Well Evaluation Methods

Renaissance Offshore - ODSI

August 31, 2016

Outline

- Overview: Find the Pressure Drop (that shouldn't be there)
- The Basics:
  - Elementary Well Test Analysis
  - Decline Analysis
  - Inverse Productivity Analysis
  - Nodal Analysis, Simulation & Transient Nodal
- Test Planning/Design Basics
  - Do you already have the answer?
  - What are the objectives?
  - What do you need to measure?
- Advanced Diagnostics

Well Diagnostics: Pressure Drop

- Well Bore (head & friction + obstructions)
- Completion (Plugging and Skin)
- 1-phase Reservoir (Perm and Compaction)
- Multi-phase Reservoir (blockage and preferential flow)

- Always consider: Is it a wellbore or a reservoir effect?

What is Well Testing (PTA)?

- Build-up (PBU)
- Drawdown
- 2-rate (PBU or DD)

- What Does it Get you?

  kh, skin, PI and Preservoir

What is Decline/IP Analysis

- Conventional: DP/DT
- TTA or IPA: D(P/Q)/DT

- What Does it Get You?

  Hydraulically Connected Volume

  Mobile Compressible Volume

What Is Nodal Analysis

- Plot Reservoir Inflow Equation/Inflow Performance Curve
- Plot Vertical Lift Performance

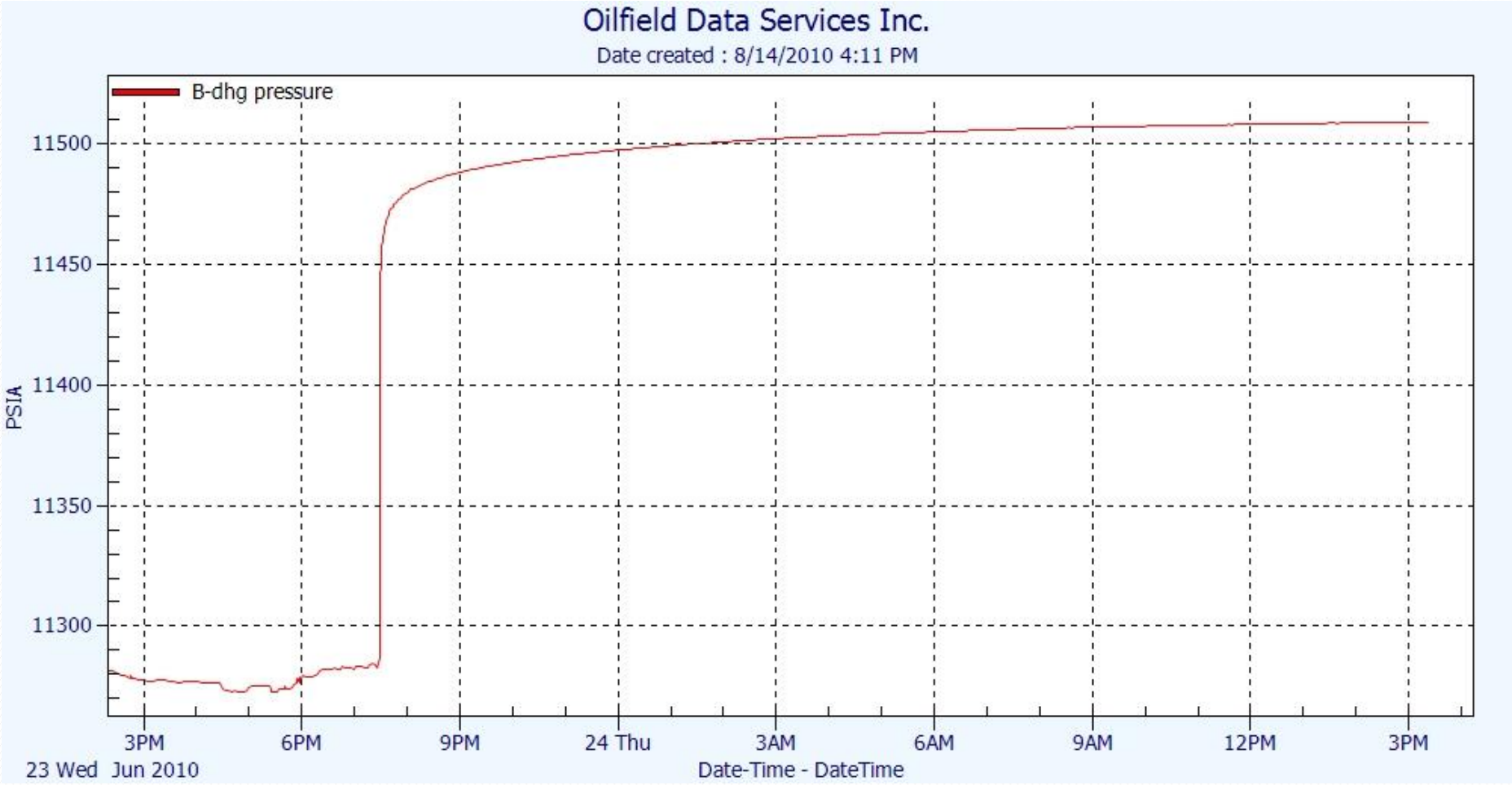
- What does it get you?
  - Ability to predict BHP at a given rate or vice versa
  - Ability to determine change in skin for constant perm
  - Ability to determine change in perm for a constant skin

- What it doesn't get you: skin and perm

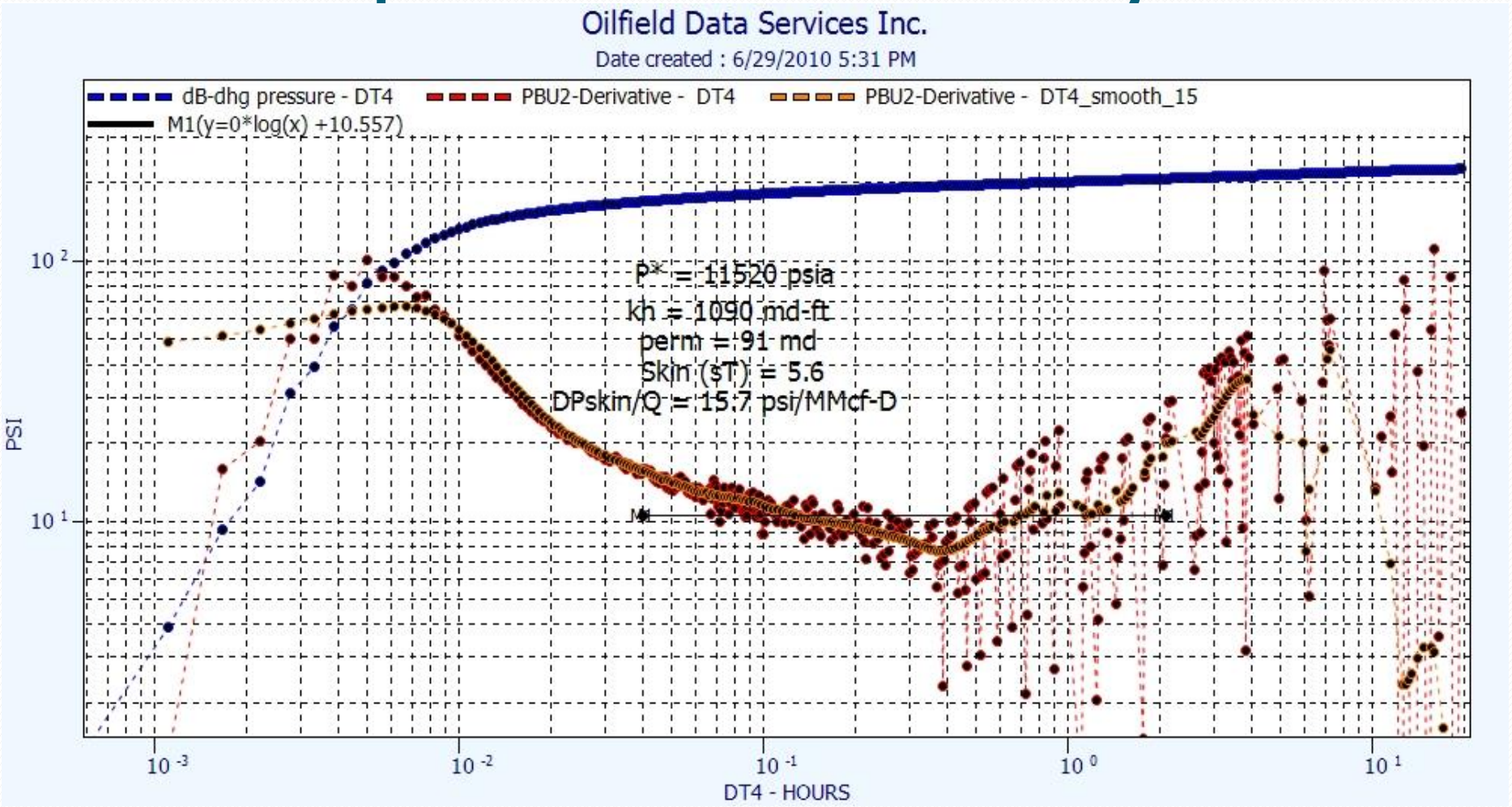
Analysis Type Examples

- Build-up PTA Derivative
- Drawdown PTA Semilog
- Horner – P*
- 2-Rate Test
- RTA (Rate Transient)
- P/z (gas) or Static MBAL (oil)
- Conventional Decline Analysis (Running MBAL)
- IPA (Running EBAL)
- MBAL/EBAL “bookends”
- NODAL ANALYSIS
- Simulated Rates/Pressure vs. Actual

