An Examination of the Effects of Surface Data Acquisition Methods on Well Performance Evaluations and Completion Optimization

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Agenda

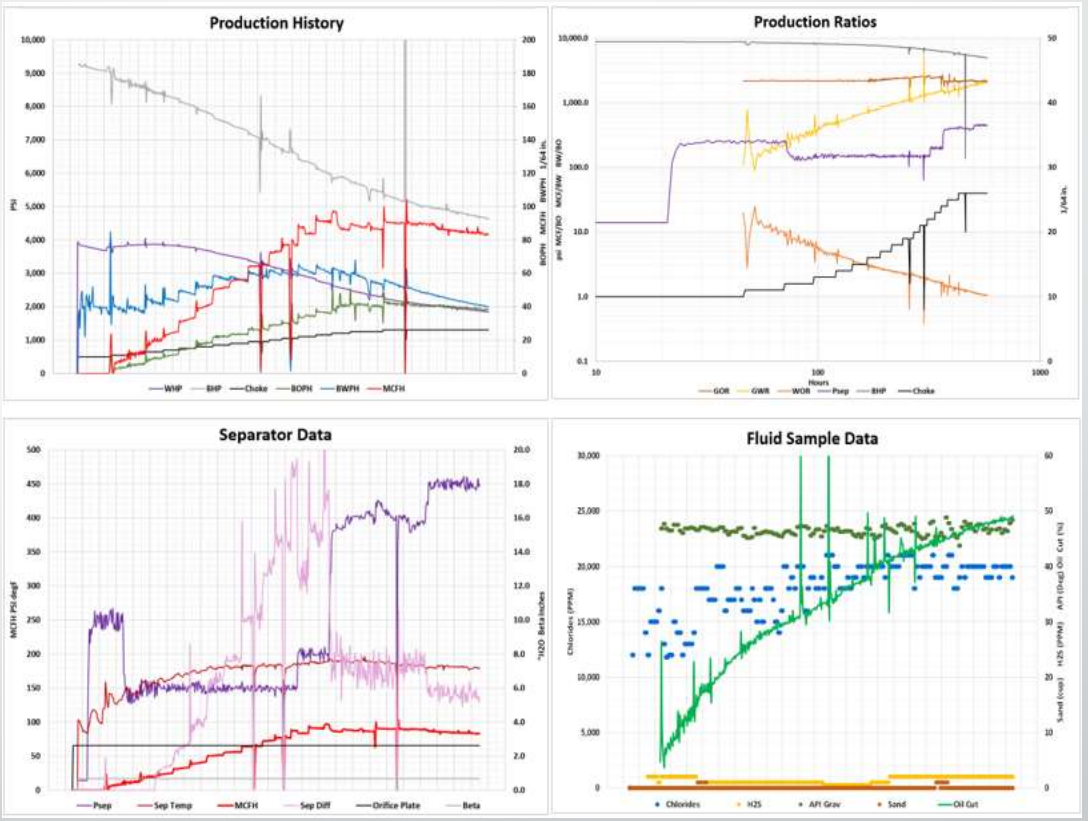
- Initial production data diagnostics and surface data acquisition methods
- Case Study 1: Measurement Error Identification
- Case Study 2: Data Quality Effects on Well Performance Assessments
- Case Study 3: Data Quality Effects on Draw Down Optimization
- Case Study 4: Data Quality Effects on Completion Optimization
- Conclusions
- Questions

- Rate Transient Analysis (“RTA”) straight line analysis methods used on specialized diagnostic plots of the initial production period (first 5-30 days of production) are a common technique used for draw down optimization and completion evaluations
- Operators typically optimize completions iteratively with small (5-15%) changes in the major completion design parameters (stage length, cluster length, prop / cluster, water / ft., etc.)
- Data quality from different surface data acquisition methods commonly used during the initial production (flowback) period significantly impact well performance interpretations

Initial Production Data Diagnostics

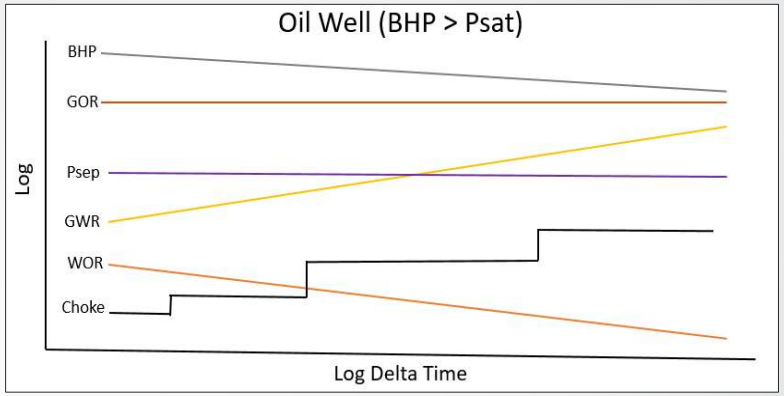
- Preferred dashboard includes:
  - Production History
  - Production Ratios (PR)
  - Separator Data
  - Fluid Sample Data

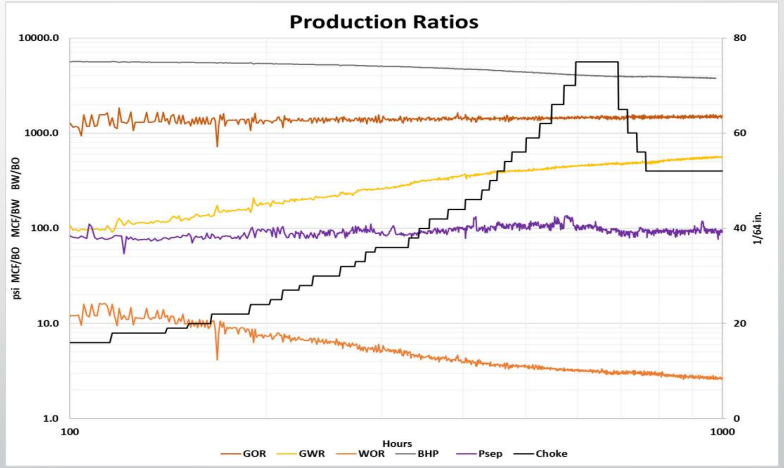
- Scan for anomalies
  - Noise
  - Rate / Pressure
  - PR deviations from expected trends



Production Ratios Plot

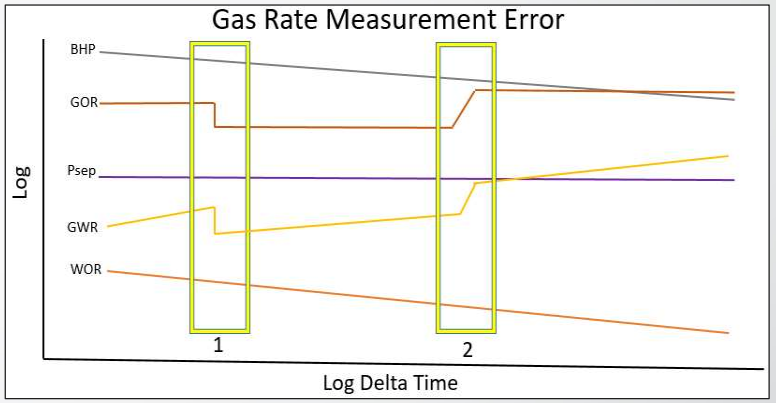
- Trend lines to include on this plot:
  - BHP, GOR, Psep, GWR, WOR, Choke
- GOR should be constant when BHP>Psat and Psep is constant
- GWR and WOR diverging for wells cleaning up
- BHP gradually decreasing when choke is constant or increasing
- Psep should be as constant as possible

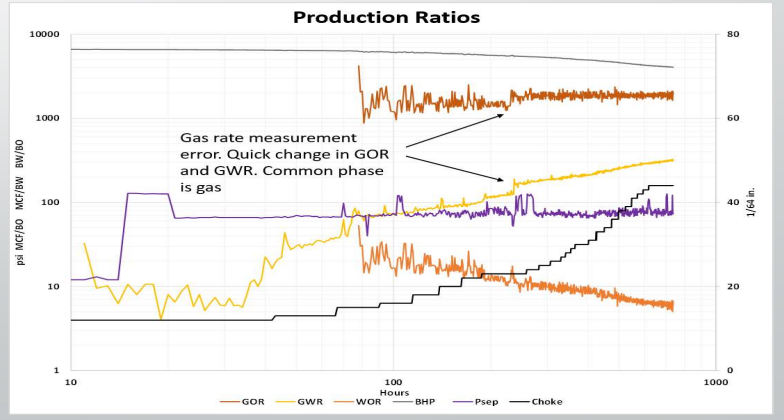




Measurement Error Identification

- When a change is seen on two PR trend lines the common phase between them is likely the one with the measurement error
- Change in GOR and GWR with gas being the common phase indicates a gas rate measurement error
- Error could have occurred at the point or have been corrected at that point





