OLJEDIREKTORATET

Case study: Simulation of storage of CO2 rich combustion gas in a shallow offshore reservoir

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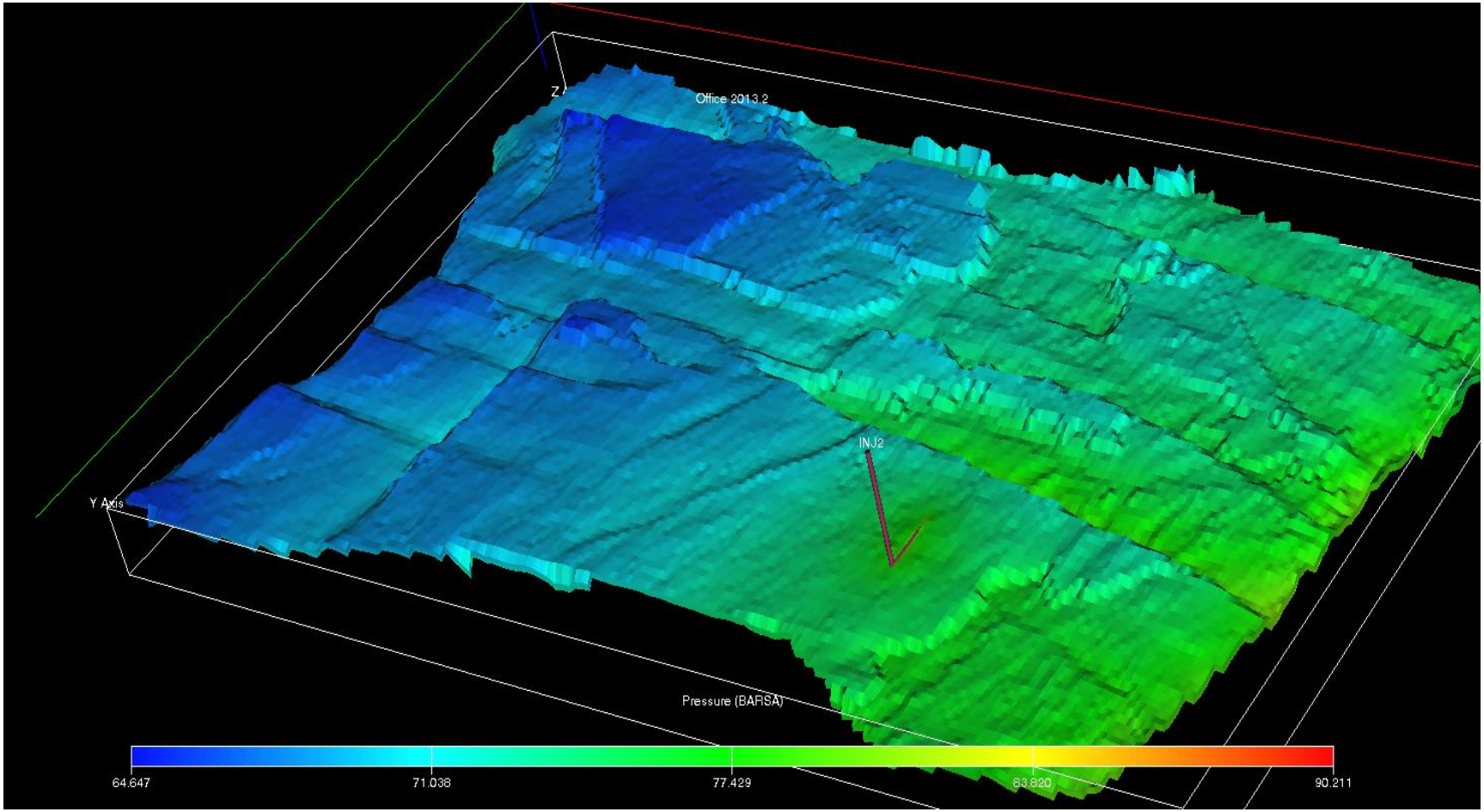
Model of saline aquifer and well location



The model of the saline aquifer is based on a real geological case. It is approximately 13x10 km with a reservoir thickness of 10-20 m.
Simulations were run with open and closed boundaries.
The colours show initial pressure, which is hydrostatic and varies from 65 to 75 bar, 70 bar in the well position.
Average reservoir properties: Porosity 20 %, permeability 400 mD.

Gas injection

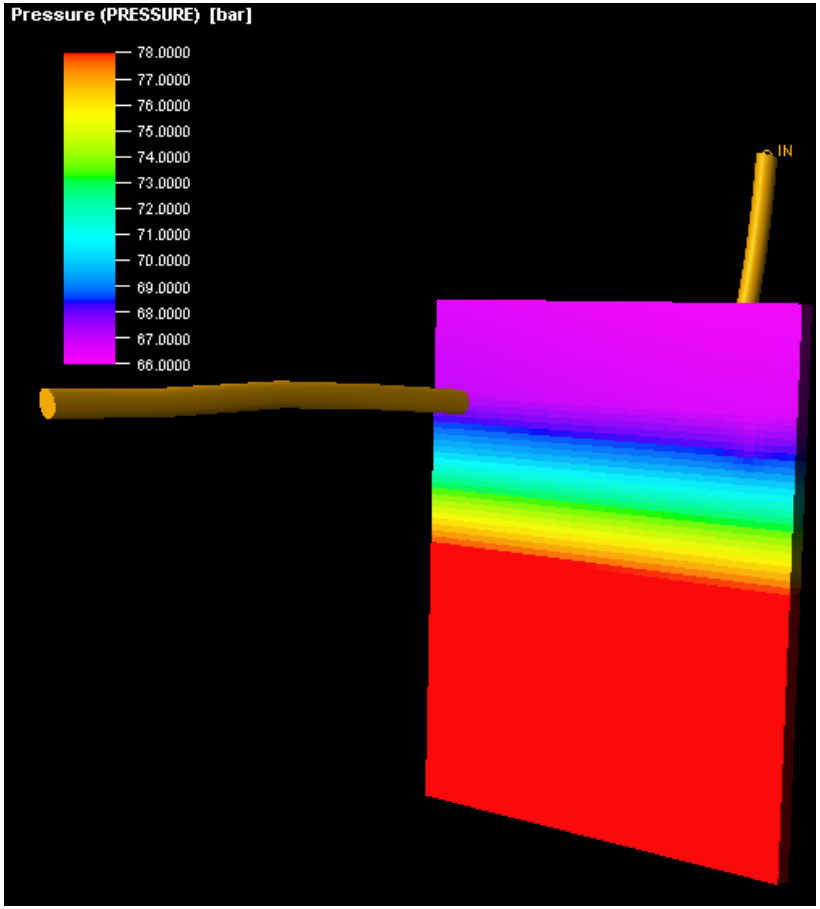
- Gas composition of combustion gas used for injection,

