CO_2 Capture, Utilization and Sequestration

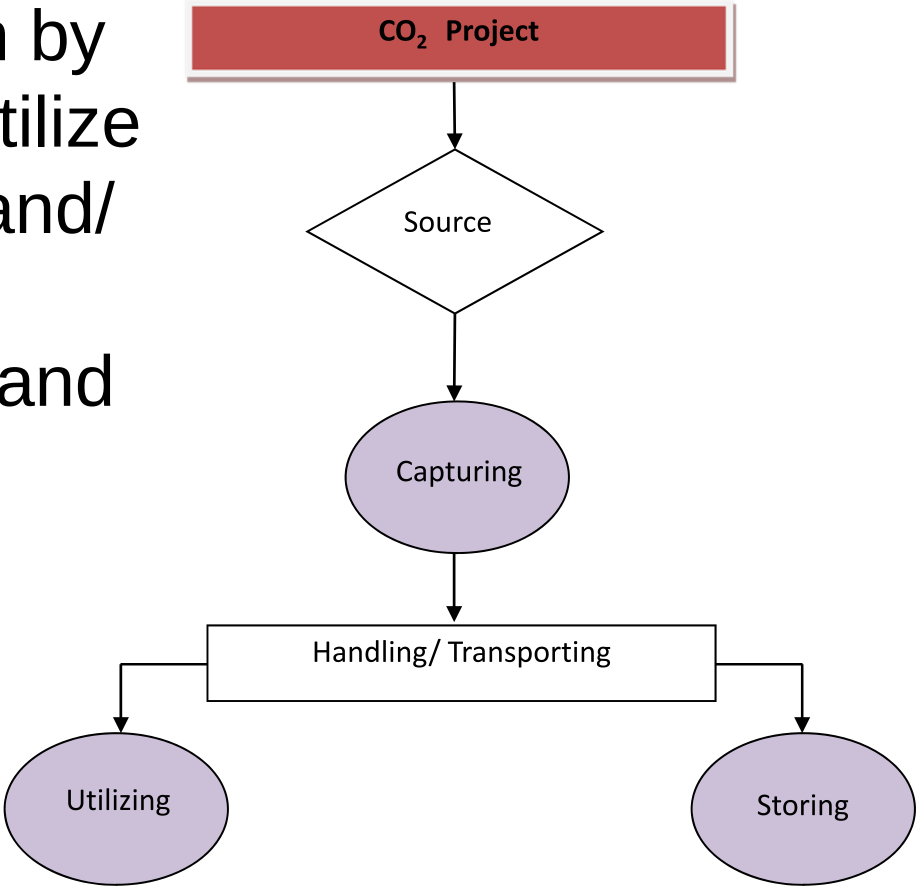
Bander Al Ghamdi
Kyungsoo Kim
Seyhan Emre Gorucu
Yogesh Bansal

Outline

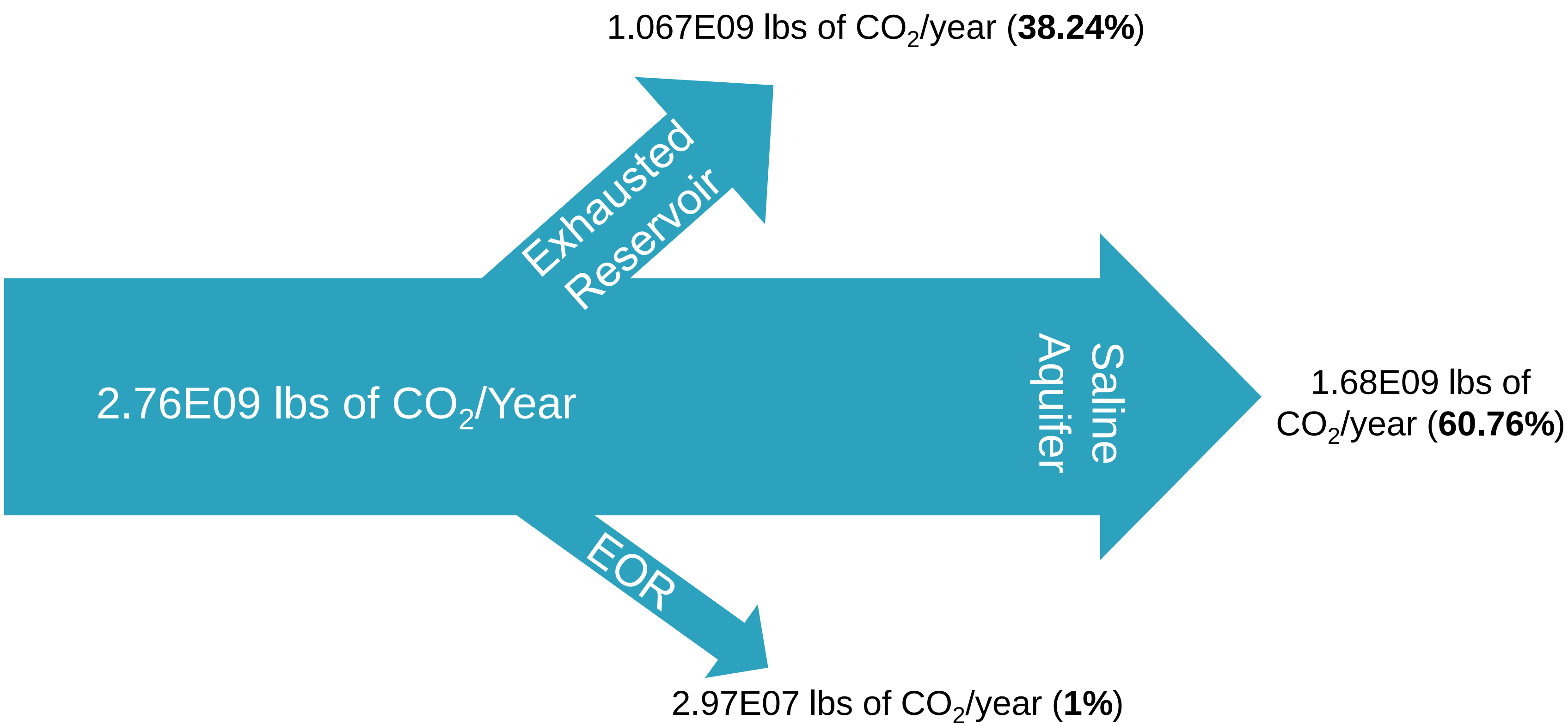
- Team Statement
- Results
- Approach
  - Capturing
  - Sequestration
  - Utilization
- Conclusion

Team Statement

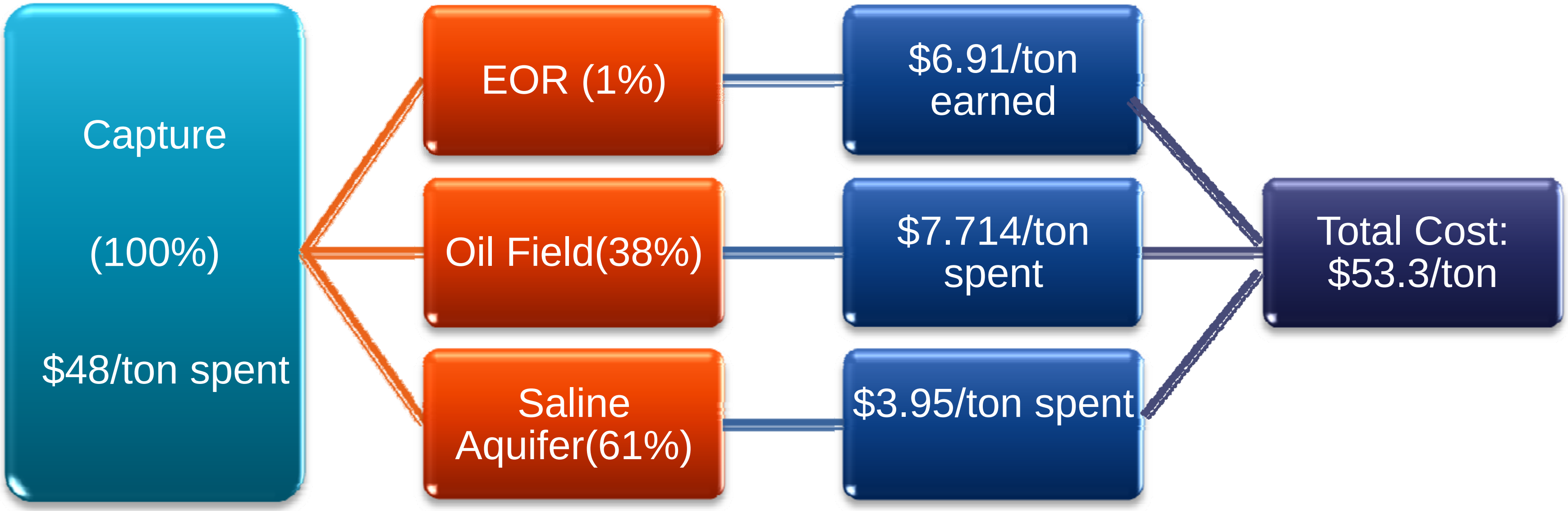
- Reduce CO_2 emission by efficiently capture it, utilize it for EOR purposes, and/ or sequester it, while considering technical and economical analysis.



