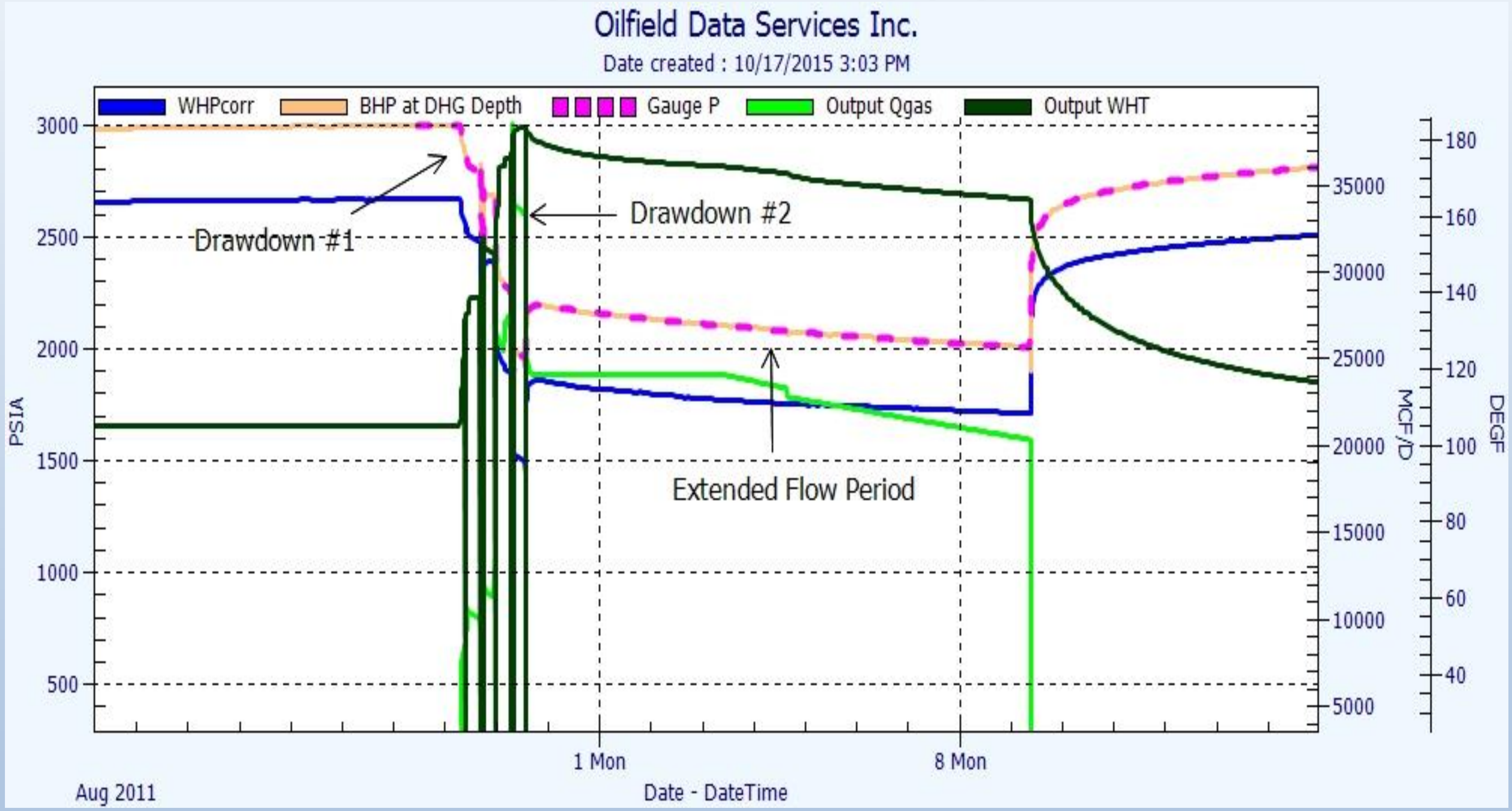
Water Production Detection

- For any of the methods to work, the wellbore model has to be fine-tuned (more details on next slide)

