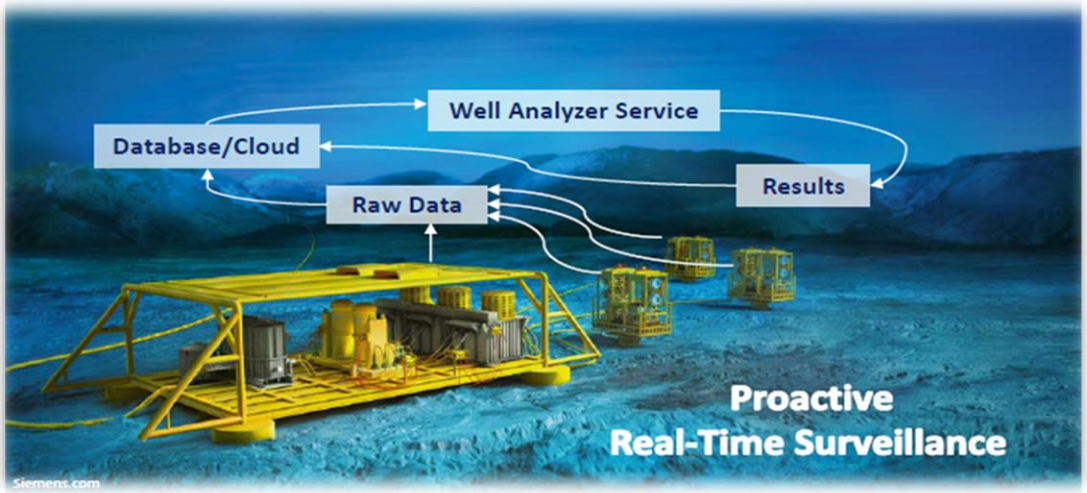
# Well Analyzer

*Pro-Active*

*Automated Real-Time Surveillance **(RTS)***

*Well/Reservoir Evaluation Software Package*




## *Oilfield Data Services, Inc.*



- ✓ Oil & Gas Reservoir Testing and Evaluation
- ✓ Real-Time Pressure Transient Analysis
- ✓ Hydrocarbon Volume Determination
- ✓ Well(s) Performance Tracking
- ✓ Multiphase Rate & BHP Calculations
- ✓ Optimize Gas Lift / Oil Production Rates
- ✓ Life Of Well Surveillance/Analysis
- ✓ Automated PVT Calibration

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# The Well Analyzer RTS Concept:

**Experienced Surveillance Engineers**

**+**

**Automation**

**Spend your time thinking about what the results mean, not just digging for data!**




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# ODSI Well Analyzer

## Digital Operator Support Real-Time Automated System

### Real-Time Reporting on Well/Field KPI's

**The Well Analyzer RTS Concept**:

**Experienced Surveillance Engineers**

**+**

**Automation**

| VFM/PVT | Flow Assurance | Production & Reservoir Performance Optimization | | Field Development & NPV Optimization |
|---|---|---|---|---|
| Virtual Metering | Wax, Hydrates, Asphaltenes, Scale, Corrosion, Emulsion Detection & Mitigation | Auto Real-Time PTA & Reporting | In-place and recoverable hydrocarbon volume monitoring | Short- and long-term asset and NPV Optimization |
| Auto Real-Time PVT Tuning & Calibration | | Scale, Asphaltene detection in reservoir & wellbore | In-place and recoverable hydrocarbon volume monitoring | Drilling Decisions – Optimal Well Placement |

**Asset Modeling, Monitoring & Diagnostics**

Raw sensor data → Data Communication → Intermediate Data Repository → Real-Time Data Management

Photo credit: www.energyglobalnews.com

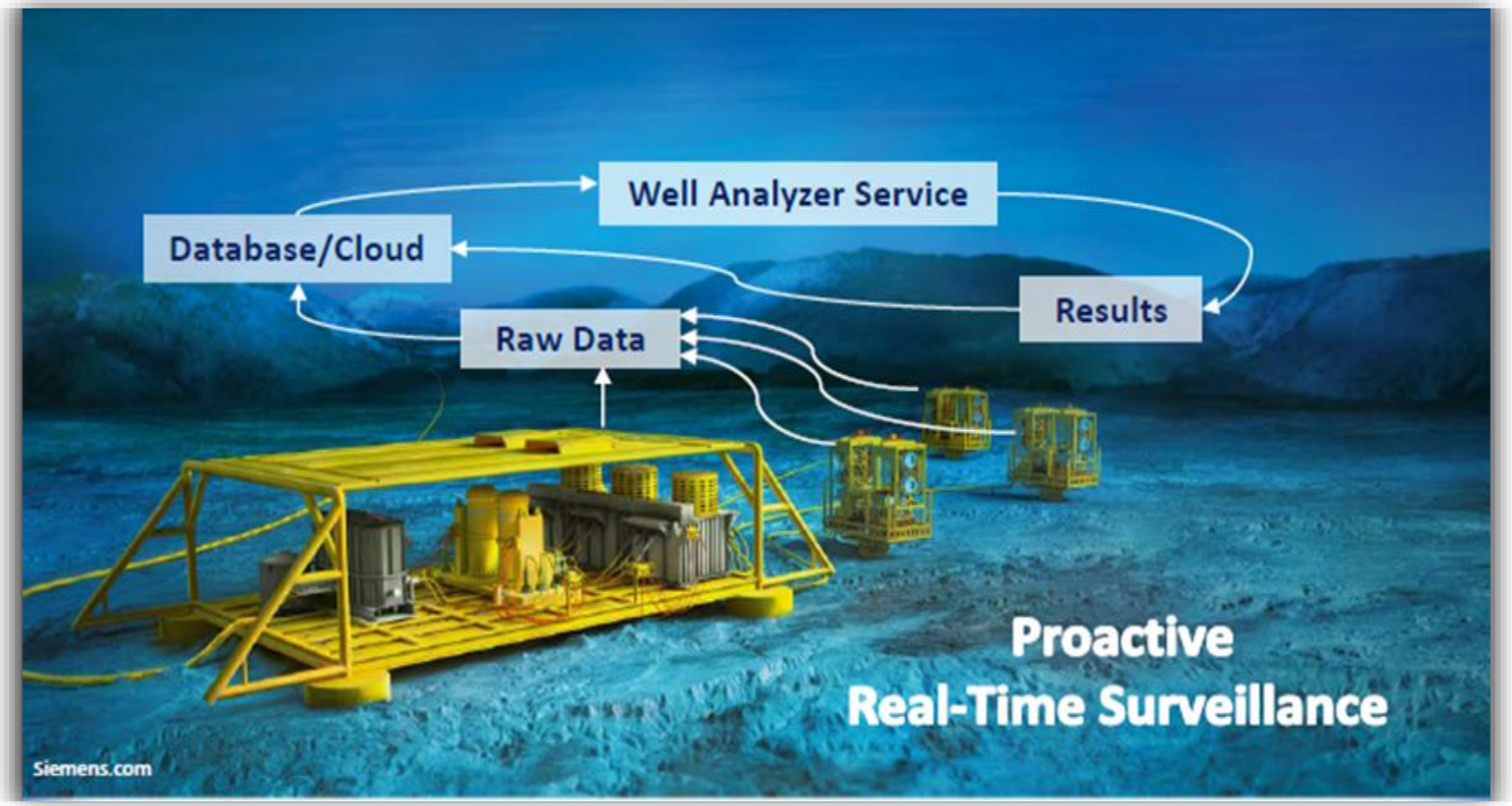
# The Well Analyzer RTS Solution

Presentation Outline

1. Introduction & Setup
2. Features
3. Wellbore Solution
4. Quick Review of Horizontal Well Evaluation
5. Automatic Time-Lapse PTA Results (Skin, Permeability, etc.)
6. Case Studies (Mostly Horizontal Wells)
7. ODSI's Well Analyzer Benefits Summary

# Well Analyzer RTS – Introduction

## Real-Time Proactive Surveillance, Physics-based Modeling and Production Optimization

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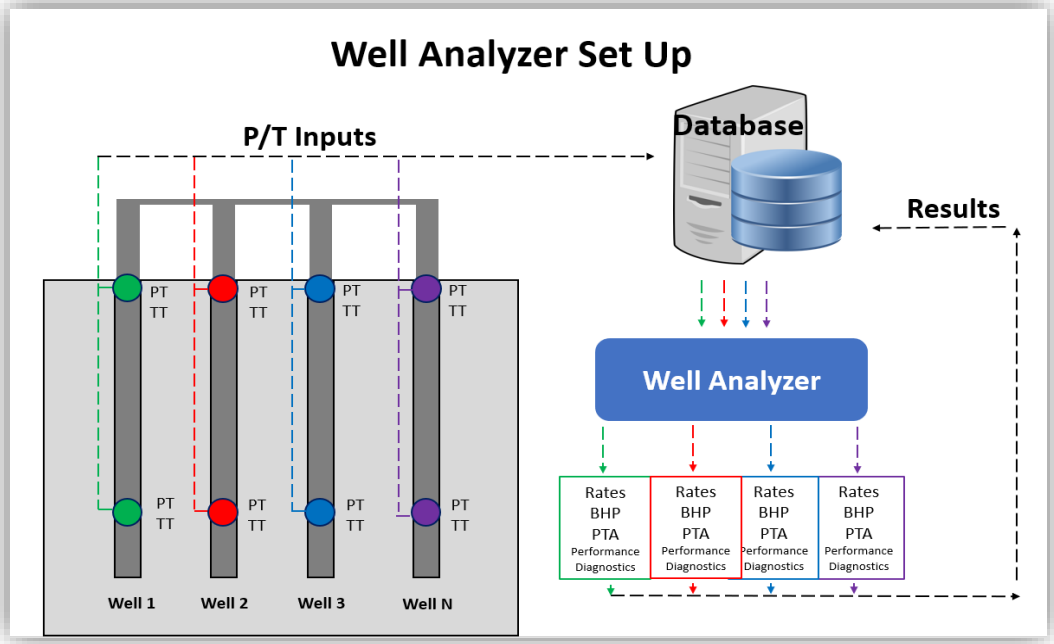
# Well Analyzer - Real-Time System Set Up

- Setup
  - Dynamic EOS-based phase-thermal and wellbore models setup by ODSI engineers
  - Well Analyzer is installed on client's **existing database**
- Operation - works in **Real-Time** and on **Historic** data
  - Well Analyzer **polls** the required data tags from the database/historian, **performs** the calculations, validates the results and **writes** them **back** to the database
- Maintenance
  - Complementary software and features updates
  - Monthly well performance reviews



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# Well Analyzer Real-Time Features

- Automated 3-Phase Rate Calculations and PVT Adjustments
- Conversion to BHP/Datum Depth
- Automated Pressure Transient Interpretation of Build-ups (PBUs) and Drawdowns (DDs), Injection & Inj Fall-off Tests
- Static MBAL
- Flowing MBAL
- Conventional Decline
- TTA Decline (Thermodynamic Transient Analysis)
- Time-Lapse Skin, Perm, Mobility-Thickness, P* and P.I. or I.I.

# Well Analyzer - Wellbore Solution

The only existing software based on a direct numerical solution to the Mechanical Energy Balance (MEB) equation

- Does not rely on vertical lift correlations and, hence, it provides more accurate and reliable results, or flags when the well is slugging or loading

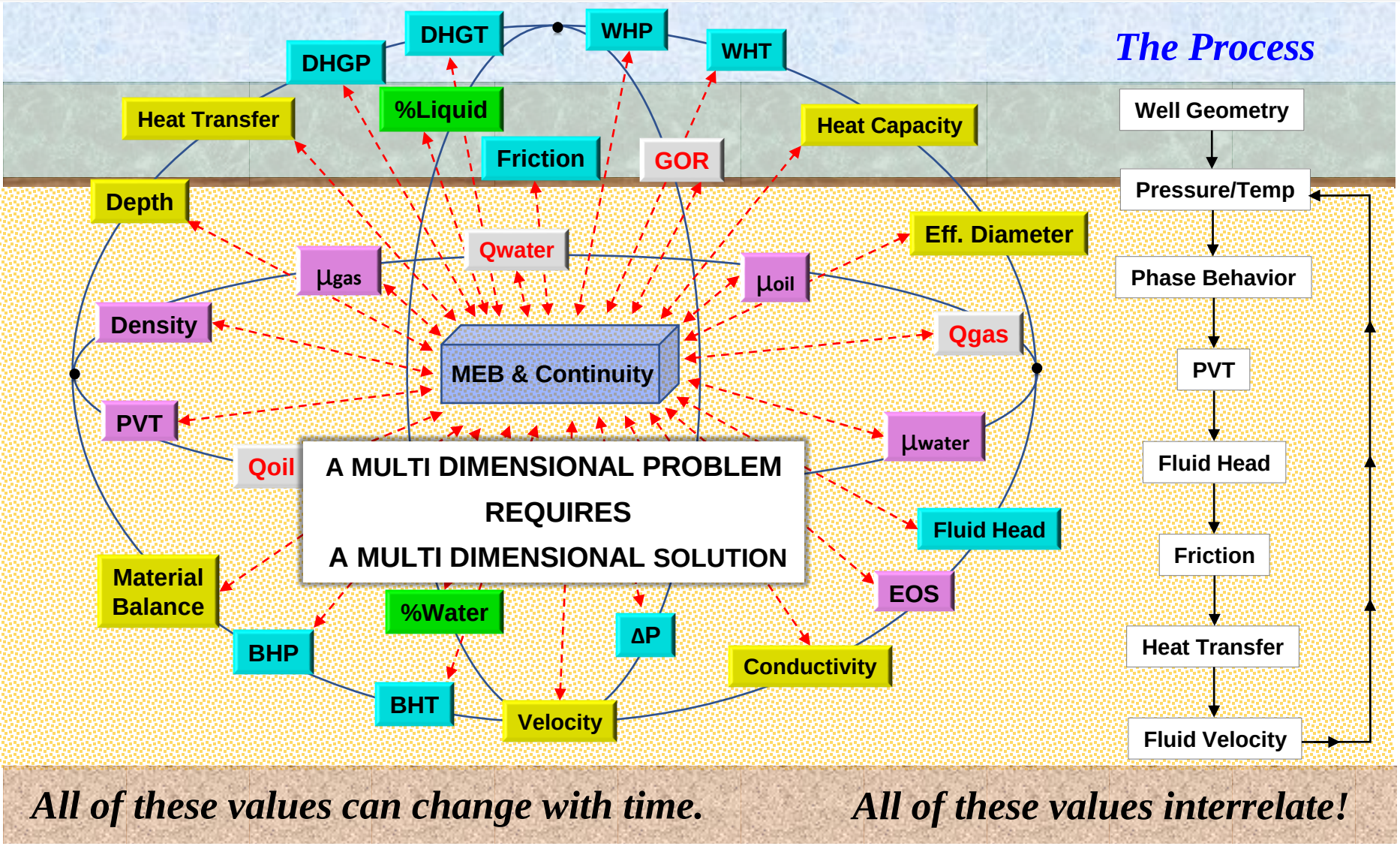
The wellbore model

- Accounts for dynamic temperature behavior
- Adjusts the fluid properties/PVT accordingly
- Performs wellbore flash calculations to determine the composition of the fluid in the wellbore

The wellbore flash calculations can be used to determine the water cut or GORs for oil wells and the condensate or water yield for gas wells

- Within 3 BBL/MMcf for Yield Cals (gas wells) and within 2% (percentage points, not absolute error) for water cuts

# ODSI's Wellbore Solution, a Brief Overview




*All of these values can change with time.*

*All of these values interrelate!*

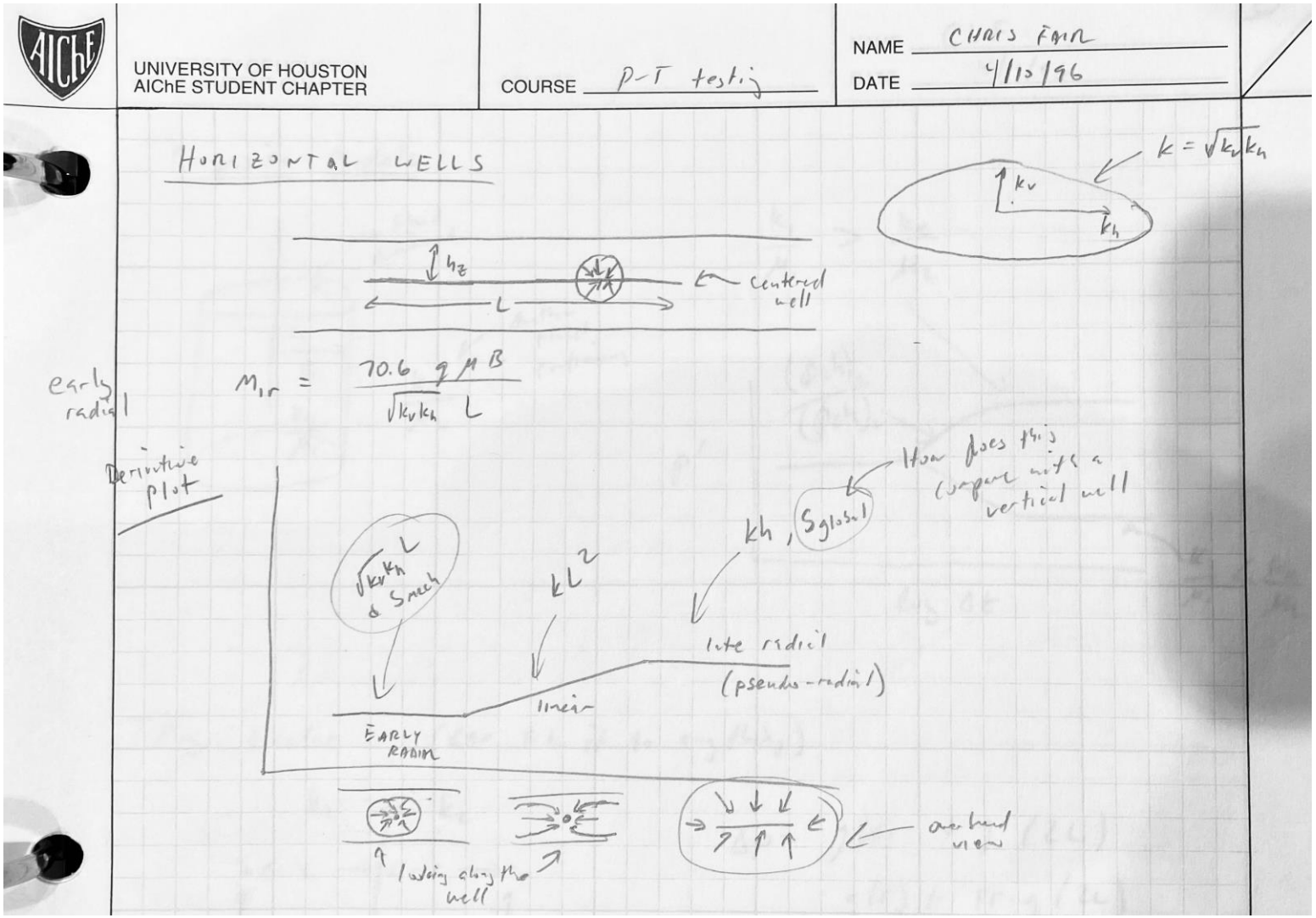
# ODSI's Workflow

- Build Well Model (Flow Path, Petrophysics, PVT)
- Tune Well Model with Dynamic Data
- Begin Running Auto-Analysis Features
  - Rate Calcs, BHPs, Auto-PTA, Static MBAL, Decline Analysis, etc.
- Determine Initial Condition of the Well/Reservoir
  - PTA Parameters, KPIs, Well Potential
  - Location (Time & Distance) and Types of Reservoir Boundaries (OWC)
  - Work with Subsurface Team to fine tune reservoir size/drainage volume
- Use Decline Analysis to Determine Drive Mechanism components and how they may be changing with time
- How are things changing? What does it mean?

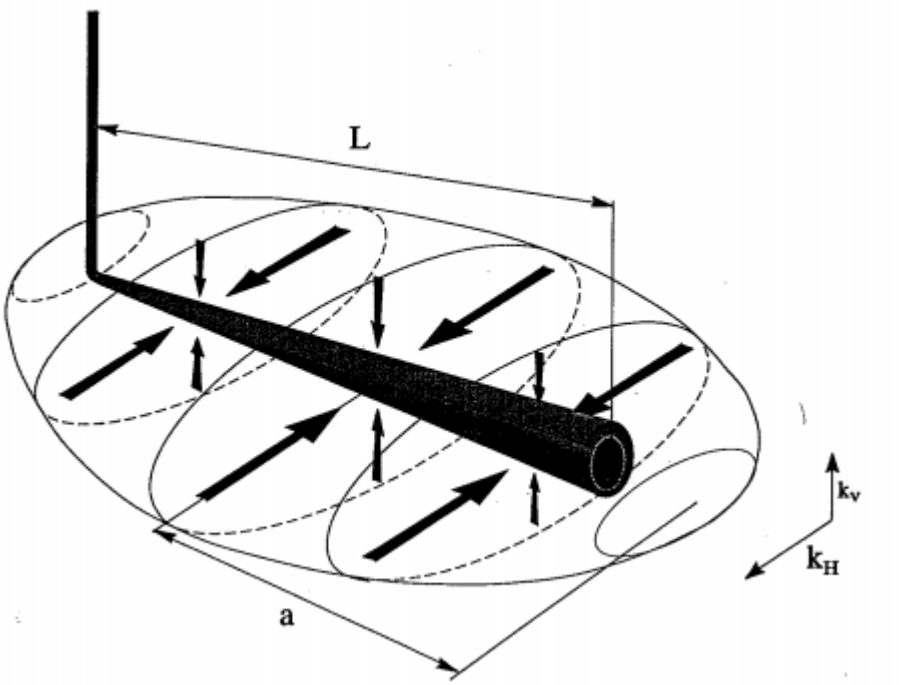
# A Quick Review of Conventional Horizontal Wells

## Flow Regimes & Order of Appearance

# Back in the Dark Ages…



# Conventional Horizontal Well Production




**Order Of Observation (Flow Regime)**

1) **Storage/Near Well "Afterflow"**
2) **1st Radial Flow**
3) **Linear Horizontal**
4) **Ellipsoidal Flow**
5) **2nd Radial Flow**
6) **Boundary Dominated Radial Flow**
7) **Transition to some form of Steady State Flow (SS, PSS, etc.)**

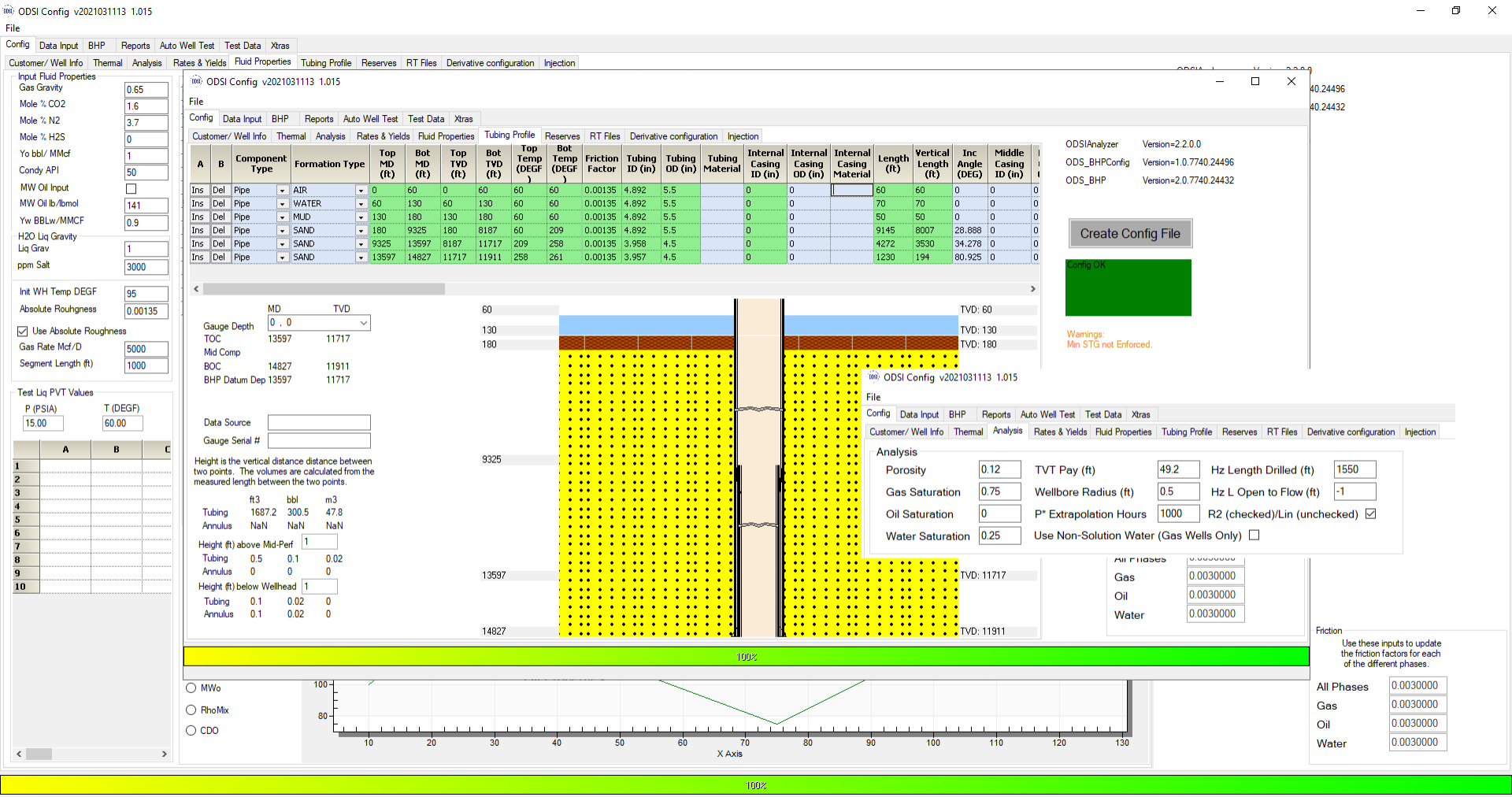
http://www.fekete.com/san/webhelp/welltest/webhelp/content/html_files/reference_materials/flow_regimes.htm#Linear_Horizontal_Flow

# General Issues with Horizontal Well Evaluation

- How much of the lateral is open to flow
- Where along the lateral is the flow coming into the well?
- How 'standard' is the flow regime response
  - First Radial
  - Linear/Channel Flow
  - **Second Radial** (**Circular** or Ellipsoidal?)
  - **Boundary Dominated Radial Flow**
  - **PSS/SS Flow**
  - Response to Resegregation, Re-Injection & Surge?
- Is there a way to evaluate the well performance with short-term data?

