MRT
Multiwell Retrospective Test Report

Well 9812

Report date	22.12.2017
Testing package	Multiwell Retrospective Test
Operating company	XXX
Field	YYY
Tested wells	9812 – oil producer 9830 – oil producer 9832 – oil producer 9835 – oil producer 912 – oil producer 9855 – oil producer
Service company	Sofoil
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TABLE OF CONTENT

1. OBJECTIVES

1. Reconstruct the formation pressure history of pressure-tested well **9812.**
2. Reconstruct the history of cross-well interference with **9812.**
3. Estimate cross-well transmissibility between pressure-tested **9812** and other rate-tested wells.
4. Assess gross impact from non-tested wells on well **9812.**
5. Estimate skin-factor and near-zone transmissibility of the well **9812**.

2. CONCLUSIONS

2.1. Results vs objectives

1. Formation pressure history has been reconstructed for pressure-tested well (within the period of the test: from 02.2009 to 10.2017).

Table. 2.1. Initial / current formation pressure at depth of 5050 m at drainage area of the pressure-tested well **9812**.

Initial pressure	**556 bara** @ 02.2009
Current formation pressure	**429.3 bara** @ 10.2017
Further trend	**Decrease**

Formation pressure reconstruction by MRT technology does not require well shut-ins. It can be used to build a formation pressure surveillance system avoiding production losses.

2. Quantitative parameters of cross-well interference are presented at Fig.2.1-2.2 and at table 2.2

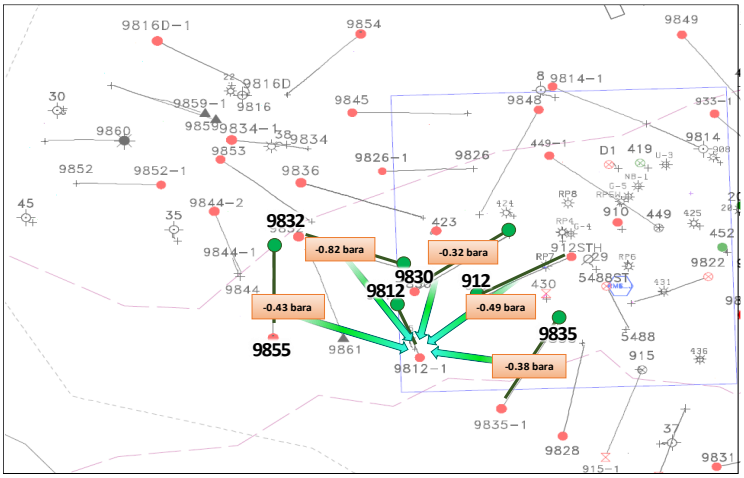

Fig. 2.1. Current interference @ 02.10.2017 (monthly pressure change in the pressure-tested well **9812** due to interfering wells).

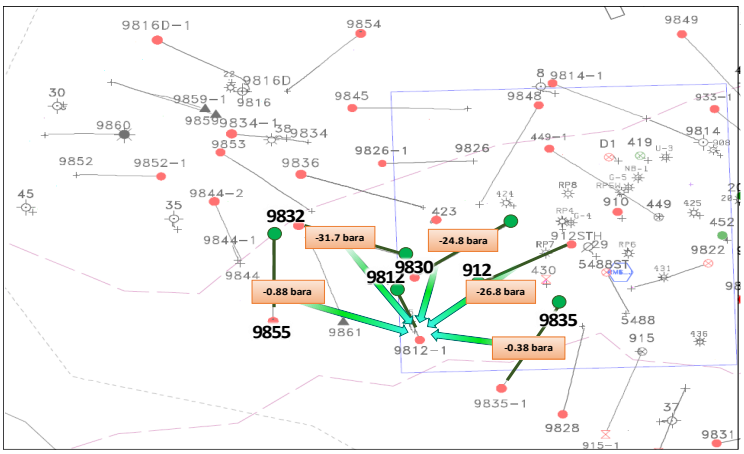

Fig. 2.2. Cumulative interference @ 02.10.2017 (total pressure change in the tested pressure-tested **9812** due to interfering wells).

3. Quantitative parameters of cross-well transmissibility are presented at Fig.2.3 and at table 2.2.

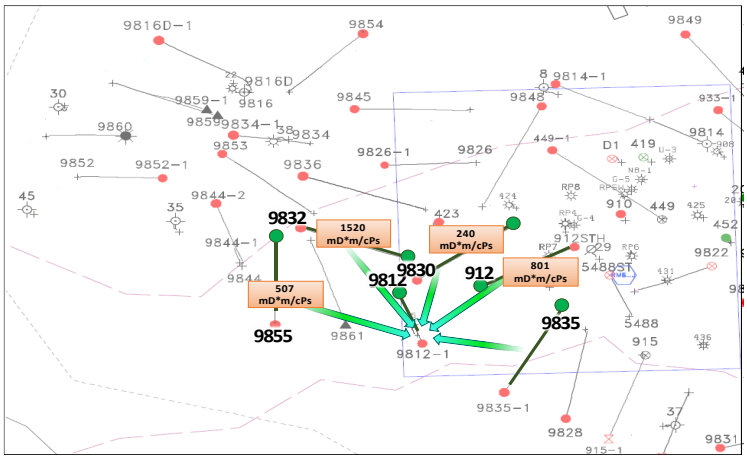

Fig. 2.3. Cross-well transmissibility between the wells.

Table. 2.2. Summary of the well interference and cross-well transmissibility

#	Interval	Cumulative impact δP, bara	Current impact * δP_{cur}, bara/month	Transmissibility σ, mD · m / cPs
1	9830 → 9812	-24.8	-0.32	240
2	9832 → 9812	-31.7	-0.82	1520
3	9835 → 9812	-9.6	-0.38	-
4	912 → 9812	-26.8	-0.49	801
5	9855 → 9812	-0.88	-0.43	507

* – for the last month of the test period

4. According to Multiwell Deconvolution analysis of pressure at drainage area of pressure-tested well **9812** remote wells' impact leads to formation pressure decline.

5. Reservoir/well diffusion model parameters are presented at table 2.3.

Table. 2.3. Pressure-tested well **9812** transient response results

Parameter, (units)	Value
Formation transmissibility, (mD·m/cPs)	485.1
Total Skin	-6.94
Formation permeability, (md)	0.79
Well productivity index (at the end of the test), (m3/(day·bara))	4.24
Formation pressure at 5050 m (at the end of the test), (bara)	429.3

2.2. Additional findings

1. Well productivity index was relatively constant during the test up to 05.2013 and was about 6.1 m^3/(day·bara). When BHP was decreased at 10.2017 well productivity index decreased to the value of 4.4 m^3/(day·bara). It can be due to formation damage or dissolved gas liberation near the wellbore because of BHP drop.

2. The biggest value of cross-well transmissibility is between the wells **9812** and **9832** (1520 md*m/cPs). Well **9832** also has the biggest current and cumulative influence in well **9812**.

3. Wells are in strong interference. Formation pressure decline due to production of the most influencing well **9832** (-31.7 bar) is only 1.03 times less than pressure decline due to production of well **9812** itself (-32.92 bar).

2.3. Recommendations

1. It is recommended to consider organizing a pressure maintenance system as formation pressure continues to drop, causing well productivity drop due to gas liberation. For best candidates for switching to injection it is recommended to perform MRT for all the wells in the area.

2. As production losses during PBU's are substantial, it is recommended to build a formation pressure surveillance system based on MRT, which will cancel frequent PBU's necessity.

3. FIELD SUMMARY

3.1. History and current production of the area around well 9812

Well **9812** was chosen as pressure-tested well.

Wells **9830**, **9832**, **2935**, **912**, **9855** were chosen as offset rate-tested wells.

According to well location and cumulative production (Fig. 3.1.1.) these wells could affect pressure-tested well **9812** the most.