CO2	N2	O2	H2O
0.114	0.8797	0.006	0.0003

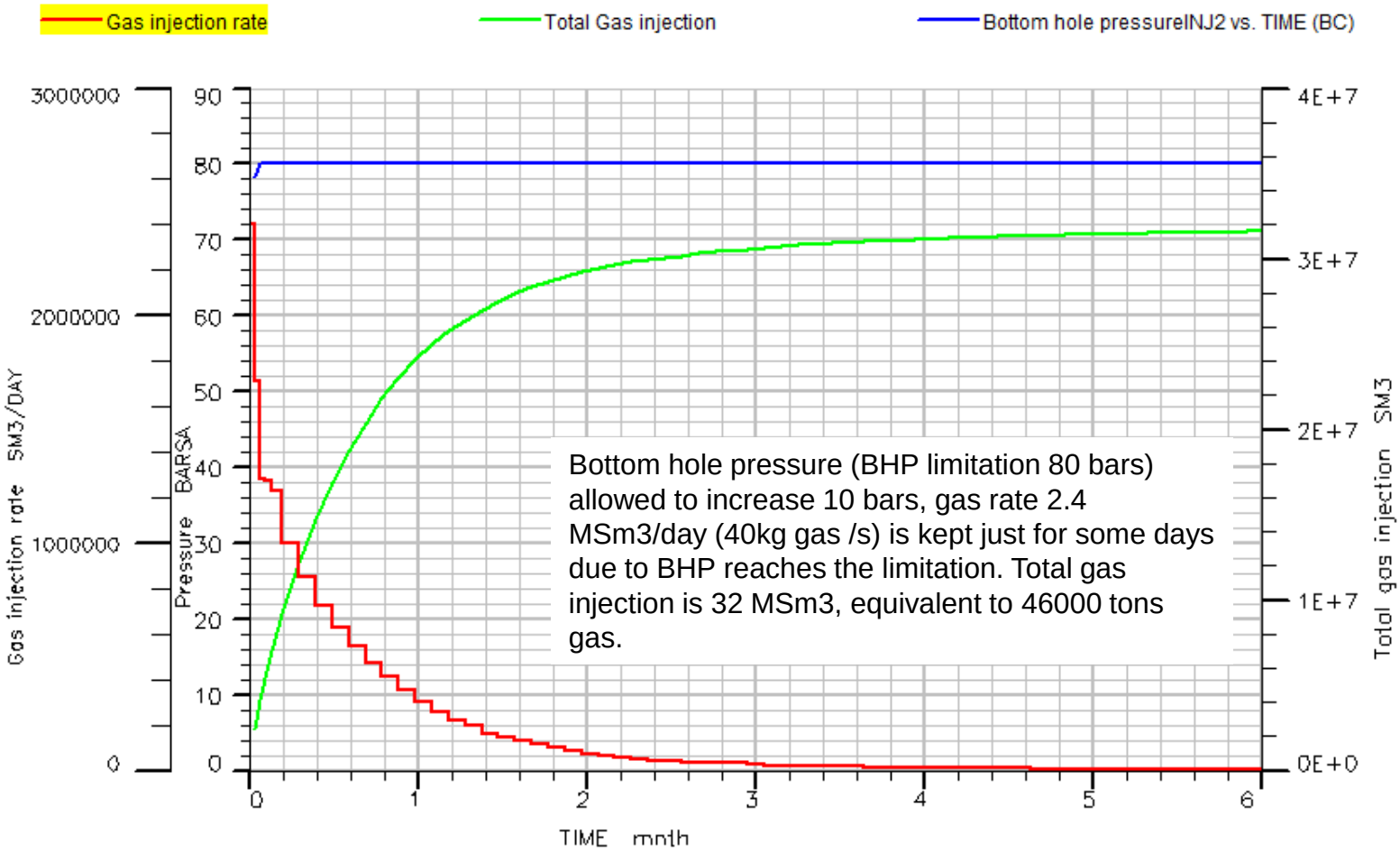
- In the model, gas did not include Ar because lack of properties data in the library, Ar fraction was converted into N2 fraction.

- Injection control method in the simulation was BHP-bottom hole pressure, Cases were run with maximum BHP 10 and 20 bars above initial pressure.

