

Demo for

Water Injector

Well A

Automated Real-Time

Well/Reservoir Evaluation Software Package

Software Trial for

Allocations, BHP Conversion, Auto-PTA

Performed by Venera Zhumagulova & Chris Fair

Executive Summary I

- No obvious reason for reduction in injectivity by analyzing the long-term Fall-offs
 - Slight increase in skin and slight increase in kh
- Near-well Auto-PTA conclusively indicated a reduction in the near-well kh and injectivity
- Difference in measured vs. calculated injection rates was a clear indication of scale build-up in the well bore
- The acid job fixed both the scale issues in the well bore and the injectivity losses in the near-well region

Executive Summary II

- Rate Measurements compared to ODSI's d/p wellbore method can diagnose scale
- Automatic PTA saves time and provides consistency for 'apples to apples' comparisons
- Near-well kh provided the most reliable diagnostic of completion performance for this well
- After the stimulation job (Jan 2017), the measured and calculated rates matched again, indicating a cleaned well bore

Outline

- Well Analyzer Software Features
- Well A background info
- Trial Objectives
- Data Processing
- Trial Results
 - Allocations
 - BHP
 - PTA
- Conclusions and Observations

About Well Analyzer

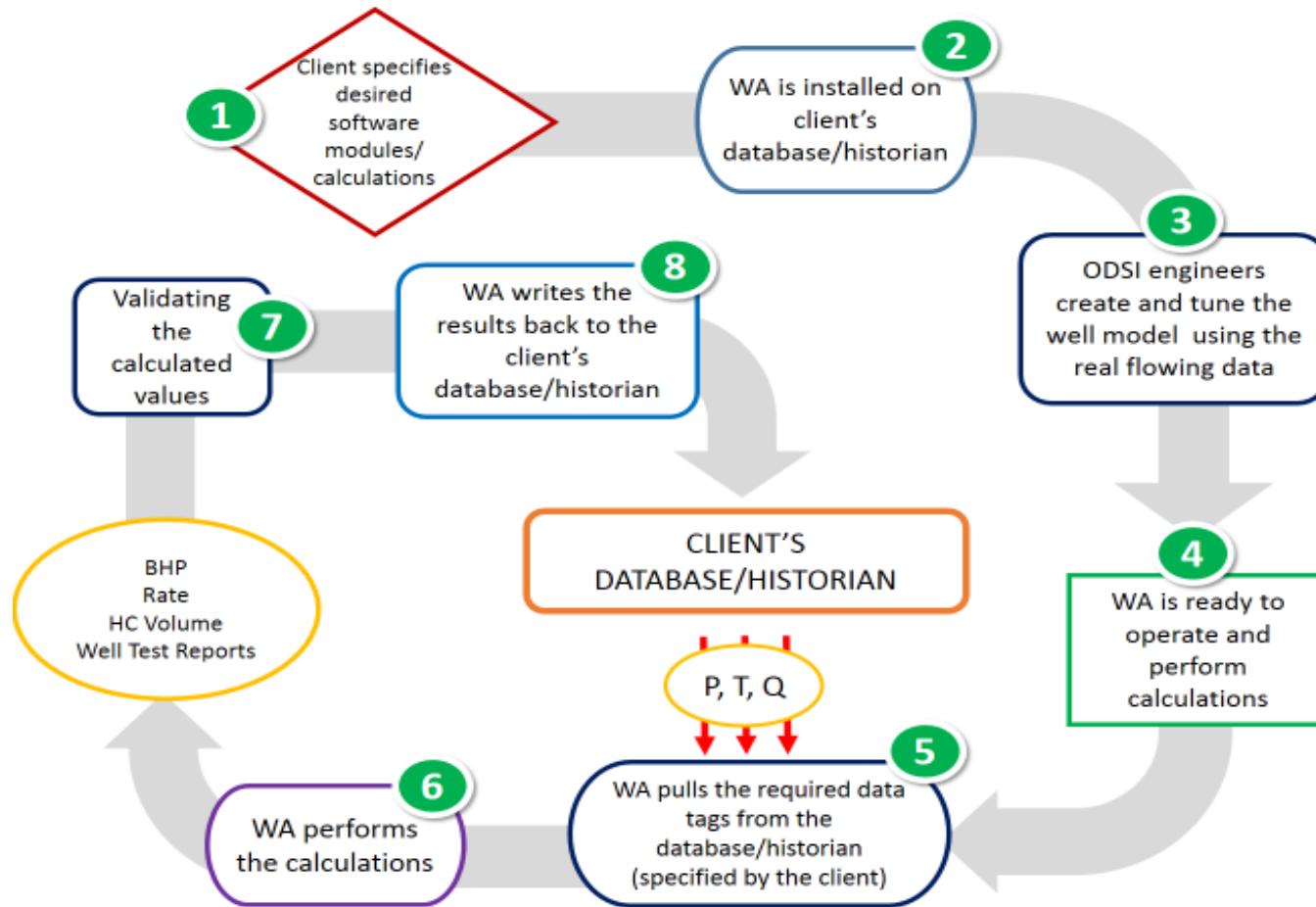
Well Analyzer is the only existing software package that is based on a direct solution to the Mechanical Energy Balance equation, which is the basis of the most VLP correlations, including:

- Cullendar & Smith
- Beggs & Brill
- Hagedorn & Brown

Well Analyzer's method uses a direct solution, hence it provides **more accurate** and **reliable** results

How does it Work ?

- Works both in Real-Time and on Historic data
- Polls the required data tags from the database, performs the calculations, validates the results and writes them back to the database



Well Analyzer Real-Time Features

- Virtual metering
 - Oil, gas and water rate calculations
 - Detects errors in allocations
- Bottomhole pressure calculation from the surface data
 - Can replace downhole pressure gauge in case it fails
- Automated Transient Interpretation of build-up & drawdown tests and injectivity & injection fall-off tests
 - Skin
 - Permeability
 - Avg.Pres/P*

Well Analyzer - PTA

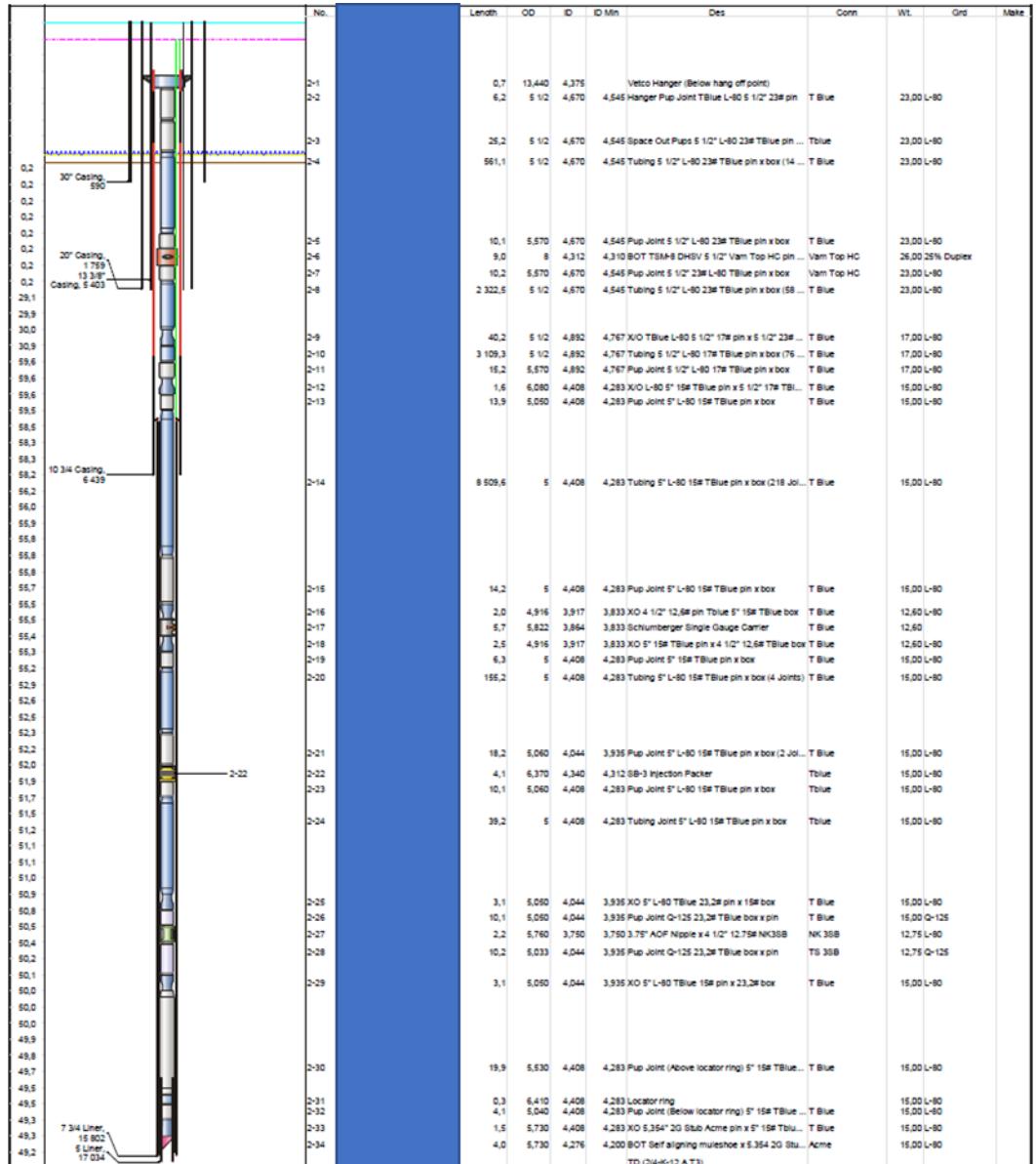
Well Analyzer polls the data and looks for new transients. Once identified, the software analyzes them for:

- Permeability
- Skin
- Pressure drop due to skin
- Reservoir pressure
- Productivity Index/Injectivity Index
- Completion Efficiency
- Allows engineers to ‘catch’ new transients
- Monitoring of PTA parameters and well performance (changes) with time

Background

- 4.5 (July 2012- Feb 2017) years of production data was provided to ODSI to demonstrate software's real-time features
 - Virtual metering
 - BHP conversion
 - Auto-PTA
- The well equipped with
 - WHP
 - DHGP/DHGT
 - Water rates were being measured

Completion Schematics



Donwhole pressure gauge @ XXX TVD

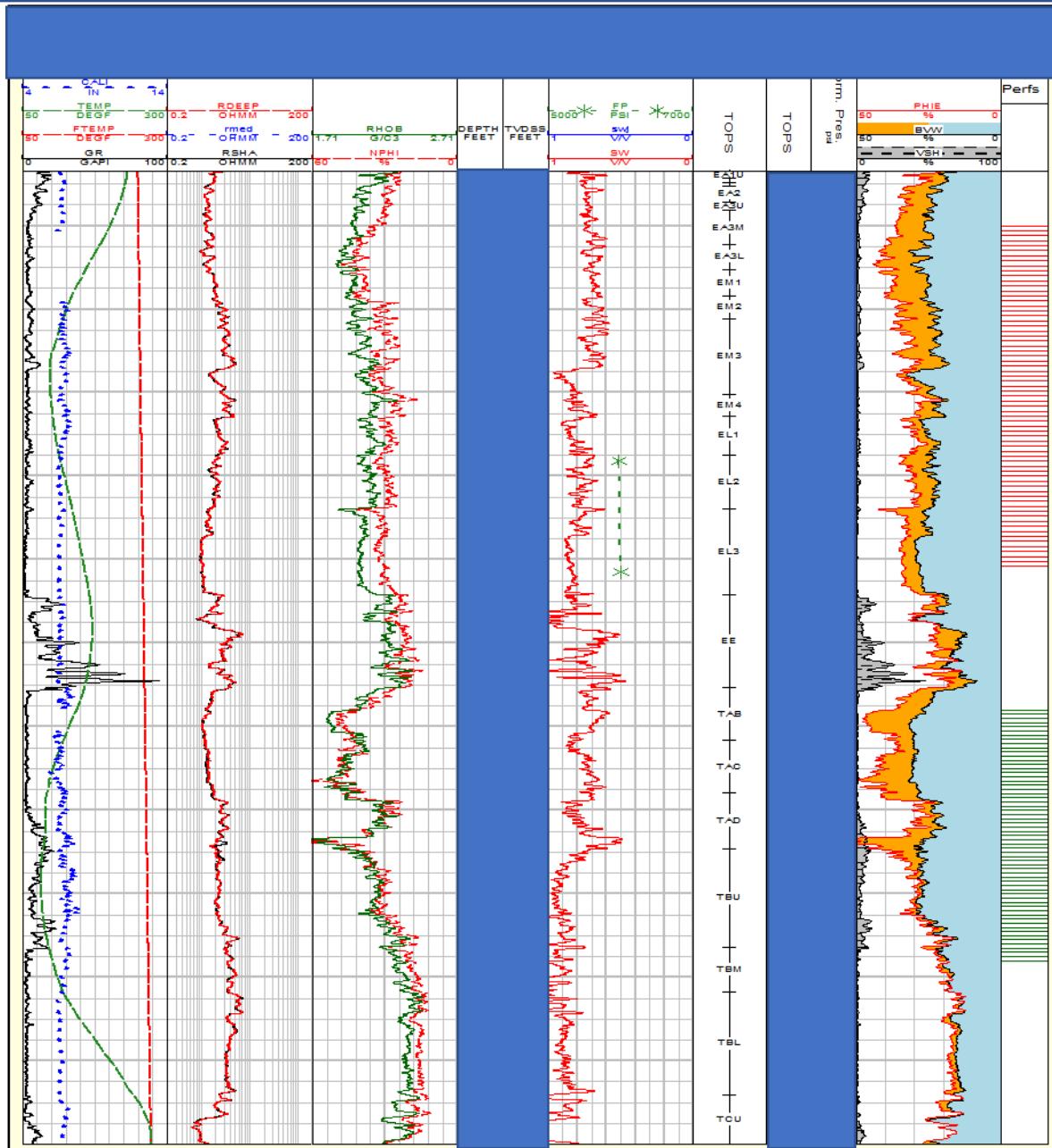


Vertical separation of 1017 ft TVD



Datum P (BHP) @ XXX TVD

Well Logs

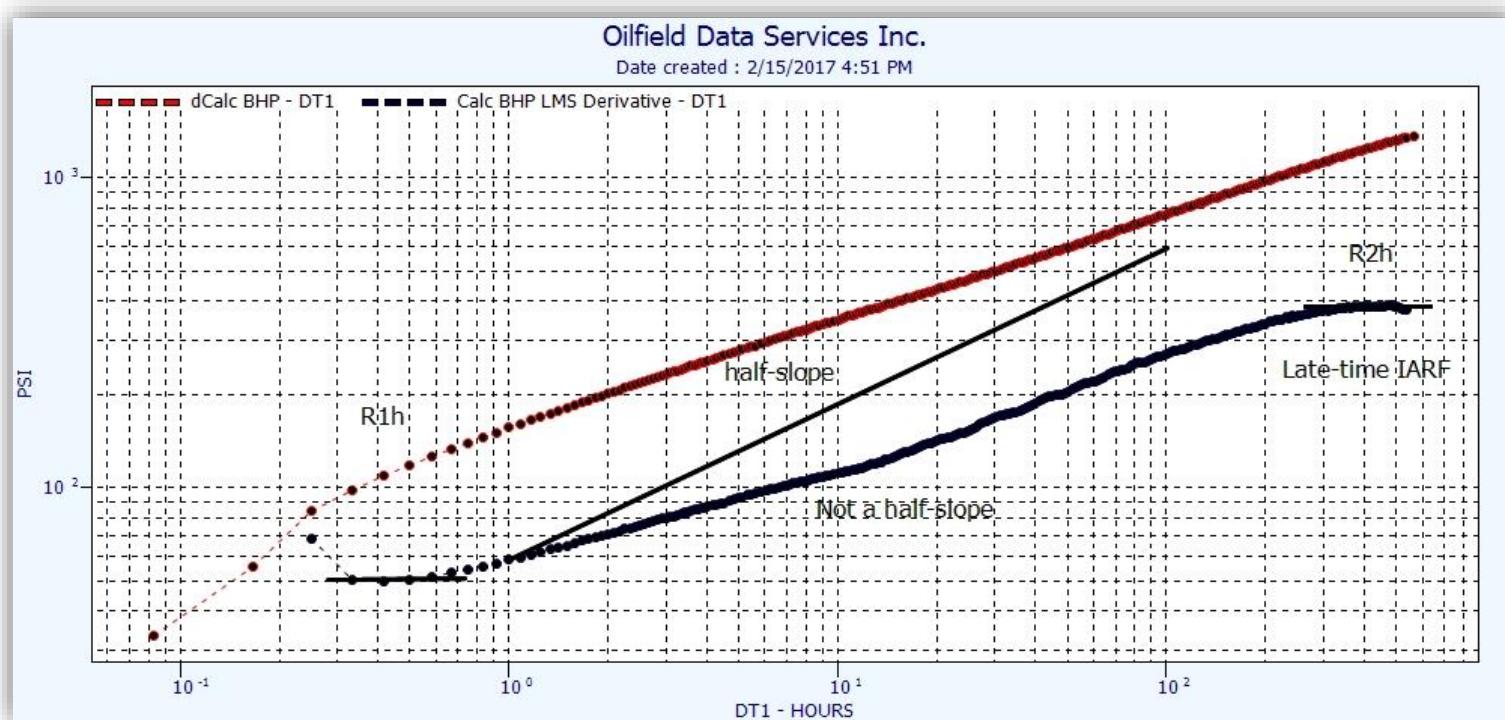


Trial Objectives

- Build a well configuration for Well A
 - Tubing profile
 - Fine tune PVT (Water Density)
 - Well's thermal profile
- Calculate water injection rates using DP wellbore
 - DP between a tree and downhole pressure gauges
- Calculate Datum P/BHP
- Perform automated interpretation of injection fall off tests
- Provide conclusions and observations

Trial Objectives - 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: $0.2 \sim 0.9$ hrs
 - Late-time IARF: $300 \sim 400+$ hrs



Trial Objective – PTA

- Upon Operator's request, 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
 - (Shown on Slides 46 – 62)

Trial Expectations

Demonstrate automated features of Well Analyzer software

- The ability to calculate the water injection rate using DP wellbore
 - Compare the results to the measured rates
- The ability to calculate Datum P/BHP
- The ability to perform auto-PTA
 - Injection Fall-off

Trial Results

Real-Time Inputs

The calculations (Inj. rate, BHP, auto-PTA) were performed using the following inputs:

- WHP
- DHGP/DHGT

Inputs Summary Outputs Reports

Select Input Data

WHP	WHP	PSIA
WHT	None	
DHGP	DHGP	PSIA
DHGT	DHGT	DEGC
QGas	None	
GG	None	
Yo	None	
Yw	None	
SCSSV	None	
Ext QGas	None	
Qo	None	
Qw	None	
QTotal	None	
BHP	None	

Config

SamplesPerUpdate
1000

Config Ok

Load Config

Analysis Enabled

Reserves Enabled

MLTO (DEGF)
15

Legacy MLTO (not used in rate calc)