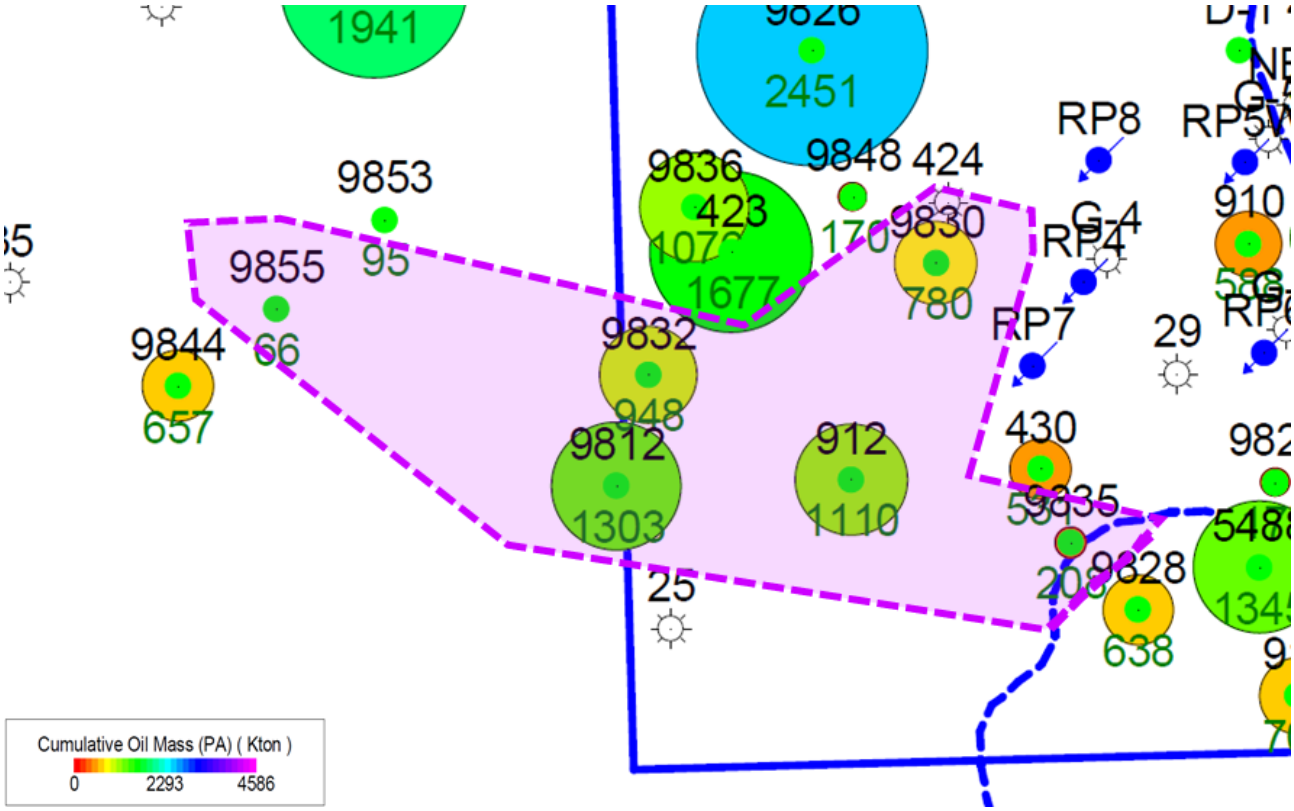

Fig. 3.1.1. Cumulative production bubble map

Current production map presented at Fig. 3.1.2.

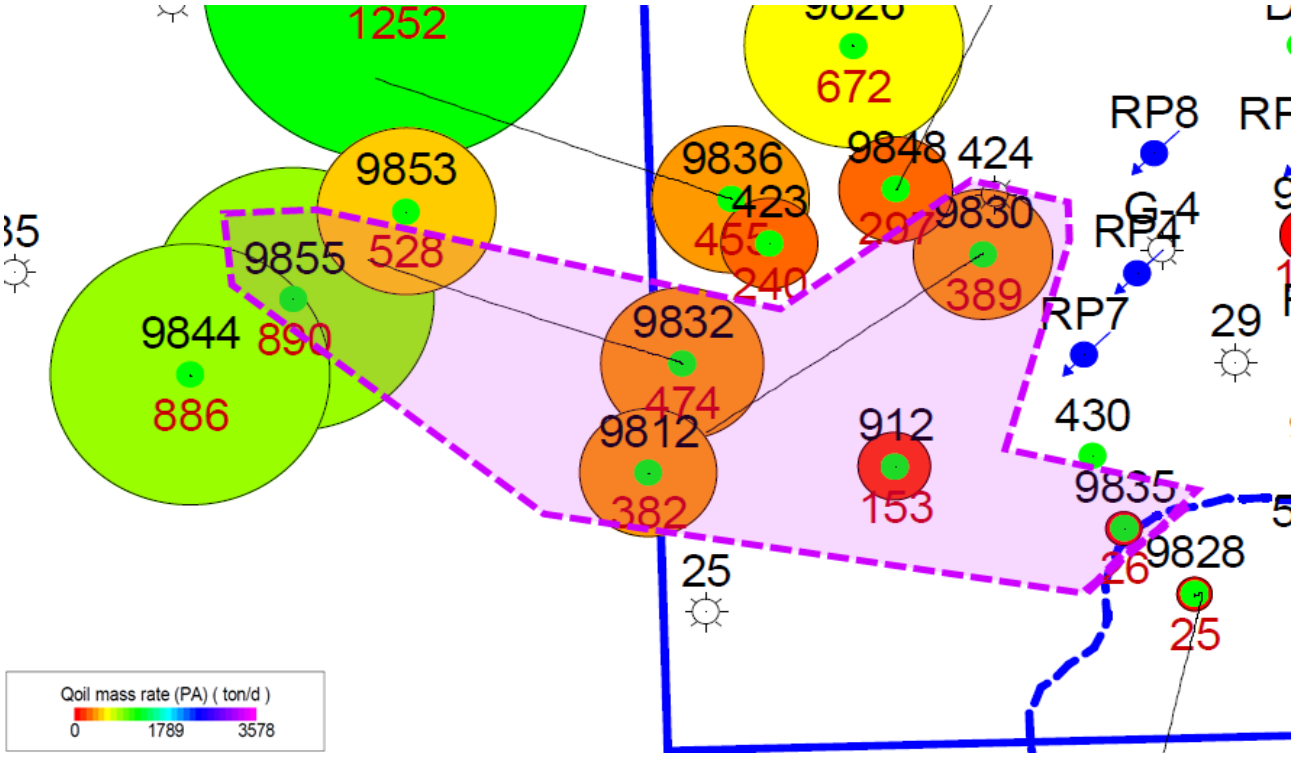

Fig. 3.1.2. Current production bubble map

3.2. Fluid PVT data

Table. 3.2.1. Reservoir fluid PVT data

#	Parameter	Abbreves	Value	Unit	Source
1	Formation temperature	T	70-90	^{0}C	FDP
2	Initial formation pressure	P_i	520-595	bara	FDP
3	Bubble point pressure	P_b	482-574	bara	FDP
4	Oil density @ surface	ρ_o	800	kg/m^3	FDP
5	Formation volume factor	B_o	1.8-2.3	m^3/m^3	FDP
6	Oil viscosity	μ_o	0.28-0.48	cPs	FDP

3.3. Formation properties

Table. 3.3.1. Average formation properties

#	Parameter	Abbreves	Value	Unit	Source
1	Average reservoir depth (TVDSS)	Z_{top}	5020	m	FDP
2	Reference depth (TVDSS)	Z	5050	m	FDP
4	Average effective oil formation thickness	h_{eff}	200	m	FDP
5	Initial formation pressure	P_i	520-595	bara	FDP
6	Average formation porosity	Φ	0.088	frac.	FDP
7	Total compressibility	c_t	$2.41 \cdot 10^{-4}$	1/bara	FDP

4. JOB SUMMARY

Period of production from 02.2009 to 10.2017 was analyzed. The production in tested area has started in 02.2009 with oil producer **9812**. Well locations are given at Fig.4.1. Wells production history is given at Fig.4.2.