**Note: Bolded Regimes** are Almost the Same as a Vertical Well

# Horizontal Well Example



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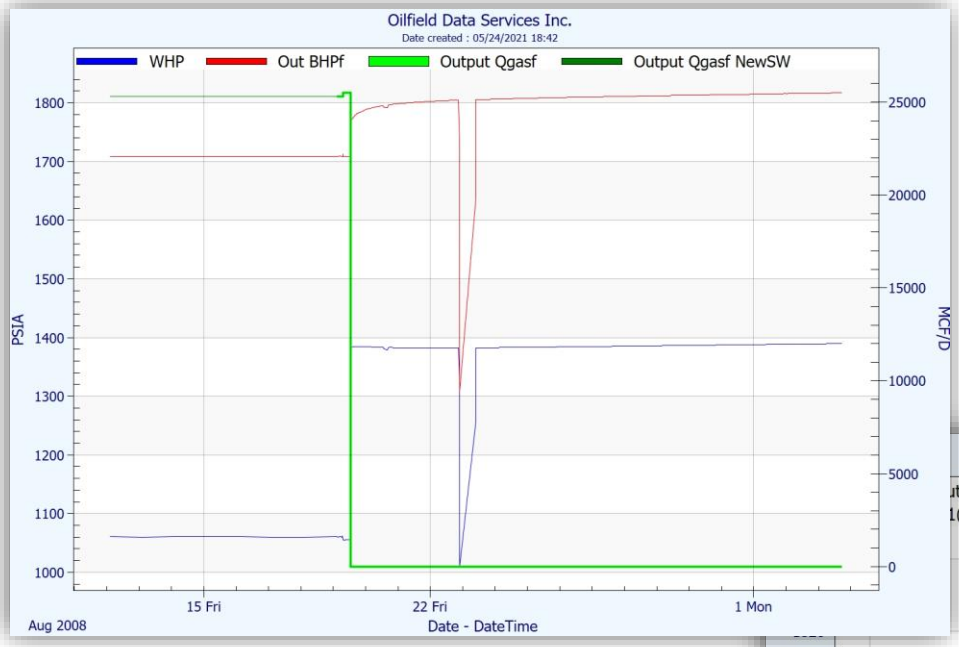
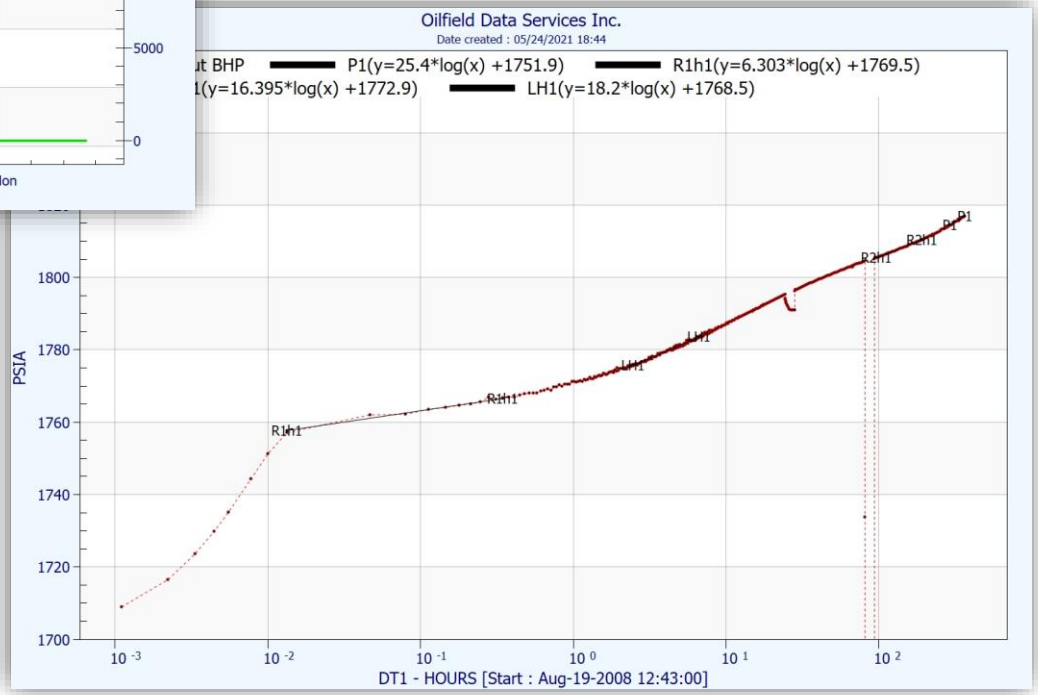
# A Textbook Horizontal Build-up (Yes, This is Real Data!)



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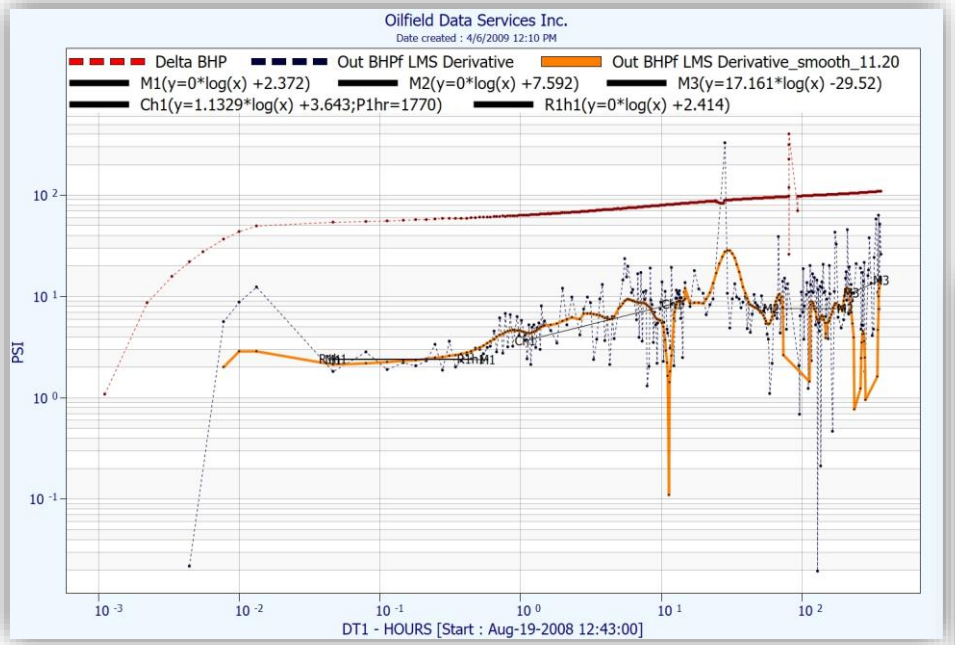
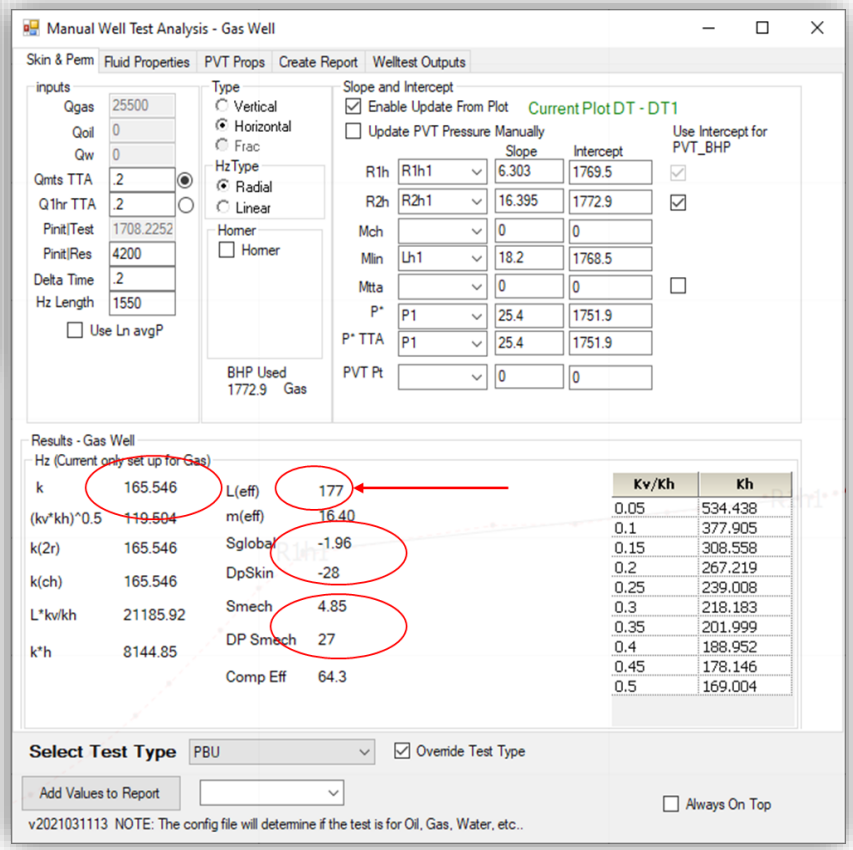
# Derivative Plot & Results



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# Hz Example Well – Automatic PTA

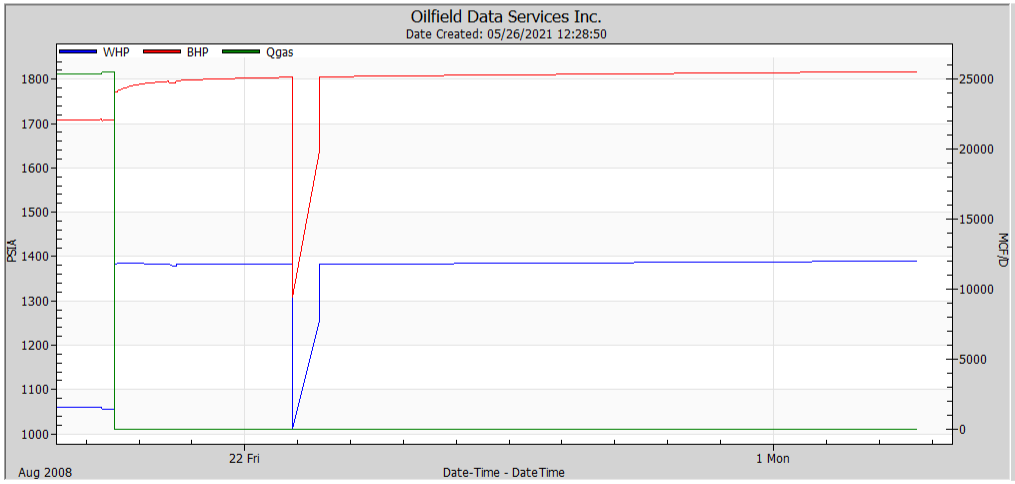
x64 (Pbp) ODSI-Well Analyzer - D:\WORK\RTS Demos - March 30 2016 sw\Horizontal Well Ex\May 24 2021 sw - Horizontal Well Example - North Sea.ProData - [Real Ti]

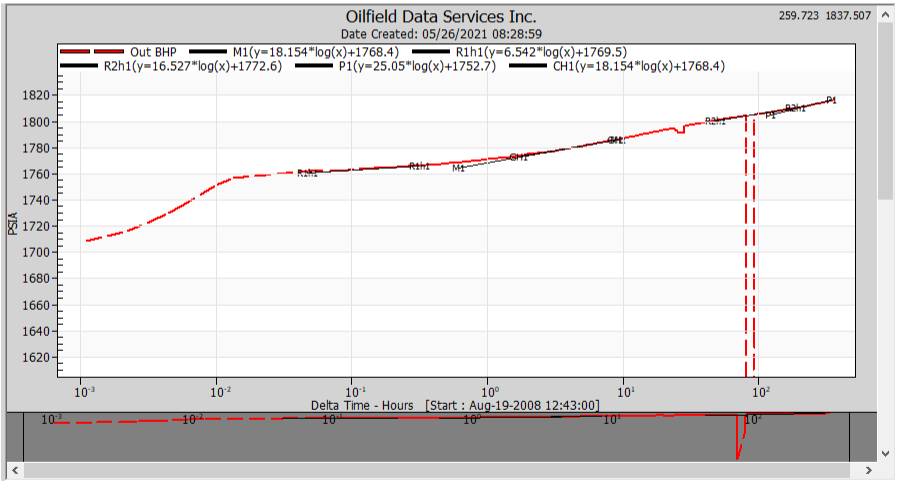
File Memory Analysis Plot View Tools Help Notes

Inputs Summary Outputs Reports

Summary PBU DD Derivative Daily Values PTA/ Productivity HC Volumes P/z OilWaterRates Analysis Events Analysis

| | Start D/T ddMmmyyyy hh:mm:ss | End D/T ddMmmyyyy hh:mm:ss | Test Length Hours | Test Type | WHPi psia | WHPf psia | DHGPi psia | DHGPf psia | BHPi psia | BHPf psia | QGasi Mcf/D | QGas Mcf/D | Perm md | Skin | DPskin psi | PStar psia | PI Eff % | DPs/Q psi/MMcf | kh/mu md-ft/cp | Report Link |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 19Aug2008 12:43:00 | 03Sep2008 17:24:00 | 364.68 | PBU | 1055 | 1390 | -1 | -1 | 1708 | 1817 | 25500 | 25500 | 164.7 | -2 | -29 | 1828 | 164 | -1.13 | NaN | ODSIRTRep_2008Aug19_124300 |




Finished. Valid Inputs 10930/10930

BHP/Analysis: Sep-03-2008 17:24:00 Samples Processed: 10930/10930

Processing Times:: Input: 20.7s Analysis: 6.6s MemoryColumns and UI: 9.1s Total: 32.7s

100%

100%

Go Pause Cancel

Ready v2021052614

12:29 PM 5/26/2021

# Auto PTA – Items from the PTA Report

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## ANALYSIS RESULTS

PBU Hz
Aug/19 - Sep/03/2008

### Calculated Reservoir & Completion Properties

| | | |
|---|---|---|
| GLOBAL SKIN | -2.0 | |
| DP GLOBAL SKIN | -29 | PSI |
| PI EFFICIENCY | 164.3 | MCF/PSI |
| MECHANICAL SKIN | 4.5 | |
| DP MECHANICAL SKIN | 26 | PSI |
| PERMEABILITY | 164.7 | md |
| Length of Drilled Horizontal Section | 1,550 | ft |
| Length of Horizontal Section Open to Flow | 179 | ft |

### Inputs for Calculated Results

| | | |
|---|---|---|
| GAS RATE PRIOR TO SHUT-IN | 25,500 | MCF/D |
| MID-TIME SLOPE (2nd Radial) | 16.53 | PSI/CYCLE |
| 1st SLOPE (1st Radial) | 6.54 | PSI/CYCLE |
| Linear Slope (Horizontal Length Dominant) | 18.15 | PSI/CYCLE |
| BHPwf | 1,708 | PSIA |
| BHP* (est. @T=1000hrs.) | 1,828 | PSIA |
| BHP 1hr (Psia) – 2nd Radial | 1,773 | PSIA |
| NET PAY (TVT) | 49 | FT |
| POROSITY | 12.0 | % |
| WATER SATURATION | 25.0 | % |
| WELL BORE RADIUS | 0.50 | FT |

Analysis Fluid Properties @ P=1,768.4 PSIA & T=261 DEGF

| | | |
|---|---|---|
| GAS FORMATION VOLUME FACTOR (Bg) | 1.907 | RB/MCF |
| SYSTEM COMPRESSIBILITY (Ct) | 433 | µsip |
| GAS VISCOSITY | 0.017 | cp |

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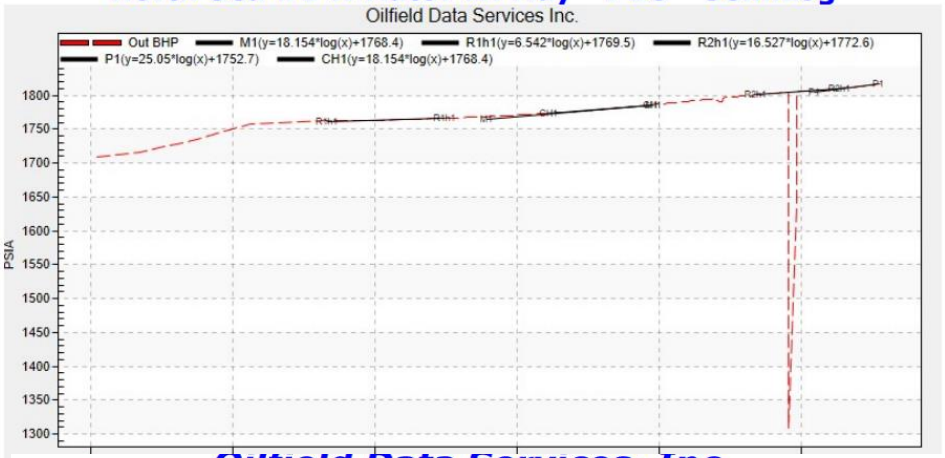
**North Sea #1 w AutoPTA May - PBU - SemiLog**

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**North Sea #1 w AutoPTA May - PBU - Derivative**

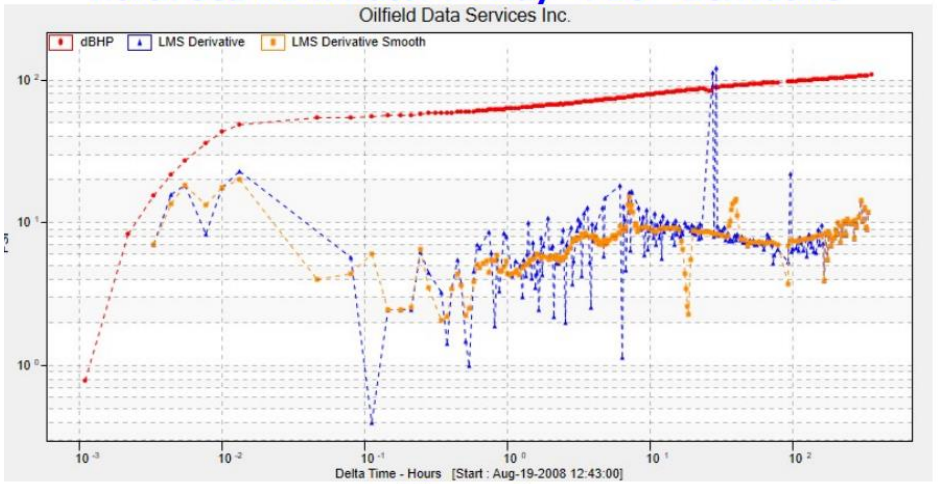
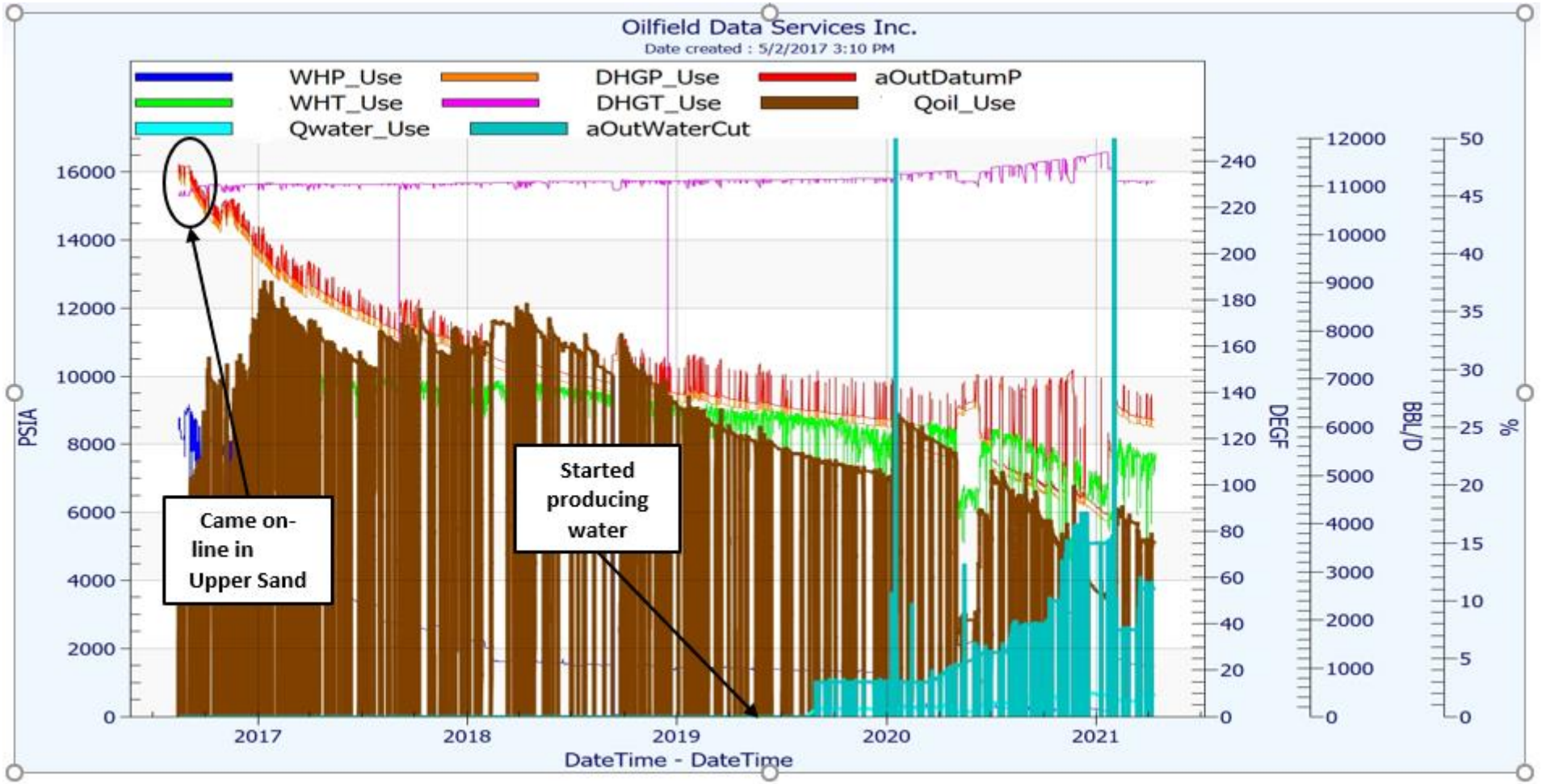



**Figure 9**

# Time-Lapse Auto PTA

- Automatically analyze every PBU and Drawdown (not just the PBUs that you have time to analyze)
- Get a Baseline Analysis – Teach the computer how to analyze the well
- See how things are changing (and think about the causes…and what you can do to fix it)!

