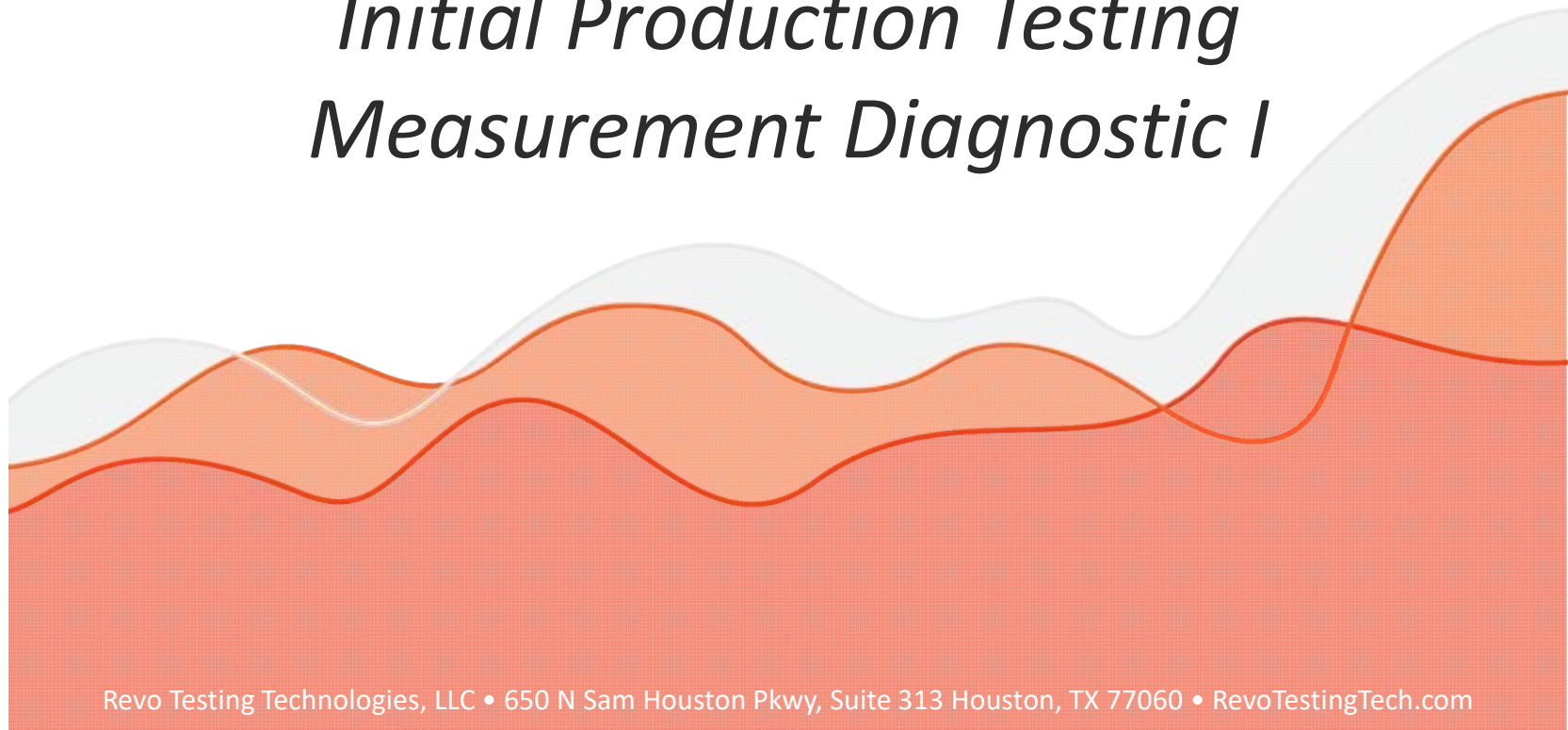




Initial Production Testing Measurement Diagnostic I



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Initial Production Testing: *Measurement Diagnostic I*

Flowing parameters such as rates and pressures seen at surface can tell us a great deal about reservoir and completion performance. However, quite often sub-optimal methods of data acquisition are used to acquire the data used for evaluating well performance. It is important for those responsible for data acquisition in the field to have a working knowledge of how to properly assess the quality of measurements (Refer to: URTeC 2515 “An Examination of the Effects of Surface Data Acquisition Methods on Well Performance Evaluation and Completion Optimization” for a more detailed discussion on how measurements effect well performance)

The Revo iQ™ software allows for automated data acquisition and on demand visualization of all the primary parameters of interest collected during production testing. This enables testing teams to quickly identify measurement errors, improve test data quality, and increase confidence in assessing well performance

The RPM software has 5 primary sections for data visualization:

- Section 1 – Revo iQ™ Key Performance Indicators
- Section 2 – Production History Plot
- Section 3 – Production Ratios Plot
- Section 4 – Separator Data Plot
- Section 5 – Fluid Sample Data Plot



Revo iQ™ Software



- Revo iQ™ software is used by customers and the Revo Well Test Operations Team
- Revo iQ™ is a valuable tool to help visualize data trends, assess well performance and quickly identify problems



Revo iQ™ Key Performance Indicators

iQ Gauges

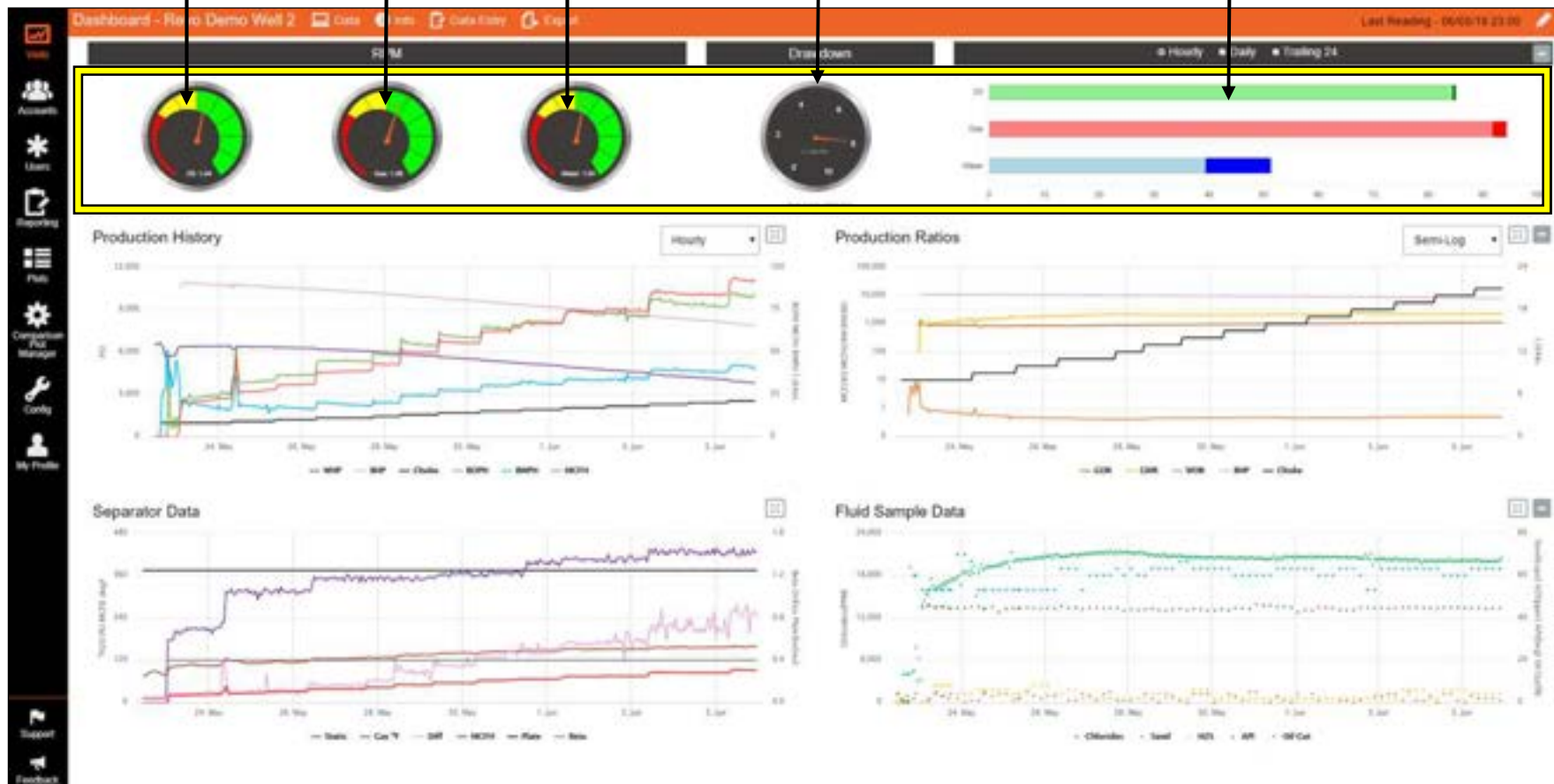
Quick Visual of how efficiently the well is producing each phase. Green = Good, Yellow = Ok, Red = Not Good

Draw Down Gauge

Displays the current BHP and amount of draw down applied on the well so far

Rate Comparison

Current rate compared to max rate. Hover over the dark color with your mouse to see max rate so far in the test and over the lighter color to see current rate



Revo iQ™ Production History Plot

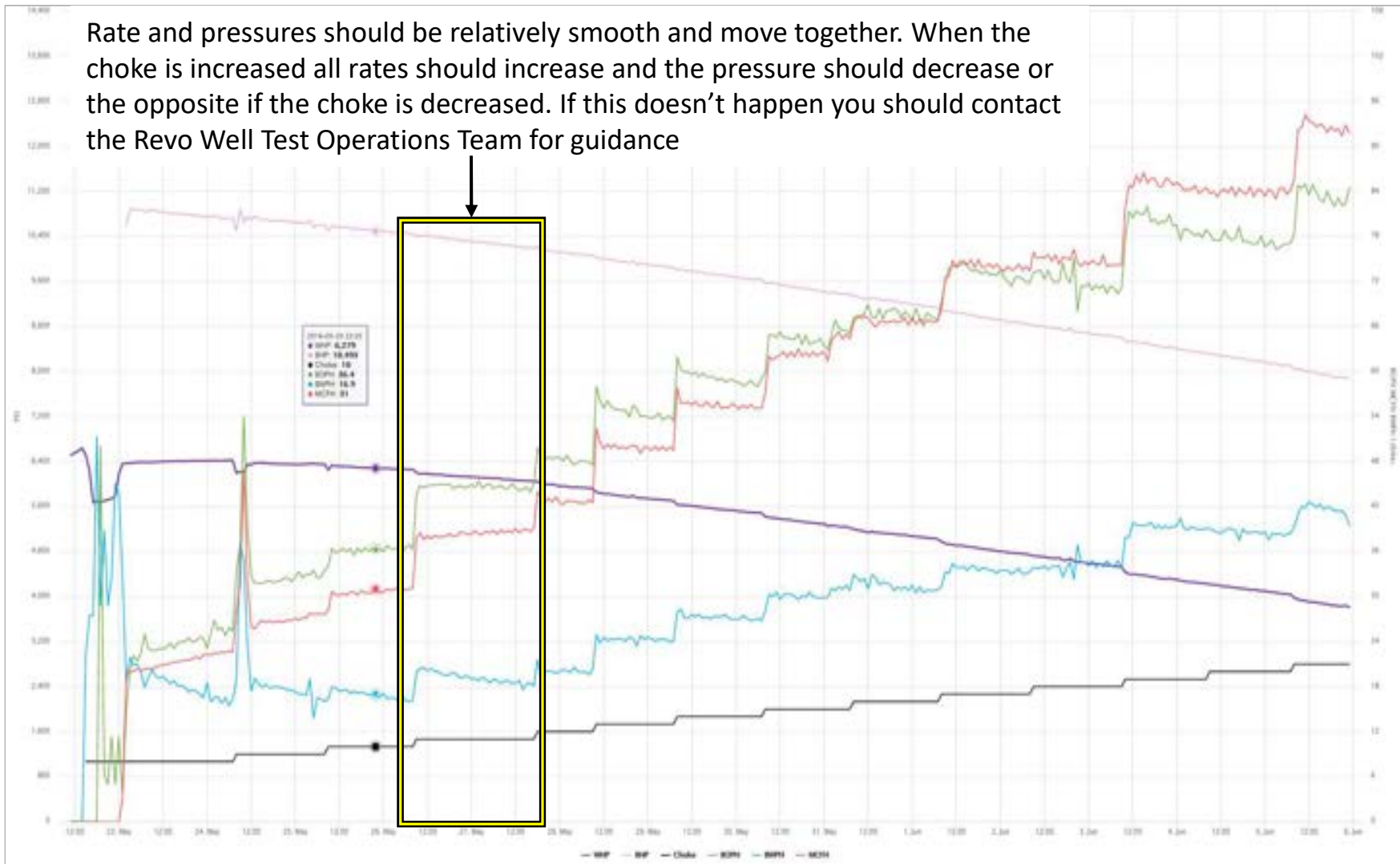


- The Production History Plot in the upper left of the dashboard shows rates and pressure trends that can be displayed in hourly, daily or trailing 24 when selected from drop down at upper right of the plot
- It is challenging to determine rate measurement errors or reservoir responses from this plot alone so we have to use the other plots in the Revo iQ™ Software



