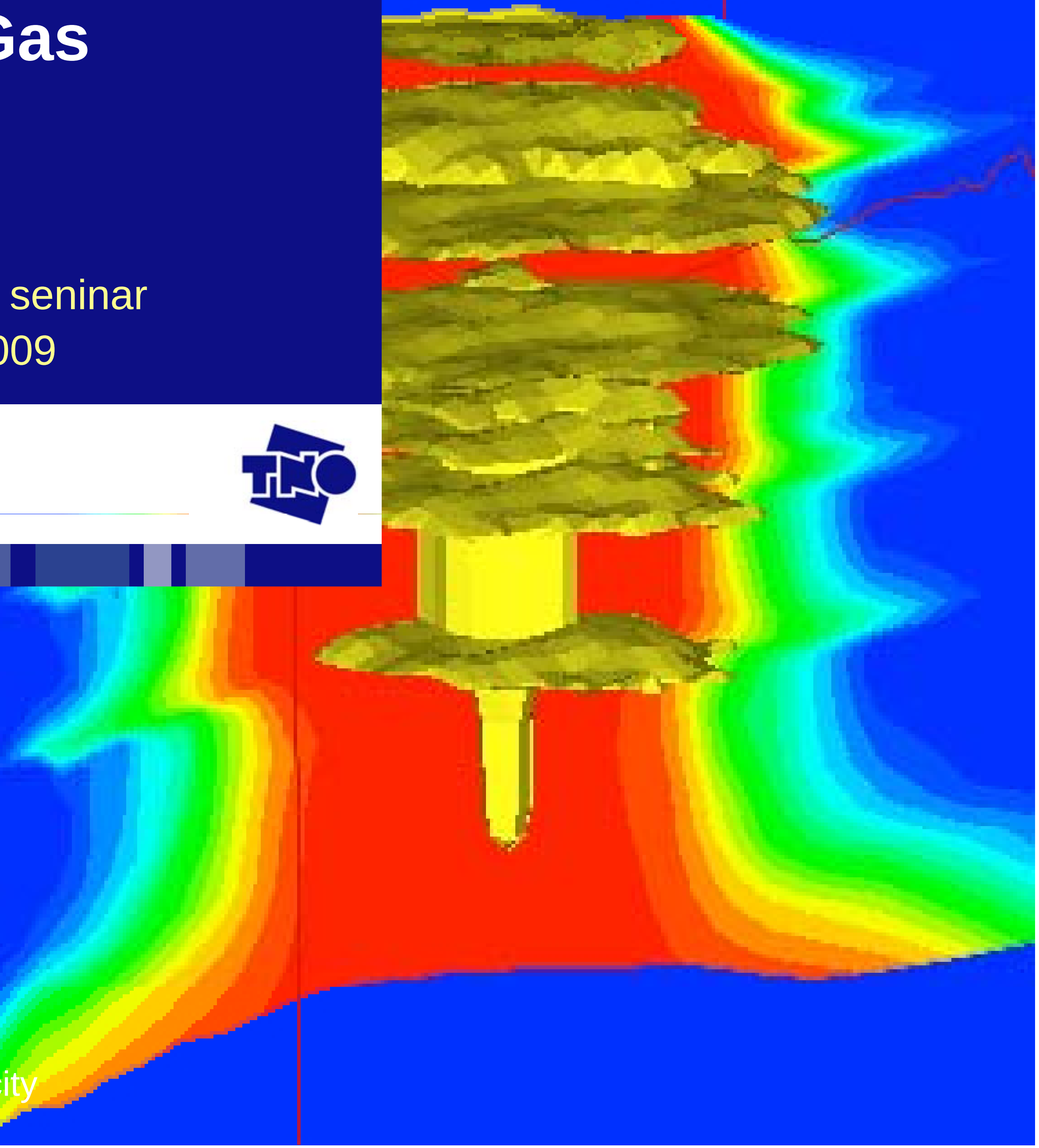
Subsurface Waste Gas Storage Capacity

Petrad – MLR – CGS SINOPEC seninar
Chengdu, 15 – 18 September 2009

TNO | Knowledge for business



Overview

- Introduction
- Example
- Storage Capacity
- Injectivity
- Trap Efficiency
- Probability of storage
- Previous estimation
- New estimation
- Conclusions

Overview

- **Introduction** **(principles only)**
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Introduction

