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A Methodology for Reducing Bias in the Design & Evaluation of Hydraulic Fractures

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Society of Petroleum Engineers

What is Bias?

As defined by dictionary.com:

Bi·as, {**bahy**-*uhs*} - a particular tendency or inclination, especially one that prevents unprejudiced consideration of a question; prejudice.

Common Bias Types

- Decision already made
  - Refuse to acknowledge or attack contrary information
    - See Iraq WMD, re: Bush, G.W.; Cheney, Dick
- Play it safe
  - Do the same thing everyone else is doing
- Inside View
  - Refuse to consider the outside view or poor results
    - Bad results = bad luck
- Results matter, but not as much as the process
  - Focus on Process Optimization, not whether the process is any good to begin with
    - See Polishing, re: Turd

Hydraulic Fracturing Is NOT Simple

Mud Logs
Acoustic Logs
Log Analysis
Geo-Mechanical Layers
Stress Profiles
Minifrac Analysis
Closure Strength
Proppant Selection
Frac Design
Fluid Selection
Rate Selection
Volume Selection
Conductivity

Perforating Scheme
Plug Types
Zonal Isolation
Service Providers (Equipment)
Proppant Supplier
Chemicals (3rd Party)
Logistics
Data Collection
Micro-Seismic
Consultants
Field Supervisors
Safety Compliance
Environmental Regulation

Common Bias Types in Frac'ing

- Decision already made
  - We have our design; why change it?
  - We know which zones we want to frac & how…Don't bother me with geo-mechanics and sonic logs
- Play it safe
  - We use the same frac design as everybody else in this area
- Inside View
  - We have a good program; we don't need to consider the downside
- Process over Results
  - We pumped all our proppant, so it must be a good frac job

Concentrate in 3 Areas

- Engineered Frac Design
  - MiniFrac (DFIT) Diagnostics
  - Geo-Mechanical Model Refinement
  - Simulation Runs
- Frac Replay (Pressure/History Matching)
  - Frac Geometry
  - Placement
- Frac Flowback
  - Production Analysis
  - Pressure Transient Testing

Workflow

- Perform independent analyses
- Compare afterwards
- Determine if/why discrepancies exist

- When all questions are satisfied, then use this info to move to the next well!

- Do not look for answers in the data.
  - Let the data show you the answers.

Engineered Frac Design?

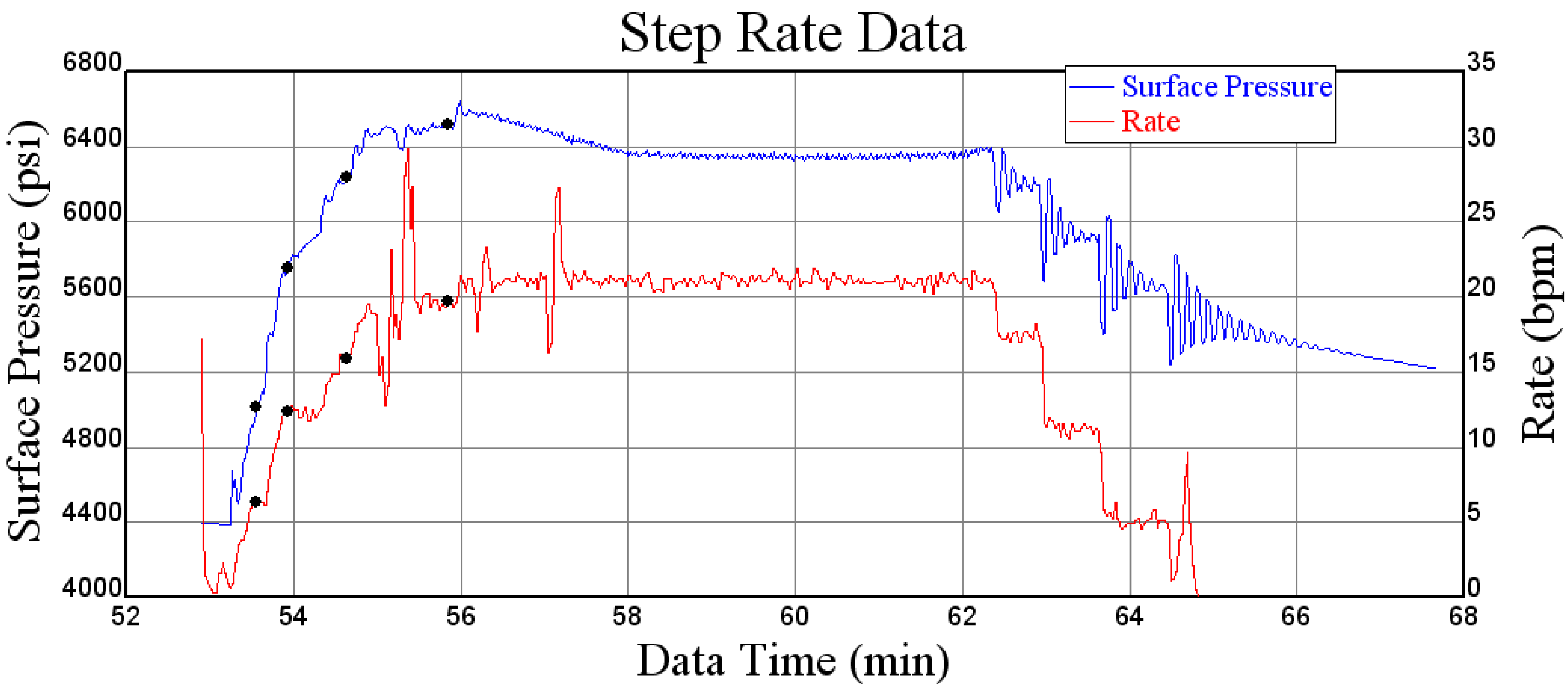
- What is the most common type of frac design?
  - Fully planned and simulated before reaching the well?
  - Rigorous testing of key input elements?
    - Formation Perm
      - Leakoff
    - Stress Profiles
    - Acoustic Log Data
  - Refined Geomechanical Model/Stress Profile?

  - Unfortunately, not!

