Highly Viscous Friction Reducer Slickwater in Tight Reservoirs Enhancing Fracture Network and Performance Evaluation

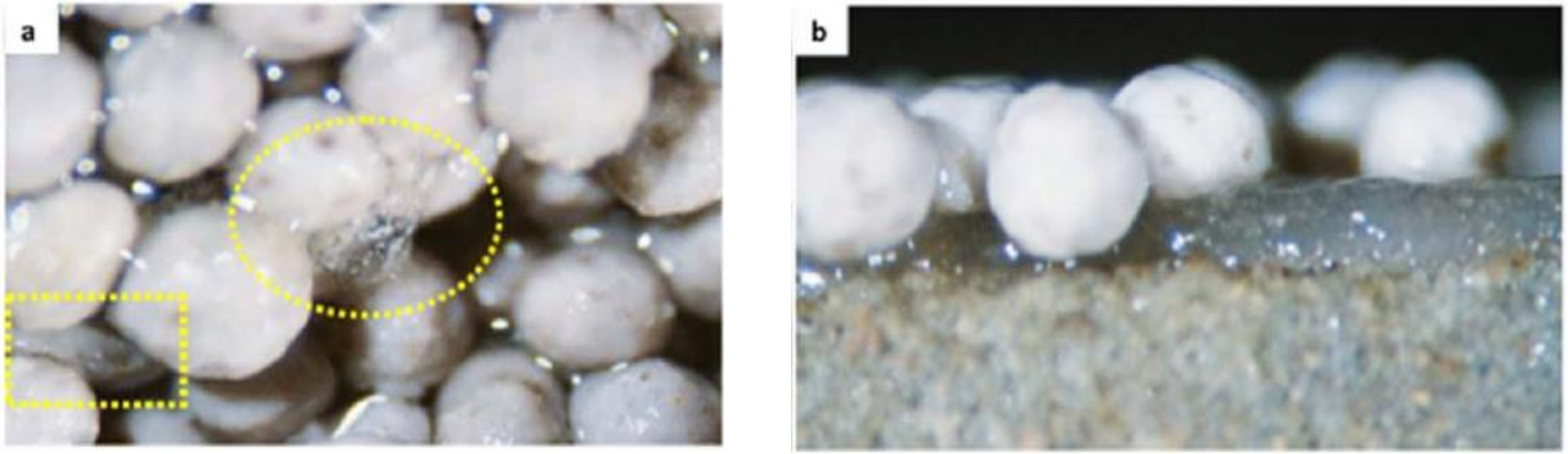
NESR

Oct. 2023

Agenda

- HVFR SlickWater Introduction
- NORI Research and Innovation Centre
- Fracturing Capabilities
  - Lab Capabilities
  - Lab Carrying Performance Experiments
- HVFR Candidate wells
- Conventional & Unconventional Frac Services in Egypt

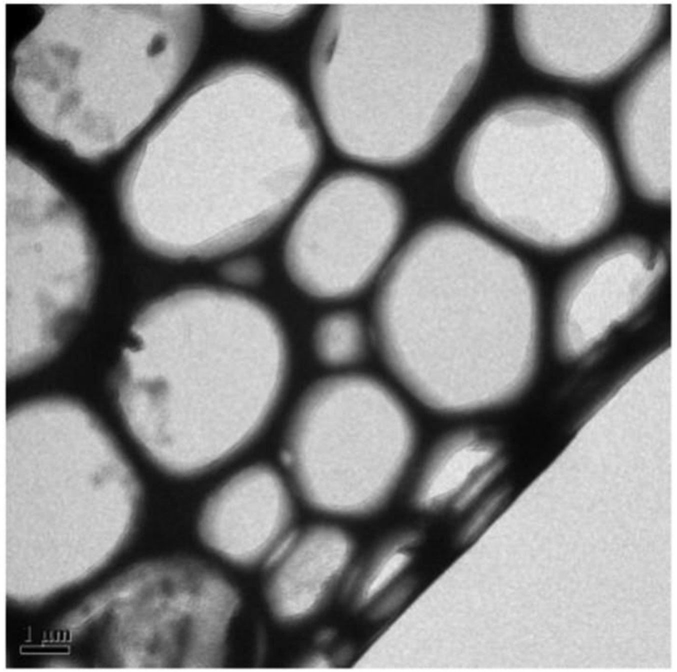
Introduction to Slick Water Frac Treatment



Fig(1): Residual gel damage remain after breaking X-Linked fluid

- Crosslinked gels have excellent proppant transport properties and are relatively easy to mix. They are also very reliable through the use of normal QA/QC methods. They control fluid loss in reservoirs very effectively. All-in-all they sound like pretty good fluids. However, they also do extensive damage to proppant pack conductivity. The damage results from the gels dehydrating and concentrating in the proppant pack as shown.

Introduction to Slick Water Frac Treatment

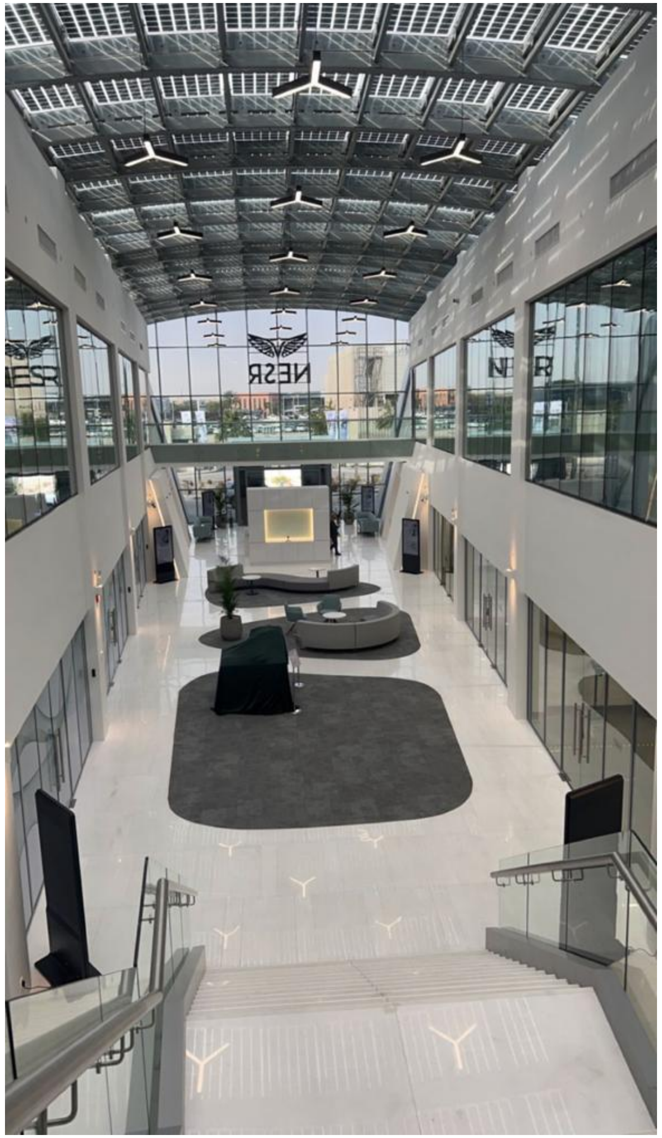


Fig(2): Residual HVFR damage remain after dehydrating

Fig(3): Residual gel damage remain after breaking X-Linked fluid

- HVFR is a slurry of polyacrylamide polymer or low concentrations of linear gel added as a friction reducer in a hydrocarbon solvent. The anionic polymer will hydrate into water during pumping and will reduce friction pressure.
- More than 70% friction pressure can be reduced using HVFR. This fluid can also give viscoelastic properties to suspend 3 to 5 ppa of proppant without significant damage of the proppant pack.
- The Slick water fluid system consist from HVFR, Clay Stabilizer, Surfactant, and Biocide additives. That why the reason behind the low damage percentage for the fluid system.

NESR Oilfield Research and Innovation Centre



- 9000 sq. meters Facility
- Chemical Labs
- Rock Mechanics Lab
- Perforation Lab
- Downhole and Surface Technologies Lab
- Remote Performance Center
- Startup Incubator

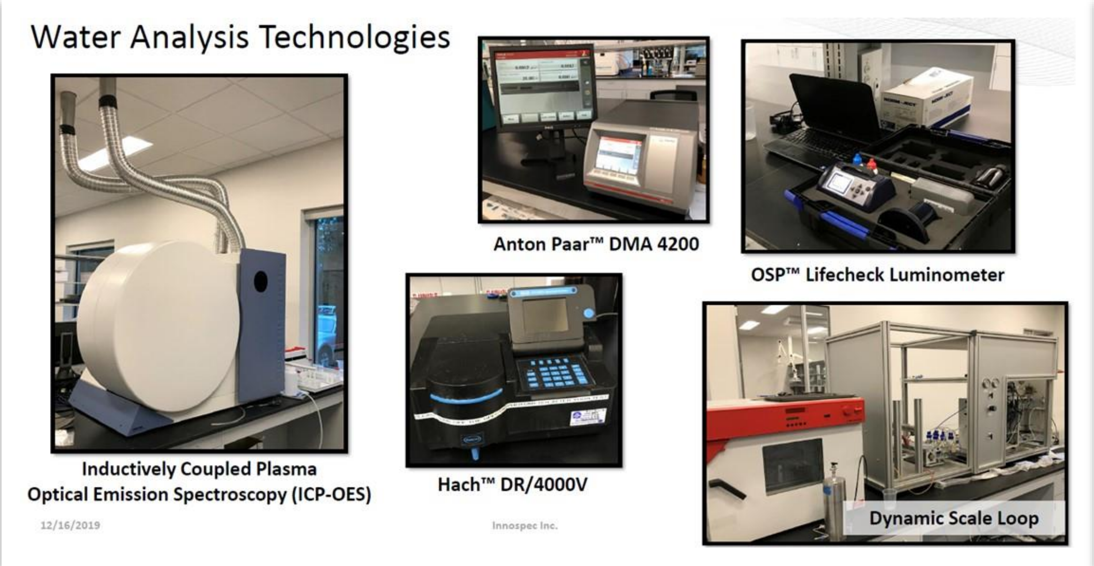
Frac Capabilities: Fracture Fluid Innovation

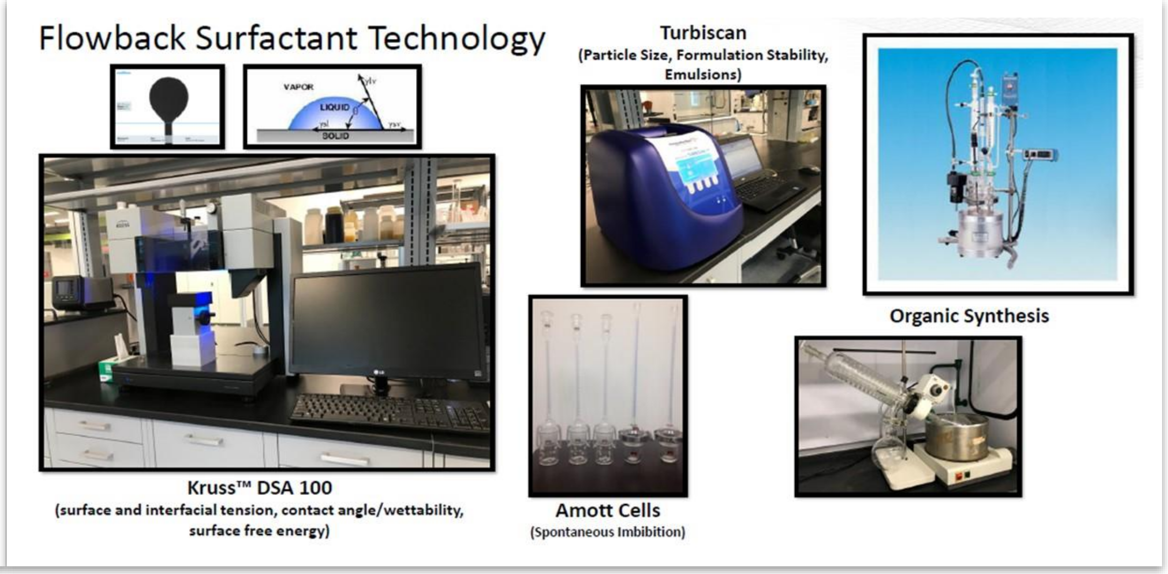
2600 TECHNOLOGY FOREST, THE WOODLANDS, TX