1990 – Dutch solubility approach

- Surface of the Netherlands x aquifer thickness x porosity x solubility

1992 – Amsterdam - not a large open space – 2 % rule

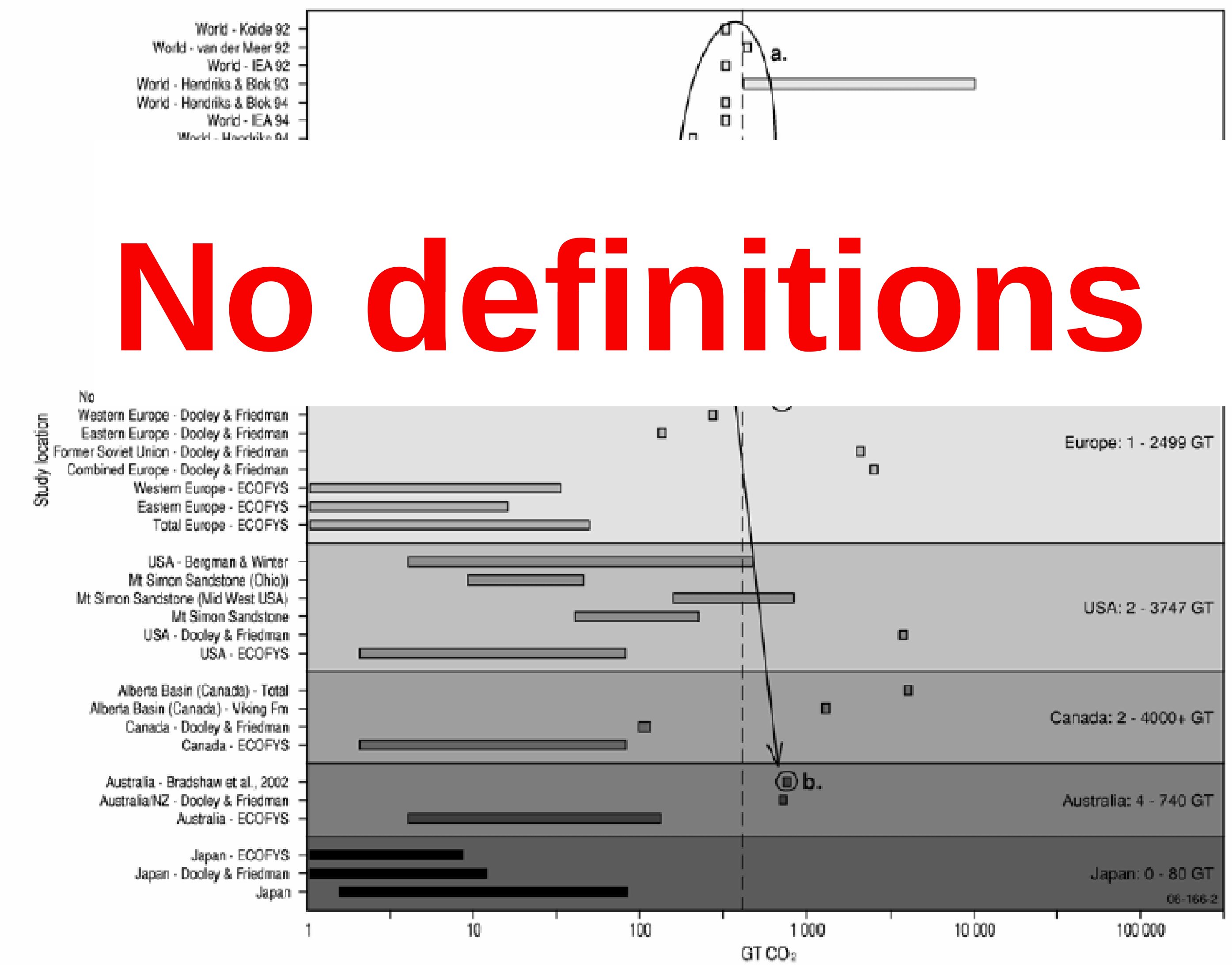
- Disappointing - => up to 6 %

2005 – IPPC Special Report

- Alberta Basin – 4000 $GtCO_2$ – based on solubility
- Permeability is very low

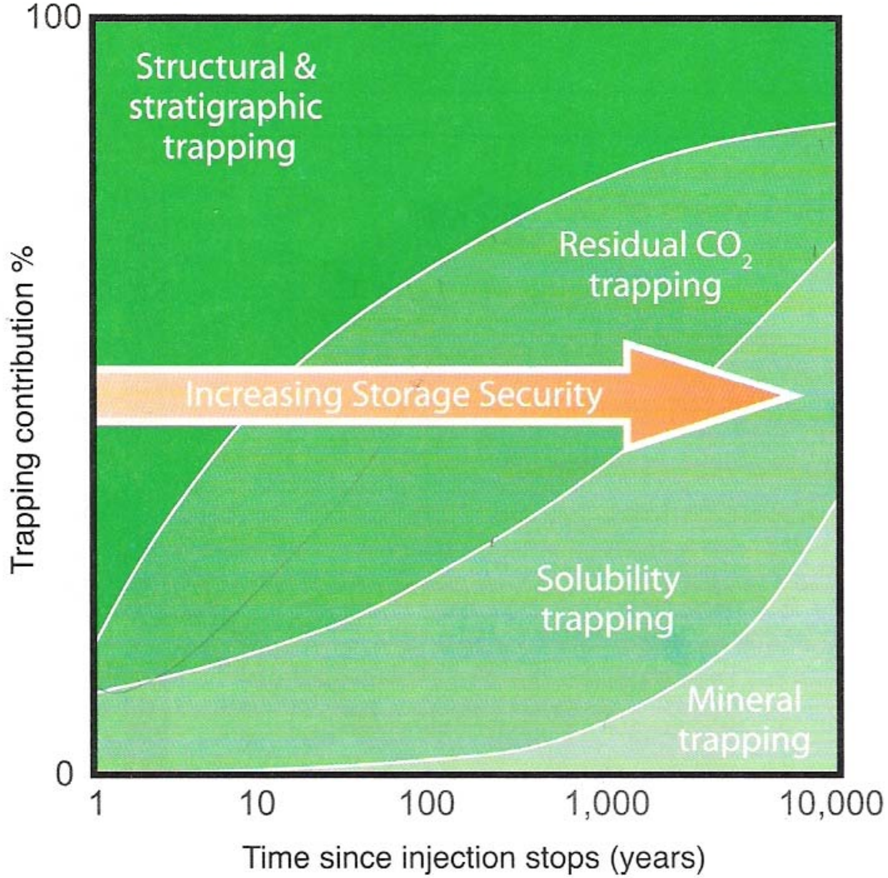
Introduction