VSSV Open

Ignore invalid events

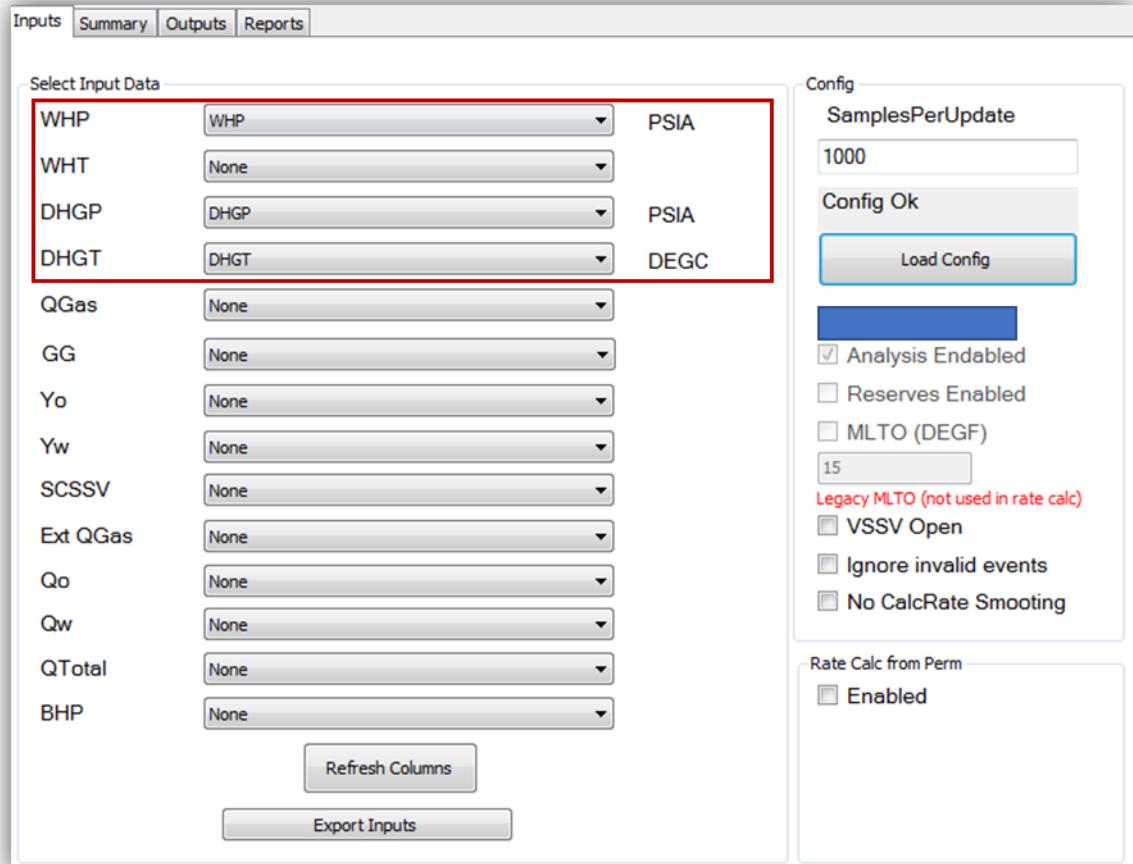
No CalcRate Smoothing

Rate Calc from Perm

Enabled

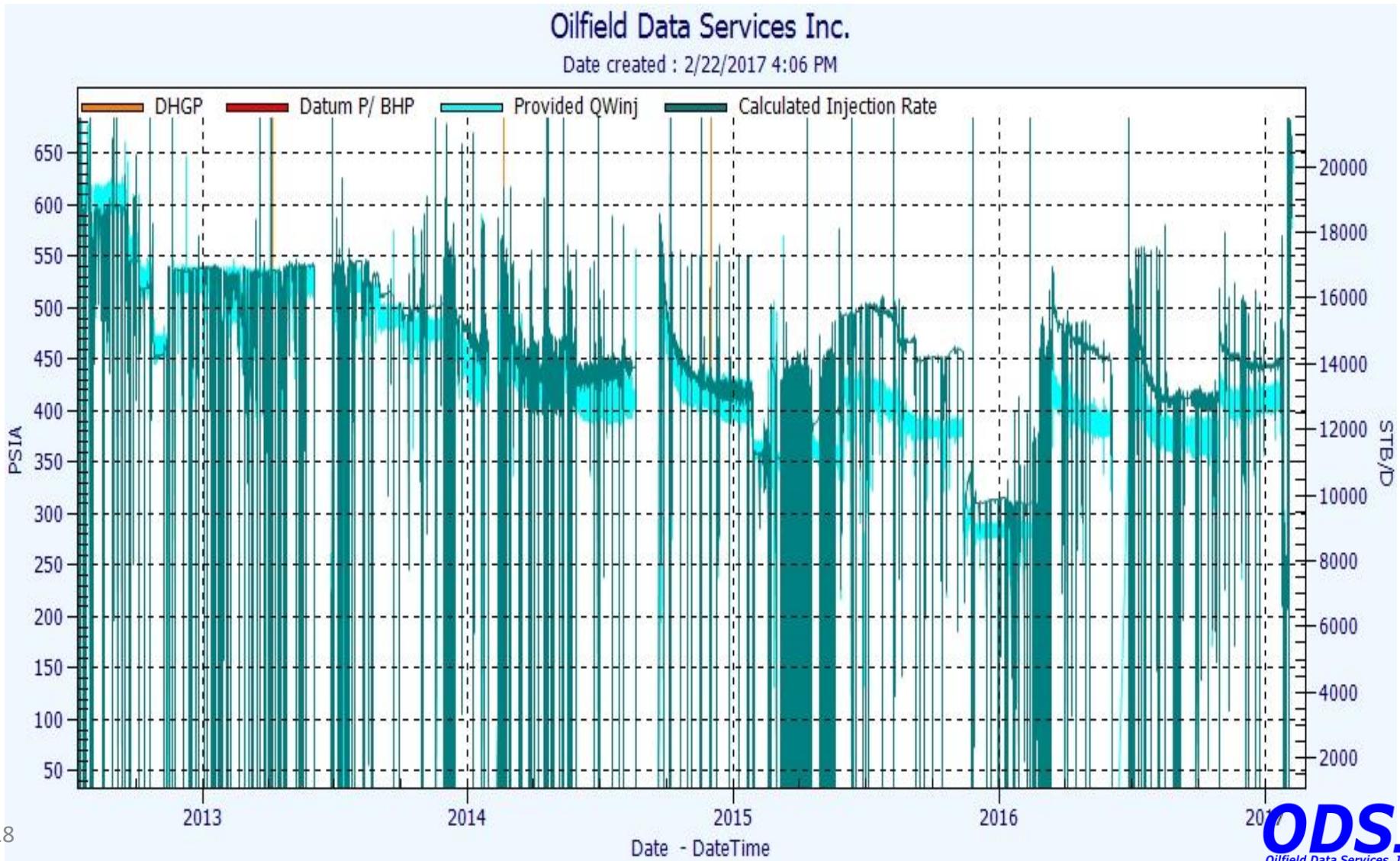
Refresh Columns

Export Inputs



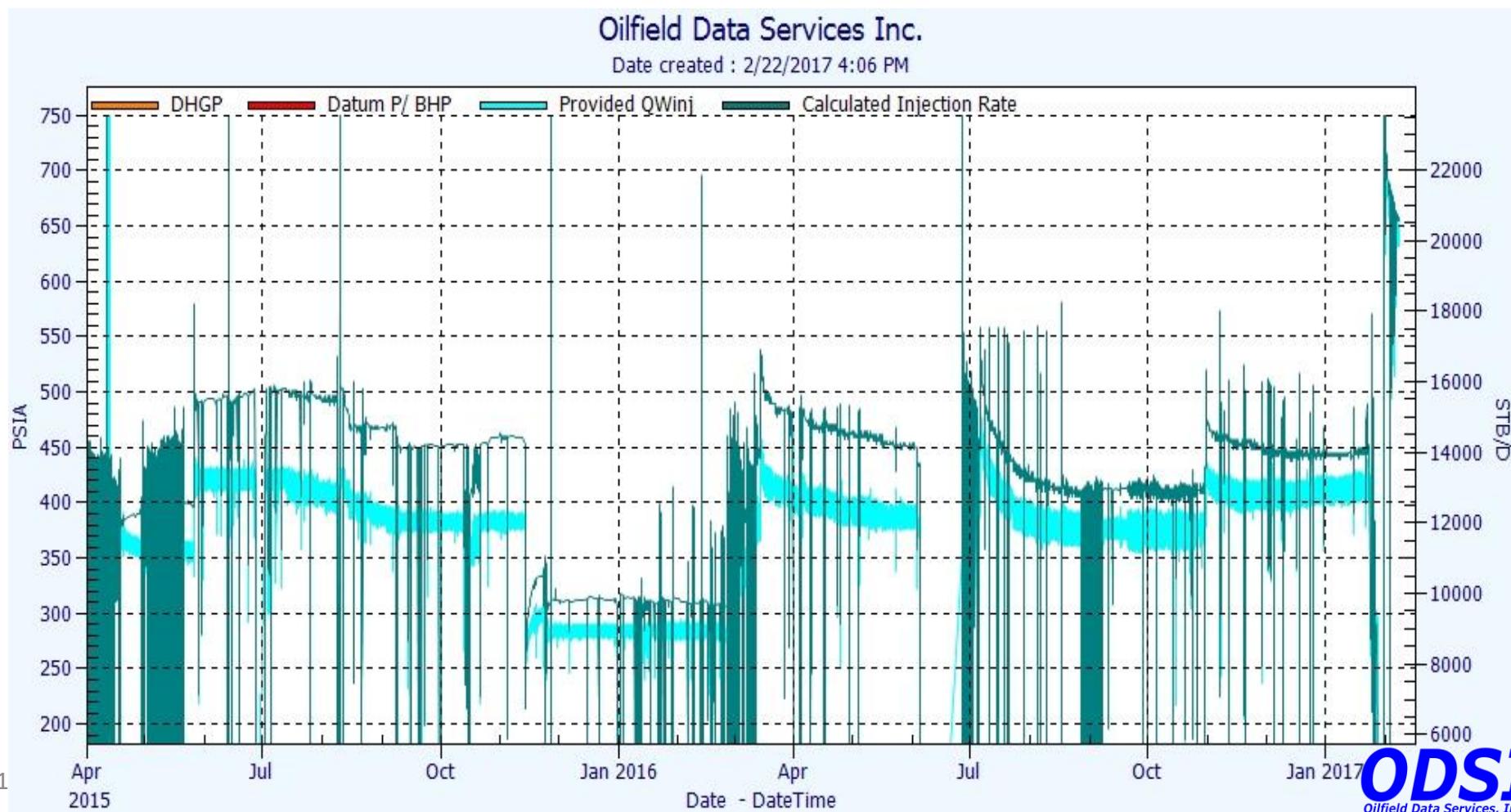
Injection Rate Comparison

The plot shows a comparison of the calculated and measured rates



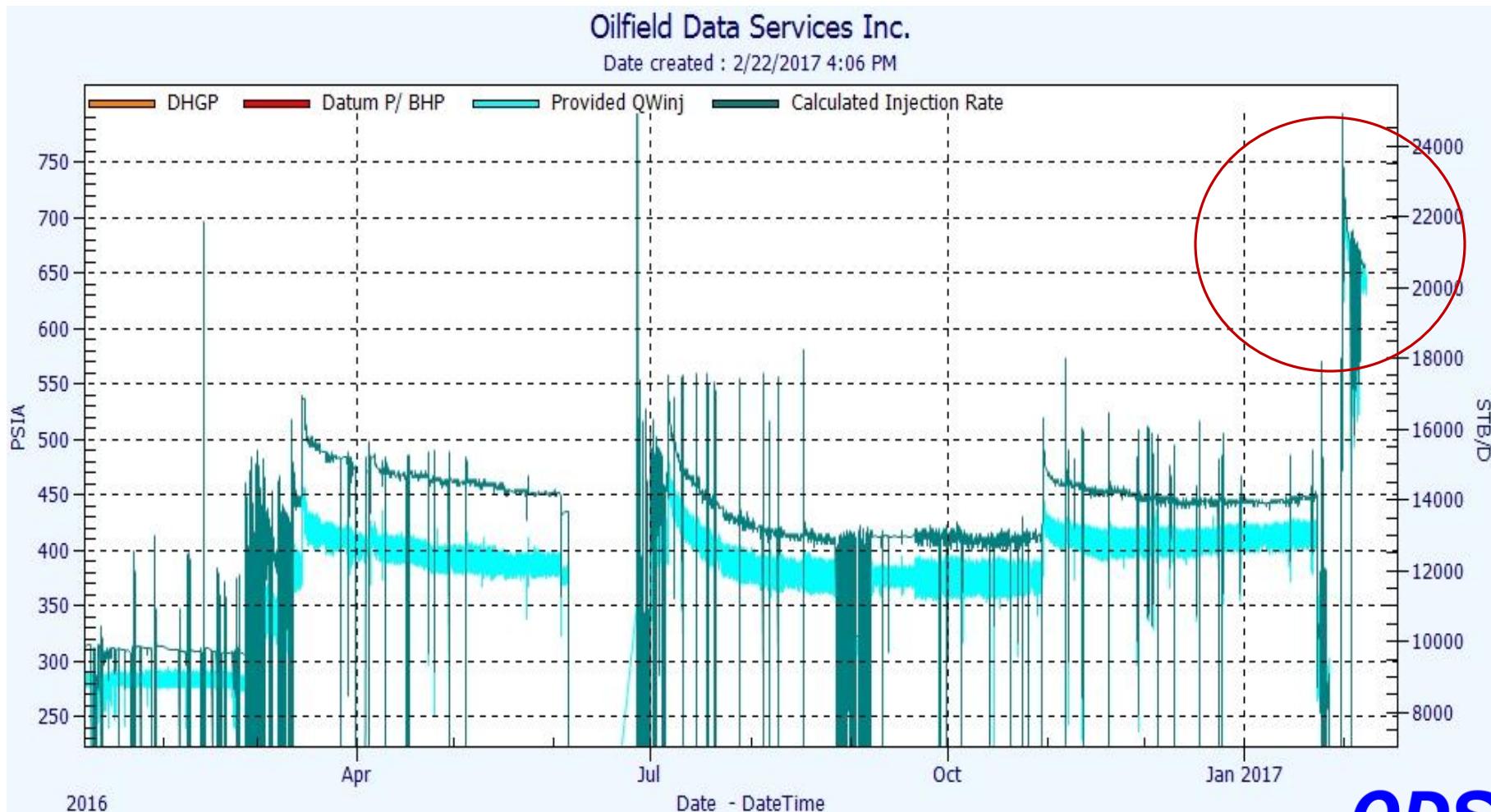
Injection Rate Comparison

- Starting early April 2015 the measured and the calculated rates started to deviate
 - Up to 2000 STB/D difference
- After the stimulation job (late Jan 2017), the rates matched again



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Discussion on Rate Comparison

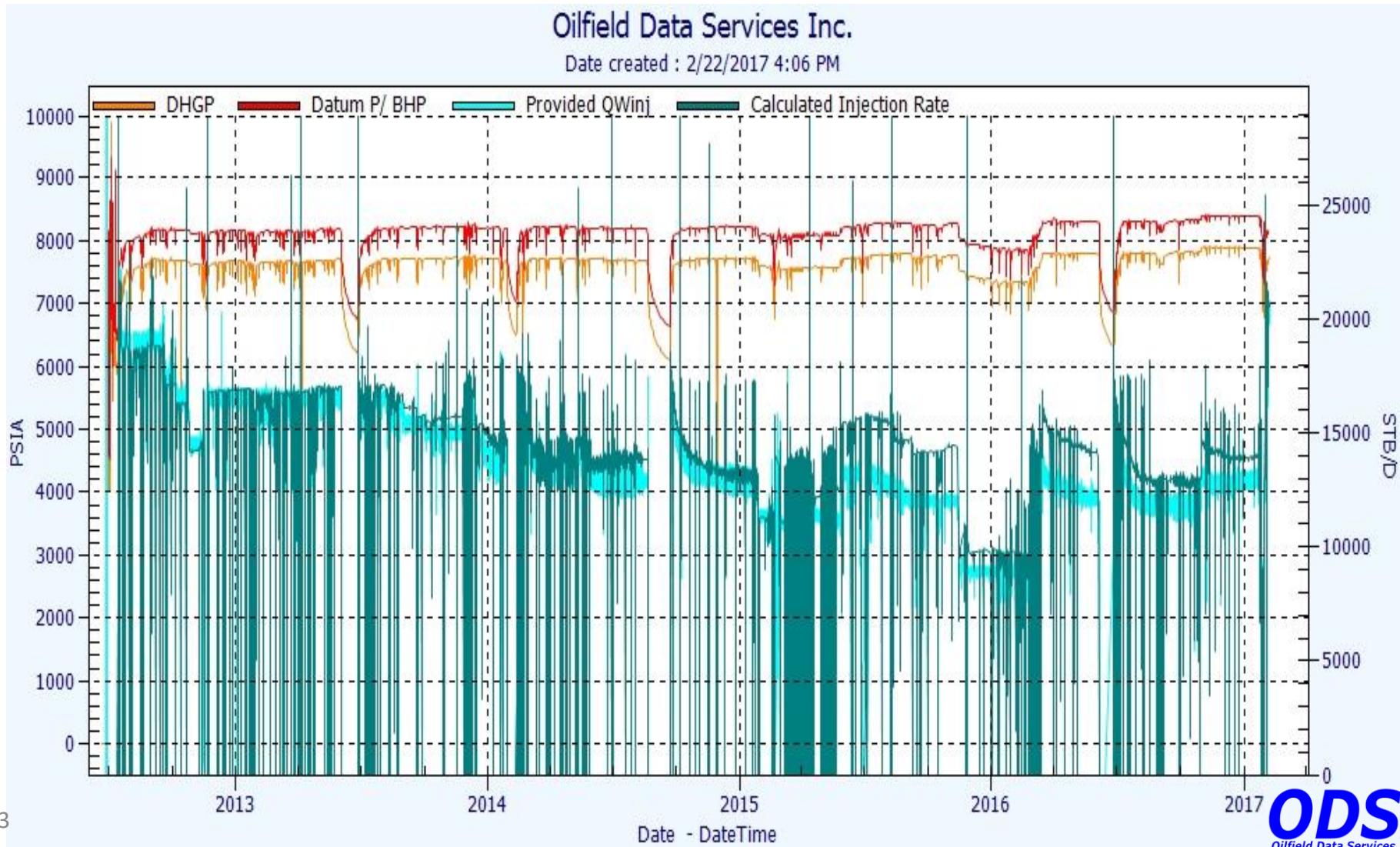
- ODSI uses a direct solution to the Mechanical Energy Balance equation for the rate calculations

$$\frac{dp}{d\rho} + \frac{vdv}{g_c} + \frac{g}{g_c} dz + \frac{2f_f v^2 dL}{g_c D} + dW_s = 0$$

- where, head and friction are dominant components
- The difference in the measured and the calculated rates could be explained either by a heavier fluid in the wellbore (head) or additional friction
- It was more likely that the difference in rates was caused by scaling, which caused the additional friction in pipe
 - Measured & calculated rates matched again after the scale was removed with the stimulation job
- The scaling was also confirmed with PTA results
 - Decreasing kh with time
 - Decreasing II (Injectivity Index) with time

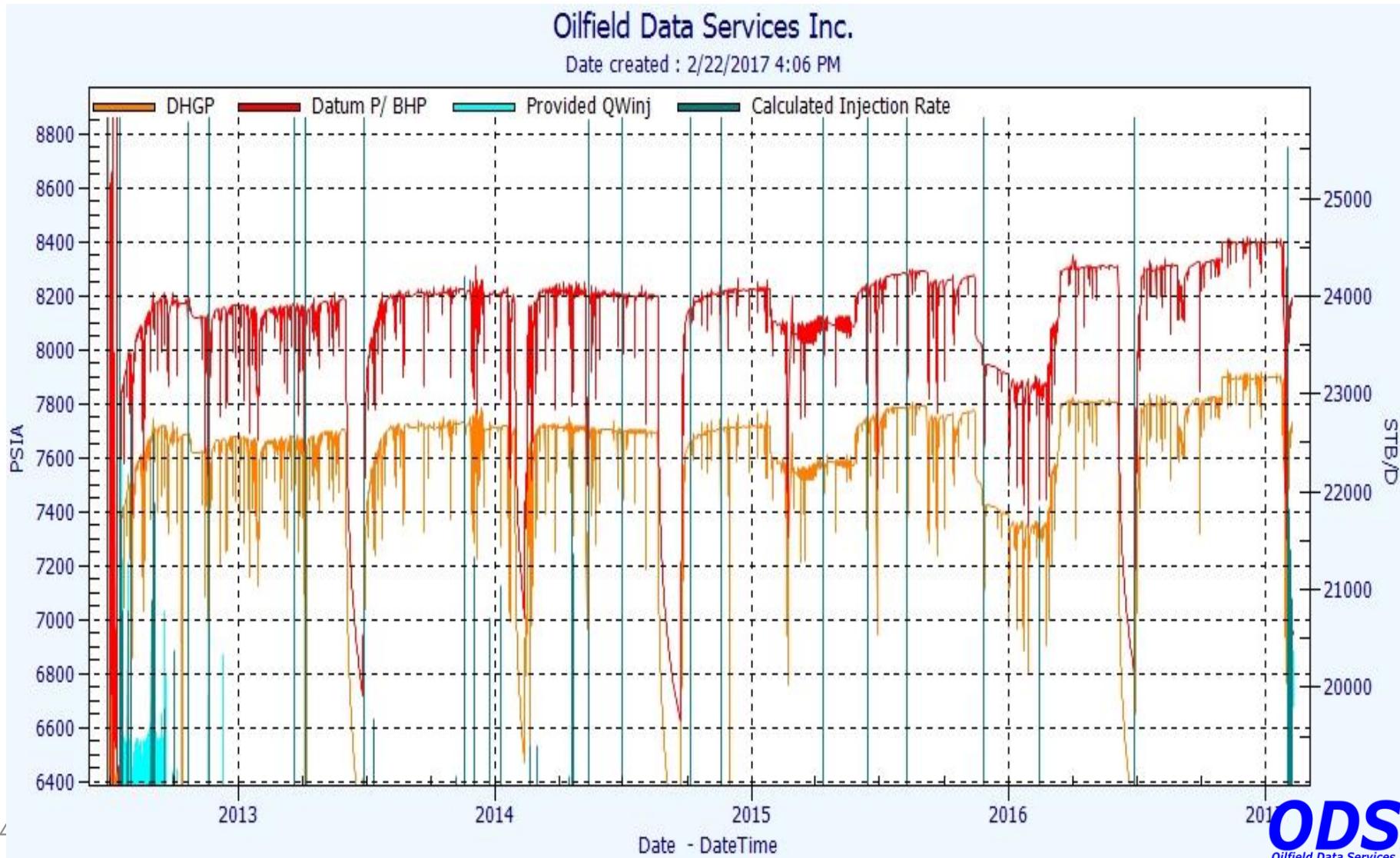
BHP Results

The software simultaneously calculated BHP using the DHGP and the calculated rate



BHP Results Zoom

The software simultaneously calculated BHP using the DHGP and the calculated rate



Auto-PTA Results

with ODSI's Calculated Rates

Auto PTA Summary

- Auto-PTA was performed for both:
 - Early-time IARF
 - Late-time IARF

Overall-observations:

- k_h was decreasing with time
 - From 16 000 md-ft (August 2012) to 8 000 md-ft (Jan 2017) over the course of ~ 4.5 years
 - Successful re-stimulation job in late Jan 2017
 - K_h immediately increased from 8 000 md-ft to 18 337 md-ft (Feb 11, 2017 INJ fall-off test)
- Injectivity Index was gradually decreasing over the course of well's life
 - From 88 STB/psi (Aug 2012) to 47 STB/psi (Jan 2017)
 - Inj Index increased to 103 STB/psi after the stimulation job

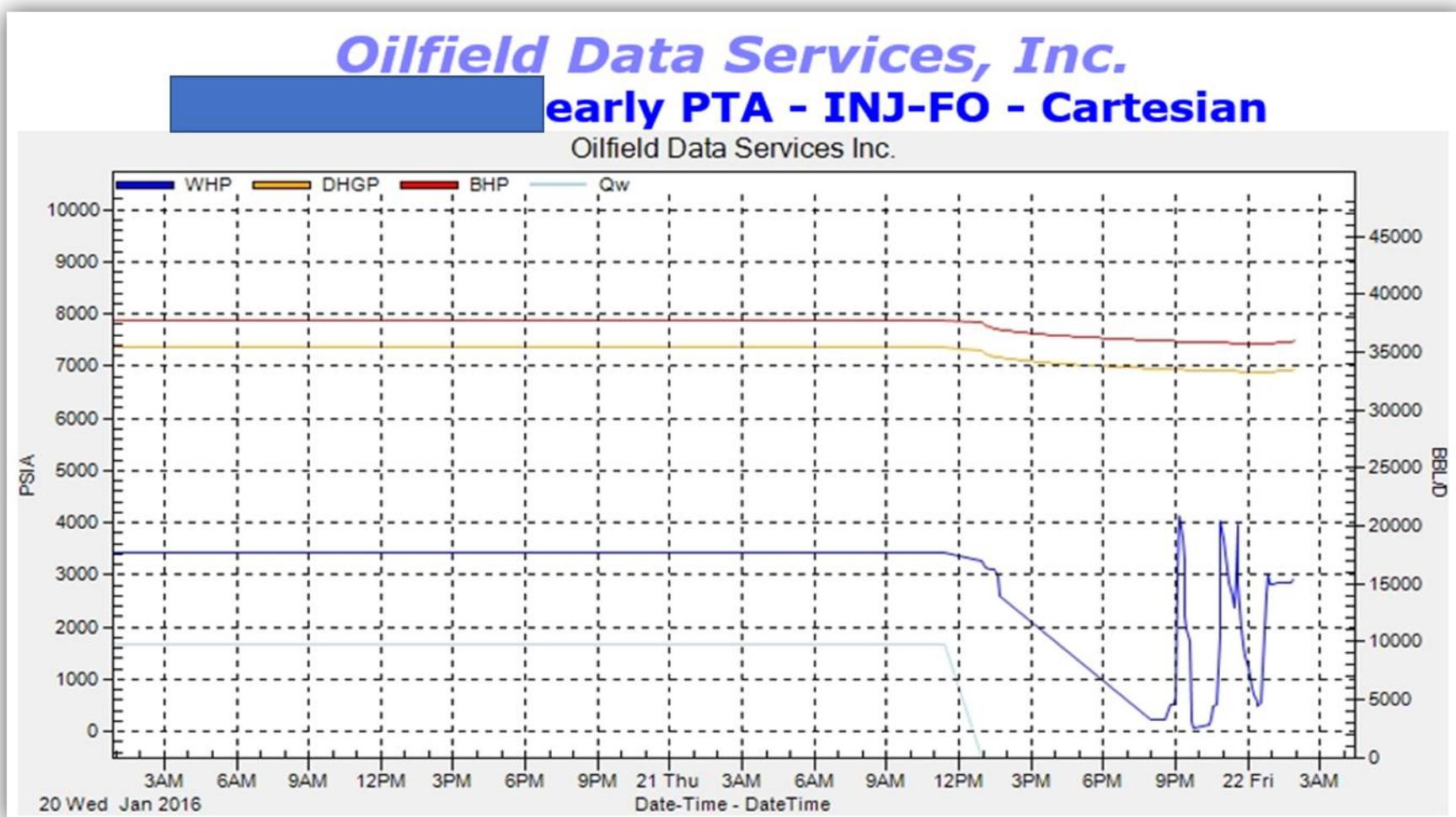
Auto-PTA Summary Table (Early-Time IARF)

