Field Re-Development Planning for an Oil Rim – North Africa

SIS Forum 2019

17-19 Sep. 2019

Schlumberger

Project Goals & Objectives

- Creating a field reservoir simulation for Hassi R'Mel South field, Reservoir TAG-A.
- Assess the gas injection reduction and/or stop on the gas, condensate and water production.
- Evaluate the reservoir pressure decline associated to these gas injection sensitivities.
- Highest recovery factor related to the most optimum cost will be selected among the development plan scenarios that will be agreed between Sonatrach and Schlumberger

Project Plan

Task	Description	March				April				May				June				July				August				September				October			
		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20	W21	W22	W23	W24	W25	W26	W27	W28	W30	W31	W32	W33
Milestones					♦														♦						♦								♦
1	Phase 1 - Data Collection and Database Creation																																
2	Phase 2 - Static Model Review																																
2a	Phase 2a Optional - Static Model Update																																
3	Phase 3 - Basic Reservoir Engineering Review and Analysis																																
4	Phase 4 - Dynamic Model Construction, Initialization and Upscaling																																
5	Phase 5 - Dynamic Model History Matching																																
6	Phase 6 - Production Forecasting																																
7	Phase 7 - Reporting and Presentations																																
8	Integrated Asset Model																																
		March				April				May				June				July				August				September				October			
		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20	W21	W22	W23	W24	W25	W26	W27	W28	W30	W31	W32	W33

Milestones

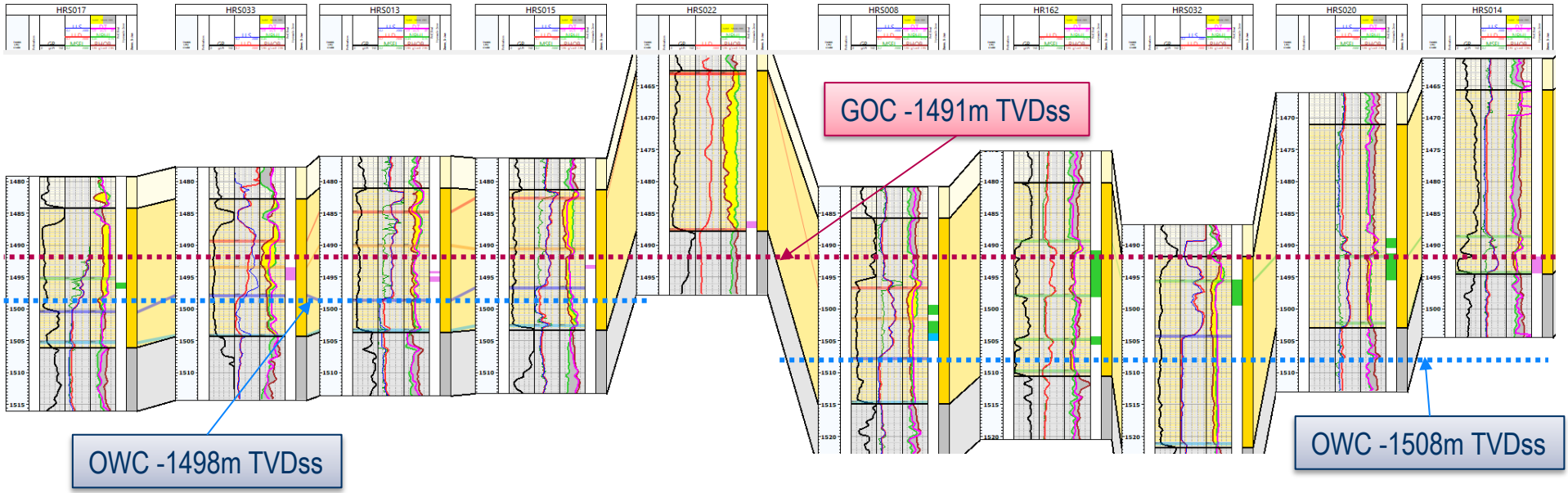
- Upon completion of Phase 2 – Static Model Review.
- Upon completion of Phase 4 – Construction and Initialization of Dynamic Model
- Upon completion of Phase 5 – Dynamic Model History Matching
- Upon completion of the project.

Fluid contacts

Production results flags
- Gas+Oil
- Oil
- Water

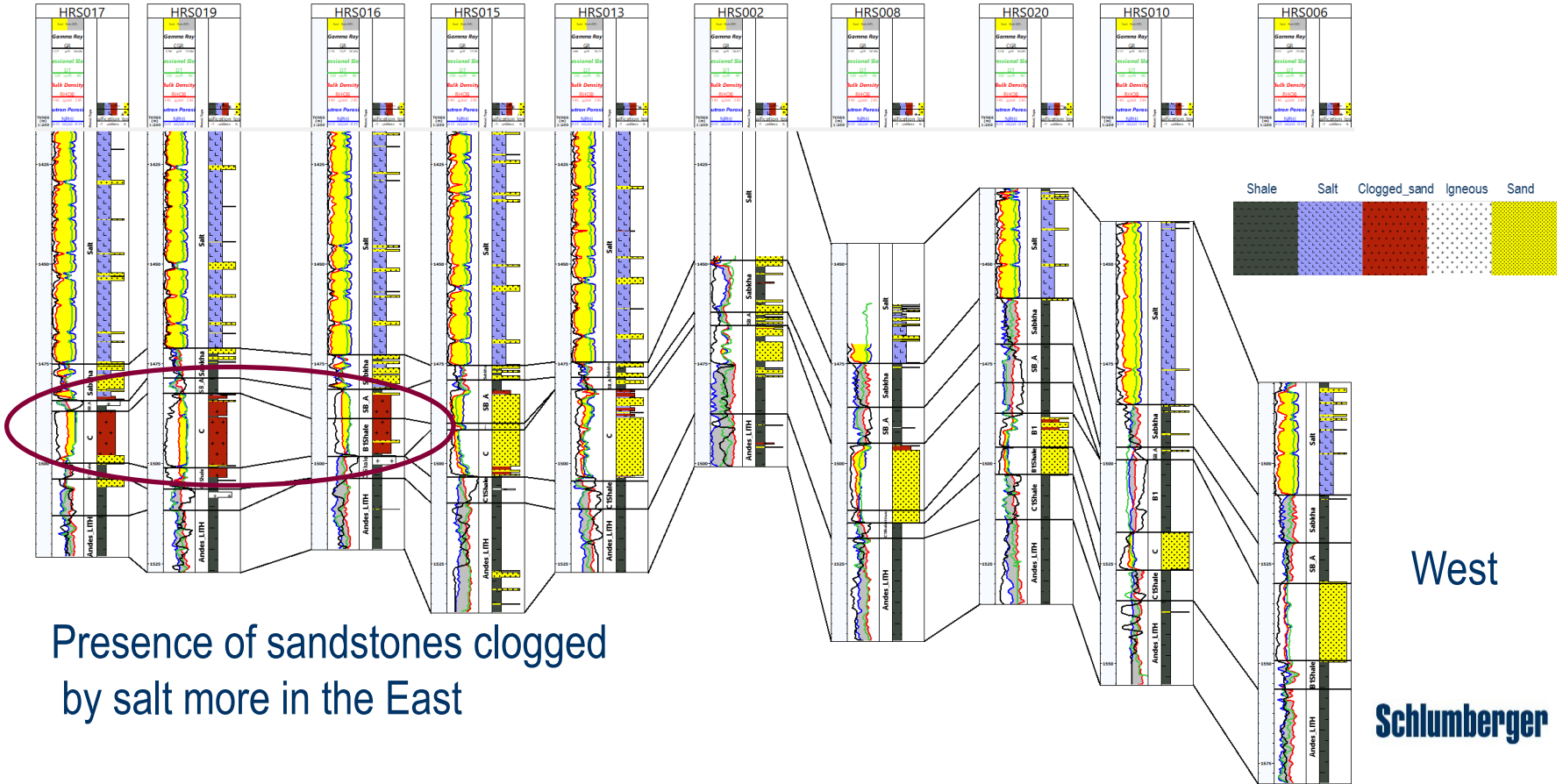
West

East



Schlumberger

Lithofacies correlations between wells



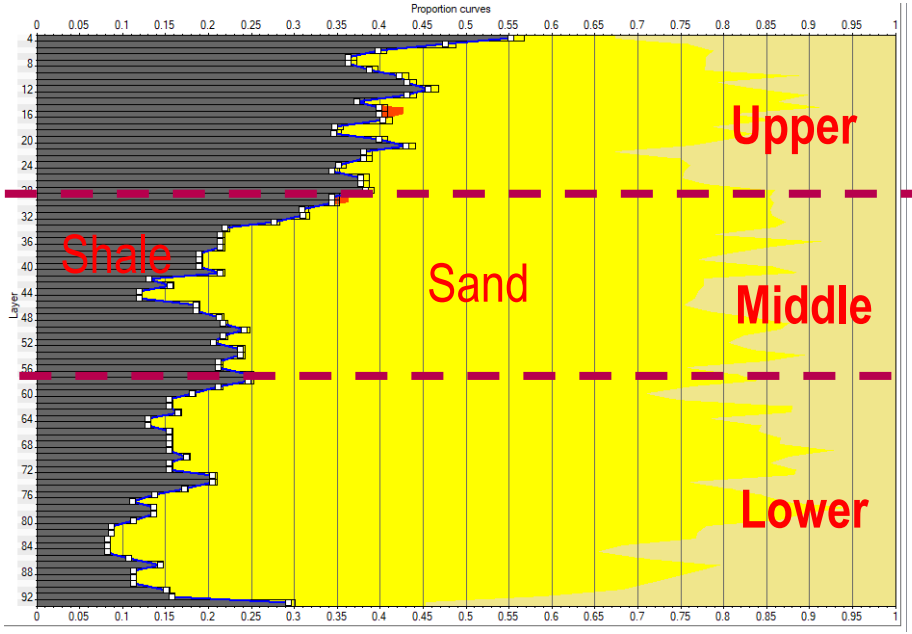
Presence of sandstones clogged by salt more in the East

Schlumberger

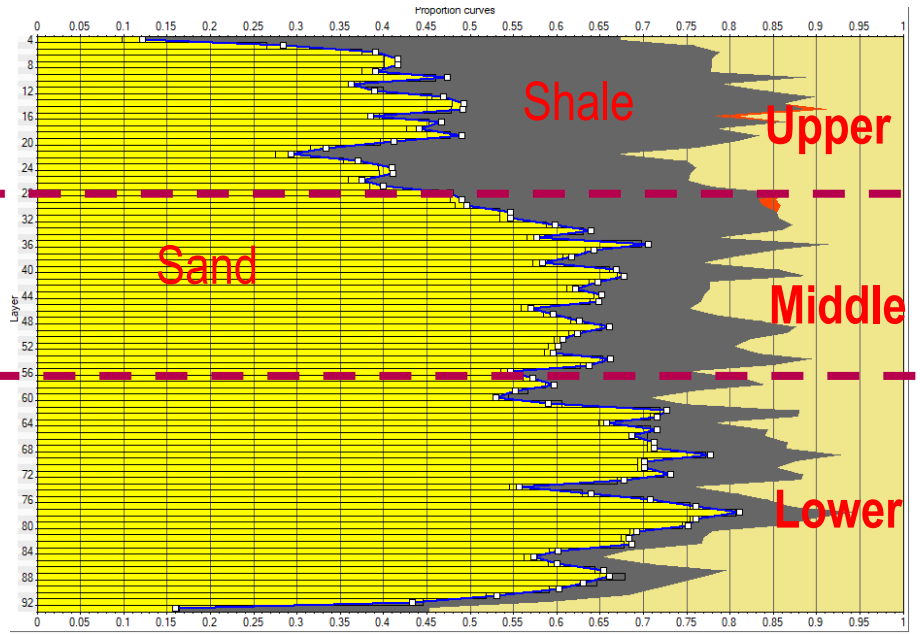
Phase-2a : HRS Static Model

Triassic (A+B+C)

Vertical Proportion of Shale



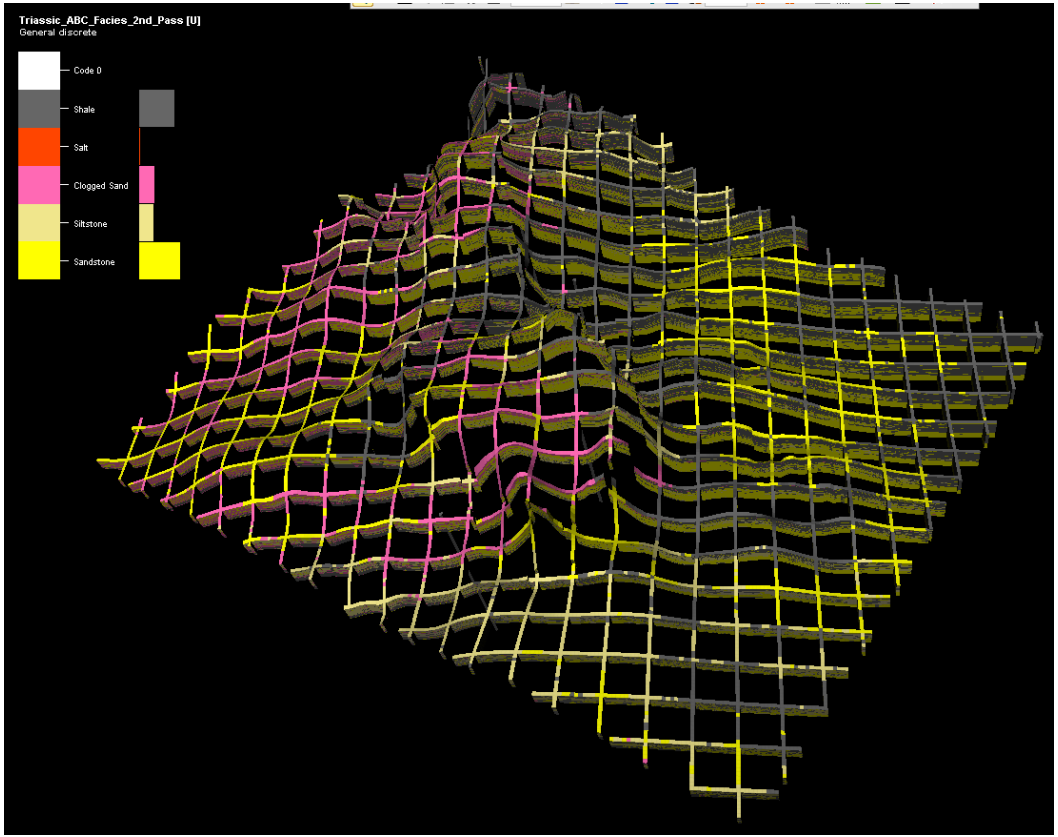
Vertical Proportion of Sandstone



Fluvial energy reduces towards top of the reservoir

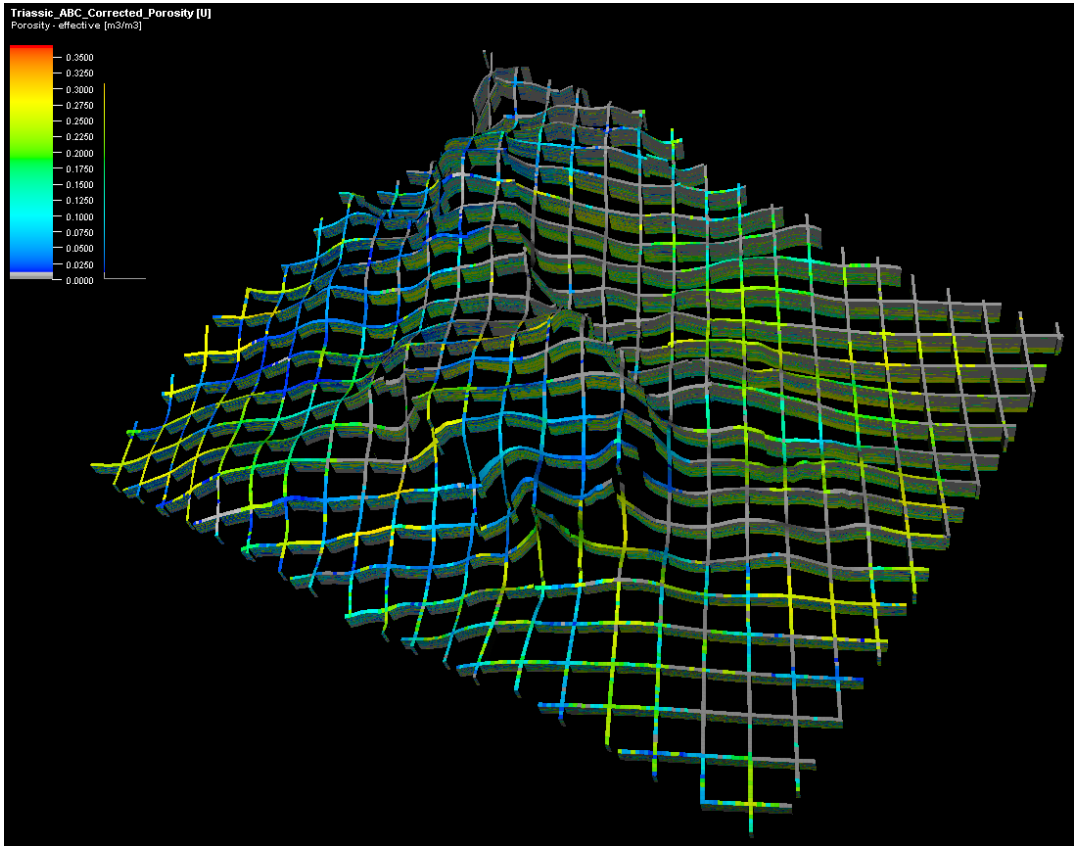
Phase-2a : HRS Static Model Update

View of the 3D Facies Model



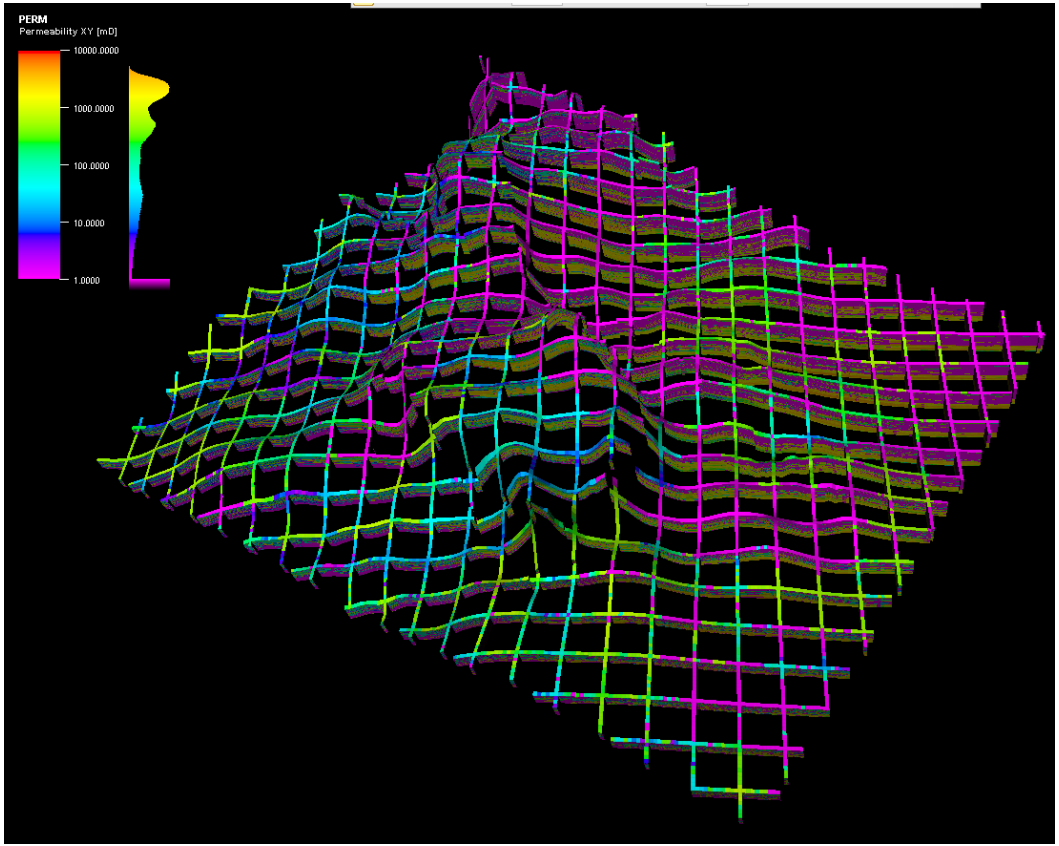
Phase-2a : HRS Static Model Update

View of the 3D Porosity Model



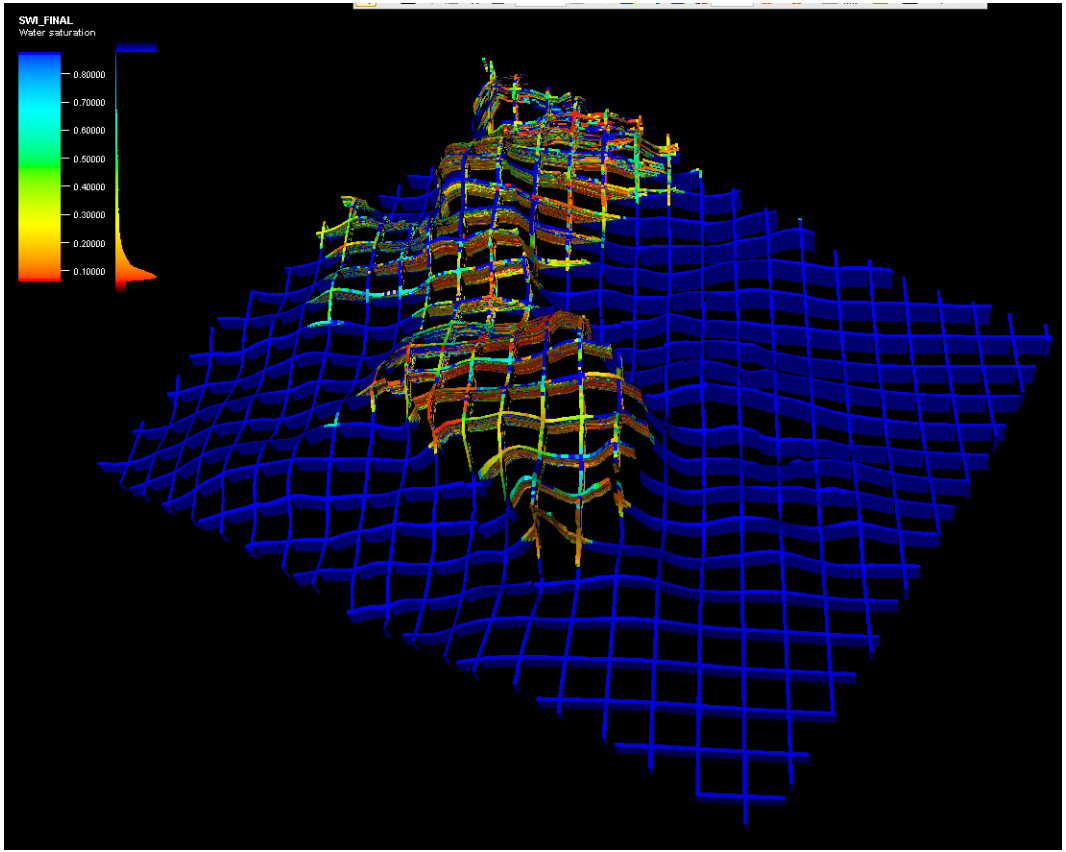
Phase-2a : HRS Static Model Update

View of the 3D Permeability Model



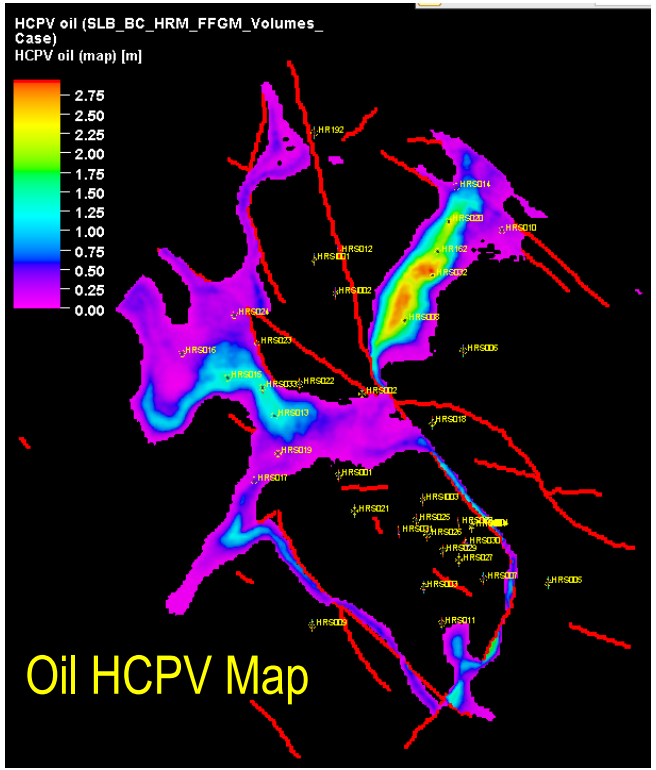
Phase-2a : HRS Static Model Update

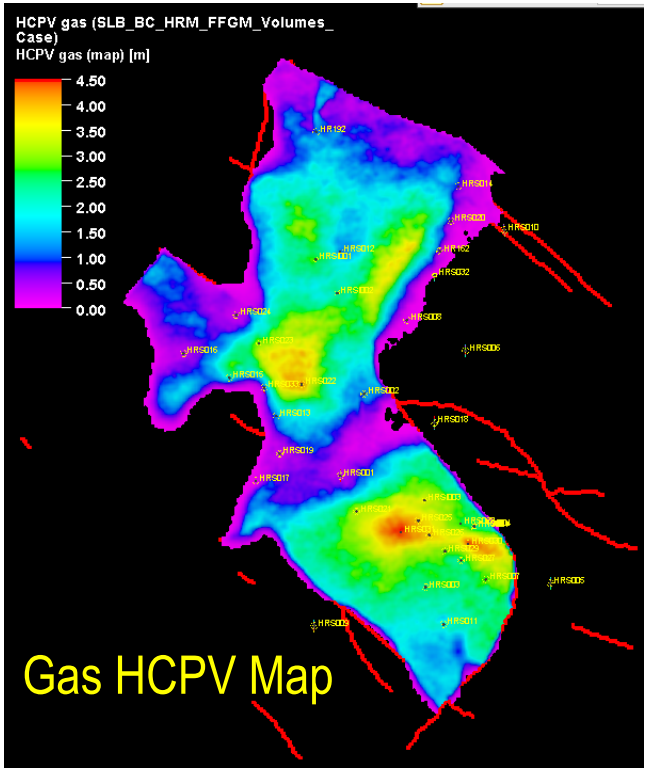
View of the 3D Sw Model



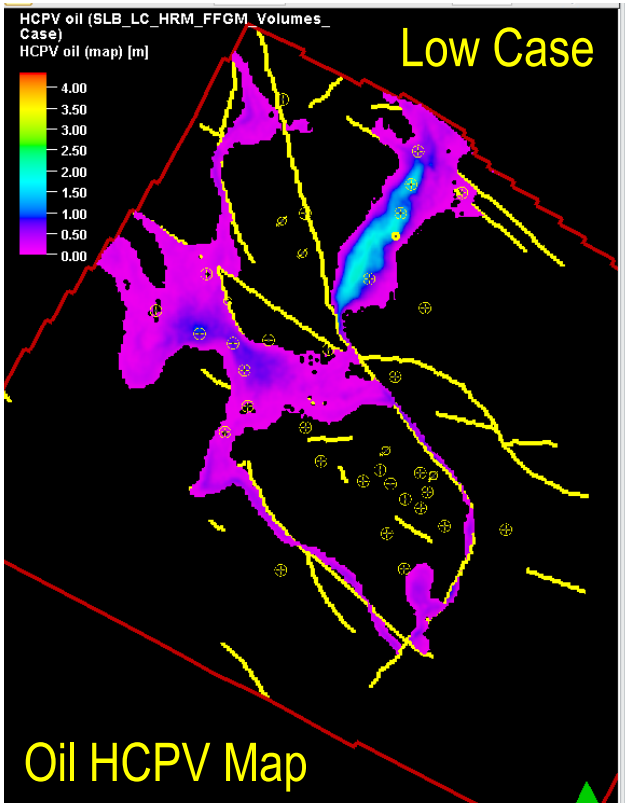
Phase-2a : HRS Static Model Update

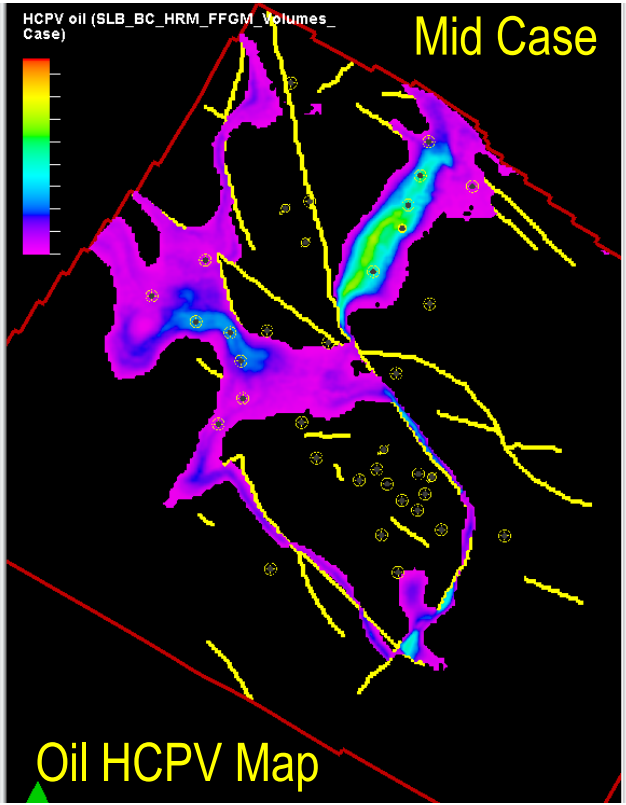
Mid Case or Best Case Volumetric Estimation Results