After: Bradshaw J. et al, Carbon Sequestration leadership Forum



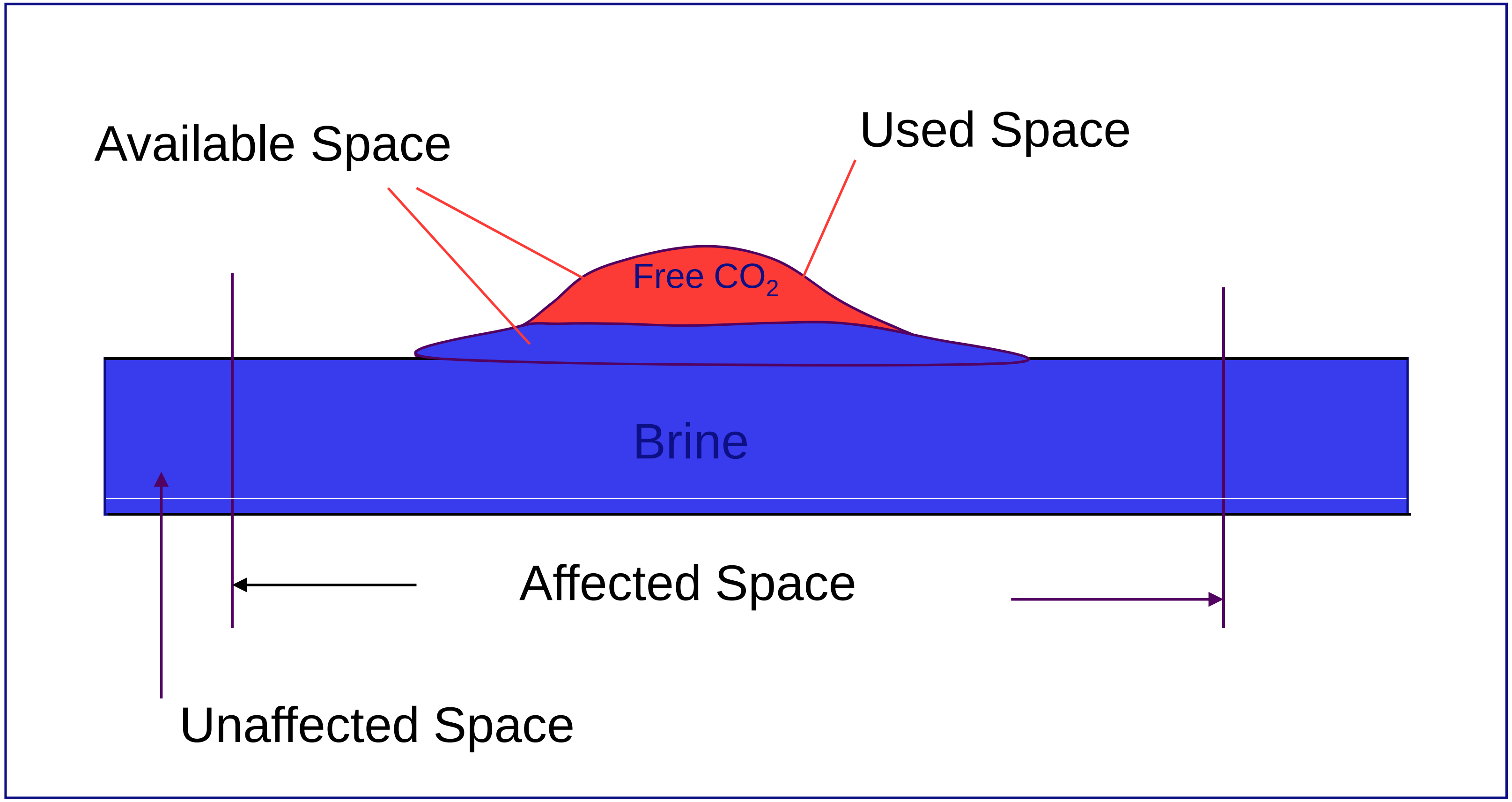
No definitions

Storage Principle

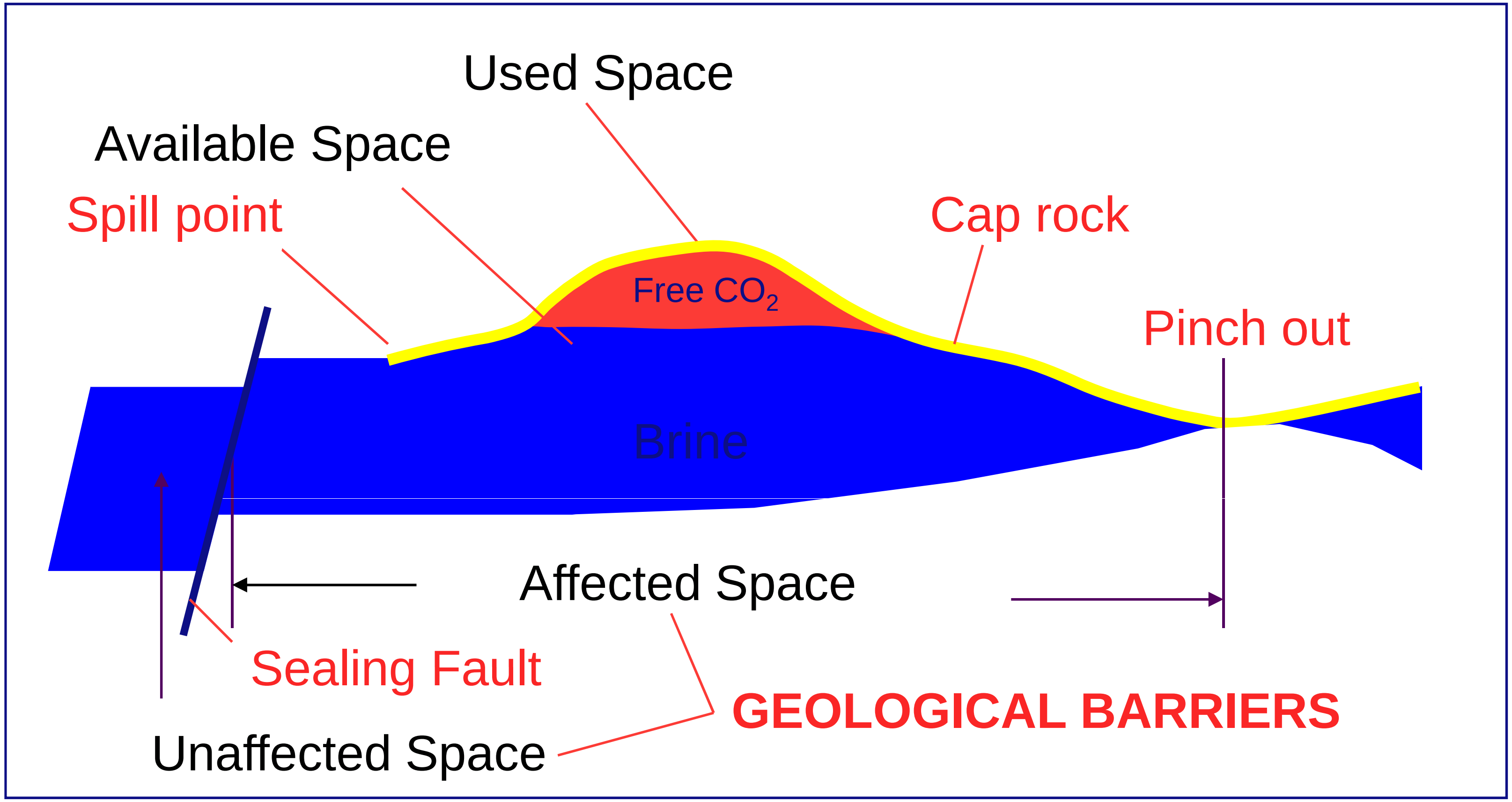


IPPC report, 2005

Conceptual Model



Conceptual Model



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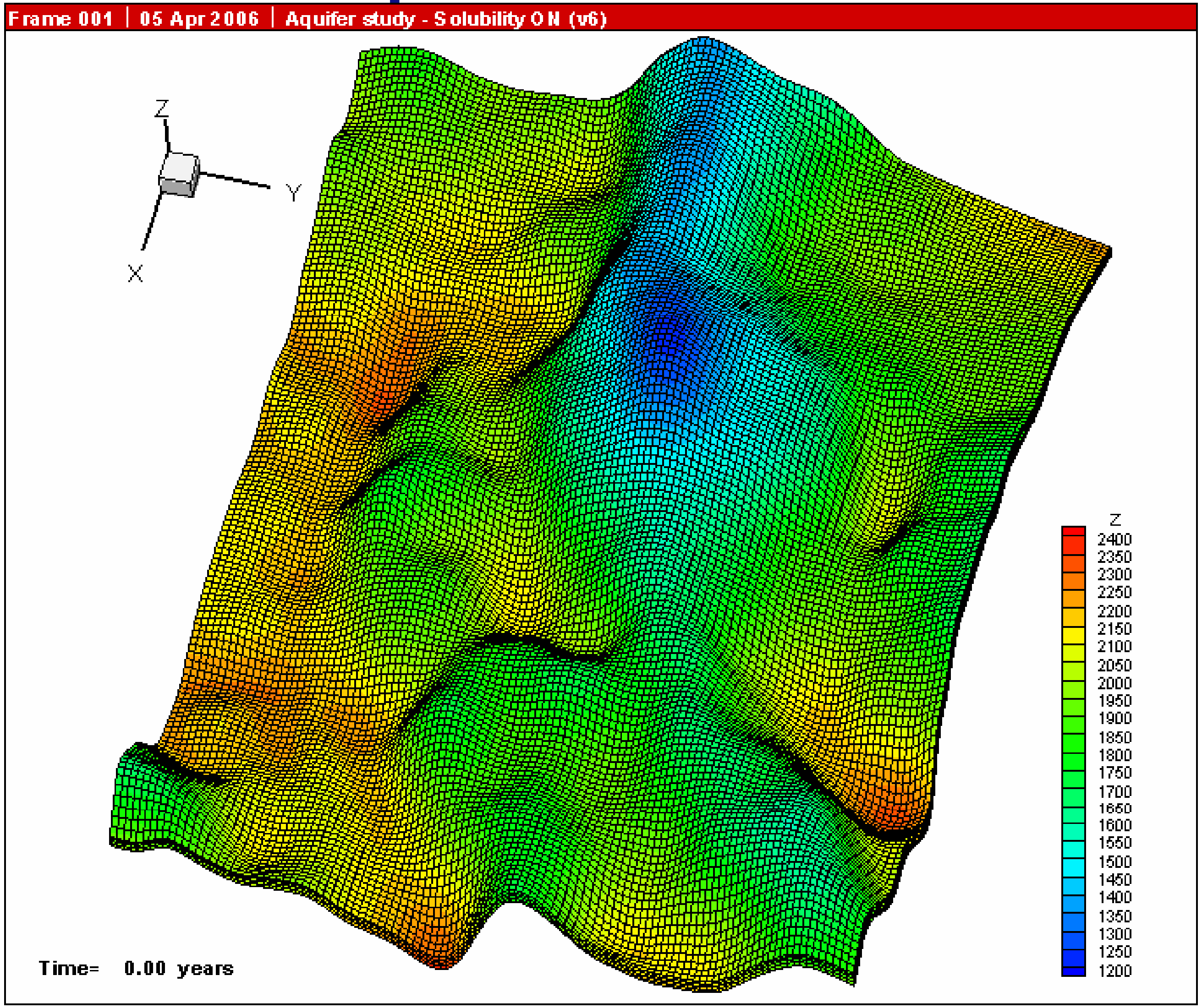
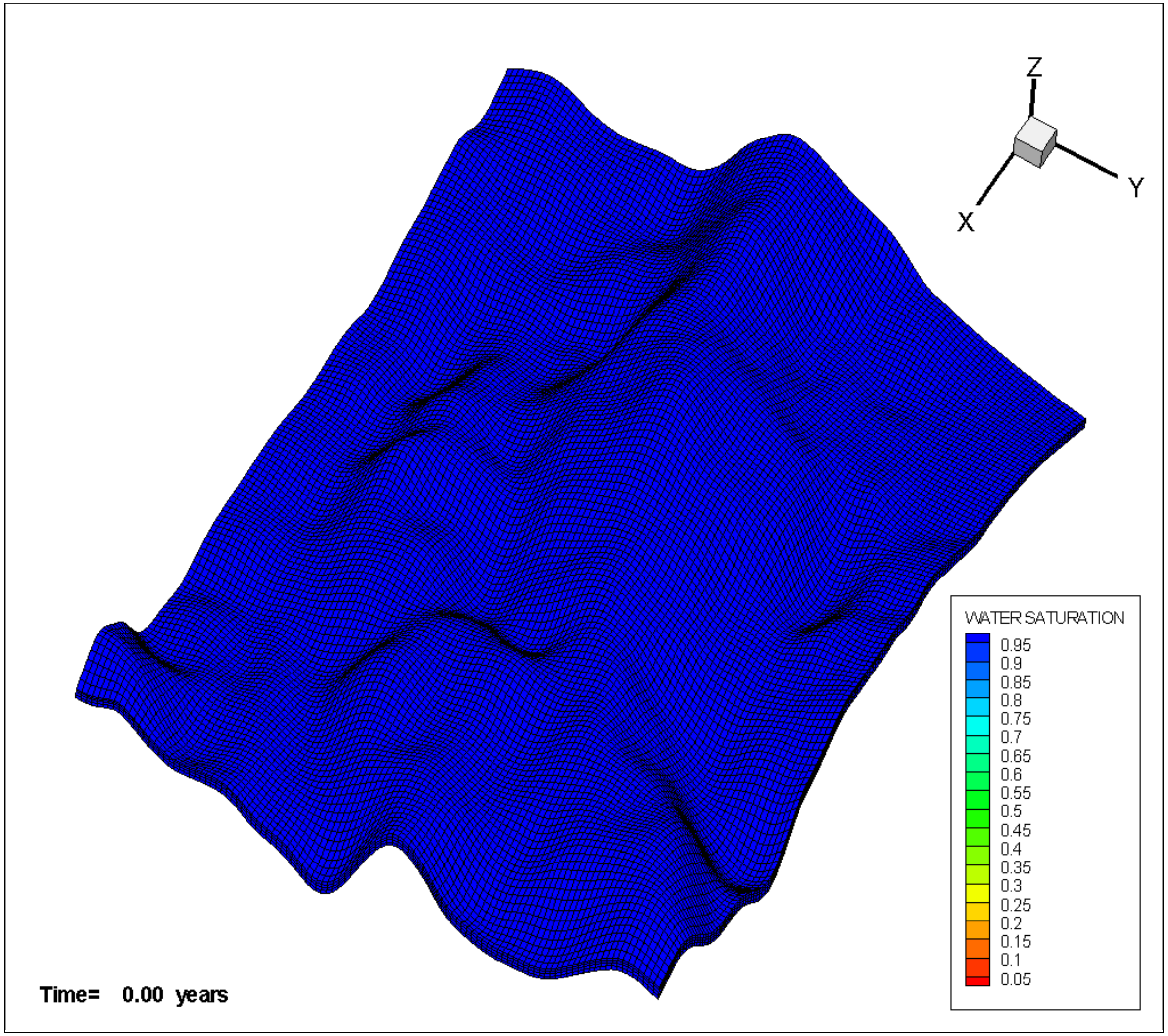
Realistic Example

