

Well Analyzer
for
Producing Oil & Gas Wells

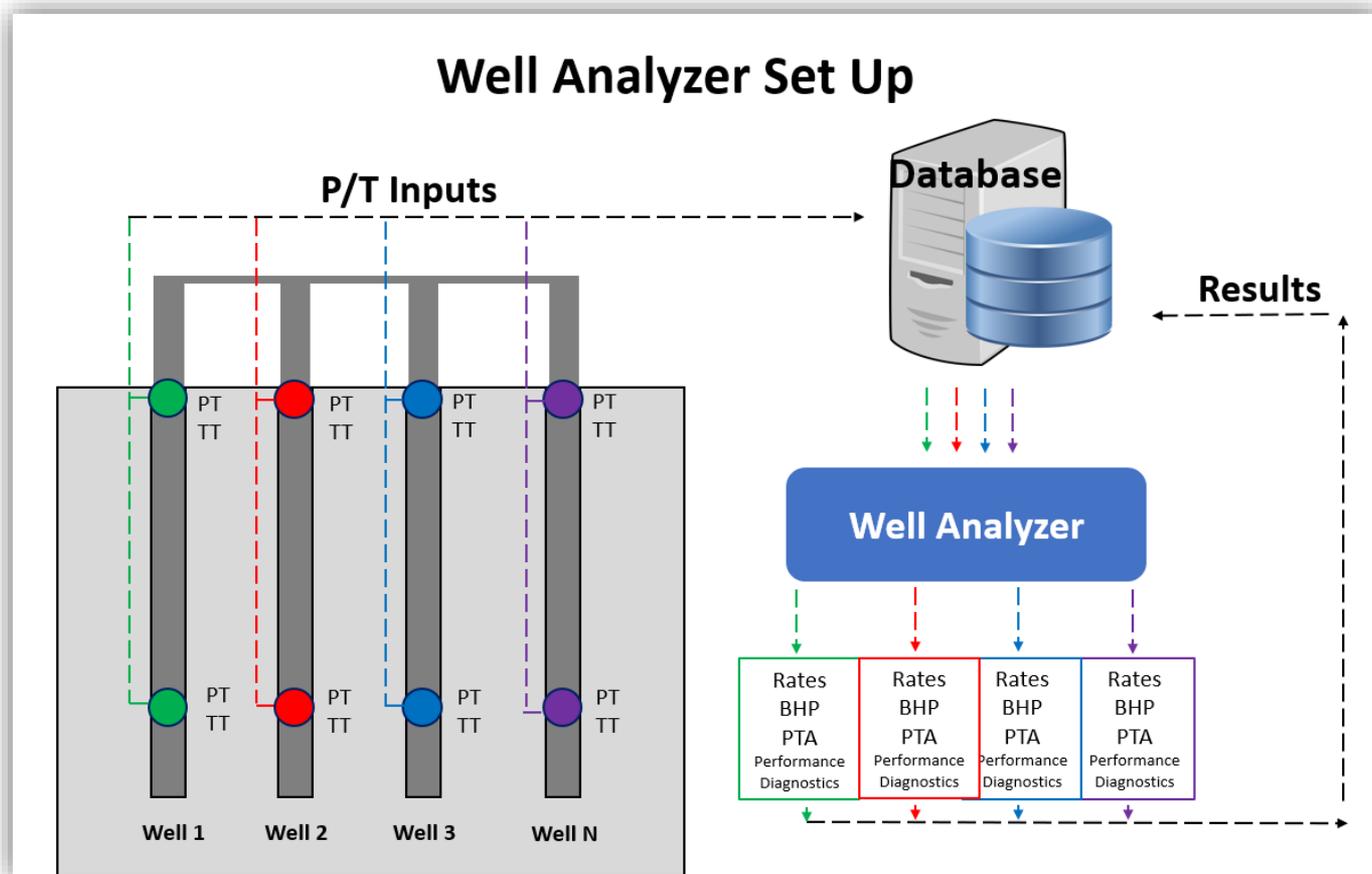
Automated Real-Time Surveillance
Well/Reservoir Evaluation Software Package

Oilfield Data Services, Inc.

Well Analyzer - Real-Time Set Up

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

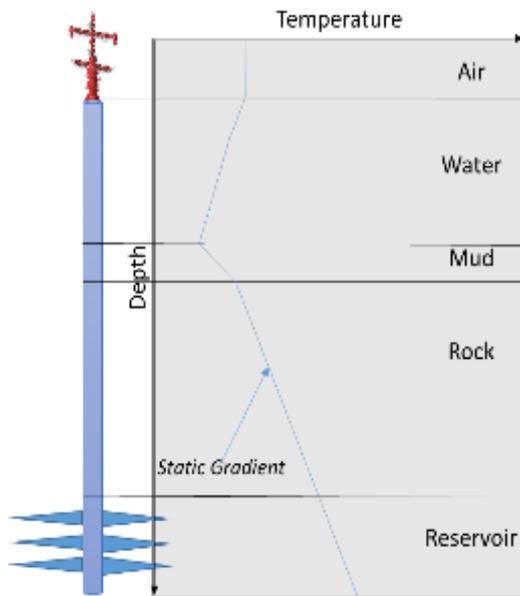
It polls the required data tags from the client's database/historian, performs the calculations, validates the results and writes them back to the database



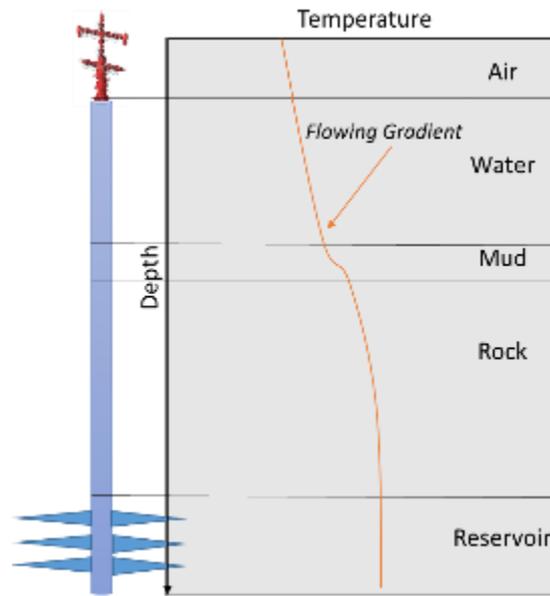
About Well Analyzer (Wellbore Model)

- The only existing software based on a direct numerical solution to the Mechanical Energy Balance (MEB) equation
 - Does not rely on correlations and, hence, it provides **more accurate** and **reliable results**
- The wellbore model
 - Accounts for dynamic temperature behavior
 - Adjusts the fluid properties accordingly
 - Performs wellbore flash calculations (See Case Study 1) to determine the composition of the fluid in the wellbore
- The wellbore flash calculations can be used to determine the water cut for oil wells and the condensate/water yield for gas wells
 - Our accuracy on the flash calculations is normally within 0.5 bbl/MMcf

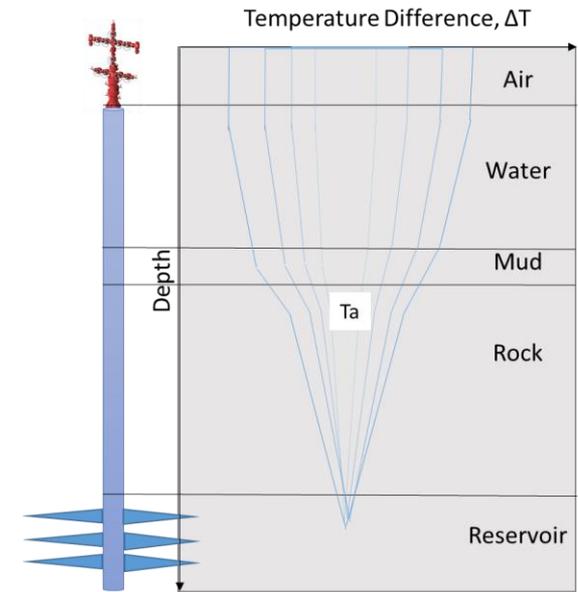
Heat Transfer in a Well Bore (Offshore Dry Tree)



Static Offshore Well



Flowing Offshore Well



Changing Temperature Gradients with Time

Note: Need to account for conduction, convection and forced convection

Well Analyzer Real-Time Features

- Rate Calculations and PVT Adjustments
 - Oil/Condensate, gas and water rates
 - Metered rate validation
 - PVT re-calibration during S/I
- BHP conversion
 - Datum P/Mid-Completion BHP conversion
 - BHP conversions from the surface data if downhole gauge fails
- Automated Pressure Transient Interpretation of buildups and drawdowns
 - Skin
 - Permeability
 - Avg. P_{res}/P^*
 - Productivity Index (PI)

Well Analyzer Real-Time Features

- Static Material Balance
 - Total in-place hydrocarbon (HC) volume
- Flowing Material Balance and Decline Analysis
 - For Hydraulically Connected and Mobile HC volumes
 - How much of the apparent reservoir volume is:
 - Hydrocarbons?
 - Water?
 - How much is due to formation compression/compaction?
 - How much of the total volume is connected to the well?
 - How much of the total volume is actually mobile?
 - How much is likely to be produced?
- Accurate and fast results that are updated in real-time
- Allows to monitor well's performance and changes in the apparent volumes with time

Well Analyzer Benefits

- Not intrusive
 - Does not require additional instrumentation
 - Connects to client's database with the ability to read/write
- Provides fast and accurate results
- Can be used to detect errors in rate allocations
- Database/Server Service installation only
- Low Cost investment for Proactive Surveillance

Well Analyzer – Case Study Outline

The following case studies will be shown to demonstrate Well Analyzer (WA) capabilities and benefits of the software installation

- Case Study 1
 - Offshore Australia – Gas Condensate Well
- Case Study 2
 - North Sea – Gas Condensate Well
- Case Study 3
 - North Sea – Wet Gas Subsea Wells
- Case Study 4
 - Gulf of Mexico – Gas Condensate Well
- Case Study 5
 - Gulf of Mexico – Subsea Deepwater Oil Well

Case Study 1

Case Study 1: Background

- NWS Australia
- Gas Condensate well (~ 70 bbl/mmcft) equipped with
 - WHP Gauge
 - Downhole Gauge
- Gas Rate was occasionally measured from a test separator
- Objectives:
 - Calculate gas rate continuously
 - Demonstrate automated PVT tuning/liquid yield calibration during shut-ins
 - Calculate mid-completion BHP
 - Calculate oil rates (Stock Tank Conditions)
 - Demonstrate auto-PTA feature

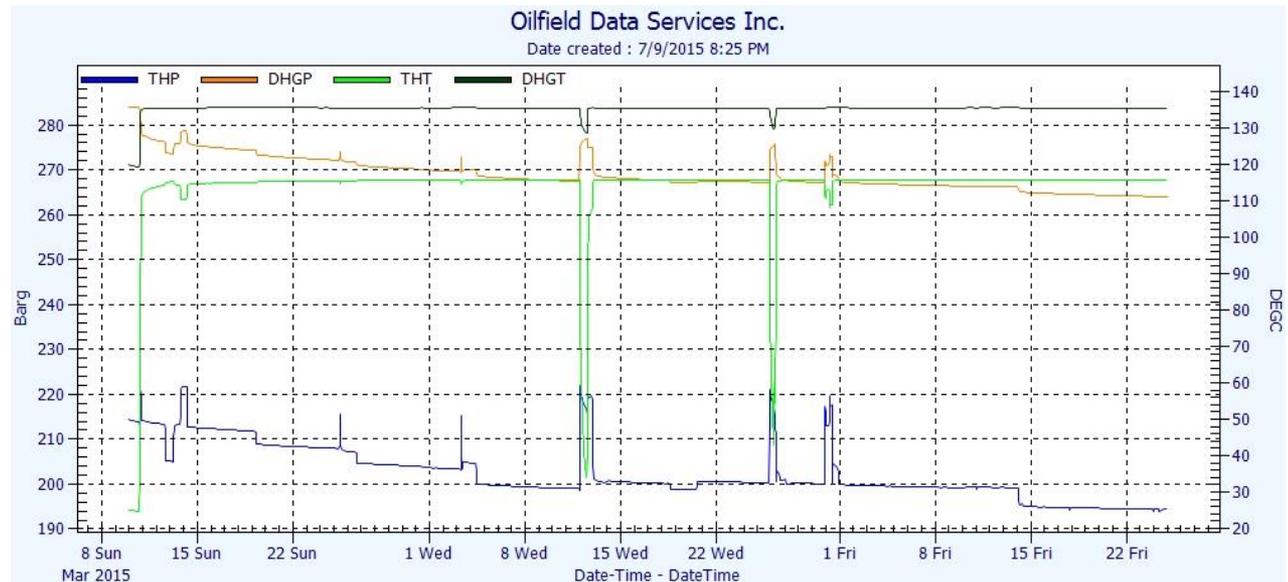
Case Study 1: Real-Time System Inputs

- Inputs

- WHP and WHT
- DHGP and DHGT

- Outputs

- Gas rate
- Condensate Yield/PVT recalibration
- Mid-completion BHP
- Auto-PTA interpretation



Select Input Data

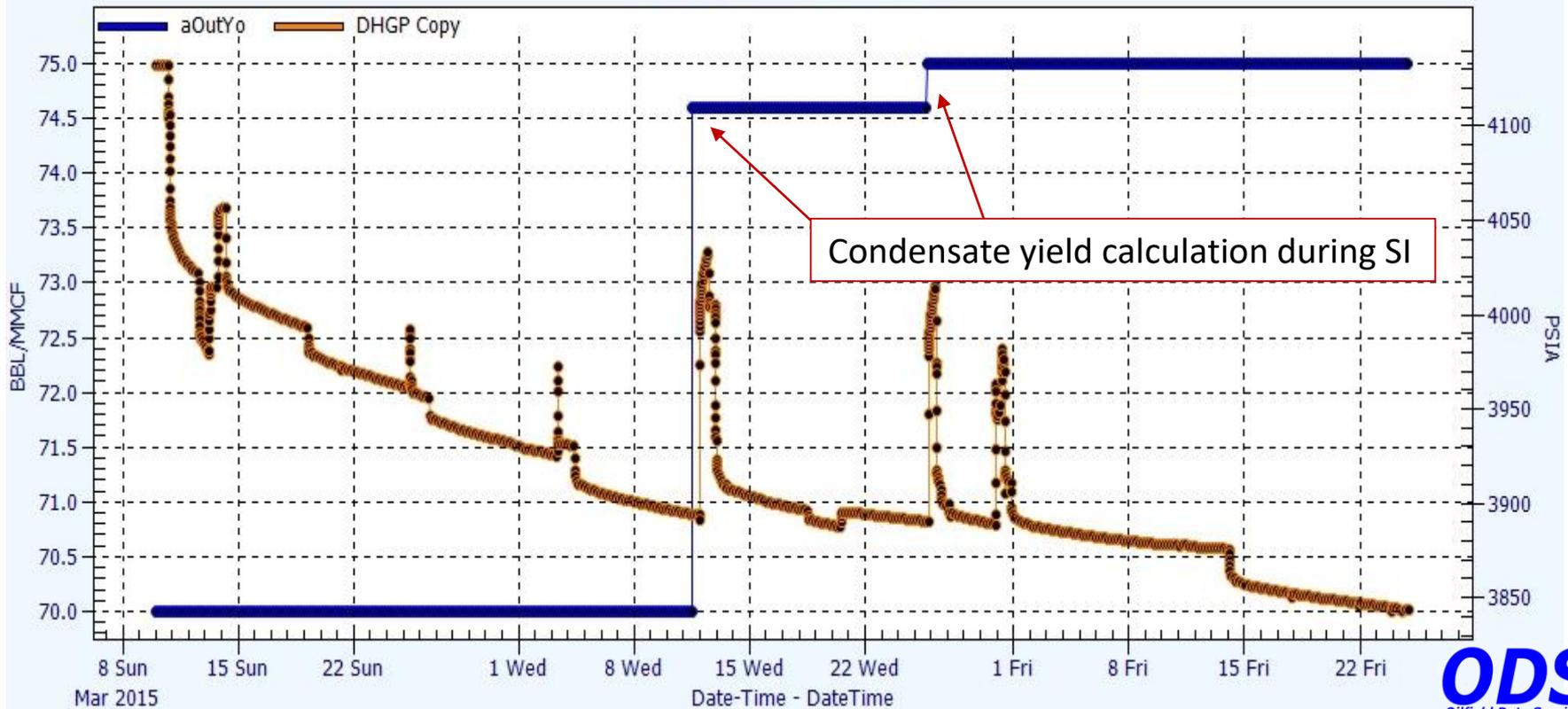
WHP	THP Copy	PSIA
WHT	THT Copy	DEGF
DHGP	DHGP Copy	PSIA
DHGT	DHGT Copy	DEGF
QGas	None	
Yo	None	
Yw	None	
SCSSV	None	
Ext QGas	None	
Qo	None	
Qw	None	
QTotal	None	
BHP	None	

Case Study 1: PVT Calibration during Shut-ins

- At every S/I, gas gravity, condensate yield or water cut are recalibrated automatically & the rates/BHP are adjusted accordingly
 - Frictional component is zero when the well is shut-in; DP in the wellbore corresponds to the head; That DP during the first 10-15 mins of shut-in (before fluid re-segregation) can be used for PVT/condensate yield/WC re-calibration

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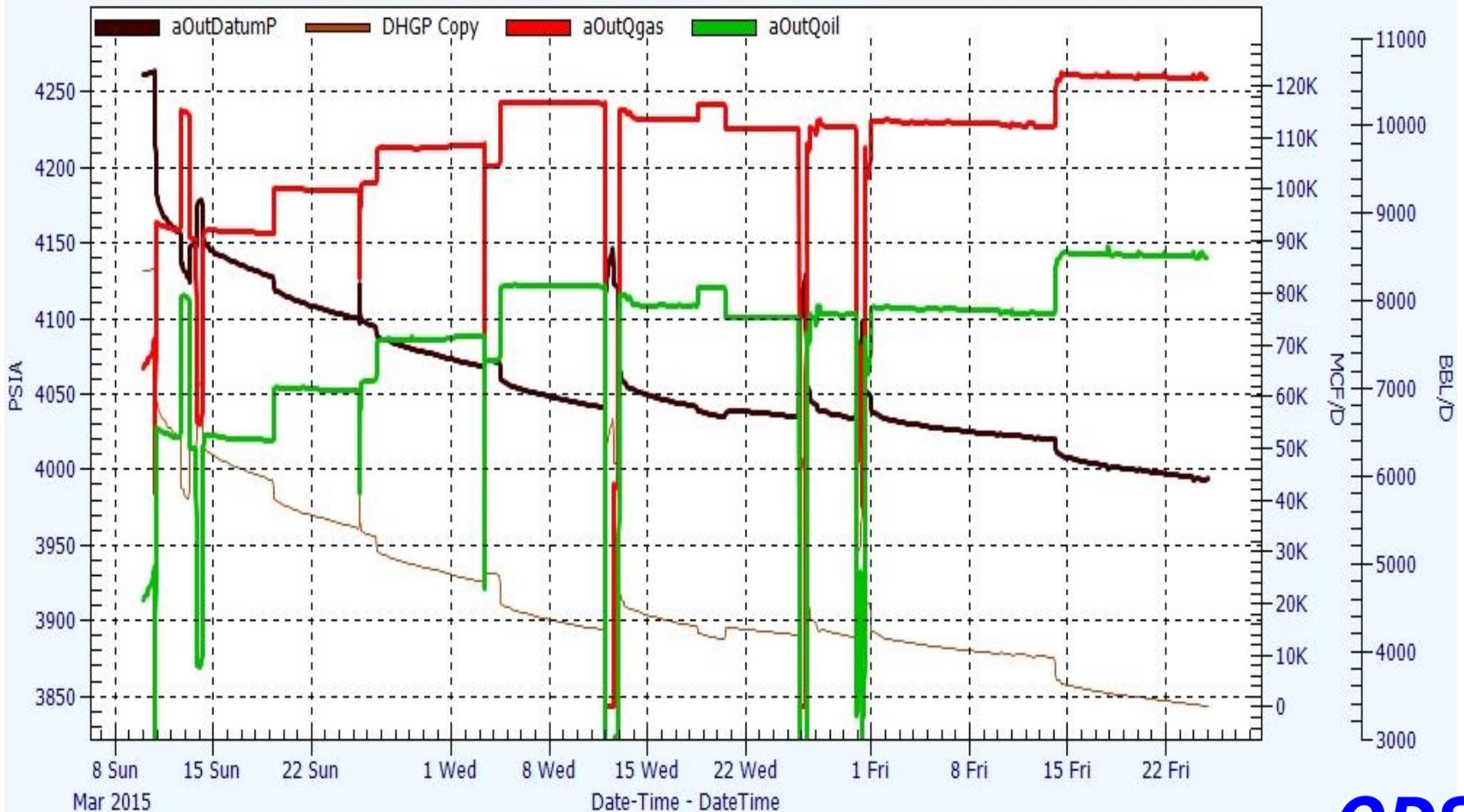
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Case Study 1: Processed Data