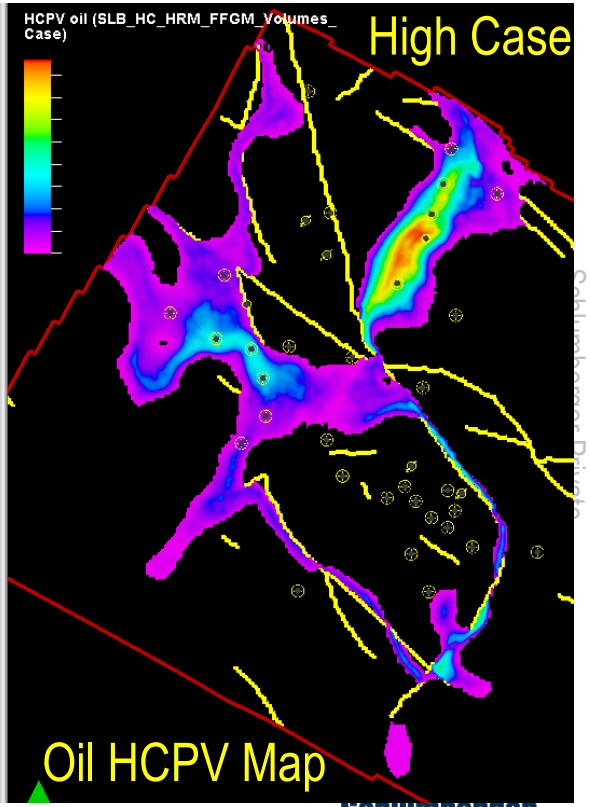




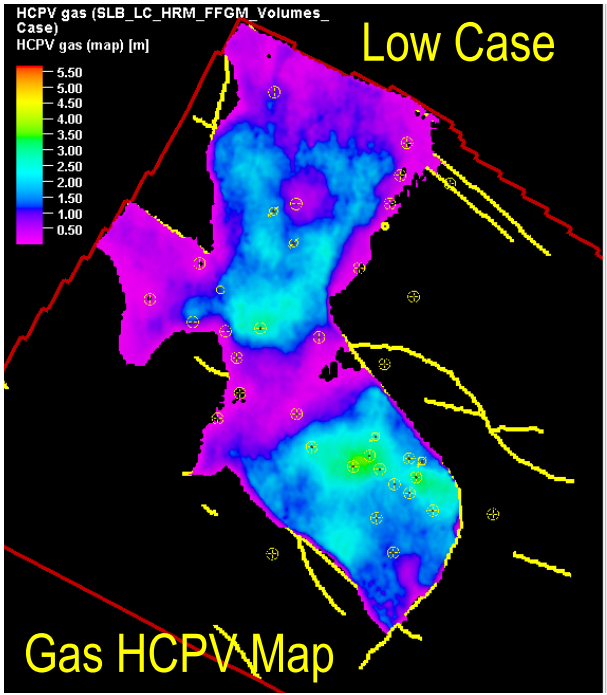
Phase-2a : HRS Static Model Update

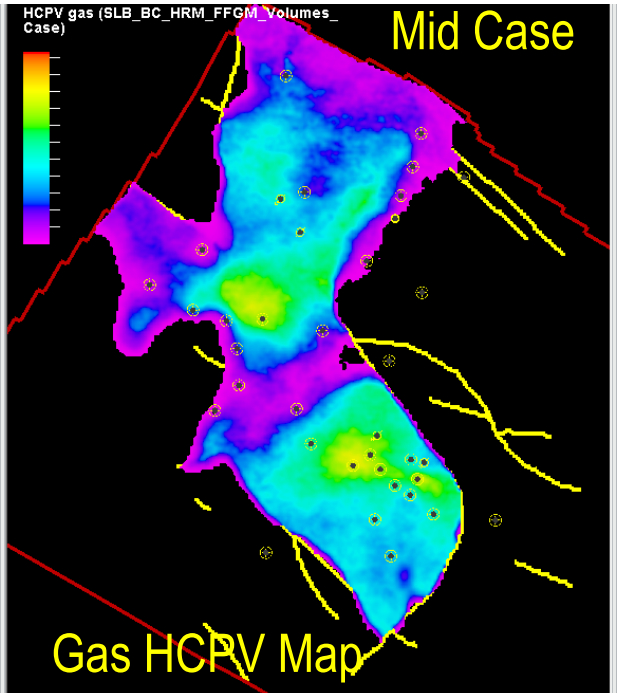


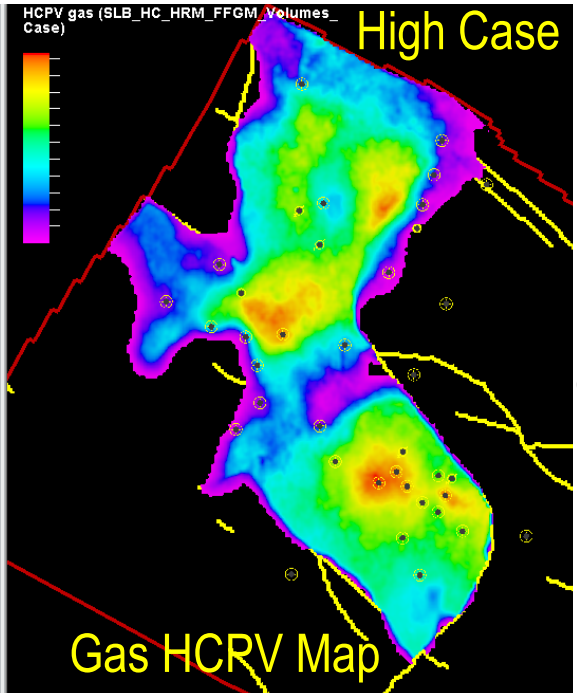




Phase-2a : HRS Static Model Update

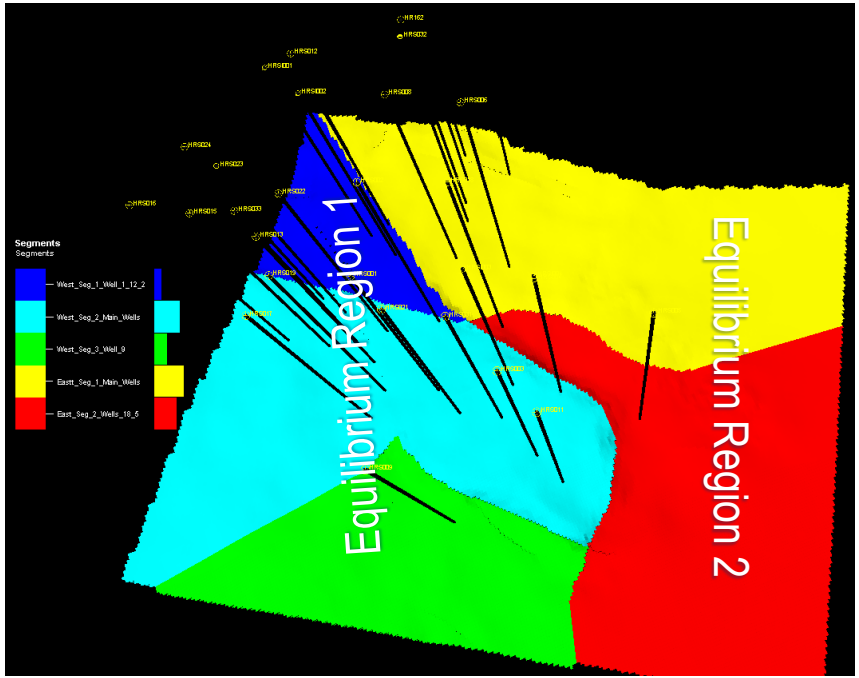






Dynamic Simulation Model Input Data

- Equilibrium Regions and Model Segments



Make fluid model

Make fluid model

Create new: Compositional model 1

Edit existing: EOS_Sample_15_May_4_Region_Swap_WOC

Model type: Compositional

General | Components | Interactions | Samples | Water | Initial conditions

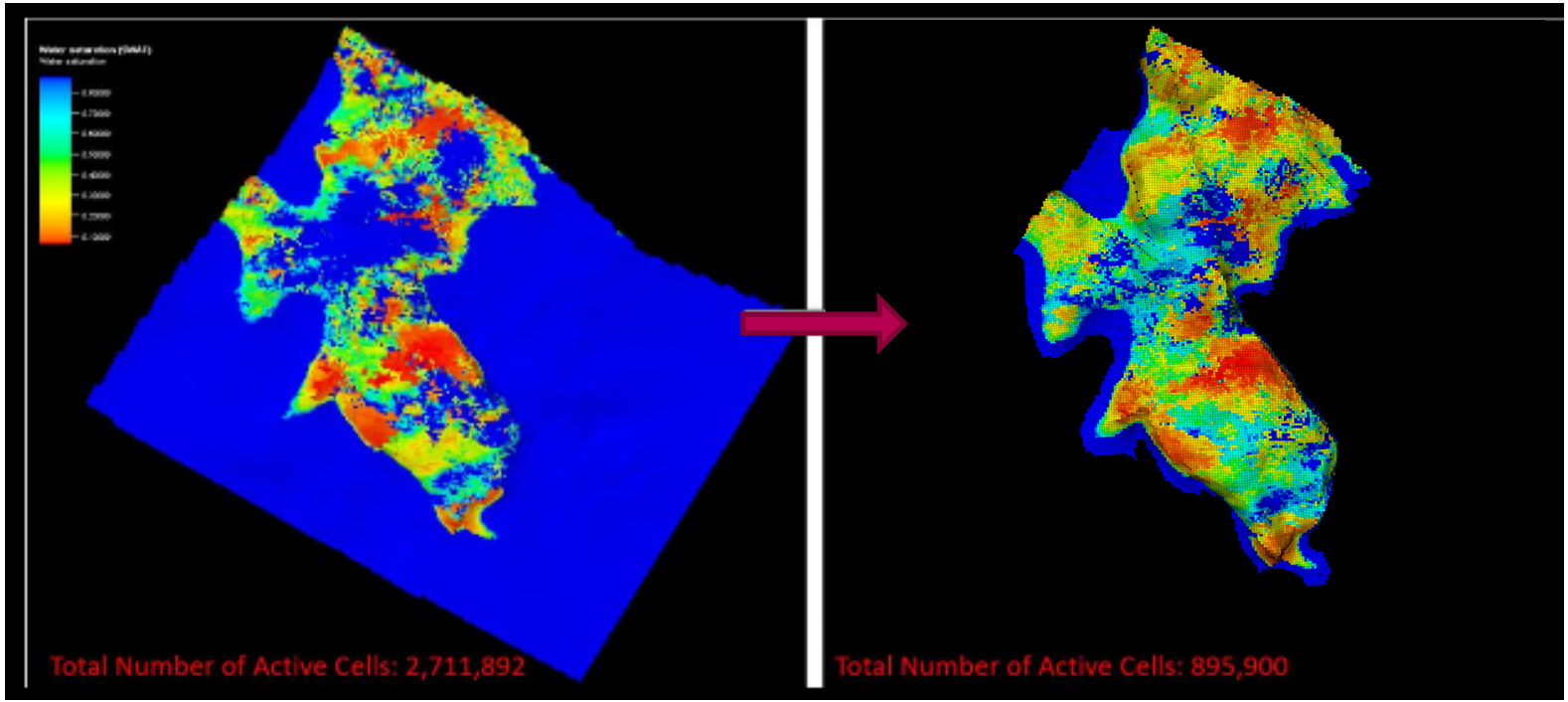
Use contact set:

Target number of initial conditions: 5

Surface elevation: 0.00

	Unit	Region	Region	Region	Region
Name		West_Gas_Sampel_1	West_Oil_Sample_2	East_Gas_Sample_3	East_Oil_Sample_4
Initialization type		Gas	Oil	Gas	Oil
Pressure	bar	☑ 303.4383	☑ 303.4383	☑ 303.4383	☑ 303.4383
Datum depth	m	☑ -1495.00	☑ -1495.00	☑ -1495.00	☑ -1495.00
Gas-oil contact	m				
Oil-gas Pc	bar	0.0000	0.0000	0.0000	0.0000
Water contact	m	-1498.00	-1498.00	-1508.00	-1508.00
Pc at water contact	bar	0.0000	0.0000	0.0000	0.0000
Temp. type		Samples	Samples	Samples	Samples
Temp. function					
Temp. constant	degC				
Gas_Top		☑ 80.06	☐	☑ 80.06	☐
Gas_Sample		☑ 80.46	☐	☑ 80.46	☐
Gas_GOC		☑ 81.56	☐	☑ 81.56	☐
Oil_GOC		☐	☑ 81.56	☐	☑ 81.56
Oil_Sample		☐	☑ 81.6	☐	☑ 81.6
Oil_Base_1508		☐	☑ 81.79	☐	☑ 81.79

Initialization and Upscaling Recap



EOS Tuning – Saturation Pressure

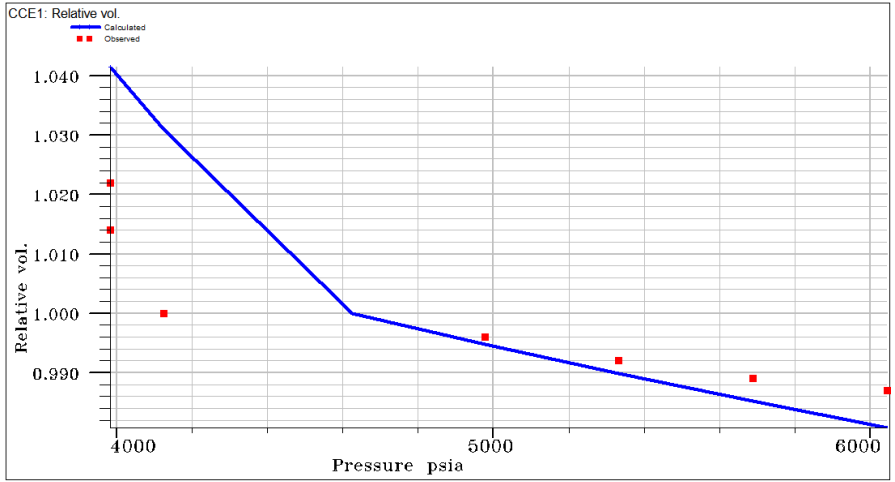
HRS162 – 1987 – OSLM

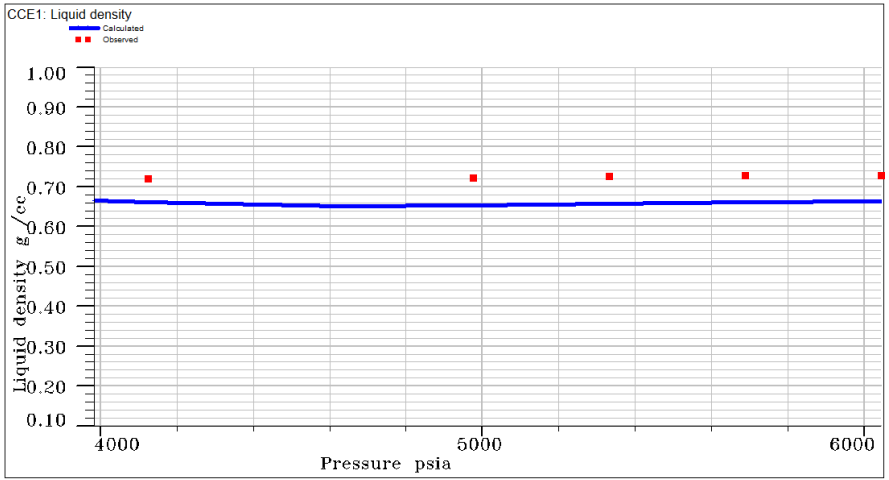
HRS 162 1987 Oil Sample

HRS 162 1987 Sample Bubble Point Pressure psia Observed	HRS 162 1987 Sample Bubble Point Pressure psia Simulated
4622	4633