# Time-Lapse Auto PTA – Production History



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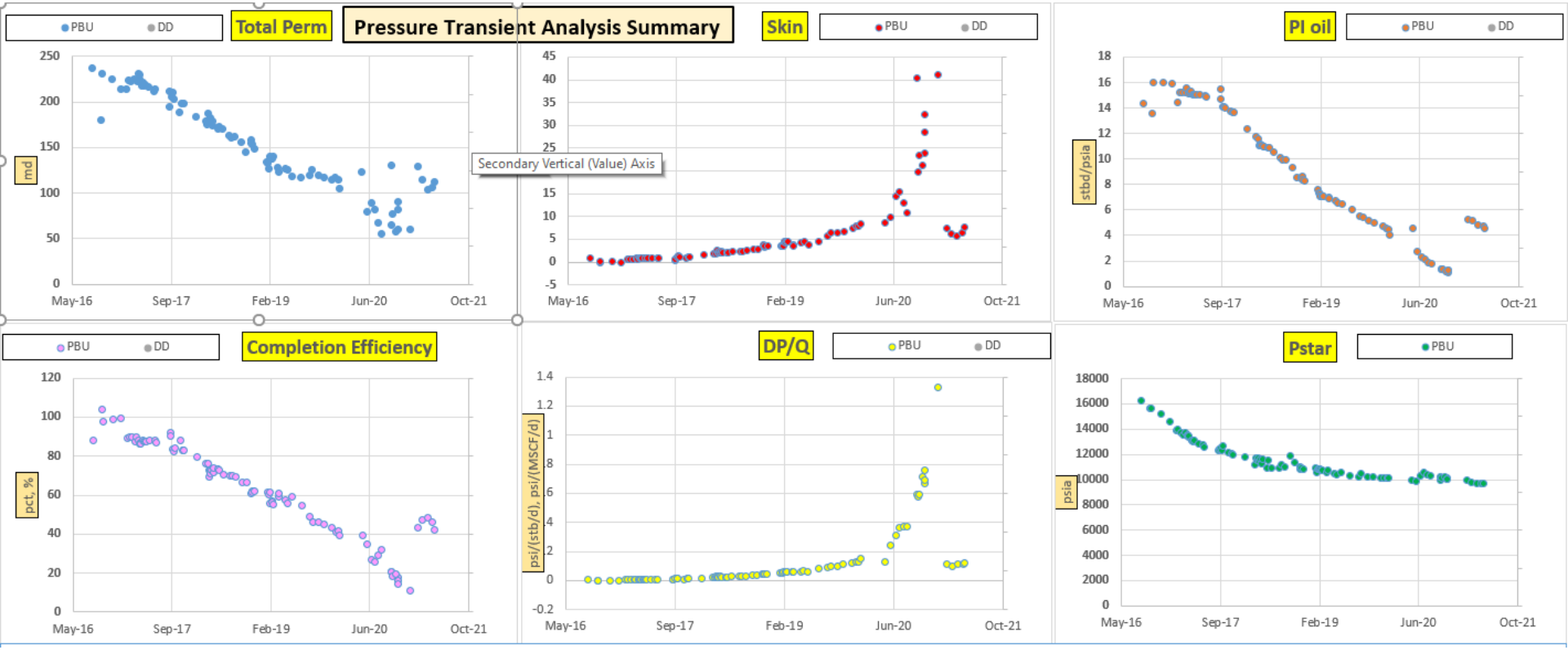
# PTA Dashboard – Accreting Skin Example

## What can a few simple plots tell you?



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# PTA Dashboard – Accreting Skin Example

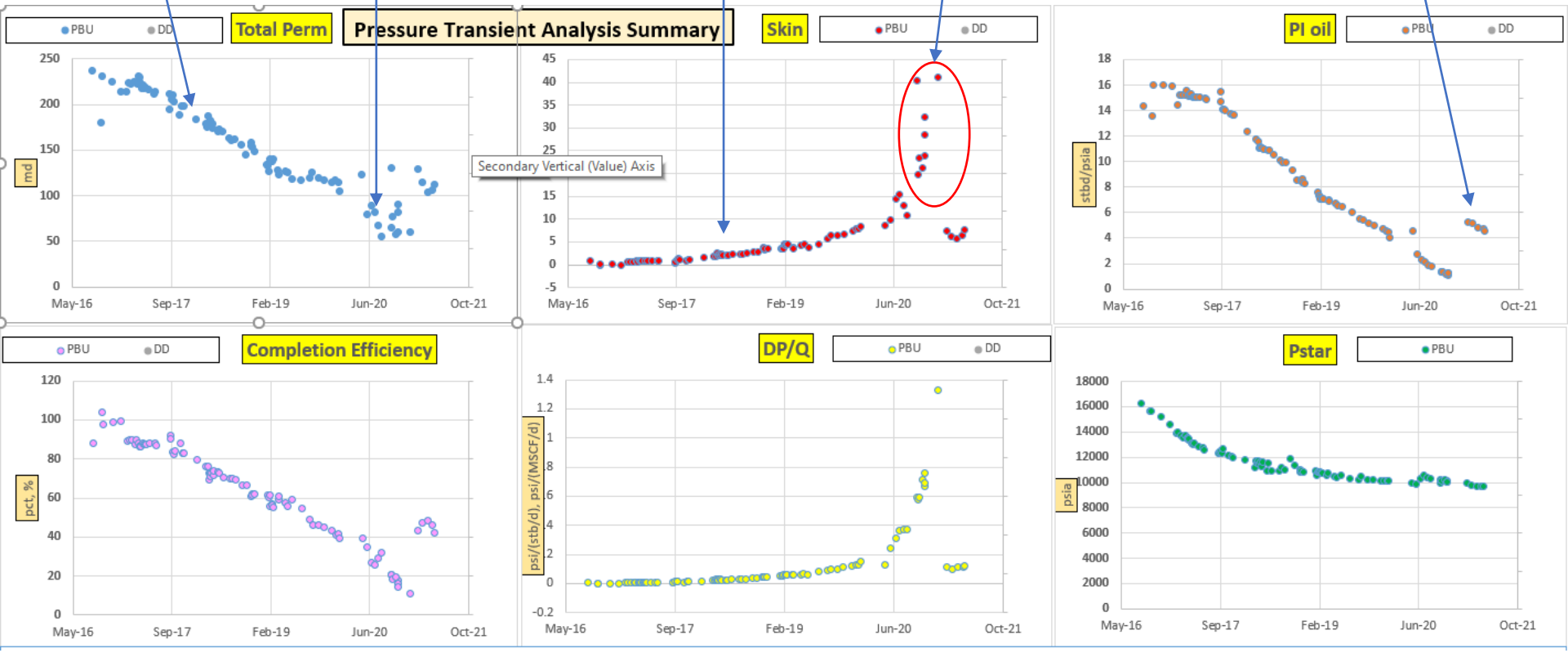
Compaction

Significant & Unexpected Decrease in Perm Asphaltenes?

Fines, meh!

Oh my!!! Better pump some xylene!

Post-stim job – Back to Normal



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# Well Analyzer – Case Study Outline

The following case studies will be shown to demonstrate Well Analyzer RTS's capabilities and benefits of the software installation and work process

Case Study 1

- Subsea Horizontal Oil Producer with H2O Injection

Case Study 2

- Horizontal Water Injector

Case Study 3

- Vertical Gas Injector

Case Study 4

- Multi-Phase Horizontal Producer (Oil, Gas & Water)

Case Study 5

- Multi-Zone Completion w/Weak Water Drive (Oil & Water)

# Case Study 1

## Horizontal Producer (w/H2O Inj) - North Sea

- **Equipped with:**
  - WHP and Downhole Gauges
  - MPFM
  - Injected Gas Lift Venturi


- **Objectives:**
  - Demonstrate WA's rate calculations
  - Perform diagnostic PTA
    - **Skin, Perm, P***
    - **Effective Length of Open Lateral**
  - Determine Likely Recoverable Oil

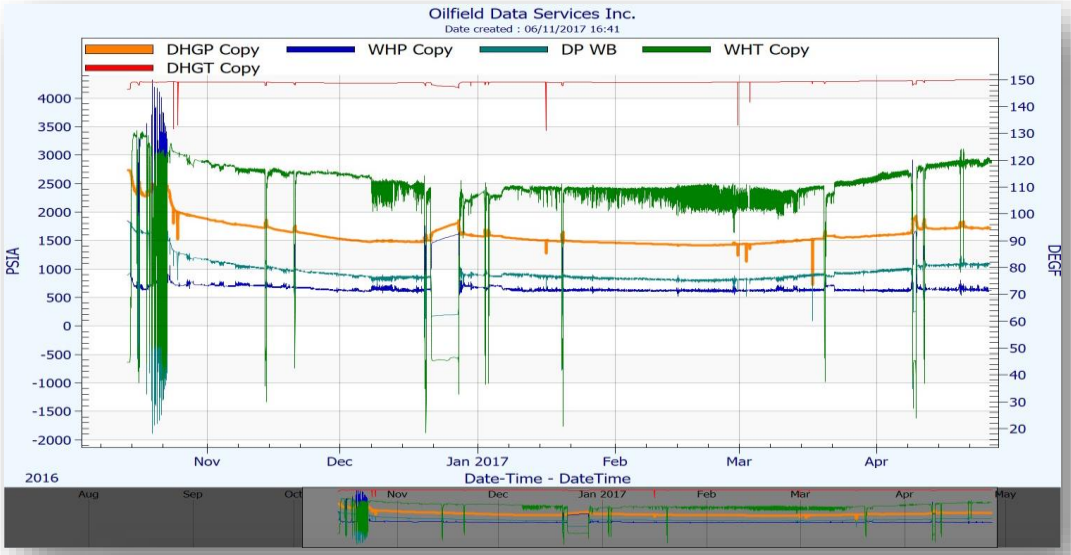
# Case Study 1: Real-Time System Inputs

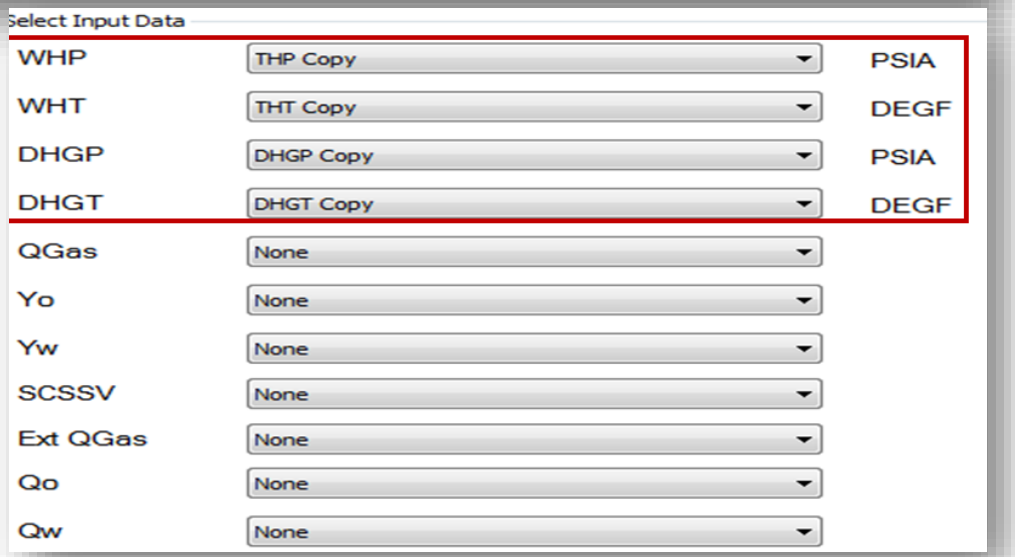
## Inputs

- WHP and WHT
- DHGP and DHGT

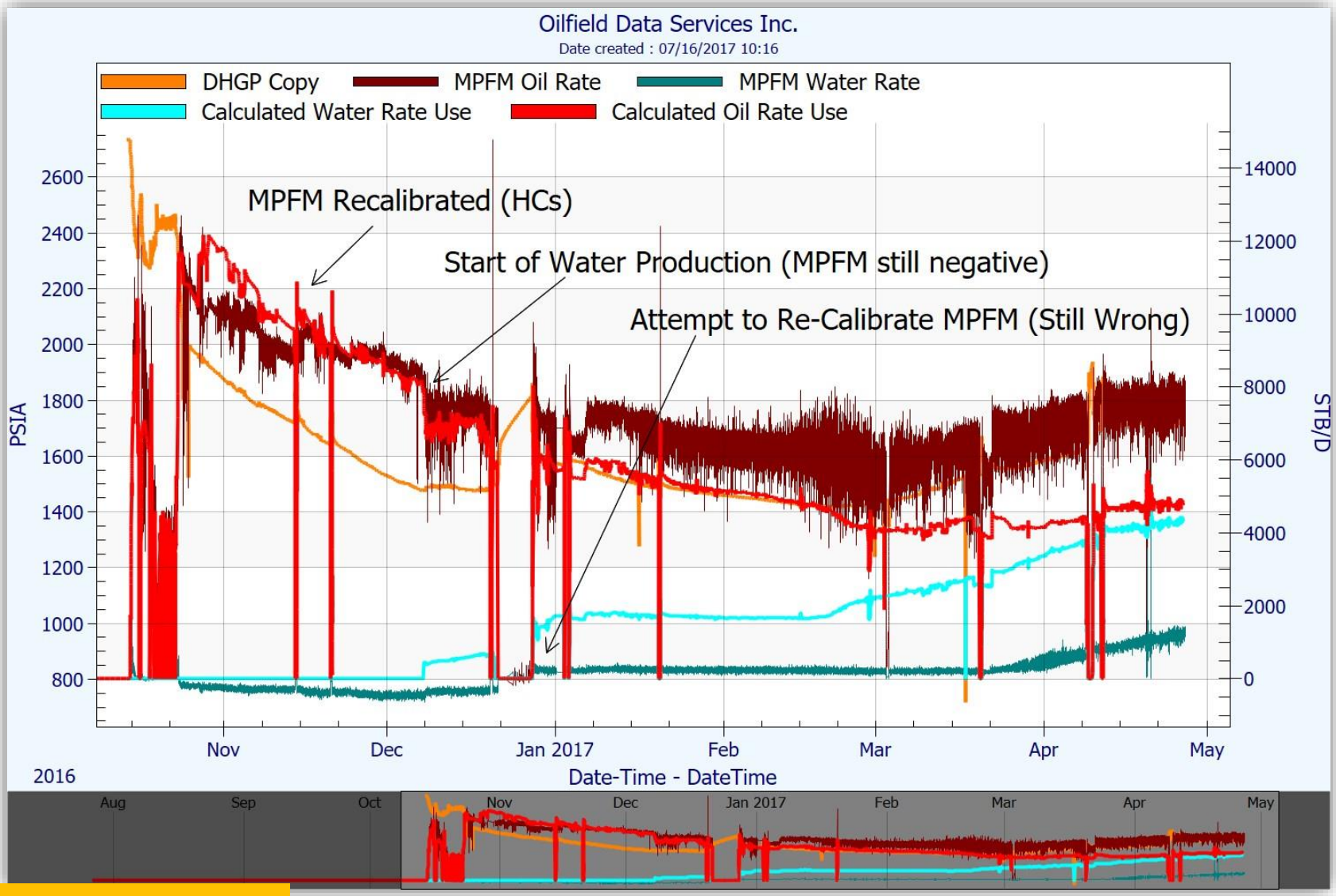
## RTS Outputs

- Oil & Water Rates
- Mid-completion BHP
- Auto-PTA interpretation
- Static MBAL
- Apparent Pushed Oil



# Case Study 1: Calculated vs. MPFM Rates



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# Case Study 1: Auto PTA Dashboard (only 2 good tests)

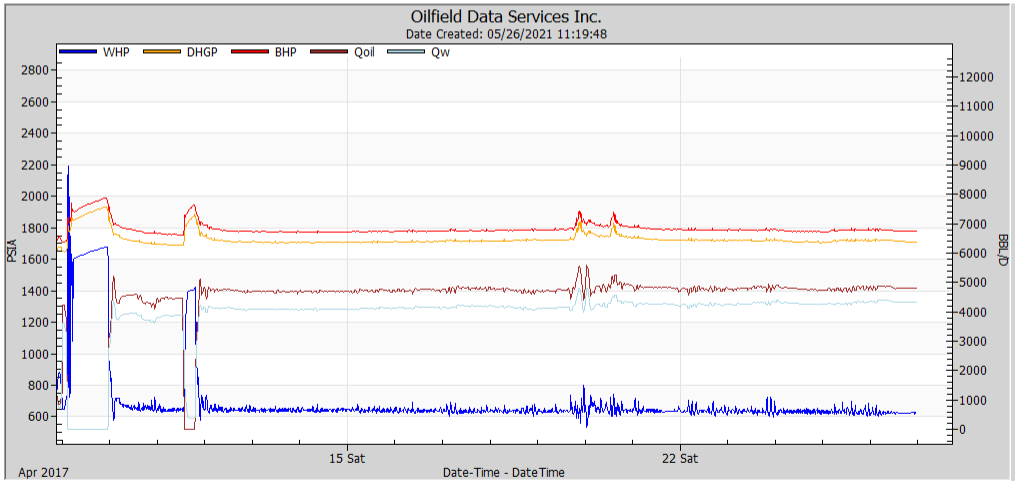
x64 (Pbp) ODSI-Well Analyzer - D:\WORK\RTS Demos - March 30 2016 sw\Horizontal Conventional Oil Producer.ProData - [Real Time Testing]

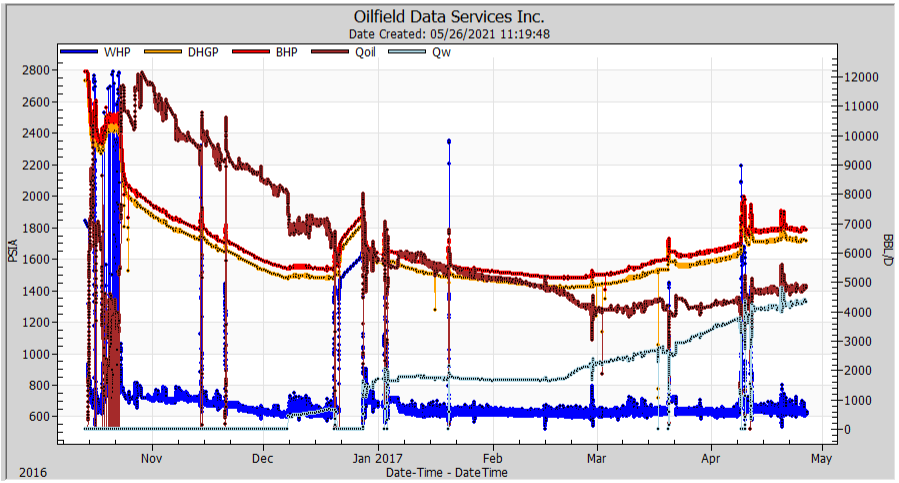
File Memory Analysis Plot View Tools Help Notes

Inputs Summary Outputs Reports

Summary PBU DD Derivative Daily Values PTA/Productivity HC Volumes 1Φ-MBAL OilWaterRates Analysis Events Analysis

| | Start D/T ddMmmyyyy hh:mm:ss | End D/T ddMmmyyyy hh:mm:ss | Test Length Hours | Test Type | WHPi psia | WHPf psia | DHGPi psia | DHGPf psia | BHPi psia | BHPf psia | Qoil_i BBL/D | Qoil BBL/D | Perm md | Skin | DPskin psi | PStar psia | PI Eff % | DPs/Q psi/BBL | kh/mu md-ft/cp | Report Link |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 14Oct2016 15:35:00 | 16Oct2016 07:55:00 | 40.33 | DD | 1815 | 741 | 2735 | 2403 | 2791 | 2462 | 0 | 7882 | 113 | -6.3 | -3252 | 1729 | 792 | -0.41 | NaN | ODSIRTRep_2016Oct14_153500 |
| 2 | 21Dec2016 11:40:00 | 27Dec2016 19:50:00 | 152.17 | PBU | 639 | 1490 | 1496 | 1707 | 1551 | 1761 | 5929 | 5929 | 633.2 | -5.2 | -338 | 2173 | 593 | -0.06 | NaN | ODSIRTRep_2016Dec21_114000 |
| 3 | 27Dec2016 19:45:00 | 28Dec2016 18:20:00 | 22.58 | DD | 1615 | 805 | 1818 | 1632 | 1873 | 1691 | 0 | 6448 | 3288.6 | 6.6 | 91 | 1584 | 52 | 0.01 | NaN | ODSIRTRep_2016Dec27_194500 |
| 4 | 09Apr2017 02:25:00 | 09Apr2017 23:15:00 | 20.83 | PBU | 792 | 1571 | 1672 | 1860 | 1732 | 1915 | 1070 | 1070 | 52.9 | -4.9 | -720 | 2285 | 1874 | -0.67 | NaN | ODSIRTRep_2017Apr09_022500 |
| 5 | 09Apr2017 23:15:00 | 11Apr2017 13:25:00 | 38.17 | DD | 1670 | 655 | 1927 | 1688 | 1982 | 1754 | 0 | 4370 | 502.9 | -4.4 | -274 | 1639 | 327 | -0.06 | NaN | ODSIRTRep_2017Apr09_231500 |




Finished. Valid Inputs 55582/56239

BHP/Analysis: Apr-26-2017 23:50:00 Samples Processed: 55582/55582

Processing Times:: Input: 6.3s Analysis: 67.1s MemoryColumns and UI: 11.7s Total: 74.0s

Go Pause Cancel

Ready v2021052614

11:20 AM 5/26/2021

# Case Study 1: Auto PTA

- WA **recognizes** new **transients in real-time** (buildups and drawdowns), **analyzes** them for skin, perm, Pres/P*, Productivity Index etc. and **generates a report** for each test
- The reports and the PTA summary table are stored on client's database

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## ANALYSIS RESULTS

PBU Hz
Dec/21 - 27/2016

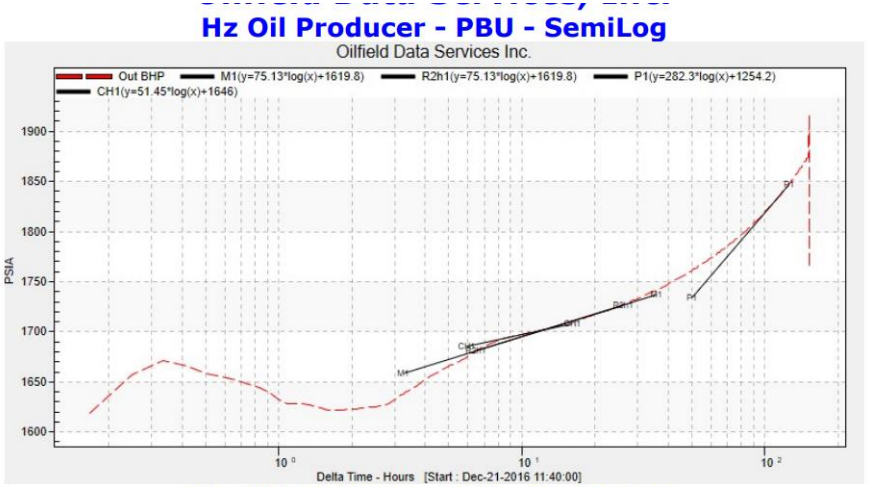
### Calculated Reservoir & Completion Properties

