3/31/2023

Eagle Newsletter

Eagle Reservoir Services

Special points of interest:

- The EPA requires that non exempt disposal wells are evaluated with technical adequacy to demonstrate no migration and fulfill UIC permits. This annual requirement consists of analysis through pressure buildup in the injection zone, and a shut down of the well for a time sufficient to evaluate the pressure falloff curve. Eagle Reservoir Services provides the expertise necessary for this data collection and analysis
- Array Production Logging and Analysis identifies and quantifies the areas of production in the complex scenario of a horizontal wellbore, as well as stage efficiency and problem stages that may be affected by drilling trajectory and frac inefficiency in a discrete stage. Eagle Reservoir Services provides the top tier equipment and probabilistic analysis required for these difficult production operations.

Inside this issue:

Annual EPA Requirement - Pressure Falloff Test and Transient Analysis

Overview:

- Injection history of 3.4 years (water rate and surface pressure).
- Pressure falloff (PFO) test duration of 72 hours (bottomhole pressure gauge).
- Objectives:
  - —Review injection rate and estimated bottomhole pressure history (Fig. 1).
  - —Review pressure falloff test pressure and pressure derivative functions (Fig. 2).
  - —Perform analysis of pressure falloff test data (Fig. 3).
  - —Use analysis of pressure falloff test data to model prior injection rate and estimated bottomhole pressure (Fig. 4).

Workflow:

- Review injection history data for anomalies:
  - —Reported monthly "rates" are "spot rates".
  - —Reported monthly surface pressures are also "spot pressures," but are sufficient for analysis/interpretation.
  - —Used reported monthly injection volumes (separate data stream) and divided by days-per-month to yield monthly rates.
  - —Used bottomhole pressure data from pressure falloff test and "shifted" monthly injection pressures to estimate BHP.
  - —From Fig. 1, erratic injection rates, roughly correlate with features in the pressure profile.
- Review/analysis of pressure falloff data:
  - —Input the monthly injection rate and pressure data.
  - —Input the pressure falloff data.
  - —Input the relevant reservoir and fluid properties.
  - —Estimated the net injection interval from the provided records (e.g., the wellbore diagram with injection depths and injection profile from November 18, 2022).
  - —Performed analysis of the pressure falloff data using diagnostic plots and reservoir model (fractured well) (Fig. 3).
  - —*Results*: Fractured Vertical Well (Uniform Flux case), k = 2.15 md, x_f = 442 ft, s = 0.03 (dim-less), c_s=0.05 RB/psi.
- Independent review of the pressure falloff data:
  - —Reduced the data to 1000 data points using interpolation (these 1000 points are used for presentation purposes).
  - —Independently prepared pressure derivative functions and created diagnostic plot, labelled flow regimes (Fig. 2).
  - —This step was not "necessary," but helps the reviewer visualize the data, and provides validation of the flow regimes.
- History match of all data:
  - —Used the history match for the pressure falloff data and projected this onto the prior injection history (Fig. 4).
- Summary comment:
  - —Excellent/outstanding match of pressure falloff functions.
  - —Very good match of prior injection history.

