KUALA LUMPUR 2012 WORLD GAS CONFERENCE

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"Gas: Sustaining Future Global Growth"

A Field Case of CO_2 Storage and EOR

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Summary

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- Numerical Simulation of Field History
- Geological Storage and EOR – CO2 Injection
- Geological Storage and EOR – Flue Gas Injection
- Economical Analysis
- Conclusions

Introduction

Carbon dioxide (CO_2) emissions have become a major environmental concern due to their potential negative impact on the Earth's climate. It is hoped that the vast majority of CO_2 emissions from industry can be captured and gradually immobilised by various trapping mechanisms.

The CO_2 trapping mechanisms must be properly understood and modelled in order to optimize each particular application. A well selected, designed, and managed geological storage site can in theory retain CO_2 for millions of years

field case using compositional simulation of CO_2 injection for enhanced recovery is presented. The incremental oil and the amount of injected CO_2 stored in the reservoir are quantified and an economical analysis comparing CO_2 with Flue gas injection is performed.

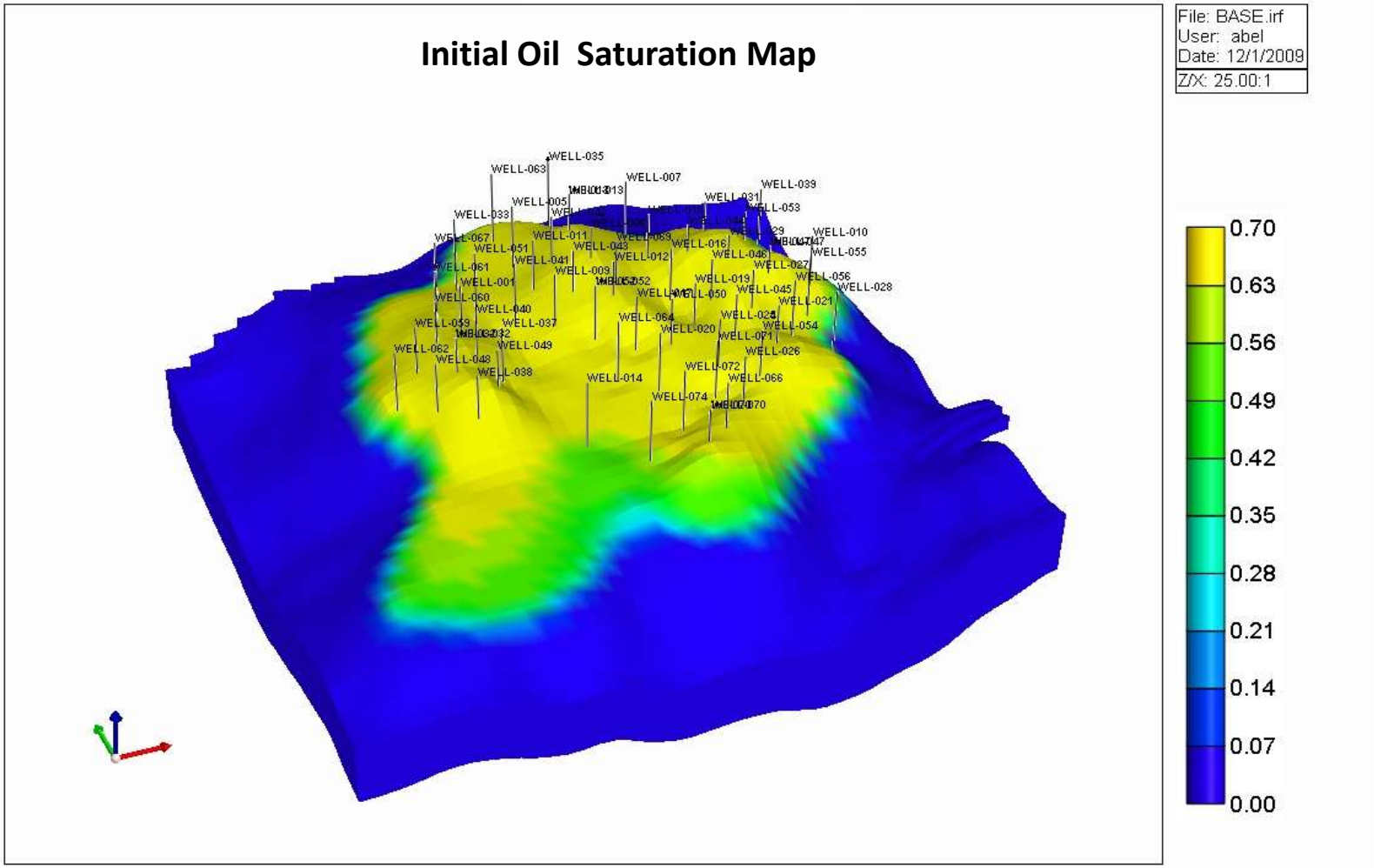
Numerical Simulation of Field History

Location

Numerical Model

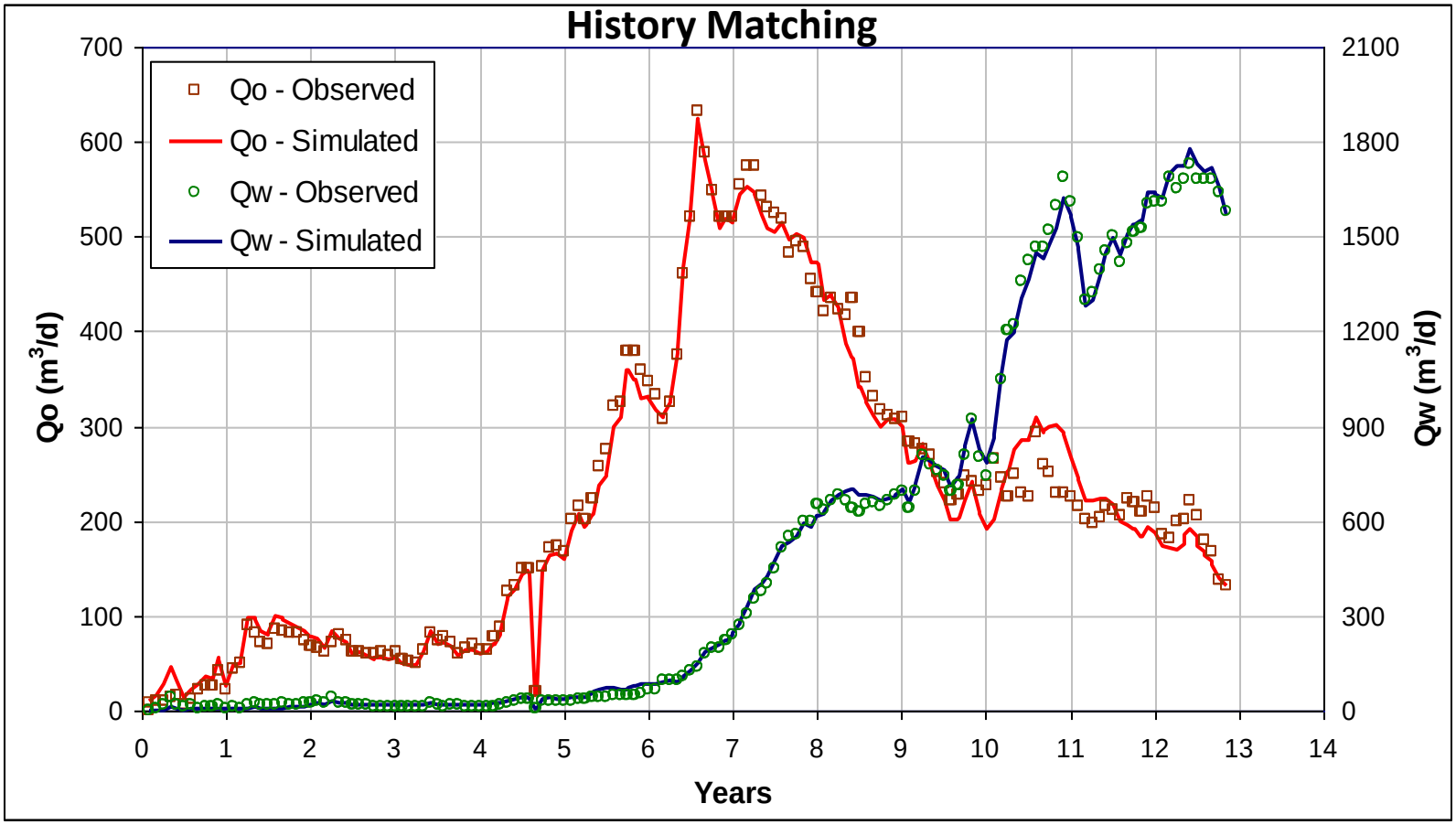
- Grid 47x50x7
- Dimensions (I,J) 70 m
- Depth 1,100 m
- Temperature 62 ^{o}C
- Salinity 1,000 ppm
- Porosity 25 %
- Permeability 1,500 mD
- Oil Volume 2.927 MMm^3
- Gas Solubility Ratio 20.2 stm^3/m^3
- 59 producing wells
- Oil characterized with 5 components
- Bottom Analytical Aquifer