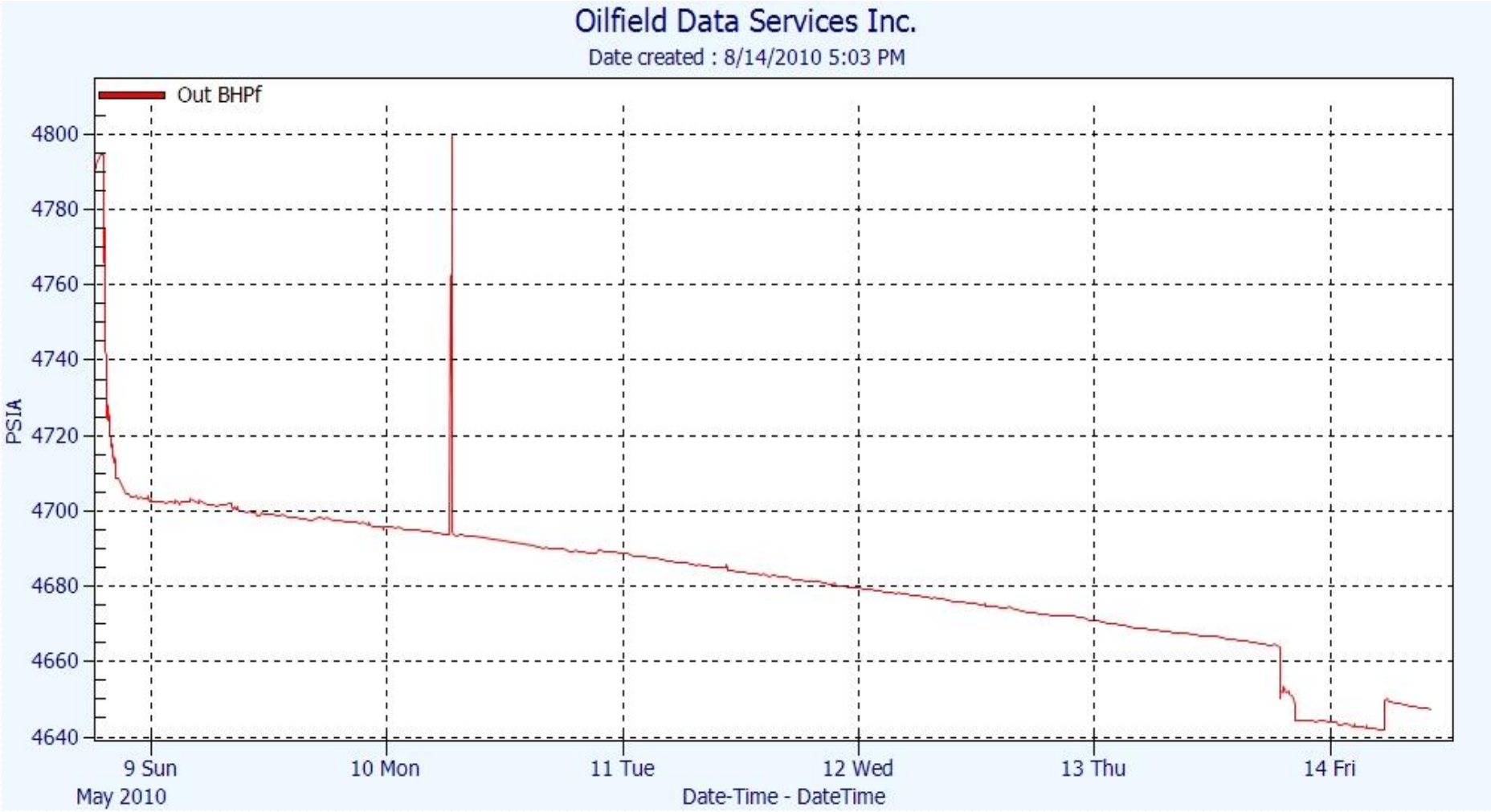
Build-up PTA


Oilfield Data Services Inc.
Date created : 8/14/2010 4:11 PM
B-dhg pressure
11500
11450
11400
11350
11300
PSIA
3PM
6PM
9PM
24 Thu
3AM
6AM
9AM
12PM
3PM
23 Wed Jun 2010
Date-Time - DateTime