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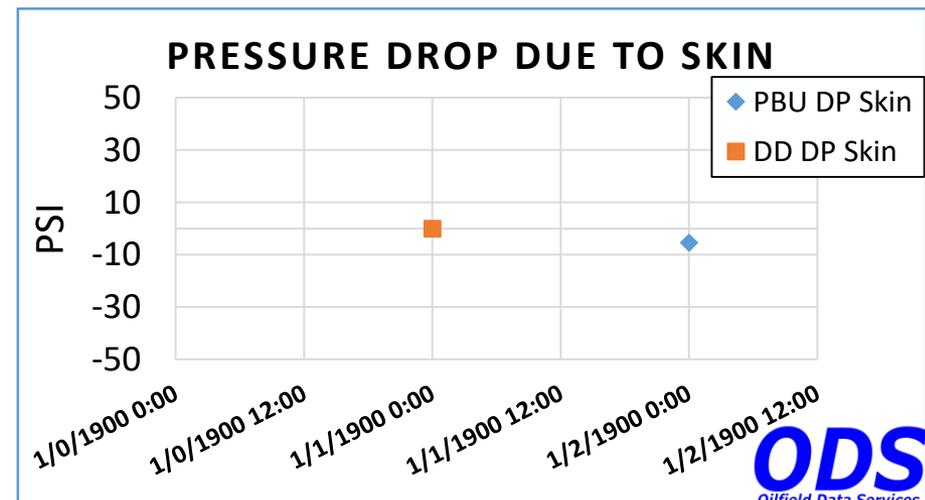
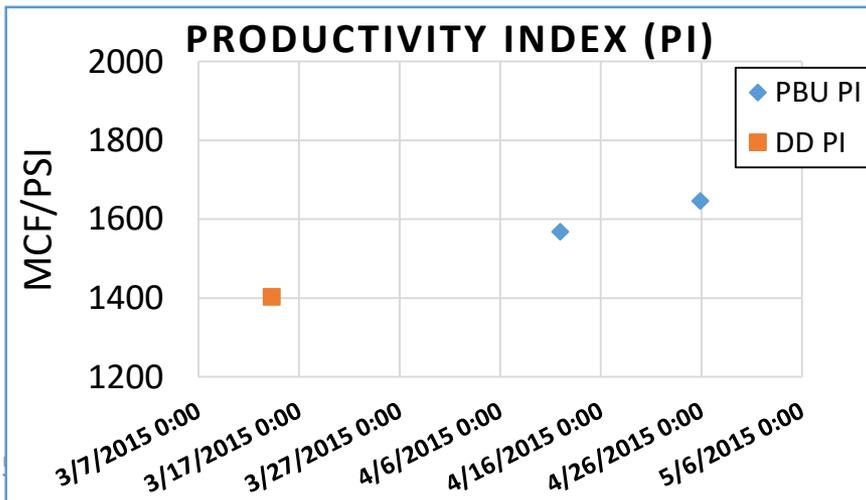
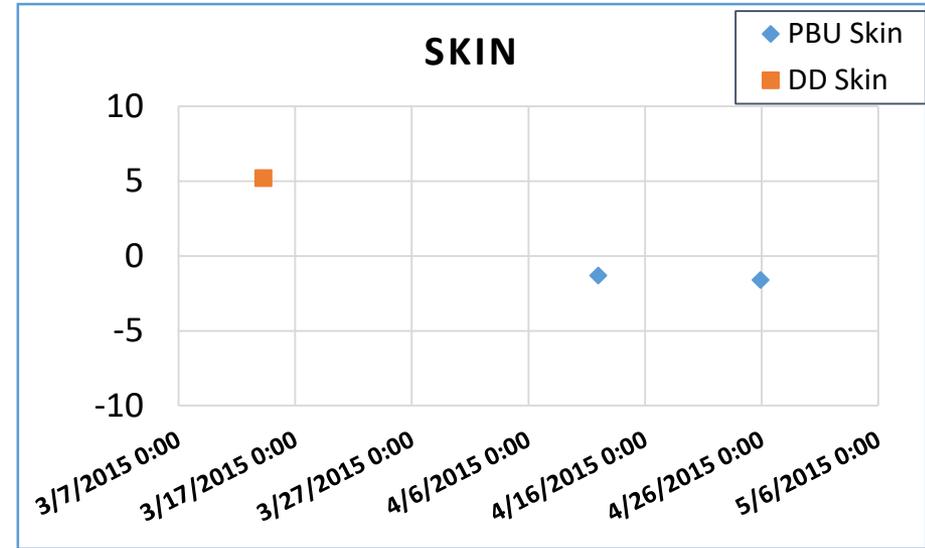
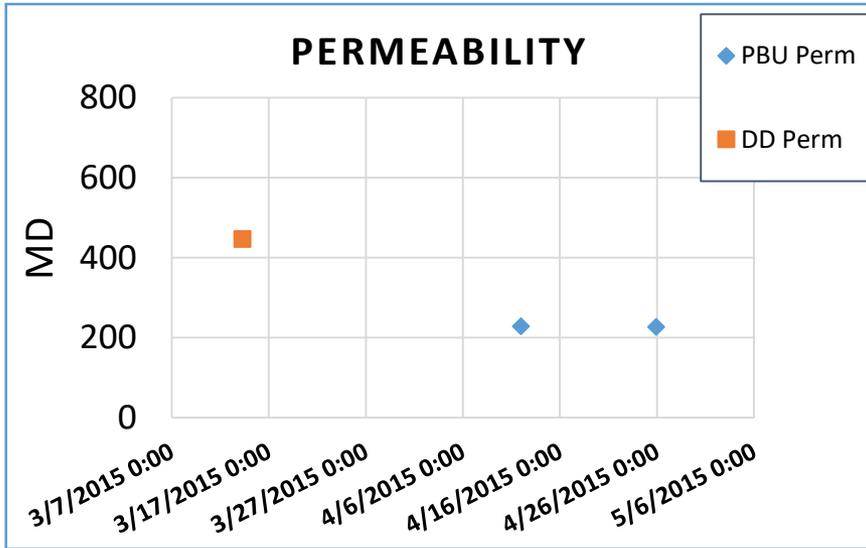
Case Study 1: Rate Comparison

- The calculated rates were compared to the sparsely measured separator rates
 - Some of the rates matched
 - Some of the separator rates were recorded erroneously
 - The red values in the table below did not match the calculated rates because the rates were changed during the well test

Date	Separator Measured Qg (MMscfd)	WA RTS Calculated Qgas (MMscf/D)
10-Mar-15	92	92.6
13-Mar-15	115.2	114.3
13-Mar-15	90.4	89.5
14-Mar-15	60.1	54.0
14-Mar-15	93.8	91.5
26-Mar-15	105	107.3
4-Apr-15	107	104.0
30-Apr-15	67.1	64.9
30-Apr-15	99.6	98.6

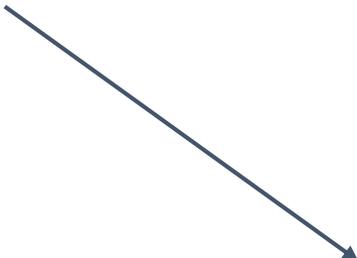
Case Study 1: Auto-PTA

- 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



Case Study 1: Auto Well Test Example

- 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 Length	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: Results & Summary

- Gas rate was calculated using pressure drop in the wellbore
 - Calculated gas rate matched measured separator test rates
 - The rates that did not match were changing during well tests
- Condensate yield was re-calibrated during shut-ins, and oil rates were adjusted accordingly
 - WA re-calibrated PVT (density portion of EOS) accounting for changing condensate yield
 - The method can be used for gas gravity and water yield re-calibration
- BHP was calculated accurately at the mid-completion depth
- WA recognized new transients and generated a PTA report for each test
 - High perm: 200 md – 450 md
 - Low skin: 0 – 5
 - High productivity well: 1400 MCF/psi – 1650 MCF/psi

Case Study 1: Summary

- Accurate Rate calculation using pressure drop in the wellbore
 - Gas rate
 - Oil Rate
 - Water Rate
 - Allocation error detection
- Continuous PVT calibration using shut-ins
 - Condensate yield
 - Water yield
 - Gas gravity

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

Case Study 2

Case Study 2: Background

- Gas Condensate Well – North Sea
- Well was equipped with multiple gauges
 - WHP gauge
 - Upper downhole gauge
 - Lower downhole gauge
- The gas rate was being measured
- Objectives:
 - Calculate and validate the metered gas rate
 - Demonstrate ODSI's BHP conversion from the surface data feature
 - Perform well test analysis and determine if the well is a stimulation candidate

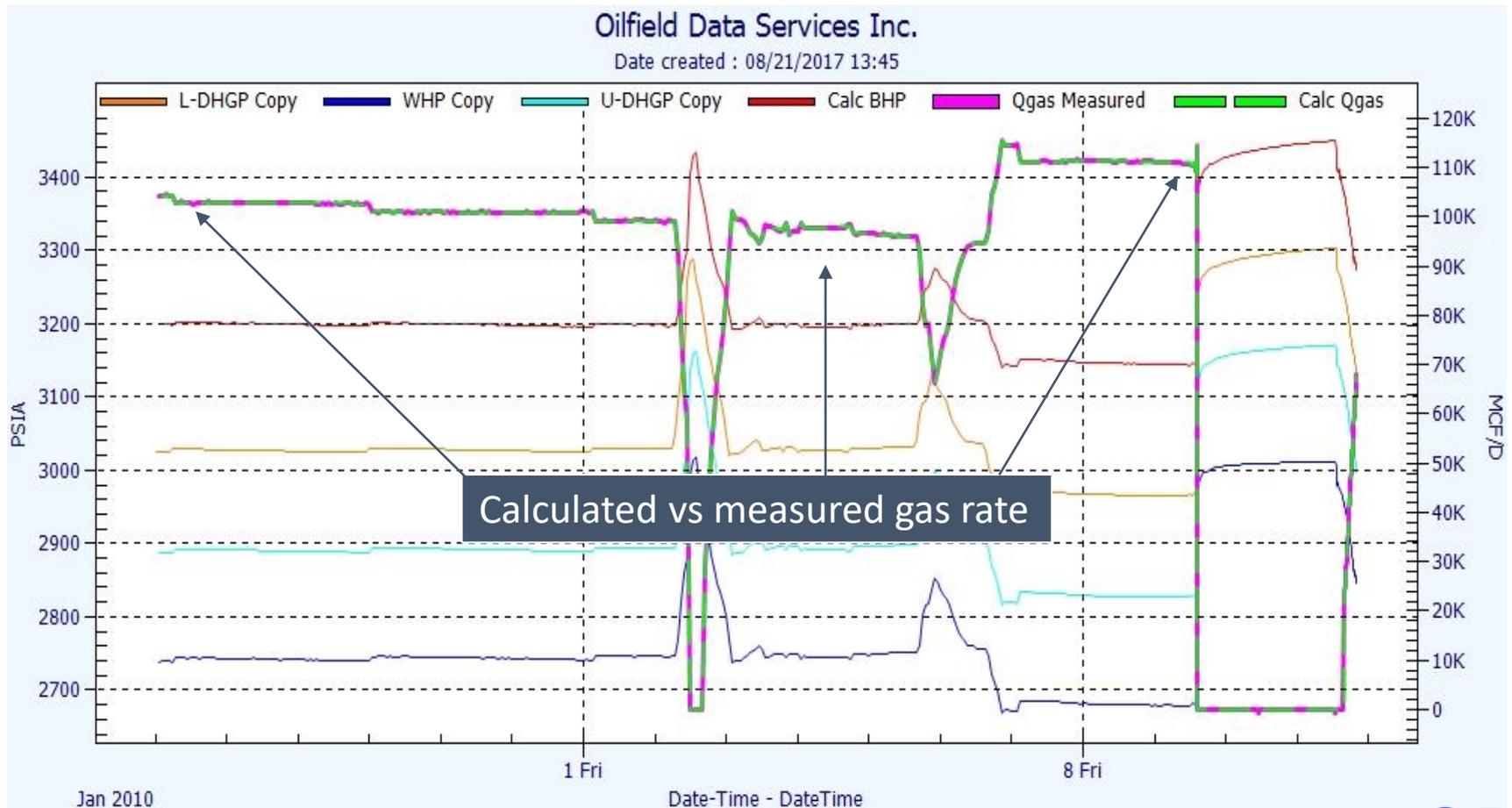
Note: All of the downhole gauges failed. The interpretation was performed on the historical data with functional gauges to demonstrate the accuracy of ODSI's BHP conversion and to demonstrate that the well was not a stimulation candidate

Case Study 2: Workflow

- The gas rate was calculated using the DP between wellhead and the lowest downhole gauge
- **Proof of concept:** Pressure was calculated at the Upper and Lower DHGP gauge depths to demonstrate the ability to calculate pressure at any point along the wellbore
- The importance of mid-completion BHP conversion was shown by performing a buildup analysis on the following:
 - WHP
 - Middle gauge pressure
 - Lower gauge pressure
 - Calculated mid-completion BHP

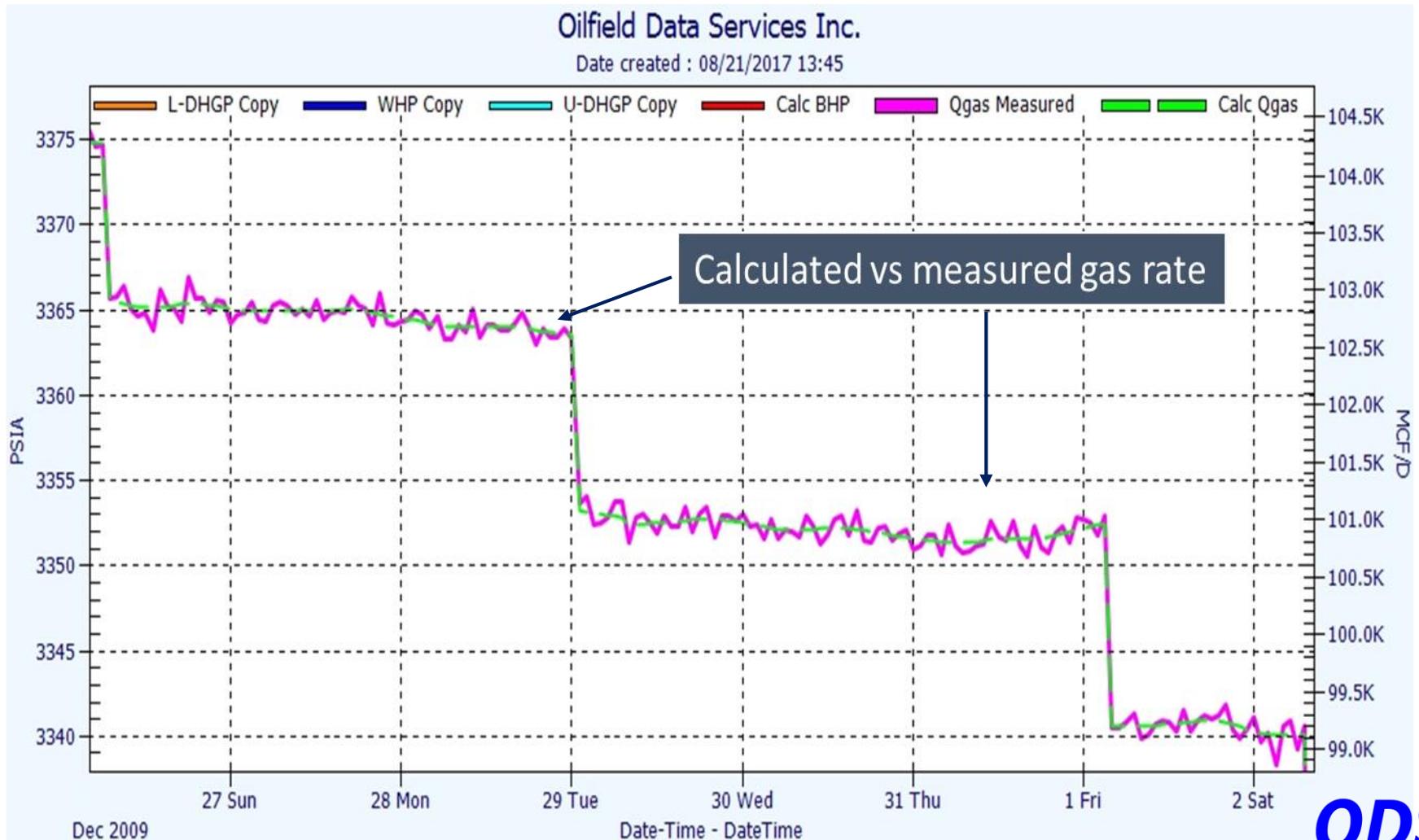
Case Study 2: Gas Rate Comparison

- Gas rate calculated using DP wellbore & compared to the metered gas rate
 - Less than 1 % error between the measured and the calculated gas rates



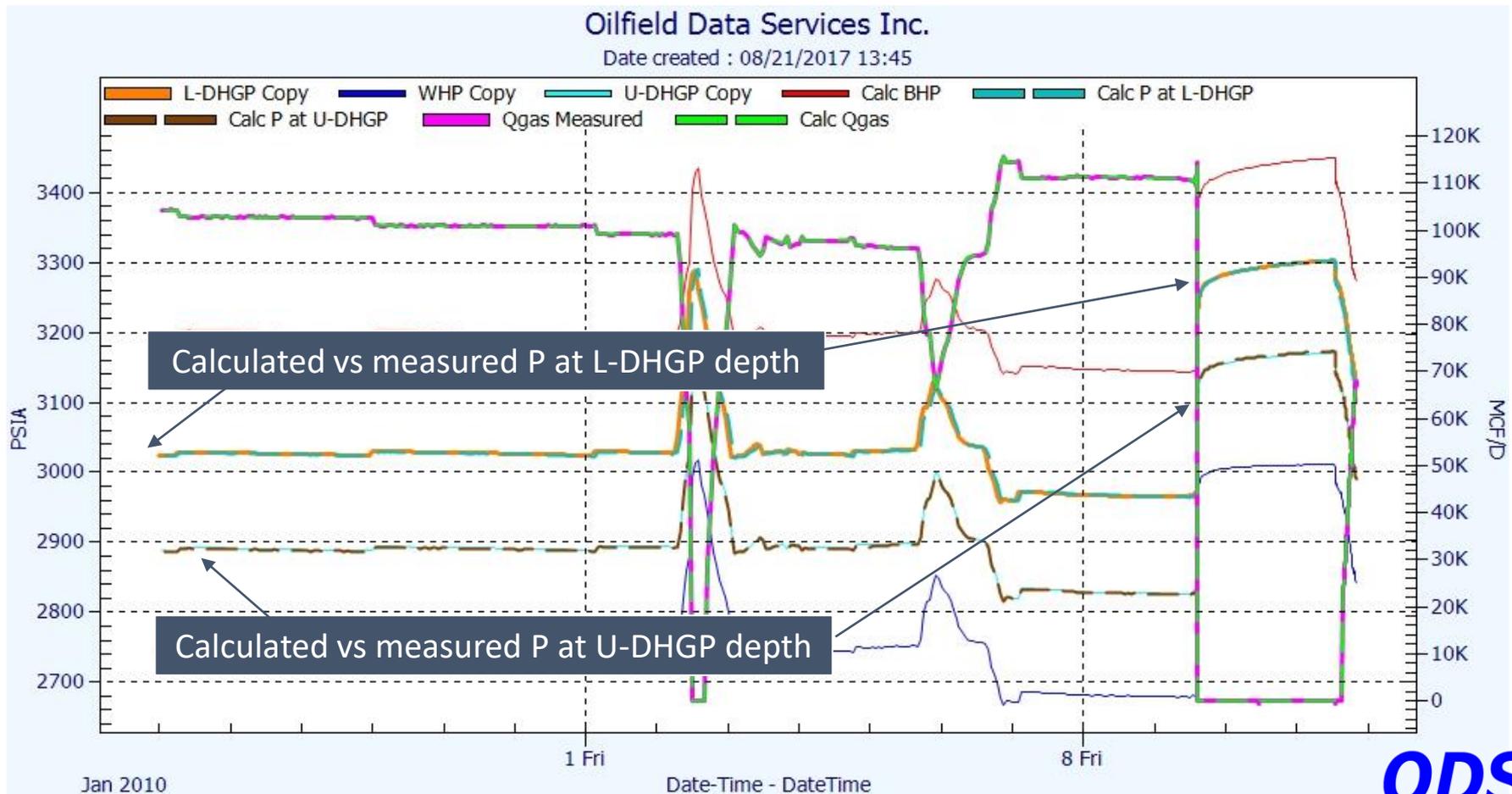
Case Study 2: Rate Comparison (Zoom)