Common Measurement Methods Used During the Initial Production Period

	Tank Straps	Pulse Radar	Guided Wave Radar	Turbine	Electro Mag.	Coriolis	Orifice Plate	Analogue Gauge	Digital Gauge
Oil					N/A		N/A	N/A	N/A
Gas	N/A	N/A	N/A	N/A	N/A			N/A	N/A
Water							N/A	N/A	N/A
Pressure	N/A	N/A	N/A	N/A	N/A	N/A	N/A		

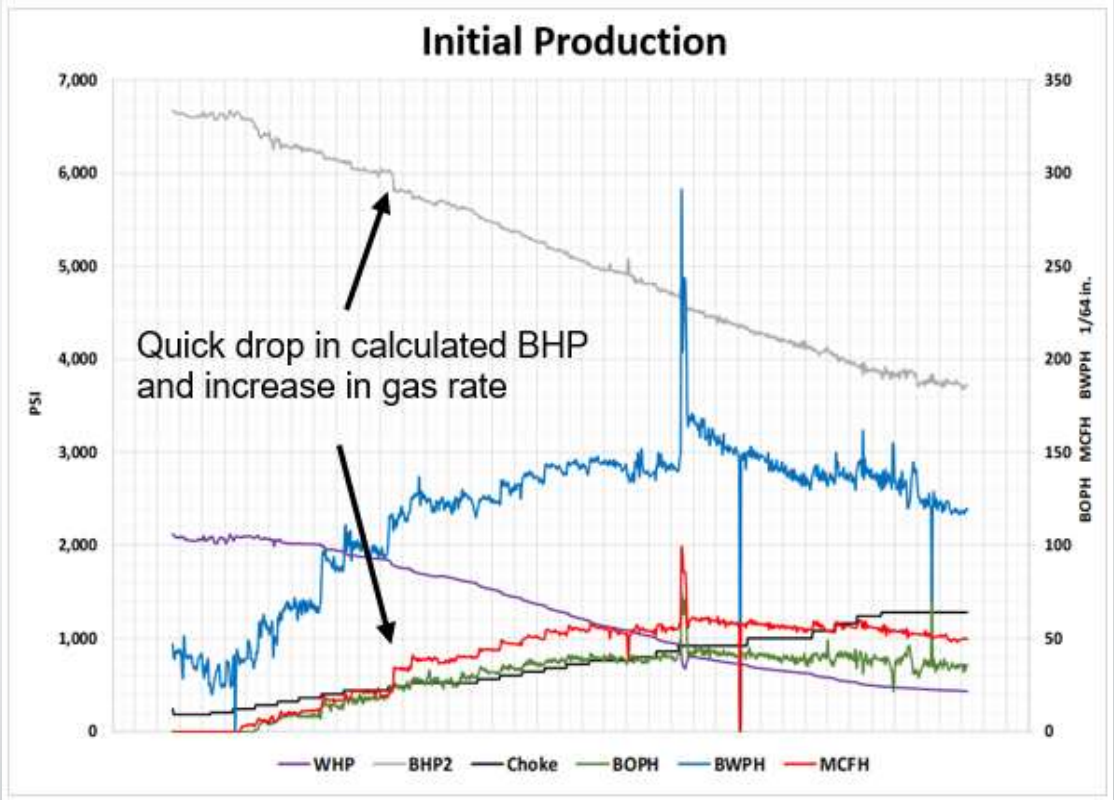
- Tank Straps (liquids) and Analogue gauges (WHP) have the worst data quality
- Orifice plates (gas) and Pulse Radar (liquids) can have good data quality under the right conditions
- Guided Wave Radar (liquids), Electro-Mag (water), Coriolis (liquids and gas) and Digital gauges (WHP) provide the highest data quality

Additional Sources of Measurement Error

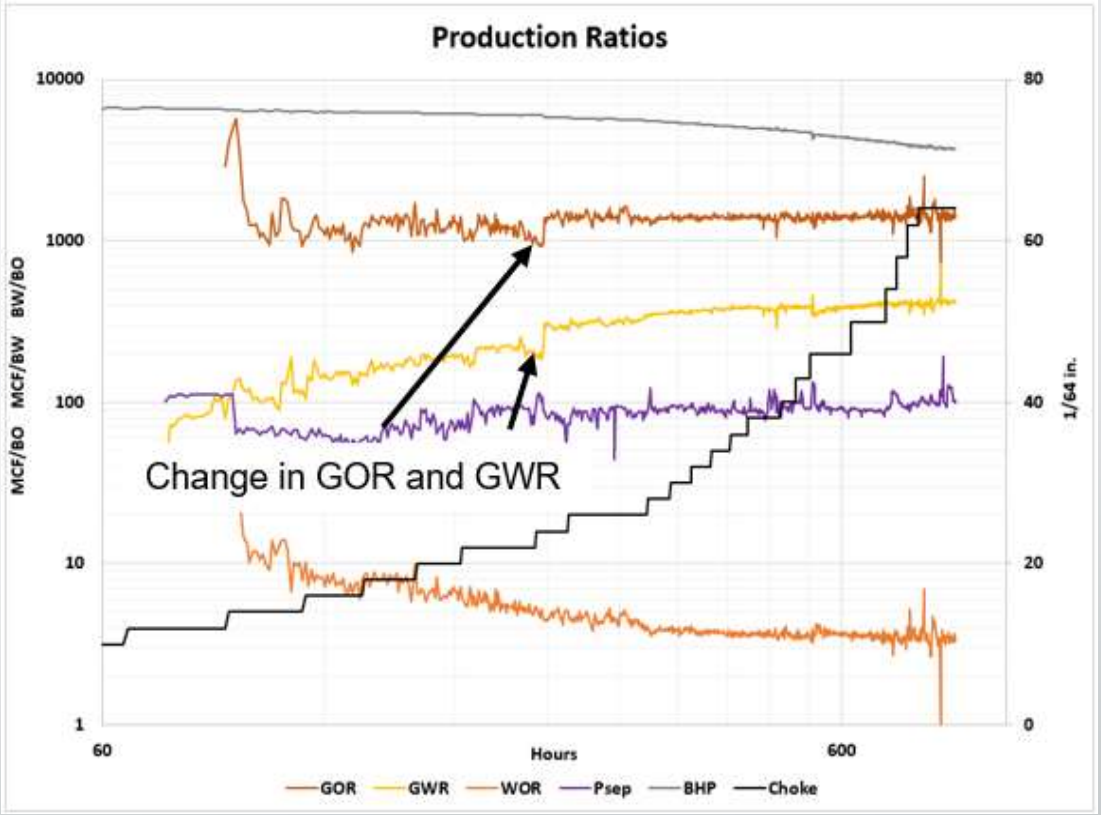
- Separation Efficiency – poor separation efficiency causes phase carry over and distorts measurements. Caused by undersized separators, emulsions, foam, operator error, insufficient internals, and separator control
- Oil Shrinkage – effects tanks straps and level sensors the most. Coriolis at separator conditions effected the least. 15-20% difference between Coriolis and tanks straps
- Measurement Timing - causes noise in the data due to difference in when measurements are taken every hour