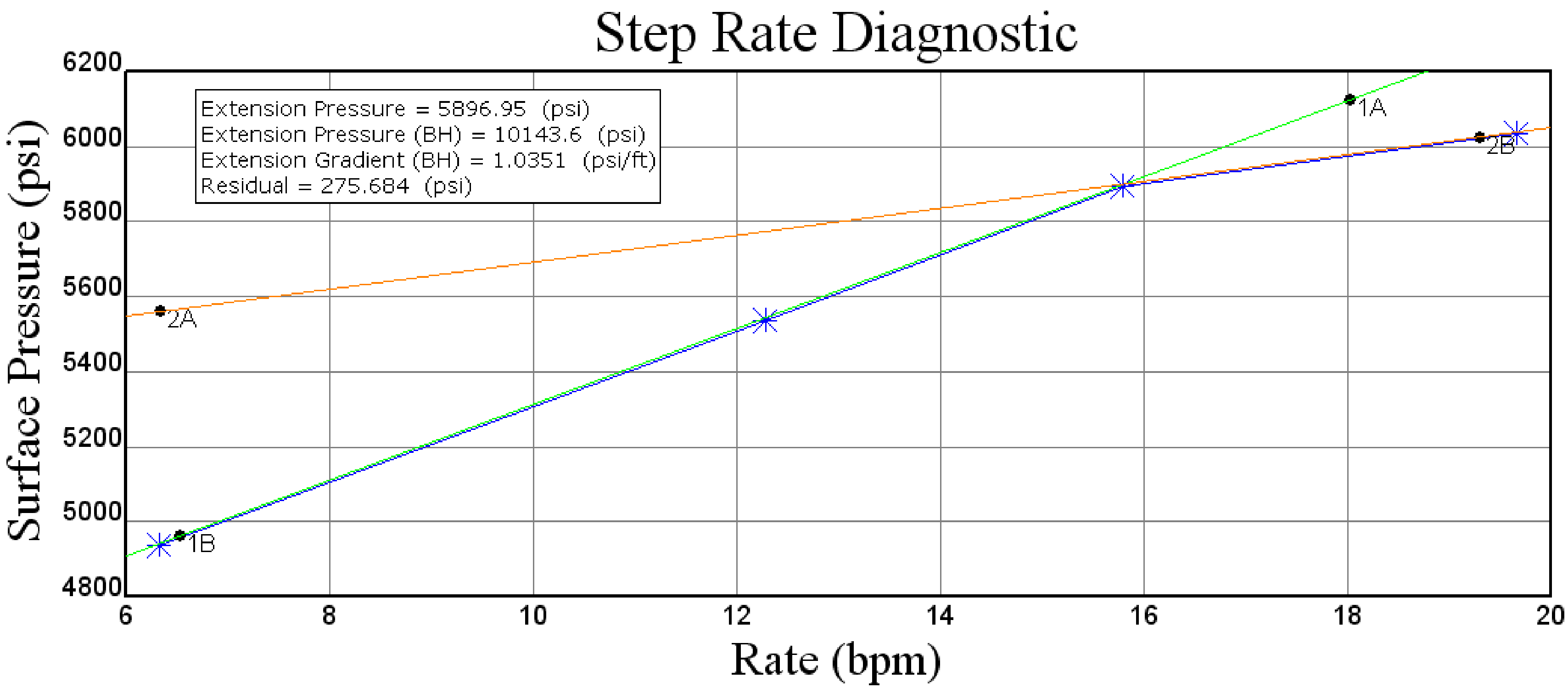
MiniFrac Analysis

- Step Rate
  - Max Closure Pressure (Pc)
- Step Down
  - Near Wellbore Losses
    - # Perfs Open
- Horner
  - Minimum Pc
- Regression
  - ISIP, Pc, ΔPnet, Time to closure, Efficiency
- History Matching of Data
  - Rock Properties, Frac Geometry
- After Closure Analysis
  - Pore Pressure (P*), Permeability