Capture, Sequestration, and Utilization



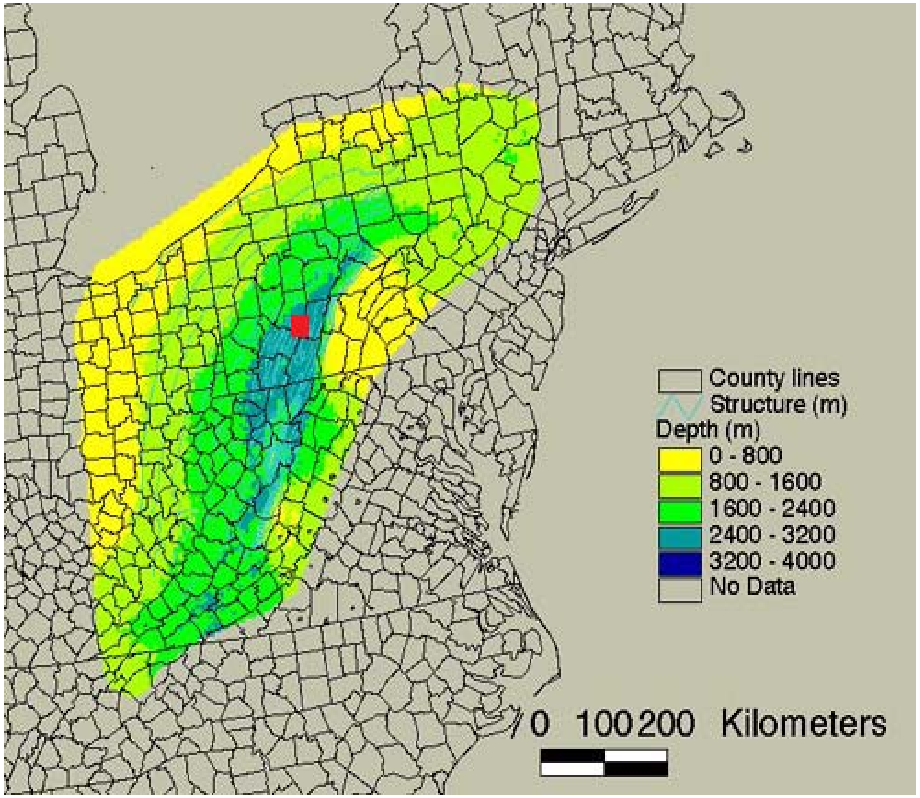
Economical Balance



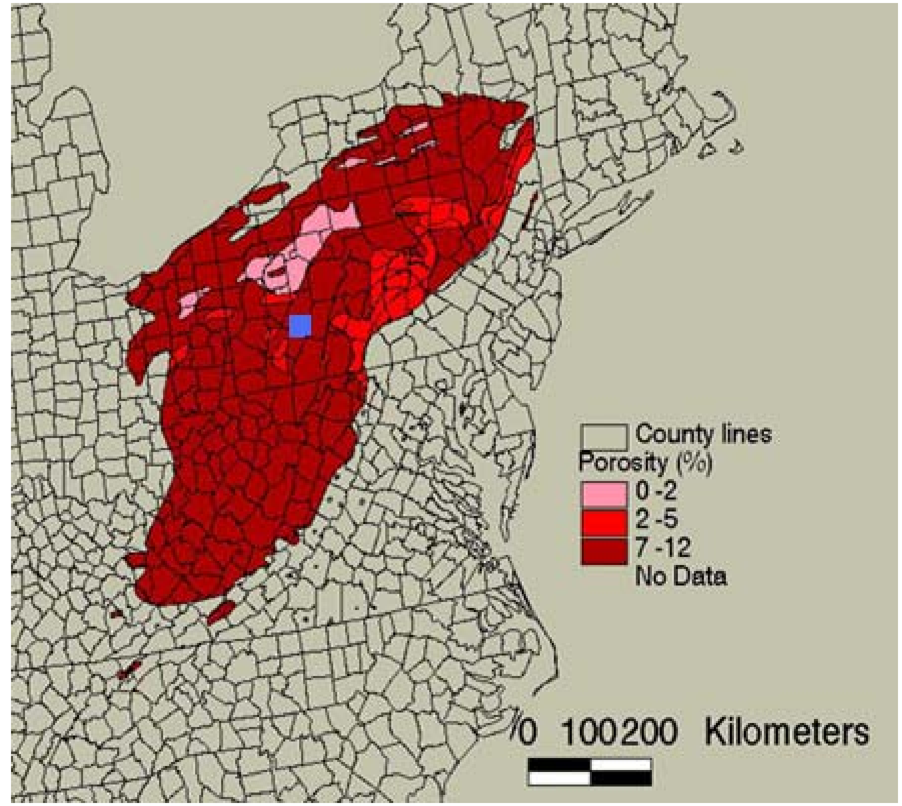
Electricity Production Cost

Cost without CCS	3.7cent/kWh
Cost with Capture only	5.4 cent/kWh
Cost with CCS	5.9 cent/kWh

Oriskany Saline Aquifer, Seward, Pennsylvania



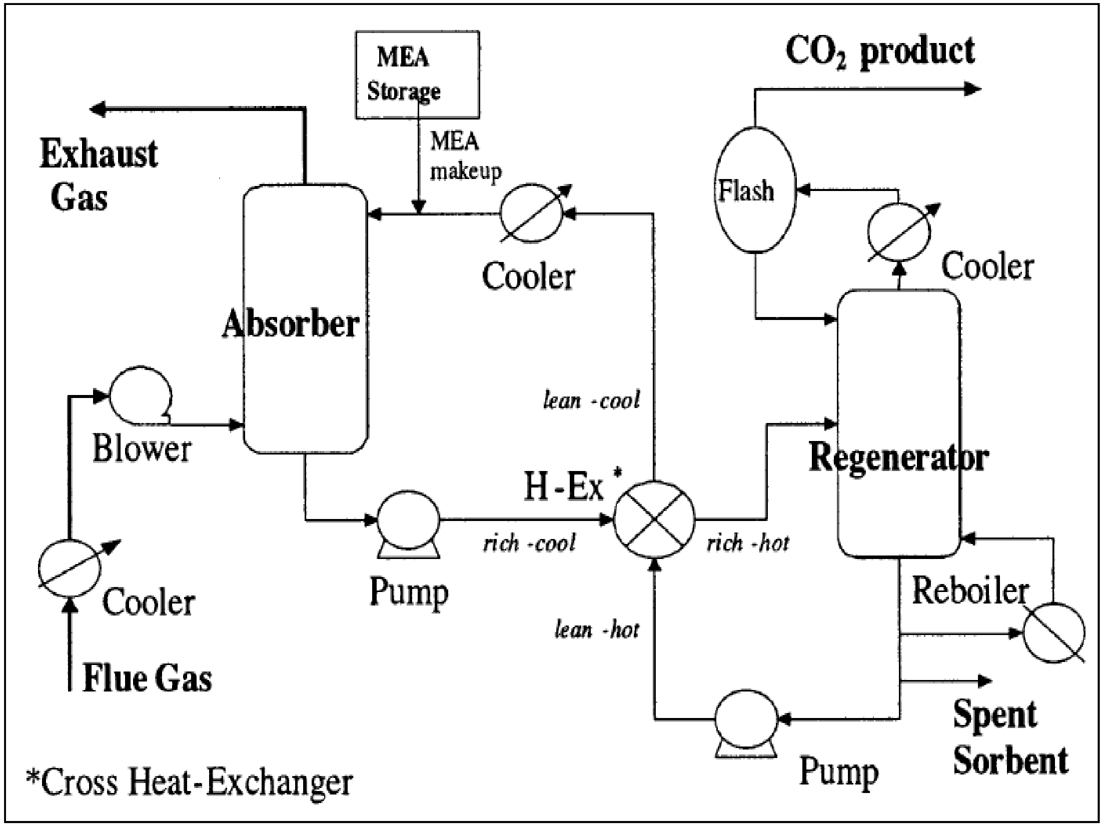
Depth Map



Porosity Map

CO_2 capture

- Capture method
  - Post-combustion
    - Chemical absorption
    - Membrane
  - Pre-combustion
  - Oxy-fuel



Data Source :
Rao A, Rubin E, A technical, economic, and environmental assessment of Amine-based CO2 capture technology for power plant greenhouse gas control in Environ1

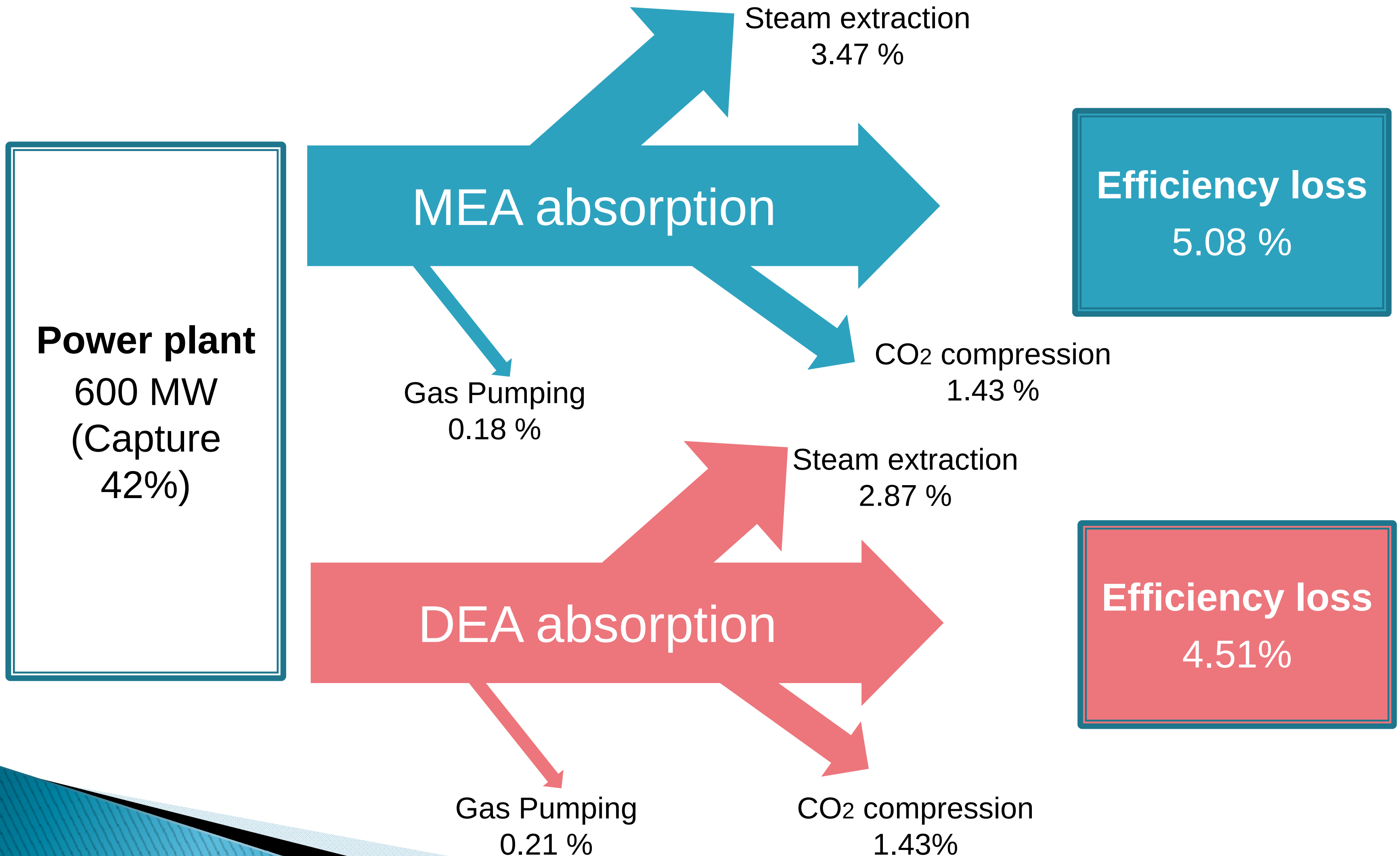
Assumptions

- Reduce 1% of PA's annual CO_2 emission from the power industry and keep the emission amount the same for ten years
- Values for power plant efficiency and capital cost are the same as those of similar power plants
- No capital cost for power plant, the capital cost for power plant starts to be paid from the first running point of the capture process

<Economic analysis assumptions>

Project life (years)	10
Operating hours (hour/year)	6000
Operation and maintenance cost (% of capital cost)	3
Spent solvent making up ($/ton CO_2 captured)	4
Interest rate (%)	5
Coal price ($/ton)	48
SO_x, NO_x in flue gas (ppm)	70