Start Time dd/MMM/yyy	End Time dd/MMM/yyy	Test Lengh HOURS	Test Type	DHGPi PSIA	DHGPf PSIA	BHPi PSIA	BHPf PSIA	Qwi STB/D	Qw STB/D	Total Perm md	KH md-ft	Total Skin	DP Skin PSI	PStar PSIA	Comp Eff %	II Water BBL/PSI	DPs/Q PSI/(STB/D)
7/14/2012 23:55	7/15/2012 15:50	15.9	Fall-Off	6169	5899	6684	6435	10977	10977	22.3	12265	-3.5	-324	6261	350.06	84.76	-0.03
7/21/2012 9:40	7/21/2012 12:20	2.7	Fall-Off	7401	7111	7877	7648	18748	18748	29.8	16390	-3.2	-372	7137	265.71	83.47	-0.02
8/15/2012 15:25	8/15/2012 18:10	2.8	Fall-Off	7552	7307	8040	7844	16674	16674	30.5	16775	-3.1	-322	7380	263.15	84.41	-0.02
8/19/2012 7:55	8/19/2012 10:20	2.4	Fall-Off	7567	7295	8043	7832	18766	18766	24.2	13310	-3.4	-499	7297	325.58	84.89	-0.03
8/29/2012 1:40	8/29/2012 3:20	1.7	Fall-Off	7678	7523	8154	8060	18802	18802	26.2	14410	-3.4	-458	7529	315.21	88.29	-0.02
9/22/2012 1:20	9/22/2012 4:05	2.8	Fall-Off	7678	7384	8164	7921	17125	17125	31.6	17380	-3.2	-323	7519	267.3	88.62	-0.02
10/4/2012 16:25	10/4/2012 19:55	3.5	Fall-Off	7700	7468	8185	8005	17195	17195	26.9	14795	-3.4	-413	7482	319.97	91.56	-0.02
10/21/2012 1:45	10/21/2012 3:20	1.6	Fall-Off	7692	7424	8182	7961	16382	16382	31.8	17490	-3.1	-303	7669	260.73	86.91	-0.02
11/13/2012 4:20	11/14/2012 13:55	33.6	Fall-Off	7613	7206	8113	7743	14559	14559	27.2	14960	-3.3	-335	7222	297.93	86.14	-0.02
11/17/2012 4:15	11/20/2012 3:45	71.5	Fall-Off	7646	6873	8133	7410	16928	16928	30.7	16885	-3.2	-326	7034	263.89	85.23	-0.02
12/5/2012 6:50	12/5/2012 16:45	9.9	Fall-Off	7669	7318	8157	7855	16826	16826	31	17050	-3.1	-316	7248	257.69	83.98	-0.02
12/12/2012 18:05	12/13/2012 1:00	6.9	Fall-Off	7674	7376	8162	7913	16876	16876	30.6	16830	-3.1	-325	7312	262.94	84.51	-0.02
12/14/2012 16:05	12/14/2012 22:25	6.3	Fall-Off	7659	7377	8147	7914	16797	16797	26.9	14795	-3.3	-387	7430	293.61	83.98	-0.02
1/7/2013 16:50	1/8/2013 1:25	8.6	Fall-Off	7678	7421	8166	7958	16891	16891	29.7	16335	-3.4	-364	7368	307.14	96.11	-0.02
1/24/2013 23:35	1/25/2013 1:10	1.6	Fall-Off	7658	7389	8149	7926	16261	16261	26.7	14685	-3.3	-372	7582	286.75	81.65	-0.02
3/6/2013 10:30	3/6/2013 13:20	2.8	Fall-Off	7673	7345	8160	7882	16876	16876	25.7	14135	-3.3	-406	7454	296.12	81.48	-0.02
3/26/2013 9:20	3/26/2013 16:05	6.8	Fall-Off	7683	7244	8171	7781	16748	16748	32.6	17930	-2.8	-272	7327	223.18	75.91	-0.02
4/2/2013 0:45	4/2/2013 2:30	1.8	Fall-Off	7671	7489	8160	8025	16542	16542	26.9	14795	-3.2	-370	7565	277.72	79.52	-0.02
4/3/2013 19:40	4/5/2013 1:55	30.3	Fall-Off	7667	7028	8157	7565	16359	16359	29.8	16390	-3	-306	7088	242.89	76.32	-0.02
6/2/2013 22:55	6/26/2013 19:00	572.1	Fall-Off	7577	6227	8094	6764	10620	10620	22.7	12485	-3.1	-272	6975	270.58	66.61	-0.03
7/12/2013 19:45	7/12/2013 21:50	2.1	Fall-Off	7595	7326	8082	7862	16933	16933	20.8	11440	-3.3	-498	7277	301.37	68.53	-0.03
8/21/2013 17:10	8/21/2013 19:20	2.2	Fall-Off	7709	7417	8200	7954	16365	16365	22.7	12485	-3.2	-436	7489	289.44	71.12	-0.03
9/20/2013 14:15	9/20/2013 17:05	2.8	Fall-Off	7722	7465	8214	8002	16094	16094	21.6	11880	-3.3	-457	7432	299.85	70.39	-0.03
10/29/2013 0:05	10/29/2013 2:50	2.8	Fall-Off	7722	7463	8216	7999	15722	15722	21.4	11770	-3.2	-446	7438	295.55	68.96	-0.03
11/17/2013 13:20	11/17/2013 15:05	1.8	Fall-Off	7731	7427	8224	7964	15802	15802	20.1	11055	-3.3	-490	7541	316.55	69.76	-0.03
11/18/2013 2:15	11/18/2013 6:55	4.7	Fall-Off	7710	7463	8203	8000	15796	15796	27.2	14960	-2.9	-312	7466	232.91	67.39	-0.02
11/28/2013 3:35	11/28/2013 6:05	2.5	Fall-Off	7732	7492	8225	8029	15859	15859	21.3	11715	-3.3	-457	7466	303.26	70.53	-0.03
1/8/2014 5:25	1/8/2014 13:05	7.7	Fall-Off	7713	7272	8212	7809	14826	14826	23.9	13145	-3.1	-365	7337	272.59	70.14	-0.02
1/29/2014 3:45	2/11/2014 21:35	329.8	Fall-Off	7708	6470	8209	7006	14496	14496	20.7	11385	-3.3	-430	6986	303.86	68.79	-0.03
2/21/2014 5:45	2/22/2014 0:20	18.6	Fall-Off	7670	7100	8164	7636	15547	15547	21	11550	-3.1	-425	6835	267.2	61.13	-0.03
3/12/2014 0:45	3/12/2014 2:50	2.1	Fall-Off	7720	7387	8223	7923	14028	14028	20.6	11330	-3.1	-394	7494	271.37	61.08	-0.03
4/20/2014 15:05	4/20/2014 17:50	2.8	Fall-Off	7664	7309	8158	7846	15842	15842	19.8	10890	-3.4	-507	7384	329.13	71.56	-0.03
5/10/2014 2:05	5/11/2014 19:40	41.6	Fall-Off	7709	7015	8213	7552	13740	13740	19.3	10615	-3.2	-428	6982	294.69	62.54	-0.03
5/18/2014 10:25	5/18/2014 12:10	1.8	Fall-Off	7700	7465	8202	8002	14213	14213	20.6	11330	-3	-392	7511	264.66	59.67	-0.03
5/22/2014 15:20	5/22/2014 20:20	5	Fall-Off	7700	7404	8205	7941	13696	13696	20	11000	-3.1	-396	7268	272.93	59.88	-0.03
6/29/2014 11:05	6/29/2014 19:30	8.4	Fall-Off	7699	7207	8203	7743	13750	13750	19.8	10890	-3.1	-406	7189	280.06	60.98	-0.03
8/2/2014 14:25	8/3/2014 0:15	9.8	Fall-Off	7698	7268	8204	7805	13481	13481	20	11000	-3.1	-387	7153	269.94	59.16	-0.03
8/20/2014 17:50	9/22/2014 9:15	783.4	Fall-Off	7696	6153	8199	6690	13931	13931	22.9	12595	-2.9	-331	6869	243.16	60.32	-0.02
9/26/2014 8:00	9/26/2014 9:35	1.6	Fall-Off	7571	7314	8054	7851	17510	17510	17.4	9570	-3.1	-585	7133	282.75	54.7	-0.03
10/5/2014 19:55	10/6/2014 3:55	8	Fall-Off	7659	7066	8158	7603	14912	14912	18	9900	-3.1	-478	6906	277.29	55.29	-0.03
3/16/2015 14:05	3/16/2015 17:30	3.4	Fall-Off	7545	7303	8059	7840	11572	11572	16.3	8965	-3.1	-412	7681	285.67	52.16	-0.04
8/9/2015 5:55	8/9/2015 22:25	16.5	Fall-Off	7785	7109	8280	7646	15518	15518	19.7	10835	-3.2	-473	6925	293.64	63.56	-0.03
9/20/2015 12:20	9/20/2015 15:35	3.3	Fall-Off	7755	7434	8258	7971	14023	14023	18.4	10120	-3.1	-445	7610	281.93	57.33	-0.03
9/30/2015 21:10	10/1/2015 1:45	4.6	Fall-Off	7759	7403	8261	7940	14183	14183	18.8	10340	-3.1	-441	7470	280.65	58.16	-0.03
11/26/2015 22:40	11/27/2015 3:05	4.4	Fall-Off	7441	7183	7962	7720	9711	9711	19.9	10945	-2.9	-267	7293	249.9	54.62	-0.03
1/1/2016 14:35	1/1/2016 18:45	4.2	Fall-Off	7171	7022	7703	7559	5199	5199	13.2	7260	-2.9	-213	7309	261.79	39.56	-0.04
1/12/2016 7:25	1/12/2016 14:20	6.9	Fall-Off	7355	7011	7875	7548	9916	9916	17.6	9680	-2.9	-309	6978	256.77	50.35	-0.03
1/21/2016 12:50	1/22/2016 2:00	13.2	Fall-Off	7365	6953	7886	7489	9634	9634	15	8250	-3.1	-378	6926	299.56	50.92	-0.04
1/22/2016 8:20	1/22/2016 12:30	4.2	Fall-Off	7181	6970	7701	7506	9872	9872	19.8	10890	-3	-282	7242	263.61	57.23	-0.03
6/5/2016 7:05	6/26/2016 20:20	517.3	Fall-Off	7779	6292	8284	6829	13651	13651	19.1	10505	-3.1	-422	6757	285.25	59.94	-0.03
9/28/2016 8:00	9/28/2016 15:10	7.2	Fall-Off	7817	7413	8324	7950	13108	13108	16.1	8855	-3.1	-472	7276	286.18	51.74	-0.04
1/27/2017 12:45	1/30/2017 23:15	82.5	Fall-Off	7600	6863	8122	7400	9130	9130	14.6	8030	-3	-355	6879	280.85	46.48	-0.04
2/11/2017	2/13/2017	51	Fall-off	7746	6932	8209	7434	32.9	18095	33	18377	-3.4	-392	6852	296	102.9	-0.0193

Auto-PTA: Example Report

Jan 21, 2016 Inj Fall-off – Cartesian Plot

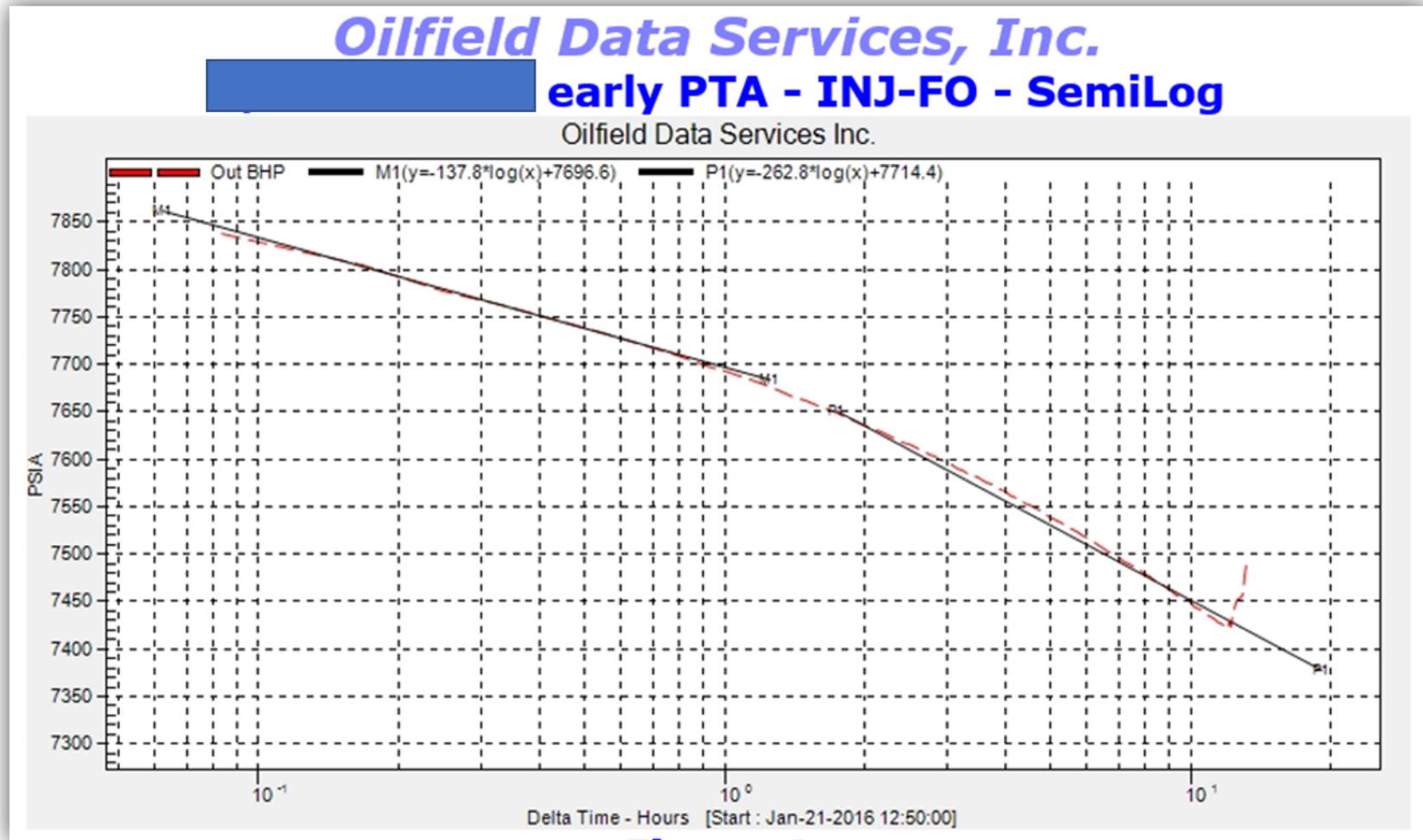
Note: This plot is a screenshot from the automatically generated PTA report



Auto-PTA: Example Report

Jan 21, 2016 Inj Fall-off – Semi-log Plot

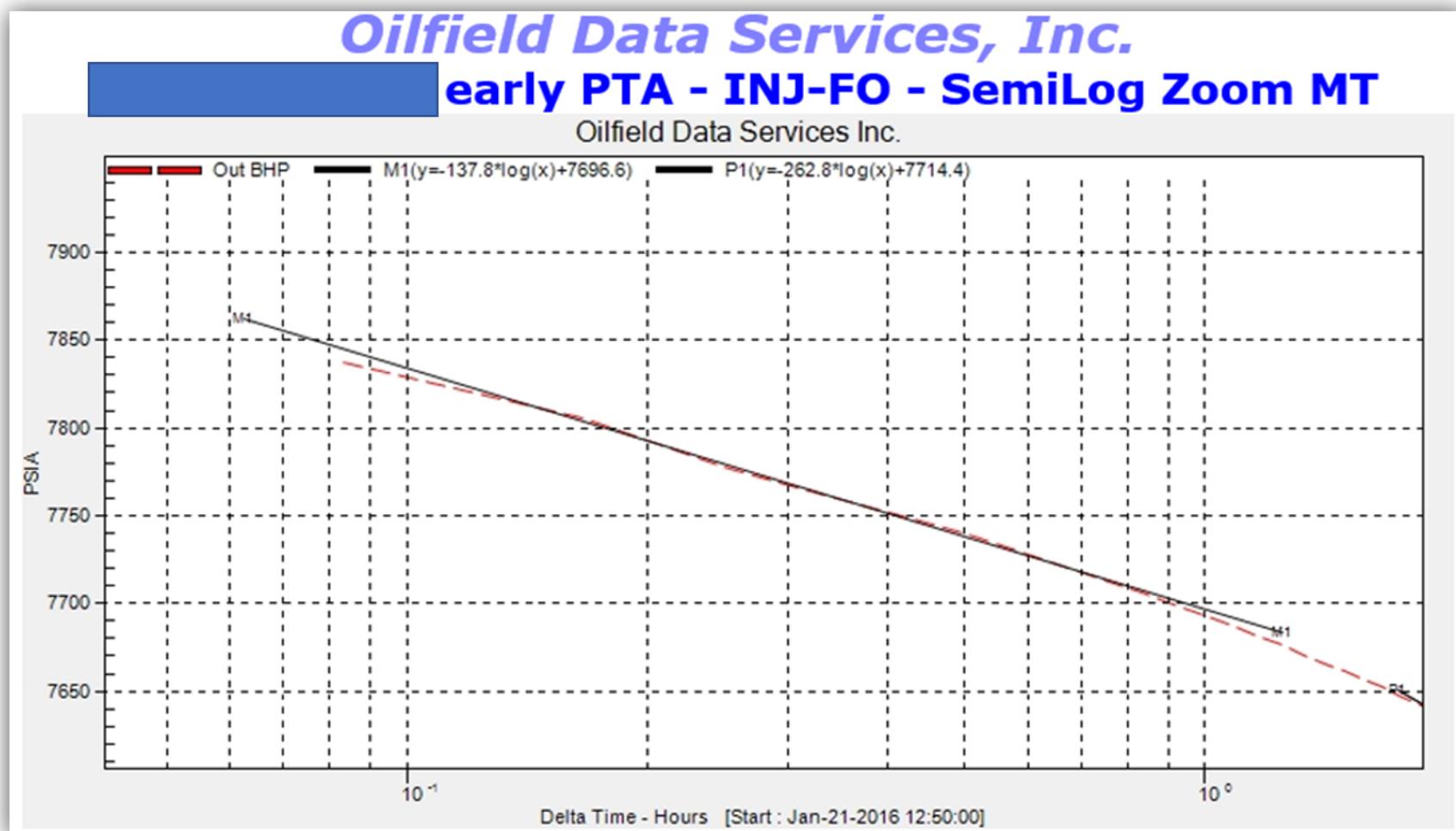
Note: This plot is a screenshot from the automatically generated PTA report



Auto-PTA: Example Report

Jan 21, 2016 Inj Fall-off – Sem-Log MTS Zoom Plot

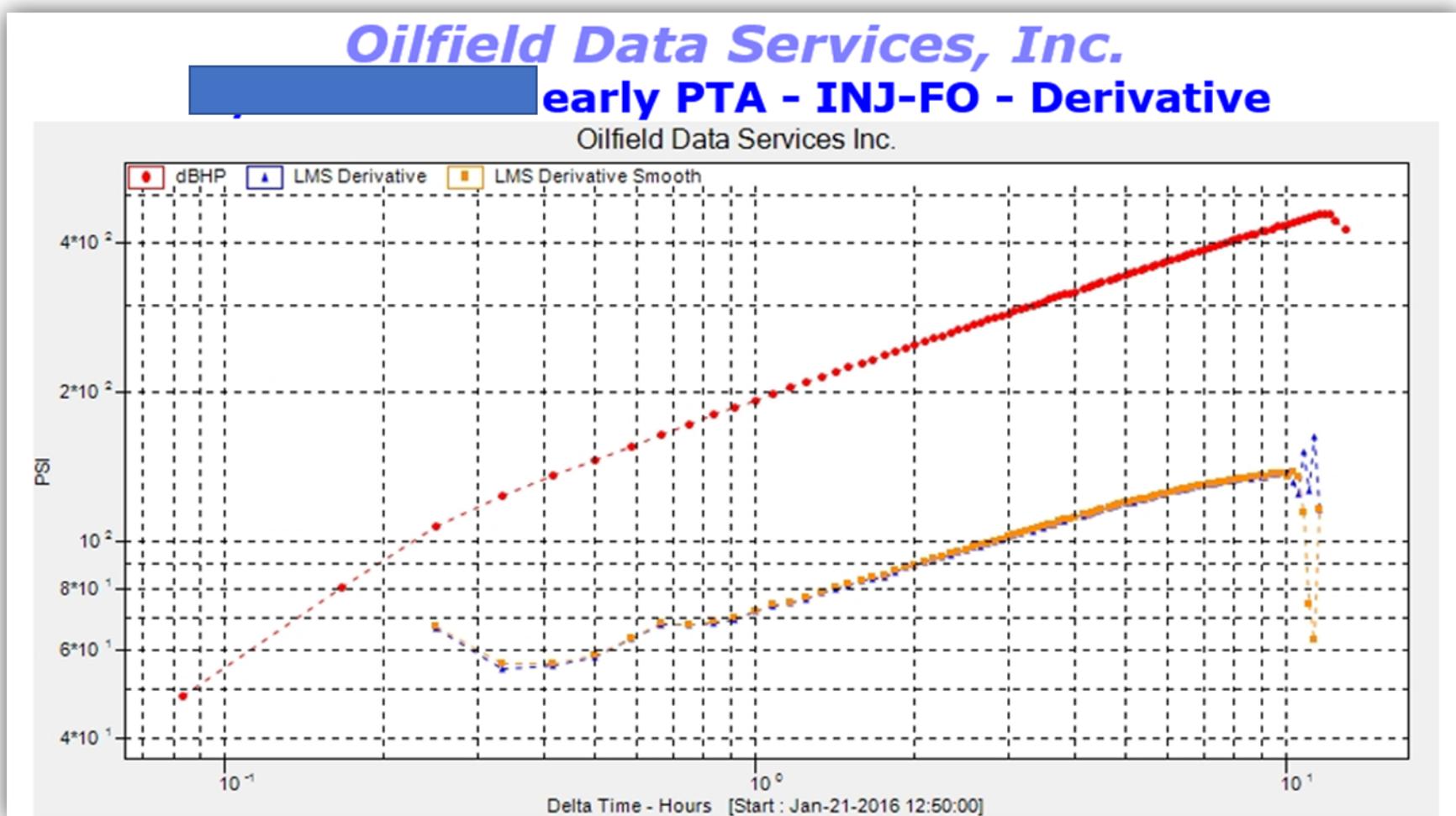
Note: This plot is a screenshot from the automatically generated PTA report



Auto-PTA: Example Report

Jan 21, 2016 Inj Fall-off – Derivative Plot

Note: This plot is a screenshot from the automatically generated PTA report



Auto-PTA: Example Report

Jan 21, 2016 Inj Fall-off – Derivative Plot

Note: This plot is a screenshot from the automatically generated PTA report

Net Pay used = 550 ft

Oilfield Data Services, Inc.