- Some 46 by 58 km
- 100 m thick
- 200 – 350 mD range
- 10 injectors down dip
- 10 Mt/y
- 400 Mt in 40 years
- Model to small – Average pressure increase of 230 bar (in affected/adopted space)

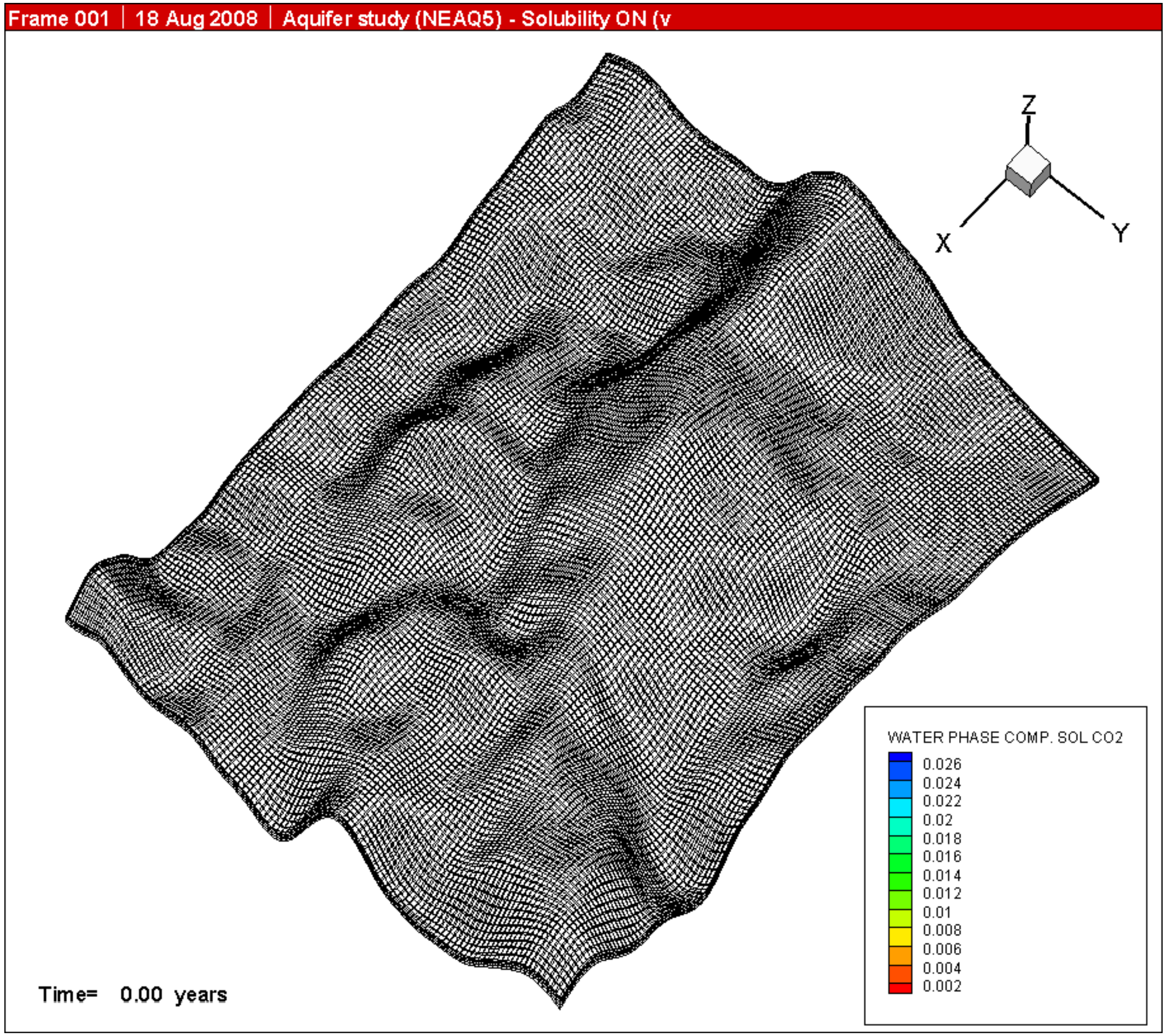
Realistic Example



Example - Free CO2



Example - CO2 Saturated water



Controlling Factors?

4 Important factors controlling the volume of CO_2 we can store in a predefine subsurface space

- Storage Capacity (Volume - Average Pressure)
- Potential Injectivity (Permeability - Local Pressure)
- Trap Efficiency (Available Space - Used Space)
- Data Available and Quality