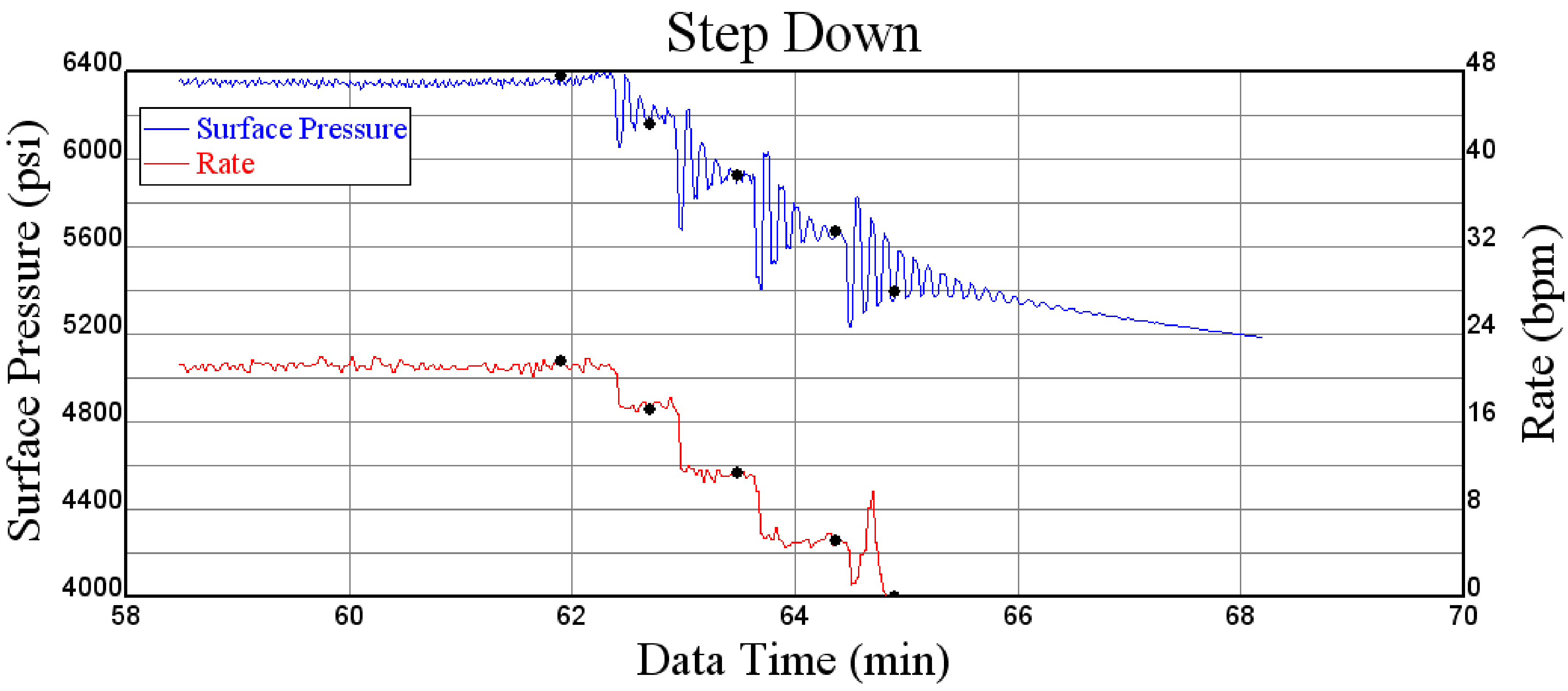
MiniFrac – Step Rate



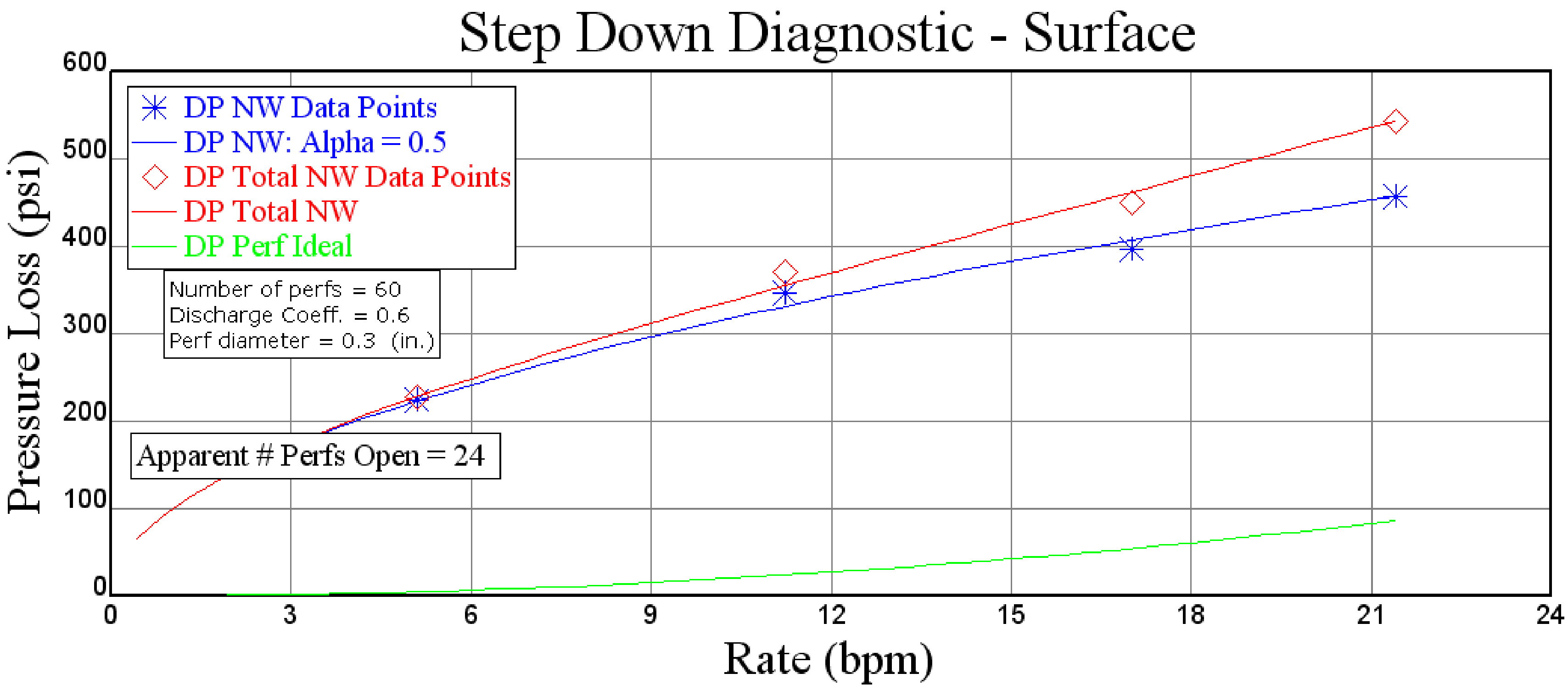
MiniFrac – Step Rate



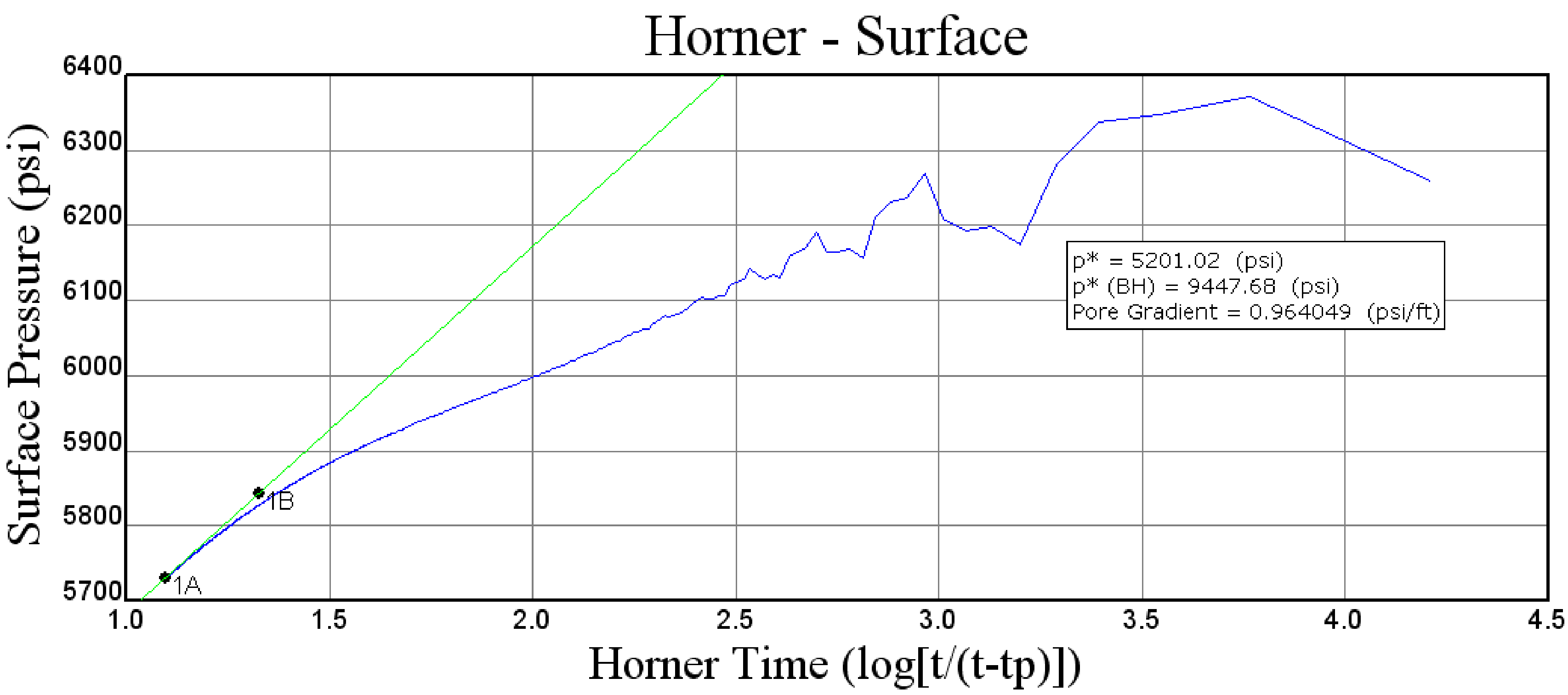
MiniFrac – Step Down



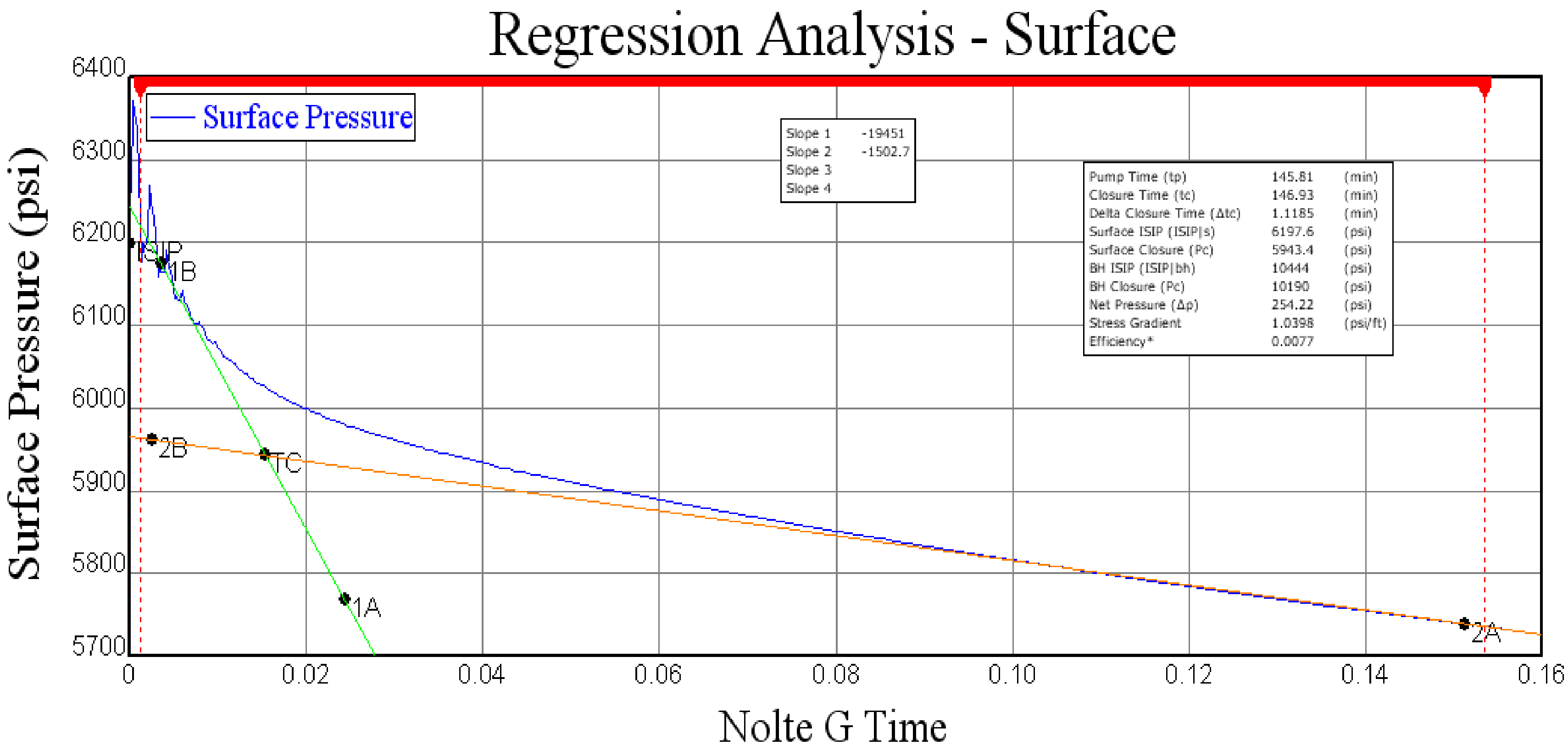
MiniFrac – Step Down



MiniFrac – Horner



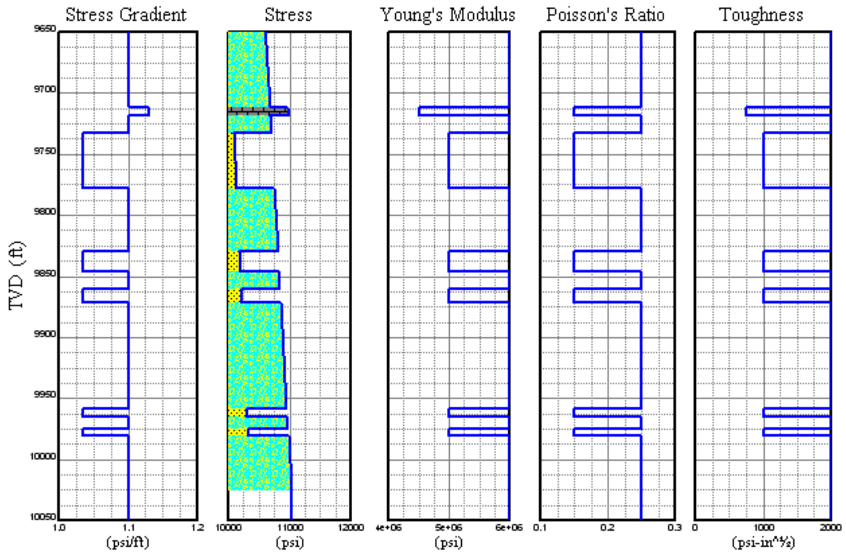
Regression Results (Linear Plot)



