Teapot Dome Enhanced Oil Recovery-CO2 Injection

Final Presentation

Beau Green, Charlie Kloss, Jack Kern, Quinn Morrison, Michael Seidlich

Enhanced Oil Recovery Group- Leaders in Industry

Objective

- Create a Petrel Static model and a CMG dynamic model to simulate CO_2 injection into the Tensleep formation of the Teapot dome. From our models, we will recommend a CO_2 injection technique.

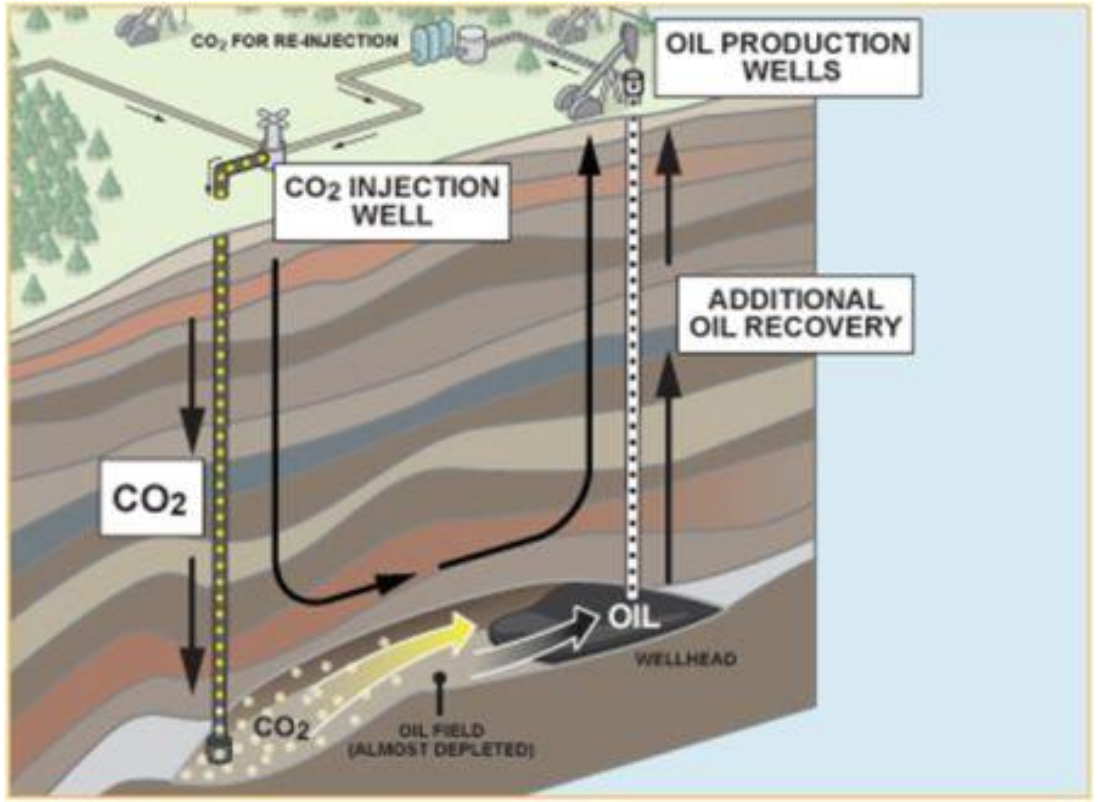


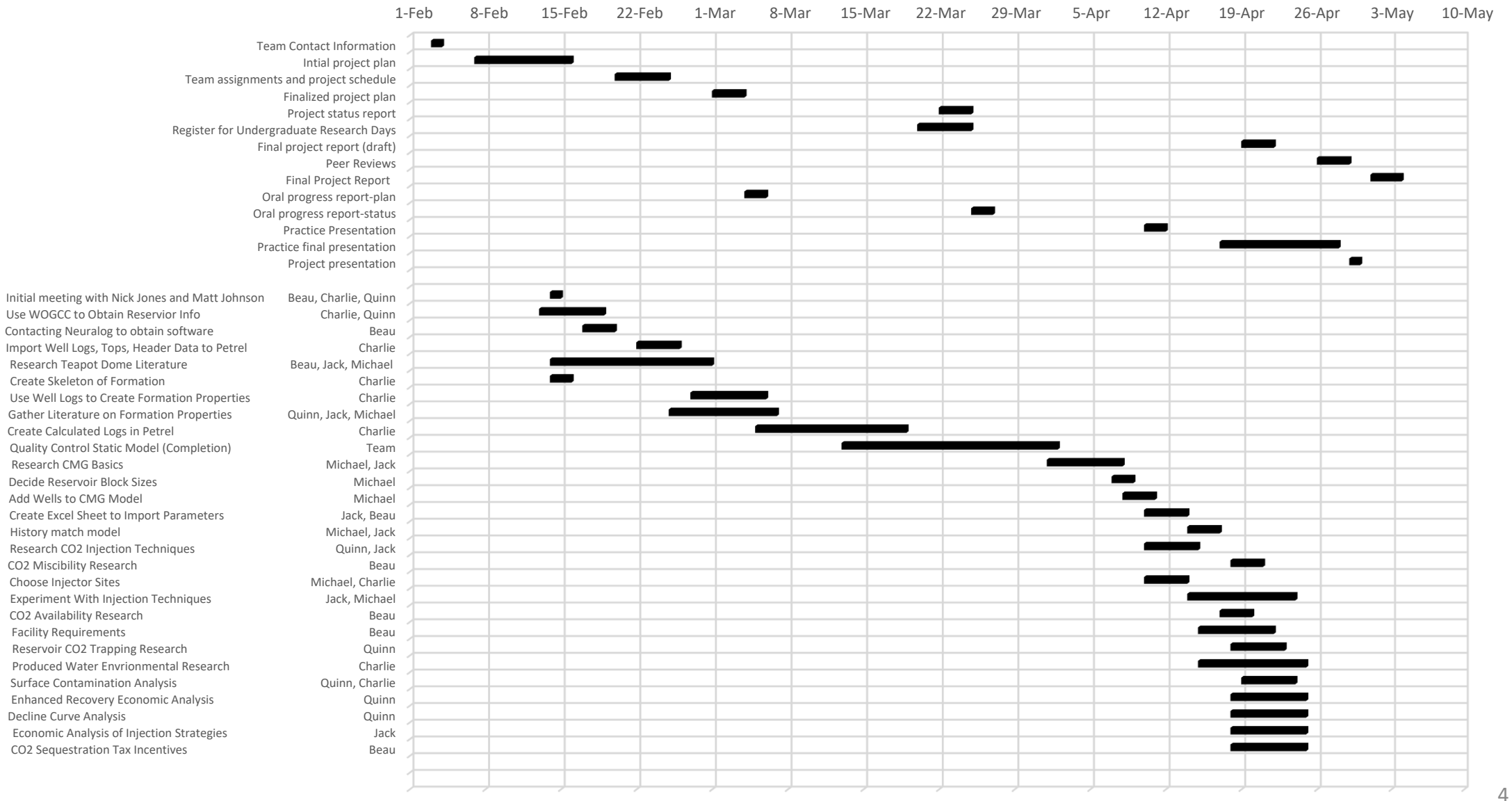
Image only (emersonclimate 2016)