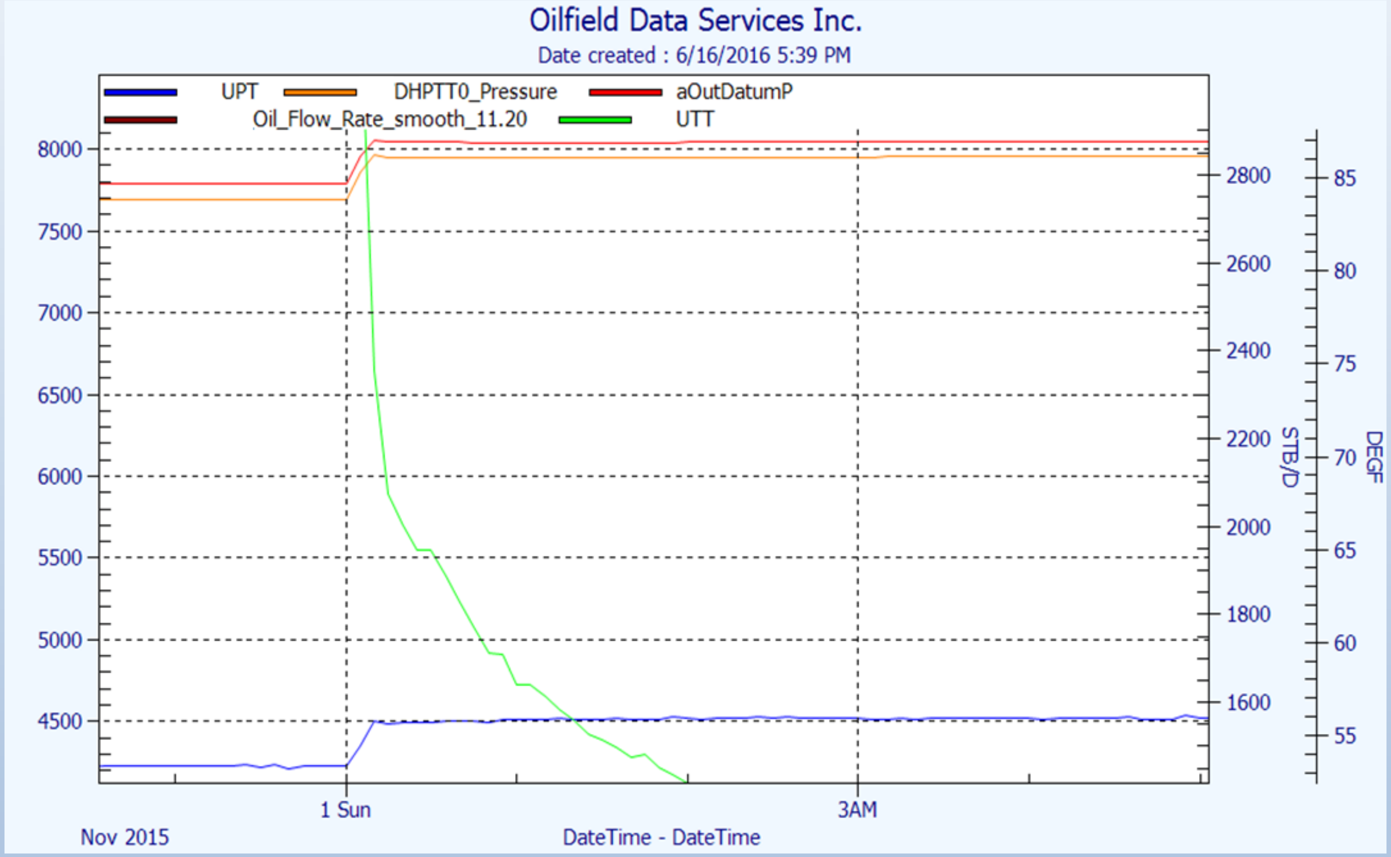
- If a well is equipped with surface and downhole permanent gauges, the onset of water production can be detected using 3 different methods:
  1. Looking at the wellhead temperature response (this method is qualitative)
  2. Making use of the liquid fallback & re-injection cycle
  3. Performing a flash calculation before the lifted liquids fall back down the well bore

Water Detection – Fine-tuning the Wellbore Model



- The dynamic response of the well for single-phase conditions (or for known composition of entrained fluids) needs to be calibrated using a multi-rate test