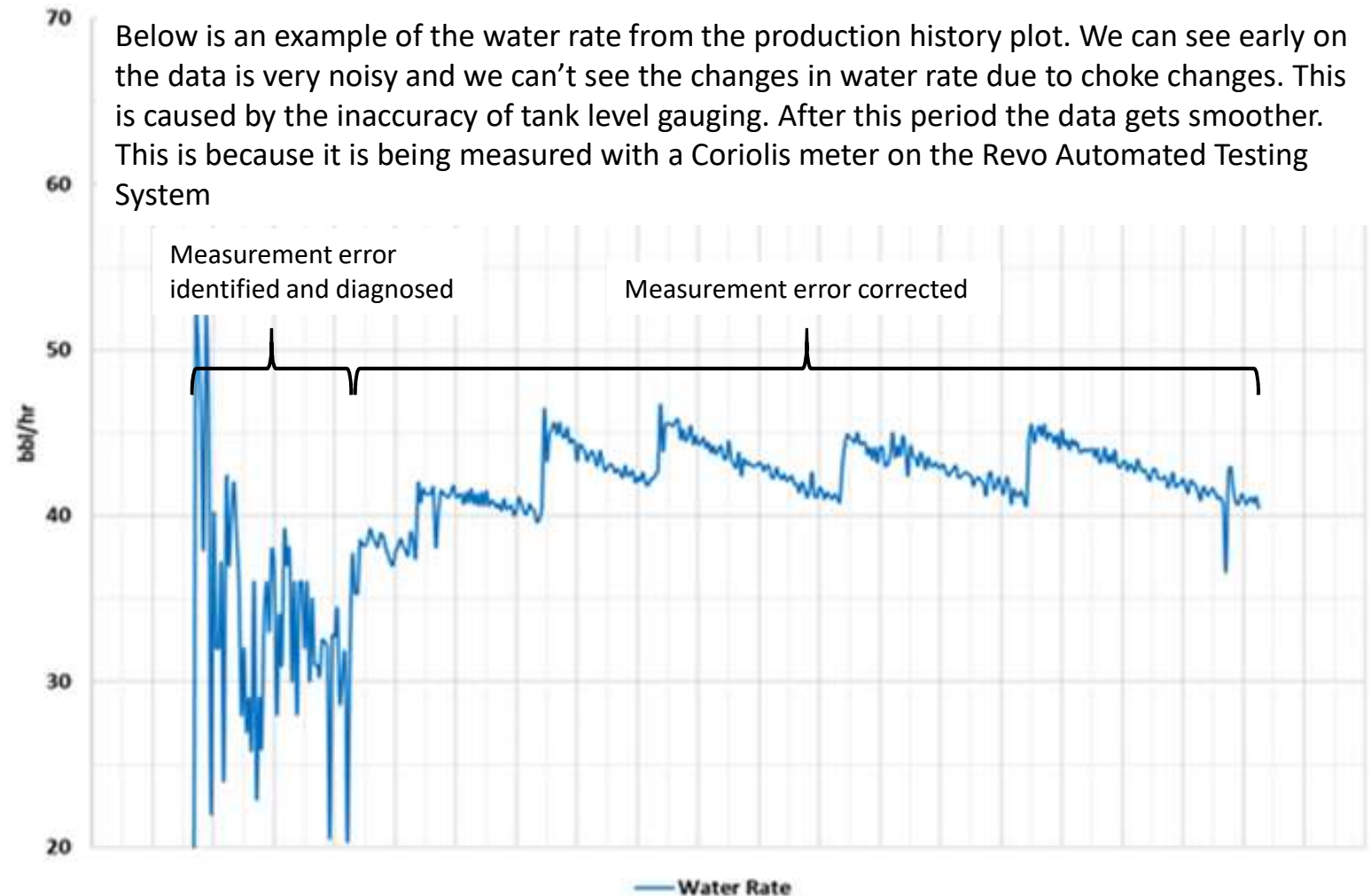
Revo iQ™ Production History Plot

Rate and pressures should be relatively smooth and move together. When the choke is increased all rates should increase and the pressure should decrease or the opposite if the choke is decreased. If this doesn't happen you should contact the Revo Well Test Operations Team for guidance



Production History Plot

Measurement Error Identification



Revo iQ™ Production History Plot



- The Production Ratios plot located in the upper right of the dashboard is **the most important plot for identifying rate measurement errors!**
- Production ratio trends can be displayed in log-log or semi-log when selected from the drop down list at the upper right of the plot
- Generally we look at production ratios on log-log scale to more easily identify trends



Definitions

Saturation Pressure (P_{sat}), AKA Bubble Point Pressure (Oil Wells) AKA Dew Point Pressure (Condensate/Wet Gas wells)

- Bubble Point (Oil wells)
 - Pressure that gas starts to bubble out of the oil
 - Similar to opening a cool refreshing Lone Star beer. There is carbon dioxide gas dissolved in the beer. When you crack it open and release the wonderful nectar of mother Texas the pressure inside decreases and gas starts to bubble out
- Dew Point (Condensate/Wet Gas wells)
 - Pressure that liquid condenses out of gas
 - Similar to the moisture that collects on the outside of a cool refreshing Lone Star beer on a hot humid day. When the water vapor in the humid air touches the side of the can it condenses out of the air and turns into water droplets on the side of the can

Separator Back Pressure (P_{sep}), AKA Separator Static Pressure

- Pressure inside the separator
- Changes in separator back pressure can change the measured surface GOR

Bottom Hole Pressure (BHP)

- Revo Engineering Team uses the water, oil, and gas rate combined with surface pressure to calculate the bottom hole pressure
- This is then used in the performance diagnostics, although some wells have bottom hole pressure gauges
- When a bottom hole gauge is used we label it “BHGP” for Bottom Hole Gauge Pressure



Definitions

$$\text{Gas-Oil Ratio (GOR)} = \frac{\text{GasRate}}{\text{OilRate}}$$

- When bottom hole pressure (BHP) is greater than the Saturation pressure (Psat) of the reservoir the GOR at surface should be nearly constant
- Most wells have an expected GOR determined from what has been seen from other wells in the area. If the GOR measured at surface is significantly different than what is expected this can be an indication of a measurement error either in the gas rate or the oil rate
- Deviations from the straight line trend can be due to several reasons
 - Bottom hole pressure (BHP) is lower than saturation pressure (BHP < Psat)
 - Changes in separator back pressure (Psep)
 - Measurement error

$$\text{Gas-Water Ratio} = \frac{\text{GasRate}}{\text{WaterRate}}$$

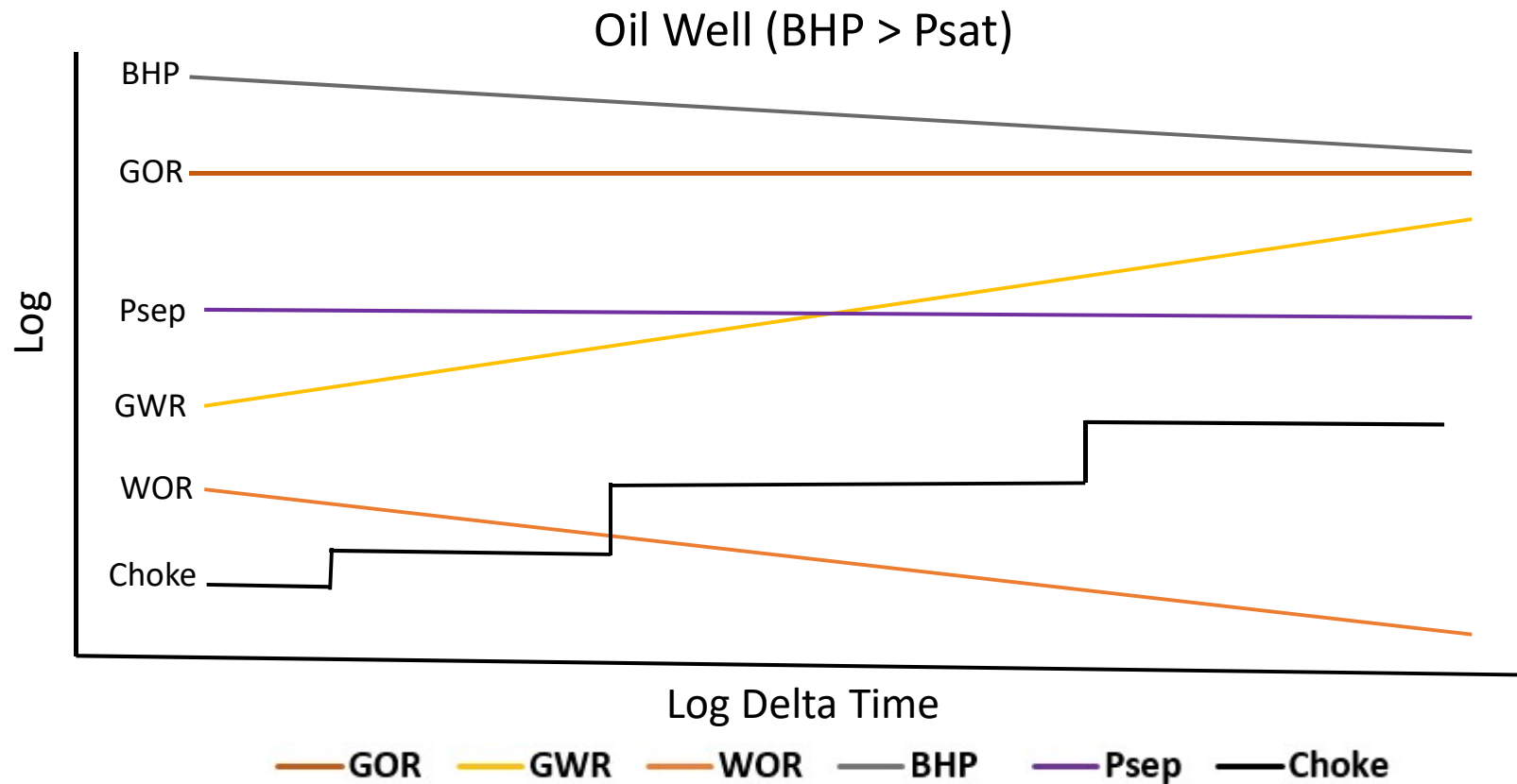
- Gradually increases for the duration of the flowback and can become constant later on
- Can increase faster when BHP < Psat
- Quick changes are likely due to measurement error and/or changes in Psep
- Decreasing trend likely due to fluid imbibition or water influx from offsets or other zone

$$\text{Water-Oil Ratio} = \frac{\text{WaterRate}}{\text{OilRate}}$$

- Gradually decreases for duration of flowback and can become constant later on
- Quick changes are likely due to measurement error and/or changes in Psep
- Increasing trend can be from fluid imbibition or water influx from offsets or other zone