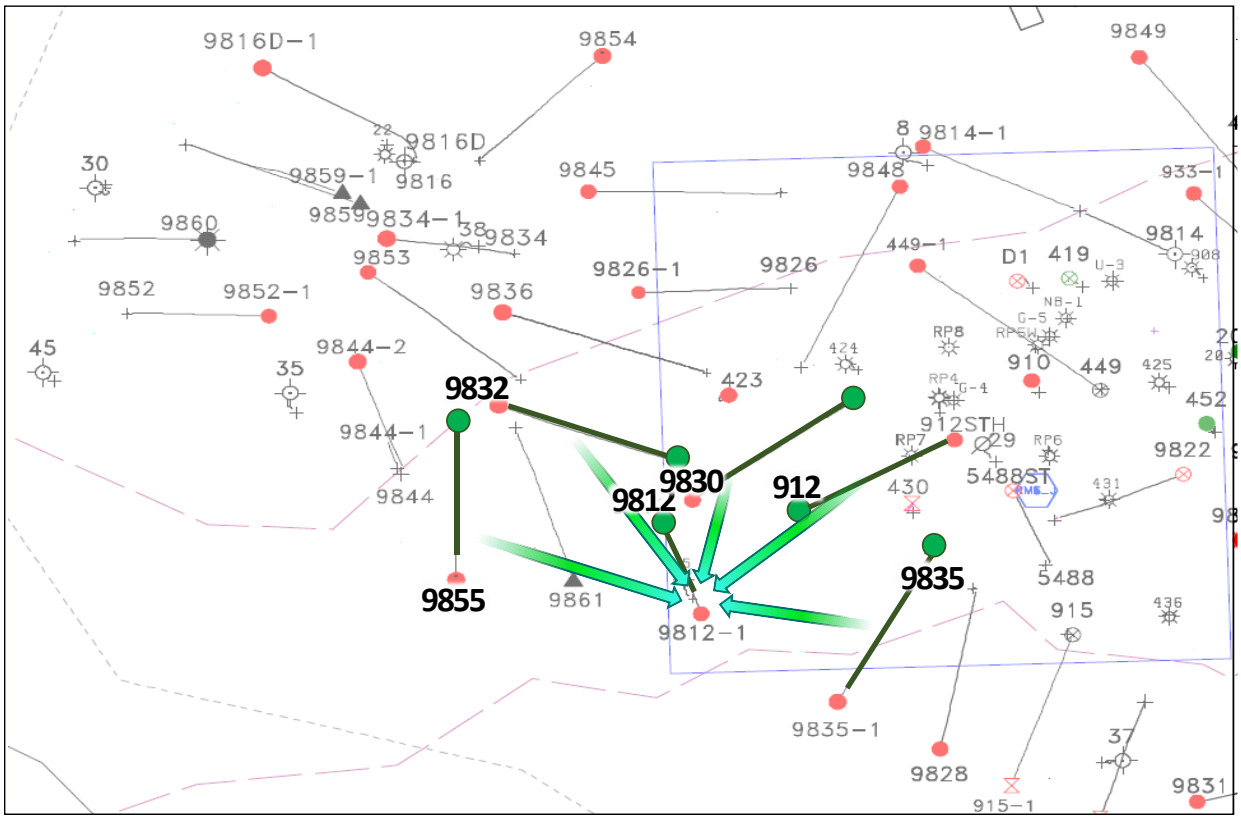

Fig. 4.1. Location map

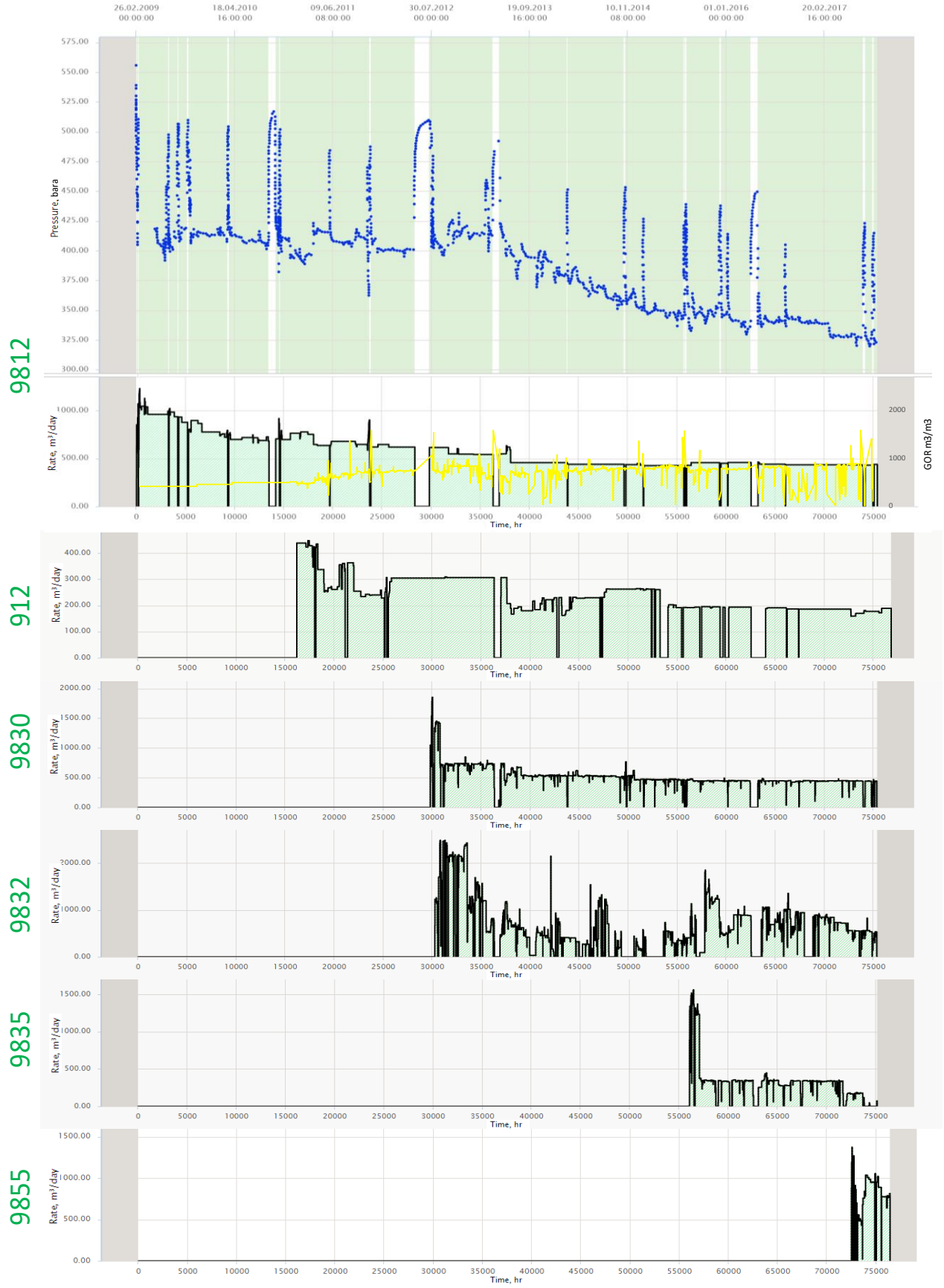

Fig. 4.2. Wells production history

5. DATA QC AND PROCESSING

5.1. Formation pressure Pe (t) reconstruction

Formation pressure history around pressure-tested well **9812** was reconstructed with multiwell deconvolution, results are given at Fig. 5.1.1.

Formation pressure estimates were taken from synthetic 1000 hrs build-ups, which corresponds to average pressure in drainage area.

Pressure drop was 148 bara at start, then decreased to 94 bara.

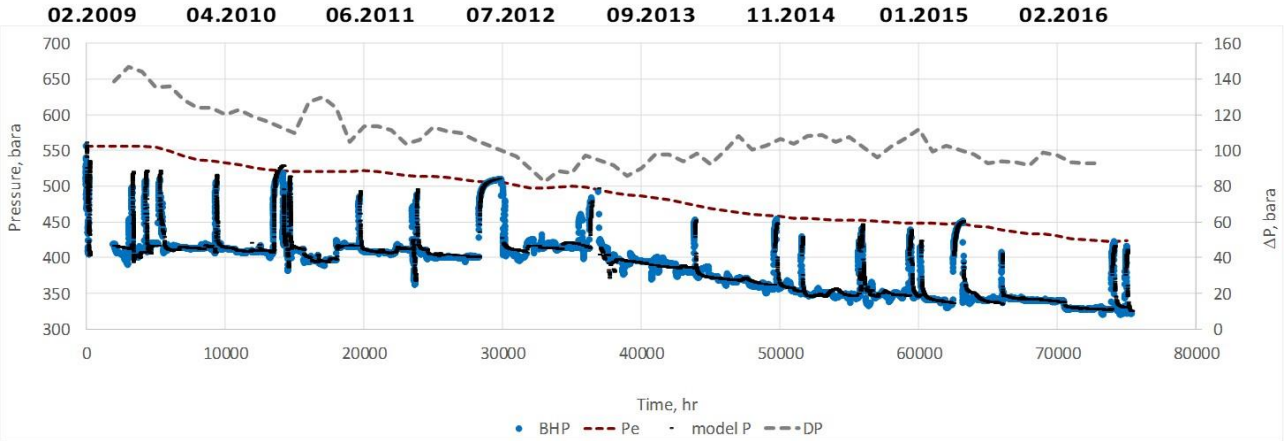

Fig. 5.1.1. Formation pressure history around well **9812** (green dotted line), reconstructed with multiwell deconvolution, pressure drop (red dotted line).

5.2. Cross-well influence Ψ

Cross-well influence estimates are given in table 5.2.1.

The key notices are:

- Well **9832** has the most negative influence on well **9812** BHP.

Table. 5.2.1 Cross-well influence estimates.