Topics

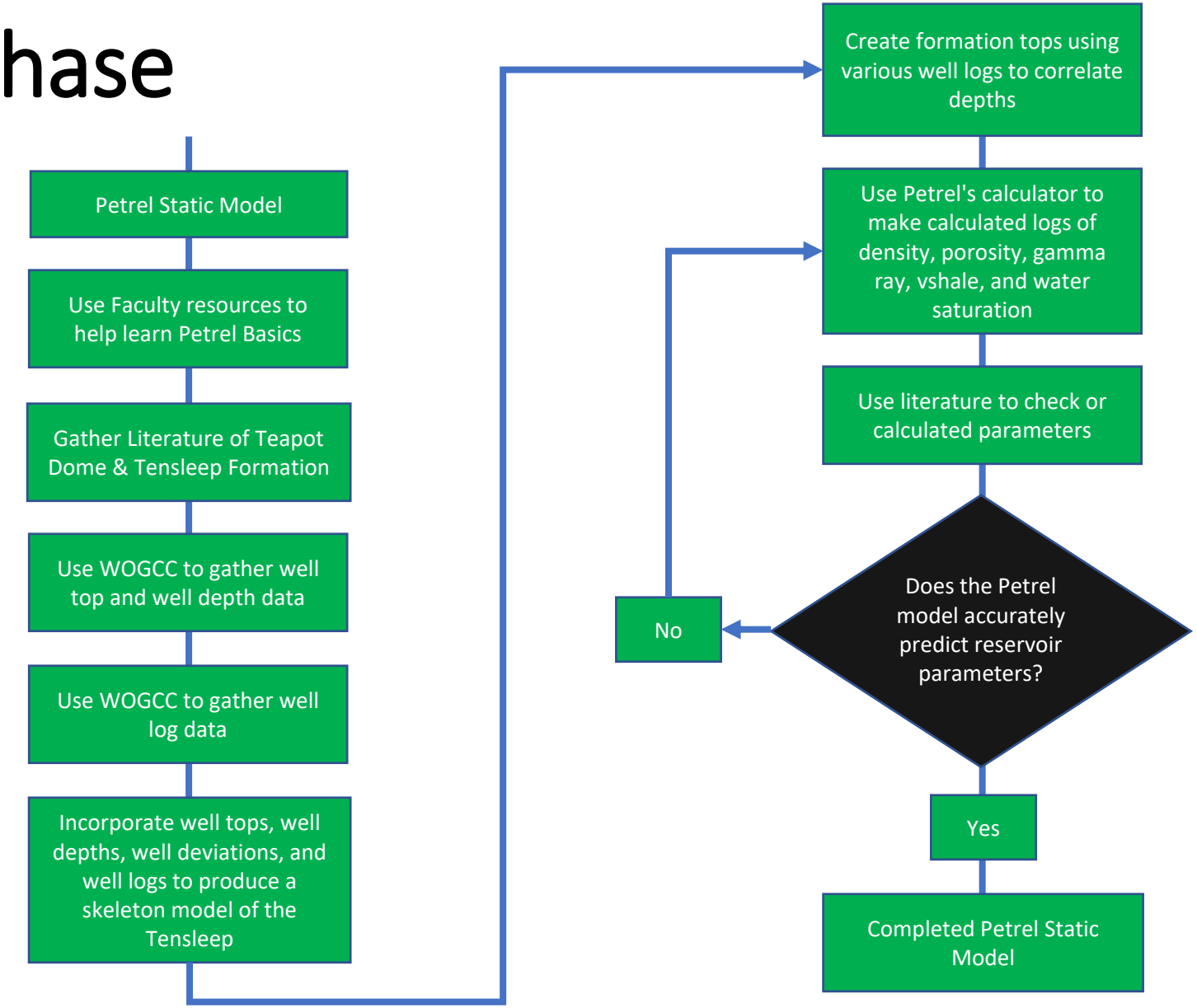
- Project Schedule
- Where is the Teapot Dome
- Petrel Static Model
- CMG Dynamic Model
- CO_2 Injection
- Economic Analysis
- Environmental Risks
- Recommendation

Image only (trib 2017)