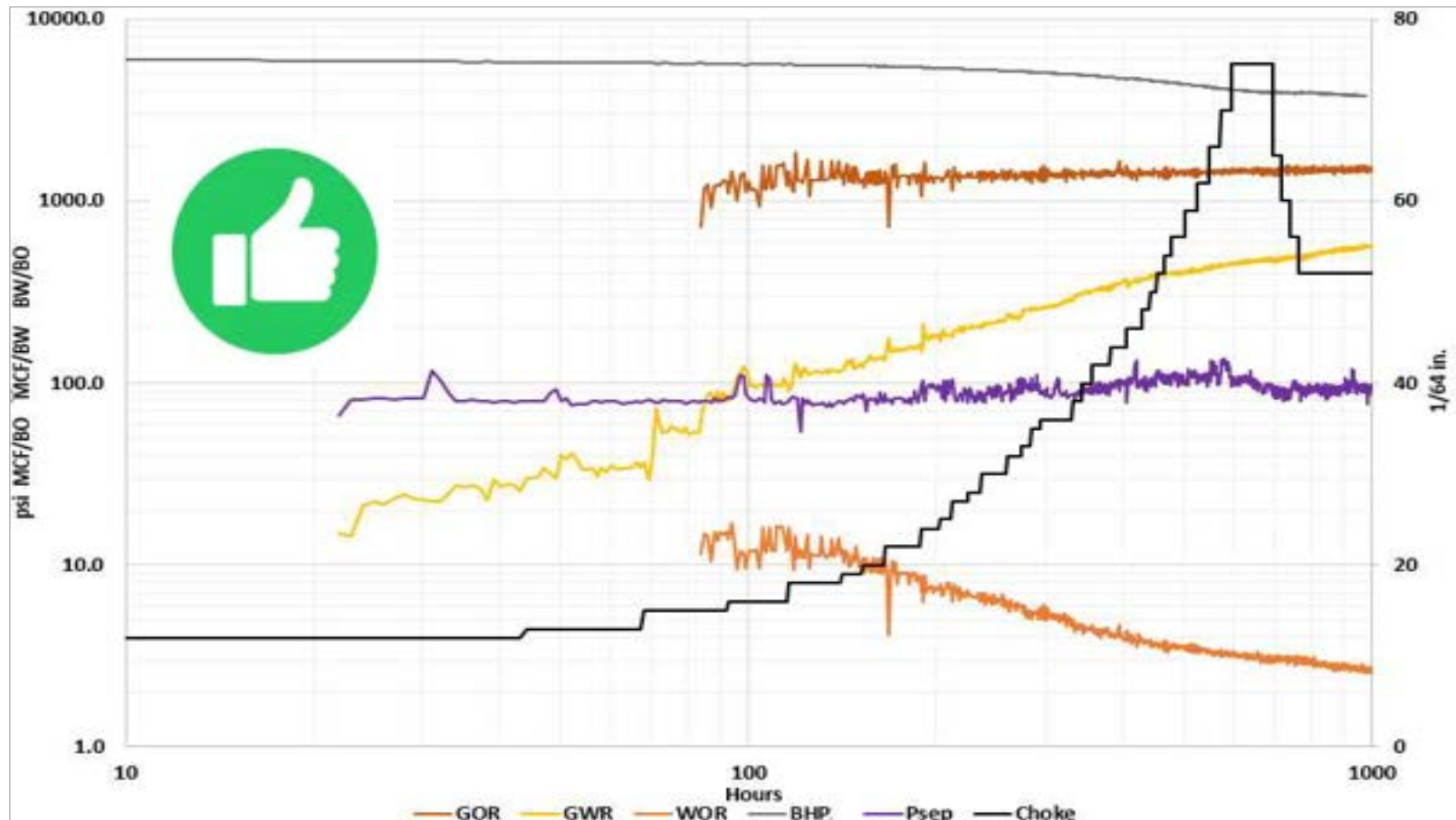
Production Ratio Trends



- The data should be smooth. Fluctuations / noise are usually rate measurement errors
- BHP should be gradually decreasing
- GOR should be constant
- Psep should be kept constant when possible
- GWR should be gradually increasing and sometimes eventually become constant
- WOR should be gradually decreasing and sometimes eventually become constant



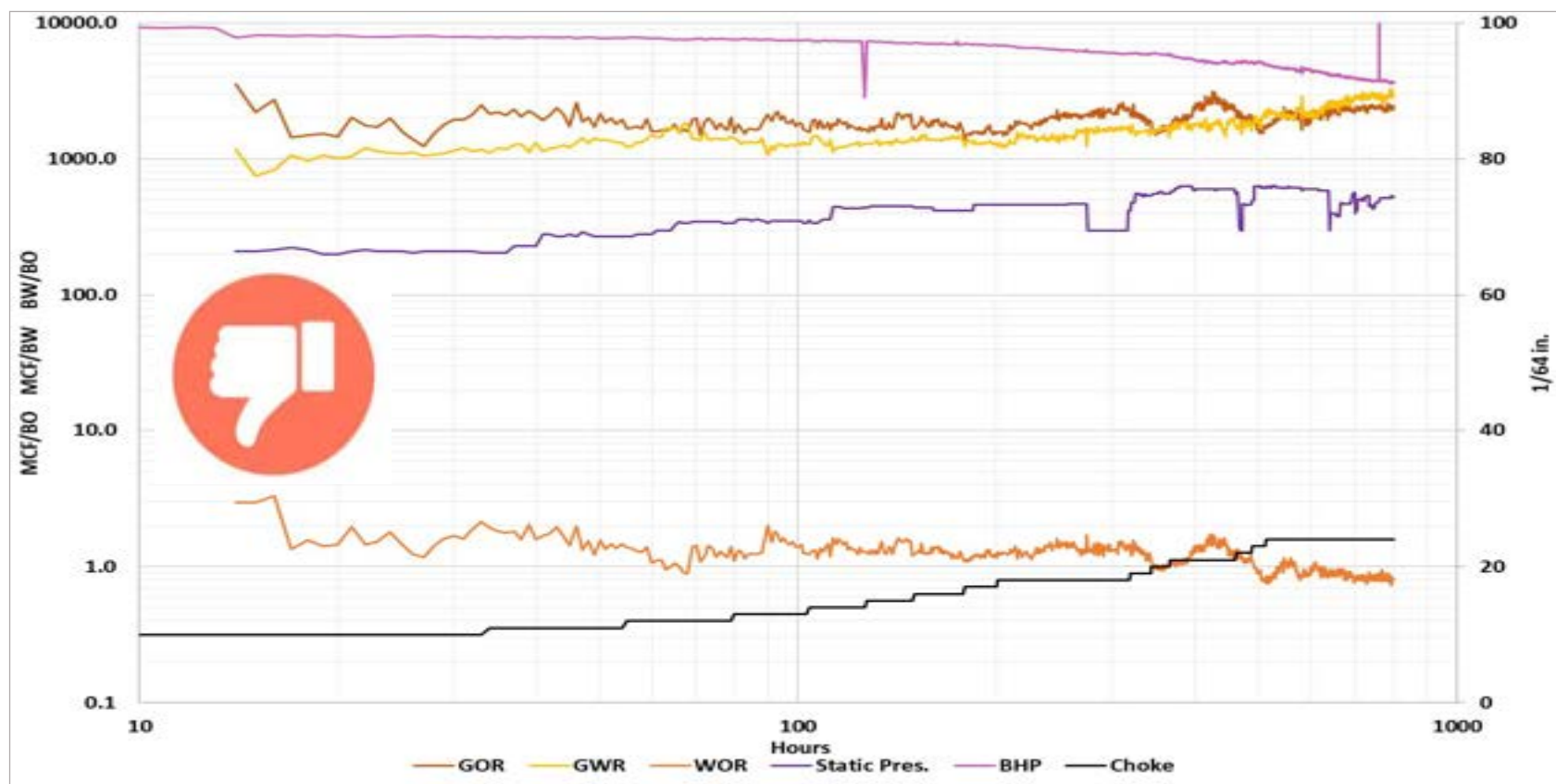
Production Ratio Trends – Field Example



- Data is generally smooth with some small fluctuations in the data but not very much noise
- BHP is gradually decreasing
- GOR is generally constant without much noise
- Psep is nearly constant for most of the test
- GWR is gradually increasing and WOR is gradually decreasing



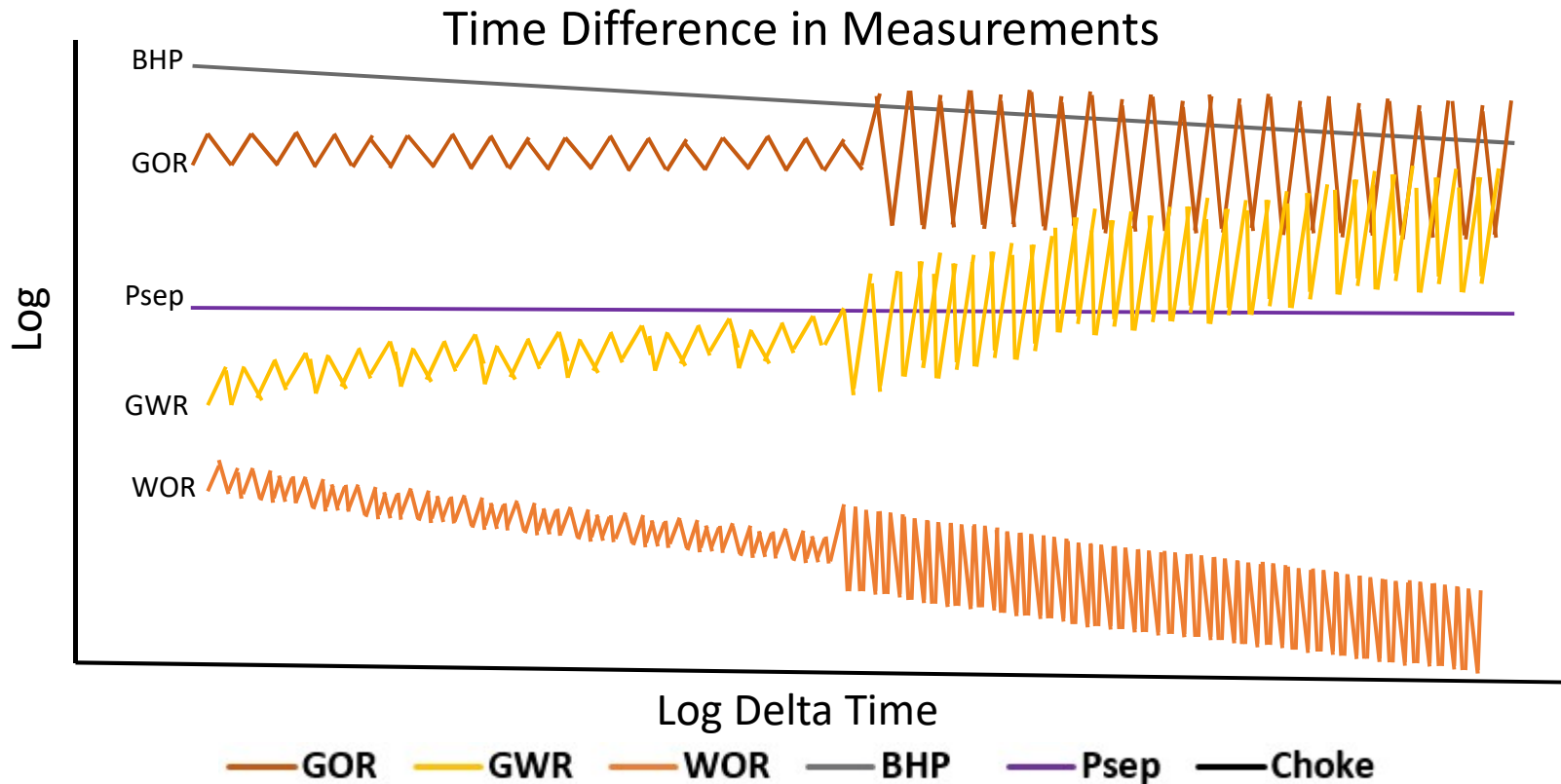
Production Ratio Trends – Field Example



- Data is not very smooth and looks noisy
- BHP is gradually decreasing but has some noise in it
- Psep increased and decreased several hundred psi in short periods
- GOR has many fluctuation
- GWR gradually increasing but noisy
- WOR fluctuating similar to GOR indicating possible oil rate measurement errors
- Measurement errors are masking the reservoir response