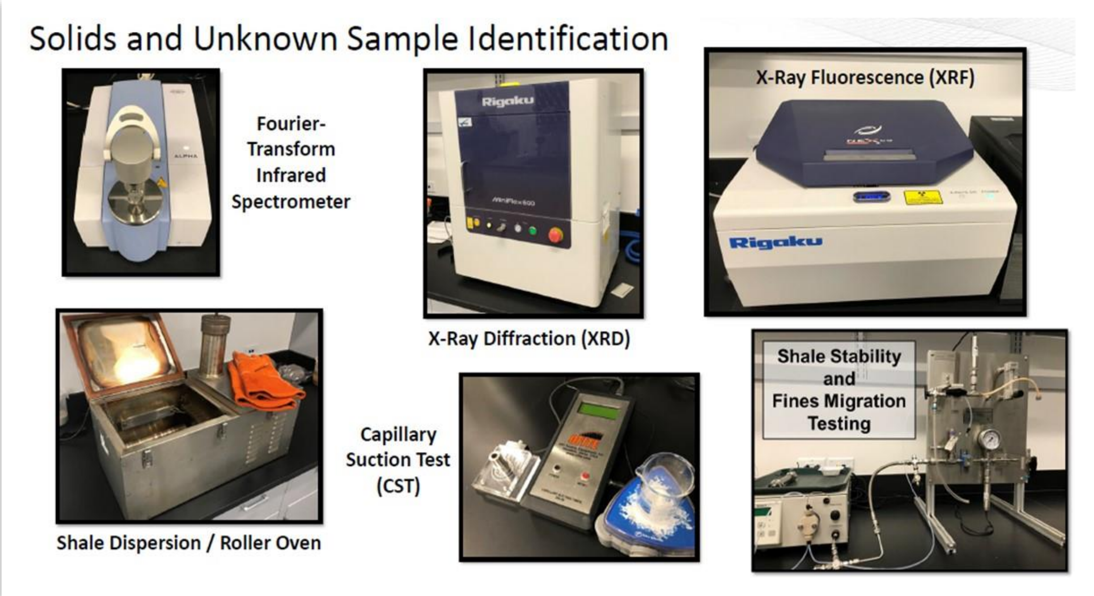
OUR TECHNICAL TEAM

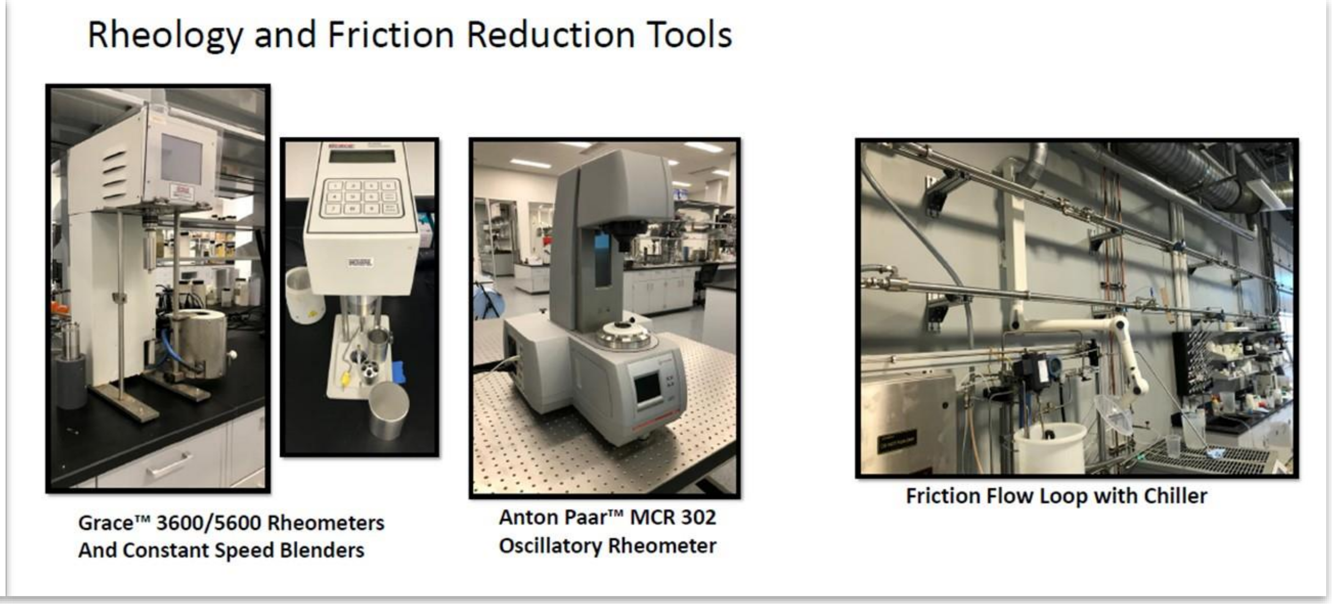
- ✓ Fluid Design
- ✓ Surfactants
- ✓ Clay Control
- ✓ Scale Inhibitors
- ✓ Friction Reducers

Lab capabilities









Static Carrying Performance Experiments

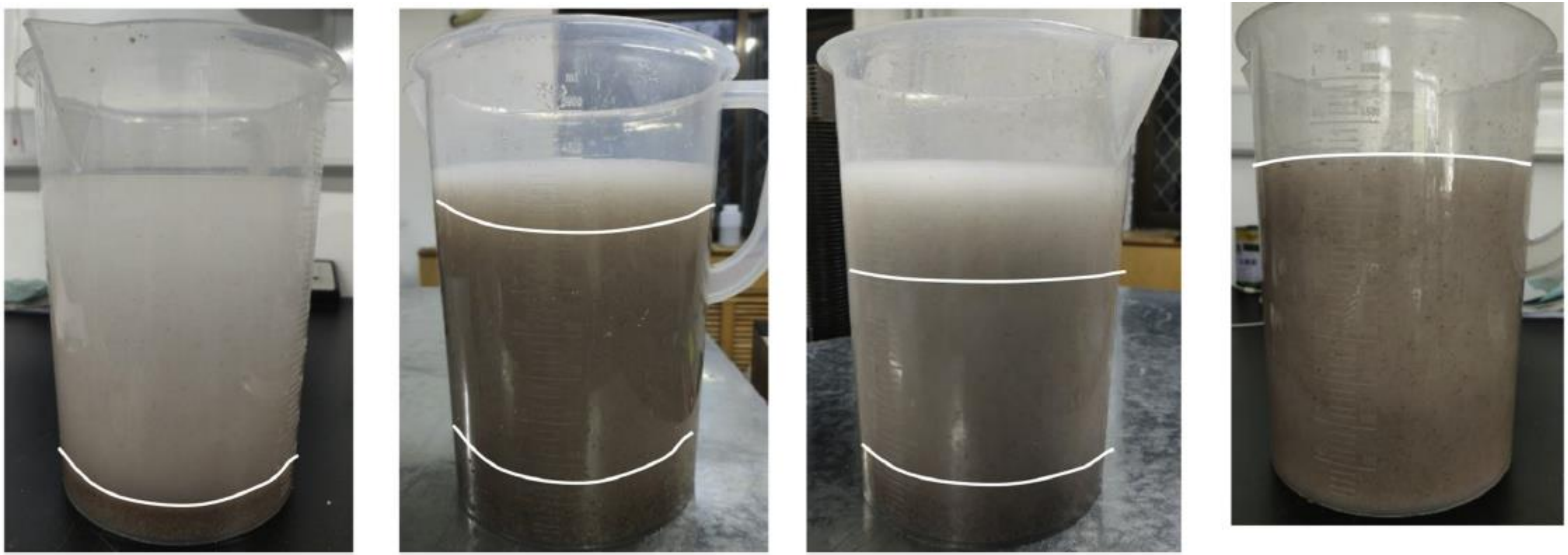
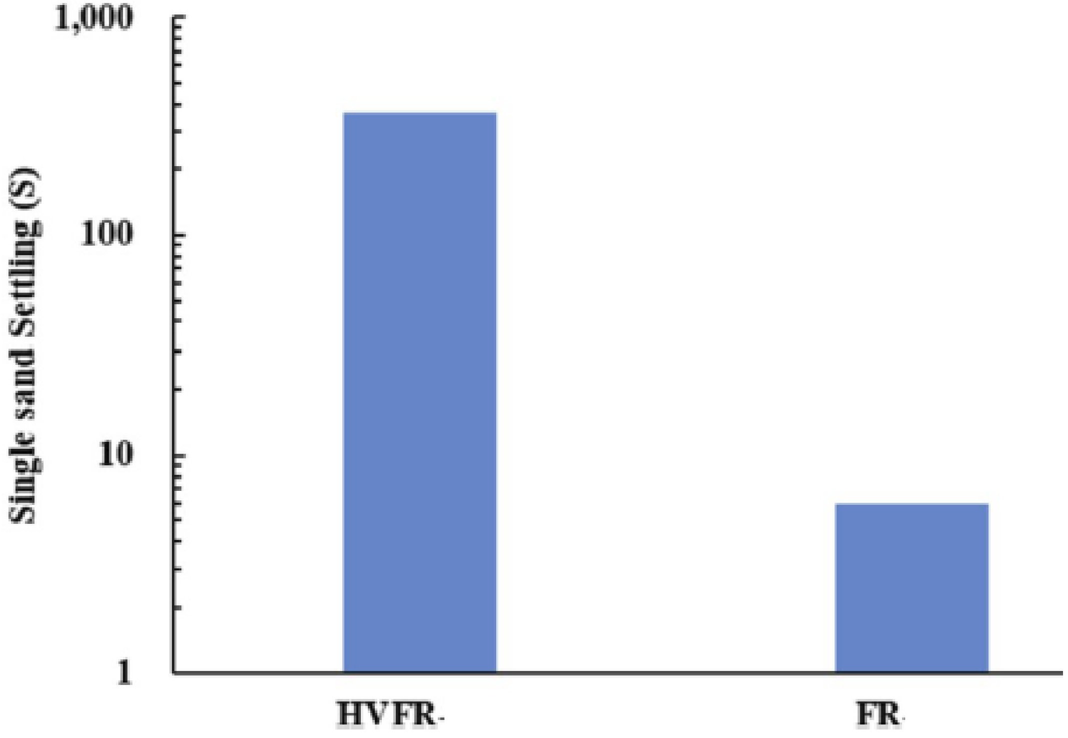


Fig. (5): The 40/70-mesh quartz sand was added to the slickwater at a sand concentration of 1.25 PPA, and the sand settling performance was determined after stirring and standing for 0.5 min

Single Particle Sand Settling Experiments



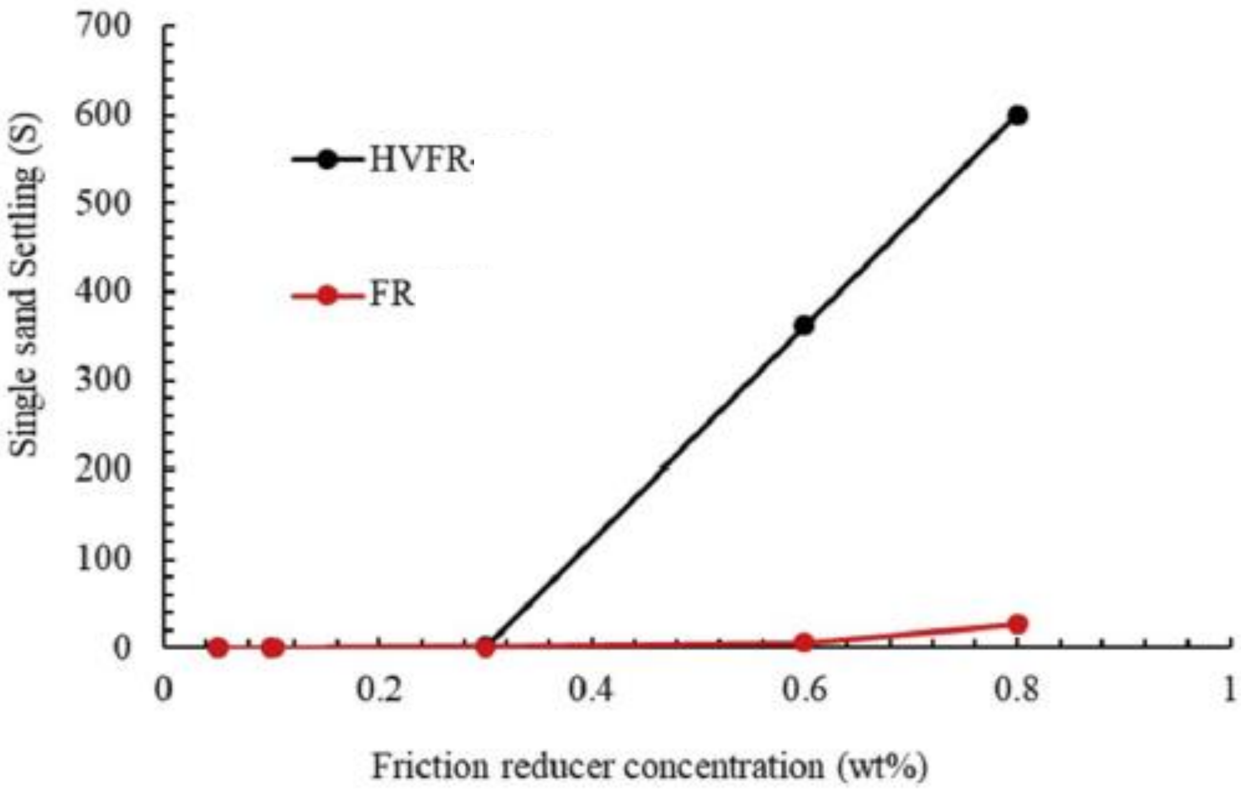


Fig. (6): We prepared the friction reducer fluids at different concentrations and tested the average times when five 40/70-mesh sands fell at 500 mL high. When the concentrations were below 0.30 wt%, the sand-carrying performances of the two types of slickwater were almost same. When the concentrations were higher than 0.30 wt%, the sedimentation time of HVFR was significantly higher than that of the FR fluid.