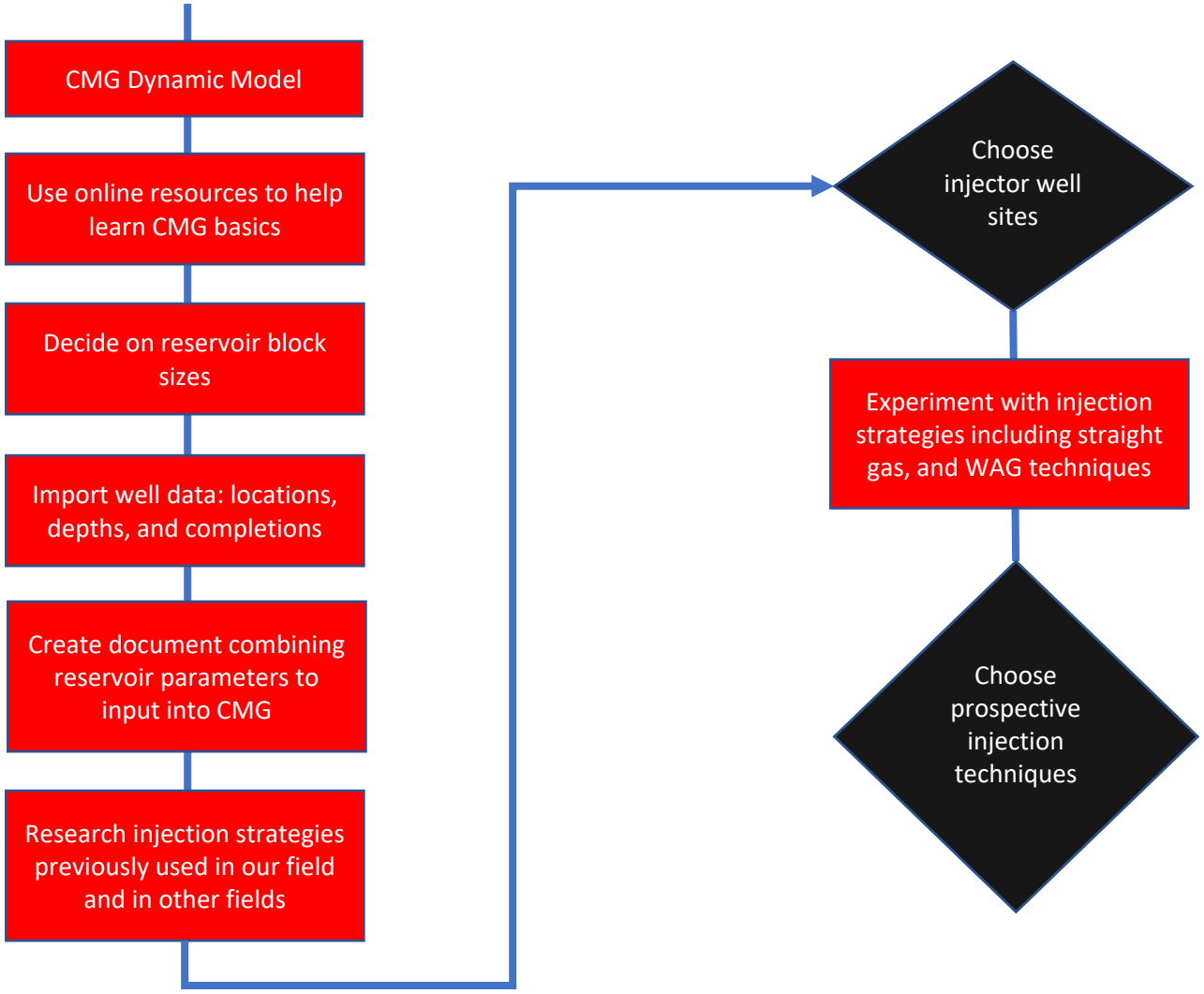
Project Schedule



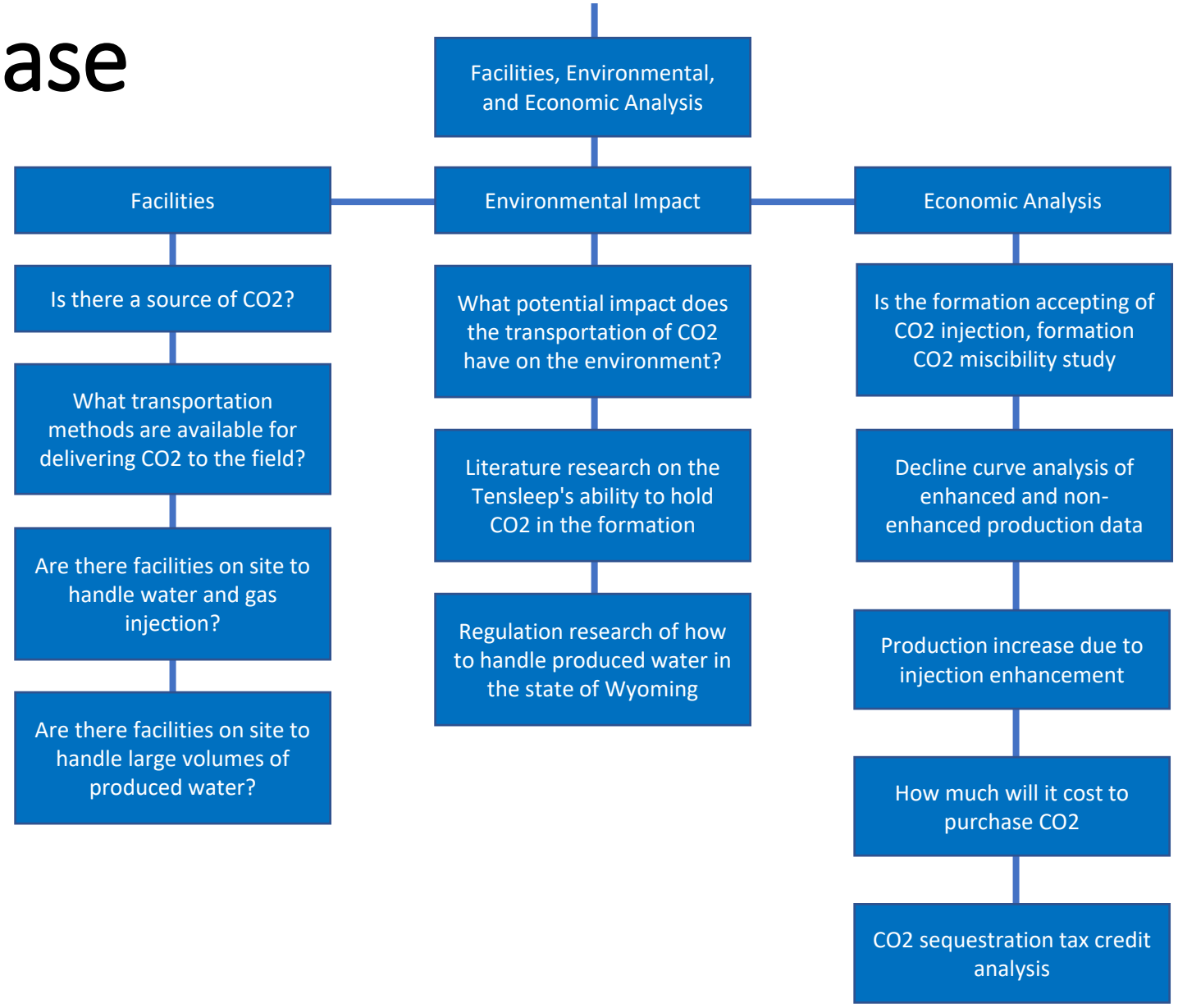
Petrel Phase



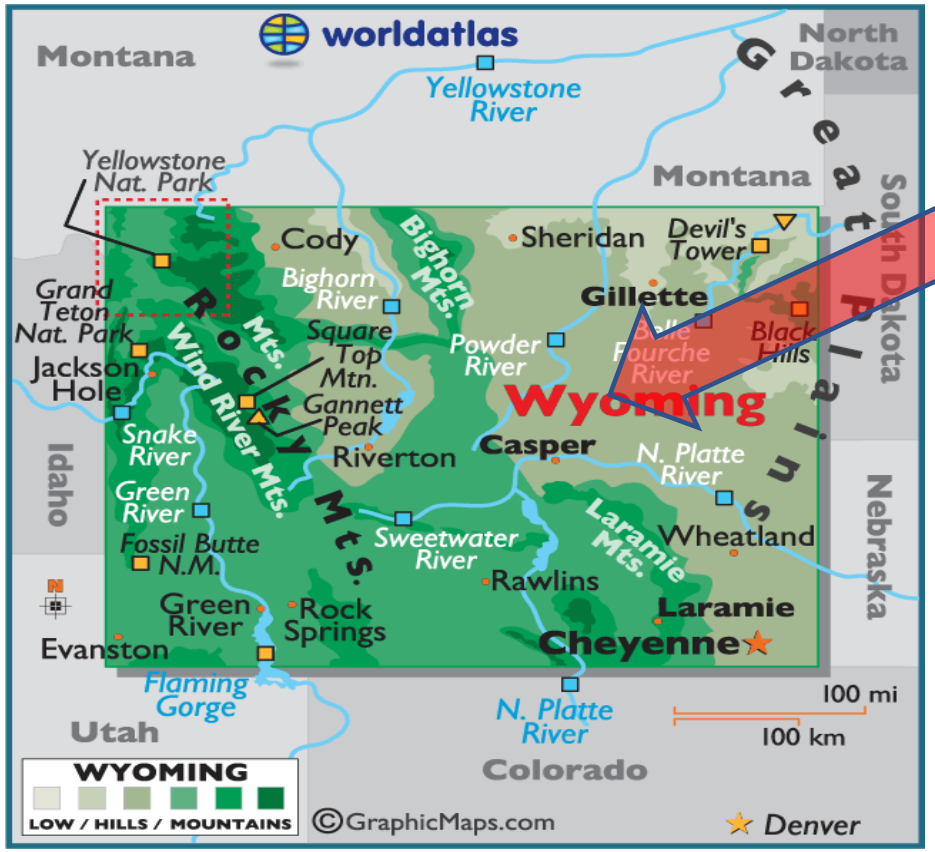
Dynamic Model Phase



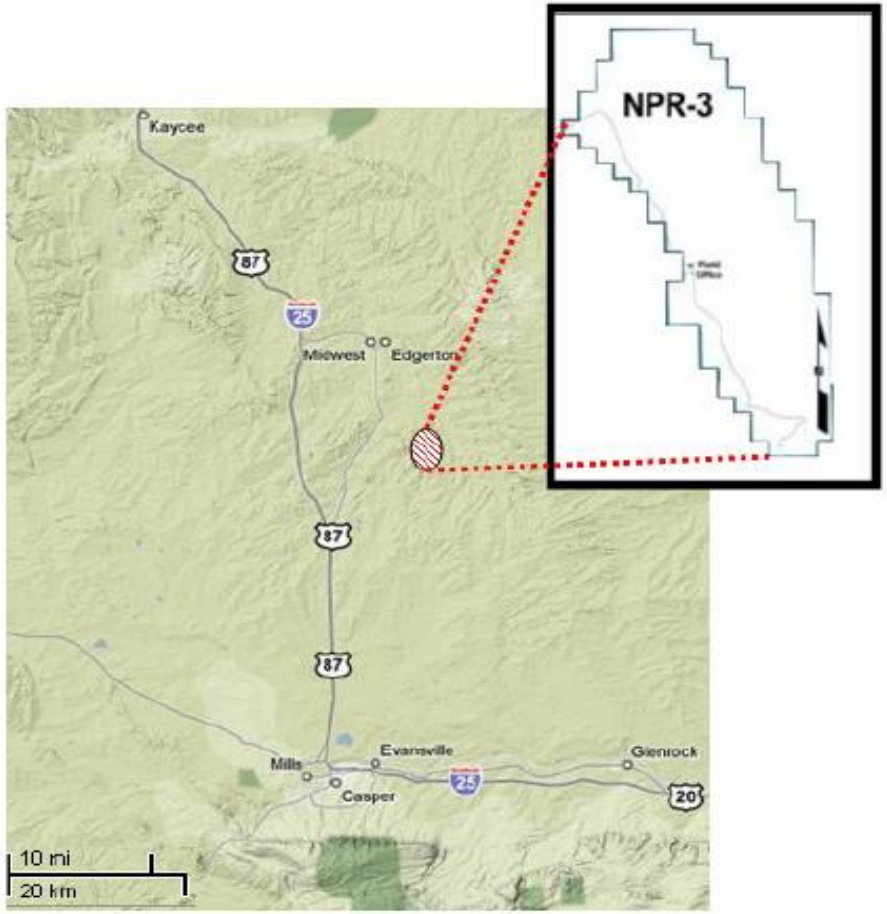
Final Phase


Facilities, Environmental, and Economic Analysis
Facilities
Is there a source of CO2?
What transportation methods are available for delivering CO2 to the field?
Are there facilities on site to handle water and gas injection?
Are there facilities on site to handle large volumes of produced water?
Environmental Impact
What potential impact does the transportation of CO2 have on the environment?
Literature research on the Tensleep's ability to hold CO2 in the formation
Regulation research of how to handle produced water in the state of Wyoming
Economic Analysis
Is the formation accepting of CO2 injection, formation CO2 miscibility study
Decline curve analysis of enhanced and non-enhanced production data
Production increase due to injection enhancement
How much will it cost to purchase CO2
CO2 sequestration tax credit analysis