Energy balance



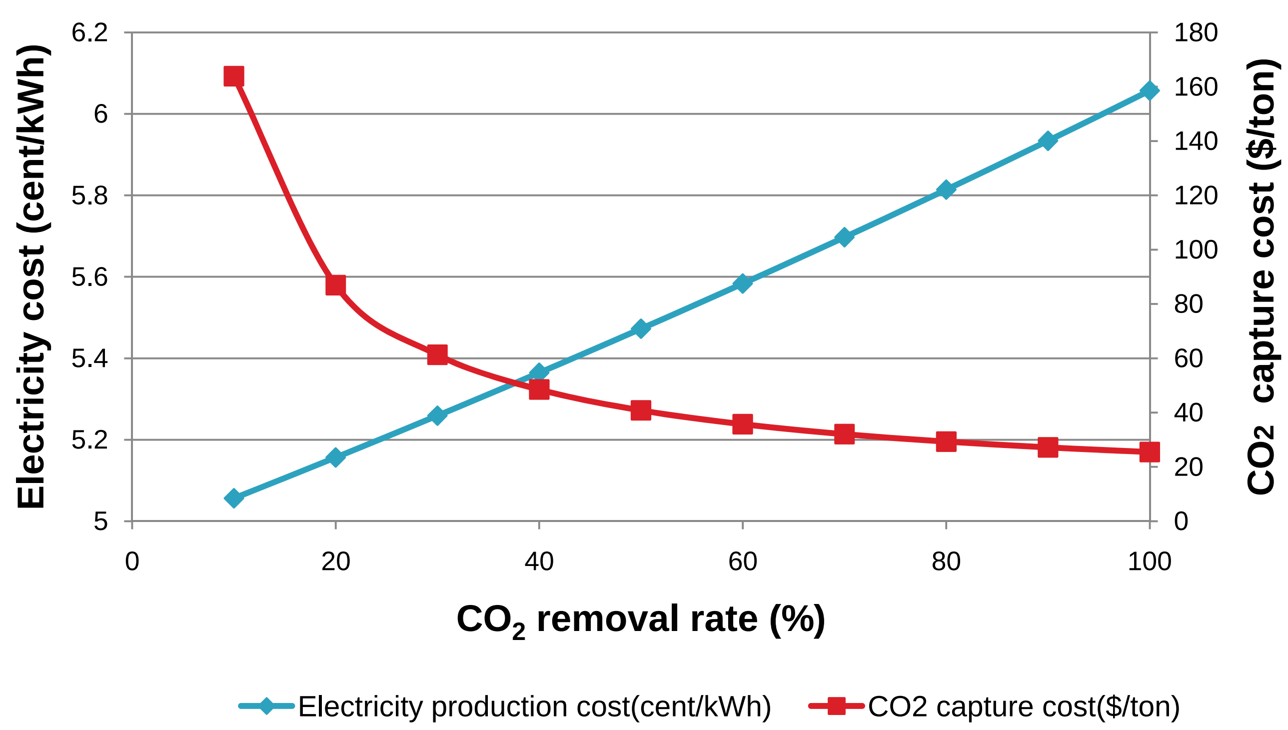
Economical analysis

- CO_2 capture with MEA

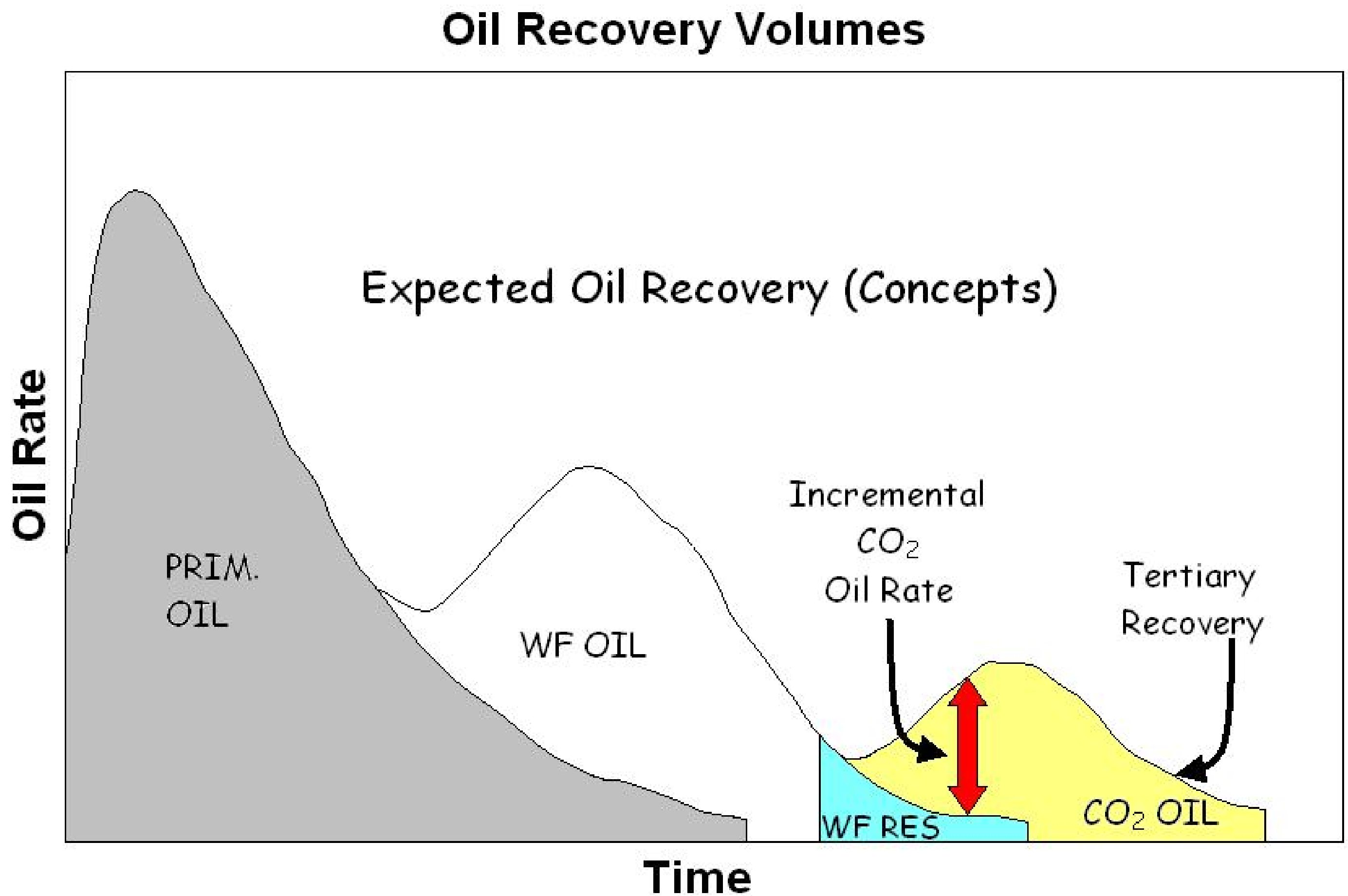
Capital cost(million USD)	957
Reference plant Construction	690
Chemical absorption unit	182
CO2 compressor	25
Interest during construction and land site	59
Annualized cost(million USD/year)	162
Capital charges for reference plant	49
Capital charges for CO2 capture components	19
Coal feedstock	63
Operation and maintenance cost for reference plant	22
Operation and maintenance cost for CO2 capture process	9

Net power production(MW)	
Reference plant	600
Power plant with CO2 capture	568
Specific CO2 emission (lb/kWh)	
Reference plant	1.8
Power plant with CO2 capture	1.1
Electricity production cost(cent/kWh)	
Reference plant	**3.7**
Power plant with CO2 capture	**5.4**
CO2 capture cost ($/ton CO_2)	**48.6**

Further analysis



CO_2 for EOR



Data Source:

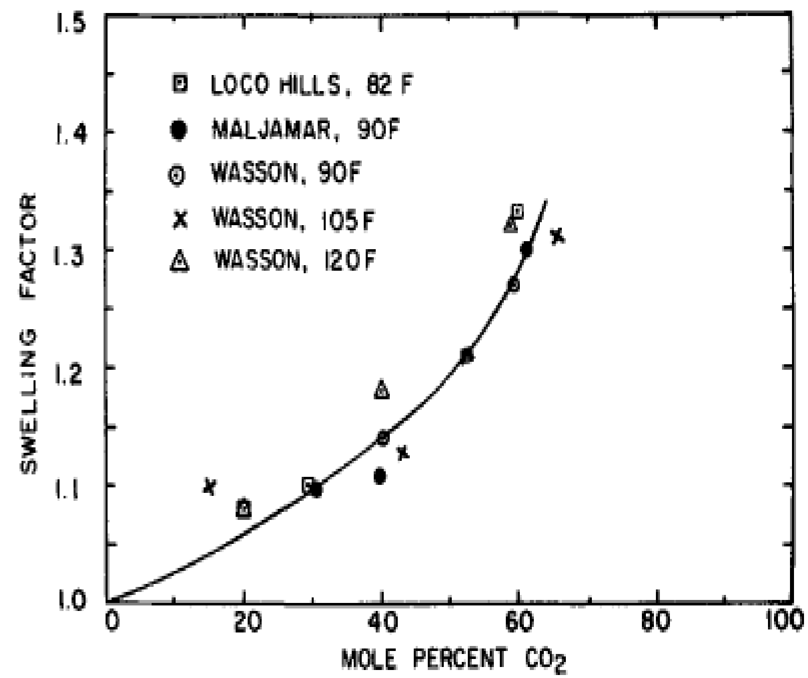
1. *www.apegga.org/Members/Presentations/Baker.ppt*

Why EOR?