Case Study 1: Measurement Error Identification

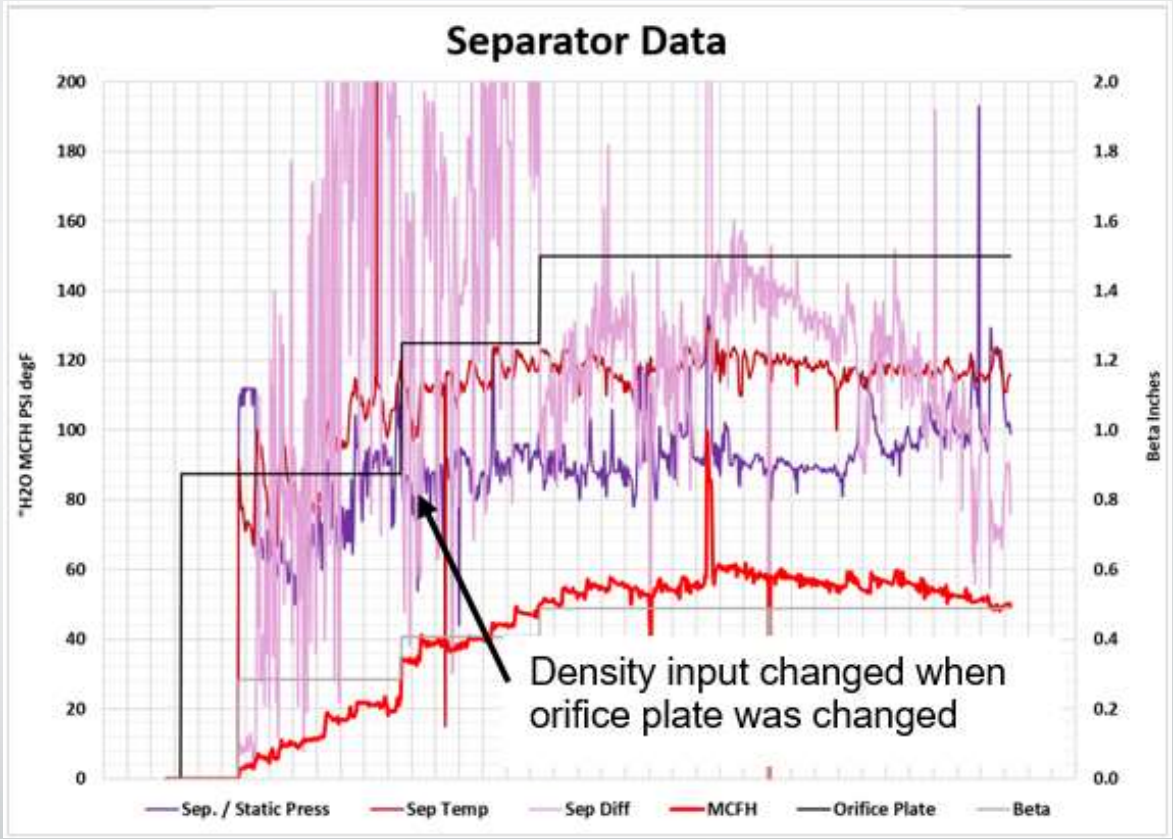
- Recommended dashboard plots used to identify gas rate measurement error
- Quick 200 psi drop at the same time gas rate and water rate increase but oil rate doesn't seem to change
- Check PR plot for which phase could have measurement error



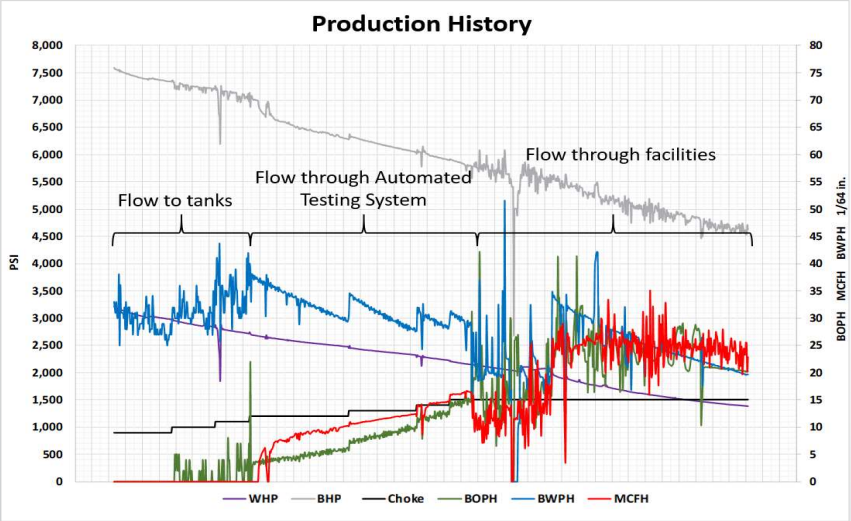
- GOR and GWR increase quickly at the same time gas rate increases on the production history
- Common phase between GOR and GWR is gas indicating possible gas rate measurement error
- Check separator data plot for possible causes to change in gas rate

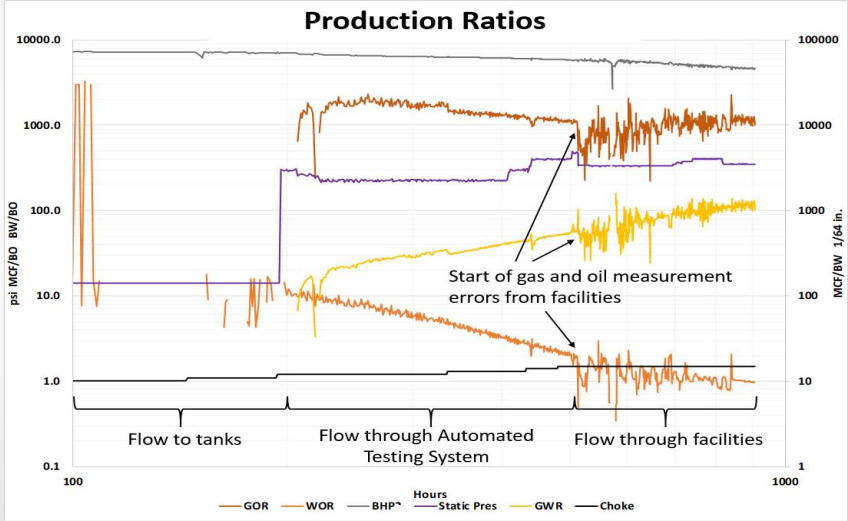


- Orifice plate changed and gas rate increased at same time
- Orifice plate change should not change gas rate
- Discussion with field operators found the density input on gas rate calculation had also been changed at the same time



Case Study 2: Data Quality Effects on Well Performance Evaluations

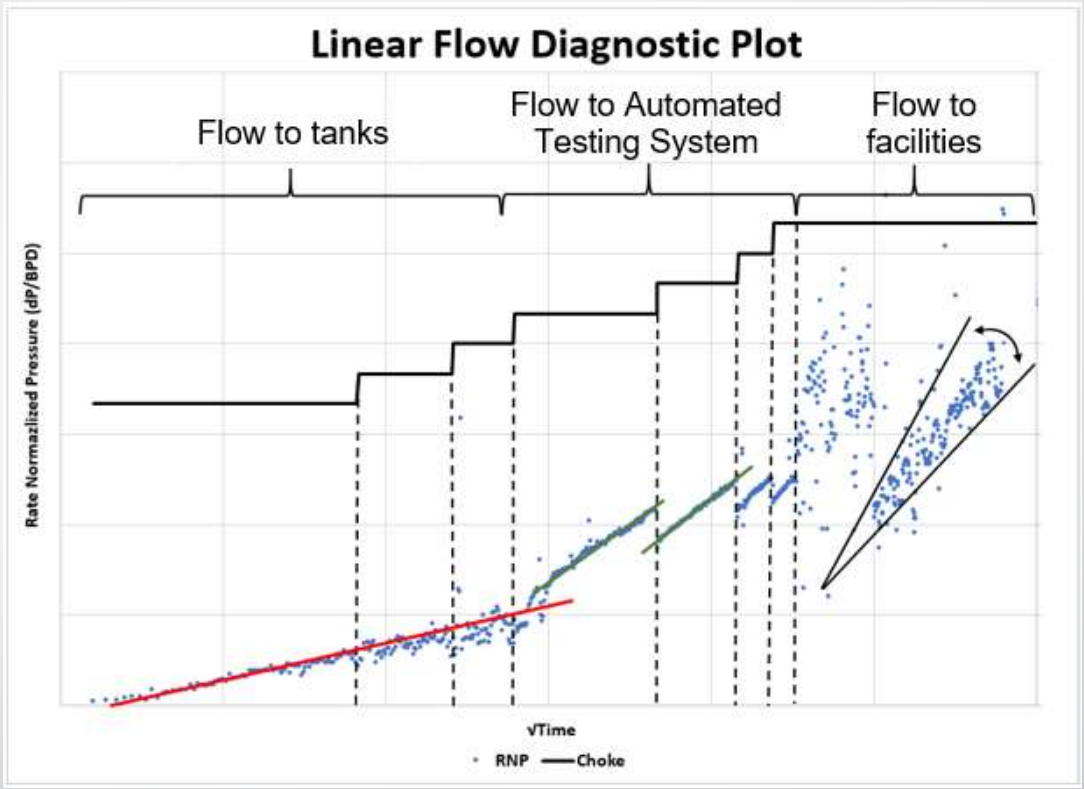




- Flow to tanks using tank straps is very noisy
- Flow through automated testing system very smooth
- Flow to facilities using turbine meters and orifice plate is very noisy