ANALYSIS RESULTS

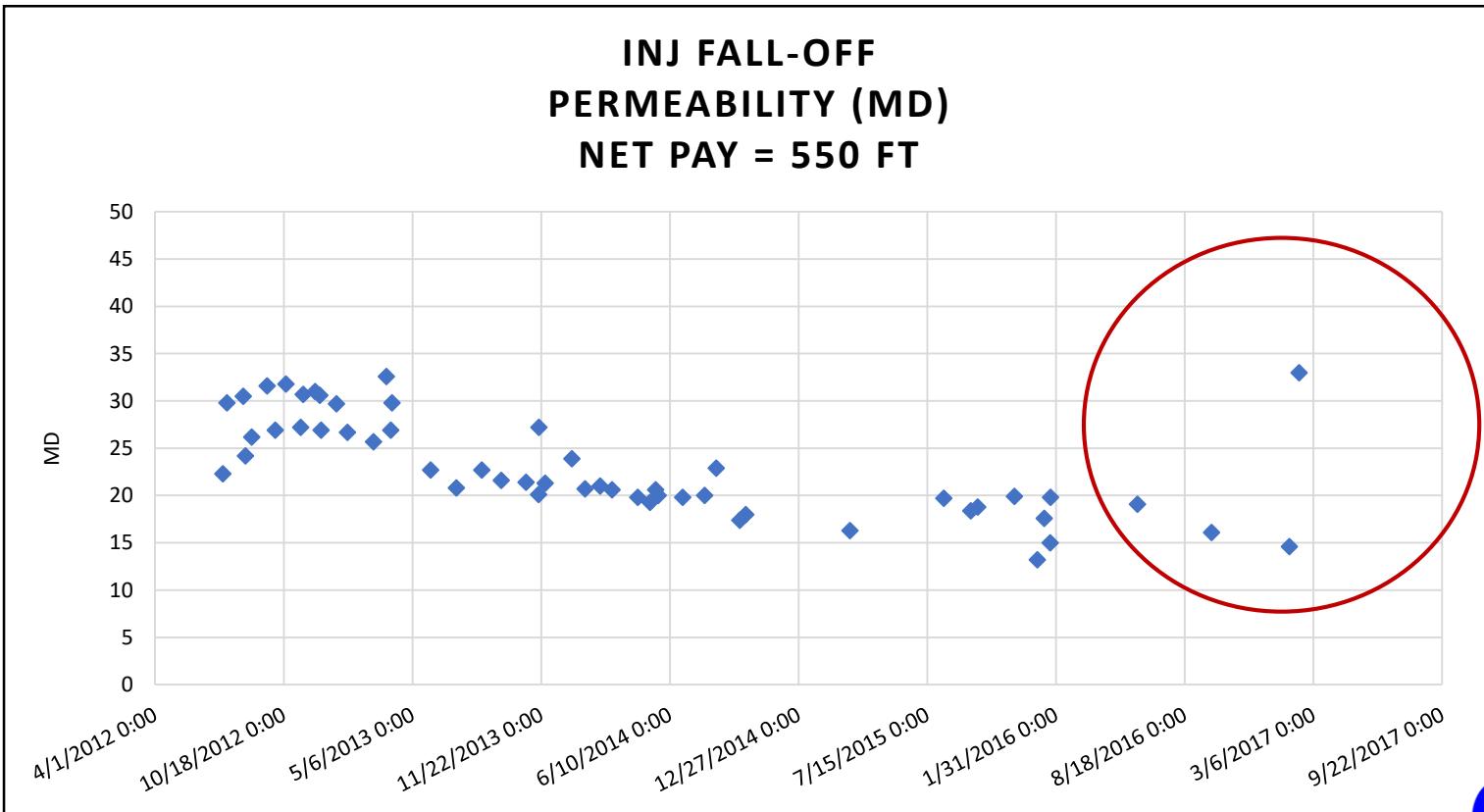
INJECTION FALL OFF Jan/21 - 22/2016

Calculated Reservoir & Completion Properties

SKIN	-3.1	
PRESSURE DROP DUE TO SKIN	-378	PSI
COMPLETION EFFICIENCY	300	%
PERMEABILITY	15	md
RADIAL FLOW INJECTIVITY INDEX (II)	50.9	STB/PSI
SKINLESS RADIAL FLOW II	17.0	STB/PSI
PERMEABILITY THICKNESS	8,274	md-ft
MOBILITY THICKNESS	11,819	md-ft/cp

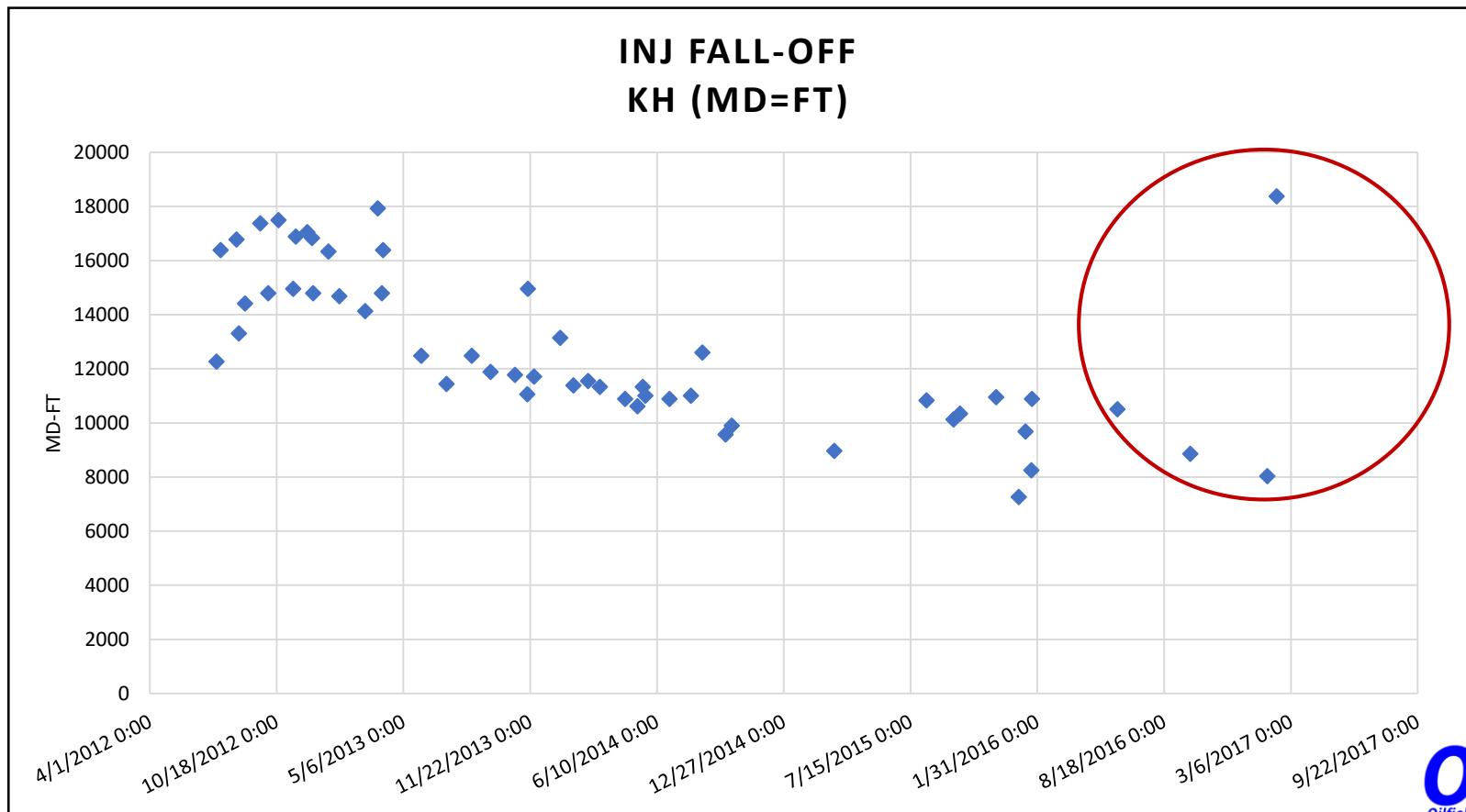
Auto-PTA: Permeability (Early-time IARF)

- Permeability was gradually decreasing with time
 - An indication of scale build-up
- Big increase in permeability was observed from Feb 11, 2017 Fall-off test after the well was re-stimulated in late Jan 2017
 - From 14 md (Jan 27, 2017) to 32.9 md (Feb 11, 2017)
 - 135 % increase in perm



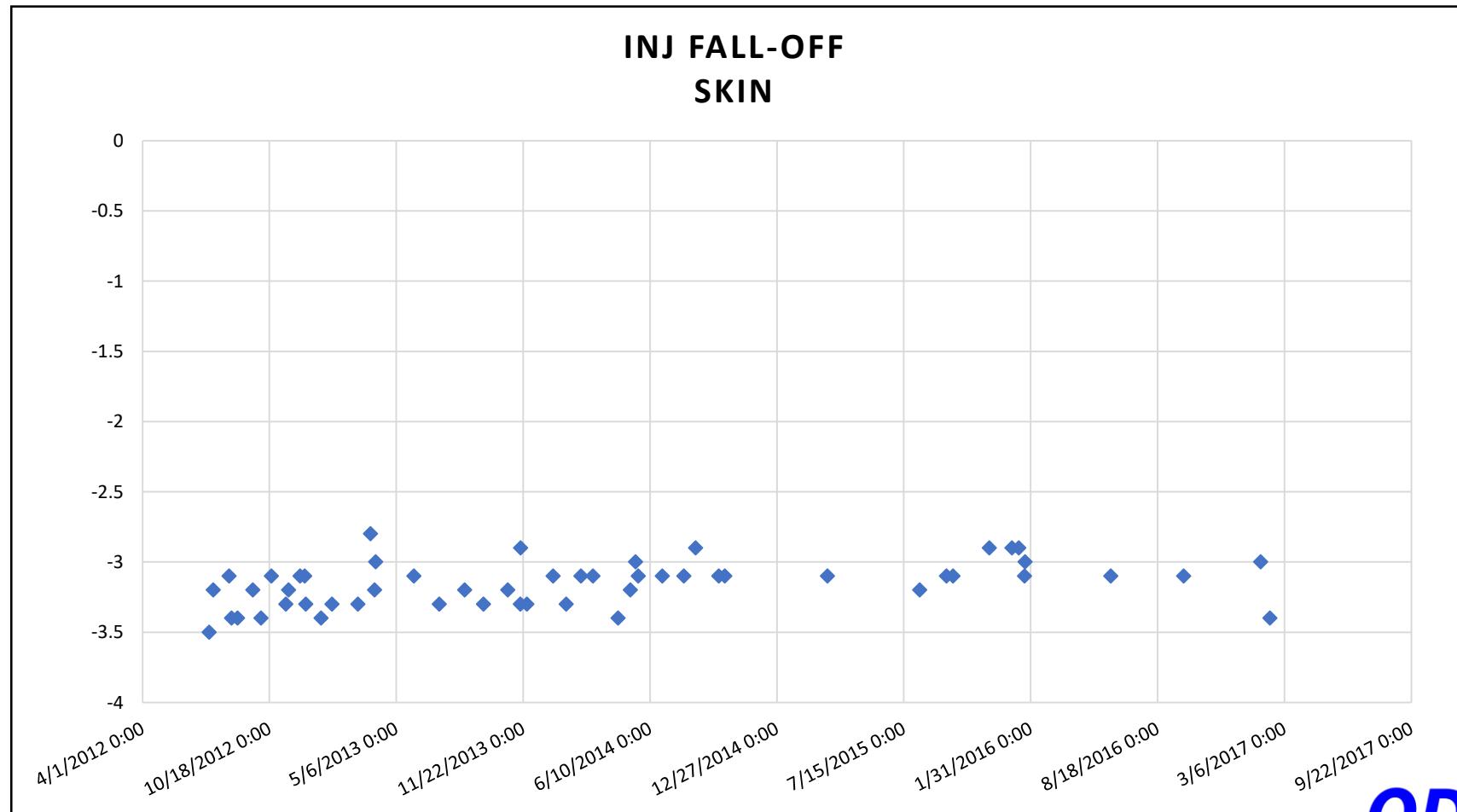
Auto-PTA: kh (Early-time IARF)

- kh was gradually decreasing with time
 - An indication of scale build-up
- Big increase in kh was observed from Feb 11, 2017 Fall-off test after the well was re-stimulated in late Jan 2017
 - From 8 030 md-ft (Jan 27, 2017) to 18 377 md-ft (Feb 11, 2017)
 - 135 % increase in kh



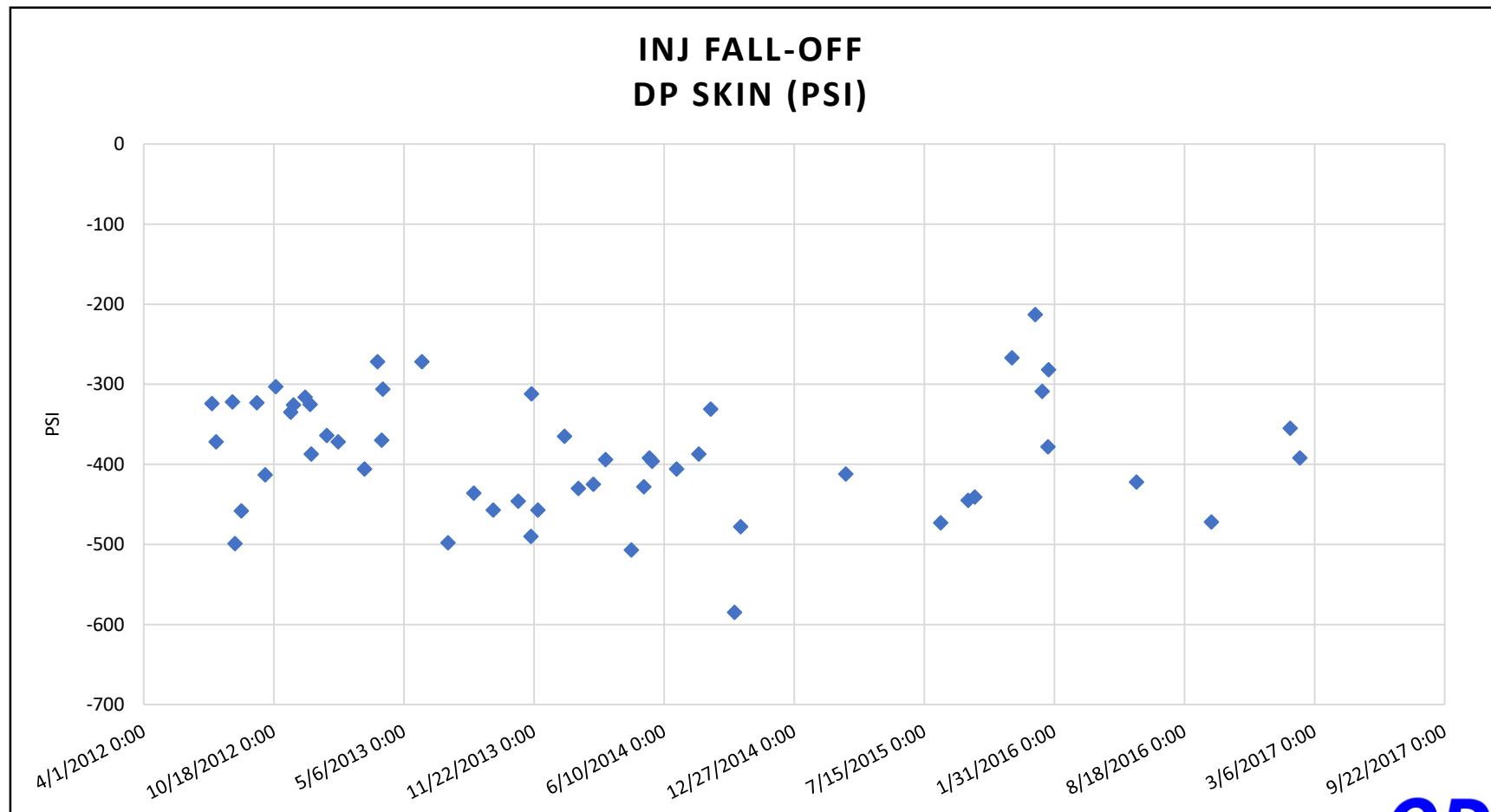
Auto-PTA: Skin (Early-time IARF)

- Negative (stimulated) skin
- Fairly constant throughout the well's life



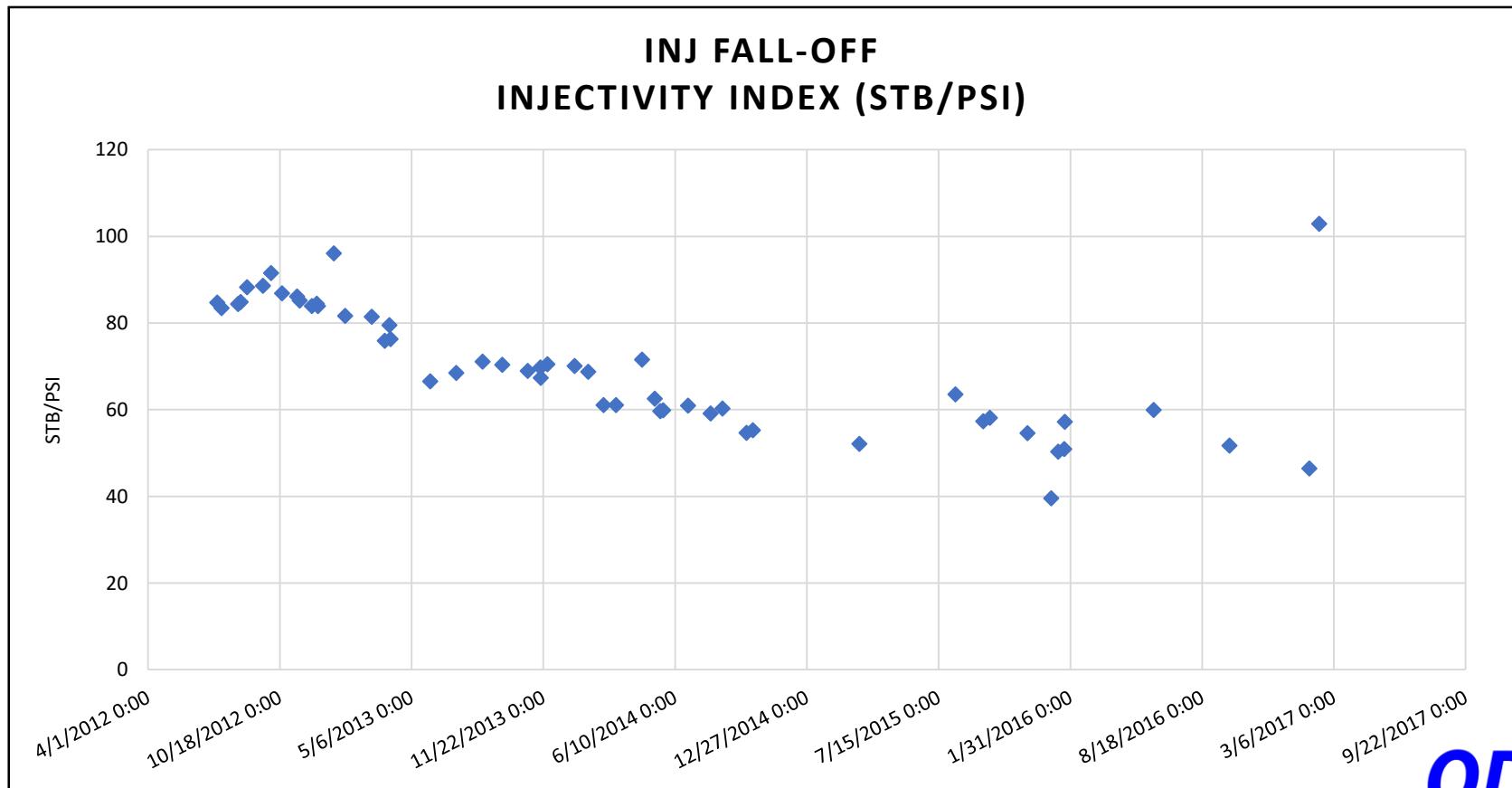
Auto-PTA: DP Skin (Early-time IARF)

- Negative (stimulated) skin
- Fairly constant pressure drop due to skin throughout the well's life



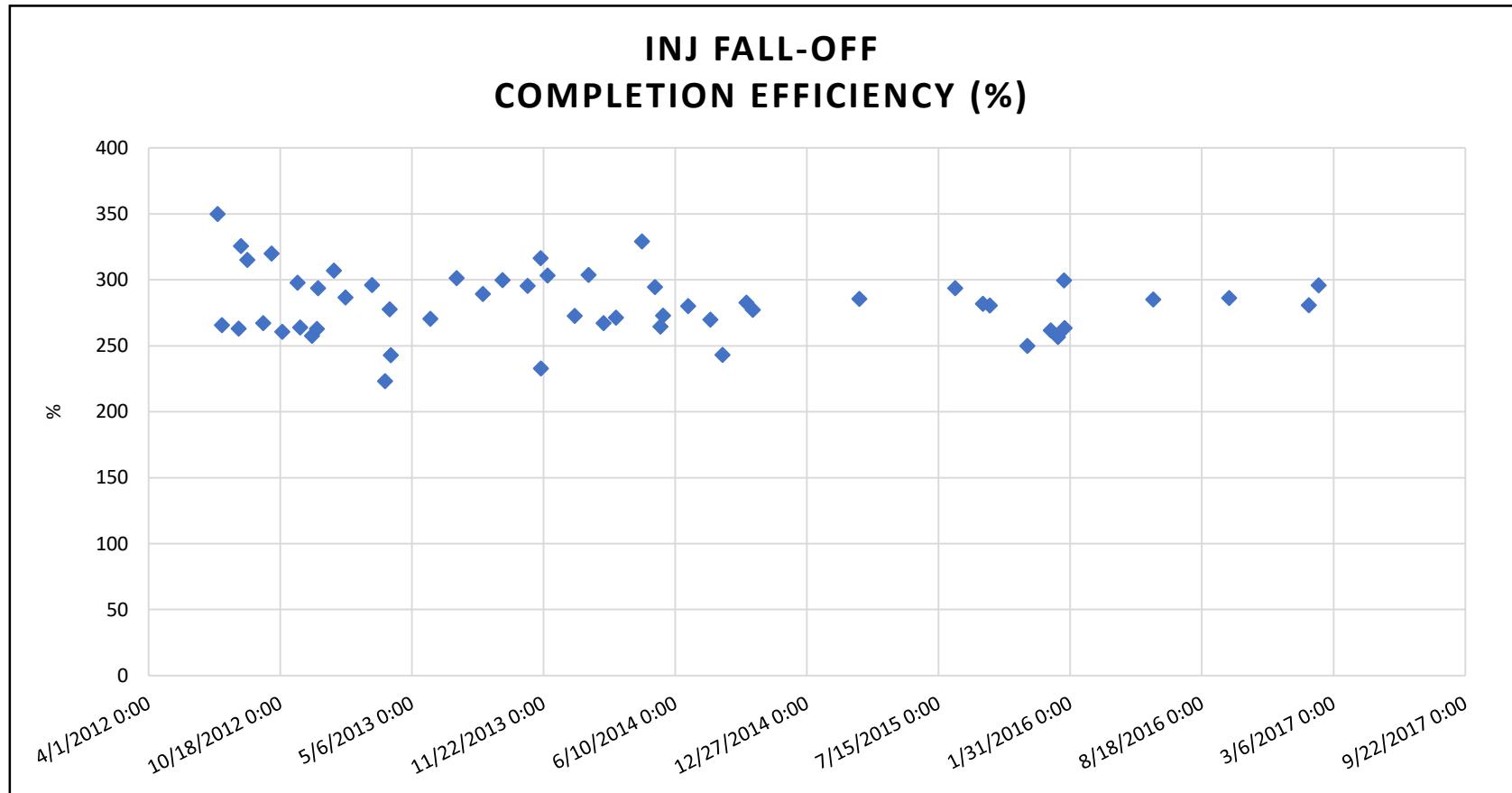
Auto-PTA: II (Early-time IARF)

- Gradually decreasing Inj Index with time
 - From 88 STB/psi (Aug 2012) to 47 STB/psi (Jan 2017)
 - An indication of scale build-up
- Inj Index jumped from 47 STB/psi to 103 STB/psi after the re-stimulation job in late Jan 2017
 - 120 % increase



Auto-PTA: Completion Efficiency (Early-time IARF)