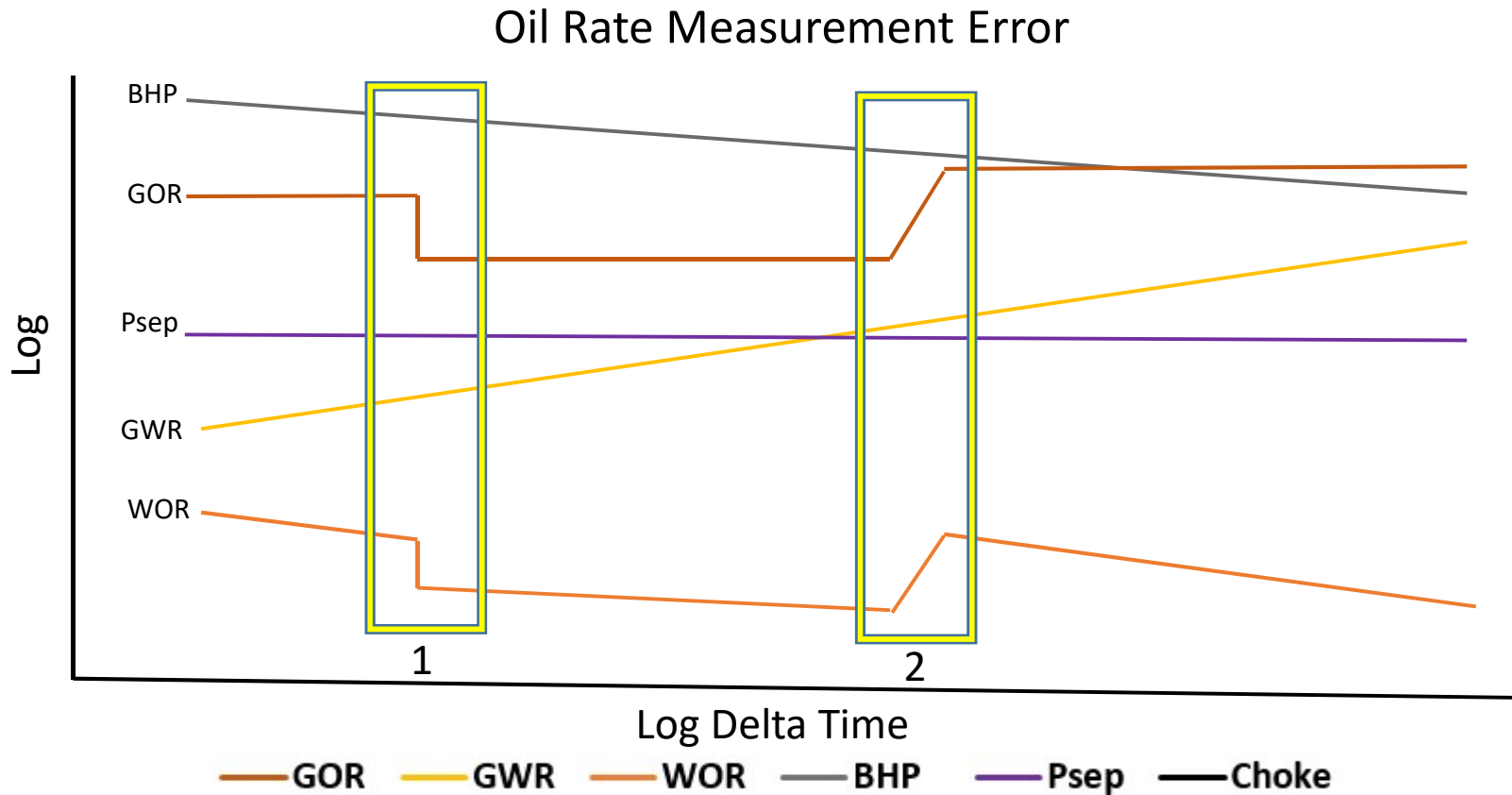
Diagnosing Measurement Errors



- When there is noise in the data caused by rapid changes in GOR, GWR and / or WOR this could be due to the time difference in when measurements are taken
- The higher the magnitude of fluctuations the longer the time between when readings are being taken
- Example: If a well is flowing 60 BWPH and the reading is taken 10 minutes early it will be recorded as 50 BWPH for that hour. If the reading is taken on the hour the next hour it will be recorded as 70 BWPH
- This type of error can be fixed by using an automated systems that records all the measurements at the same time every hour



Diagnosing Measurement Errors

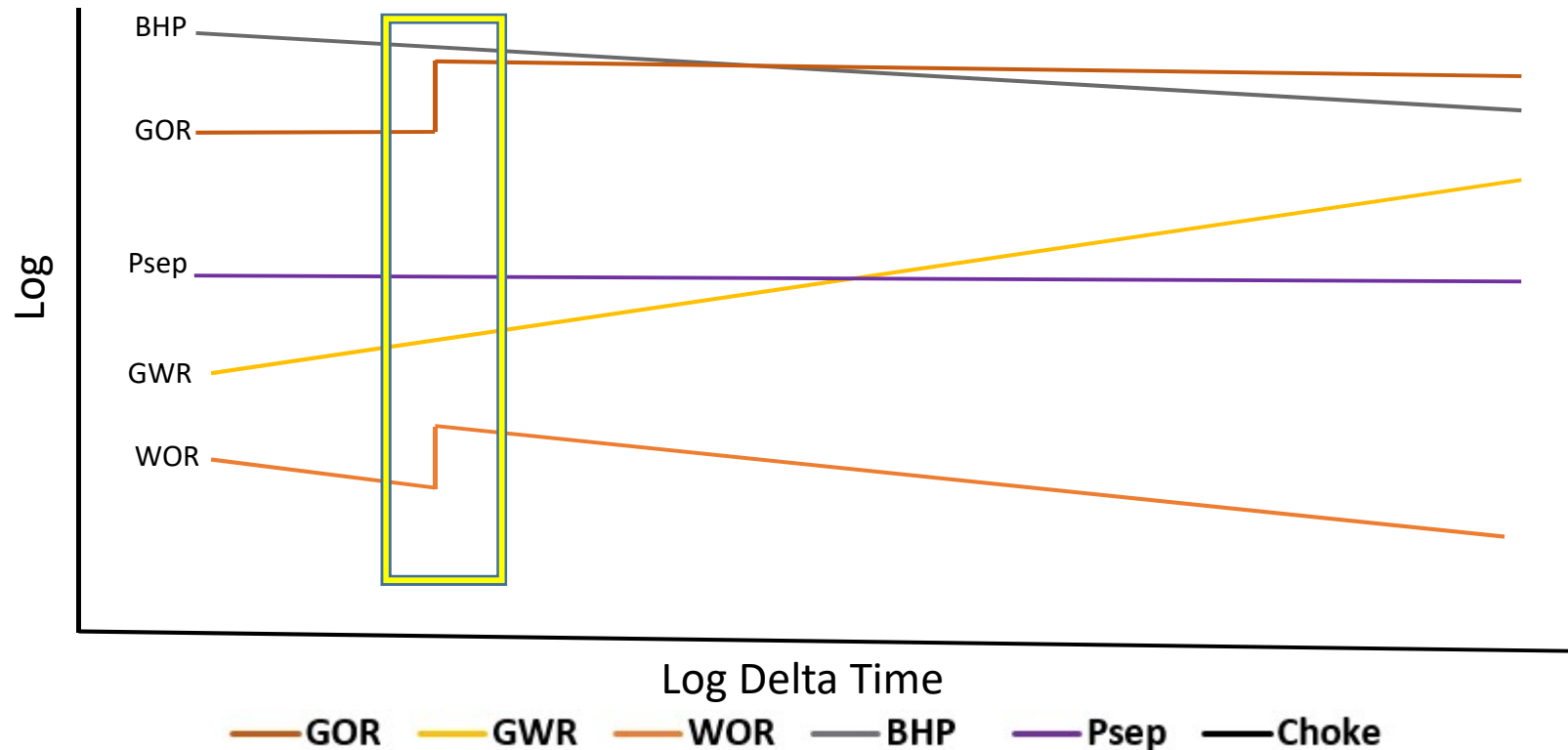


- When there is a quick change in two of the production ratio trends the phase that is common between them is often the phase that is in error
- In this case there is a change in the GOR and a change in the WOR during period 1 and 2 outlined by the yellow box
- The common phase between GOR and WOR is oil indicating a possible oil rate measurement error
- The rate measurement error could have started when the change is seen or was corrected when the change is seen