Teapot Dome Field

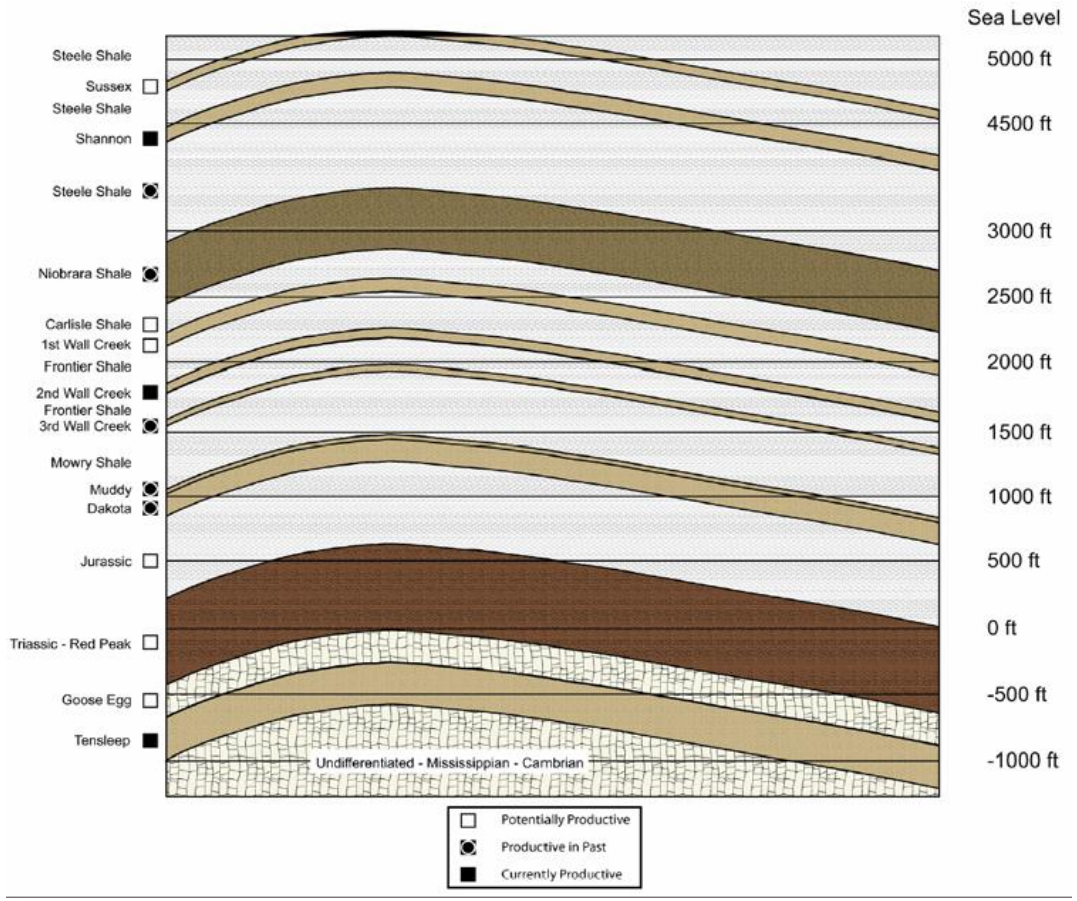


(Worldatlas 2016)

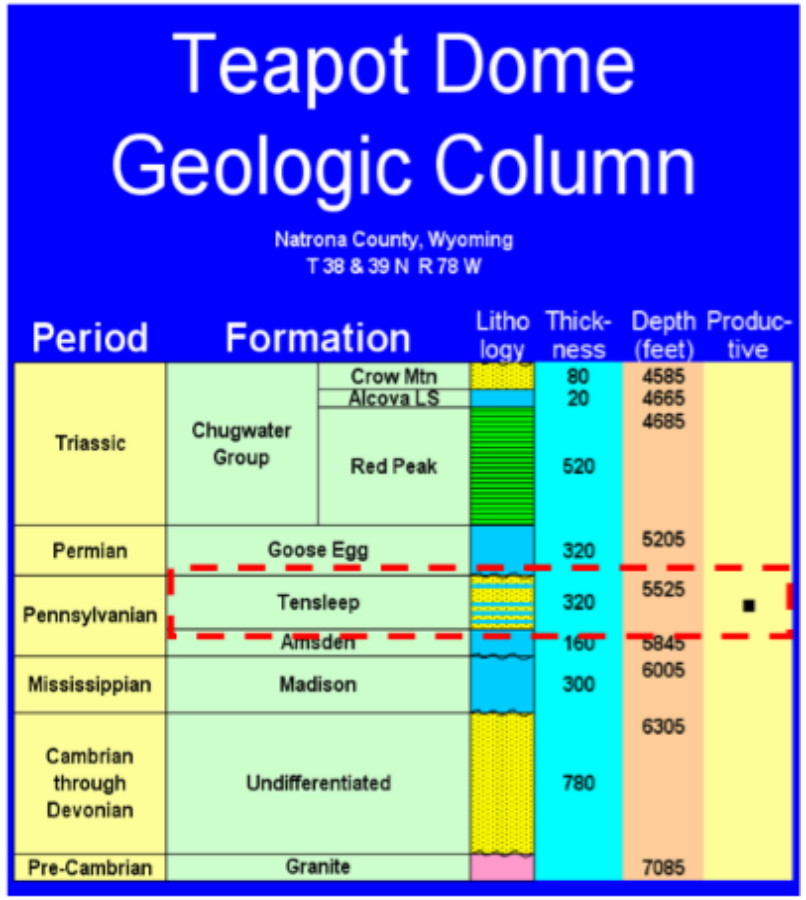


(Ounes et. Al. 2010)