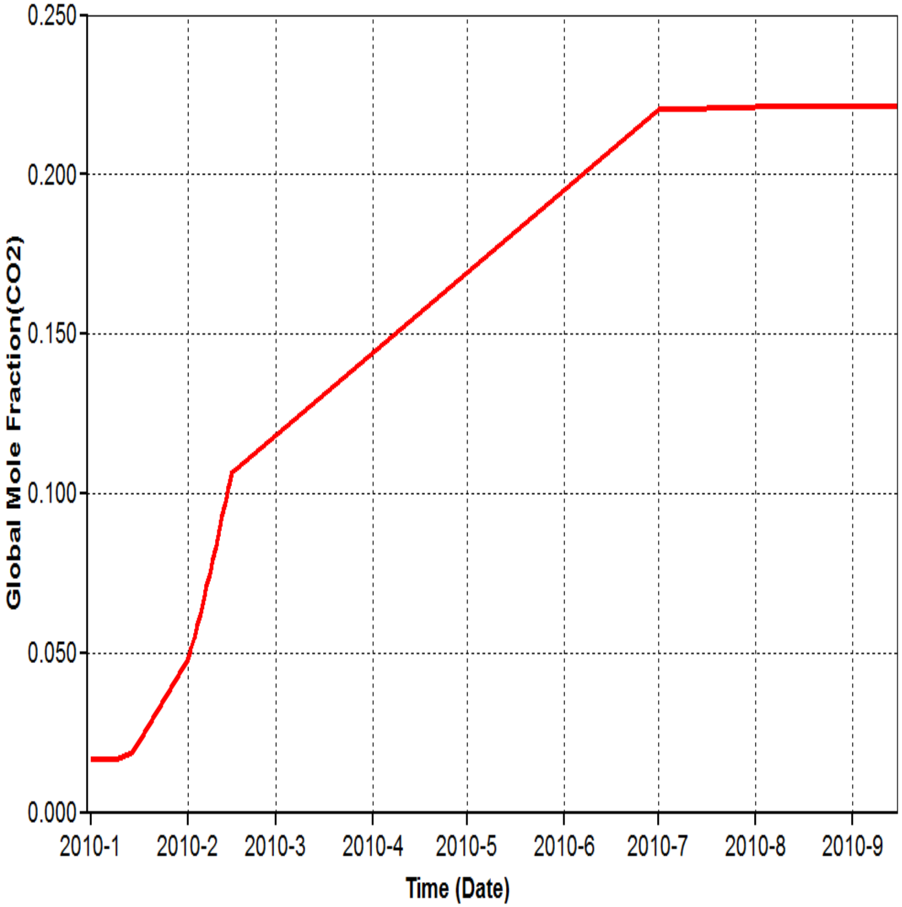
- Field production is a strong function of (P and T)
  - Lithology of the reservoir
  - Properties of oil
- Oil could be at a high viscosity that prevents it from flowing, or it could be strongly attached to the grains inside the pore spaces where it is unreachable.
- A mechanism has to take place to make oil more soluble and be pushed to the production zones.

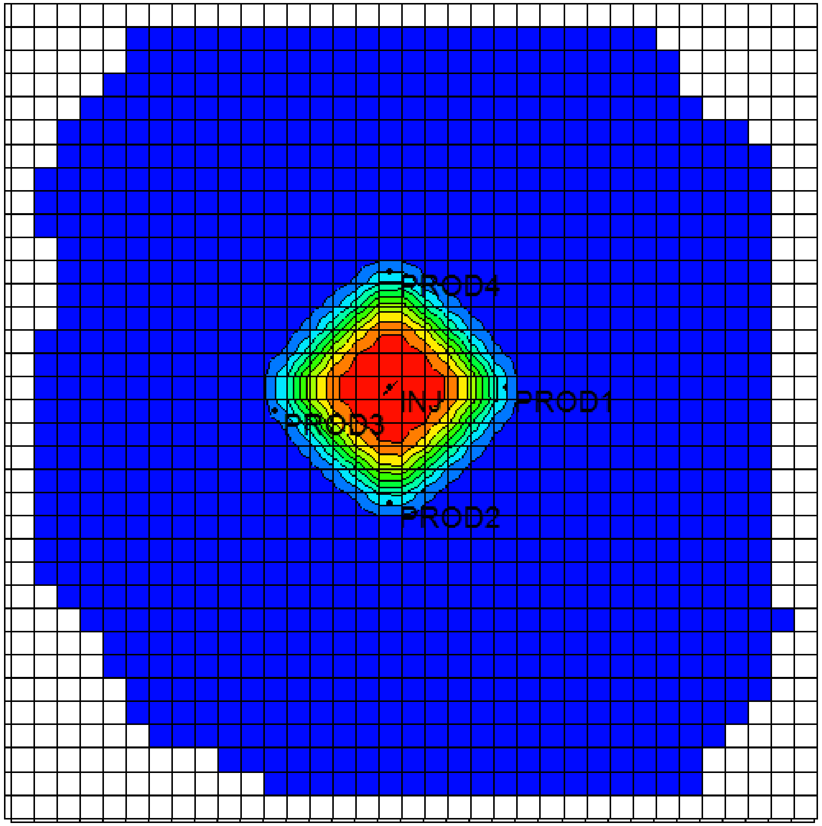
Swelling vs. Concentration

- As the CO_2 comes in contact with oil, it dissolves in the droplets of oil and occupies some volume allowing the oil to swell
- Oil droplets will merge together to unite in one body of fluid flow more easier to reach the production zones



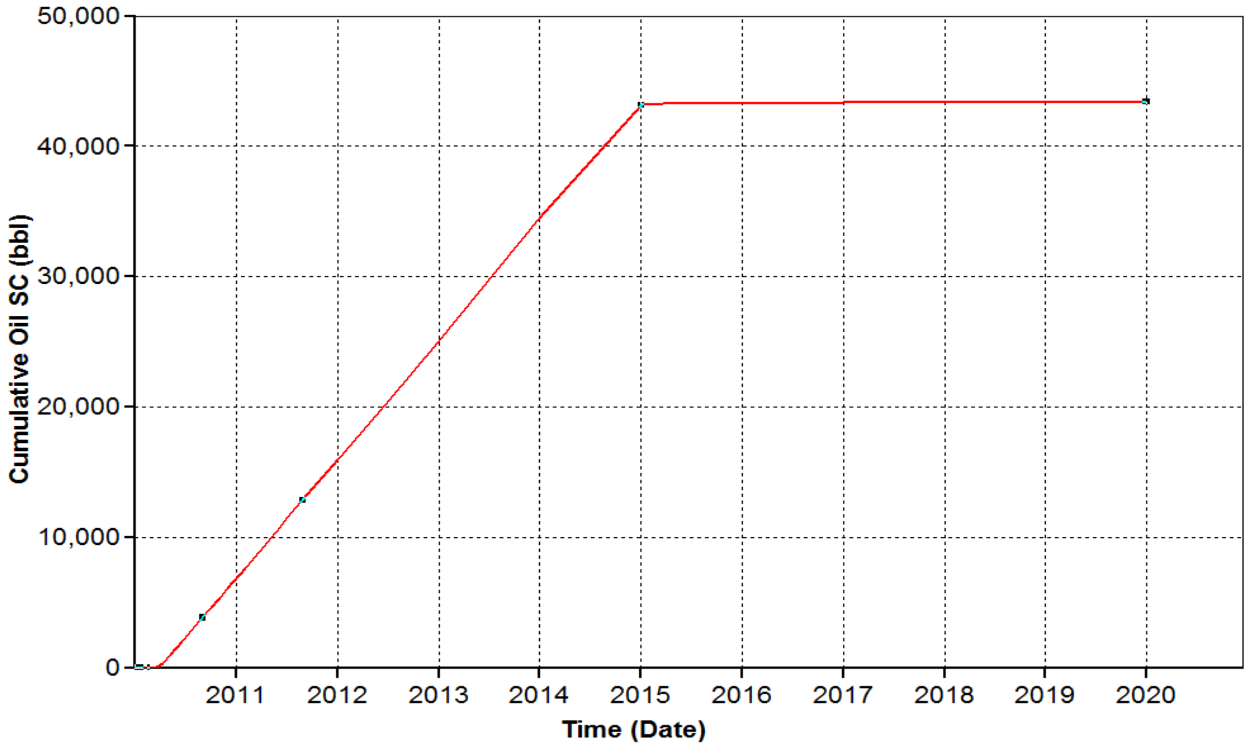
Displacement of CO_2



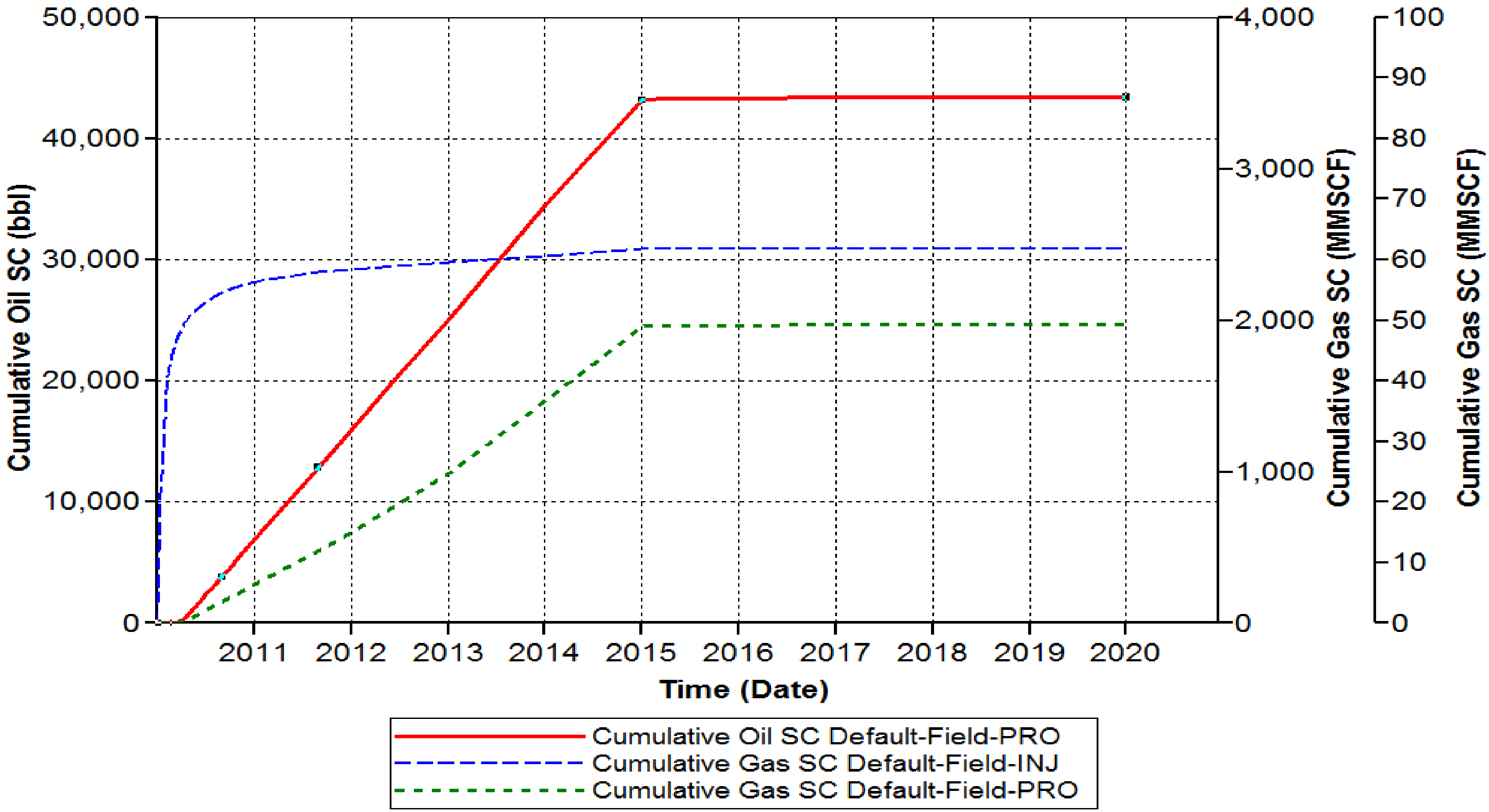


Production Scenario

Injection Rate (MMSCF/D)	Cum. Oil Produced (MSTB)	Recovery Factor (%)
70	43	35.8



Cycling CO_2



50,000
40,000
30,000
20,000
10,000
0
Cumulative Oil SC (bbl)
4,000
3,000
2,000
1,000
0
Cumulative Gas SC (MMSCF)
100
90
80
70
60
50
40
30
20
10
0
Cumulative Gas SC (MMSCF)
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Time (Date)
Cumulative Oil SC Default-Field-PRO
Cumulative Gas SC Default-Field-INJ
Cumulative Gas SC Default-Field-PRO

