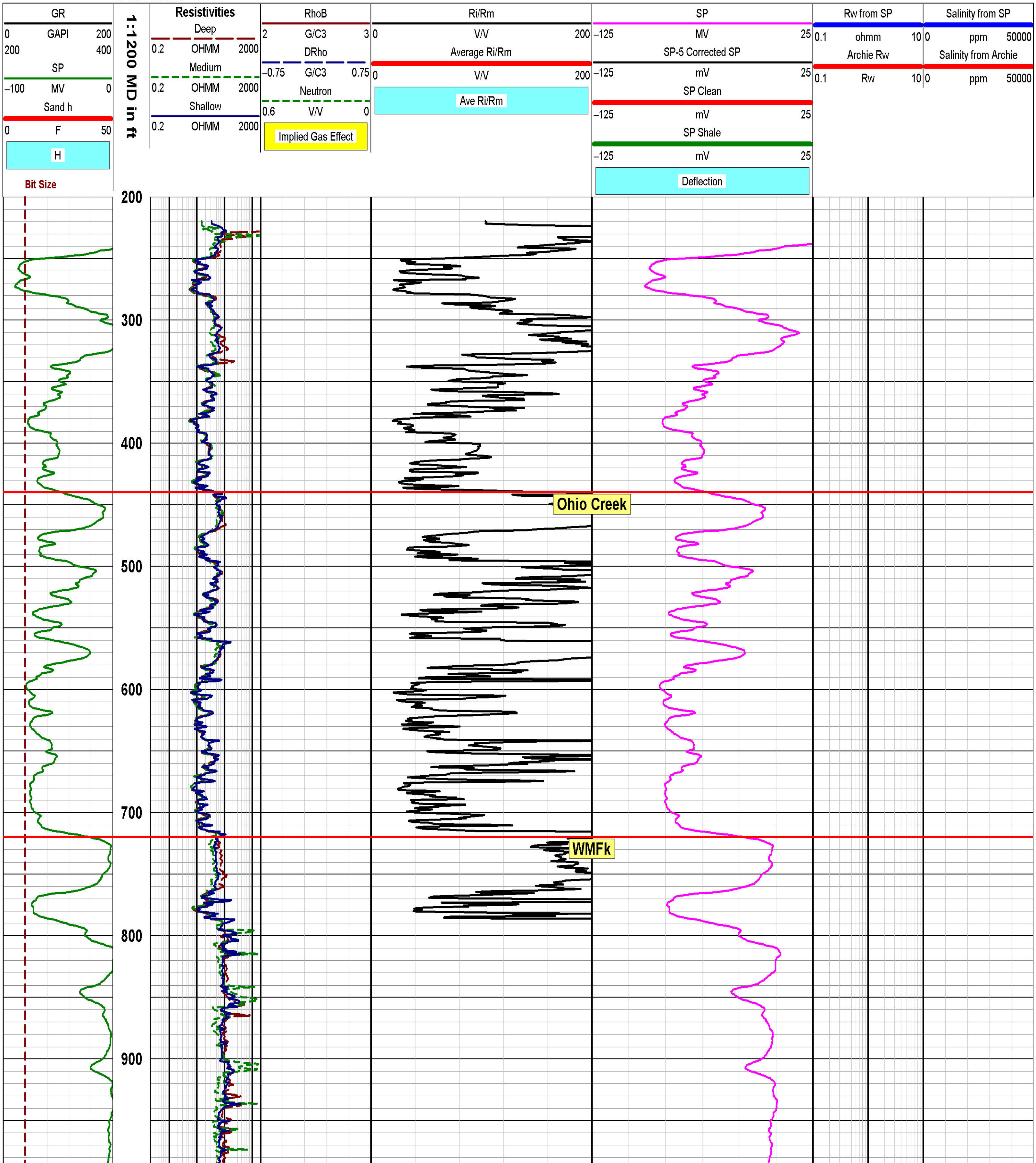
Ranges: User Ranges
220-1300

Time: 11:15 AM   Date: Mon, Jun 15, 2020

Section: SECTION   Township: TOWNSHIP   API #: 05077081330000

Location: LOCATION   Range: RANGE   UWI: 05077081330000

Comments: N/A



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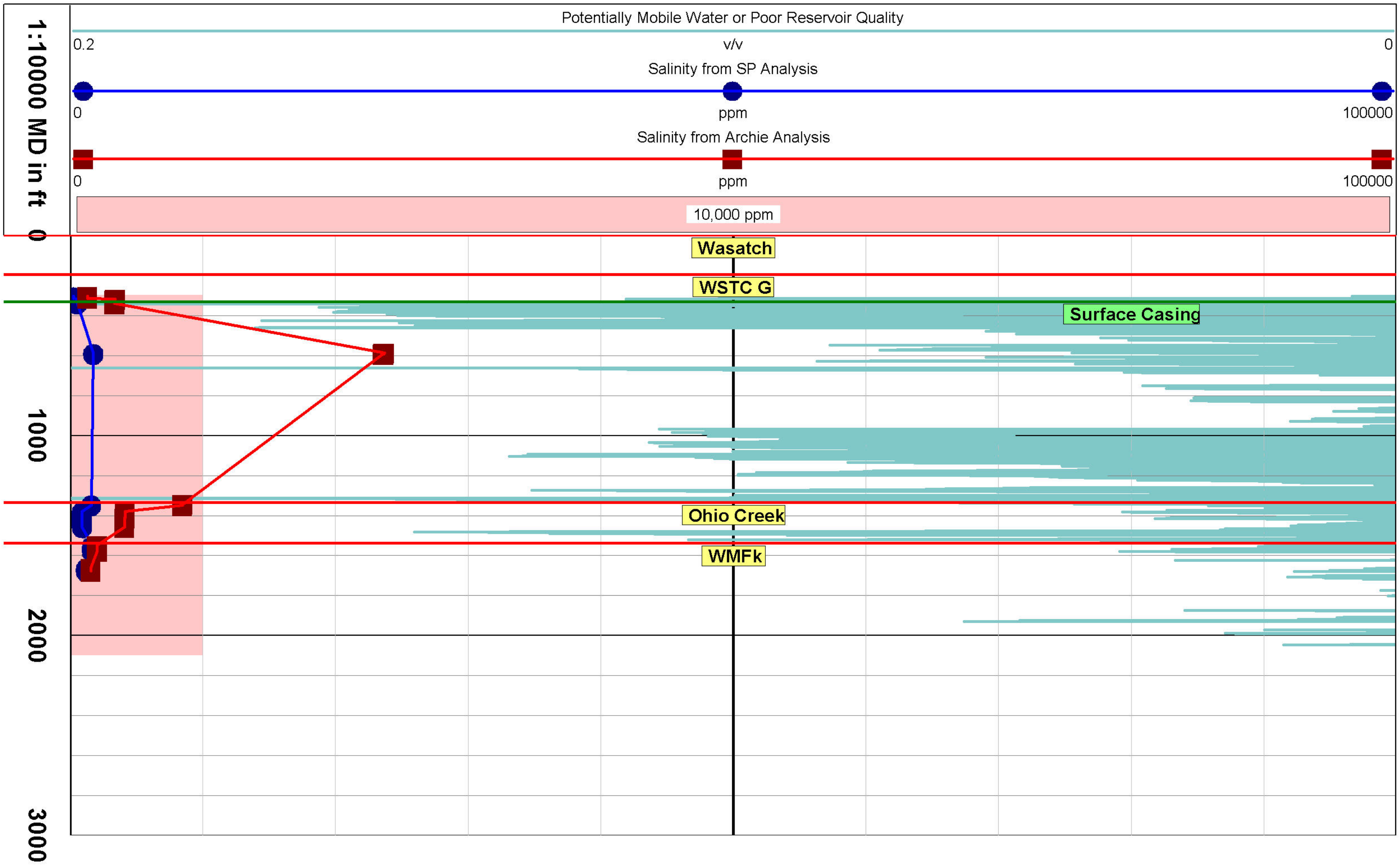
File: 05077082860000 Ducray 3.lbs
Well Name: Ducray 3
Plot: Salinity by Depth
Gross Interval: 300 to 2100 by 0.5 F
Ranges: User Ranges 300-2100
Time: 11:10 AM
Date: Mon, Jun 15, 2020
Section: SECTION
Township: TOWNSHIP
API #: 05077082860000
Location: LOCATION
Range: RANGE
UWI: 05077082860000
Comments: N/A



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File: 05077082860000 Ducray 3.lbs   Well Name: Ducray 3