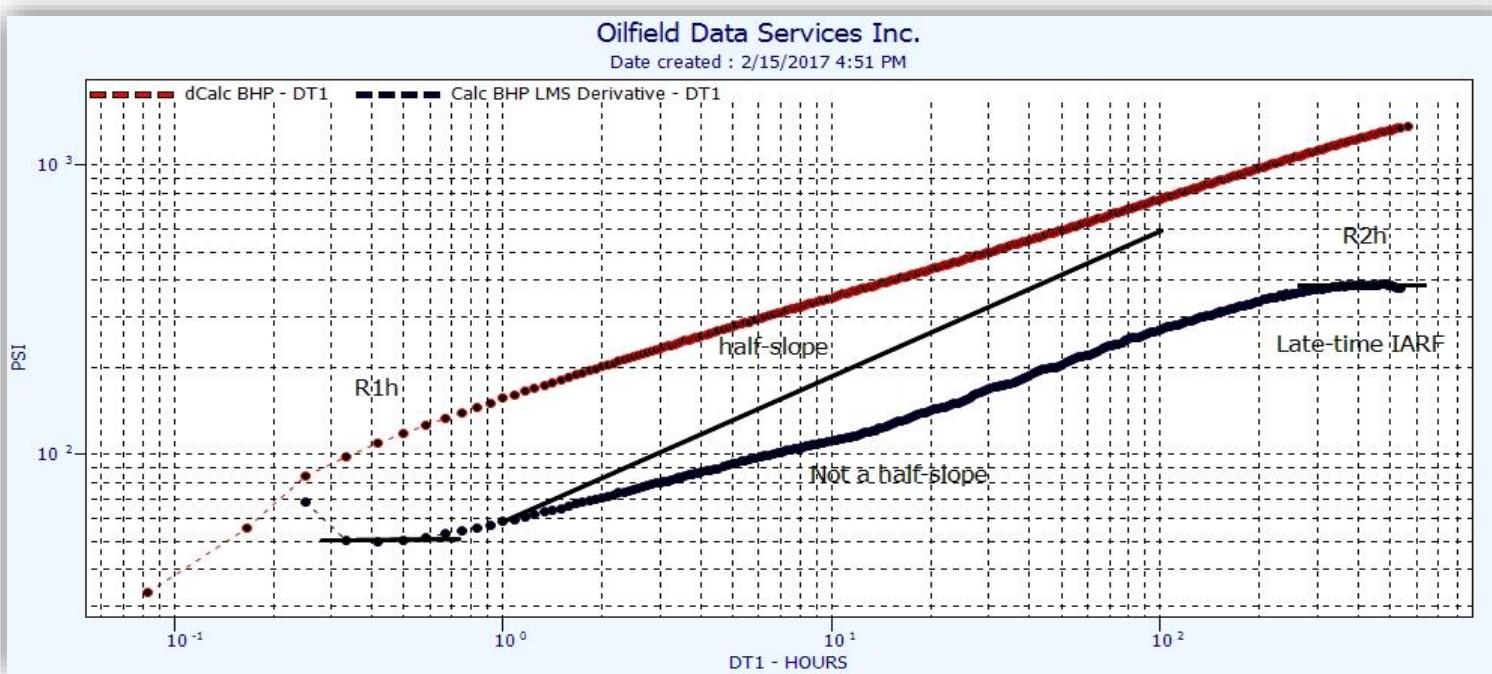
- Good Completion Efficiency
- Fairly constant throughout the production history as skin was not changing much



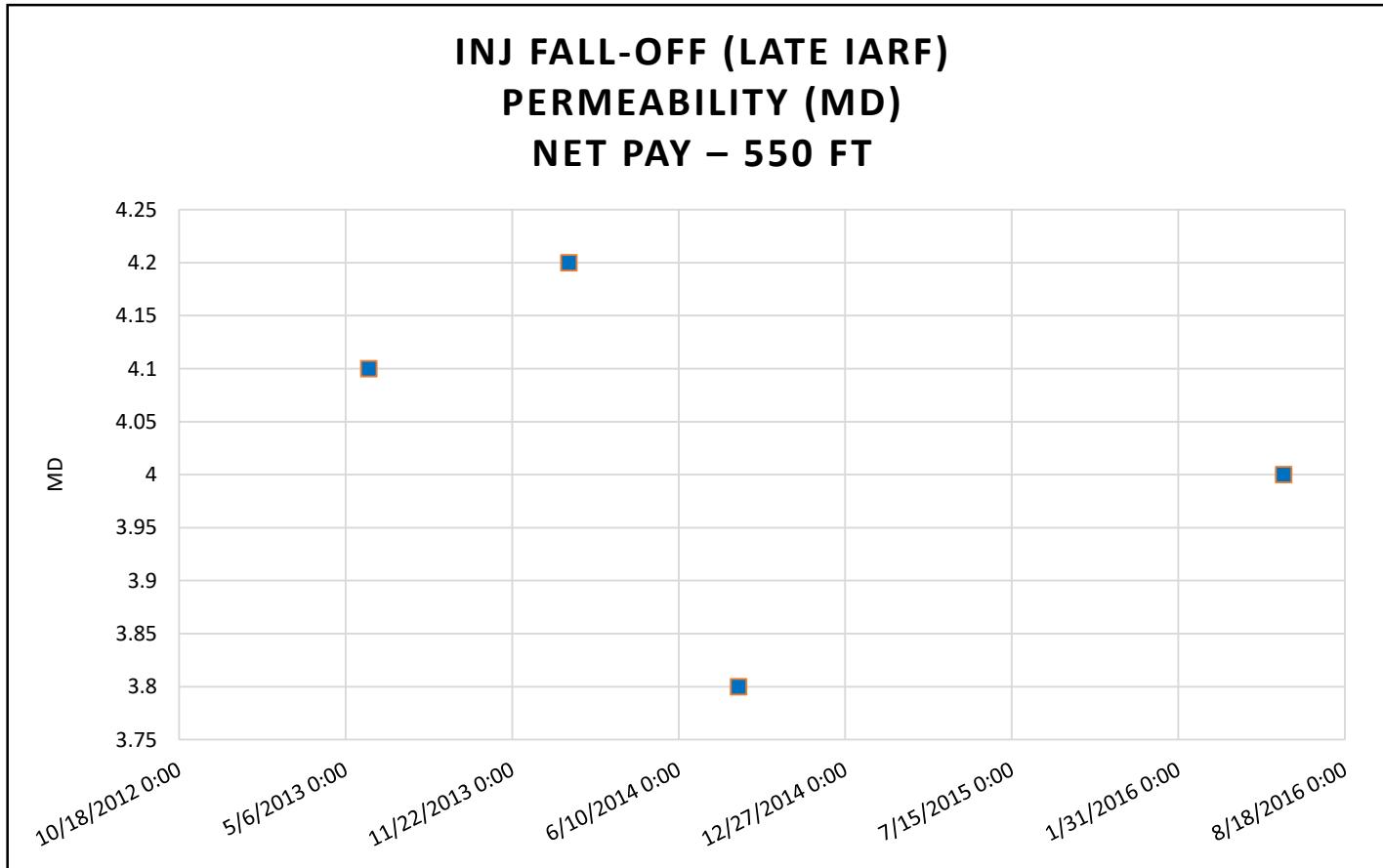
Auto-PTA Summary Table (Late-time IARF)

Start Time ddMMMyyyy HH:mm:ss	End Time ddMMMyyyy HH:mm:ss	Test Length HOURS	Type	DHGpi PSIA	DHGpf PSIA	BHPi PSIA	BHPf STB/D	Qwi	Total Perm STB/D	kh md-ft	Total Skin md	P Total Sk PSI	PStar PSIA	Comp Eff %	PI_Water BBL/PSI	DPS/Q PSI/(STB/D)	
6/2/2013 23:45	6/26/2013 16:55	569.2	Fall-Off	-1	-1	8188	6720	17001	17001	4.1	2255	-5.4	-4144	6502	521.38	17.29	-0.24
1/29/2014 3:45	2/11/2014 5:05	313.3	Fall-Off	7705	6484	8205	7021	14558	14558	4.2	2310	-5.1	-3371	6653	585.42	20.96	-0.23
8/20/2014 17:50	9/22/2014 9:05	783.3	Fall-Off	7696	6082	8199	6619	13855	13855	3.8	2090	-5.1	-3468	6536	595.23	19.78	-0.25
6/5/2016 7:05	6/26/2016 22:10	519.1	Fall-Off	7780	6291	8284	6578	13623	13623	4	2200	-4.9	-3168	6618	673.11	24.65	-0.23

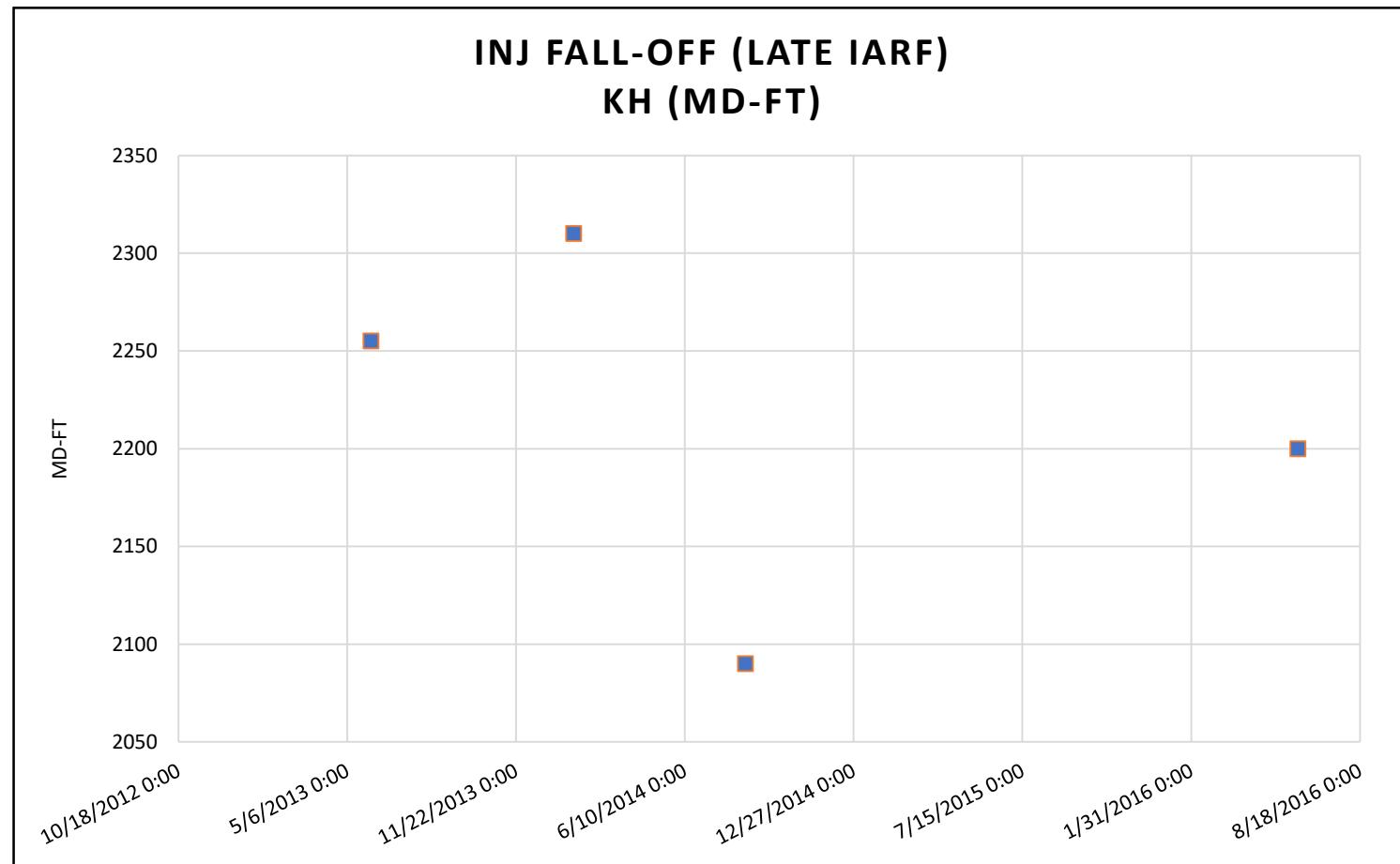
Late IARF was observed at around ~ 300 hrs



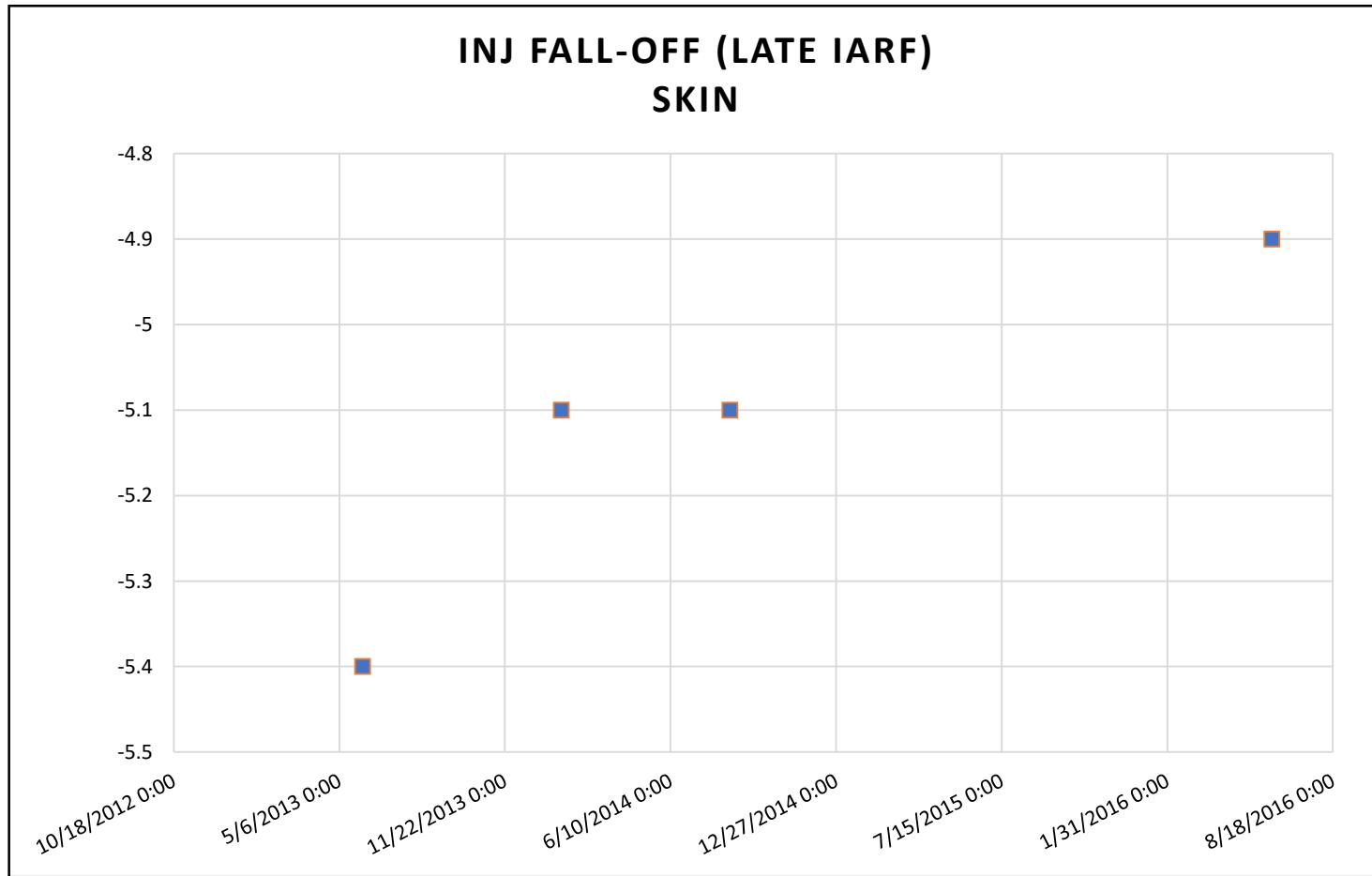
Auto-PTA: Permeability (Late-time IARF)



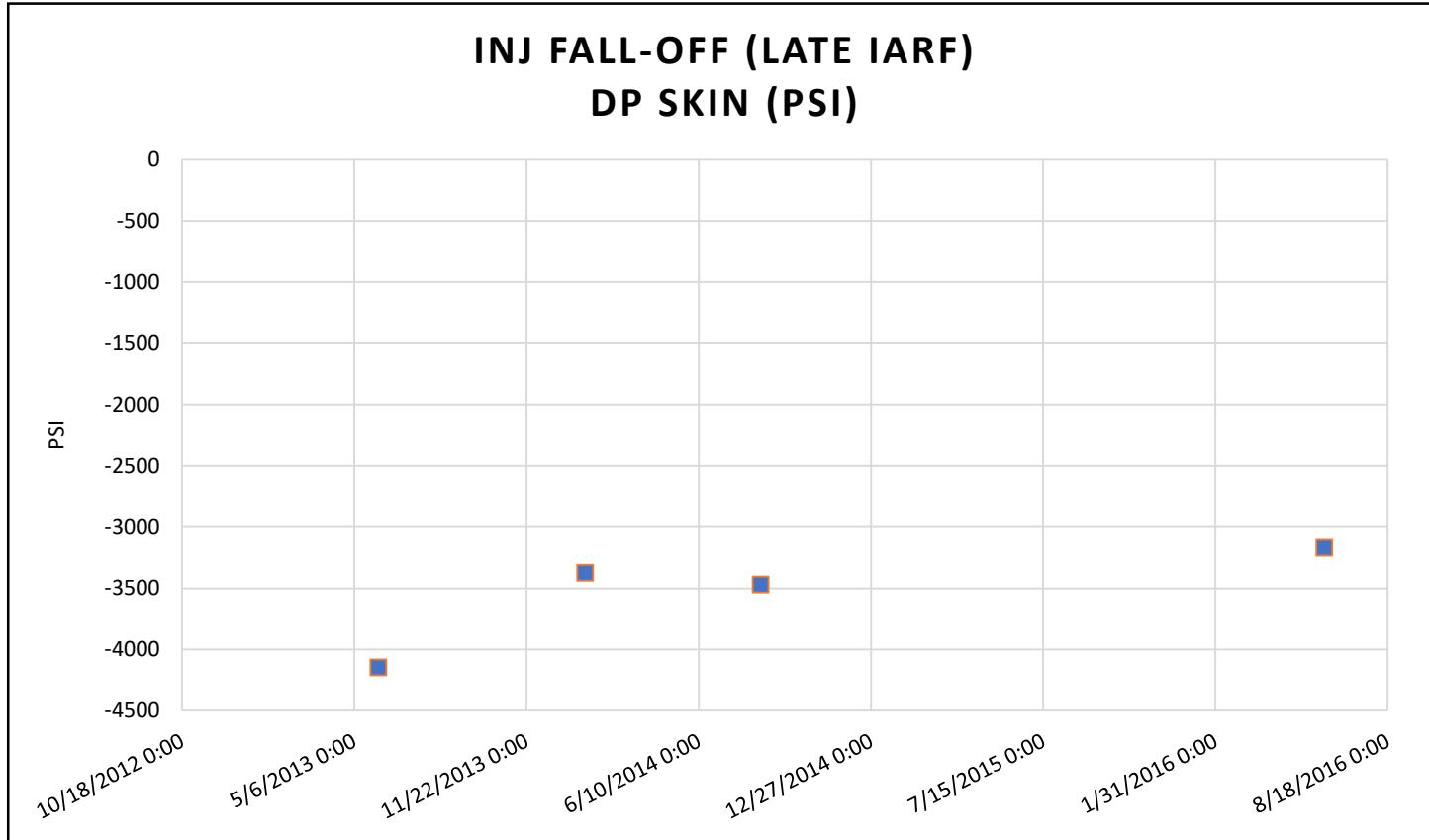
Auto-PTA: kh (Late-time IARF)



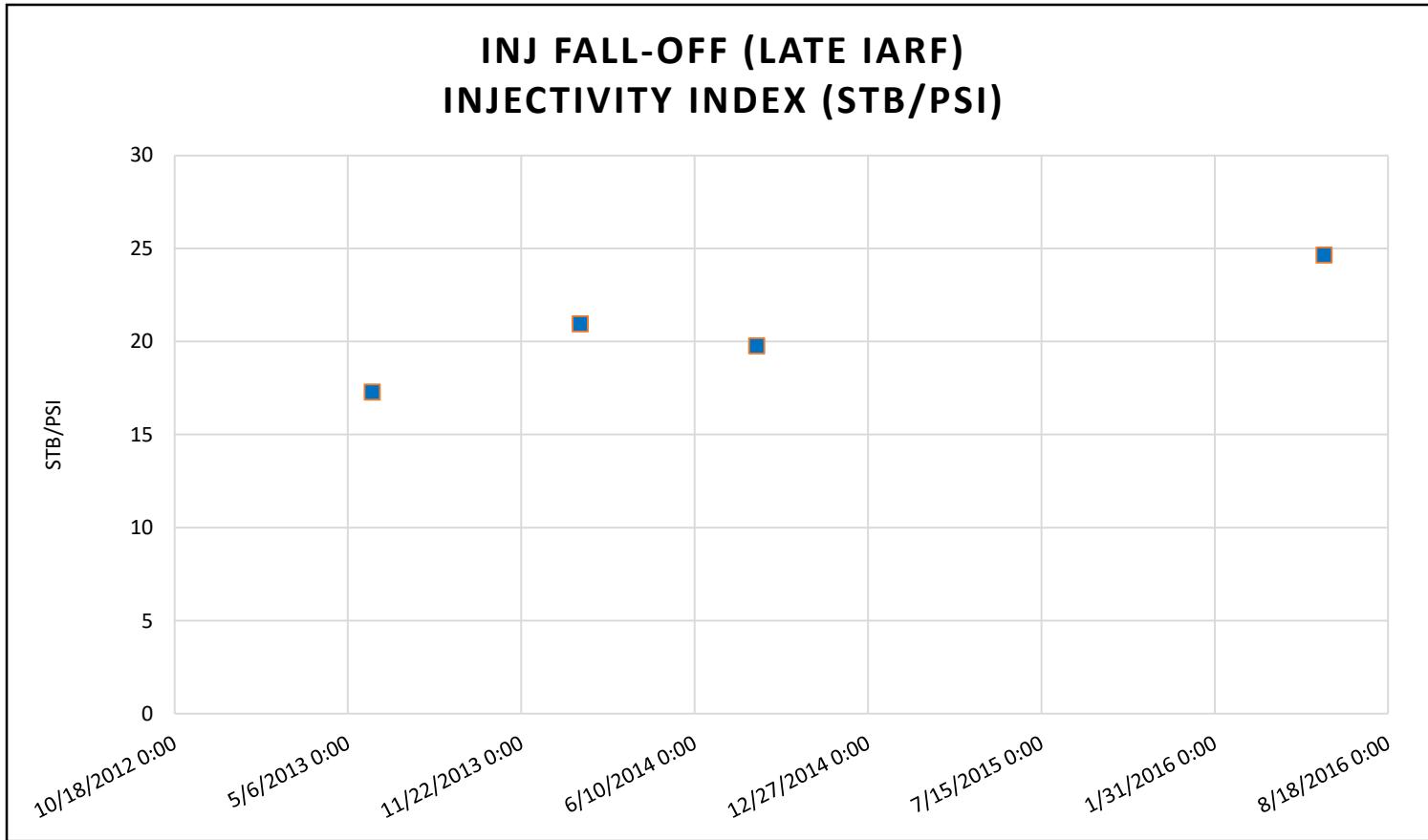
Auto-PTA: Skin (Late-time IARF)