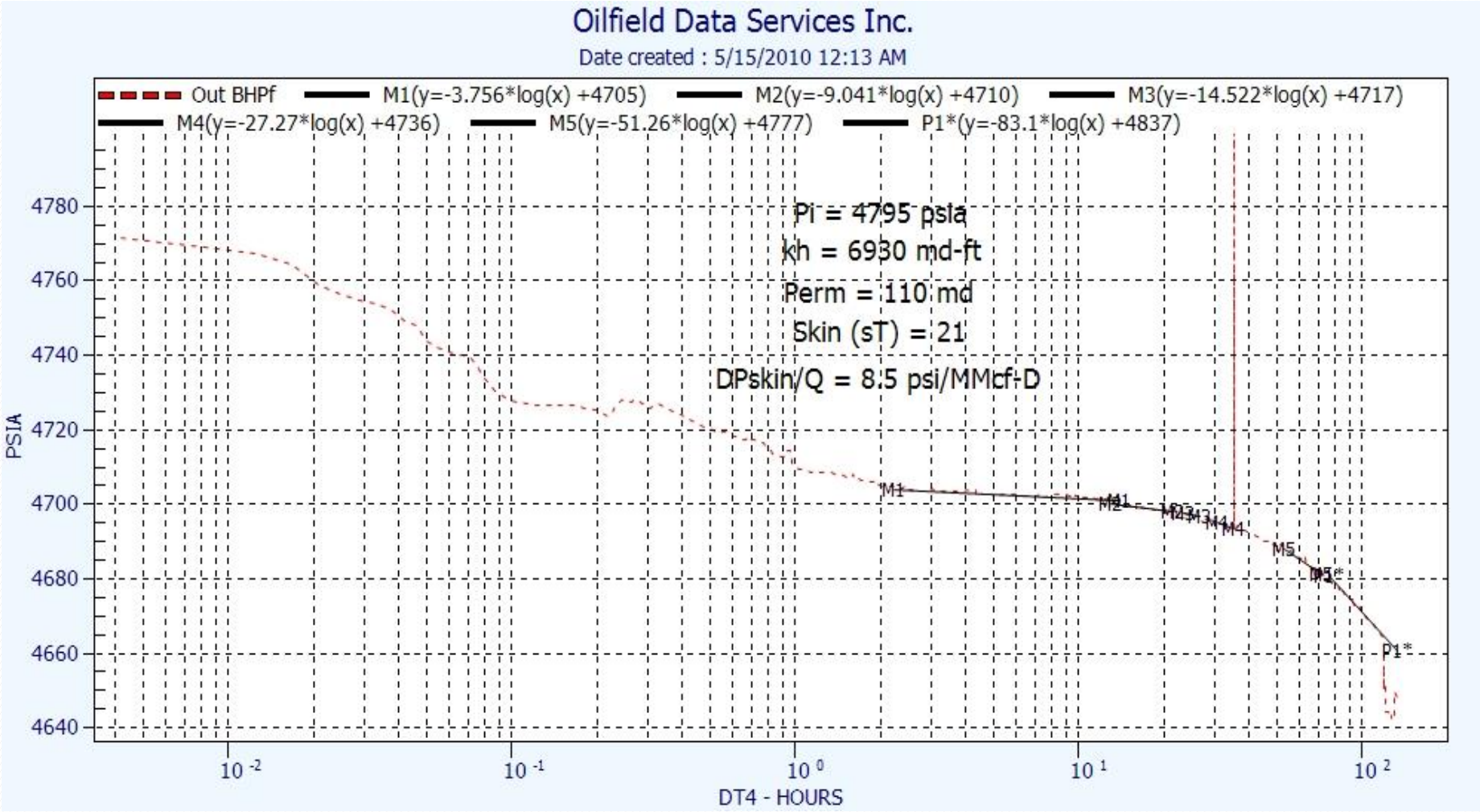
Build-up Derivative Analysis



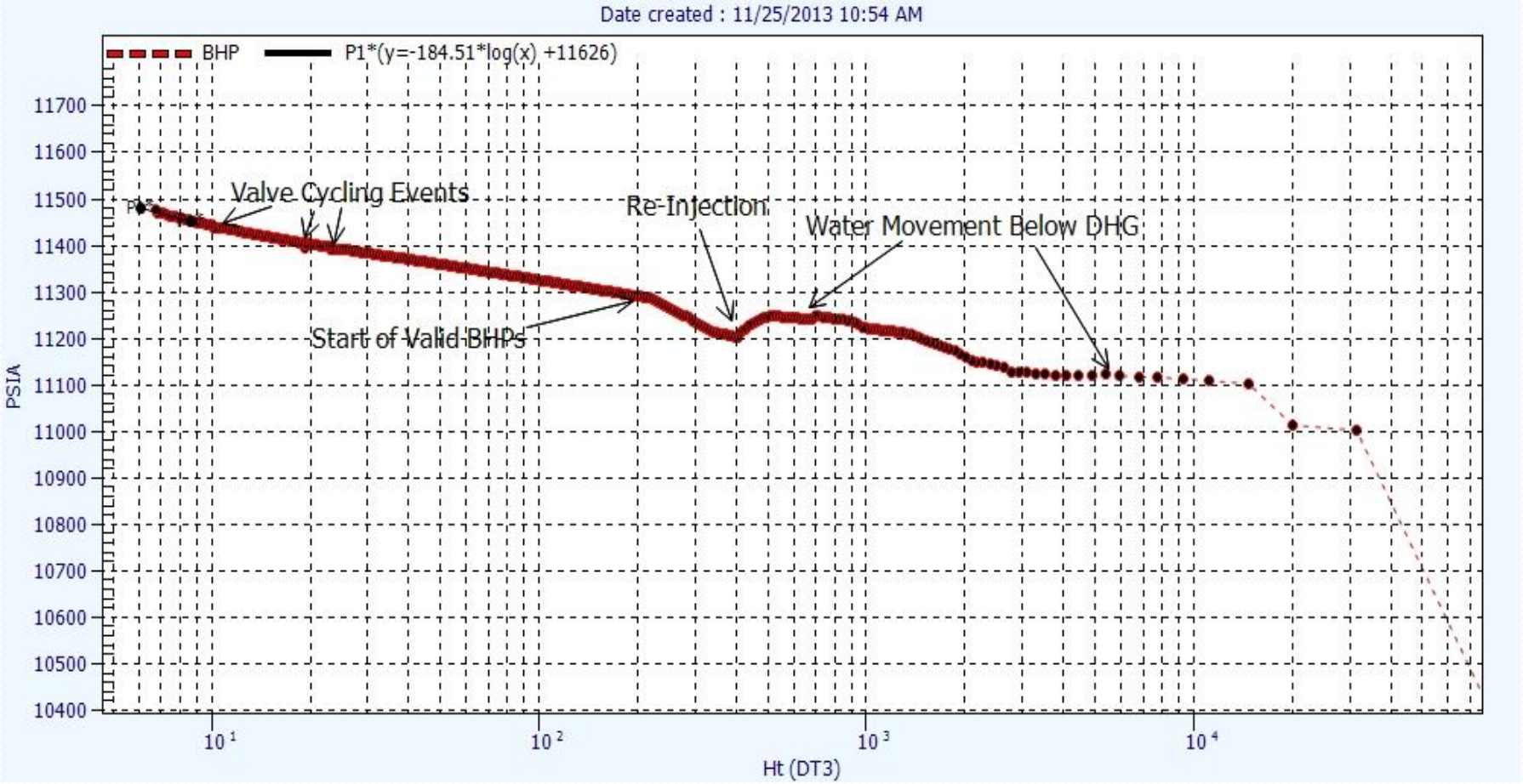
Drawdown - PTA



Drawdown PTA – Semi-log Analysis

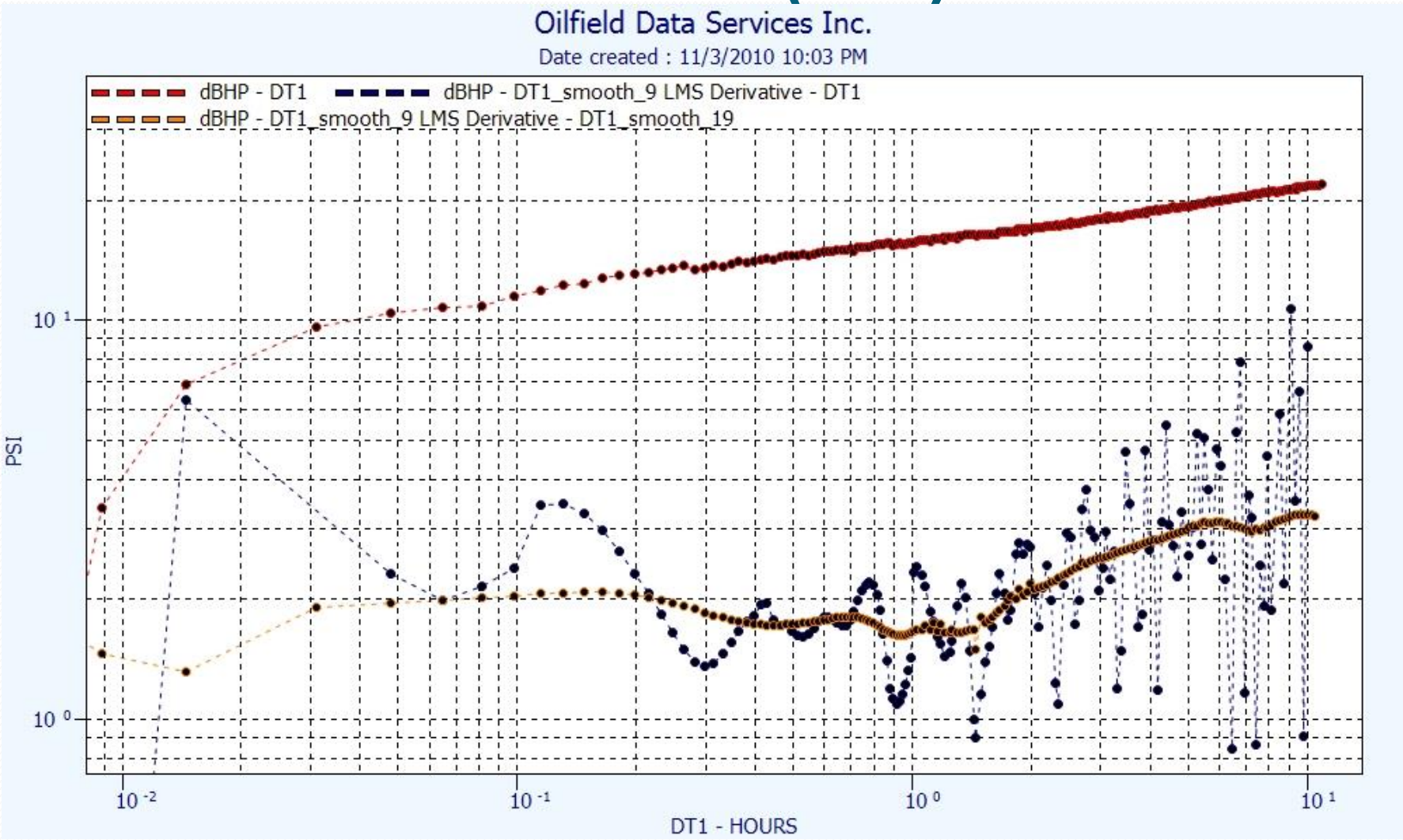


Horner Plot – P* Determination

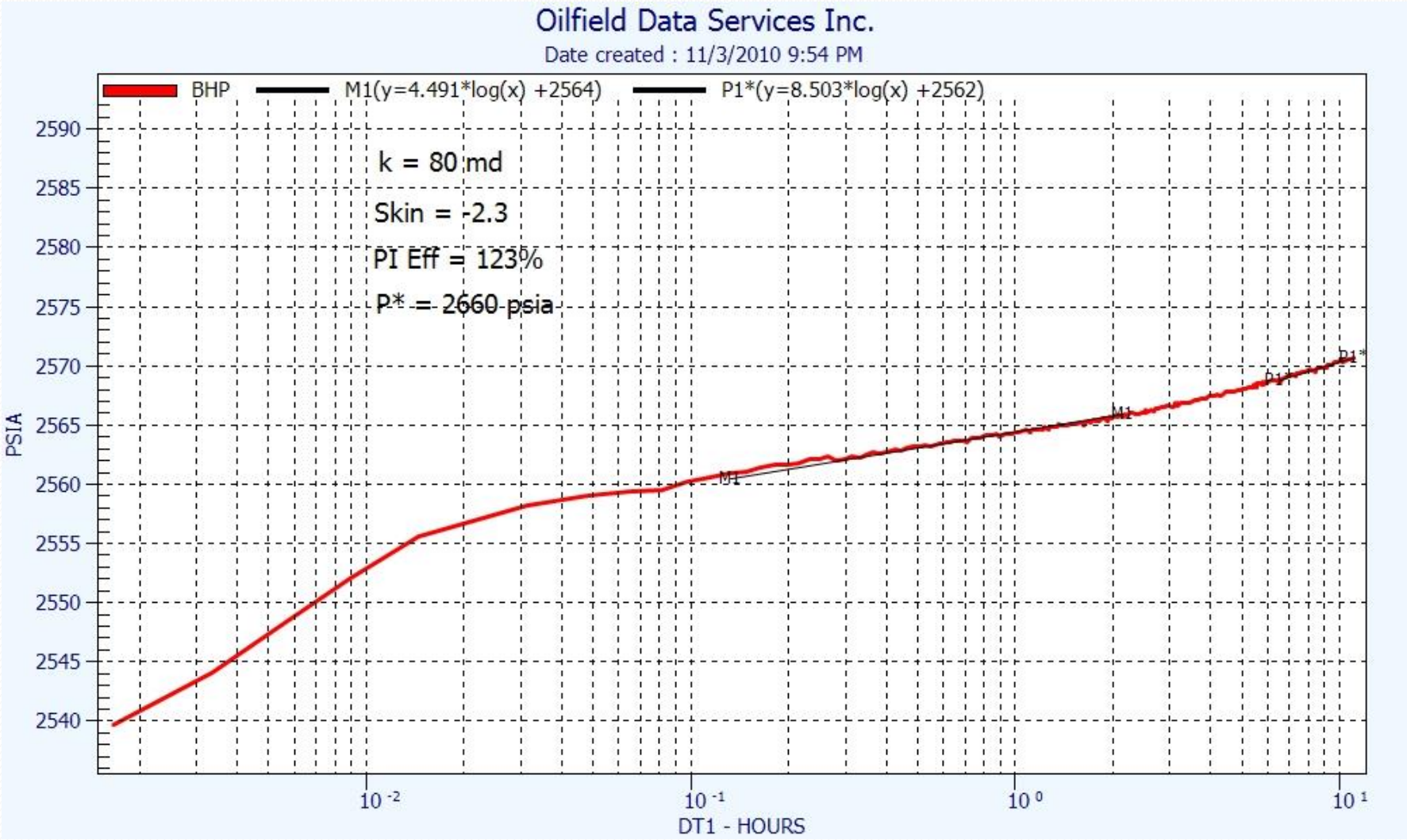


2-Rate Test (Esp. for Oil)

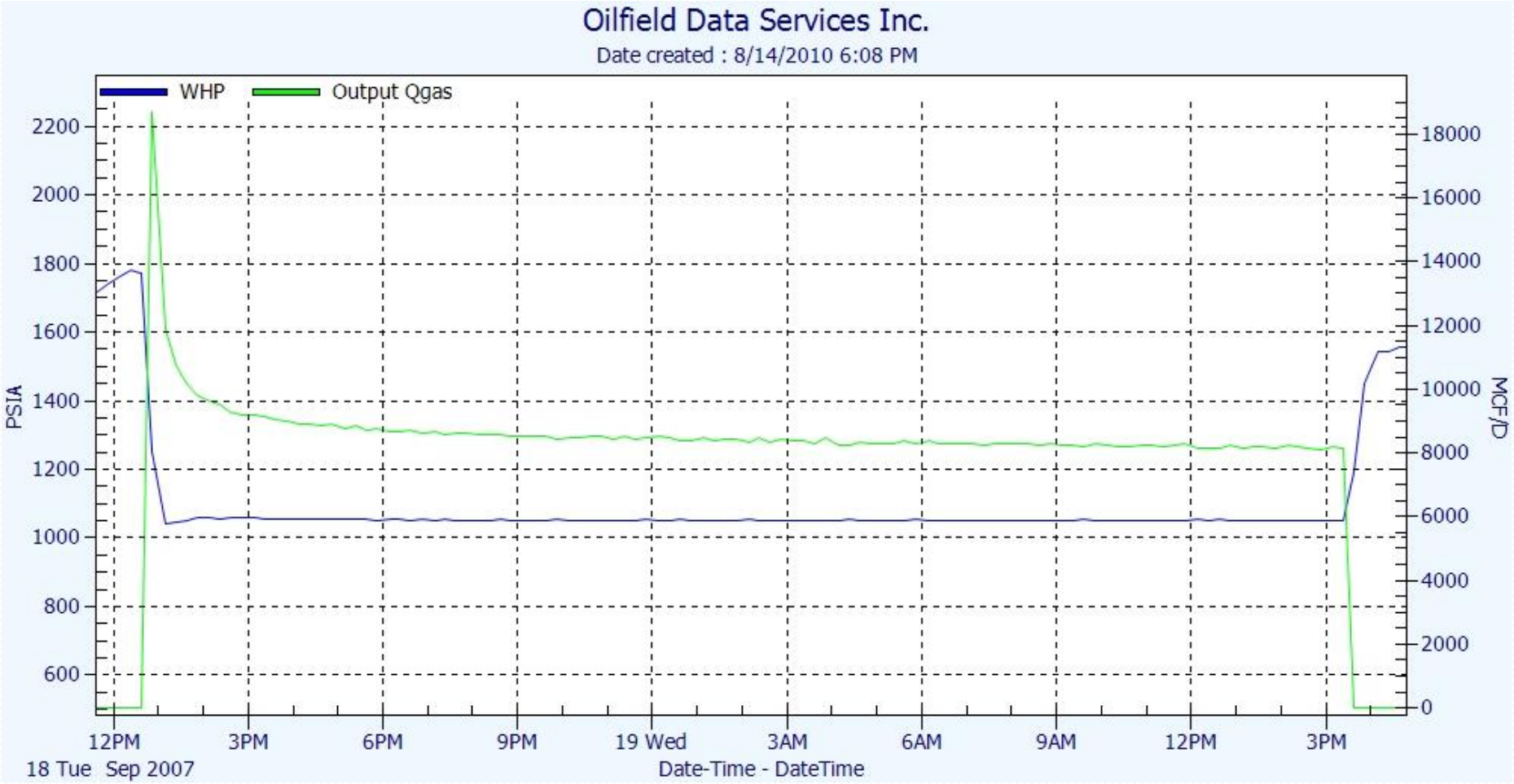
2-Rate Derivative (Oil)