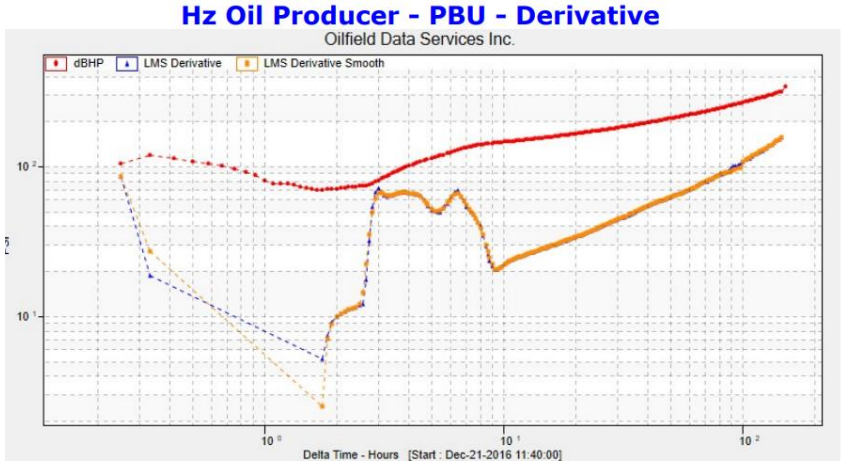
| | | |
|---|---|---|
| GLOBAL SKIN | -5.2 | |
| DP GLOBAL SKIN | -338 | PSI |
| PI EFFICIENCY | 593.3 | STB/PSI |
| MECHANICAL SKIN | ---- | |
| DP MECHANICAL SKIN | --- | PSI |
| PERMEABILITY | 633.2 | md |
| Length of Drilled Horizontal Section | 1,300 | ft |
| Length of Horizontal Section Open to Flow | 666 | ft |

1st Radial Flow not observed

### Inputs for Calculated Results

| | | |
|---|---|---|
| OIL RATE PRIOR TO SHUT-IN | 5,929 | STB/D |
| GAS RATE PRIOR TO SHUT-IN | 1,542 | MCF/D |
| MID-TIME SLOPE (2nd Radial) | 75.13 | PSI/CYCLE |
| 1st SLOPE (1st Radial) | ---- | PSI/CYCLE |
| Linear Slope (Horizontal Length Dominant) | 51.45 | PSI/CYCLE |
| BHPwf | 1,551 | PSIA |
| BHP* (est. @T=1800hrs.) | 2,173 | PSIA |
| BHP 1hr (Psia) – 2nd Radial | 1,620 | PSIA |
| NET PAY (TVT) | 115 | FT |
| POROSITY | 25.0 | % |
| WATER SATURATION | 16.0 | % |
| WELL BORE RADIUS | 0.35 | FT |
| Analysis Fluid Properties @ P=1,619.8 PSIA & T=152 DEGF | | |
| OIL FORMATION VOLUME FACTOR (Bo) | 1.135 | (RB/STB) |
| OIL VISCOSITY | 5.00 | cp |






- ✓ Oil & Gas Reservoir Testing and Evaluation
- ✓ Real-Time Pressure Transient Analysis
- ✓ Hydrocarbon Volume Determination
- ✓ Well(s) Performance Tracking
- ✓ Multiphase Rate & BHP Calculations
- ✓ Optimize Gas Lift / Oil Production Rates
- ✓ Life Of Well Surveillance/Analysis
- ✓ Automated PVT Calibration

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# Case Study 1: Auto Well Test Example (Different Well)

- PTA Summary Table as well as individual well test reports will be stored on client's database
- Please click on the **'Report Link'** to view automatically generated individual PTAs

| Date-Time | Test Lengh | Test Type | BHPi | BHPf | Qgasi | Qgasf | Perm | Skin | DP Skin | P* | PI | PI Eff | Report Link |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| mm/dd/yyyy | hrs | | psia | psia | MCF/D | MCF/D | md | | psia | psia | MCF/PSI | % | |
| 3/14/2015 6:35 | 482 | 2-Rate DD | 4179 | 4086 | 56230 | 92225 | 447.1 | 5.2 | 27 | 4043 | 1402.7 | 59 | |
| 4/11/2015 23:15 | 13.75 | PBU | 4041 | 4135 | 116610 | 116610 | 228.9 | -1.3 | -17 | 4208 | 1567.6 | 123 | |
| 4/25/2015 21:20 | 9.08 | PBU | 4035 | 4127 | 111695 | 111695 | 226.9 | -1.6 | -20 | 4181 | 1646.3 | 130 | |

# Case Study 1: Running Productivity Index

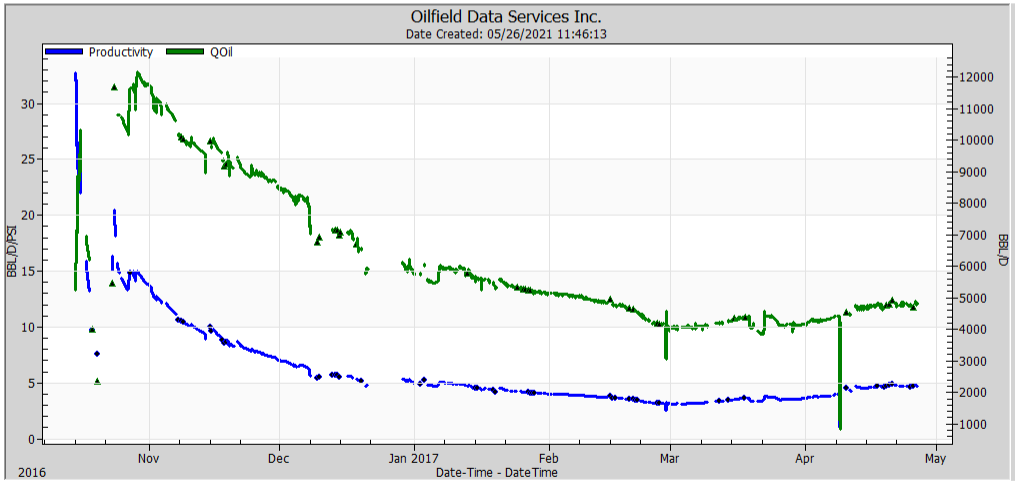
x64 (Pbp) ODSI-Well Analyzer - D:\WORK\RTS Demos - March 30 2016 sw\Horizontal Conventional Oil Producer.ProData - [Real Time Testing]

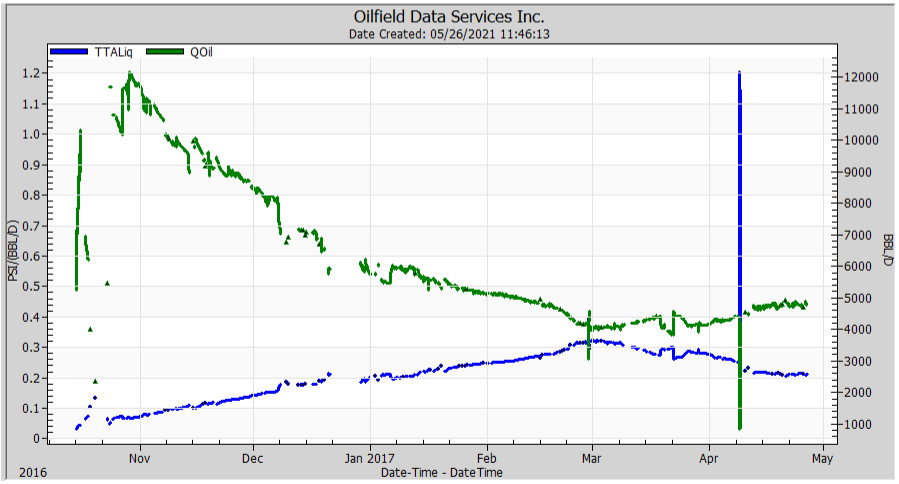
File Memory Analysis Plot View Tools Help Notes

Inputs Summary Outputs Reports

Summary PBU DD Derivative Daily Values PTA/ Productivity HC Volumes 1Φ-MBAL OilWaterRates Analysis Events Analysis

| | | |
|---|---|---|
| Initial Pres (PSIA) | 2800 | |
| Last PBU DPskin/Q (PSI/(BBL/D)) | -.67 | 04/09/2017 23:15:00 |
| Last DD DPskin/Q (PSI/(BBL/D)) | -.06 | 04/11/2017 13:25:00 |
| Last P* (PSIA) | 2328 | 04/09/2017 23:15:00 |
| Last Productivity Q/DP (BBL/D/PSI) | 4.70 | 04/26/2017 23:50:00 |
| Last TTA (PSI/(BBL/D)) | 0.21 | 04/26/2017 23:50:00 |




Finished. Valid Inputs 55582/56239

BHP/Analysis: Apr-26-2017 23:50:00 Samples Processed: 55582/55582

Processing Times:: Input: 7.5s Analysis: 60.2s MemoryColumns and UI: 8.5s Total: 66.7s

100%
100%

Go Pause Cancel

Ready v2021052614

11:46 AM 5/26/2021



- ✓ Oil & Gas Reservoir Testing and Evaluation
- ✓ Real-Time Pressure Transient Analysis
- ✓ Hydrocarbon Volume Determination
- ✓ Well(s) Performance Tracking
- ✓ Multiphase Rate & BHP Calculations
- ✓ Optimize Gas Lift / Oil Production Rates
- ✓ Life Of Well Surveillance/Analysis
- ✓ Automated PVT Calibration

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# Case Study 1: Static MBAL (Before Injection) and Apparent Oil Volumes

x64 (Pbp) ODSI-Well Analyzer - D:\WORK\RTS Demos - March 30 2016 sw\Horizontal Conventional Oil Producer.ProData - [Real Time Testing]

File Memory Analysis Plot View Tools Help Notes

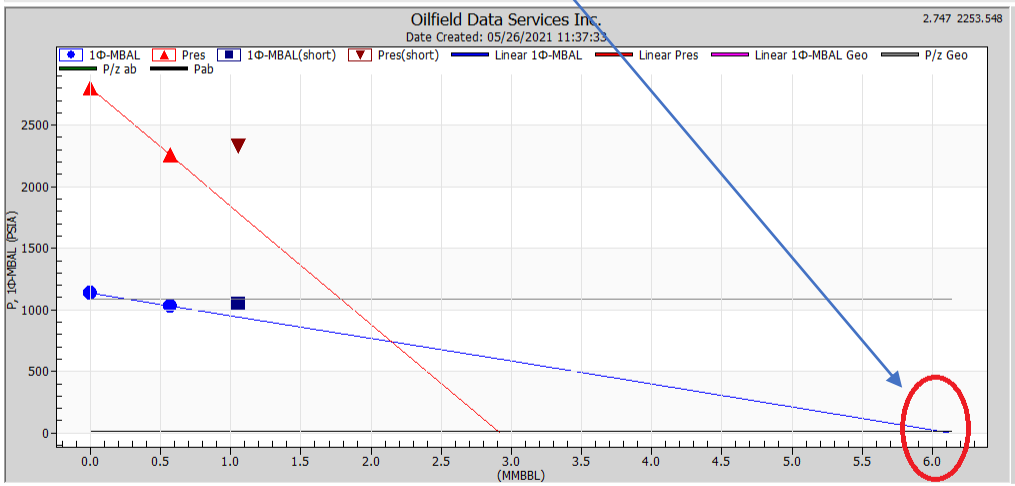
Inputs Summary Outputs Reports

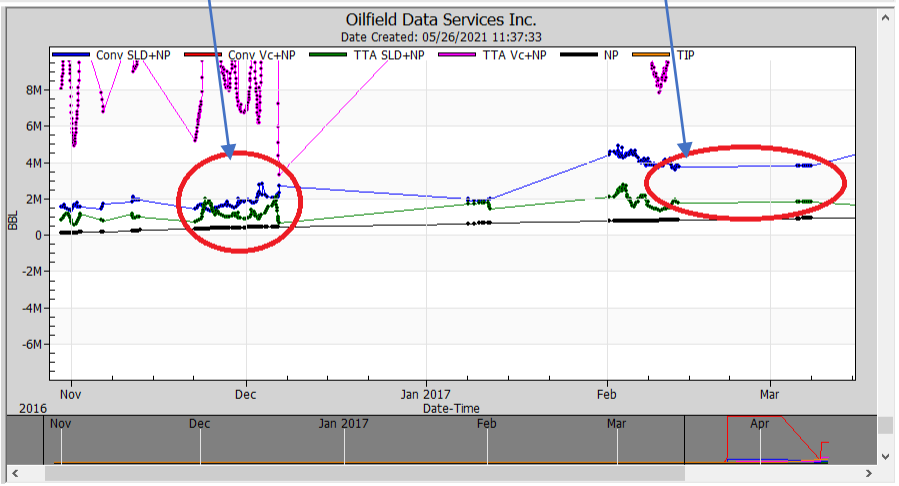
Summary PBU DD Derivative Daily Values PTA/ Productivity HC Volumes 1Φ-MBAL OilWaterRates Analysis Events Analysis

| Date Time | Oil Produced | PBU Duration | Pres | z-Factor | 1Φ-MBAL | OIP SLD @P=0 | OIP SLD @P\|ab=1 | OIP 1Φ-MBAL @P=0 | OIP 1Φ-MBAL @ab=15 | OIP 1Φ-MBAL geo @P=0 | OIP 1Φ-MBAL geo @ab=15 | m Pres | m 1Φ-MBAL | m 1Φ-MBAL G |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MM/dd/yyyy HH:mm:ss | MMBBL | HOURS | PSIA | dimless | PSIA | MMBBL | MMBBL | MMBBL | MMBBL | MMBBL | MMBBL | PSIA/MMBBL | PSIA/MMBBL | PSIA/M |
| 01/01/0001 00:00:0 | 0.000 | | 2800 | 2.457 | 1139.6 | | | | | | | | | |
| 12/27/2016 19:50:0 | 0.569 | 152 | 2255 | 2.180 | 1034.1 | 2.9 | 2.9 | 6.1 | 6.1 | | | -958.7 | -185.5 | |
| 04/09/2017 23:15:00 | 1.058 | 21 | 2328 | 2.218 | 1049.66 | 2.9 | 2.9 | 6.1 | 6.1 | | | -958.7 | -185.5 | |

6.1 MM STBo In-Place Before Injection Started

1-2 MM STBo Recoverable before Inj
2-4 MM STBo Recoverable after Inj




Finished. Valid Inputs 55582/56239
BHP/Analysis: Apr-26-2017 23:50:00 Samples Processed: 55582/55582
Processing Times:: Input: 7.5s Analysis: 60.2s MemoryColumns and UI: 8.5s Total: 66.7s

100%
100%

Go Pause Cancel

Ready v2021052614

11:38 AM 5/26/2021

# Case Study 1: Results

- The difference between ODSI's calculate rates and the MFPM rates was due to improper calibration of the MPFM
- High Perm; Highly Stimulated Global Skin
- Only Half of the Lateral is Open to Flow

- 6.1 MM STBo In Place
- 1-2 MM STBo Recoverable Without/Before Injection
- 2-4 MM STBo Recoverable After Water Injection

- Recovery values are best refined using corrected rates and BHPs in a reservoir simulator

# Case Study 1: Summary

- ✓ Accurate Rate calculation using pressure drop in the wellbore
  - ✓ Gas rate
  - ✓ Oil Rate
  - ✓ Water Rate
  - ✓ Allocation error detection
- ✓ Auto PTA and Reservoir Evaluation
  - ✓ Skin, Perm & Length of Open Lateral
  - ✓ Static MBAL (In-Place)
  - ✓ Pre- and Post-Injection Recoverable Volume Range

Well Analyzer's Rate and BHP calculations are **based on a direct solution** to the Mechanical Energy Balance and NOT VLP correlations; The solution provides accurate results as it simultaneously accounts for **frictional and PVT changes**

# Case Study 2

## Water Injector- North Sea

- Equipped with
  - WHP and Downhole Gauges
  - Flowmeter
- **Objectives:**
  - Demonstrate WA's wellbore calculations
  - Perform diagnostic PTA
  - Recommend remedial procedures (drop acid!); confirm the results of the stim job

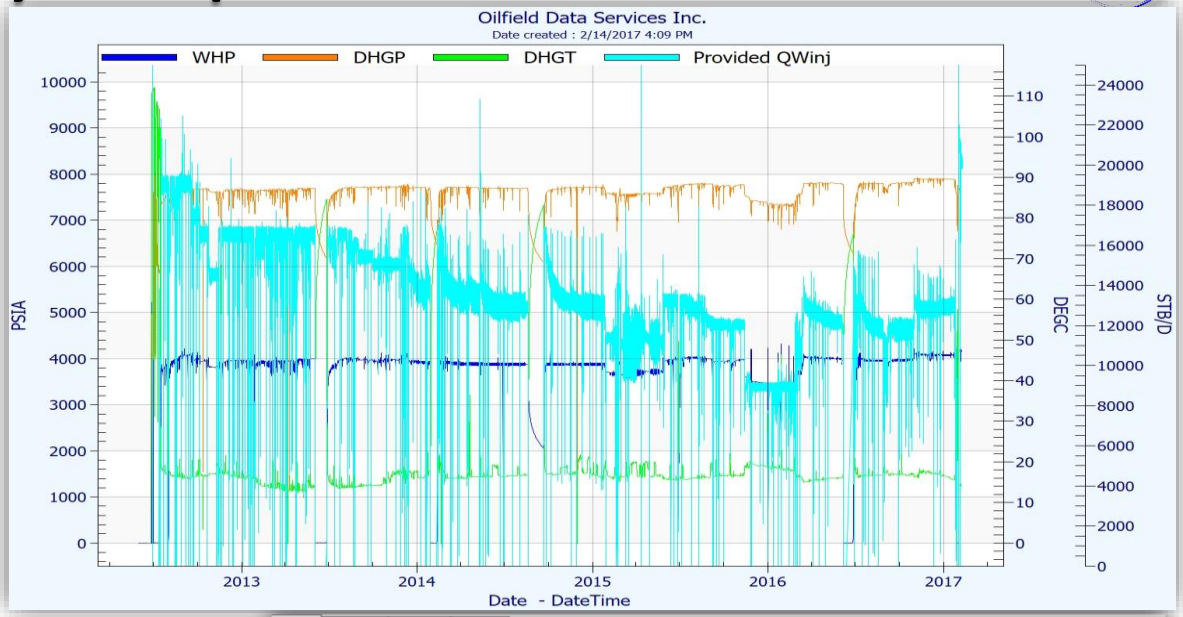
# Case Study 2: Real-Time System Inputs

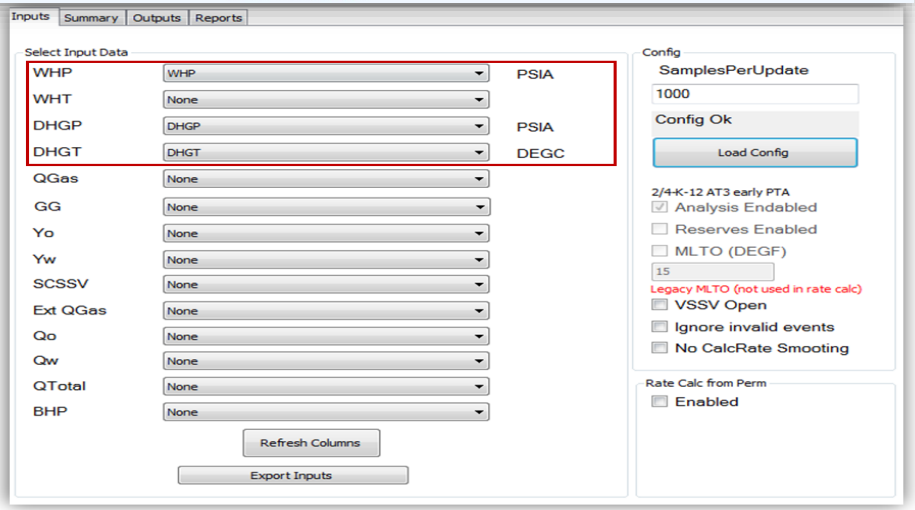
## Inputs

- WHP and WHT
- DHGP and DHGT

## RTS Outputs

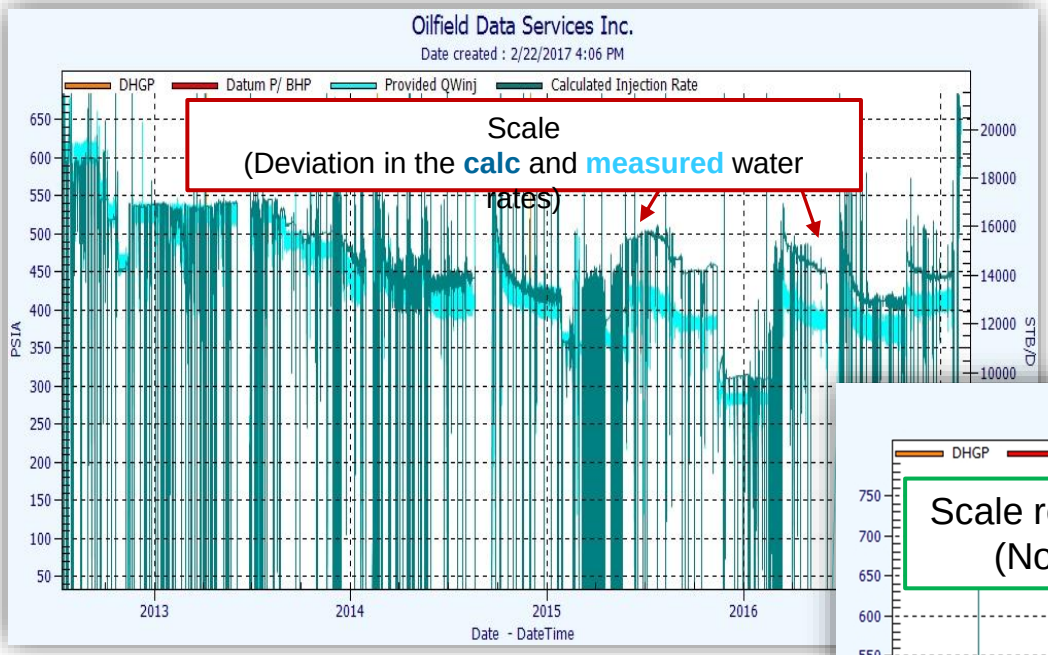
- Water Rates
- Mid-completion BHP
- Diagnostic Auto-PTA