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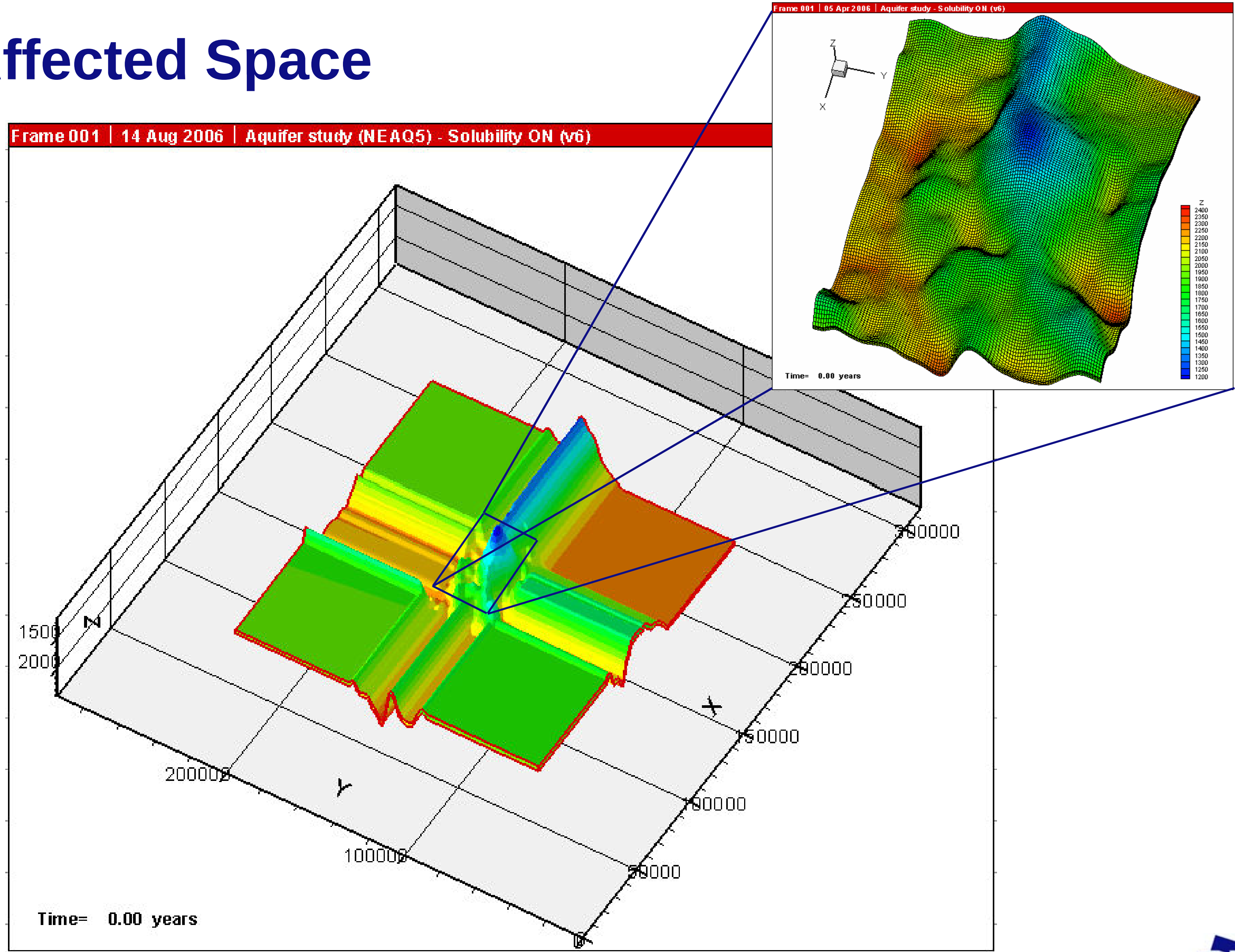
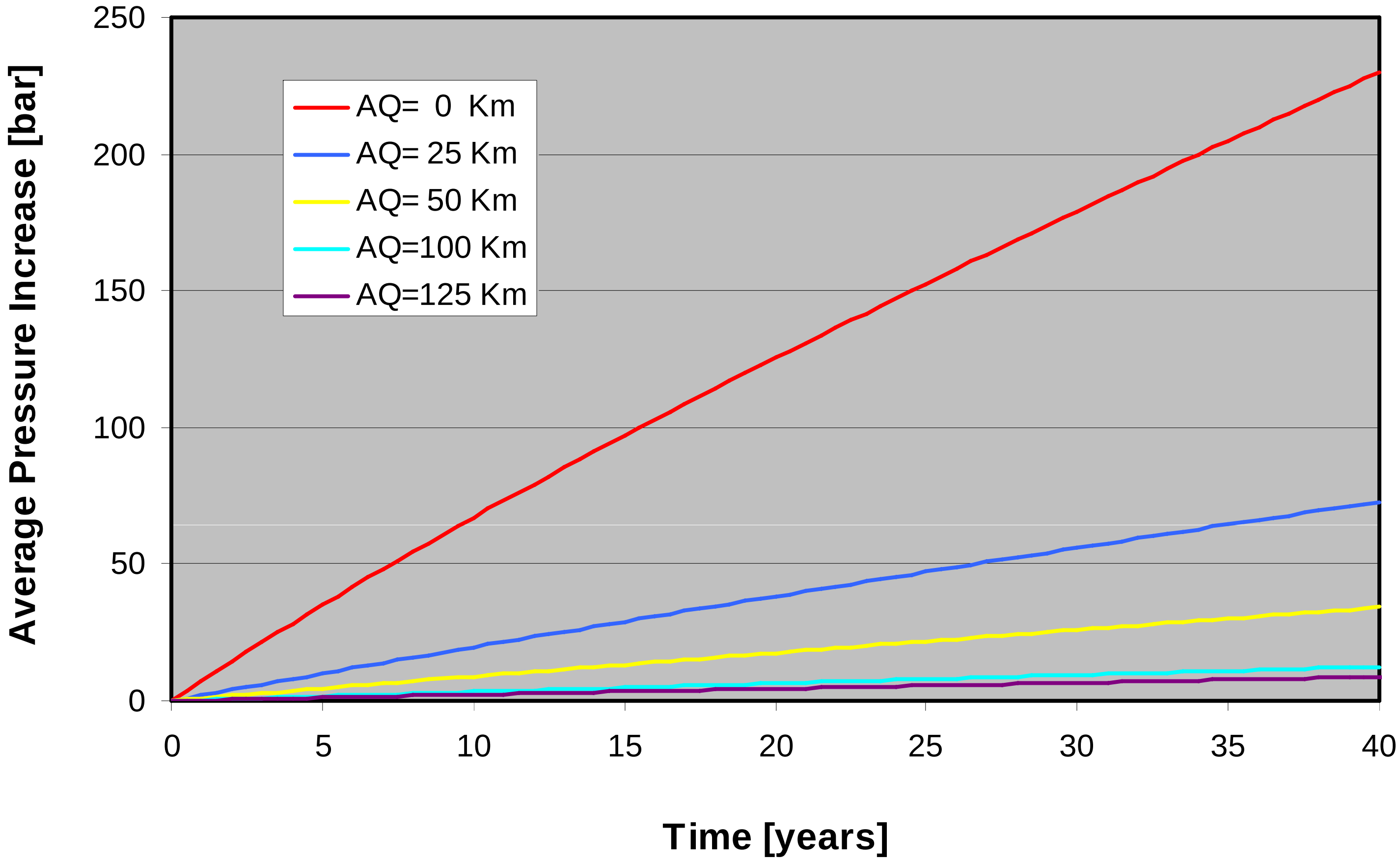
Affected Space



Affected Space – Average Pressure Respond



Conclusions (Storage Capacity)

- Affected space is full (rock and water)
- More space via pressure increase and compressibility
- length * width * height * N/G * poro - (Cw +Cr) * Pavg
- Pavg = Allowed average pressure increase in affected area
- If pressure increase too large => more affected space or less CO_2
- In example nearly 300 x 300 km, 400 Mt is 10.5 bar increase in average volume weighted pressure
- (2 x 10^{-5} 1/bar * 10 bar => 0.0002 % Earlier calculations with 100 bar via the geostatic approach/limitation max. 2 %)