#	Well	Cum. impact, bara	Current impact, bara/month
1	**9830**	-24.8	-0.32
2	**9832**	-31.7	-0.82
3	**9835**	-9.6	-0.38
4	**912**	-26.8	-0.49
5	9855	-0.88	-0.43

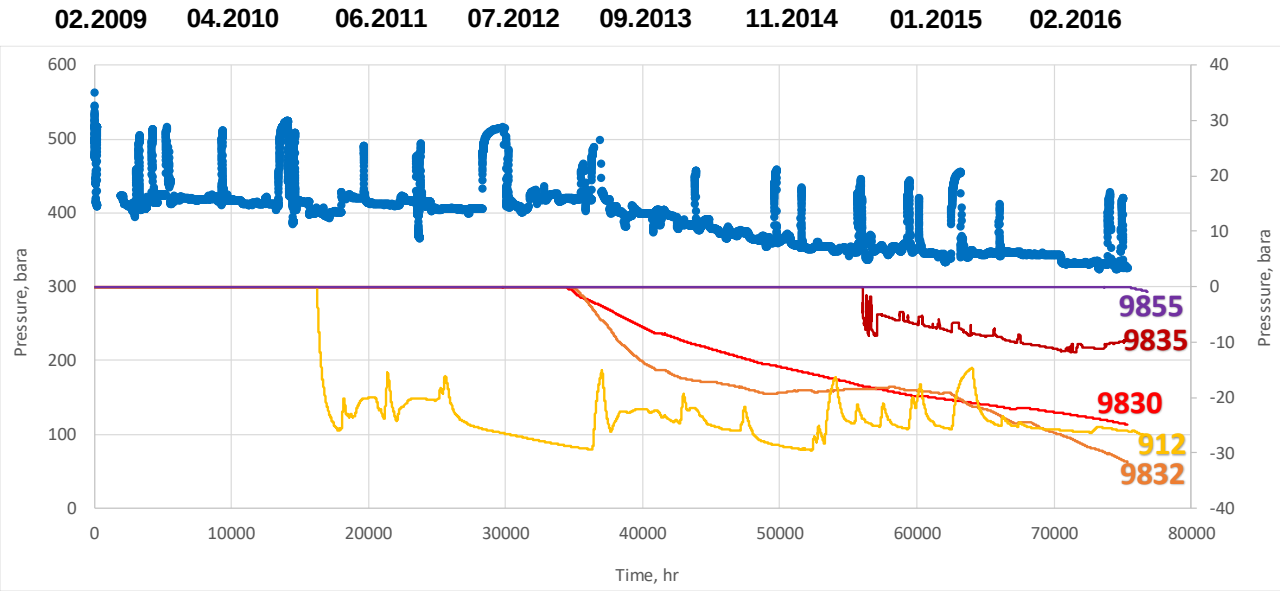

Fig. 5.2.1. Well **9812** BHP and restored pressure change history due to well interference

5.3. Cross-well transmissibility

Cross-well transmissibility estimates are given in table 5.3.1.

Transmissibility was estimated analysing cross-well transient responses (CTR) calculated with multiwell deconvolution. CTR is a function representing BHP response to neighbour well single rate production. CTR is being interpreted with interference test technique thus estimating transmissibility values.

Table. 5.3.1. Cross-well transmissibility

#	Interval	Cur. transmissibility σ, mD ·m / cPs
1	9830 → 9812	240
2	9832 → 9812	1520
3	9835 → 9812	-
4	912 → 9812	801
5	9855 → 9812	507

5.4. Far zone influence

Fig. 5.4.1. shows diagonal transient response of pressure-tested well **9812**.

Diagonal transient response (DTR) is a function representing BHP response to well single rate production.

Late time shows steady state flow.

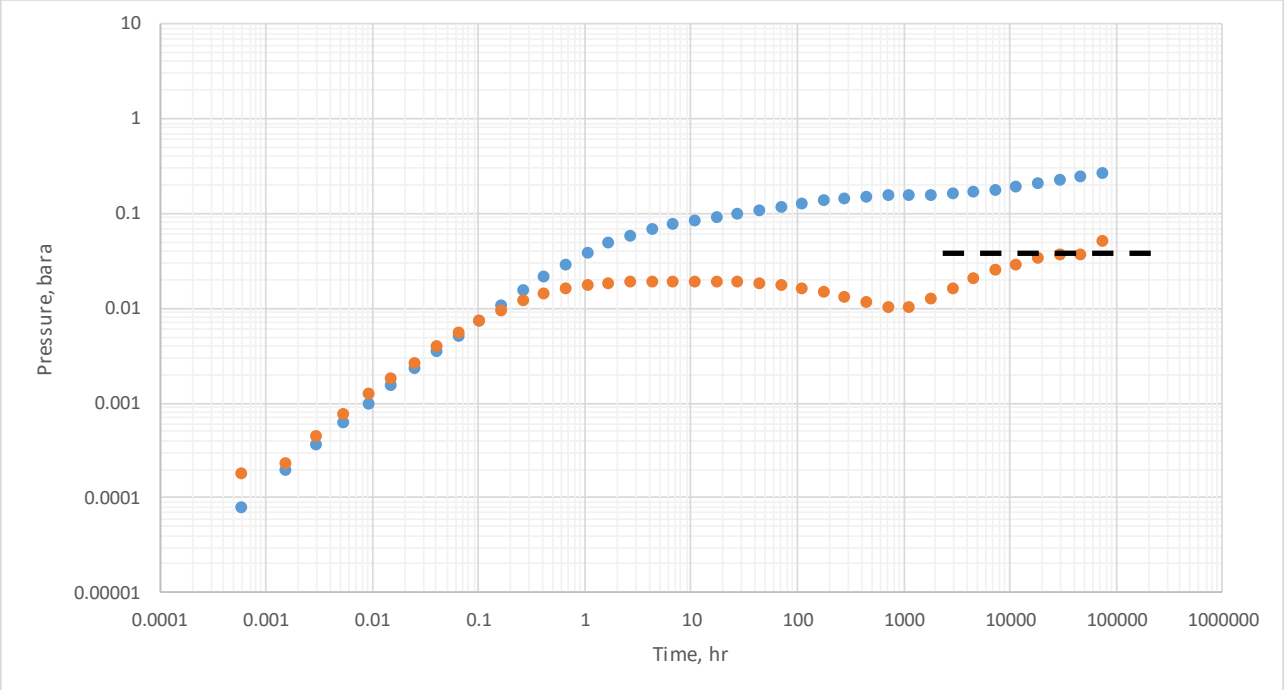

Fig. 5.4.1. Well **9812** transient response.

5.5. Well and formation parameters

The well was pressure-tested with multiwell retrospective testing technology. Long-term BHP monitoring was performed with PDHG pressure gauge.

“PolyGon” software has been used for interpreting.

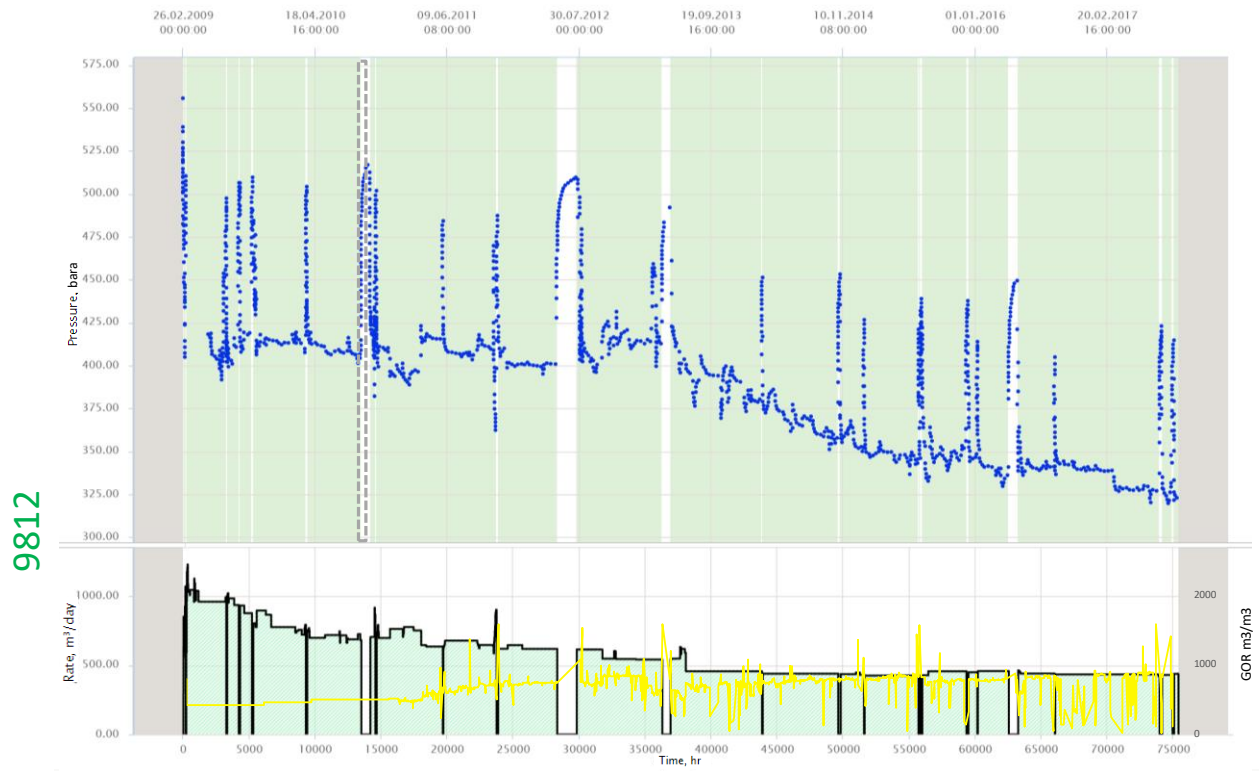

Fig. 5.5.1. Well **9812** production history where oil rate (black line) and GOR (yellow line) are shown.