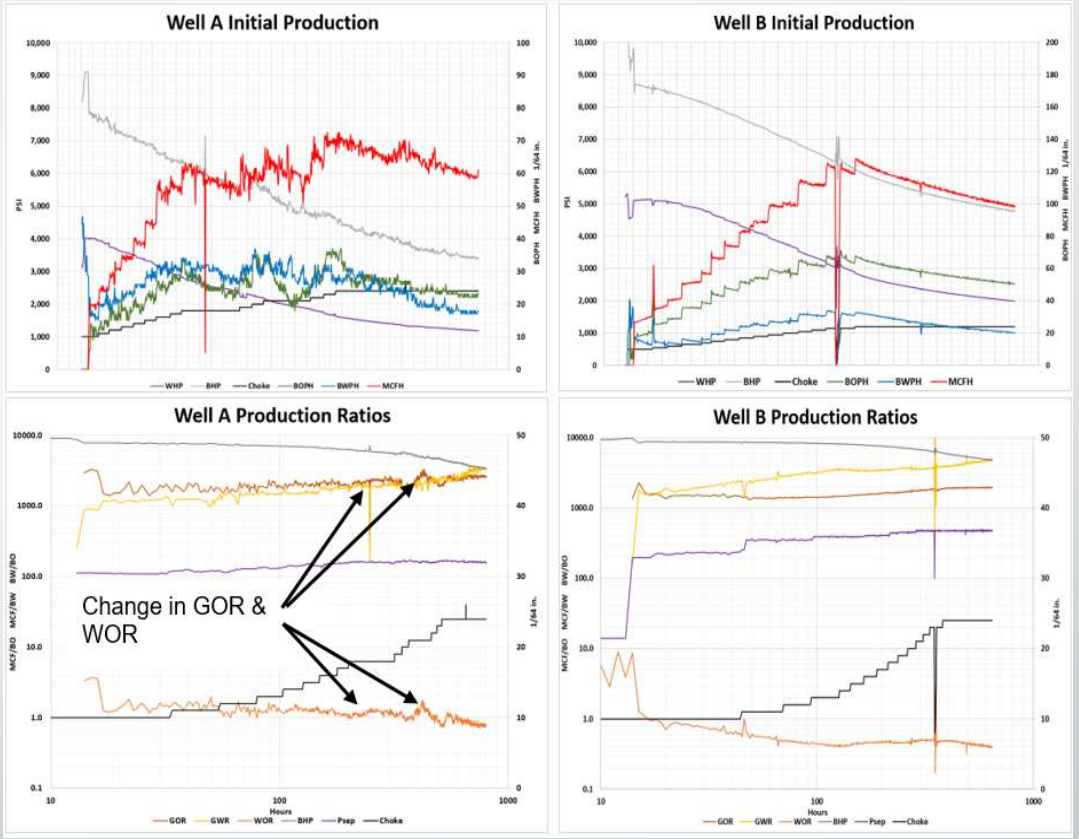
Well Performance Evaluation

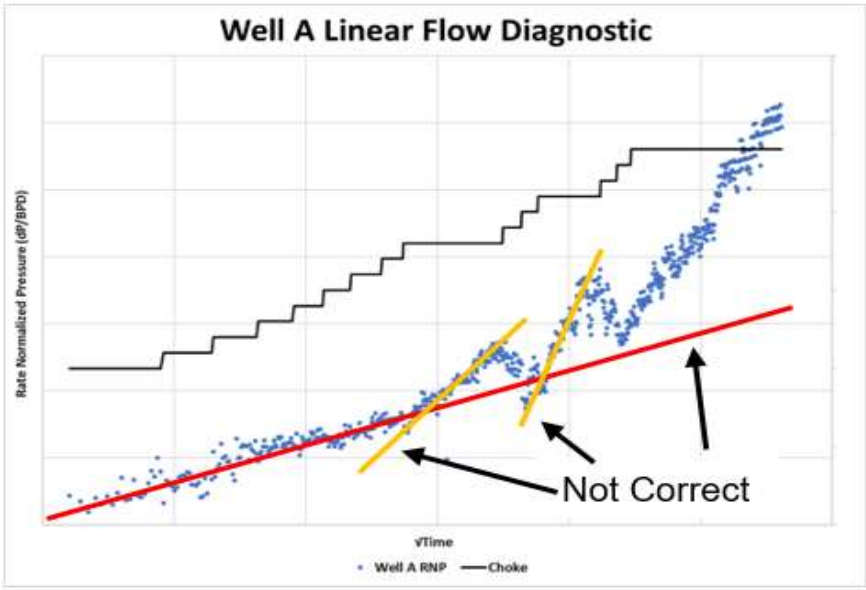
- No apparent change in slope when choke is changed while flowing to tanks
- Clear changes in trend seen while flowing to automated testing system
- Can’t identify straight line trend when flowing to facilities

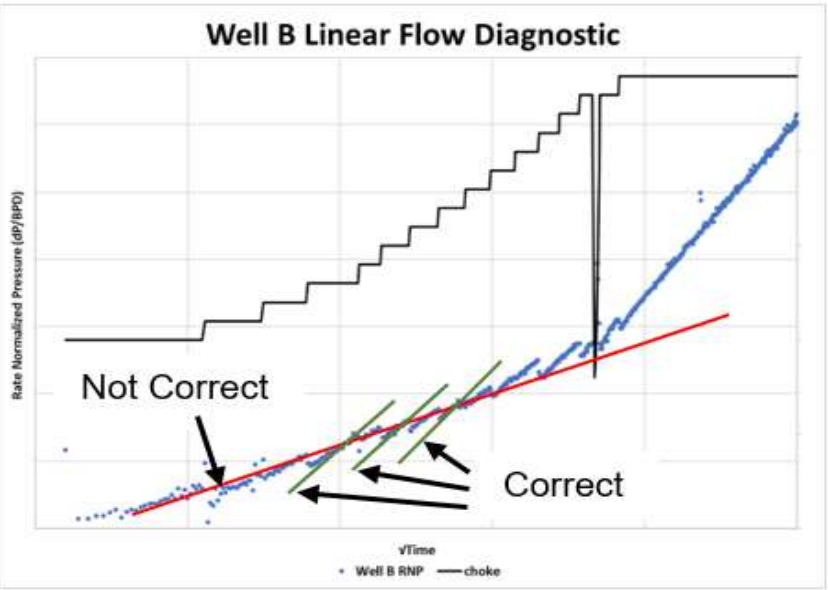


Case Study 3: Data Quality Effects on Draw Down Optimization

- Two wells close to each other with similar completion designs flowed back at the same time
- Well A has poor quality data from standard separator
- Well B has high quality data from fully automated testing package