Plot: SP Shift Deflection

Gross Interval: 300 to 2100 by 0.5 F

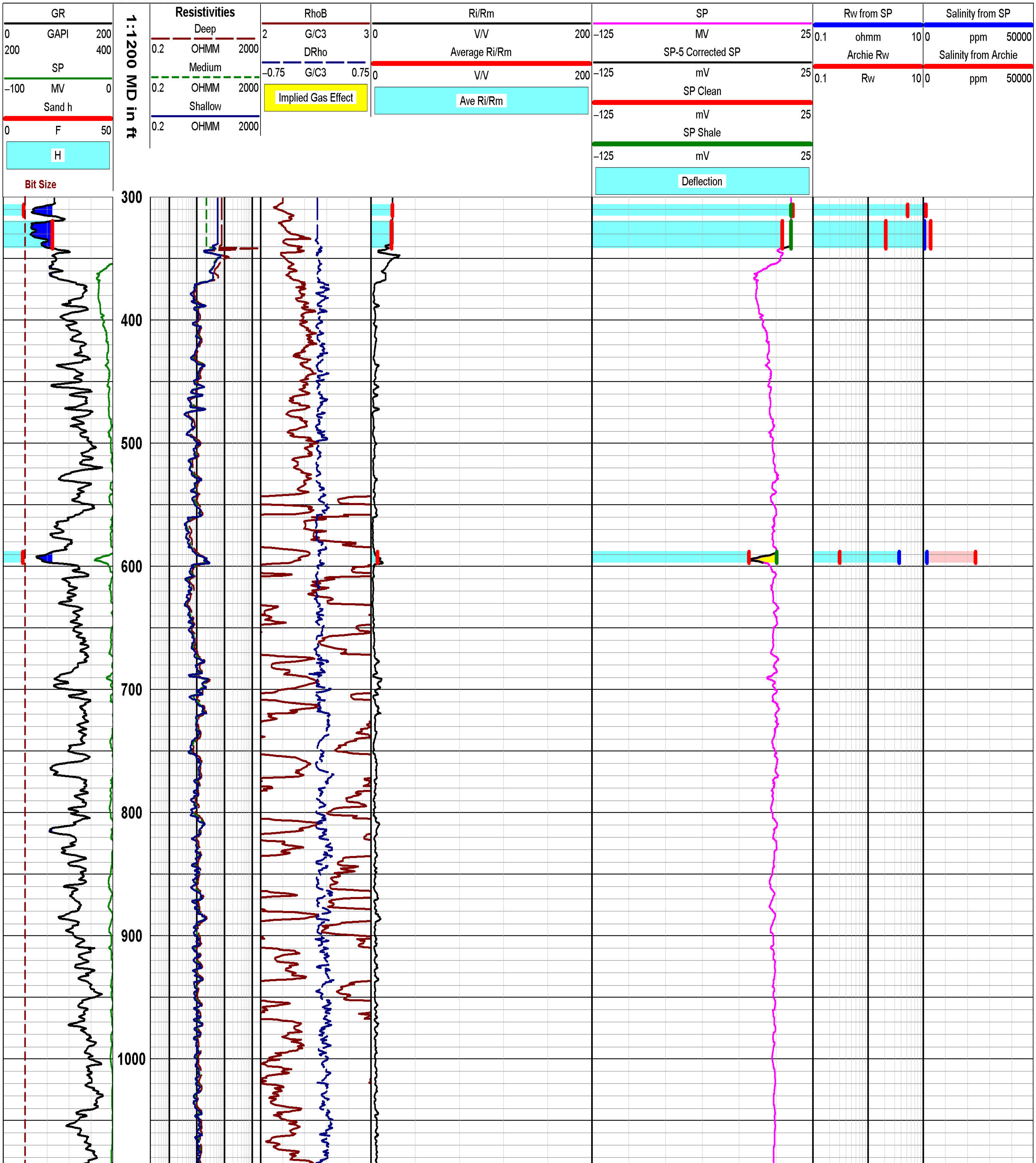
Ranges: User Ranges
300-2100

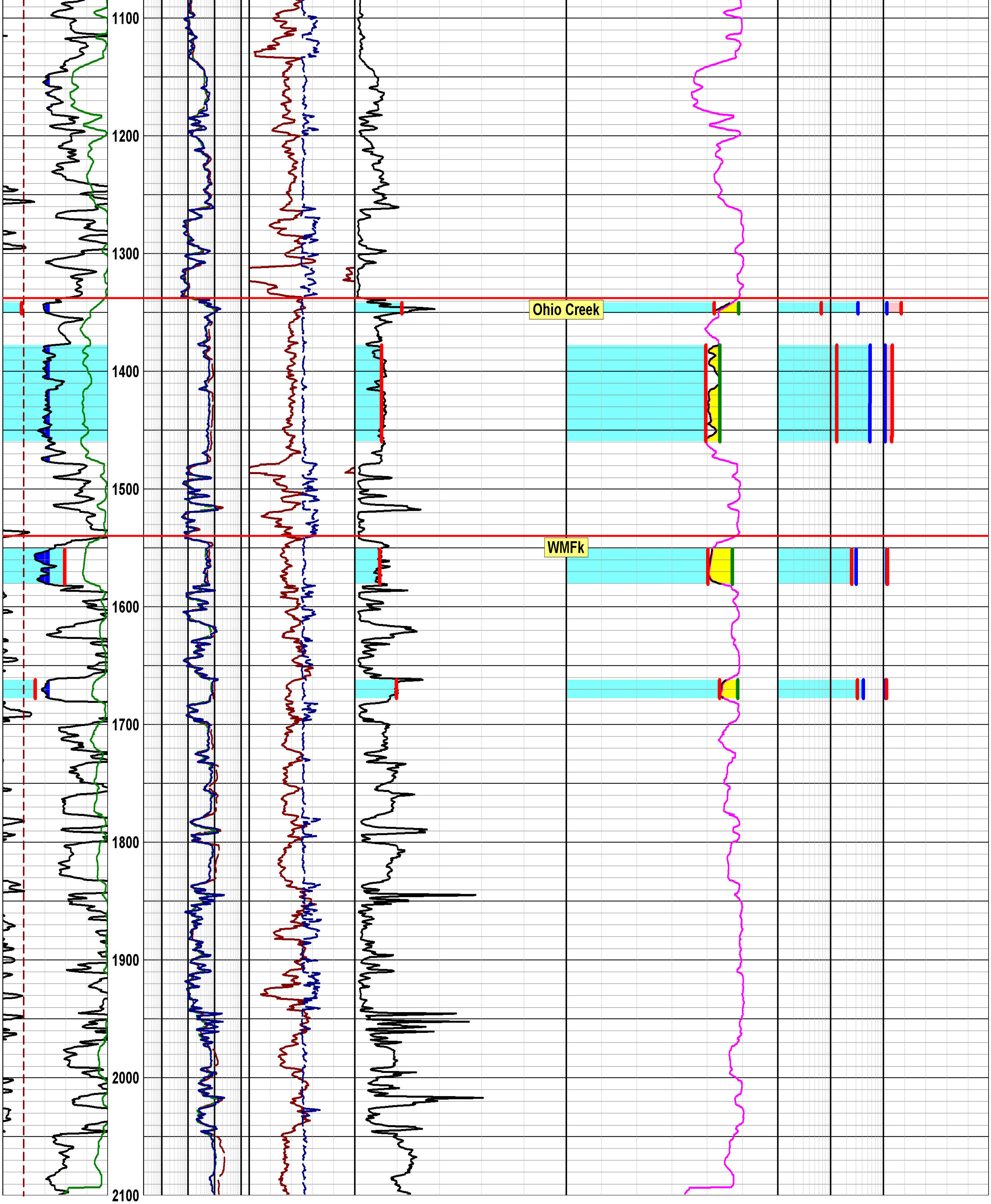
Time: 11:15 AM   Date: Mon, Jun 15, 2020

Section: SECTION   Township: TOWNSHIP   API #: 05077082860000

Location: LOCATION   Range: RANGE   UWI: 05077082860000

Comments: N/A

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1200
1300
Ohio Creek
1400
1500
WMFk
1600
1700
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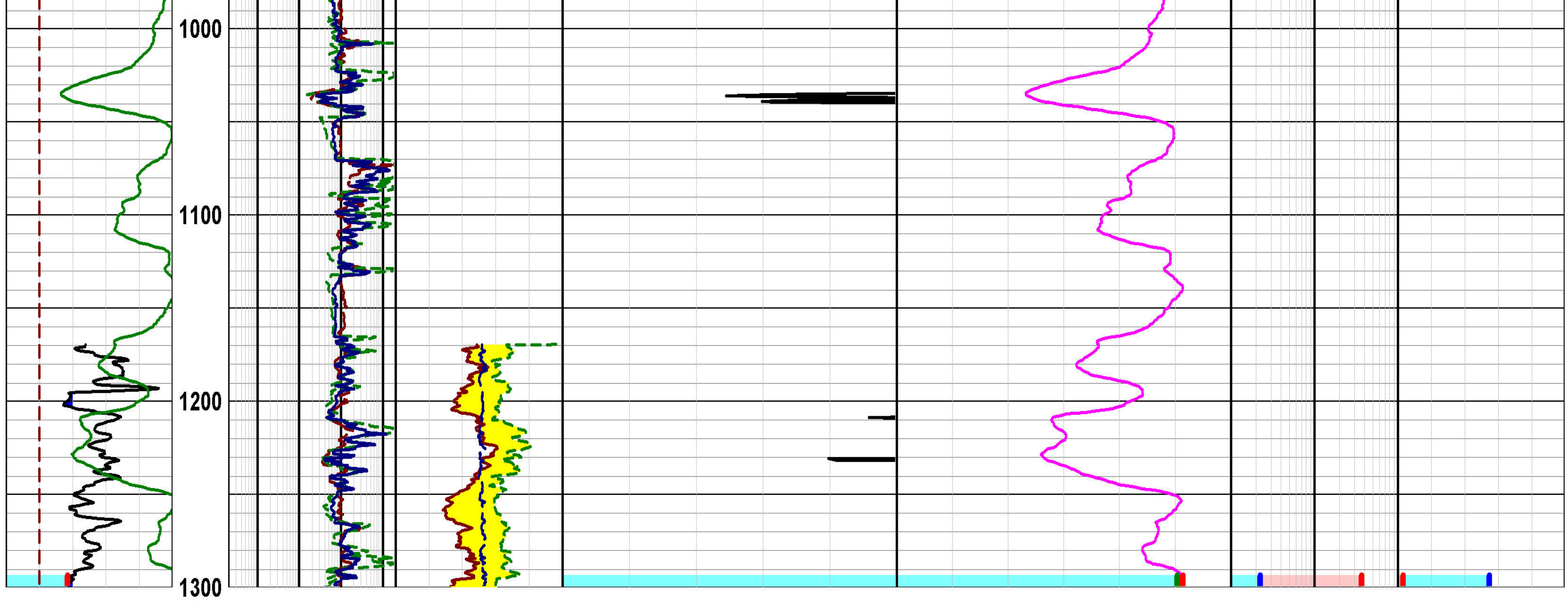
1900
2000
2100


1000
1100
1200
1300

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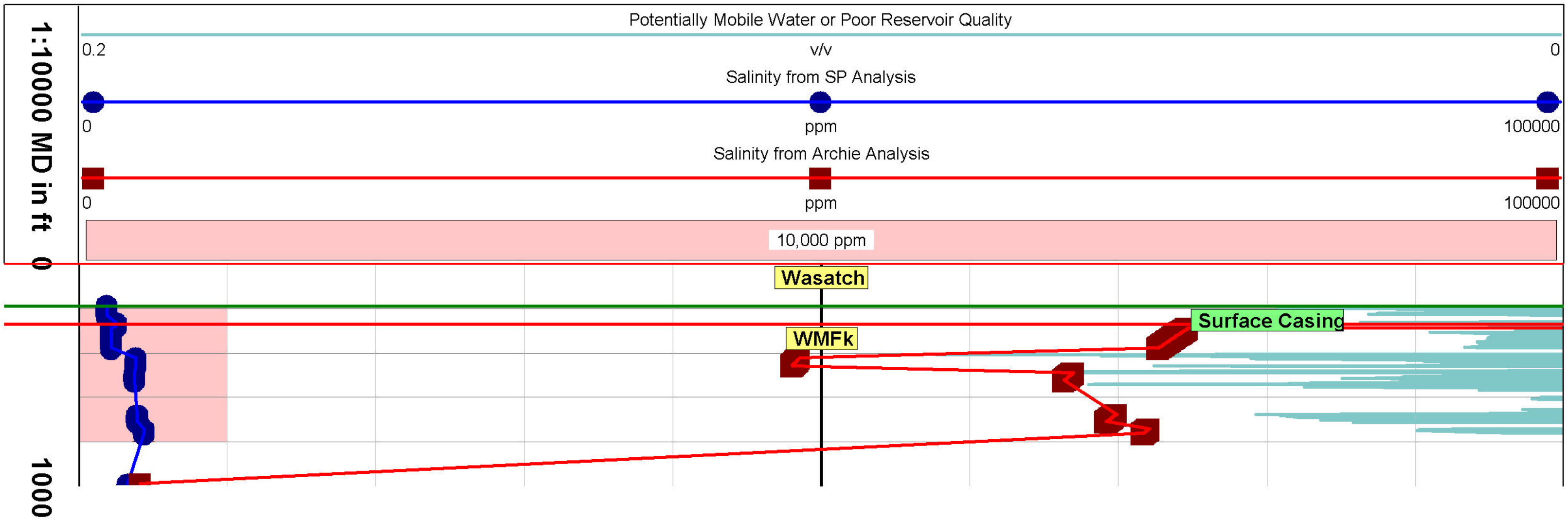
File:	05077083150000 Nichols 1-23-CM.lbs	Well Name:	Nichols 1-23-CM
Plot:	Salinity by Depth		
Gross Interval:	190 to 2800 by 0.5 F		
Ranges:	User Ranges 190-800		
Time:	11:10 AM	Date:	Mon, Jun 15, 2020
Section:	SECTION	Township:	TOWNSHIP
Location:	LOCATION	Range:	RANGE
Comments:	N/A		

API #: 05077083150000

UWI: 05077083150000



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File: 05077083150000 Nichols 1-23-CM.lbs   Well Name: Nichols 1-23-CM

Plot: SP Shift Deflection

Gross Interval: 190 to 2800 by 0.5 F

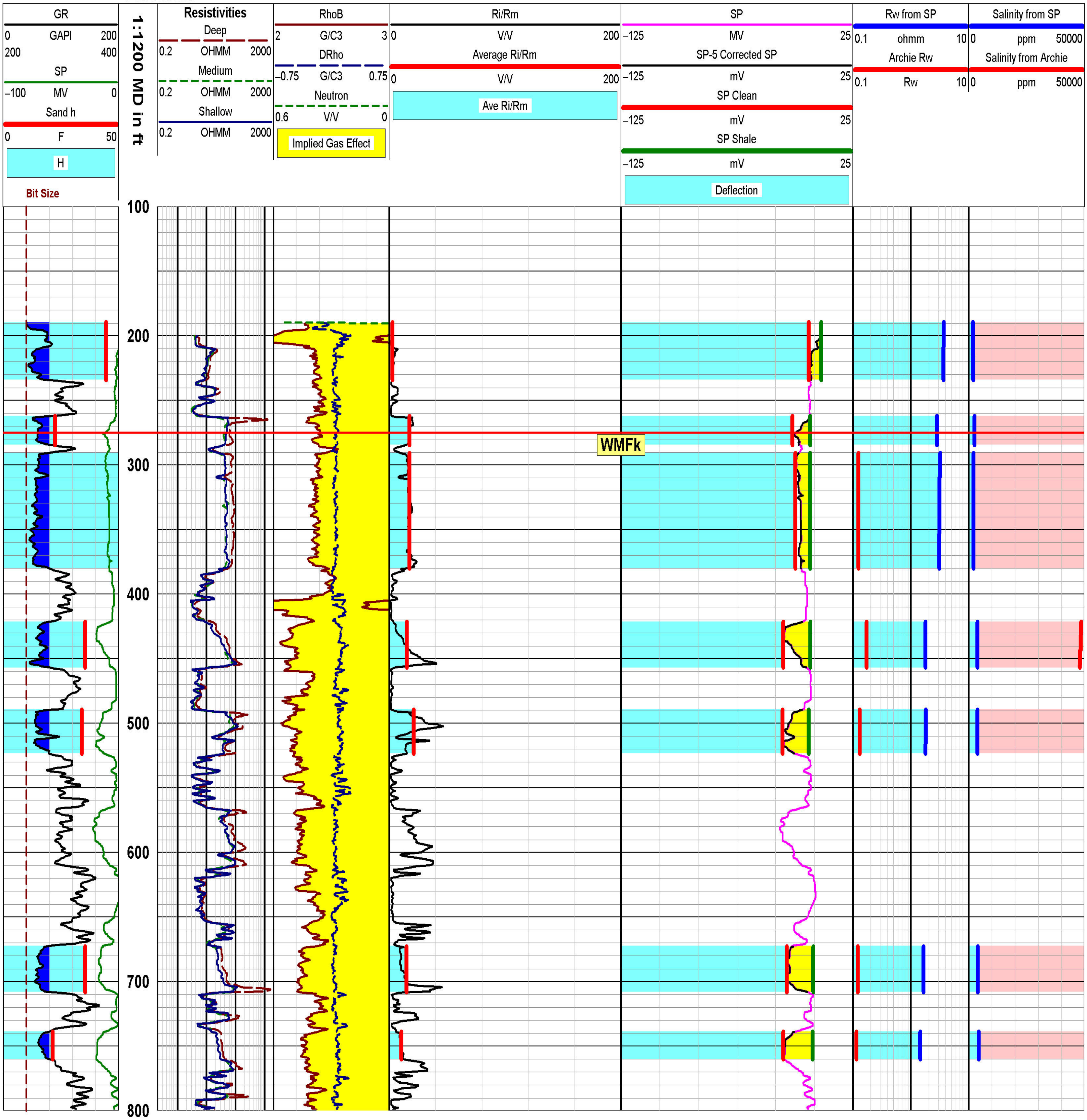
Ranges: User Ranges 190-800

Time: 11:16 AM   Date: Mon, Jun 15, 2020

Section: SECTION   Township: TOWNSHIP   API #: 05077083150000

Location: LOCATION   Range: RANGE   UWI: 05077083150000

Comments: N/A



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File: 05077083200000 Stites 12-3.lbs