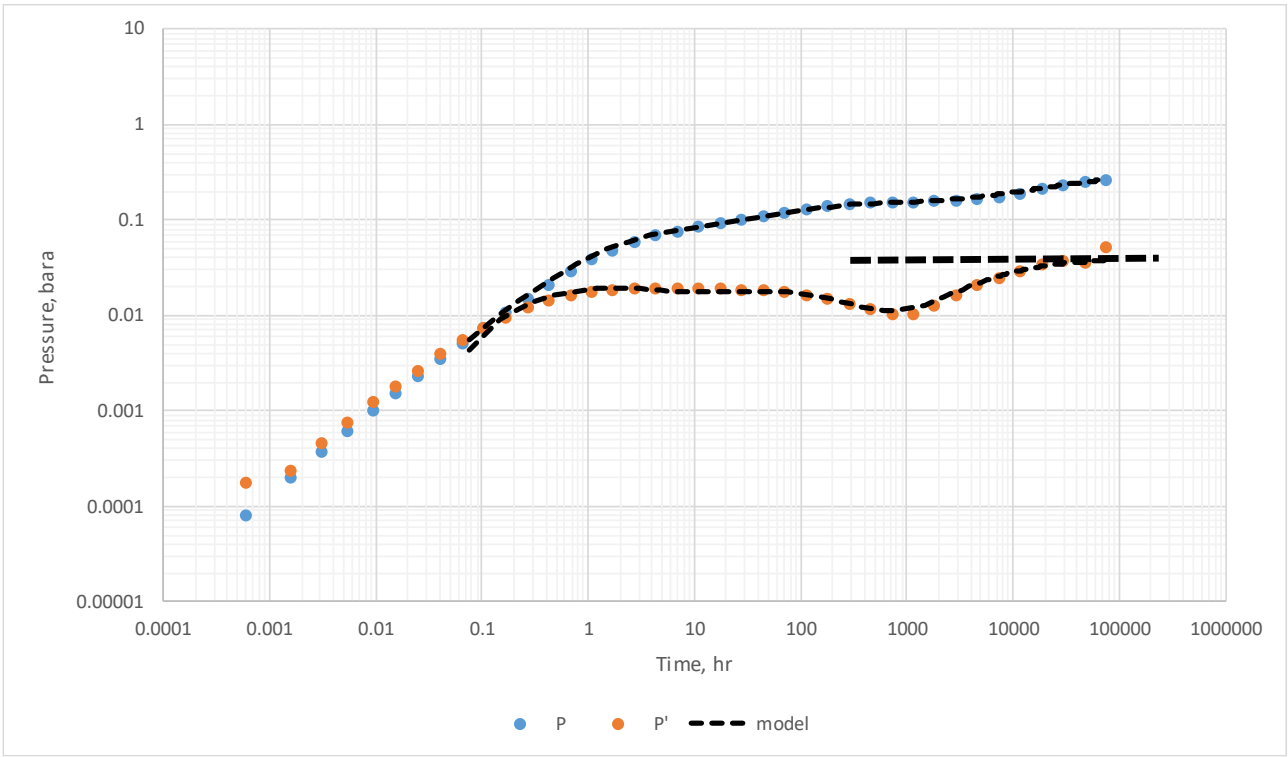

Fig. 5.5.2. Log-Log plot.

Transient response calculated with multiwell deconvolution was fit using the following diffusion model (see Table. 5.5.1):

Well model - Horizontal

Formation model - Homogenous

Boundary type - no boundary

Table. 5.5.1. 9812 well diffusion model parameters.

Parameter	Value
Transmissibility, (md·m/cP)	485.1
Skin Factor	-6.94
Permeability, (mD)	0.79
PI, (m3/(day·bara))	4.24
Formation pressure @ 02.10.2017, (bara)	429.3
BHP @ 02.10.2017r, (bara)	325.9

5.6. Quality check and statistics.

- **Rate history**

Rates of producing and injecting wells are provided by the contractor (av. 1 value per day).

- **Pressure history**

Pressure is provided in xls sheet with PDHG gauge values (av. 1 value per 1-2 sec).

Pressure data was recalculated to the reference depth (5050 m) using hydrostatic equation.

5.7. PI analysis

Surface productivity index at the end of the test was

J_{sep} = 4.24 m^3/(day·bara).

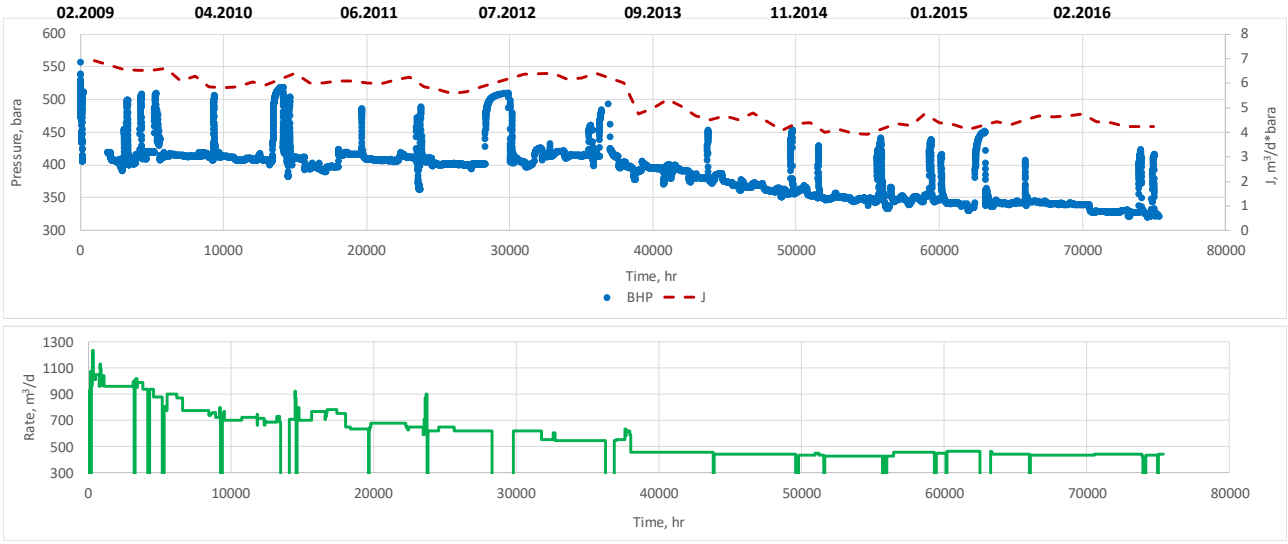

Fig. 5.7.1. Pressure (blue line), rate (green line) and PI (red dotted line) of well **9812**

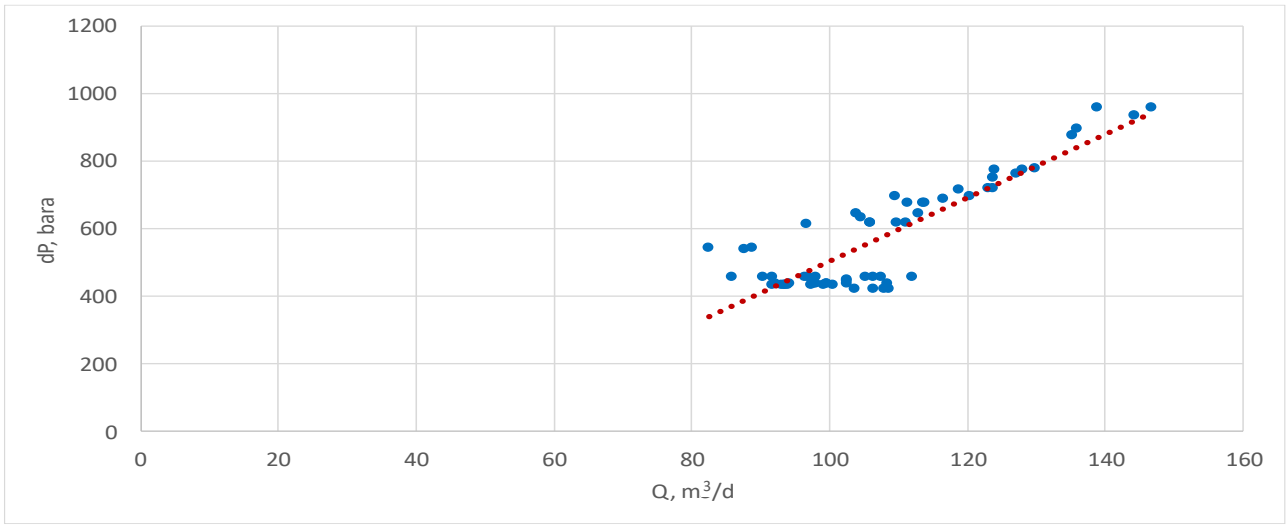

Fig. 5.7.2. Indicator plot for well **9812**.