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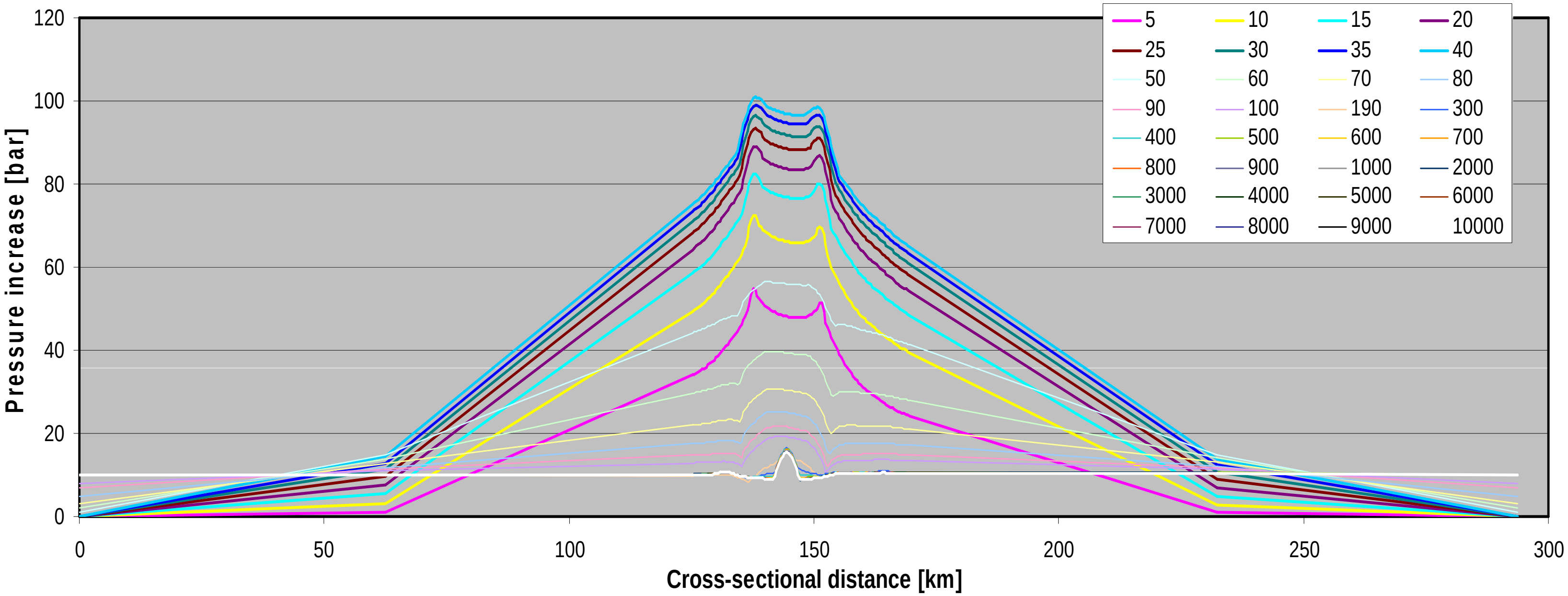
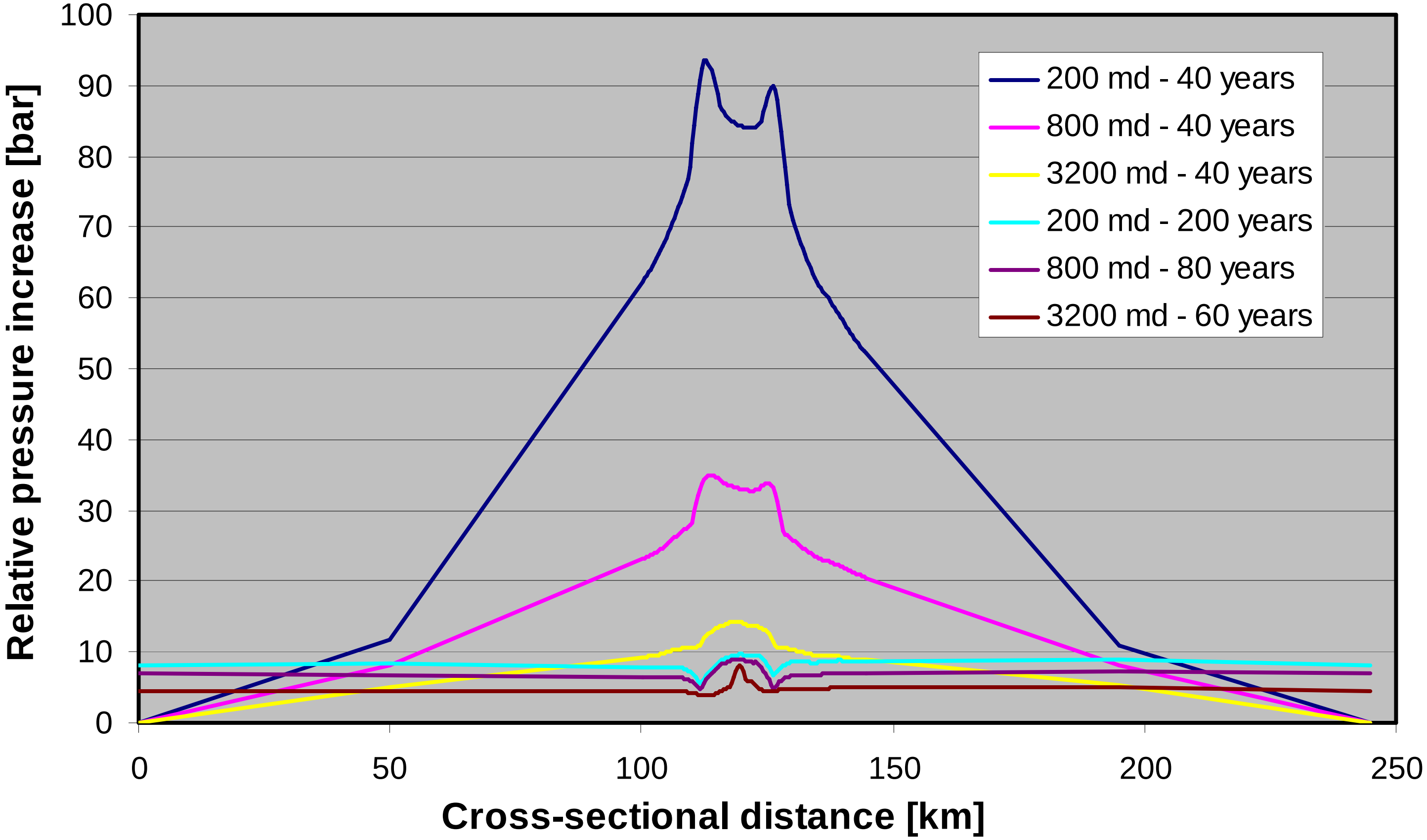
Potential Injectivity 1 (Permeability vs. Local Pressure)



Potential Injectivity 2 (Permeability vs. Local Pressure)



Conclusion (Potential Injectivity)

- Permeability (transmissibility) can reduce the total injection rate
- The higher the permeability the better
- Thicker also
- Pressure dispersion is important
- We developed a simple model to estimate pressure profile and maximum injection pressure
- Total injection volume rate important above individual well rate

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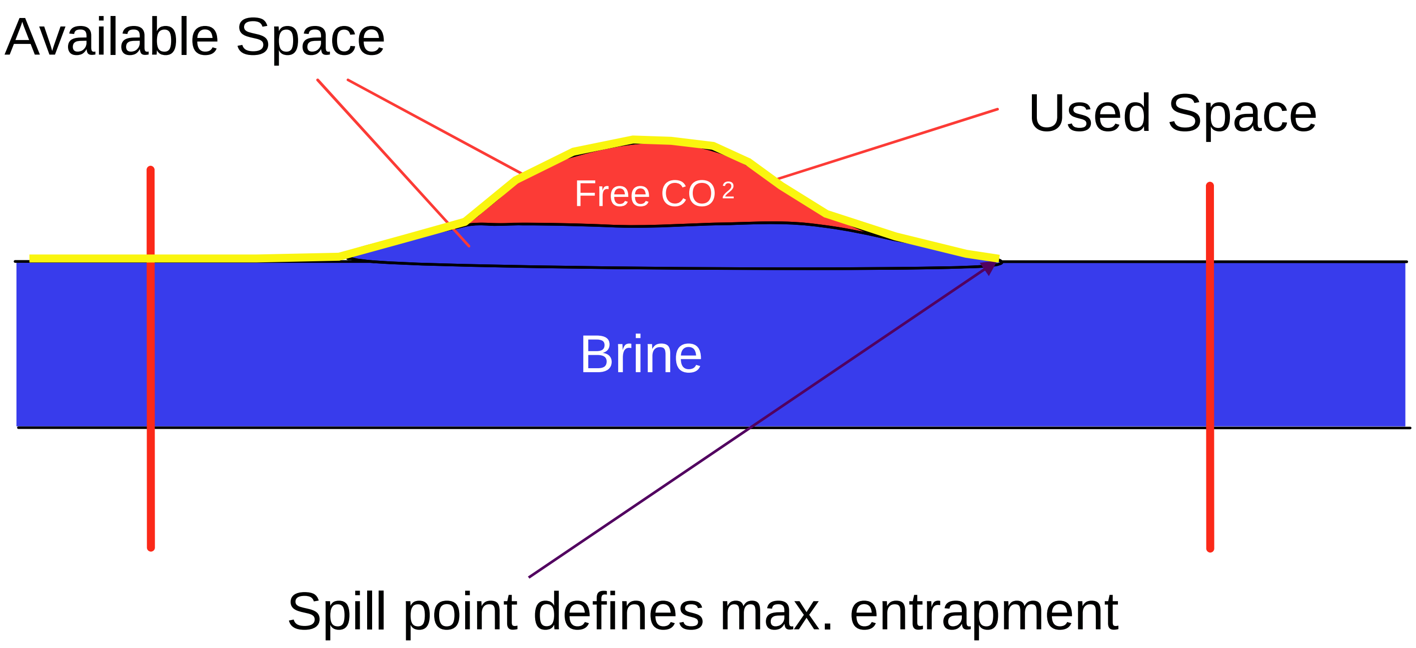
Trap Efficiency (Available Space vs. Used Space)



