Old Wells, Potable Water, and Carbon Dioxide-Enhanced Oil Recovery and Sequestration Projects in the Appalachian and Illinois Basins of Kentucky*

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Abstract

Seventy Paleozoic reservoirs in 51 oil fields were evaluated with data from the Tertiary Oil Recovery Information System for carbon dioxide-enhanced oil recovery (CO_2-EOR) and sequestration potential. The fields and their respective reservoirs were ranked into quartiles using the reservoir parameters oil gravity, CO_2 storage density, porosity X oil saturation, and permeability X net pay thickness. Our analysis also showed that if maximum allowable EPA injection pressures (0.8 X lithostatic gradient) were attained during CO_2 injection, then near-miscible or miscible conditions could occur in approximately 60 percent of the fields. In doing so, however, reservoir pressures would exceed initial pressure in 92 percent of the fields.

For environmental and project efficacy reasons, repressurization is a concern in older, preregulatory fields (pre-1960) having large numbers of wells, where locations may be poorly documented and plugging integrity suspect. For example, the number of wells in the top-quartile fields ranged from 88 to 802 and discovery dates ranged from 1929 to 1965. An additional concern is possible contamination of potable groundwater as CO_2 migrates upward along improperly plugged wells or breached seal rocks. The former seems to be more likely inasmuch as the average thickness of strata between the top of the oil reservoir and base of the potable water zone equals 1,957 ft.

References

Bachu, S., and M.A. Celia, 2009, Assessing the potential for CO_2 leakage, particularly through wells, from geological storage sites, AGU, Carbon Sequestration and It's Role in the Global Carbon Cycle, Geophysical Monograph Series 183, p. 203-216.

Carr, T., S. Frailey, S. Reeves, J. Rupp, and S. Smith, 2008, Methodology for development of geologic storage estimates for carbon dioxide: Capacity and Fairways Subgroup, Geologic Working Group, Department of Energy Regional Carbon Sequestration Partnerships, United States Department of Energy, National Energy Technology Laboratory Carbon Sequestration Program, 36 p.

Kovscek, A.R., 2002, Screening criteria for CO_2 storage in oil reservoirs: Petroleum Science and Technology, v. 20, nos. 7-8, p. 841 -866.

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Previous EOR Evaluation

- 70 Paleozoic reservoirs in 51 oil fields were evaluated for carbon dioxide-enhanced oil recovery (CO_2-EOR) and sequestration potential using Tertiary Oil Recovery Information System (TORIS) data
- BUT—what we did not know is the condition of the infrastructure, and we still don't