Exhausted oil/gas reservoir

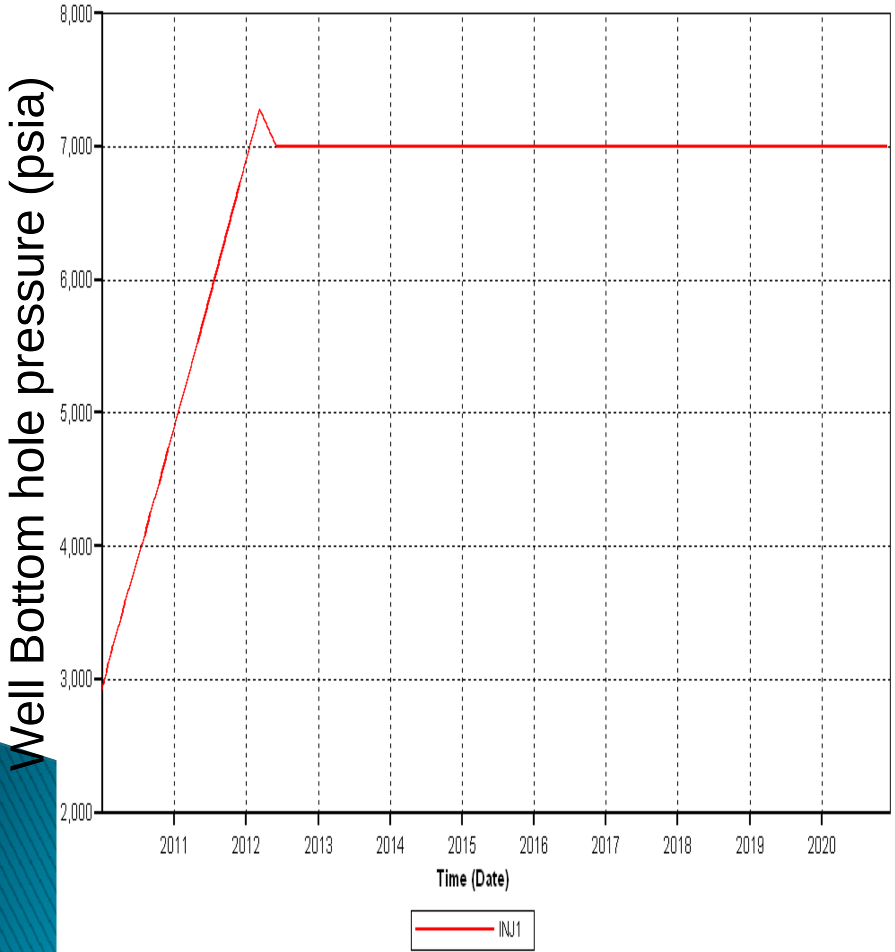
Pore volume calculations

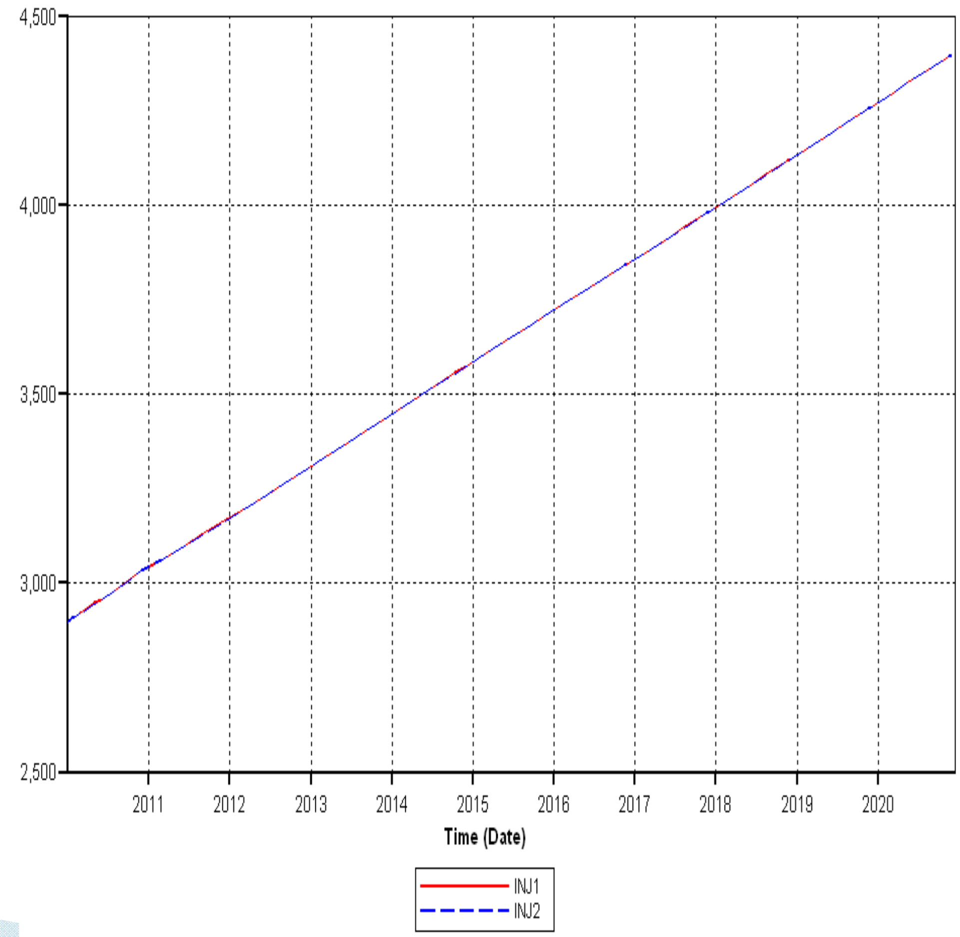
Layer	# of Active reservoir blocks	Δx	Δy	h	ϕ	Pore Volume (ft^3)
1	972	300	300	16	0.1373	$1.922*10^8$
3	972	300	300	12	0.1622	$1.703*10^8$
5	972	300	300	6	0.075	$0.394*10^8$
7	972	300	300	6	0.075	$0.394*10^8$
					Total	$4.413*10^8$ ft^3

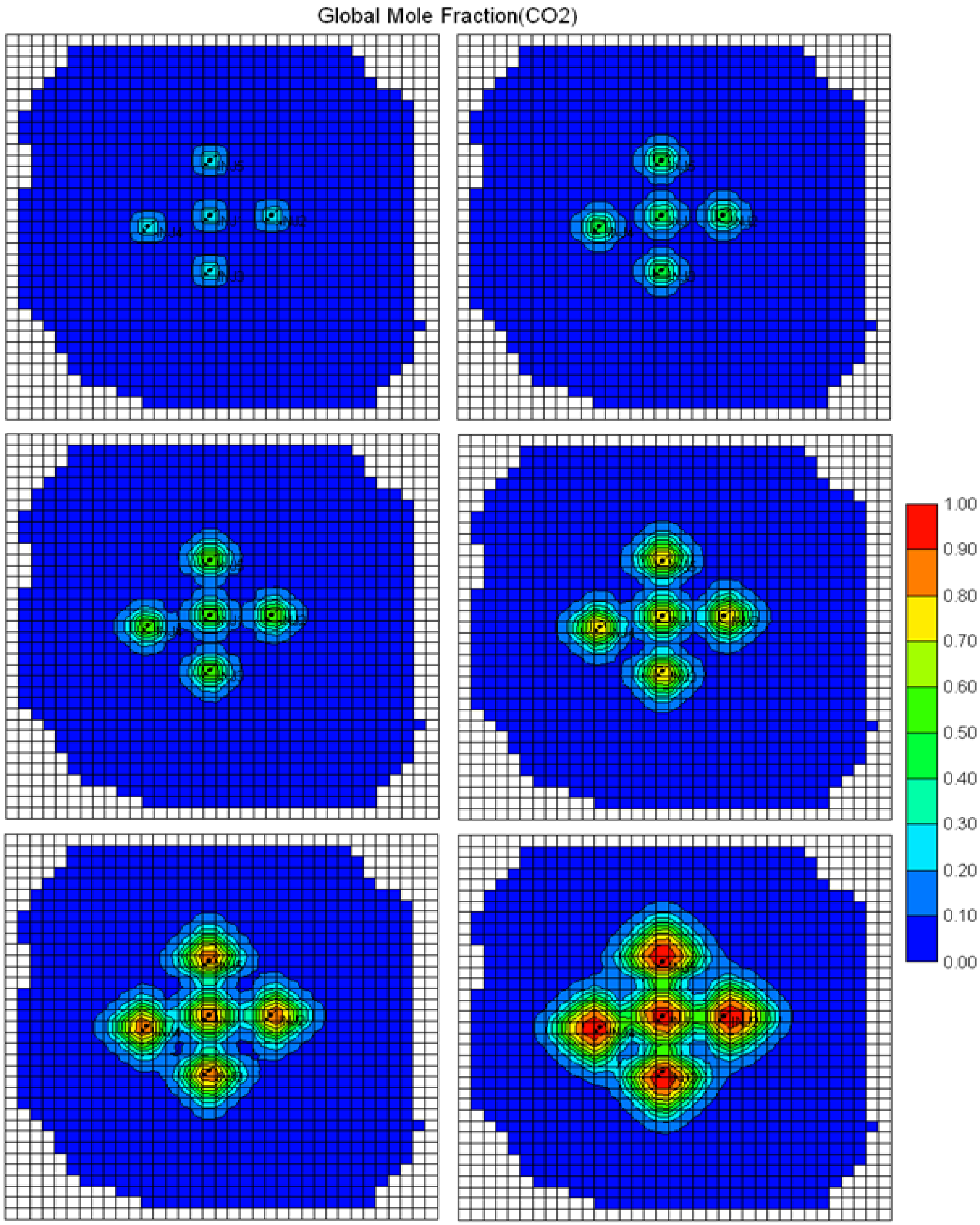
- Formation volume factor for CO_2 as 0.0048
- $9.194*10^{10}ft^3$ CO_2 can be sequestered in the reservoir
- Two possibilities
  - Entire amount sequestered in the reservoir for nearly 4 years
  - Fraction of the captured amount

- When entire amount of CO_2 is sequestered
  - Using all five wells
  - Pressure crossed 7000 psia at the wells
  - Formation fracture risks