Conclusions (Trap Efficiency)

- Storage space defined by containment boundary and a spill point
- Trap Efficiency = Used Space / Available Space * 100 %
- Due to the solubility of CO_2 in water the Storage Efficiency could be specified in a form of a dynamic parameter

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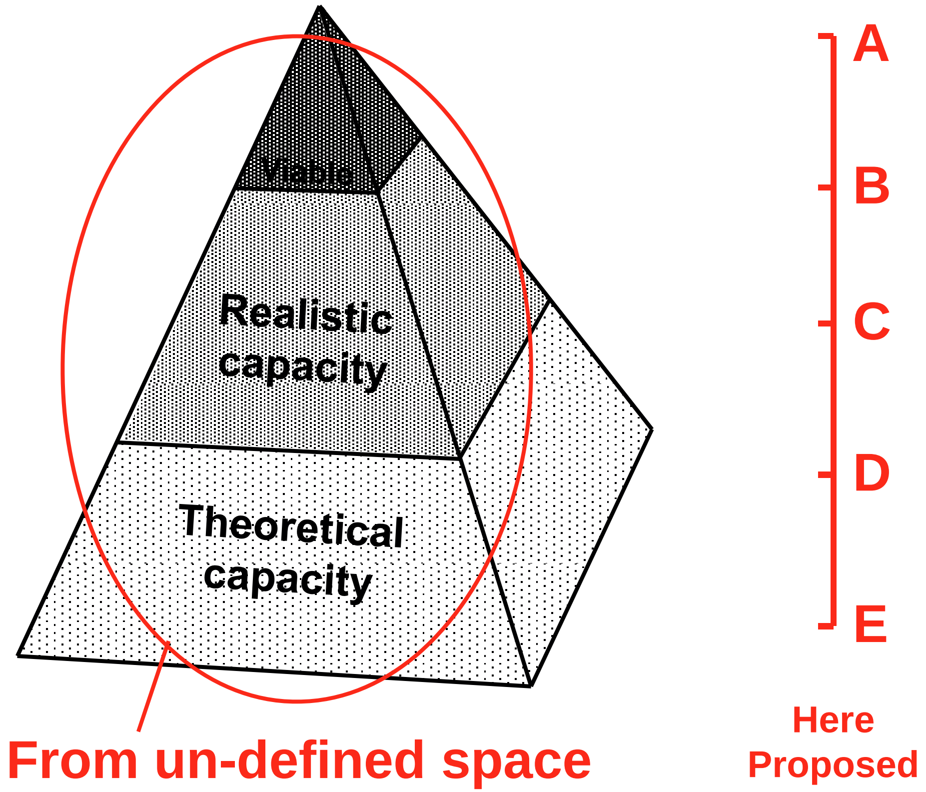
Data and probability of results

Classificati on	Description
A (Absolute)	All data used is b averaging is base methods. The dat Description of the and geological stu by sufficient well
B	As "A", with the e two important par permeability. The situation.
C	The main descrip estimation is mad some uncertainty they are not be ba
D	Measurements in as a storage loca speculations or b permeability, seal
E (Estimate)	All data items are



Techno-Economic Resource Pyramid, after Bradshaw

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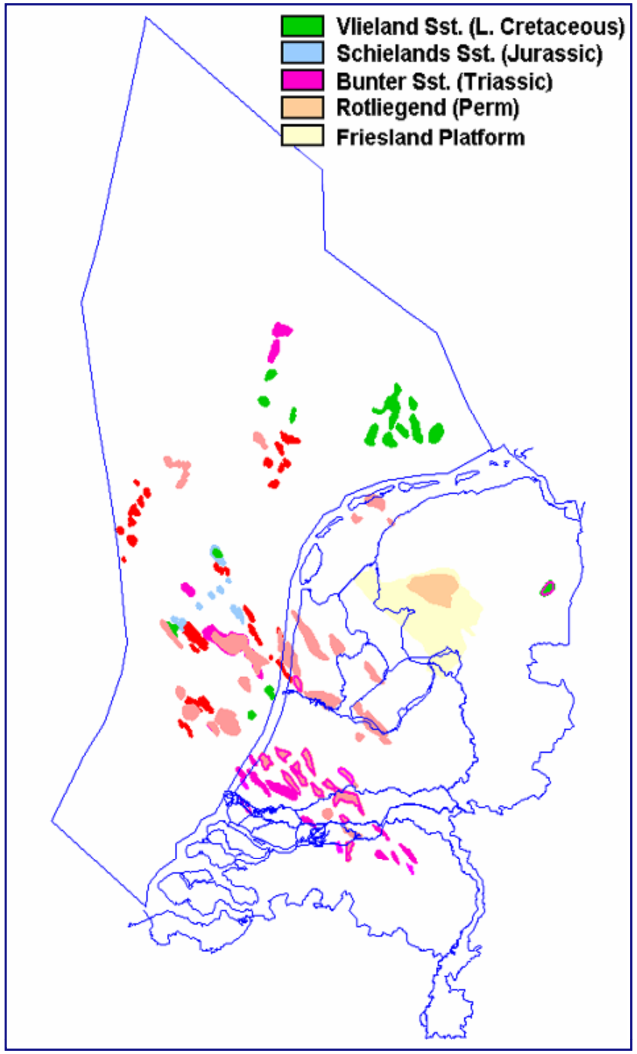
Previous estimation

- Results of trap screen study
- Traps planimetered, starting point a spill point.
- No pressure considerations

- CO_2 *(kg) = Vr * N/G * E * Φ * ρ.*

Vr = Bulk aquifer volume (m³)
N/G = Nett to gross ratio (-)
E = Efficiency factor (constant = 0.02)
Φ. = Porosity (-)
ρ = CO_2 density at depth (Rotliegend = 700 kg/m³, Triassic = 650 kg/m³)



Previous estimation

Group	Member	Number of traps	Gross Volume	Net Volume (2%efficiency factor)
Permian (Rotliegend)	Slochteren Sst.	37	16849	337 Mton
Triassic	Bunter Sst.	31	3857 Mton	77 Mton
Jurassic Lower Cretaceous	Schieland Sst Mb. Vlieland Sst.	24	1207 Mton	24 Mton
Tertiary		0		
Total			21913 Mton	**438 Mton**

Proportion:

CO_2 of 3 - 4 power stations for 40 years

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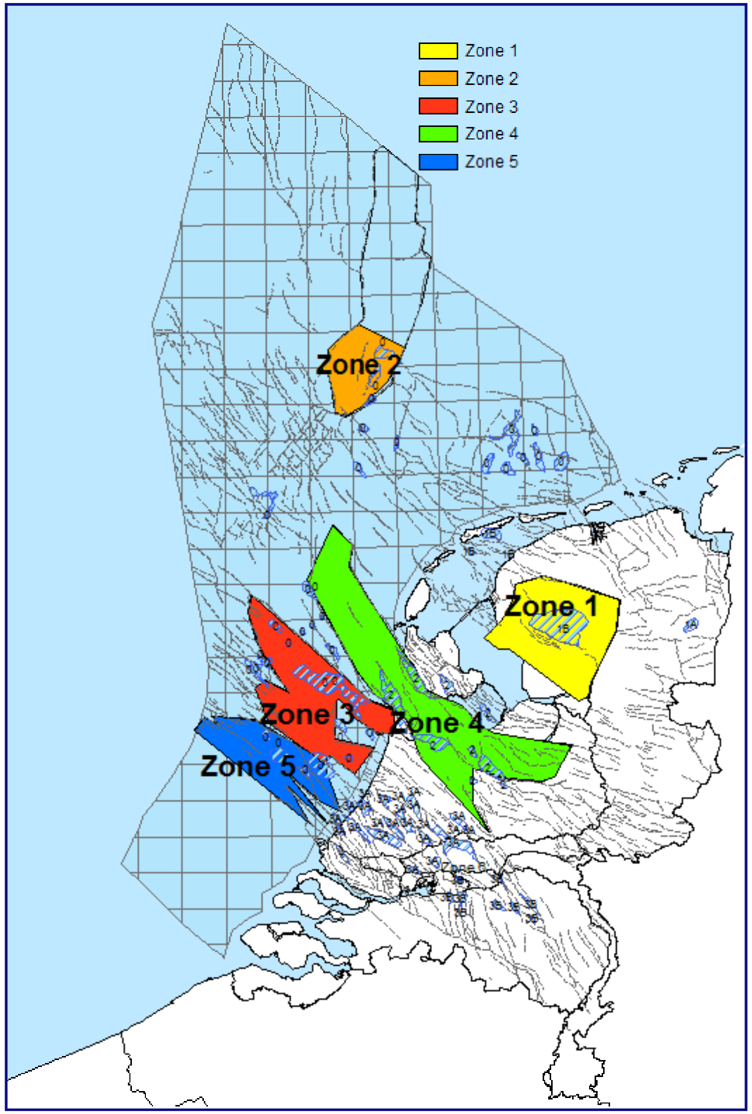
New estimation