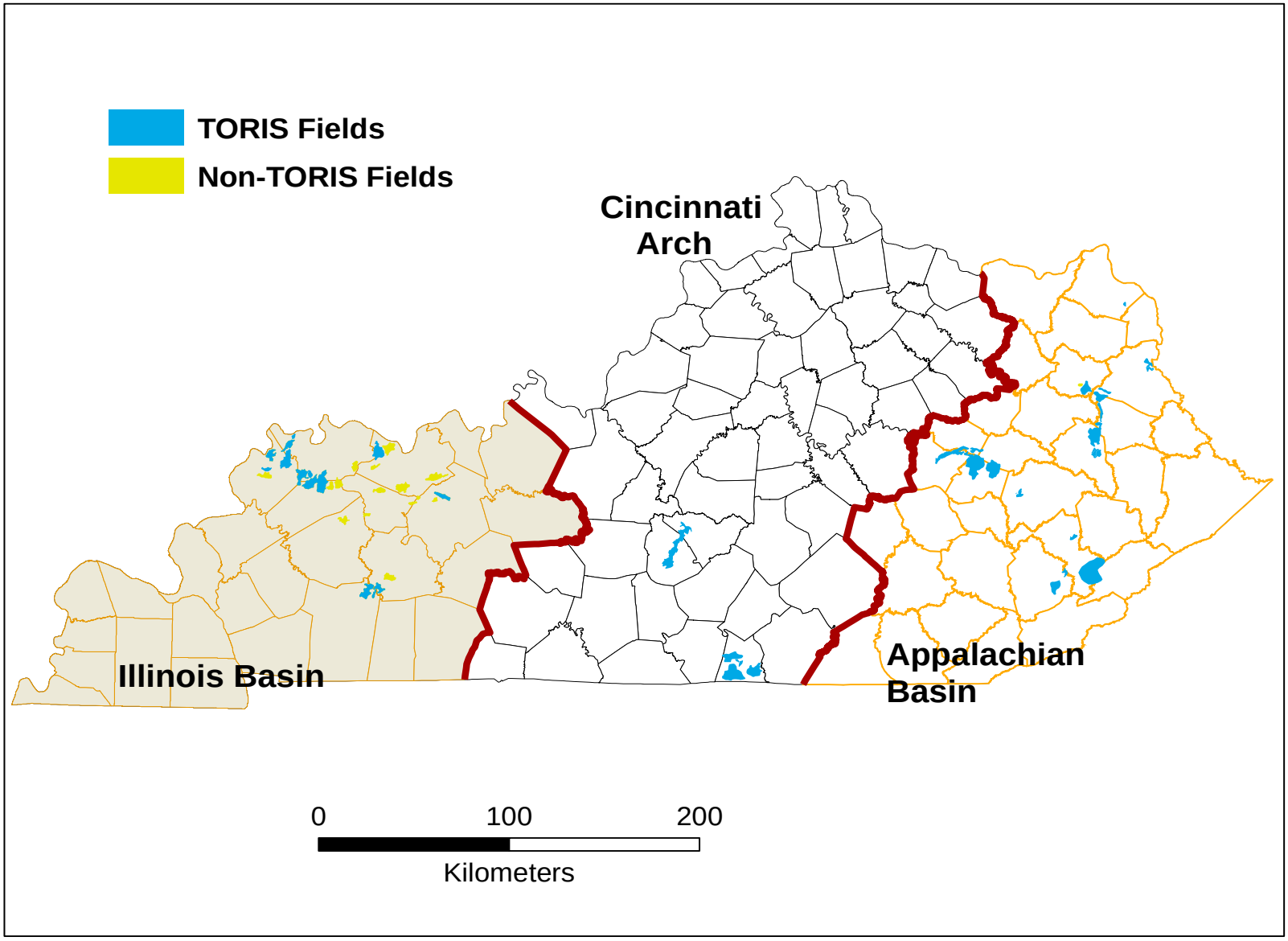
Introduction

- Possible Injected CO_2 Leakage paths:
  - Injected CO_2 encounters faults, fractures, groundwater recharge areas
    - Possibility of seal fracture
  - Injected CO_2 flows beyond spillover point of stratigraphic or structural trap
  - Leakage out of injection wellbore or other wellbores in field

Introduction

- In KY, pre-regulatory (pre-1960) fields with a large number of wells, are a big concern for potential well leakage during CO_2-EOR projects
  - Poorly documented and unknown well locations
  - Suspect plugging methods/wellbore cement integrity

Previous Reservoir Assessment



Reservoir Screening Criteria

- The reservoirs were ranked in Excel using the parameters:

1. porosity (φ) * oil saturation (S_o),
2. permeability (*k*) * pay thickness (h),
3. API oil gravity,

Kovscek, A.R., 2002, Screening criteria for CO_2 storage in oil reservoirs: Petroleum Science and Technology, v. 20, nos. 7 - 8, p. 841 - 866.

Reservoir Screening Criteria

4. effective CO_2 storage capacity:
   - ESC (kilotons) = $43{,}560 * \varphi * \rho * S_o * 0.001$
     φ=porosity, ρ=density CO_2, S_o=oil saturation

Carr, T., Frailey, S., Reeves, S., Rupp, J., and Smith, S., 2008, Methodology for development of geologic storage estimates for carbon dioxide: Capacity and Fairways Subgroup, Geologic Working Group, Department of Energy Regional Carbon Sequestration Partnerships, United States Department of Energy, National Energy Technology Laboratory Carbon Sequestration Program, 36 p.