- There was < 1 % error between the metered and the calculated gas rates



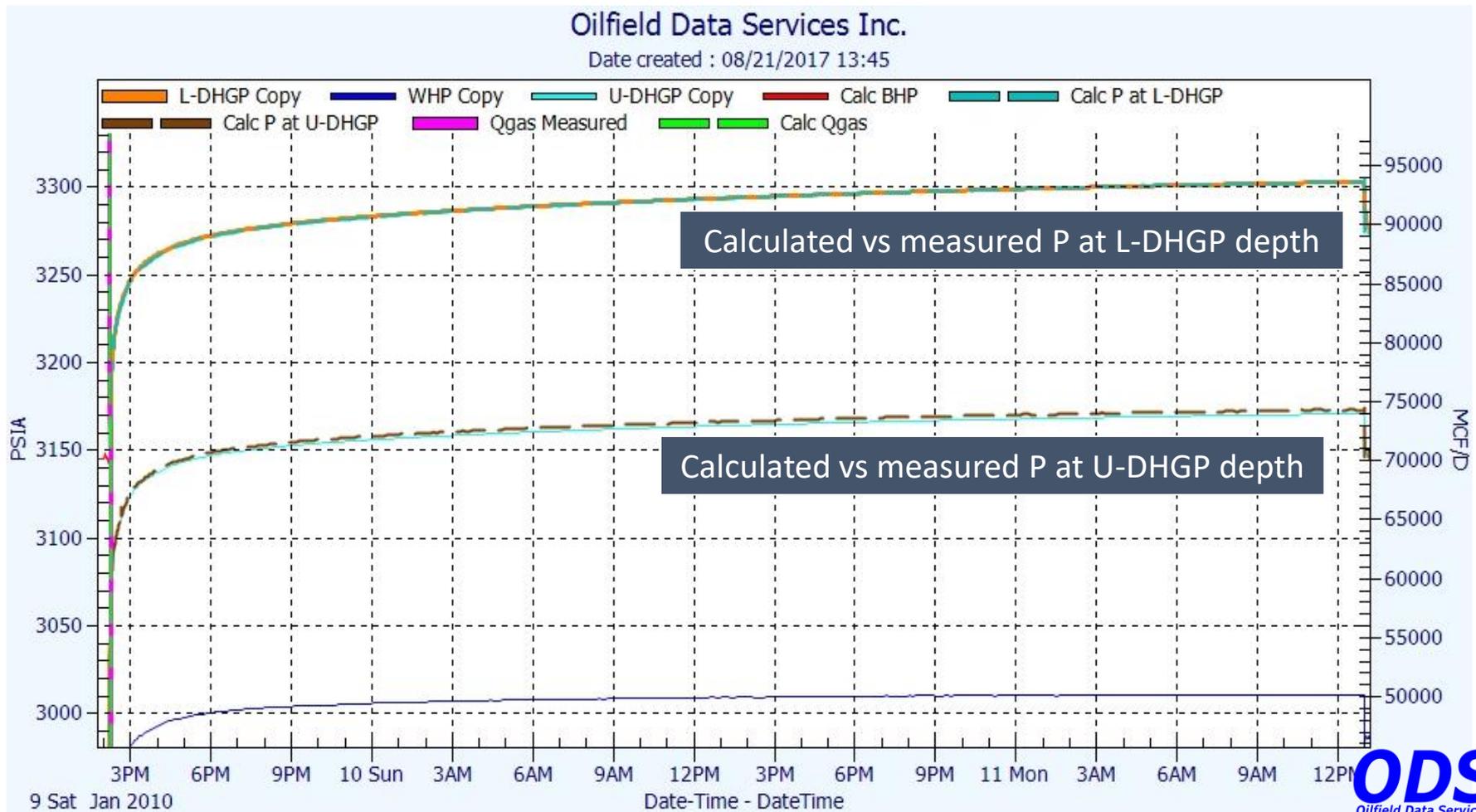
Case Study 2: Pressure Comparison

- Pressure conversion was performed at the Upper and Lower DHGP depths using the WHP and the calculated gas rate (proof of concept)
 - Less than 2 psi error



Case Study 2: Pressure Comparison

- Accurate Pressure conversion: calculated vs. measured pressures matched
 - 2 psi difference
 - The feature is useful for wells with failed DHGPs or without downhole gauge



Case Study 2: Buildup Analysis

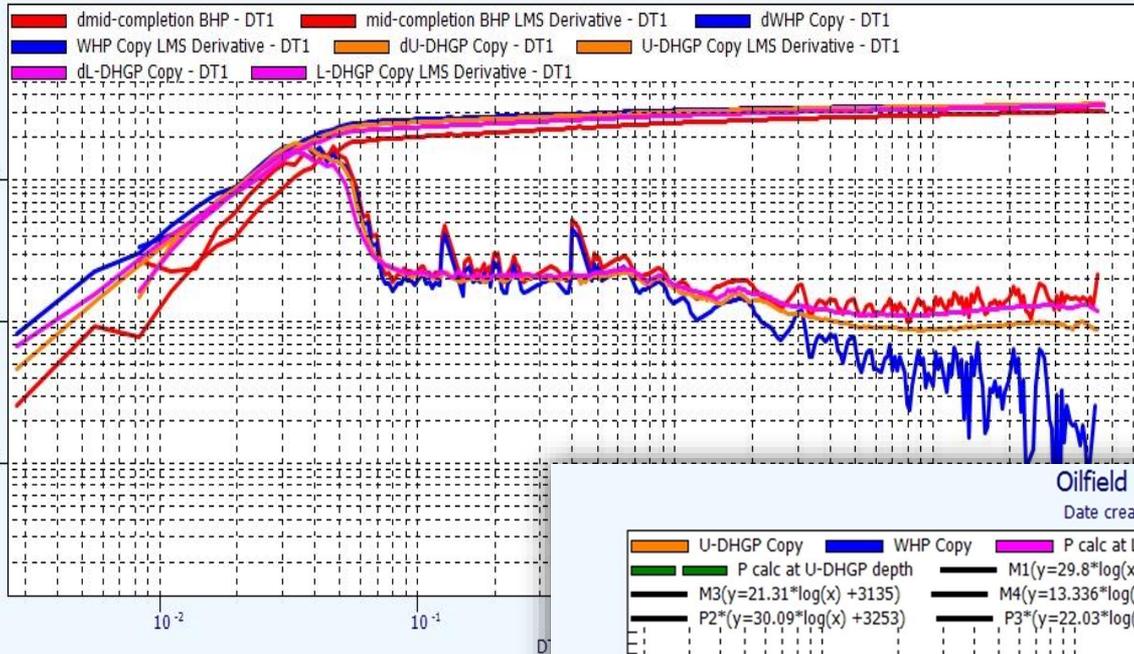
Importance of mid-completion BHP

- It is crucial to have a valid mid-completion BHP
- Failure to perform an analysis on mid-completion BHP leads to:
 - Overestimation of Permeability
 - Overestimation of Skin
 - Underestimation of P^* /Reservoir Pressure
- The next slides show how this well could be incorrectly considered to be a stimulation candidate

Case Study 2: Buildup Analysis

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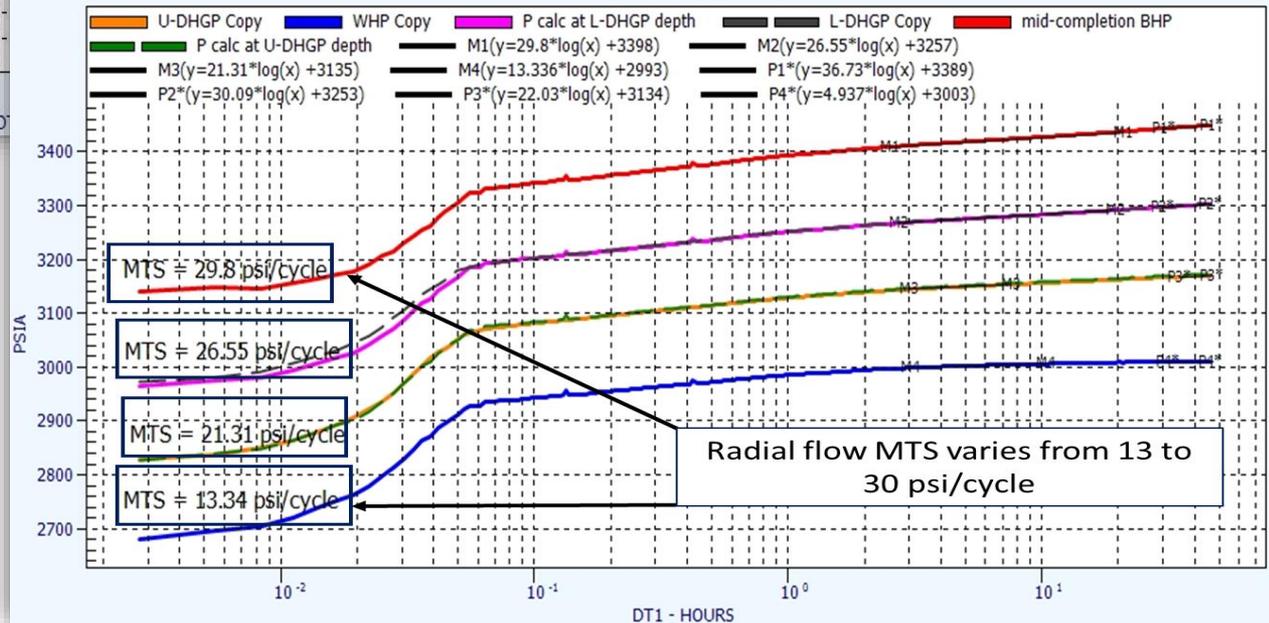
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Importance of mid-completion BHP conversion

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Case Study 2: Buildup Analysis

Importance of BHP conversion

- The difference in the mid-time slope values was caused by wellbore cooling
- **During a shut-in**, the head is **NOT CONSTANT**; wellbore cooling causes fluid density (head) to increase
- **BHP increases** as the reservoir pressure builds up
- However, if the RATE of an increase in the density term is significant, it can result in SLOPE SUPPRESSION on the WHP or even cause DECREASING WHP during a shut-in!

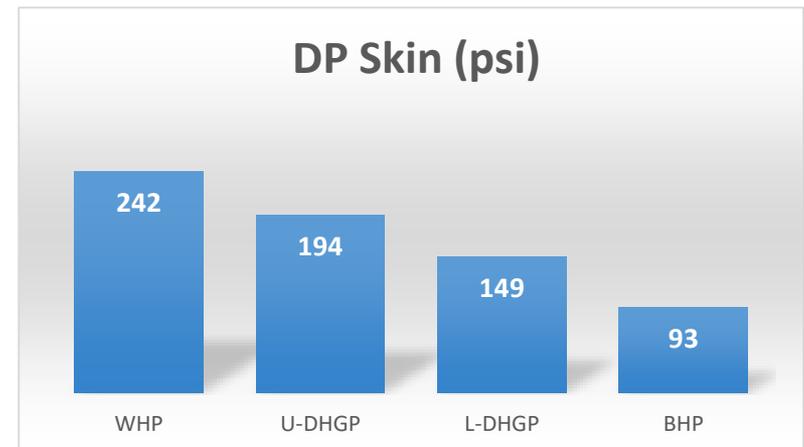
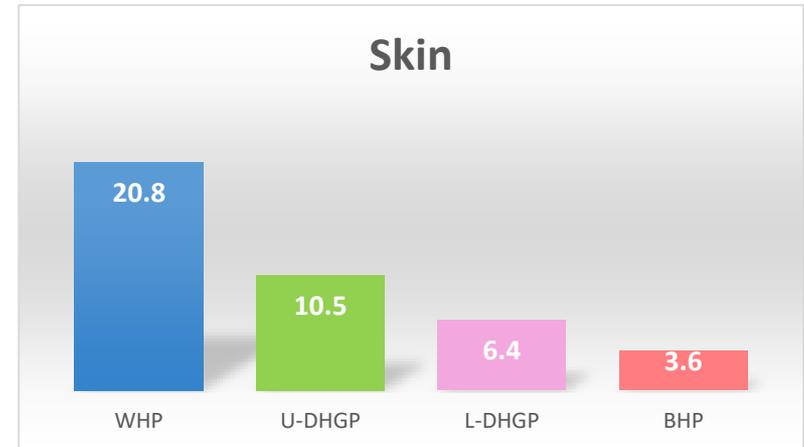
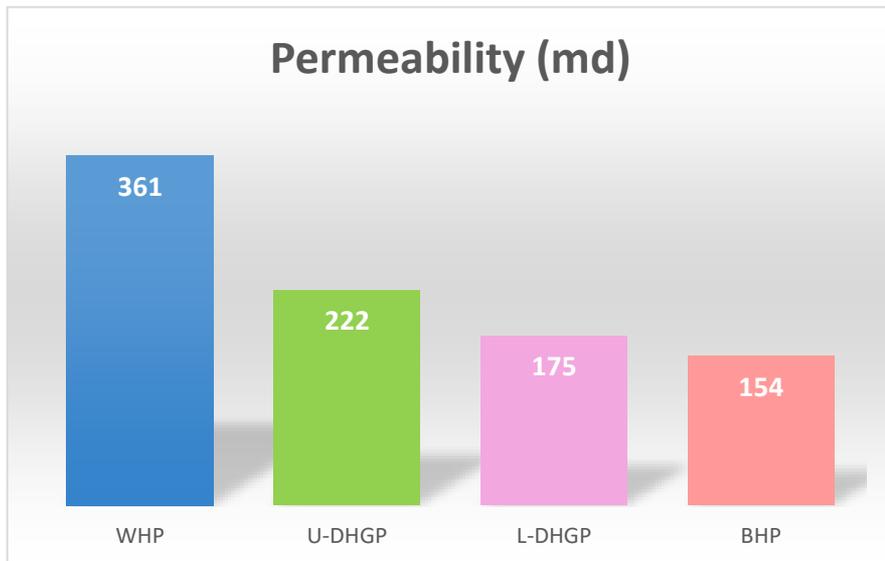
$$\downarrow \text{WHP} = \uparrow \text{BHP} - \uparrow \text{HEAD}$$

- **Artificially lower MTS would provide artificially higher skin & perm**
 - **WA accounts for phase-thermal changes in the wellbore and calculates BHP accurately**

Case Study 2: Buildup Analysis Results

Importance of BHP conversion

- To show the importance of valid mid-completion BHP conversion, the buildup was analyzed using the following:
 - WHP
 - Upper Downhole gauge pressure
 - Lower Downhole gauge pressure
 - Calculated mid-completion BHP



Is the well really a stimulation candidate? No!

Case Study 2: Summary

- Direct solution to the Mechanical Energy Balance accounts for PVT, thermal and frictional changes in the wellbore and allows
 - Accurate Gas Rate calculation
 - Less than 1 % error between measured and the calculate gas rates
 - Accurate Pressure Conversions at any point along the wellbore
 - Within 2 psi error margin
- Valid PTA Results
 - Failure to perform valid mid-completion BHP leads to overestimation of skin & permeability and underestimation of reservoir pressure
- The well was NOT a stimulation candidate
 - Treatment would not improve the well's performance
 - The skin appeared artificially high because of the wellbore cooling effects and friction below the gauge

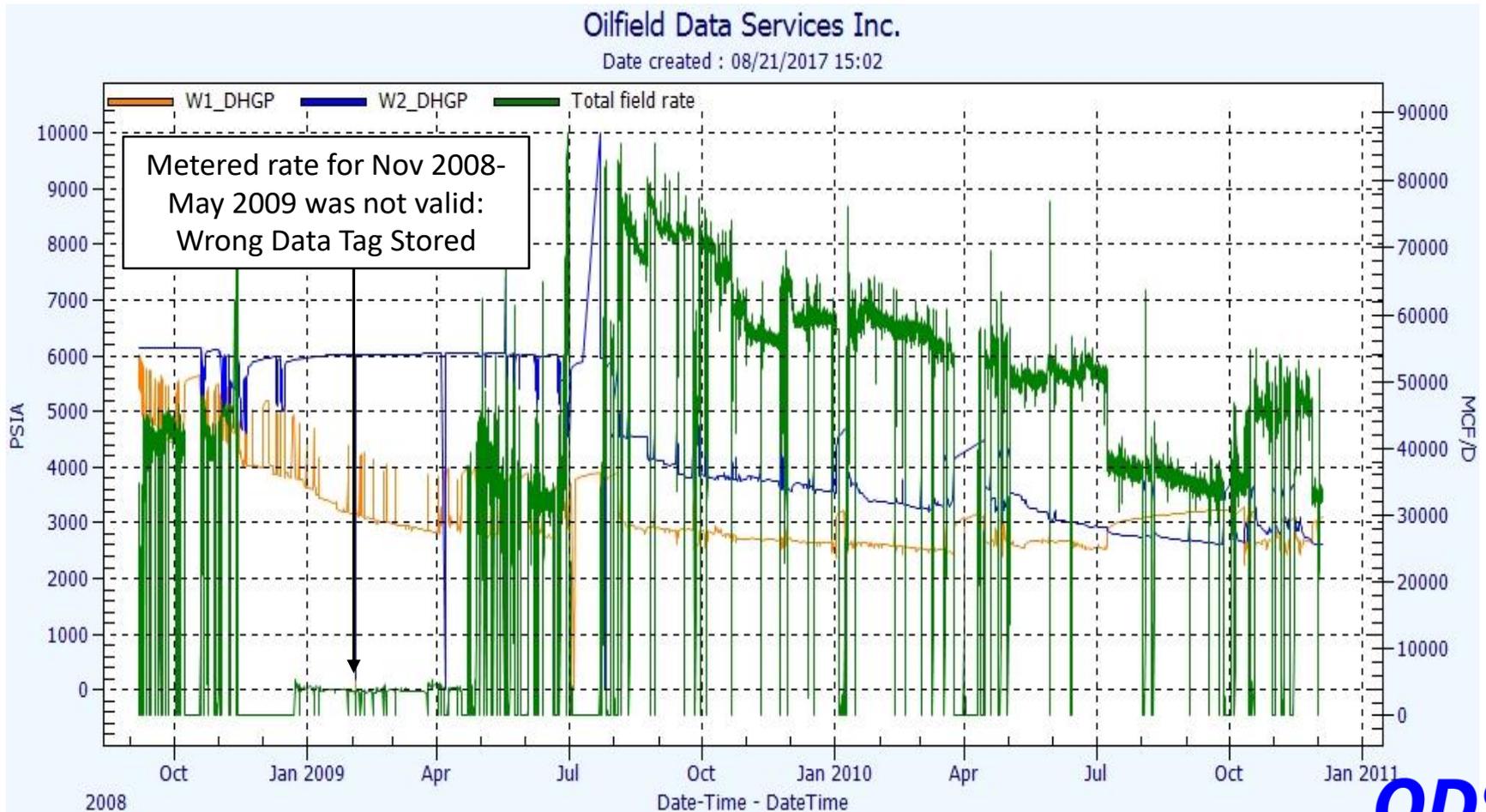
Case Study 3

Case Study 3: Background

- North Sea - Dutch Sector
- Two subsea wet gas wells
 - The wells were equipped with tree and downhole gauges
- Both wells lost communication with subsea Wet Gas meters
 - Individual well rates were not available
- The wells were tied-back to the host facility, where the total field rate was measured
- Objectives
 - Demonstrate the ability to calculate individual gas rates
 - Calculate BHP at mid-completion
 - Perform auto-PTA