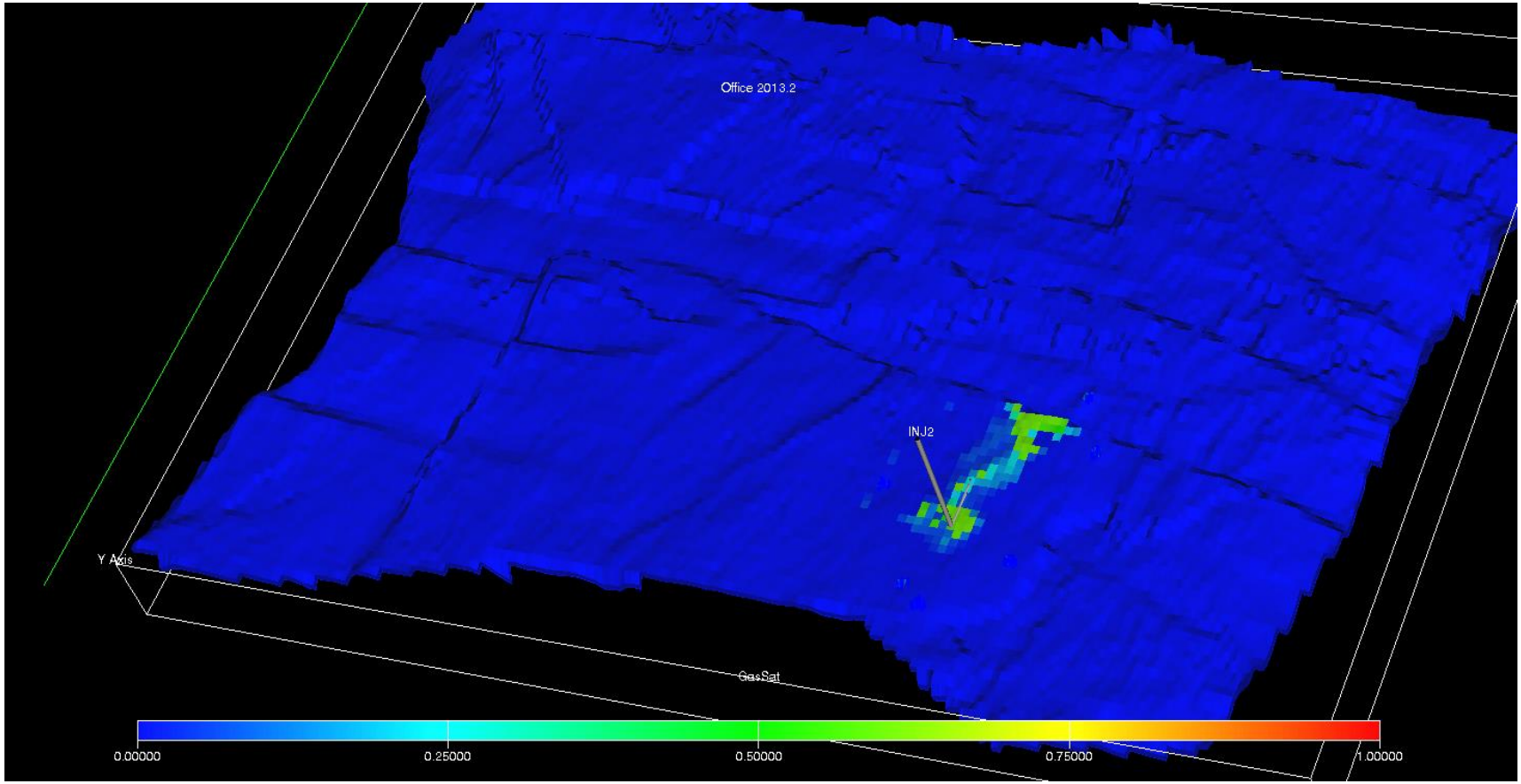
- Simulated injection rates:
  - 1000000 Sm3/d - 17Kg/s
  - 2590000 Sm3/d - 40Kg/s
  - 5180000 Sm3/d - 80Kg/s