Well Name: Stites 12-3

Plot: Salinity by Depth

Gross Interval: 290 to 3100 by 0.5 F

Ranges: User Ranges 290-3100

Time: 11:10 AM

Date: Mon, Jun 15, 2020

Section: SECTION

Township: TOWNSHIP

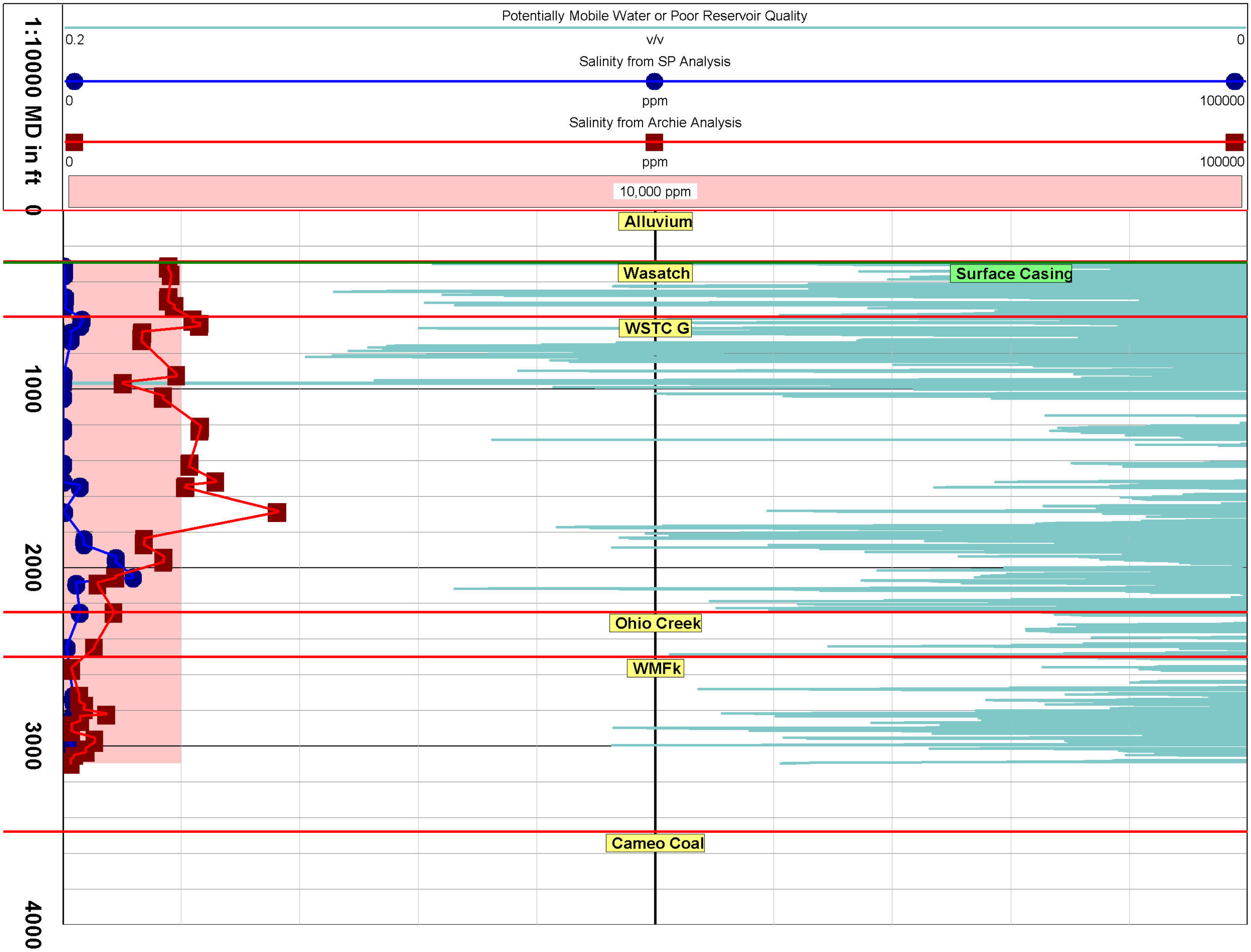
API #: 05077083200000

Location: LOCATION

Range: RANGE

UWI: 05077083200000

Comments: N/A



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File: 05077083200000 Stites 12-3.lbs | Well Name: Stites 12-3

Plot: SP Shift Deflection

Gross Interval: 290 to 3100 by 0.5 F

Ranges: User Ranges
290-3100

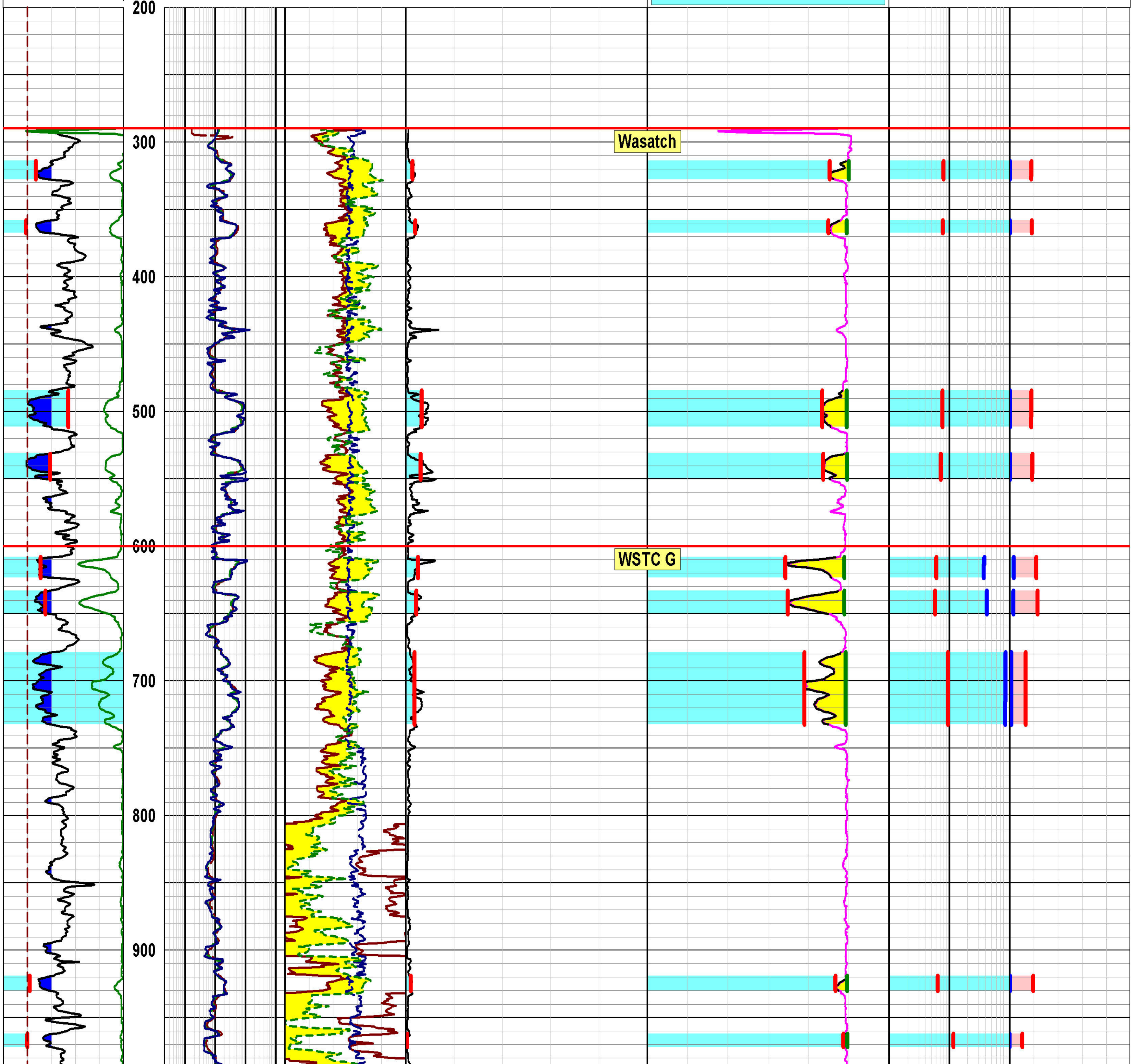
Time: 11:16 AM | Date: Mon, Jun 15, 2020

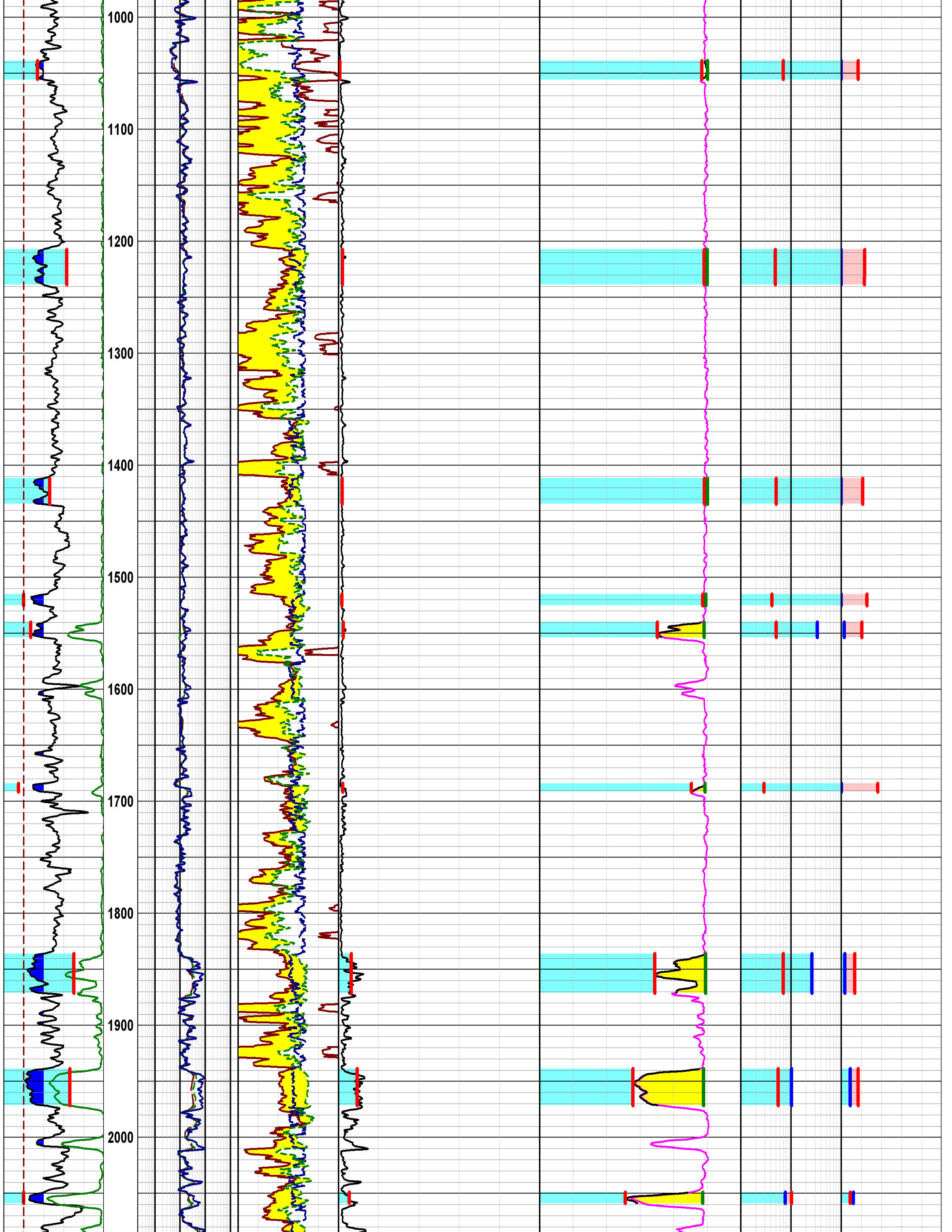
Section: SECTION | Township: TOWNSHIP | API #: 05077083200000

Location: LOCATION | Range: RANGE | UWI: 05077083200000

Comments: N/A

GR	1:1200 MD in ft	Resistivities	RhoB	Ri/Rm	SP	Rw from SP	Salinity from SP
0 GAPI 200 200 400 SP –100 MV 0 Sand h 0 F 50 H Bit Size		Deep 0.2 OHMM 2000 Medium 0.2 OHMM 2000 Shallow 0.2 OHMM 2000	2 G/C3 3 DRho –0.75 G/C3 0.75 Neutron 0.6 V/V 0 Implied Gas Effect	0 V/V 200 Average Ri/Rm 0 V/V 200 Ave Ri/Rm	–125 MV 25 SP-5 Corrected SP –125 mV 25 SP Clean –125 mV 25 SP Shale –125 mV 25 Deflection	0.1 ohmm 10 Archie Rw 0.1 Rw 10	0 ppm 50000 Salinity from Archie 0 ppm 50000