Water Detection – Fine-tuning the Wellbore Model

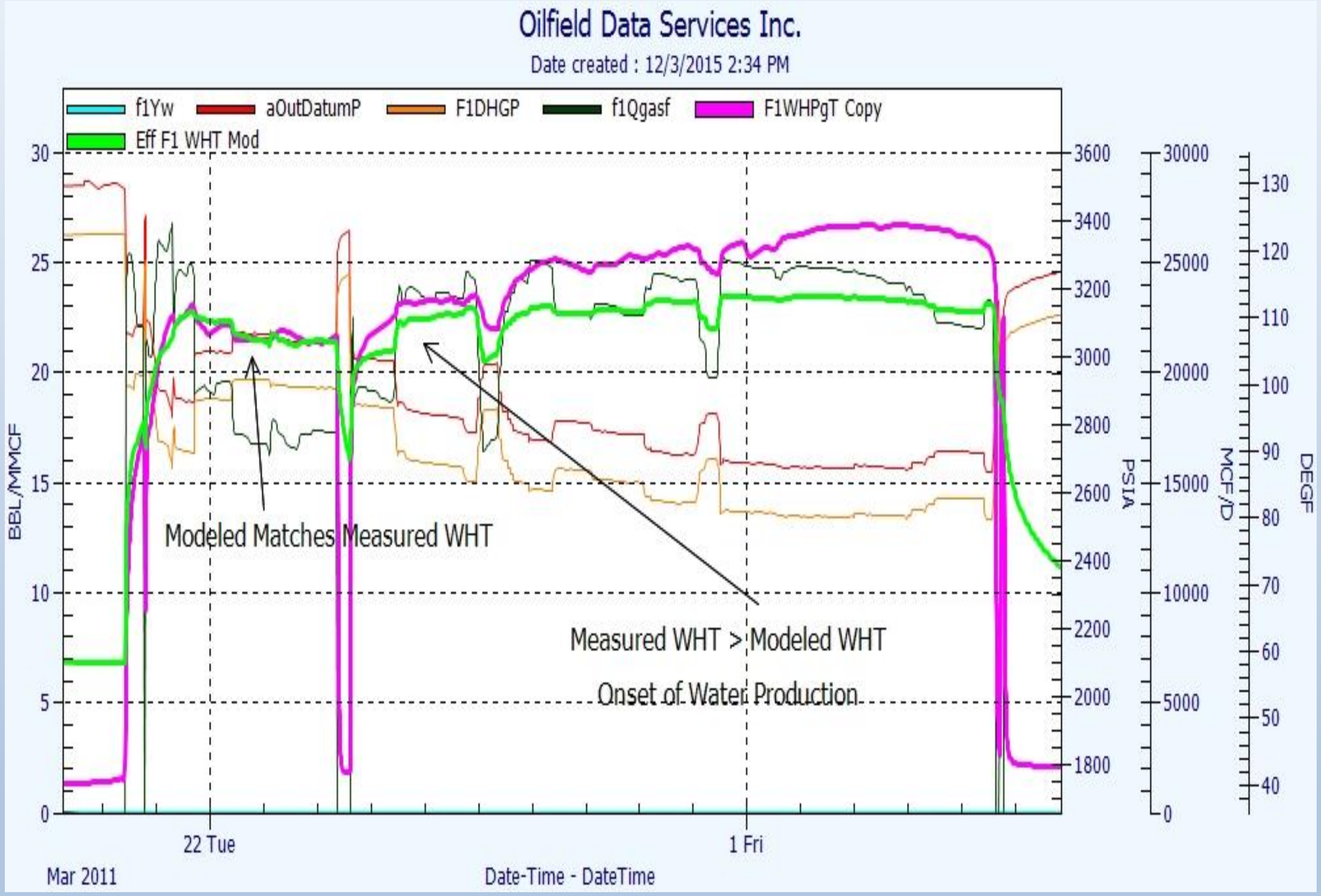


- The portion of the EOS that relates to density for the gas or gas condensate well is tuned using the **shut-in** conditions
- In order for this to work the fluid between the two gauges has to be single phase

Water Detection Method #1
Temperature Response

- This is a qualitative method.
- If the measured WHT is higher than the modeled WHT (for a calibrated thermal/PVT model), the well is either:
  - Producing at a higher gas rate than is being measured/calculated OR
  - It is producing free liquids (water)
- The thermal model can be adjusted by adding water (higher heat capacity than gas) until the modeled temperatures match the measured temperature