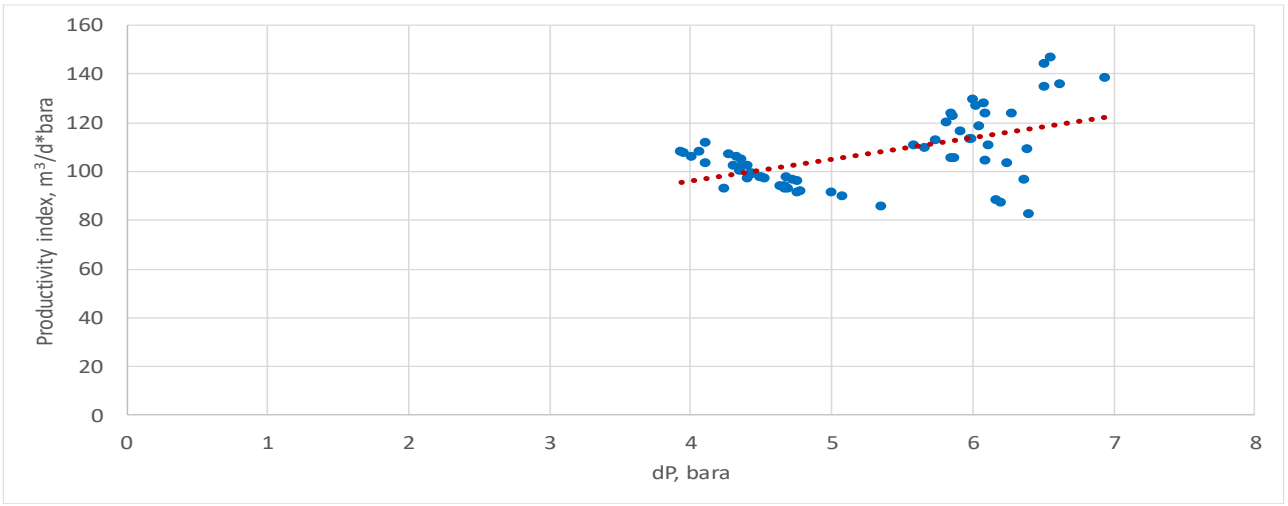

Fig. 5.7.3. PI of well **9812** depending on pressure drop.

5.8. Transient analysis

Fig. 5.8.1 shows conventional transient analysis for well **9812** (Pressure build-up).

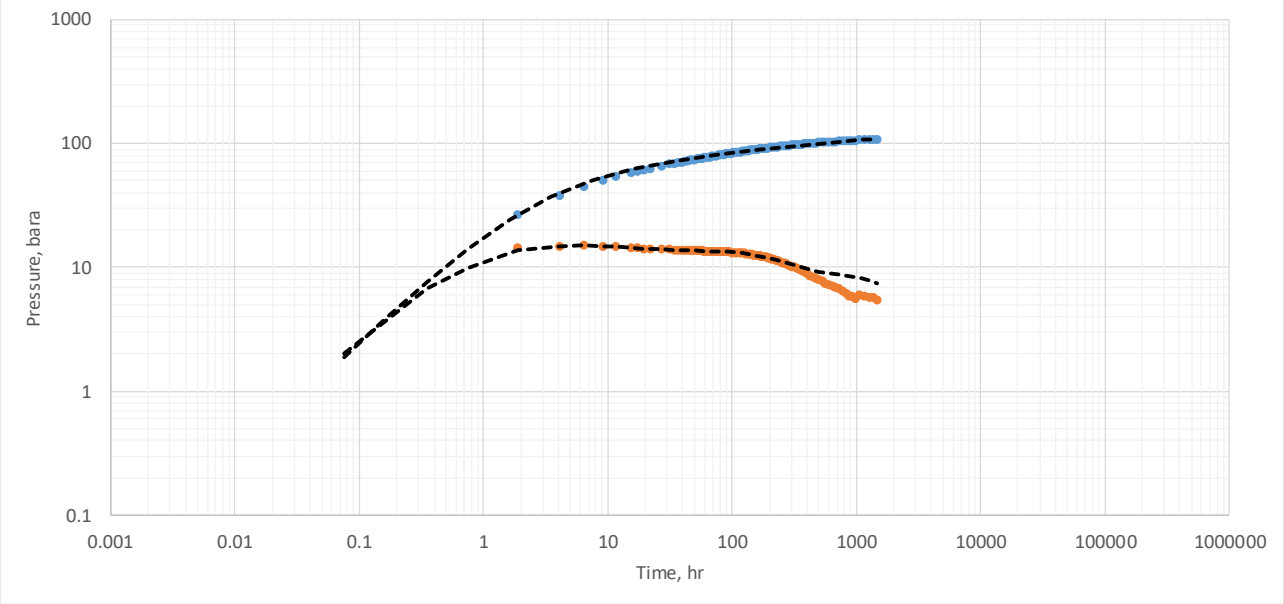

Fig. 5.8.1. PBU log-log plot.

Table. 5.8.1. Diffusion model by conventional transient analysis (incorrect).

Parameter	Value	Units
Total Skin	-6.5	
Transmissibility	428	mD ·m/cPs
WBS	1.97	m^3 / MPa
Permeability	0.7	mD
Well length	780	m
kz/kr	0.3	
Boundary	230	m

5.9. Radial deconvolution

Rates and pressures history of well **9812** were processed with radial multiwell deconvolution considering cross-well influence of wells (**9830**, **9832**, **9835**, **912**, **9855**).

Radial deconvolution is a task where only one well pressure curve is being processed, fitting its history and the influence of neighbor wells.

Radial deconvolution (RDCV) weights calibration

Weights Wc и Wq were calibrated using all historical pressure/rate data.

Following weights were used:

W_c	W_q
10	1

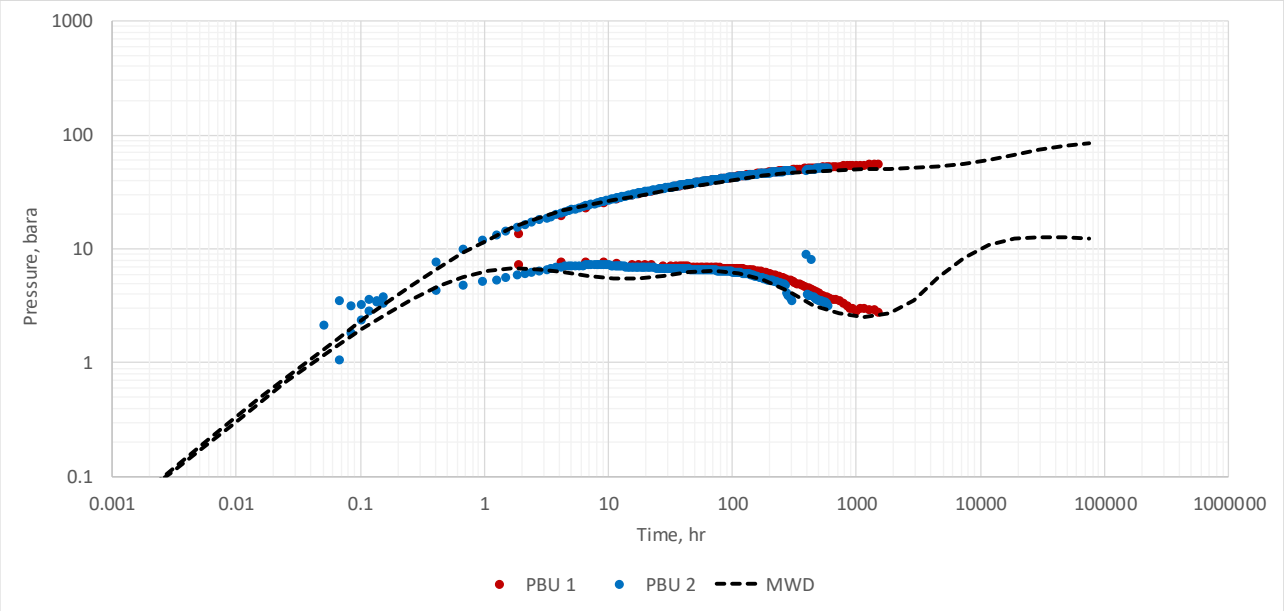

Fig. 5.9.1. Log-log comparison of DTR by RDCV and conventional transient analysis

Data processing

As a result of radial deconvolution:

- Rate history was corrected (Fig. 5.9.2)
- Formation pressure and pressure drop history was restored (Fig. 5.9.2.)
- 5 transient responses reconstructed: 1 diagonal (Fig. 6.4.4) and 4 cross-well (Figs. 5.9.3 – 5.9.7)

Radial deconvolution fitting quality control is shown at Fig. 5.9.2.