Case Study 3: Production History

Due to high MPFM installation cost for subsea wells, ODSI was asked to demonstrate accuracy of the DP Wellbore method by calculating the individual gas rates and comparing the sum to the total rate measured at the platform



Case Study 3: System Inputs

- The following inputs were used for Well 1 and Well 2:
 - WHP/WHT
 - DHGP/DHGT
- To perform the following calculations:
 - Gas Rate
 - BHP at mid-completion
 - Automated interpretation of buildups and drawdowns

Well 1

Select Input Data		
WHP	W1_WHP	PSIA
WHT	W1_WHT	DEGF
DHGP	W1_DHGP	PSIA
DHGT	W1_DHGT	DEGF
QGas	None	
GG	None	
Yo	None	
Yw	None	
SCSSV	None	
Ext QGas	None	
Qo	None	
Qw	None	
QTotal	None	
BHP	None	
Friction	None	
Inj Qg (Lift)	None	

Config	
SamplesPerUpdate	1000
Config Ok	
Load Config	
Well #1	
<input checked="" type="checkbox"/> Analysis Enabled	
<input checked="" type="checkbox"/> Reserves Enabled	
<input type="checkbox"/> MLTO (DEGF)	0
Legacy MLTO (not used in rate calc)	
<input type="checkbox"/> VSSV Open	
<input type="checkbox"/> Ignore invalid events	
<input type="checkbox"/> No CalcRate Smoothing	
Rate Calc from Perm	
<input type="checkbox"/> Enabled	

Well 2

Select Input Data		
WHP	W2_WHP	PSIA
WHT	W2_WHT	DEGF
DHGP	W2_DHGP	PSIA
DHGT	W2_DHGT	DEGF
QGas	None	
GG	None	
Yo	None	
Yw	None	
SCSSV	None	
Ext QGas	None	
Qo	None	
Qw	None	
QTotal	None	
BHP	None	
Friction	None	
Inj Qg (Lift)	None	

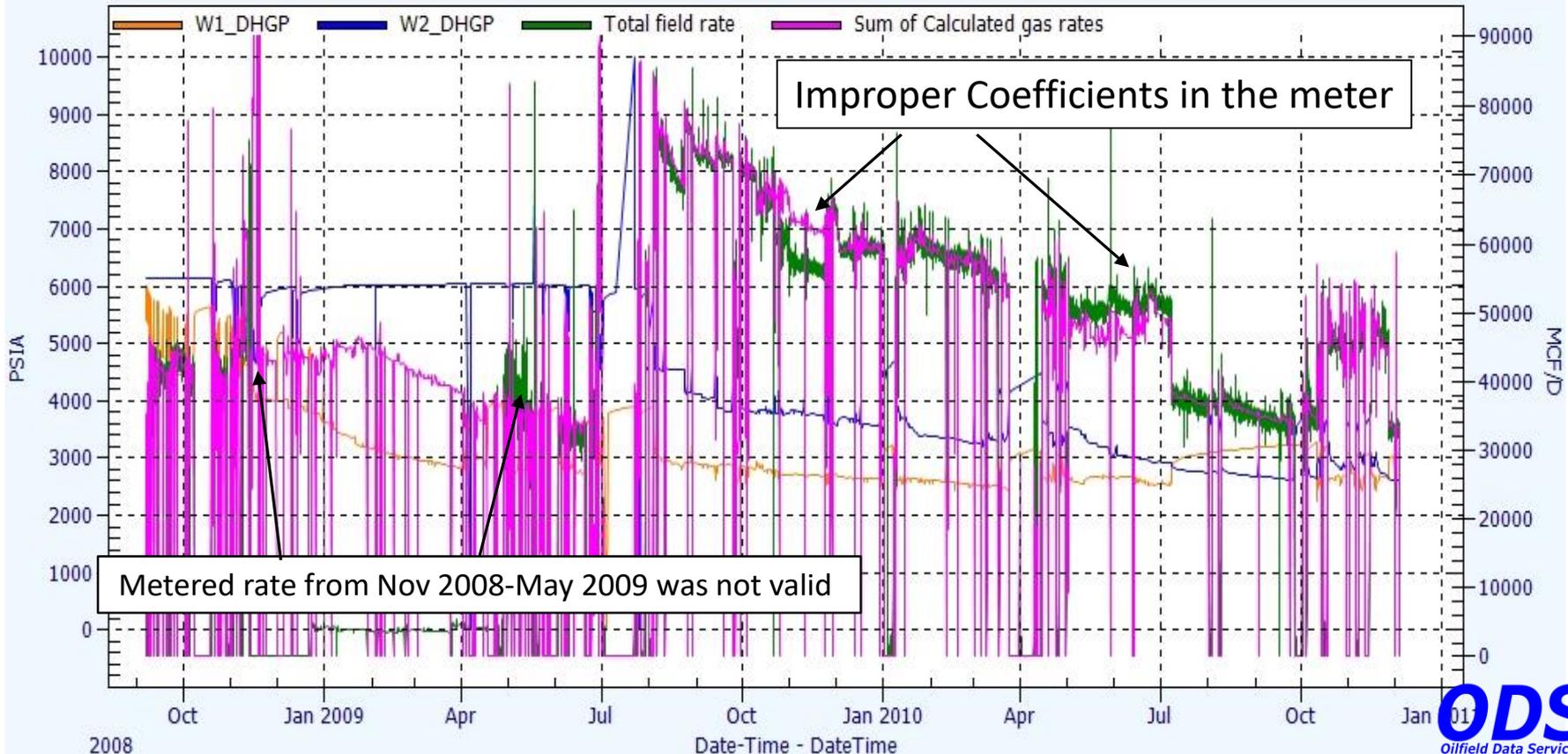
Config	
SamplesPerUpdate	100
Config Ok	
Load Config	
Well #2	
<input checked="" type="checkbox"/> Analysis Enabled	
<input checked="" type="checkbox"/> Reserves Enabled	
<input type="checkbox"/> MLTO (DEGF)	0
Legacy MLTO (not used in rate calc)	
<input type="checkbox"/> VSSV Open	
<input type="checkbox"/> Ignore invalid events	
<input type="checkbox"/> No CalcRate Smoothing	
Rate Calc from Perm	
<input type="checkbox"/> Enabled	

Case Study 3: Rate Comparison

- The plot below shows the rate comparison: Green (total field rate measured at the platform) vs Purple (sum of the calculated gas rates for Well 1 and Well 2)
- The operator was satisfied with the results and decided not to install the meters for this field and for future developments

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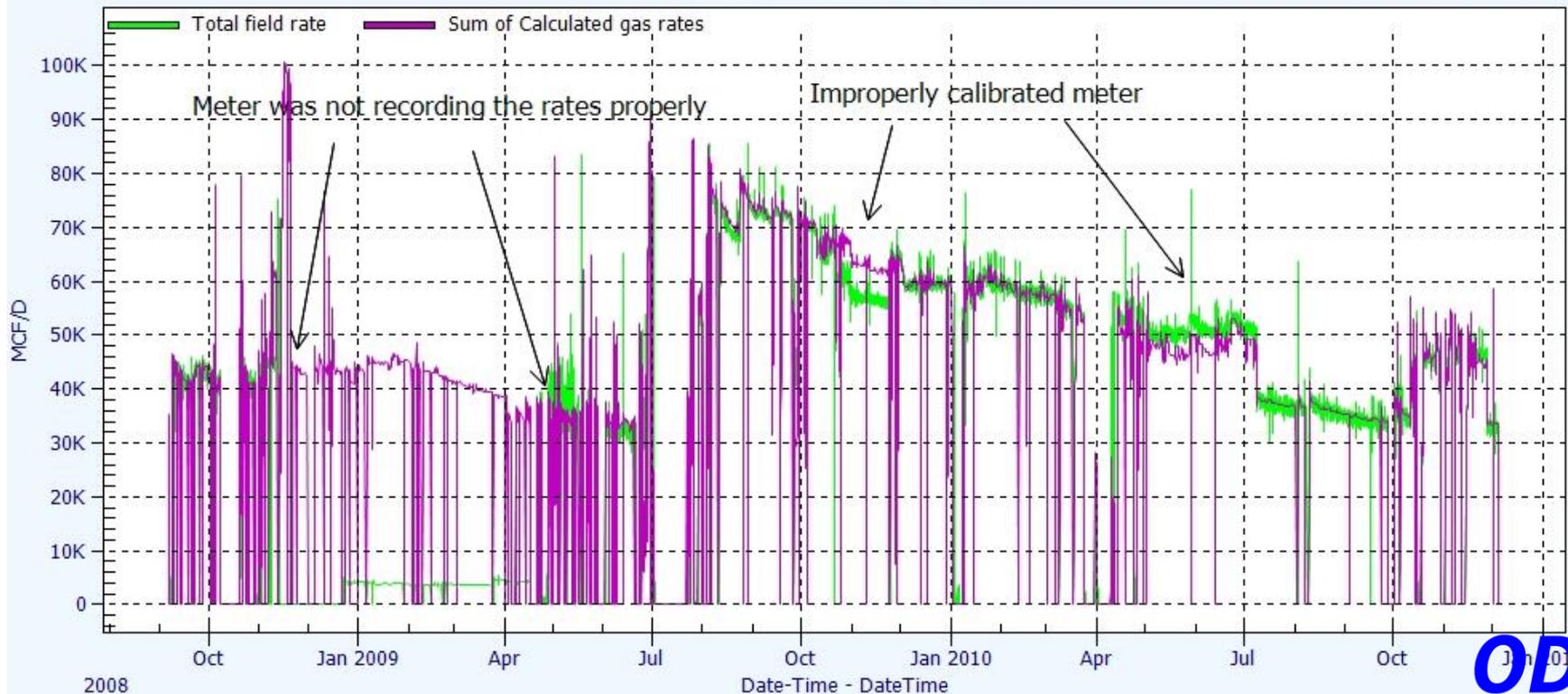


Case Study 3: Rate Comparison

- The platform rates from Nov 2008 - Apr 2009 were not stored on client's database
- The deviation in Oct-Nov 2009 and May - Jul 2010 was because of the improper meter calibration (wrong plate coefficient)
 - Once the deviation was detected and the plate coefficient fixed, the calculated and the measured rates matched again
 - WA can be used to detect errors in allocations/MPFM calibration

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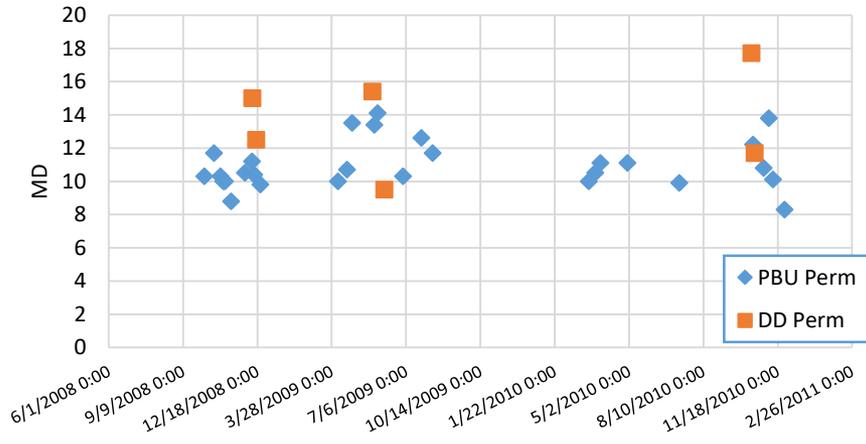
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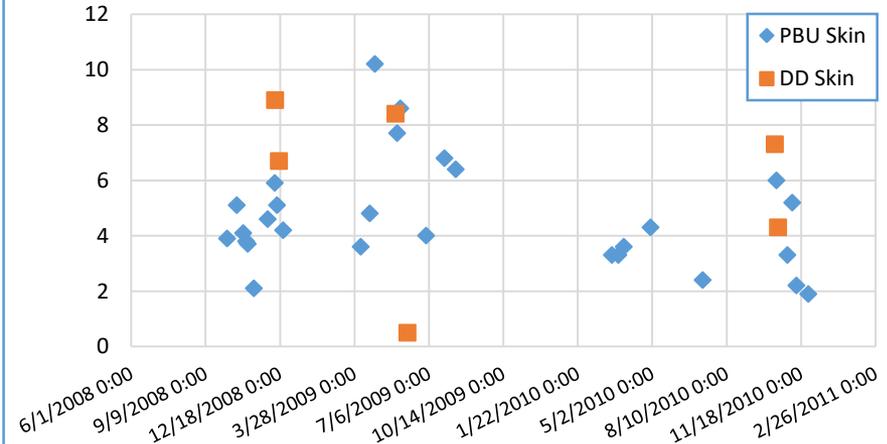
Case Study 3: Auto-PTA Example

Well 1 PTA interpretation is shown as an example

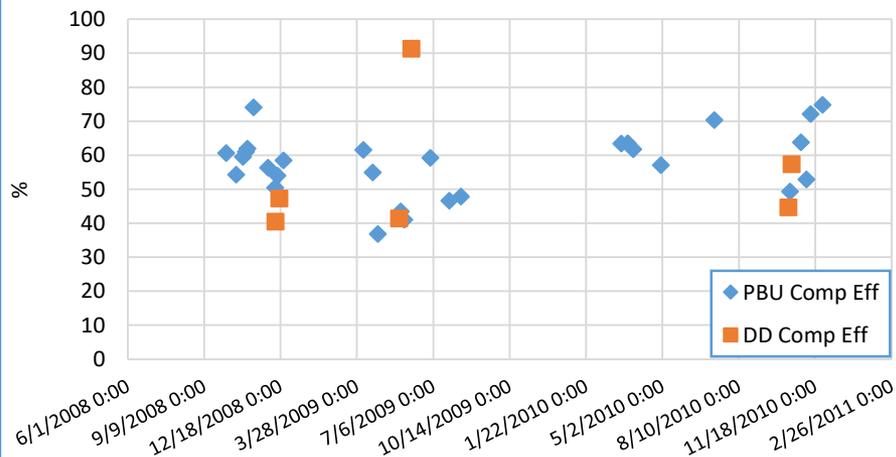
WELL #1 PERMEABILITY



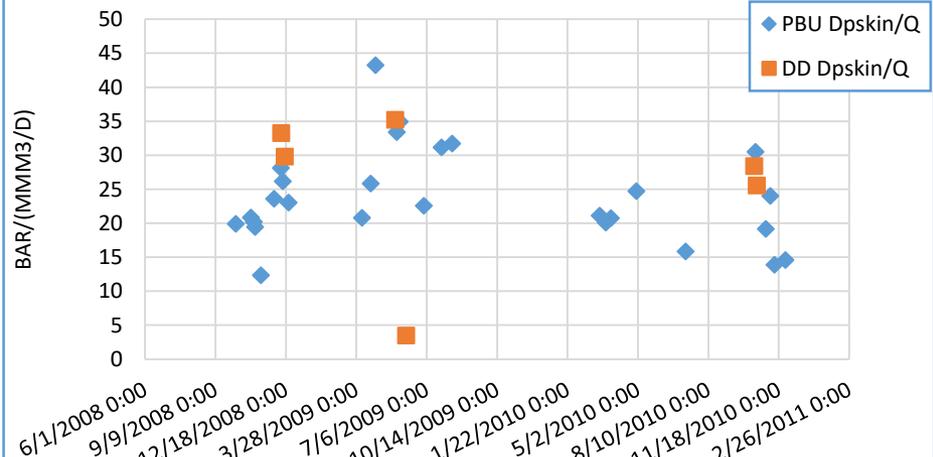
WELL #1 SKIN



WELL #1 COMPLETION EFFICIENCY (%)



PRESSURE DROP DUE TO SKIN



Case Study 3: Summary Table

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

Start Time	Test Length	Type	BHPI	BHPf	Qgasi	Qgas	Perm	Skin	DP Skin	PStar	Comp Eff	DPs/Q	Report Link
ddMMMyyyy HH:mm:ss	HOURS		Bara	Bara	kNm3/D	kNm3/D	md		Bar	Bara	%	r/(MMm3/	
10/7/2008 19:03	285.2	PBU	324	373	1138	1138	10.3	3.9	24	411	60.61	19.92	
10/22/2008 12:09	26.6	2-Rate DD	376	323	378	1175	17.8	12	45	313	34.09	27.5	
10/29/2008 12:33	55.1	PBU	321	383	1094	1094	10.3	4.1	24	405	59.51	20.85	
11/2/2008 9:45	31.6	PBU	322	391	1079	1079	10	3.8	23	401	61.05	20.2	
11/4/2008 10:09	23.3	PBU	323	391	1099	1099	10	3.7	23	400	61.92	19.45	
11/12/2008 13:21	27.3	PBU	332	366	907	907	8.8	2.1	12	395	74.07	12.37	
12/1/2008 8:15	97.5	PBU	290	372	1139	1139	10.5	4.6	28	385	56.35	23.59	
12/10/2008 17:51	11.9	PBU	282	353	1185	1185	11.2	5.9	35	375	50.45	28.13	
12/11/2008 5:45	58.6	DD	360	281	0	1180	15	8.9	42	269	40.43	33.27	
12/13/2008 17:51	65.2	PBU	280	360	1169	1169	10.4	5.1	32	378	54.01	26.15	
12/16/2008 11:03	130.9	DD	365	279	0	1202	12.5	6.7	38	261	47.26	29.79	
12/21/2008 21:57	46.6	PBU	278	282	1150	1150	9.8	4.2	28	378	58.52	23.06	
4/5/2009 7:15	77.6	PBU	221	262	892	892	10	3.6	20	299	61.6	20.78	
4/17/2009 10:33	98	PBU	210	281	982	982	10.7	4.8	27	298	54.99	25.86	
4/24/2009 9:51	82.9	PBU	204	286	993	993	13.5	10.2	45	296	36.88	43.26	
5/9/2009 9:33	13.8	PBU	206	273	947	947	10.5	5.4	30	288	51.95	29.54	
5/21/2009 23:45	21.2	DD	271	207	0	1007	15.4	8.4	38	200	41.4	35.24	
5/24/2009 8:39	60.9	PBU	211	254	897	897	13.4	7.7	32	286	43.46	33.41	
5/28/2009 17:03	122.1	PBU	210	234	936	936	14.1	8.6	35	288	41.08	34.94	
6/2/2009 19:09	36.5	DD	280	212	0	947	24	18	48	202	25.43	47.58	
6/6/2009 21:45	10.5	DD	261	202	0	772	9.5	0.5	3	220	91.38	3.49	
7/2/2009 1:45	495.4	PBU	228	274	574	574	10.3	4	14	284	59.26	22.57	
7/26/2009 19:33	187.3	PBU	219	270	780	780	12.6	6.8	26	285	46.62	31.15	
8/10/2009 23:27	24.7	PBU	213	250	778	778	11.7	6.4	26	280	47.86	31.7	
3/8/2010 18:15	23.6	PBU	183	196	469	469	10	3.3	10	226	63.42	21.13	
3/17/2010 10:57	30.2	PBU	182	192	490	490	10.5	3.3	10	226	63.53	20.09	
3/24/2010 15:03	167	PBU	179	194	532	532	11.1	3.6	12	233	61.74	20.73	
4/29/2010 20:09	39.6	PBU	191	198	416	416	11.1	4.3	11	229	57.05	24.73	
7/8/2010 17:09	2084.7	PBU	182	205	390	390	9.9	2.4	7	229	70.39	15.83	
10/13/2010 20:09	18.5	DD	221	185	0	617	17.7	7.3	19	184	44.72	28.39	
10/15/2010 17:09	51.5	PBU	188	212	564	564	12.2	6	18	237	49.39	30.49	
10/17/2010 20:39	13.5	DD	230	174	0	789	11.7	4.3	21	164	57.34	25.54	
10/30/2010 7:21	61	PBU	187	213	510	510	10.8	3.3	10	232	63.85	19.15	
11/11/2010 18:57	87.5	PBU	188	223	485	485	10.1	2.2	7	232	72.09	13.91	