Numerical Simulation of Field History



Numerical Simulation of Field History

Wells producing with total liquid rate specified



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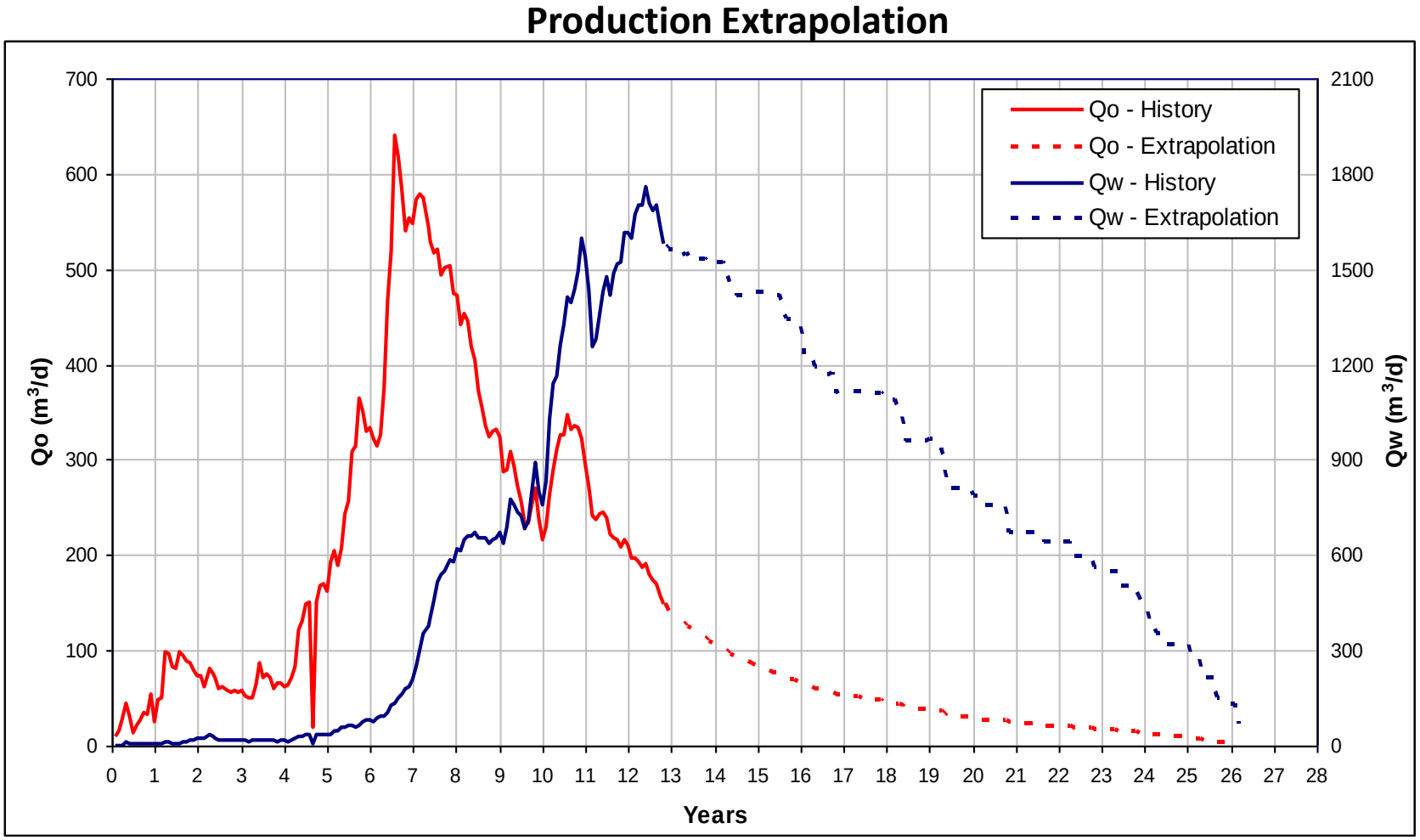
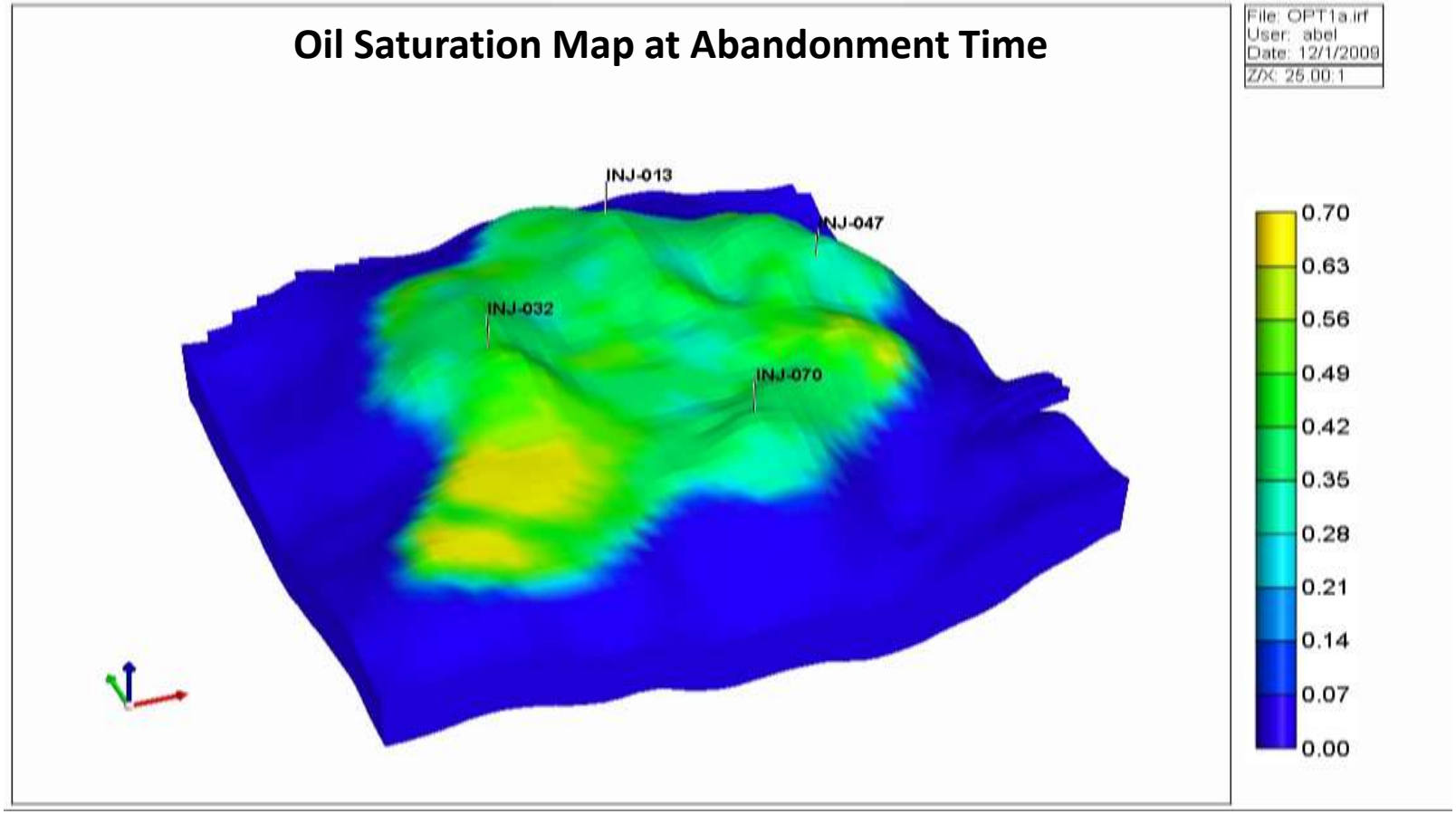