Water Detection Method #1
Temperature Response



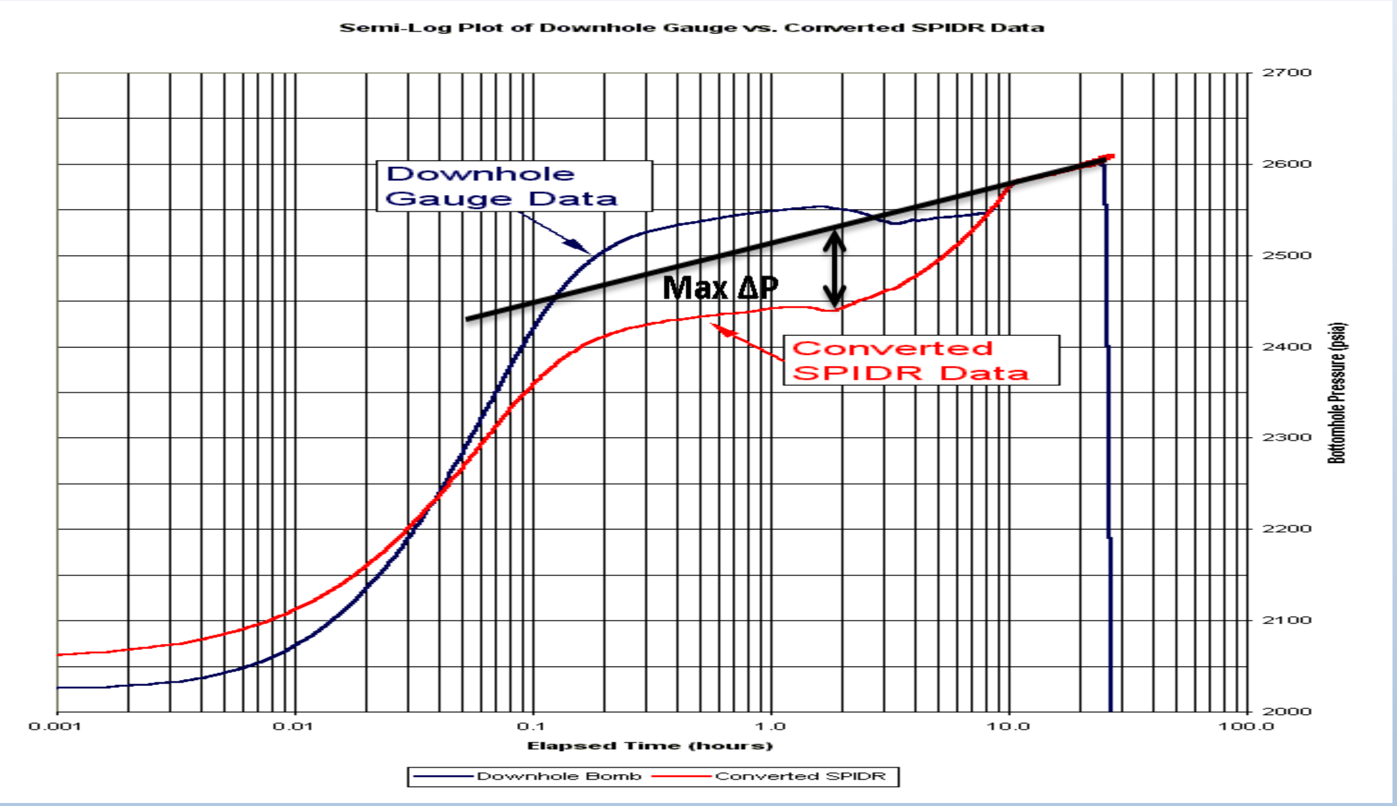
The function in purple is the measured wellhead temperature. Notice the sudden increase in the measured temperature and departure from the modeled temperature

Water Detection Method #2
Re-injection Cycle

- Liquid fallback and re-injection in gas wells occurs when
  - The reservoir/wellbore pressure is below the dew point pressure OR
  - **When a gas well starts producing free water**
- After the shut-in occurs, the liquids that were being lifted fall to the bottom of the well, forming a column on top of the completion interval
- Gas forces the liquids to be re-injected into the formation
- The liquid level then falls to the top of the completion, forming a continuous gas phase in the wellbore
- The Water yield can be determined by determining the height of the liquid column at its maximum (Slide 8)

Water Detection Method #2

<u>Re-injection Cycle</u>



The maximum pressure difference between the measured data before and after re-injection occurs can be used to calculate the water yield after the onset of water production