EOS Tuning – CCE
HRS 162 1987 Oil Sample

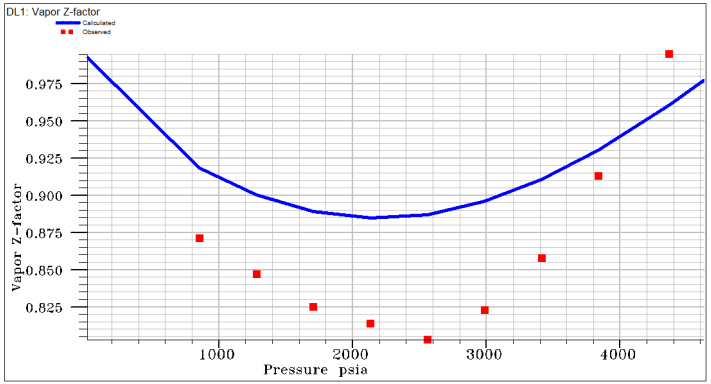
HRS162 – 1987 – OSLM

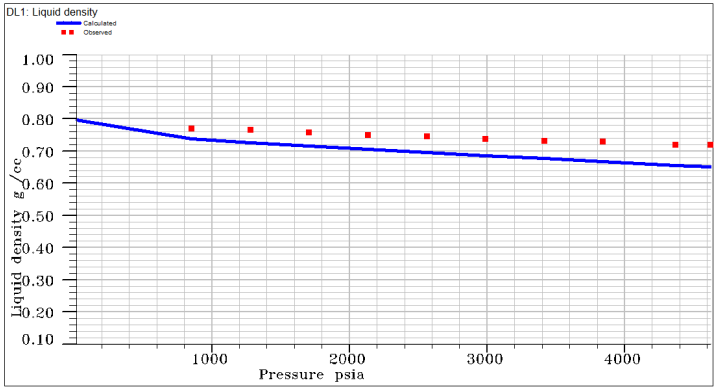


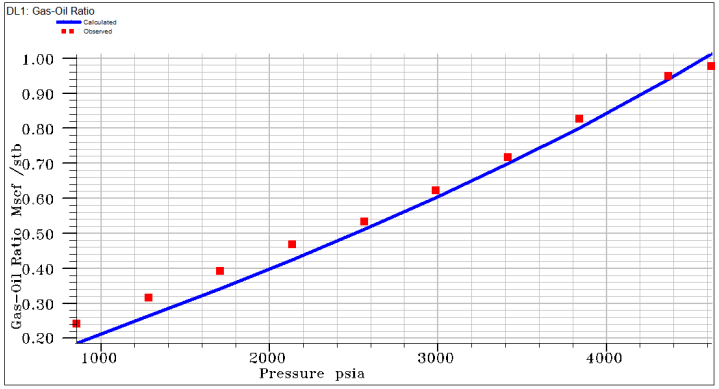


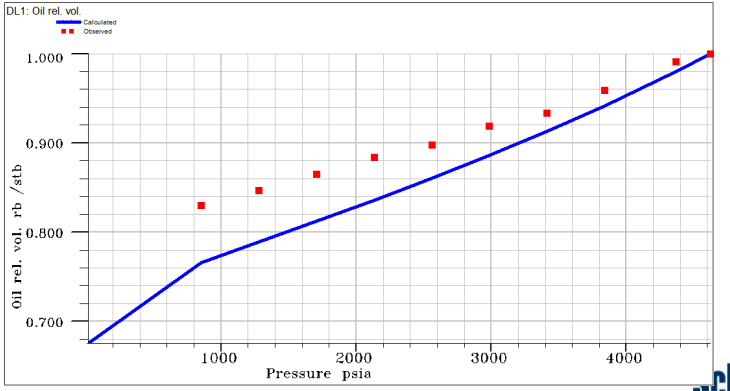
EOS Tuning – DL
HRS 162 1987 Oil Sample

HRS162 – 1987 – OSLM



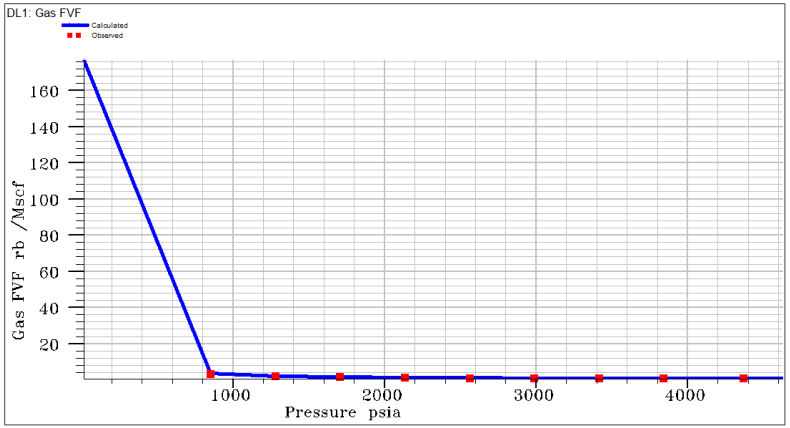


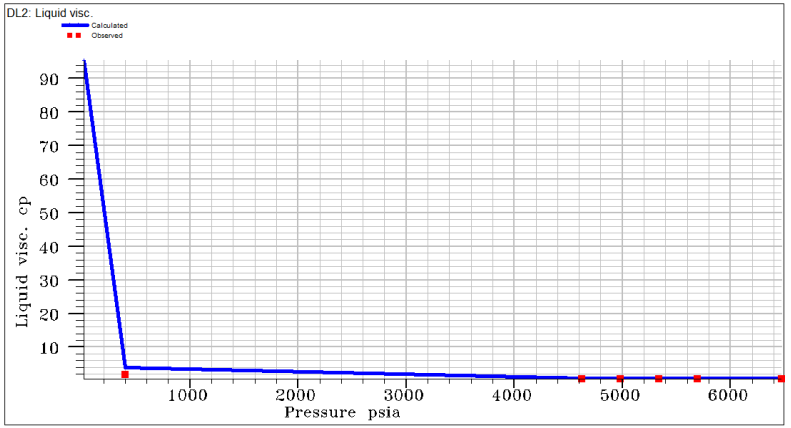




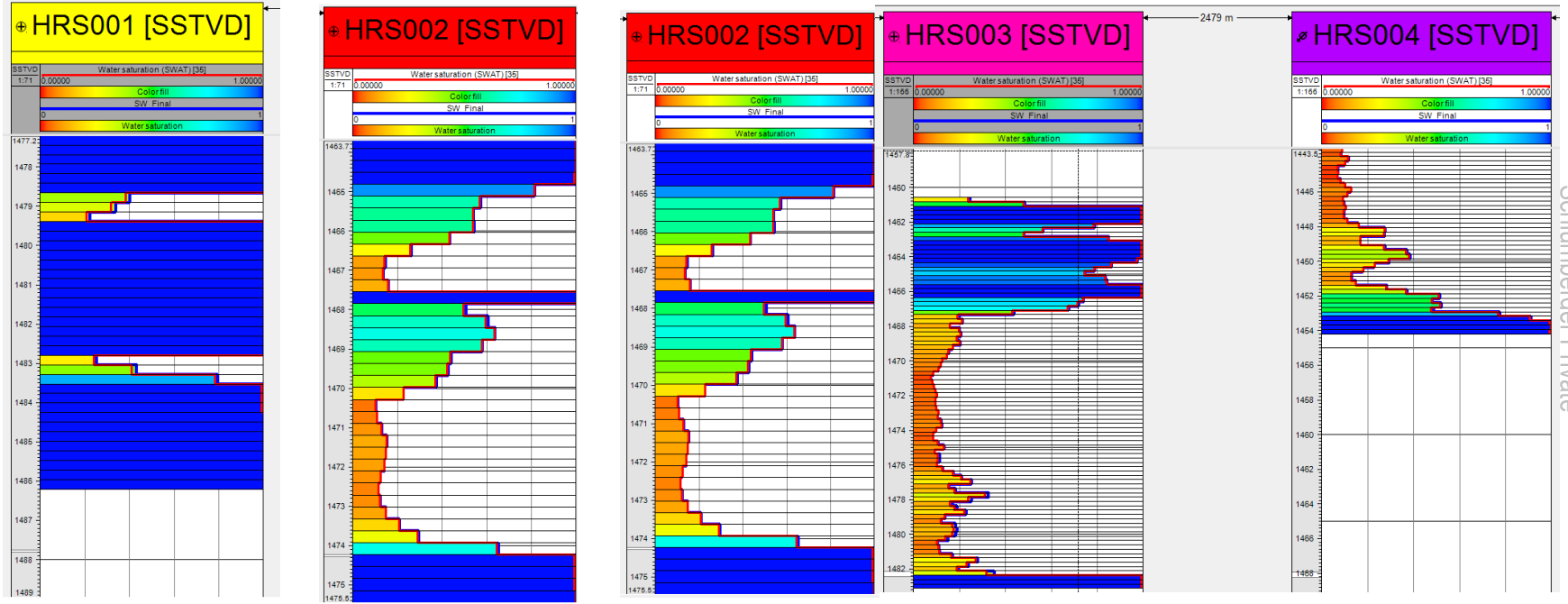
EOS Tuning – DL
HRS 162 1987 Oil Sample

HRS162 – 1987 – OSLM

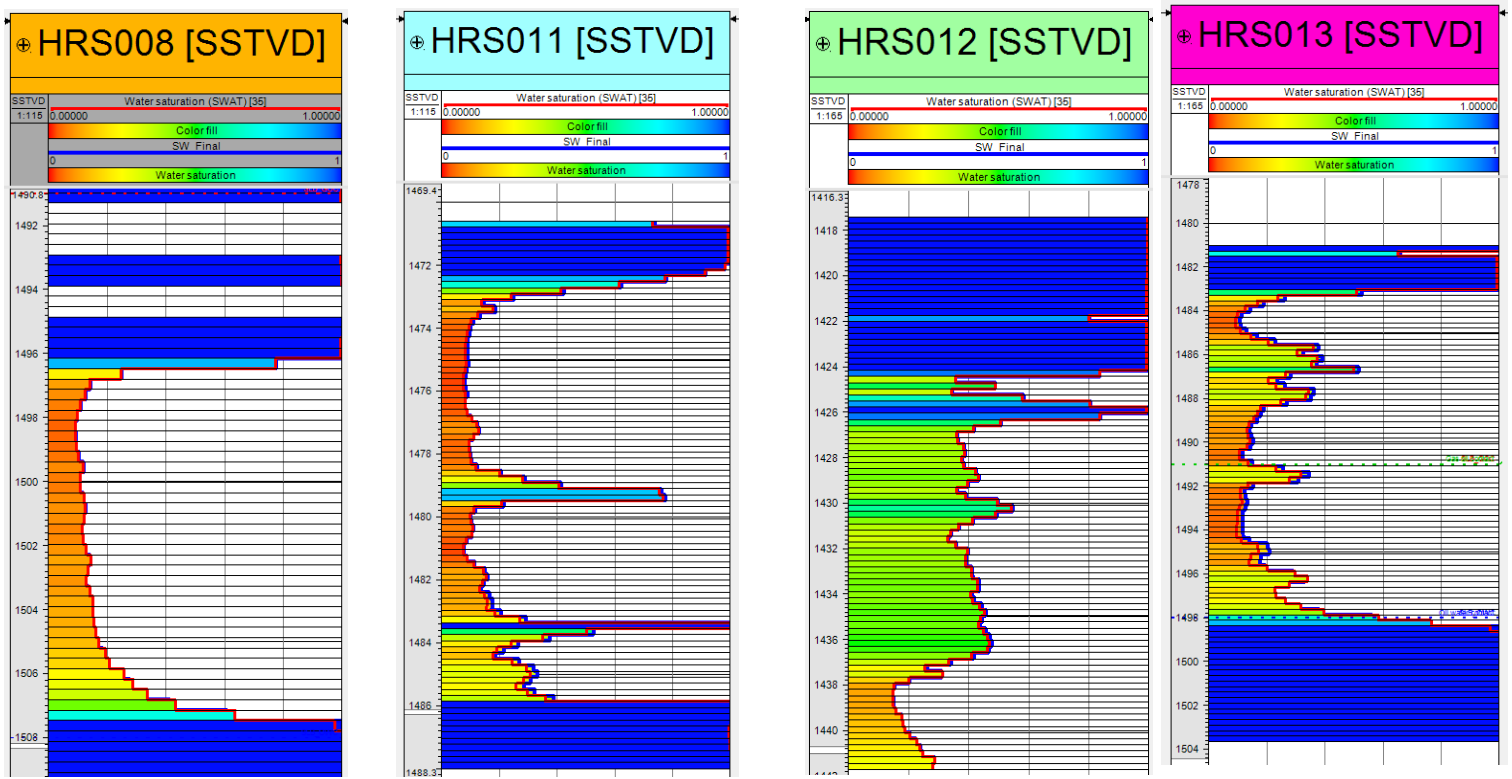




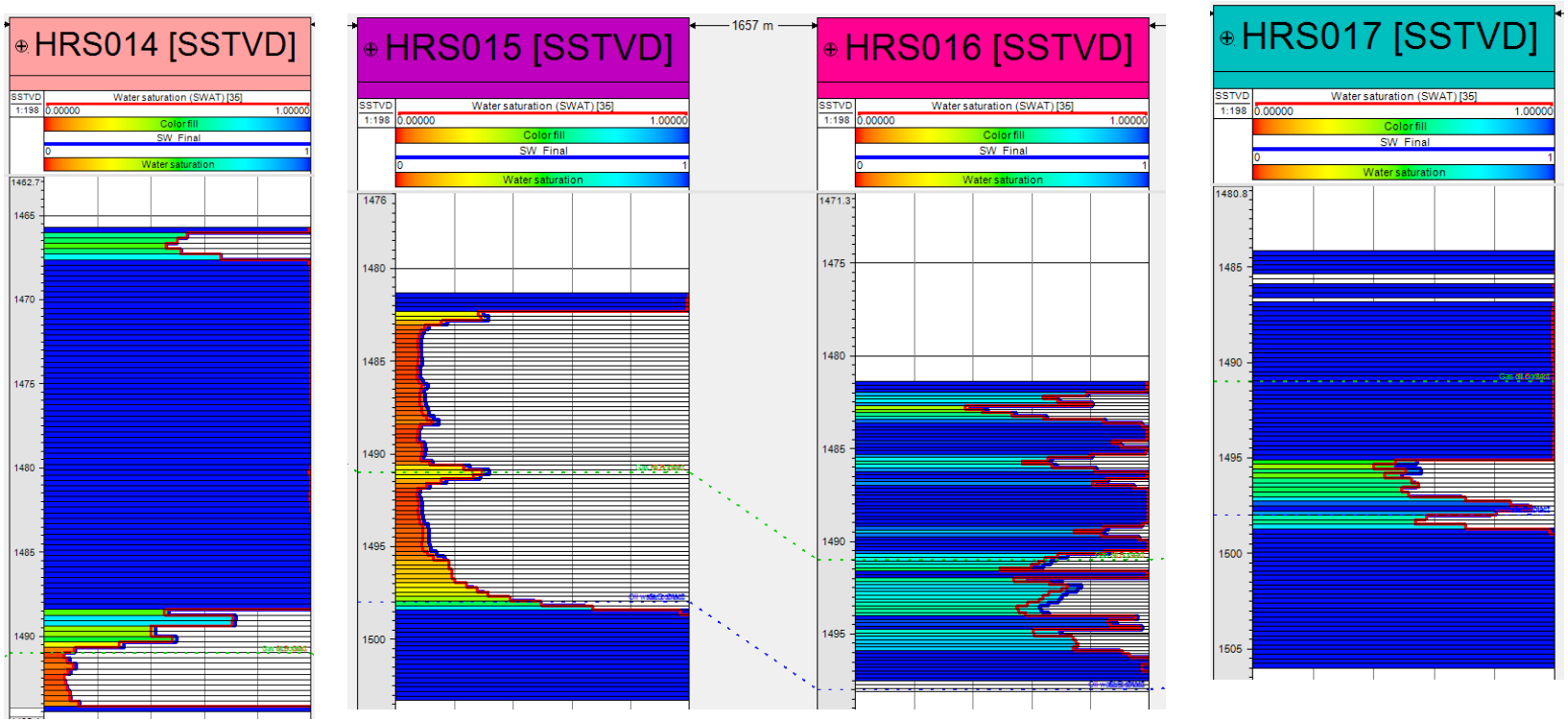
Model Initialization Results: Well by Well Saturation Validation



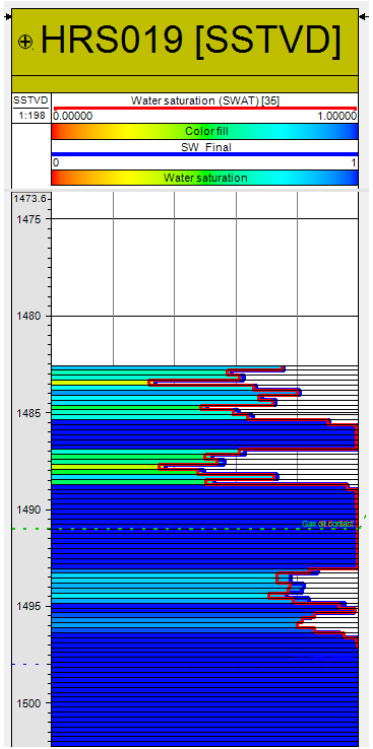
Model Initialization Results: Well by Well Saturation Validation

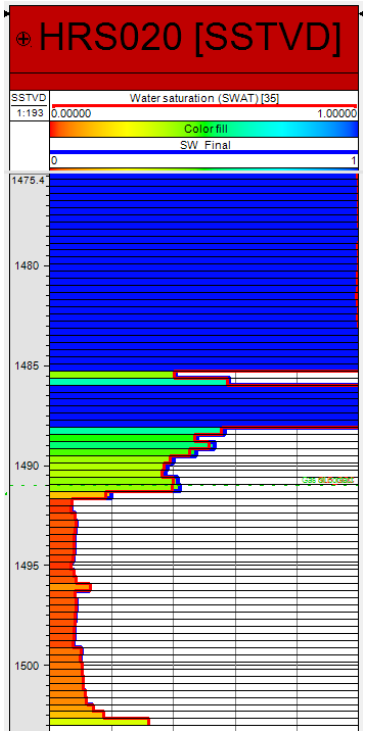


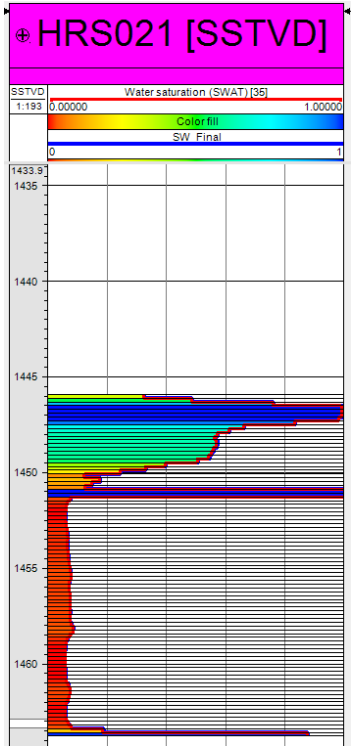
Model Initialization Results: Well by Well Saturation Validation

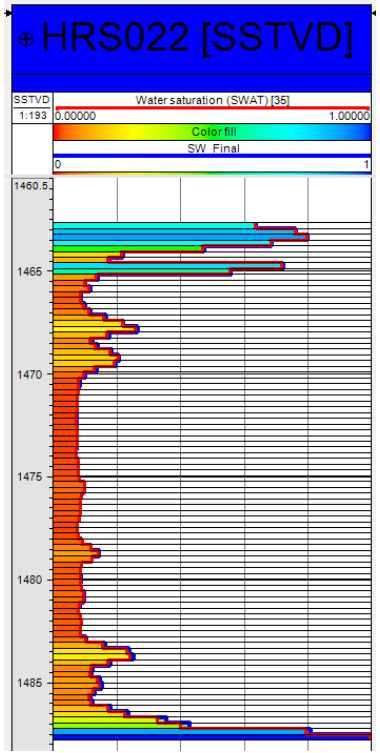


Model Initialization Results: Well by Well Saturation Validation

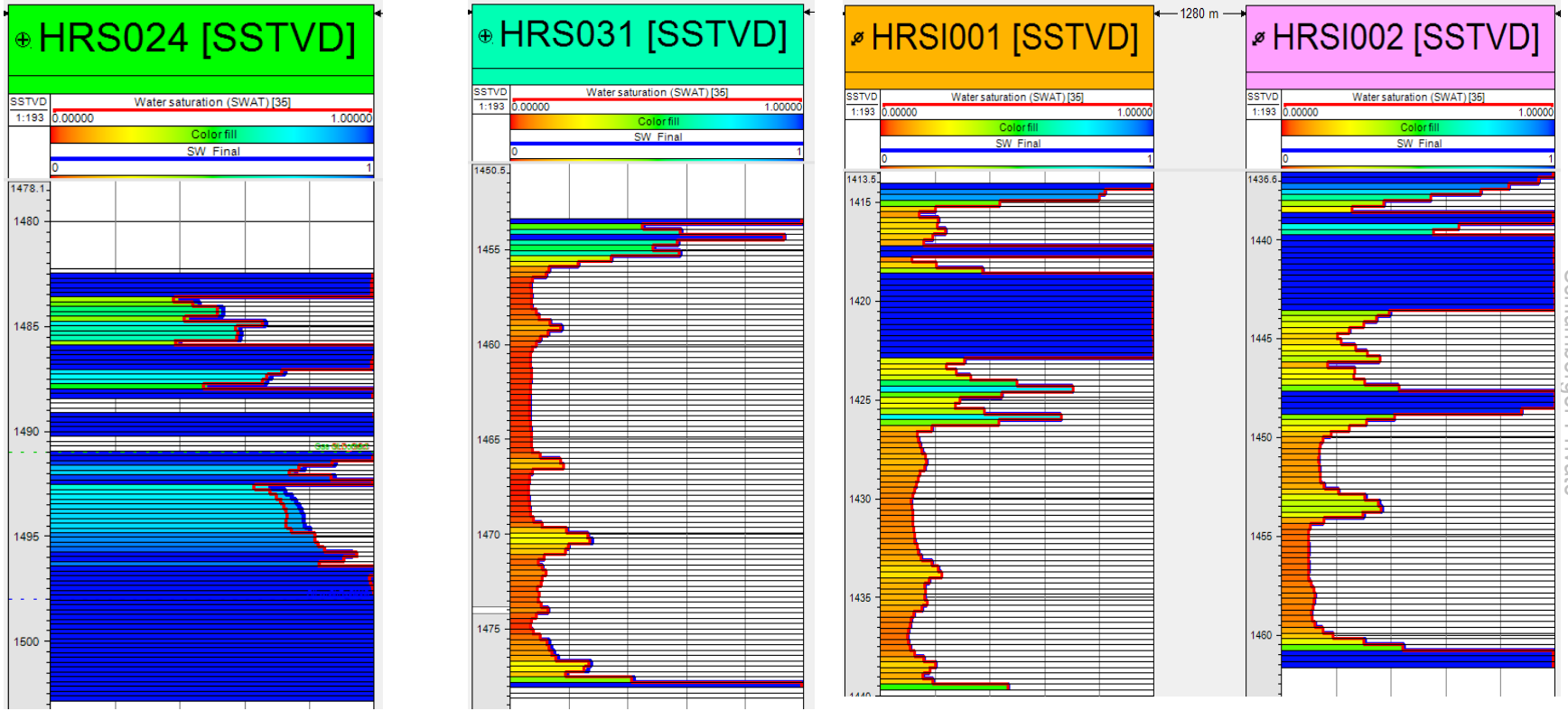






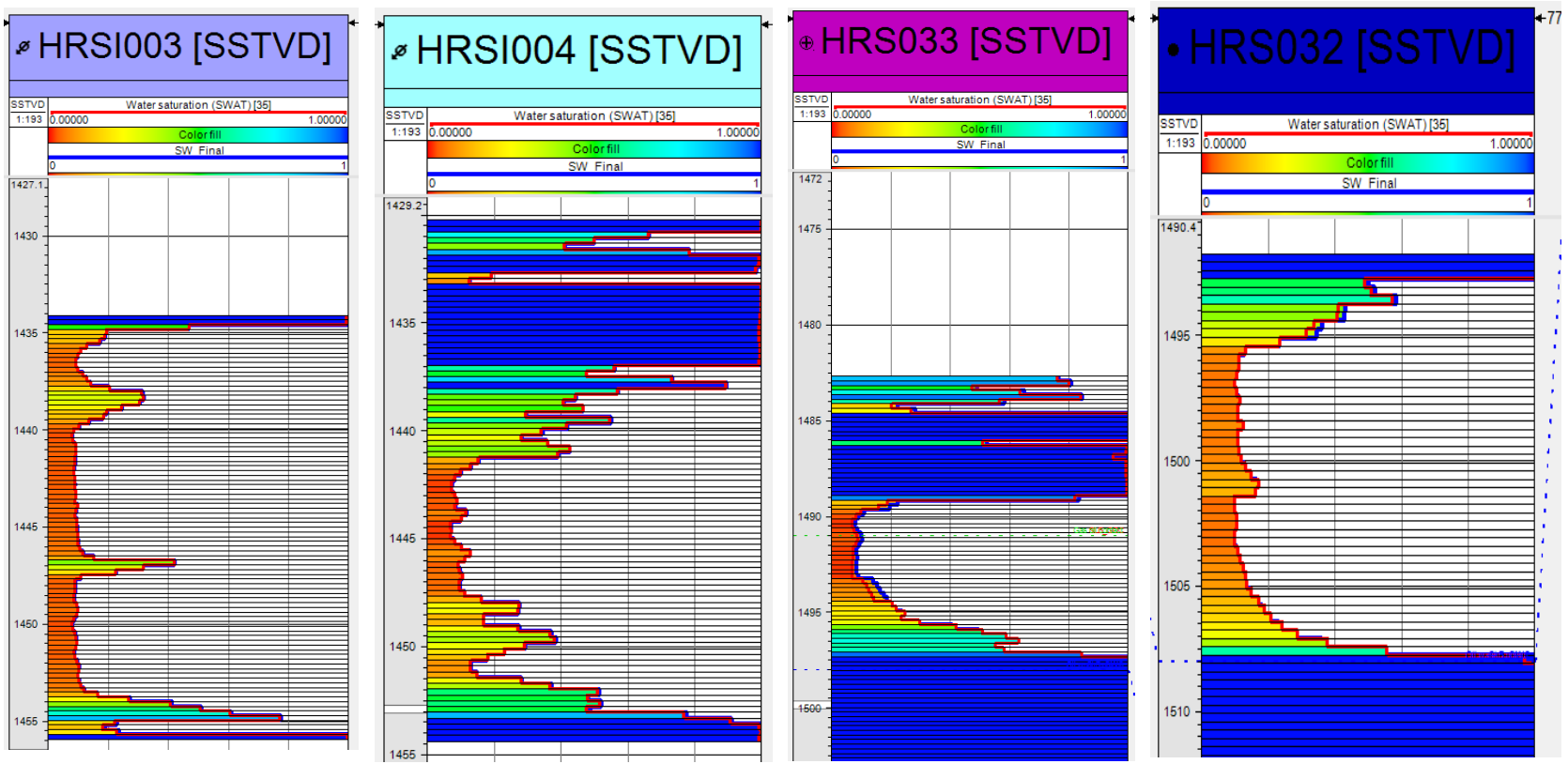


Model Initialization Results: Well by Well Saturation Validation



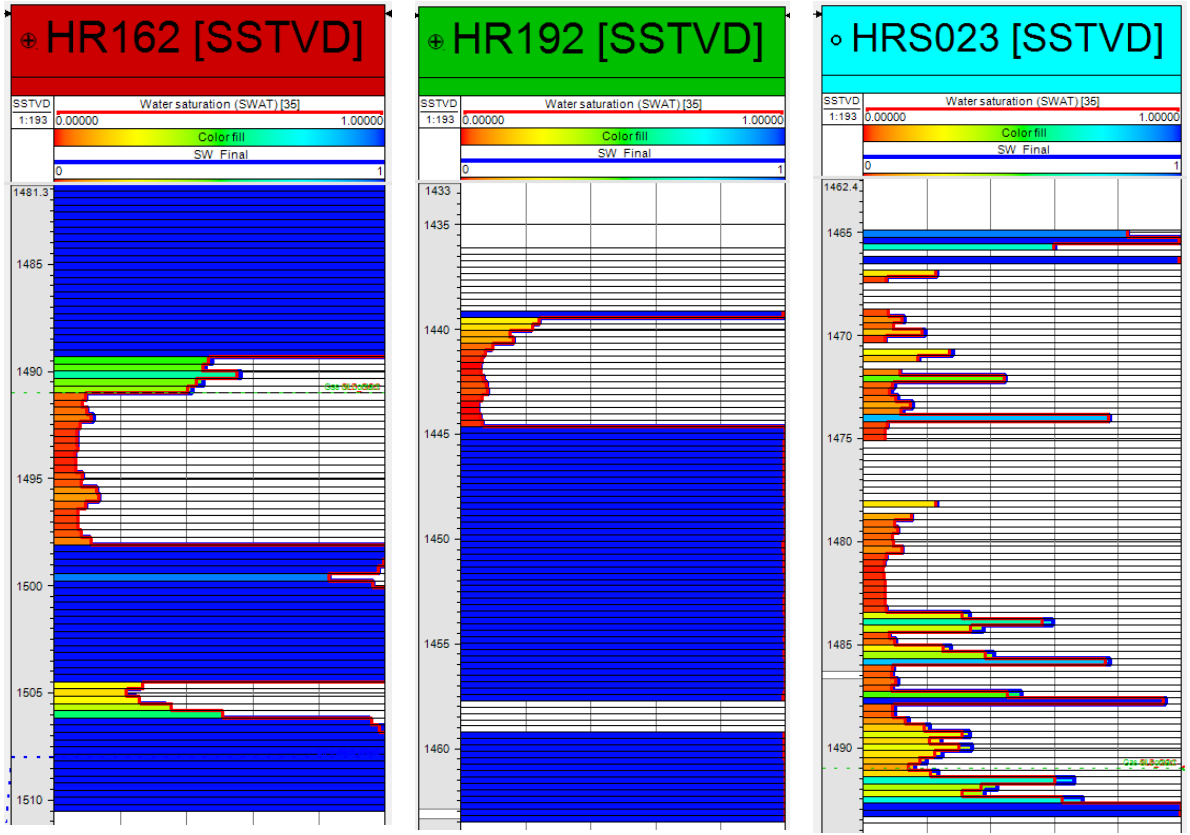
Schlumberger

Model Initialization Results: Well by Well Saturation Validation



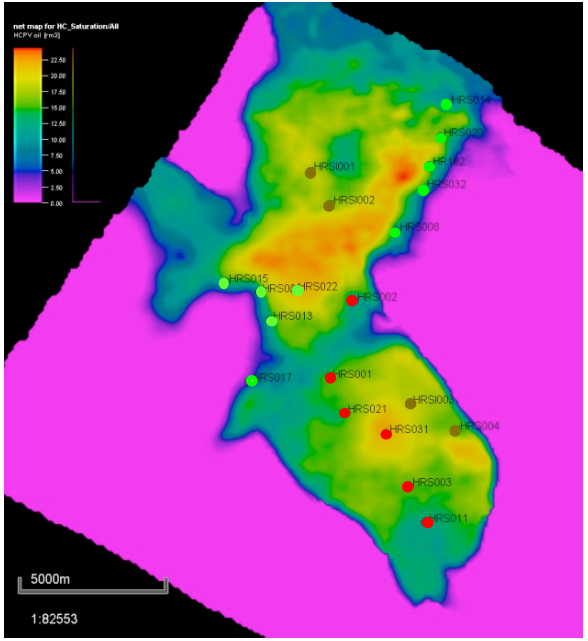
Schlumberger

Model Initialization Results: Well by Well Saturation Validation



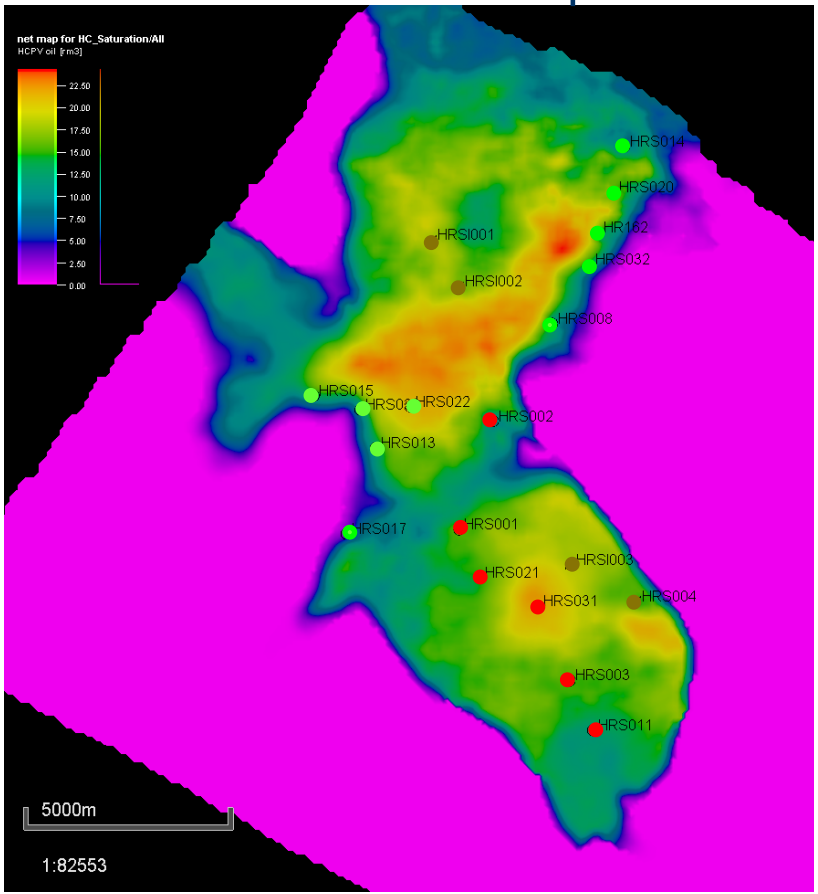
History Match Approach

- Started with:
  - Normal Relative Permeability
    - Corey exponents for oil, water and gas (2-4)
    - Residual oil saturation (0.1-0.3)
  - PVT
  - Gas wells on GRAT & Oil wells on ORAT control
  - Sensitivity Runs on different parameters
    - Permeability, KvKh, GOC,
    - Relative Permeability,
    - PORV(Aquifer, Oil Rim, Gas cap)
    - Perforation
    - Gas Injection rate



Schlumberger

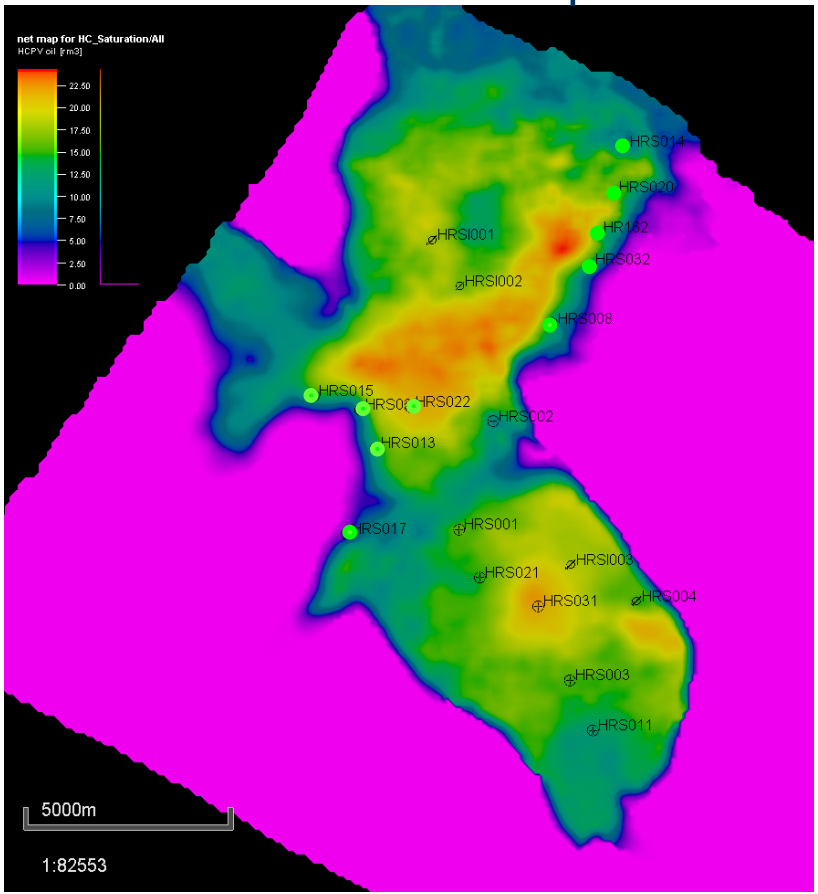
Hassi R'mel South Well Location Map



Hasi Rmel Field Well List

No.	Well Name	Type	Segment
1	HRS001	Gas Wells	South Central
2	HRS002	Gas Wells	South Central
3	HRS003	Gas Wells	South Central
4	HRS011	Gas Wells	South Central
5	HRS021	Gas Wells	South Central
6	HRS031	Gas Wells	South Central
7	HRS013	Gas Wells (Pseudo)	West
8	HRS015	Gas Wells (Pseudo)	West
9	HRS022	Gas Wells (Pseudo)	West
10	HRS033	Gas Wells (Pseudo)	West
11	HRS008	Oil Wells	East
12	HRS014	Oil Wells	East
13	HRS020	Oil Wells	East
14	HRS032	Oil Wells	East
15	HRS162	Oil Wells	East
16	HRSI001	Gas Injector	North Central
17	HRSI002	Gas Injector	North Central
18	HRSI003	Gas Injector	South East
19	HR004	Gas Injector	South East