Geological Storage and EOR – CO_2 Injection

Beginning of CO_2 Injection – 4 Injection Wells



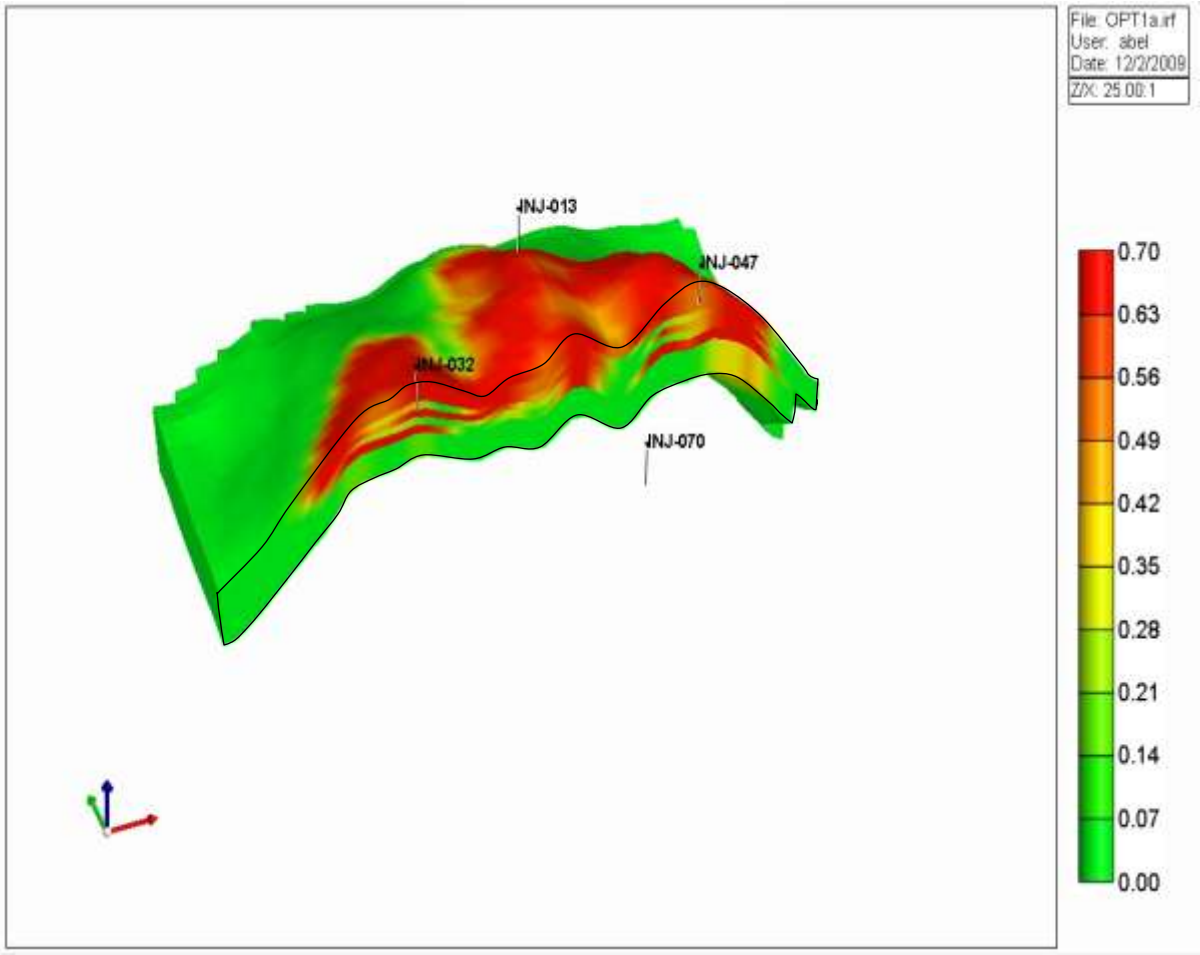
Geological Storage and EOR – CO_2 Injection