Water Detection Method #2

Workflow for Yield Determination from Re-injection Cycle

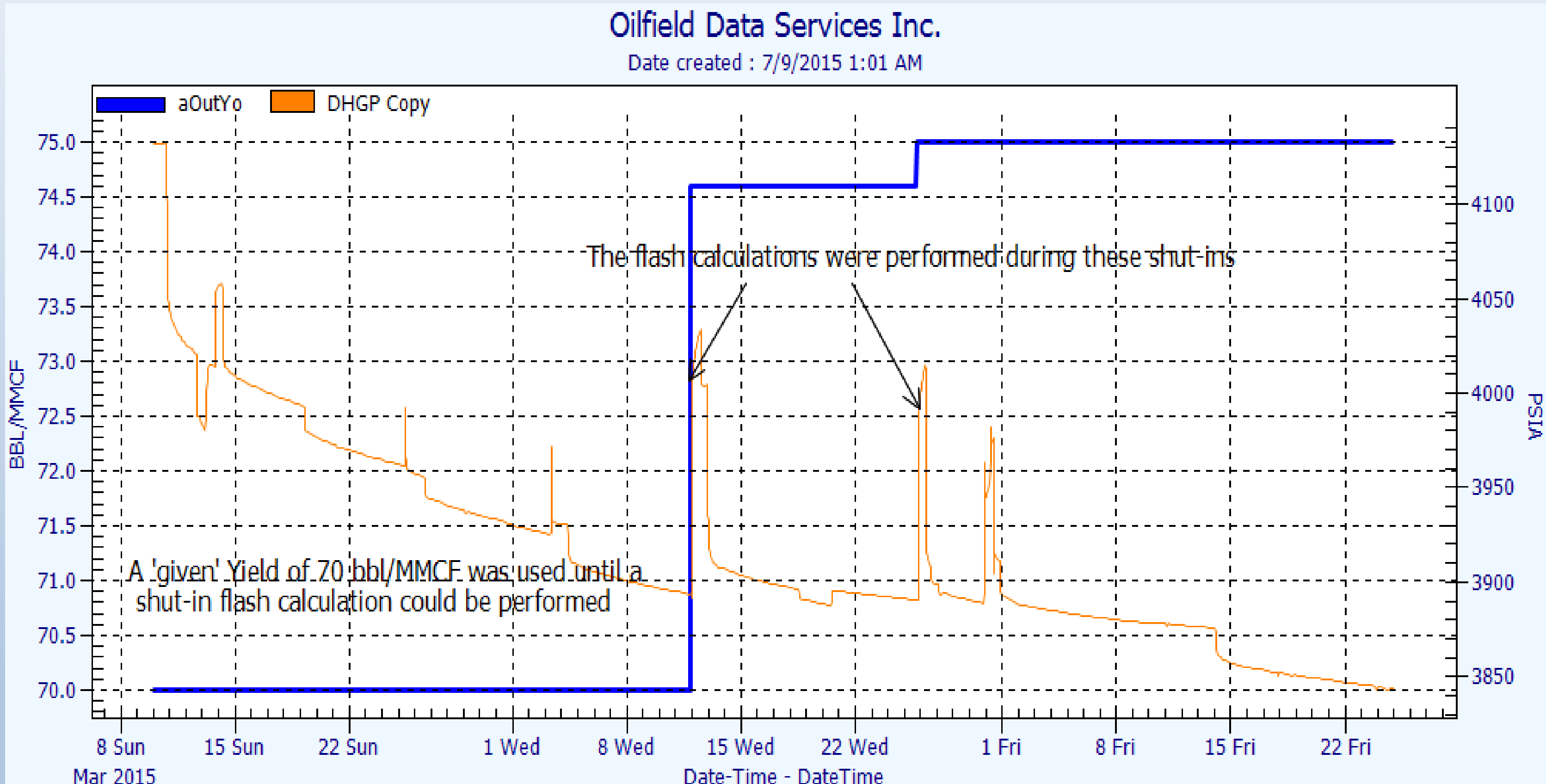
Water yield can be determined by:

1. Determining the height of the liquid column at its maximum
2. Calculating the volume of water based on the tubing/casing volume occupied by the water
3. Calculating the Volume of gas in the well bore (wellbore volume minus water volume)
4. Dividing the water volume in bbl by the gas volume in MMscf