(So)(φ)	(So*φ)	Rank (So*φ)	(k)(h)	(k*h)	Rank k*h	API Gravity	Rank API Gravity	ESC CO_2 (kilotons/acft)	Rank ESC CO_2 (kilotons/acft)	Sum of Ranks	Rank of Sum
(0.47)(0.18)	0.0846	15	(750)(15)	11,250	3	42	1	2200	12	31	1
(0.67)(0.1											2
(0.67)(0.14)	0.0938	6	(309)(16)	4,944	5	36	26	3706	3	40	3
(0.72)(0.17)	0.1224	1	(21)(27)	567	52	42*	1	5836	1	55	4
(0.34)(0.2)	0.068	27	(309)(16)	4,944	5	36	26	1733	15	73	5
(0.34)(0.2)	0.068	27	(309)(16)	4,944	5	34.39	39	2944	6	77	6
(0.34)(0.2)	0.068	27	(309)(16)	4,944	5	37	24	1058	22	78	7
(0.34)(0.2)	0.068	27	(309)(16)	4,944	5	37.6	21	746	28	81	8
(0.67)(0.14)	0.0938	6	(309)(16)	4,944	5	36	26	374	46	83	9
(0.44)(0.21)	0.0924	11	(95)(19)	1,805	28	42	1	301	50	90	10
(0.49)(0.17)	0.0833	19	(150)(20)	3,000	23	36	26	968	24	92	11
(0.34)(0.2)	0.068	27	(309)(16)	4,944	5	37.8	20	428	42	94	12
(0.46)(0.17)	0.0782	23	(309)(12)	3,708	20	36	26	760	27	96	13
(0.37)(0.18)	0.0666	38	(150)(20)	3,000	23	36	26	1776	14	101	14
(0.34)(0.2)	0.068	27	(309)(16)	4,944	5	32.5	63	2685	7	102	15
(0.46)(0.16)	0.0736	25	(58)(8)	464	58	41	10	2247	11	104	16
(0.43)(0.13)	0.0559	45	(21)(24)	504	55	42*	1	3434	4	105	17
(0.46)(0.18)	0.0828	20	(184)(14)	2,576	25	34.39	39	1099	21	105	17

21 reservoirs in 19 oil fields fell into the top quartile

Summary of Reservoir Analysis

- Top quartile fields/reservoirs-83% are Miss. Ss. reservoirs in W. KY; 67% of these fields are 1,500 ft or deeper, & 83% initially exceed MMP.
- Statistical analysis shows top quartile ranking results from composite influence of all ranking parameters.
- Gross estimated CO_2 storage capacity in all 71 fields/reservoirs= 79,134,000 tons, 44% occurs in the upper quartile fields.

http://kgs.uky.edu/kgsweb/olops/pub/kgs/Energy/RI21_12/RI21_12_Chapter2.pdf

Assessing Potential for CO_2 Leakage

- Try to find data on wellbore condition
  - Well age, producing status, casing, direction, cemented intervals, timeline of field drilling activity, regulations, drilling and plugging practices before and after regulations enacted (Bachu and Celia, 2009)
  - Any wells in a field that penetrate seal rock
  - Well cement integrity