Total amount of CO_2 injection
1.17×10^9 m^3

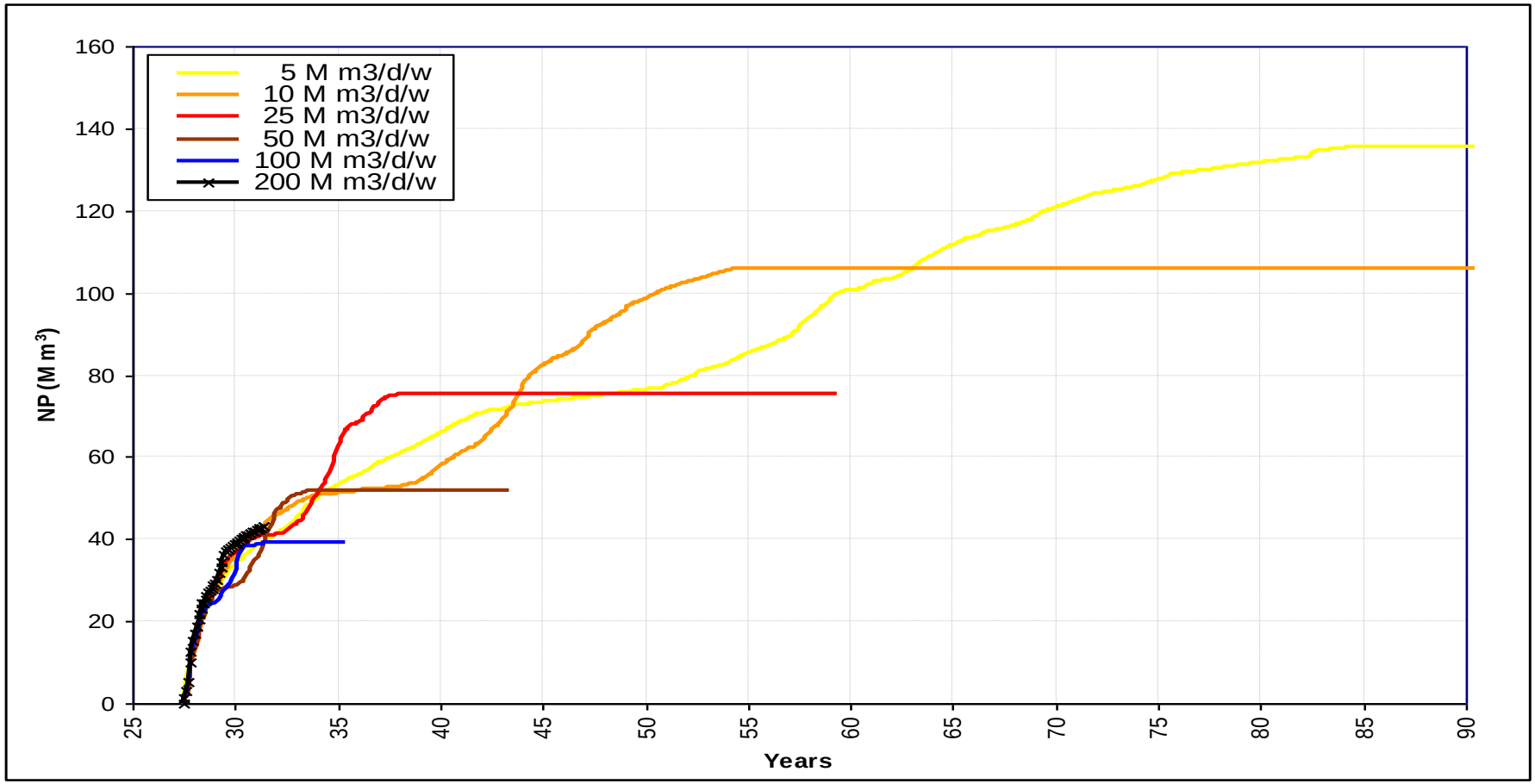
Workover in 32 wells

CO_2 Injection Schemes
5 M scm/d/w during 160 years
10 M scm/d/w during 80 years
25 M scm/d/w during 32 years
50 M scm/d/w during 16 years
100 M scm/d/w during 8 years
200 M scm/d/w during 4 years