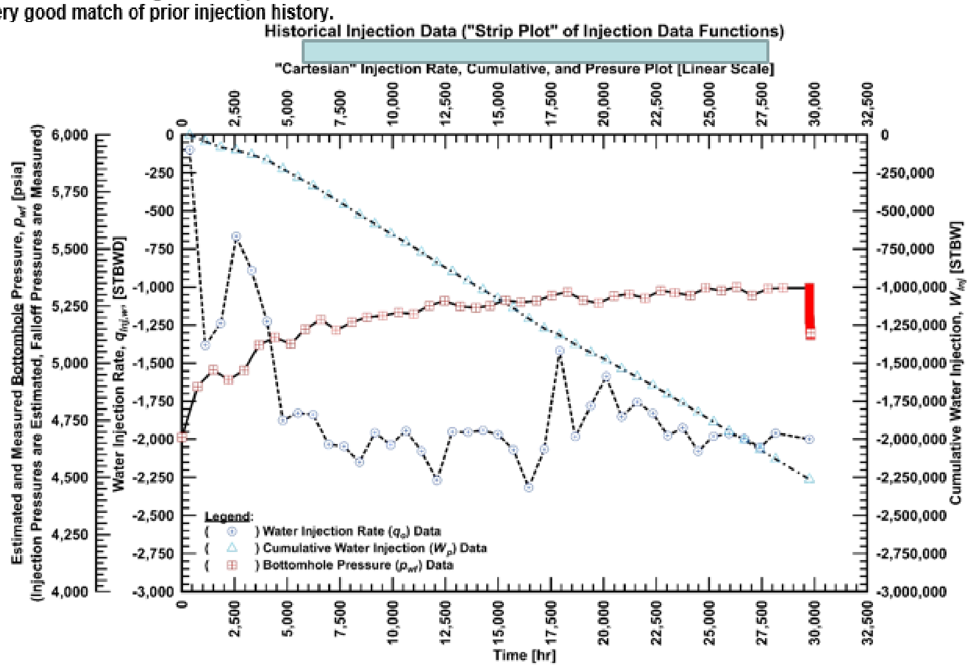


Figure 1 — "Strip Plot" of Injection Rates, Cumulatives, and Pressures (includes PFO test data).

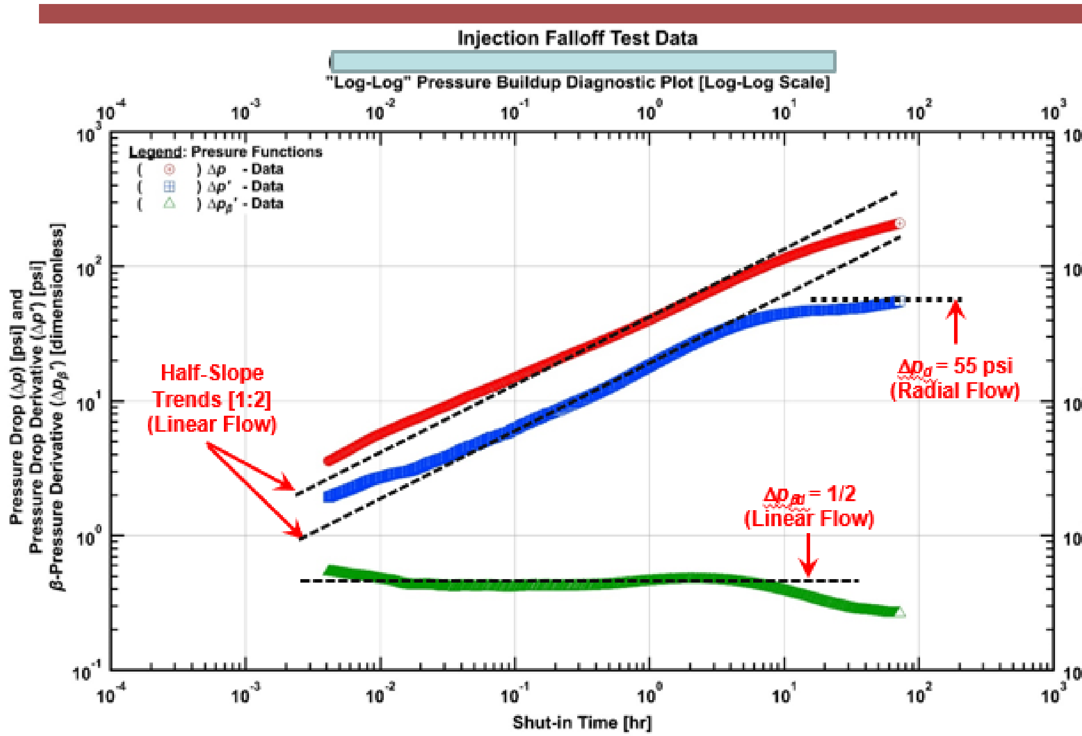


Figure 2 — Diagnostic analysis of pressure and pressure derivative data — linear and radial flow regimes are strongly evident (data down-sampled to 1000 pts for clarity).

Dynamic injection passes were also made to establish no communication below and above packer. Do not get behind in mandates! Eagle can acquire and analyze all necessary data and reporting requirements.