Case Study 3: Summary

- The gas rates for individual wells were accurately calculated
 - The sum of the calculated gas rates matched the total field rate measured at the platform
 - The operator was satisfied with the results and decided not to install subsea meters and used ODSI's rate calculation feature for this field and all future subsea developments
- The method can be used for meter calibration and to detect errors in allocations
 - Deviations between the total platform rate and the calculated rates around Nov 2009 indicated improper meter calibration – wrong plate coefficient
 - The rates matched again once the meter was recalibrated
- The method can also be used to re-calibrate the PVT and detect the onset of water production
- Real-time well performance monitoring (auto-PTA)
 - Fairly constant perm: 10 – 18 md (variation due to multiple zones)
 - Fairly constant skin: 4 – 7 (variation due to varying perm)

Case Study 3: Supplemental I

- Demonstration of ODSI's Water Yield ISIP Flash Calculations
- Method works on wells with one or more downhole gauges
- Yw calculations are performed on shut-ins with the SCSSV open
- The calculations can be revisited using well's Thermal Response or by using liquid fallback and re-injection

Case Study 3: Supplemental II

- Process:
 - When the well is S/I and the SCSSV is not closed, use the PVT of the Gas to determine the amount of condensate or water present in the well bore
 - Use the thermal response to determine if the liquid yield is valid
 - Proceed with the calculated liquid yield when the well comes back on-line

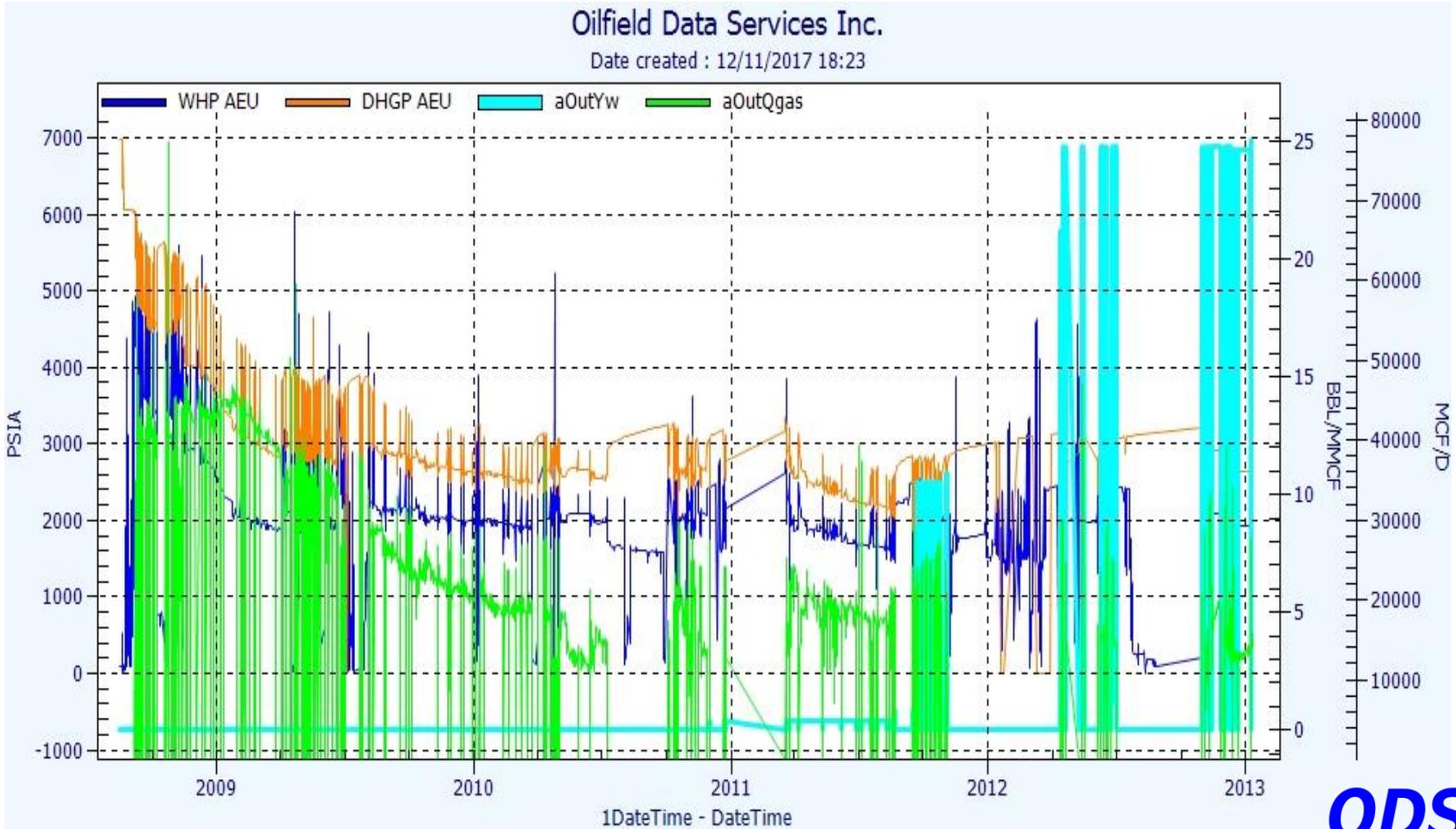
Note: When the well is shut-in, the Y_w drops to zero

Case Study 3: Supplemental III

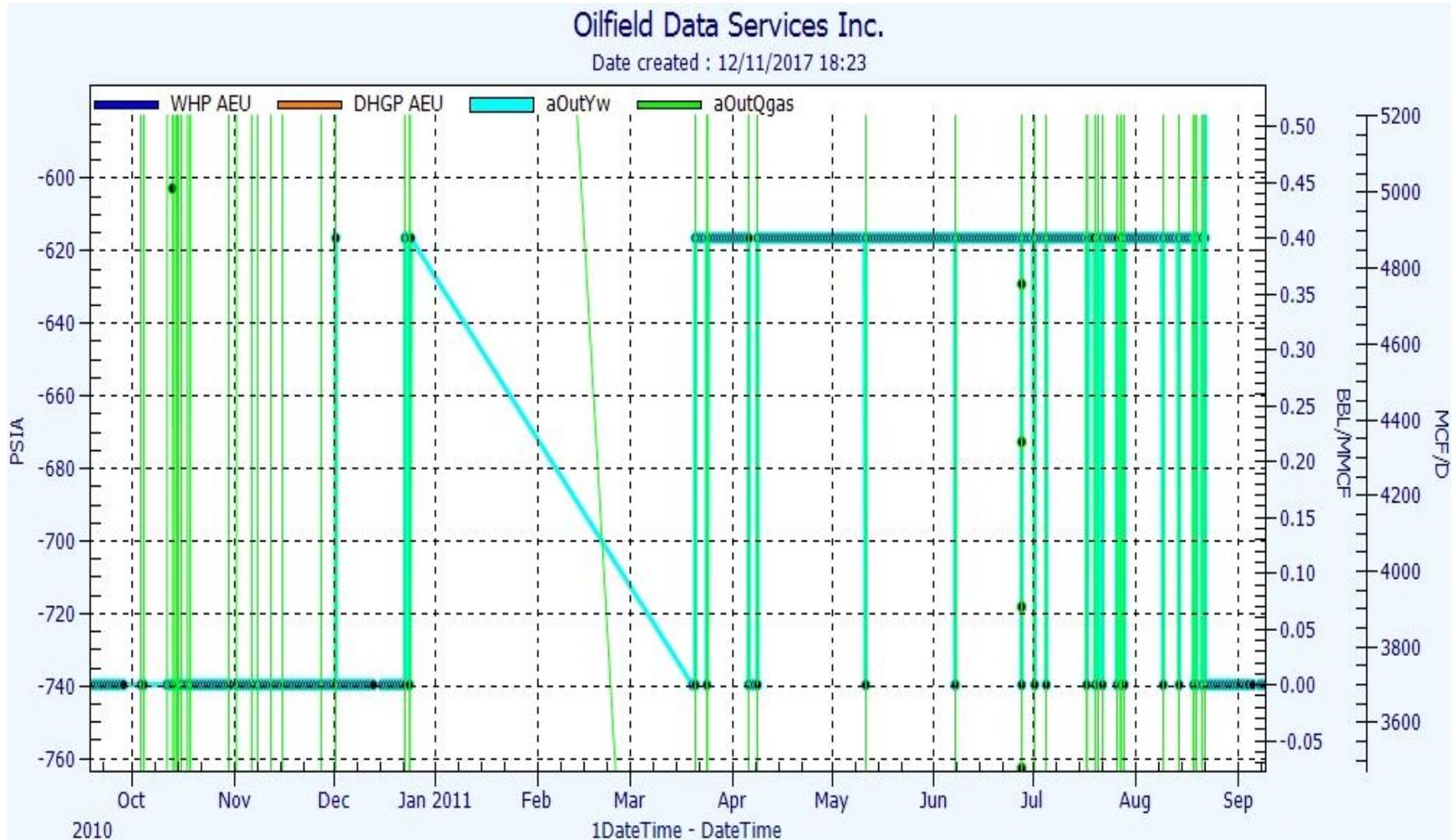
- Summary:
 - Only solution water observed until Aug 22, 2011
 - Only <1 BBL/MMcf of free water observed until Sept 18, 2011
 - Rapid water breakthrough on Sep 18, 2011
 - 0.8 BBL/MMcf up to nearly 10 bbl/MMcf by the end of the day
 - Further increase in Yw from 10.5 to 21.2 bbl/MMcf from Oct 27, 2011 to Nov 3, 2011
 - Continued increases in Yw afterwards
 - Well Shut-in and only flowed intermittently due to pipeline loading problems

Case Study 3: Pressures, Rates and Yw

Every time there is S/I with SCSSV open, it is possible to accurately calculate Yw

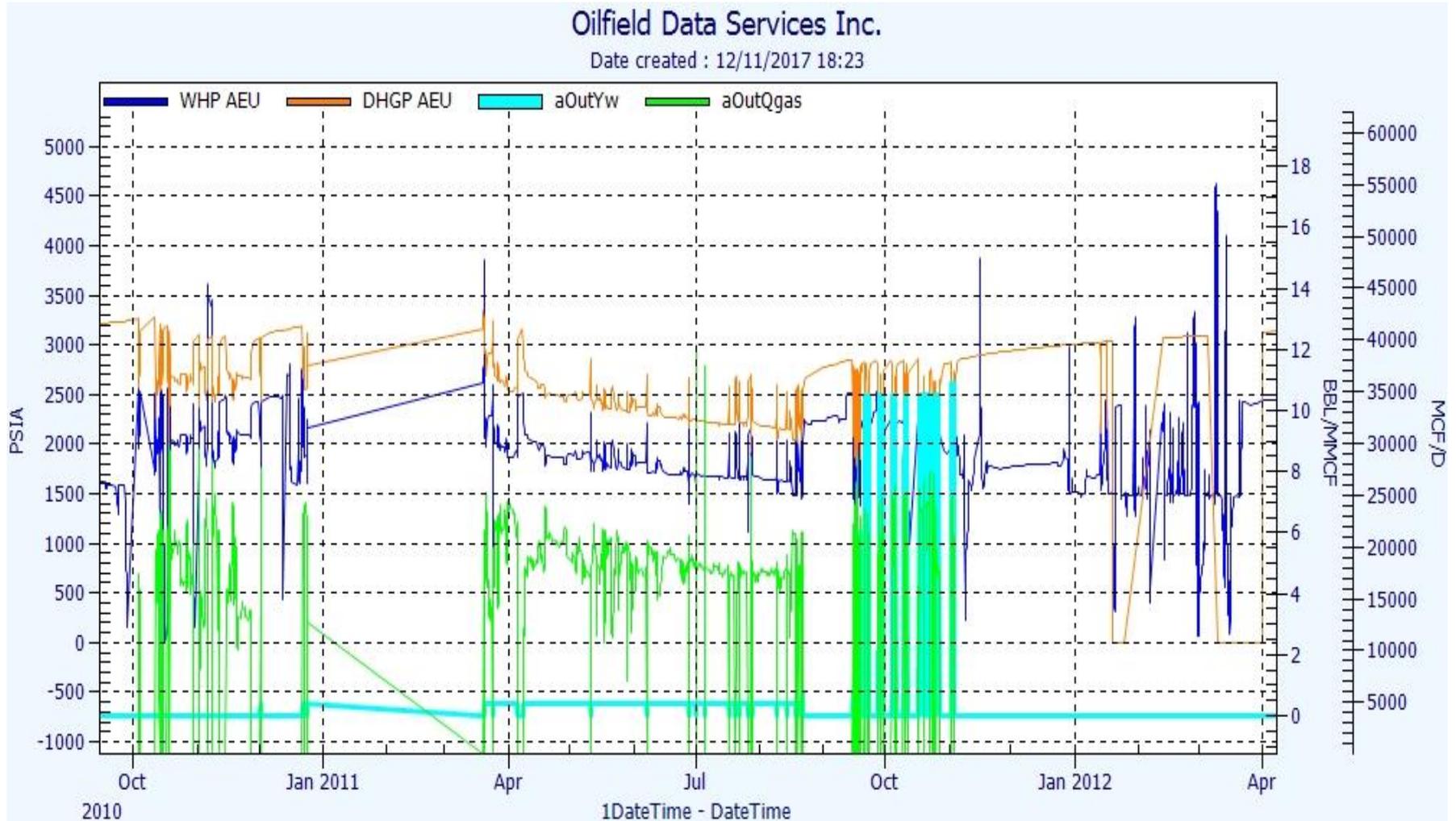


Case Study 3: Early Yw's (Slightly more than Solution Water)



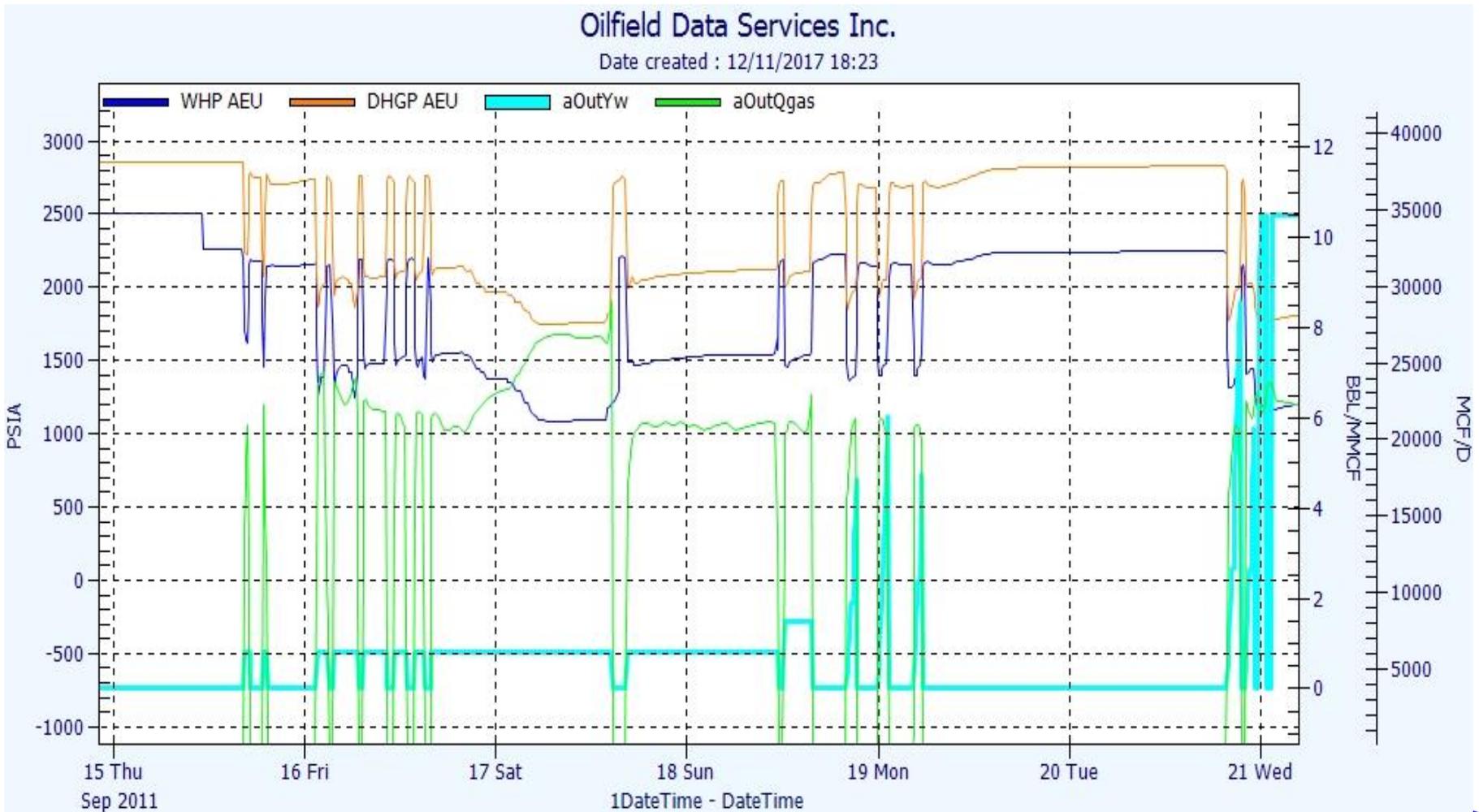
Case Study 3: Onset of Significant Water Production

Every time there is S/I with the SCSSV open, it is possible to accurately calculate Yw



Case Study 3: Onset of Water Production Zoom

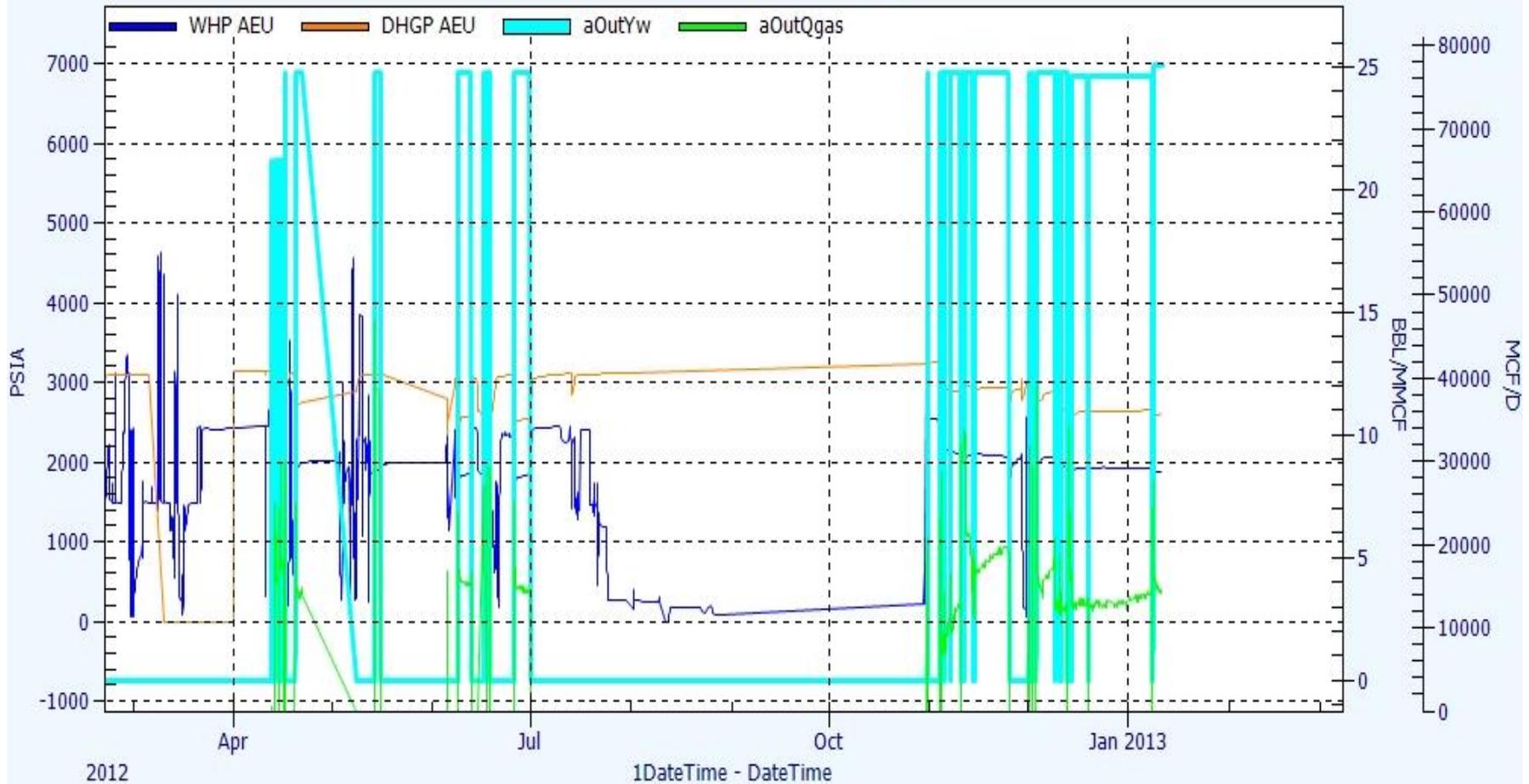
Every time there is S/I with SCSSV open, it is possible to accurately calculate Yw



Case Study 3: Well Brought Back On-Line...Water Didn't Go Away

Oilfield Data Services Inc.