Teapot Dome Stratigraphy

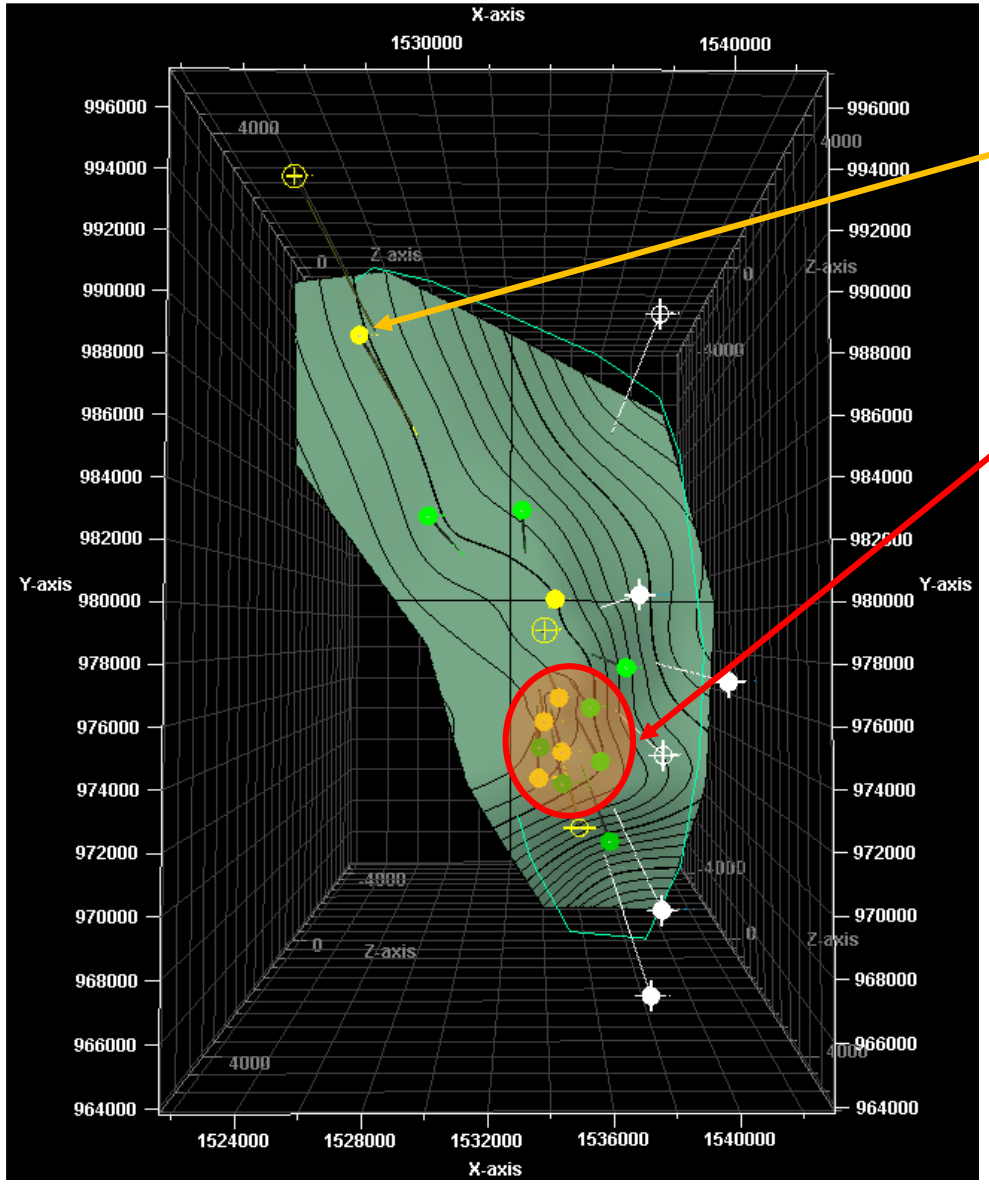


(Searchanddiscovery.com)



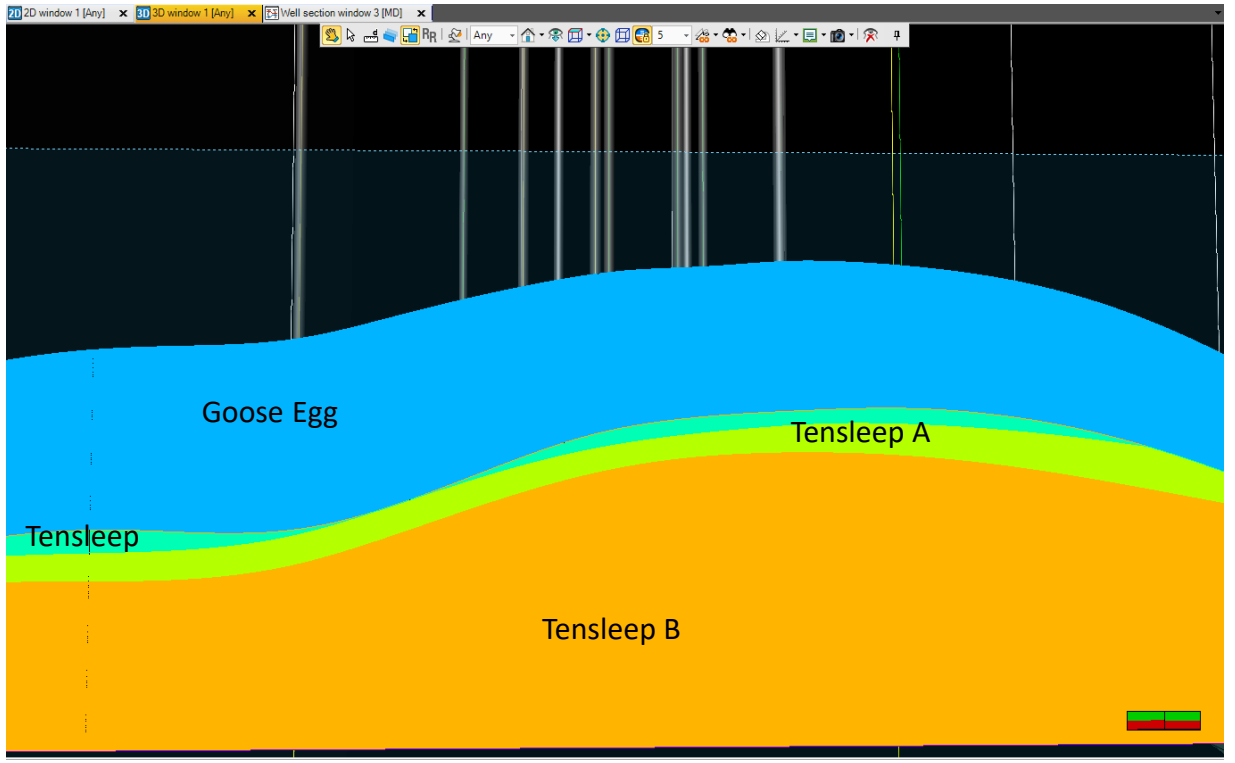
(Ouenes et al 2010)