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1600
1700
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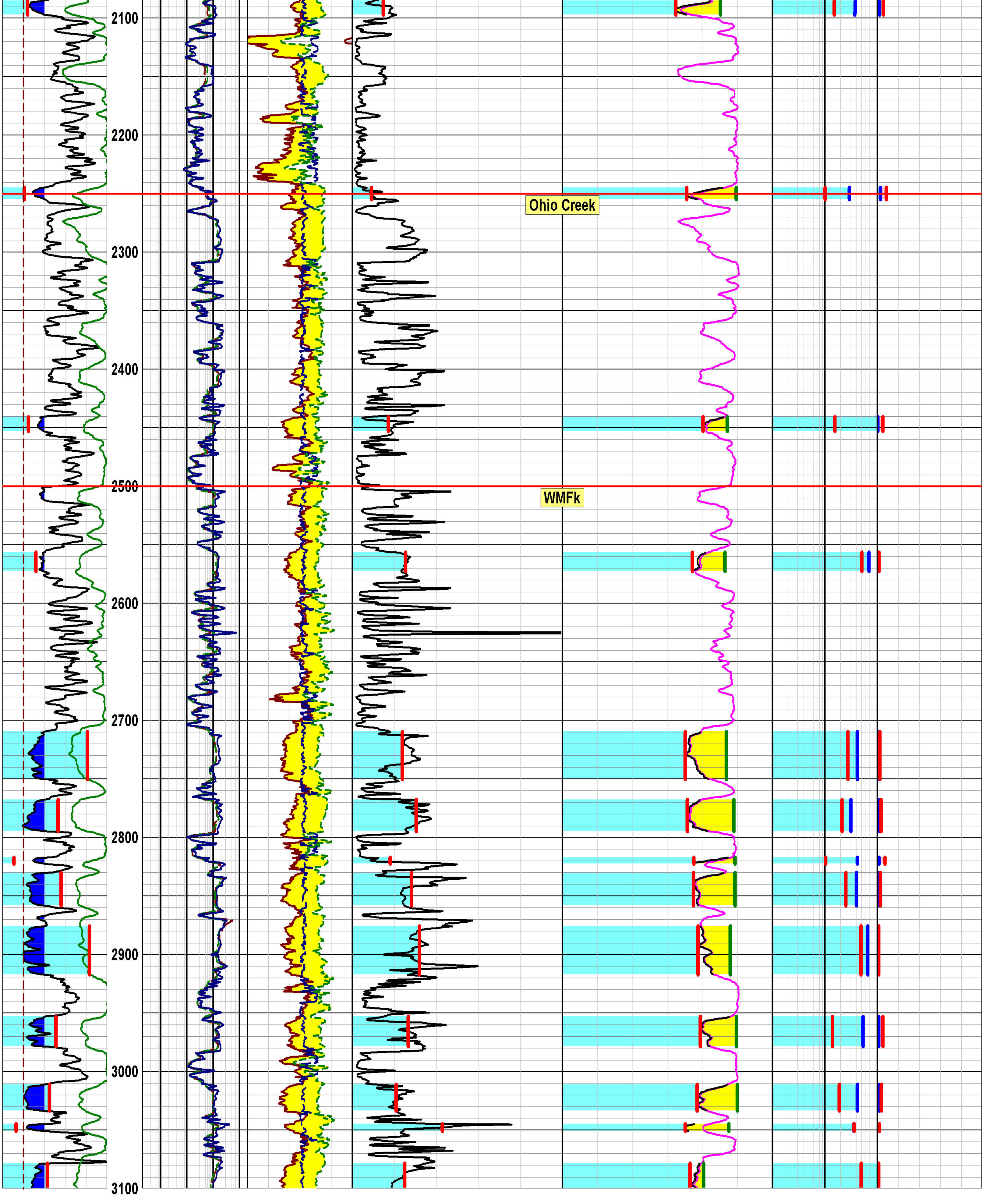
1900
2000



2100
2200
Ohio Creek
2300
2400
2500
WMFk
2600
2700
2800
2900
3000
3100

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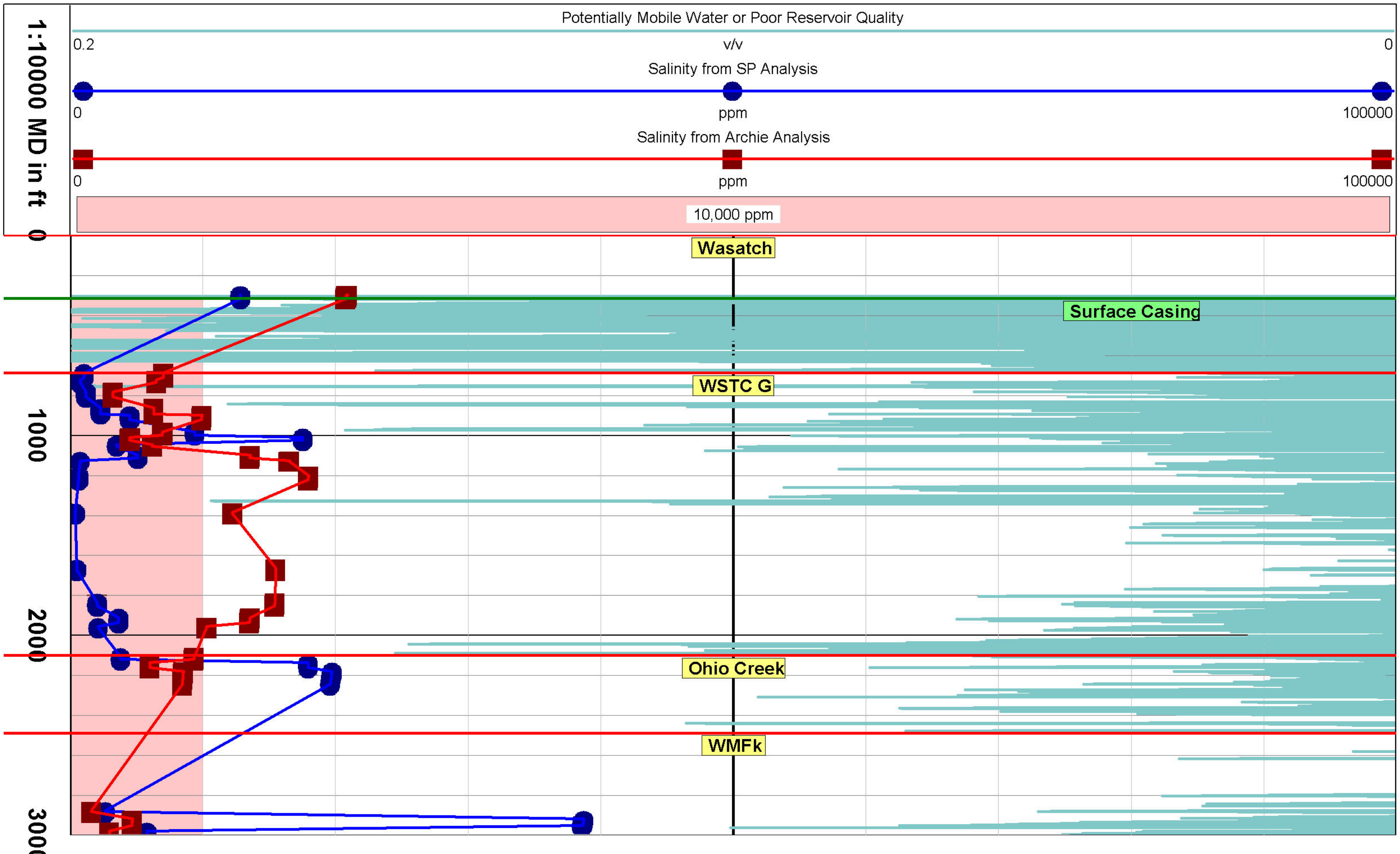
File: 05077083590000 Colo Water 15-2.lbs   Well Name: Colo Water 15-2
Plot: Salinity by Depth
Gross Interval: 300 to 3000 by 0.5 F
Ranges: User Ranges
300-3000
Time: 11:10 AM   Date: Mon, Jun 15, 2020
Section: SECTION   Township: TOWNSHIP   API #: 05077083590000
Location: LOCATION   Range: RANGE   UWI: 05077083590000
Comments: N/A



Zone Parameters   Thinbed Analysis NOT Used

Gross Range: [300] - [3000]

[300] - [3000] Zone00

Neutron Type	Auto Select		Vsh Choice:	GR - Stieber		Sonic Eq.:	Time-Series (Wylie)	
Lithology:	Limestone		PhiN sh:	0.239	fractions	Rw:	0.1	ohm-m
Rho ma:	2.71	gm/cc	Rho sh:	2.497	gm/cc	Rmf:	0.2	ohm-m
Dt ma:	48	us/ft	Dt sh:	95	us/ft	m:	1.8	
GR cl:	45		H20 Model:	Archie's		n:	1.8	
GR sh:	143		Deep Rsh:	5	ohm-m	Pressure:	129.9	psi
SP cl:	10		Shal Rsh:	5	ohm-m			
SP sh:	90		Porosity:	Best [DN]				

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File: 05077083590000 Colo Water 15-2.lbs   Well Name: Colo Water 15-2

Plot: SP Shift Deflection

Gross Interval: 300 to 3000 by 0.5 F

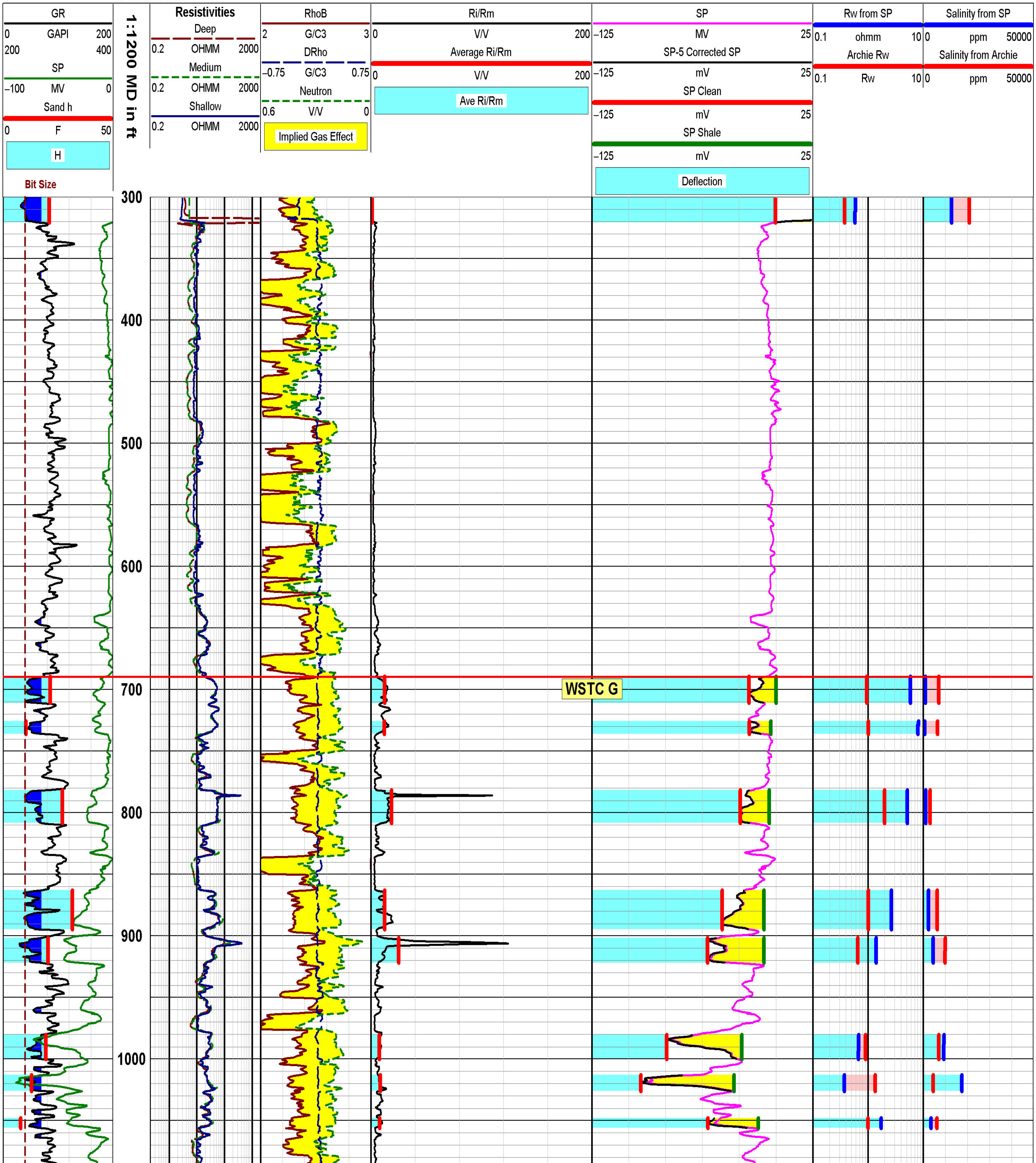
Ranges: User Ranges
300-3000

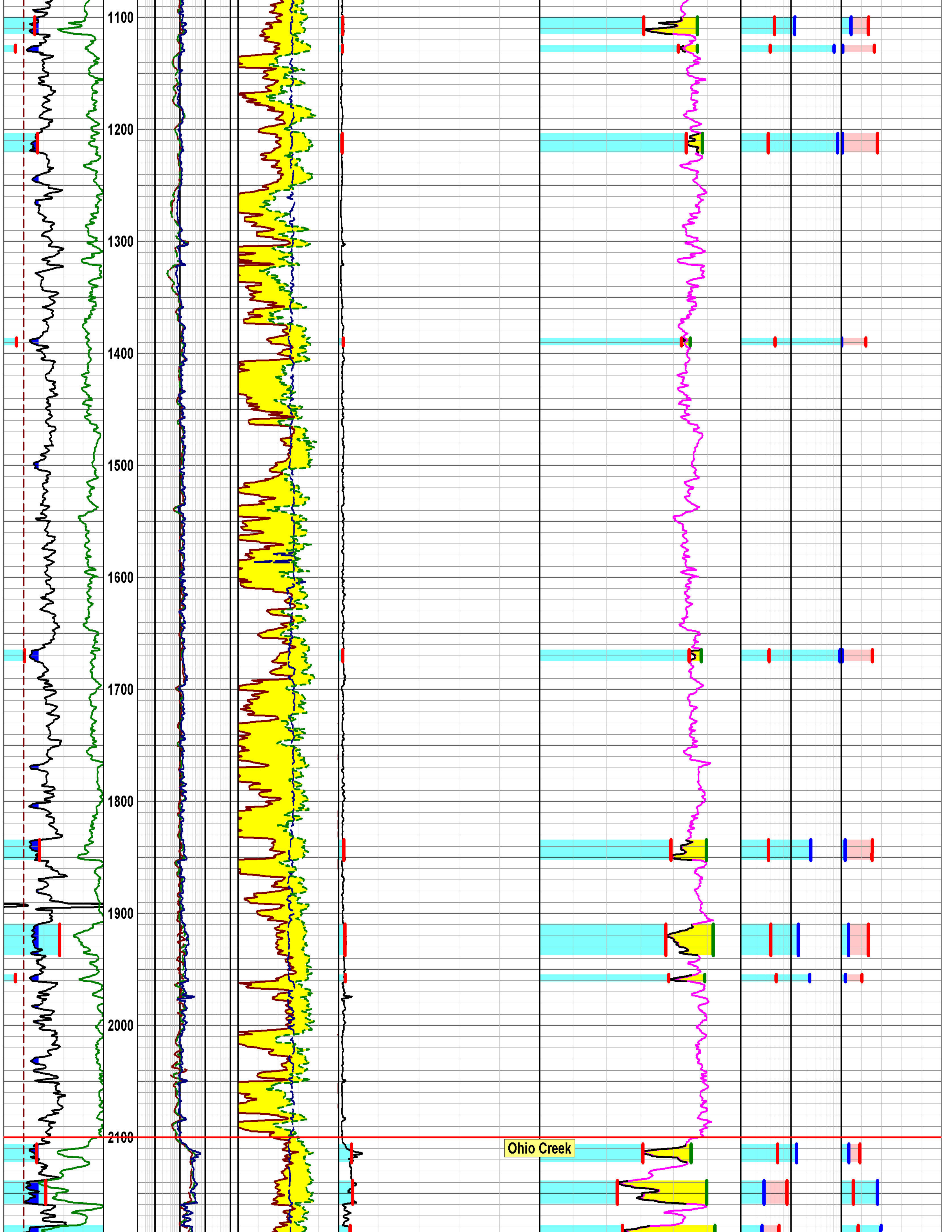
Time: 11:16 AM   Date: Mon, Jun 15, 2020