Hassi R'mel South Well Location Map: Oil Wells

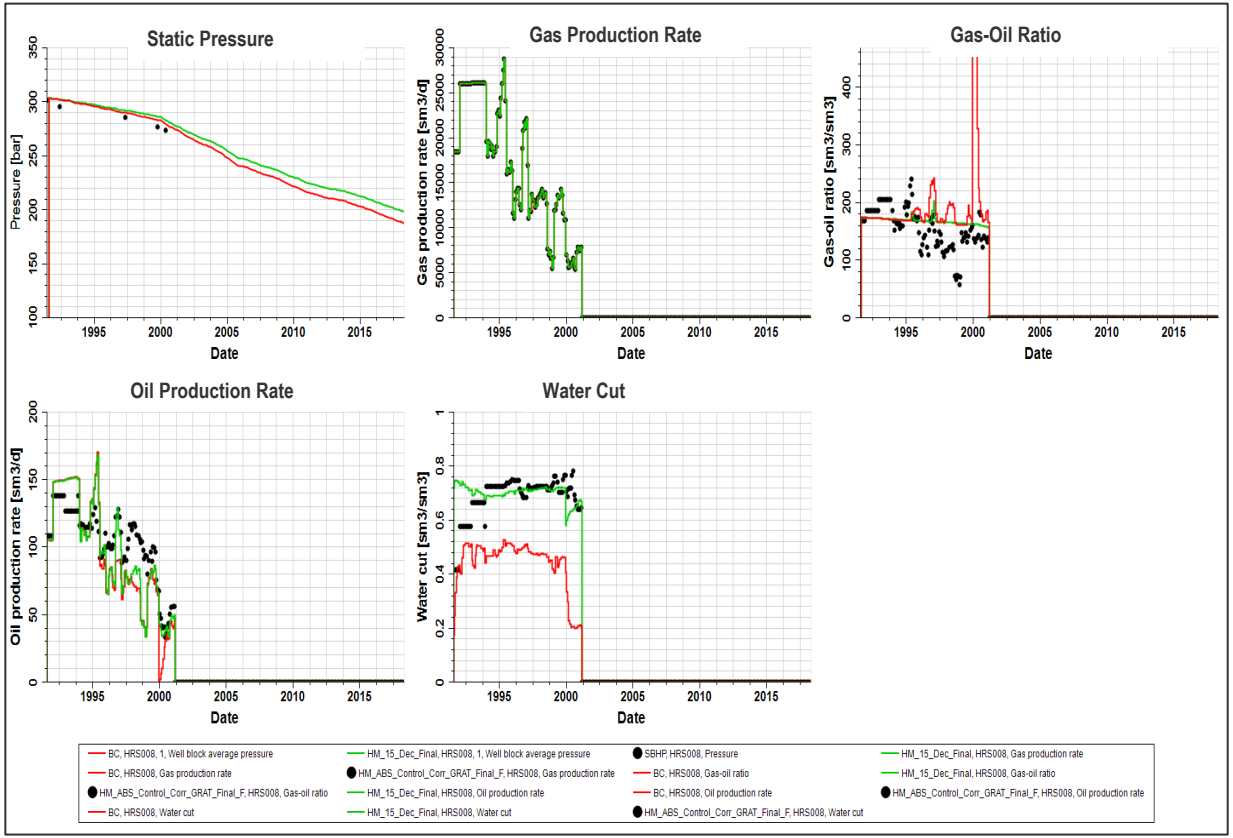


Hasi Rmel Field Well List

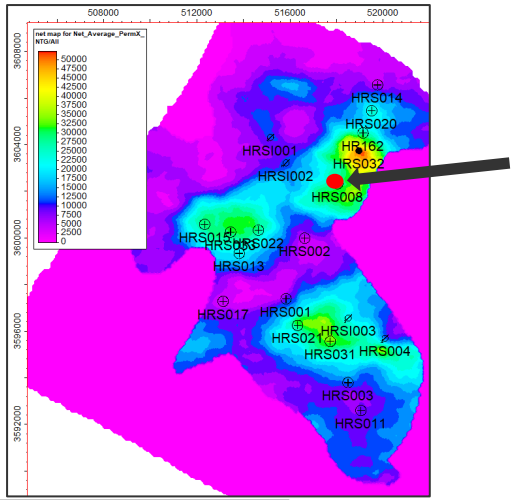
No.	Well Name	Type	Segment
1	HRS001	Gas Wells	South Central
2	HRS002	Gas Wells	South Central
3	HRS003	Gas Wells	South Central
4	HRS011	Gas Wells	South Central
5	HRS021	Gas Wells	South Central
6	HRS031	Gas Wells	South Central
7	HRS013	Gas Wells (Pseudo)	West
8	HRS015	Gas Wells (Pseudo)	West
9	HRS022	Gas Wells (Pseudo)	West
10	HRS033	Gas Wells (Pseudo)	West
11	HRS008	Oil Wells	East
12	HRS014	Oil Wells	East
13	HRS020	Oil Wells	East
14	HRS032	Oil Wells	East
15	HRS162	Oil Wells	East
16	HRSI001	Gas Injector	North Central
17	HRSI002	Gas Injector	North Central
18	HRSI003	Gas Injector	South East
19	HR004	Gas Injector	South East