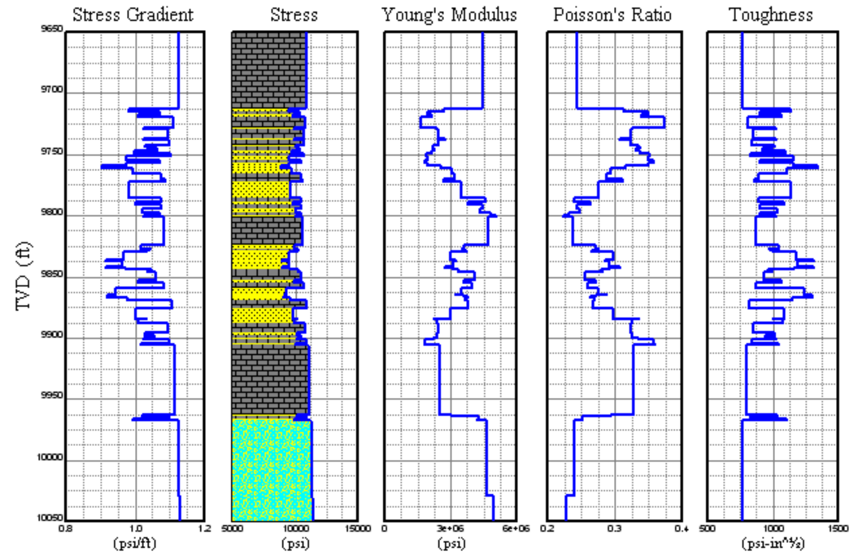
Geomechanical Model

The more data provided, the better the models get!

From Mud Log:



To Acoustic Logs:



What is Frac Replay Analysis?

- Pressure/History Matching of the Treatment
  - System used to evaluate and improve the hydraulic fracture stimulation plan
  - Tremendous amount of data gained during every frac
    - USE IT TO YOUR ADVANTAGE!!!
  - Frac data can be analyzed to gain:
    - Frac Geometry
    - Reservoir/Geomechanical Properties

Fracture Replay Simulation

- MiniFrac analyzed separately
  - No need to spend additional resources on simulation runs
  - Confirm the geomechanical model
- Focus on Actual Treatment Job
  - Pressure Match the replay file
  - Not perfect but close enough to get overall view of downhole situation after treatment
  - When the pressure matches, the parameters are dialed in for geometry