Dynamic Carrying Performance Experiments

Fig. (7): HVFR Sand Carrying fluid Performance

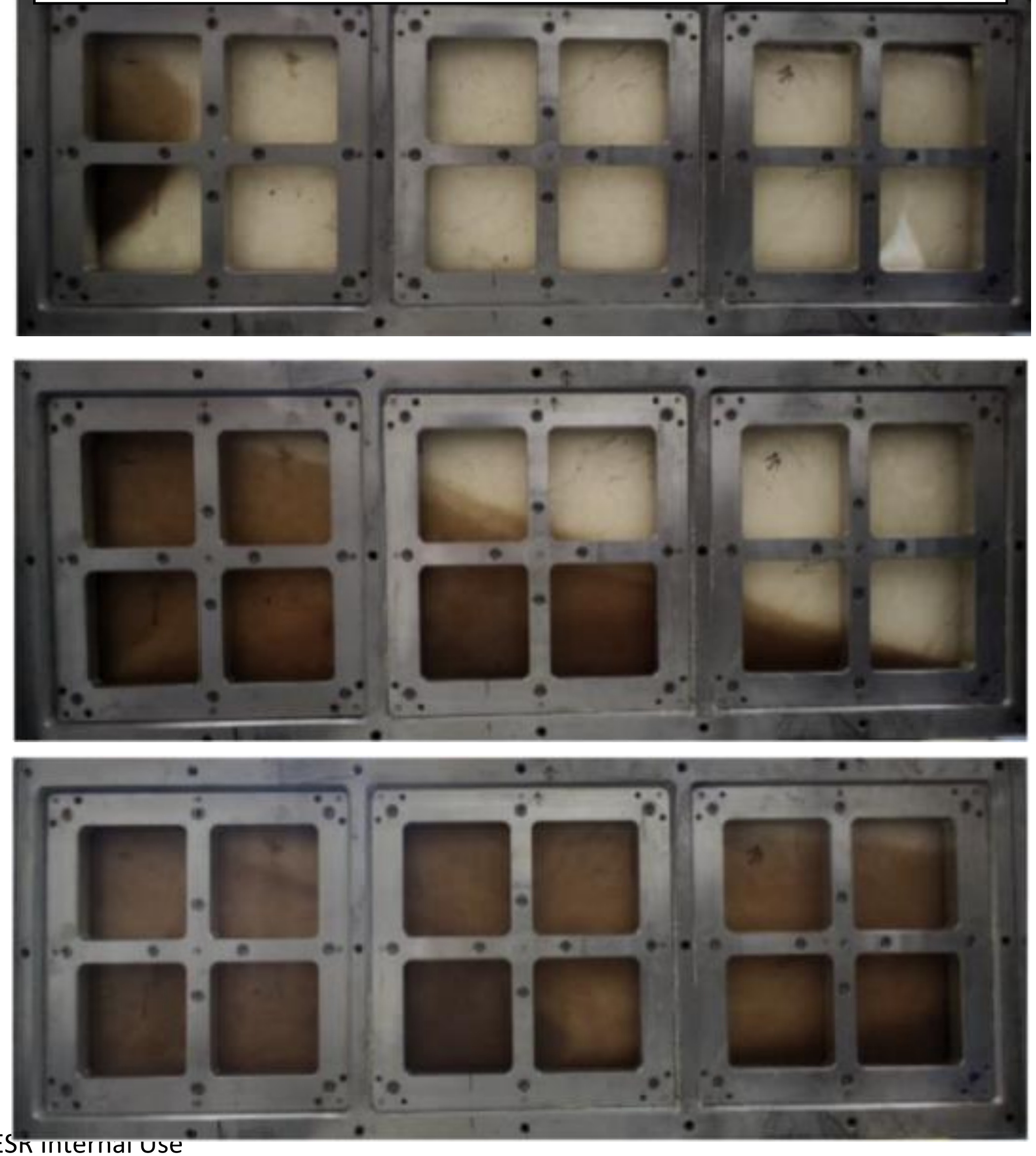
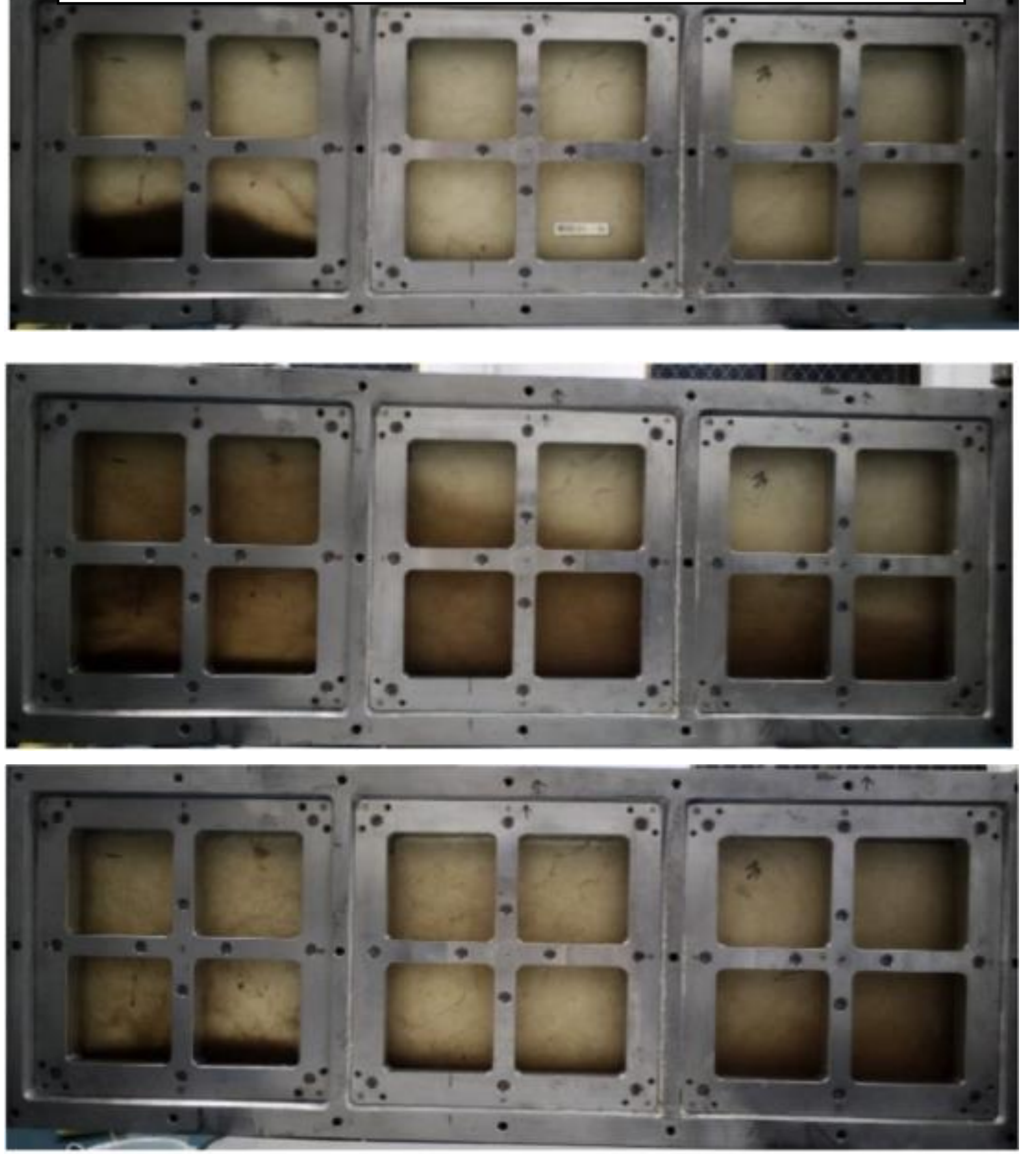


Fig. (8): FR Sand Carrying fluid Performance



SlickWater Candidates Wells

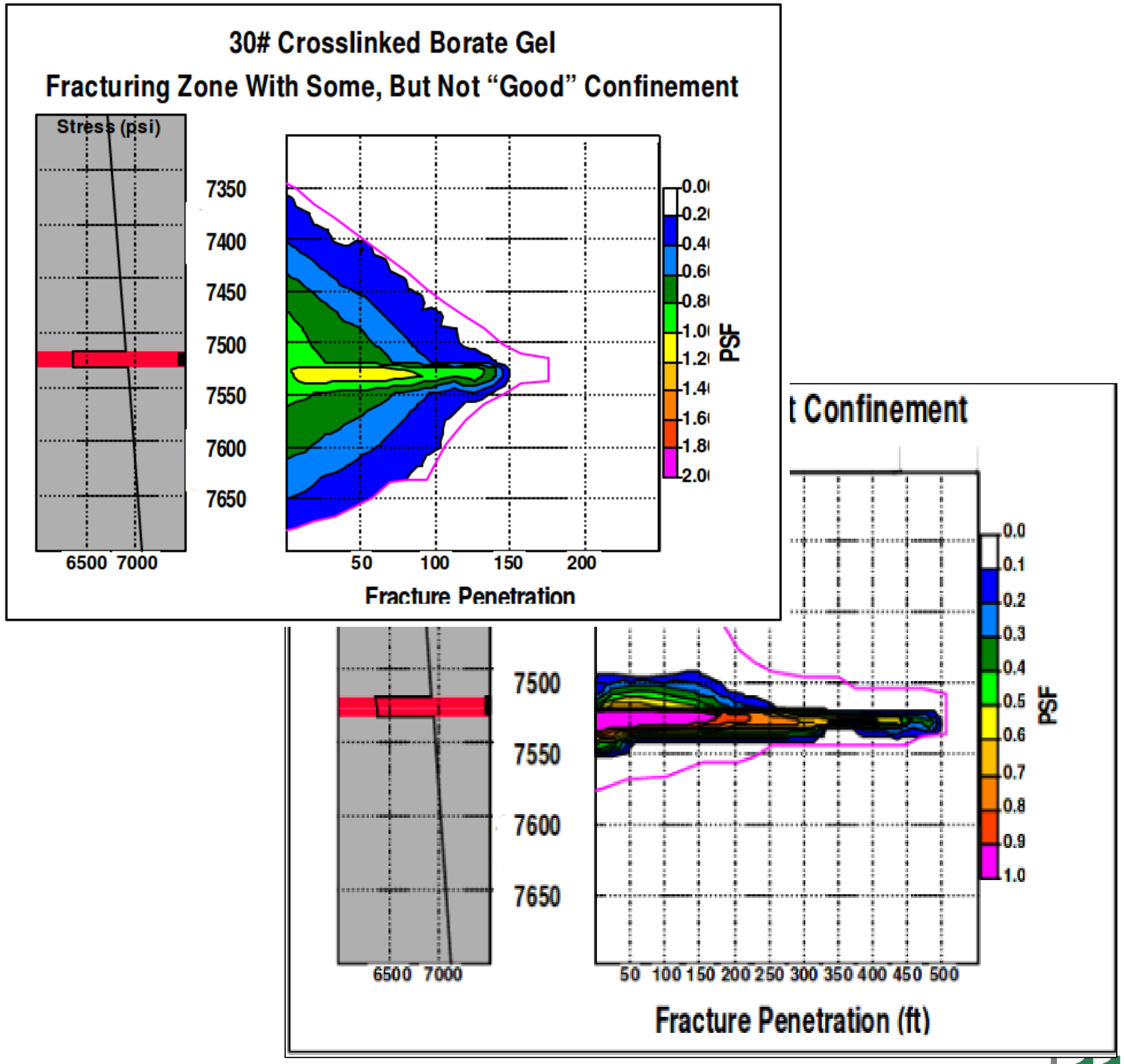
- Natural Fractures or other Microfractures Contribute to Productivity, The treatments try to link sets of natural fractures with the absolute minimum fracture conductivity. Even with such low proppant concentrations, the fracture still acts with "infinite conductivity" because matrix permeability is so low.

- Tight, Low Pressure Reservoirs May Exhibit Clean-up Problems With Conventional Gels.

- Reservoir Requires Large Surface-Area Fractures and Extension with Low Leak-off.

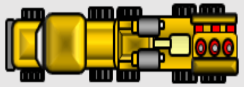
- Formation Barriers – Some Level of Barrier Above and Below the Zone to Aid in Fracture Containment.

- Wells Where Massive and Large Volume Fracs were Volumetrically Successful, Yet Economically Marginal.



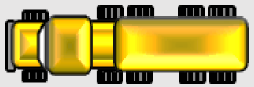
Fig(4): Half Length difference between X-Linked and HVFR

Conventional & Unconventional Frac Services in Egypt



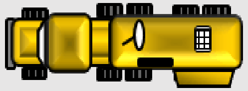
Well # 1

- **<u>1 Trial Job</u>**
- L.BAH Formation
- 100 Kib 20/40 ISP
- Max P 6962 psi
- Pumping rate 30 BPM
- Max Prop conc. 4 PPA
- Perf Interval 8600 Ft
- Gel Loading # GBX 30 & GBX# 35.
- Reservoir P 3700 Psi



Well # 2

- **<u>1 Trial Job</u>**
- U.BAH-1 Formation
- 92 Kib 20/40 & 16/30 ISP
- Max P 6450 psi
- Pumping rate 22 BPM
- Max Prop conc. 7 PPA
- Perf Interval 6000 Ft
- Gel Loading # GBX#30
- Reservoir P 2300 Psi

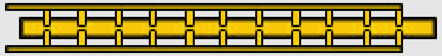


Well # 3

- **<u>3 Trial Job</u> & <u>5 Main Frac Contractor.</u>**
- U.BAH-1 Formation
- 100-170 Kib 20/40 & 16/30 ISP
- Pumping rate 22-30 BPM
- Max Prop conc. 7 PPA
- Gel Loading # GBX#30 & 35.