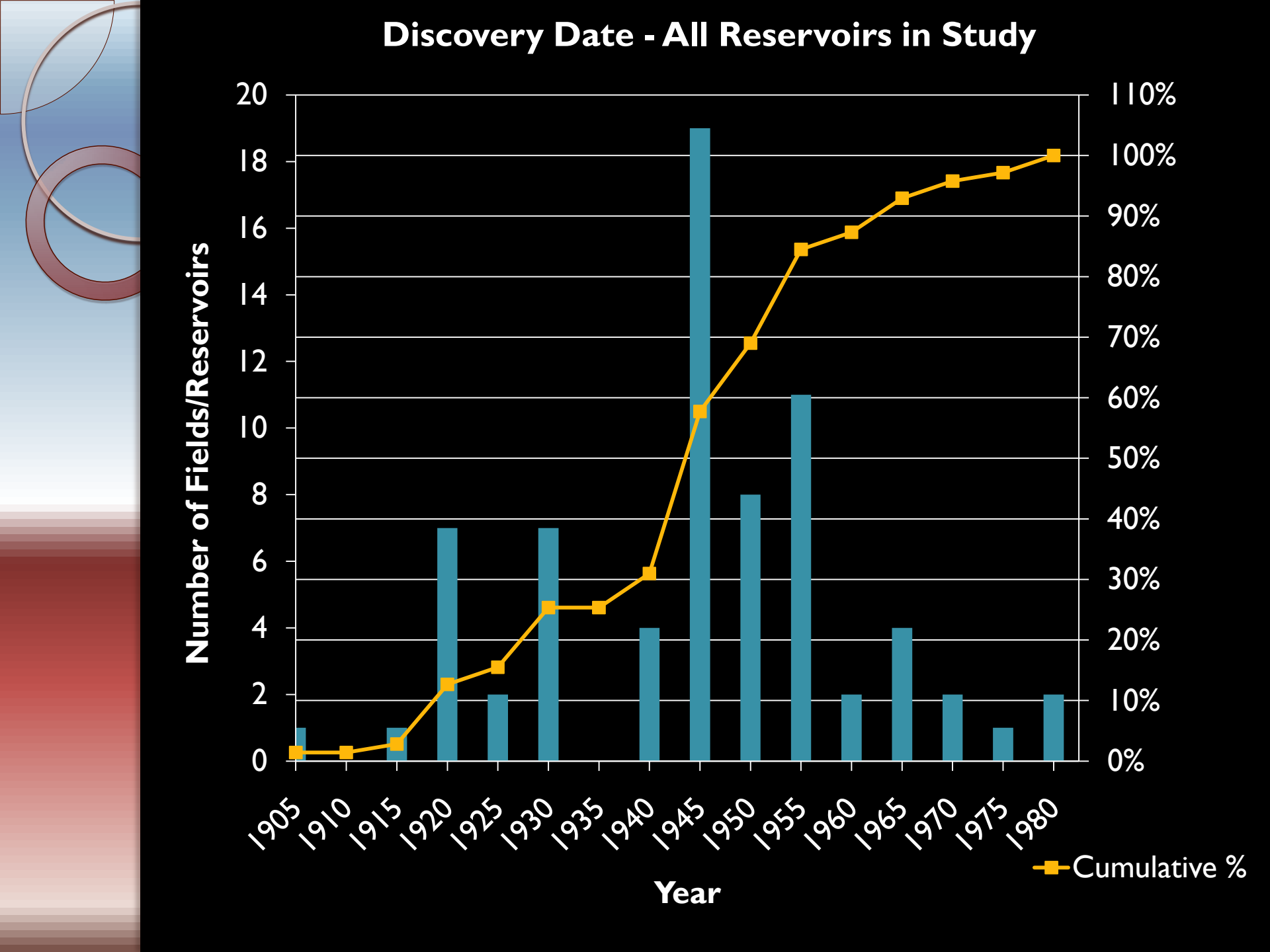
Bachu, S. and Celia, M.A., 2009, Assessing the potential for CO2 leakage, particularly through wells, from geological storage sites, AGU, Carbon Sequestration and It's Role in the Global Carbon Cycle, Geophysical Monograph Series 183, p. 203-216.