Petrel Static Model: *Reservoir Overview*

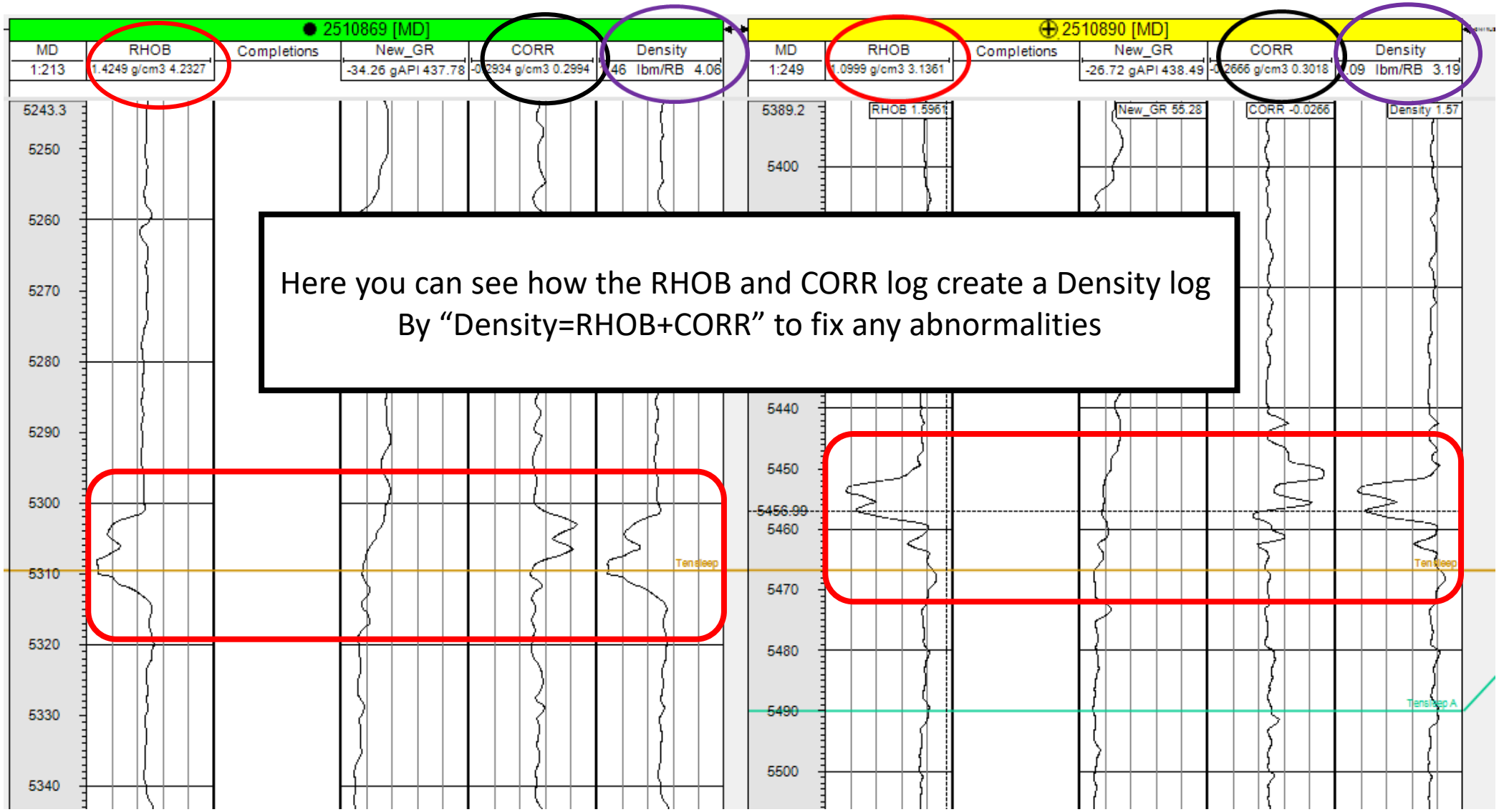


Location of well 48-X-28 which core was taken from for permeability modeling

Cluster of wells of interest for production purposes

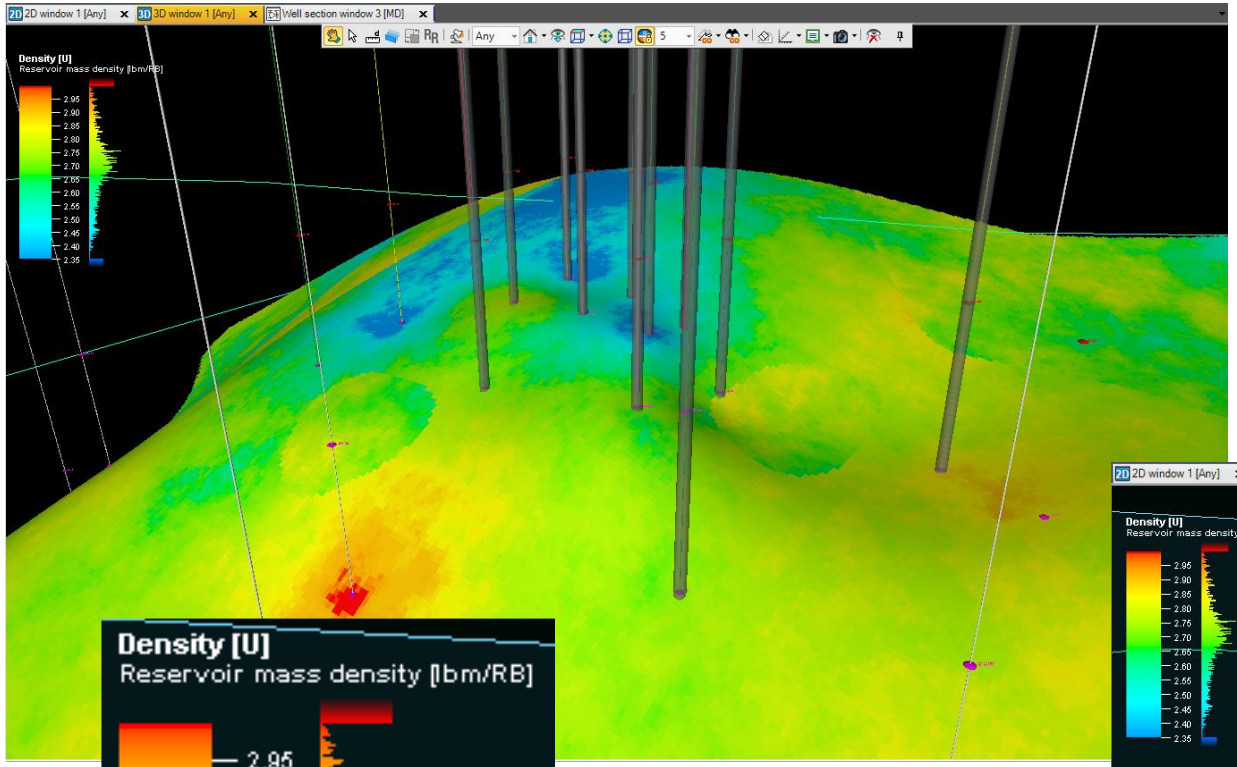


Petrel Static Model: *Quality Control*

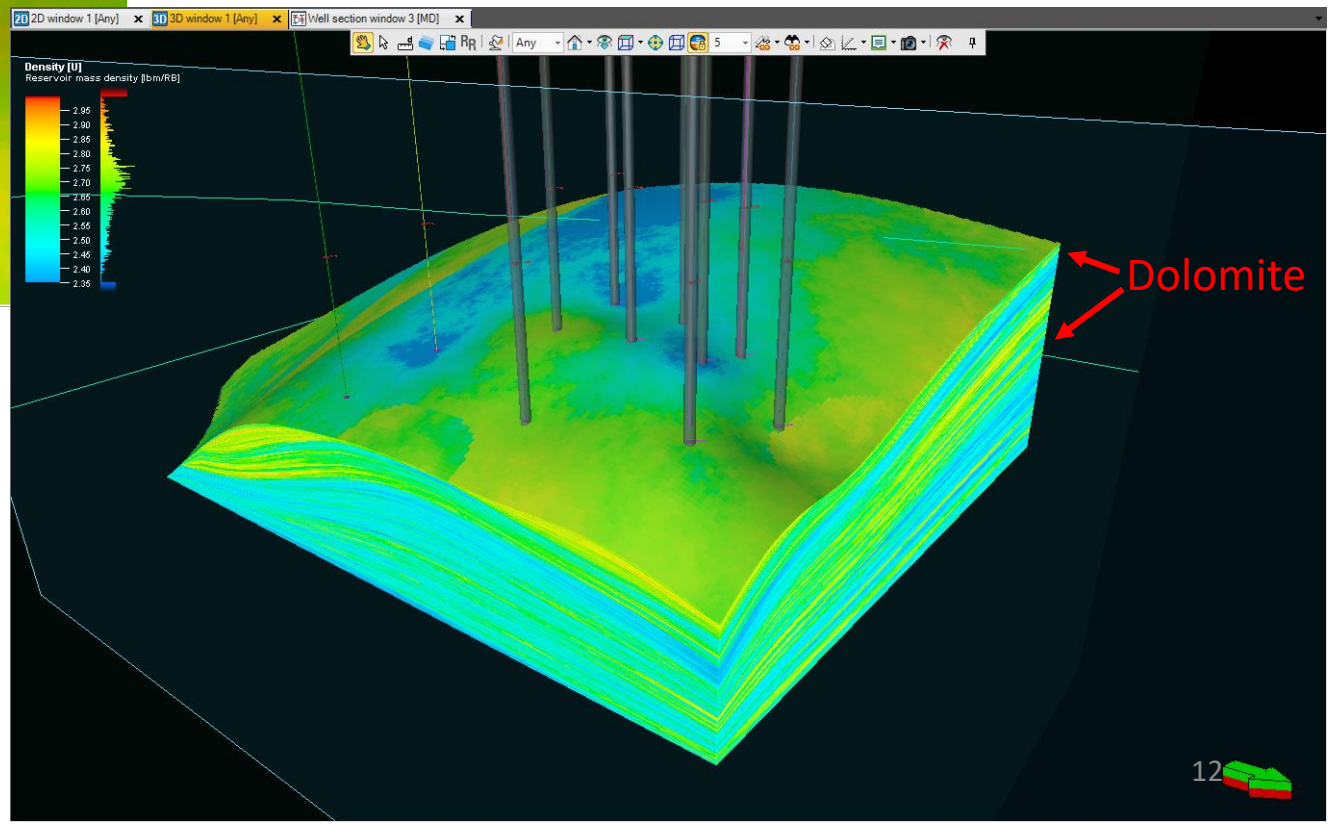


Here you can see how the RHOB and CORR log create a Density log
By “Density=RHOB+CORR” to fix any abnormalities