Operation profile, BHP limitation 80 bar, closed system

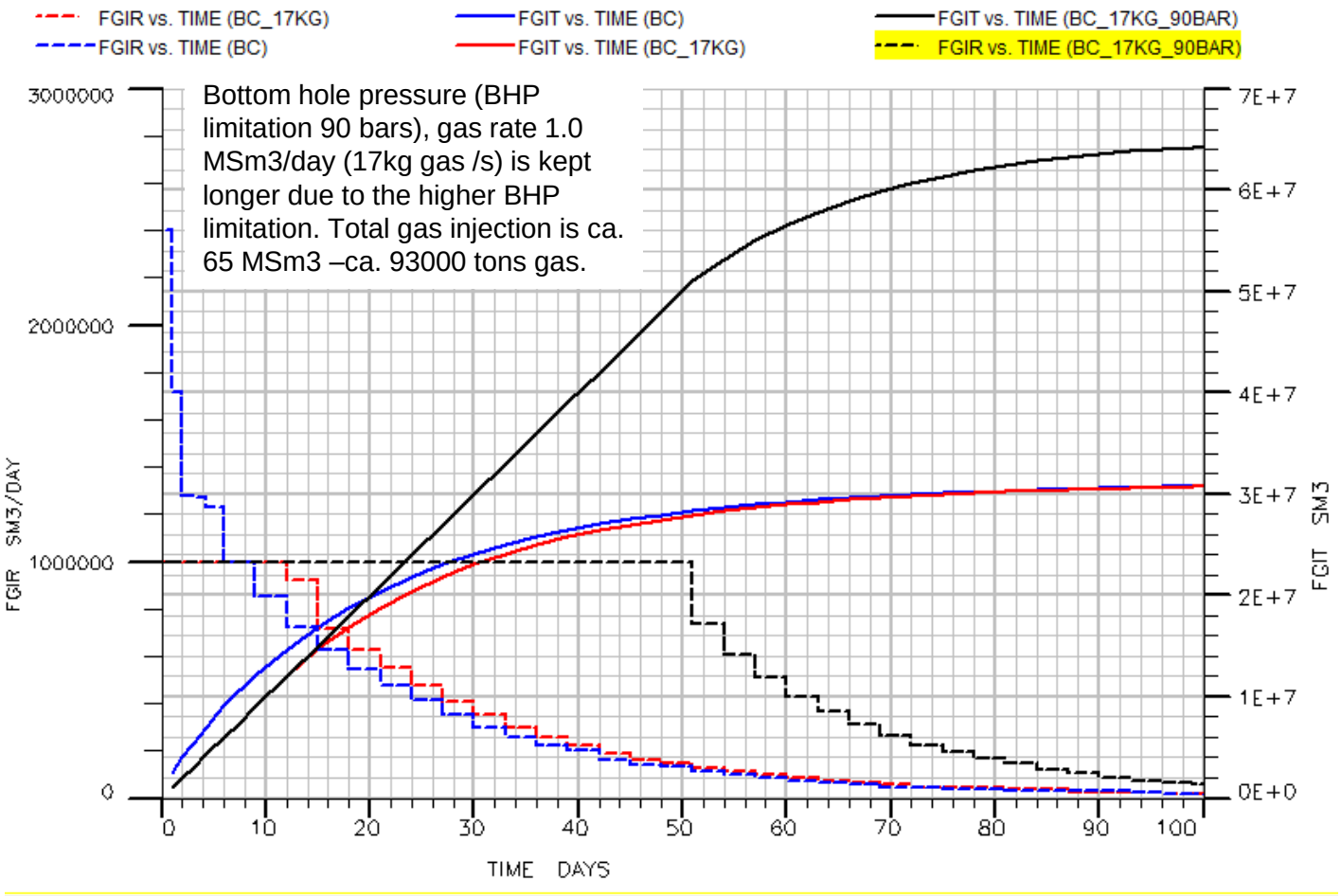


Gas plume after 5 years.