Diagnosing Measurement Errors

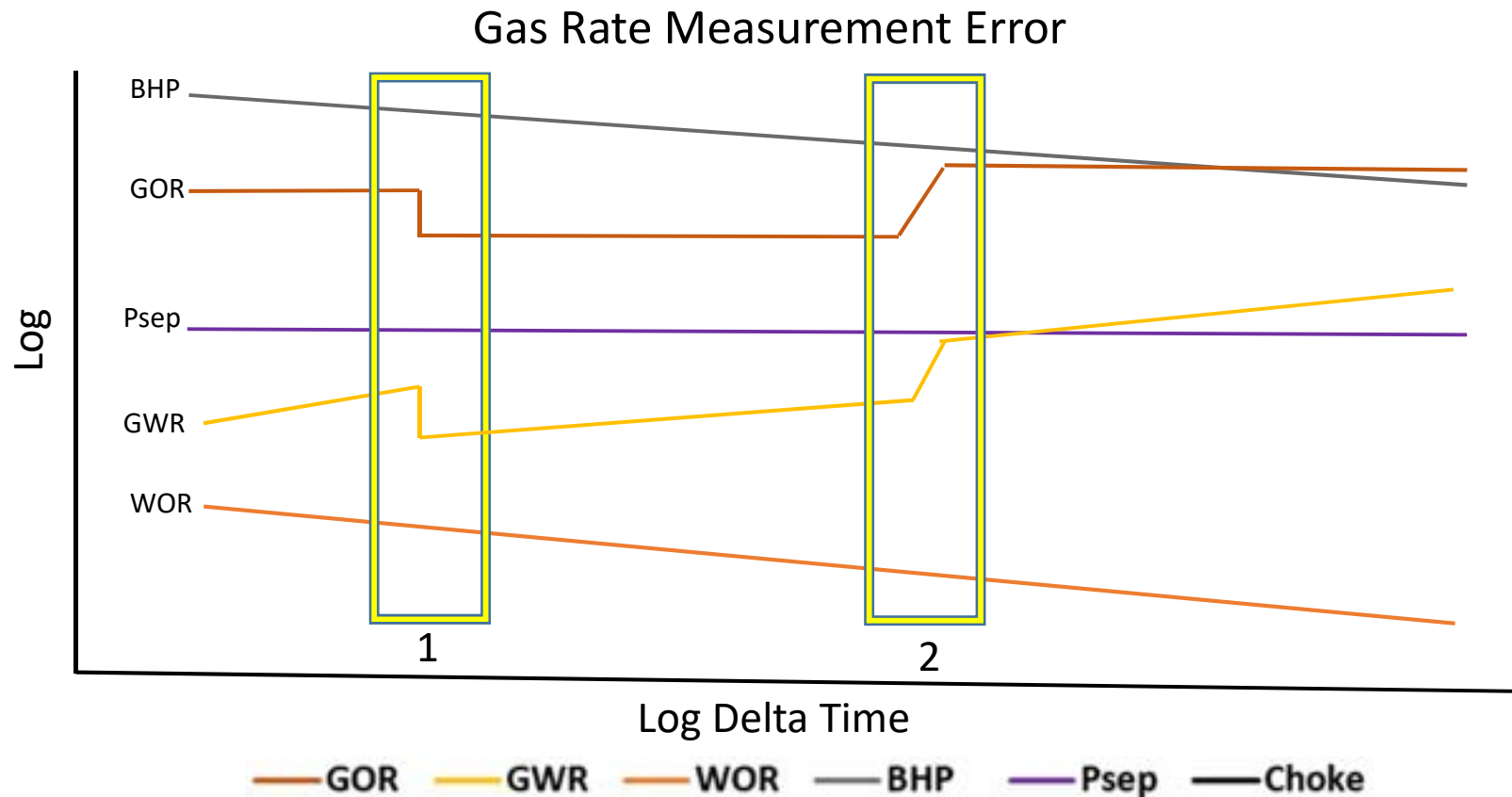
Oil Rate Measurement Error Example



- Quick increase in GOR and WOR indicating oil rate measurement error
- This could either be caused by the oil rate being higher than actual prior to when the change in trends is seen or the oil rate being lower than actual after the change in trends is seen
- Contact Revo Well Test Operations Team for further guidance



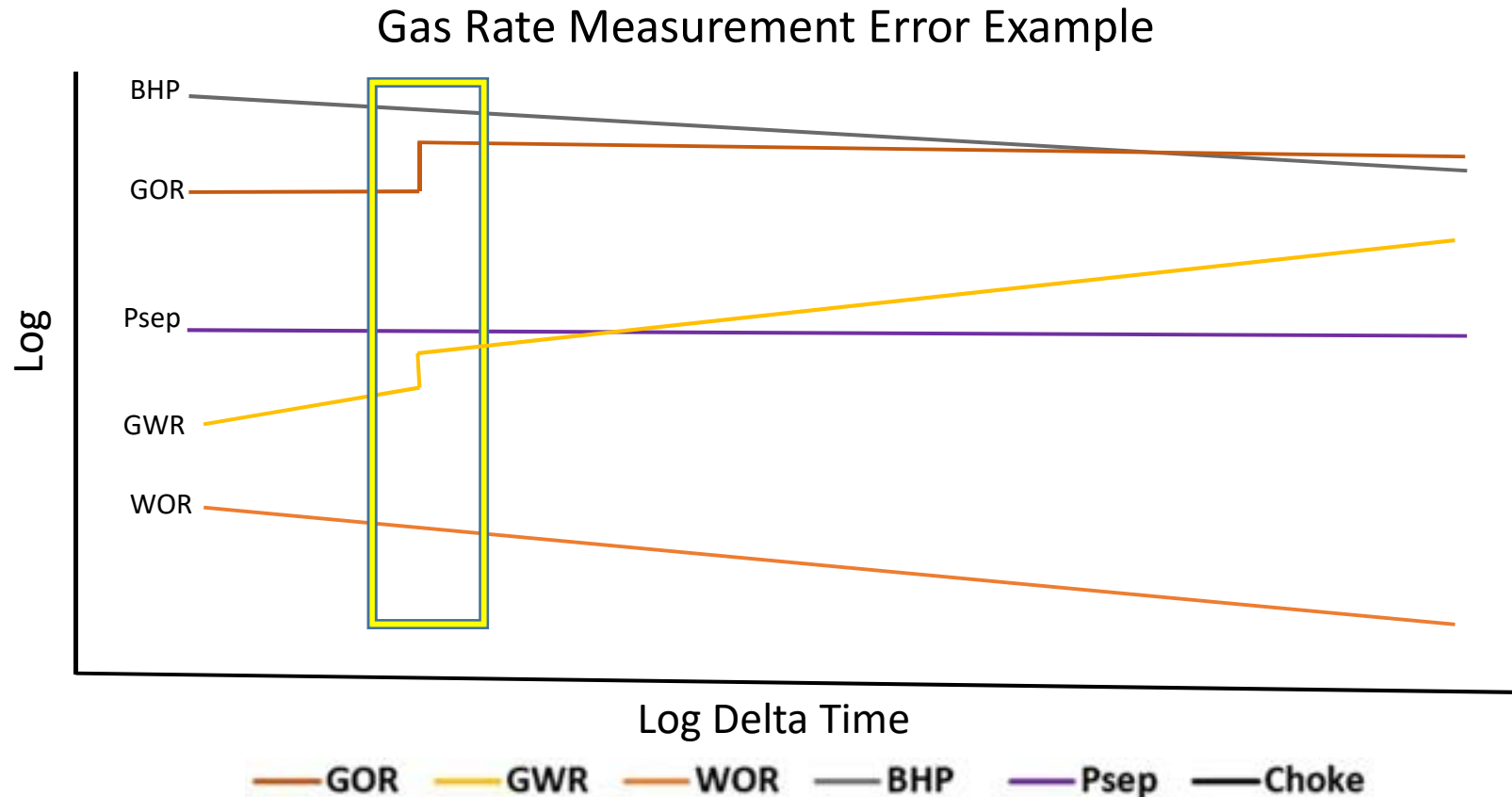
Diagnosing Measurement Errors



- In this case there is a change in the GOR and a change in the GWR during period 1 and 2 outlined by the yellow box
- The common phase between GOR and GWR is gas indicating a possible gas rate measurement error
- The rate measurement error could have started when the change is seen or was corrected when the change is seen



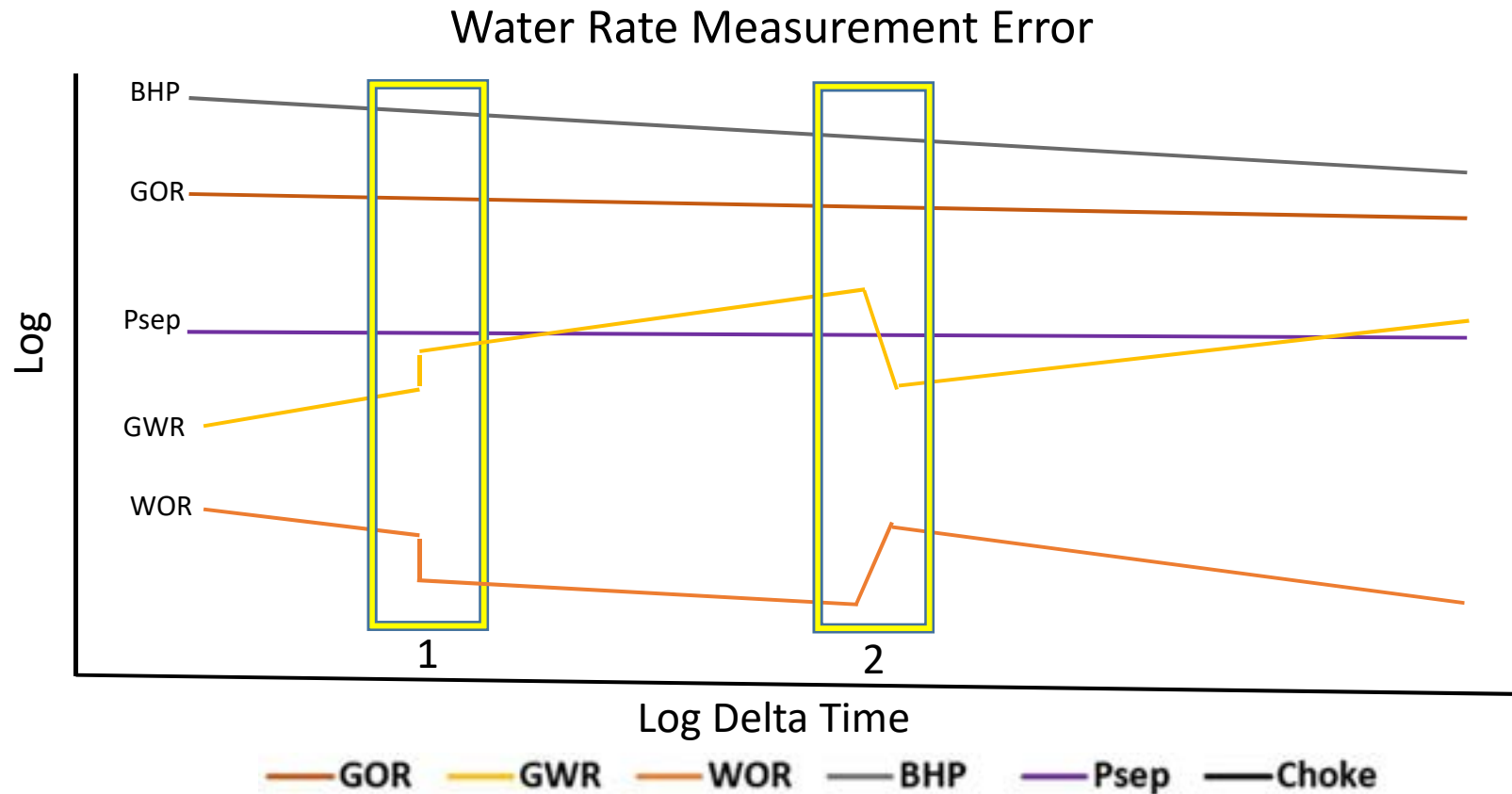
Diagnosing Measurement Errors



- Quick increase in GOR and GWR indicating gas rate measurement error
- This could either be caused by the gas rate being lower than actual prior to when the change in trends is seen or the gas rate being higher than actual after the change in trends is seen
- Contact Revo Well Test Operations Team for further guidance