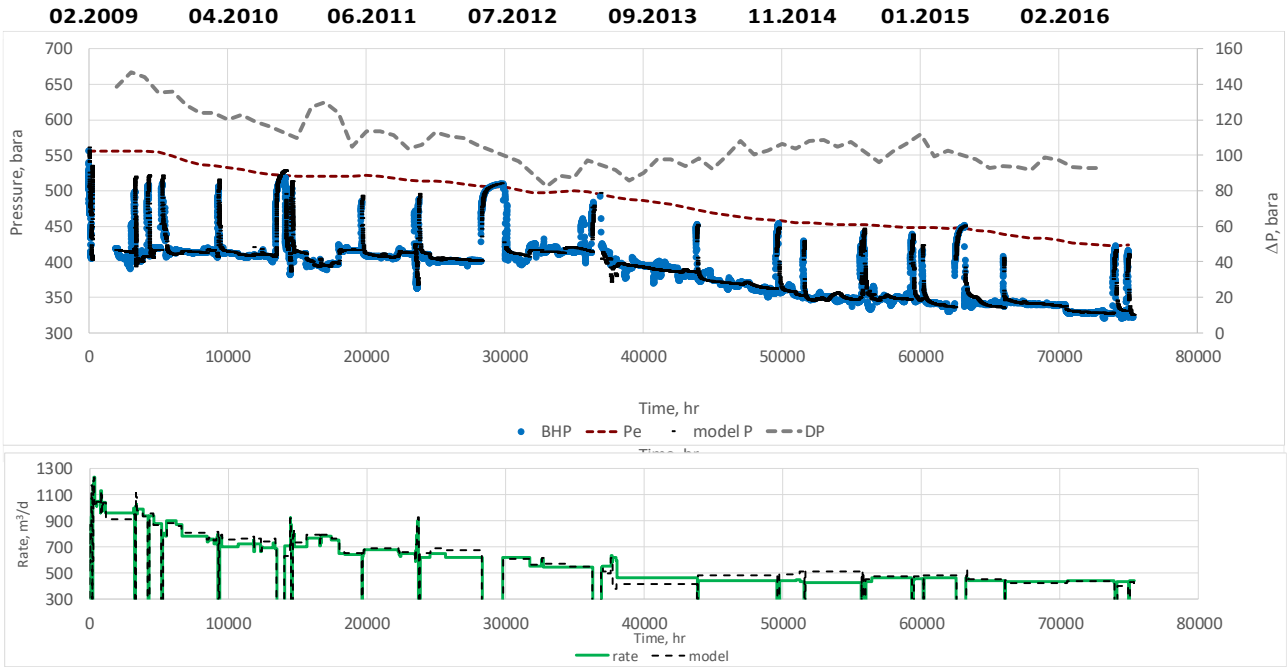

Fig. 5.9.2. RDCV fitting quality control.

Rate/pressure correction analysis

Rates mean square deviation is 12.7 m^3/day, which is 2.07 %.

Pressures mean square deviation is 9 bara, which is 1.06 %.

It means that the rate was registered relatively accurately for well **9812.**

Restored formation pressure analysis

History of formation pressure (green dotted line at Fig. 5.9.2) shows the monotonous decrease.

Analysis of Diagonal Transient response

Late time shows steady state flow without the nearest wells influence.

Cross-well influence analysis

Table. 5.9.1. Cross-well influence parameters.

#	Interval	Cum. impact δP, bara	Cur. impact δP_{cur}, bara/month	Transmissibility σ, mD·m / cPs
1	9830 → 9812	-24.8	-0.32	240
2	9832 → 9812	-31.7	-0.82	1520
3	9835 → 9812	-9.6	-0.38	-
4	912 → 9812	-26.8	-0.49	801
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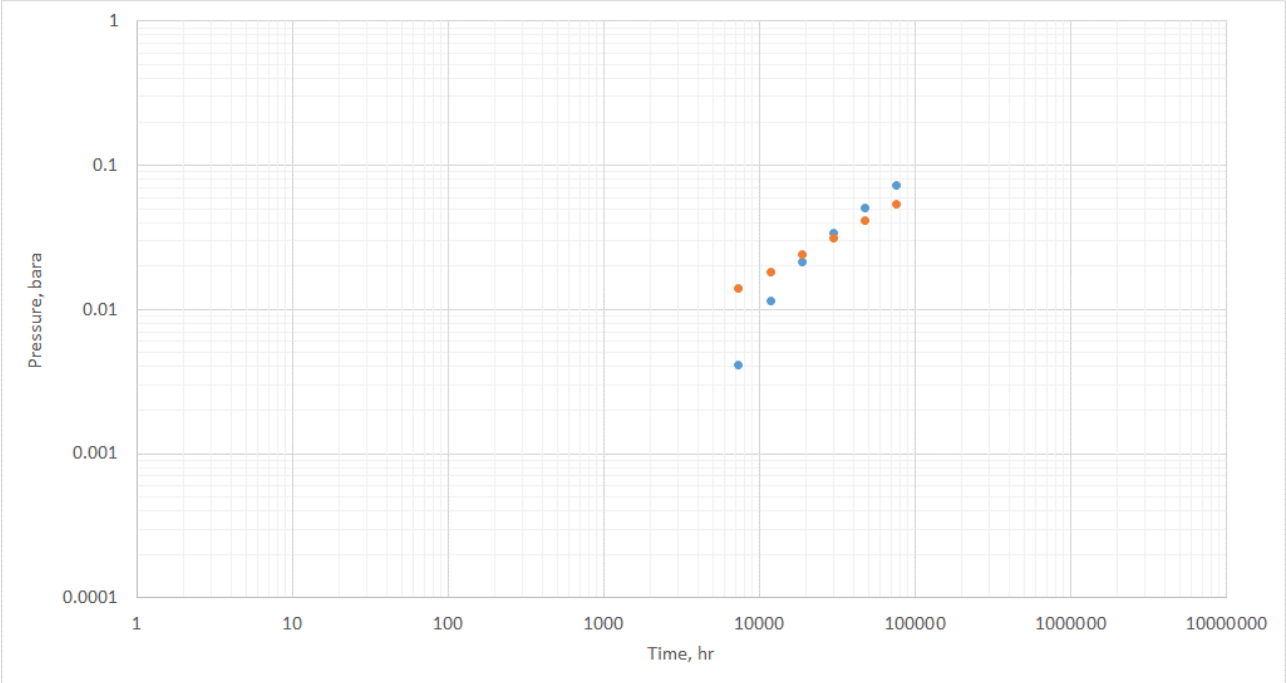