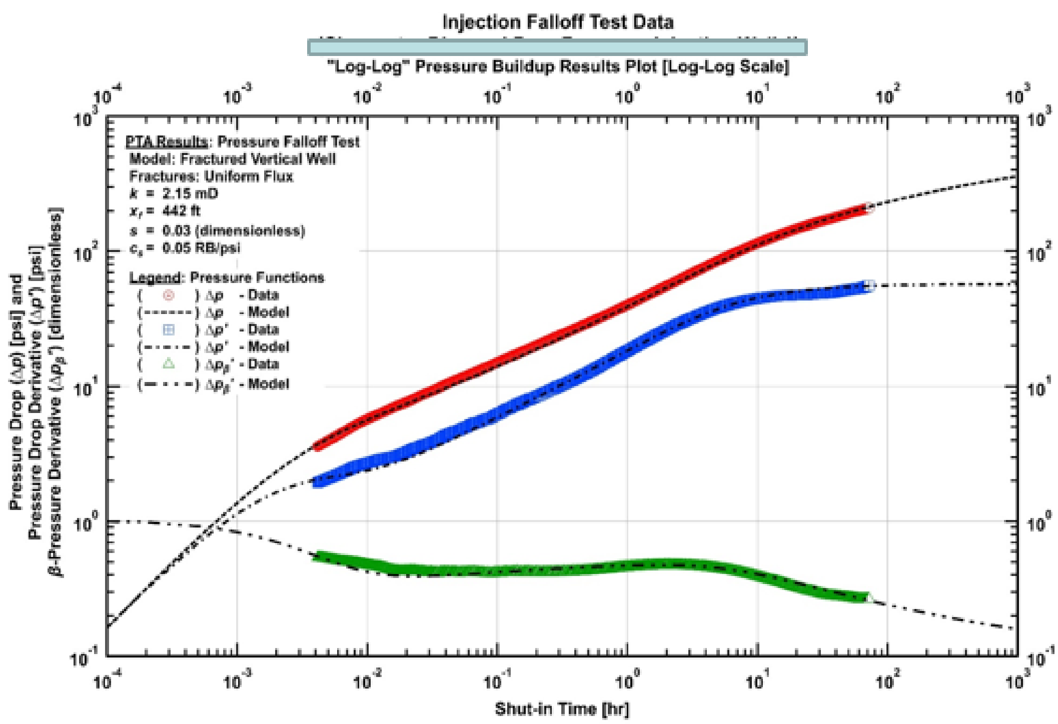


Figure 3 — Excellent model match of PFO pressure and derivative functions, hydraulic fracture model used to capture linear flow behavior (data down-sampled to 1000 pts for clarity).

Fulfilling all mandates and monitoring your well or field for the life of your asset

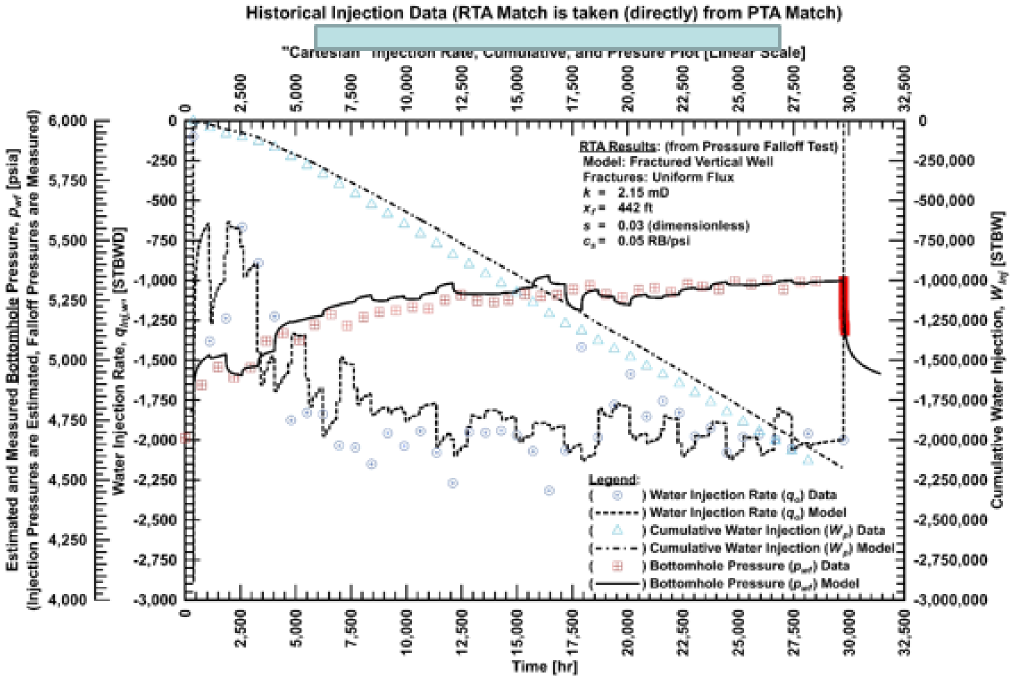
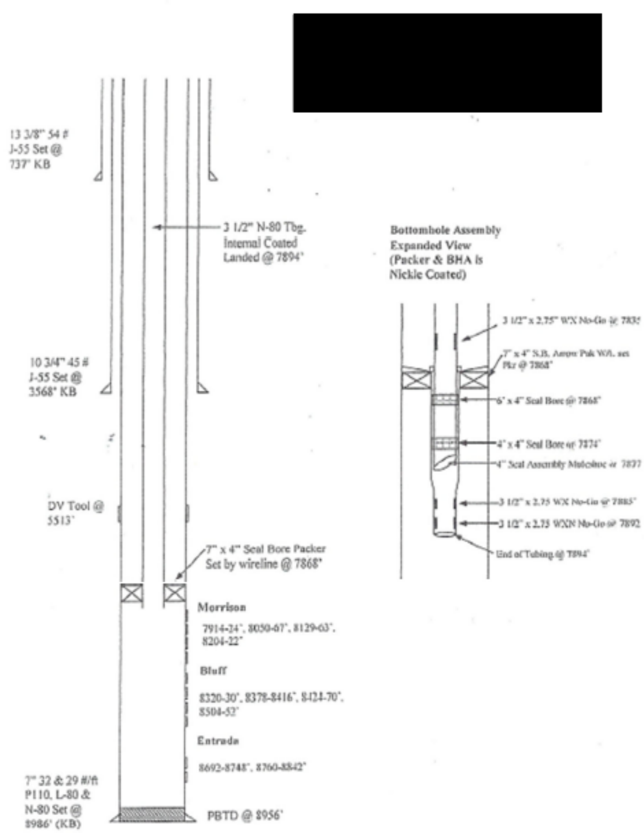