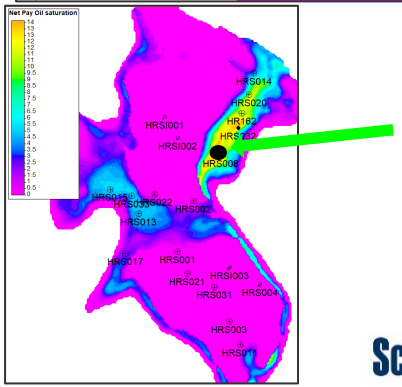
Latest HM Results: HRS008

Base Case
HM



Average PermX Net Map



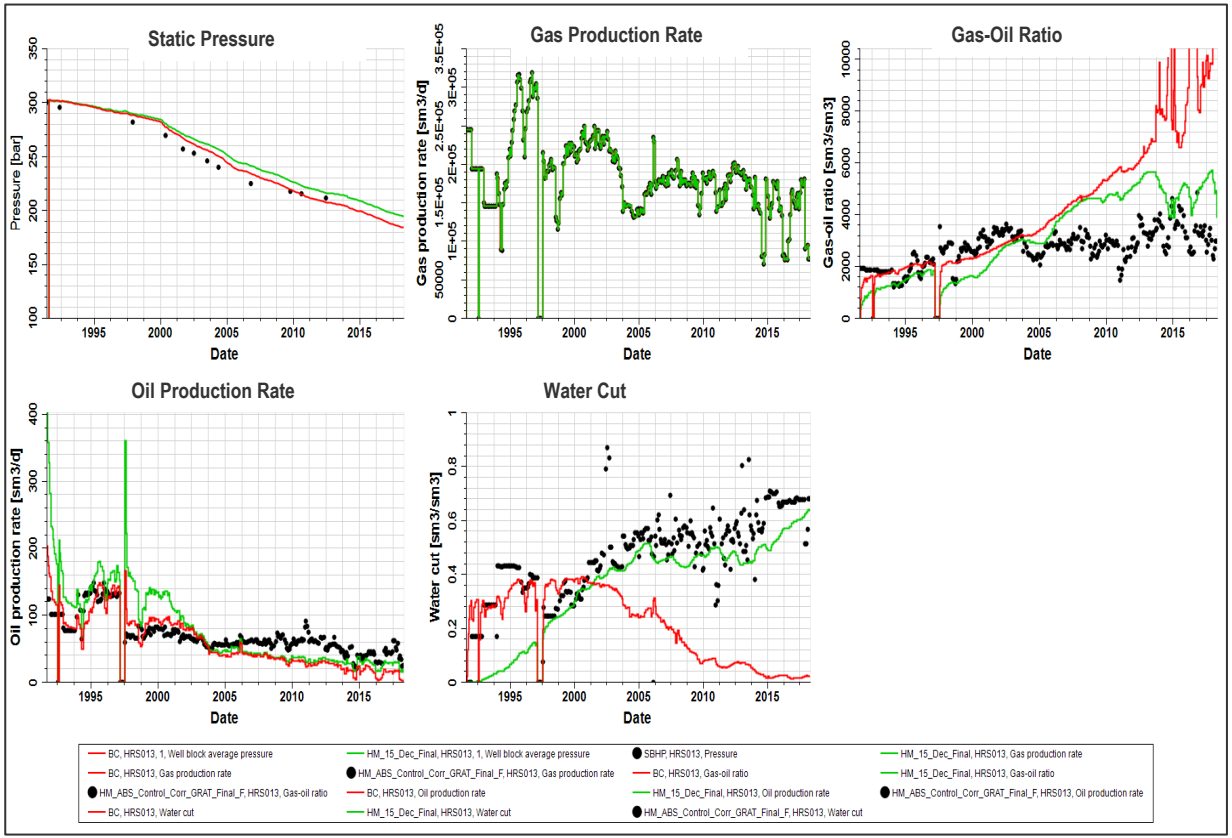


Average Oil Saturation Net Map

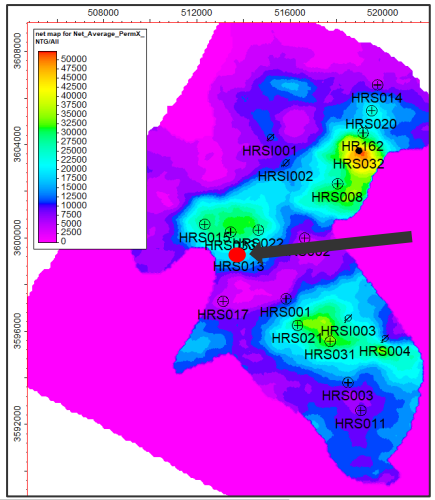
Schlumberger

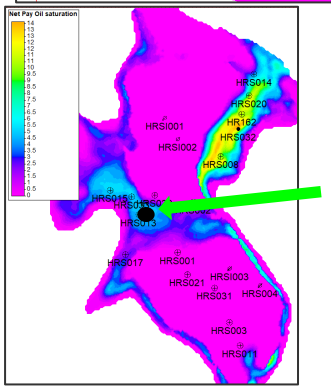
Latest HM Results: HRS013

Base Case
HM



Average PermX Net Map



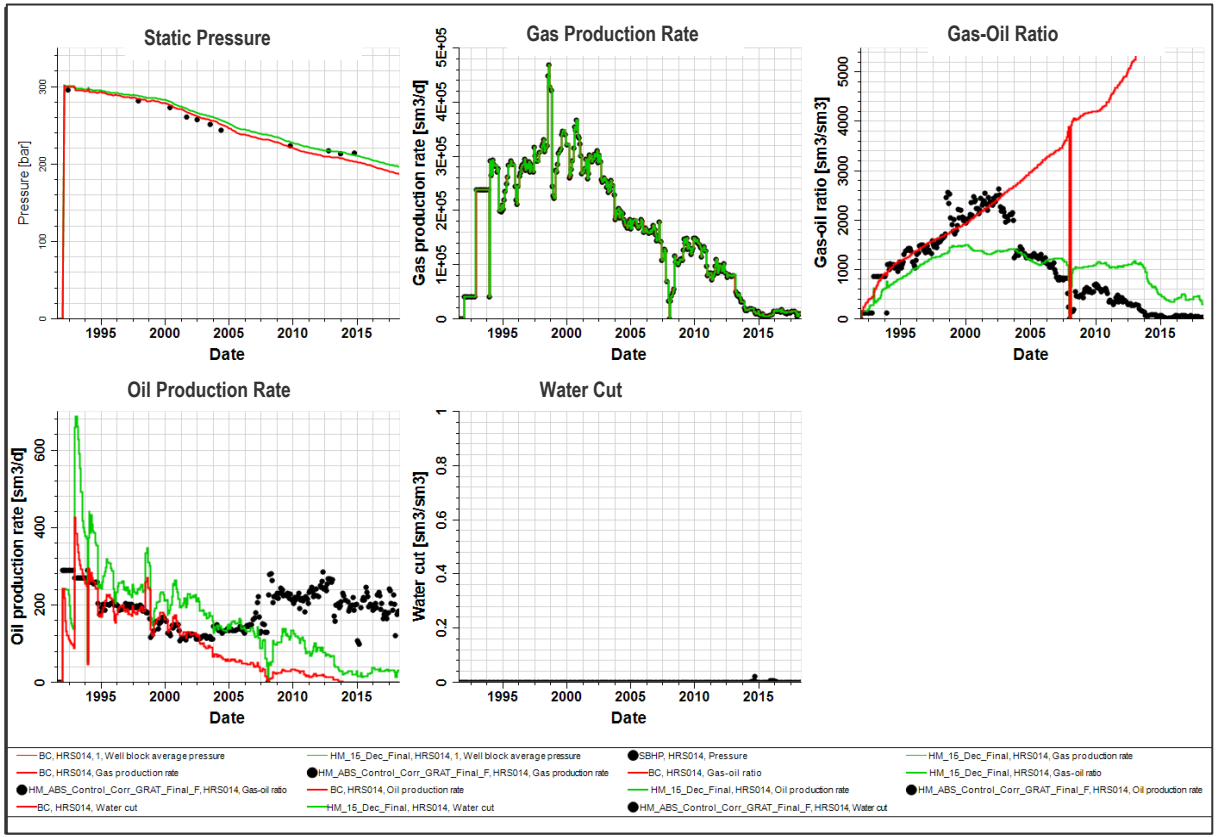


Average Oil Saturation Net Map

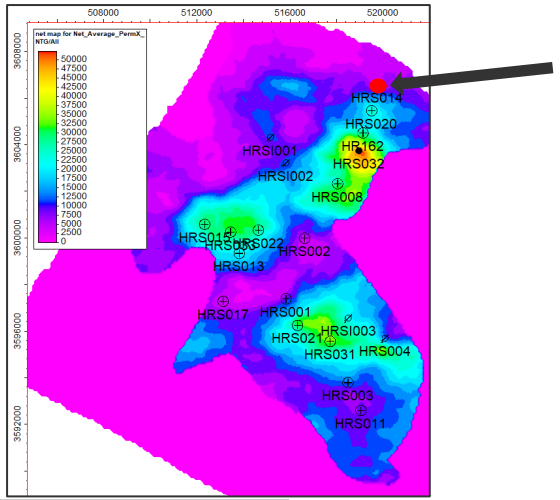
Schlumberger

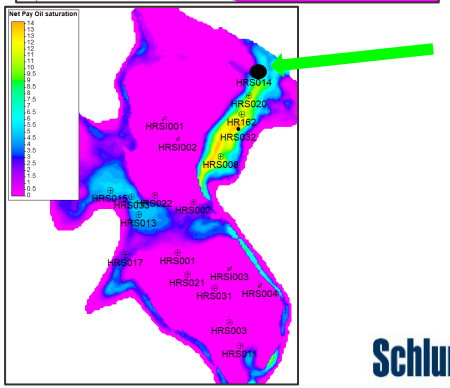
Latest HM Results: HRS014

Base Case
HM



Average PermX Net Map

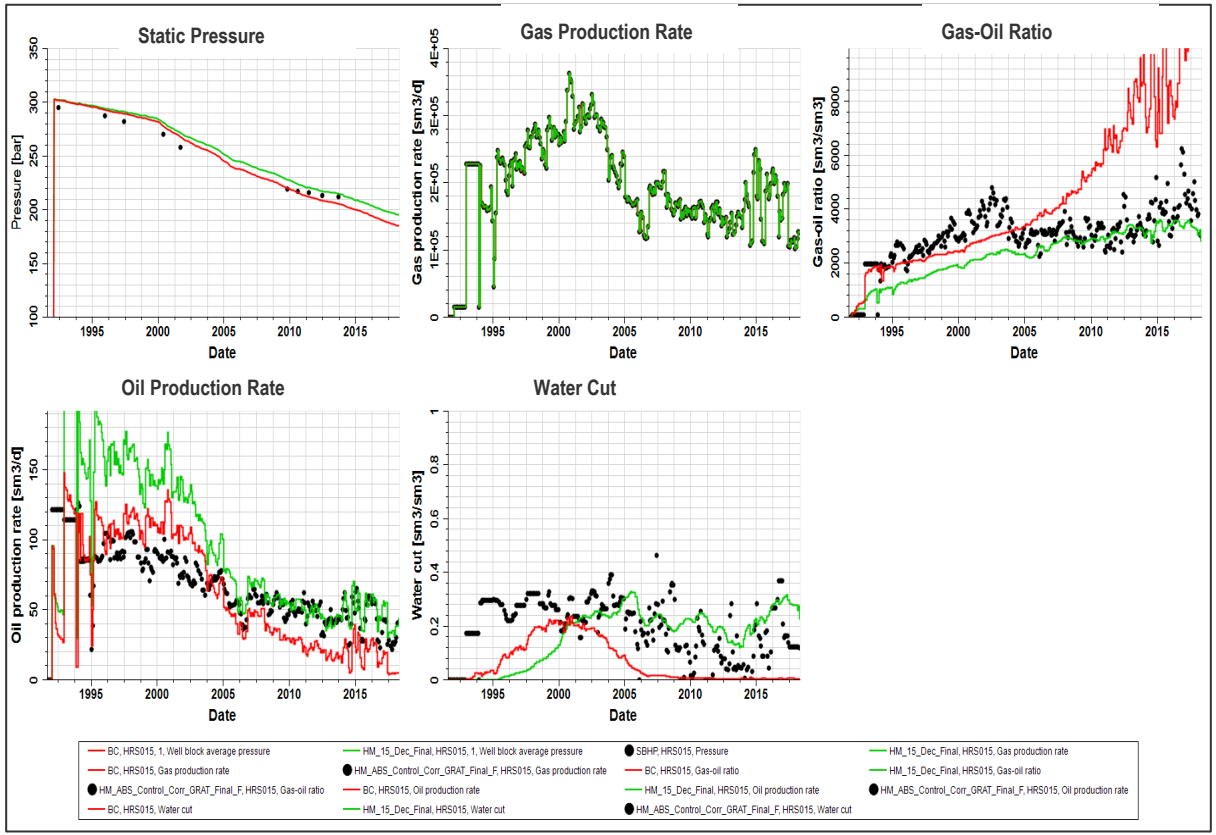




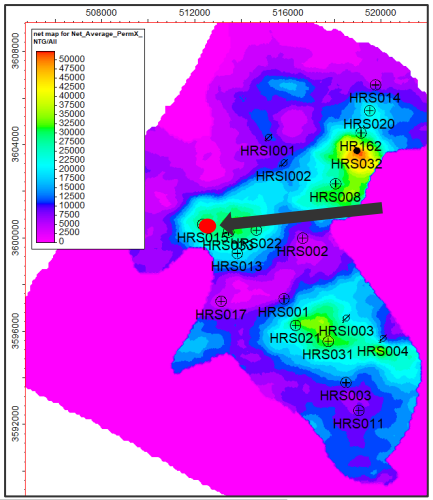
Average Oil Saturation Net Map

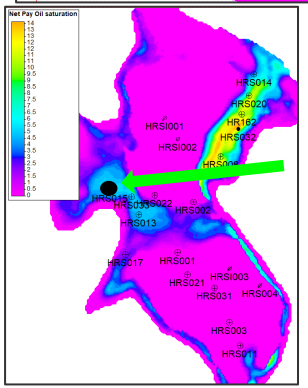
Latest HM Results: HRS015

Base Case
HM



Average PermX Net Map

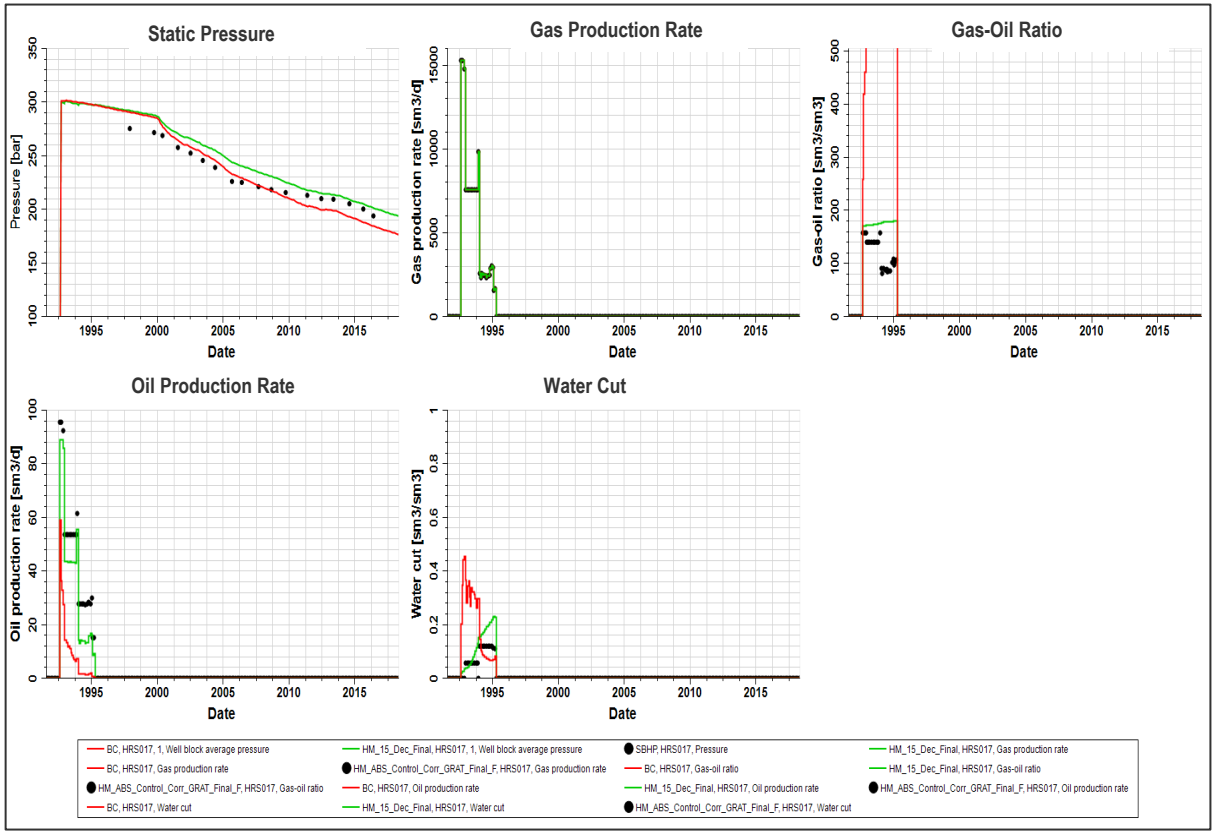




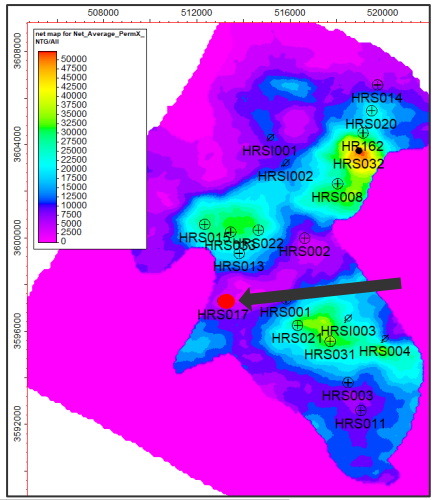
Average Oil Saturation Net Map

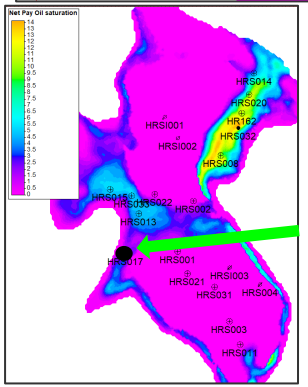
Latest HM Results: HRS017

Base Case
HM



Average PermX Net Map



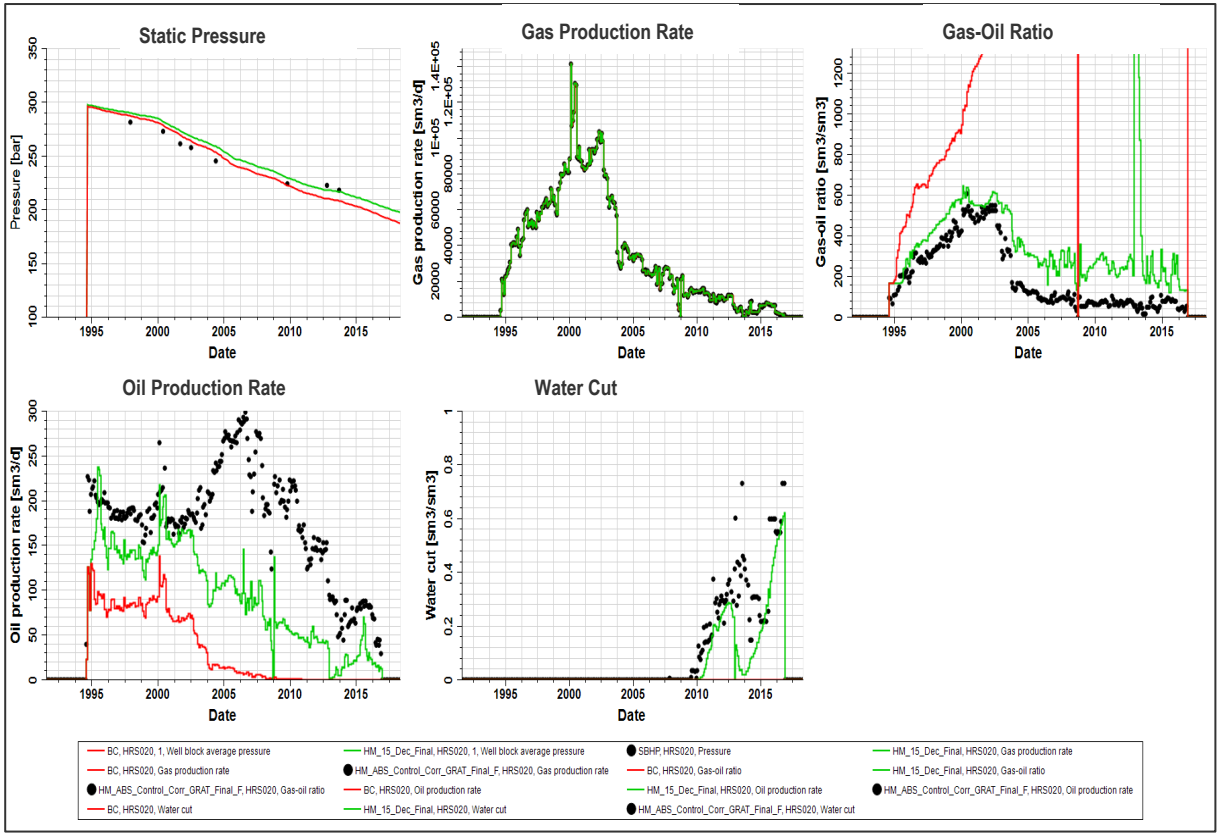


Average Oil Saturation Net Map

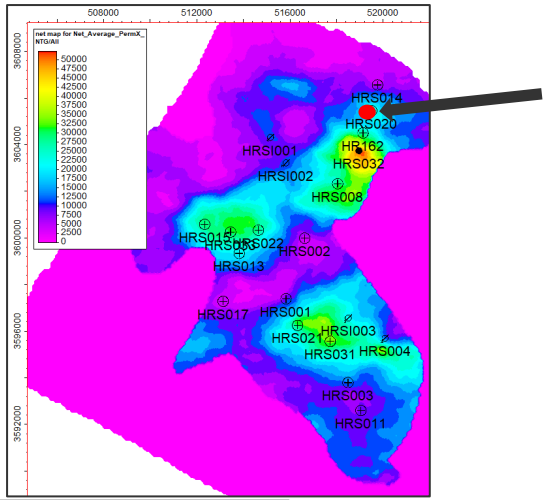
Schlumberger

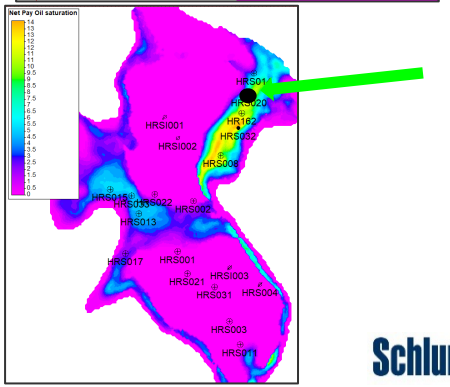
Latest HM Results: HRS020

Base Case
HM



Average PermX Net Map

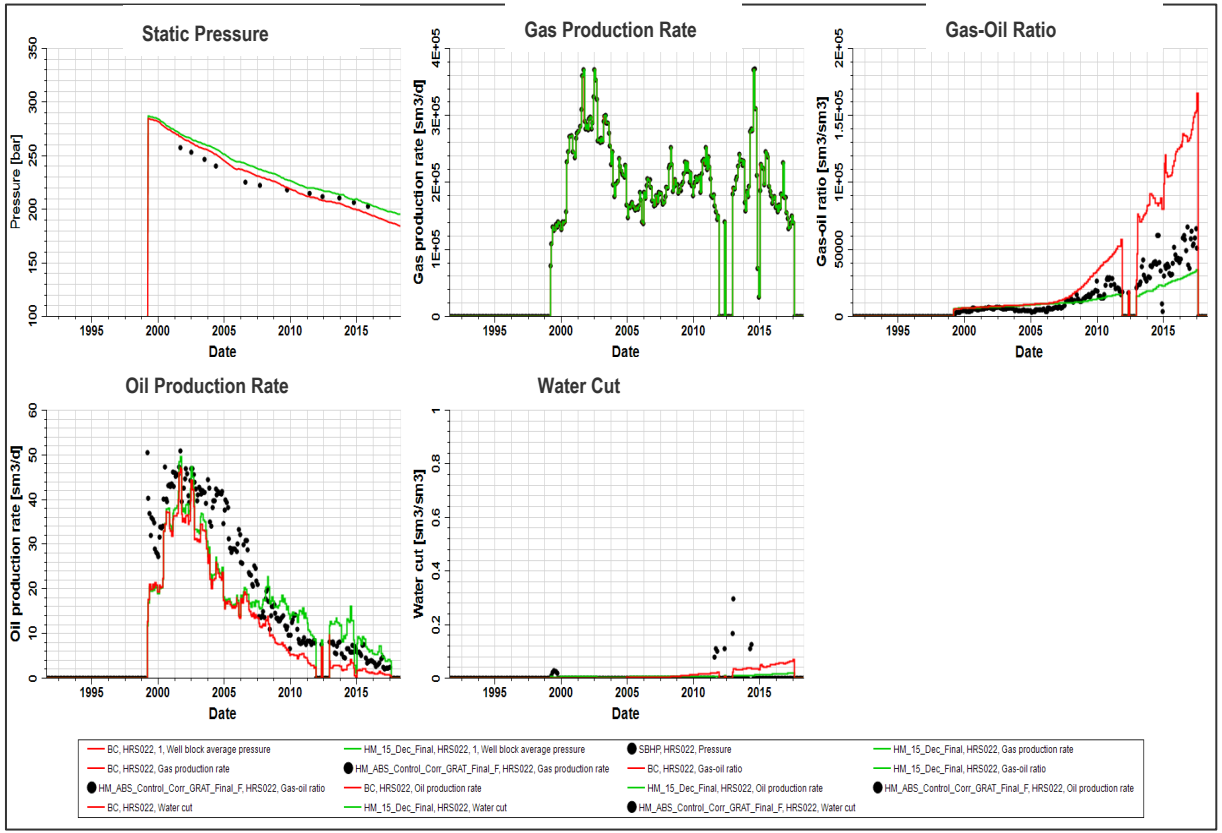




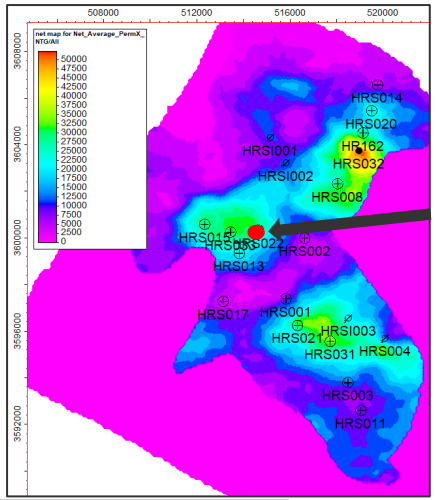
Average Oil Saturation Net Map

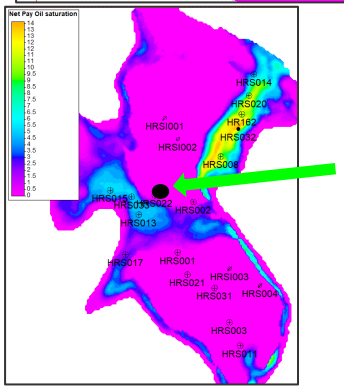
Latest HM Results: HRS022

Base Case
HM



Average PermX Net Map



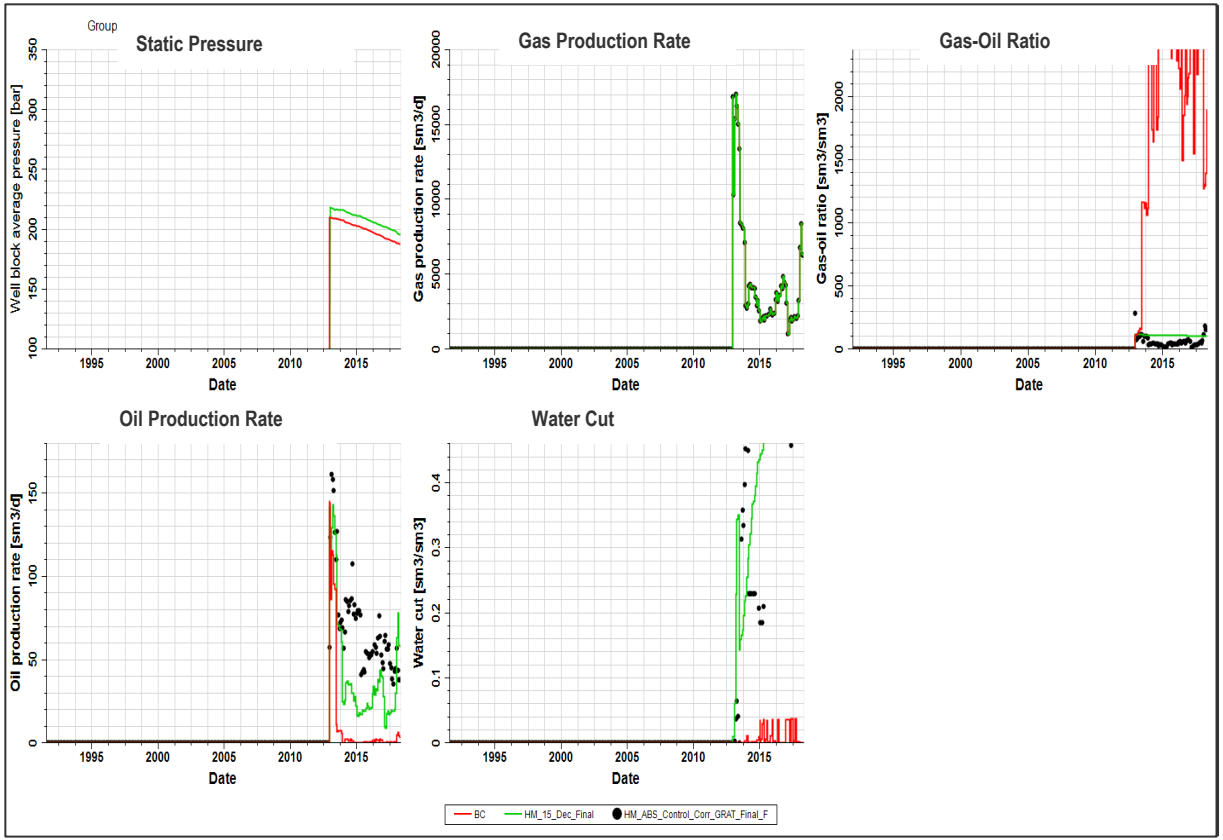


Average Oil Saturation Net Map

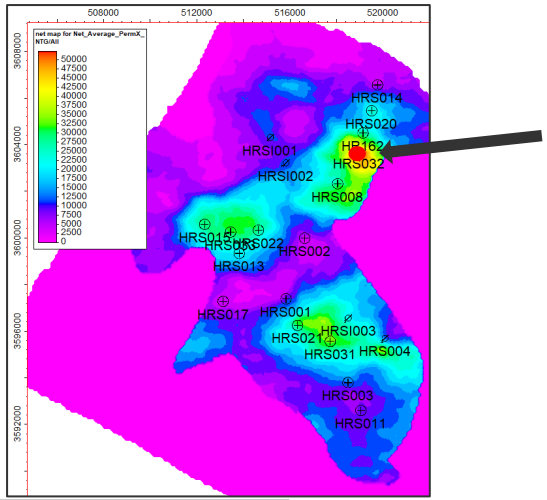
Schlumberger

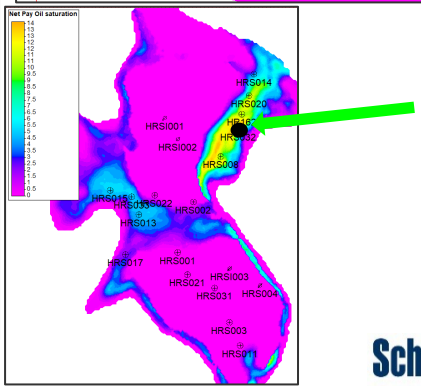
Latest HM Results: HRS032

Base Case
HM



Average PermX Net Map

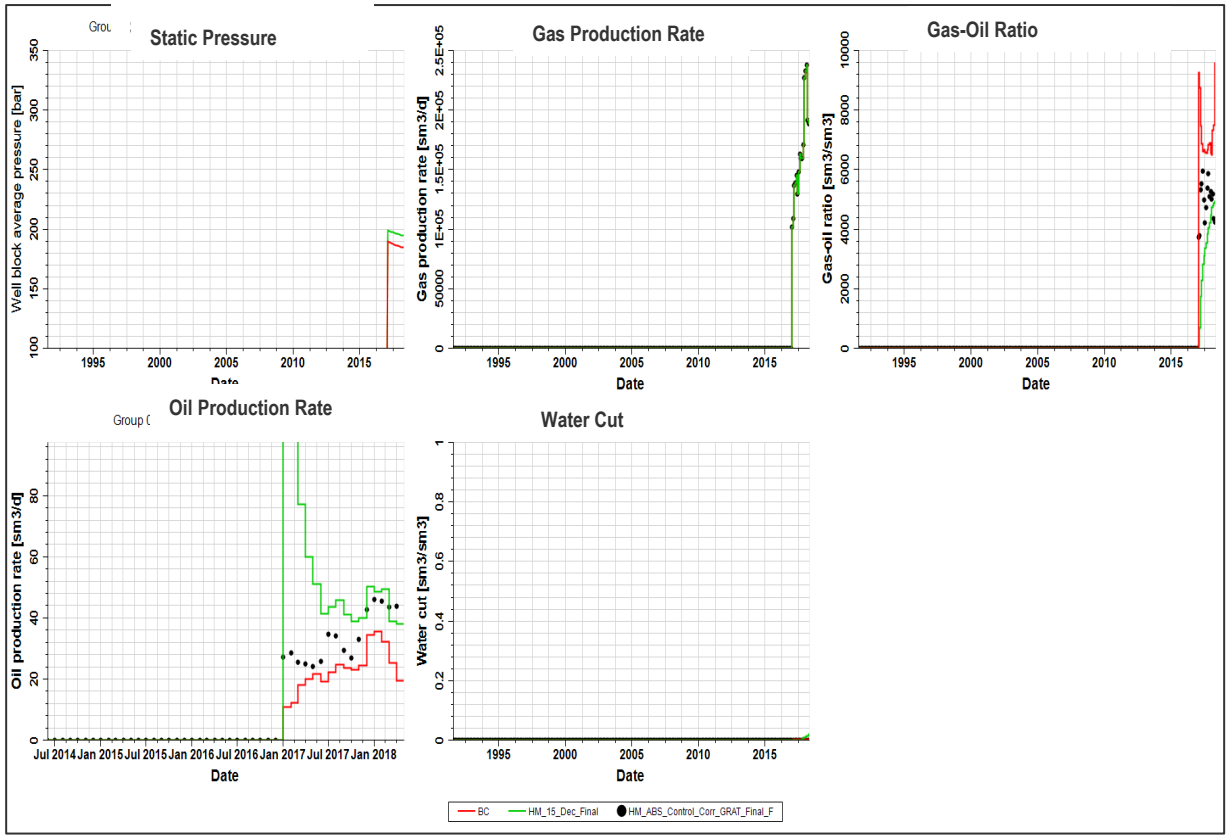




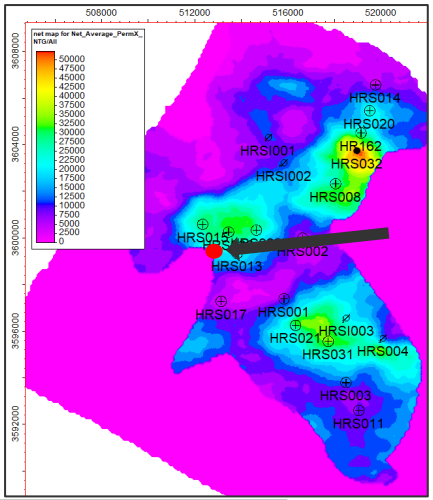
Average Oil Saturation Net Map

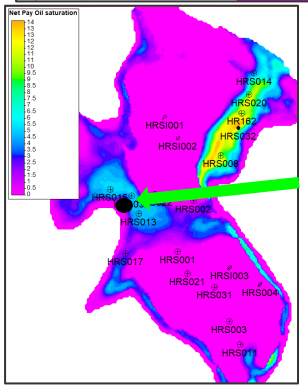
Latest HM Results: HRS033

Base Case
HM



Average PermX Net Map

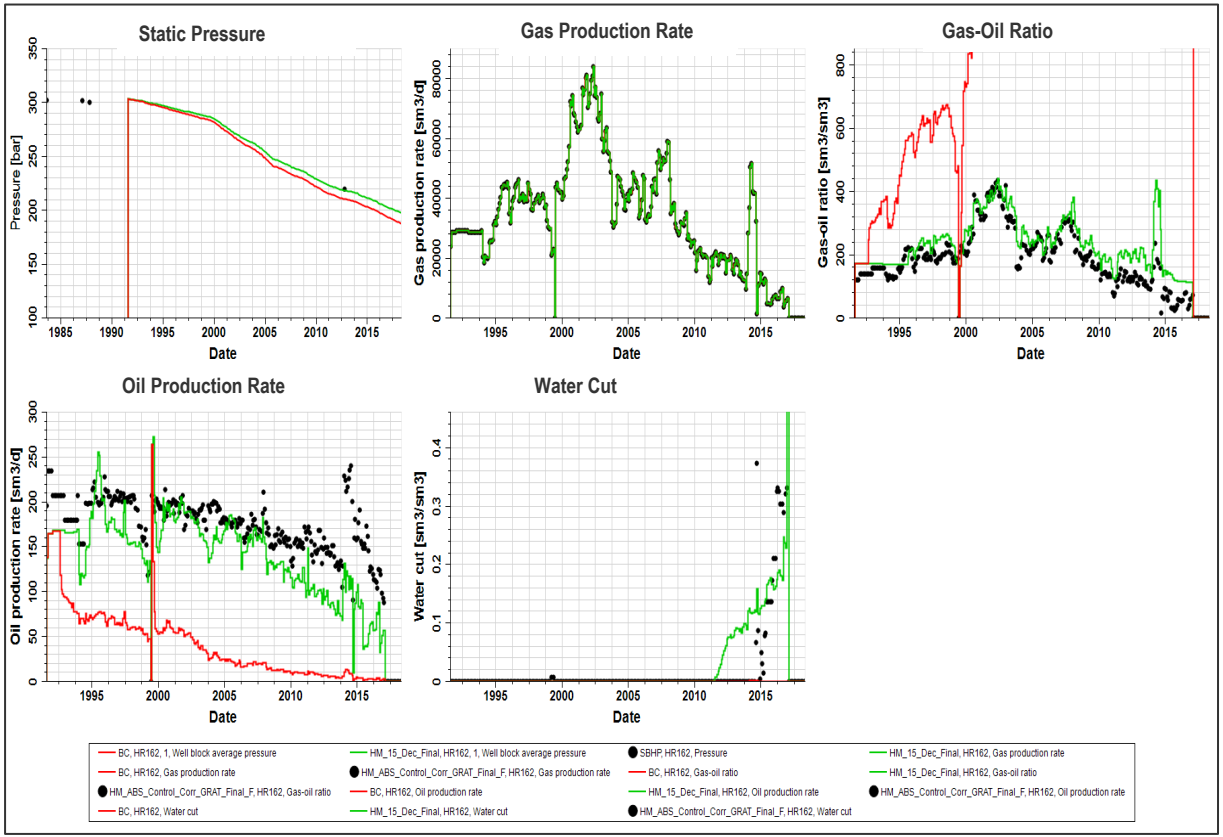




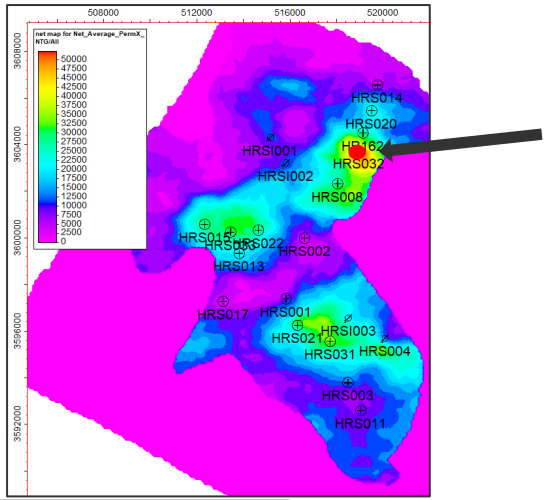
Average Oil Saturation Net Map

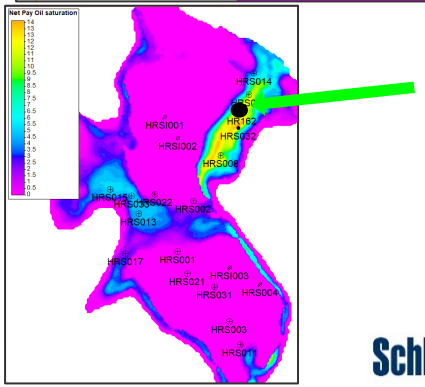
Latest HM Results: HRS162

Base Case
HM



Average PermX Net Map

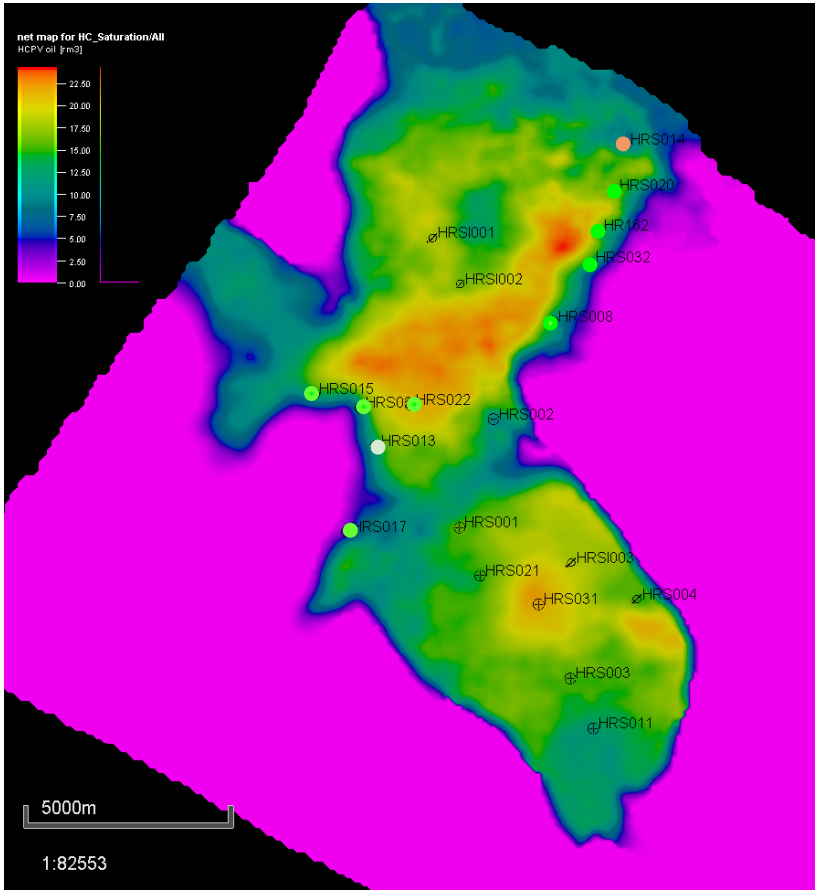




Average Oil Saturation Net Map

Schlumberger

Hassi R'mel South Well Location Map: Oil Wells



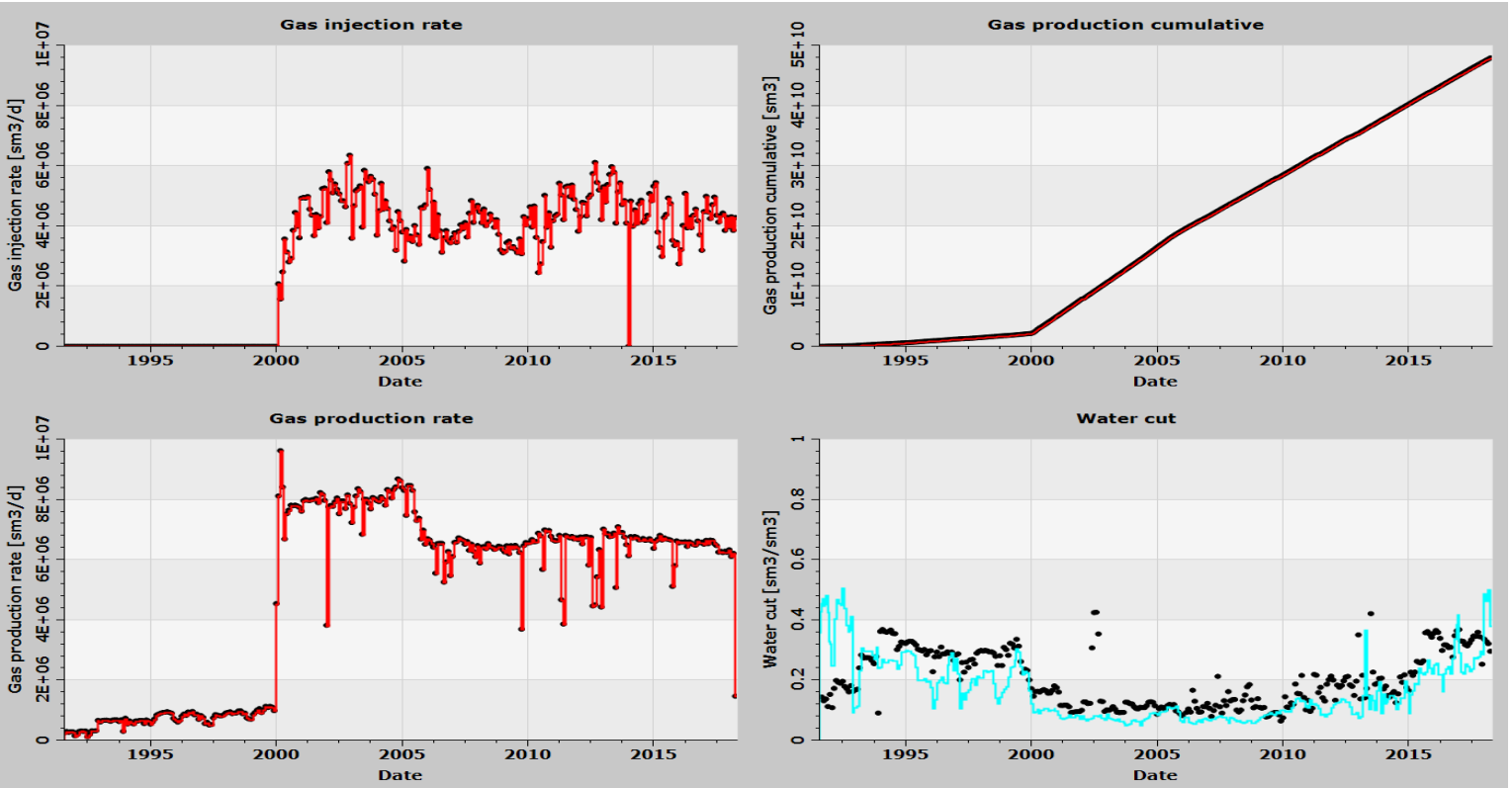
Good
Fair
Poor

Well Name	Well Type	Segment	Gas Rate	Oil Rate	GOR	Water Cut	Pressure
HRS008	Oil	East	NA	Good	Good	Good	Good
HRS013	Oil	West	NA	Fair	Fair	Good	Fair
HRS014	Oil	East	NA	Poor	Fair	Good	Fair
HRS015	Oil	West	NA	Good	Good	Fair	Good
HRS017	Oil	West	NA	Good	Good	Good	Good
HRS020	Oil	East	NA	Good	Good	Good	Good
HRS022	Oil	West	NA	Good	Good	Good	Good
HRS032	Oil	West	NA	Good	Good	Good	Good
HRS033	Oil	West	NA	Good	Good	Good	Good
HR162	Oil	East	NA	Good	Good	Good	Good