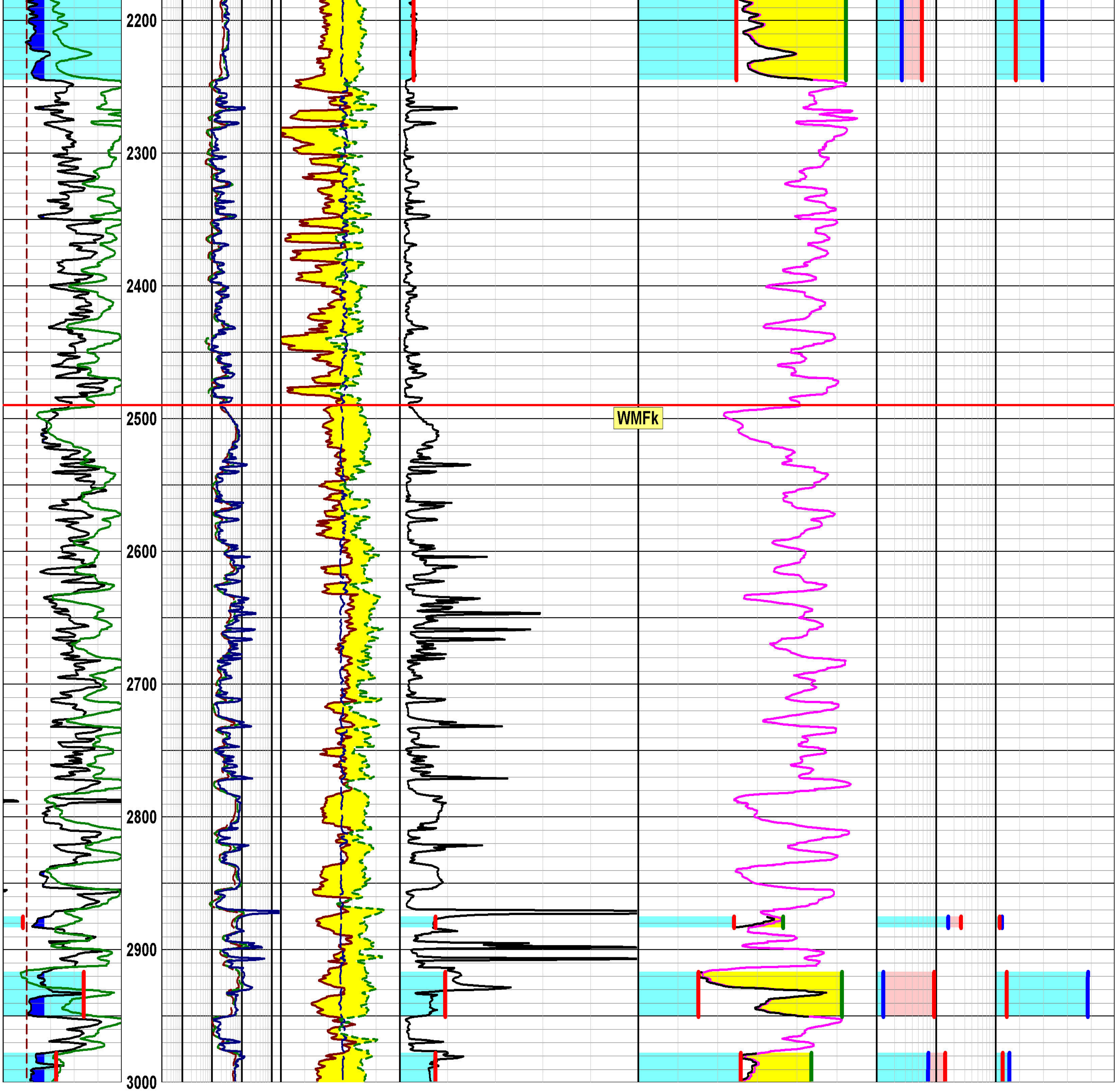
Section: SECTION   Township: TOWNSHIP   API #: 05077083590000

Location: LOCATION   Range: RANGE   UWI: 05077083590000

Comments: N/A




1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
Ohio Creek



Zone Parameters

Thinbed Analysis NOT Used

Gross Range: [300] - [3000]

[300] - [3000] Zone00

Neutron Type	Auto Select		Vsh Choice:	GR - Stieber		Sonic Eq.:	Time-Series (Wylie)	
Lithology:	Limestone		PhiN sh:	0.239	fractions	Rw:	0.1	ohm-m
Rho ma:	2.71	gm/cc	Rho sh:	2.497	gm/cc	Rmf:	0.2	ohm-m
Dt ma:	48	us/ft	Dt sh:	95	us/ft	m:	1.8	
GR cl:	45		H20 Model:	Archie's		n:	1.8	
GR sh:	143		Deep Rsh:	5	ohm-m	Pressure:	129.9	psi
SP cl:	10		Shal Rsh:	5	ohm-m			
SP sh:	90		Porosity:	Best [DN]				

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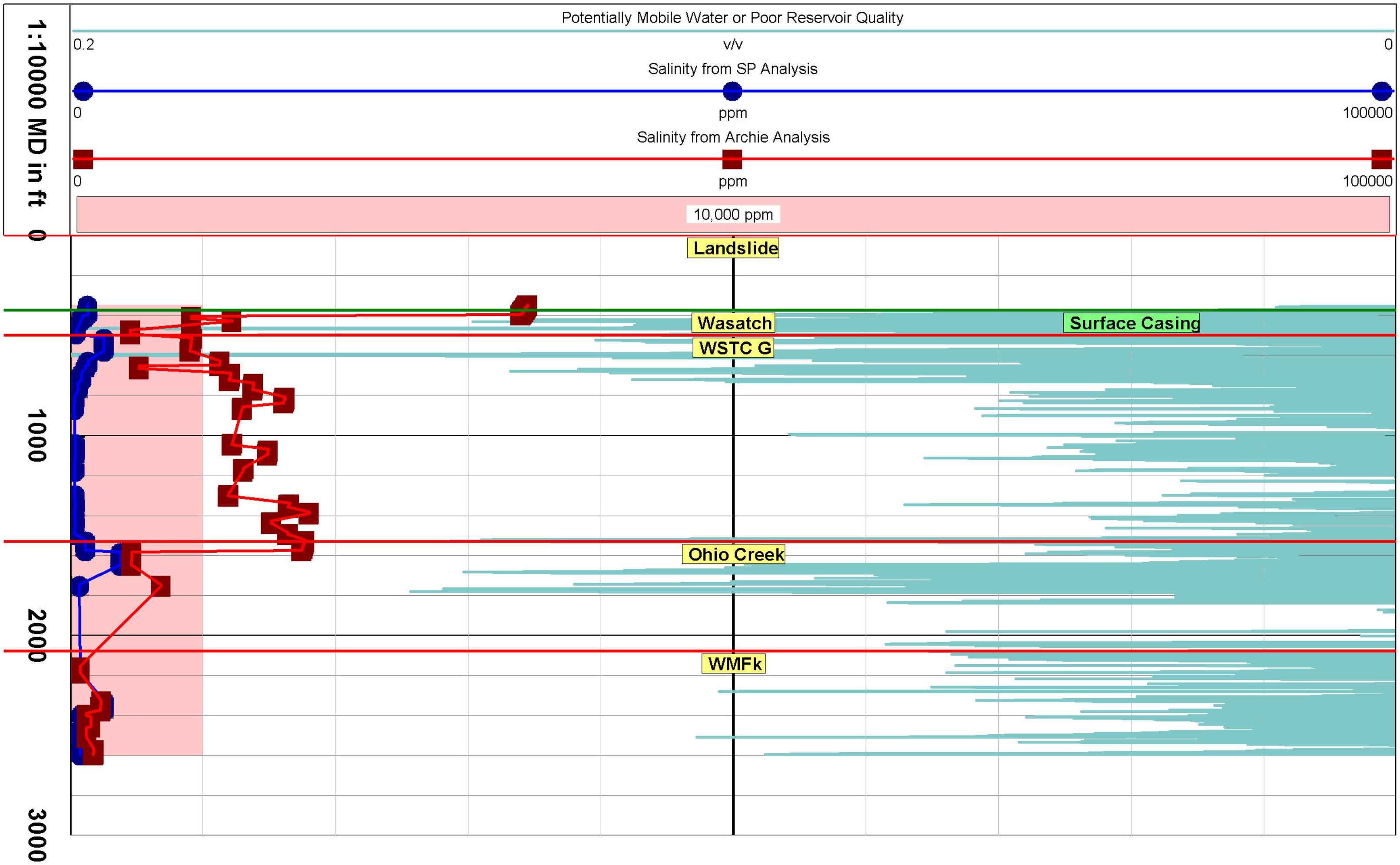
File: 05077084450000 Nichols 1-29.lbs | Well Name: Nichols 1-29
Plot: Salinity by Depth
Gross Interval: 350 to 2600 by 0.5 F
Ranges: User Ranges
350-2600
Time: 11:10 AM | Date: Mon, Jun 15, 2020
Section: SECTION | Township: TOWNSHIP | API #: 05077084450000
Location: LOCATION | Range: RANGE | UWI: 05077084450000
Comments: N/A



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File: 05077084450000 Nichols 1-29.lbs Well Name: Nichols 1-29