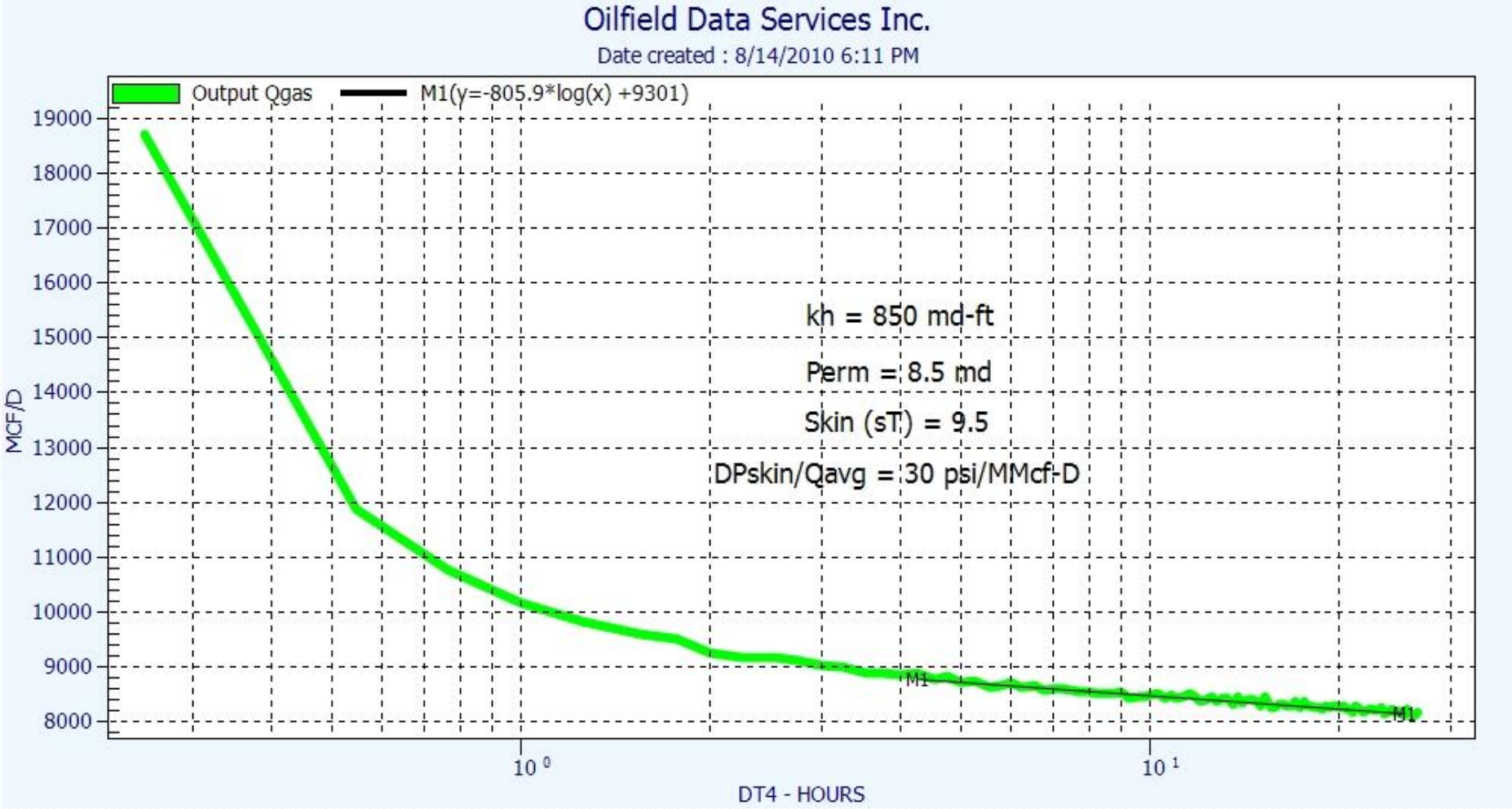
2-Rate Oil Semilog



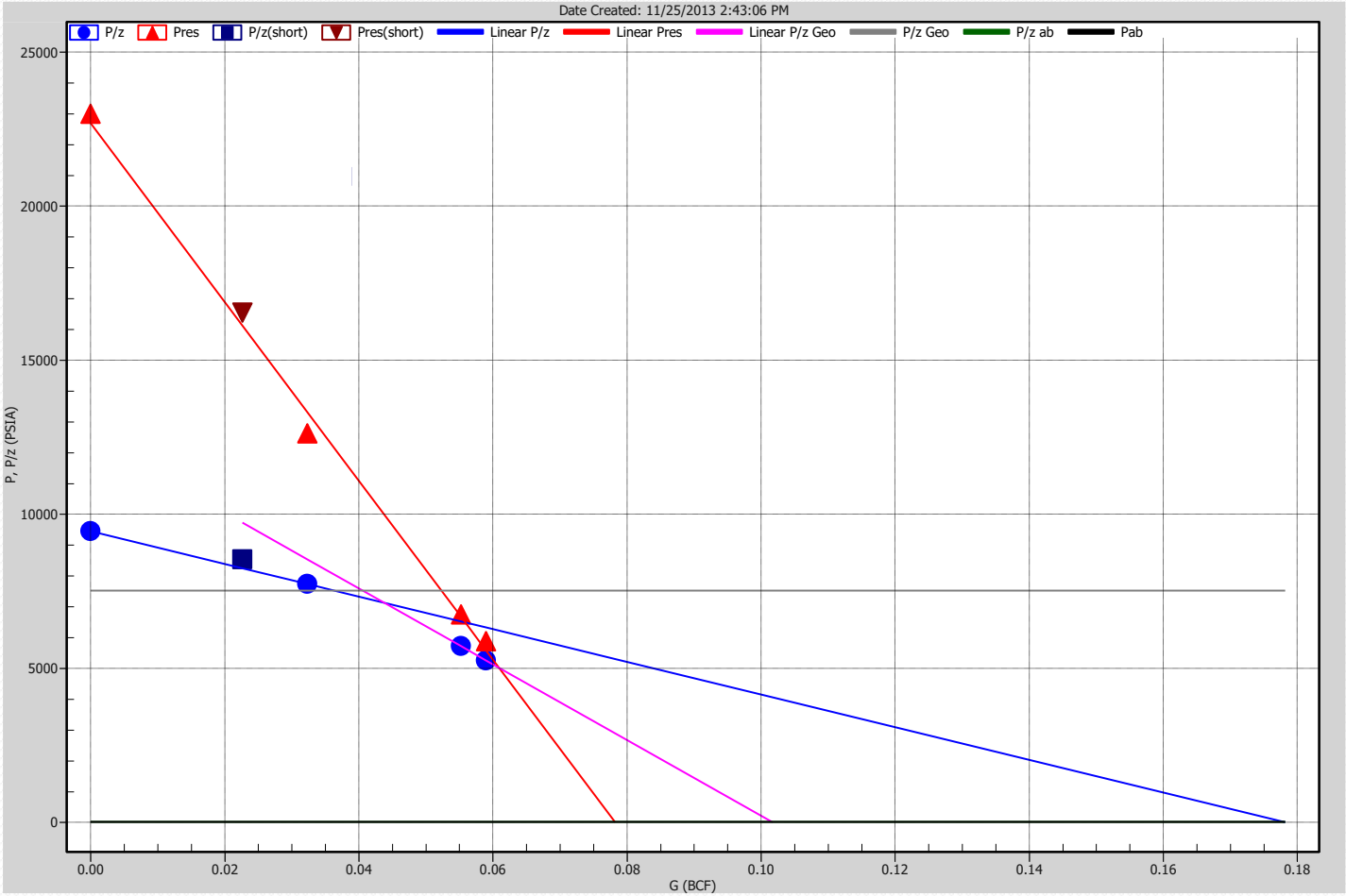
RTA Example - Cartesian



RTA – Semi-log Analysis



P/z Example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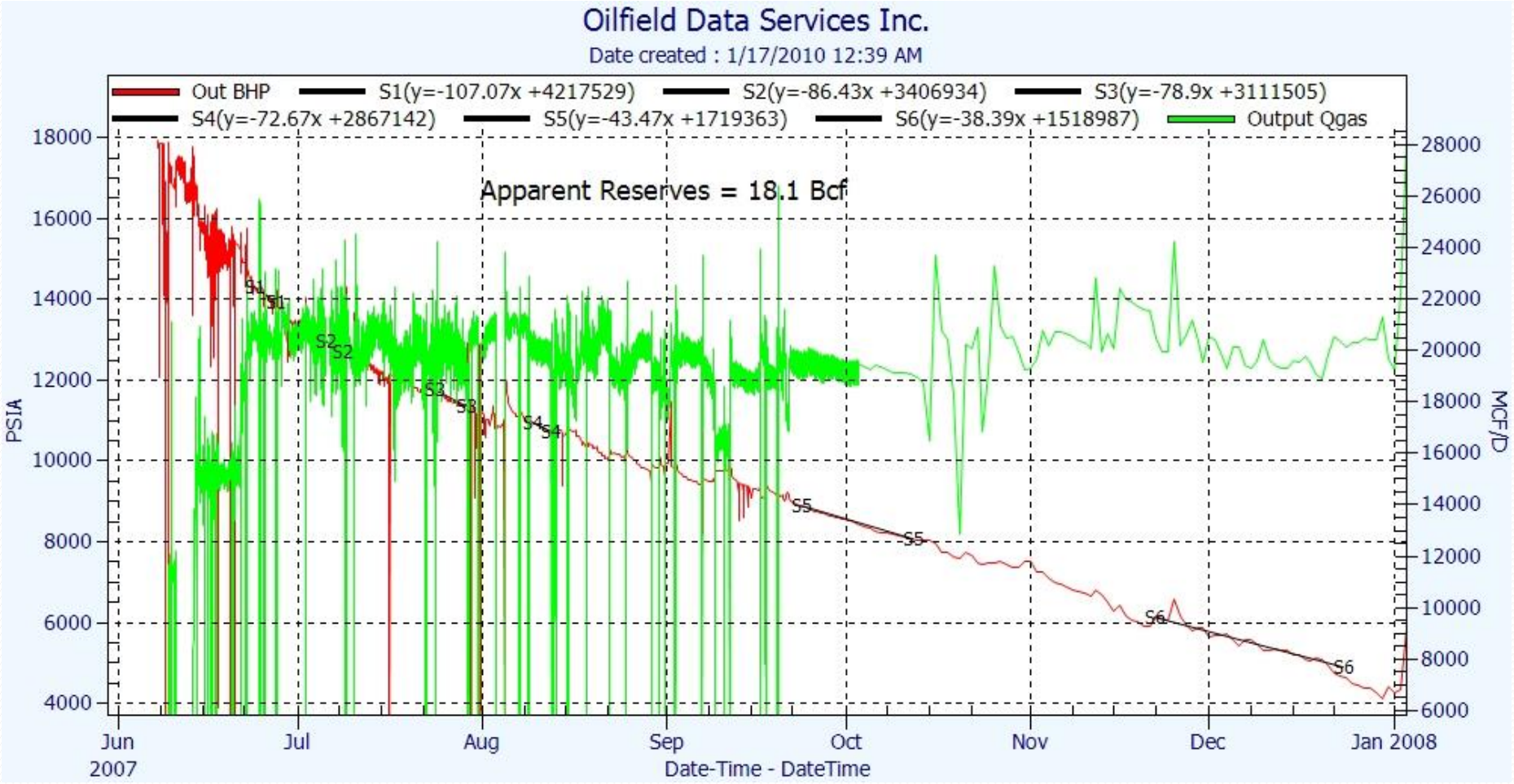
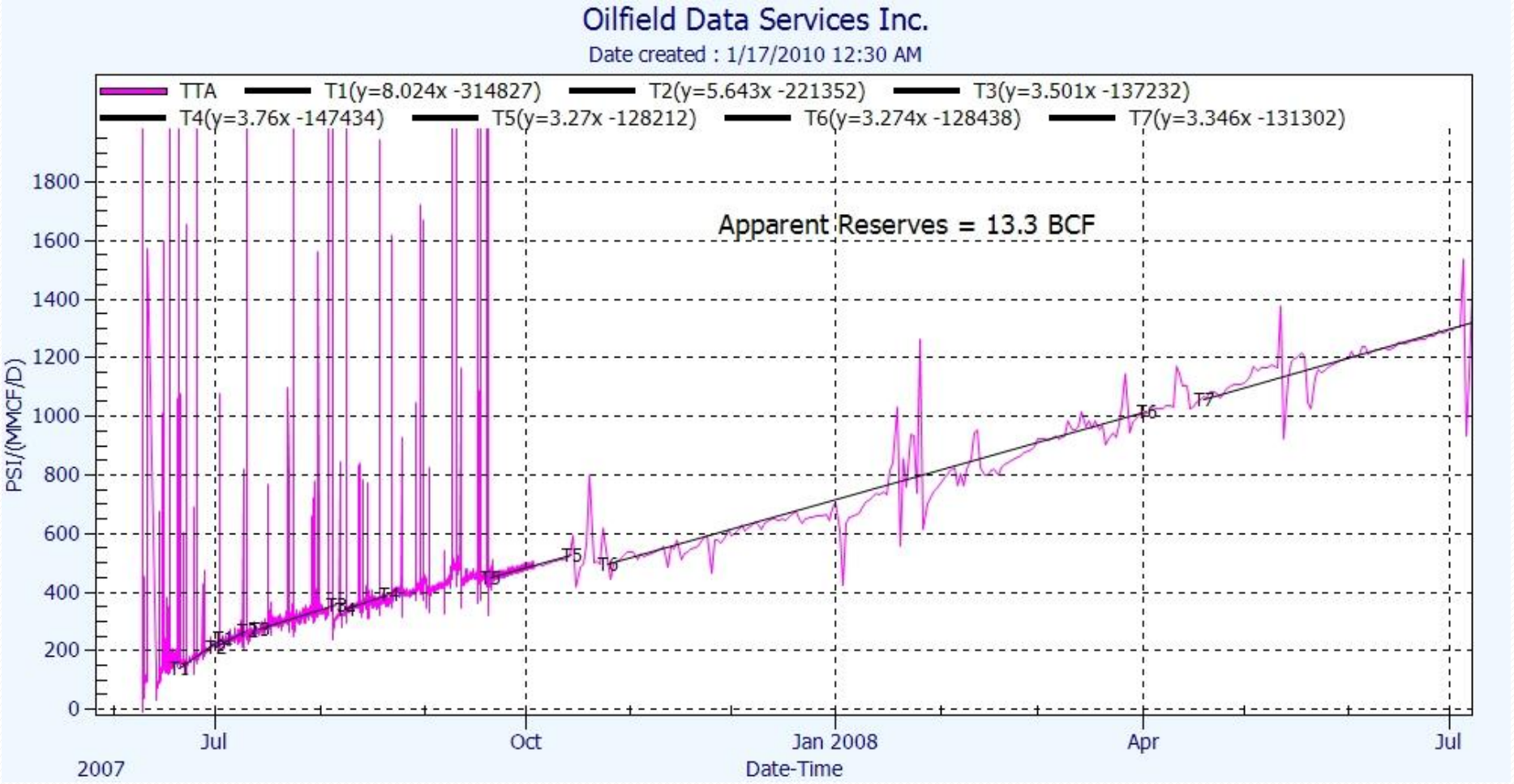
P/z
Pres
P/z(short)
Pres(short)
Linear P/z
Linear Pres
Linear P/z Geo
P/z Geo
P/z ab
Pab
P, P/z (PSIA)
25000
20000
15000
10000
5000
0
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
G (BCF)