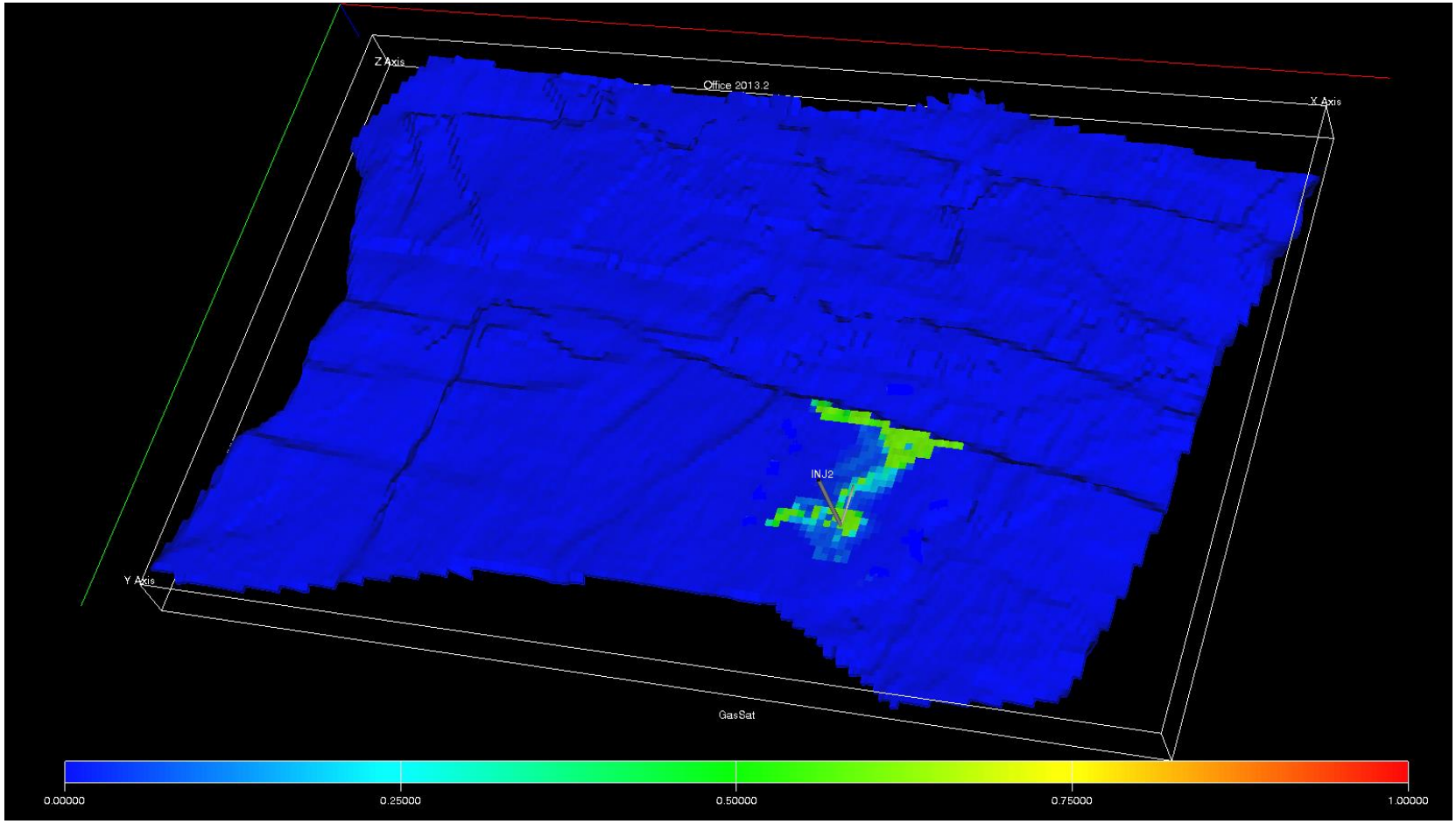


Colours show gas saturation

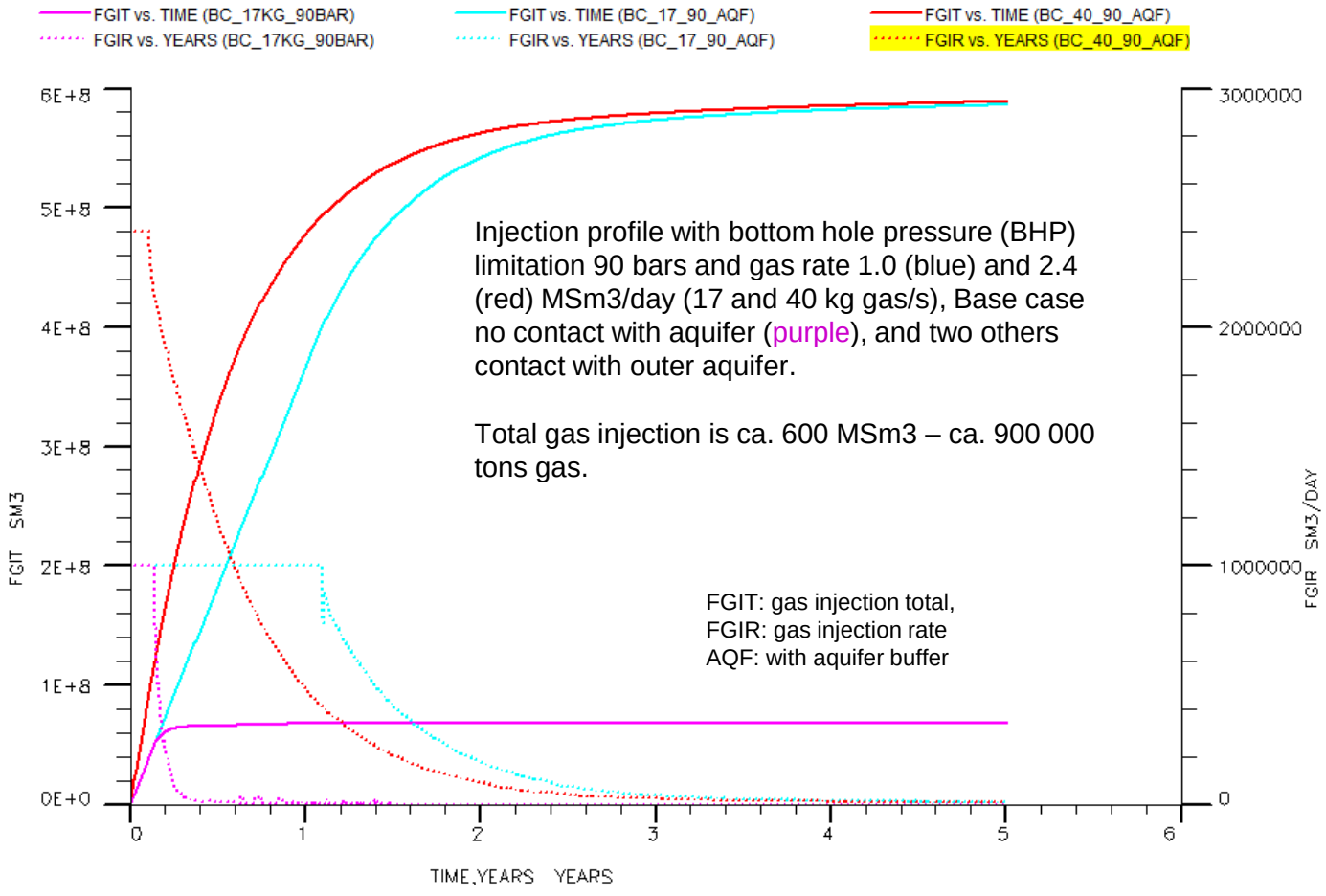
Simulation with BHP limitation 90 Bars, closed system