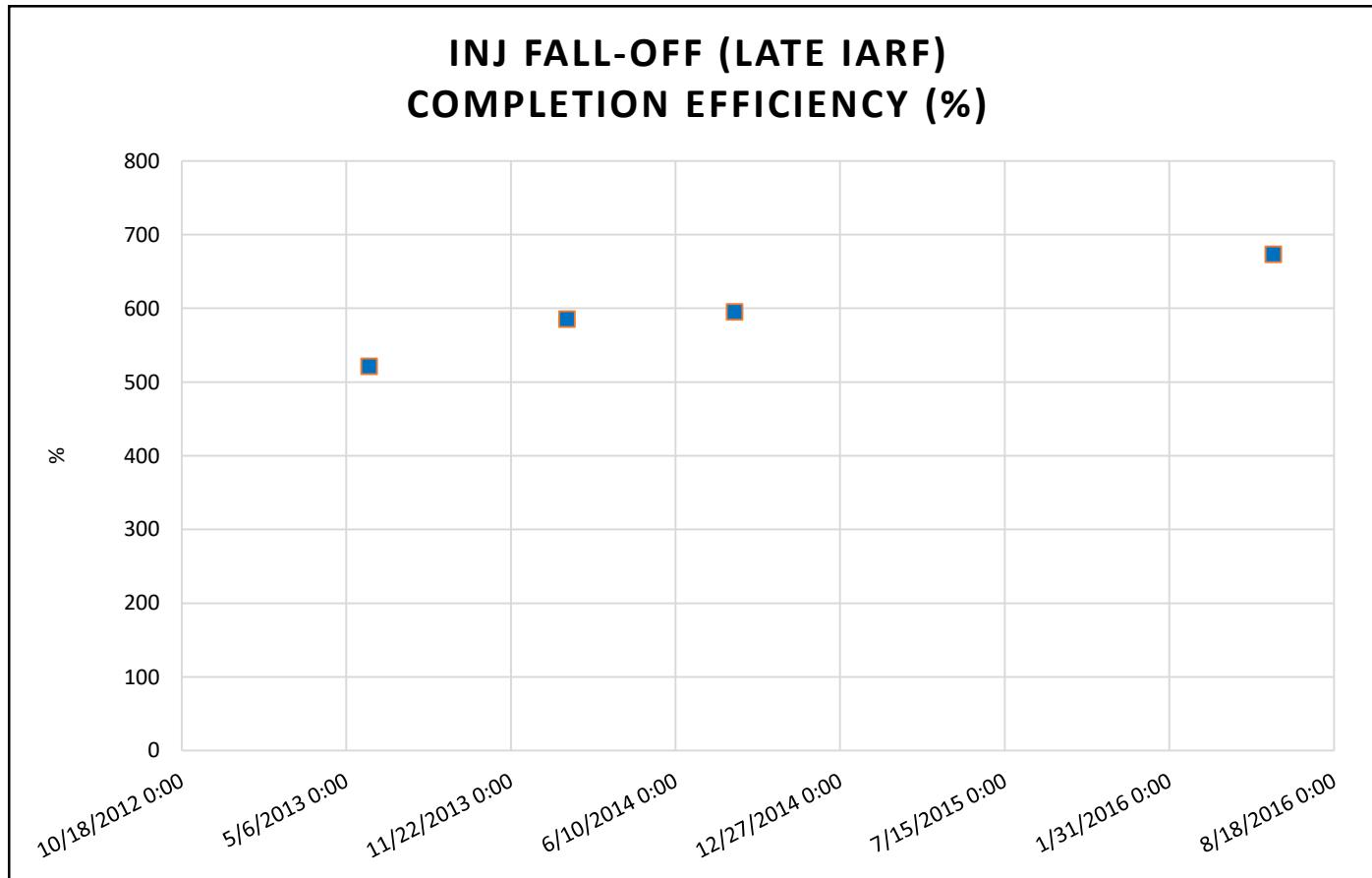
Auto-PTA: DP Skin (Late-time IARF)



Auto-PTA: Inj Index (Late-time IARF)



Auto-PTA: Completion Efficiency (Late-time IARF)



Auto-PTA Results

(Using Measured Rates)

Auto-PTA with Measured Rates

- Upon Operator's request, automated PTA was performed using measured rates for the comparison purposes
- Similarly, PTA was done for both early and late time radial flow
- The following slides compare the results obtained from both measured and calculated rates

PTA with Measured Rates

- Inputs for auto-PTA
 - WHP
 - DHGP/T
 - Measured Injection Rate

Inputs Summary Outputs Reports

Select Input Data

WHP	WHP	PSIA
WHT	None	
DHGP	DHGP	PSIA
DHGT	DHGT	DEGC
QGas	None	
GG	None	
Yo	None	
Yw	None	
SCSSV	None	
Ext QGas	None	
Qo	None	
Qw	Provided QWinj	STB/D
QTotal	None	
BHP	None	

Config

SamplesPerUpdate
100

Config Ok

Load Config

Analysis Enabled

Reserves Enabled

MLTO (DEGF)
15

Legacy MLTO (not used in rate calc)

VSSV Open

Ignore invalid events

No CalcRate Smoothing

Rate Calc from Perm

Enabled

Refresh Columns

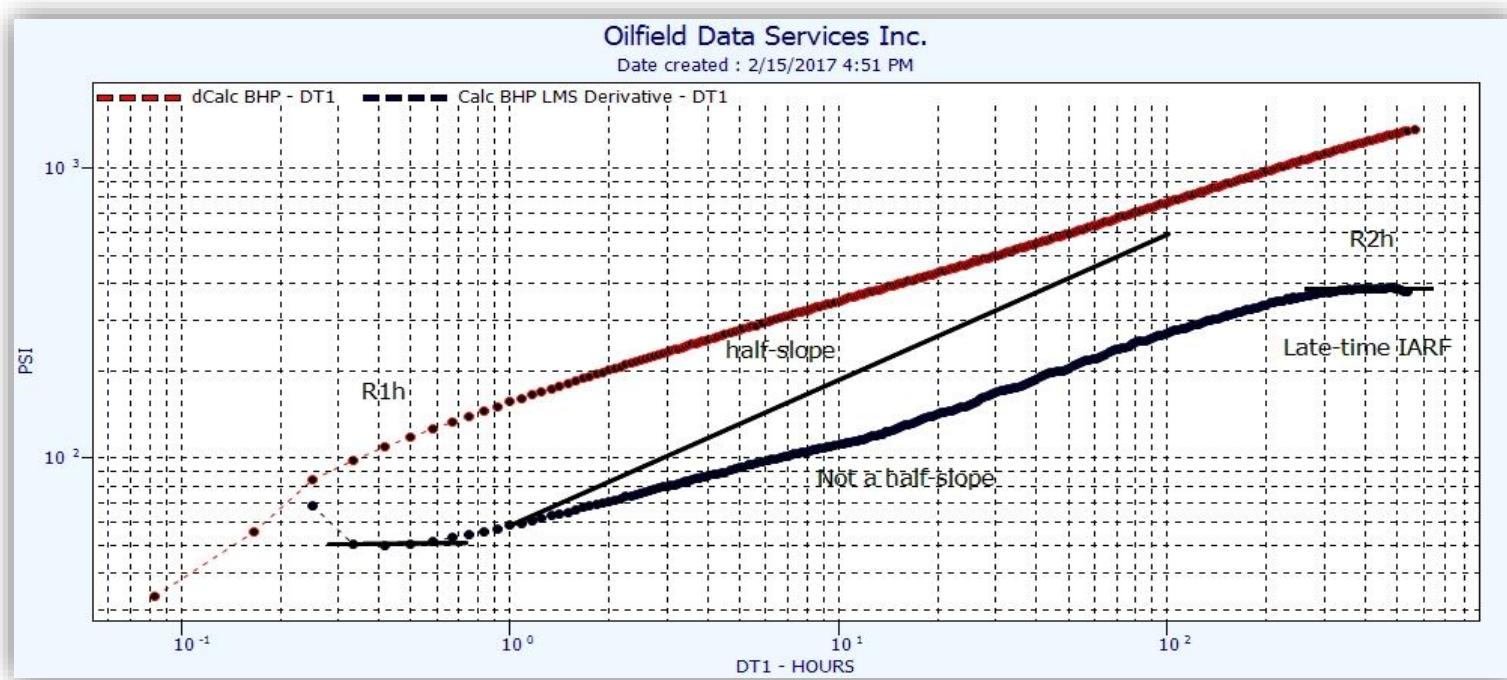
Export Inputs

Auto-PTA Summary Table (Early-time IARF)

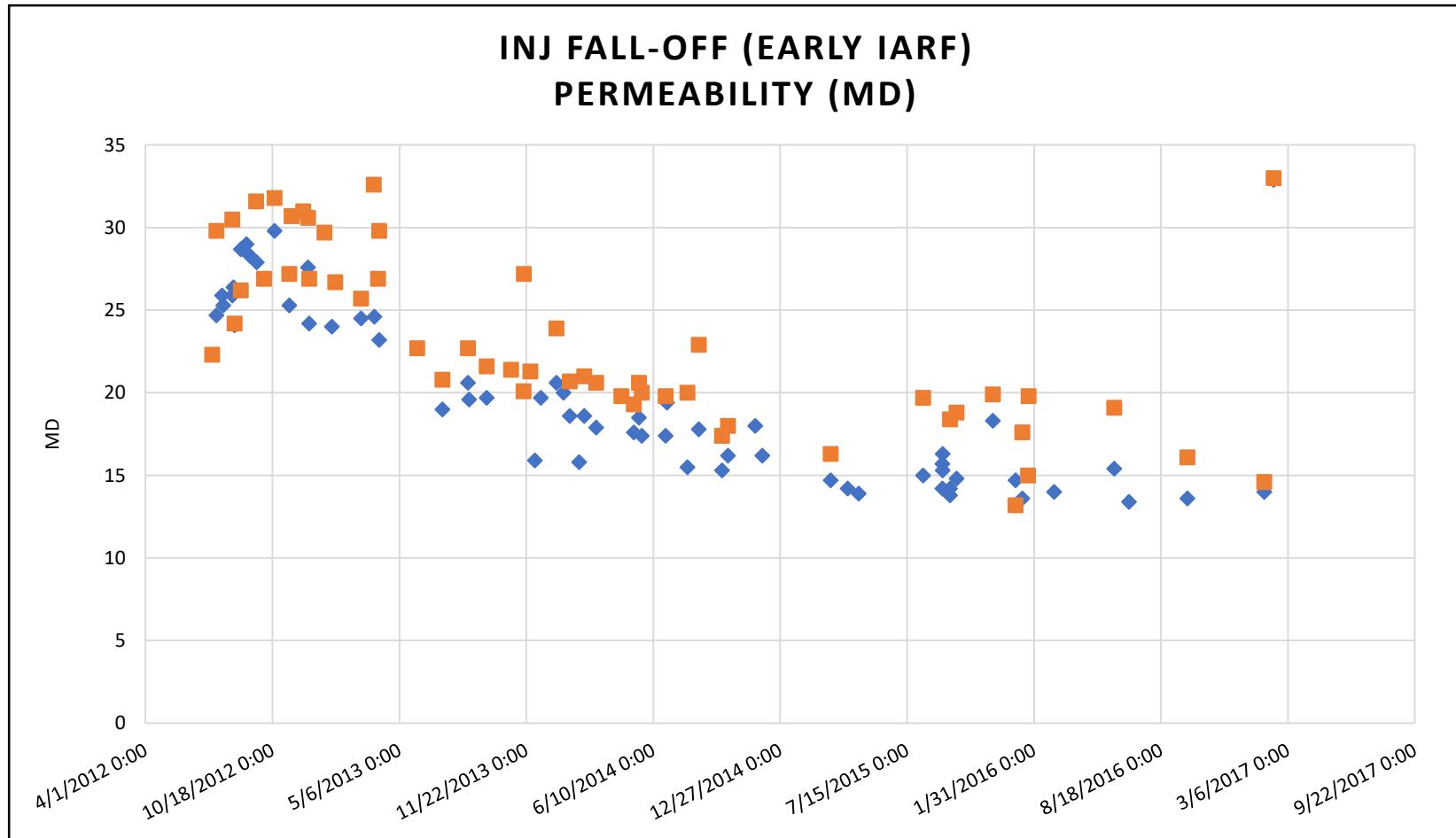
Start Time	End Time	Test Lengh	Test Type	DHGPi	DHGPF	BHPi	BHPF	Qwi	Qw	Total PERM	kh	Total SKIN	DP SKIN	PStar	Comp Eff %	II Water	DPS/Q
ddMMMyyyy	ddMMMyyyy	HOURS		PSIA	PSIA	PSIA	PSIA	STB/D	STB/D	md	md-ft	PSI	PSIA	PSIA	BBL/PSI/(STB/		
7/21/2012 9:35	7/21/2012 12:40	3.1	Fall-off	7401	7241	7877	7736	18728	18728	24.7	13585	-3.4	-486	7552	319.9	84.76	-0.03
7/30/2012 10:10	7/30/2012 11:35	1.4	Fall-off	7513	7378	7993	7865	18103	18103	25.9	14245	-3.3	-434	7419	297.03	82.15	-0.02
8/1/2012 2:50	8/1/2012 23:00	20.2	Fall-off	7515	6935	7993	7471	18359	18359	25.3	13915	-3.4	-459	6751	309.85	83.85	-0.03
8/15/2012 15:20	8/15/2012 21:45	6.4	Fall-off	7552	7444	8039	7938	16957	16957	25.9	14245	-3.4	-419	7837	317.04	87.76	-0.02
8/17/2012 4:00	8/17/2012 20:10	16.2	Fall-off	7599	7410	8086	7899	16909	16909	26.4	14520	-3.1	-373	7574	264.18	74.37	-0.02
8/19/2012 7:55	8/19/2012 10:15	2.3	Fall-off	7567	7210	8041	7747	19103	19103	24.1	13255	-3.5	-518	7329	336.09	87.14	-0.03
8/29/2012 1:45	8/29/2012 3:30	1.8	Fall-off	7678	7561	8153	8049	18865	18865	28.7	15785	-3.3	-403	7453	284.31	86.22	-0.02
9/7/2012 3:15	9/12/2012 8:55	125.7	Fall-off	7703	7716	8177	8202	19064	19064	29	15950	-3.3	-412	7631	295.2	90.33	-0.02
9/12/2012 8:55	9/12/2012 11:50	2.9	Fall-off	7715	7618	8193	8110	18504	18504	28.3	15565	-3.3	-402	7903	286.8	86.06	-0.02
9/23/2012 4:30	9/23/2012 5:55	1.4	Fall-off	7615	7523	8102	8012	16942	16942	27.9	15345	-3.3	-375	7864	289.16	85.5	-0.02
10/21/2012 1:45	11/9/2012 8:10	462.4	Fall-off	7692	7626	8184	8133	16082	16082	29.8	16390	-3.2	-321	8159	267.98	84.08	-0.02
11/13/2012 4:20	11/20/2012 3:55	167.6	Fall-off	7613	6873	8115	7409	14252	14252	25.3	13915	-3.4	-355	7223	306.63	83	-0.02
12/12/2012 18:05	12/13/2012 0:55	6.8	Fall-off	7674	7248	8164	7785	16477	16477	27.6	15180	-3.2	-358	7282	275.55	80.84	-0.02
12/14/2012 16:05	12/14/2012 22:45	6.7	Fall-off	7659	7400	8152	7912	15913	15913	24.2	13310	-3.3	-405	7633	296.15	77.12	-0.03
1/19/2013 8:20	1/19/2013 9:45	1.4	Fall-off	7664	7438	8156	7965	16007	16007	24	13200	-3.3	-405	7837	290.07	75.03	-0.03
3/6/2013 10:30	3/6/2013 13:55	3.4	Fall-off	7673	7471	8163	7979	16378	16378	24.5	13475	-3.3	-411	7676	295.13	77.81	-0.03
3/27/2013 7:55	3/27/2013 8:55	1	Fall-off	7619	7362	8112	7899	15761	15761	24.6	13530	-3.2	-385	7662	282.41	74.74	-0.02
4/3/2013 19:35	4/5/2013 2:00	30.4	Fall-off	7667	7034	8163	7571	15233	15233	23.2	12760	-3.2	-390	7087	280.03	70.32	-0.03
7/12/2013 19:45	7/12/2013 22:10	2.4	Fall-off	7595	7443	8086	7943	16240	16240	19	10450	-3.3	-522	7598	306.64	64.24	-0.03
8/21/2013 17:10	8/22/2013 3:00	9.8	Fall-off	7709	7597	8204	8107	15577	15577	20.6	11330	-3.2	-456	7620	293.36	66.01	-0.03
8/23/2013 17:50	8/23/2013 19:35	1.8	Fall-off	7703	7573	8198	8085	15648	15648	19.6	10780	-3.3	-487	7651	304.87	65.8	-0.03
9/20/2013 14:15	9/20/2013 17:20	3.1	Fall-off	7722	7546	8219	8047	15234	15234	19.7	10835	-3.2	-471	7492	300.76	64.96	-0.03
12/5/2013 10:40	12/5/2013 19:35	8.9	Fall-off	7571	7222	8096	7759	7938	7938	15.9	8745	-3.2	-300	7260	309.08	55.26	-0.04
12/14/2013 16:55	1/8/2014 5:25	588.5	Fall-off	7732	7694	8231	8198	14718	14718	19.7	10835	-3.2	-452	8194	298.04	64.52	-0.03
1/8/2014 5:25	1/8/2014 13:05	7.7	Fall-off	7713	7272	8218	7809	13714	13714	20.6	11330	-3.1	-390	7314	278.22	62.69	-0.03
1/19/2014 7:05	1/19/2014 10:45	3.7	Fall-off	7716	7360	8221	7897	13456	13456	20	11000	-3.2	-401	7450	288.86	63.4	-0.03
1/29/2014 3:45	2/13/2014 0:55	357.2	Fall-off	7708	6936	8213	7462	13622	13622	18.6	10230	-3.3	-447	6986	306.65	62.95	-0.03
2/13/2014 0:55	2/13/2014 5:20	4.4	Fall-off	6943	6933	7468	7458	8309	8309	15.8	8690	-3.2	-316	7410	308.28	54.81	-0.04
2/21/2014 5:45	2/22/2014 12:35	30.8	Fall-off	7670	7580	8168	8091	14893	14893	18.6	10230	-3.1	-465	7251	278.79	57.22	-0.03
3/12/2014 0:45	3/12/2014 3:10	2.4	Fall-off	7720	7597	8227	8094	13127	13127	17.9	9845	-3.1	-425	7525	279.97	55.62	-0.03
5/10/2014 2:05	5/11/2014 19:35	41.5	Fall-off	7709	6958	8215	7495	13234	13234	17.6	9680	-3.2	-452	6982	302.23	59.17	-0.03
5/18/2014 10:25	5/18/2014 12:05	1.7	Fall-off	7700	7378	8204	7914	13693	13693	18.5	10175	-3.1	-426	7568	275.49	56.4	-0.03
5/22/2014 15:20	5/22/2014 20:15	4.9	Fall-off	7700	7271	8209	7808	12650	12650	17.4	9570	-3.1	-419	7247	278.05	53.77	-0.03
6/29/2014 11:05	6/29/2014 19:35	8.5	Fall-off	7699	7231	8207	7768	12875	12875	17.4	9570	-3.1	-434	7146	287.39	55.62	-0.03
7/1/2014 16:00	7/1/2014 16:45	0.8	Fall-off	7690	7442	8197	7979	13212	13212	19.4	10670	-3	-383	7523	263.46	56.33	-0.03
8/2/2014 14:20	8/3/2014 1:05	10.8	Fall-off	7699	7271	8209	7798	12524	12524	15.5	8525	-3.2	-486	7134	312.46	54.7	-0.04
8/20/2014 17:45	9/23/2014 9:05	807.3	Fall-off	7696	7211	8203	7715	13038	13038	17.8	9790	-3.1	-428	6868	284.93	56.32	-0.03
9/26/2014 8:00	9/26/2014 9:45	1.8	Fall-off	7571	7380	8060	7874	16466	16466	15.3	8415	-3.1	-625	7121	289.92	50.03	-0.04
10/5/2014 19:55	10/28/2014 20:30	552.6	Fall-off	7659	7686	8160	8201	14352	14352	16.2	8910	-3.1	-517	7461	288	52.19	-0.04
11/17/2014 15:35	11/17/2014 17:30	1.9	Fall-off	7670	7317	8166	7854	15364	15364	18	9900	-3.2	-509	7449	294.51	58.7	-0.03
11/28/2014 15:00	11/28/2014 20:40	5.7	Fall-off	7711	7706	8218	8213	13111	13111	16.2	8910	-3.1	-475	8141	294.03	53.54	-0.04
3/16/2015 14:05	3/16/2015 17:00	2.9	Fall-off	7540	7275	8055	7805	11029	11029	14.7	8085	-3.1	-444	7622	301.41	50.04	-0.04
4/12/2015 8:25	4/29/2015 14:50	414.4	Fall-off	7576	7582	8092	8098	11023	11023	14.2	7810	-3.1	-449	7576	292.89	47.4	-0.04
4/29/2015 14:50	4/30/2015 1:35	10.8	Fall-off	7580	7573	8095	8086	11202	11202	13.9	7645	-3.1	-471	8064	299.62	47.47	-0.04
8/9/2015 5:55	8/9/2015 22:25	16.5	Fall-off	7785	7109	8295	7646	12531	12531	15	8250	-3.1	-479	6923	283.87	48.05	-0.04
9/8/2015 8:20	9/8/2015 12:15	3.9	Fall-off	7786	7435	8298	7966	12058	12058	14.2	7810	-3	-478	7901	277.9	44.84	-0.04
9/8/2015 14:50	9/8/2015 16:45	1.9	Fall-off	7631	7385	8145	7916	11420	11420	15.7	8635	-3.1	-419	7794	283.49	49.95	-0.04
9/8/2015 19:05	9/8/2015 22:00	2.9	Fall-off	7589	7419	8103	7943	11361	11361	15.3	8415	-3.2	-440	7530	300.41	51.71	-0.04
9/9/2015 0:20	9/9/2015 1:45	1.4	Fall-off	7539	7448	8055	7963	10854	10854	16.3	8965	-3.1	-386	7567	286.29	52.39	-0.04
9/20/2015 12:20	9/20/2015 15:35	3.3	Fall-off	7755	7434	8268	7966	11629	11629	14.2	7810	-3	-463	7872	279.64	45.15	-0.04
9/20/2015 16:55	9/21/2015 0:50	7.9	Fall-off	7484	7593	8011	8104	7728	7728	13.8	7590	-3.5	-362	7669	381.22	60.12	-0.05
9/30/2015 21:10	10/1/2015 1:55	4.8	Fall-off	7759	7426	8271	7956	12009	12009	14.8	8140	-3	-461	7796	280.07	46.89	-0.04
11/26/2015 22:40	11/27/2015 9:40	11	Fall-off	7441	7323	7965	7846	8814	8814	18.3	10065	-2.8	-254	6884	240.6	48.85	-0.03
1/1/2016 14:35	1/1/2016 18:40	4.1	Fall-off	7171	7008	7701	7542	6264	6264	14.7	8085	-3.1	-246	7457	288.52	47.95	-0.04
1/12/2016 7:25	1/12/2016 15:20	7.9	Fall-off	7354	7087	7879	7616	8302	8302	13.6	7480	-2.9	-330	7375	262.18	40.82	-0.04
3/2/2016 10:40	3/2/2016 13:55	3.3	Fall-off	7545	7270	8060	7799	11150	11150	14	7700	-3.1	-455	7582	287.46	45.95	-0.04
6/5/2016 7:05	6/27/2016 22:55	543.8	Fall-off	7779	6917	8292	7441	11838	11838	15.4	8470	-3.1	-442	6757	285.92	49.76	-0.04
6/28/2016 8:30	6/28/2016 10:55	2.4	Fall-off	6882	6671	7405	7203	8873	8873	13.4	7370	-3.1	-380	7141	291.2	44.69	-0.04
9/28/2016 8:00	9/28/2016 15:40	7.7	Fall-off	7817	7442	8329	7969	11803	11803	13.6	7480	-3.1	-501	7600	291.68	45.16	-0.04
1/27/2017 12:45	2/3/2017 1:00	156.3	Fall-off	7600	7702	8122	8205	9267	9267	14	7700	-3.1	-384	6938	294.62	46.91	-0.04
2/11/2017	2/13/2017	51	Fall-off	7746	6932	8211	7469	32.9	18095	32.9	18095	-2.52	-291	6852	196.96	67.4	-0.01433