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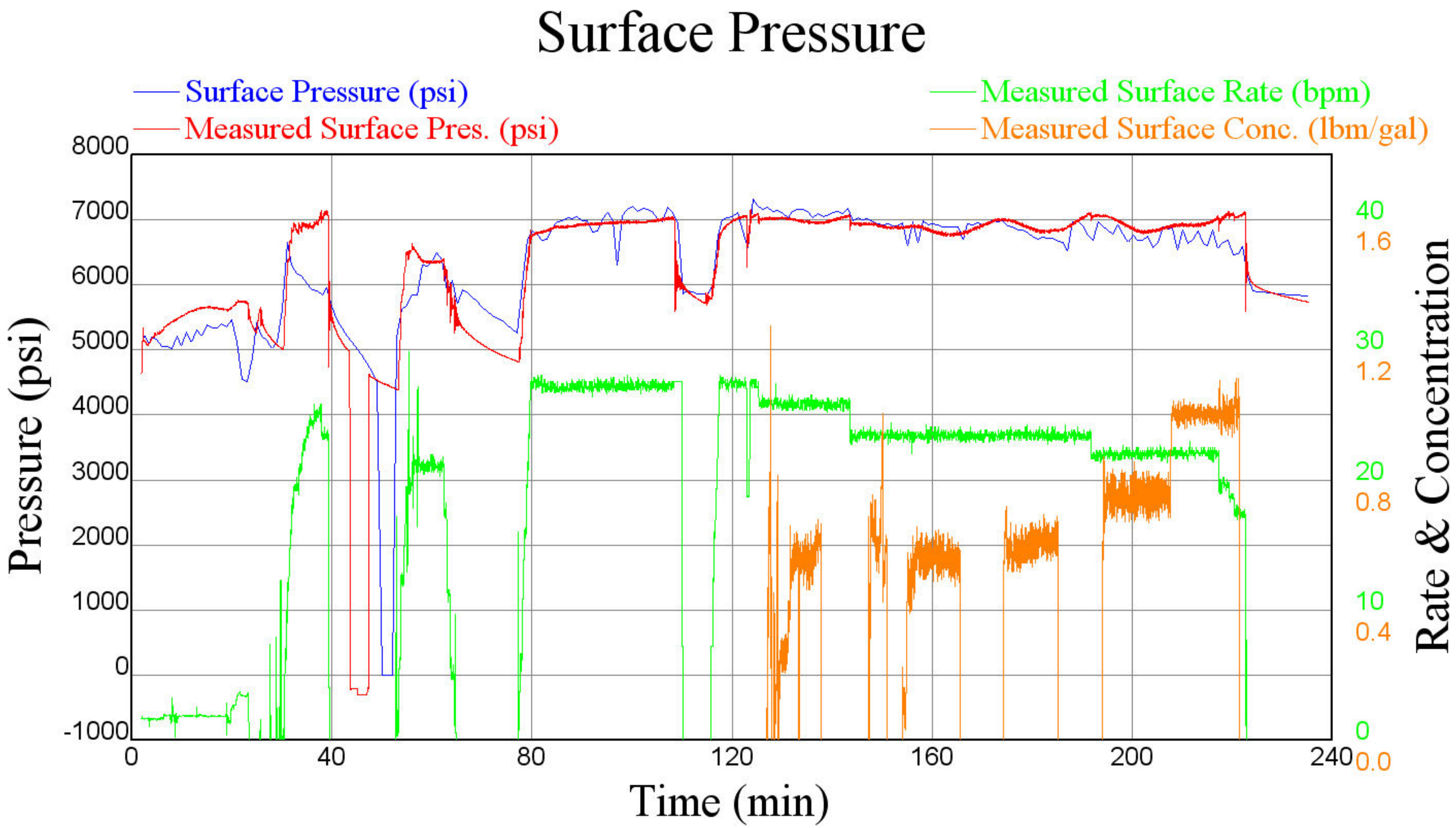
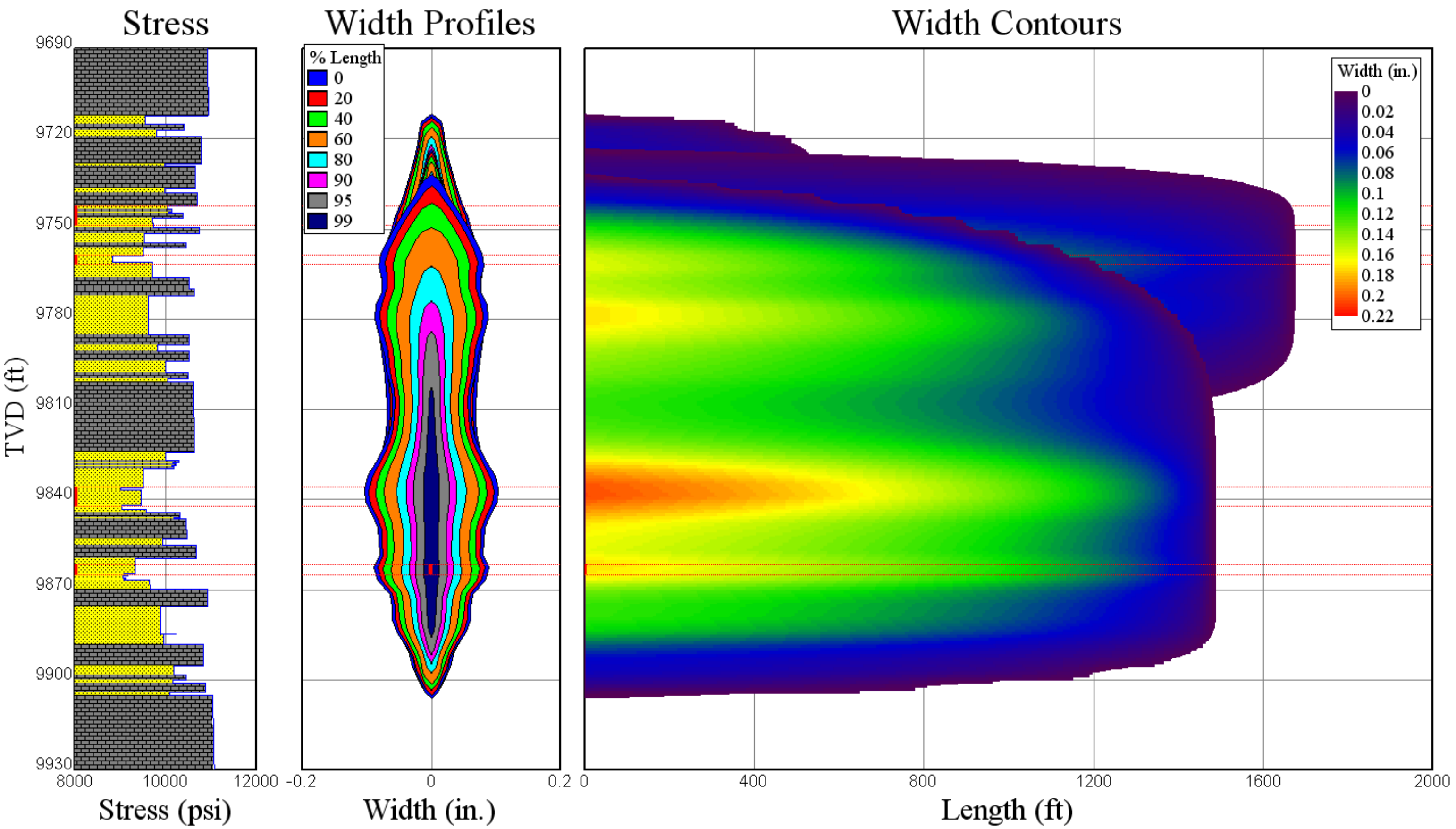
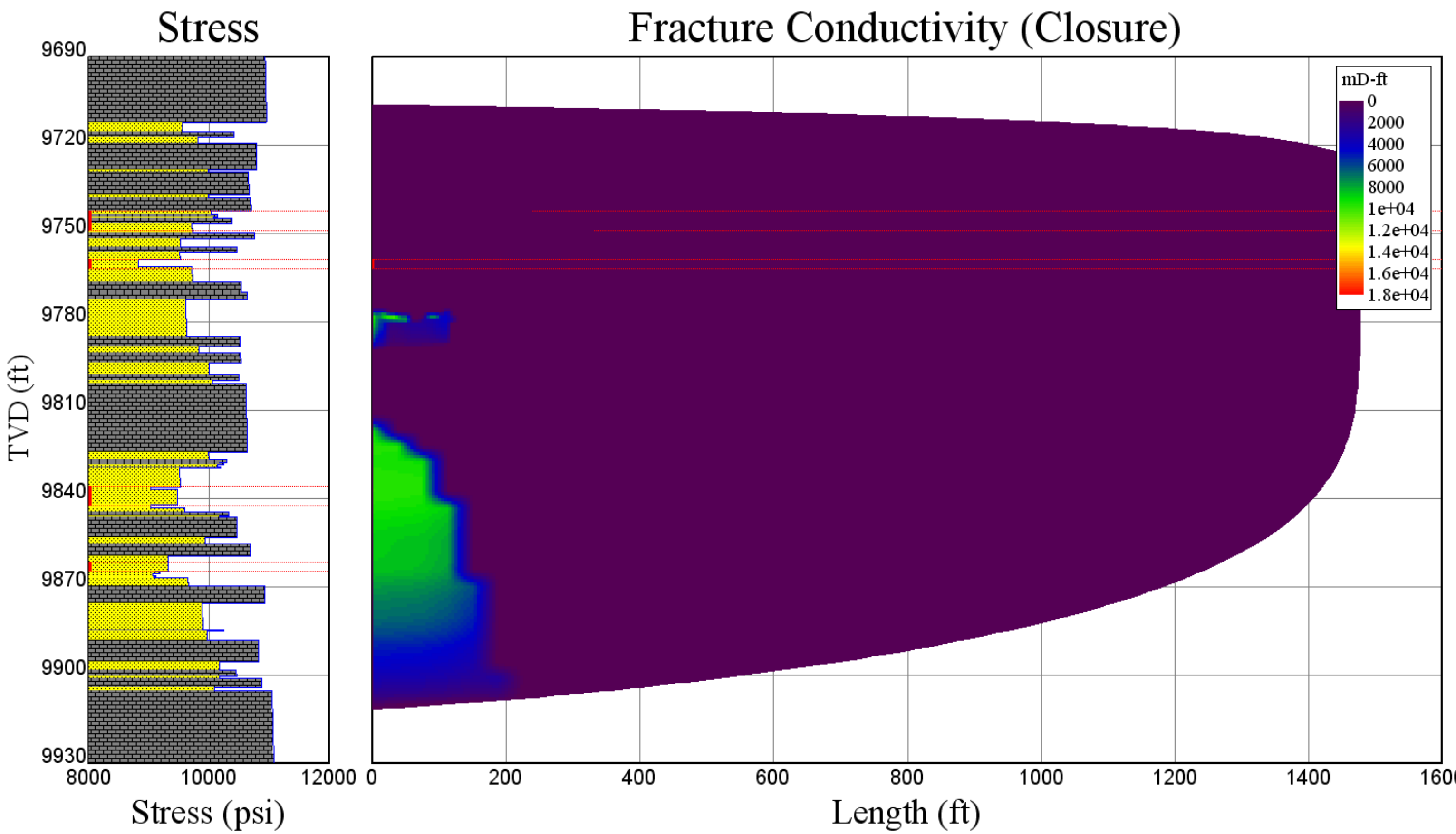
Pressure Match



Fracture Geometry



Fracture Conductivity



Frac Replay Results

- Frac Replay Analysis
  - Simplistic Geomechanical model can be proven to be sufficient through minifrac analysis and simulation runs of actual job
  - Actual resultant frac from Stimulation Treatment
    - Total 3-dimensional spacing during and after job
      - Height, Length, and Width
    - Proppant Placement during and after job (Conductivity)
    - Zonal Identification
      - Which zones were actually receptive to frac?