Well # 4

- **<u>1 Main Frac Contractor</u>**
- A/R"F" Formation
- 270 Kib 40/70 sand & 40/70 LWP
- Max P 7000 psi
- Pumping rate 52 BPM
- Max Prop conc. 5 PPA
- Perf Interval 10400 Ft
- Slickwater fluid system
- Reservoir P 5000 Psi

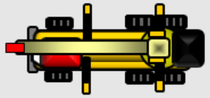


Well # 5

- **<u>1 Backup Frac Contractor</u>**
- U.BAH Formation
- 100 Kib 16/30 ISP
- Max P 7400 psi
- Pumping rate 22 BPM
- Max Prop conc. 7 PPA
- Perf Interval 6800 Ft
- Gel Loading # GBX#30.
- Reservoir P 2790 Psi

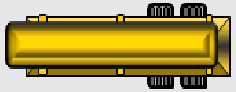
19 Frac Treatment Job within One Year

Conventional & Unconventional Frac Services in Egypt



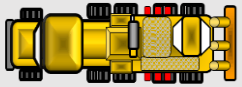
Well # 6

- **<u>1 Trial Job</u>**
- A/R"C" Formation
- 112 Kib 20/40 & 16/30 ISP
- Max P 7000 psi
- Pumping rate 25 BPM
- Max Prop conc. 5 PPA
- Perf Interval 9950 Ft
- Gel Loading # GBX#35.
- Reservoir P 1550 Psi



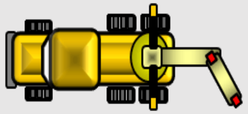
Well # 7

- **<u>1 Trial Job</u>**
- Basal Dahab Formation
- 92 Kib 20/40 & 16/30 ISP
- Max P 7000 psi
- Pumping rate 24 BPM
- Max Prop conc. 6 PPA
- Perf Interval 8150 Ft
- Gel Loading # GBX#30.
- Reservoir P 3550 Psi



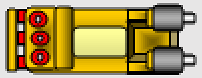
Well # 8

- **<u>1 Trial Job</u>**
- U.Dolomite "A" Formation
- 112 Kib 12/18 & 16/30 ISP
- Max P 678 psi
- Pumping rate 46 BPM
- Max Prop conc. 8 PPA
- Perf Interval 700 Ft
- Gel Loading # GBX#25.
- Reservoir P 300 Psi



Well # 9

- **<u>1 Trial Job (Two stage)</u>**
- Matualla, Sudr & Duwi Formation
- 225 Kib 40/70 Natural Sand
- Max P 6000 psi
- Pumping rate 50 BPM
- Max Prop conc. 3.5 PPA
- Perf Interval 9000 Ft
- Slickwater fluid system
- Reservoir P 1700 Psi

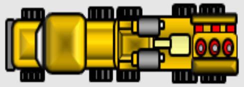


Well # 10

- **<u>2 Trial Job</u>**
- A/R"G-2" Formation
- 80-110 Kib 20/40 ISP
- Max P 7500 psi
- Pumping rate 25 BPM
- Max Prop conc. 5 PPA
- Perf Interval 10160 Ft
- Gel Loading # GBX#35.
- Reservoir P 1600 Psi

19 Frac Treatment Job within One Year

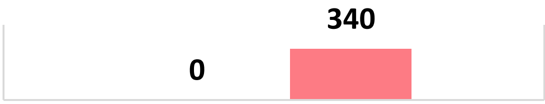
Conventional & Unconventional Frac Services in Egypt

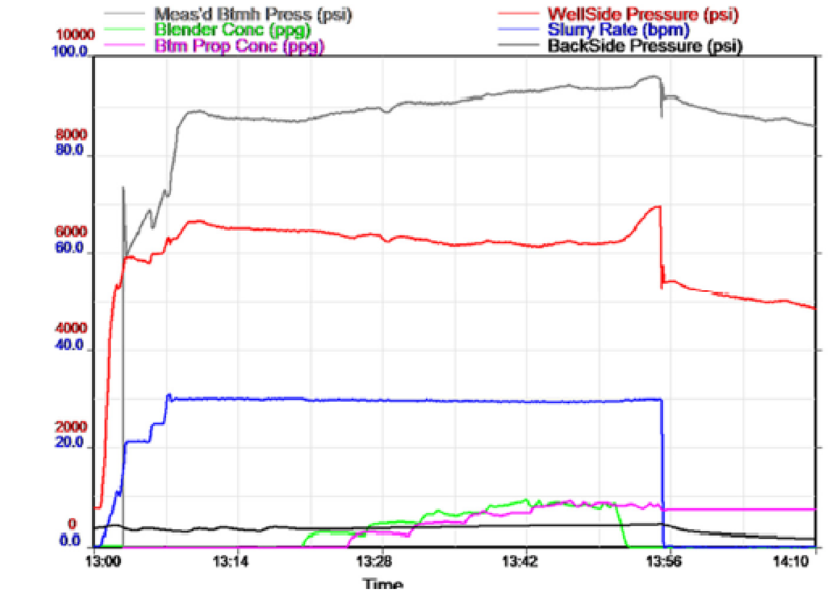


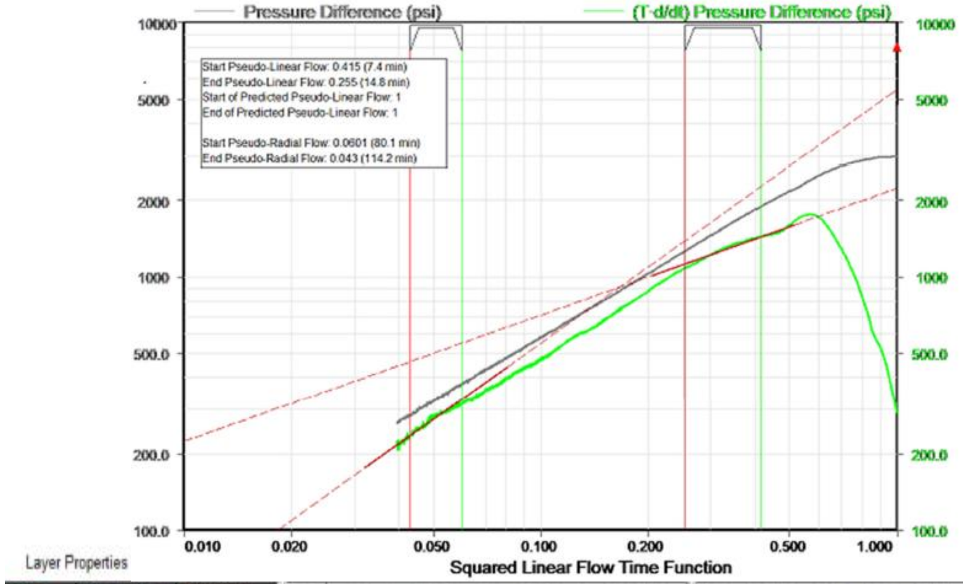
Well # 1

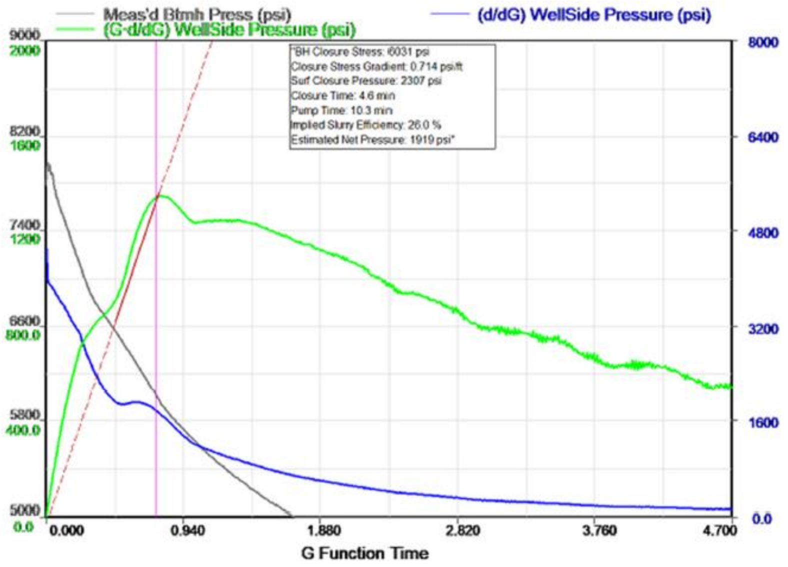
- ❑ **<u>1 Trial Job</u>**
- ❑ L.BAH Formation
- ❑ 100 Kib 20/40 ISP
- ❑ Max P 6962 psi
- ❑ Pumping rate 30 BPM
- ❑ Max Prop conc. 4 PPA
- ❑ Perf Interval 8600 Ft
- ❑ Gel Loading # GBX 30 & GBX# 35.
- ❑ Reservoir P 3700 Psi