Slab - Gas Saturation at the end of Injection

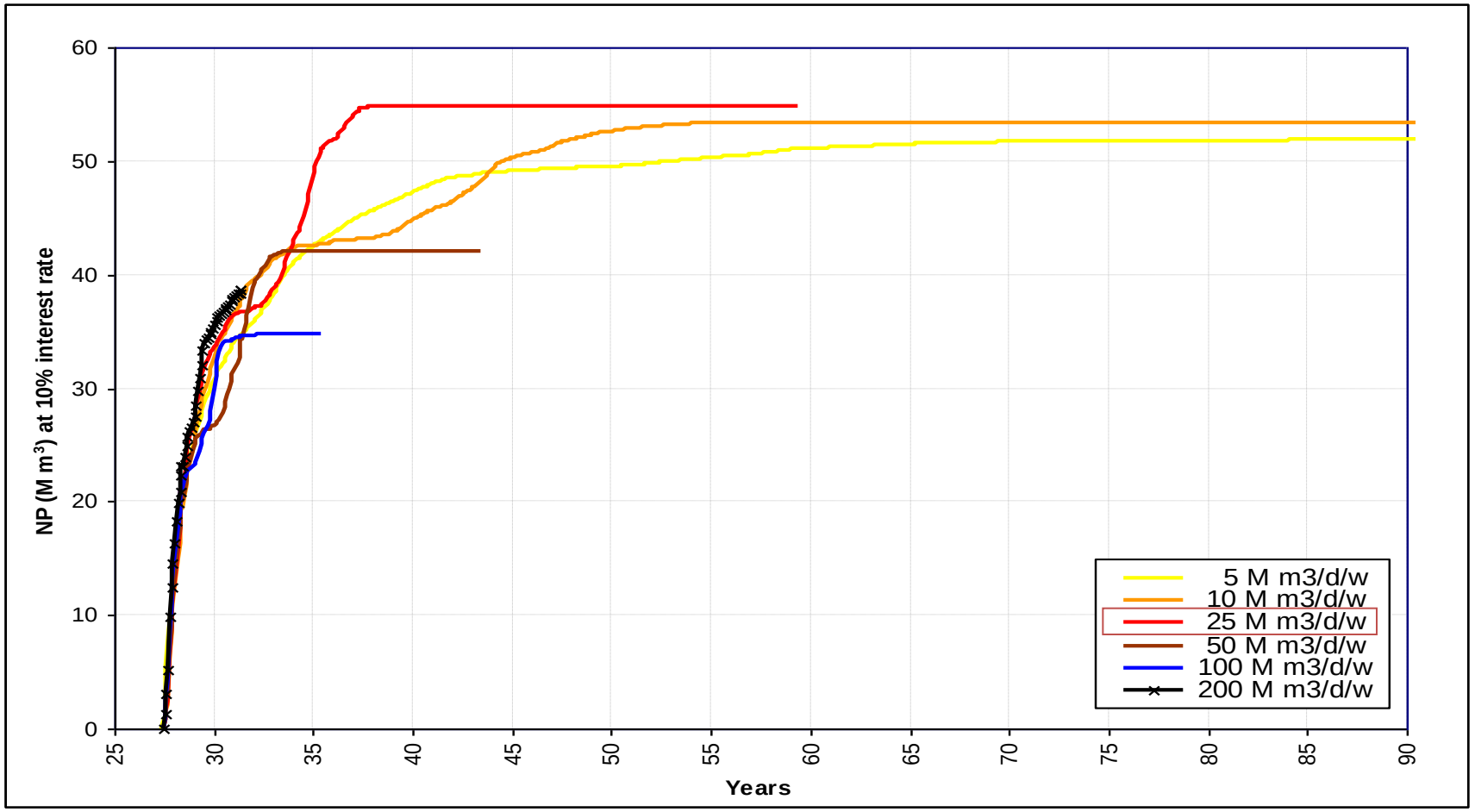


Incremental Cumulative Oil Production



Incremental Cumulative Oil Production

NP (10^3 m^3) - Updated at 10% interest rate



Geological Storage and EOR - CO_2 Injection

Injection Rate scm/d/well	Injection Time years	Production Time of Incremental Oil years	Incremental NP 10^3 scm	Incremental Recovery % OOIP	Discounted NP by 10%/year 10^3 scm
5,000	160	56.87	135.38	4.63	51.83
10,000	80	26.76	105.76	3.61	53.31
25,000	32	10.67	75.85	2.59	54.87
50,000	16	6.16	53.22	1.82	42.04
100,000	8	4.25	40.83	1.39	34.71
200,000	4	4.08	44.30	1.51	38.72

- Injection of 25 x 10^3 m^3/d/w of CO_2 during 32 years in a reservoir with 45% of recovery at abandonment.
- Production during almost 11 years
- Incremental recovery 75.85 Mm^3, corresponding to 2.6 % OOIP
- CO_2 injected = 1.1688 x 10^9 m^3
- CO_2 produced = 0.045 x 10^9 m^3
- CO_2 accum. = 1.1238 x 10^9 m^3