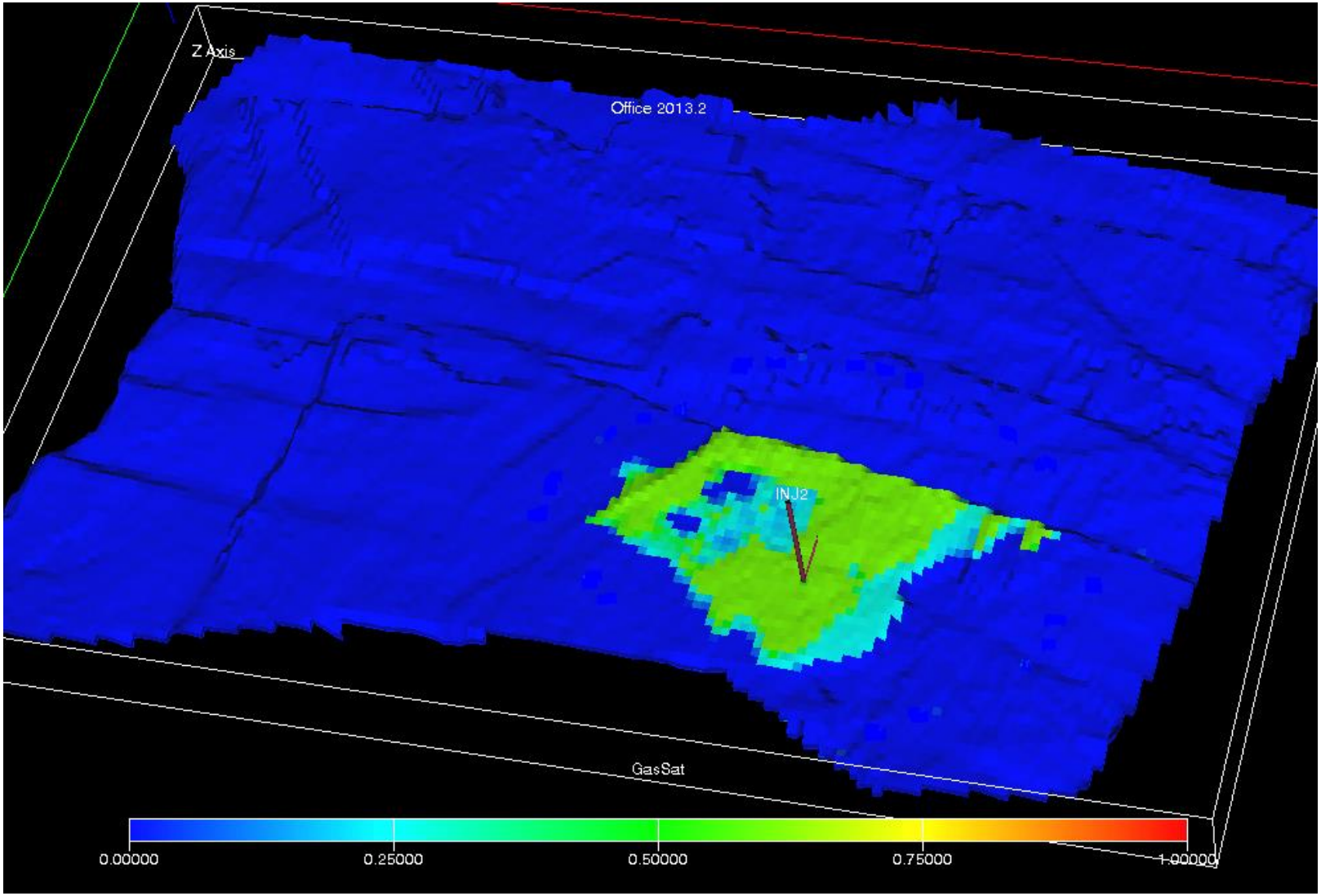
Case 90 bars, Gas plume after 5 years



Simulation with open system, aquifer is in communication with a regional aquifer outside the model, BHP-90bars



Gas plume after 5 years for the best case BC40_90_AQF



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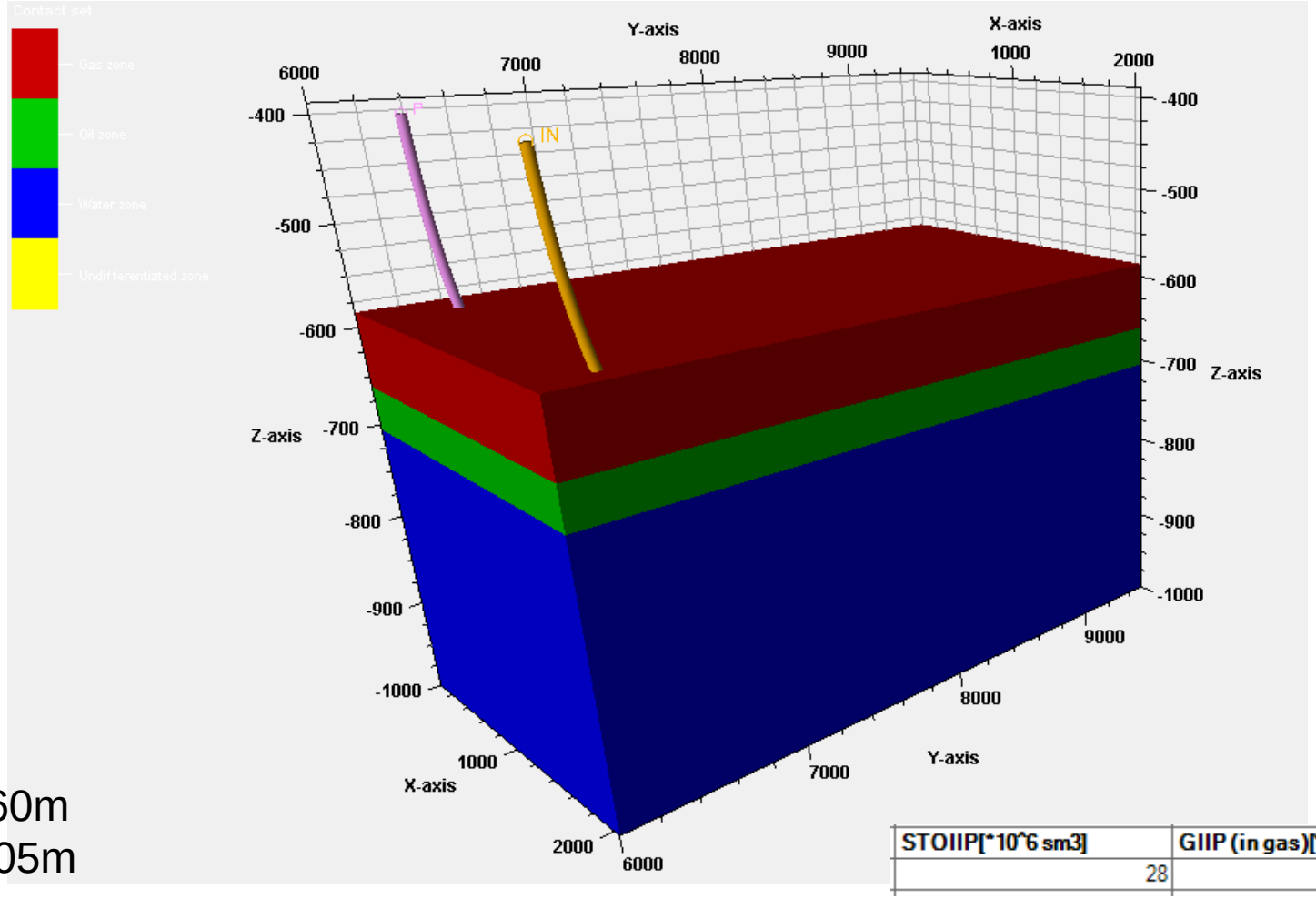
Simulation of combustion gas to EOR project

Van Pham

19.12.2014

Model



GOC: -660m
OWC: -705m

STOIIP[*10^6 sm3]	GIIP (in gas)[*10^6 sm3]
28	11063

Yellow, horizontal exhaust gas injector,
Purple, horizontal oil producer

Properties

Porosity	0.1500	0.2500	0.1000

Description	Value
Type of data:	Continuous
Min:	0.1500
Max:	0.2500
Delta:	0.1000
Number of defined values:	232400
Mean:	0.1957
Std. dev.	0.0267
Variance:	0.0007
Sum:	45489.9959