Water Detection Method #3
Flash Calculation

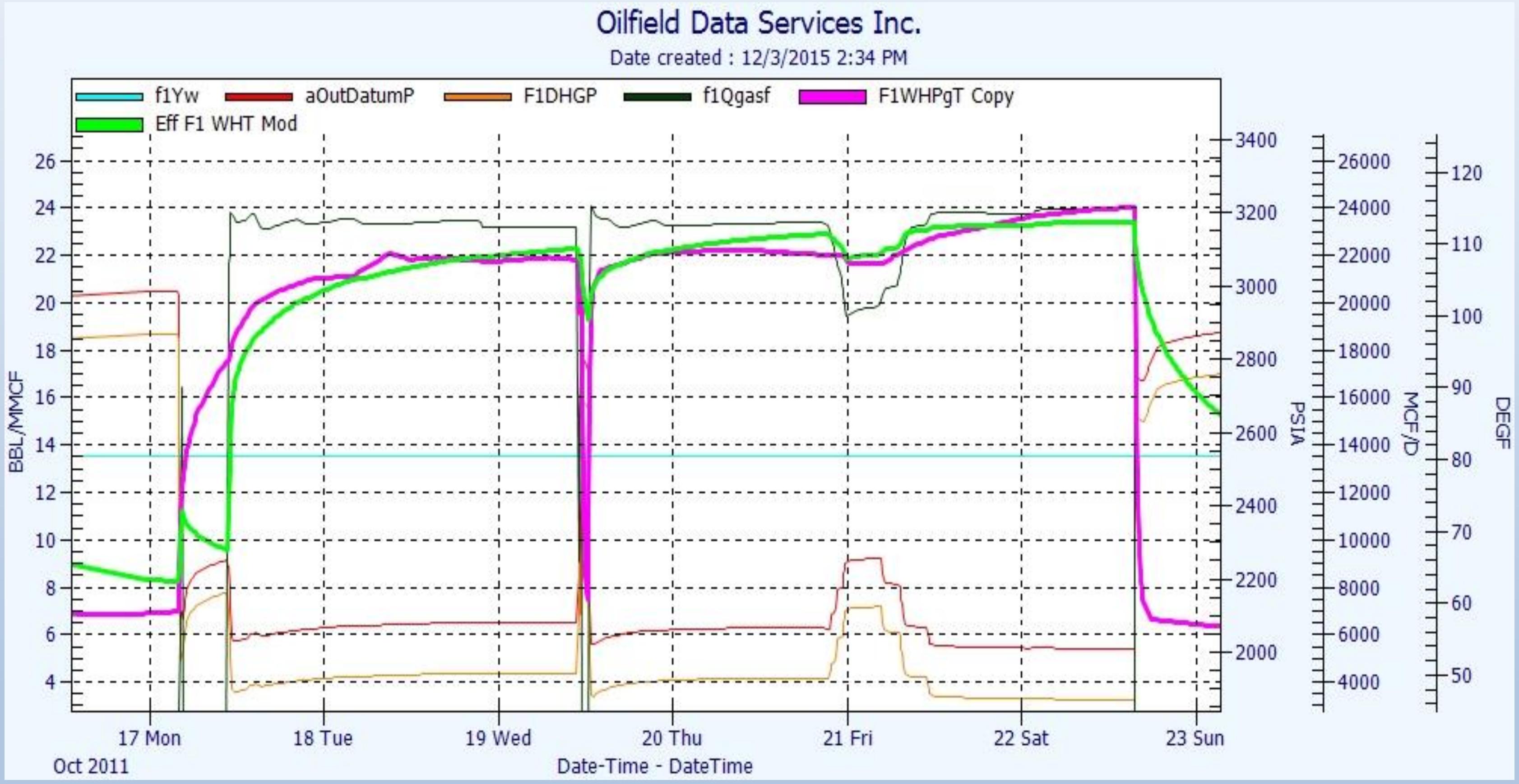
- As soon as a well is shut-in, the pressure drop due to friction goes away
- Now, the pressure drop between the surface and downhole gauges is only due to the ‘head’ of the fluid column
- ODSI Well Analyzer can use this pressure information early into the shut-in to perform a flash calculation to calculate the liquid yield
  - Can be split into stock tank, separator or plant conditions (T, P)

Water Detection Method #3
Flash Calculation



A 'flash' calculation can be performed automatically after the well is shut-in. The liquid yield can be calculated during every shut-in and can then be used as an input for the pressure and rate calculations

Modeled vs Measured Temperature



The modeled and WHT will match with each other once the water yield is determined and used for the modeling