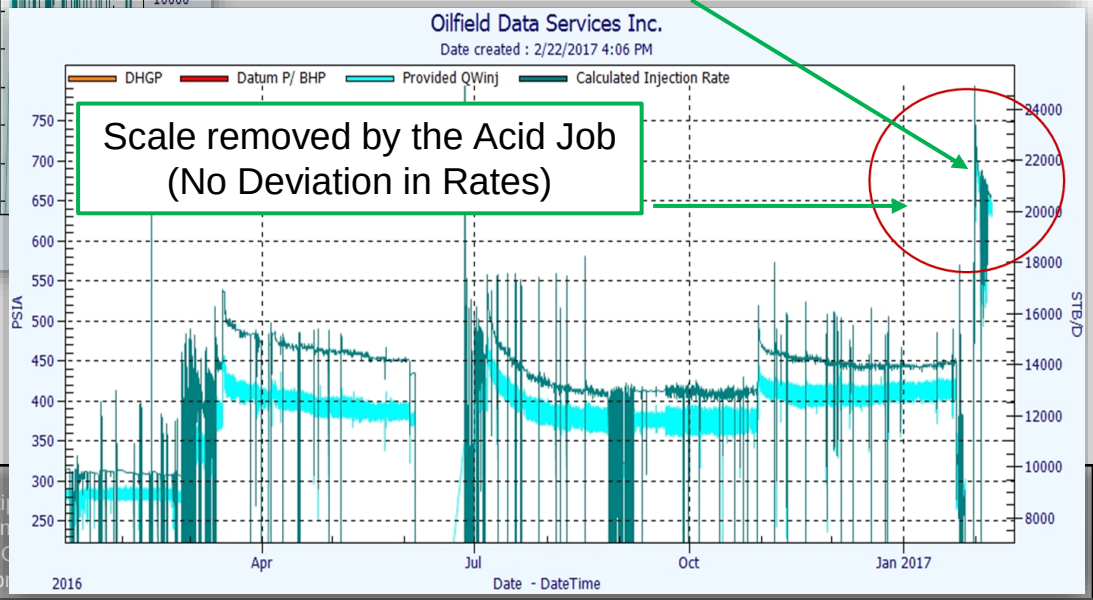



# Case Study 2: Results

- Spot water rates were calculated from dP wellbore
  - ODSI's numerical integration to Mechanical Energy Balance eq.
- Deviation between the measurement and the calculation is indicative of **scale** (additional frictional pressure drop in the wellbore)



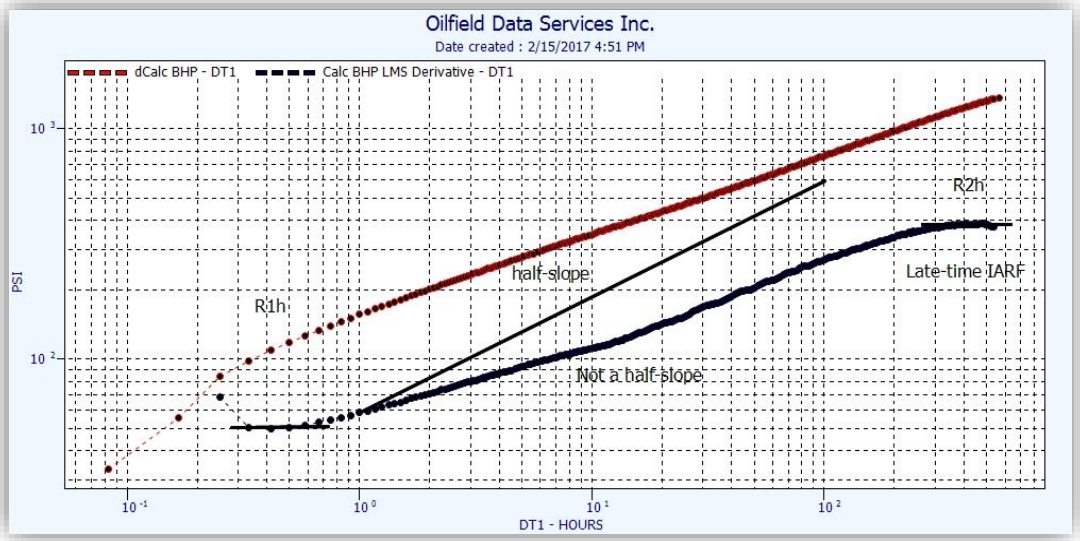

- Scale was removed by the acid job
- The measured and calculated rates matched again
- The method helped the operator to recognize successful stim job



# Case Study 2: Diagnostic PTA

- From data QA/QC process, it was determined that the well had an unusual flow regime based on the derivative response, therefore, PTA was performed for both early and late time radial flow

- Early-time IARF: 0.2 ~ 0.9 hrs
- Late-time IARF: 300 ~ 400 hrs




- Upon client's, automated PTA was performed using both the measured and the calculated rates for the comparison purposes
- Therefore, there were a total of 4 sets of PTA results:
  - Early-time IARF with calculated rates
  - Late-time IARF with calculated rates

  - Early-time IARF with measured rates
  - Late-time IARF with measured rates



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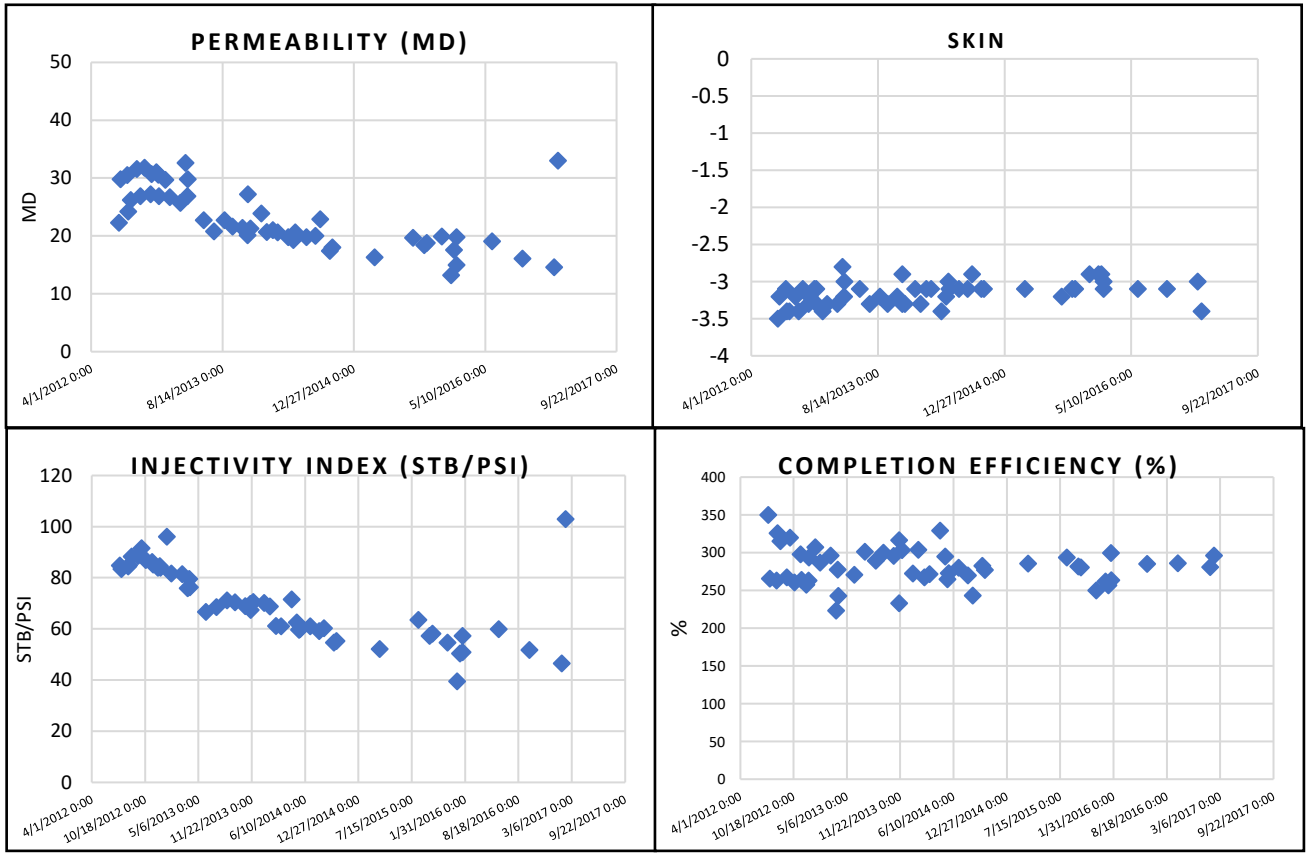
# Case Study 2: Diagnostic PTA (Early-Time PTA)

## Injectivity and Injection Fall-Off Tests



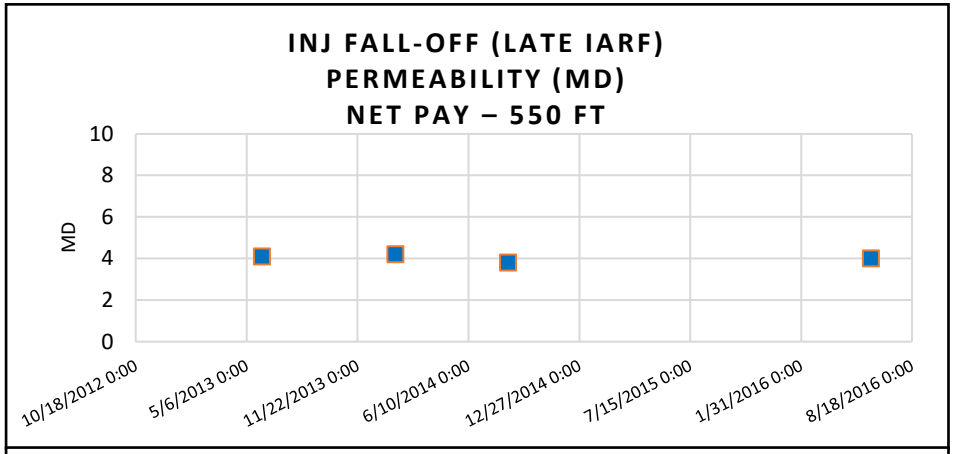

- **Each Fall off and Injection test** are analyzed for diagnostic PTA parameters in real-time
- A **report** is generated for each test
- **Historic PTA** tables and plots are updated every time there is a new test
- **'Notification/Alarm'** tags are outputted if skin/perm reaches a certain 'reg flag' value (customized per well)

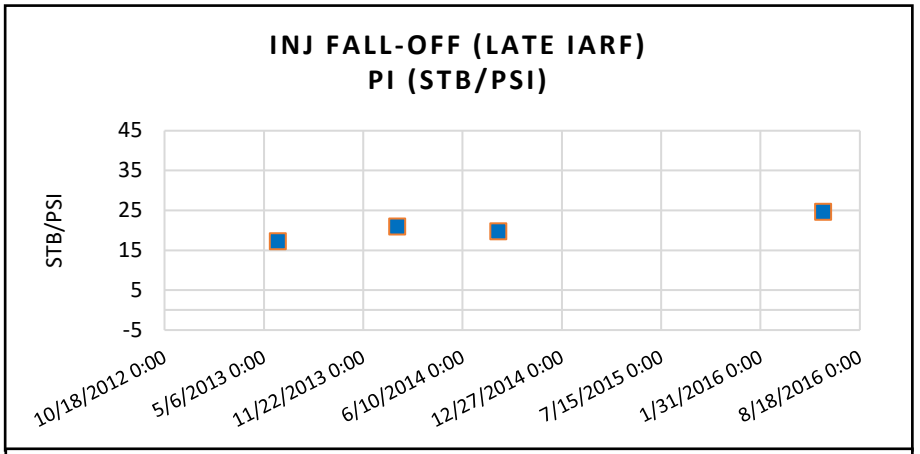
- Gradually decreasing injectivity index with time (scale buildup)
  - 120 % increase in the injectivity index after the stim job
- If the software was running in real-time on client's server, the Operator could have detected the scale immediately and performed the stim job 2 years earlier

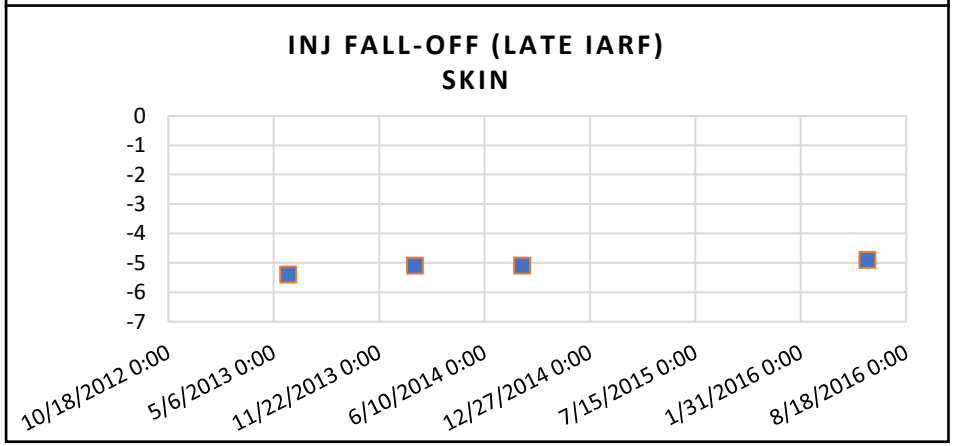
# Case Study 2: Diagnostic PTA (Early-Time PTA)

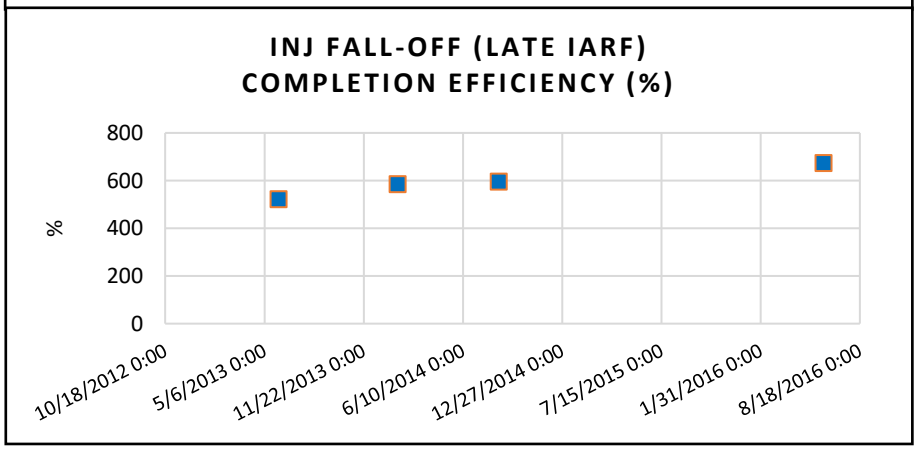
## Injectivity and Injection Fall-Off Tests

- Late IARF was observed at around ~ 300 hrs
- During 4.5 years, there were only 4 PBUs of sufficient duration to 'see' late IARF




- **No indication of scale or performance degradation from the proper PTA interpretation**
  - **No changes in skin, perm, PI in the reservoir**
  - **No indications of scale implying the scale is near the wellbore or in the tubing**

# Case Study 2: Conclusions

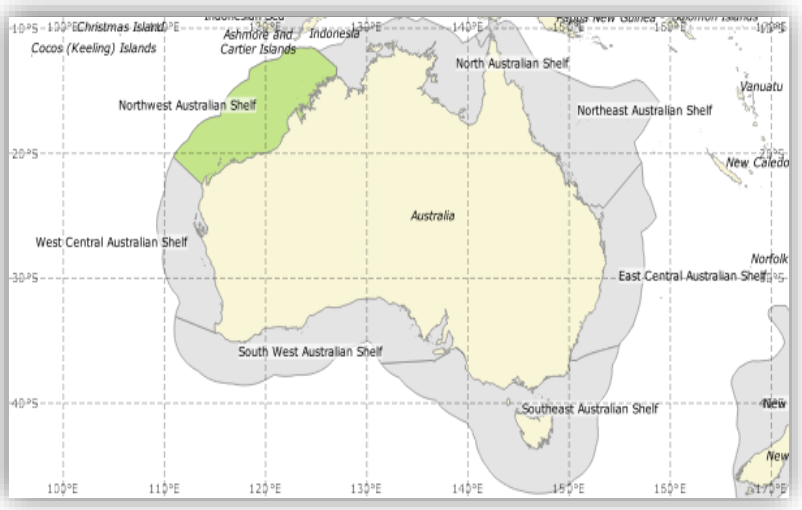
- ODSI calculated rates matched the measured rates accurately until the well started to scale in the well bore (and in the completion)
- The deviation between measured and the calculated rates was indicative of additional pressure drop in the wellbore
- Scale build-up caused additional friction in the wellbore
- Diagnostic early-time (near-wellbore) PTA confirmed scale buildup in the tubing

- The software helps to detect errors in Allocations and to diagnose changes in well's performance!

# CASE STUDY 3

## Gas Injector – Onshore Australia

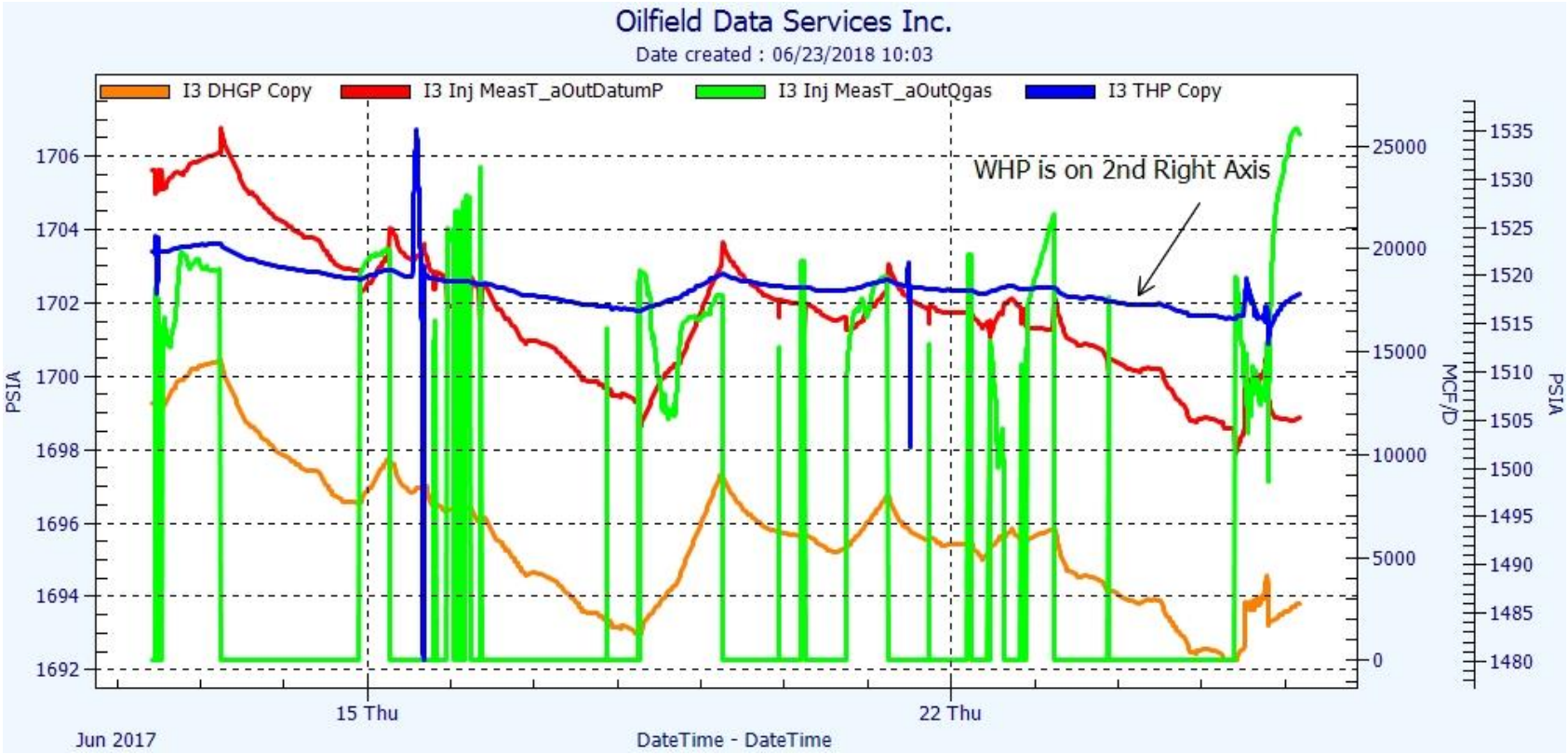
- Gas Storage
  - Well Equipped with tree and downhole gauges
  - Occasional Gas Chromatograph Data
  - Production and Injection Cycles
  - “Mined” completion (feet of underreaming at completion)



# Gas Injector Deliverables

- **P/T surveillance**
  - Wellbore integrity
  - OOZI
  - Breach of OB
- **PTA (Fall off & Injection Tests Analysis & Reporting)**
  - Skin
  - Permeability
  - Injectivity Index
  - Completion Efficiency
  - Reservoir pressure
- **Fracture Monitoring**
  - 'Alarm/Notifications' if BHP gets close to fracture gradient pressure
- **Virtual Metering/Spot Gas Rates**
  - Backup if meter fails
- **Composition/PVT Changes**
- **BHP Conversion**

# Gas Injector Surveillance Example




- Gas rates from dP wellbore
- Venturi Meter Backup
- P/T Surveillance
- Auto-PTA
  - Injectivity and Reservoir Pressure Tracking



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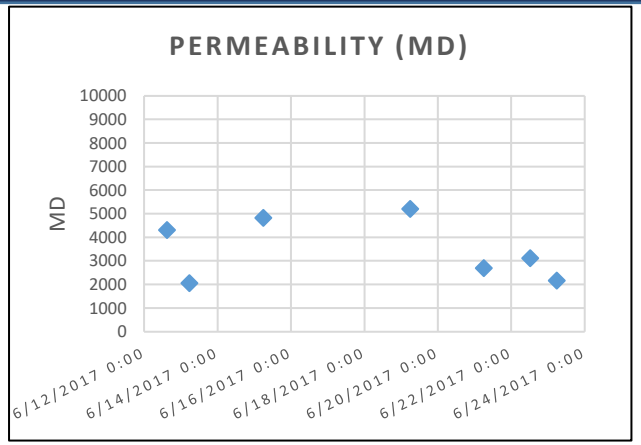
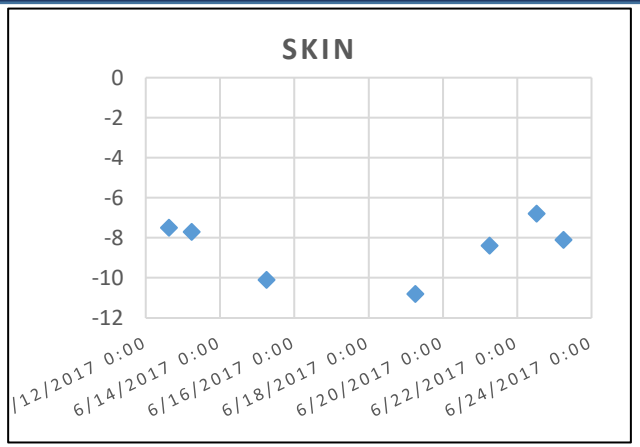
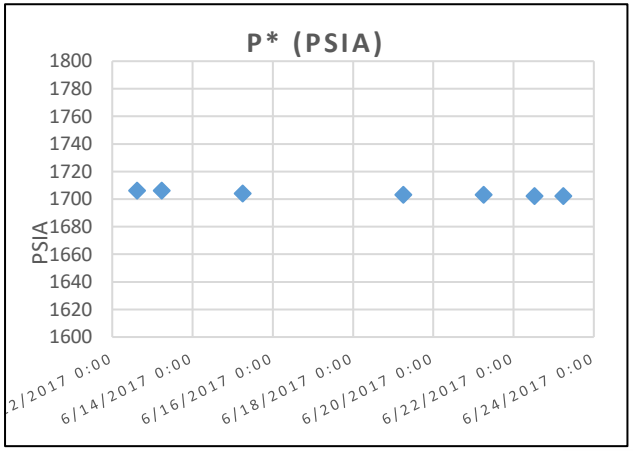
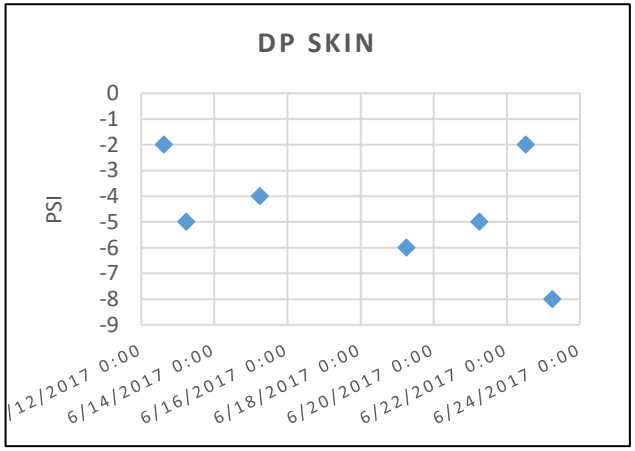
# Gas Injector Surveillance Example – Auto PTA