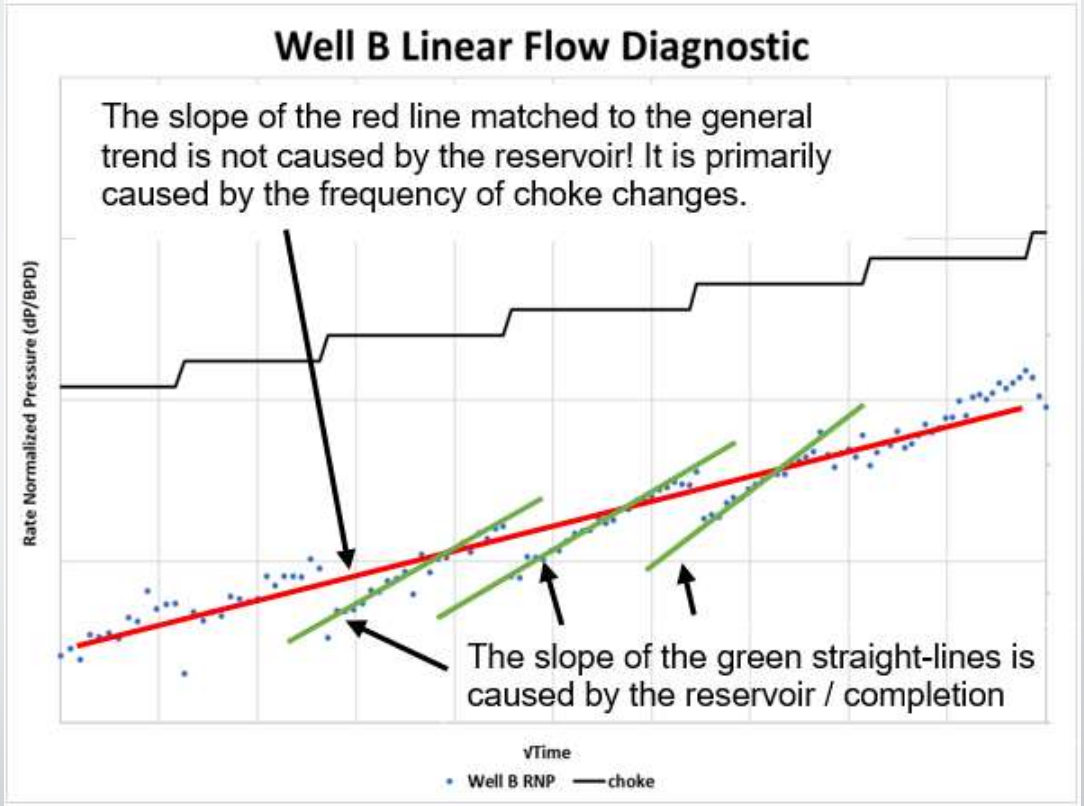




- Straight line trend on Well A linear flow diagnostic and changes in the trend are caused by poor quality data
- Clear changes in slope seen on Well B linear flow diagnostic plot each time the choke is changed

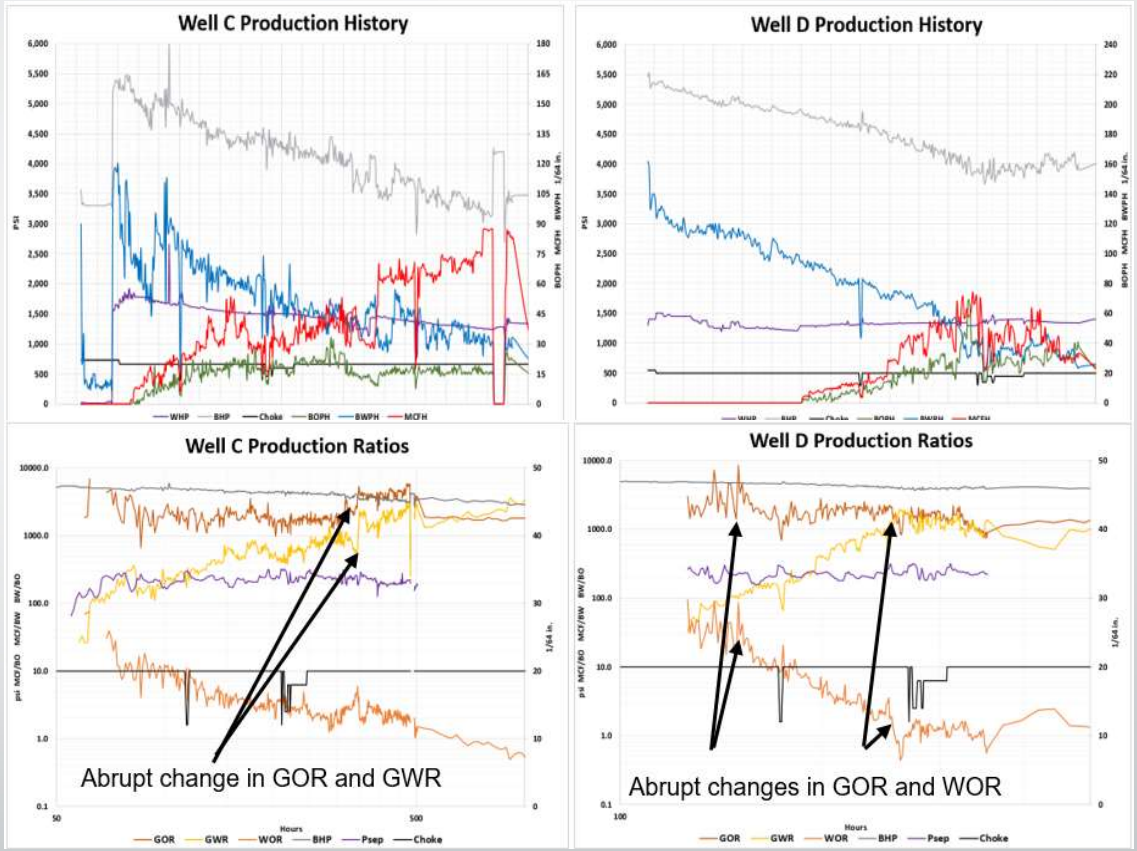
Expanded Plot of Well B Linear Flow Diagnostic

- Straight line trend in red is mostly a function of the choke change frequency
- Reservoir responses clearly seen with each choke change
- Changes in slope of the data in between each choke change is indicative of changes in well performance due to draw down



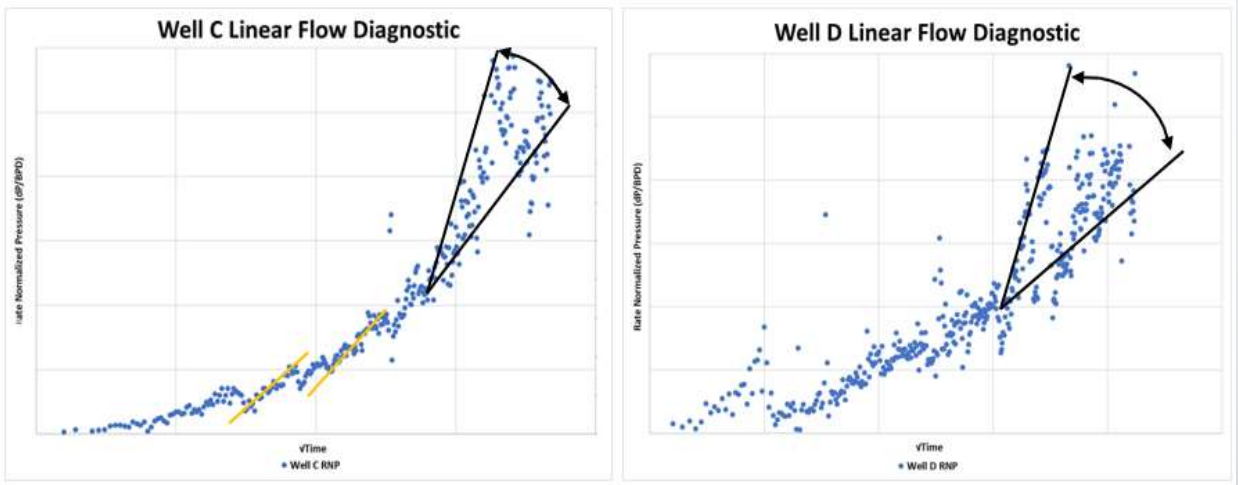
Case Study 4: Data Quality Effects on Completion Optimization

- Well C and D are close to each other in the same formation with different completion designs
- Data noise is apparent in production history and multiple rate measurement errors identified in PR plot