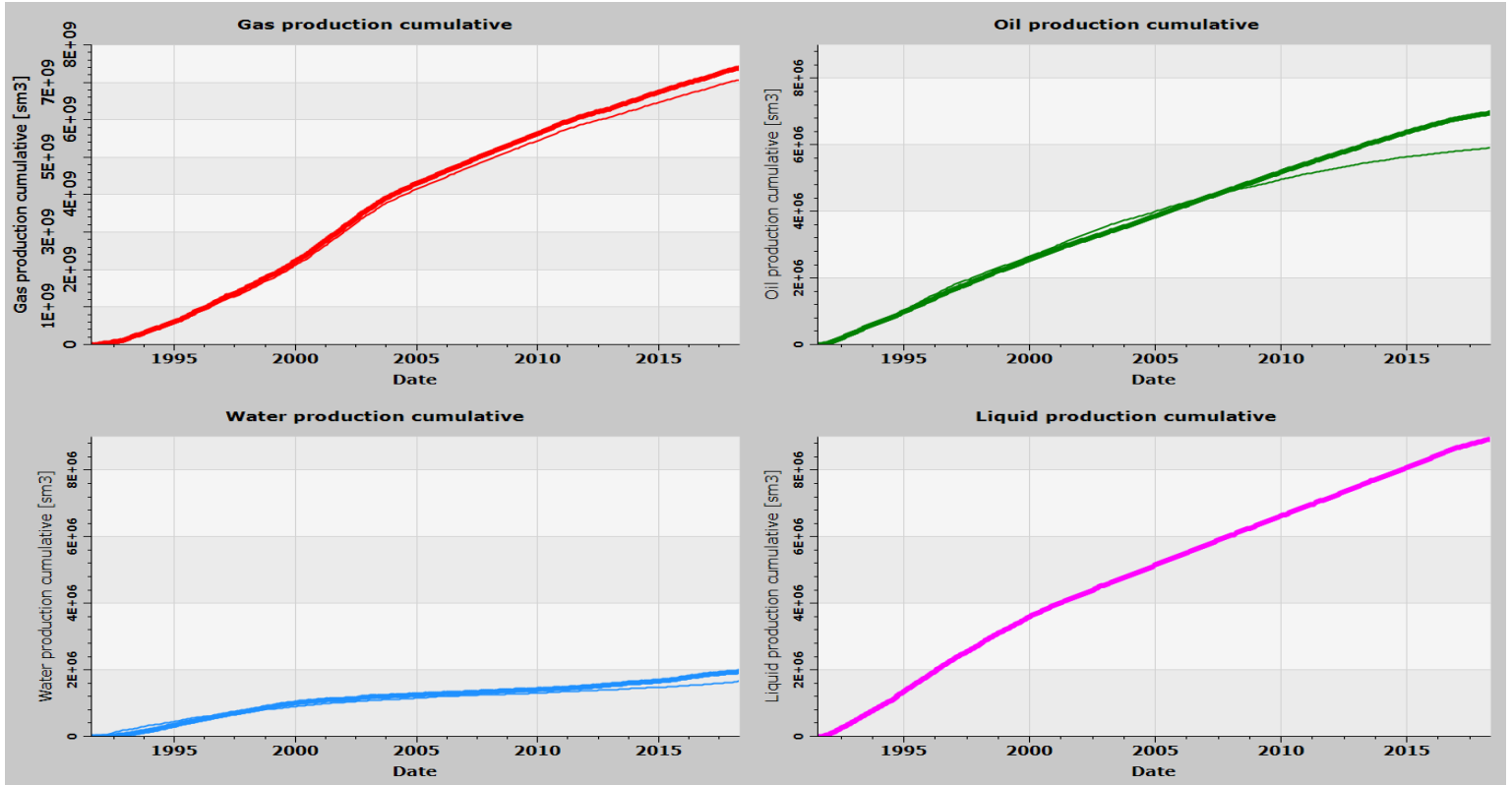
NA Not Applicable

Schlumberger

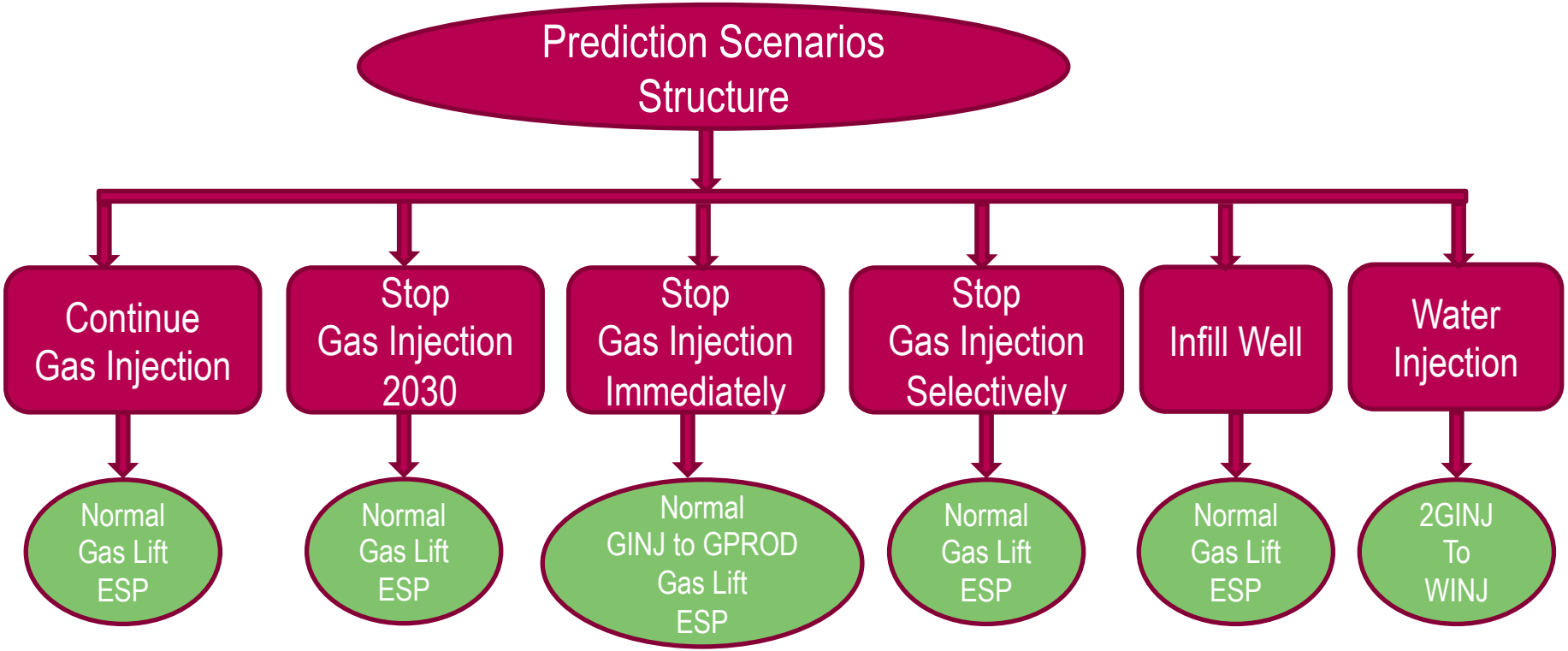
Final HM Model Results: Field Level



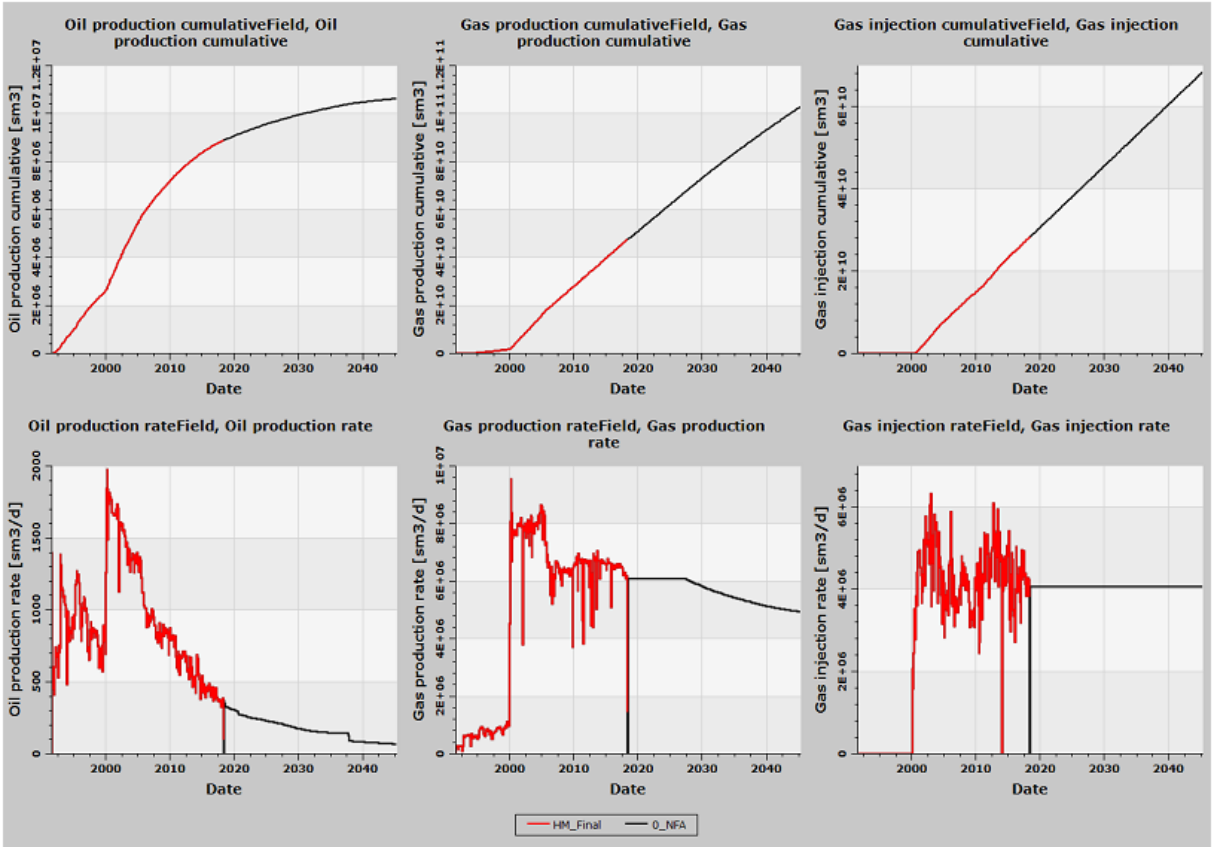
Final HM Model Results: Field Level



Prediction Scenarios Structure



No further Activity

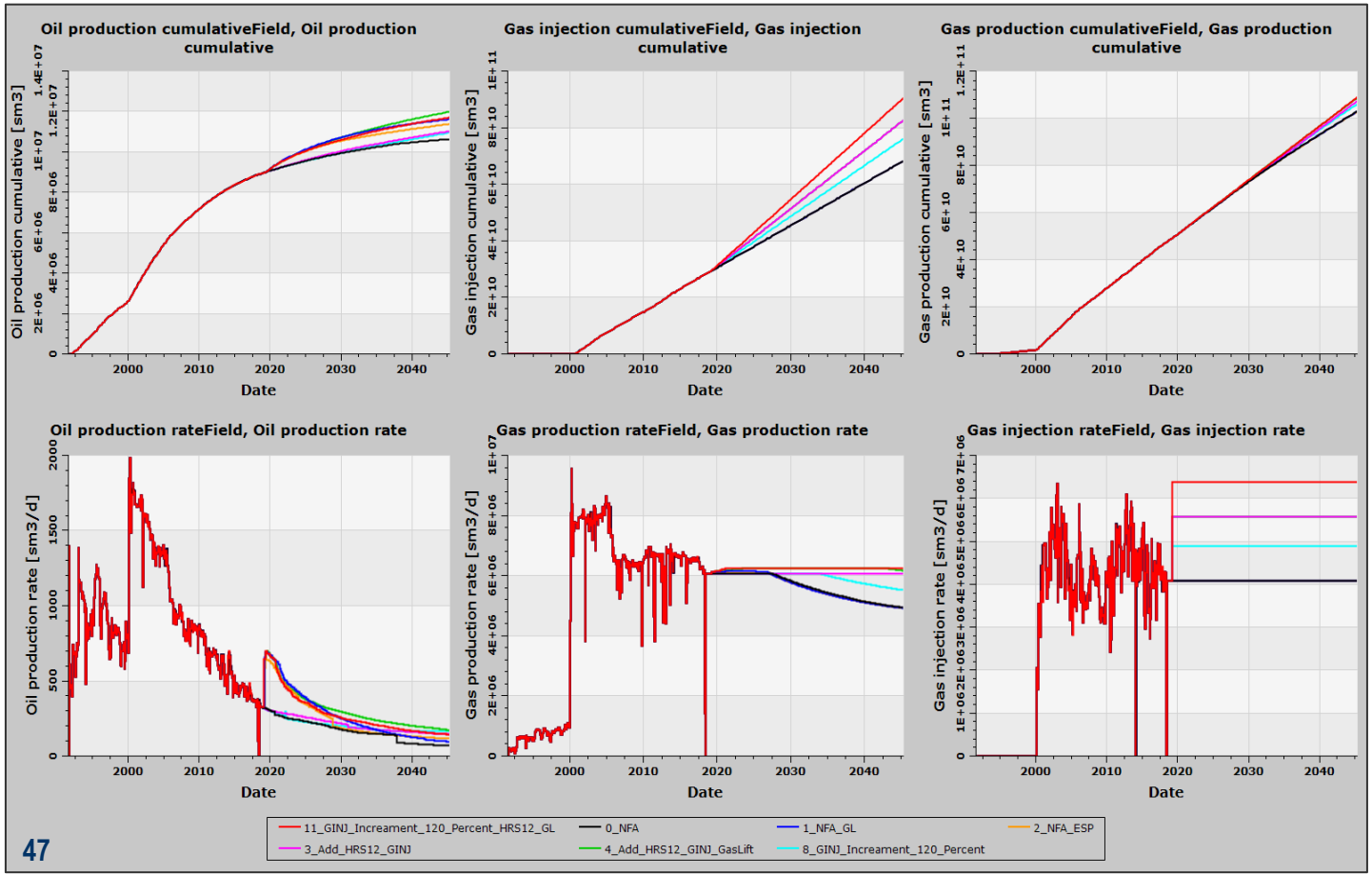


Continue Gas Injection: Gas Injection Rate Continue as History:
Conclusion: VRR Vs ESP, GL (Field)

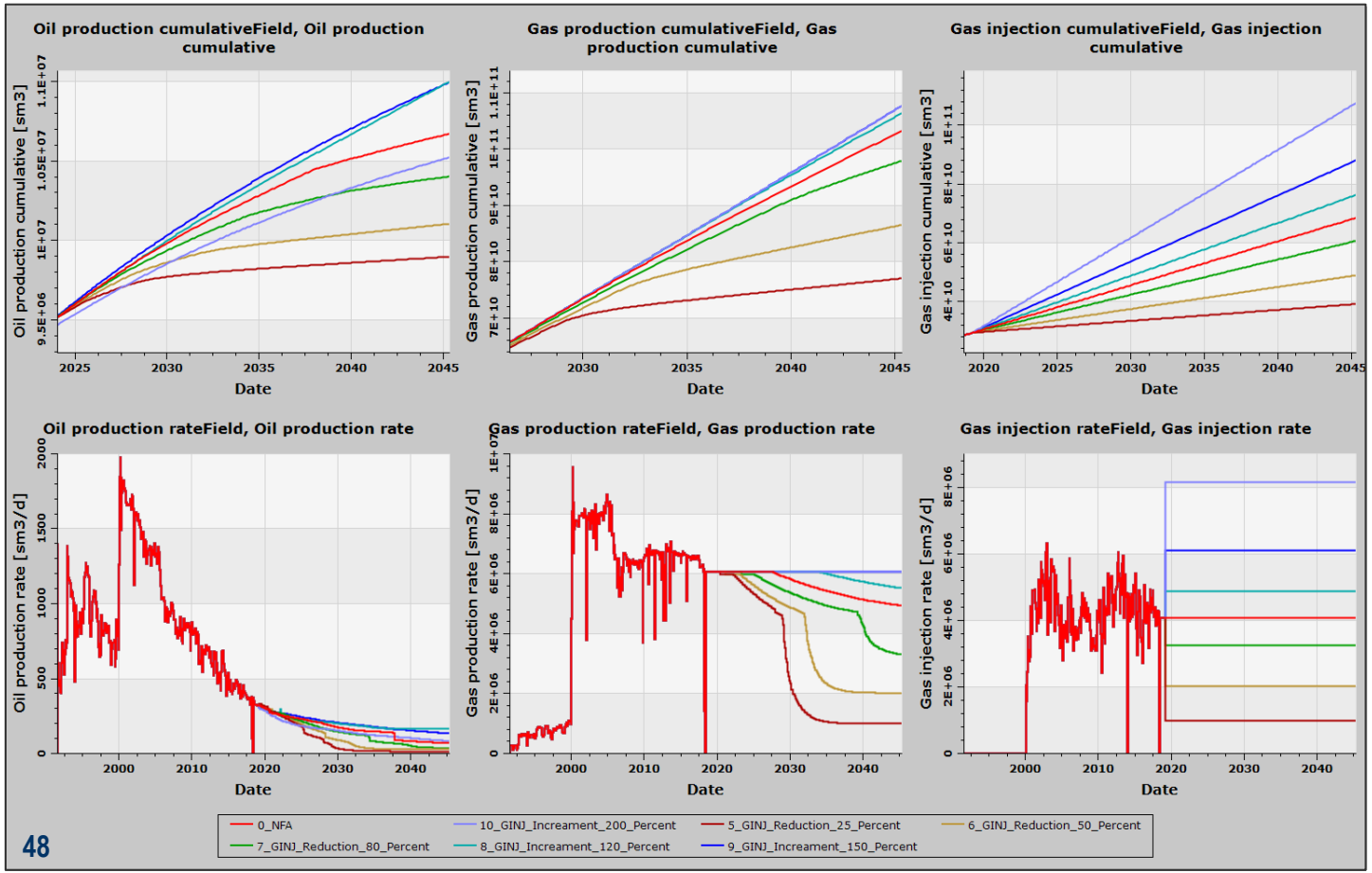
HRML Prediction Cases: Continue Gas Injection				
Injection Status	**Case Number**	**Case Definition**	**Simulation Case Name**	**GL or ESP**
NFA	0	No Further Field Activity (keep condition as it is till 2045)	0_NFA	None
Continue Gas Injection	1	Continue Gas Injection with Gas Lift	1_GL	GL
	2	Continue Gas Injection with ESP	2_ESP	ESP
	3	Continue Gas Injection and Adding HRA012 as Gas Injector	3_Add_HRS12_GINJ	Normal
	4	Add HRS12 as Injector+Gas Lift	4_Add_HRS12_GINJ_GL	GL
	5	Sensitivity on Injection Rate25% of Current Rate	5_GINJ_Reduction_25_Percent	Normal
	6	Sensitivity on Injection Rate 50% of Current Rate	6_GINJ_Reduction_50_Percent	Normal
	7	Sensitivity on Injection Rate 80% of Current Rate	7_GINJ_Reduction_80_Percent	Normal
	8	Sensitivity on Injection Rate 120% of Current Rate	8_GINJ_Increament_120_Percent	Normal
	9	Sensitivity on Injection Rate 150% of Current Rate	9_GINJ_Increament_150_Percent	Normal
	10	1Sensitivity on Injection Rate 200% of Current Rate	10_GINJ_Increament_200_Percent	Normal
	11	Best INJ Rate (120%)+HRS12 as Injector+Gas Lift	11_GINJ_Increament_120_Percent_HRS12_GL	GL

- Adding HRS012 as gas injector with implementing Gas lift has the maximum oil recovery factor.
- Increasing gas injection scenarios shows that the adding 20% to current injection can give the highest oil recovery. Increasing more gas injection will deteriorate the oil recovery.

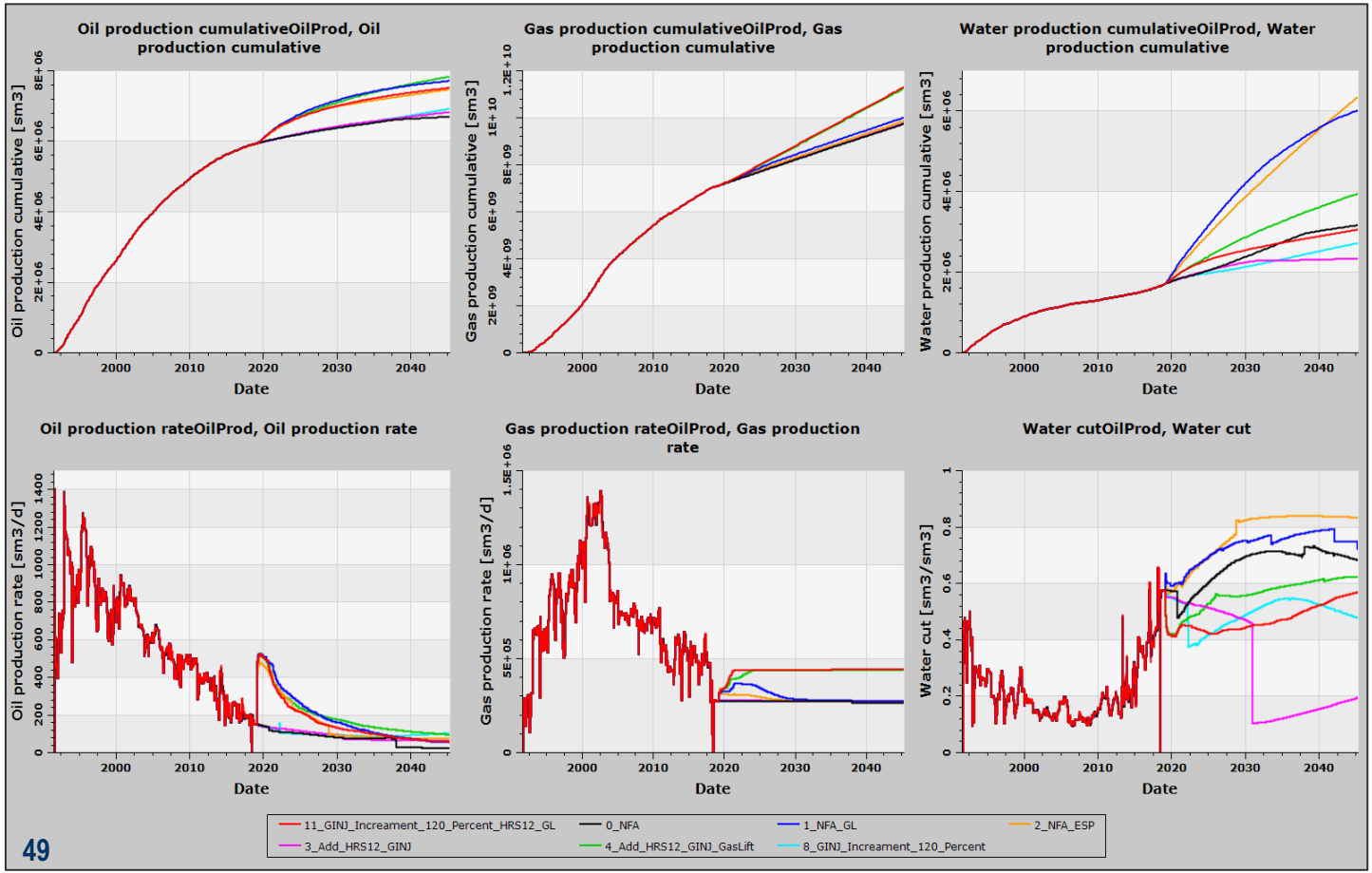
Continue Gas Injection: Conclusion: VRR Vs ESP, GL (Field)



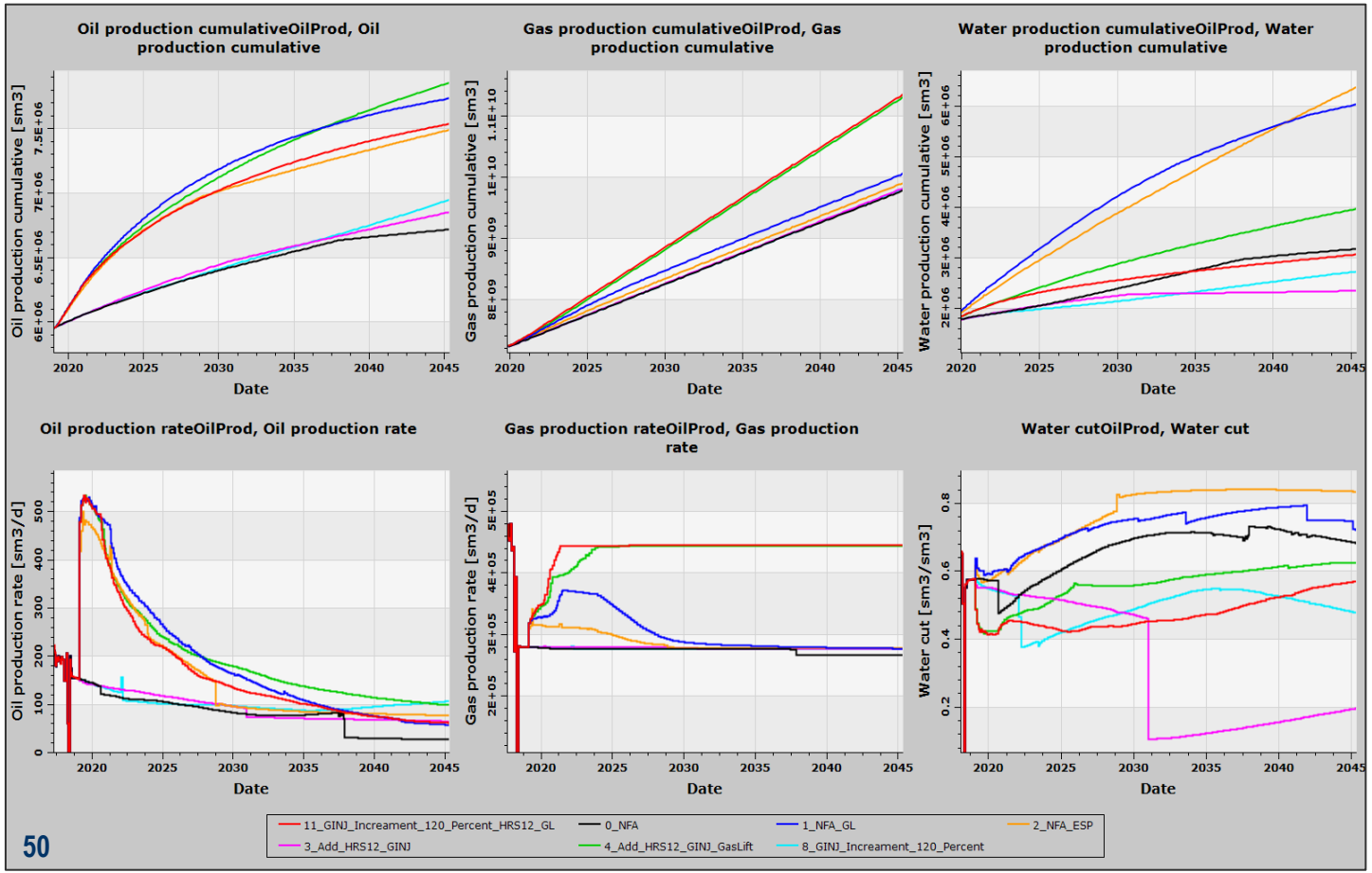
Continue Gas Injection: Conclusion: VRR Vs ESP, GL (Field) : Zoomed



Continue Gas Injection: Conclusion: VRR Vs ESP, GL (Field) (Oil Producers)

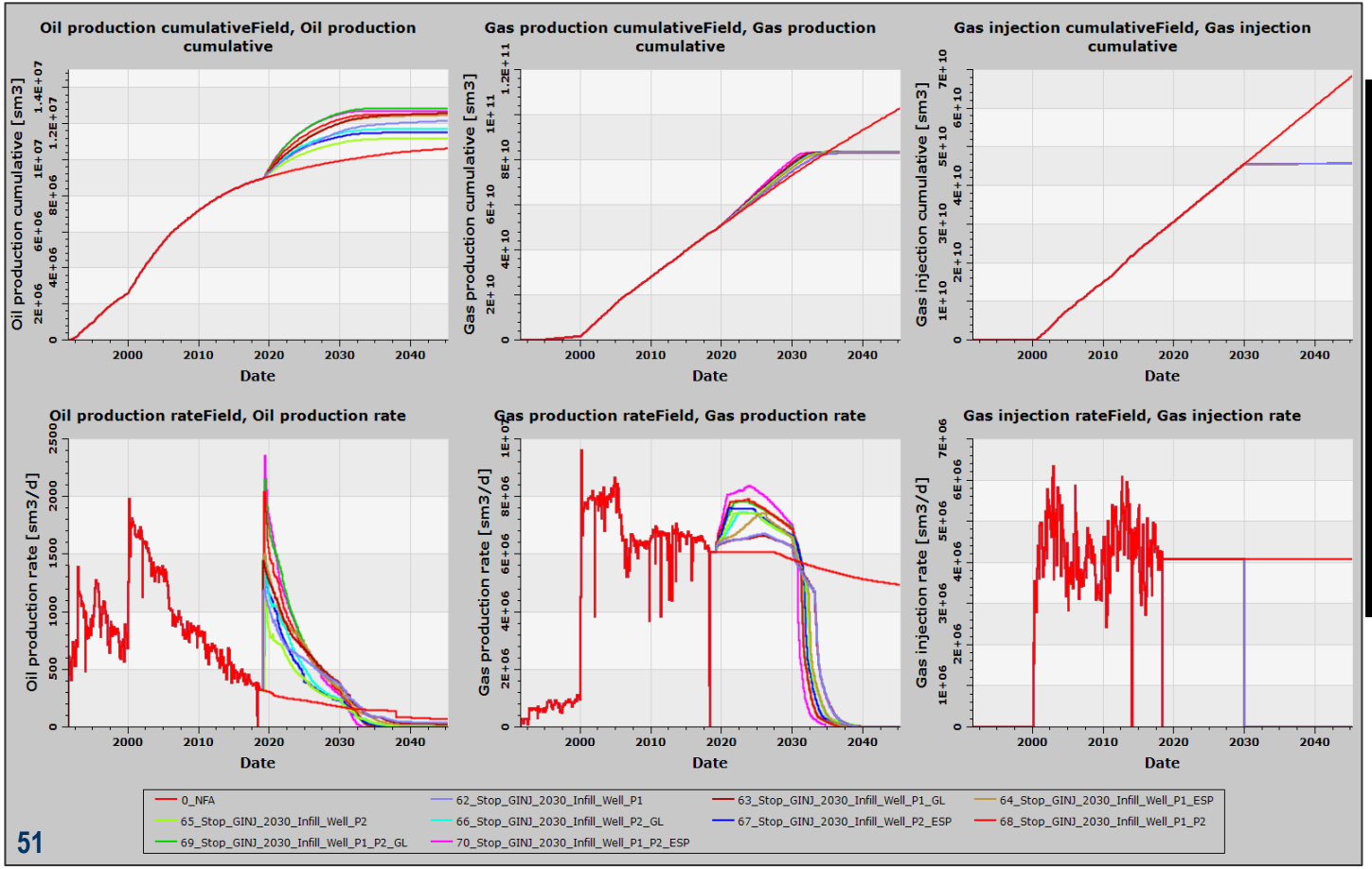


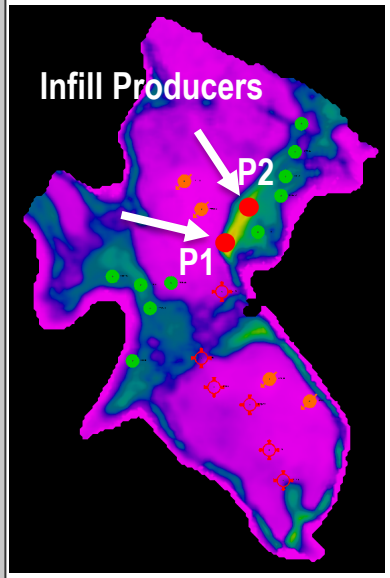
Continue Gas Injection: Conclusion: VRR Vs ESP, GL (Field) (Oil Producers): Zoomed