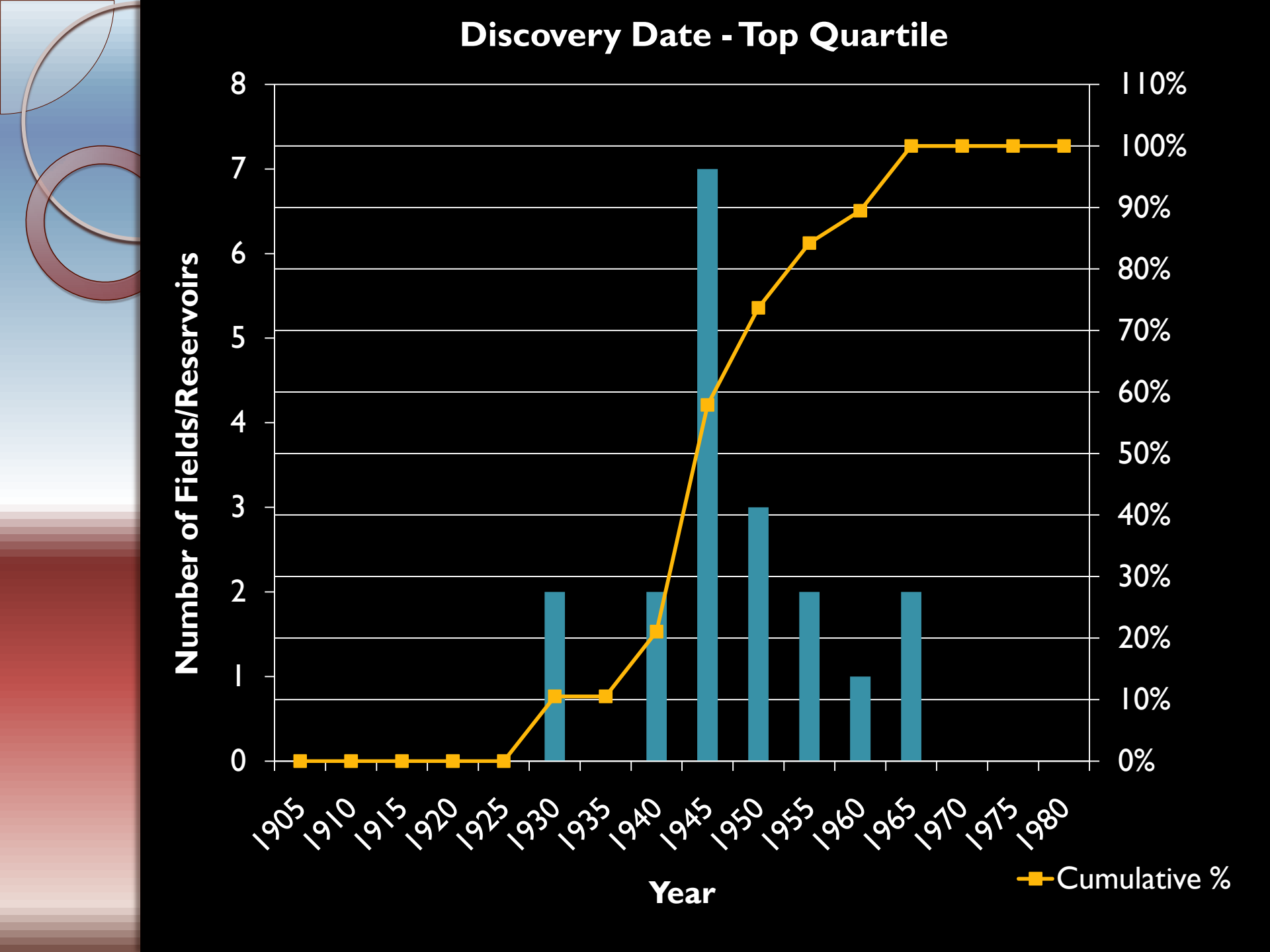
Injection Pressure and Possible Miscibility

- EPA suggested max. injection pressure = 0.8 * lithostatic gradient (1 psi per foot)
- Near-miscible or miscible conditions could occur in ~60% of the reservoirs in this study
- However, initial reservoir pressures would be exceeded in 92% of the reservoirs in this study
- Corollary: Many oil reservoirs were initially under pressure