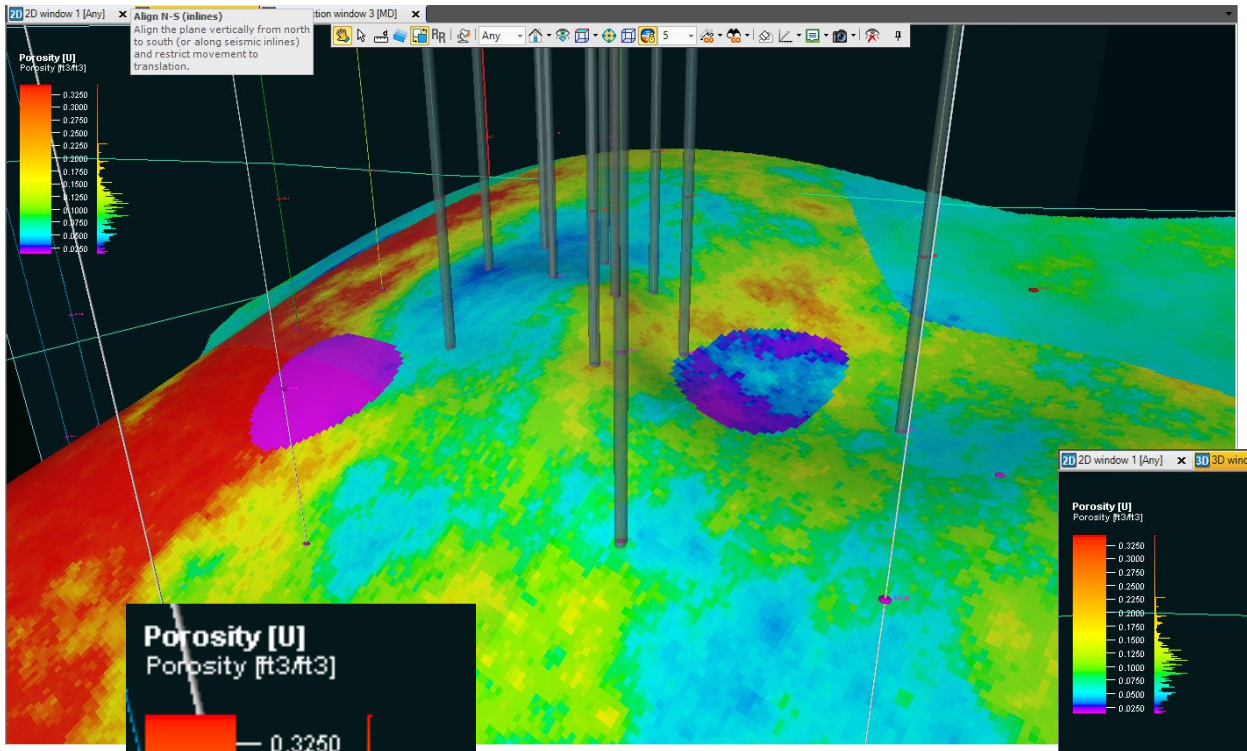
Petrel Static Model: *Density Distribution*

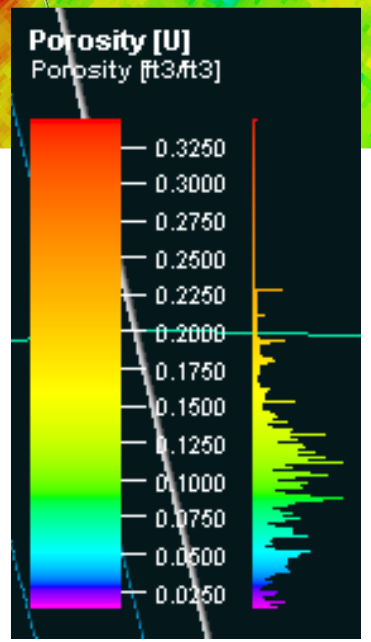


View of density distribution of the Tensleep Formation. Wells observed are cluster of wells of interest for CO2 injection.