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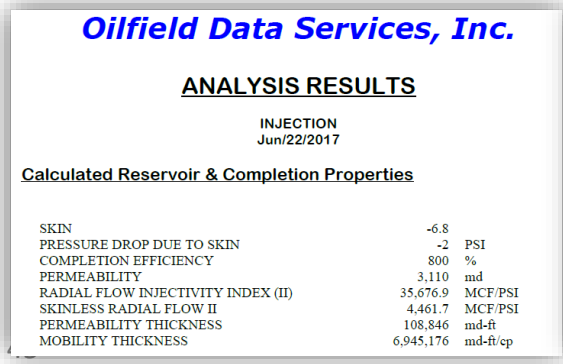

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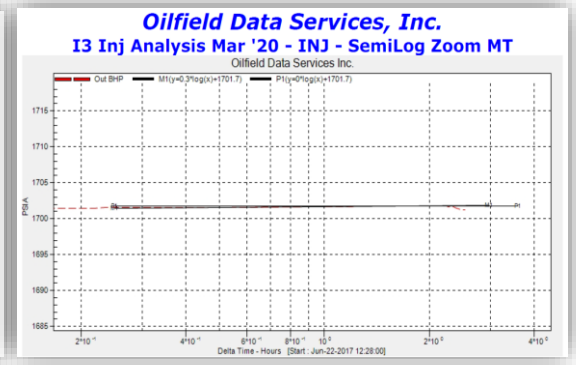
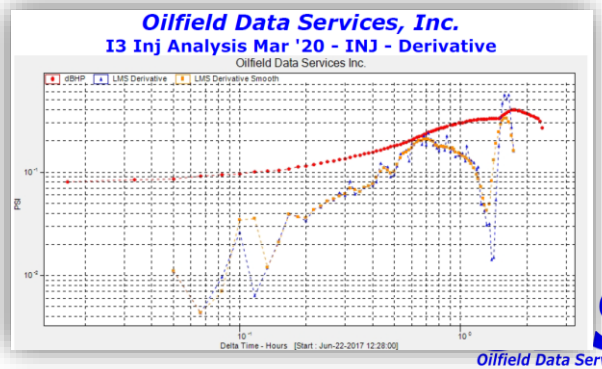
**ANALYSIS RESULTS**

**INJECTION**
**Jun/22/2017**

**Calculated Reservoir & Completion Properties**

| | | |
|---|---|---|
| SKIN | -6.8 | |
| PRESSURE DROP DUE TO SKIN | -2 | PSI |
| COMPLETION EFFICIENCY | 800 | % |
| PERMEABILITY | 3,110 | md |
| RADIAL FLOW INJECTIVITY INDEX (II) | 35,676.9 | MCF/PSI |
| SKINLESS RADIAL FLOW II | 4,461.7 | MCF/PSI |
| PERMEABILITY THICKNESS | 108,846 | md-ft |
| MOBILITY THICKNESS | 6,945,176 | md-ft/cp |

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# Case Study 3 - Results

Even though the well flows at relatively low gas rates at times, the Auto-PTA still provided valid results

No observed OOZI

No observed breach/frac'ing during injection

Measured vs. Calculated Rates were quite close

Slight increase in GG (wetter gas injected) around June 22-23

Auto-PTA worked for both Injection and Falloff Cycles

Auto-PTA worked for Production and Build-up Cycles

# Case Study 4

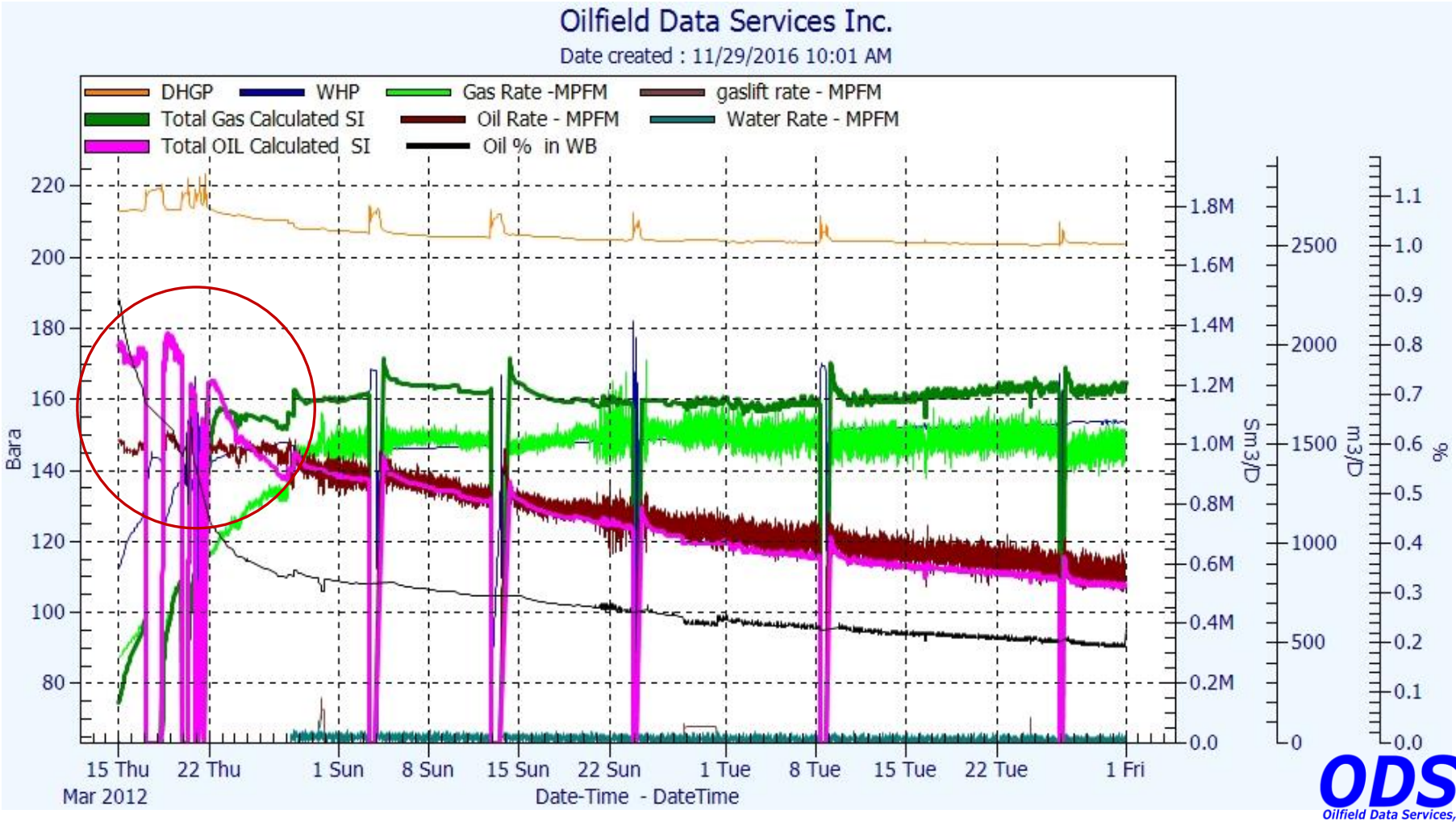
## Horizontal Oil & Gas Producer - North Sea

- **Equipped with:**
  - WHP and Downhole Gauges
  - MPFM


- **Objectives:**
  - Demonstrate WA's rate calculations
    - Split into Gas and Oil Reservoirs
  - Perform diagnostic PTA
    - Skin, Perm, P*
  - Determine Why the well makes so much gas!

# Case 4: Data Processing – Total Rates

- Total Oil Rate = Oil from Oil leg + Oil from Gas Reservoir
- Total Gas Rate = Gas from Gas reservoir + Gas from Oil leg
- Note: The total oil rate was higher than reported for the March 14-24, 2012 period



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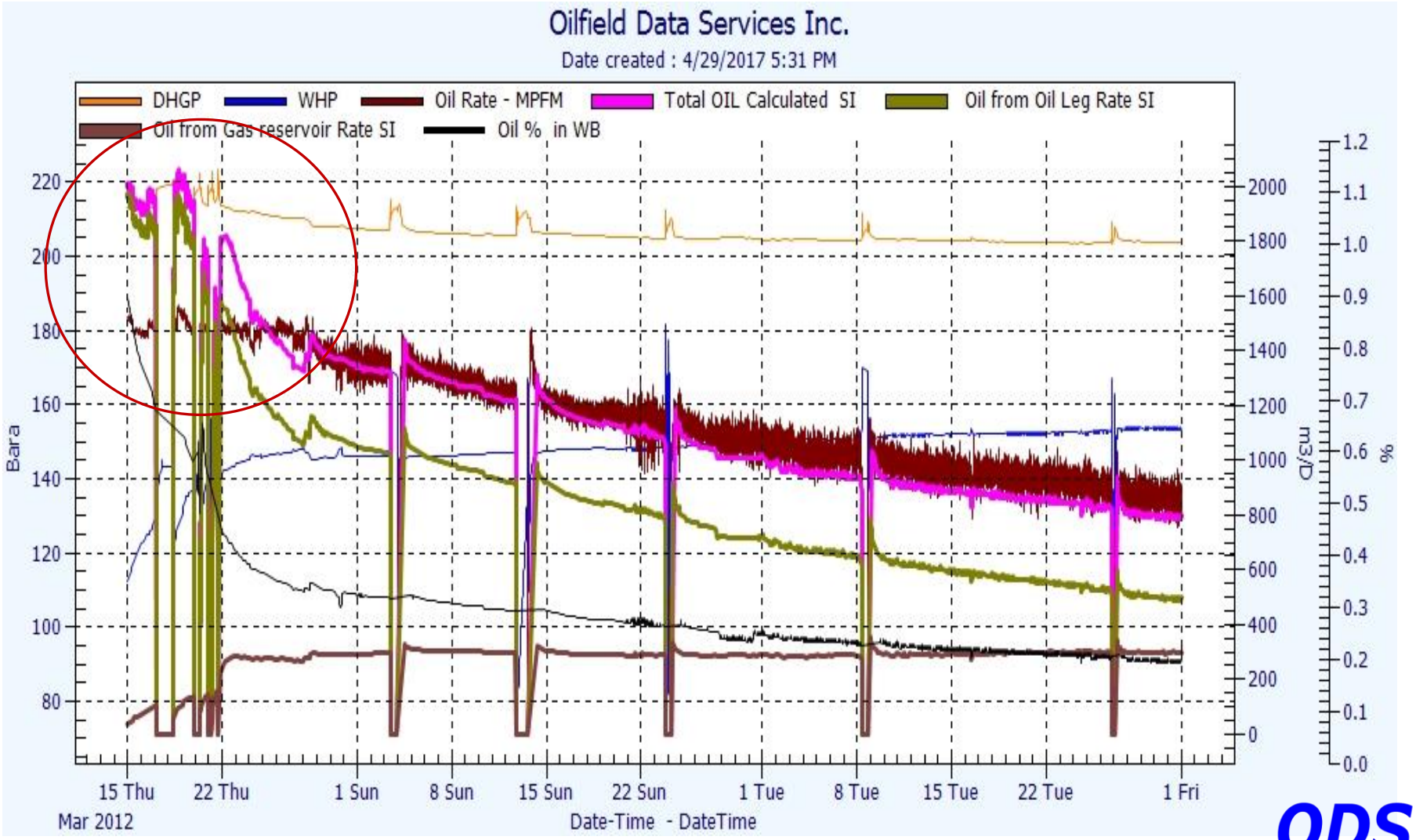
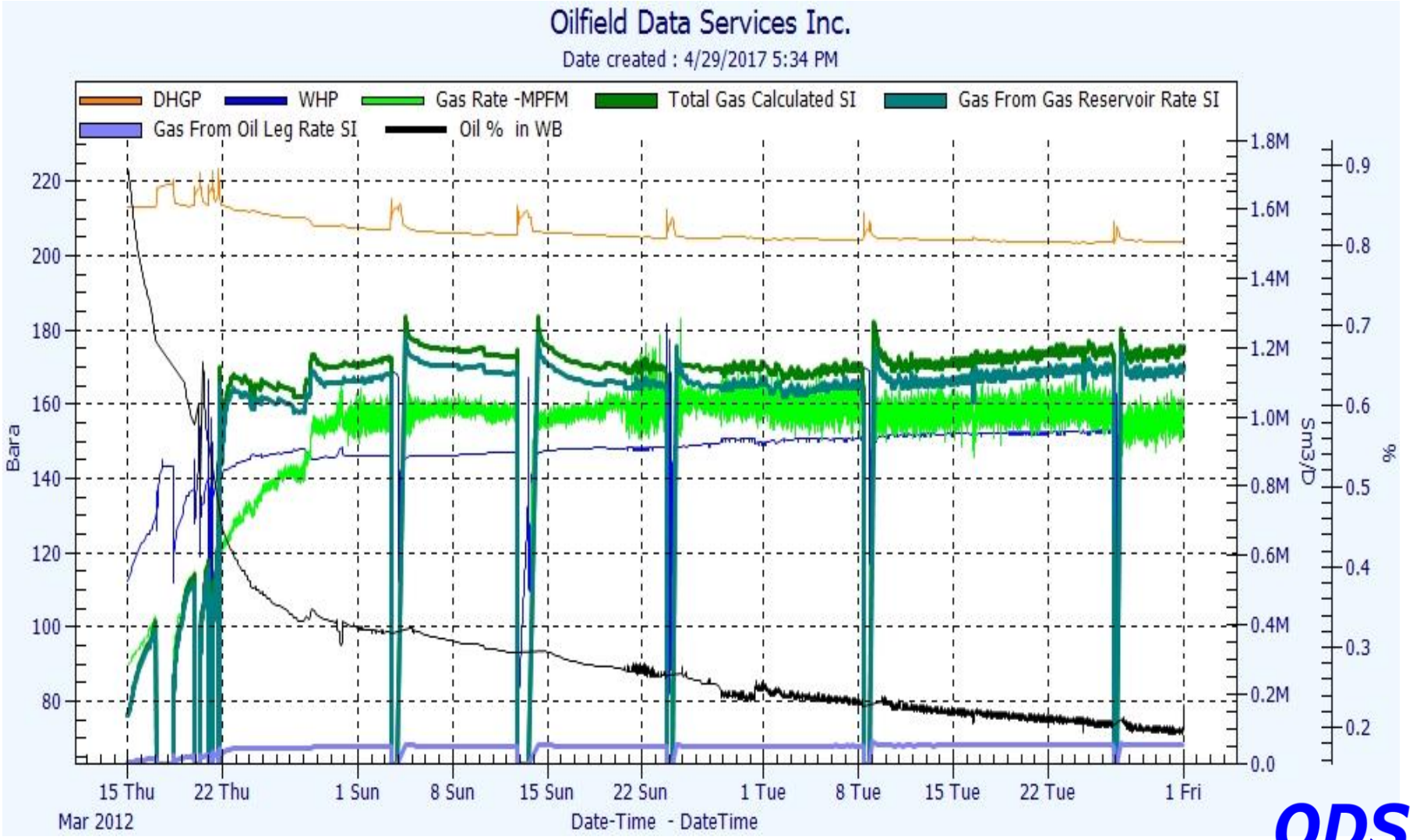
# Case 4: Data Processing – Oil Rates

The total oil rate was higher than reported for the March 14-24, 2012 period



# Case 4: Data Processing – Gas Rates

The calculated gas rates were slightly higher than the metered rates ~ 15 % deviation



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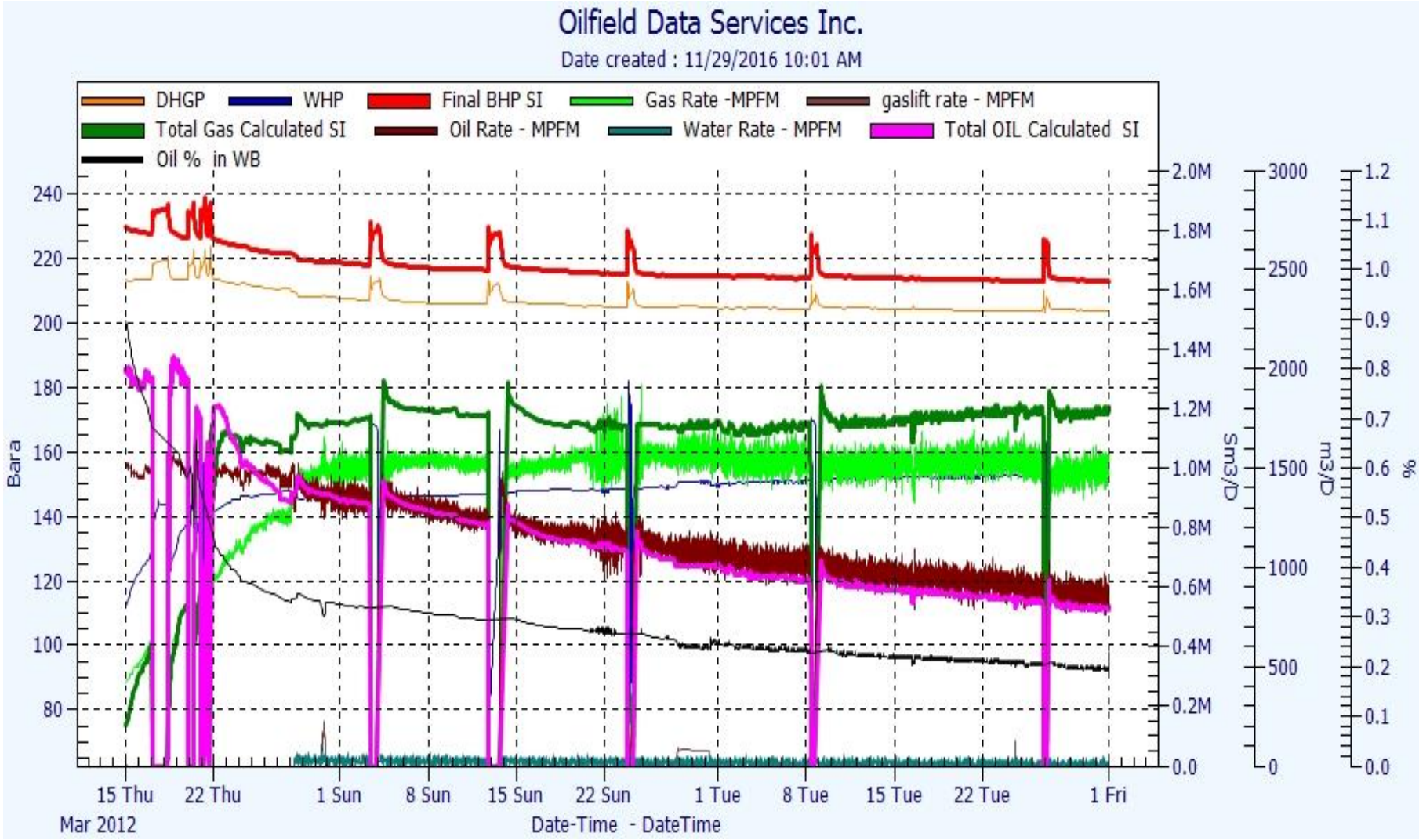
# Case 4: Data Processing – BHP

- Once the rates were adjusted for each phase, BHP conversion was performed
- Note: Conversion to bottomhole pressure (BHP) was accomplished by using ODSI's direct solution to the Bernoulli's equation (Mechanical Energy Balance) accounting for thermals, friction and fluid density
- Failure to perform the analysis on the BHP leads to overestimation of permeability, overestimation of skin and underestimation of reservoir pressure

# Case 4: Data Processing – BHP



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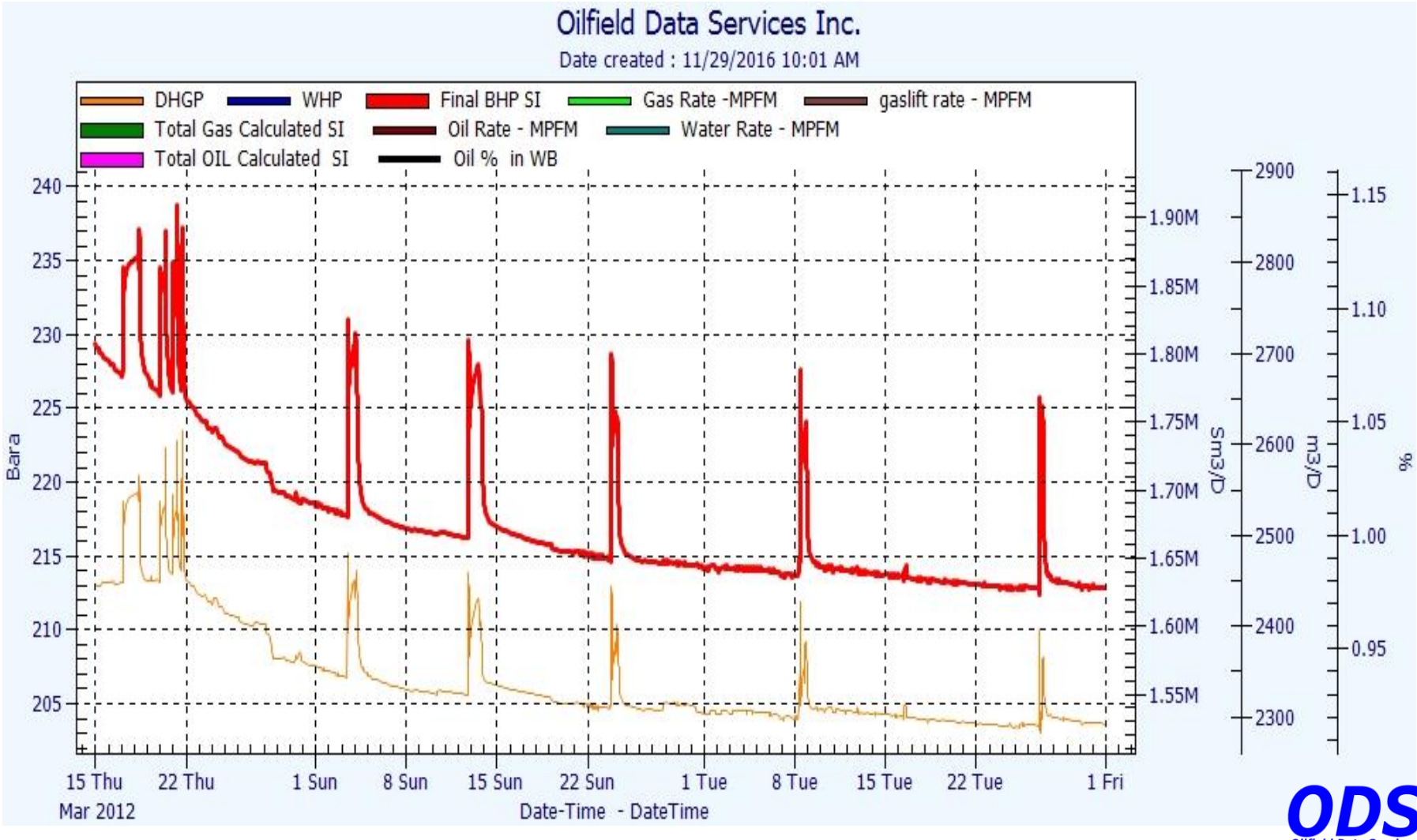
# Case 4: Data Processing – BHP Zoom

It was likely that the gas provided additional energy/pressure support, therefore pressure 'flattened' after early-mid Apr, 2012



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# Case 4:

## Pressure Transient Interpretation

# Case 4: PTA

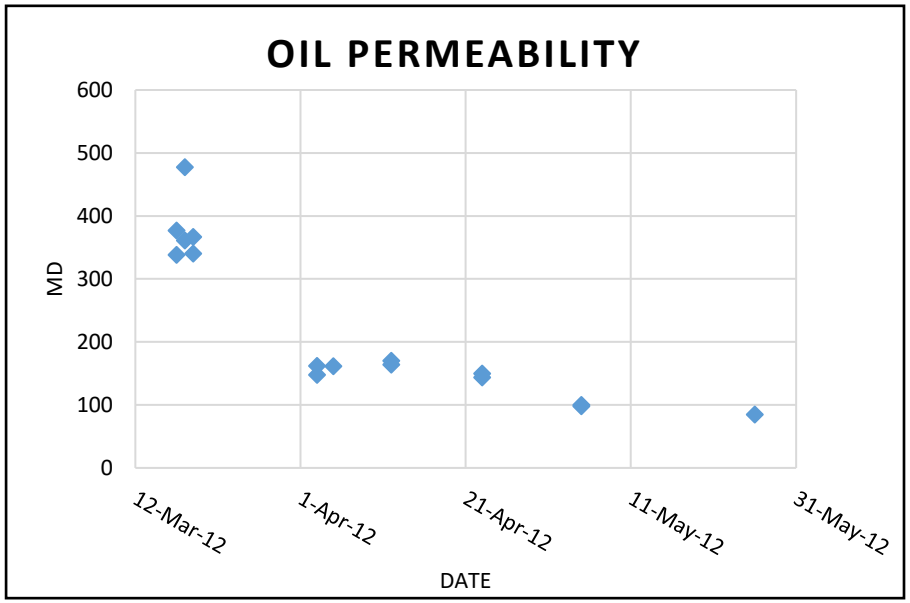
- There were several valid PTAs that were analyzed for skin, permeability, P.I. and overall well performance
- The well was analyzed as a vertical well because it did not have a typical horizontal well behavior
- Both oil and gas phases were evaluated
  - The oil phase was dominant during the mid – late Mar, 2012 period, and then the gas started to dominate
- Net pay thickness used = 24.5 m

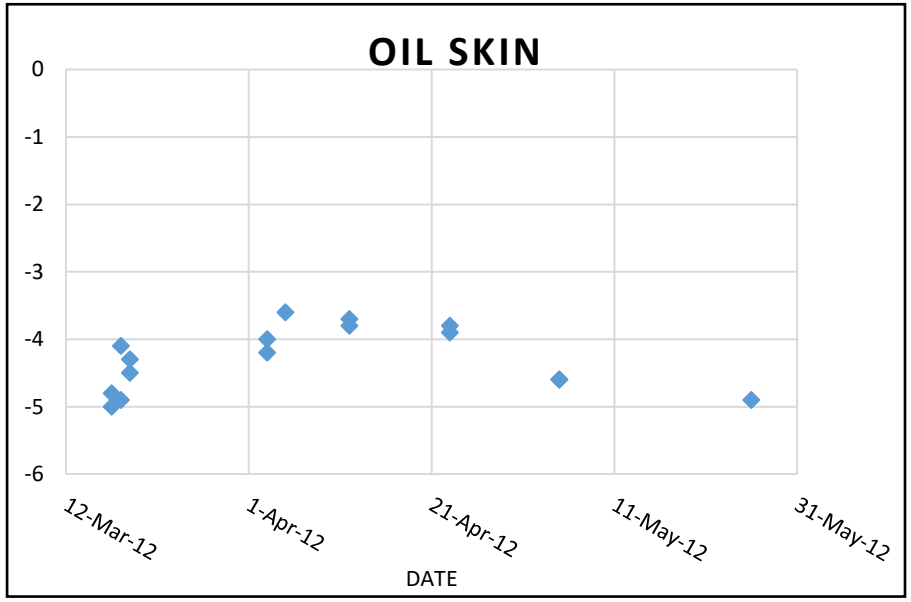
# Case 4: PTA Results – Oil Phase

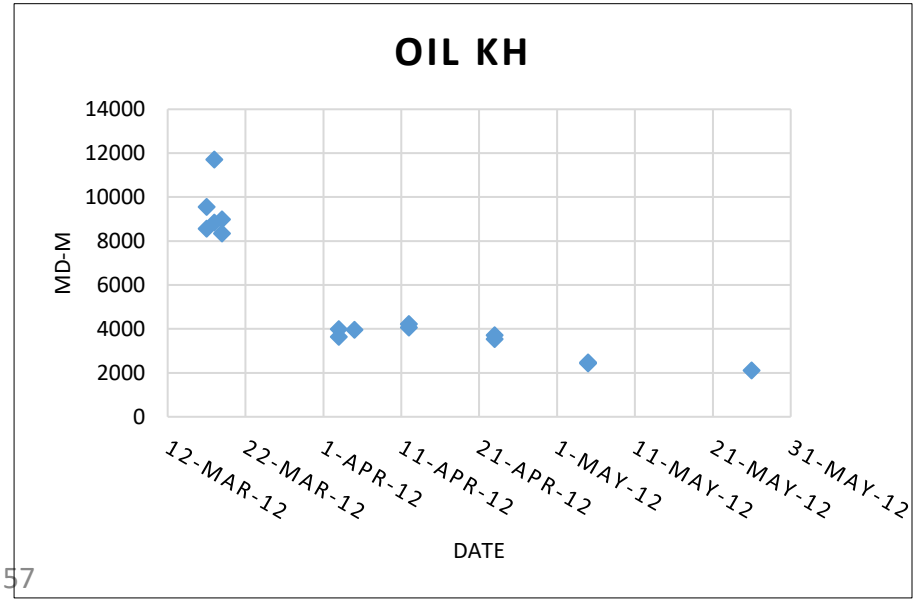
Net Pay Thickness used = 24.5 m

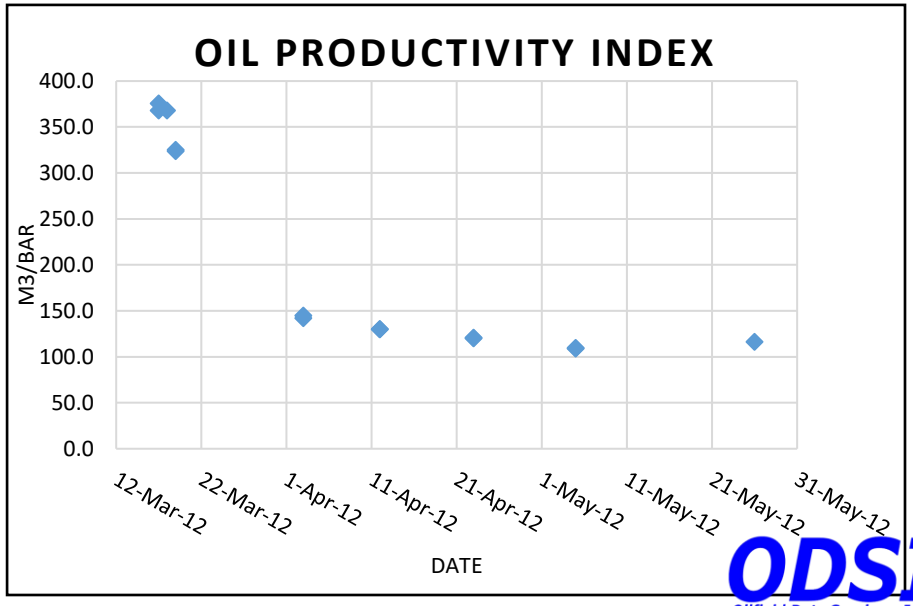
| Oil | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Test | Comments | Skin | DP Skin | Comp Eff | PI | Skinless PI | K total | Koil | Kgas | kh | P* |
| | | | ( ) | Bar | % | m3/Bar | m3/Bar | md | md | md | md-m | Bara |
| 17-Mar-12 | PBU | Horner | -5 | -13.9 | 382 | 375.4 | 98.23 | 350 | 338 | N/A | 8563 | 236.1 |
| 17-Mar-12 | PBU | Semi-log | -4.8 | -12.0 | 339 | 368.0 | 108.61 | 390 | 377 | N/A | 9553 | 237.0 |
| 18-Mar-12 | DD | BHP | -4.1 | -8.3 | 233 | 368.0 | 139.28 | 478 | 478 | 14.8 | 11702 | 215.6 |
| 18-Mar-12 | DD | TTA | -4.9 | -12.8 | 348 | N/A | N/A | 361 | 361 | N/A | 8845 | 223.6 |
| 19-Mar-12 | PBU | Semi-log | -4.3 | 10.8 | 296 | 324.9 | 109.99 | 367 | 367 | 19.2 | 8990 | 237.8 |
| 19-Mar-12 | PBU | Horner | -4.5 | -12.0 | 316 | 323.5 | 102.38 | 340 | 340 | 17.7 | 8337 | 227.9 |
| 3-Apr-12 | PBU | Semi-log | -4 | -13.0 | 279 | 141.8 | 50.73 | 163 | 162 | 31.6 | 3993 | 236.3 |
| 3-Apr-12 | PBU | Horner | -4.2 | -15.2 | 315 | 144.6 | 45.89 | 148 | 148 | 29.4 | 3636 | 236.3 |
| 5-Apr-12 | DD | TTA | -3.6 | -21.6 | 198 | N/A | N/A | 162 | 162 | N/A | 3958 | 213.7 |
| 12-Apr-12 | PBU | Semi-log | -3.7 | 10.5 | 249 | 129.8 | 52.11 | 172 | 170 | 35.7 | 4219 | 234.1 |
| 12-Apr-12 | PBU | Horner | -3.8 | 11.2 | 258 | 130.3 | 50.50 | 166 | 164 | 35.7 | 4068 | 216.2 |
| 23-Apr-12 | PBU | Semi-log | -3.9 | -11.7 | 275 | 120.6 | 43.81 | 145 | 144 | 35.7 | 3541 | 233.5 |
| 23-Apr-12 | PBU | Horner | -3.8 | -10.9 | 261 | 119.9 | 45.89 | 152 | 150 | 35.7 | 3717 | 231.3 |
| 5-May-12 | PBU | Semi-log | -4.6 | -15.7 | 369 | 108.8 | 29.52 | 101 | 100 | 32.0 | 2475 | 216.2 |
| 5-May-12 | PBU | Horner | -4.6 | -16.1 | 377 | 109.5 | 29.05 | 99 | 98 | 30.9 | 2426 | 229.3 |
| 26-May-12 | PBU | Horner | -4.9 | -16.8 | 462 | 116.2 | 25.13 | 86 | 85 | 42.0 | 2107 | 227.6 |

# Case 4: PTA Results – Oil Phase



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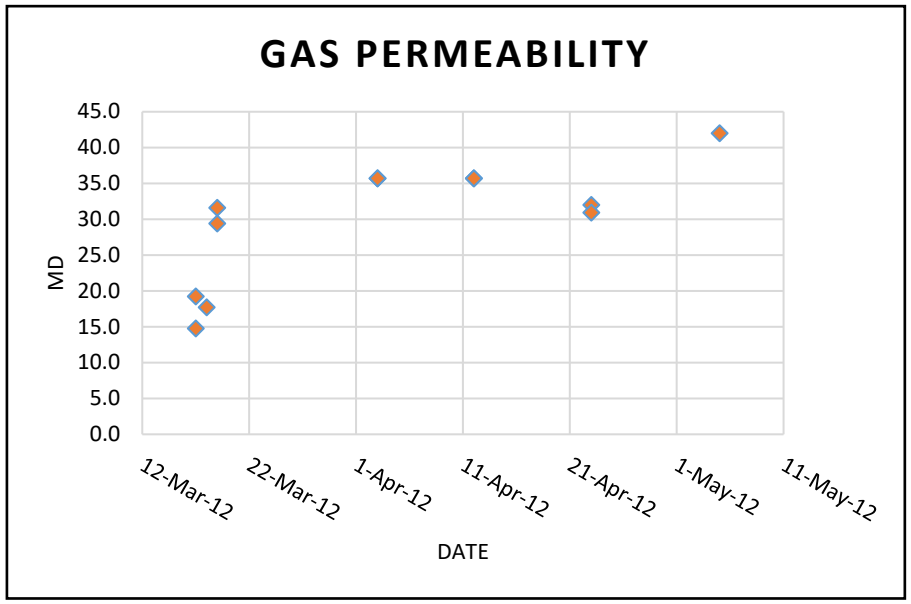
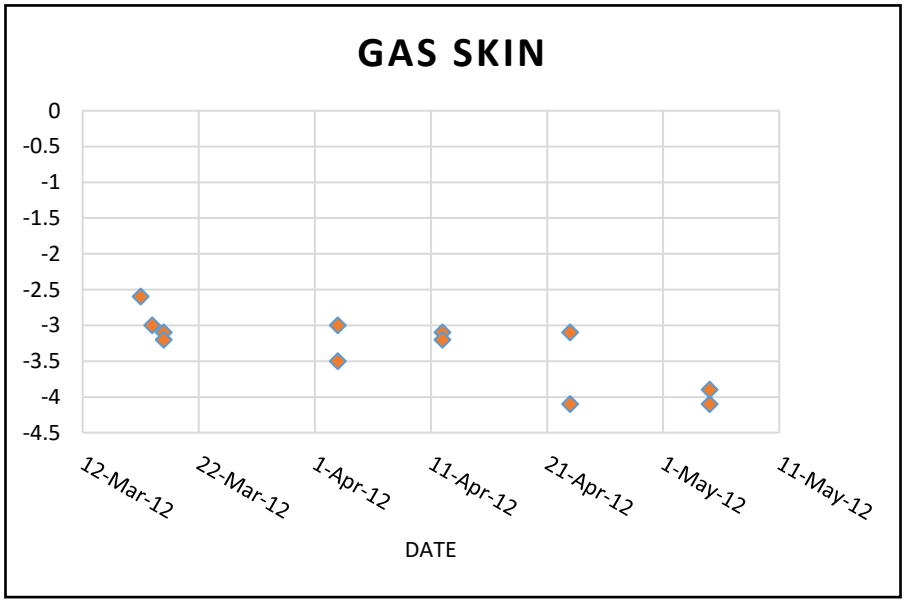
# Case 4: PTA Results – Gas Phase

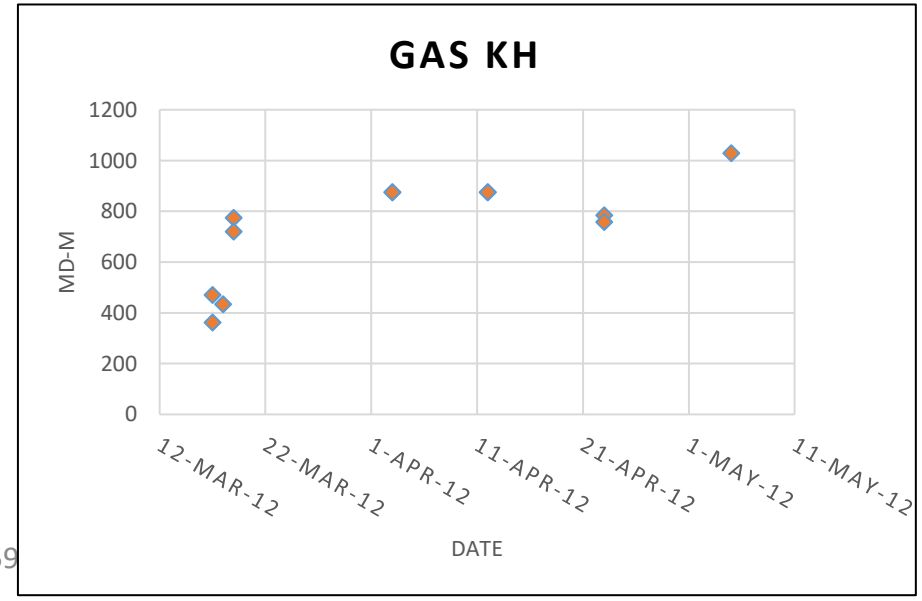
Net Pay Thickness used = 24.5 m

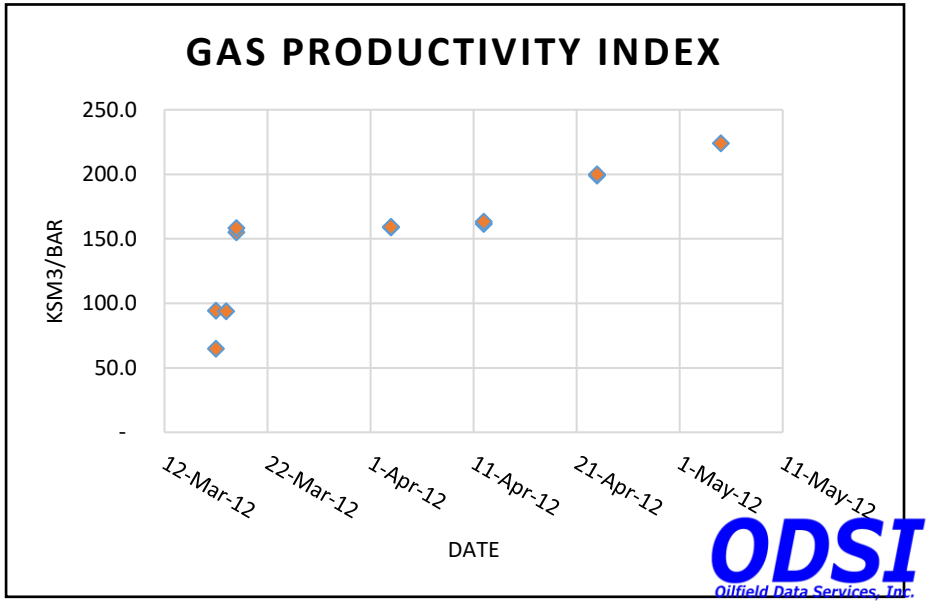
| Gas | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Test | Comments | Skin | DP Skin | Comp Eff | PI | Skinless PI | K gas | kh | P* |
| | | | ( ) | Bar | % | kSm3/Bar | kSm3/Bar | md | md-m | Bara |
| 17-Mar-12 | PBU | Horner | Oil Dominates Here | | | | | | | |
| 17-Mar-12 | PBU | Semi-log | | | | | | | | |
| 18-Mar-12 | DD | BHP | -2.6 | -5.1 | 202 | 64.7 | 32.1 | 14.8 | 362 | 215.6 |
| 19-Mar-12 | PBU | Semi-log | -3 | -7.5 | 236 | 94.2 | 40.0 | 19.2 | 470 | 237.8 |
| 19-Mar-12 | PBU | Horner | -3.1 | -8.4 | 251 | 93.8 | 37.4 | 17.7 | 434 | 227.9 |
| 3-Apr-12 | PBU | Semi-log | -3.2 | 10.5 | 246 | 155.0 | 63.0 | 31.6 | 774 | 236.3 |
| 3-Apr-12 | PBU | Horner | -3.5 | -12.6 | 277 | 158.2 | 57.0 | 29.4 | 720 | 236.3 |
| 12-Apr-12 | PBU | Semi-log | -3 | -8.6 | 221 | 158.7 | 71.7 | 35.7 | 875 | 234.1 |
| 12-Apr-12 | PBU | Horner | -3.1 | -9.2 | 230 | 159.2 | 69.3 | 35.7 | 875 | 216.2 |
| 23-Apr-12 | PBU | Semi-log | -3.2 | -9.8 | 230 | 161.5 | 70.3 | 35.7 | 875 | 233.5 |
| 23-Apr-12 | PBU | Horner | -3.1 | -9.0 | 233 | 163.2 | 69.9 | 35.7 | 875 | 231.3 |
| 5-May-12 | PBU | Semi-log | -4.1 | -13.9 | 338 | 198.9 | 58.8 | 32.0 | 784 | 246.1 |
| 5-May-12 | PBU | Horner | -4.1 | -14.3 | 346 | 200.0 | 57.9 | 30.9 | 757 | 229.3 |
| 26-May-12 | PBU | Horner | -3.9 | -9.8 | 293 | 224.0 | 76.4 | 42.0 | 1029 | 227.6 |

# Case 4: PTA Results – Gas Phase



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# Case 4: PTA Summary & Conclusions

Oil Reservoir

- High permeability: 100 – 370 md
- Stimulated completion with high negative skin
- Both oil perm and P.I. were decreasing with time because the gas phase started to dominate
  - P.I.: 370 $m^3$/Bar (Mar 17, 2012) vs 116 $m^3$/Bar (May 26, 2012)
  - Permeability: 350 md (Mar 17, 2012) vs 100 md (May 26, 2012)

Gas Reservoir

- Moderate permeability: 30 – 42 md
- Stimulated completion with high negative skin
- Both permeability and P.I. improved when the gas phase began to dominate
  - P.I.: 65 $kSm^3$/Bar (Mar 18, 2012) vs 224 $kSm^3$/Bar (May 26, 2012)
  - Permeability: 15 md (Mar 18, 2012) vs 42 md (May 26)

# CASE STUDY 5

## Subsea Deepwater Oil Well

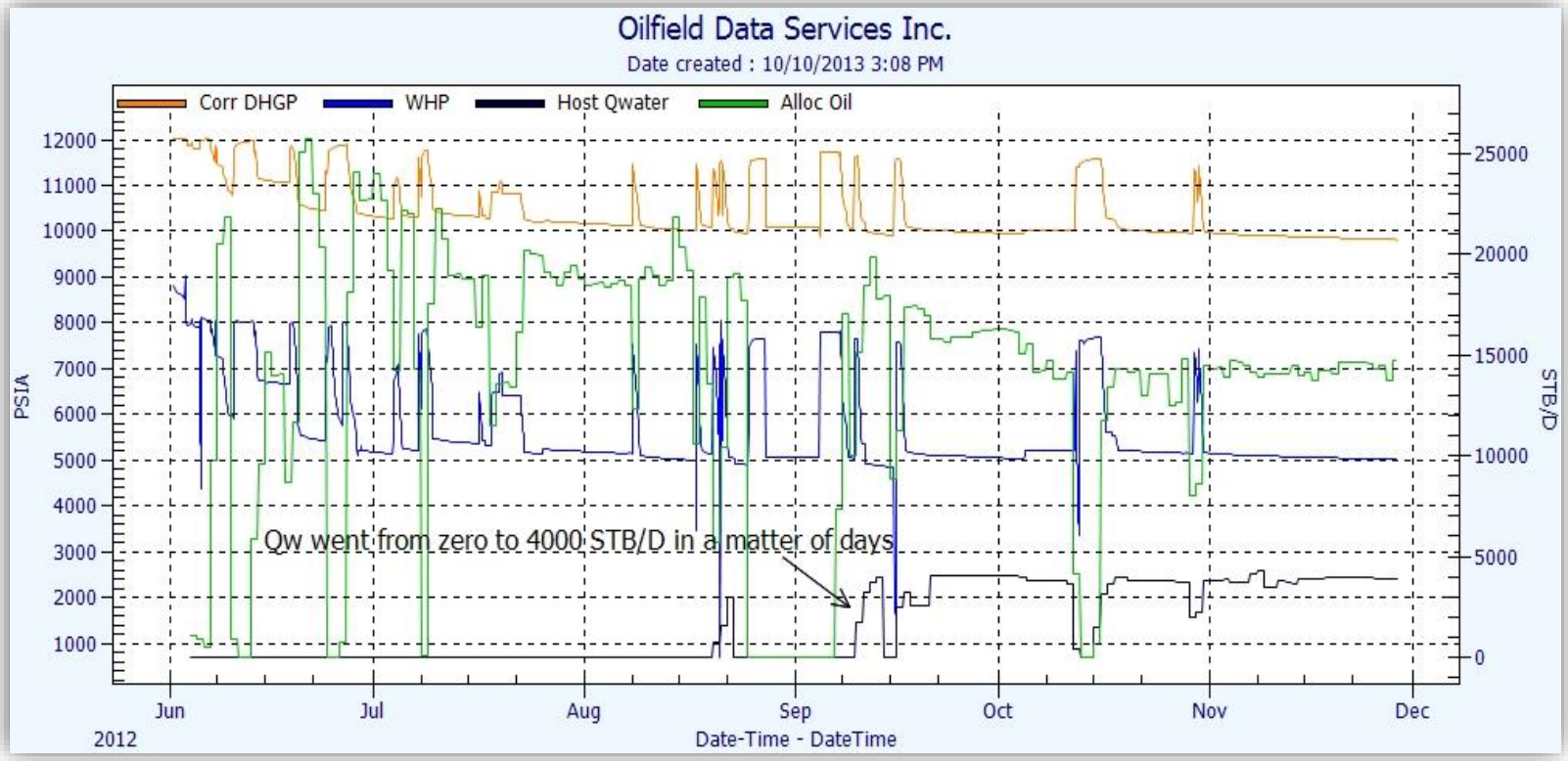
## 3 Separate Frac Packs

### Gulf of Mexico


- 3 Frac Packed Intervals – No Isolation/ICVs
- Well equipped with
  - WHP gauge
  - Downhole gauge
  - Flow meter (MPFM/Boat Anchor)
- The well suddenly started making 4000 STB/D of water
  - The Operator plans a $130 million intervention program to ‘fix’ the well; the Partner decided to find the origin of water production first
- <u>Objective:</u>
  - Validate metered rates
  - Determine the origins of water production
  - Perform Auto PTA and Decline Analysis

# Case Study 5: Provided Data

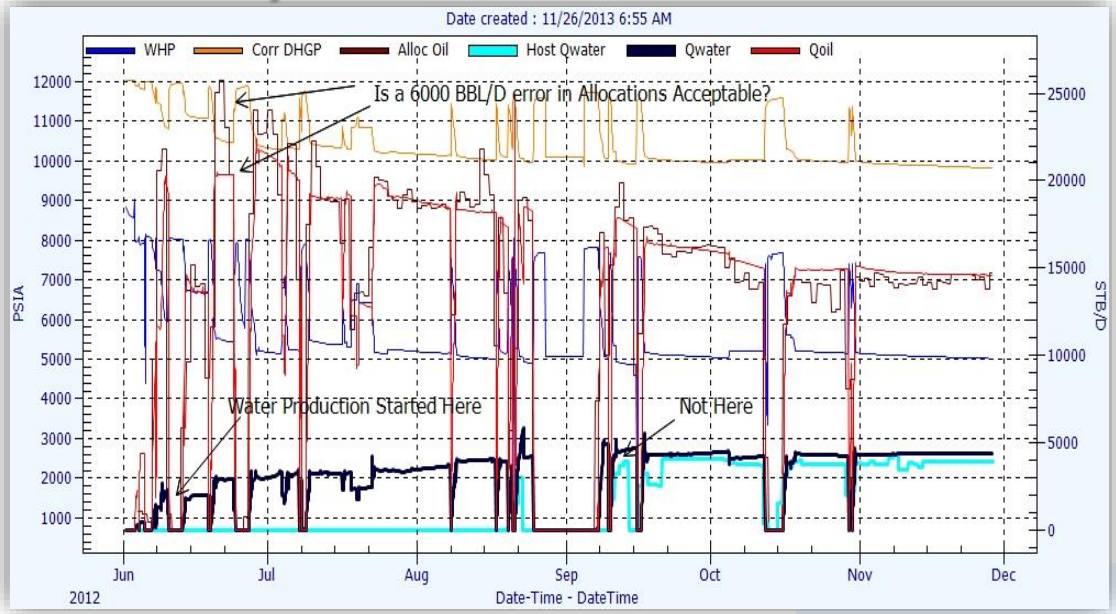
- Water rate went from 0 to 4000 STB/D in a matter of days; the Operator wanted to perform a $130 MM intervention to ‘fix’ the water problem; the Partner wanted to identify the origin of water production first…Why Spend $130 MM and Shut In a Well Making 15k STB/D because it ‘doesn’t match the models’?