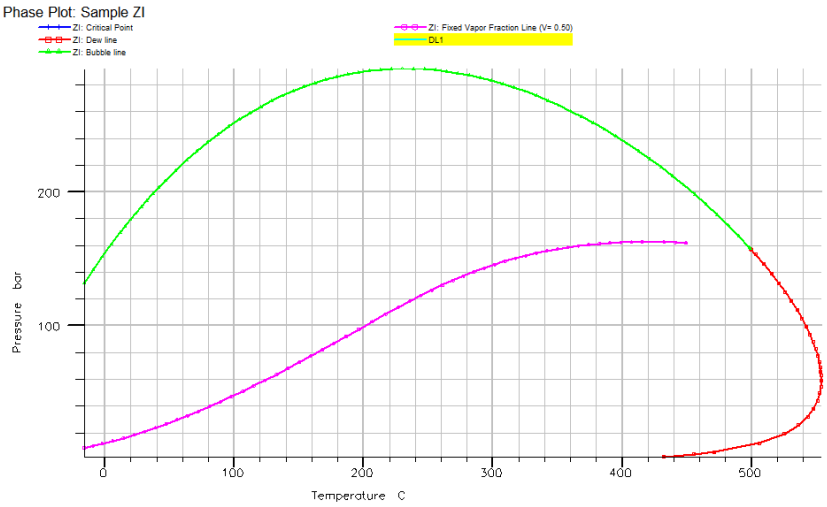
Permeability X	158.5096	653.4231	494.9135

Description	Value
Min:	158.5096
Max:	653.4231
Delta:	494.9135
Number of defined values:	232400
Mean:	384.9134
Std. dev.	132.0962
Variance:	17449.4069

Axis	Min	Max	Delta
Net/Gross	0.5600	0.7600	0.2000

Perm Z = Perm X*0.5

Modelling using PVT of an oil from a Norwegian field



At GOC 660m condition

Expt FLASH3 : Flash Calculation

Peng-Robinson (3-Parm) on ZI with PR corr.
Lohrenz-Bray-Clark Viscosity Correlation
Two phase state

Specified temperature	Deg K	303.1500
Specified pressure	BARSA	66.4000
Mole Percentage in vapour		34.7818
Calculated GOR	SM3/M3	63.1300

Fluid properties		Liquid Calculated	Vapour Calculated
Mole Weight		140.5971	18.7586
Z-factor		0.5272	0.8432
Viscosity		0.6710	0.0126
Density	KG/M3	702.4942	58.6047
Molar Vol	M3/KG-ML	0.2001	0.3201

Molar Distributions Components Mnemonic	Number	Total, Z Measured	Liquid,X Calculated	Vapour,Y Calculated	K-Values Calculated
N2	1	0.3730	0.0941	0.8959	9.5172
CO2	2	0.3910	0.3269	0.5113	1.5642
C1	3	44.2210	21.5503	86.7301	4.0245
C2	4	8.3610	8.5394	8.0266	0.9399
O2	5				1.0000
C3	6	5.6840	7.2805	2.6904	0.3695
NC4	7	2.6140	3.7407	0.5014	0.1340
IC4	8	0.9660	1.3519	0.2424	0.1793
NC5	9	1.4390	2.1432	0.1187	0.0554
IC5	10	0.9950	1.4715	0.1015	0.0690
C6	11	1.9880	3.0116	0.0687	0.0228
C7	12	3.5180	5.3648	0.0552	0.0103
C8	13	4.3100	6.5886	0.0375	0.0057
C9	14	3.1060	4.7558	0.0125	0.0026
C10	15	2.3540	3.6067	0.0050	0.0014
C11	16	1.8130	2.7790	0.0018	0.0006
C12	17	1.5580	2.3885	0.0008	0.0003
C13	18	1.5190	2.3289	0.0004	0.0002
C14	19	1.3870	2.1266	0.0002	7.6960E-05
C15+	20	13.4030	20.5510	1.3007E-10	6.3290E-12
Composition Total		100.0000	100.0000	100.0000	

Gas/WAG/Water injection

- Gas composition:
  -- CO2 N2 O2 H2O
Gas 0.114 0.8797 0.006 0.0003
- Ar fraction was converted into N2 fraction.

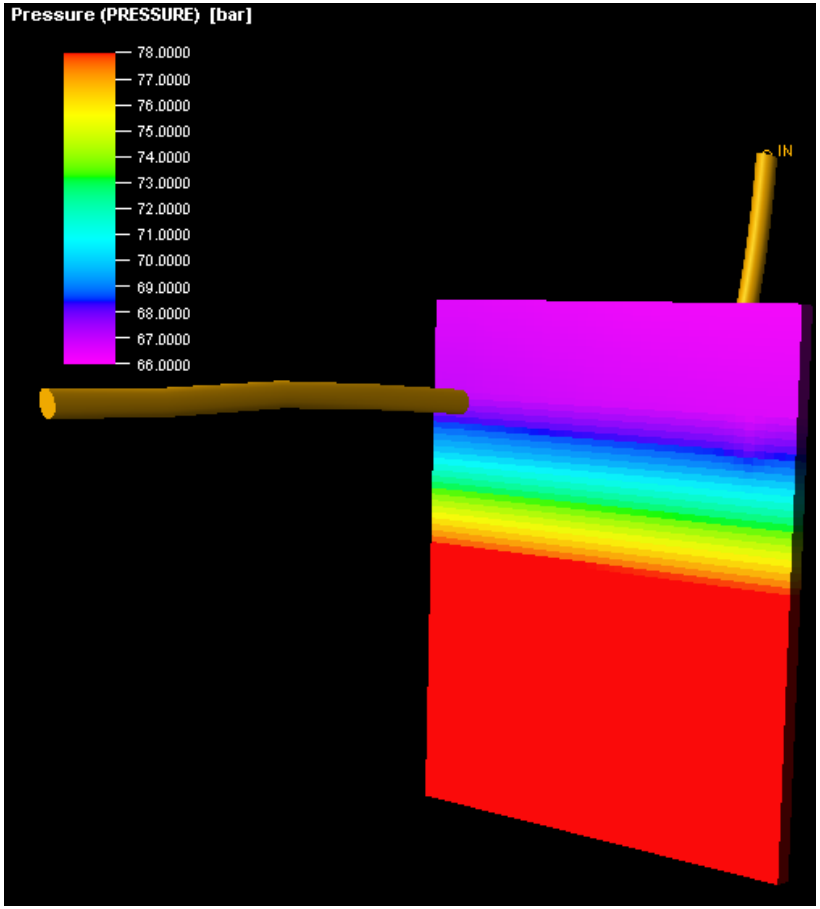
- Injection control method is BHP-bottom hole pressure, Delta: 10 Bars