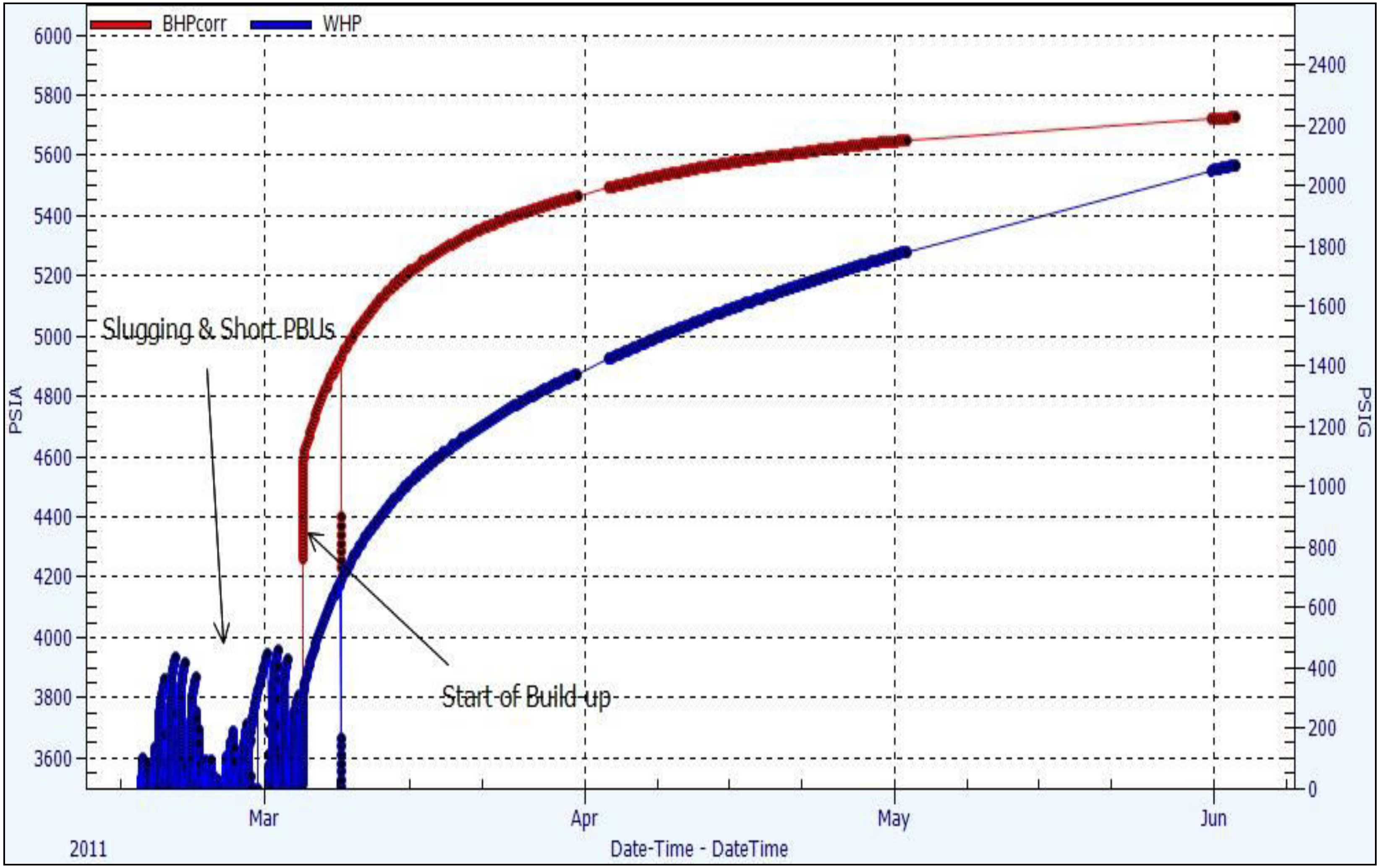
What does a “Frac Flowback” Entail?

1. The flowback of the frac fluids and associated fluids/solids
2. The continued flow of the well after hydrocarbons to surface
3. Multiple rates during 1 and/or 2
4. The build-up/shut-in of the well afterwards
5. The initial production of the well to sales (long-term test to evaluate drainage volume)

What can the data tell you?

1. Fracture Permeability and/or Conductivity
2. Matrix Perm
3. Effective Fracture half-length (global for multiple fracs)
4. Effective Frac-dominated Volume
5. Is there a change in the continuous fluid in the frac/matrix system (i.e. is the pad creating a water block)?
6. Observed Drainage Volume (long-term flow)