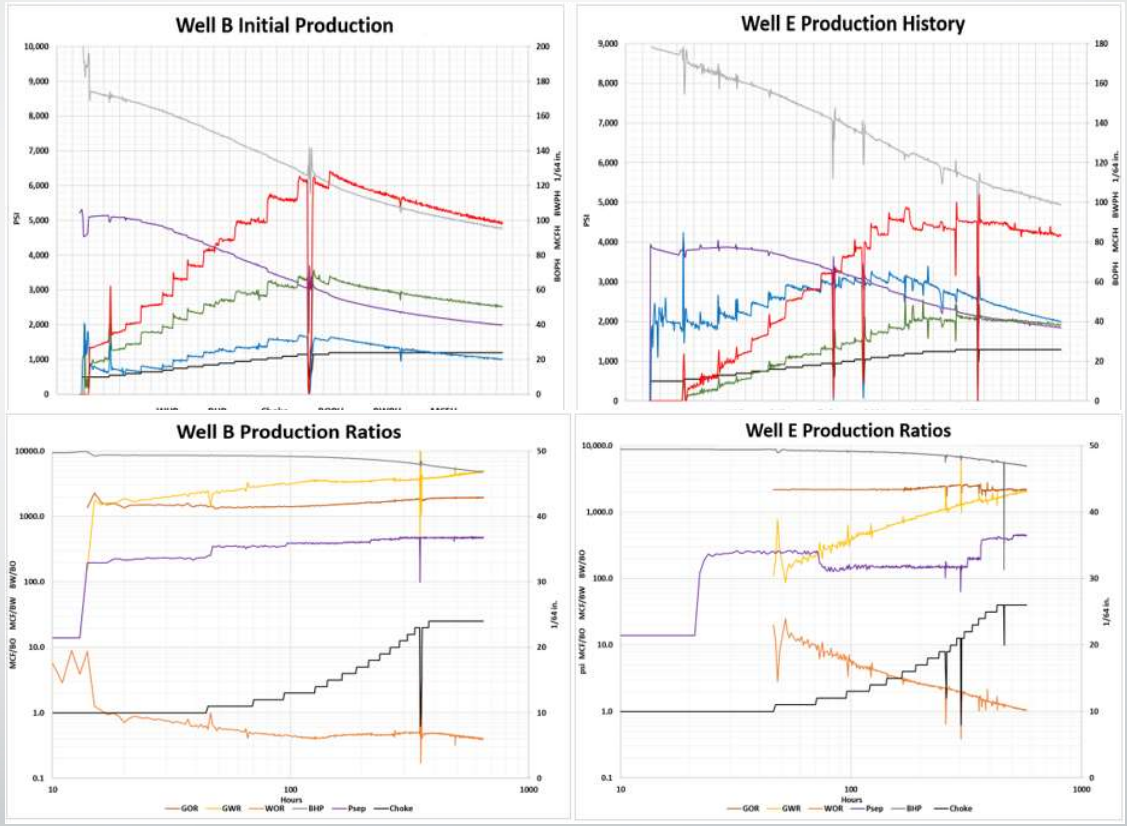
Difference in Well D relative to Well C

Major Completion Design Parameters	% Rel. Diff
Cluster Length	21%
Stage Length	21%
Proppant / Cluster	14%
Water / Cluster	22%
A√k Mid	-72%
A√k Smallest	-12%



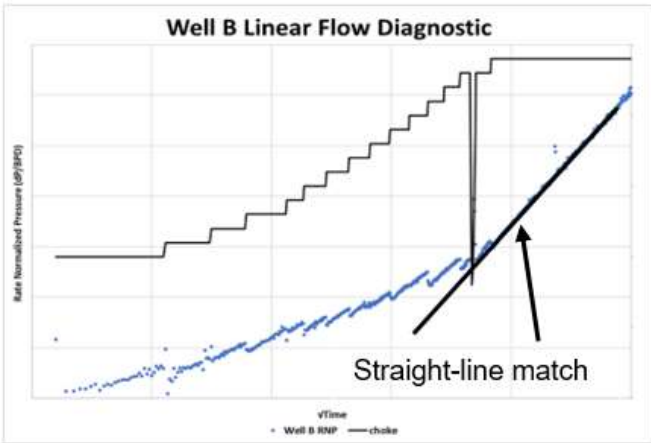
- Ambiguity from data quality makes it impossible to have high confidence in straight line match of the data
- Data quality is not sufficient to determine the benefits to changes in the completion design

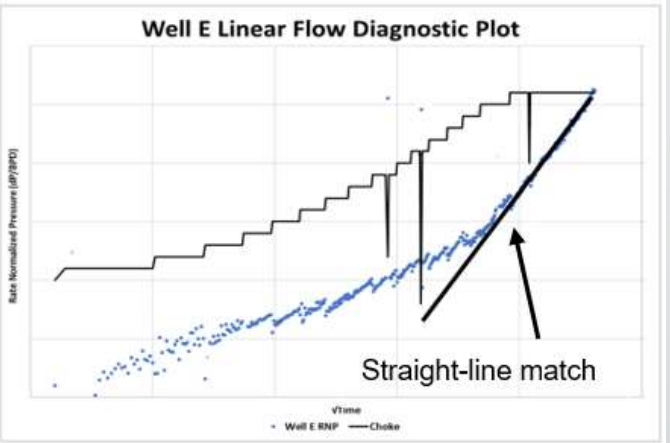
- Two wells close to each other in the same formation with different completion designs flowed back at the same time
- Wells flowed through fully automated testing system with very high measurement quality
- No noise in the data and no indication of measurement errors in PR plots



Difference in Well E relative to Well B

Major Completion Design Parameters	% Rel. Diff
Cluster Length	-15%
Stage Length	-16%
Proppant / Cluster	-8%
Proppant / ft.	9%
Water / Cluster	-10%
Water / ft.	6%
A√k	-19%