- Rate target Water: 5000 m3/d
- Oil rate target: 5000 m3/d

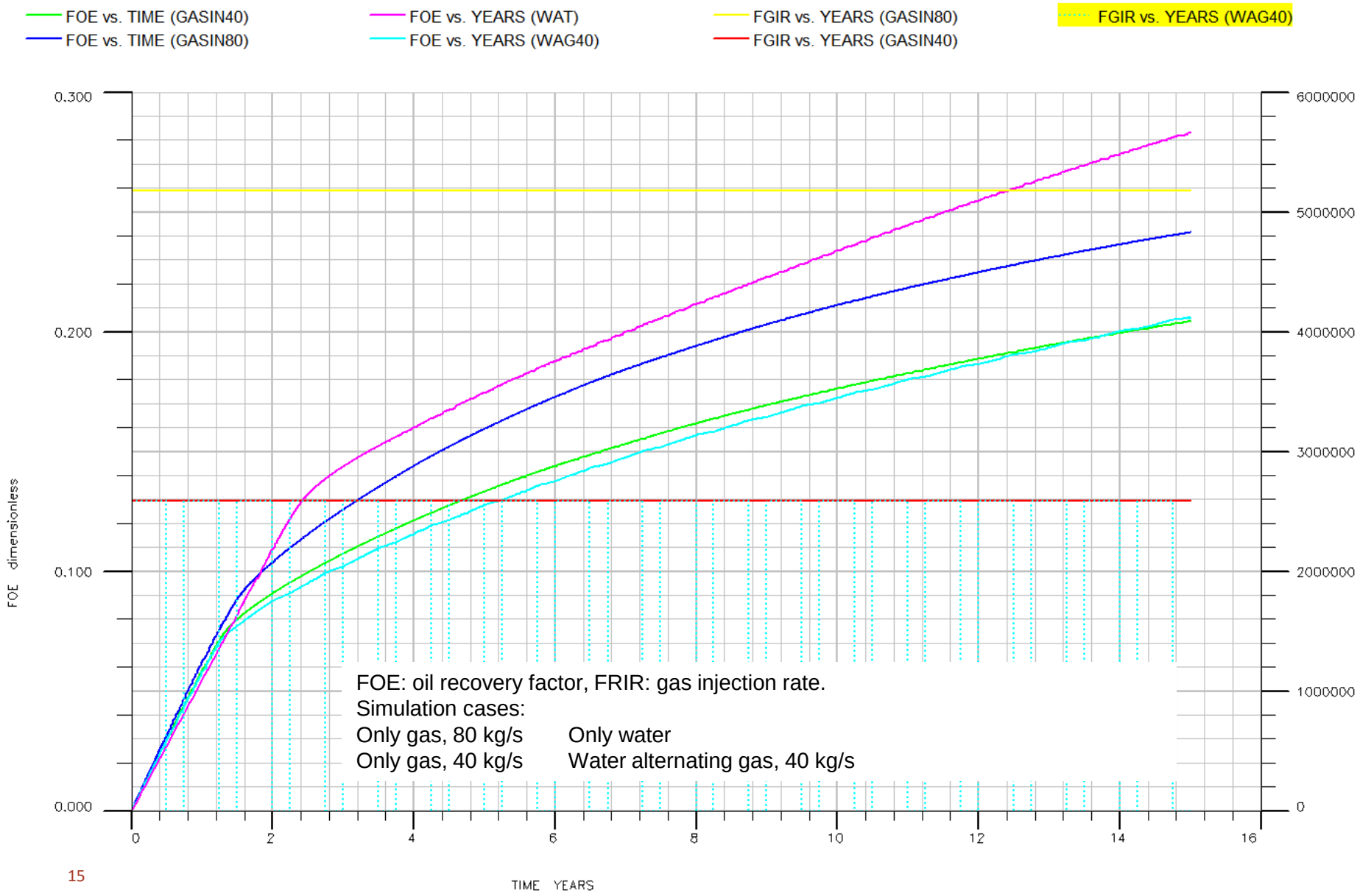
Gas injection

1000000 Sm3/d - 17Kg/s
2590000 Sm3/d - 40Kg/s
5180000 Sm3/d - 80Kg/s

Cases with injection of combustion gas only and gas alternating with water (WAG) were studied



Results


FOE vs. TIME (GASIN40)
FOE vs. TIME (GASIN80)
FOE vs. YEARS (WAT)
FOE vs. YEARS (WAG40)
FGIR vs. YEARS (GASIN80)
FGIR vs. YEARS (GASIN40)
FGIR vs. YEARS (WAG40)
0.300
0.200
0.100
0.000
FOE dimensionless
6000000
5000000
4000000
3000000
2000000
1000000
0
0
2
4
6
8
10
12
14
16
TIME YEARS
FOE: oil recovery factor, FRIR: gas injection rate.
Simulation cases:
Only gas, 80 kg/s
Only gas, 40 kg/s
Only water
Water alternating gas, 40 kg/s

Discussion

- In this simple set-up, gas rate increasing to 80kg/s (case GAS80) gives higher oil production than case GAS40 and WAG40 but injection of only water gives the highest oil production.
- The reason why RF is lower in the gas injection case than with water injection is that, after 2 years, gas breaks through from the injection well to the production well.
- After break-through, a large area with poor sweep effect remains between wells (red colour) and gas injected goes directly to the producer.