Frac Flowback & PBU

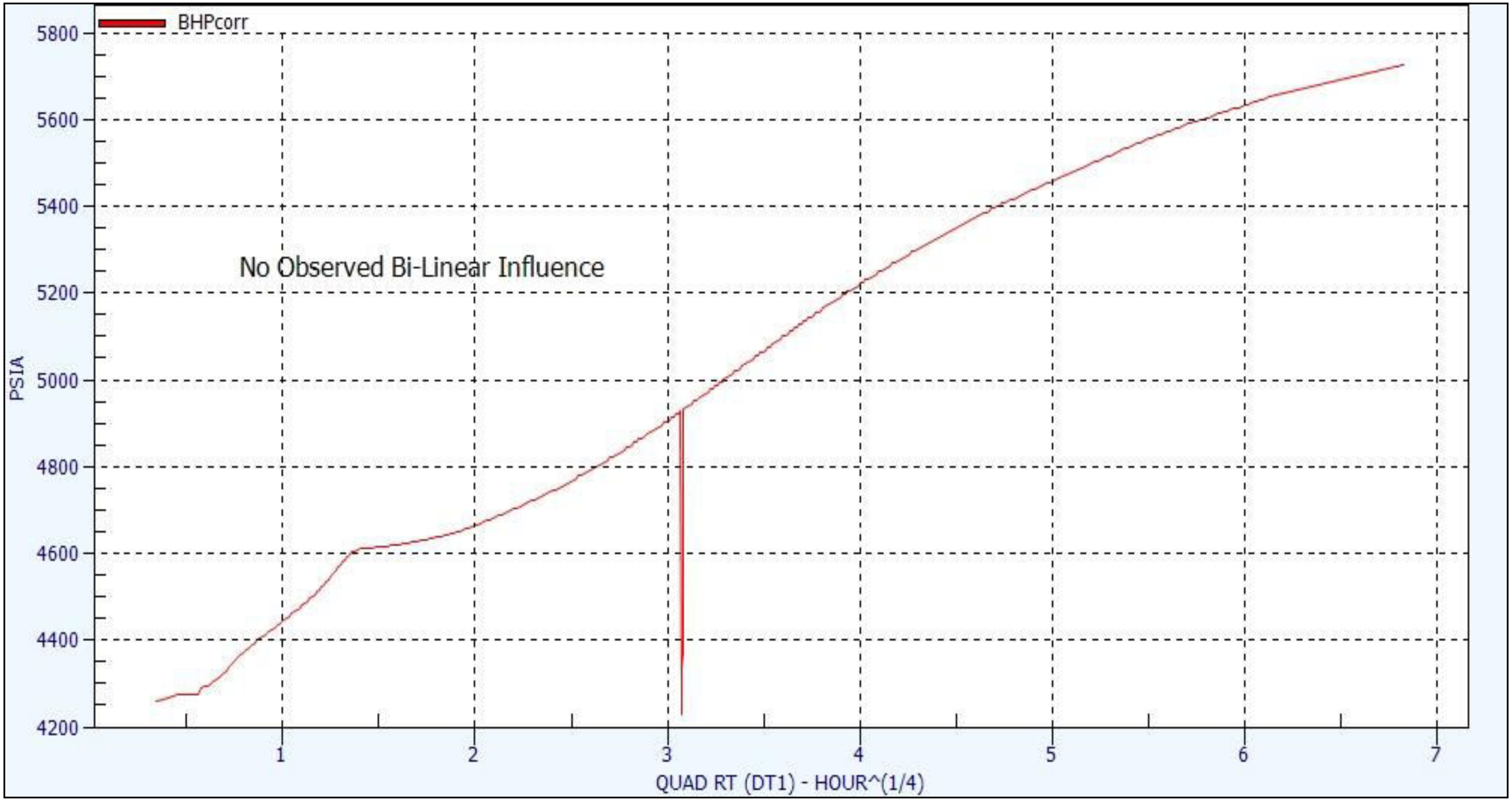


Diagnostic Plots

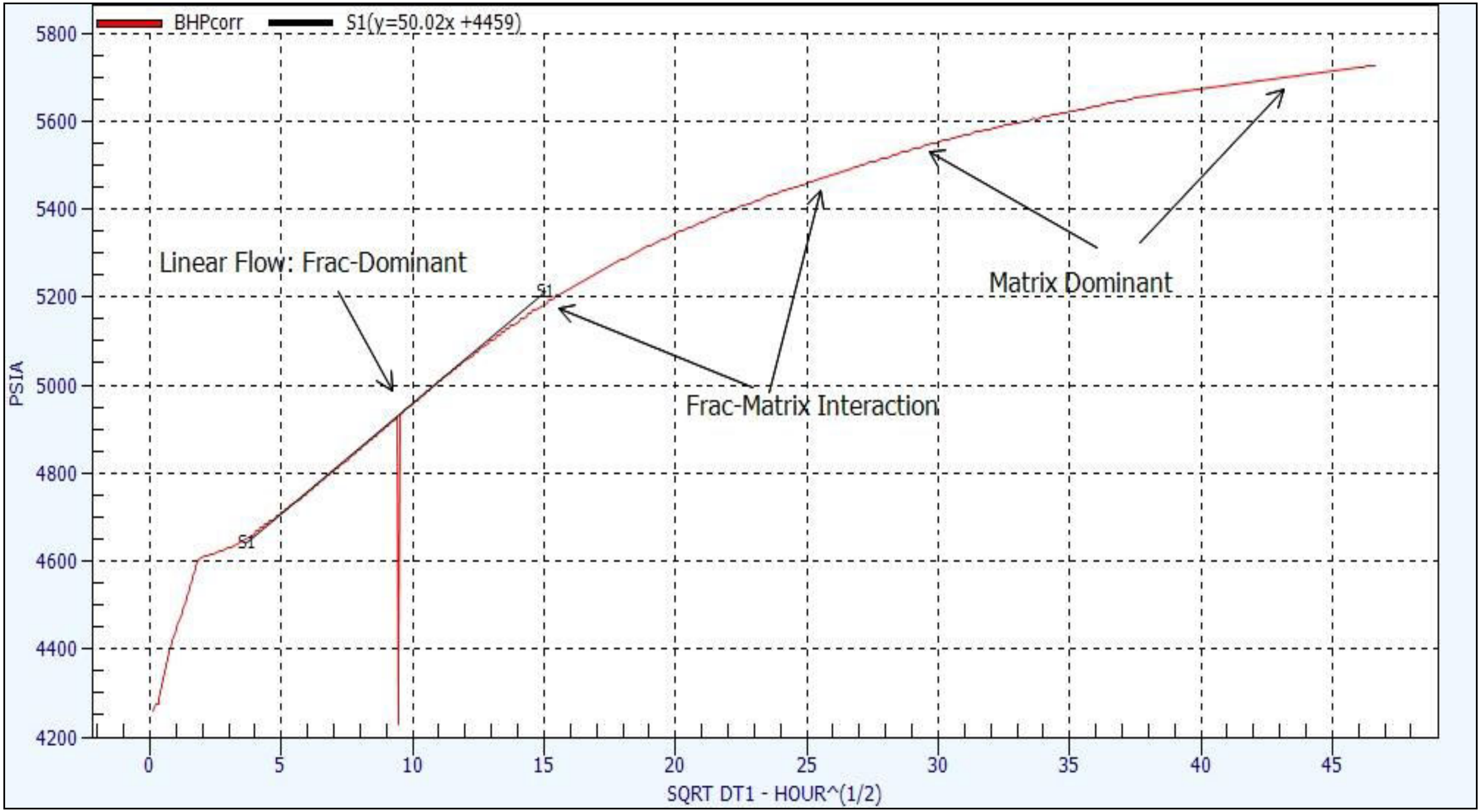
Make Them ALL – Don't just rely on one plot

1. Cartesian plot of BHP and Rates
2. Semi-log plots of individual build-ups and drawdowns
3. Derivative plots
4. Linear Flow Plot: Square-root of delta time plots
5. Bi-linear Flow Plot: ¼-root of delta time plots