Figure 4 — History match of prior injection history (performed as an RTA), RTA used the PTA match from the pressure falloff test (no parameters were adjusted).

Well Diagram

Below is the well diagram as indicated in the Overview and Objectives.



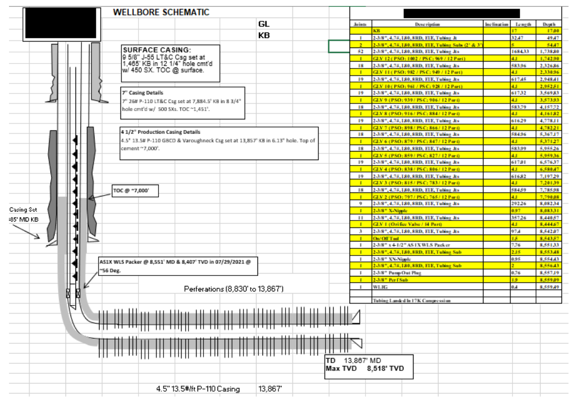
Resolving loading problems in horizontal producers

A horizontal well in Oklahoma can only sustain production from gas lift. Water production loads the well very quickly. An array Production log was run on coil while nitrogen was continually pumped to keep well flowing during logging. The completion is shown in Figure 1.

This well is a toe up oil and gas producer. The well has 24 stages with 5000' of lateral.

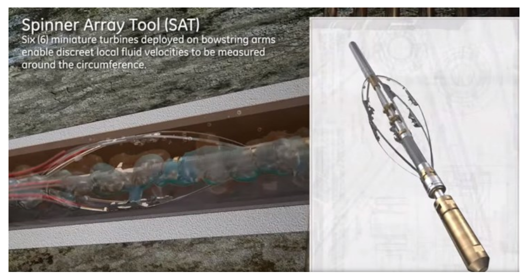
Procedure:

An array production logging string with an Array Spinner Tool (Figure 2) and Array Resistivity tool ((Figure 3), along with conventional production logging sensors (pressure, array temperature, Gamma Ray and CCL) were deployed on coil tubing and run in memory to eliminate the need for surface telemetry. These tools are the most accurate and precise design for deviated and horizontal completions (read more at www.eaglereservoir.com). While deployed, nitrogen was continually pumped from a sub above the toolstring to maintain production while logging.