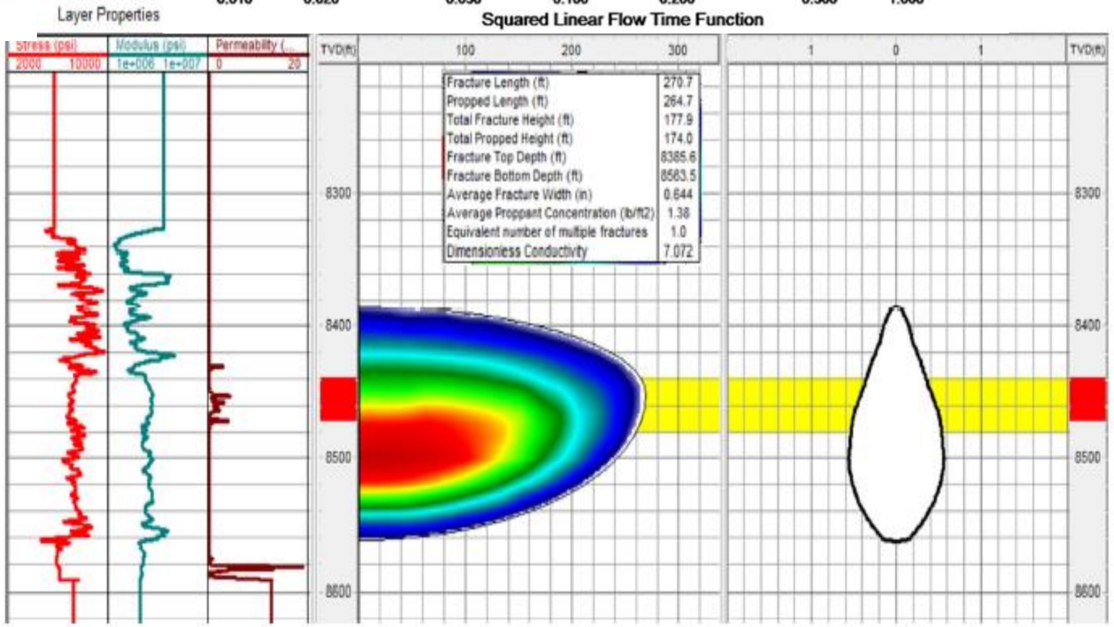
Production Profile



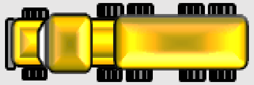






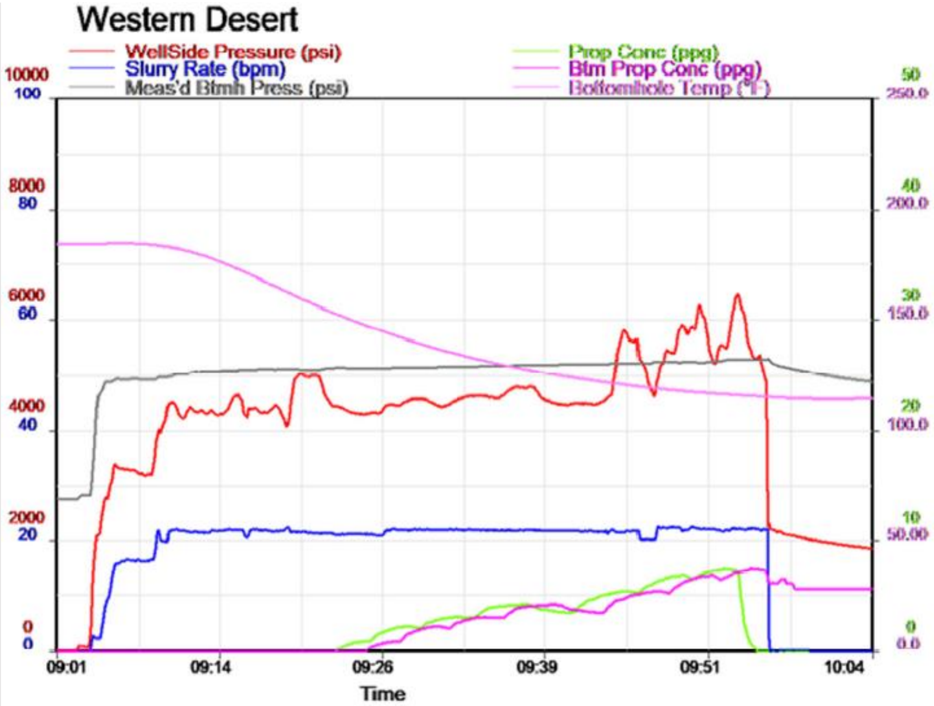


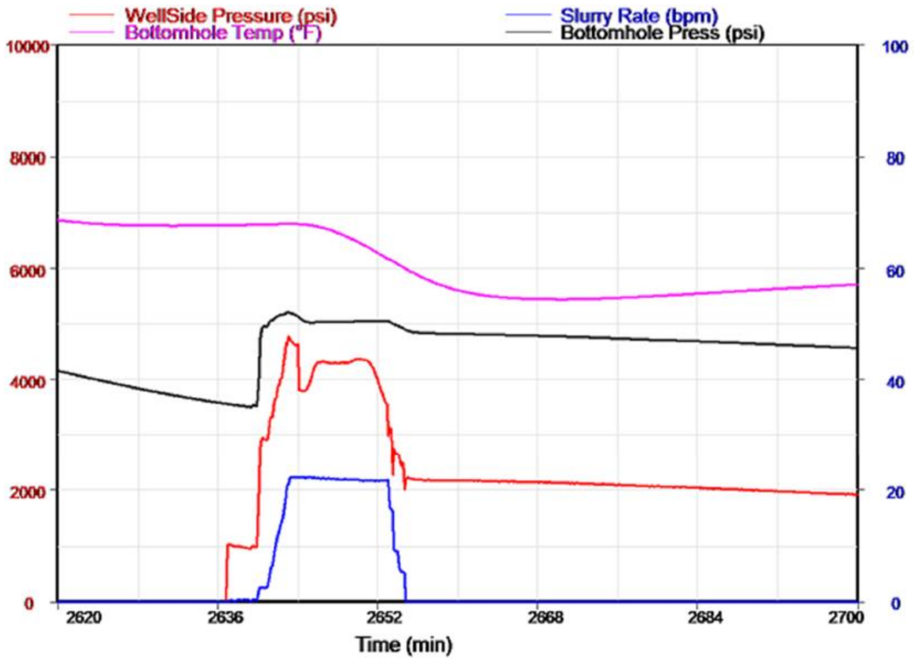
Conventional & Unconventional Frac Services in Egypt

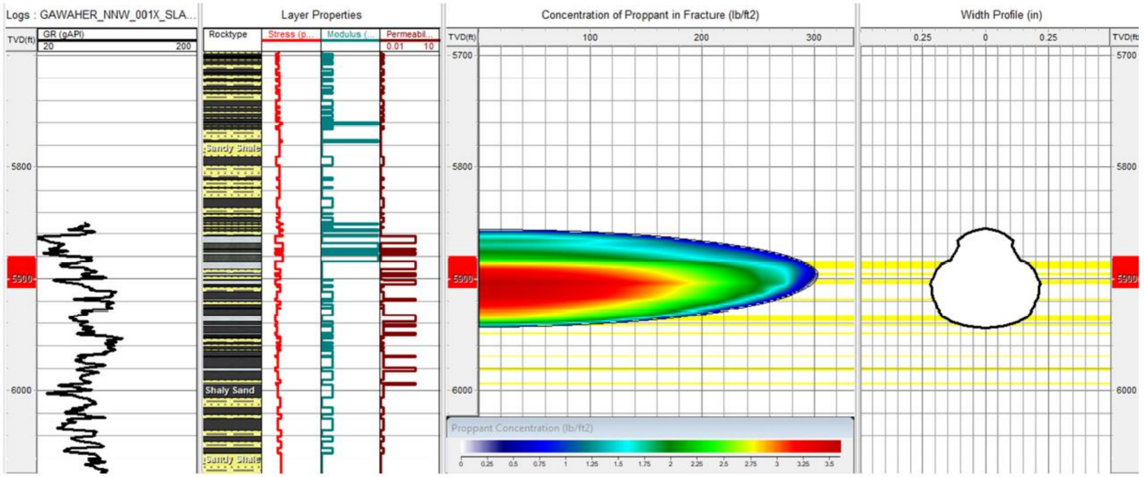


Well # 2

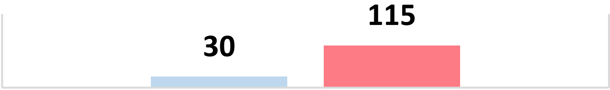
- ❑ <u>**1 Trial Job**</u>
- ❑ U.BAH-1 Formation
- ❑ 92 Kib 20/40 & 16/30 ISP
- ❑ Max P 6450 psi
- ❑ Pumping rate 22 BPM
- ❑ Max Prop conc. 7 PPA
- ❑ Perf Interval 6000 Ft
- ❑ Gel Loading # GBX#30
- ❑ Reservoir P 2300 Psi





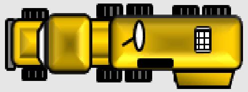


Production Profile



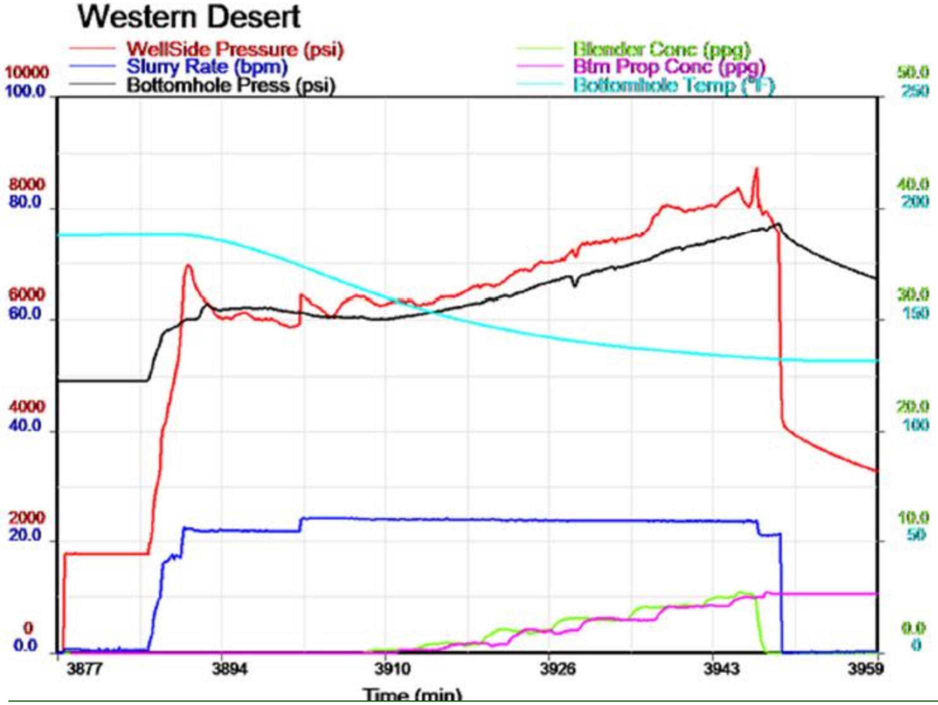
BOPD Before Frac   BOPD After Frac

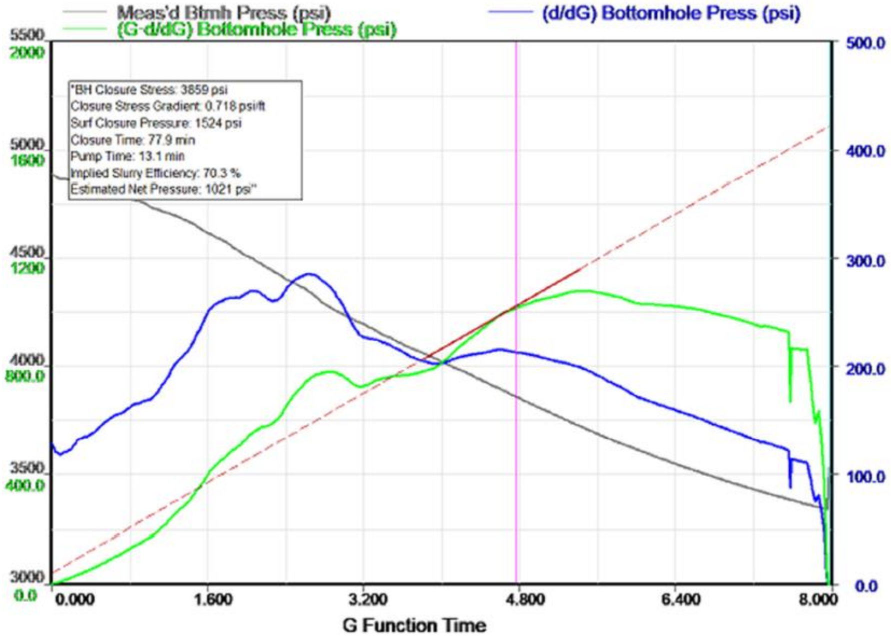
Conventional & Unconventional Frac Services in Egypt

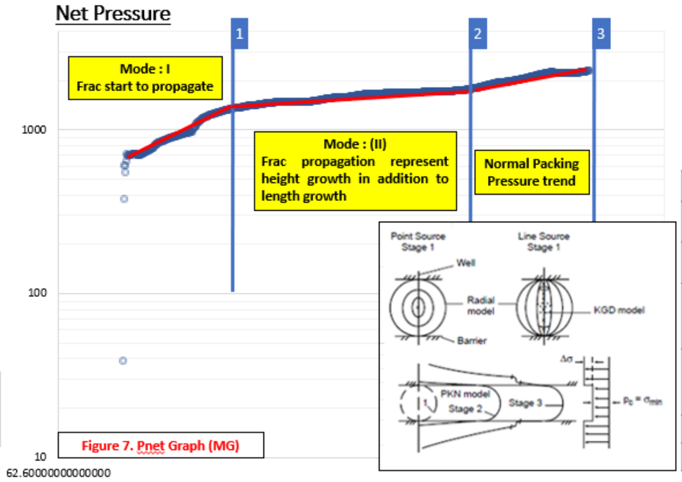


Well # 3

- ❑ <u>3 Trial Job</u> & <u>5 Main Frac Contractor.</u>
- ❑ U.BAH-1 Formation
- ❑ 100-170 Kib 20/40 & 16/30 ISP
- ❑ Pumping rate 22-30 BPM
- ❑ Max Prop conc. 7 PPA
- ❑ Gel Loading # GBX#30 & 35.







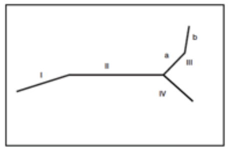
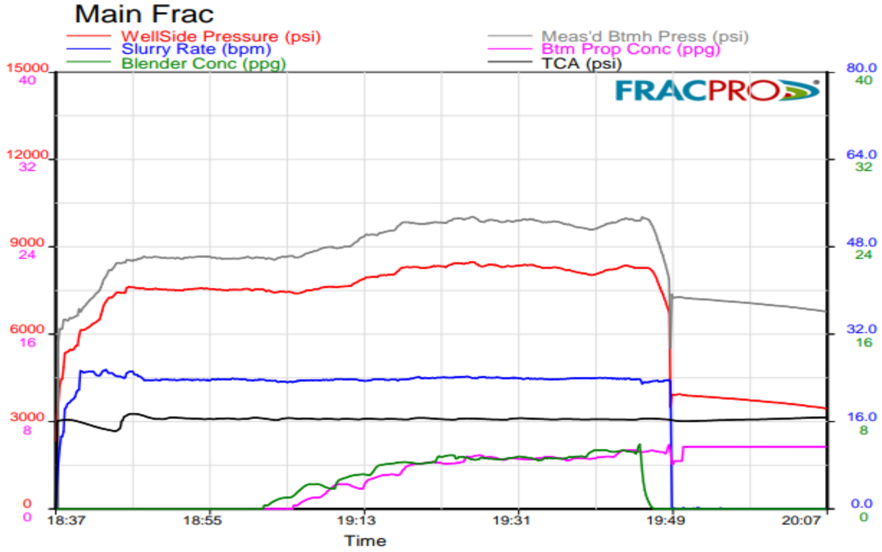
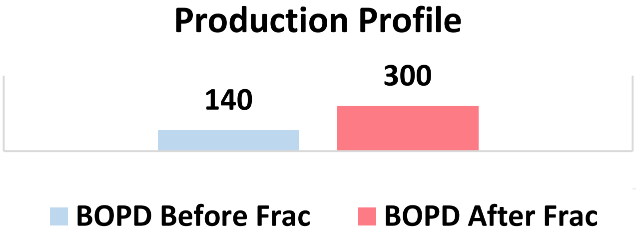


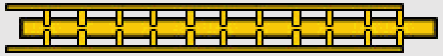
Table 4-2 Nolte-Smith Analysis Pressure Response Modes (with reference to Fig. 4-8)

Mode	Behavior
I	Propagation with PKN fracture geometry. Gradient is equal to *e* (see Eq. 4-16) for constant frac fluid rheology.
II	Constant gradient = 0. Represents height growth in addition to length growth, or increased fluid loss, or both. Can also be explained by a change in the relationship between p_{net} and w_f (see Eq. 4-5 – this implies a change in rock mechanical characteristics).
IIIa	Unit slope. This means that p_{net} is now directly proportional to time (and also to rate, as this is usually constant with respect to time). This behavior is usually associated with additional growth in w_f such as during a tip screenout (see Section 4-7.3.2).
IIIb	Slope > 2. Screenout, usually a near-wellbore event with a very rapid rise in pressure.
IV	Negative slope. Rapid height growth. Potentially KGD or radial fracture geometry.