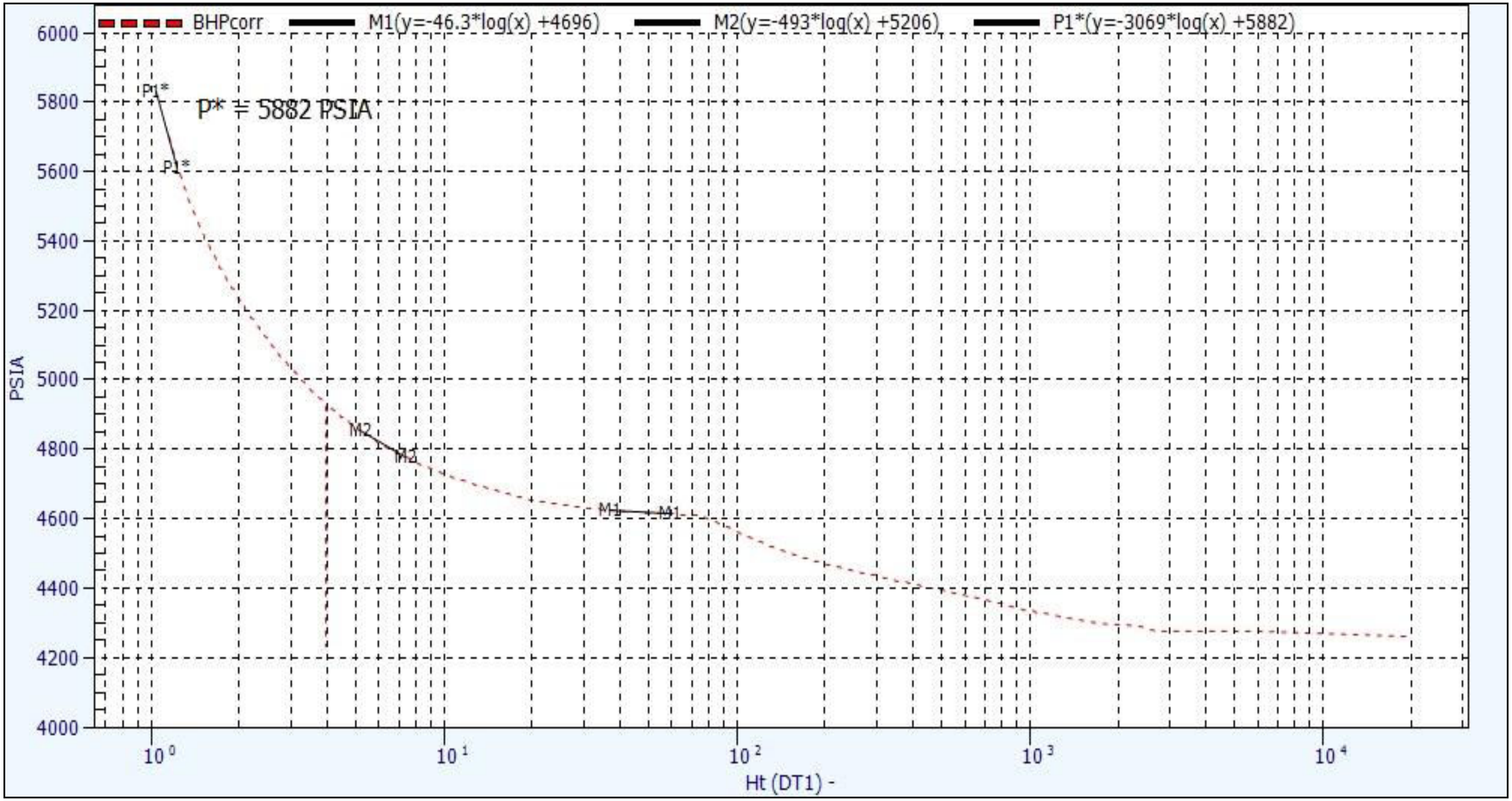
Bi-Linear Plot of PBU



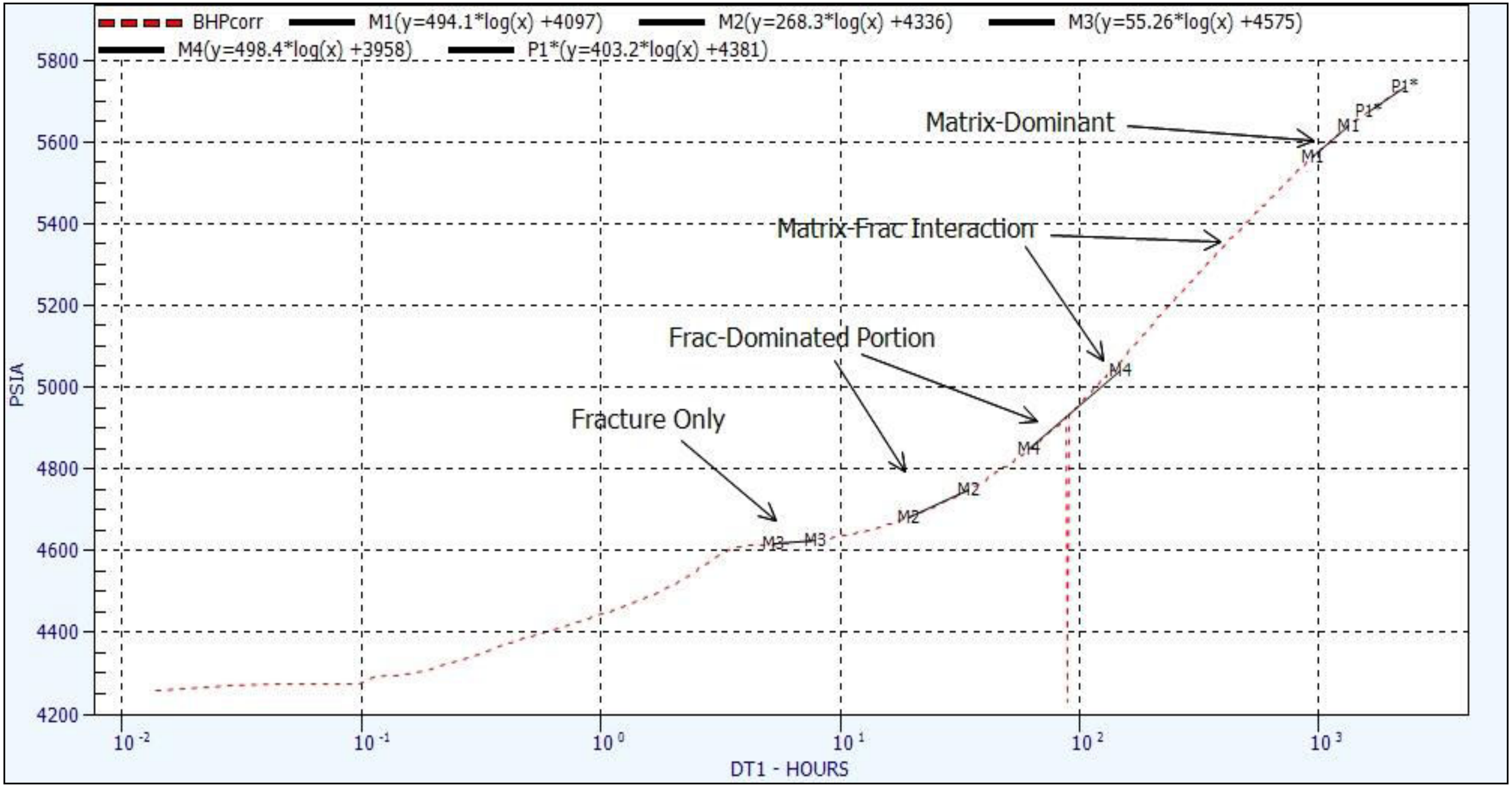
PBU – SQRT(DT) Plot – Linear Plot



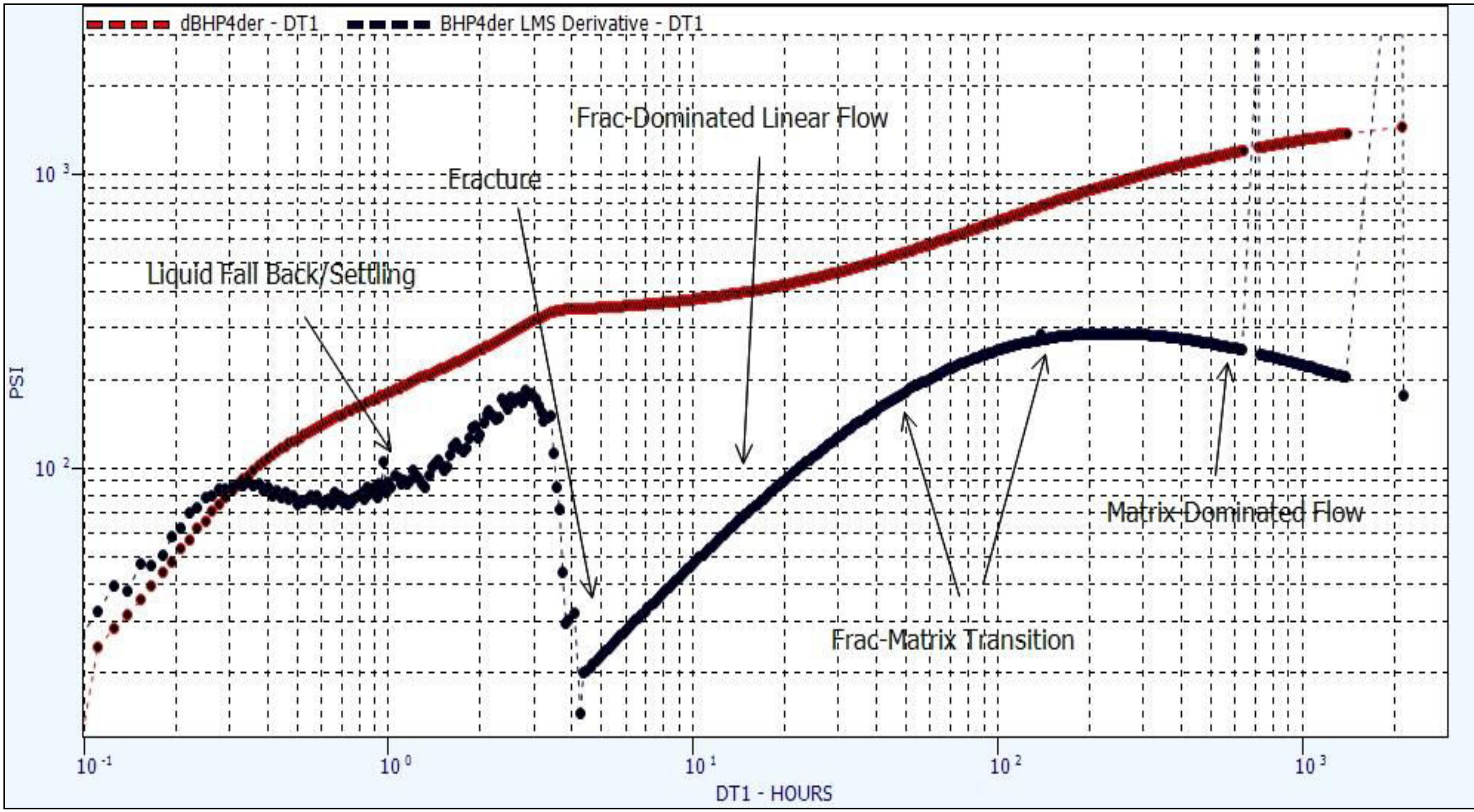
Horner Plot - PBU



Semilog Plot - PBU



Derivative Plot - PBU



Well Test Analysis - Conclusions

- Fracture Perm: 1.8 md (quite bad)
- Formation Perm: 0.20 md
- Frac Extension: 250 feet from WB
- Frac Dominated Volume: 390K Res BBL
- Observed Reservoir Volume: 2.46 MM Res BBL
- Potential Recovery: 1.9 BCF of Gas

Note: Large Water Block is Preventing Significant HC Contribution

Reconciliation with Frac Replay

- Adjust Net Pay to 12.5 feet (from 50 feet)

- Frac Perm = 7.2 md
- Matrix Perm = 0.80 md
- Frac-Dominated Volume: 177K RB
- Observed Res Volume: 1.23 MM RB
- Potential Recovery = 0.94 BCF of Gas

Water Block Still a Major Problem

Why Analyze after a treatment?

- Maximize the R.O.I. of the entire field plan
  - Allows for OPTIMAL SUCCESS by "tuning" each frac job in the field in a progressive manner.
  - Better understanding of the reservoir/geomechanical properties of the field.
- Optimize fracture designs for the future
  - Improved Geomechanical Models allow for frac design by computer modeling in the office rather than trial by error in the field
- Size the Fracture Treatments to the Reservoir
  - Optimum Rates, Proppant Types/Volumes, Fluid Types/Properties
  - Minimize Number of Effective Fracturing Stages per Well

Why repeat the same mistakes?????

Why spend money that you don't have to?????

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