Plot: SP Shift Deflection

Gross Interval: 350 to 2600 by 0.5 F

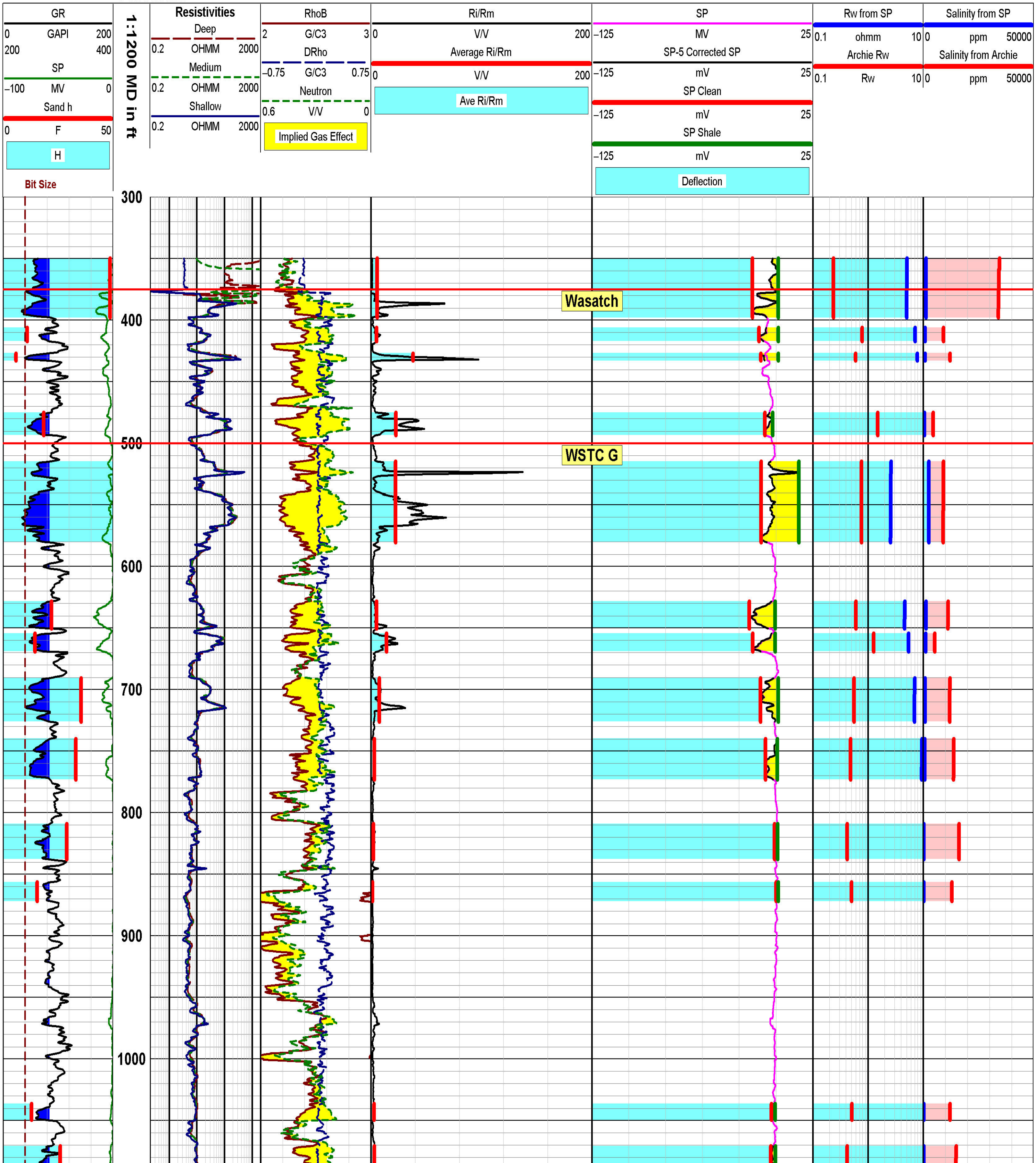
Ranges: User Ranges
350-2600

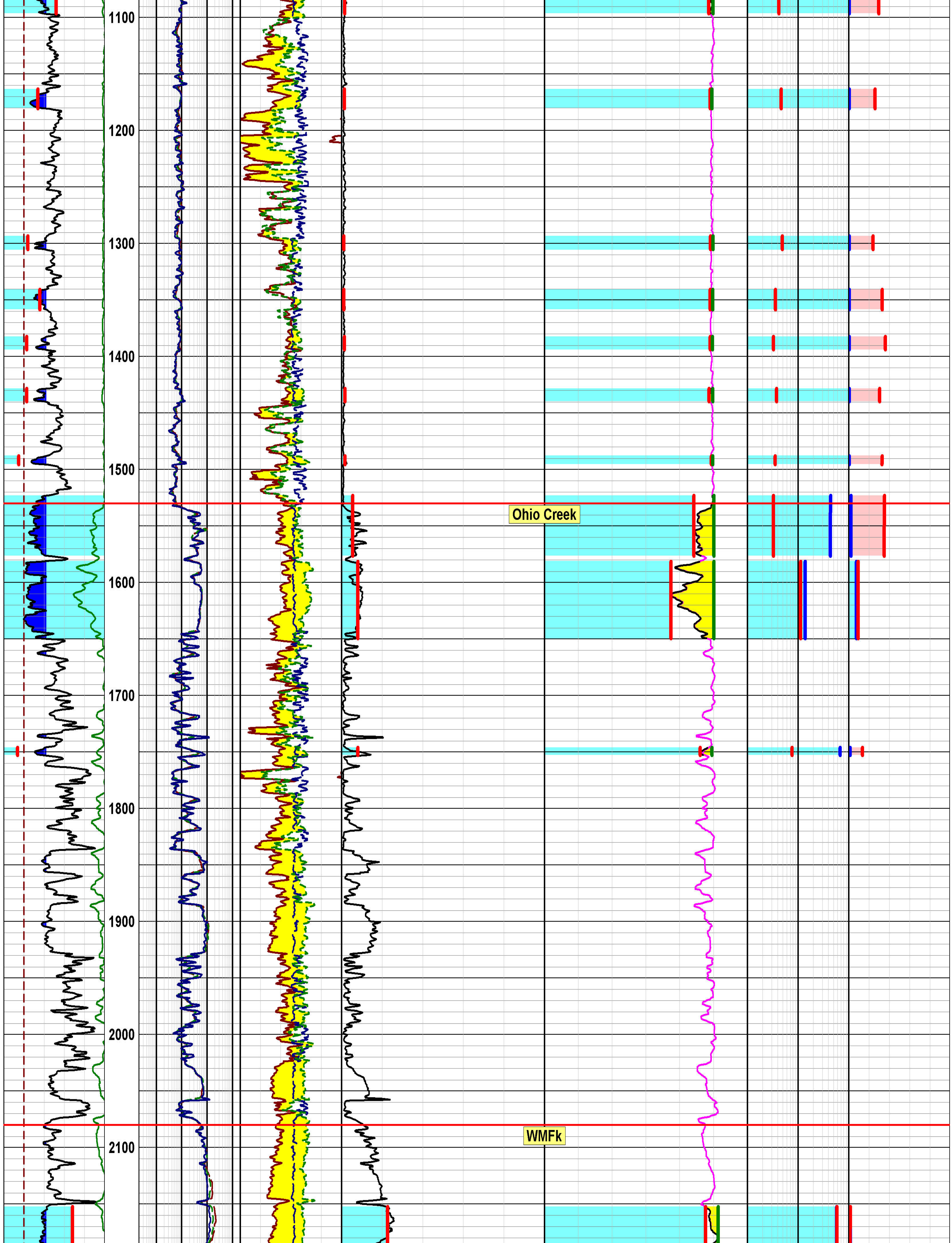
Time: 11:17 AM Date: Mon, Jun 15, 2020

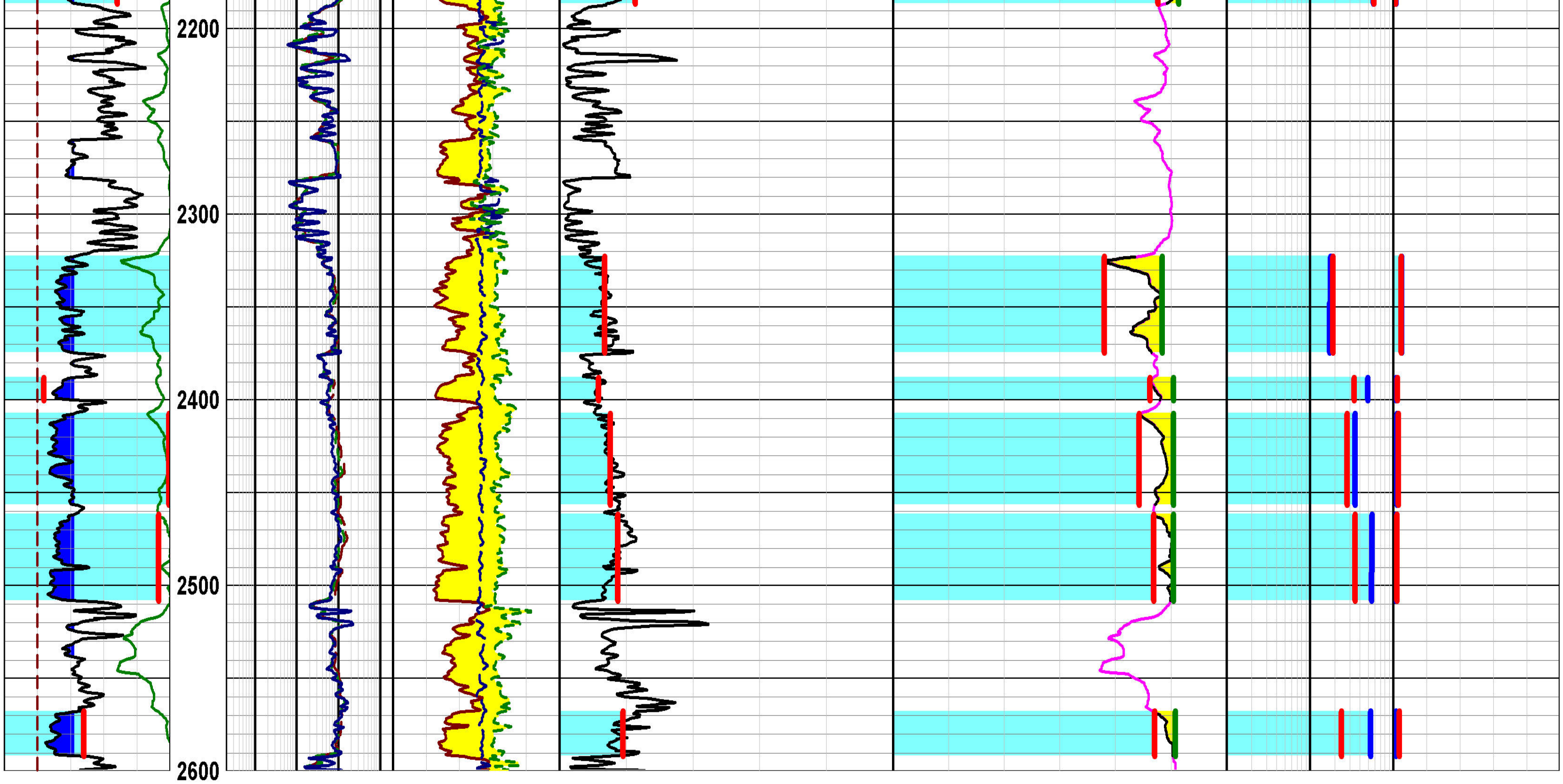
Section: SECTION Township: TOWNSHIP API #: 05077084450000

Location: LOCATION Range: RANGE UWI: 05077084450000

Comments: N/A




1100
1200
1300
1400
1500
Ohio Creek
1600
1700
1800
1900
2000
WMFk
2100


2200
2300
2400
2500
2600

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File: 05077085190000 Pallaoro 15-2.lbs

Well Name: Pallaoro 15-2

Plot: Salinity by Depth

Gross Interval: 160 to 3440 by 0.5 F

Ranges: User Ranges
160-1500

Time: 11:11 AM

Date: Mon, Jun 15, 2020

Section: SECTION

Township: TOWNSHIP

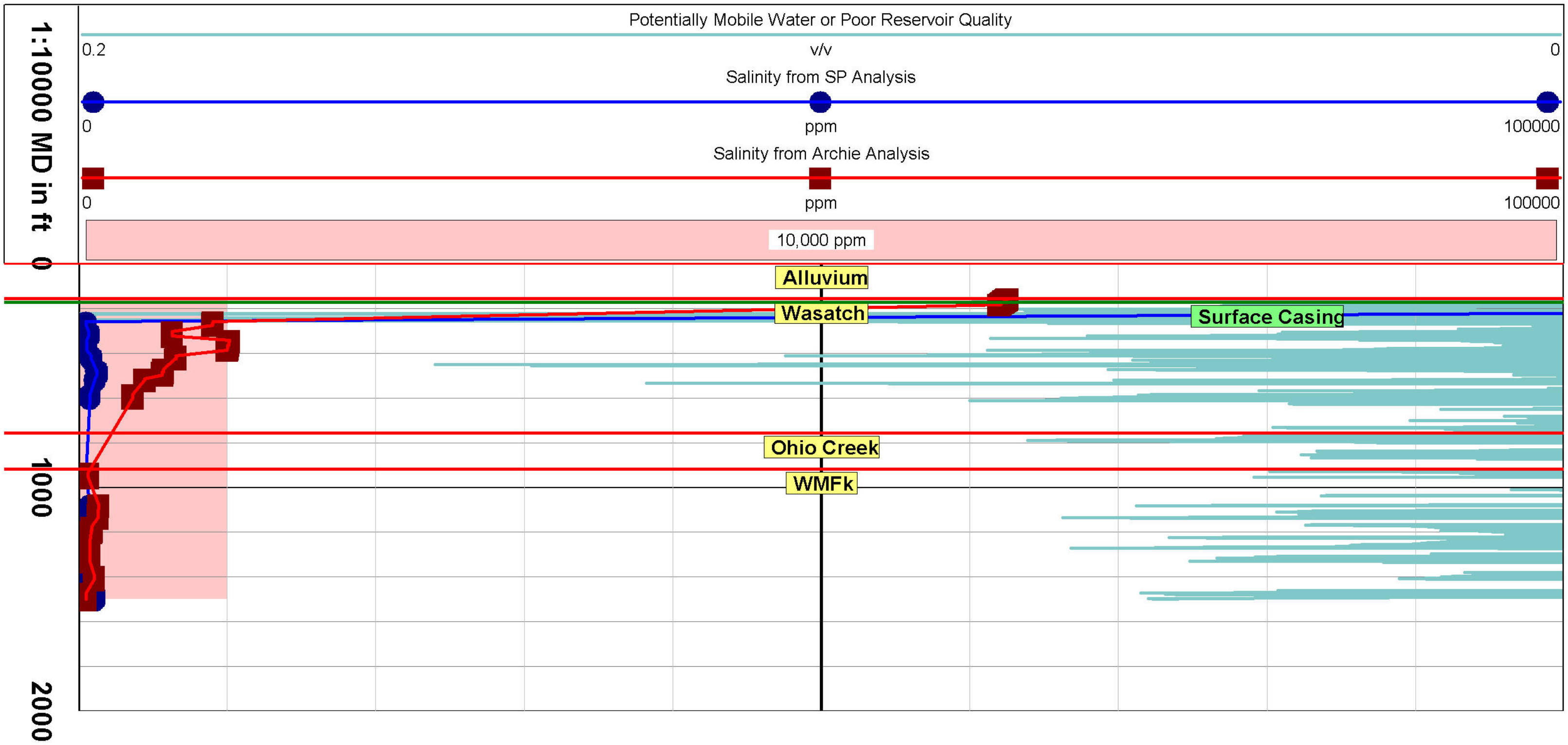
API #: 05077085190000

Location: LOCATION

Range: RANGE

UWI: 05077085190000

Comments: N/A



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File: 05077085190000 Pallaoro 15-2.lbs Well Name: Pallaoro 15-2