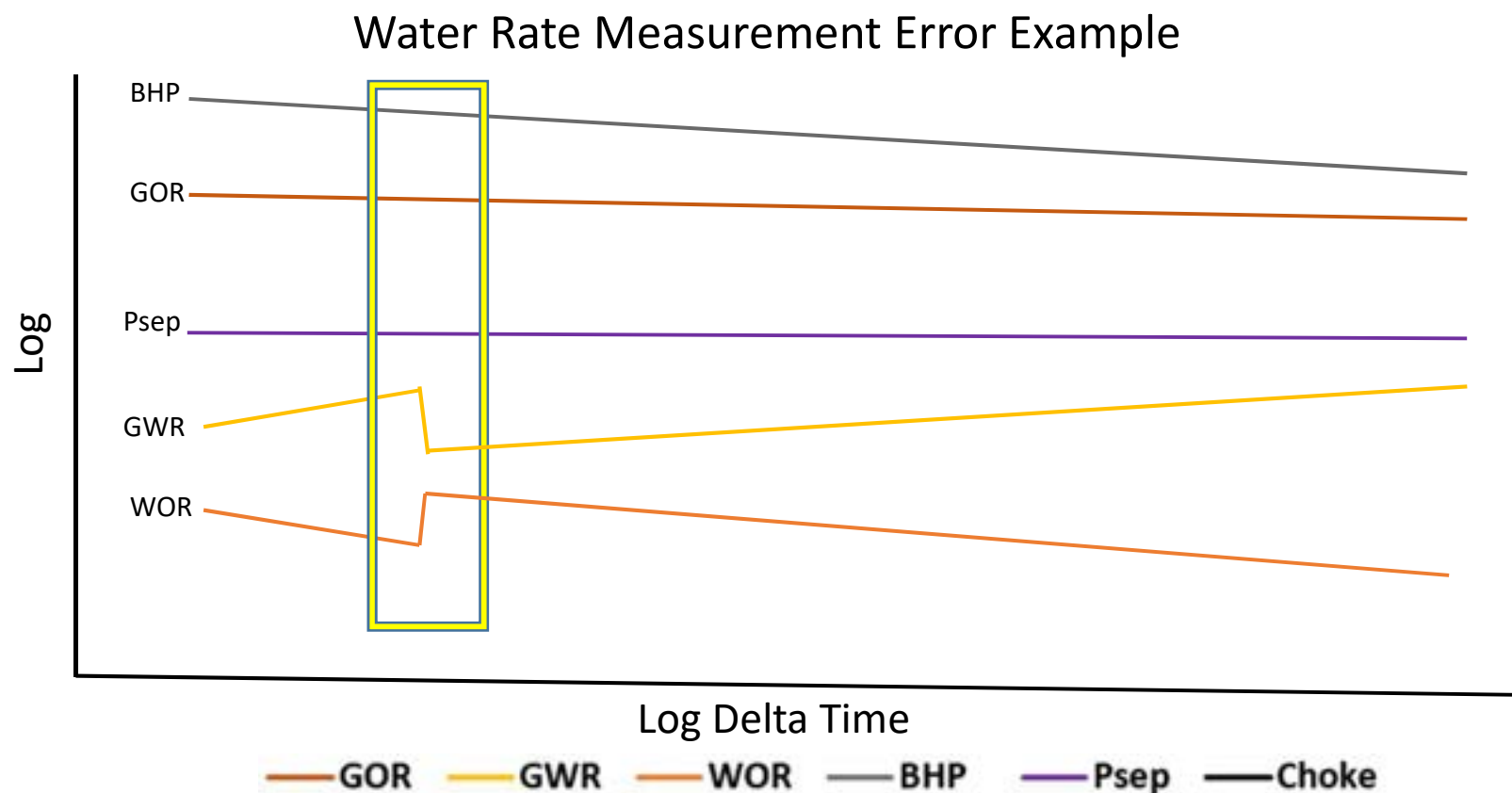
Diagnosing Measurement Errors



- In this case there is a change in the GWR and a change in the WOR during period 1 and 2 outlined by the yellow box
- The common phase between GWR and WOR is water indicating a possible water rate measurement error
- The rate measurement error could have started when the change is seen or was corrected when the change is seen



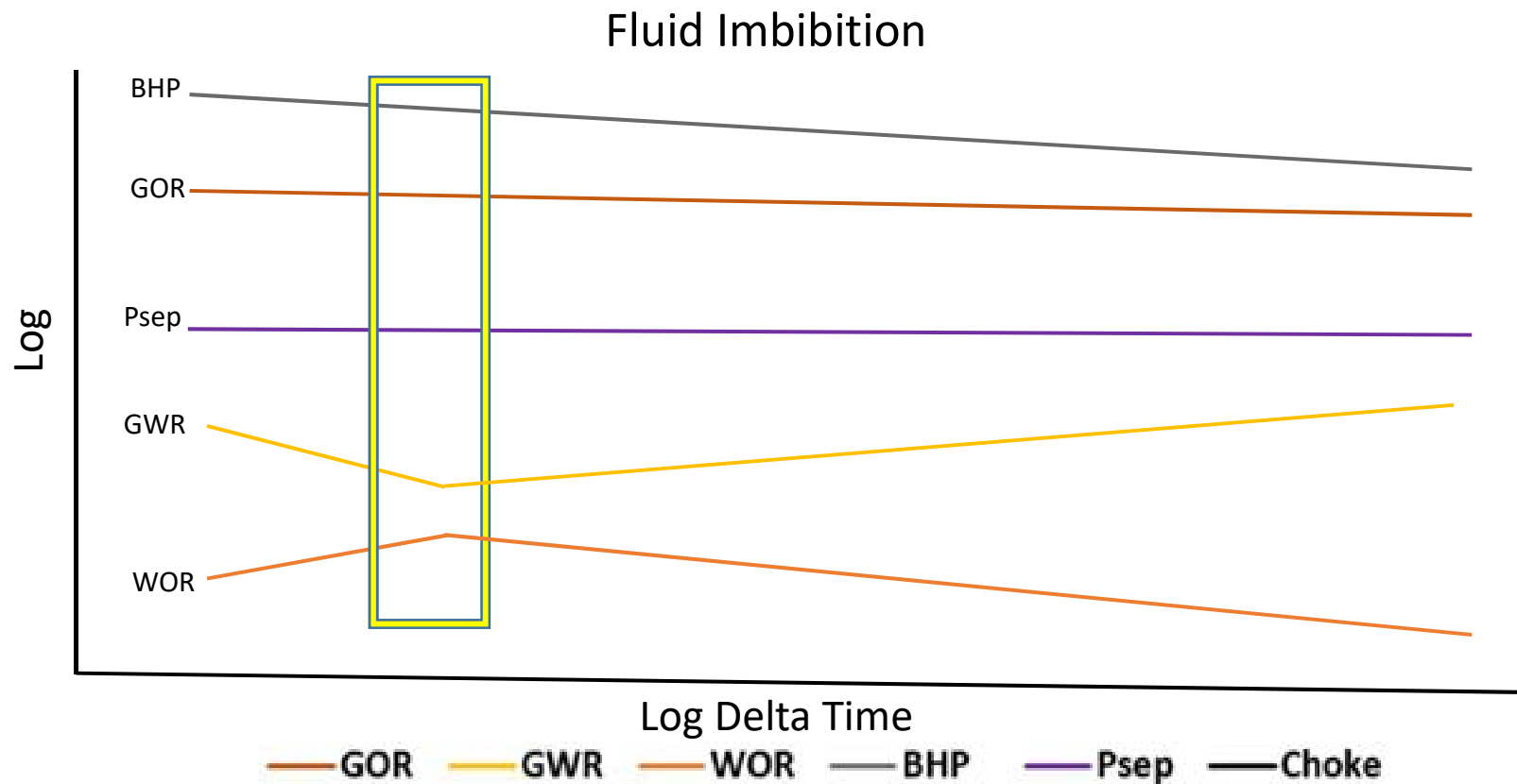
Diagnosing Measurement Errors



- Quick decrease in GWR and increase in WOR indicating water rate measurement error
- This could either be caused by the water rate being lower than actual prior to when the change in trends is seen or the water rate being higher than actual after the change in trends is seen
- Contact Revo Well Test Operations Team for further guidance



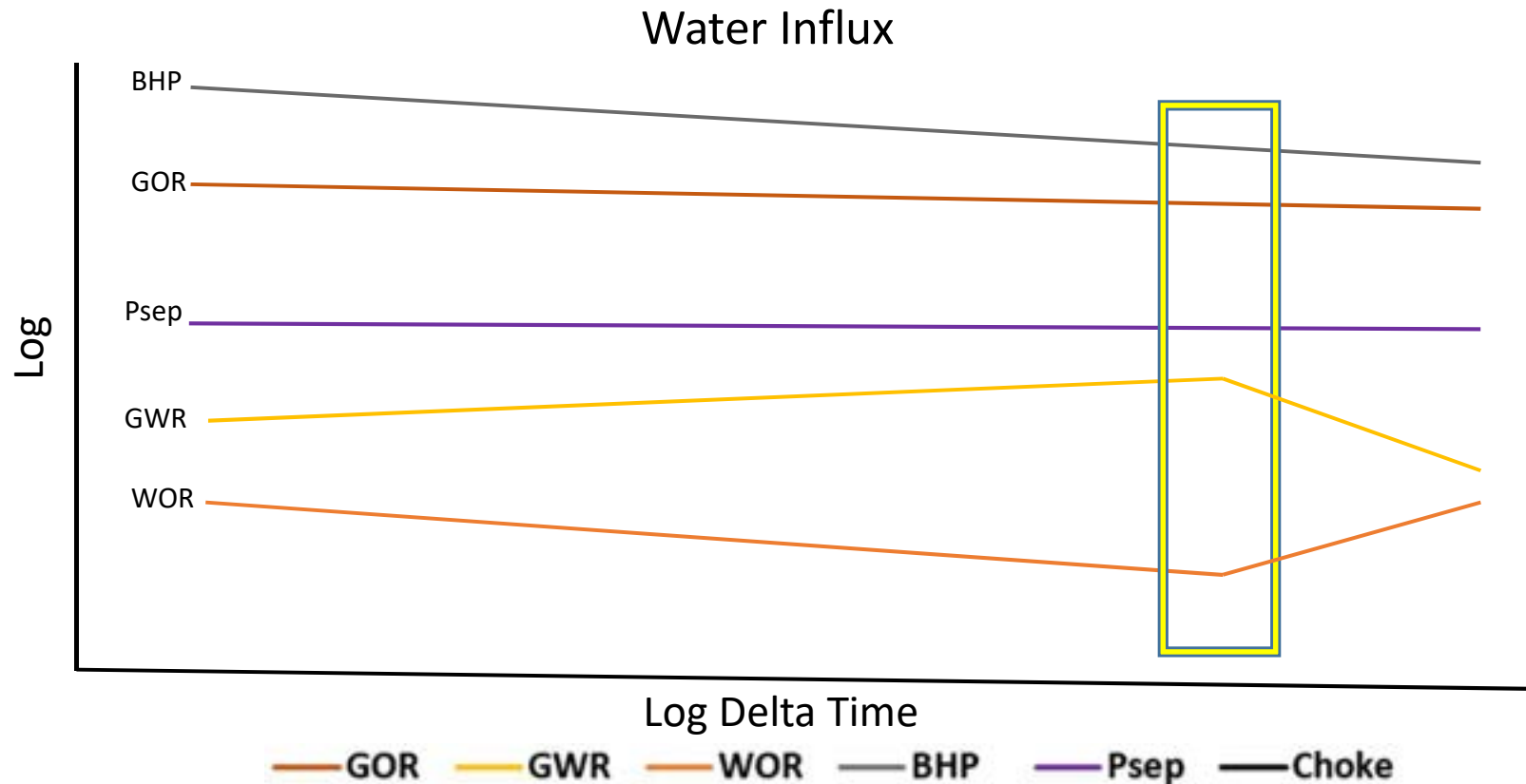
Diagnosing Measurement Errors



- GWR and WOR are gradually converging at the start of the test then change direction and start gradually diverging
- The common phase between them is water
- This is usually caused by fluid imbibition
- Contact Revo Well Test Operations Team for further guidance