Auto-PTA Summary Table (Late-time IARF)

Start Time ddMMMyyyy HH:mm:ss	End Time ddMMMyyyy HH:mm:ss	Test Length HOURS	Type	DHGpi PSIA	DHGpf PSIA	BHPi PSIA	BHPf PSIA	Qwi	Qw	Total Perm md	kh	Total Skin PSI	PStar PSIA	Comp Eff %	II_Water BBL/PSI	DPs/Q PSI/(STB/D)	
6/2/2013 22:55	6/26/2013 18:50	571.9	DD	7702	6182	8192	6719	16523	16523	4	2200	-5.3	-4140	6502	520.14	16.77	-0.25
1/29/2014 3:45	2/11/2014 21:35	329.8	DD	7709	6470	8213	7006	13744	13744	3.9	2145	-5.1	-3431	6648	573.16	18.96	-0.25
8/20/2014 17:45	9/22/2014 9:05	783.3	DD	7696	6082	8204	6619	12877	12877	3.5	1925	-5	-3439	6536	594.05	18.5	-0.27
6/5/2016 7:05	6/26/2016 2:35	499.5	DD	7780	6303	8292	6840	11801	11801	3.4	1870	-4.8	-3102	6619	674.88	21.87	-0.26

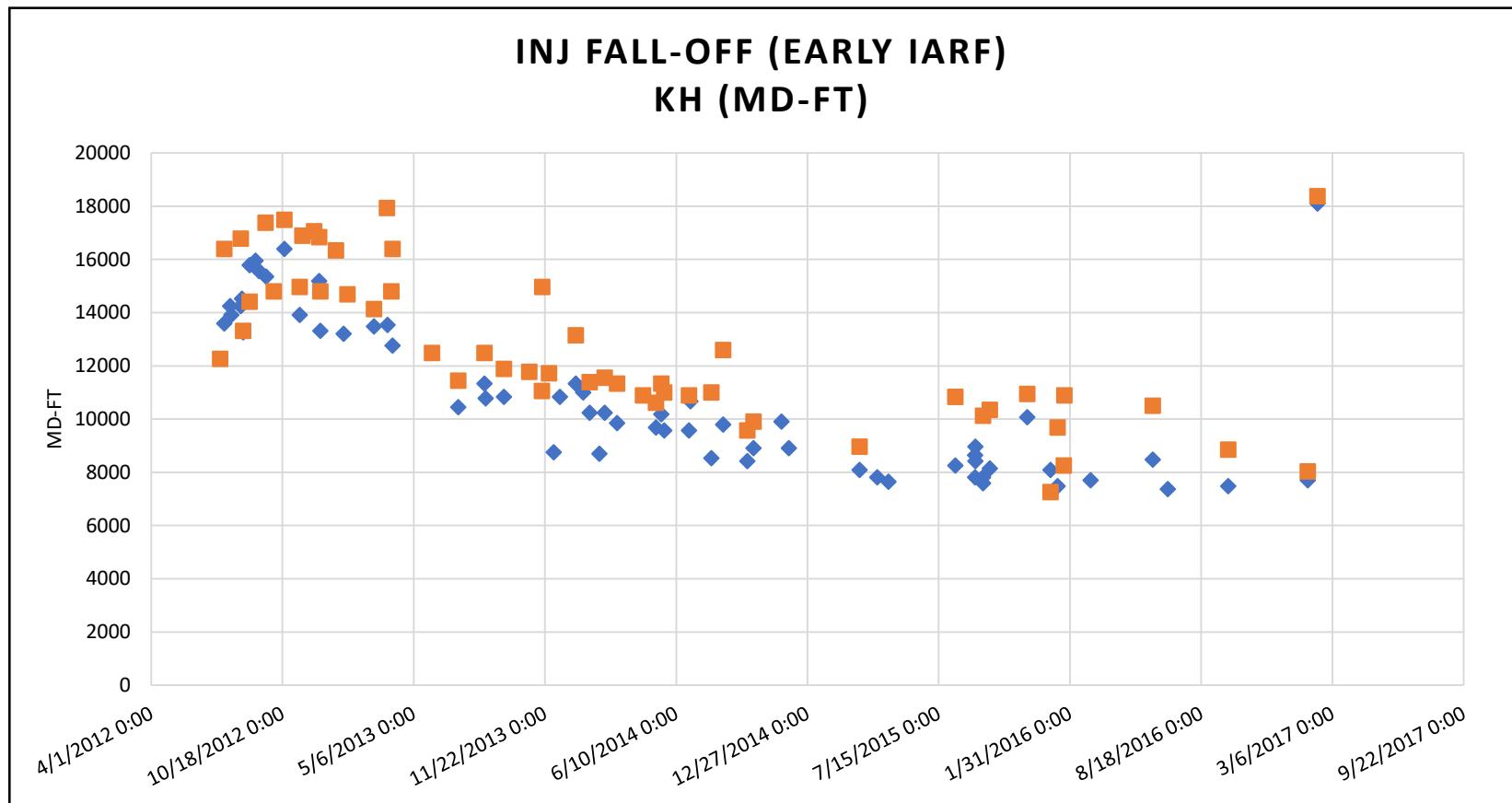


Permeability Comparison (Early-time IARF)



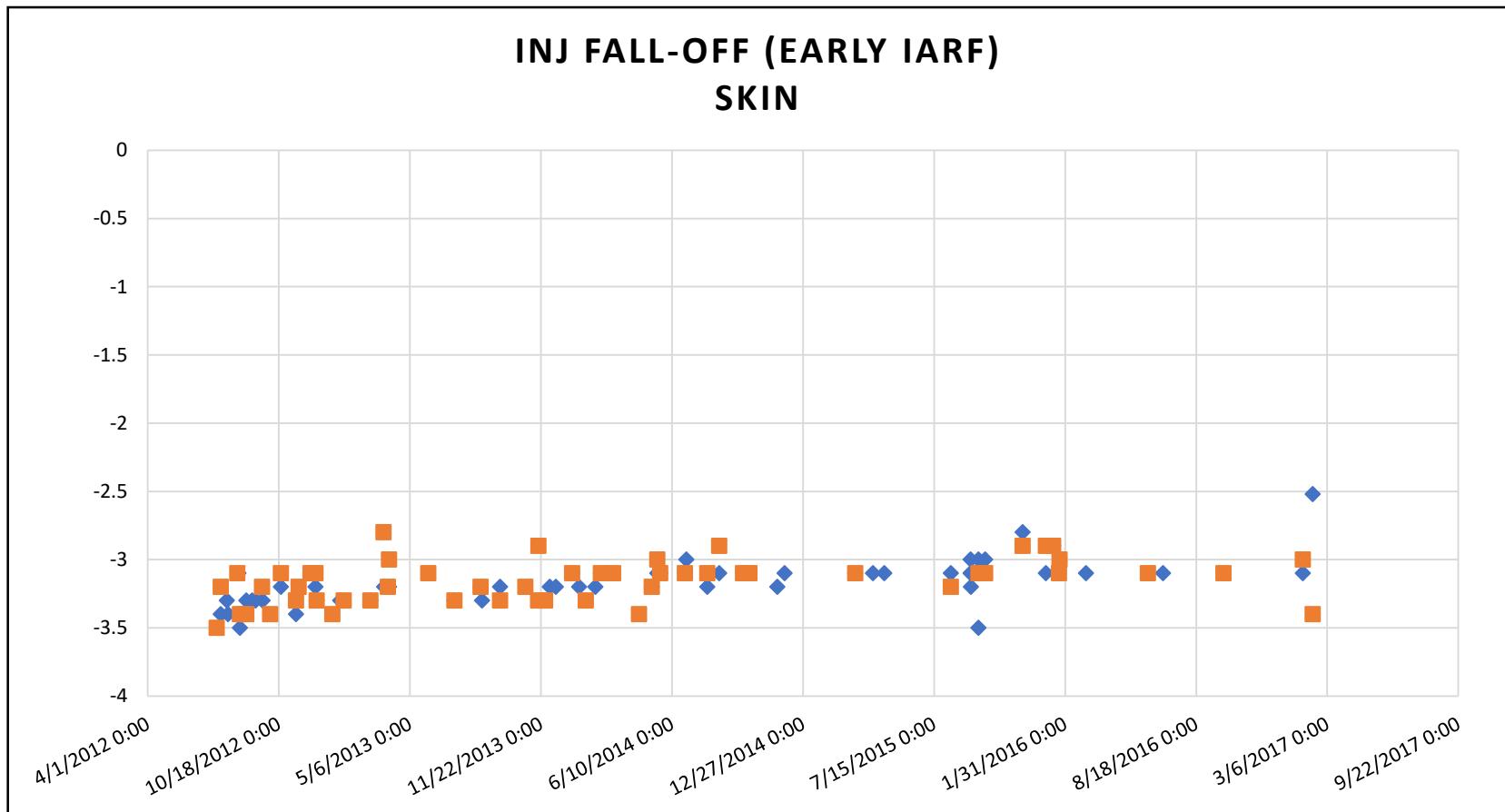
- Blue – PTA results with measured rates
- Orange – PTA with calculated rates

kh Comparison (Early-time IARF)



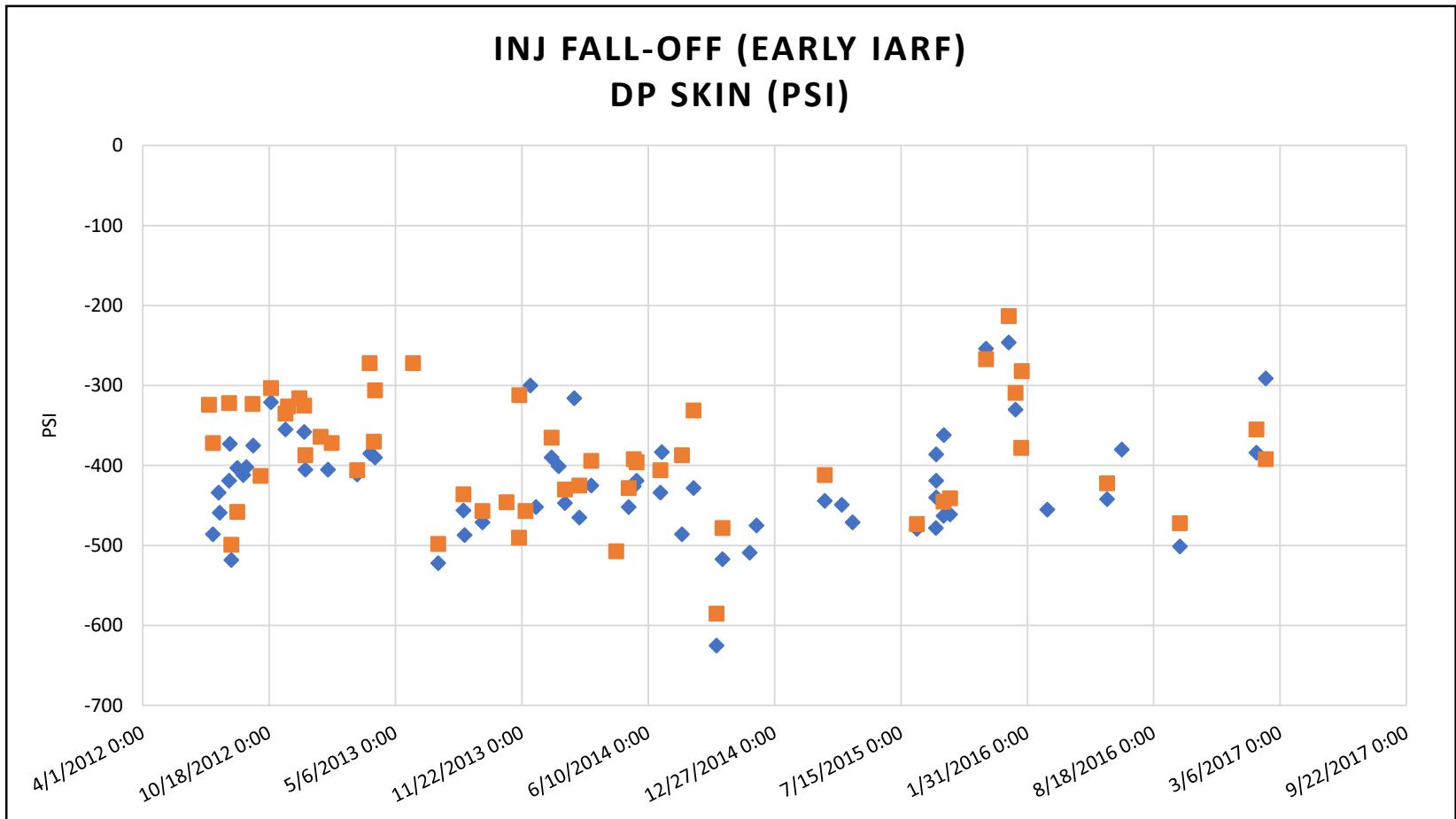
- Blue – PTA results with measured rates
- Orange – PTA with calculated rates

Skin Comparison (Early-time IARF)



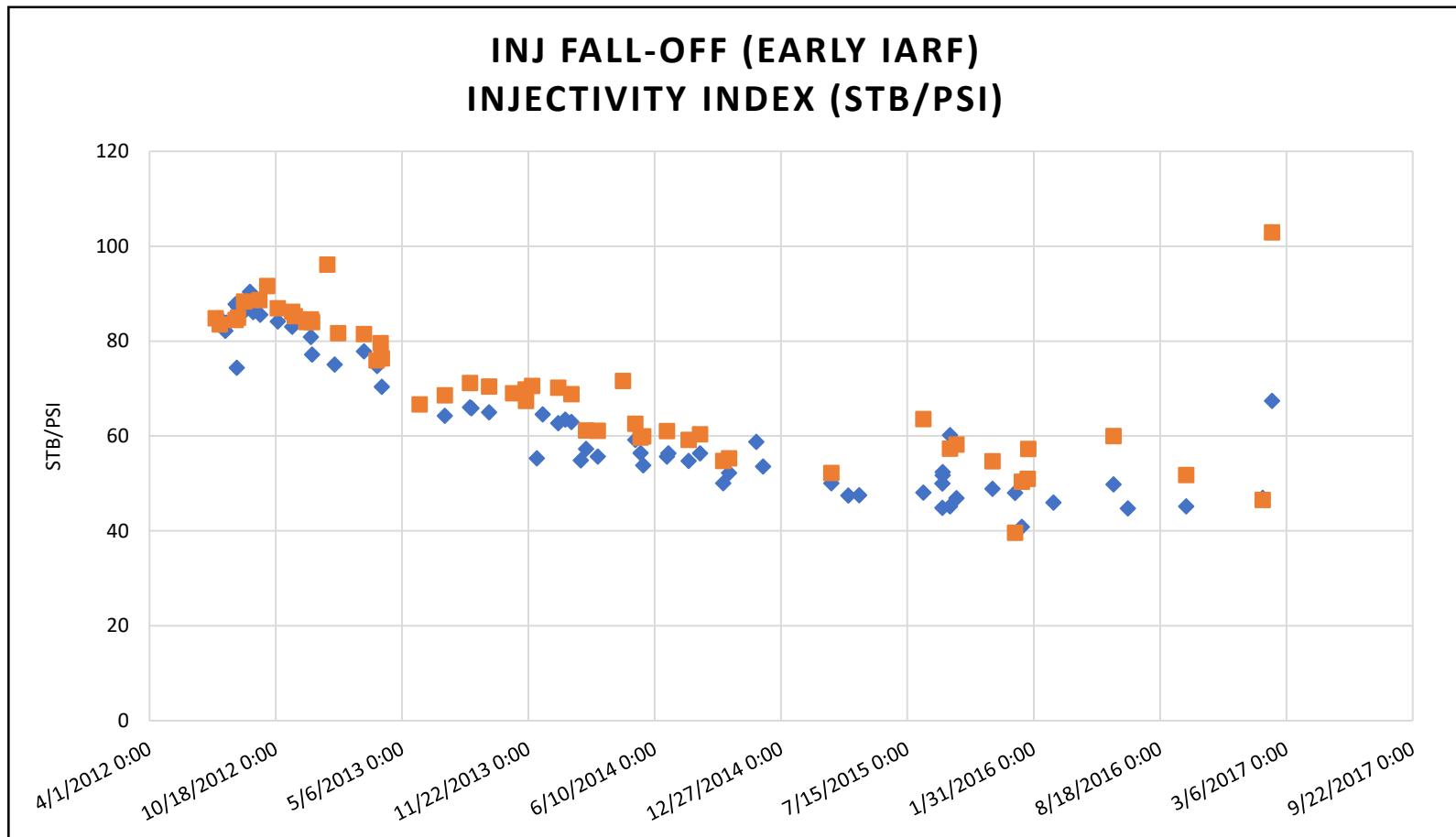
- Blue – PTA results with measured rates
- Orange – PTA with calculated rates

DP skin Comparison (Early-time IARF)



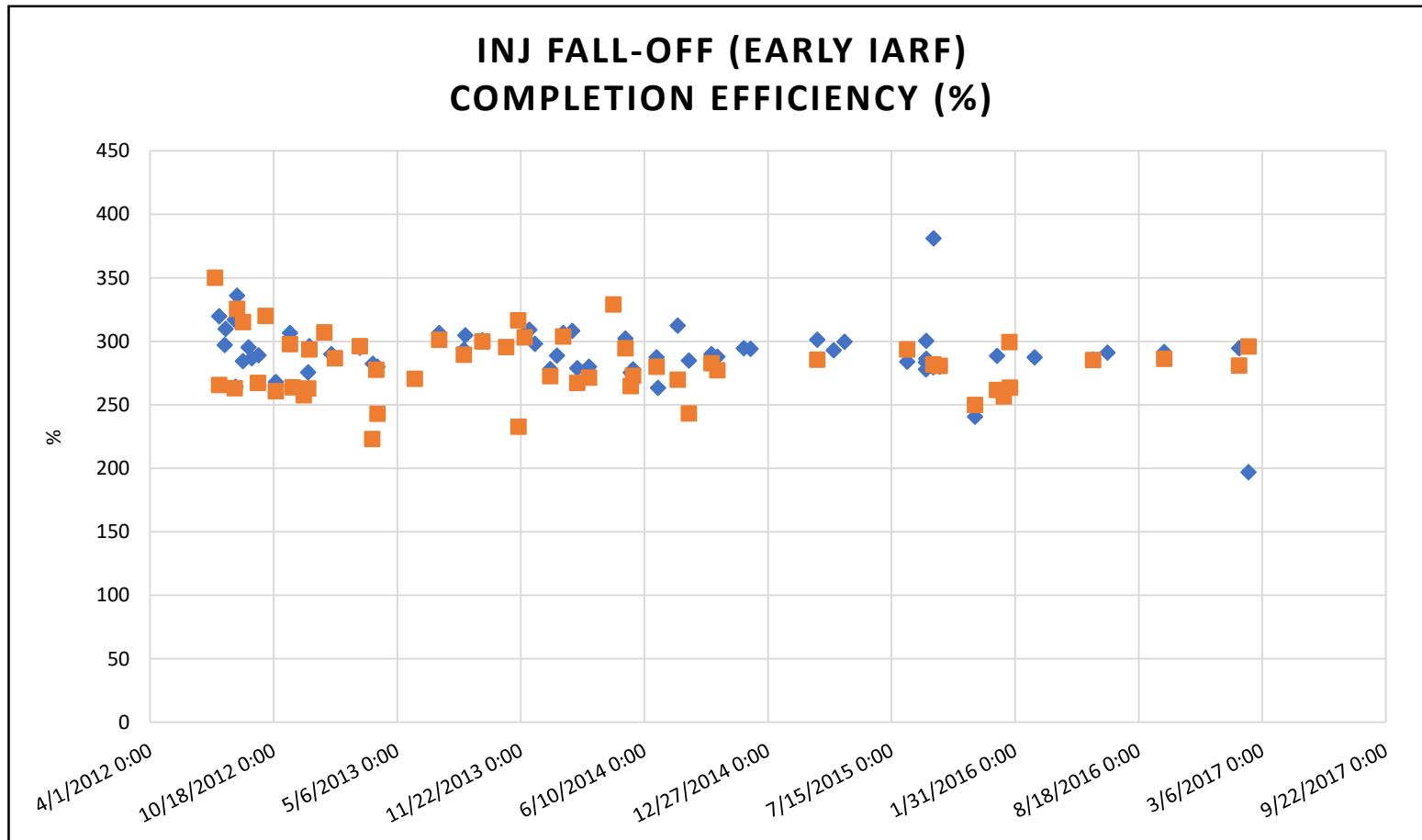
- Blue – PTA results with measured rates
- Orange – PTA with calculated rates

Inj Index Comparison (Early-time IARF)



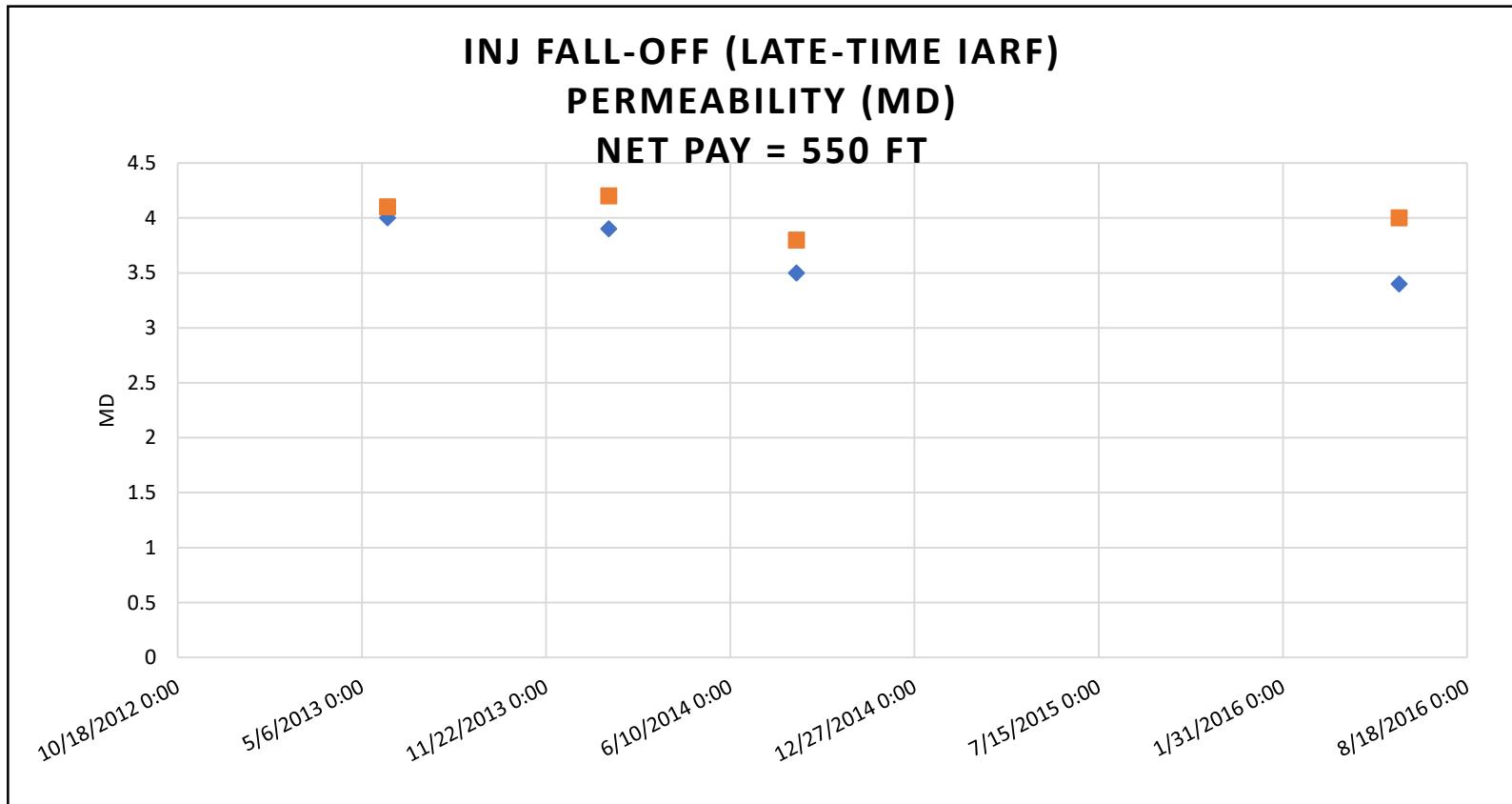
- Blue – PTA results with measured rates
- Orange – PTA with calculated rates