# Case Study 5: Process

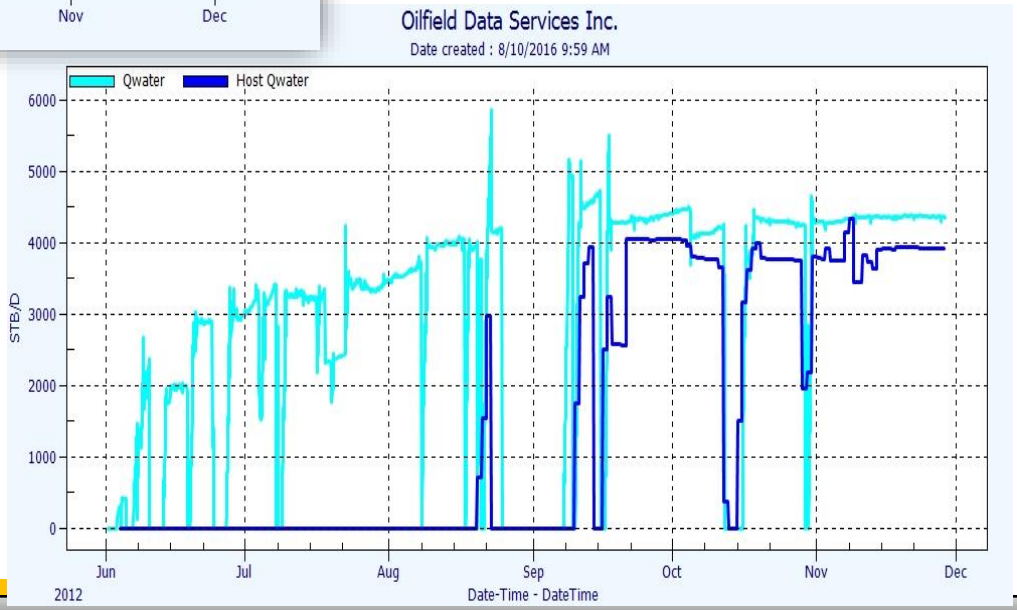
- MPFM rates were QC'd
  - Severe Errors in allocations were detected prior to Sept 2012
- Generally, MPFMs for 2-phase liquid flow are accurate on the total liquid rate measurements, but are likely to be off when it comes to individual oil and water rates (even worse if you start making free gas!)
- The total liquid rate was split into oil and water rates using the pressure drop in the wellbore and fluids' PVT properties
- It quickly became obvious that the MPFM was not calibrated when the well came on-line

# Case Study 5: Results



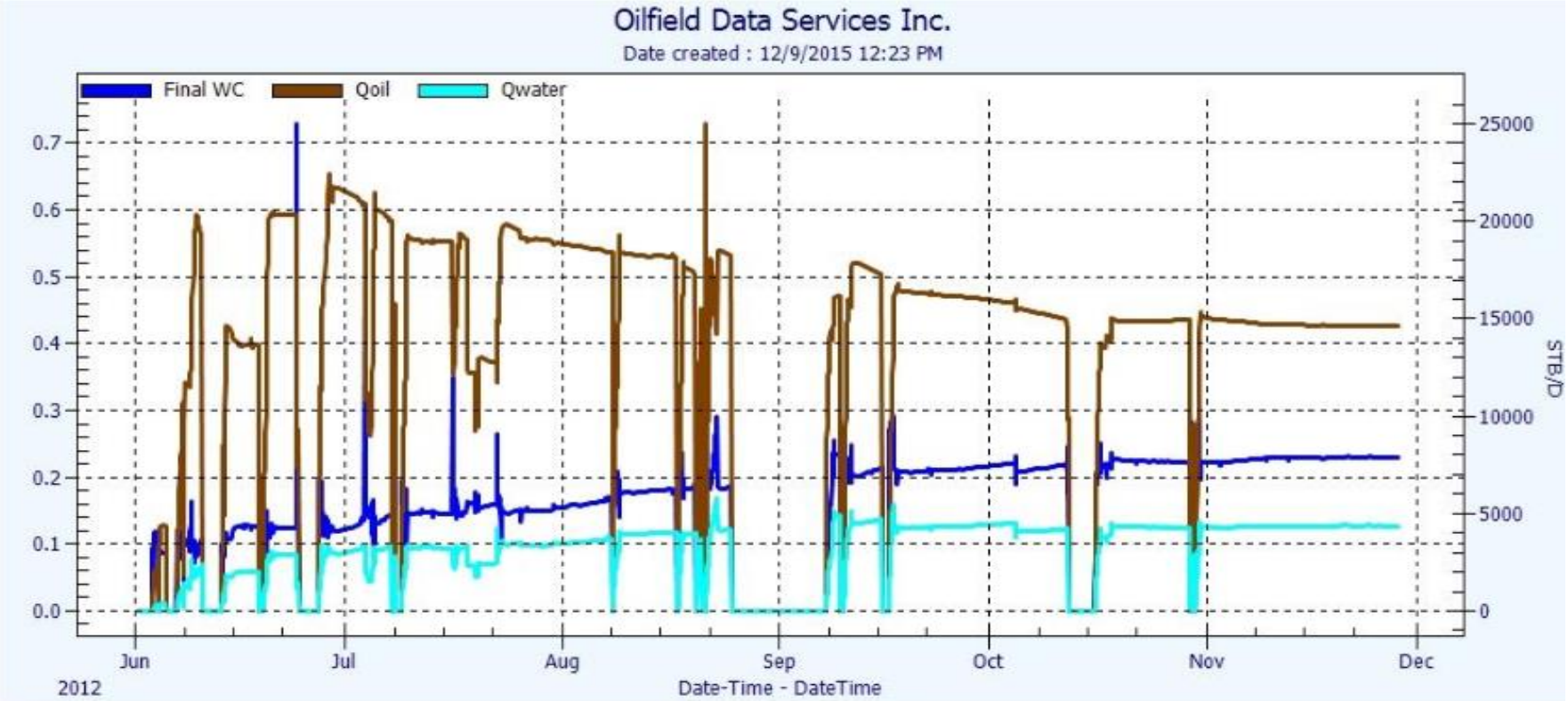

As it turned out, the water production started from the day the well was brought on-line. The operator's allocations were off up to 6000 BBL/D

- Comparison of the measured (dark blue) vs the calculated (teal) water rates
- The meter was not properly calibrated, and the well was producing water from the day it came online



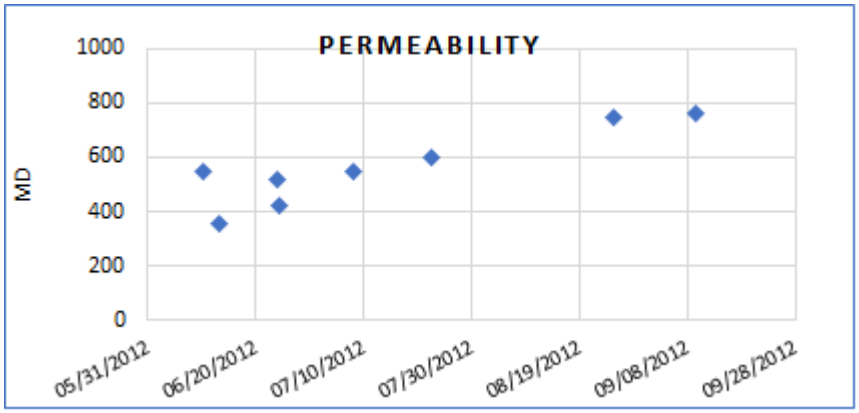
# Case Study 5: Rate Results

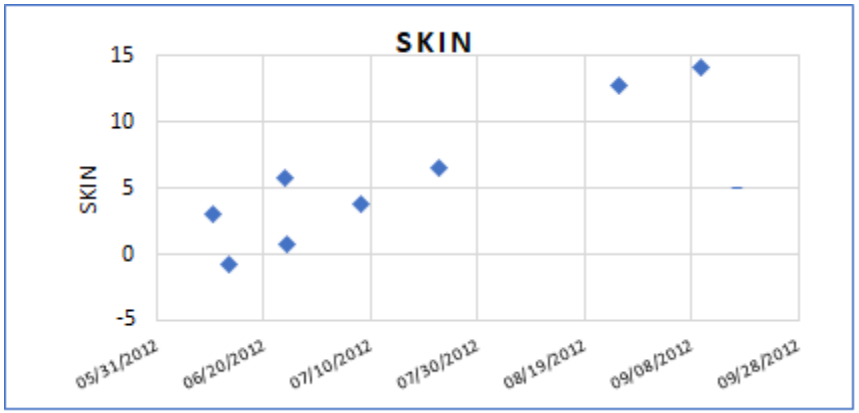
- The Final Calculated Oil and Water rates are presented below
- The water came from a WET ‘oil zone’ that was added at the last minute because the geophysicist colored the sand green ☹

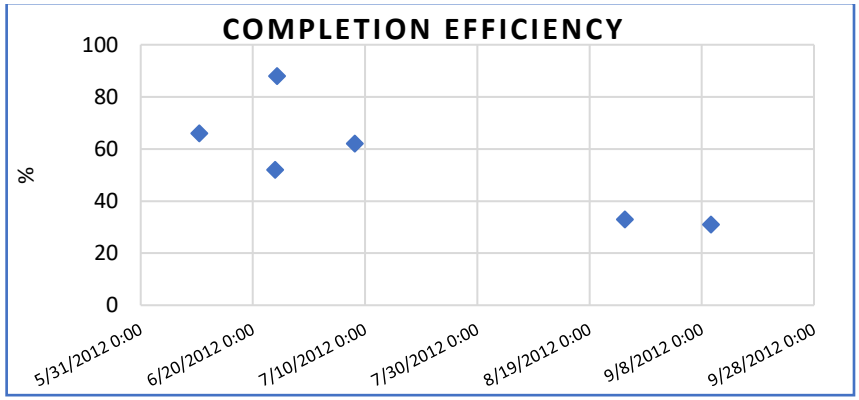


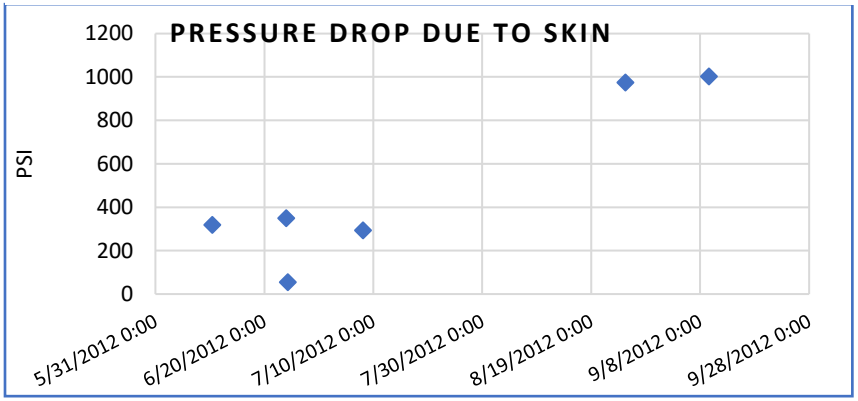
# Case Study 5: Auto-PTA

- High perm ~ 500 md
- Skin was getting worse with time
  - From 0 to 14 (screen plugging w/asphaltenes)
- Productivity was getting worse with time (increasing skin)

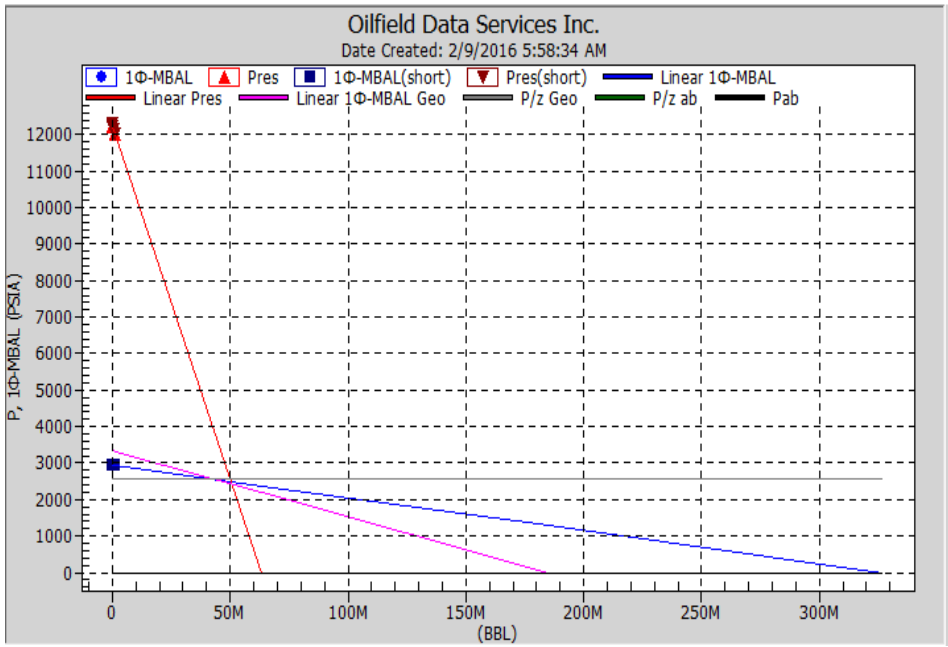


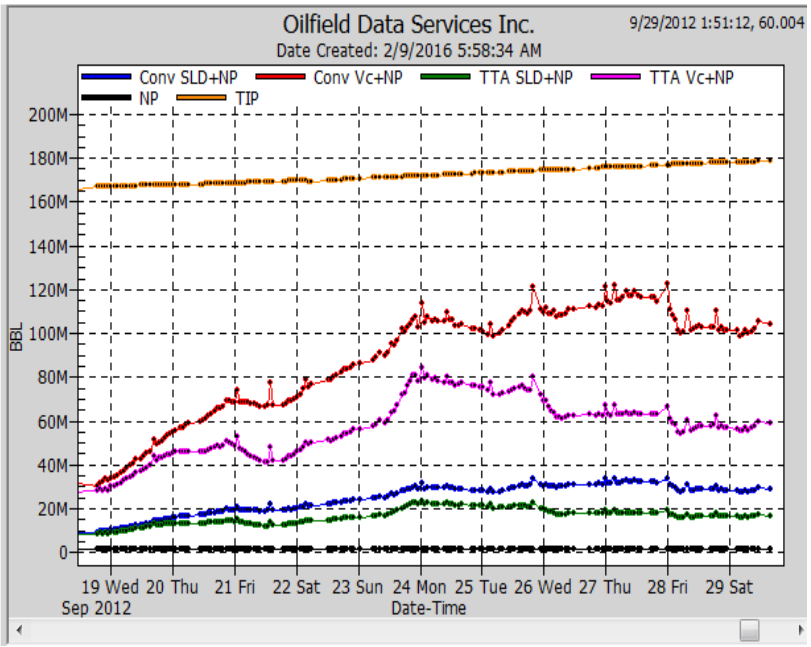



# Case Study 5: HC Volume




The well is likely to have very strong water drive, hence

- Total in-place volume is ~ 65 MM STB
- Hydraulically connected to the well volume ~ 30 MM STB
- Mobile (minimum producible) volume ~ 20 MM STB

- Note: It is important to know how big or small your reservoir can be until you know the drive mechanism. WA RTS calculates the connected and mobile HC volumes and stores those values on client's database

# Case Study 5: Results

- MPFMs were generally accurate on the total liquid rate, but were off on individual oil and water rates
- Given the pressure drop in the wellbore, the software can split the total liquid rate into its components, providing solutions for:
  - Improperly calibrated flow meters
  - Poor separator testing methods
  - Errors in oil and water allocations
- Once the rate is calculated, WA RTS can perform auto-PTA and HC volume calculations
- Water production started from Day 1, not in Month 4!
- Use the ‘thumbs out’ rule to find HC pay!
- Don’t spend money on a problem you can’t fix!

# ODSI's Well Analyzer RTS

**Review of Features/Summary**



- ✓ Oil & Gas Reservoir Testing and Evaluation
- ✓ Real-Time Pressure Transient Analysis
- ✓ Hydrocarbon Volume Determination
- ✓ Well(s) Performance Tracking
- ✓ Multiphase Rate & BHP Calculations
- ✓ Optimize Gas Lift / Oil Production Rates
- ✓ Life Of Well Surveillance/Analysis
- ✓ Automated PVT Calibration

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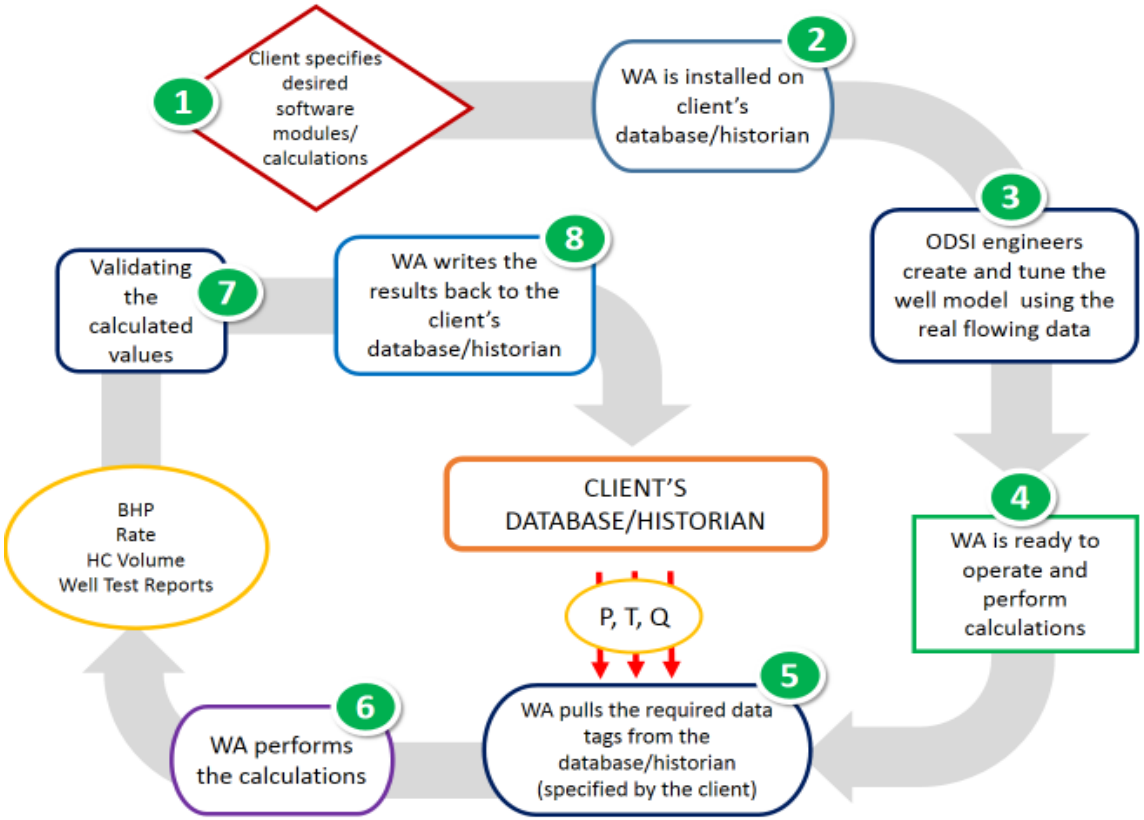
Visit: www.odsi-energy.com

# ODSI - Well Analyzer

Well Analyzer works both in Real-Time and on Historic data

It polls the required data tags from the client's database/historian, performs the calculations, and writes the results back to the database






- ✓ Oil & Gas Reservoir Testing and Evaluation
- ✓ Real-Time Pressure Transient Analysis
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# Well Analyzer Real-Time Features

- Virtual metering
  - Often more accurate than an MPFM for 3-phase flow
  - Metered rate validation
  - Detects errors in allocation/meter calibration
  - Backup if MPFM fails
- BHP conversion
  - From the surface data
  - Can replace downhole pressure gauge if it fails
- Automated Pressure Transient Interpretation of buildups and drawdowns
  - Skin & Perm
  - Lateral Length Open to Flow
  - Avg.Pres/P*
  - Productivity (PI)
- Continuous HC volumes and Mobile HC updates
  - Static and Flowing Material Balance calculations

# Well Analyzer Benefits - Summary

- Analyze ALL of the data, not just the data you have time to look at
- Optimize Production at Every Opportunity
- Understand how much Money you have left in the ground
- Train Your Team in Proactive Surveillance
- Spend Your Time Thinking about What to Do to Make More Money!