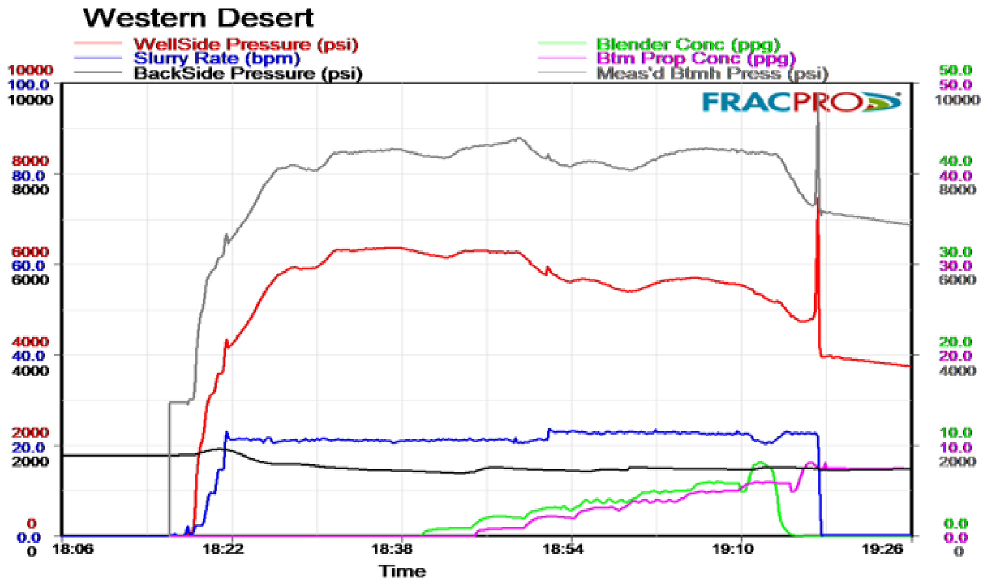


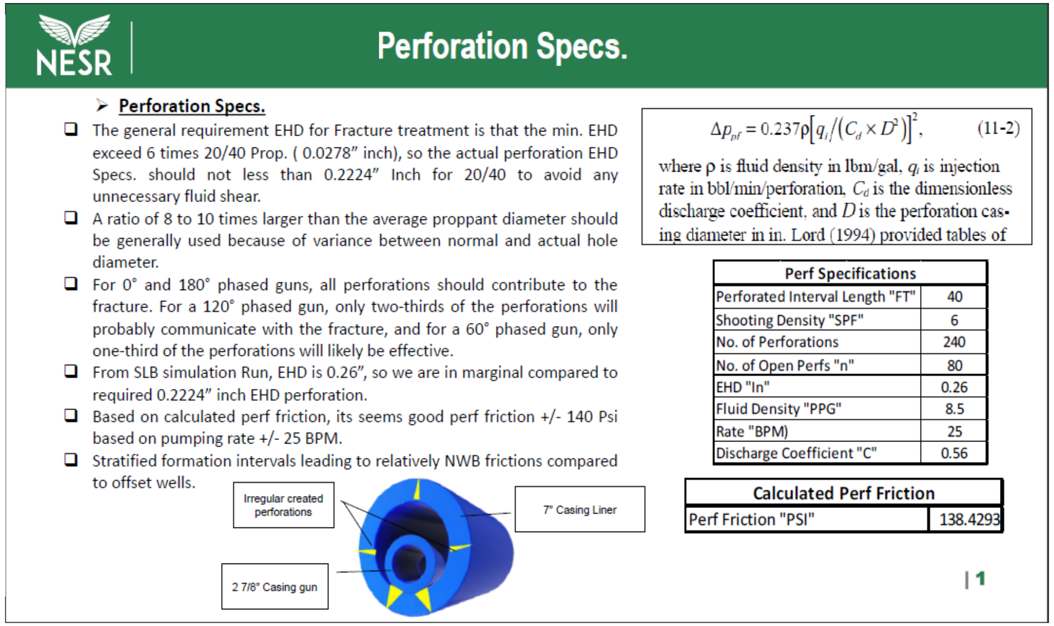
Conventional & Unconventional Frac Services in Egypt



Well # 4

- ❑ **1 Backup Frac Contractor**
- ❑ U.BAH Formation
- ❑ 100 Kib 16/30 ISP
- ❑ Max P 7400 psi
- ❑ Pumping rate 22 BPM
- ❑ Max Prop conc. 7 PPA
- ❑ Perf Interval 6800 Ft
- ❑ Gel Loading # GBX#30.
- ❑ Reservoir P 2790 Psi





Perforation Specs.

➤ Perforation Specs.

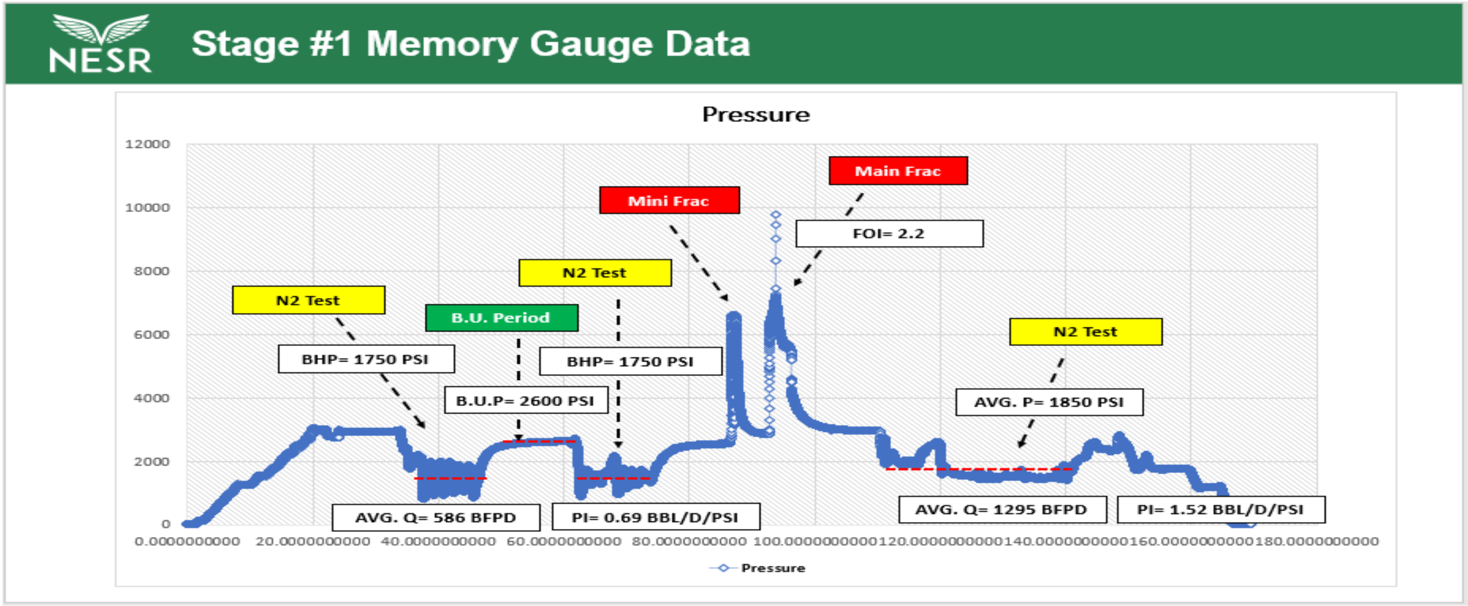
- ❑ The general requirement EHD for Fracture treatment is that the min. EHD exceed 6 times 20/40 Prop. (0.0278" inch), so the actual perforation EHD Specs. should not less than 0.2224" Inch for 20/40 to avoid any unnecessary fluid shear.
- ❑ A ratio of 8 to 10 times larger than the average proppant diameter should be generally used because of variance between normal and actual hole diameter.
- ❑ For 0° and 180° phased guns, all perforations should contribute to the fracture. For a 120° phased gun, only two-thirds of the perforations will probably communicate with the fracture, and for a 60° phased gun, only one-third of the perforations will likely be effective.
- ❑ From SLB simulation Run, EHD is 0.26", so we are in marginal compared to required 0.2224" inch EHD perforation.
- ❑ Based on calculated perf friction, its seems good perf friction +/- 140 Psi based on pumping rate +/- 25 BPM.
- ❑ Stratified formation intervals leading to relatively NWB frictions compared to offset wells.

$$\Delta p_{pf} = 0.237\rho\left[q_i/\left(C_d \times D^2\right)\right]^2, \quad (11\text{-}2)$$

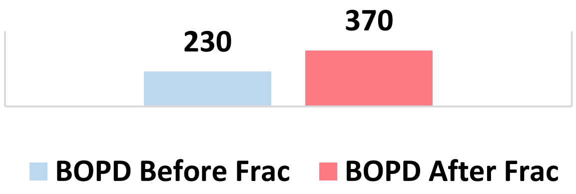
where ρ is fluid density in lbm/gal, q_i is injection rate in bbl/min/perforation, C_d is the dimensionless discharge coefficient, and D is the perforation casing diameter in in. Lord (1994) provided tables of

Perf Specifications	
Perforated Interval Length "FT"	40
Shooting Density "SPF"	6
No. of Perforations	240
No. of Open Perfs "n"	80
EHD "In"	0.26
Fluid Density "PPG"	8.5
Rate "BPM)	25
Discharge Coefficient "C"	0.56

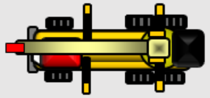
Calculated Perf Friction	
Perf Friction "PSI"	138.4293



Production Profile

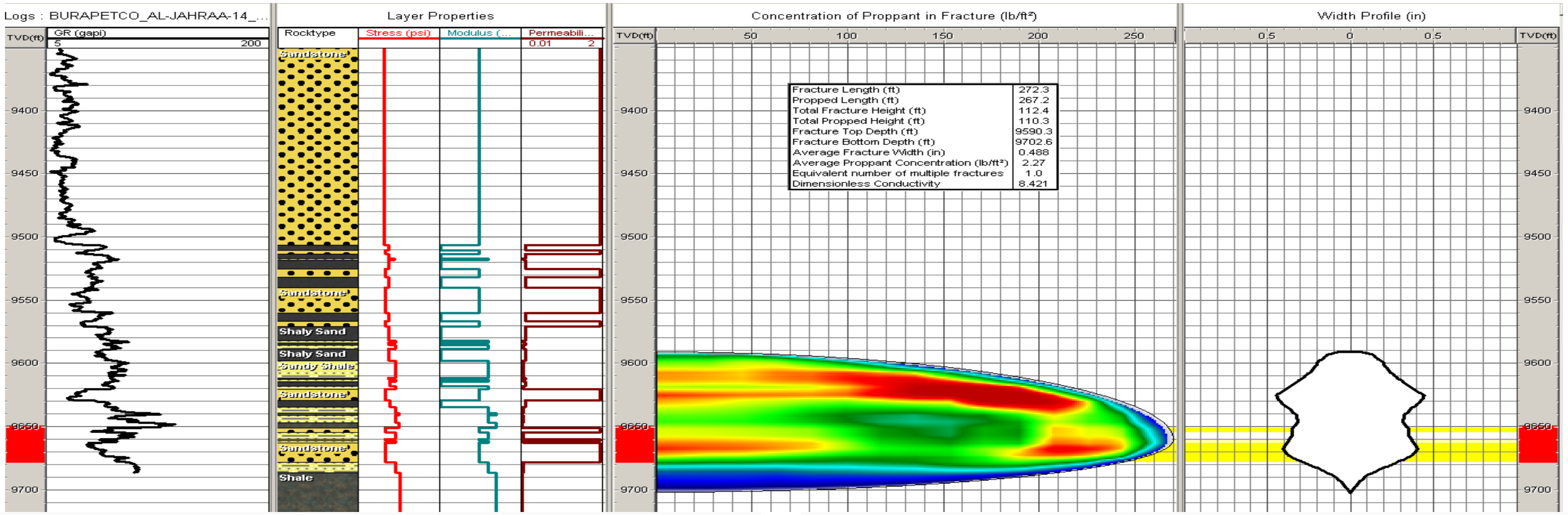


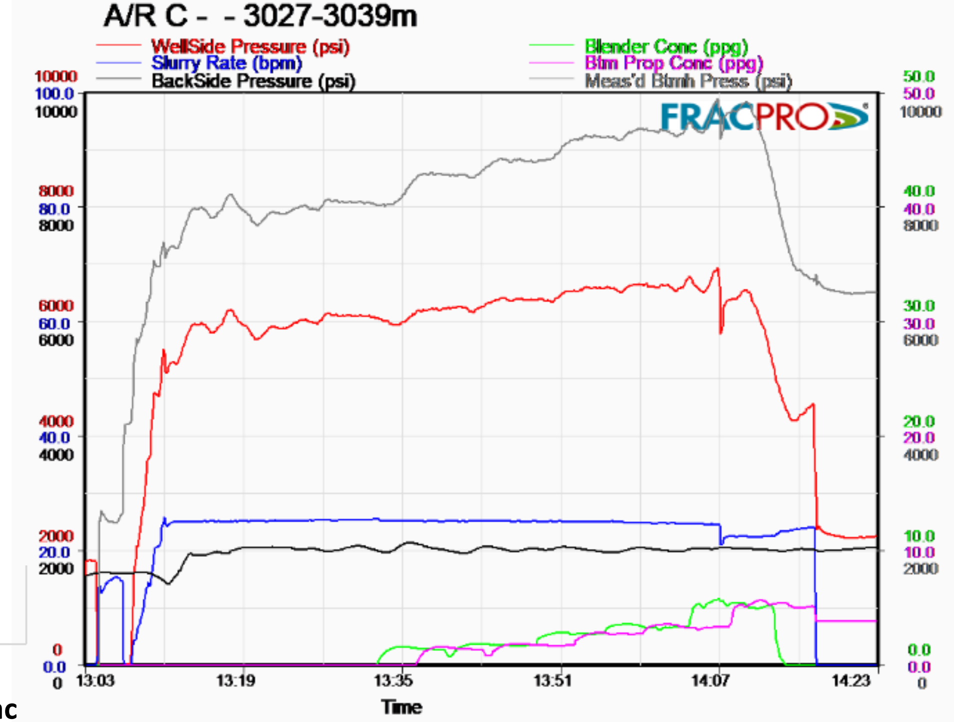
Conventional & Unconventional Frac Services in Egypt