DP-DT Decline Evaluation



Inverse Productivity Decline



“Static” Nodal Analysis

- Compares Reservoir Inflow (IPC) with Wellbore Performance (VLP)
  - Allows Prediction of DP to achieve a Rate (vice versa)
  - Allows Prediction of Liquid Loading Scenarios
  - Allows Optimization of Tubular Design
- Problems with Nodal
  - Infinite # of combos of skin & perm calculate the same rate (Can’t use nodal to determine skin or perm)
  - User has to pick the right inflow model and right VLP correlation
  - Doesn’t handle transient situations well – may match your well today, but not next month

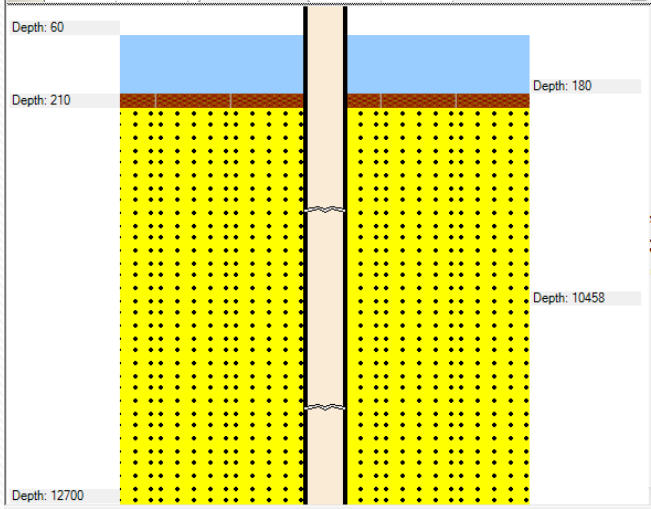
Nodal – IPC + VLP

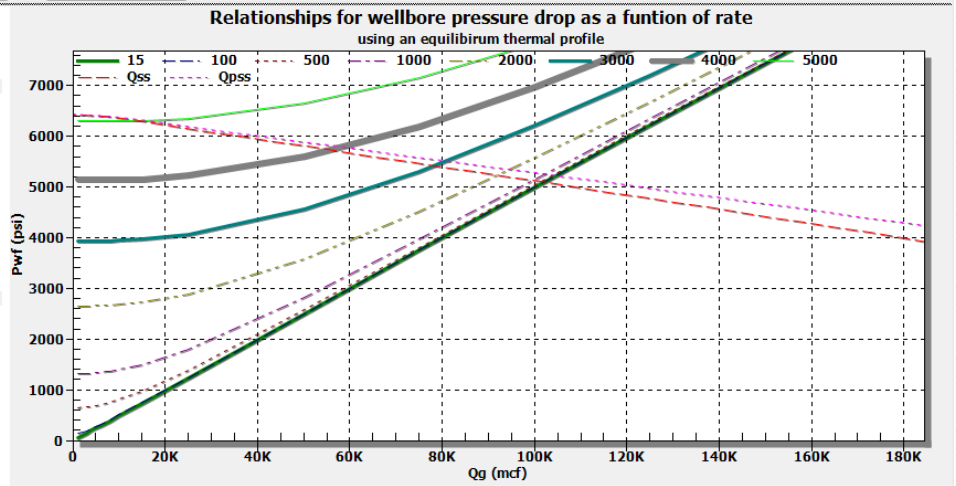
ODSI-Well Analyzer - C:\Users\ODSI\Desktop\April 15 2010\nodal out2.ProData - [WellboreDeliverabilityDialog]

File Memory Analysis Plot View Tools Help

	Gas Rate	WHP	C	Inflow	Inputs	Units
2	2000	100		PSTAR	6500	psi
3	3000	500		Max Pwf	6500	psi
4	4000	1000		Pwf Step	100	psi
5	5000	2000		Perm	10	md
6	6000	3000		Skin	-1.5	
7	7000	4000		D	.0000001	1/mcf
8	8000	5000		Time	24	Hours
9	10000			Radius Override	☐	
10	15000			Radius	0	ft
11	25000			rw	0.350	ft
12	50000			Net TVT Pay	120.0	ft
13	75000			Porosity	0.11	
14	100000			Sw	0.22	
15	125000			So	0.00	
16	150000			Sg	0.78	
17	175000			Cf	4.67	microsips
18	200000			Plot ?	☑ Qss	☑ Qpss
19	250000			WCD Pwf	4950	
20				Calculate		

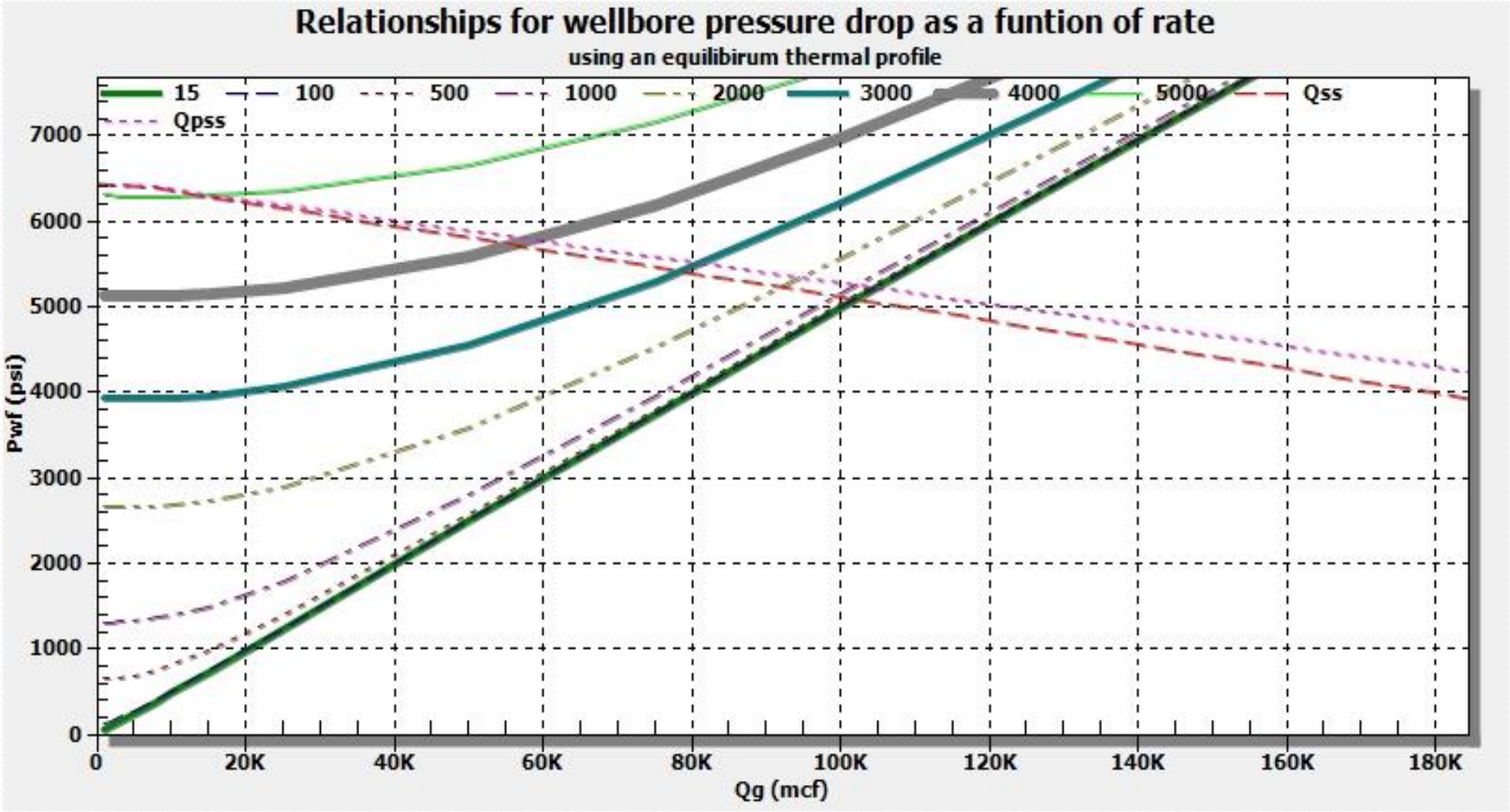
	100	500	1000	2000	3000	4000	5000	I	J	K	L	M
25000	1239.9	1393.3	1794.8	2892.1	4070.1	5230.4	6363.2					
50000	2500.0	2579.0	2812.0	3588.2	4563.2	5602.3	6658.5					
75000	3759.1	3810.6	3966.8	4530.4	5313.2	6210.0	7163.8					
100000	5000.7	5038.1	5153.0	5583.3	6217.2	6983.2	7830.9					
125000	6227.1	6256.1	6345.7	6688.4	7211.7	7867.9	8617.5					
150000	7449.3	7472.8	7545.4	7826.9	8266.8	8833.2	9496.2					
175000	8676.9	8696.4	8757.0	8993.7	9369.5	9862.5	10450.8					
200000	9862.5	9879.3	9931.5	10136.5	10465.2	10901.9	11430.0					
250000	12211.7	12224.7	12265.4	12426.1	12687.2	13039.9	13474.3					
Pwf	6400.0	6300.0	6200.0	6100.0	6000.0	5900.0	5800.0	5700.0	5600.0	5500.0	5400.0	5300.0
Qss	7294.4	14587.5	21878.7	29167.3	36452.6	43733.7	51009.9	58280.2	65543.6	72799.2	80045.8	87282.3
Qpss	8252.4	16504.2	24754.7	33003.2	41248.8	49490.7	57728.0	65959.6	74184.5	82401.6	90609.7	98807.5
Pavg	6449.9	6399.5	6348.8	6297.9	6246.7	6195.2	6143.4	6091.2	6038.8	5986.1	5933.0	5879.6
r	1008.1	1004.0	999.9	995.8	991.6	987.3	983.1	978.8	974.4	970.0	965.6	961.1
mu	0.028	0.028	0.028	0.028	0.028	0.027	0.027	0.027	0.027	0.027	0.027	0.027
B	0.642	0.645	0.648	0.652	0.655	0.658	0.662	0.665	0.669	0.673	0.677	0.681
eta	10585.865	10500.499	10414.714	10328.504	10241.863	10154.787	10067.268	9979.300	9890.876	9801.990	9712.633	9622.798