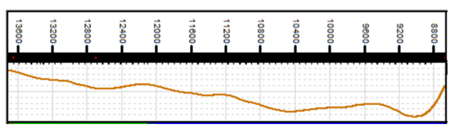
Data

As seen in Figure 4, the wellbore trajectory follows a toe up direction. Production is surging while well is loading quickly. This hinders lower TVD stages from producing efficiently. Production can be quantified accurately at cluster level with array tools and the most advanced probabilistic software. Figure 5 shows the Array Spinner (7 spinners in far right tracks, the holdup profile (top of wellbore on right side) and the velocity profile (faster red and yellow velocities seen on top of wellbore, right side), and tool rotation. Figure 6 shows the Array Resistivity (12 sensors in far right tracks, the holdup and velocity profiles and tool rotation.



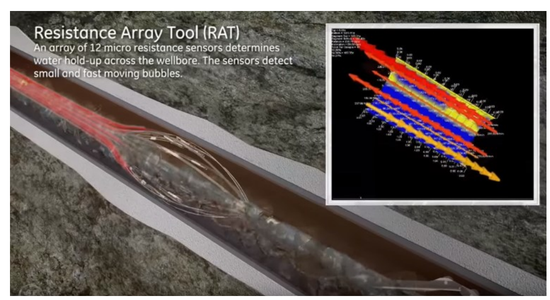
Independent Velocities in segregated horizontal flow

Spinner Array Tool. Fig. 2



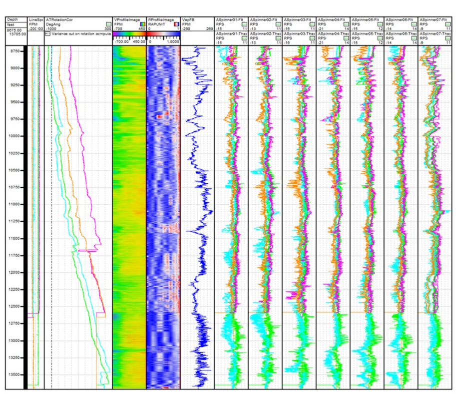
TVD profile Heel (right) to Toe (left). Fig. 4

The only true hydrocarbon bubble counter and identifier in segregated horizontal flow

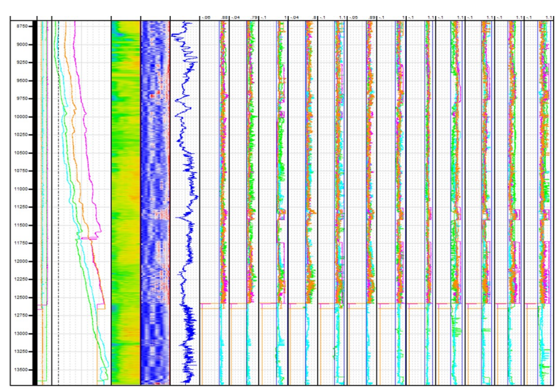


Resistivity Array Tool. Fig. 3

Accurate array data collection and a complete understanding of the well are a primary focus and prerequisite for an excellent analysis



Spinner Array Profile with holdup Fig. 5



Resistivity Array Profile with velocity Fig. 6

Resolving loading problems in horizontal producers

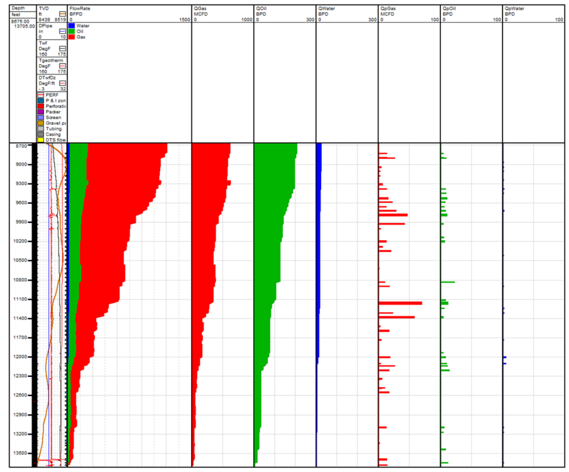
Results

Oil, water and gas production are quantified at each cluster level throughout the stages. All the data is tabulated and a profile is developed (Figure 6). The use of pressure data, as well as multi choke setting logging runs can also generate qualitative production indexes that will help determine frac efficiency as well as long term production from each stage. (see next quarter newsletter)

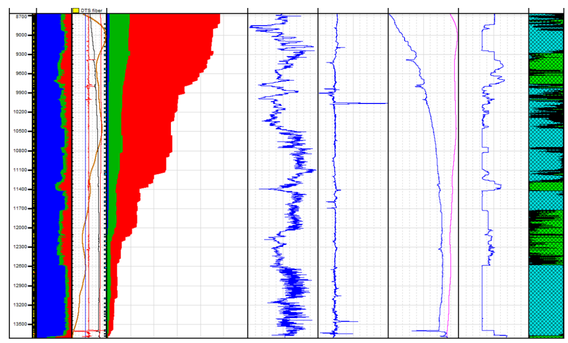
Before loading, the well is a very prolific oil and gas producer. By identifying the water entry zones and the areas of frac efficiency, the water can be shut off with remedial operations that will prevent loading for the short to mid time future.