- Starting point old study
- Affected areas
 Hydraulic connected = Zones
- Only 5 zones found
- For every zone maximum theroretical storage capacity calculated (Pavg increase of 10 bar)



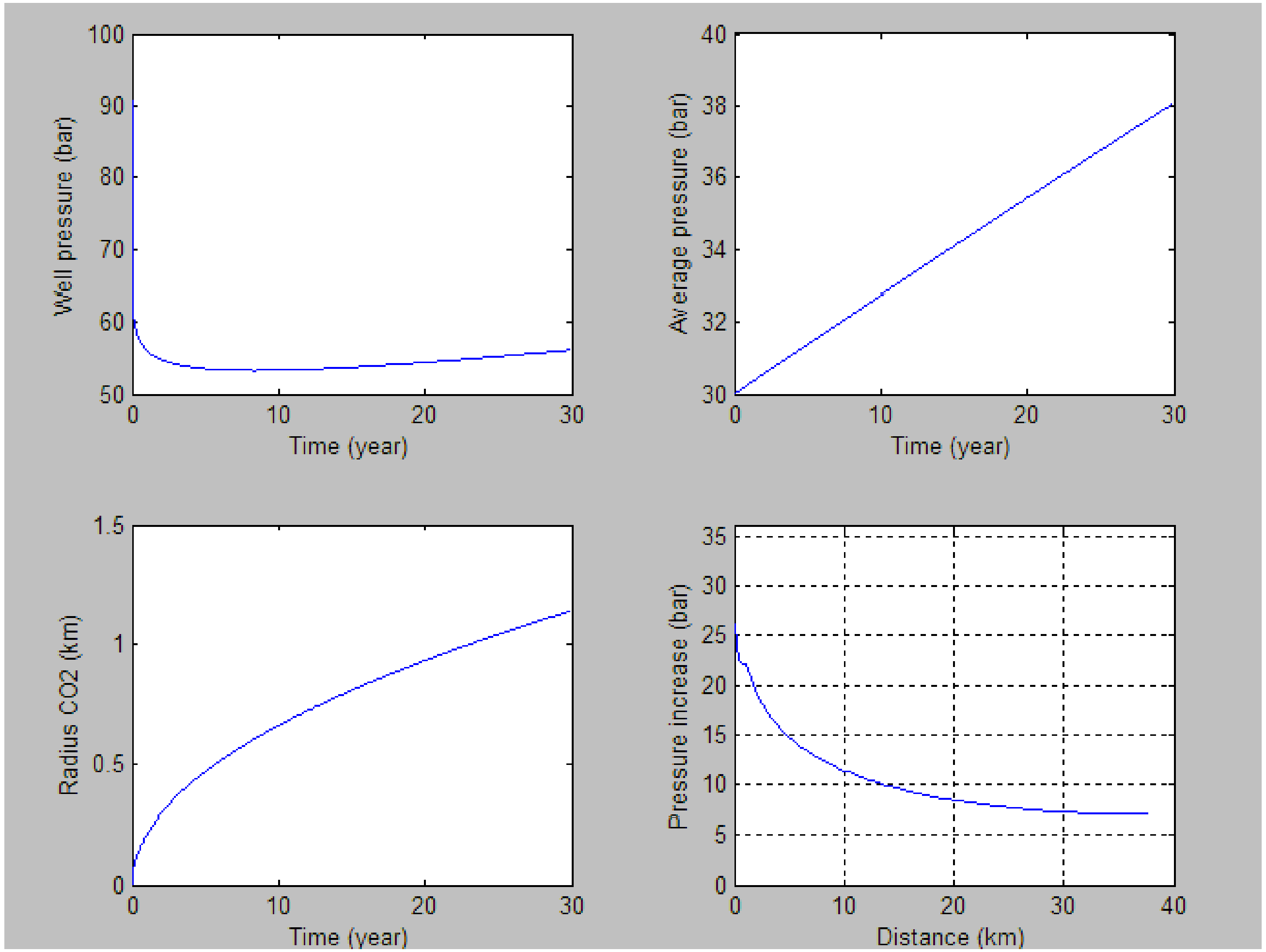
New estimation (capacity)

Zone	Area (km²)	Thickness (m)	Permeability (md)	Porosity	Theoretical Total Storage (Mtonnes)	Injec
1	2650	50	200	0.18	16,08	1 Mtoı ye
2	1180	40	100	0.08	2.55	0.25 Mt 10 y
3	2730	100	80	0.10	18,40	1 Mtoı ye
4	4500	120	150	0.18	65,52	2 Mtonr ye
5	1550	15	40	0.10	1,57	0.10 Mt ye
Total					104.12 Mton	

Theoretical Total Storage (Mtonnes)
16,08
2.55
18,40
65,52
1,57
104.12 Mton

- More than 3 times smaller
- Only one storage project possible in one Zone

New estimation (injectivity)



- Simple model to estimate pressure respond

New estimation (Injectivity)

Zone	Area(km^2)	Thickness (m)	Permeability (md)	Porosity	Theoretical Total Storage (Mtonnes)	Injectivity	Pressure built up near injection zone (bar)
1	2650	50	200	0.18	16.08	1 Mton for 16 years	23.75
2	1180	40	100	0.08	2.55	0.25 Mtonnes for 10 years	18.81
3	2730	100	80	0.10	18.40	1 Mton for 18 years	28.45
4	4500	120	150	0.18	65.52	2 Mtonnes for 30 years	26.10
5	1550	15	40	0.10	1.57	0.1 Mton for 15 years	35.11
Total						104.12 Mtonnes	

- Injection target 1Mt/year – expected

New estimation (efficiency)

Zone	Area(km²)	Thickness (m)	Permeability (md)	Porosity	Theoretical Total Storage (Mtonnes)	Injectivity	Pressure up ne injection (bar	Number of Traps
1	2650	50	200	0.18	16.08	1 Mton for 16 years	23.7	1
2	1180	40	100	0.08	2.55	0.25 Mtonnes for 10 years	18.8	3
3	2730	100	80	0.10	18.40	1 Mton for 18 years	28.4	5
4	4500	120	150	0.18	65.52	2 Mtonnes for 30 years	26.1	6
5	1550	15	40	0.10	1.57	0.1 Mton for 15 years	35.1	4
Total						**104.12 Mtonnes**		**19**

- Possible traps

New estimation (qualification)

- All Zones a "**D**" status

- Based on good large scale maps
- Fault map
- Seal continuation?
- Poro, perm, thickness, compressibility …. single estimated values

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Conclusions

- Subsurface is full (rock and water)

- More space via pressure increase and compressibility

We have specified:

- Affected Space (effect of activity is felt, needed for space)
- Storage Capacity (Volume vs. Average Pressure)
- Potential Injectivity (Permeability vs. Local Pressure)
- Trap Efficiency (Available Space vs. Used Space)
- Data / information probability schema

- For Calculations see paper (OTC 19309)

Thank you for your attention

Questions?

SPE OTC 19309