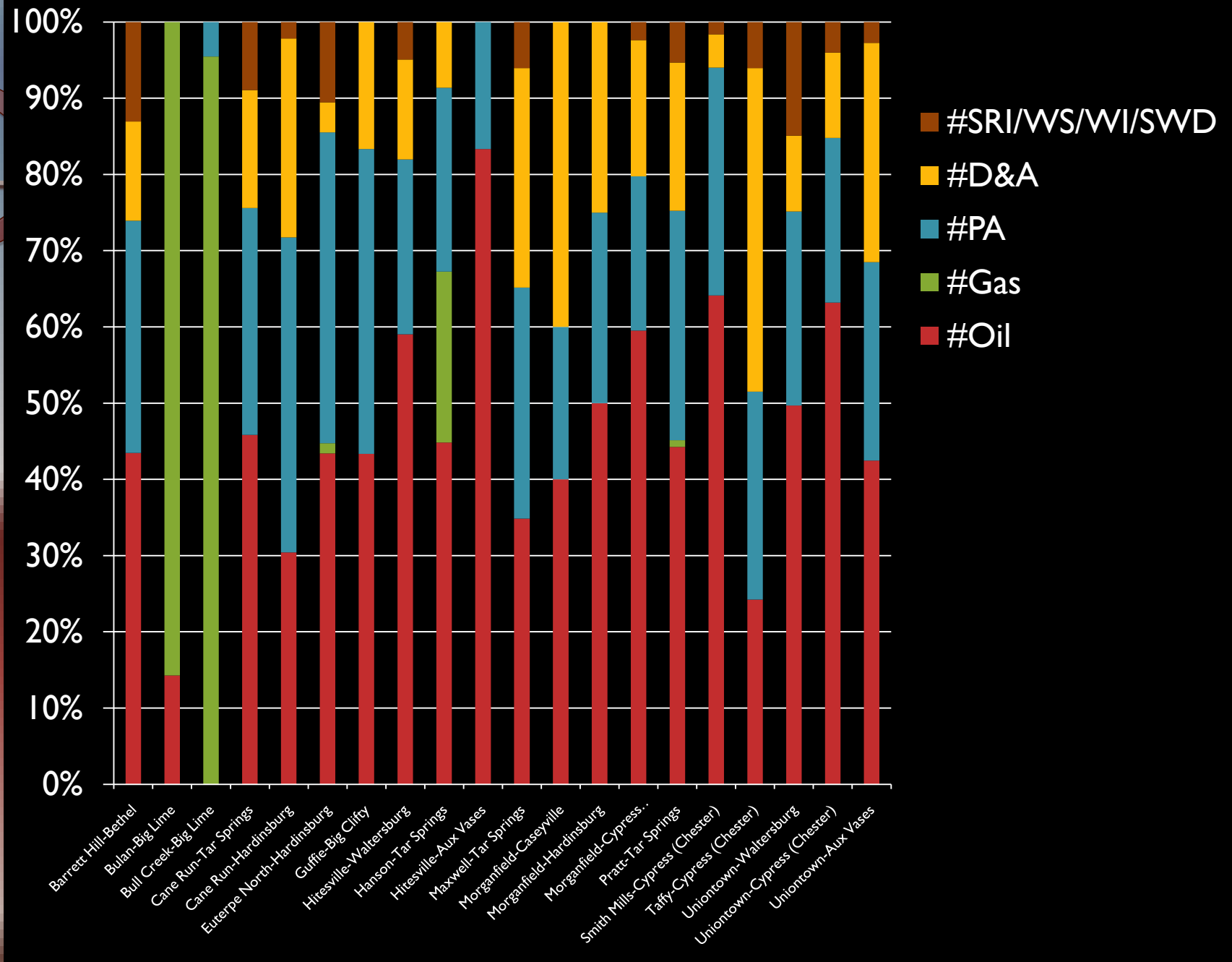
Leakage Potential and Potable Water

- Well status issues-online well data
  - Pre-1960 fields are suspect
  - Number of wells listed as Plugged & Abandoned
    - Were these wells really plugged or plugged properly?
  - Number of active producing and injection wells
- Thickness interval between wells that penetrate a reservoir and the potable groundwater table
  - CO_2, oil, brines could contaminate potable water