Plot: SP Shift Deflection

Gross Interval: 160 to 3440 by 0.5 F

Ranges: User Ranges

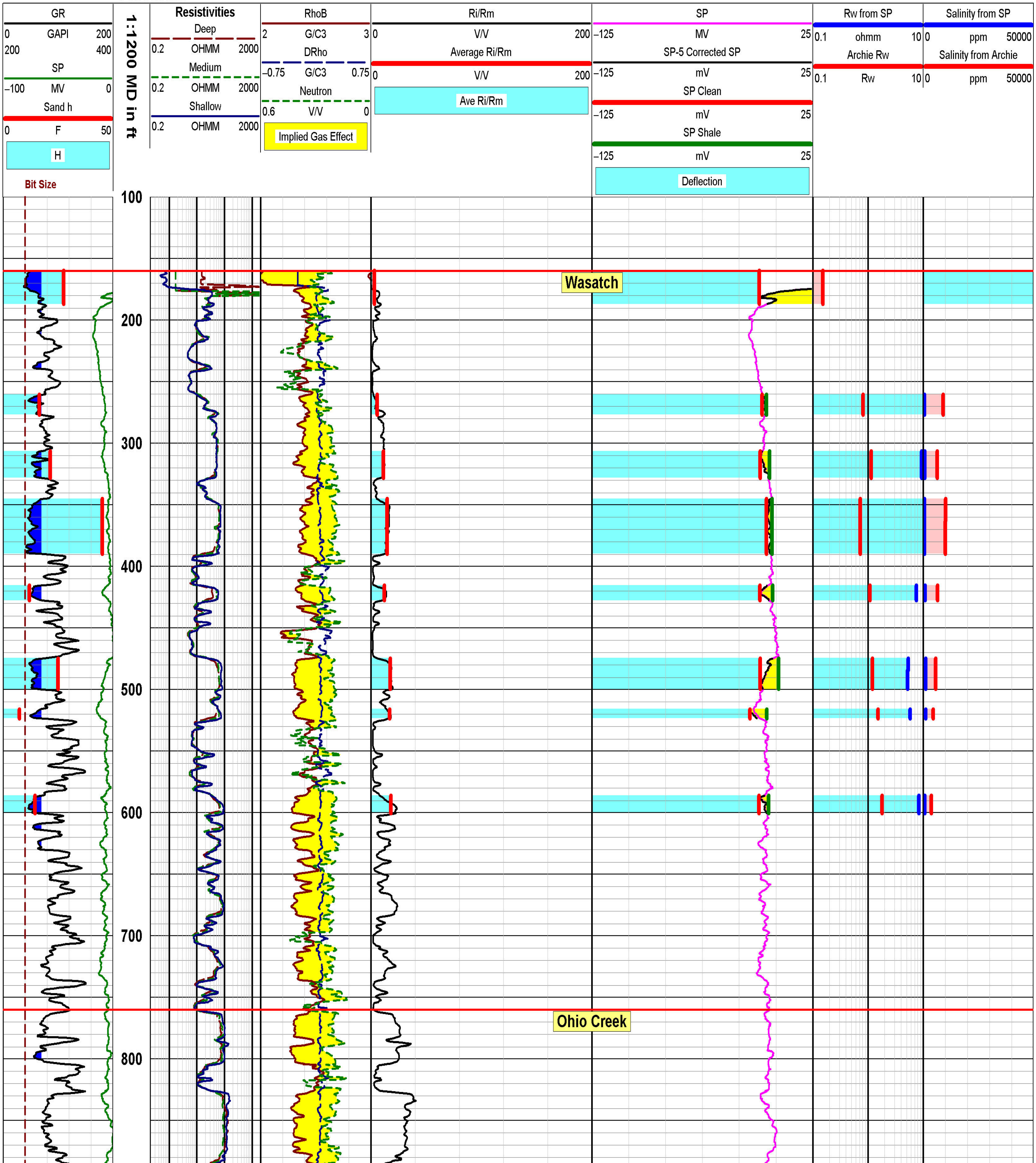
160-1500

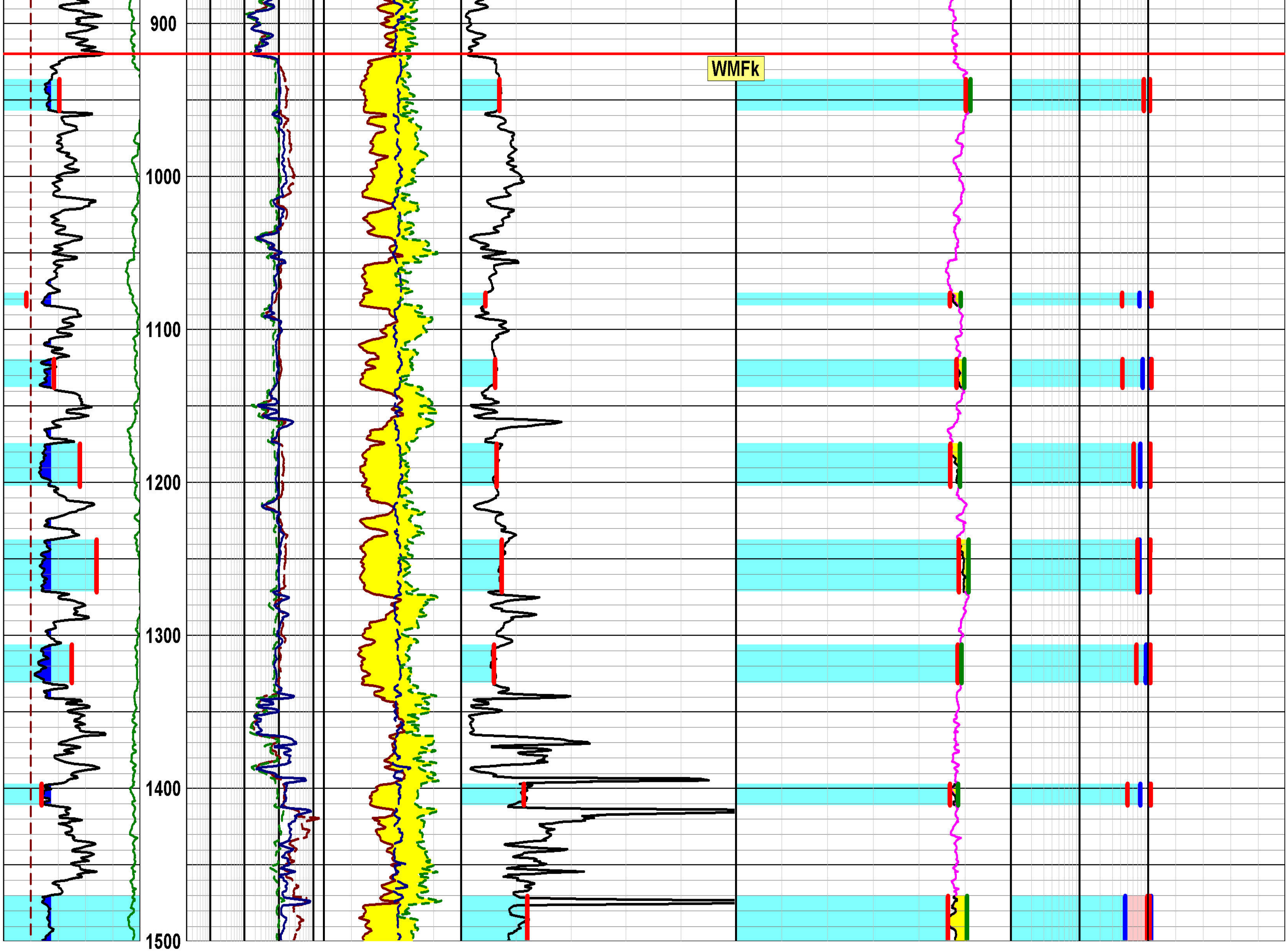
Time: 11:17 AM Date: Mon, Jun 15, 2020

Section: SECTION Township: TOWNSHIP API #: 05077085190000

Location: LOCATION Range: RANGE UWI: 05077085190000

Comments: N/A




900
WMFk
1000
1100
1200
1300
1400
1500

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File: 05077085790000 No, 3 Deep Seam 30-4.lbs | Well Name: No, 3 Deep Seam 30-4

Plot: Salinity by Depth

Gross Interval: 240 to 3600 by 0.5 F

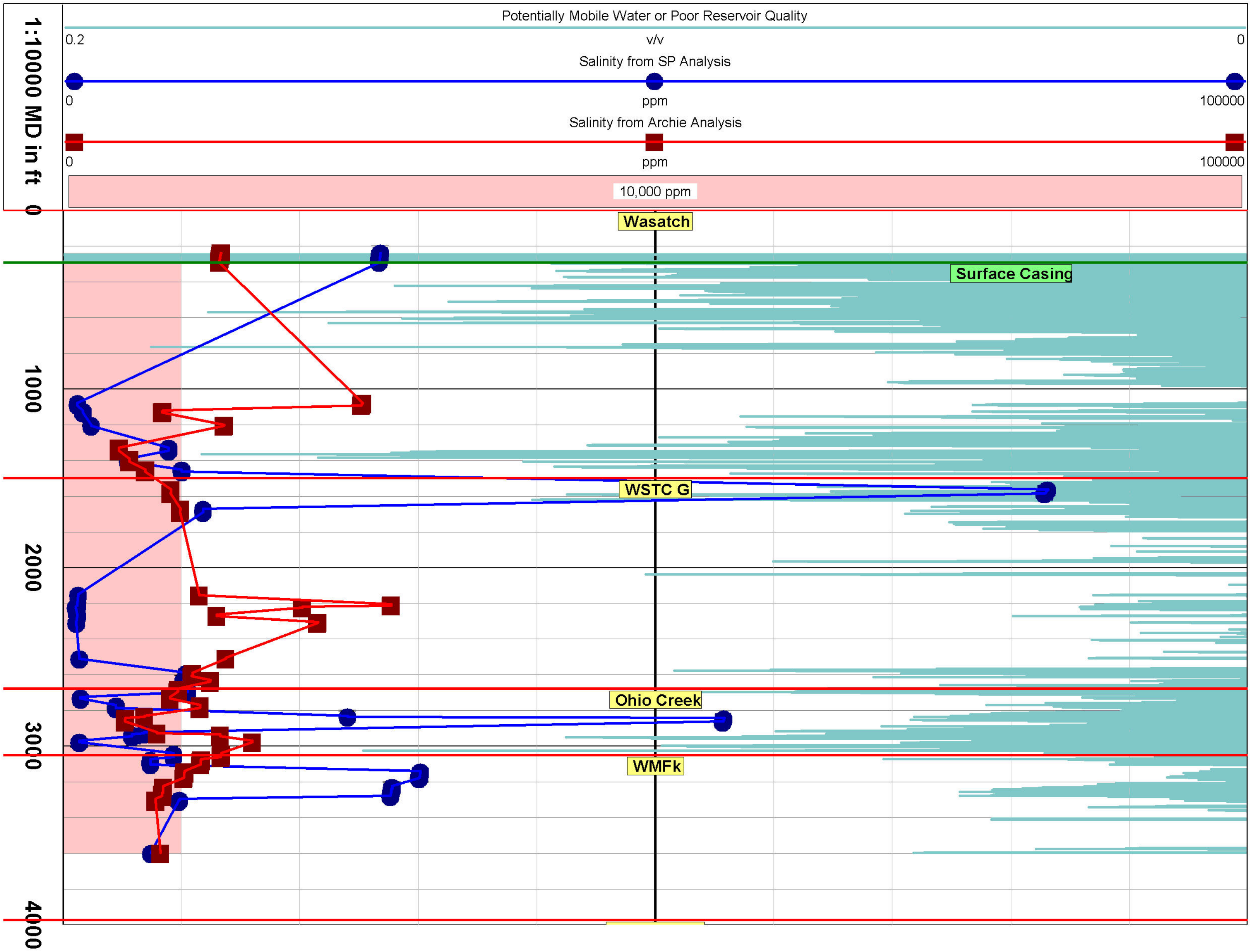
Ranges: User Ranges
240-3600

Time: 11:11 AM | Date: Mon, Jun 15, 2020

Section: SECTION | Township: TOWNSHIP | API #: 05077085790000

Location: LOCATION | Range: RANGE | UWI: 05077085790000

Comments: N/A



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File: 05077085790000 No, 3 Deep Seam 30-4.lbs   Well Name: No, 3 Deep Seam 30-4