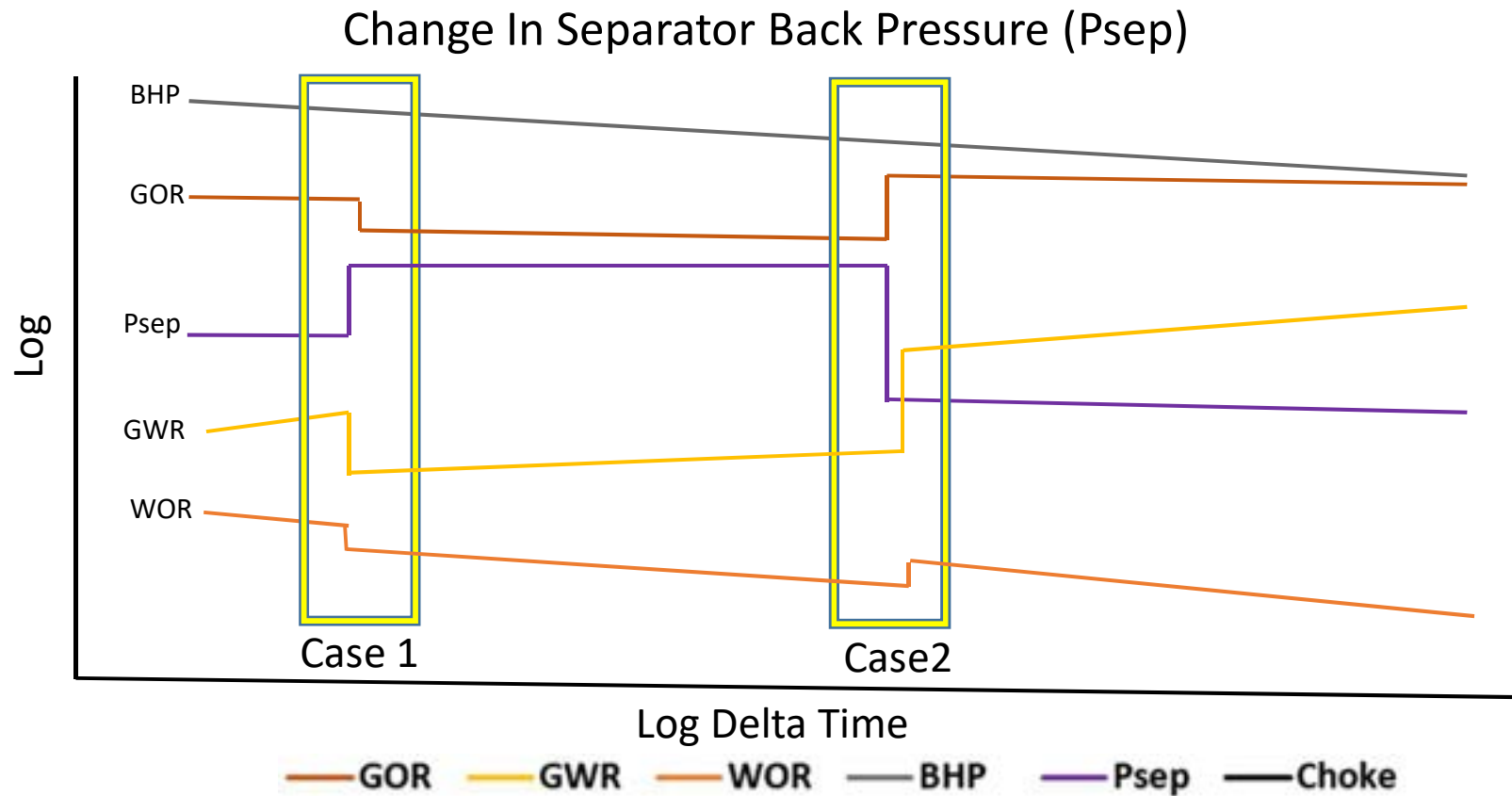
Diagnosing Measurement Errors



- GWR and WOR had been gradually diverging for most of the test and then started to converge
- The common phase between the two is water
- This is likely caused by water influx from another zone or an offset well stimulation
- This is not usually a rate measurement error but the draw down will need to be adjusted to control it
- Contact Revo Well Test Operations Team for further guidance



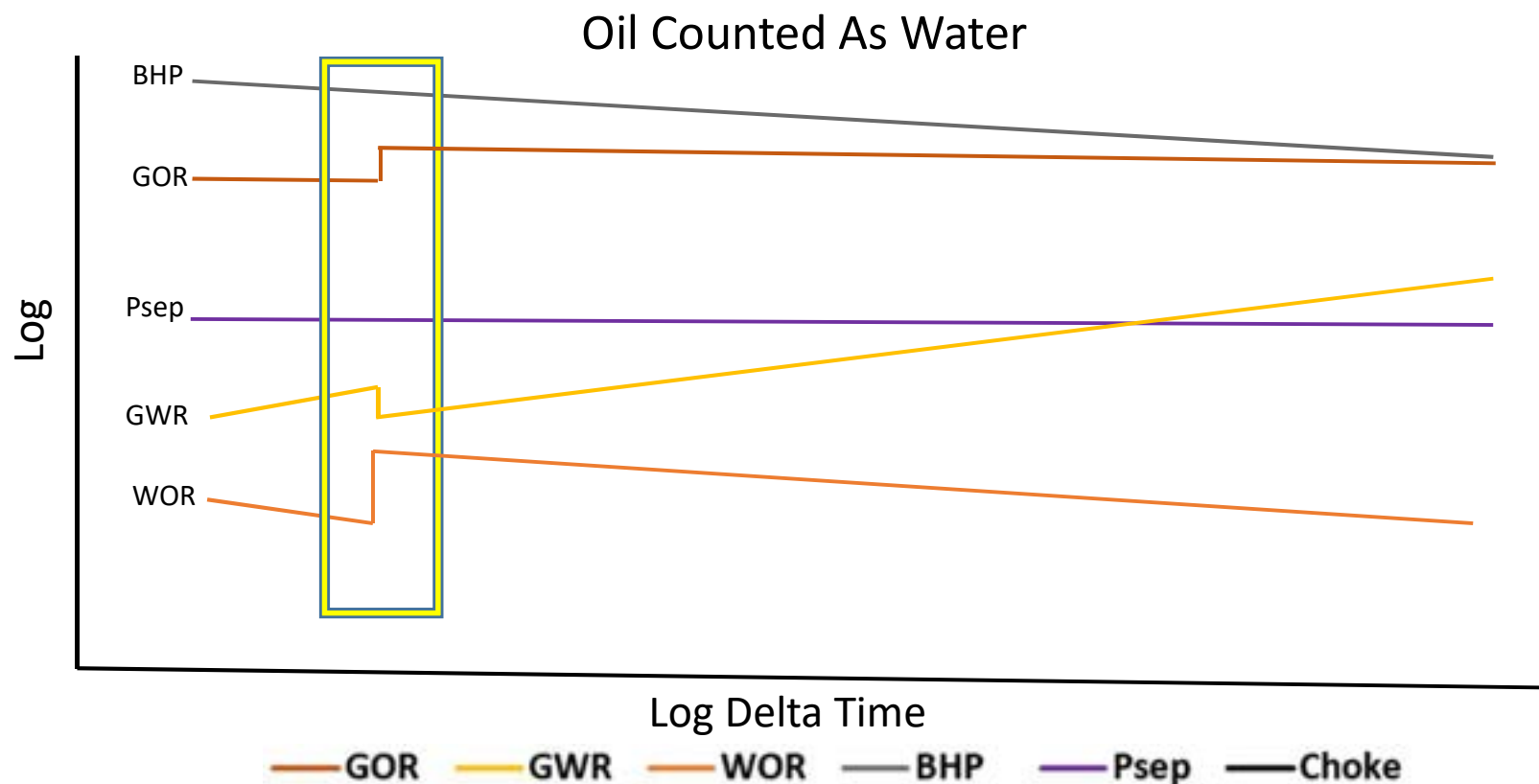
Diagnosing Measurement Errors



- In Case 1 the separator back pressure was increased which will keep more gas in solution with the oil and decrease the measured gas rate and slightly increase the measured oil rate
- In Case 2 the separator back pressure was decreased which will liberate more gas from the oil and increase the measured gas rate and slightly decrease the measured oil rate
- These changes can effect the BHP conversion and performance diagnostic
- Every effort should be made to maintain a constant separator pressure for the initial production period



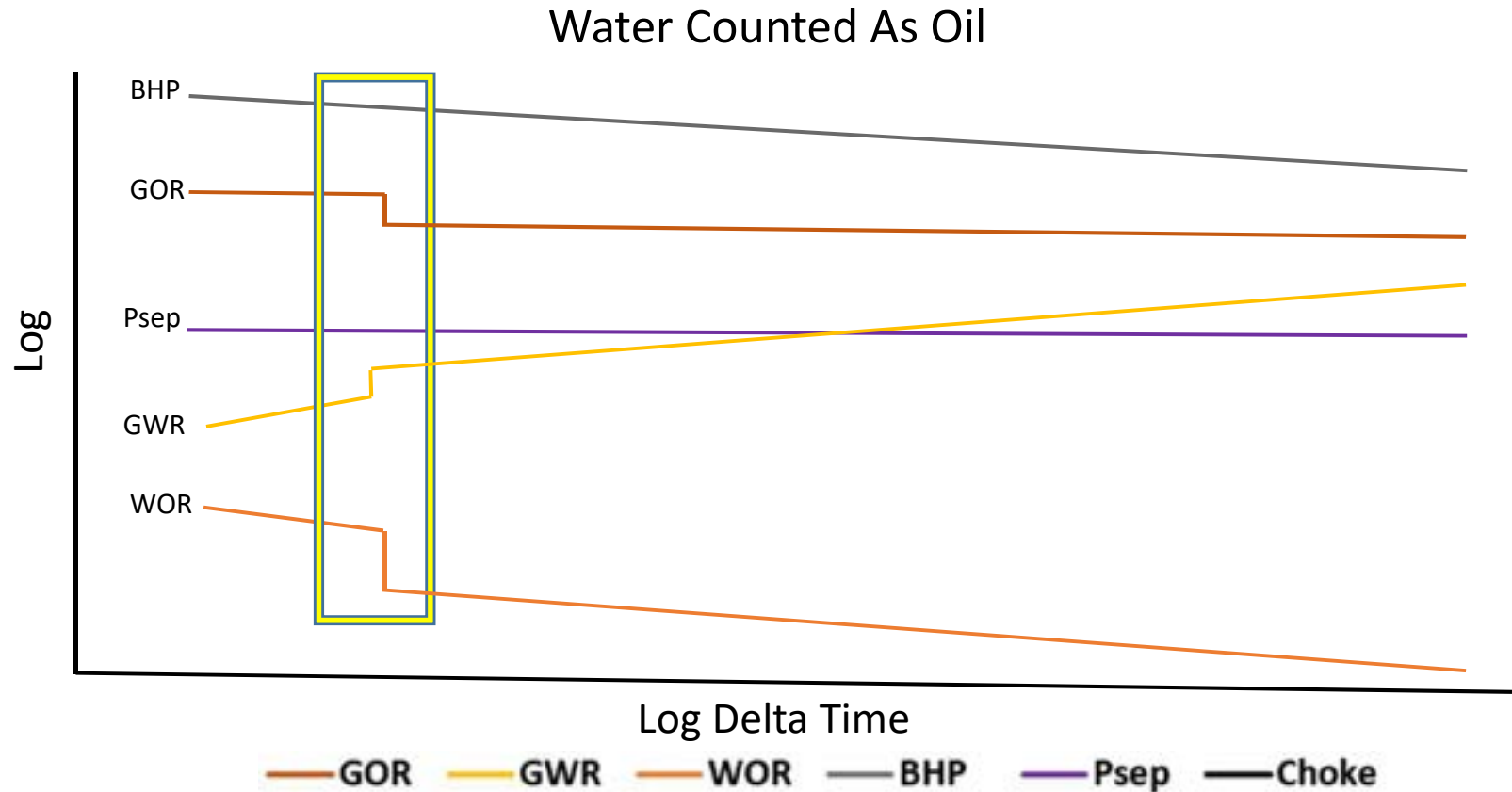
Diagnosing Measurement Errors



- This is a particularly troubling scenario where we see GOR increase, GWR decrease and WOR increase
- This can indicate oil revenue is being lost during flowback!
- It has been reported that 1-2% of the total “water” volume trucked off locations is actually oil
- This is likely caused by a low separation efficiency
- Contact Revo Well Test Operations Team for further guidance