Ready

Nodal VLP-IPC Plot



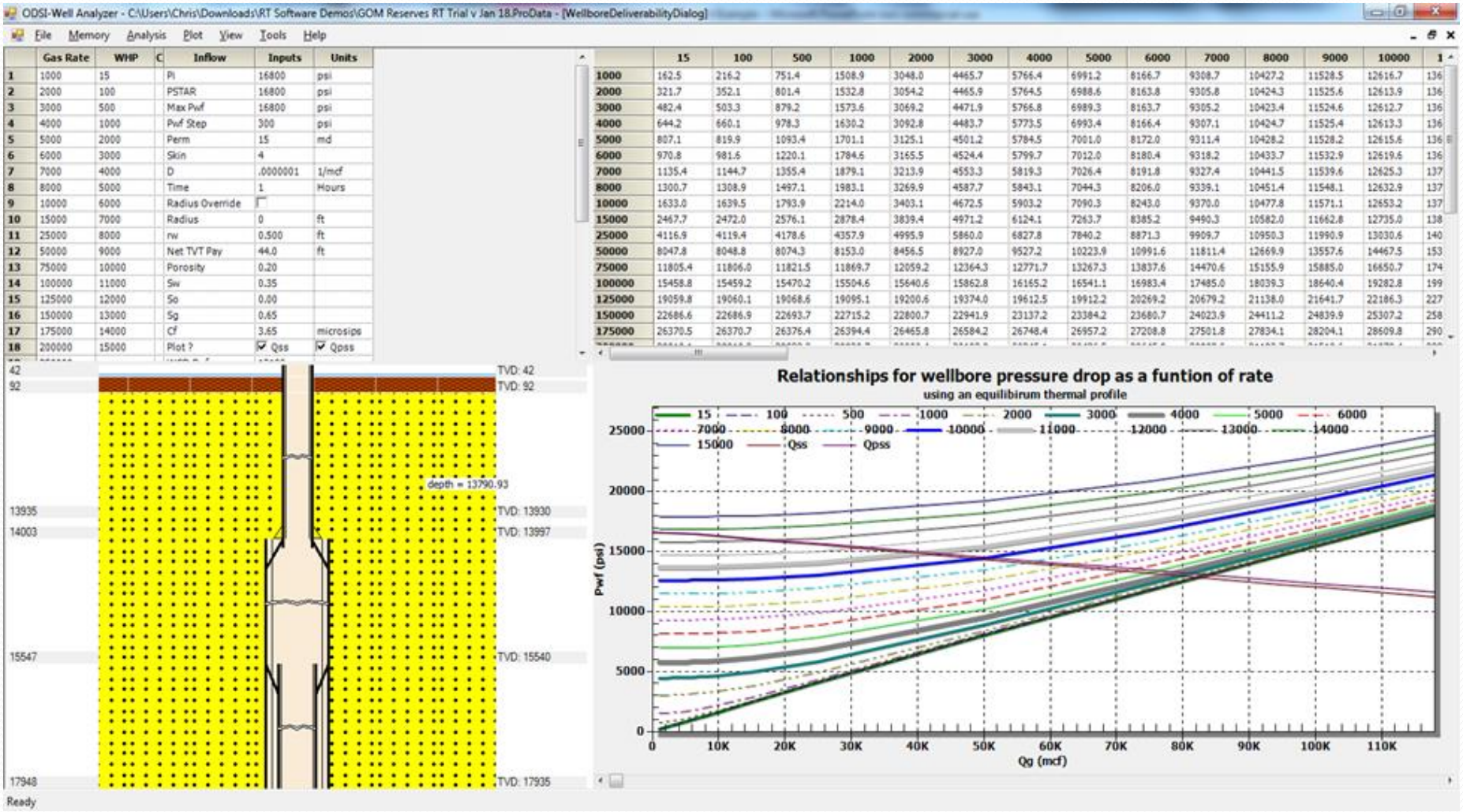
Transient Nodal Analysis Tool

- Keep track of changing produced fluid composition
- Update skin & perm from last valid PTA
- Update P* from last valid PBU
- Keep track of pressure decay during drawdown
  - Adjust Preservoir while producing
  - Use Transient Inflow model when in transient flow
  - Use Appropriate Steady State Inflow model when in SS Flow
- Link Reservoir Simulator to Wellbore Model

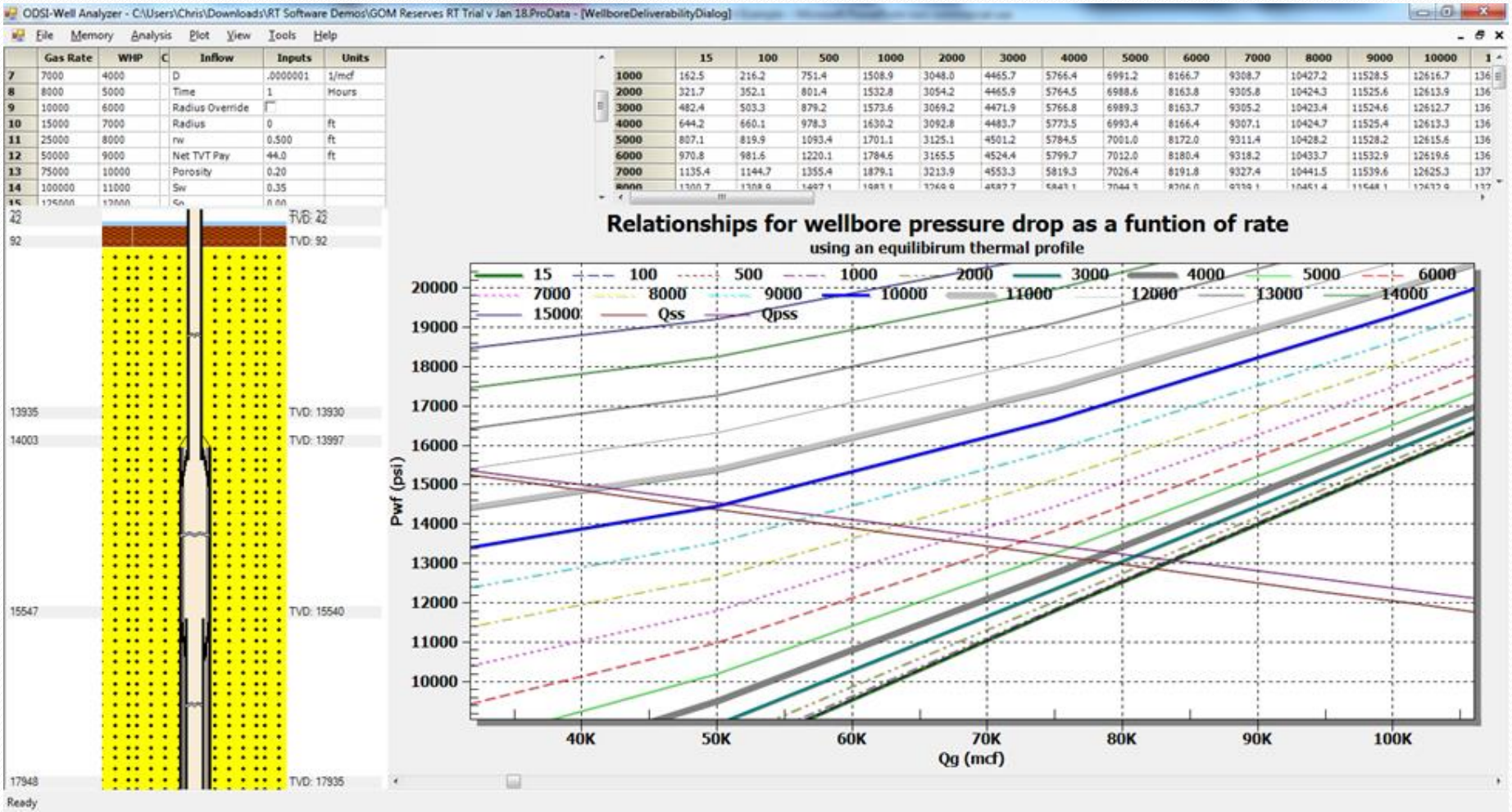
Transient Nodal Initiation

- Preservoir, Treservoir
- Skin (s & D) & Perm from Flowback PTA
- Wellbore Radius and Net TVT pay
- Fluid PVT
- Well Configuration/Geometry
- Petro-physical inputs
  - Sw, porosity, formation compressibility
- Forced Fixed Reservoir Volume or Floating Reservoir Volume
- Production Time Since last Valid P*/Pres