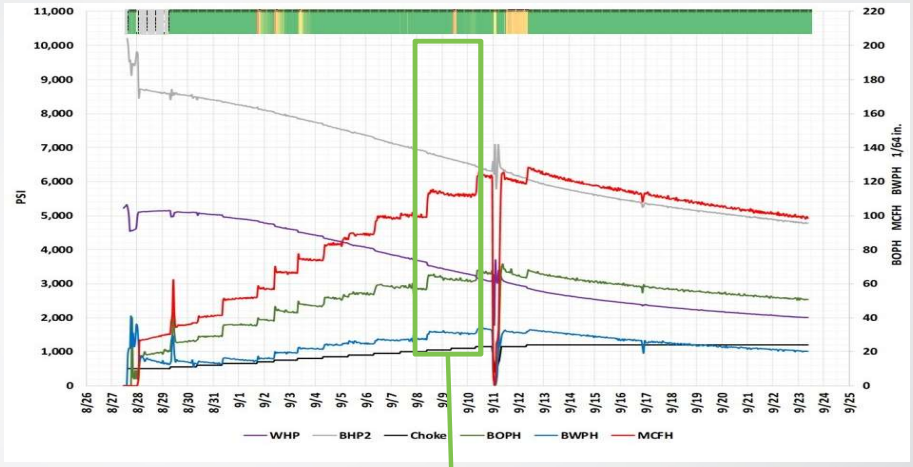


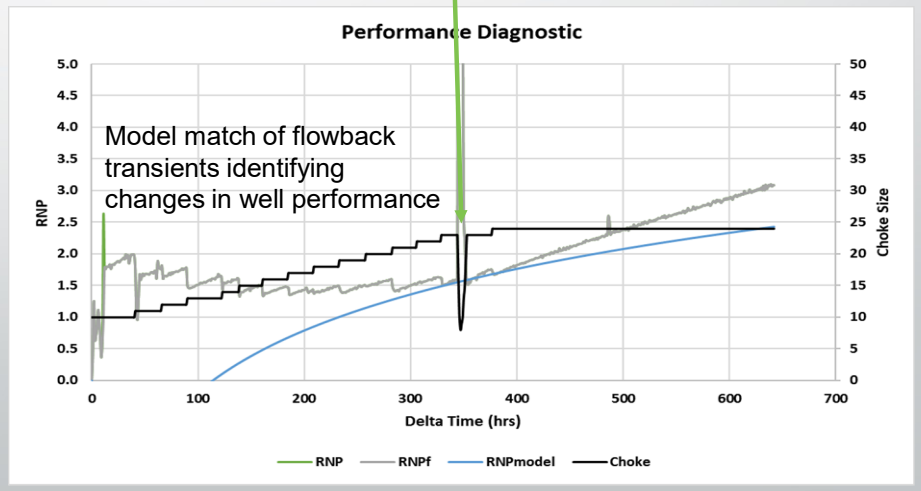


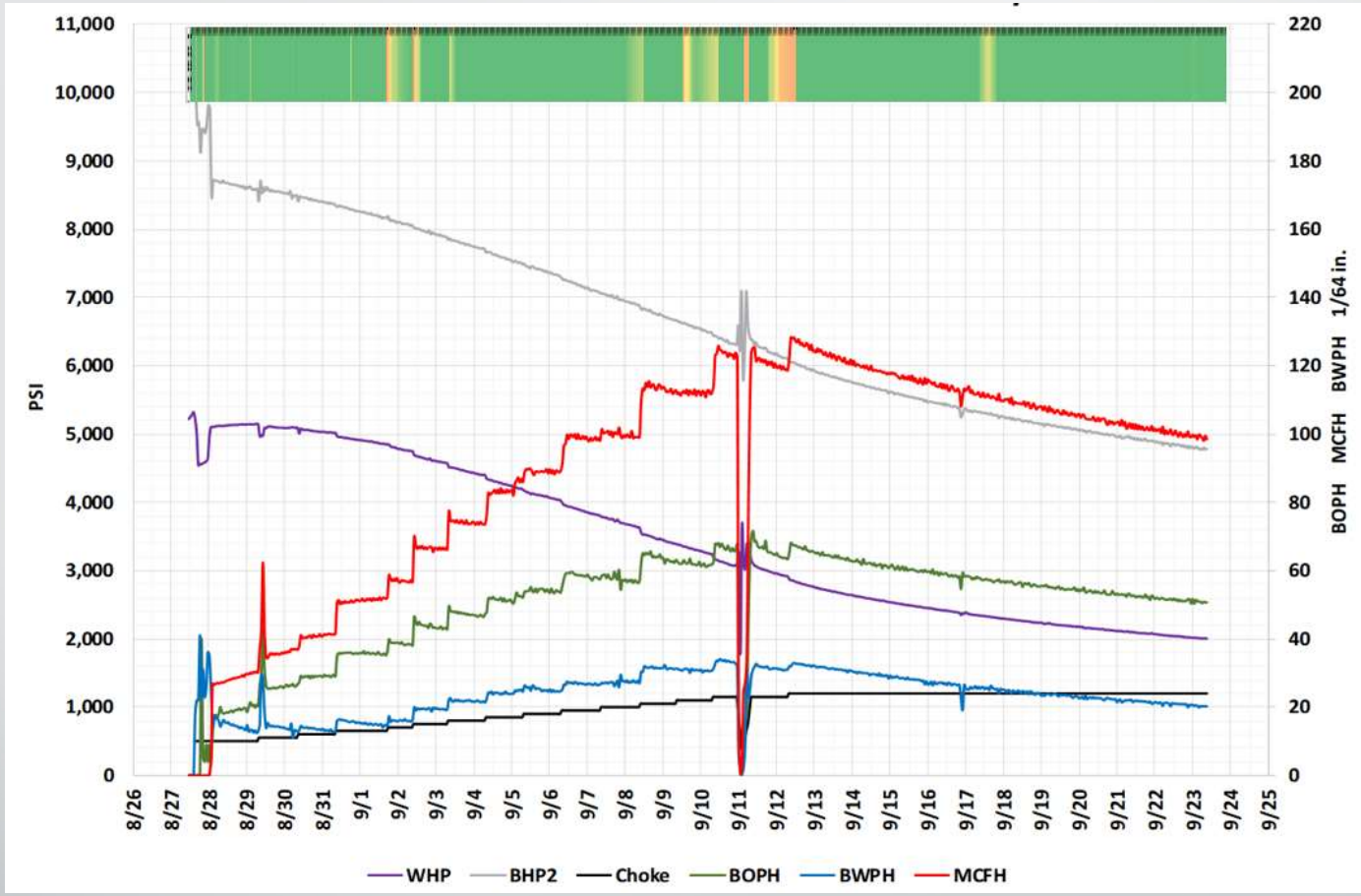
- High quality data makes it very easy to identify the straight line trend at the end of the initial production period with confidence and match the same straight line very time
- Well performance was accurately assessed and compared for optimization

Automated Performance Diagnostics “RAPD”

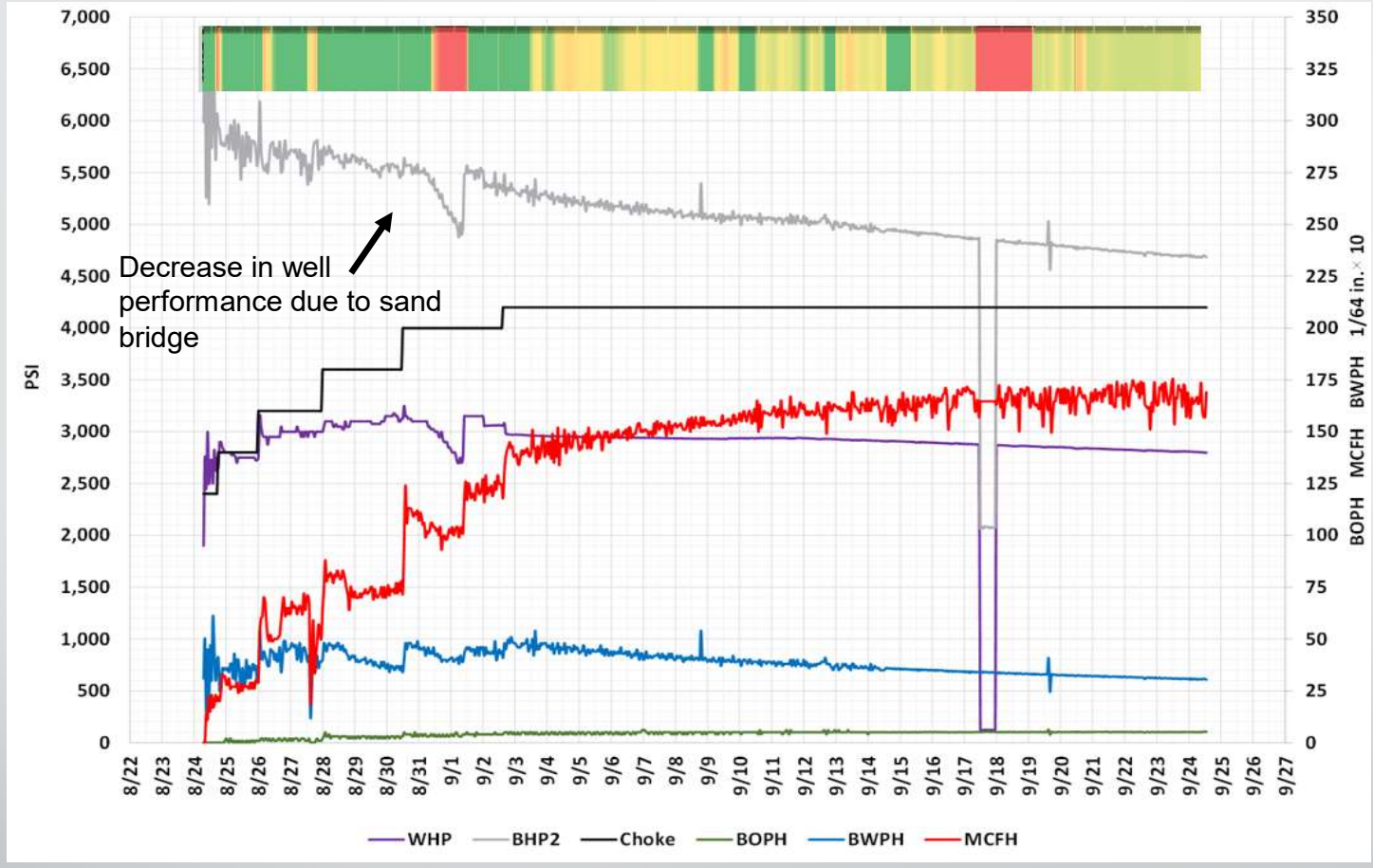
- Traditional RTA methods are not well suited for flowback analysis
- RAPD™ automatically analyzes well performance and provides real time feedback on well performance for draw down optimization
- Data quality can make it very difficult to see how performance is changing in real time