Plot: SP Shift Deflection

Gross Interval: 240 to 3600 by 0.5 F

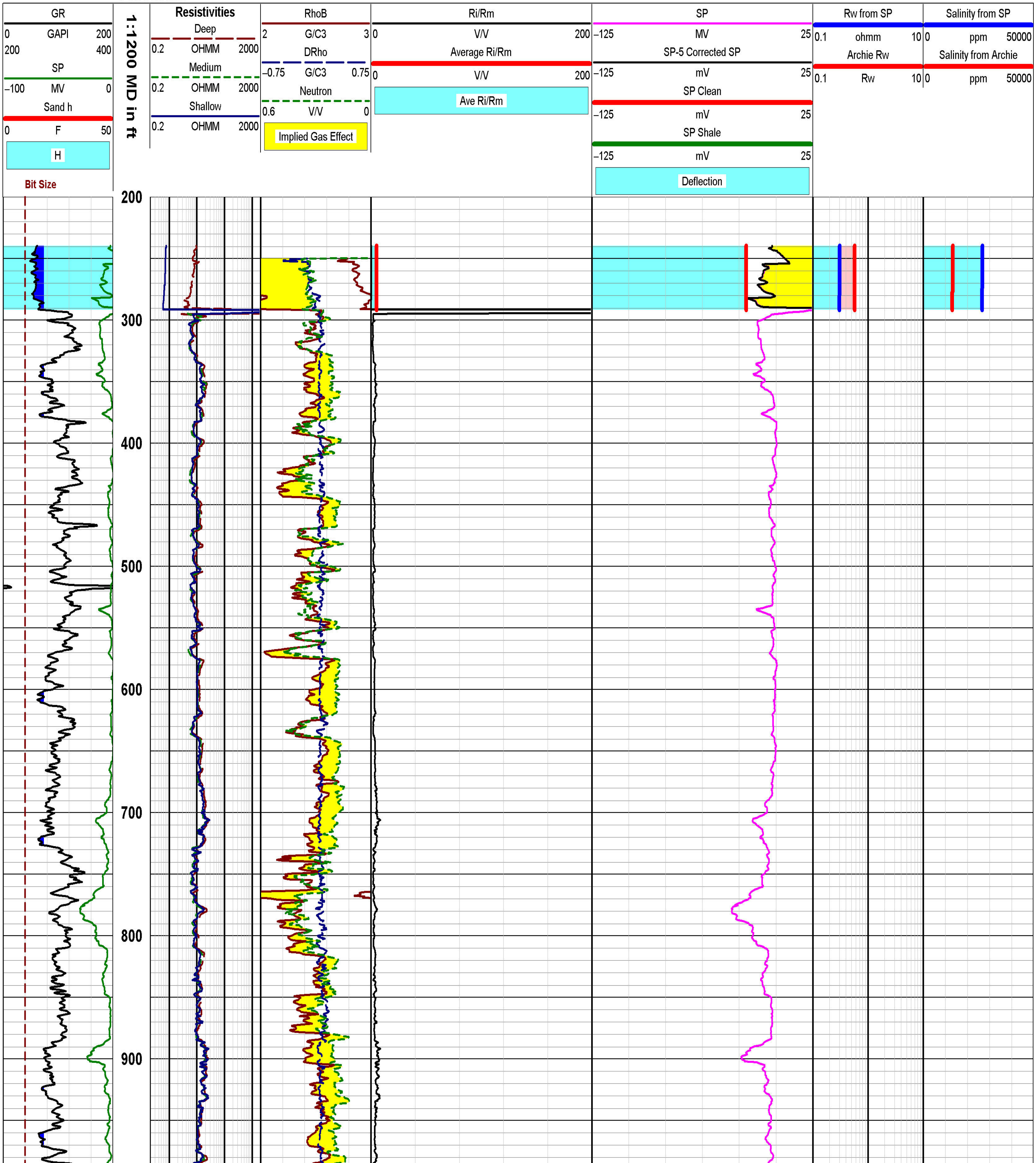
Ranges: User Ranges
240-3600

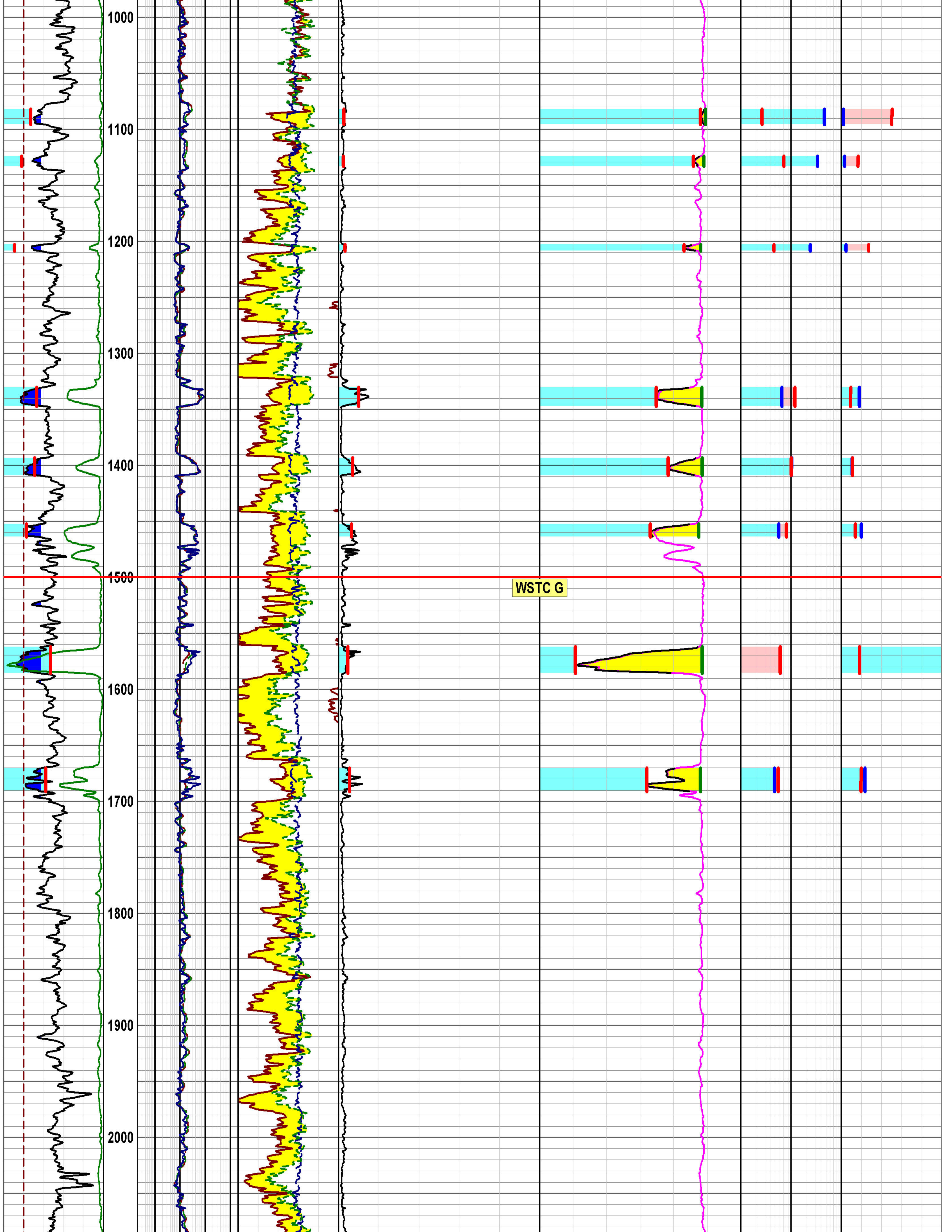
Time: 11:18 AM   Date: Mon, Jun 15, 2020

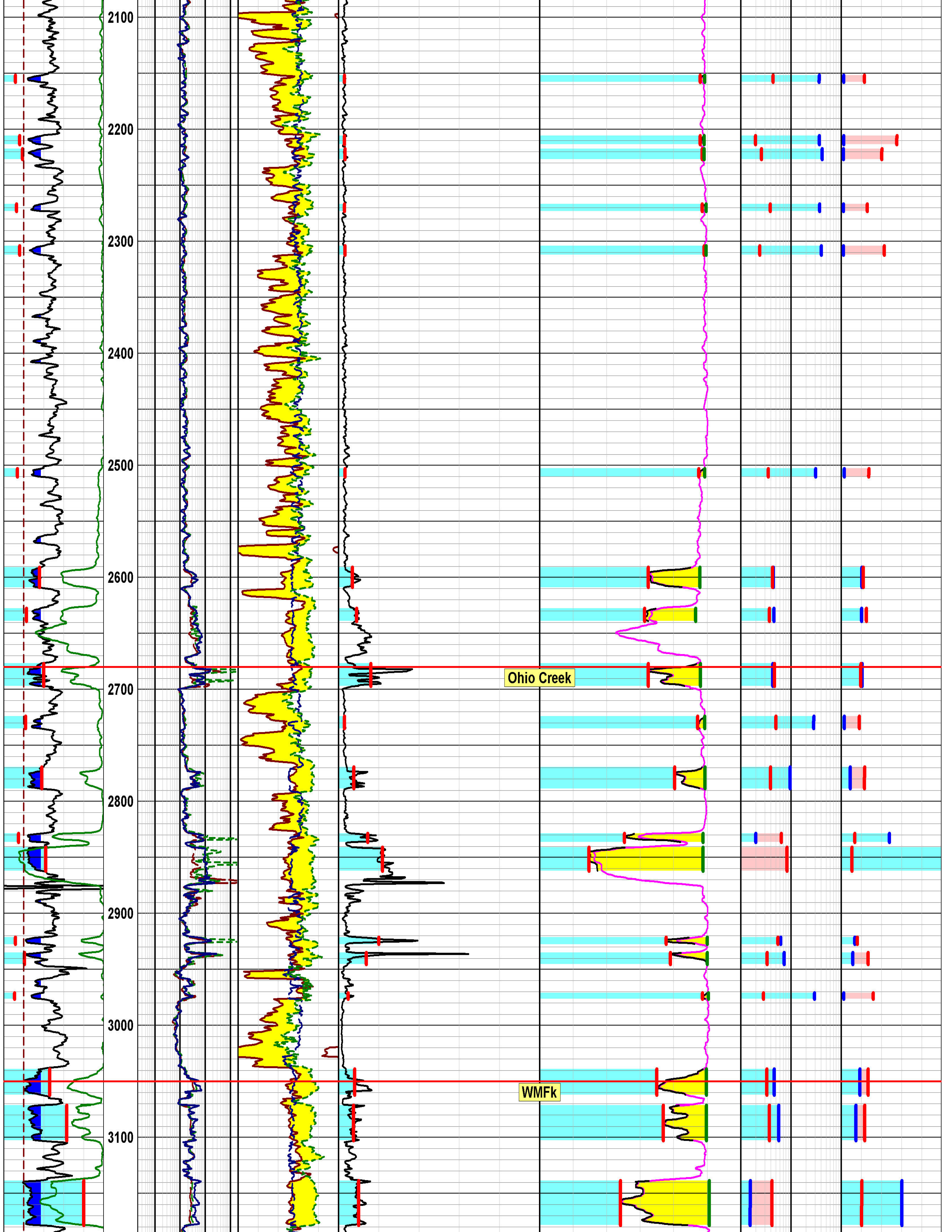
Section: SECTION   Township: TOWNSHIP   API #: 05077085790000

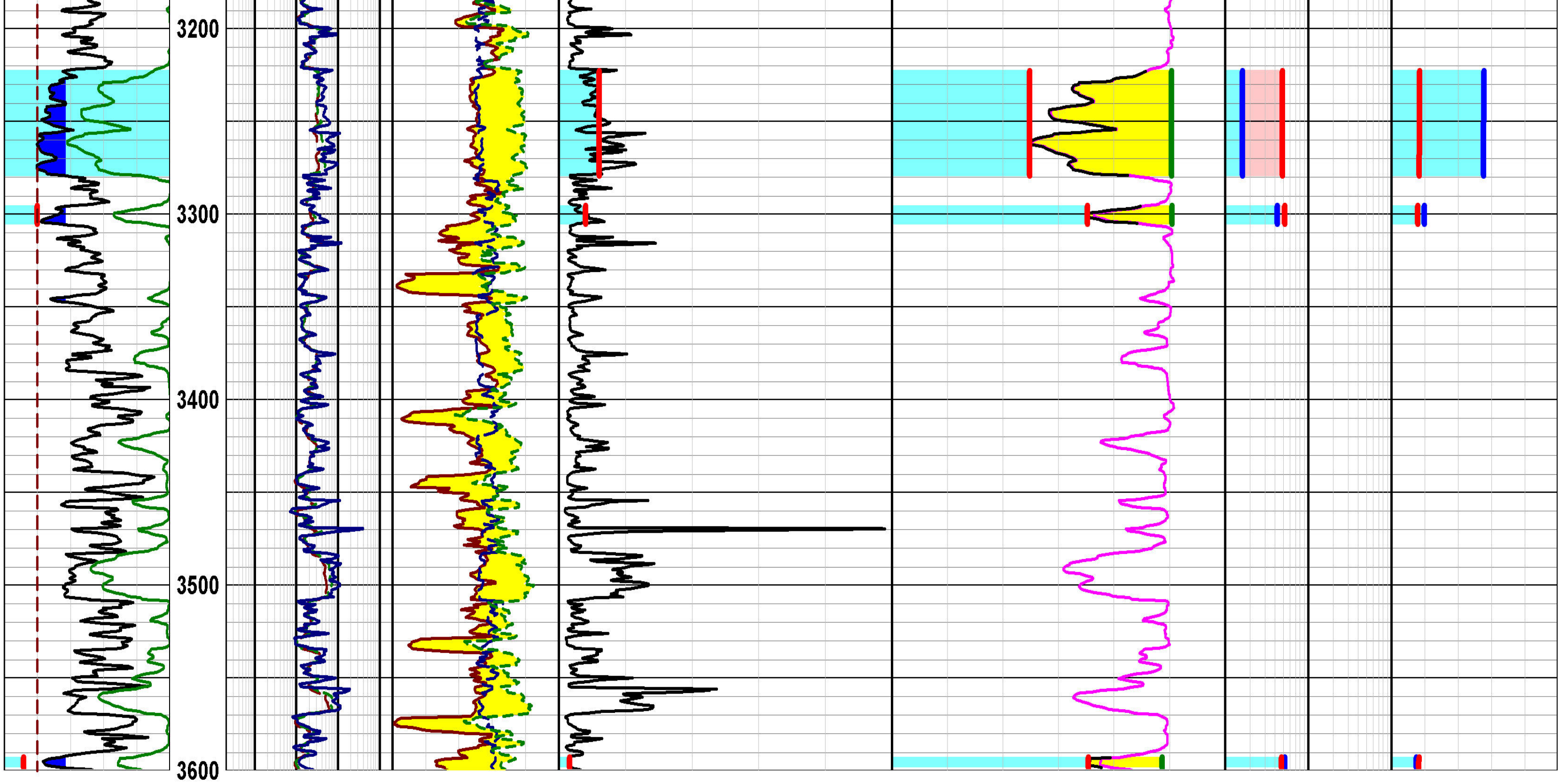
Location: LOCATION   Range: RANGE   UWI: 05077085790000

Comments: N/A




1000
1100
1200
1300
1400
1500
WSTC G
1600
1700
1800
1900
2000


2100
2200
2300
2400
2500
2600
Ohio Creek
2700
2800
2900
3000
WMFk
3100


3200
3300
3400
3500
3600