Date created : 12/11/2017 18:23



Case Study 4

Case Study 4: Background

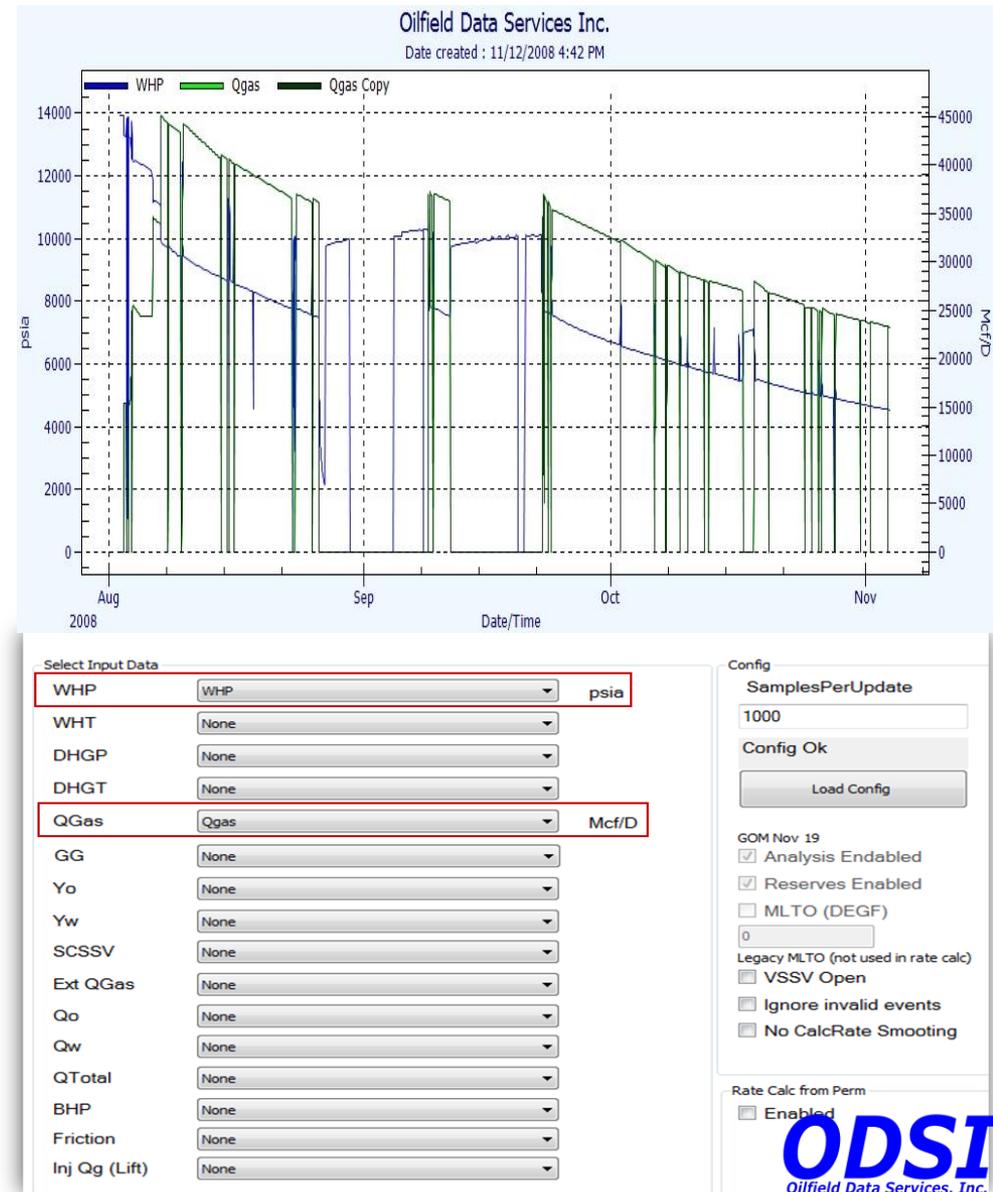
- Gulf of Mexico
- Gas Condensate well (~ 15 bbl/mmcf)
 - Tree Gauge
 - Rates were continuously measured at a dedicated test separator (1-well platform)

Objective:

- Validate/model separator rates
- BHP conversion from the WHP data
- Demonstrate auto-PTA
- Determine the Producible Gas Volumes

Case Study 4: System's Inputs

- The following inputs were used:
 - Tree gauge pressure
 - Occasionally measured gas rates from a test separator
- To calculate the following:
 - BHP at the mid-completion depth
 - Auto-PTA
 - Evaluate the In-place, hydraulically connected and mobile reservoir volumes

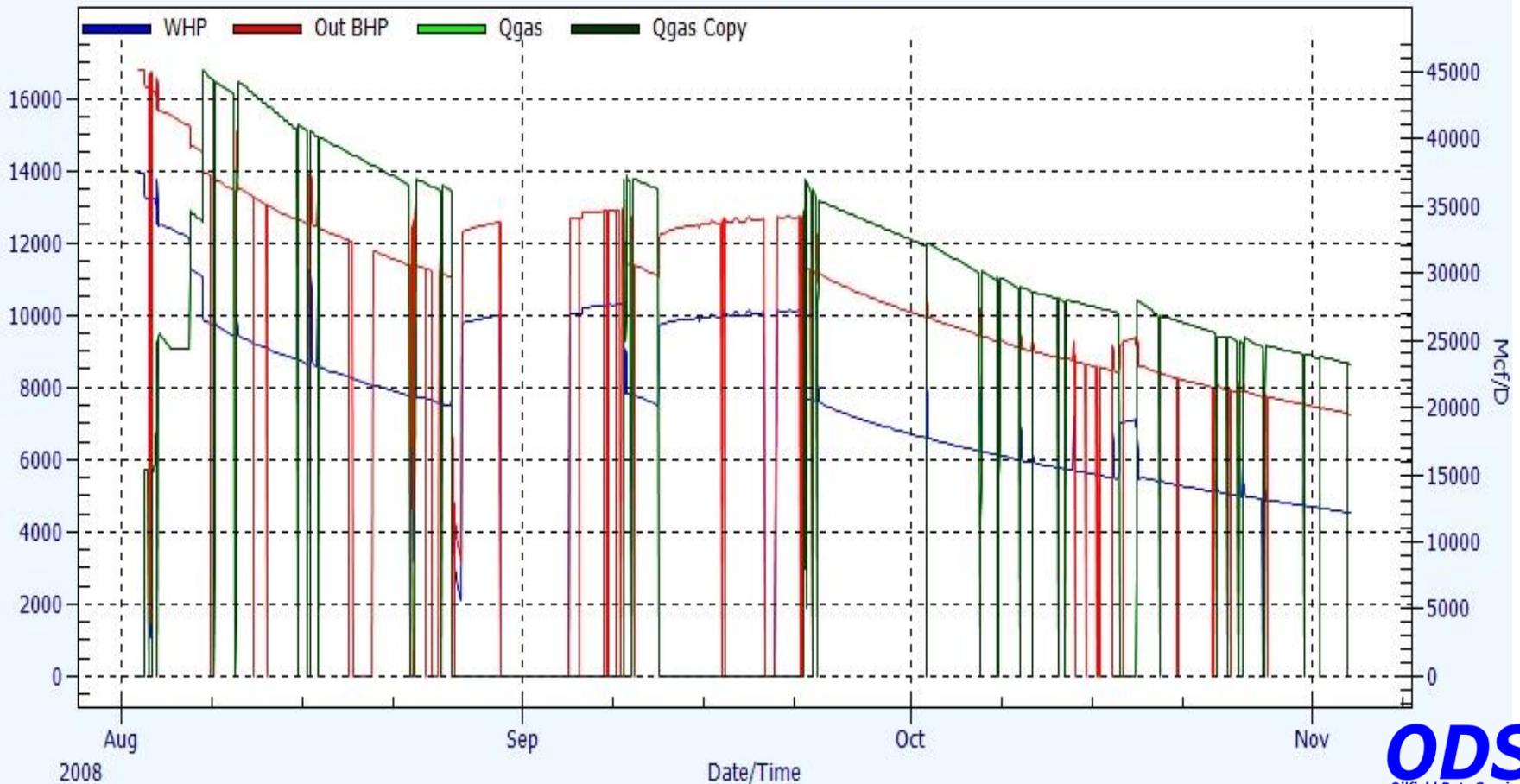


Case Study 4: BHP Results

BHP conversion was performed at the mid-completion depth using the surface pressure and the measured gas rate

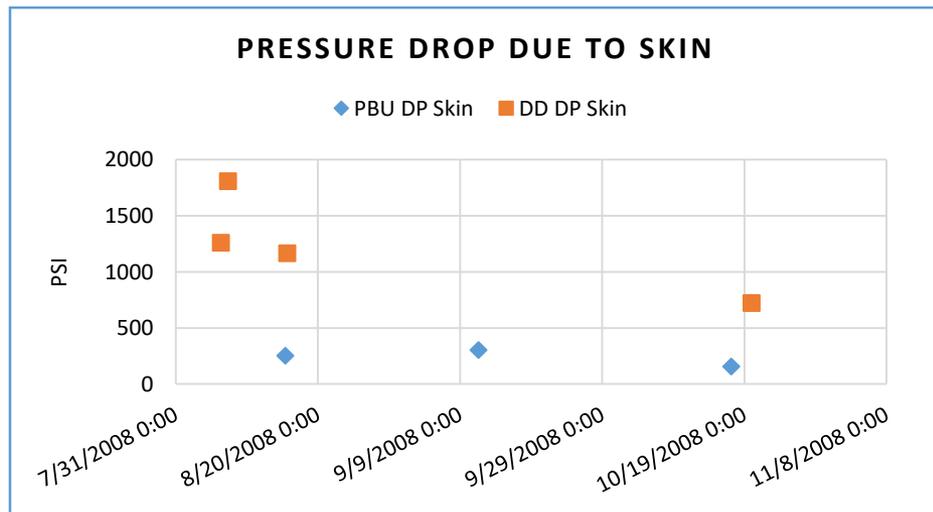
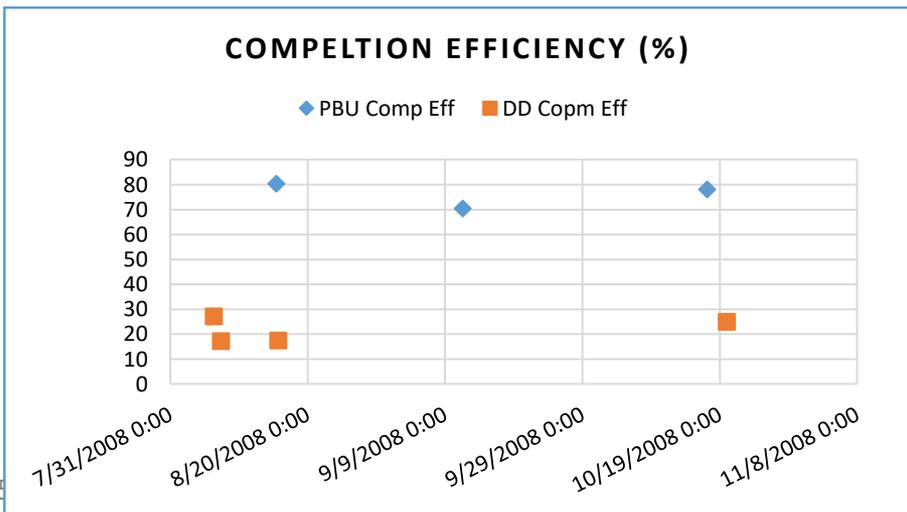
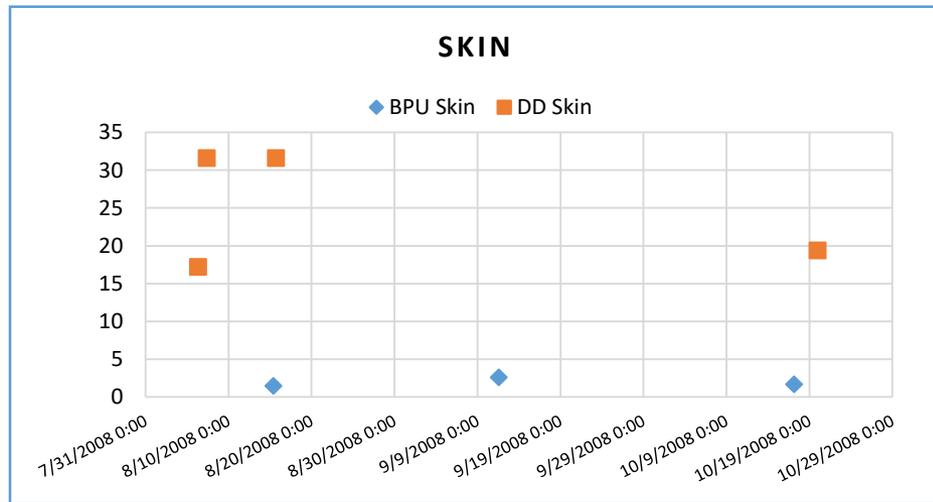
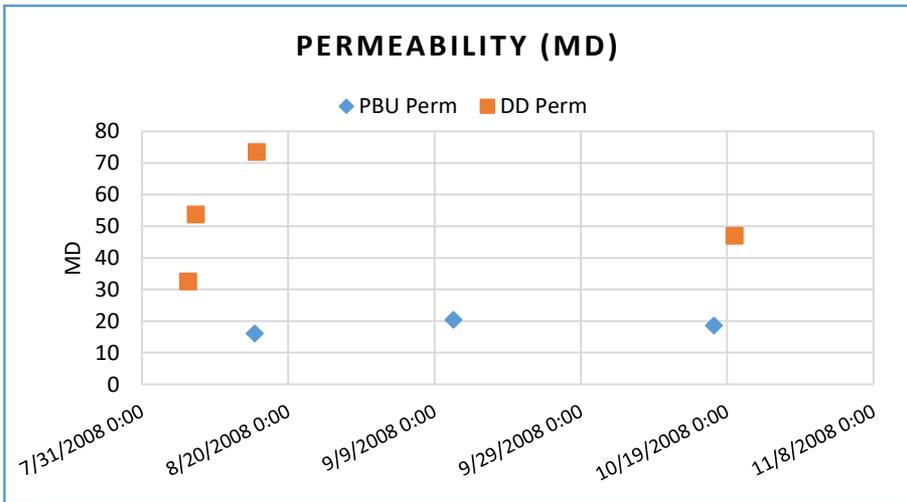
Oilfield Data Services Inc.

Date created : 11/12/2008 4:42 PM



Case Study 4: Auto PTA Results

- Well was producing from 2 different zones; PBU was seeing a lot of cross-flow, but was consistent; DD was seeing a high-perm zone for the most part, but was variable
 - High permeability zone ~ 50 md
 - Low perm zone ~ 10 md ; PBU perm 15 - 20 md



Case Study 4: Auto PTA Report Example

- Below are screenshots of an automatically generated buildup report

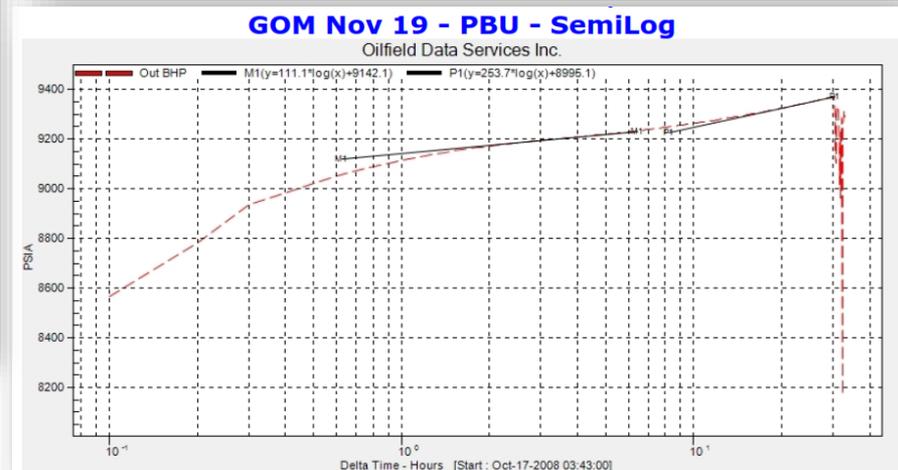
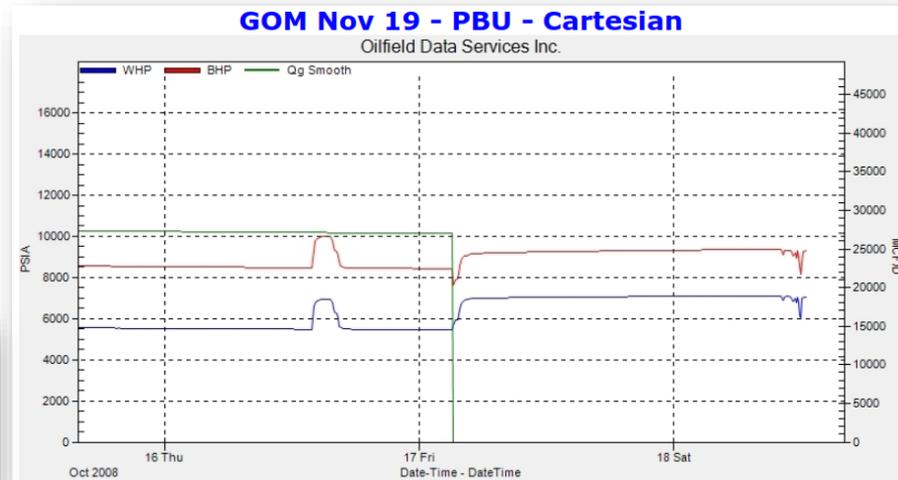
Report Link [REDACTED]