Increasing Gas injection increases the RF but after 120% it starts decreasing and in 200% it delivers less than NFA

New Infill Wells : Stop Gas Injections 2030 Infill Wells Comparison(Field)

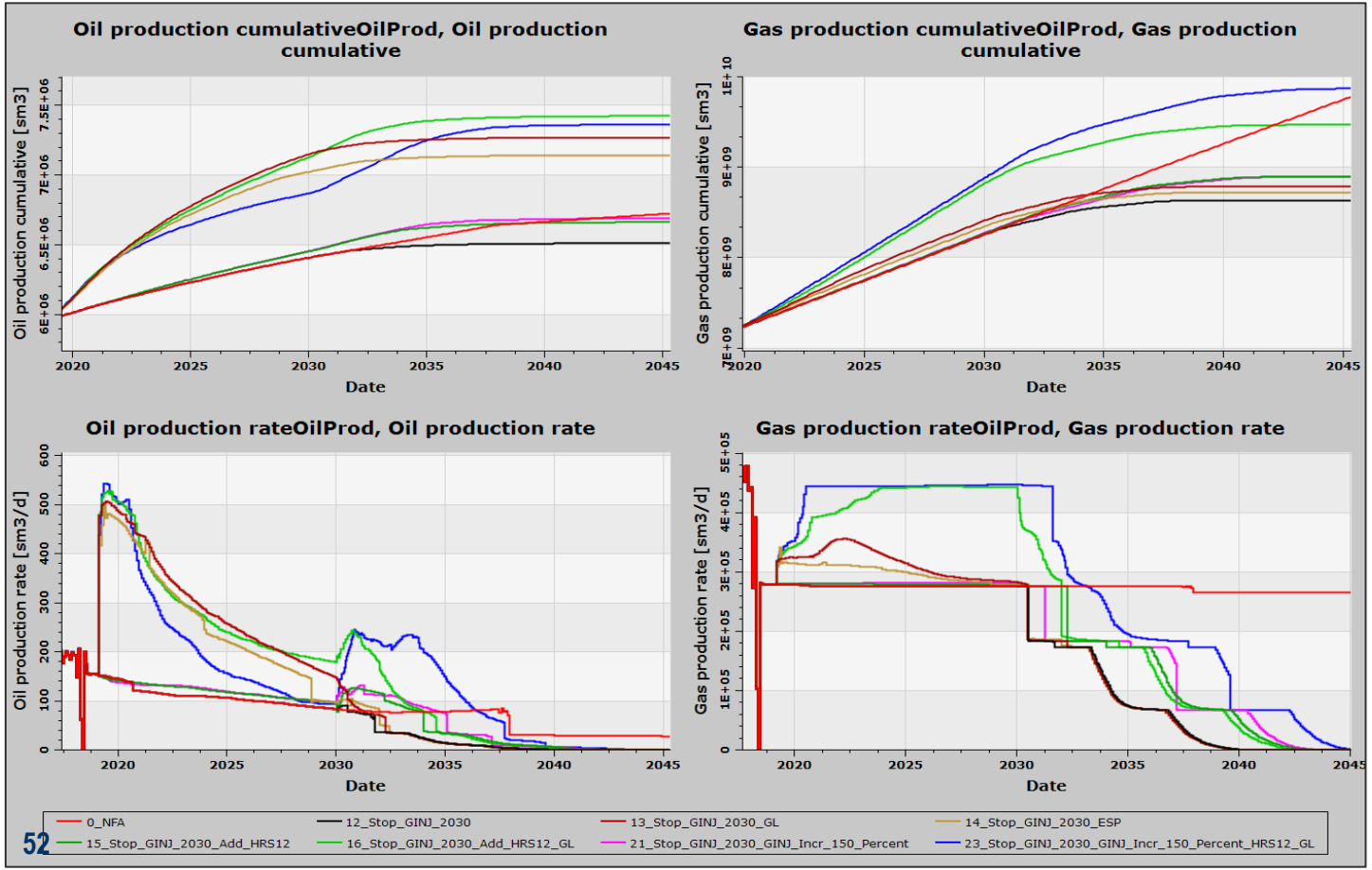




● Infill Oil Producers

Schlumberger

Stop Gas Injection 2030: Best Cases Comparison Results



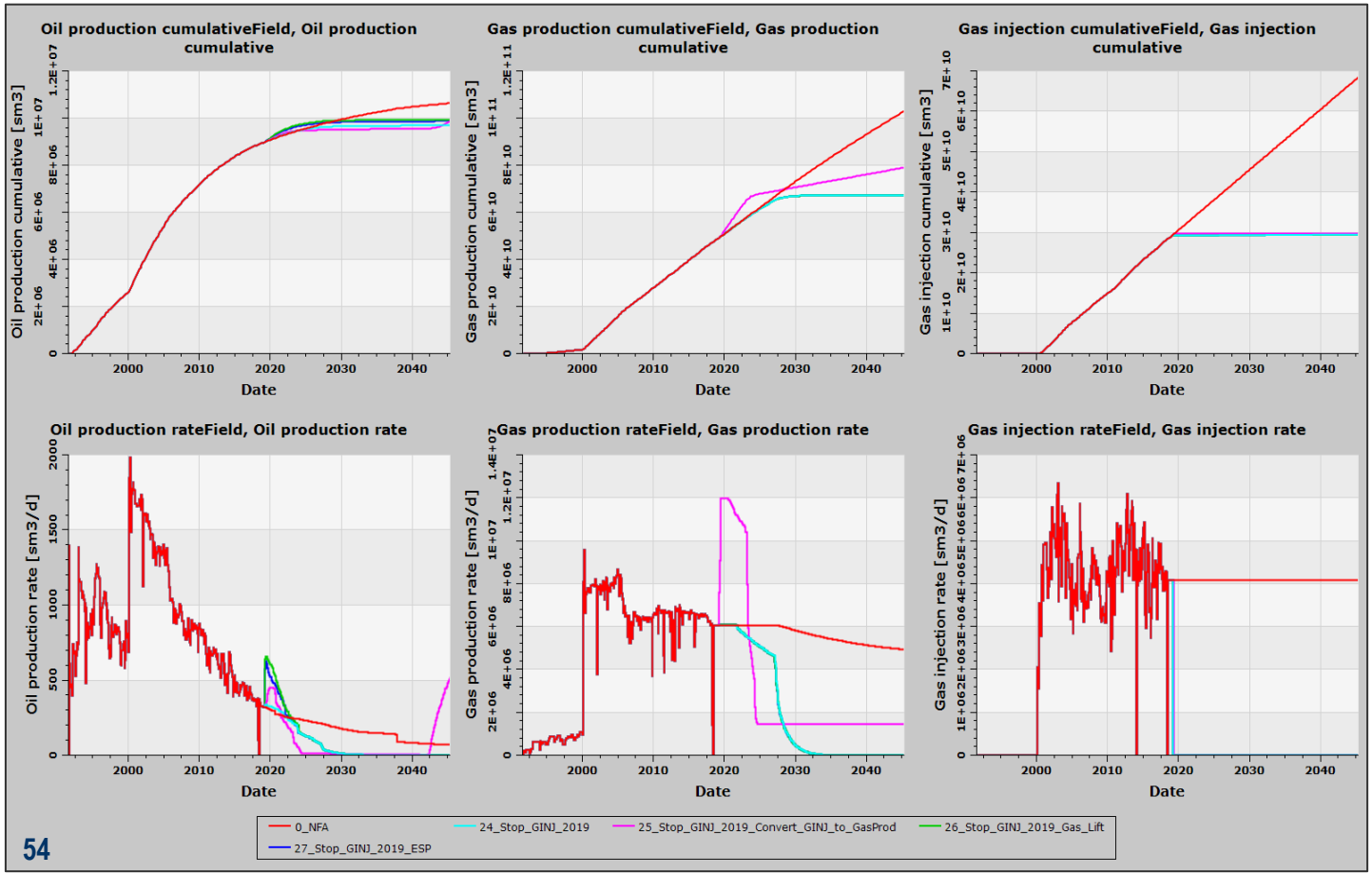
For the scenarios with stopping gas injection at 2030 , adding HRS012 with gas lift (Case 16) has the maximum recovery factor. After that adding HRS012 injector with 50% gas injection increment and gas lift (Case 23) following with the case of only gas lift (Case 13) are the main 3 top scenarios with highest oil recovery.

Stop Gas Injection Immediately: Gas Injection Stops in 2019

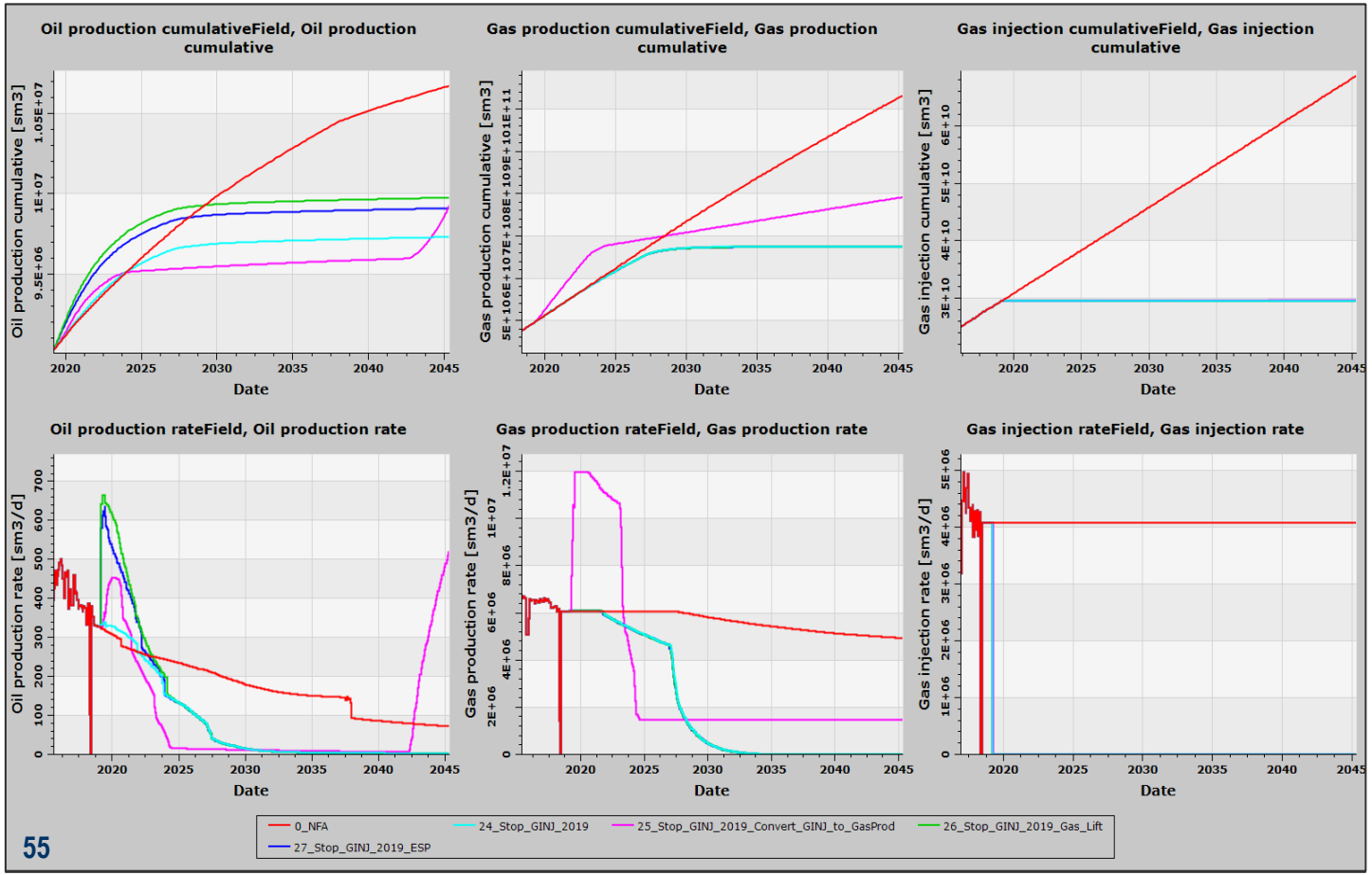
HRML Prediction Cases: Stop Gas Injection Immediately				
Injection Status	Case Number	Case Definition	Simulation Case Name	GL or ESP
NFA	0	No Further Field Activity (keep condition as it is till 2045)	0_NFA	None
Stop Gas Injection Immidiately (2019)	24	Stop Gas Injection Immidiately (2019)	24_Stop_GINJ_2019	Normal
	25	Stop Gas Injection Immidiately (2019)+Convert Gas Injectors to Gas Producers	25_Stop_GINJ_2019_Convert_GINJ_to_GasProd	Normal
	26	Stop Gas Injection Immidiately (2019)+Gas Lift	26_Stop_GINJ_2019_GL	GL
	27	Stop Gas Injection Immidiately (2019)+ESP	27_Stop_GINJ_2019_ESP	ESP

- In this scenarios gas injection Stopped in March 2019 and different development options were evaluated such as converting the gas injectors to gas producers , ESP and Gas lift scenarios

Stop Gas Injection Immediately : Conclusion: VRR Vs ESP, GL (Field)

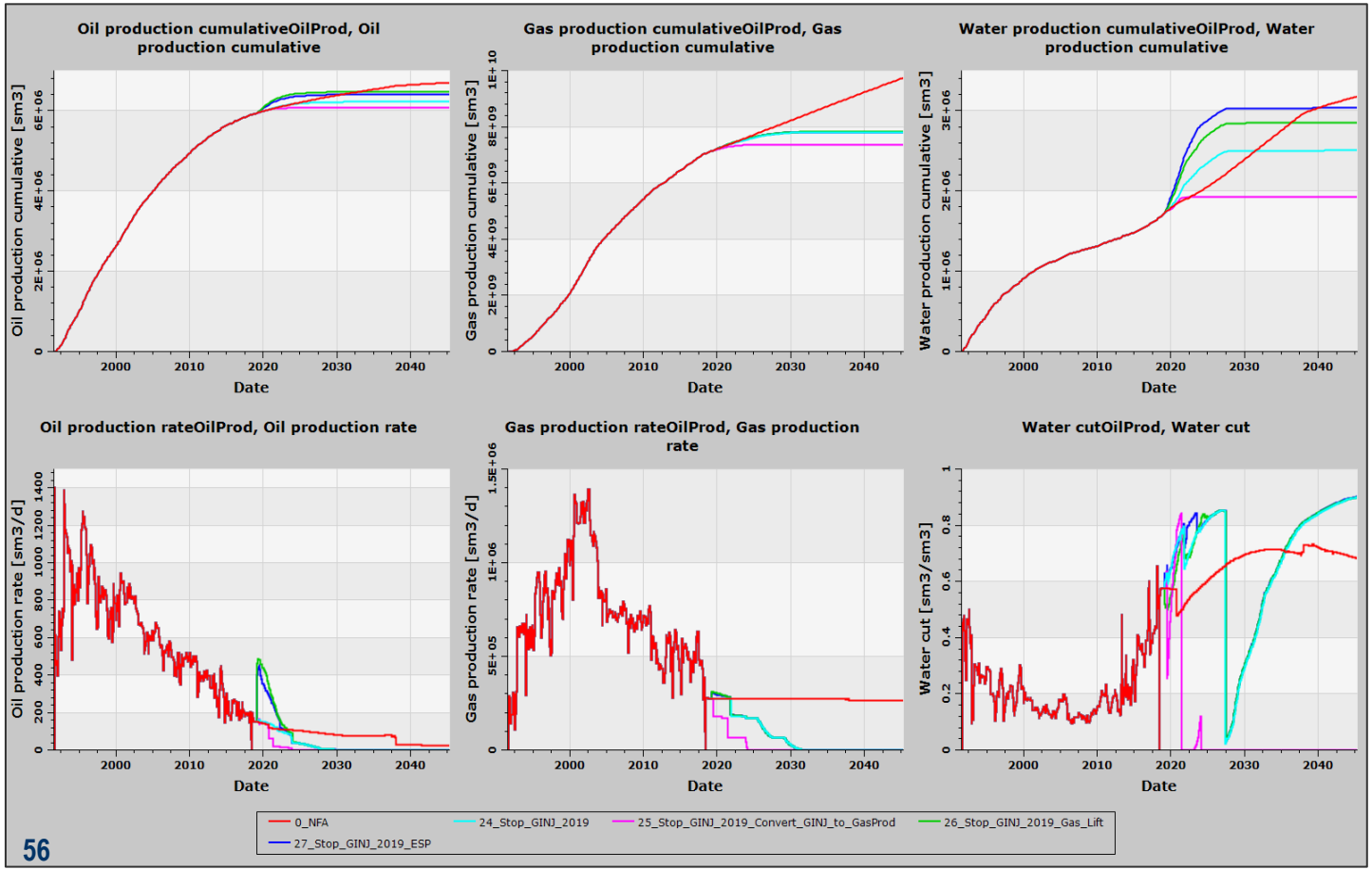


Stop Gas Injection Immediately : Conclusion: VRR Vs ESP, GL (Field) : Zoomed

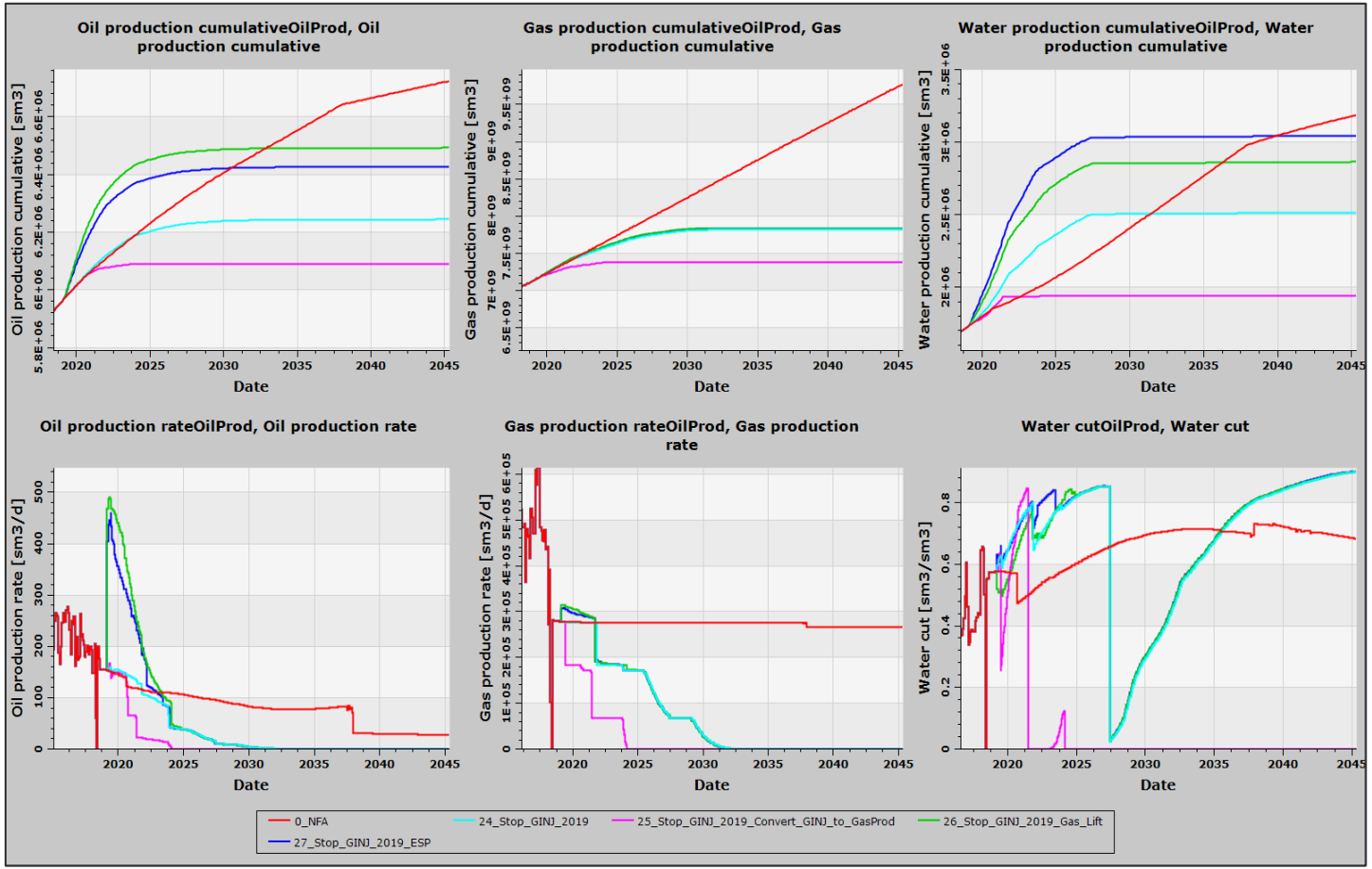


Comparing VRR scenarios with ESP and GL shows that still GL then ESP and VRR=2 have the highest RF% in Field level which is including gas condensates production

Stop Gas Injection Immediately : Conclusion: VRR Vs ESP, GL (Field) (Oil Producers)



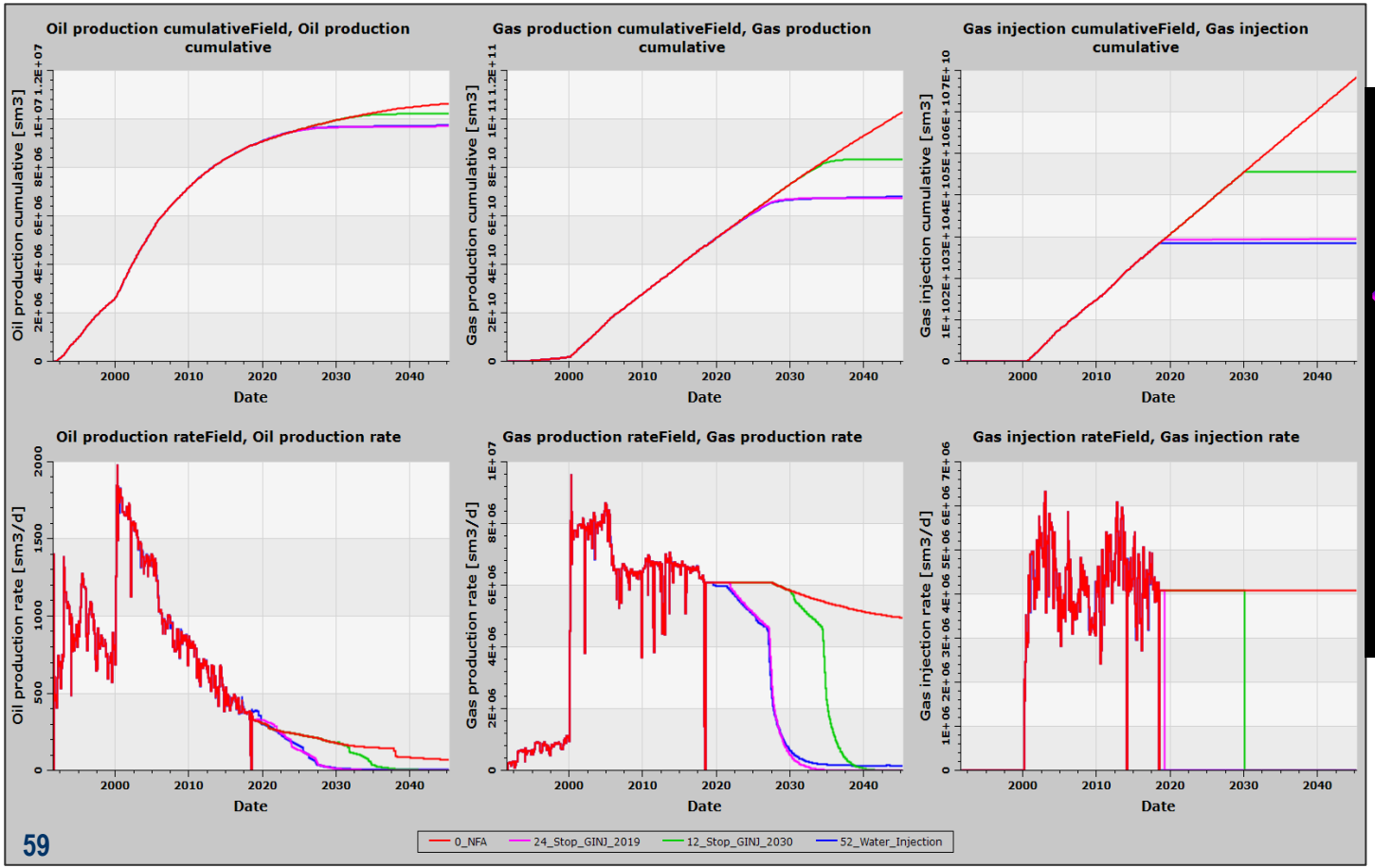
Stop Gas Injection Immediately : Conclusion: VRR Vs ESP, GL (Field) (Oil Producers): Zoomed

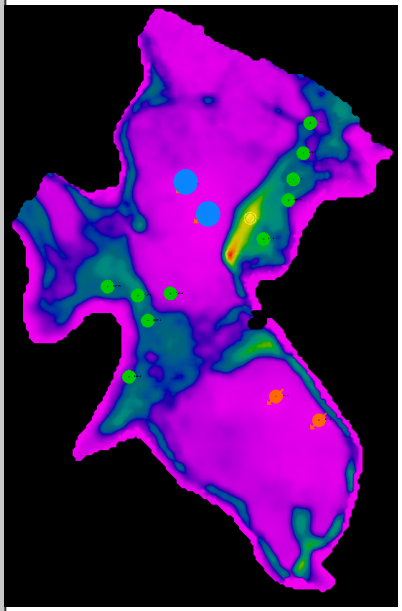


Water Injection

Hassi R'Mel South TAG-A Prediction Cases: Water Injection Scenario				
Injection Status	Case Number	Case Definition	Simulation Case Name	GL or ESP
NFA	0	No Further Field Activity (keep condition as it is till 2045)	0_NFA	None
Water Injection	52	Water Injection (Converting 2North Gas Injectors to Water Injectors)	52_Water_Injection	Normal

Water Injection : Converting Two North Gas Injector to Water Injectors (Field)