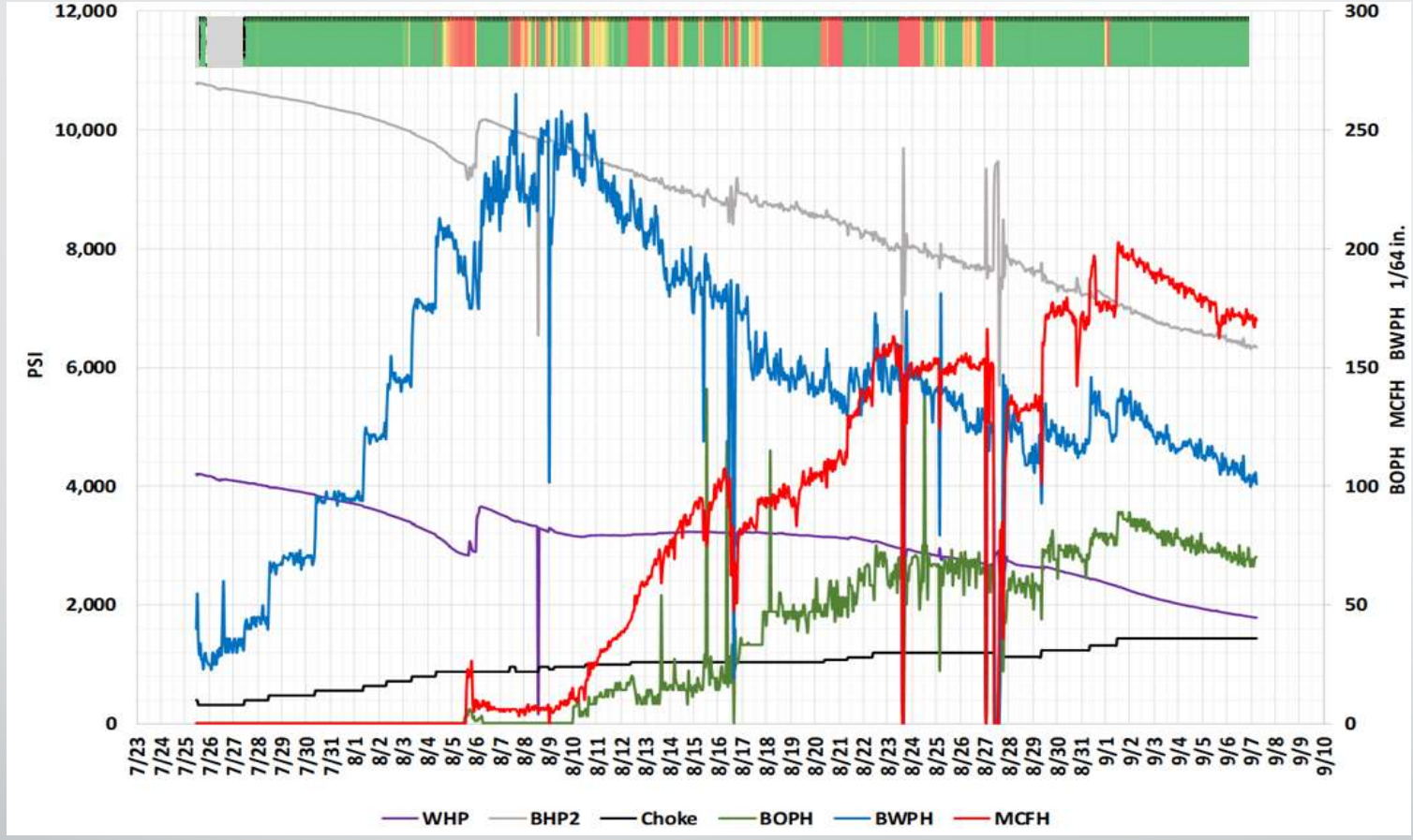




- RAPD with superior data quality
- Choke could have been increased faster

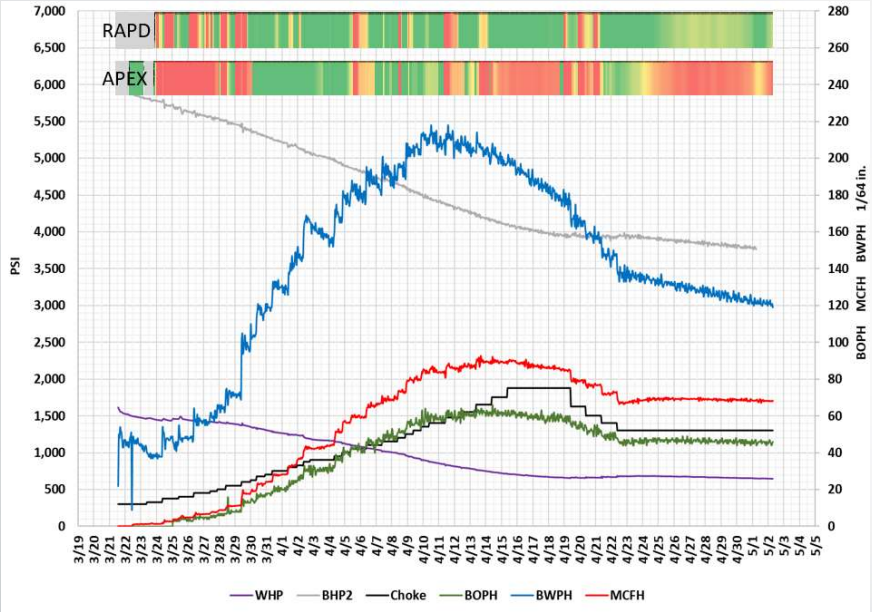


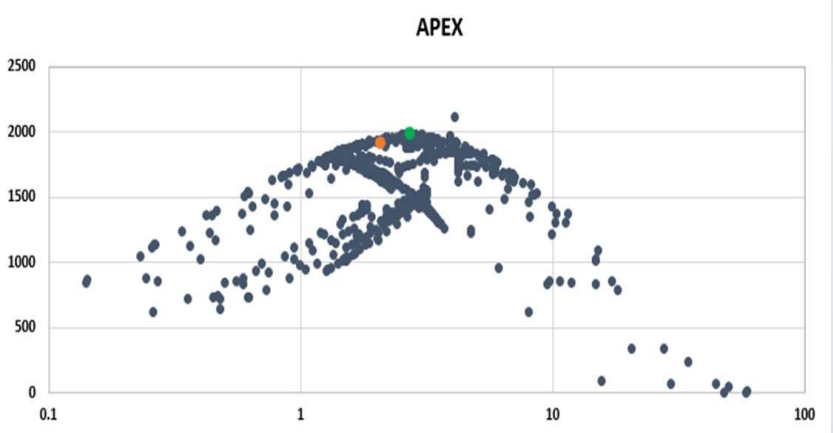
- RAPD indicating a performance loss due to sand bridging

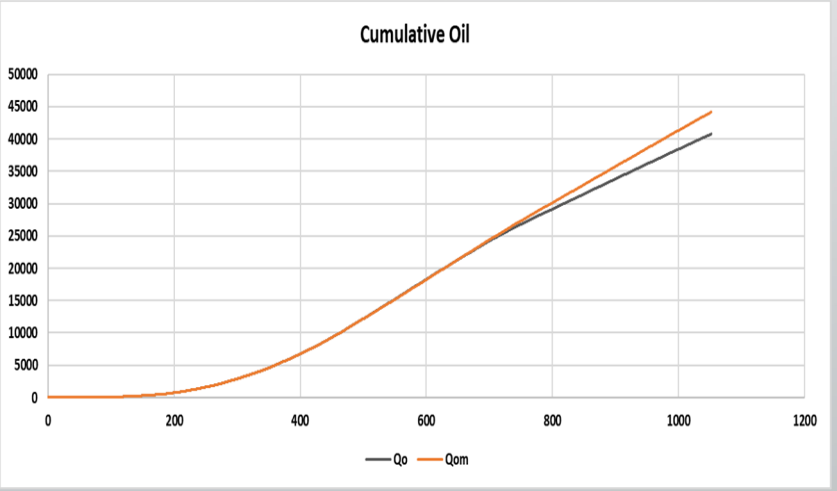


- RAPD with poor data quality and sand bridging
- Many indications of decreasing performance due to data quality

AUTOMATED PERFORMANCE MAXIMUM ("APEX")







- Automated Performance Maximum ("APEX") algorithm looks for the maximum performance seen in the test so far and models out the difference in cumulative volume since that point

Conclusions

- If the data is too noisy it is likely too poor to use confidently for an analysis of the initial production data
- A Coriolis meter operating at separator pressure is recommended for measuring oil rates
- Automated testing system is recommended that records readings at the exact same time from all the measurement devices
- Surface measurement QA/QC should always be performed during the initial production period
- It is recommended to utilize a separator that includes internal hardware that provides a higher degree of liquid / liquid and liquid / gas separation
- Real time draw down optimization and well performance evaluations can be completed using RAPD and APEX with sufficient data quality

Questions?