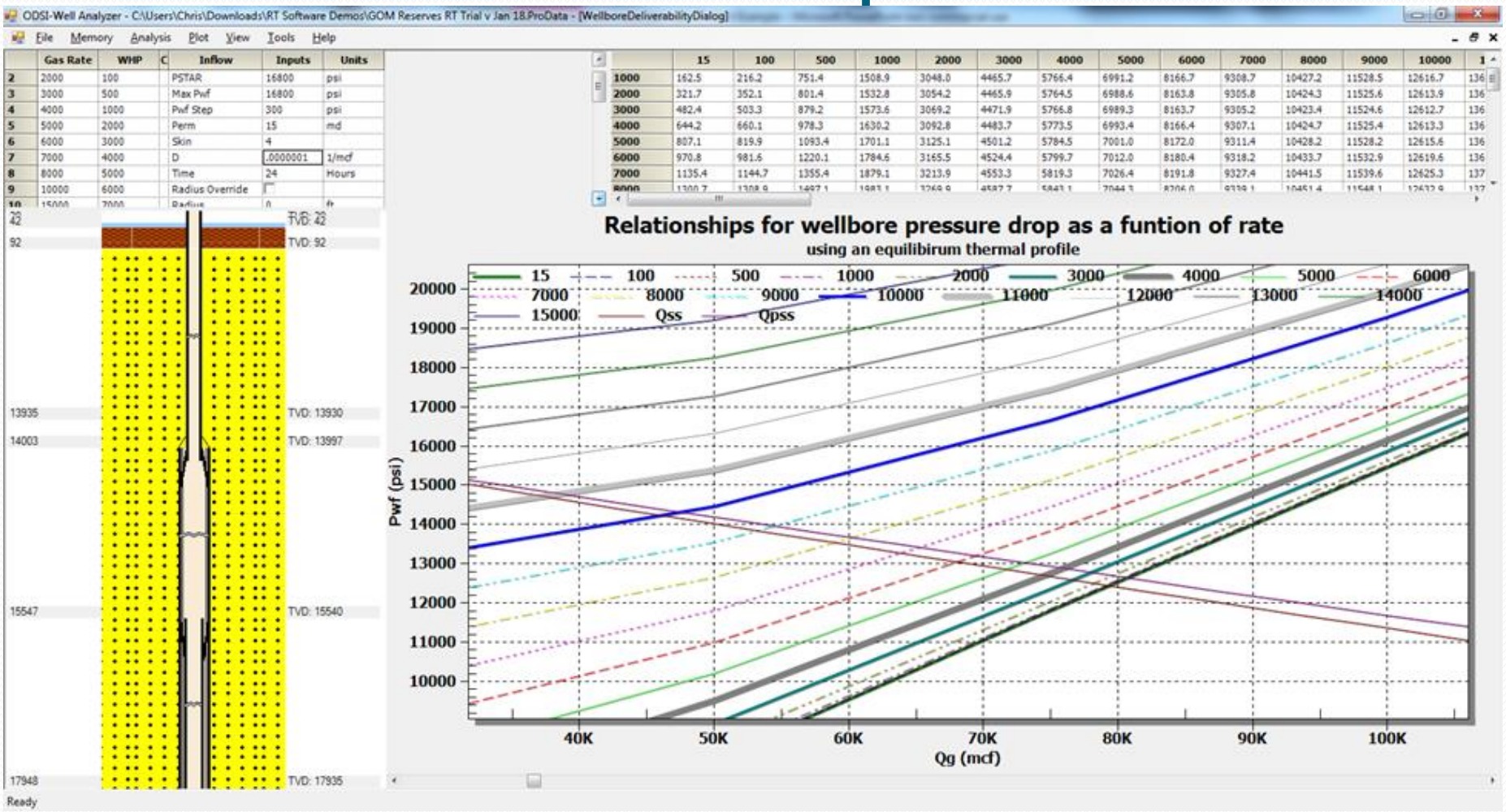
Nodal Initiation Run



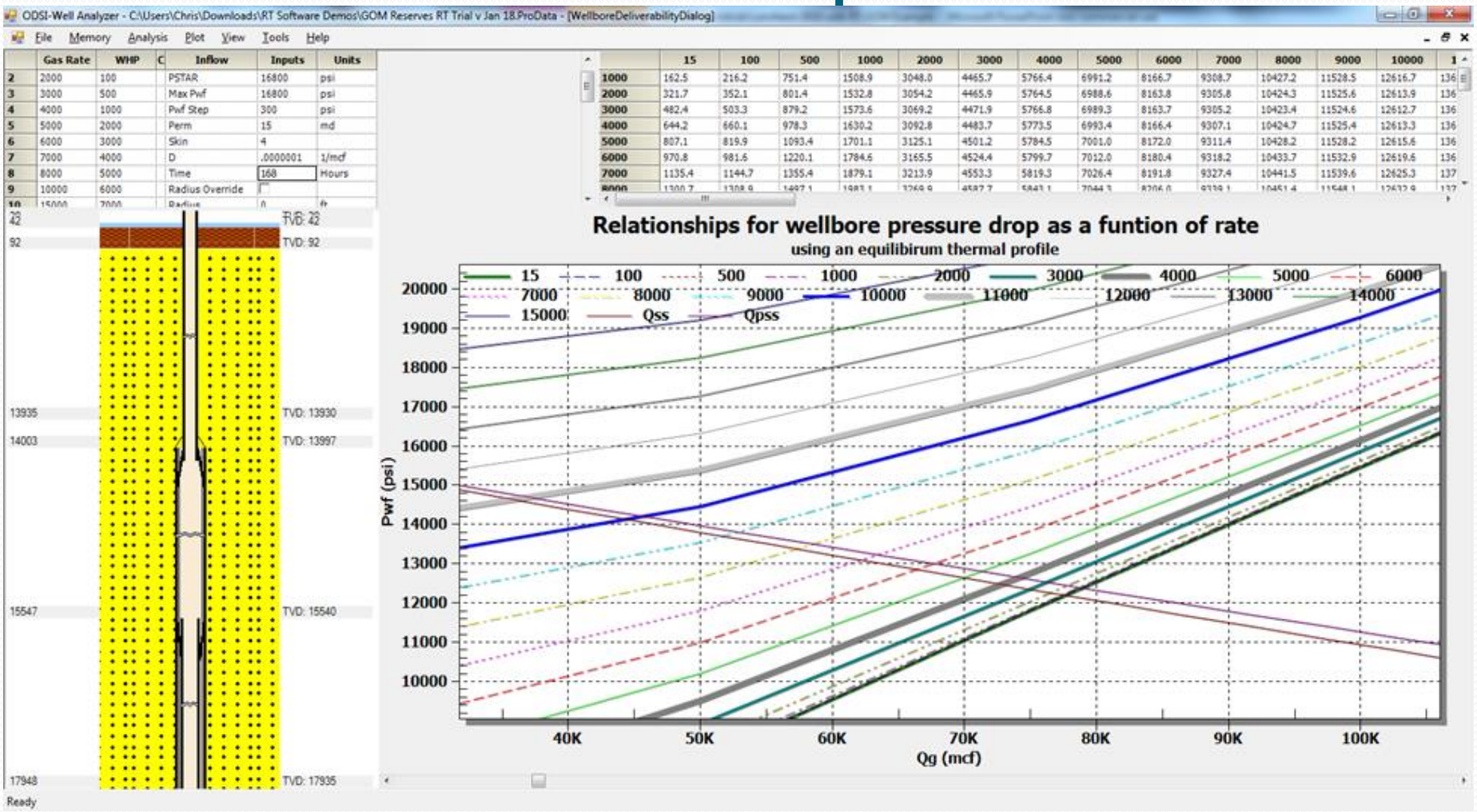
Inflow and VLP for Tp = 1 hour



Inflow and VLP for Tp = 24 hours



Inflow and VLP for Tp = 168 hours

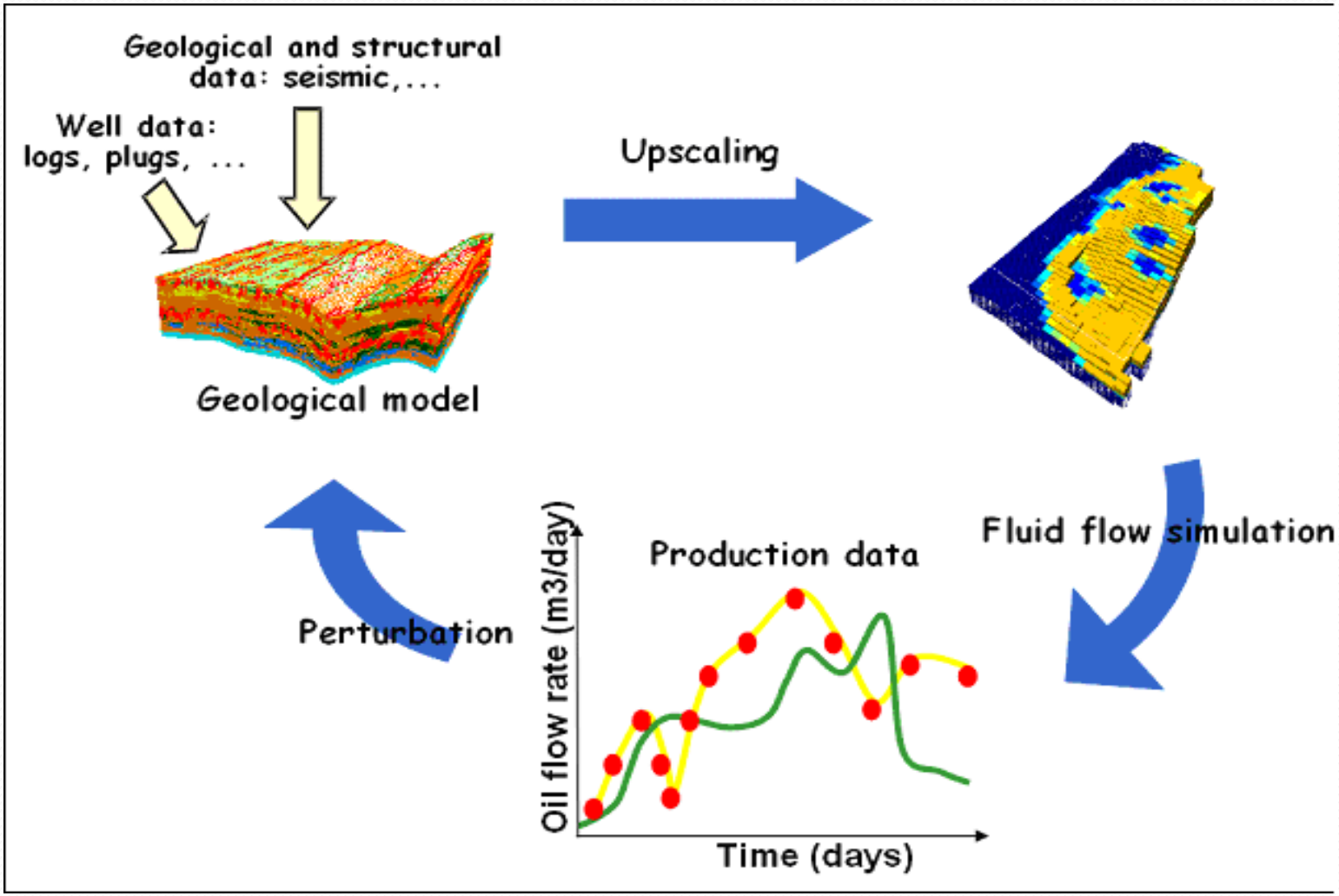


Reservoir Simulation

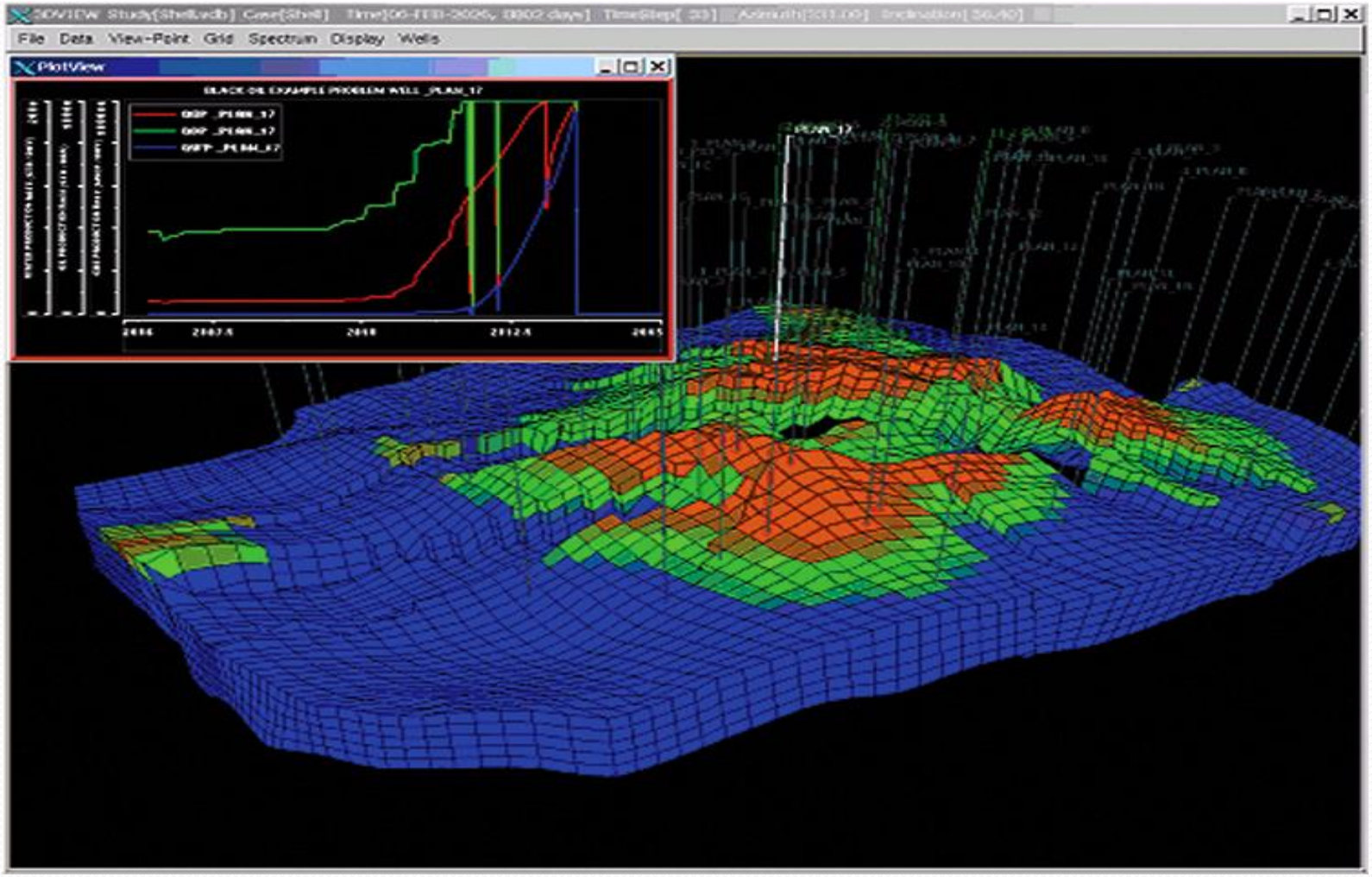
- Tracks behavior (esp Pressure and Saturation) in the reservoir
- Incorporates Multiple Wells/Multiple Zones
- Matches History and Attempts to Predict Future Performance
- Coupled with a Wellbore Simulator, can do amazing things