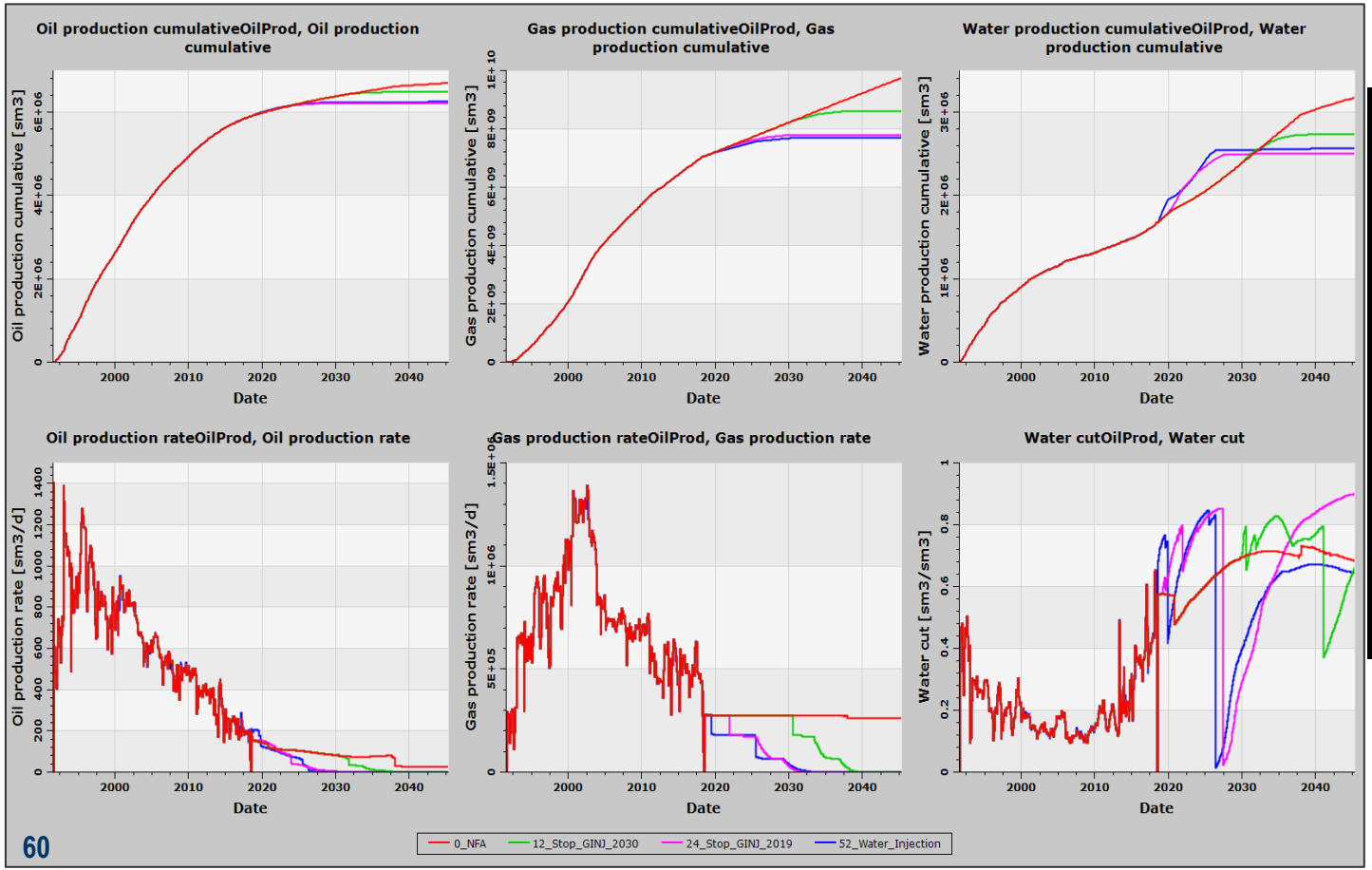
Oil Producers

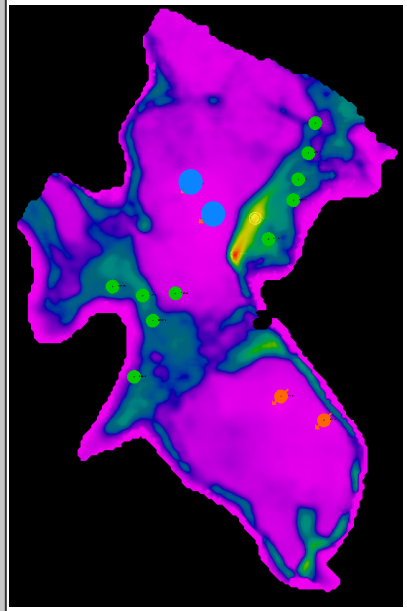
Water Injectors

Gas Injectors

Schlumberger

Water Injection : Converting Two North Gas Injector to Water Injectors (Oil Group)





- Oil Producers
- Water Injectors
- Gas Injectors

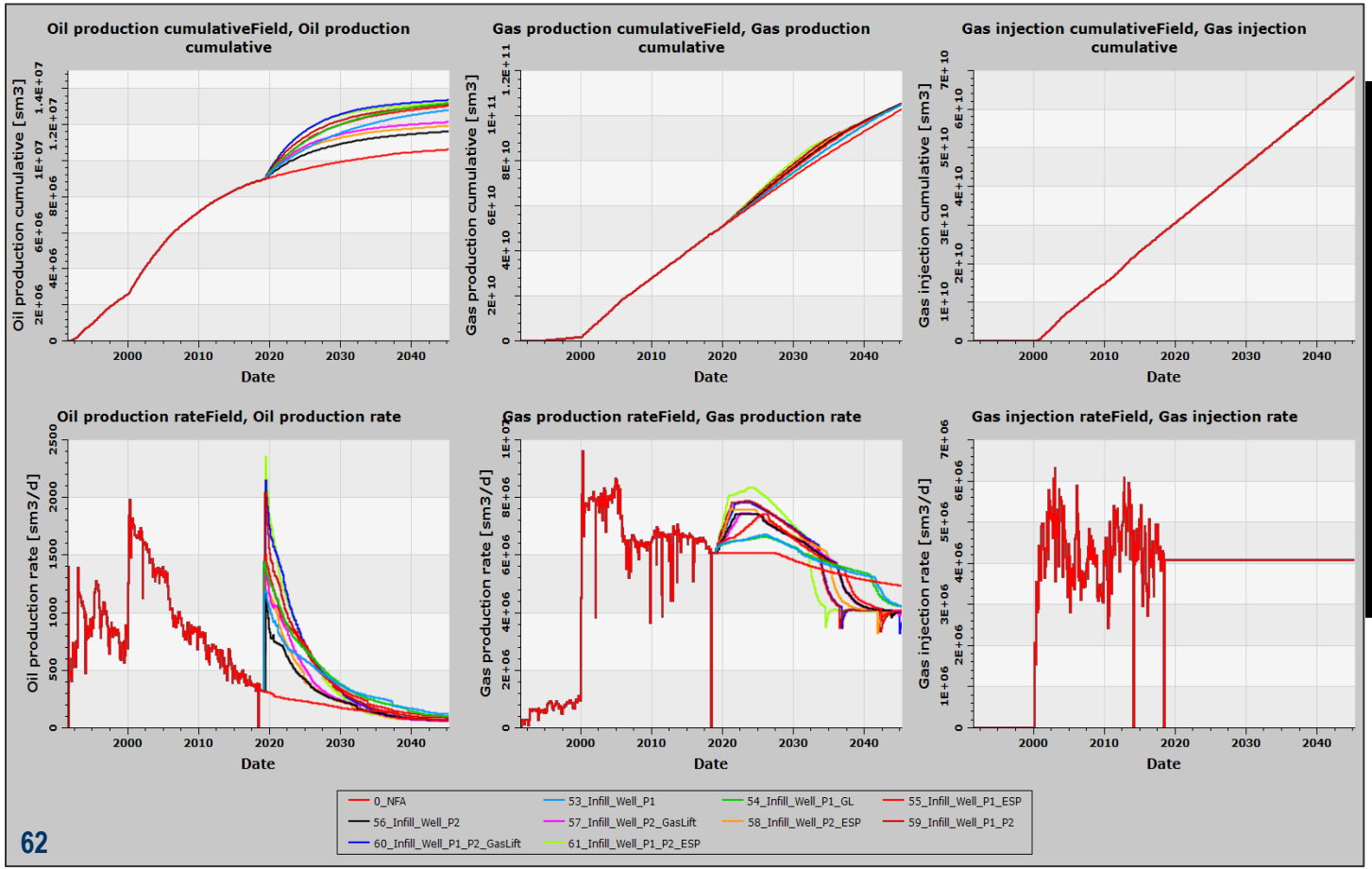
Schlumberger

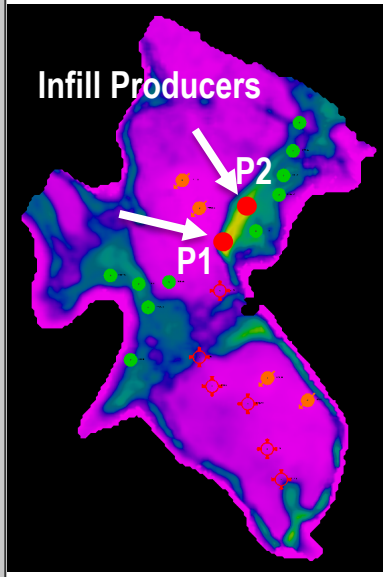
Infill Well: New Infill wells with current gas injection and stop Injection at 2030

Hassi R'Mel South TAG-A Prediction Cases: New Infill Wells				
Injection Status	Case Number	Case Definition	Simulation Case Name	GL or ESP
NFA	0	No Further Field Activity (keep condition as it is till 2045)	0_NFA	None
New Infill Wells (Producers)	53	Continue Gas Inejction+P1	53_Infill_Well_P1	Normal
	54	Continue Gas Inejction+P1+GL	54_Infill_Well_P1_GL	GL
	55	Continue Gas Inejction+P1+ESP	55_Infill_Well_P1_ESP	ESP
	56	Continue Gas Inejction+P2	56_Infill_Well_P2	Normal
	57	Continue Gas Inejction+P2+GL	57_Infill_Well_P2_GasLift	GL
	58	Continue Gas Inejction+P2+ESP	58_Infill_Well_P2_ESP	ESP
	59	Continue Gas Inejction+P1+P2	59_Infill_Well_P1_P2	Normal
	60	Continue Gas Inejction+P1+P2+GL	60_Infill_Well_P1_P2_GasLift	GL
	61	Continue Gas Inejction+P1+P2+ESP	61_Infill_Well_P1_P2_ESP	ESP
	62	Stop Gas Inejction2030+P1	62_Stop_GINJ_2030_Infill_Well_P1	Normal
	63	Stop Gas Inejction2030+P1+GL	63_Stop_GINJ_2030_Infill_Well_P1_GL	GL
	64	Stop Gas Inejction2030+P1+ESP	64_Stop_GINJ_2030_Infill_Well_P1_ESP	ESP
	65	Stop Gas Inejction2030+P2	65_Stop_GINJ_2030_Infill_Well_P2	Normal
	66	Stop Gas Inejction2030+P2+GL	66_Stop_GINJ_2030_Infill_Well_P2_GL	GL
	67	Stop Gas Inejction2030+P2+ESP	67_Stop_GINJ_2030_Infill_Well_P2_ESP	ESP
	68	Stop Gas Inejction2030+P1+P2	68_Stop_GINJ_2030_Infill_Well_P1_P2	Normal
	69	Stop Gas Inejction2030+P1+P2+GL	69_Stop_GINJ_2030_Infill_Well_P1_P2_GL	GL
	70	Stop Gas Inejction2030+P1+P2+ESP	70_Stop_GINJ_2030_Infill_Well_P1_P2_ESP	ESP

- In this scenarios sweet spots of remaining oil were selected to drill new wells and gas lift , ESP pumps were tried with continuing gas injection and stopping gas injection at 2030

New Infill Wells : Continue Gas Injections: (Field)

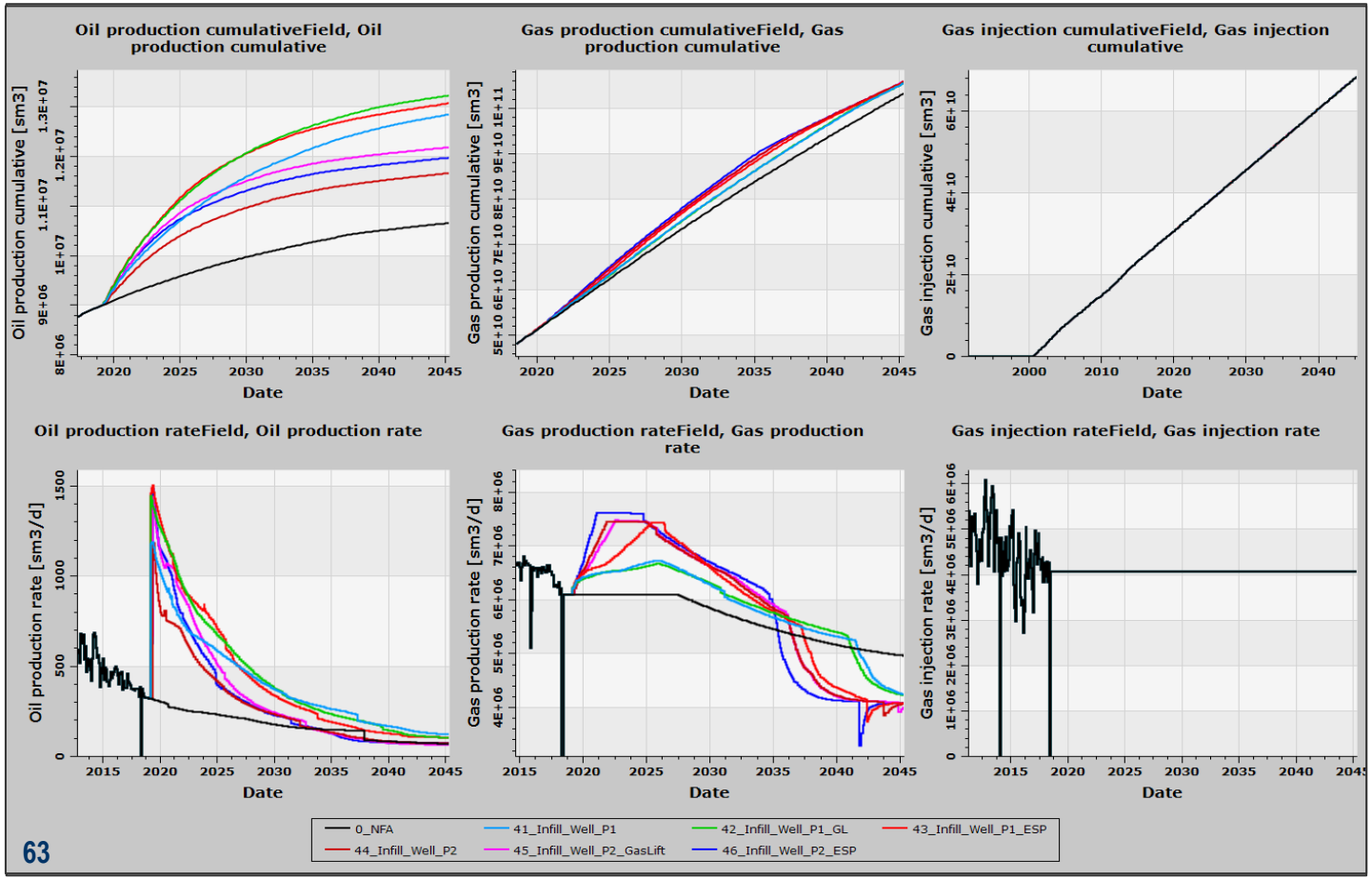


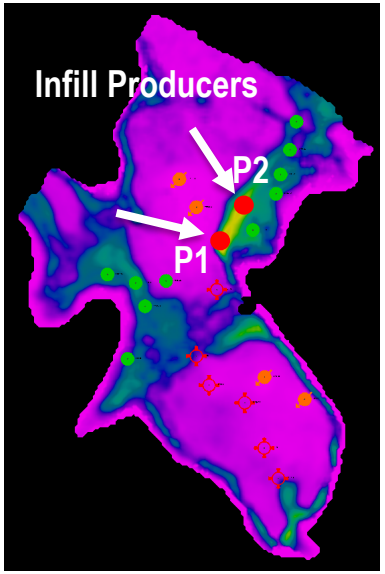


Infill Oil Producers

Schlumberger

New Infill Wells : Continue Gas Injections (Field): Zoomed

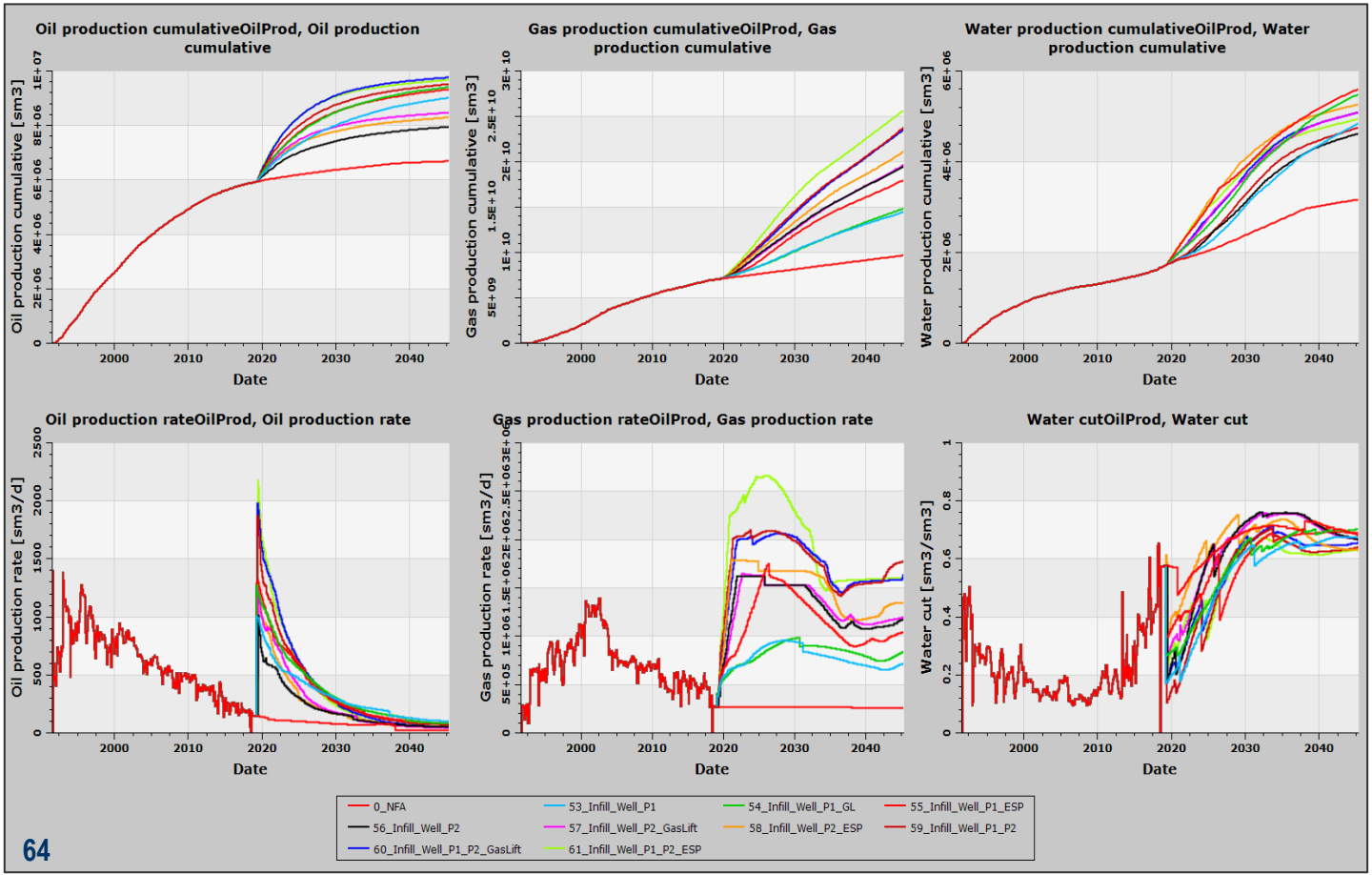


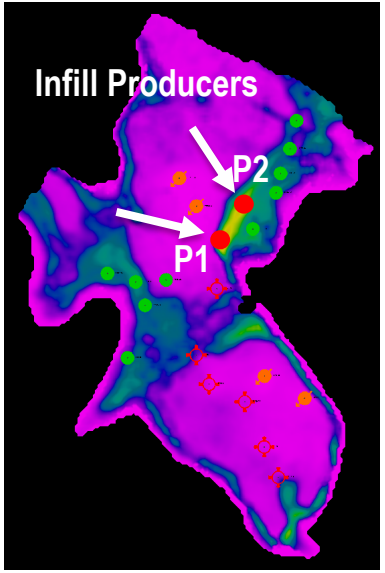


Infill Oil Producers

Schlumberger

New Infill Wells : Continue Gas Injections (Oil Group)

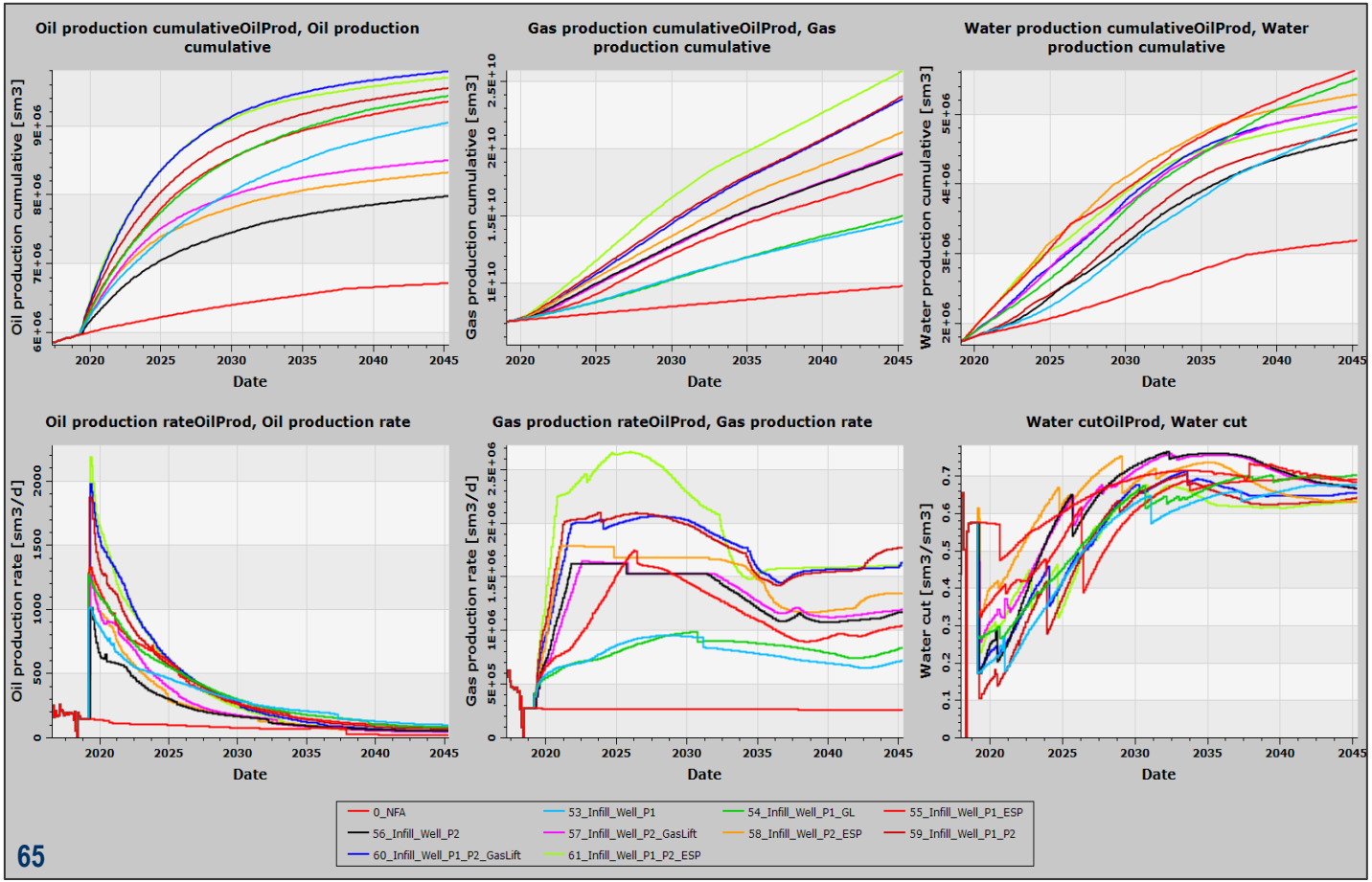


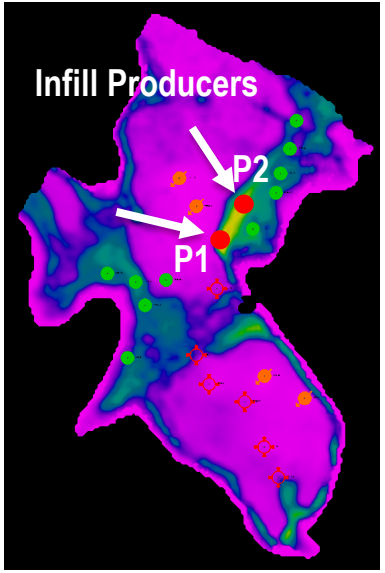


● Infill Oil Producers

Schlumberger

New Infill Wells : Continue Gas Injections (Oil Group): Zoomed





● Infill Oil Producers

Two wells P1 and P2 were drilled in sweet spots and gas lift, ESP pump were examined. As it can be seen from field and oil group wells, the scenario of P1 with implementing gas lift has the highest oil recovery compared to P2.

Schlumberger

Summary of Oil & Gas Recovery Factor of Best Scenarios

No	Scenario Name	Cum. Oil (Oil Wells)		Cum. Oil Prod. (Oil+ Condensate)		Cum. Gas Prod. (Gas Wells)	Cum. Gas Prod. (Gas Wells+ Oil Wells)	Cum. Gas Inj. (Gas Wells)	Net Total Gas Produced		Cum. Water Prod.	Cum. Water Inj.
		MMSM3 (10^6)	Oil Rim Recovery Factor	MMSM3 (10^6)	Field Oil Recovery Factor	BSM3 (10^9)	BSM3 (10^9)	BSM3 (10^9)	BSM3 (10^9)	Field Gas Recovery Factor	MSM3 (10^3)	MSM3 (10^3)
0	No Further Field Activity (keep condition as it is till 2045)	6.722	30.11%	10.666	34.44%	93.155	102.915	68.312	34.602	61.00%	3192.476	0.000
54	Continue Gas Injection+P1+GL	9.438	42.28%	13.232	42.73%	90.195	105.122	68.312	36.810	64.89%	5503.363	0.000
55	Continue Gas Injection+P1+ESP	9.358	41.91%	13.074	42.22%	87.198	105.228	68.312	36.916	65.07%	5623.457	0.000
59	Continue Gas Injection+P1+P2	9.551	42.78%	13.167	42.52%	81.690	105.451	68.312	37.139	65.47%	4772.295	0.000
60	Continue Gas Injection+P1+P2+ GL	9.796	43.88%	13.410	43.30%	82.014	105.572	68.312	37.260	65.68%	5107.652	0.000
61	Continue Gas Injection+P1+P2+ ESP	9.707	43.48%	13.268	42.84%	80.006	105.652	68.312	37.339	65.82%	4962.058	0.000

Recommendations

Based on the comprehensive assessment, the following is recommended:

- Highest priority on drilling one or two new infill wells in unswept oil rim area in north-east part of reservoir. Number to be decided based on economic evaluation.
- Any reduction or stopping gas injection should be avoided or delayed to prevent loss of oil recovery factor.
- For any development scenario implementing gas lift is the recommended option to increase ultimate oil recovery followed by ESP.

Recommendations

- Water injection scenario will significantly deteriorate the reservoir performance.
- Longer period of gas injection with gas lift (or ESP) would be the most efficient scenario. This option, combined with two infill wells, could be the best way forward to increase oil recovery.
- Stopping gas injection immediately (2019) and converting injectors to gas producers has significantly high gas recovery factor which should be evaluated through detailed economical analysis.