ANALYSIS RESULTS

PBU
Oct/17 - 18/2008

Calculated Reservoir & Completion Properties

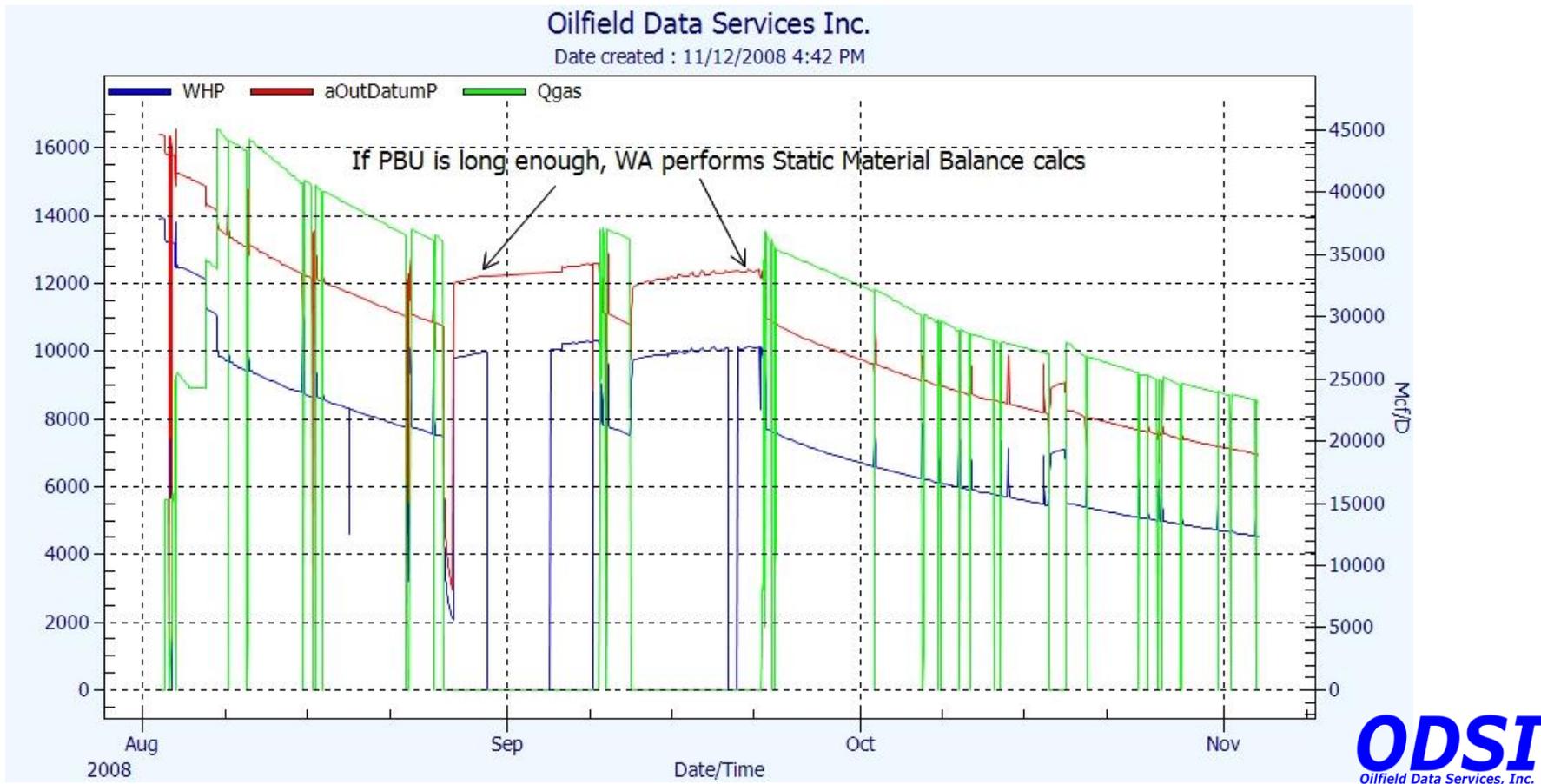
SKIN	1.7	
PRESSURE DROP DUE TO SKIN	158	PSI
COMPLETION EFFICIENCY	78	%
PERMEABILITY	19	md
RADIAL FLOW PI	37.5	MCF/PSI
SKINLESS RADIAL FLOW PI	48.0	MCF/PSI
PERMEABILITY THICKNESS	817	md-ft
MOBILITY THICKNESS	23,740	md-ft/cp



Case Study 4: Reservoir Volume

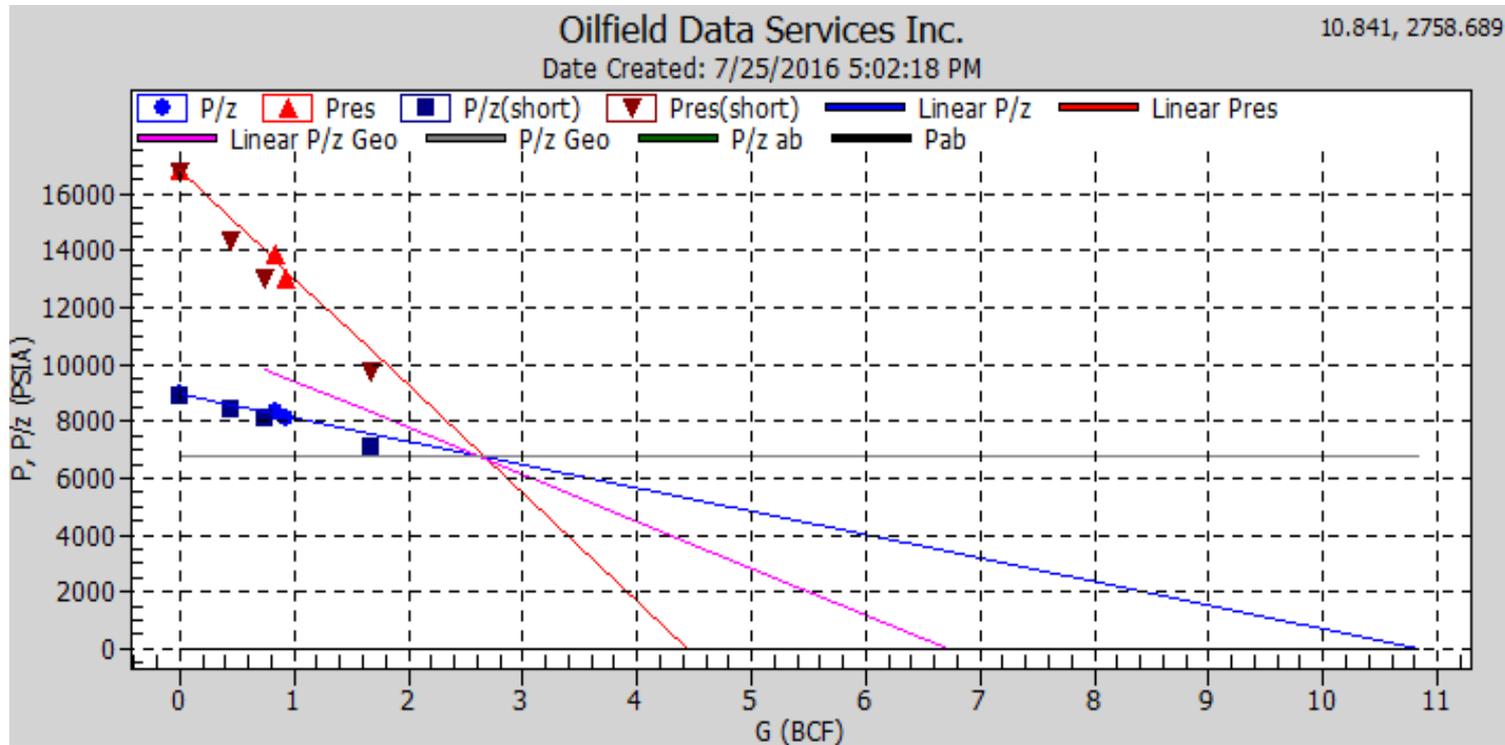
Static Material Balance (P/z plots)

- If a buildup test is sufficiently long to provide a valid P^*/P_{res} , WA is going to perform Static Material Balance calculations for the total in-place volume
- The MBAL results/plots are part of the PTA (buildup) reports



Case Study 4: Reservoir Volume

Static Material Balance (P/z plots)



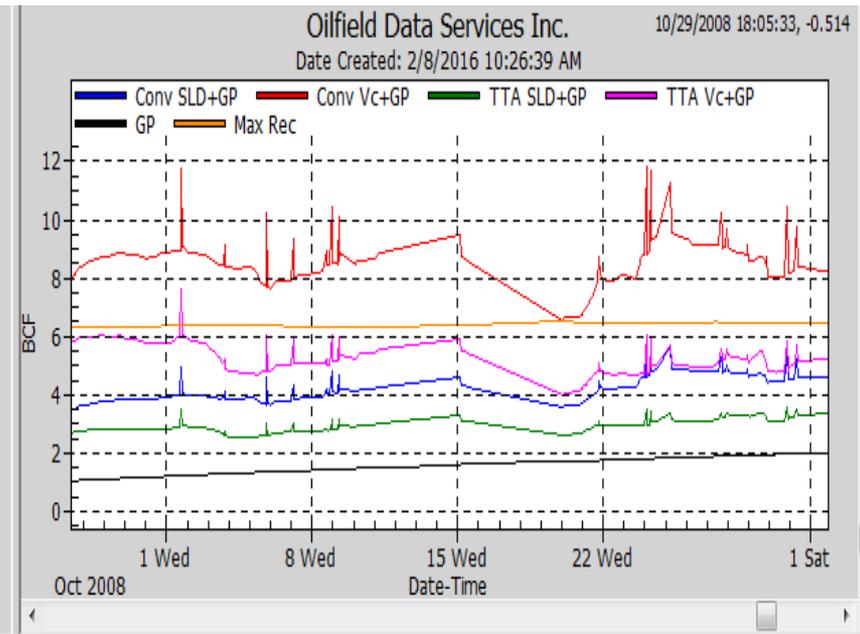
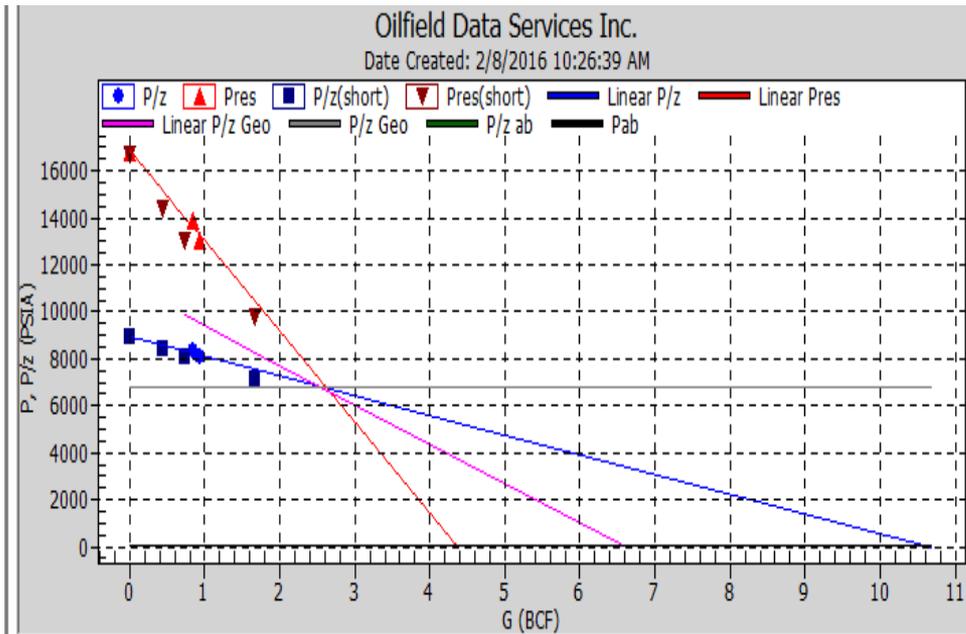
WA keeps track produced HC volumes and every time there is shut-in long enough to have a valid $P^*/Pres$, WA performs auto Static MBAL (P/z) calculations:

- The min total in-place HC volume ~ **4.5 BCF** (assuming infinite water drive)
- The max total in-place HC volume ~ **10.5 BCF** (assuming expansion drive)

Case Study 4: Flowing Material Balance

- Well analyzer tracks apparent HC volumes and a well's performance/productivity with time
- It analyzes the data for PSS flow periods and performs Flowing Material Balances to evaluate:
 - Hydraulically Connected HC Volume
 - Mobile HC Volume
 - Likely Producing Hydrocarbons

Case Study 4: Reservoir Volumes (EUR)



WA 'splits' the total in-place volume into what reservoir is made of:

- Total in-place volume ~ **10.5 BCF**
- Hydraulically Connected Volume ~ **9 BCF**
- Mobile (producibile) Volume ~ **5.5 BCF**
- Water (dead-leg) ~ **3 BCF** (equivalent)
- Rock Compaction ~ **1 BCF** (equivalent)
- Tight gas ~ **1 BCF**

Case Study 4: Summary

- BHP conversion was performed using the surface data
 - Useful for wells without DHGP or in case DHGP fails
- PTA and Reservoir Volume calculations were performed then
 - Static MBAL calcs for long PBU's with valid $P^*/Pres$
- WA is the only software package that is able to split the in-place volume into what is the connected, mobile HC evaluate EUR
 - Locks into solution from first months of production data

If you know how much 'money' you have left in the ground and how much is going to be produced – You Make Better Decisions!

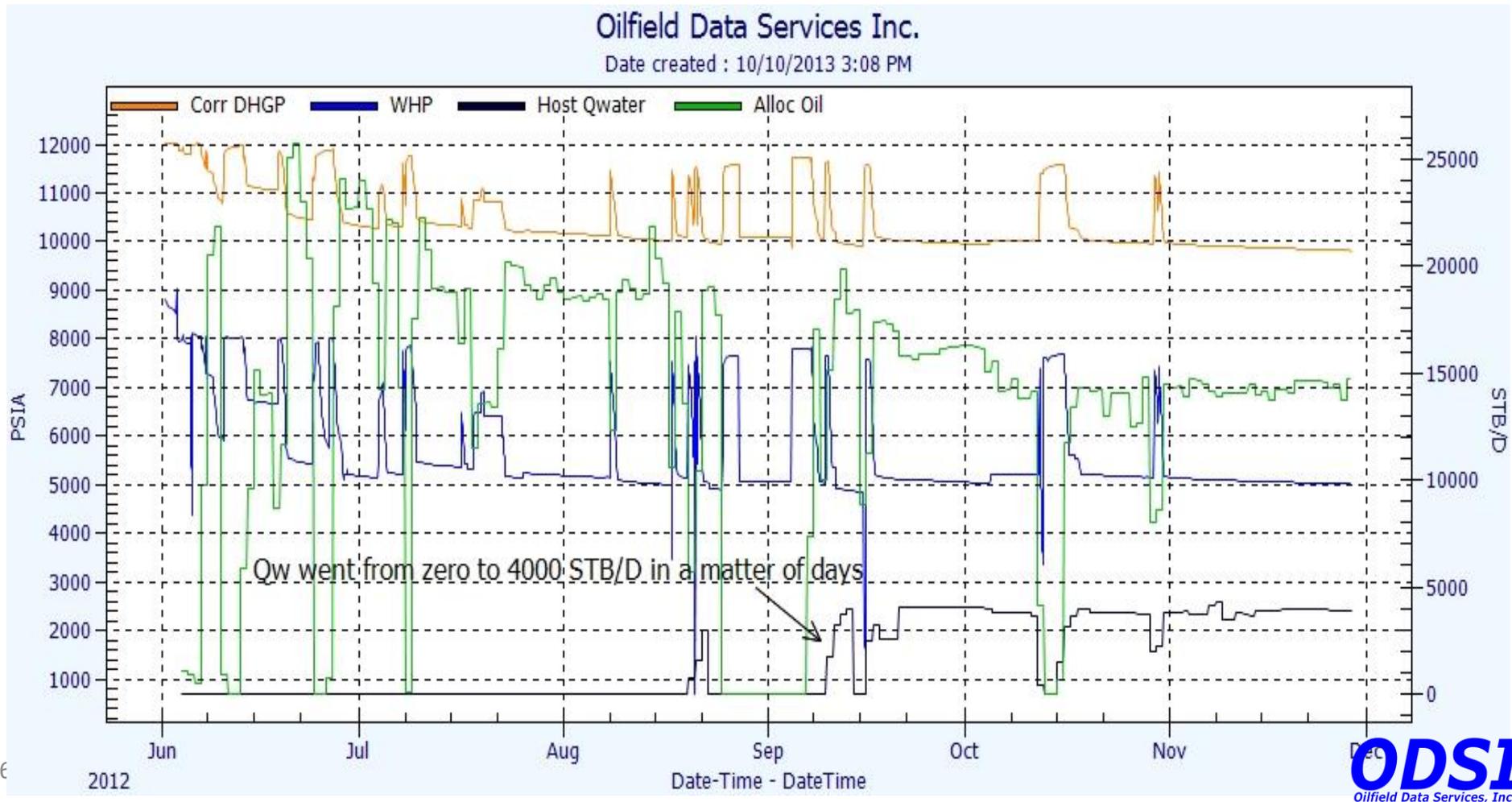
Case Study 5

Case Study 5: Background

- Gulf of Mexico
- Subsea deepwater oil well equipped with
 - WHP gauge
 - Downhole gauge
 - Flow meter
- The well suddenly started making 4000 STB/D of water
 - The Operator plans a \$130 million intervention program to 'fix' the well; the Partner decides to find the origin of water production first
- Objective:
 - Validate metered rates
 - Determine the origins of water production
 - Perform auto PTA

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

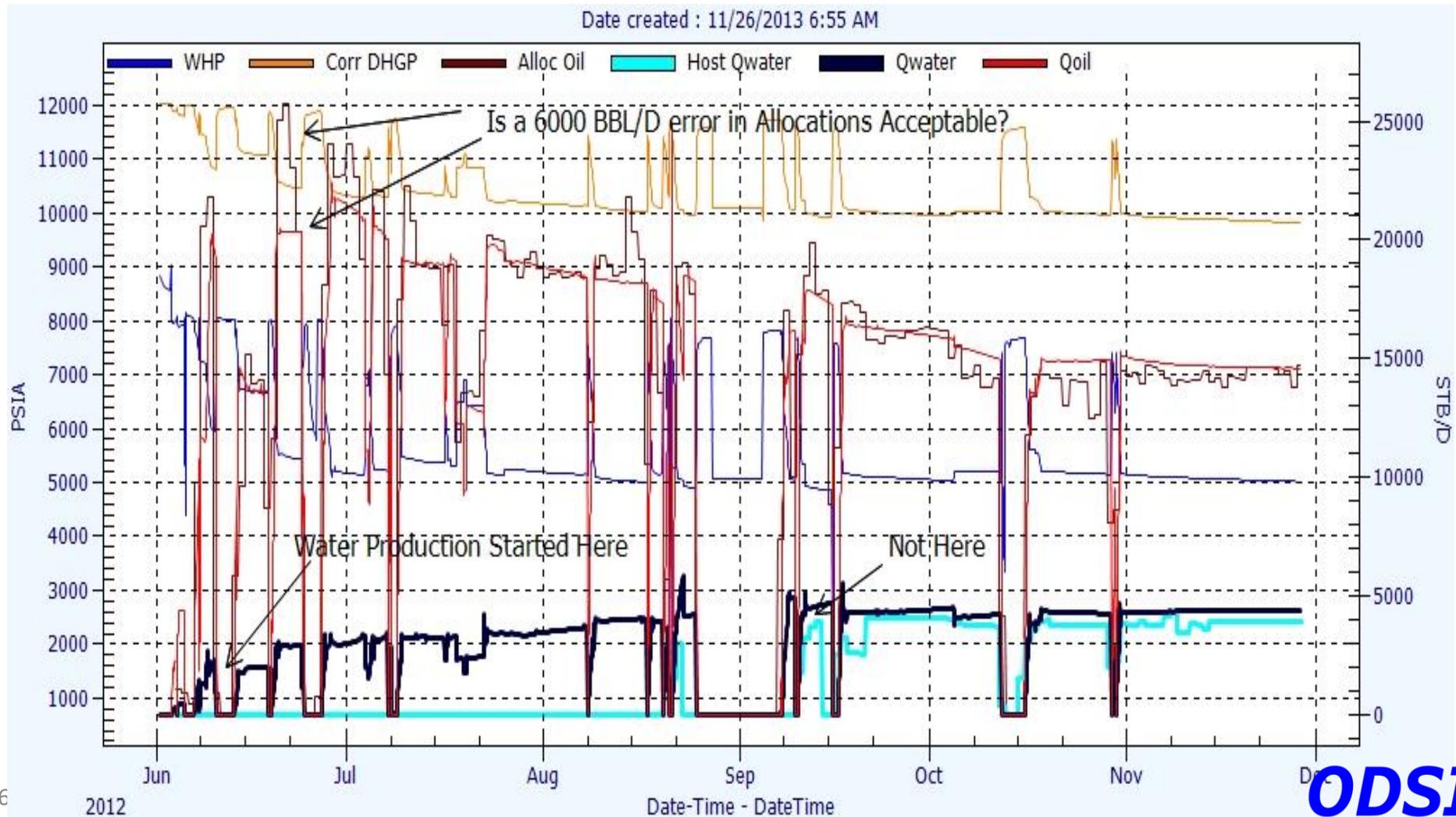


Case Study 5: Process

- MPFM rates were QC'd
 - Errors in allocations were detected
- 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
- The total liquid rate was split into oil and water rates using the pressure drop in the wellbore and fluids' PVT properties