- A study was designed to inject CO_2 for a period of 10 years
- 38.24% of the captured amount (1.067 lbs/year)



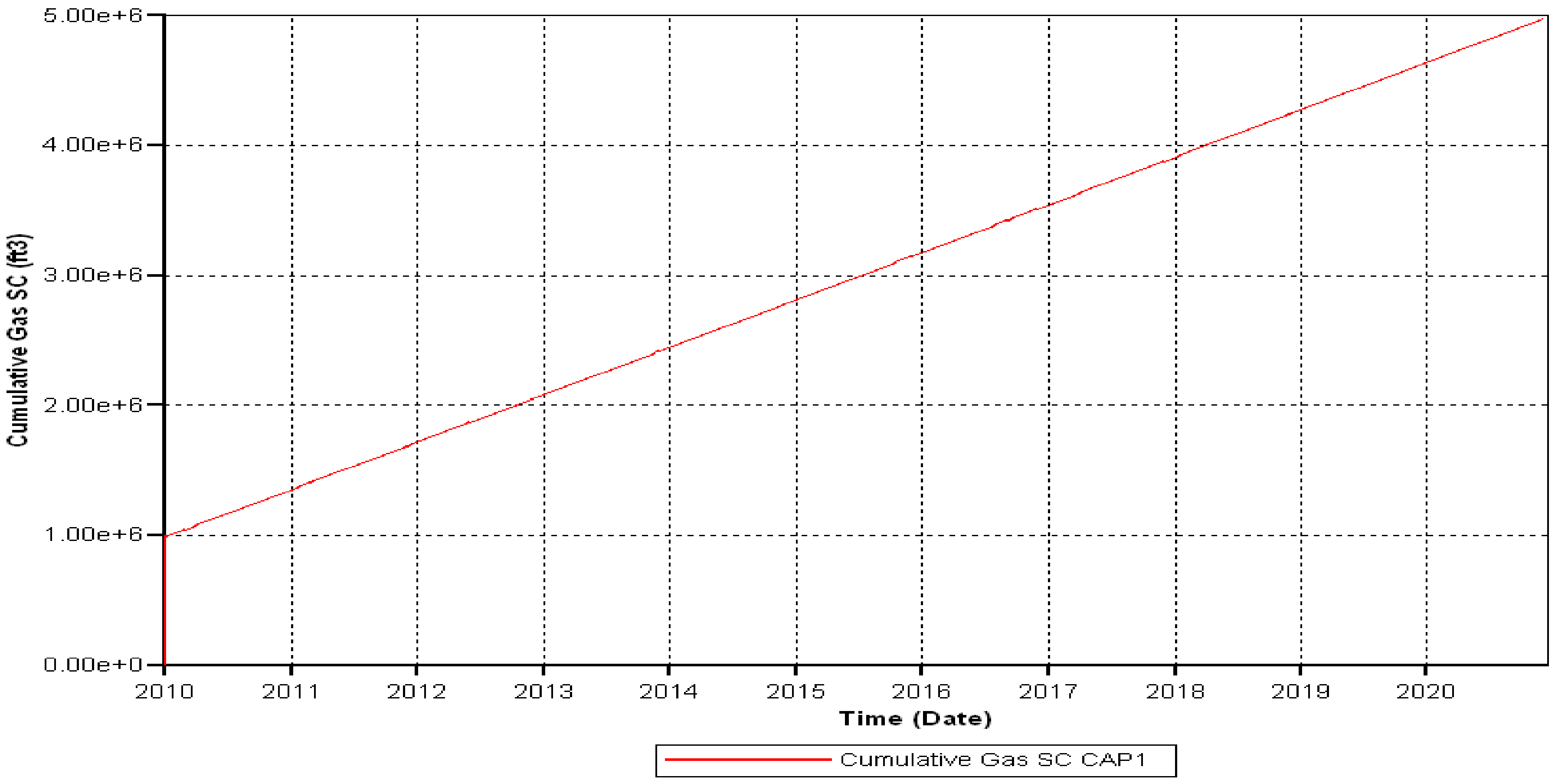


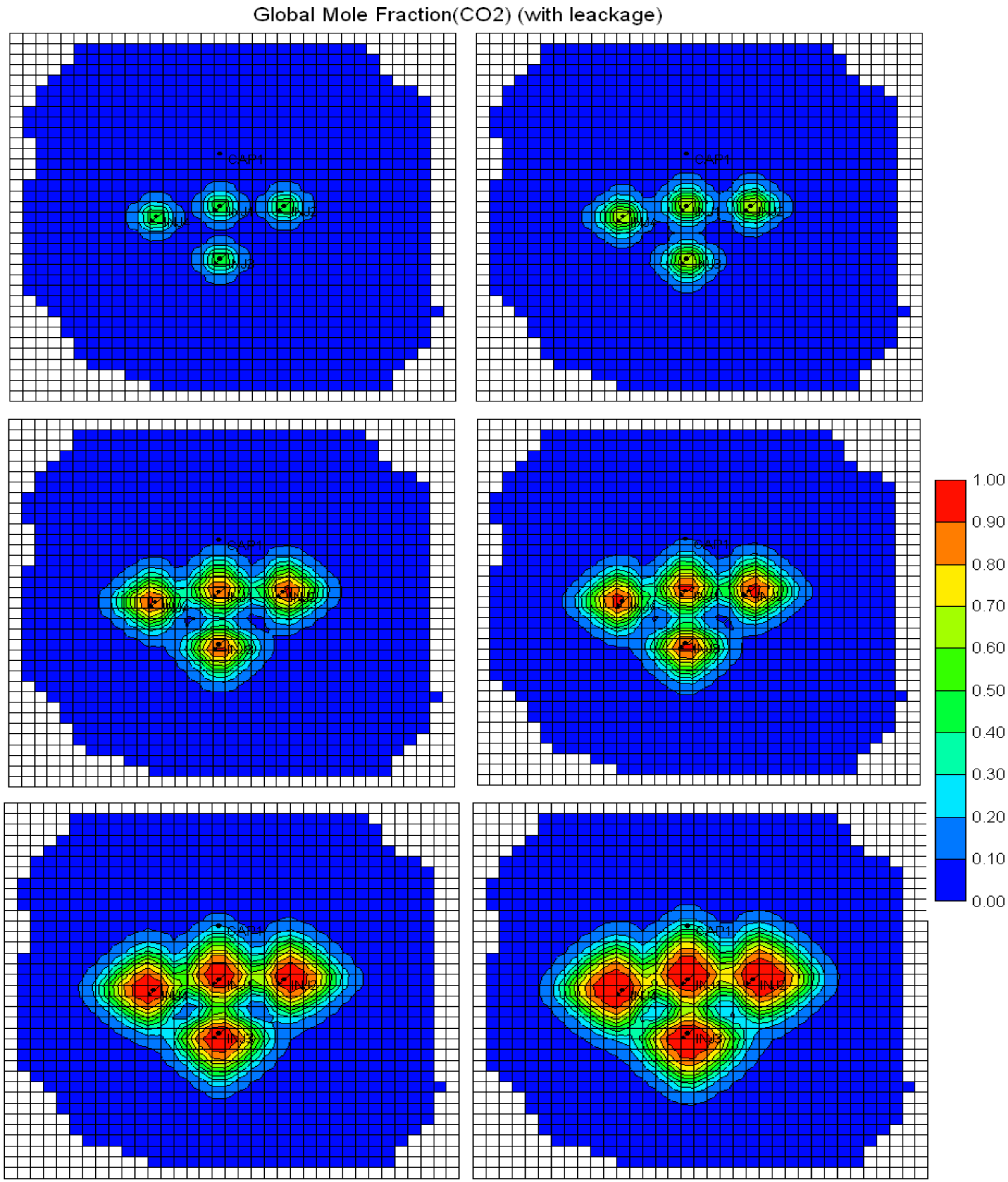


- CO_2 movement in the reservoir at various times
- Locations of the wells taken from literature

Leakage effects

- One of the wells was assumed as an abandoned well and a pressure difference of 20 psia was assumed
  - $5.43*10^{-3}$ percent of the total amount of CO_2 sequestered in the reservoir

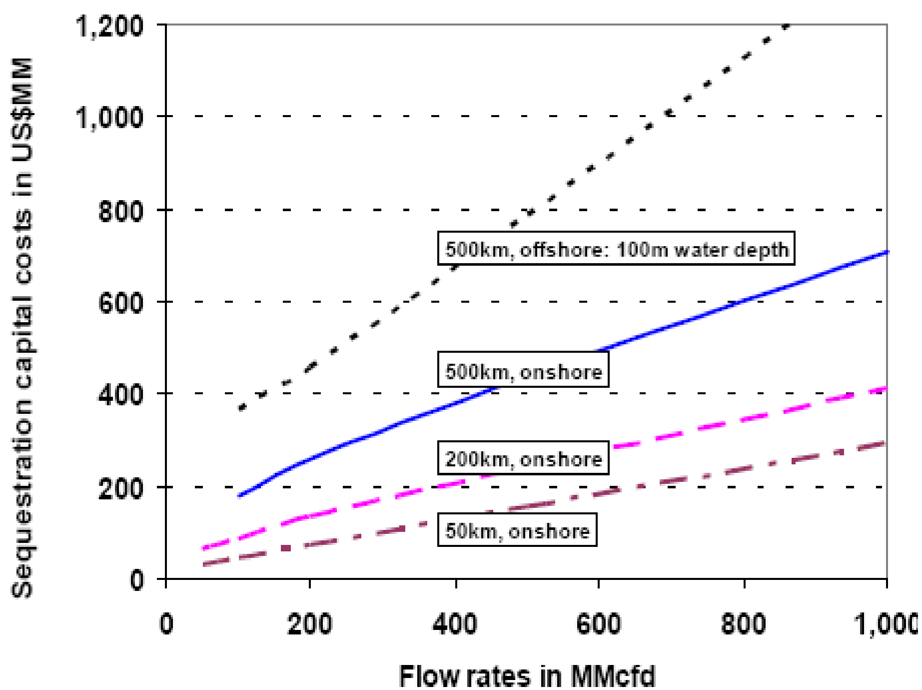


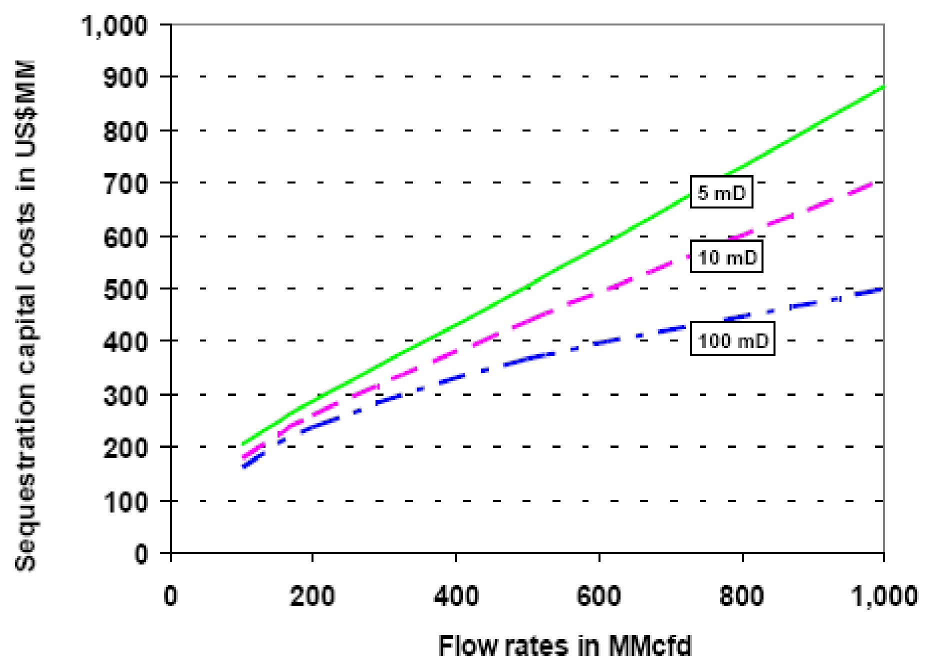


- Properties are assumed to be homogeneous in a layer
- CO_2 movement should be identical
- Leakage dampens the movement profile and low pressure were observed in the region