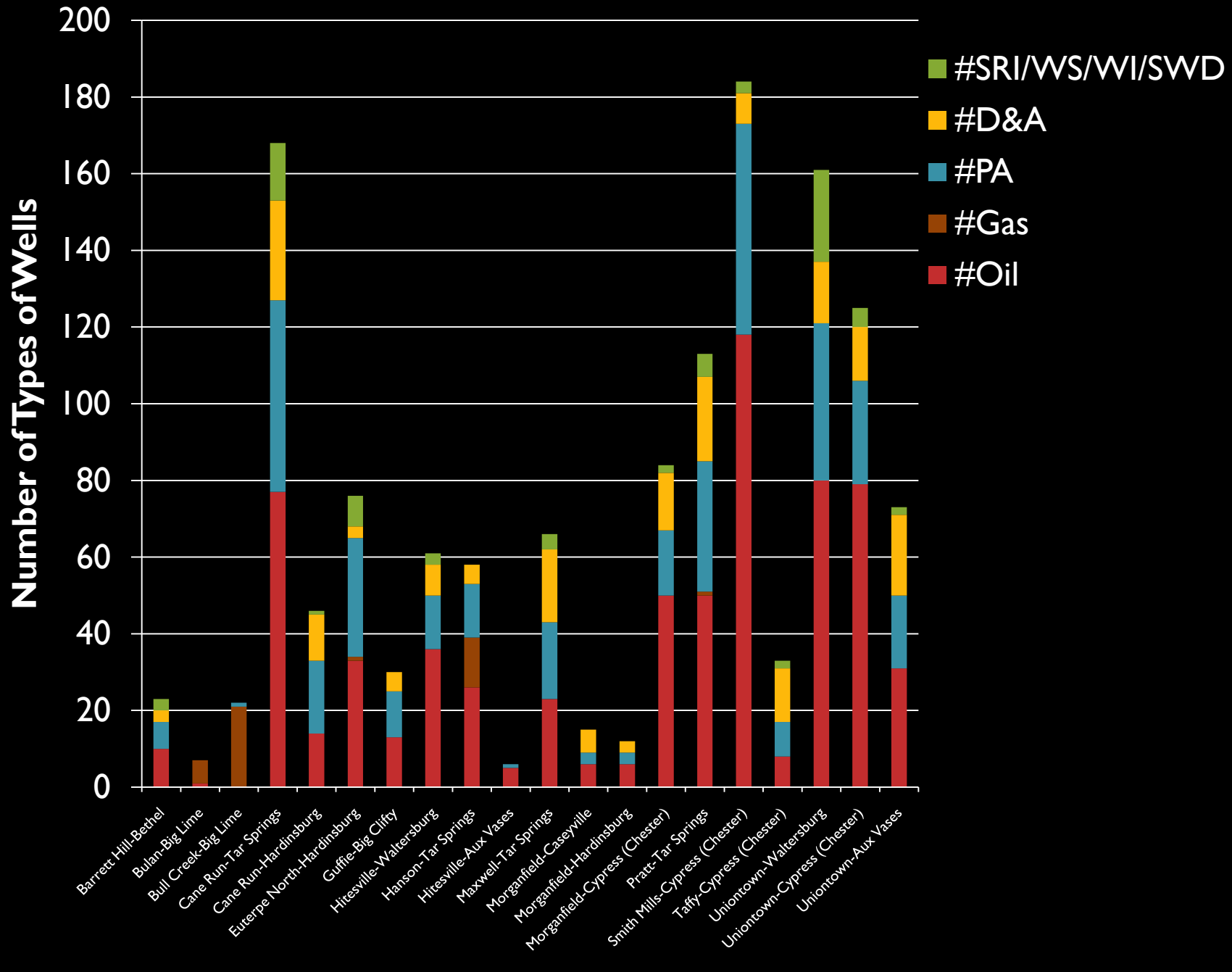

Discovery Date - All Reservoirs in Study
Number of Fields/Reservoirs
20
18
16
14
12
10
8
6
4
2
0
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
Year
Cumulative %


Discovery Date - Top Quartile
Number of Fields/Reservoirs
0
1
2
3
4
5
6
7
8
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
110%
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
Year
Cumulative %