As seen in Figure 4, the wellbore trajectory follows a toe up direction. Production is surging while well is loading quickly. This hinders lower TVD stages from producing efficiently. Production can be quantified accurately at cluster level with array tools and the most advanced probabilistic software. Figure 5 shows the production profile. Significant water production is occurring from stage 5.

Figure 7 also shows the profile with flow regime in the right track (primarily bubble (blue) and plug (green). The figure shows holdup, trajectory, profile, apparent average velocity, pressure, temperature and capacitance as supporting curves.



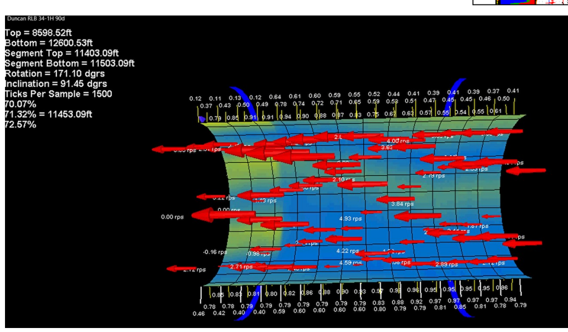
Flow Profile Fig. 6



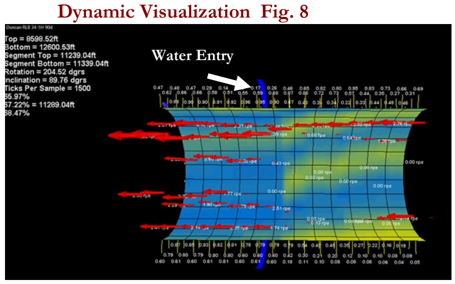
Flow Profile Fig. 7

Dynamic Production Visualization

The engineer or any user also has the ability to see the production and behavior in a video that can be modified for optimal use. The image can be viewed at any interval length. These are at about 200 foot lengths in the wellbore. The inclination is represented in the angle of the image. Al information such as inclination and segment length is described in the upper left corner. The image will move up or down the wellbore. **Figure 8** is a screenshot of it in time.. The perfs are represented by the blue bands. The velocities are the vectors that change size and shape with speed. The holdups are represented by the blue and yellow imaging. Figure 9 is an example of water entry



Dynamic Visualization Fig. 8



Water Entry Fig. 9

ACCURATE AND PRECISE ANALYSIS FROM PROBABILISTIC ENERGY CONSERVATION METHODS, QUALITY EQUIPMENT AND EXPERIENCE.

THE ANSWER ALWAYS MATTERS!