Economical analysis

- Site was assumed at a distance of 500 km
- Average permeability was calculated to find the overall capital cost
  - Average permeability is 111 mD
  - 100 mD curve was used
- Initial cost is $290 millions



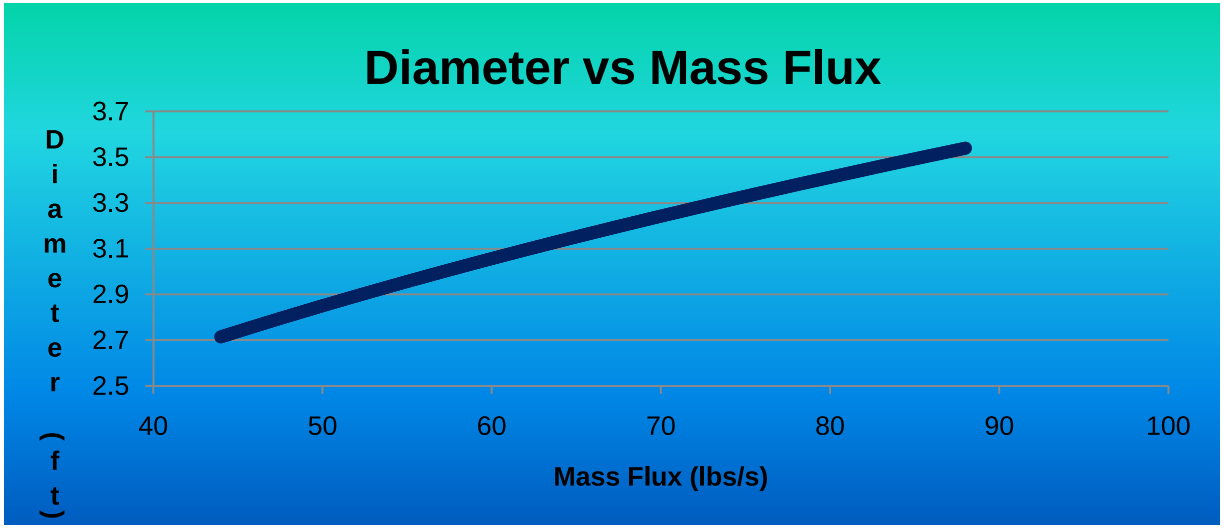


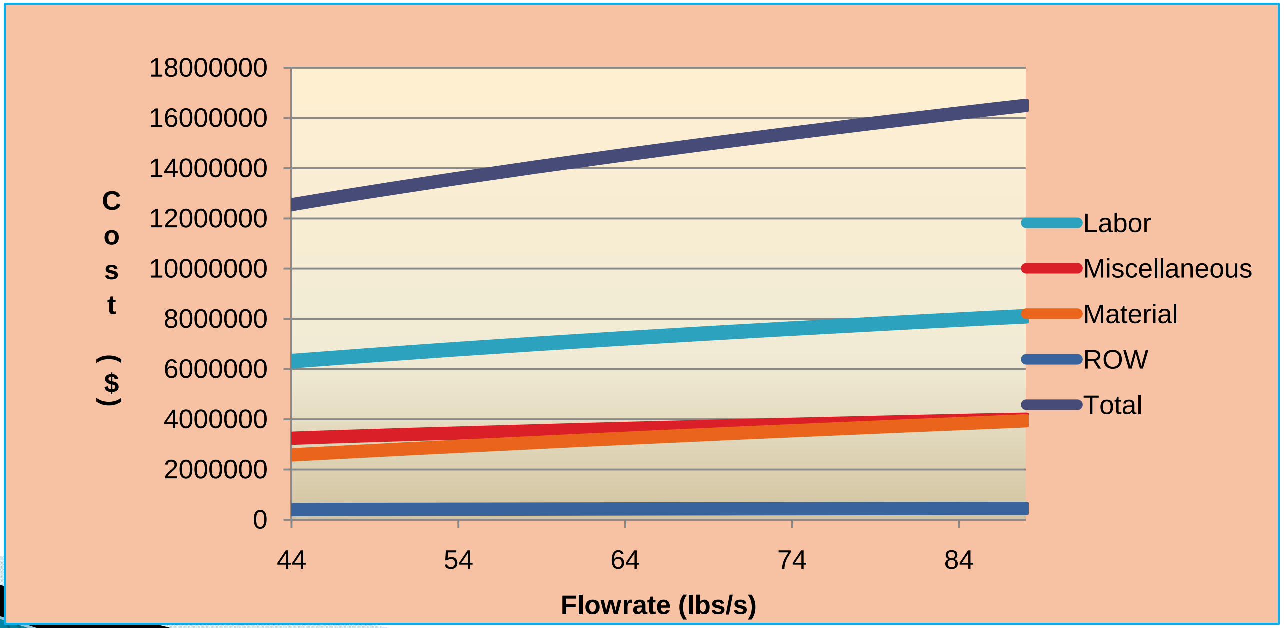
- No leasing costs were assumed
  - Exhausted oil field
- No Royalty cost
  - No production
- Operating cost is assumed to 10% of the cash flow
- Rate of return is assumed as 5% annually (0.0137% daily)

$$\frac{P}{A} = \frac{[(1+i)^n - 1]}{i(1+i)^n}$$

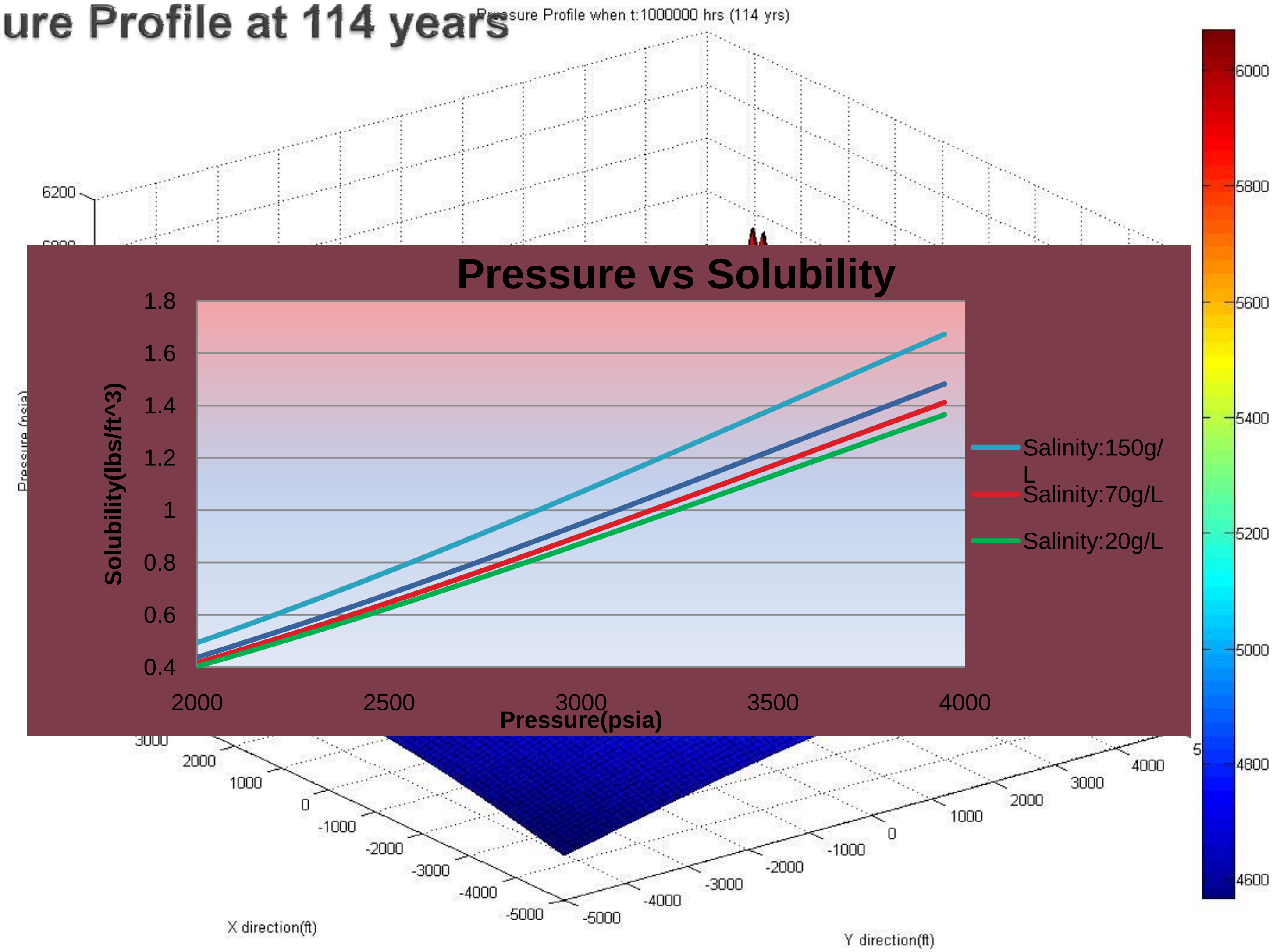
- Daily cash flow is found to be $90526
- Cost for sequestration
  - $0.4976/MSCF (or $7.714/ton of CO_2)