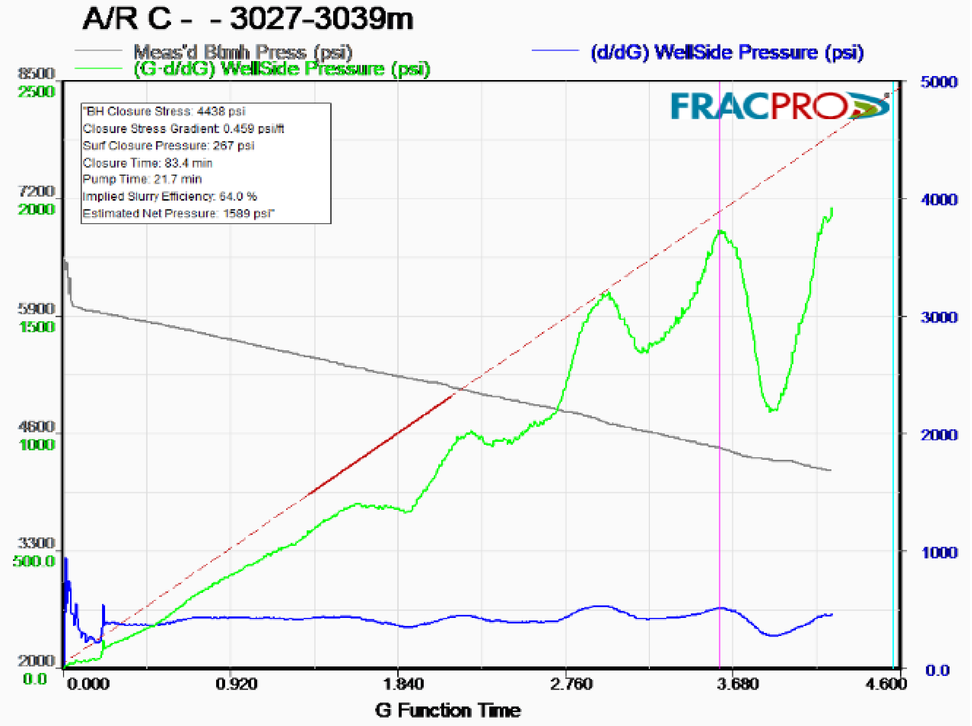


Well # 5

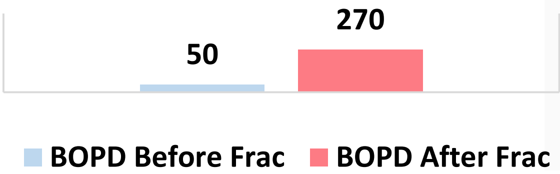
- **1 Trial Job**
- A/R"C" Formation
- 112 Kib 20/40 & 16/30 ISP
- Max P 7000 psi
- Pumping rate 25 BPM
- Max Prop conc. 5 PPA
- Perf Interval 9950 Ft
- Gel Loading # GBX#35.
- Reservoir P 1550 Psi



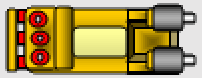




Production Profile

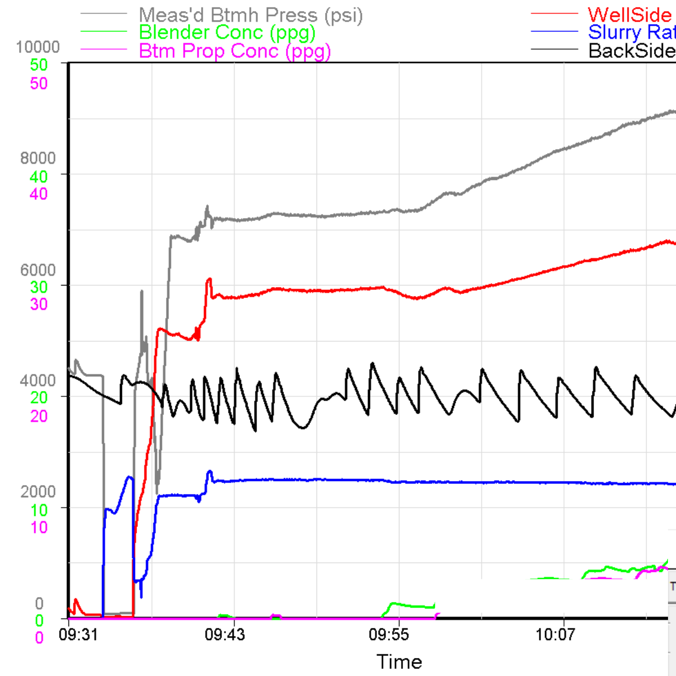


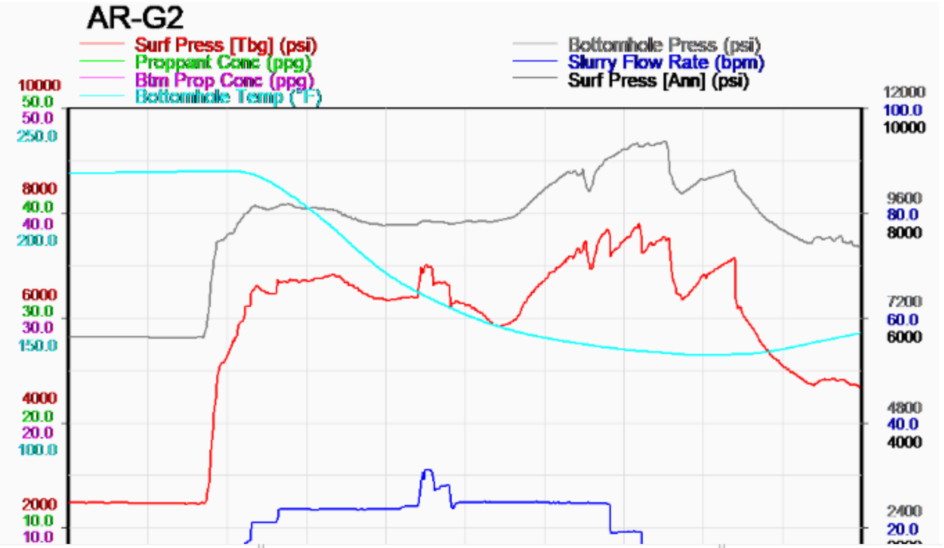
Conventional & Unconventional Frac Services in Egypt



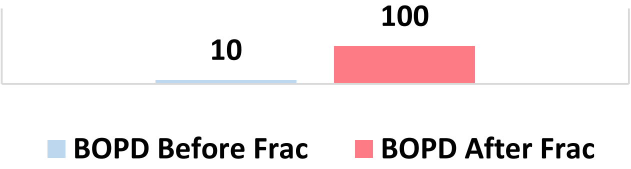
Well # 6

- **2 Trial Job**
- A/R"G-2" Formation
- 80-110 Kib 20/40 ISP
- Max P 7500 psi
- Pumping rate 25 BPM
- Max Prop conc. 5 PPA
- Perf Interval 10160 Ft
- Gel Loading # GBX#35.
- Reservoir P 1600 Psi