Completion Efficiency Comparison (Early-time IARF)



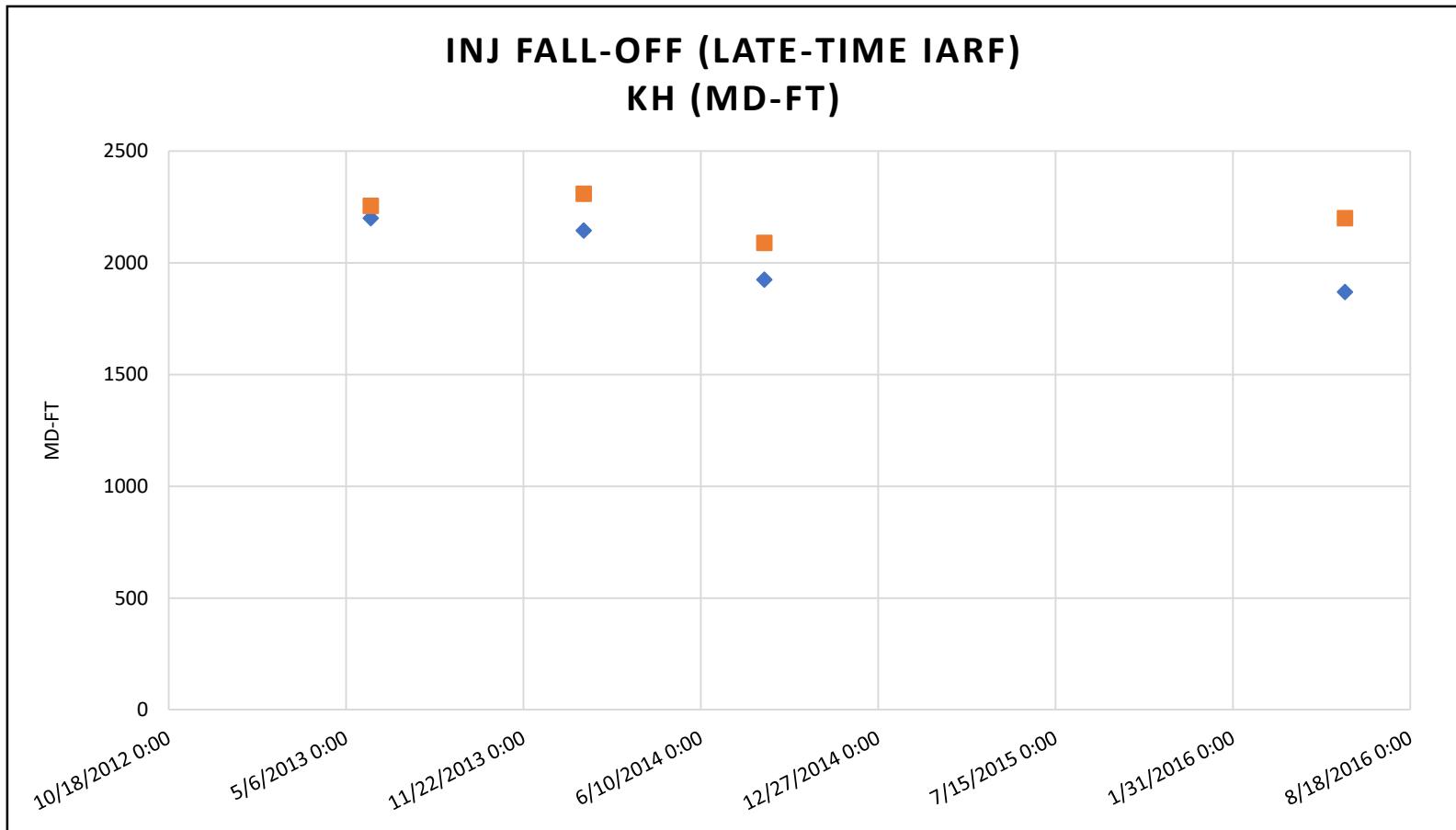
- Blue – PTA results with measured rates
- Orange – PTA with calculated rates

Permeability Comparison (Late-time IARF)



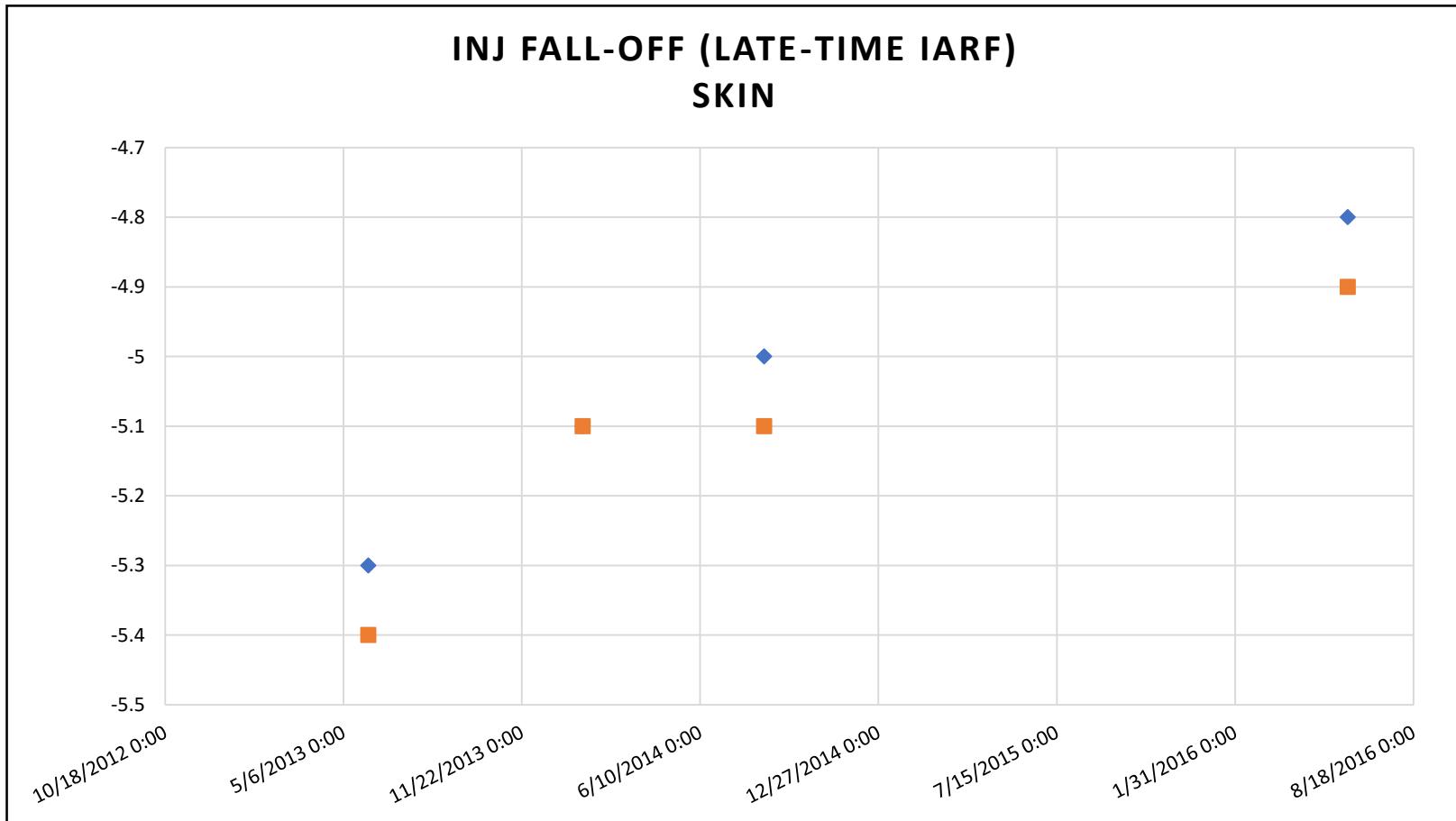
- Blue – PTA results with measured rates
- Orange – PTA with calculated rates

kh Comparison (Late-time IARF)



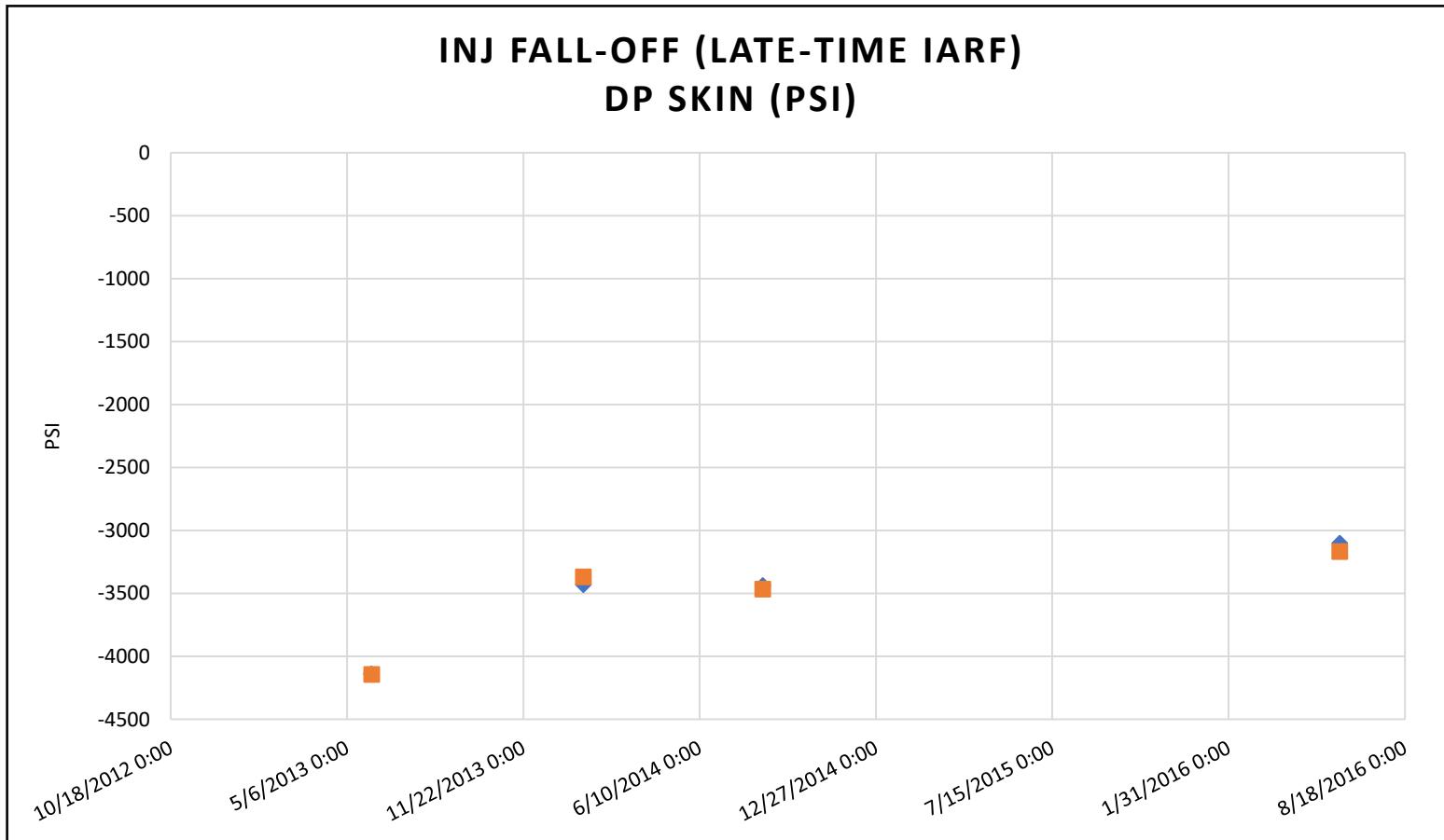
- Blue – PTA results with measured rates
- Orange – PTA with calculated rates

Skin Comparison (Late-time IARF)



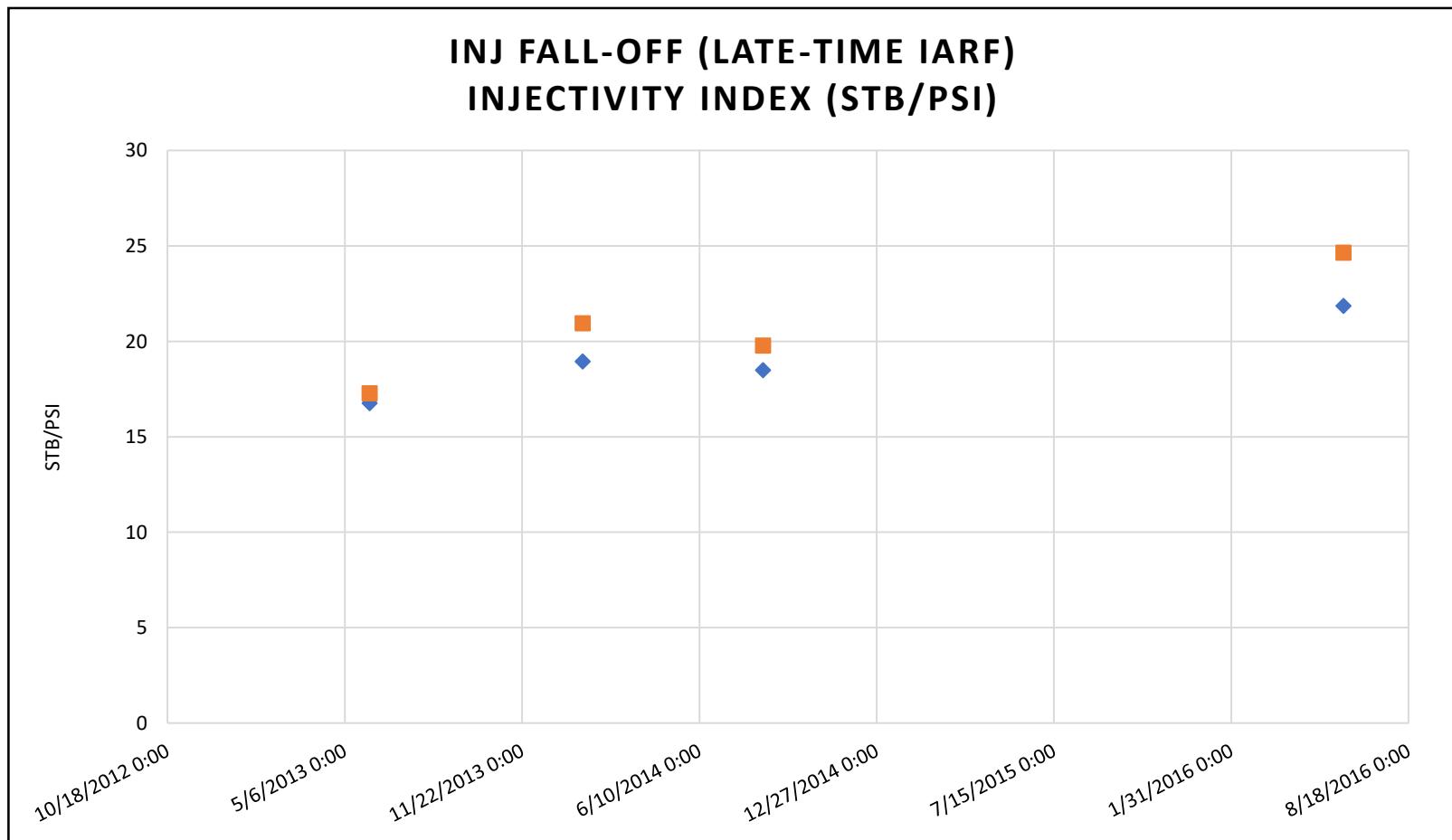
- Blue – PTA results with measured rates
- Orange – PTA with calculated rates

DP Skin Comparison (Late-time IARF)



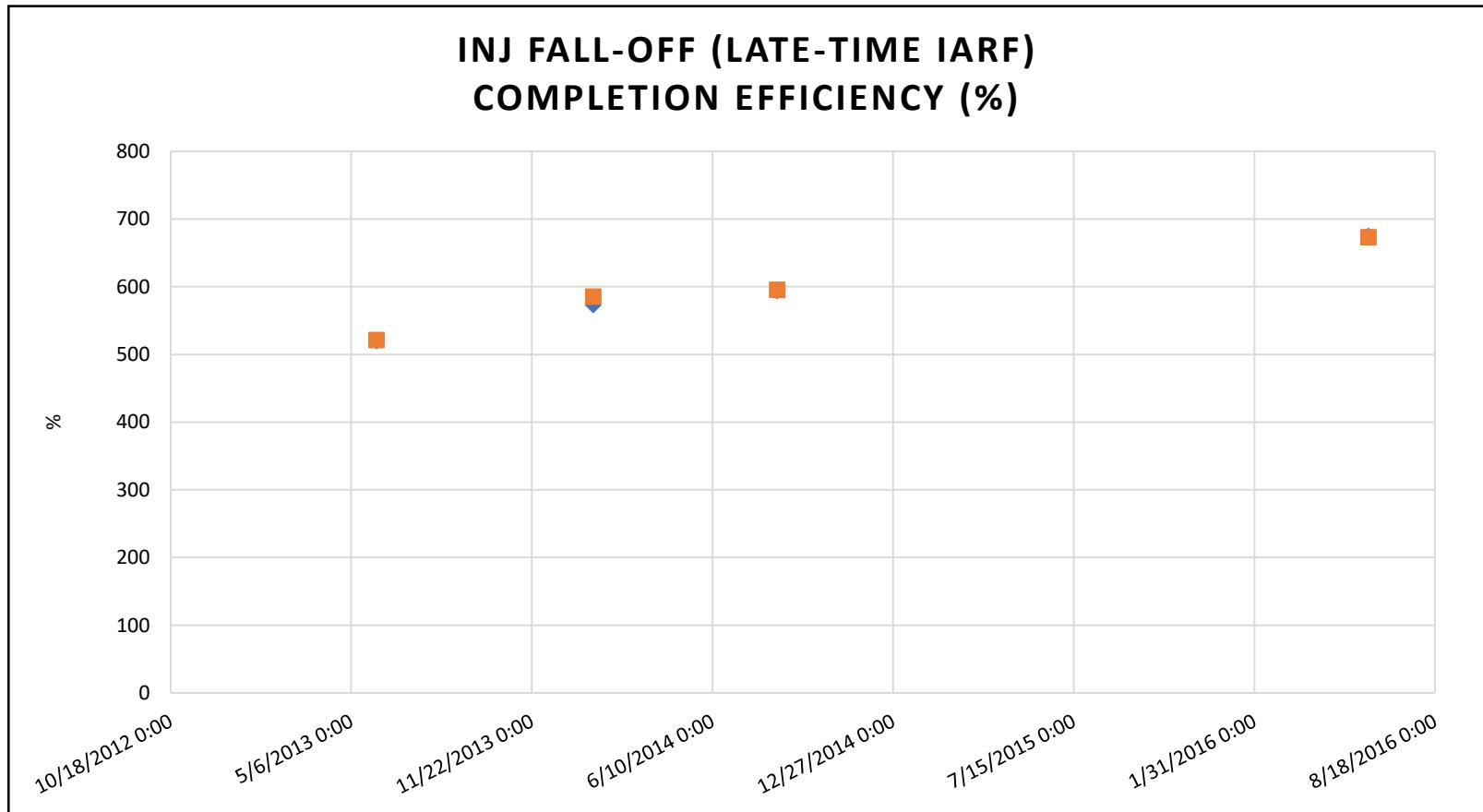
- Blue – PTA results with measured rates
- Orange – PTA with calculated rates

Inj Index Comparison (Late-time IARF)



- Blue – PTA results with measured rates
- Orange – PTA with calculated rates

Completion Efficiency Comparison (Late-time IARF)



- Blue – PTA results with measured rates
- Orange – PTA with calculated rates

Feb 11, 2017 PTA Comparison

Measured vs Calculated Rate

PTA w Measured Rate

Oilfield Data Services, Inc.

ANALYSIS RESULTS

INJECTION FALL OFF
Feb/11 - 13/2017

Calculated Reservoir & Completion Properties

SKIN	-3.4
PRESSURE DROP DUE TO SKIN	-387 PSI
COMPLETION EFFICIENCY	290 %
PERMEABILITY	33 md
RADIAL FLOW INJECTIVITY INDEX (II)	98.9 STB/PSI
SKINLESS RADIAL FLOW II	34.1 STB/PSI
PERMEABILITY THICKNESS	17,951 md-ft
MOBILITY THICKNESS	25,644 md-ft/cp

PTA with Calculated Rate

Oilfield Data Services, Inc.

ANALYSIS RESULTS

INJECTION FALL OFF
Feb/11 - 13/2017

Calculated Reservoir & Completion Properties

SKIN	-3.4
PRESSURE DROP DUE TO SKIN	-392 PSI
COMPLETION EFFICIENCY	296 %
PERMEABILITY	33 md
RADIAL FLOW INJECTIVITY INDEX (II)	102.9 STB/PSI
SKINLESS RADIAL FLOW II	34.8 STB/PSI
PERMEABILITY THICKNESS	18,377 md-ft
MOBILITY THICKNESS	26,253 md-ft/cp

Conclusions I

- ODSI calculated rates matched the measured rates accurately when there was no scale in the well bore
- A deviation between measured and the calculated rates was noted during (mid-April 2015 – Late Jan 2017)
- ODSI's rate solution is independent. Any deviation from the measurement is an indication of a change in well's performance/model (PVT, friction)
- It was likely that the scale build-up caused additional friction and caused the rates to deviate
- Scale build-up was confirmed with early-time (near well) PTA results
 - Confirmed by comparing calculated rates vs. measured rates

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

Conclusions II

- Scale build-up was confirmed with early-time (near well) PTA results
 - Gradually decreasing kh with time
 - From $\sim 16\ 000$ md-ft (Aug 2012) to 8 000 (Jan 2017)
 - Re-stimulation job in late Jan 2017 removed the scale
 - Kh immediately improved to 18 337 md-ft (Feb 11, 2017)
- Gradually decreasing near-well Inj Index with time:
 - From 88 STB/psi (Aug 2012) to 47 STB/psi (Jan 2017)
 - Immediately improved to 103 STB/psi (Feb 11, 2017) after the stimulation job
- Negative and fairly constant skin with time
- High and fairly constant completion efficiency

Well Analyzer Features

- Virtual metering
 - Oil, gas and water rate calculations
 - Detects errors in allocations
- Bottomhole pressure calculation from the surface data
 - Can replace downhole pressure gauge in case it fails
- Automated Transient Interpretation of build-up & drawdown tests and injectivity & injection fall-off tests
 - Skin
 - Permeability
 - Avg.Pres/P*

Why ODSI?

- Well Analyzer is not intrusive and provides fast and accurate results
- Accuracy of the technique assists in diagnosing errors in allocations
- Software-based installation only
- Low cost investment