CO_2 Sequestration In Saline Aquifers

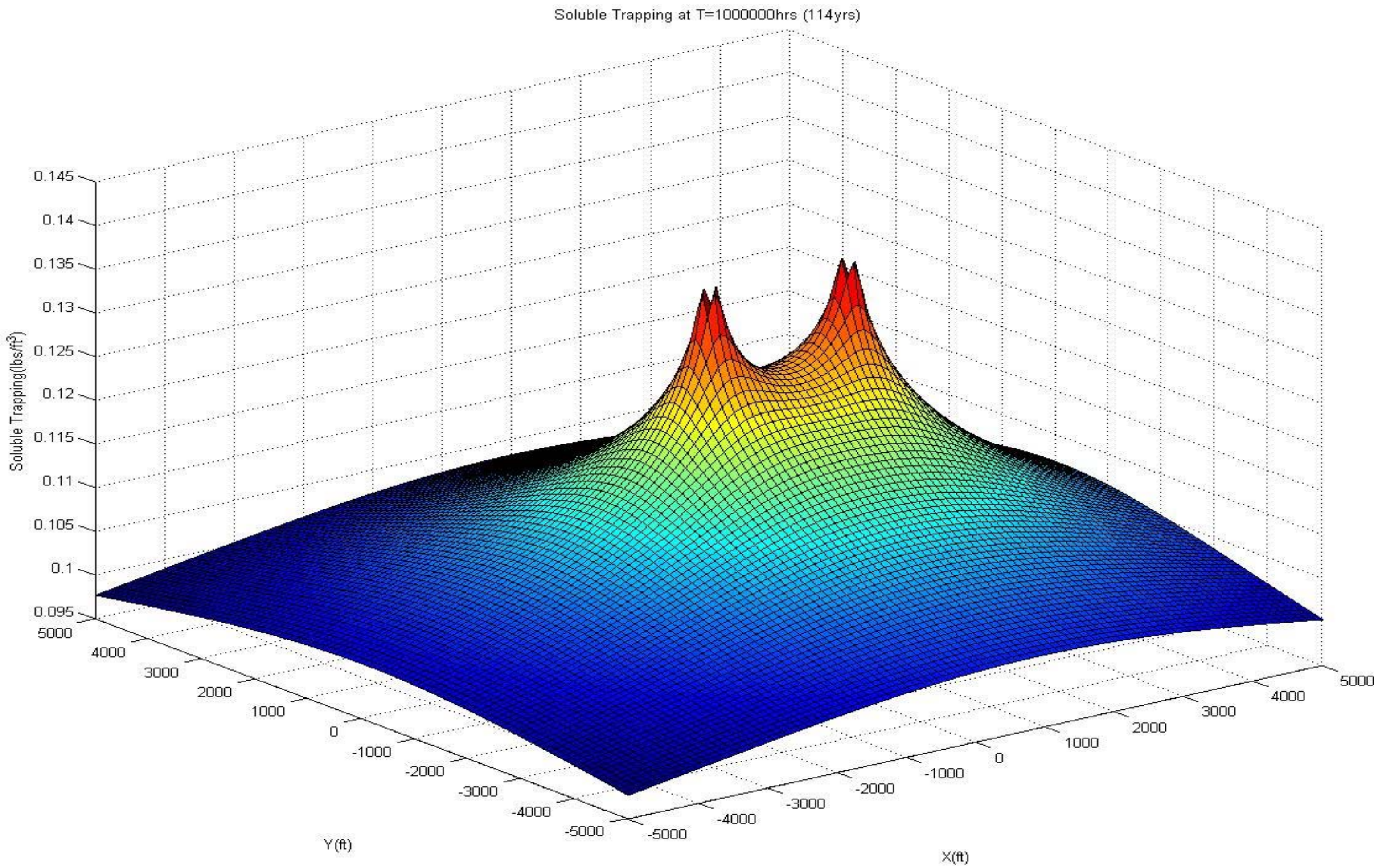




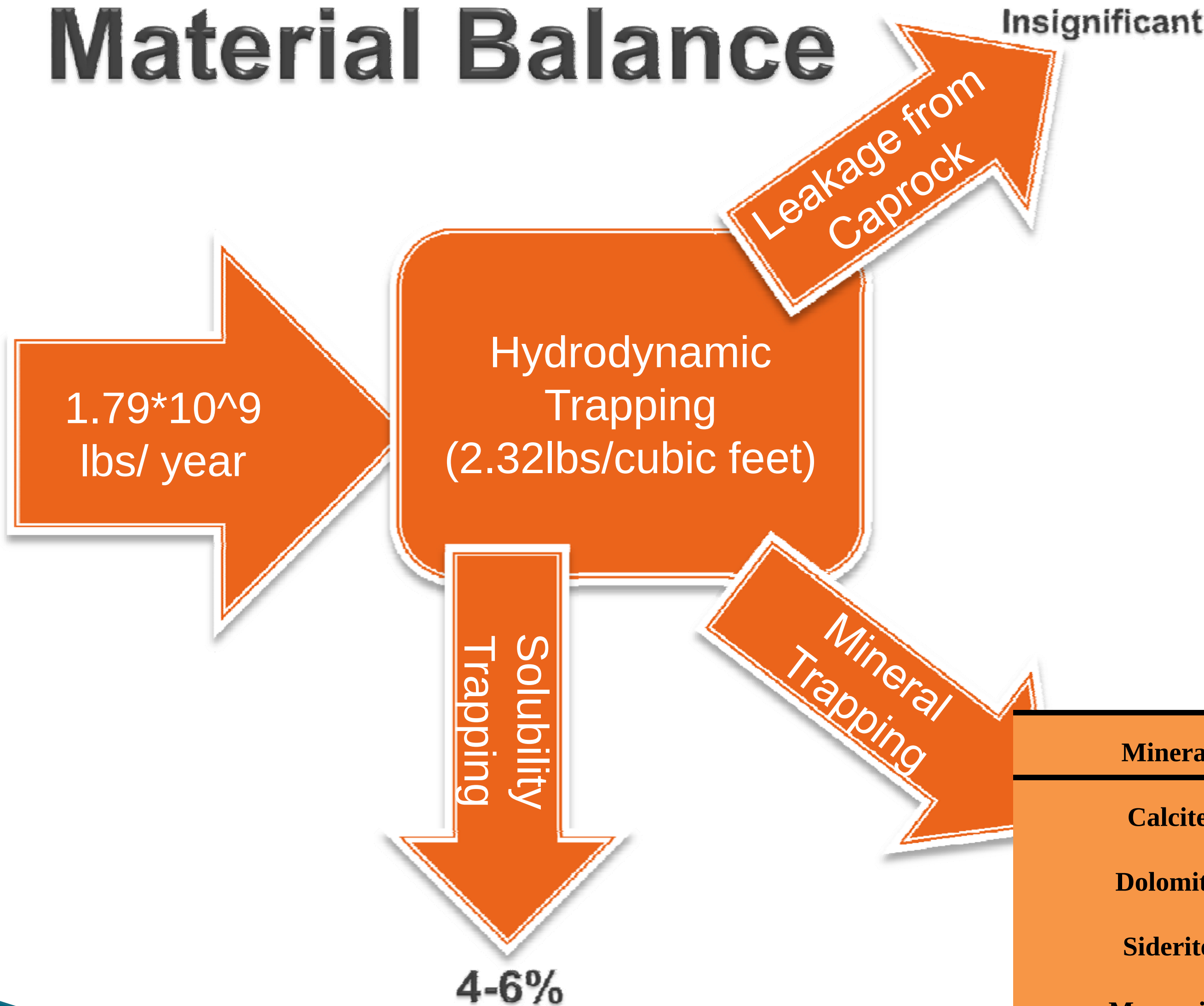
Pressure Profile at 114 years



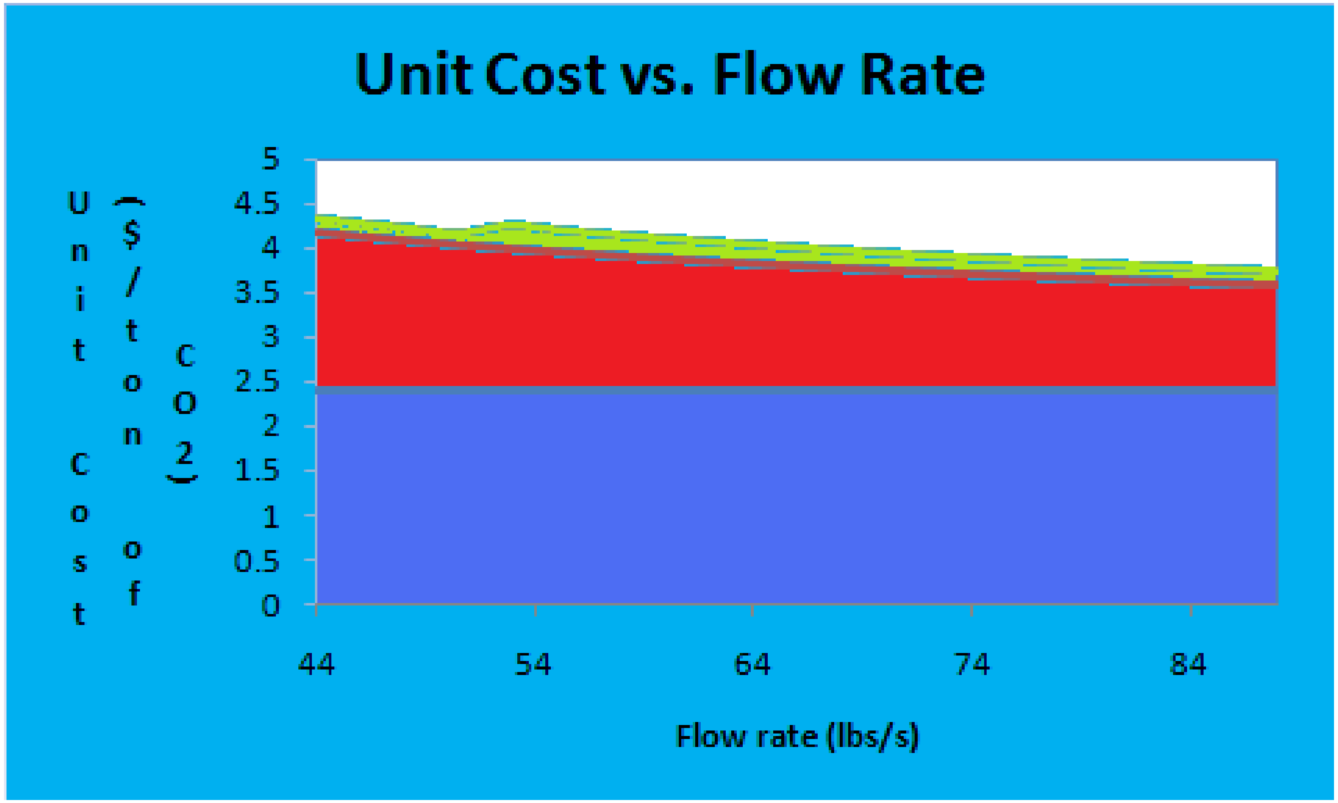
Solubility Trapping Capacity at 114 years



Material Balance



Mineral	% of total trapping
Calcite	0.035637955
Dolomite	1.466287055
Siderite	0.037164077
Magnesite	0.009867851
Total	1.548956938



-Compression Cost
-Transportation Cost
-Cost of Wells

Questions?