Status and Types of Wells in Upper Quartile

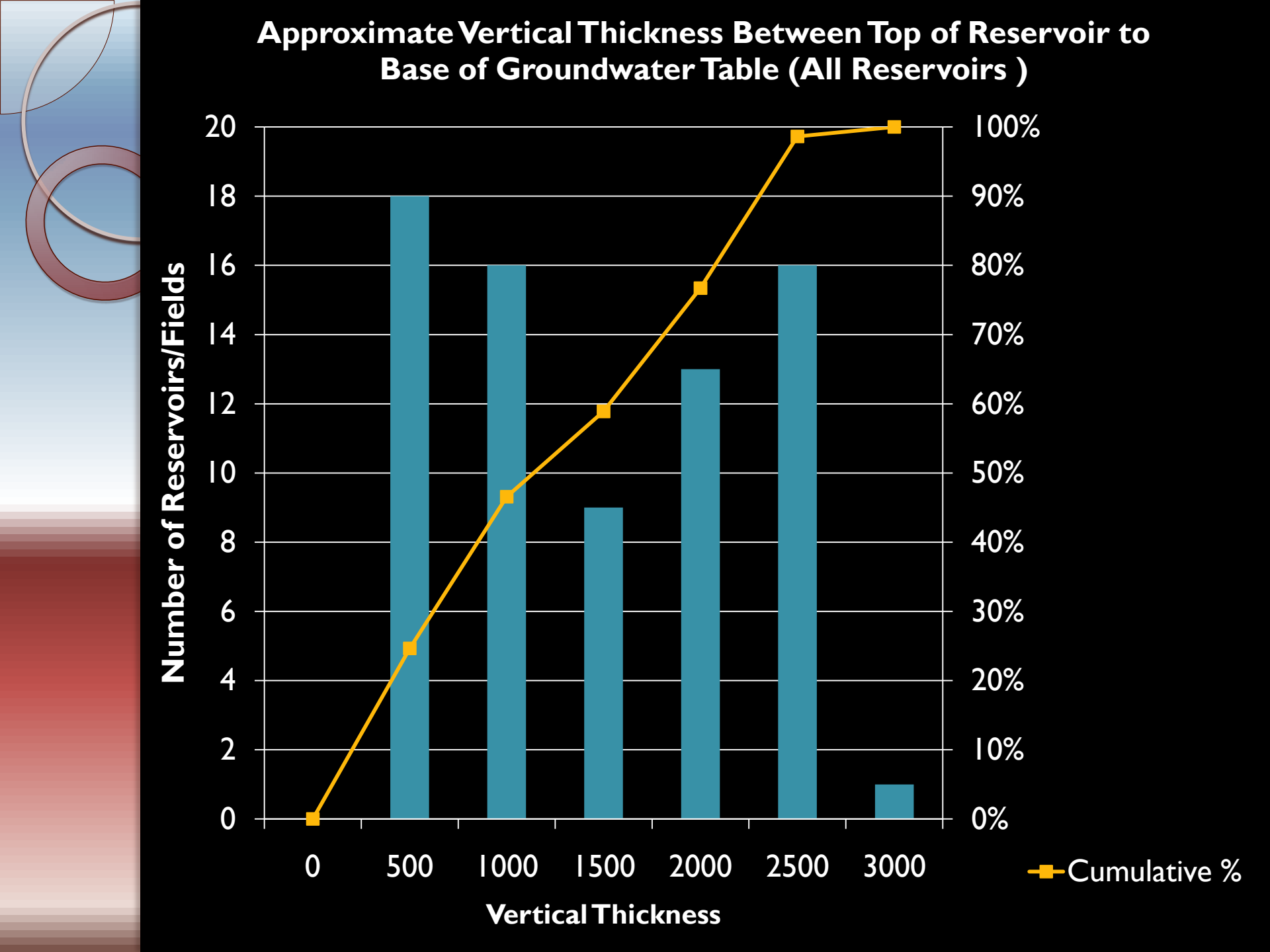


Count of Types of Wells in Upper Quartile



Target EOR-Sequestration Reservoir and Base of Potable Water Aquifer

- Thickness interval between wells that penetrate a reservoir and the potable groundwater table can be a concern
  - CO_2, oil, brines could contaminate potable water if CO_2 is able to migrate upward via wellbores


Approximate Vertical Thickness Between Top of Reservoir to Base of Groundwater Table (All Reservoirs)
Number of Reservoirs/Fields
20
18
16
14
12
10
8
6
4
2
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
500
1000
1500
2000
2500
3000
Vertical Thickness
Cumulative %

Summary

- Attaining miscible/near miscible conditions requires pressures > original pressures for 96% of fields
- Concern for leakage out of wellbores in field
- CO_2, oil, brines could contaminate potable water if CO_2 is able to migrate upward via wellbores
- 47% fields studied-vertical thickness between potable water & oil reservoir <1000 ft

Future Research

- Thorough documentation of water chemistry for reservoirs above EOR reservoir in order to corroborate possible leakage from oil reservoirs
- Assessing leakage from a large number of wellbores is an operational challenge
- Before implementing a project, use stochastic modeling to get a feel of the probability of leakage