CO_2 Trapped

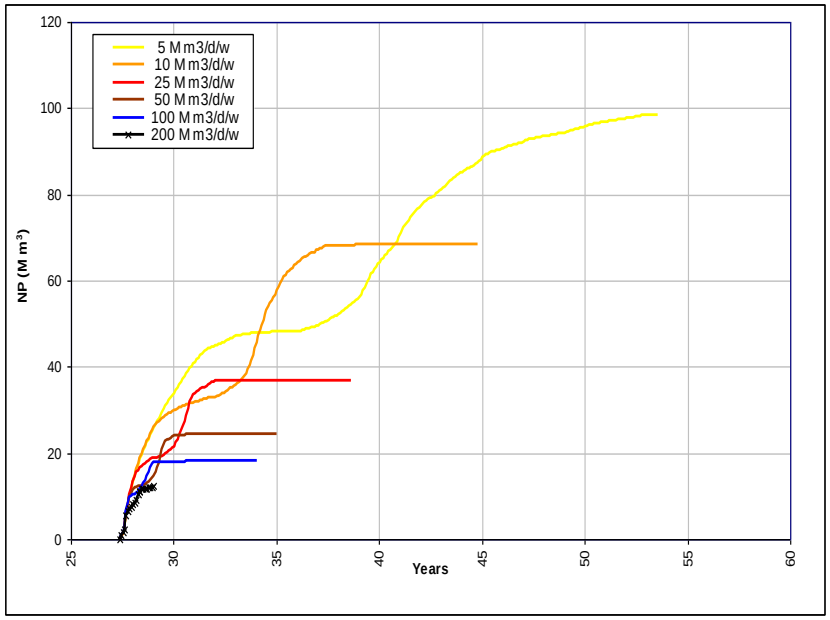
56.21 % Structural

32.50 % Residual gas

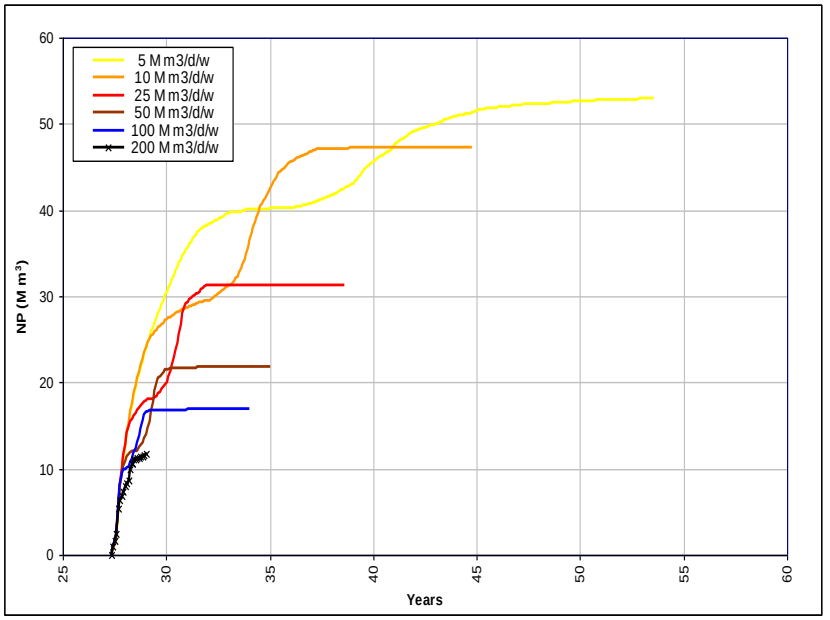
11.29 % Solubility

Incremental Cumulative Oil Production Due to Flue Gas Injection

NP (10^3 m^3)



NP (10^3 m^3) - Updated at 10% interest rate



Economic Analysis

- Economic Analysis considers injection of 25,000 std m^3/day/injection well
- In all the scenarios the power plant is operated with natural gas in a location less than 100 kilometers from the injection site
- Capture and transportation process of CO_2 can be used for more than one storage site, hence, the cost are calculated per tonne of CO_2.

Cost in US$ for Optimistic, Moderate and Pessimistic Scenarios.

Scenarios	CO2			Flue Gas		
	Optimistic	Moderate	Pessimistic	Optimistic	Moderate	Pessimistic
Cost per ton captured	15.00	38.00	60.00	6.00	7.00	8.00
Cost per ton transported	1.00	4.00	8.00	1.00	4.00	8.00
Total cost per day ready for injection	2876.64	7551.18	12,225.72	1258.53	1977.69	2876.64

Economic Analysis

CO_2

SCENARIOS	CO_2 Injection Cost			Workover Investment	Income (Oil Price - Cost)	Net Cash Flow
	per Day	total after 32 years	Present Value at 10%/year			
	US$	10^3 US$	10^3 US$	10^3 US$	10^3 US$	10^3 US$
Optimistic	2,876.64	33,599.16	10,493.25	2,520.00	20,700.94	7,687.69
Moderate	7,551.18	88,197.78	27,544.79	2,520.00	20,707.94	-9,356.85
Pessimistic	12,225.72	142,796.41	44,596.32	2,520.00	20,707.94	-26,408.38

Flue Gas

SCENARIOS	CO_2 Injection Cost			Workover Investment	Income (Oil Price - Cost)	Net Cash Flow
	per Day	total after 32 years	Present Value at 10%/year			
	US$	10^3 US$	10^3 US$	10^3 US$	10^3 US$	10^3 US$
Optimistic	1,258.53	14,699.63	4,590.80	2,520.00	11,831.00	4,720.20
Moderate	1,977.69	23,099.42	7,214.11	2,520.00	11,831.00	2,096.89
Pessimistic	2,876.64	33,599.16	10,493.25	2,520.00	11,831.00	-1,182.25

Conclusions

1. CO_2 storage in abandoned oil fields has been analyzed along with Enhanced Oil Recovery (EOR) methods with CO_2. An economic analysis of incremental oil produced with CO_2 injection and flue gas injection into abandoned petroleum reservoirs has also been performed, showing that both the injection of pure CO_2 and the injection of flue gas lead to incremental oil recovery due to oil swelling and reduced liquid viscosity, but while CO_2 injection provides more efficient displacement and capture benefits, flue gas injection may be preferred due to its lower economic cost.

2. CO_2 Injection at a rate of 100,000 scm/d for 32 years, provides 75,850 m^3 of incremental oil representing an increment of 2.59% extra-recovery of oil obtained by EOR and a CO_2 storage volume of 1.162×10^9 m^3 remaining in the reservoir, corresponding to 2.09 Mt. From this storage amount: 56.21 % is structurally trapped, 32.50 % is residual gas trapped and 11.29 % is solubility trapped.

Conclusions

3. By comparison, considering a flue gas injection rate of 100,000 scm/d for 32 years, results in 36,740 m^3 of incremental oil representing an increment of 1.26% extra-recovery of oil obtained by EOR and a CO_2 storage volume of $9.29x10^7$ m^3 remaining in the reservoir, corresponding to 0.167 Mt. From this storage amount: 83.30 % is structurally trapped, 0.14 % is residual gas trapped and 16.56 % is solubility trapped.

4. For the particular case presented, except for the optimistic scenario, the flue gas storage presented a better net cash flow than CO_2 storage and EOR due to the capture plant cost necessary to separate the CO_2.

THANK YOU