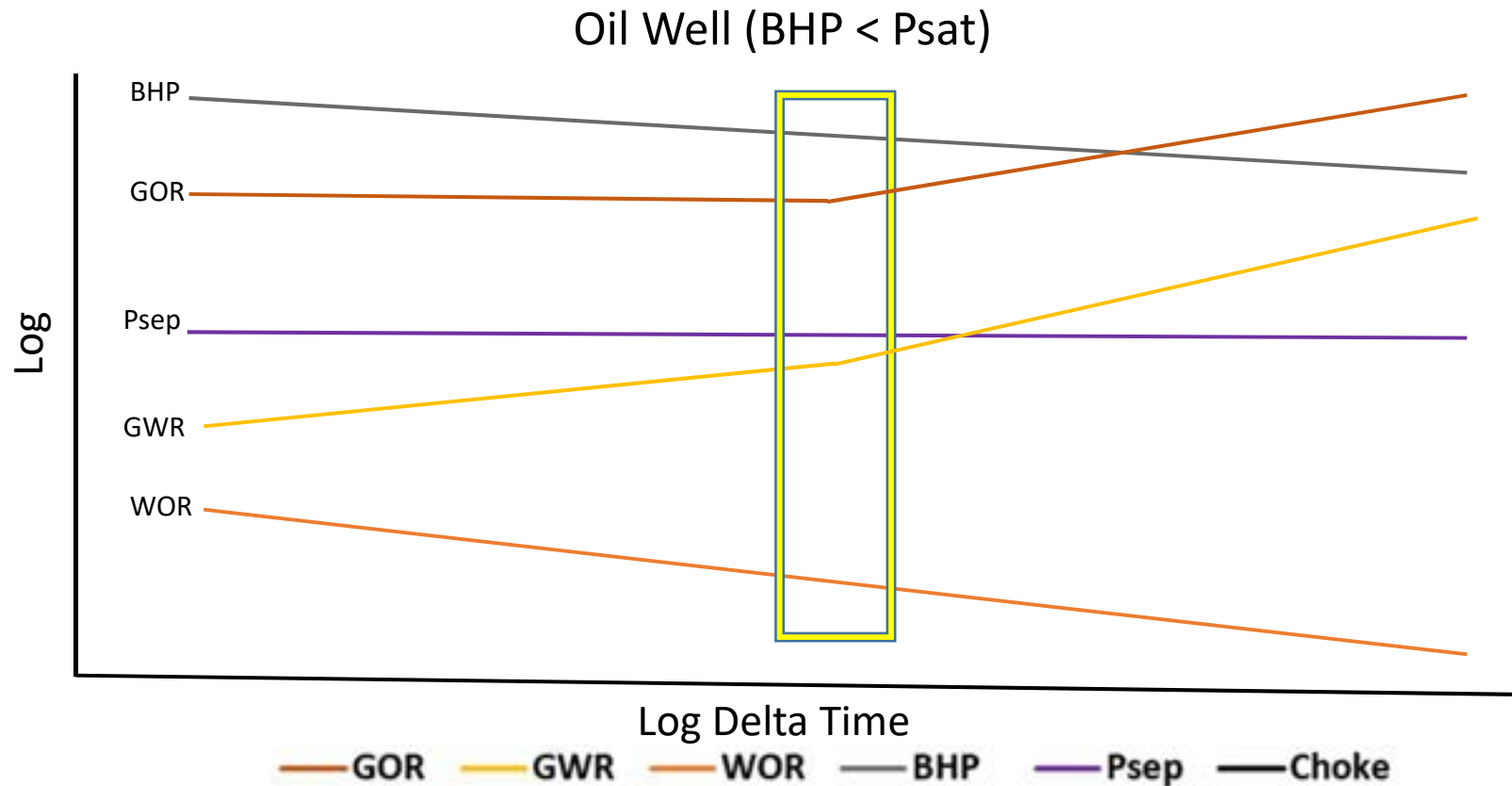
Diagnosing Measurement Errors



- GOR decreases, GWR increases and WOR decreases
- This can be caused by low separation efficiency
- This will increase BS&W and result in rejected oil loads
- Contact Revo Well Test Operations Team for further guidance



Diagnosing Measurement Errors



- In this case the GOR and GWR gradually start to increase later in the test
- This scenario can happen both early and late in a test
- This is usually caused by the bottom hole pressure going below the saturation pressure
- This is not usually a rate measurement error but it can effect well performance
- Contact Revo Well Test Operations Team for further guidance



Separator Data Plot



- The separator data plot in the lower left of the dashboard is used to monitor separator data trends and trouble shoot gas rate measurement errors



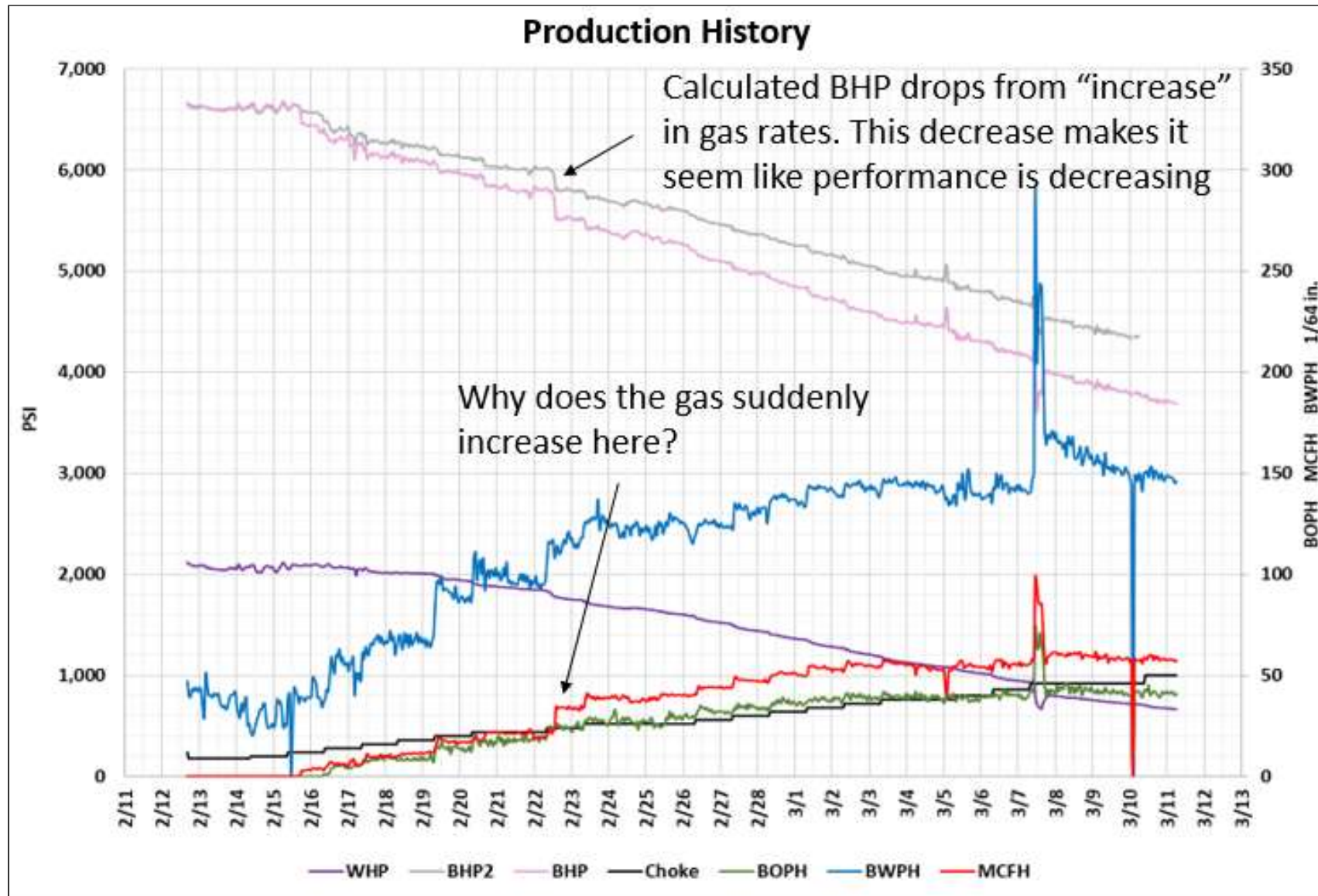
Fluid Sample Data Plot



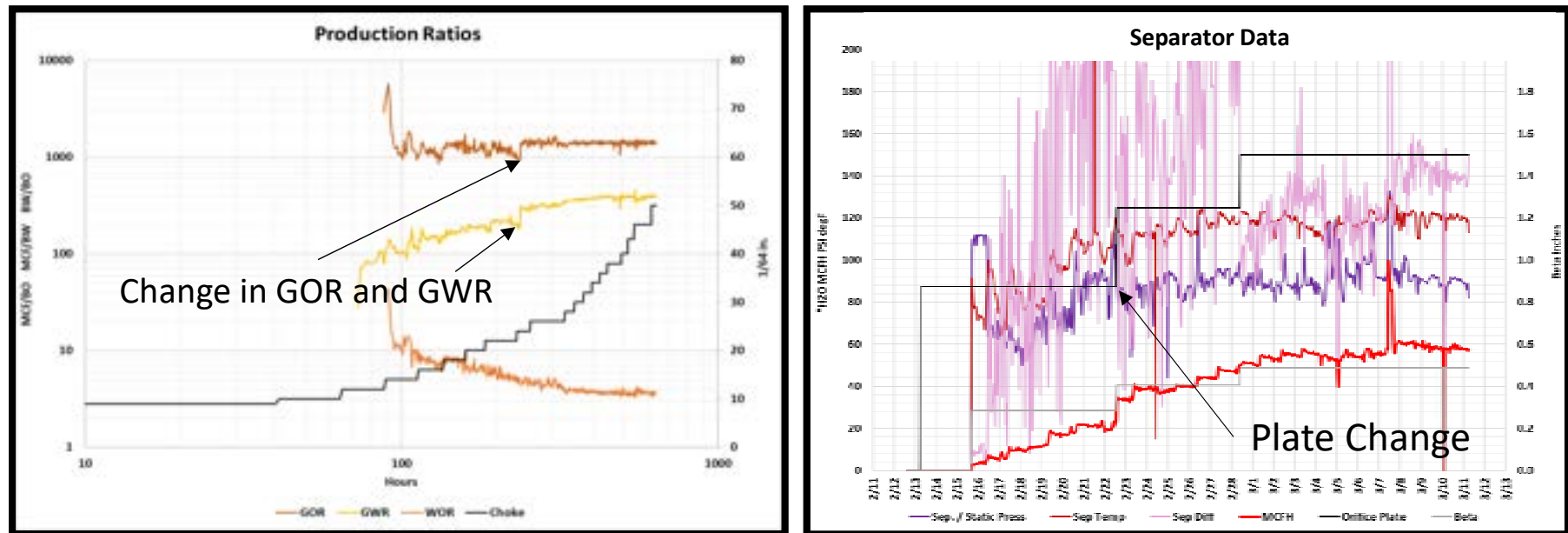
- The fluid sample data plot in the lower right of the dashboard is primarily used to identify large changes in chlorides and/or sand rate which can be an indication of problems in the well
- If you see large changes in any of the parameters on this plot contact the Revo Engineering Team



Field Example of Work Flow



Example Work Flow



- Field operations identifies a quick change in GOR and GWR and alerts Revo Well Test Operations Team
- Revo Well Test Operations Team confirms gas rate measurement error and initiates trouble shooting
- Revo Well Test Operations team reviews separator data plot for any changes that could have caused the gas rate to change
- Source of error is identified as being an caused by a change in density input in the flow meter when the orifice plate was changed



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