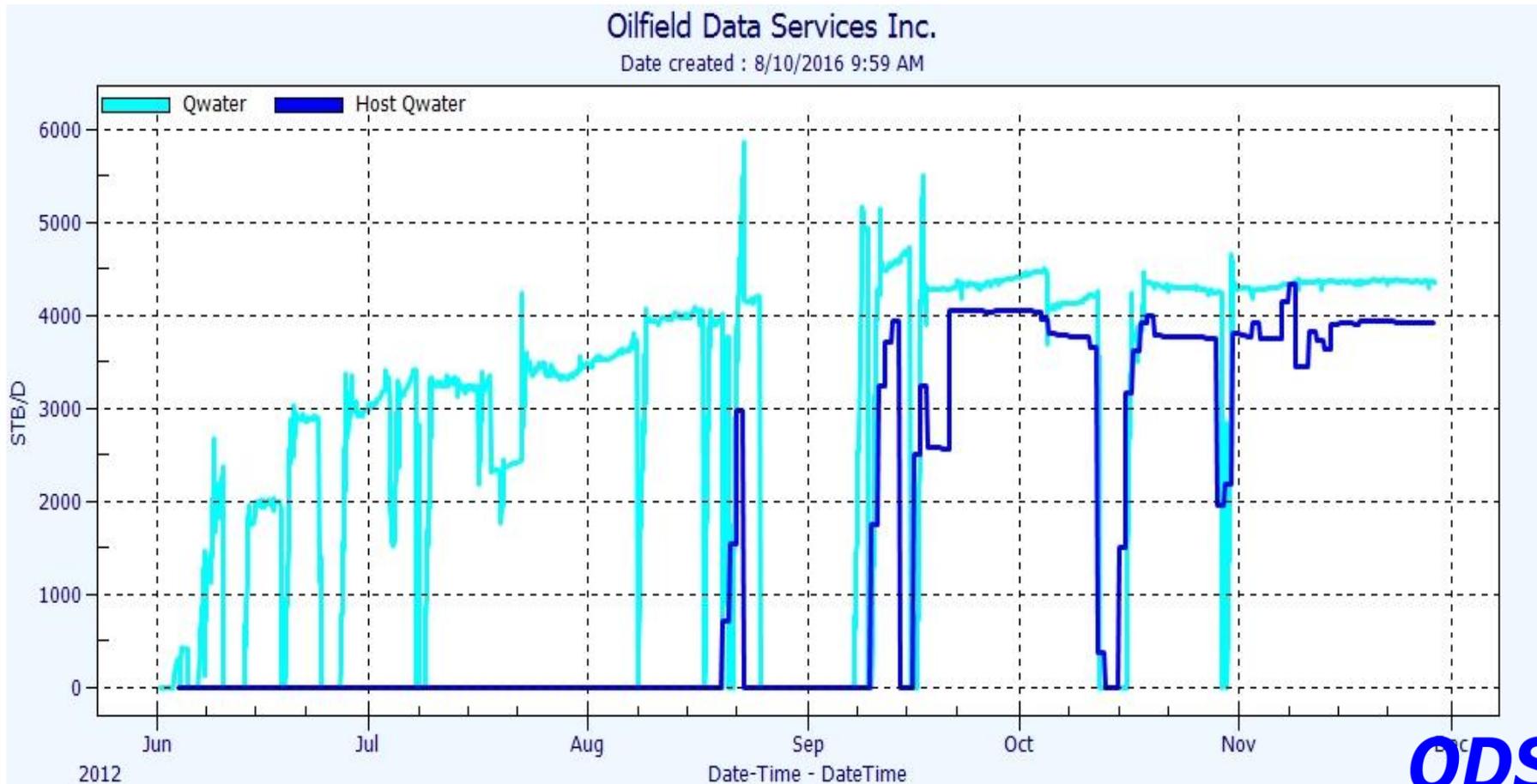
Case Study 5: Results

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



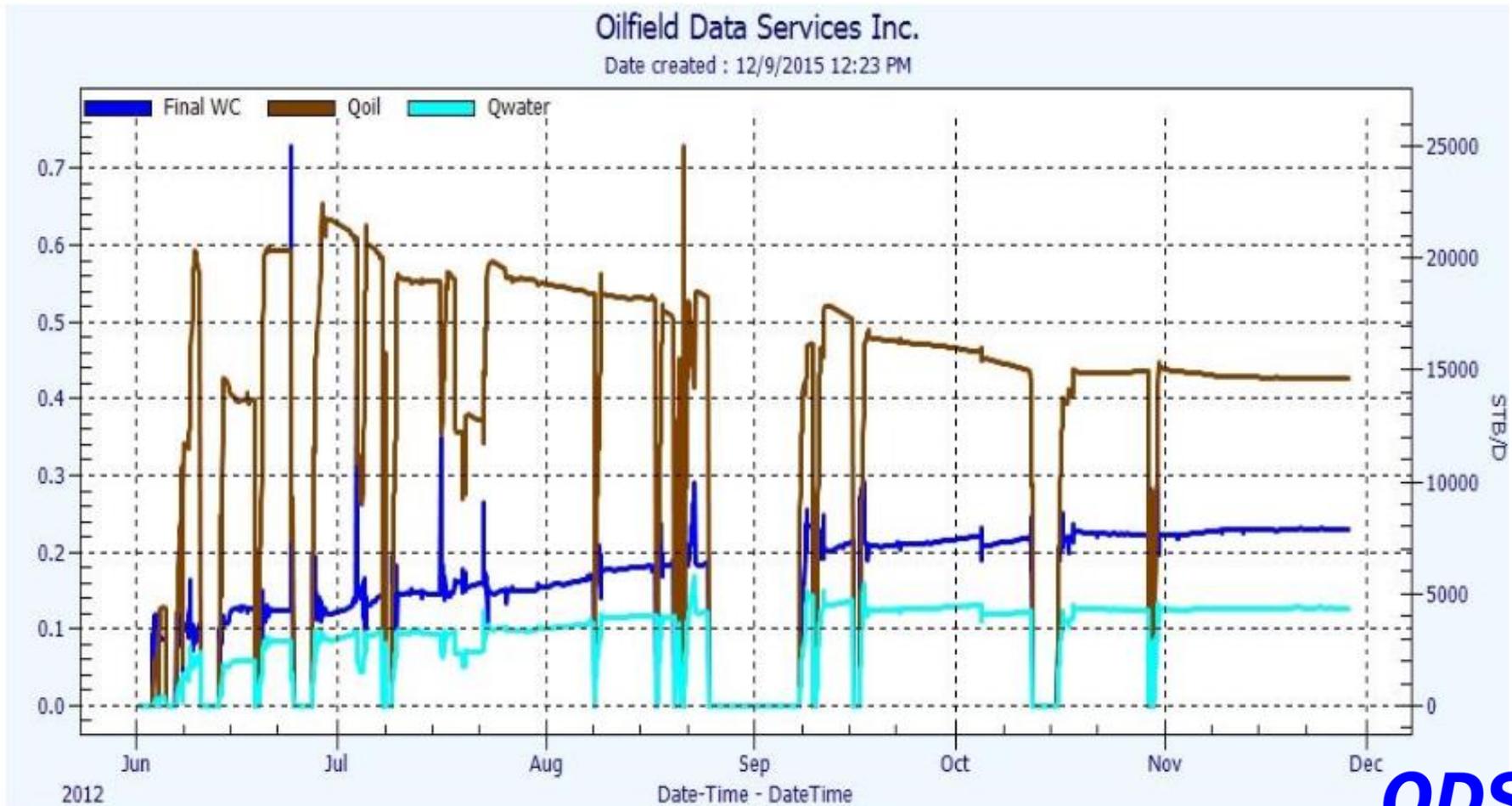
Case Study 5: Water Rates Comparison

- Below is the 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



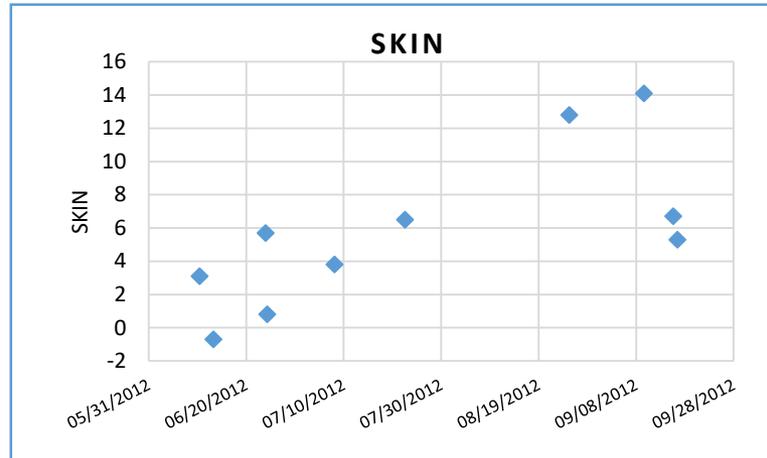
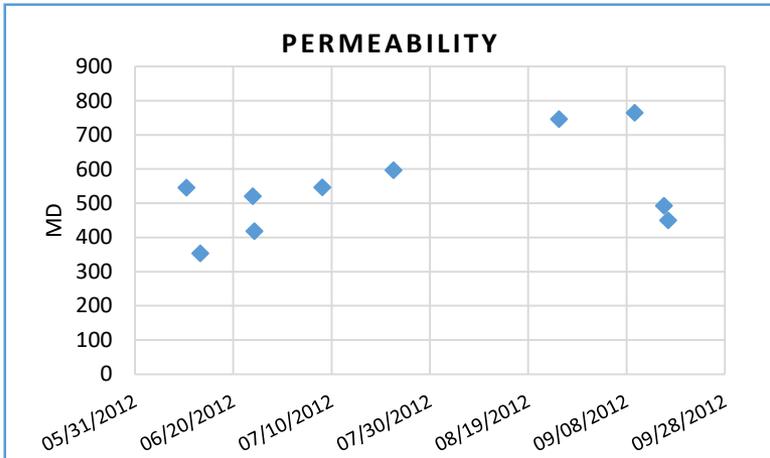
Case Study 5: Rate Results

- The Final Calculated Oil and Water rates are presented below
- The meter was up to 6000 BBL/D off in allocations

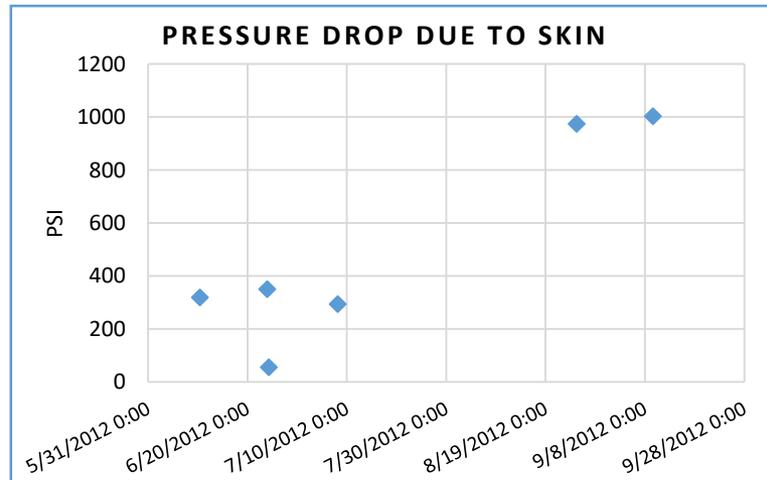
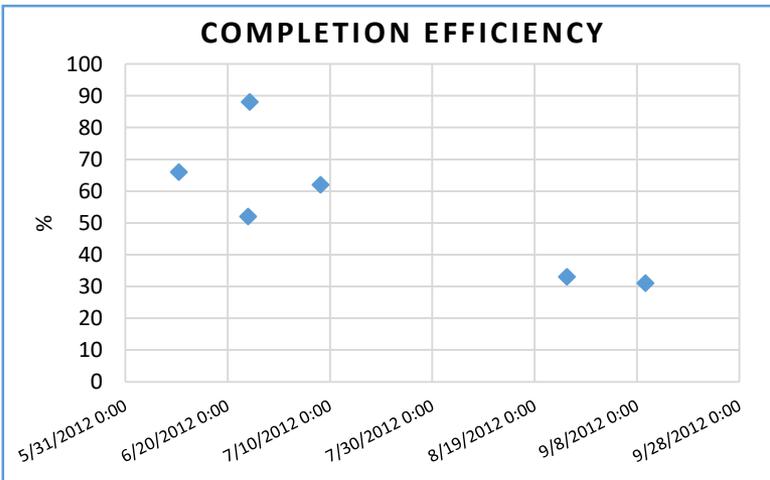


Case Study 5: Auto-PTA

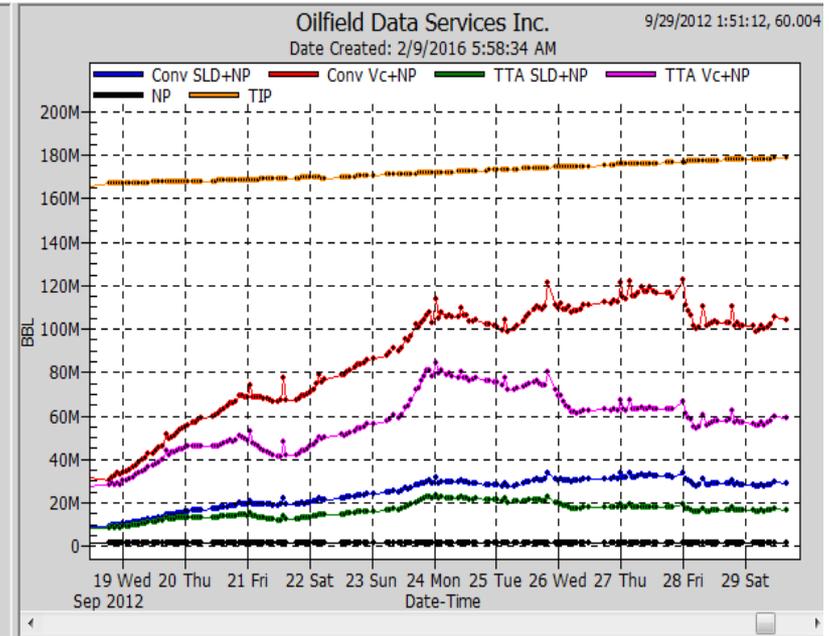
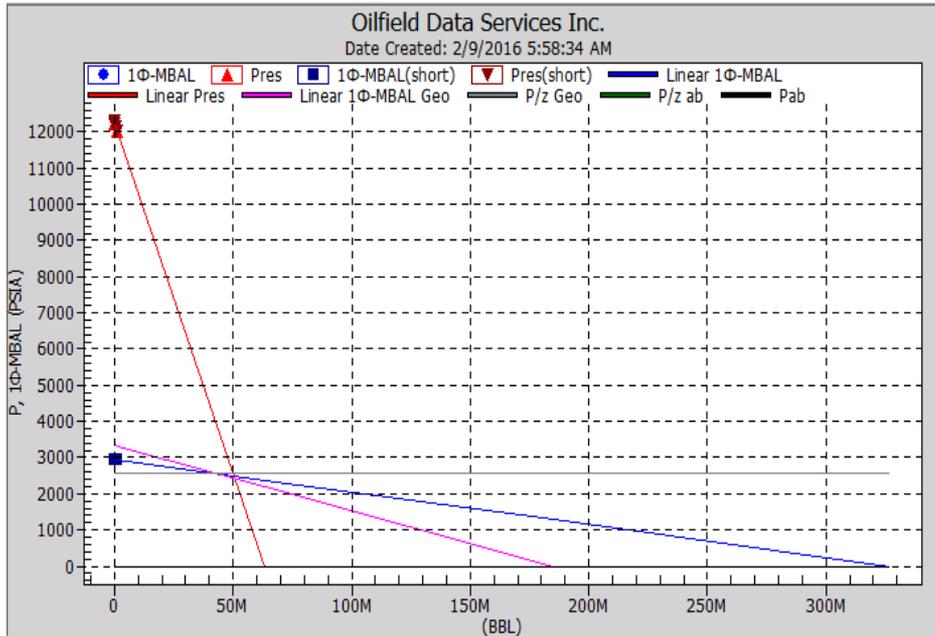
- High perm ~ 500 md
- Skin was getting worse with time
 - From 0 to 14 (screen plugging)
- Productivity was getting worse with time (increasing skin)



Sample Reports



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 and 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

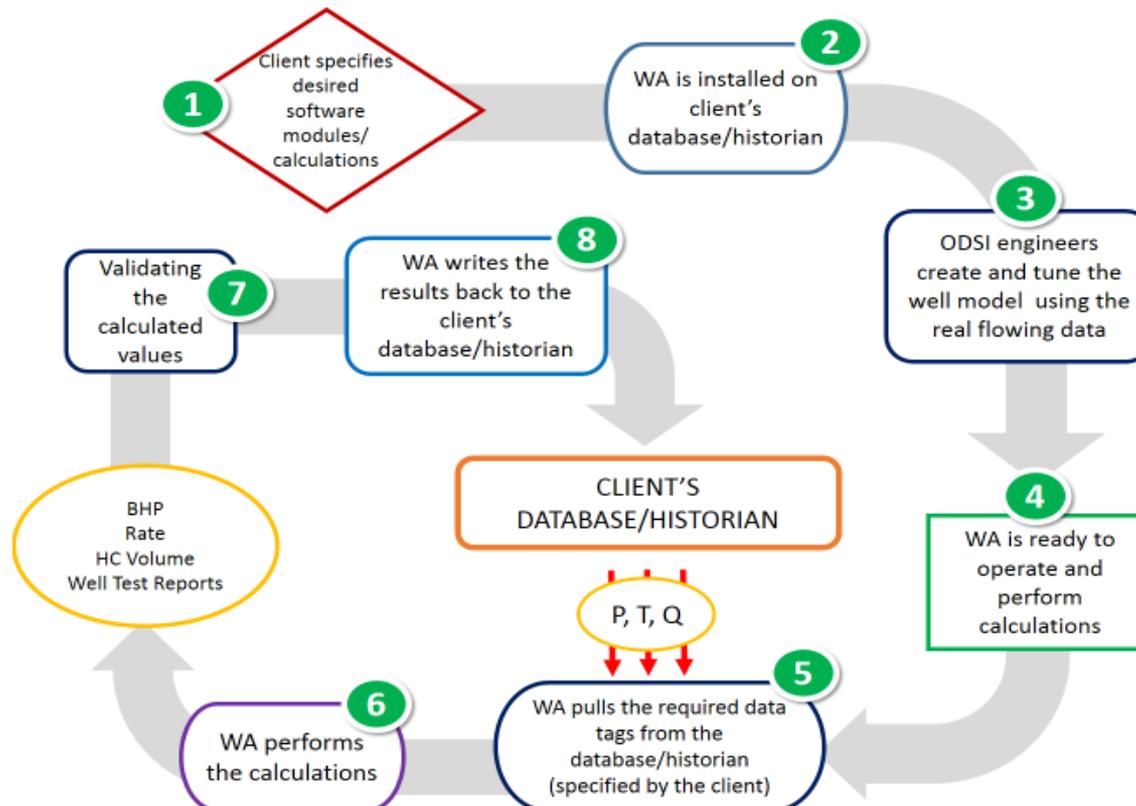
Case Study 5: Results

- 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!

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



Well Analyzer Real-Time Features

- Virtual metering
 - Multiphase rate calculation
 - Metered rate validation
 - Detects errors in allocation/meter calibration
- BHP conversion
 - From the surface data
 - Can replace downhole pressure gauge if it fails
- Automated Pressure Transient Interpretation of buildups and drawdowns
 - Skin
 - Permeability
 - Avg.Pres/P*
 - Productivity (PI)
- Continuous HC volumes and Mobile HC updates
 - Static and Flowing Material Balance calculations

Well Analyzer Benefits

- Completely automated process
- Well Analyzer is not intrusive and provides fast and accurate results
- The method is based on a direct solution of the Mechanical Energy Balance equation
- Software-based installation only
- Low cost investment