Injection Profiles Through Slotted Liners

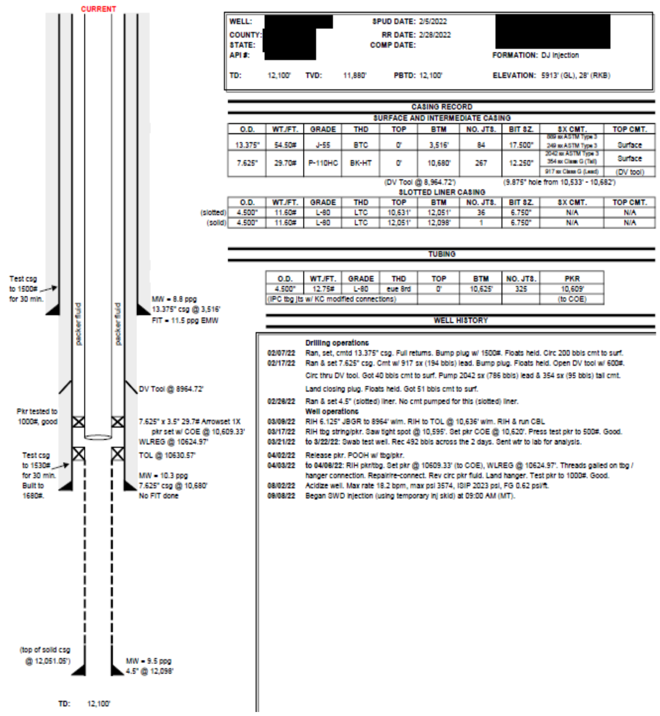
Procedure

A disposal well with a 4.5" uncemented slotted liner from 10631' to 12051' is being evaluated for vertical conformity of injection (see **Figure 1**). The well is shut in in the morning. A shut in logging pass is made later in the day, then the pumps are shut on to establish a 3.7 barrels water per minute stable rate. A production log is then run with two up and down passes ate different speeds, along with stationary measurements to evaluate injection.

Results

As the case with uncemented slotted liners, some fluid will enter the annulus of the liner and formation and cycle back into the wellbore. Determinaion is made primarily through the temperature,-pressure and spinner if the fluid is entering thre formation as crossflow or just cycling through the slotted liner.

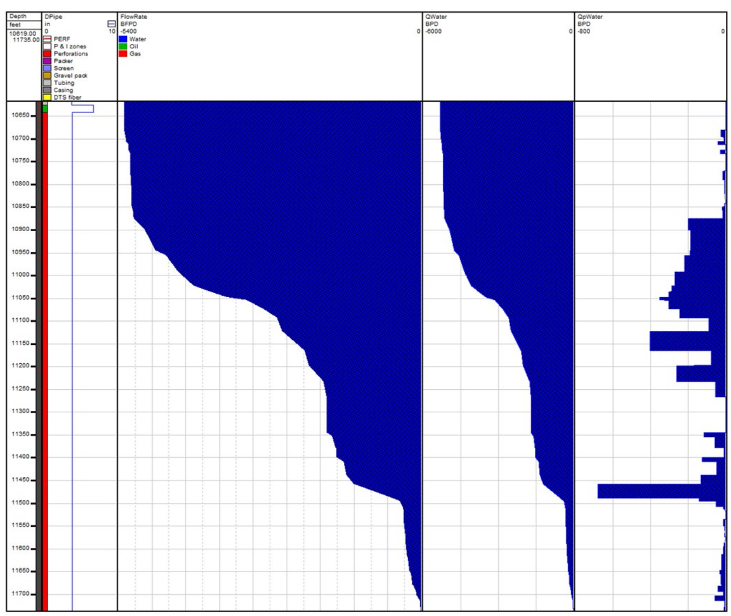
In this case, no crossflow is determined. The temperature in the shut in pass is still being affected by previous injection as not enough time elapsed for the temperature to return to near geothermal or stable. However, the spinner and pressure indicate no movement in the shut in state. The dynamic passes, however; indicate cycling in the annulus above 11053' with 41% of total injection occurring above this depth and the remaining injection below this depth, as seen on **Figure 2** and **Figure 3.** The table in Fig 2 is cut off as the entire table does not fit neatly in the letter. It is listed in its entirety in the final report



Well Schematic—Fig. 1

Depth		Profile	Q-Water-STP	Qi-Water-STP	Total Water and Percentage
Feet			BFPD	BFPD	
Surface	*10642*	*Inject*	-5322.48	0.00	-5322.48
Total Well Injection					-5322.48
10642-10732				-107.52	2.02%
10642	*10650.5*	*Inject*	-5322.48	0.00	0.00%
10650.5	*10680*	*Inject*	-5322.48	0.00	0.00%
10680	*10695.5*	*Inject*	-5322.48	-26.62	0.50%
10695.5	*10705.75*	*Inject*	-5295.86	-11.00	0.21%
10705.8	*10712*	*Inject*	-5284.86	-41.90	0.79%
10712	*10724*	*Inject*	-5242.96	0.00	0.00%
10724	*10732*	*Inject*	-5242.96	-28.00	0.53%
10732-10874.5				-64.99	1.22%
10732	*10741*	*Inject*	-5214.96	0.00	0.00%
10741	*10770*	*Inject*	-5214.96	0.00	0.00%
10770	*10789*	*Inject*	-5214.96	-16.00	0.30%
10789	*10819.75*	*Inject*	-5198.96	-5.99	0.11%
10819.8	*10832.5*	*Inject*	-5192.97	-3.00	0.06%
10832.5	*10841.75*	*Inject*	-5189.97	0.00	0.00%
10841.8	*10848.5*	*Inject*	-5189.97	-5.00	0.09%
10848.5	*10856*	*Inject*	-5184.97	-19.00	0.36%
10856	*10874.5*	*Inject*	-5165.97	-16.00	0.30%
10874.5-11053.75				-2013.00	37.82%
10874.5	*10899.75*	*Inject*	-5149.97	-200.00	3.76%
10899.8	*10944.5*	*Inject*	-4949.97	-187.00	3.51%
10944.5	*10956*	*Inject*	-4762.97	-192.00	3.61%
10956	*10992*	*Inject*	-4570.97	-219.00	4.11%
10992	*11022.25*	*Inject*	-4351.97	-272.00	5.11%
11022.3	*11035*	*Inject*	-4079.97	-287.00	5.39%
11035	*11047.5*	*Inject*	-3792.97	-305.00	5.73%
11047.5	*11053.75*	*Inject*	-3487.97	-351.00	6.59%