Fig. 5.9.3. Cross-well transient response **9830** → **9812**

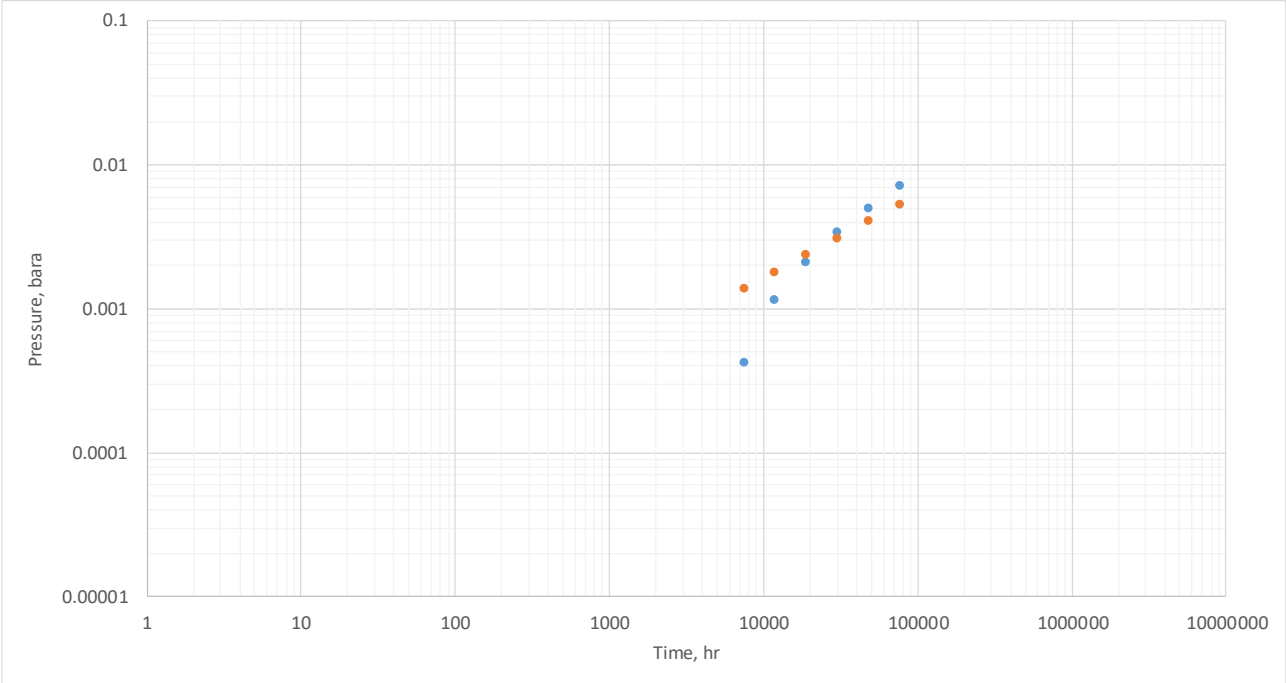

Fig. 5.9.4. Cross-well transient response **9832** → **9812**

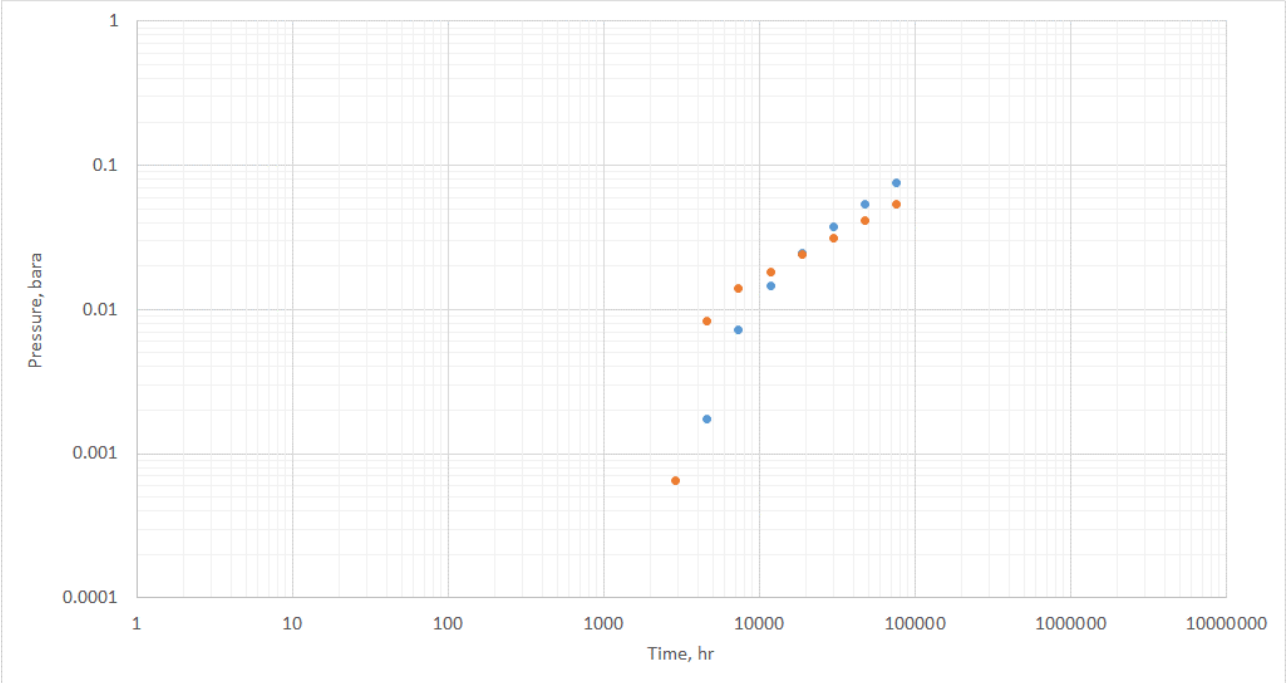

Fig. 5.9.5. Cross-well transient response **9855** → **9812**

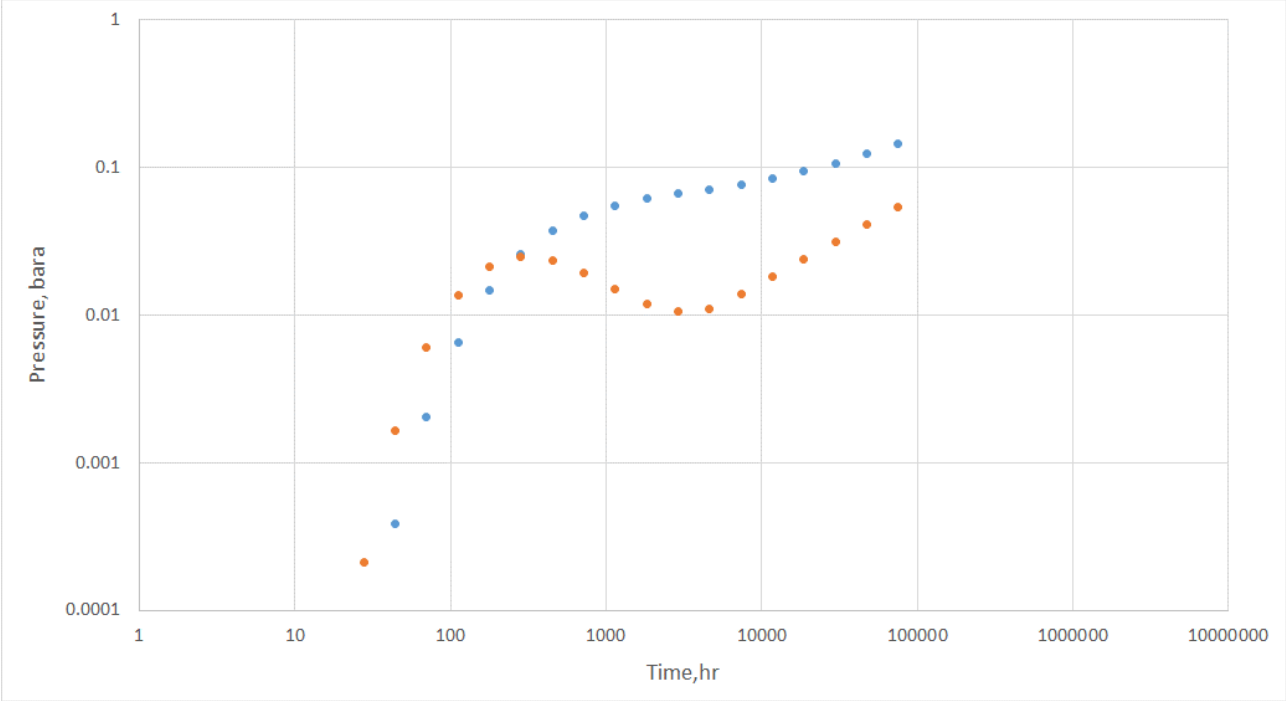

Fig. 5.9.6. Cross-well transient response **912** → **9812**

6. REFERENCE LIST

1. MRT work performance regulations, Sofoil, 2017
2. MRT report template, Sofoil, 2017
3. Multi-well deconvolution handbook, Sofoil, 2017
4. Multi-well deconvolution features for ESP gages handbook, 2017
5. PolyGon software – reference manual, Sofoil, 2016

7. ABBREVIATION

#	Abbreves.	Definition
1	MRT	Multiwell retrospective test
2	Well-test	Transient well-test analysis
3	DCV	Deconvolution
4	RDCV	Radial multiwell deconvolution
5	CTR	Cross-well transient response
6	DTR	Diagonal transient response
7	TR	Transient response
8	Sal	Water salinity
9	T	Formation temperature
10	P_b	Bubble-point pressure
11	R_s	Gas saturation
12	ρ_o	Oil density @ surface conditions
13	c_o	Oil compressibility
14	B_o	Oil formation volume factor
15	μ_o	Oil viscosity
16	ρ_w	Water density @ surface conditions
17	c_w	Water compressibility
18	μ_w	Water viscosity
19	Z_{top}	Average depth of the formation top
20	Z_{OWC}	Oil-water contact depth
21	h	Average formation thickness
22	h_{net}	Net formation thickness
24	$h_{welltest}$	Connected net formation thickness between the wells
25	P_i	Initial formation pressure
26	P_e	Current formation pressure
27	ϕ	Porosity
28	c_r	Rock compressibility
29	k_a h	Absolute permeability * net thickness product
30	J	Productivity index
31	Ψ	Cross-well influence
32	$\delta P = \left.\frac{dP}{dt}\right\|_{q=q(t)}$	Well interference (monthly pressure changes due to the influence of the nearby well)