- Drawback: It takes a while to run…but they're getting faster

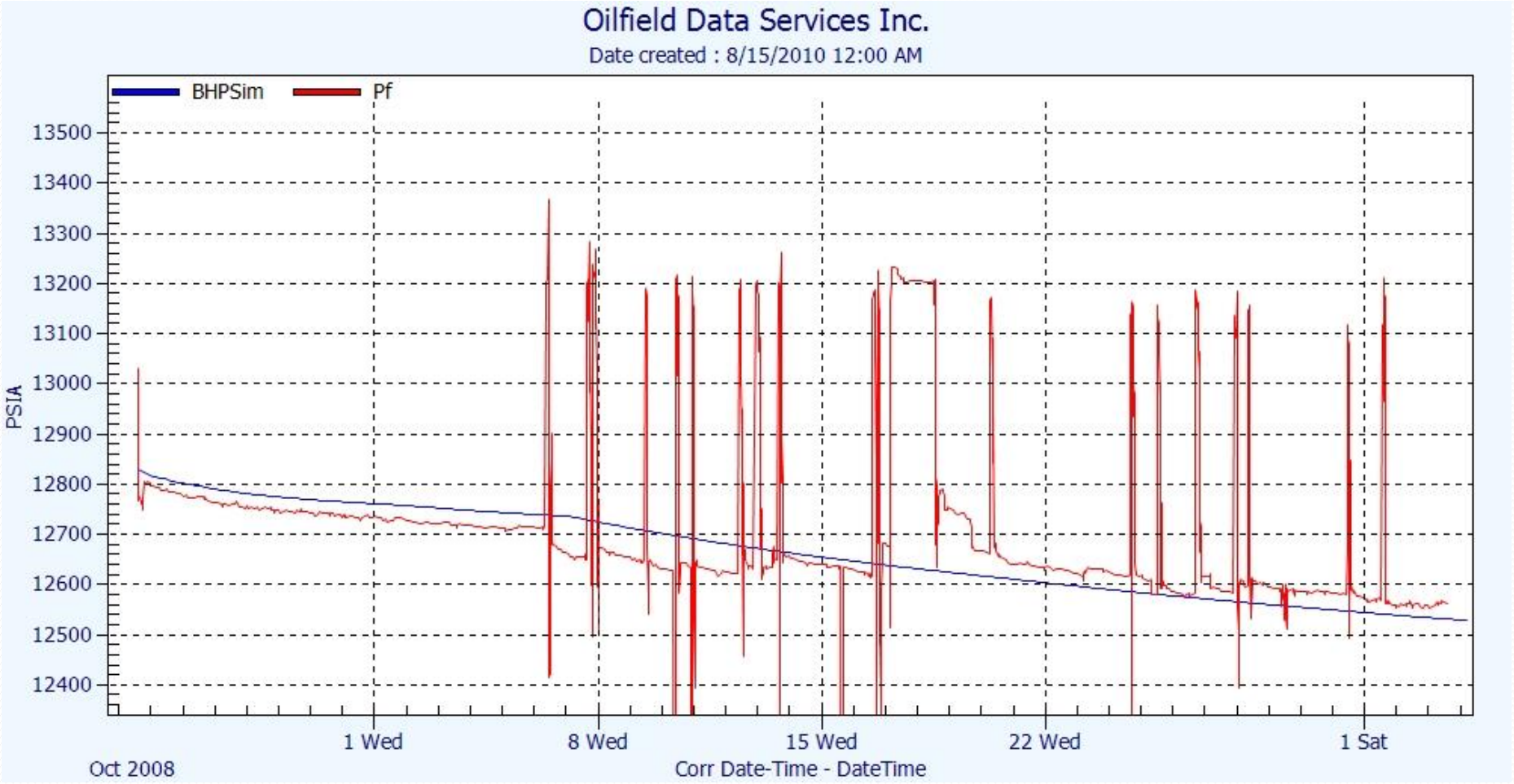
Simulation Gist…



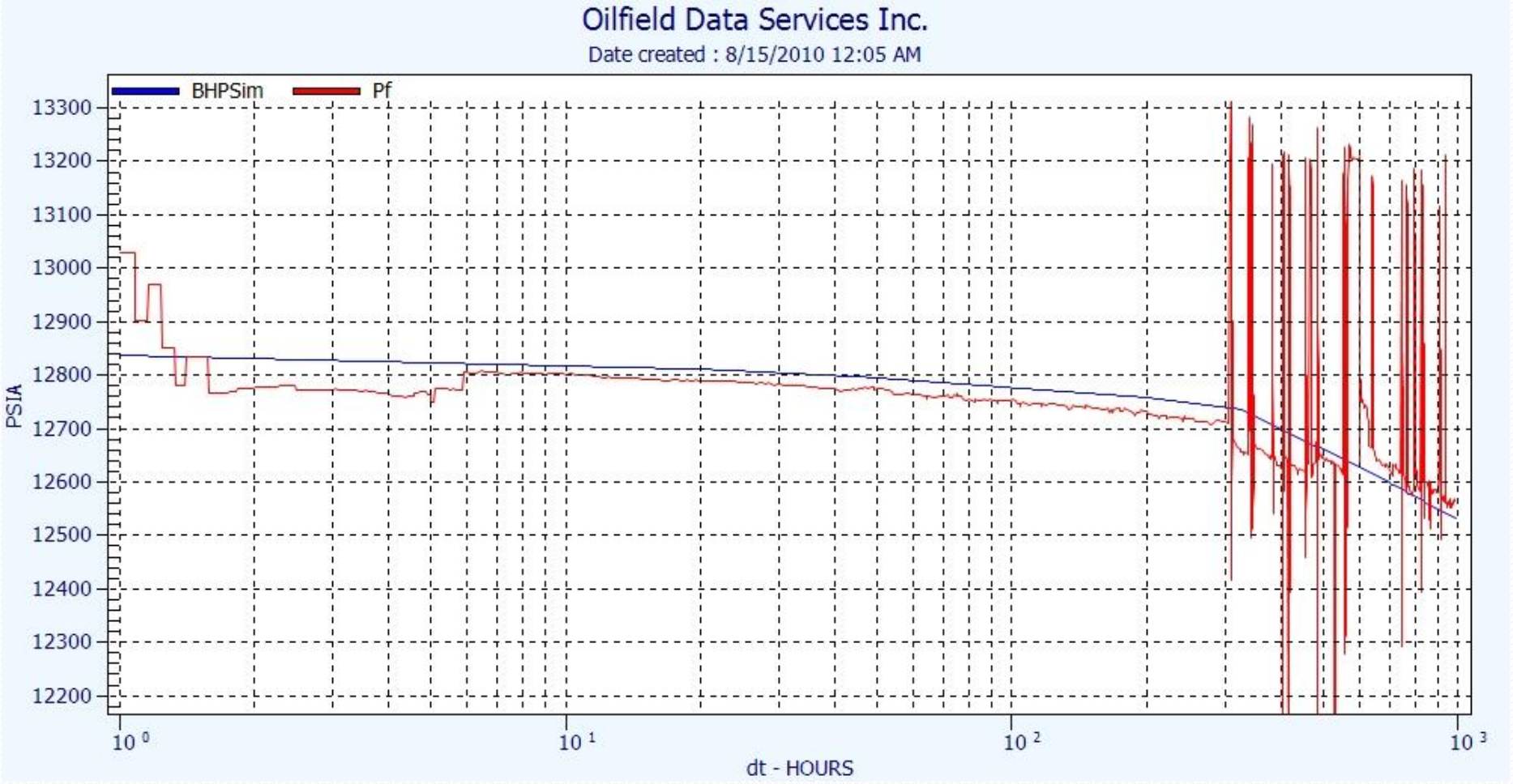
Simulation: Well Grid



Simulator Prediction vs. Actual



Simulator Prediction vs Actual - Semilog



Simulation Drawbacks

- Treats system as a tank model
  - OK for High-perm, not so good for low-perm
- Works best in SS or PSS flow (poor for transient)
- Doesn't handle discontinuities very well
- Subject to "gaming"

- Best Case Scenario: The History Match Quality is the BEST the future predictions will be…

Well Test Planning/Design

- Before you get started, ask:
  - Do you already have the answer?
  - What do you really want to know?
  - Can you use your existing equipment?
  - Do you really need to shut the well in?

Common Well Test Objectives

- Kh & skin
- Productivity
- Total System Drawdown
- Near Wellbore/Sandface DD
- Reservoir Pressure
- Any changes since the last test?

OK…so, we're going to test it…

- What's the well doing now? Is it unloading?
- Is it multi-phase in the well bore?
- Is it multi-phase in the reservoir?
- Is it making significant water?

- How are the rates measured? Are they valid?
- What kind of pressure gauge do we need?
- If RIH, where do we set the gauge?

Well Test Management Guidelines

- Make sure the well has been flowing on a constant choke for the planned length of the PBU, before the PBU begins
  - If well is shut-in to install DHGs, return the well to the previous choke for 2x the time it was shut-in to set dhgs
- Shut-in the well quickly – don't stage the shut-in
- If surface testing, leave the SCSSV open
- Be careful about PBUs in multi-layered reservoirs
- Be careful about phase-resegregation
- Do a drawdown after the build-up

Test duration based on objectives

- Skin/perm – short
- Boundaries – longer
- P* - even longer

- If the perm is known or if previous well tests have occurred, the test duration to achieve the objective can be planned in advance

What do you need to measure?

- Pressure (WHP, DHGP)
- Temperature (WHT, DHGT)
- Rates: Oil, Gas & Water

Note: Gas rate can be calculated with WHP & DHGP

- Need good PVT data on HC phases
- Need to know Net TVT Pay, Sw, So, Sg and porosity

Advanced Topics

- Water Contacts (well test analysis)
- Water Contacts (Decline analysis)
- Boundaries
- Wavex Energy Mapping

What are the Objectives of Automated Monitoring/Surveillance?

- Reduce bias in:
  - Well Productivity
  - Apparent Connected Reservoir Volume
  - Is Anything Changing (WB, Comp, Res)?
- Recognize important data/events
  - Reduce time spent hunting for data
- Rapidly perform well/reservoir evaluations
  - Reduce Software Training/Analysis time
- Give Engineers results to check and validate, not spend hours, days and weeks trying to do everything themselves

How to “Bird-Dog” a Well Production problem

- Is it a wellbore problem?
  - Scale/Wax/Asphaltenes, Loading, Parted String
- Is it a completion problem?
  - Skin Accretion, Screen Plugging, Completion Failure
- Is it a reservoir problem?
  - Perm?
  - Reserves?
  - Water Encroachment?

- Is it a combination of two or more of the above?

FIND THE PRESSURE DROP THAT SHOULDN’T BE THERE!