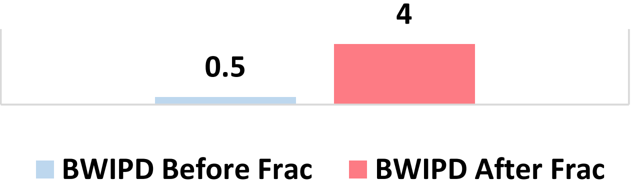


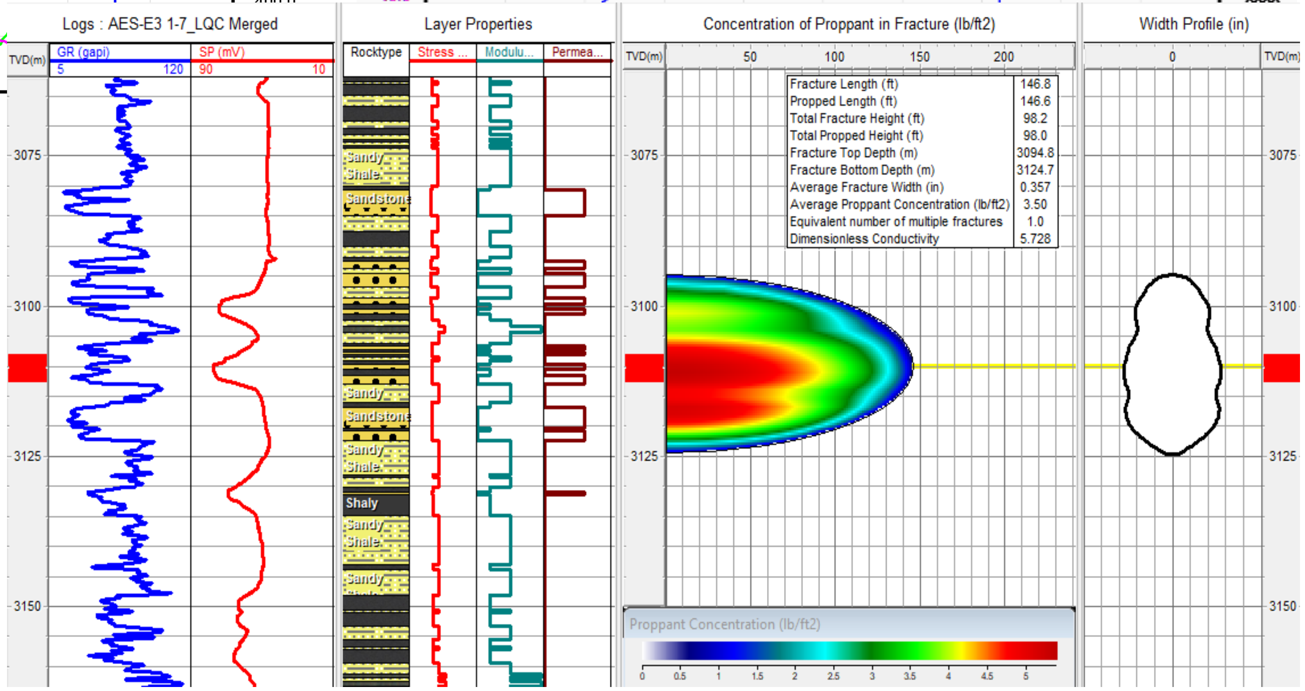


Production Profile

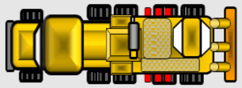


Injection Profile



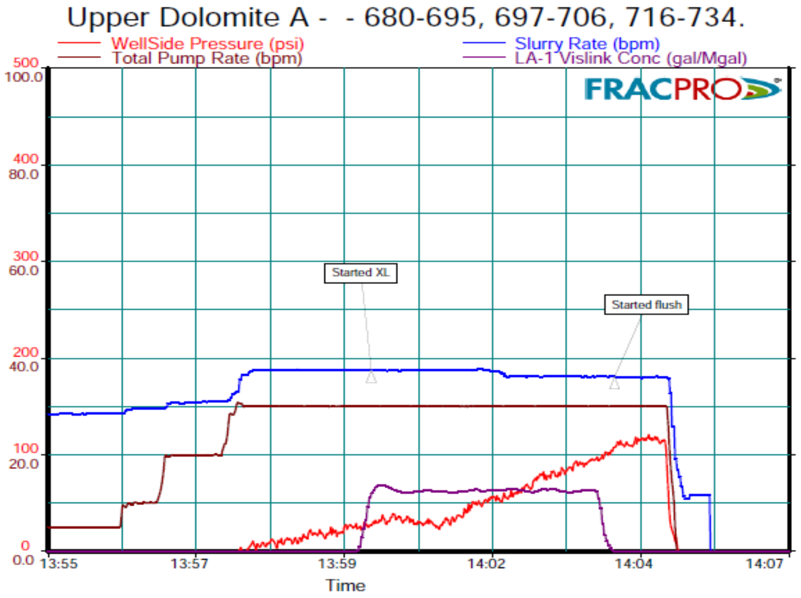


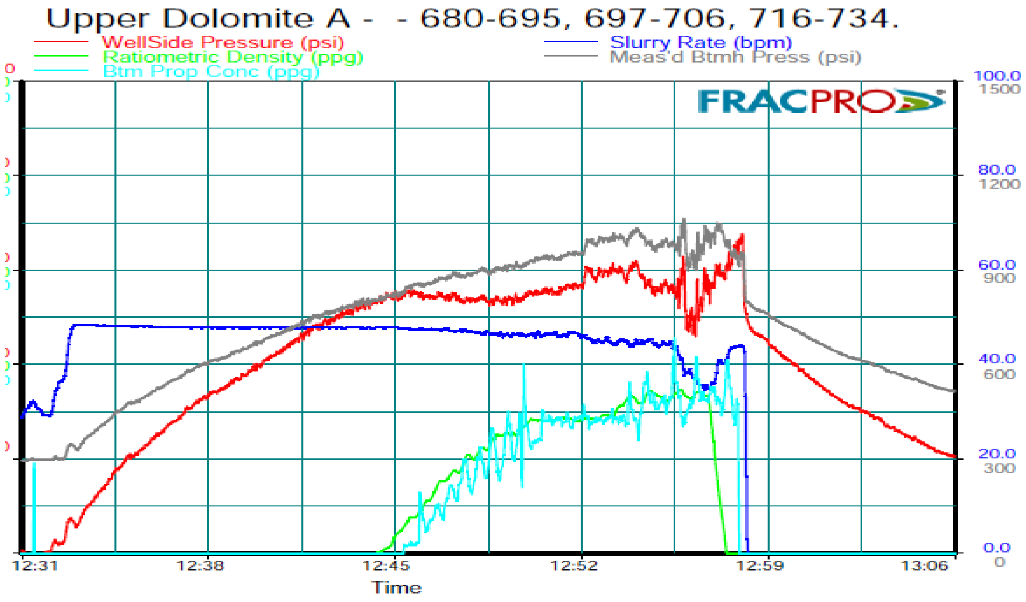
Conventional & Unconventional Frac Services in Egypt

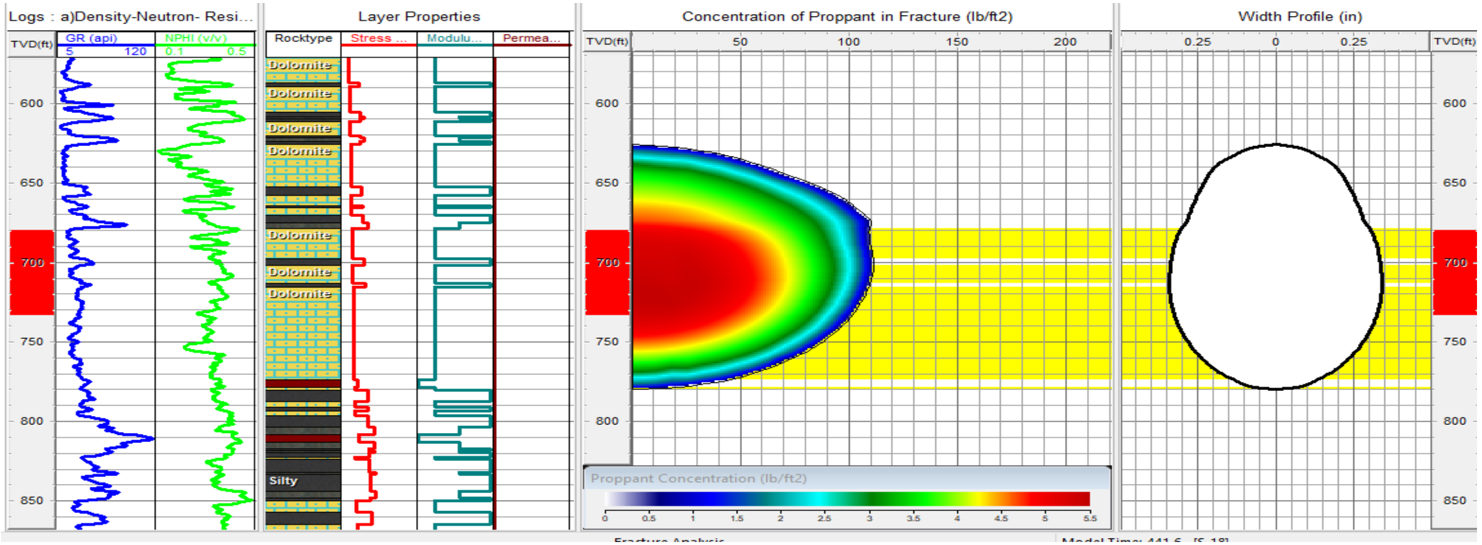


Well # 7

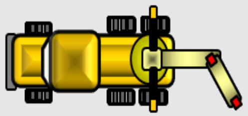
- **<u>1 Trial Job</u>**
- U.Dolomite “A” Formation
- 112 Kib 12/18 & 16/30 ISP
- Max P 678 psi
- Pumping rate 46 BPM
- Max Prop conc. 8 PPA
- Perf Interval 700 Ft
- Gel Loading # GBX#25.
- Reservoir P 300 Psi





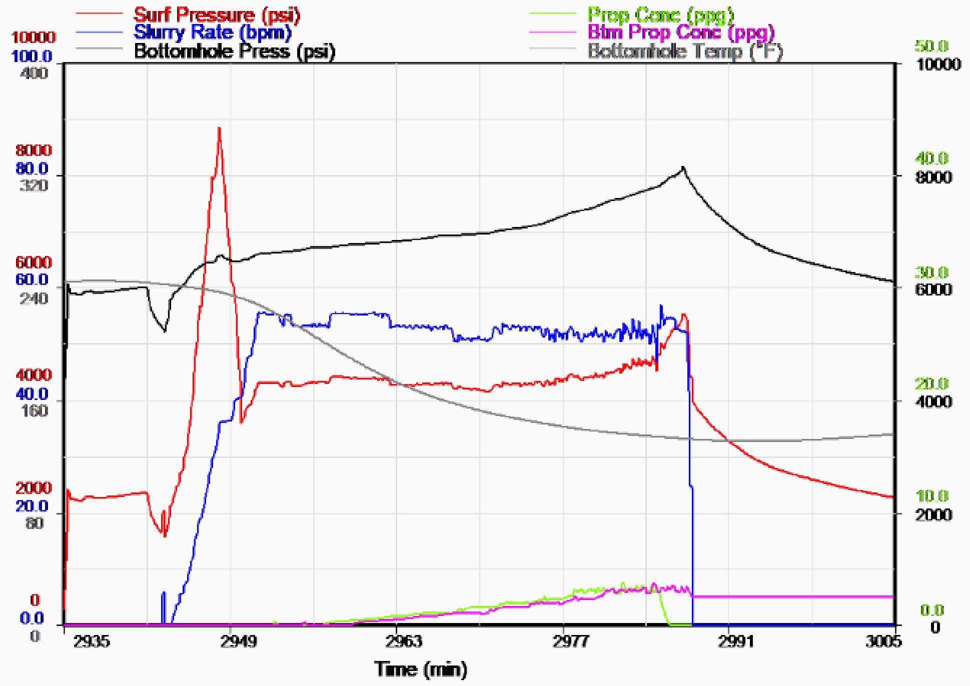


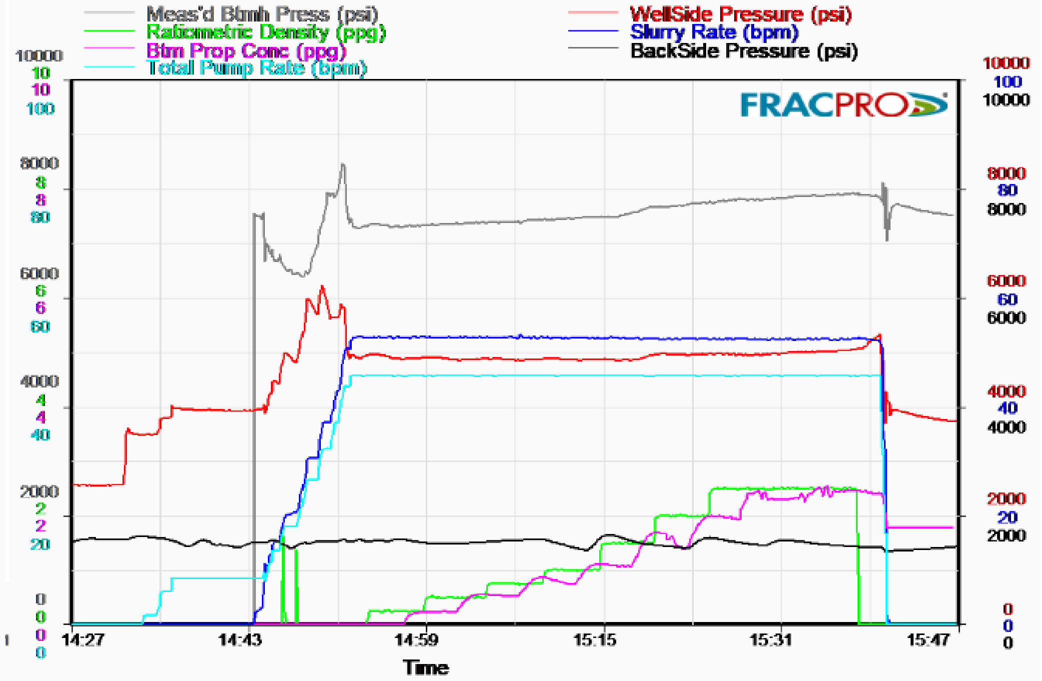
Conventional & Unconventional Frac Services in Egypt

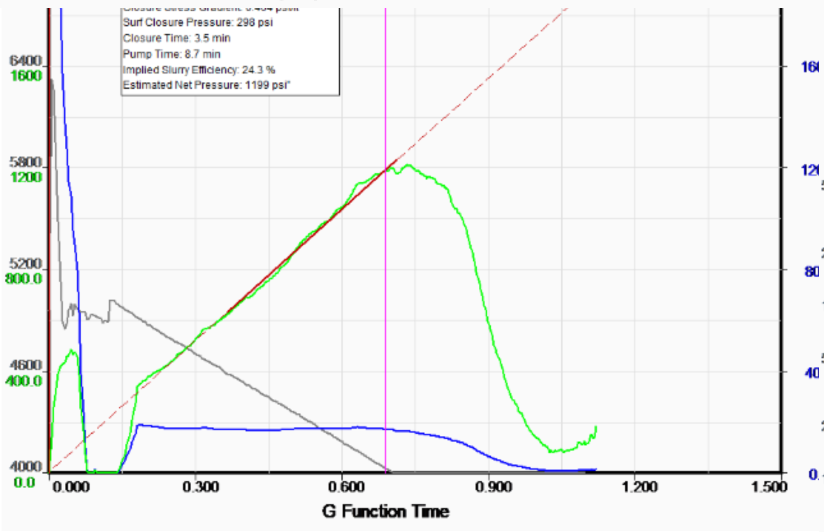


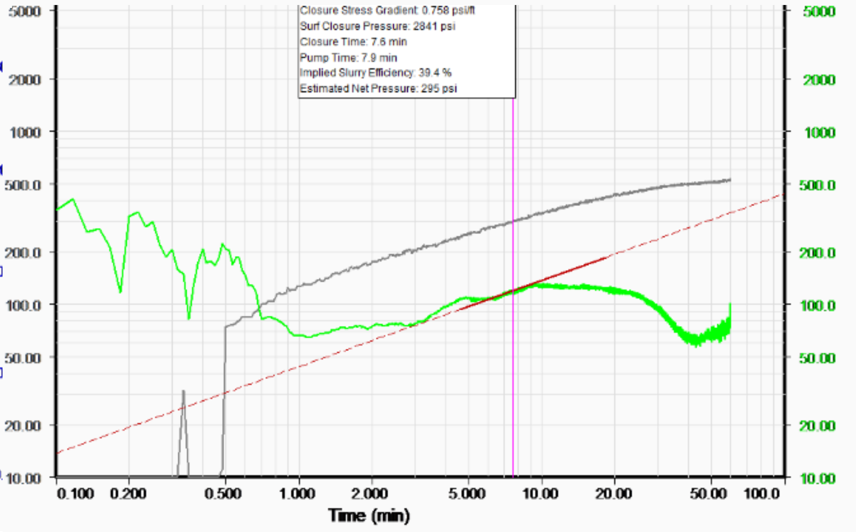
Well # 8

- <u>1 Trial Job (Two stage)</u>
- Matualla, Sudr & Duwi Formation
- 225 Kib 40/70 Natural Sand
- Max P 6000 psi
- Pumping rate 50 BPM
- Max Prop conc. 3.5 PPA
- Perf Interval 9000 Ft
- Slickwater fluid system
- Reservoir P 1340-2300 Psi









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Thanks