Injection Table Fig 2



Injection Profile Fig. 3

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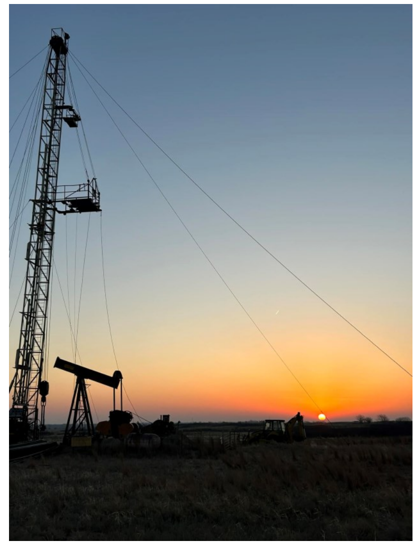
Oil and Gas Reservoir Analysis and Monitoring

Array Production Logging Operation featured in this Newsletter



Near Dodge City, Kansas

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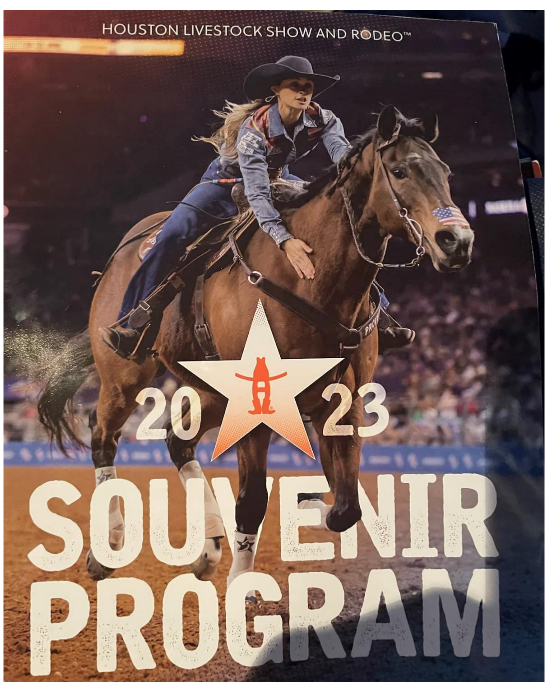

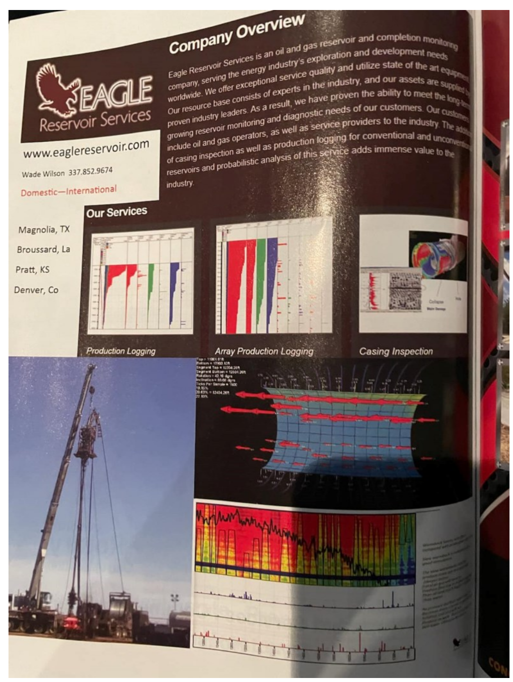

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