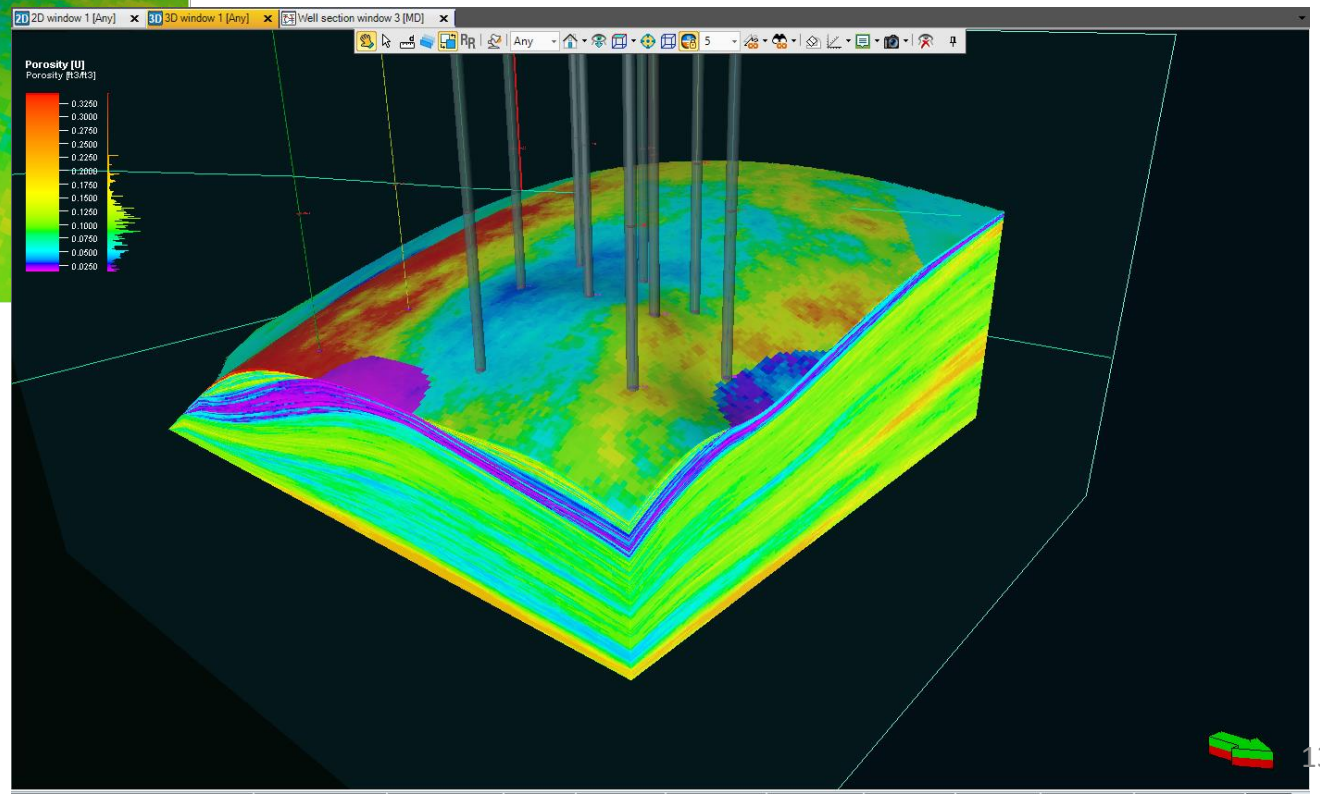


Petrel Static Model: *Porosity Distribution*

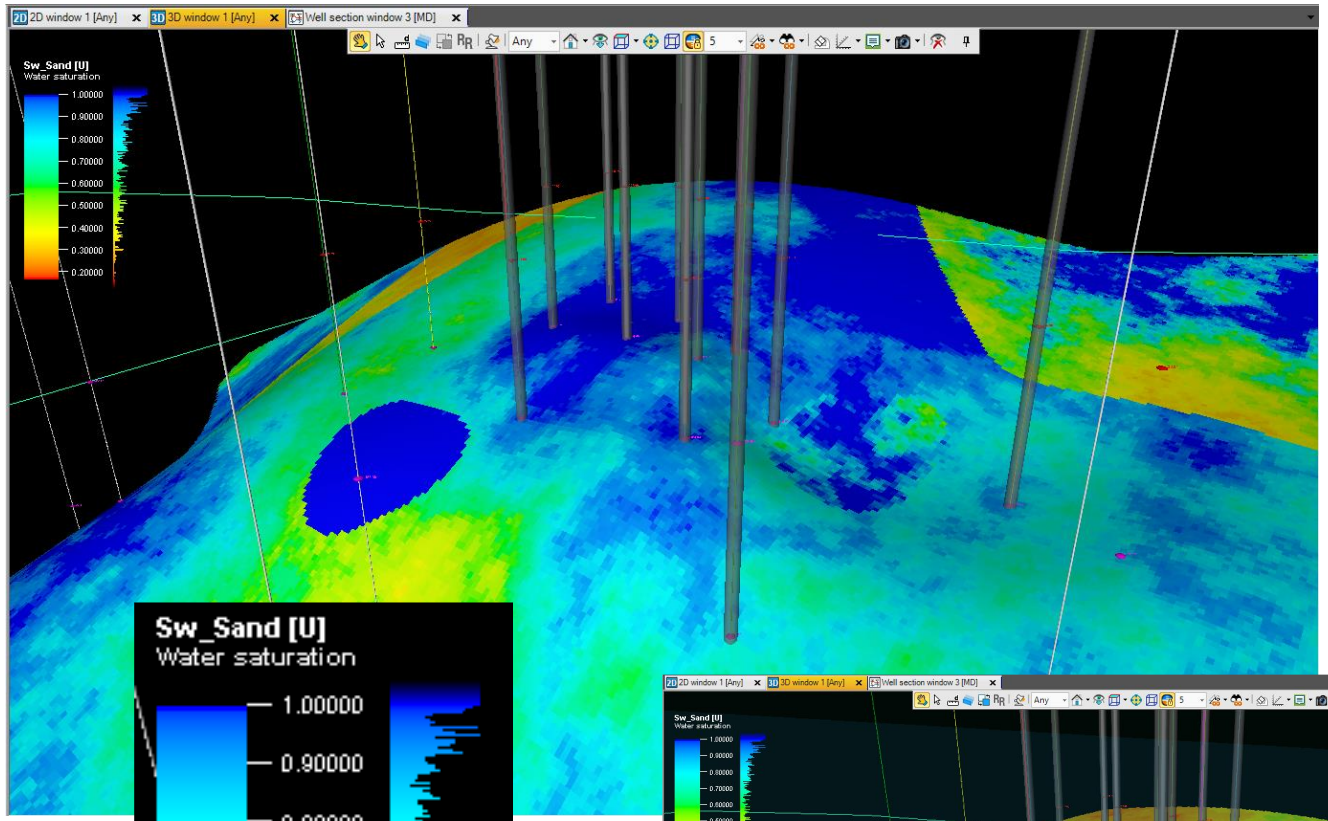


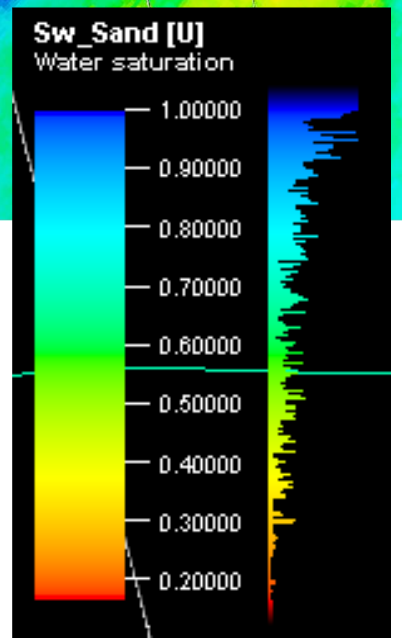


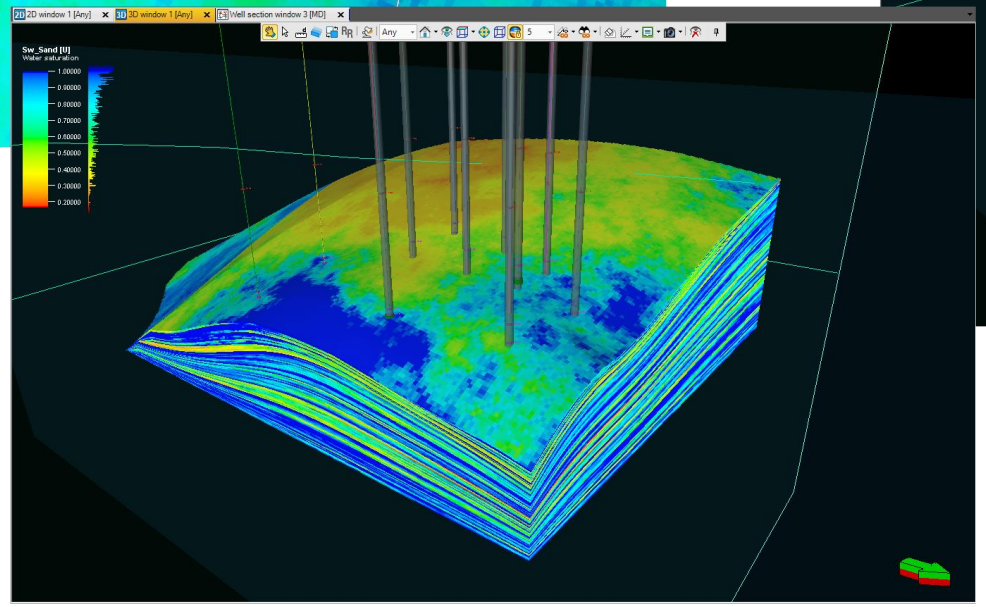
View of porosity distribution of the Tensleep Formation. Wells observed are cluster of wells of interest for CO2 injection.

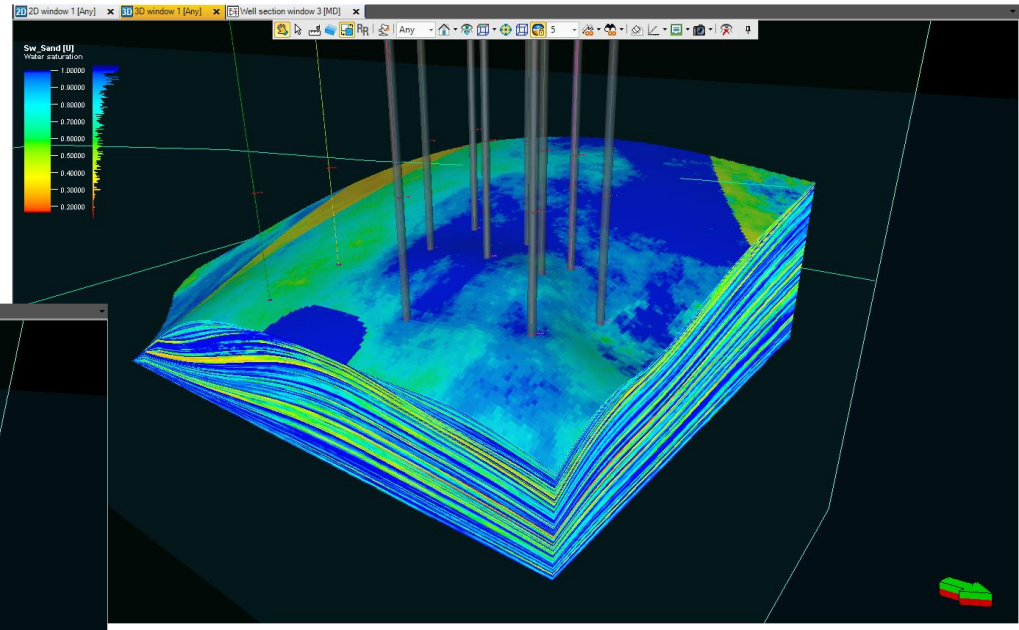


Petrel Static Model: *Water Saturation Distribution*







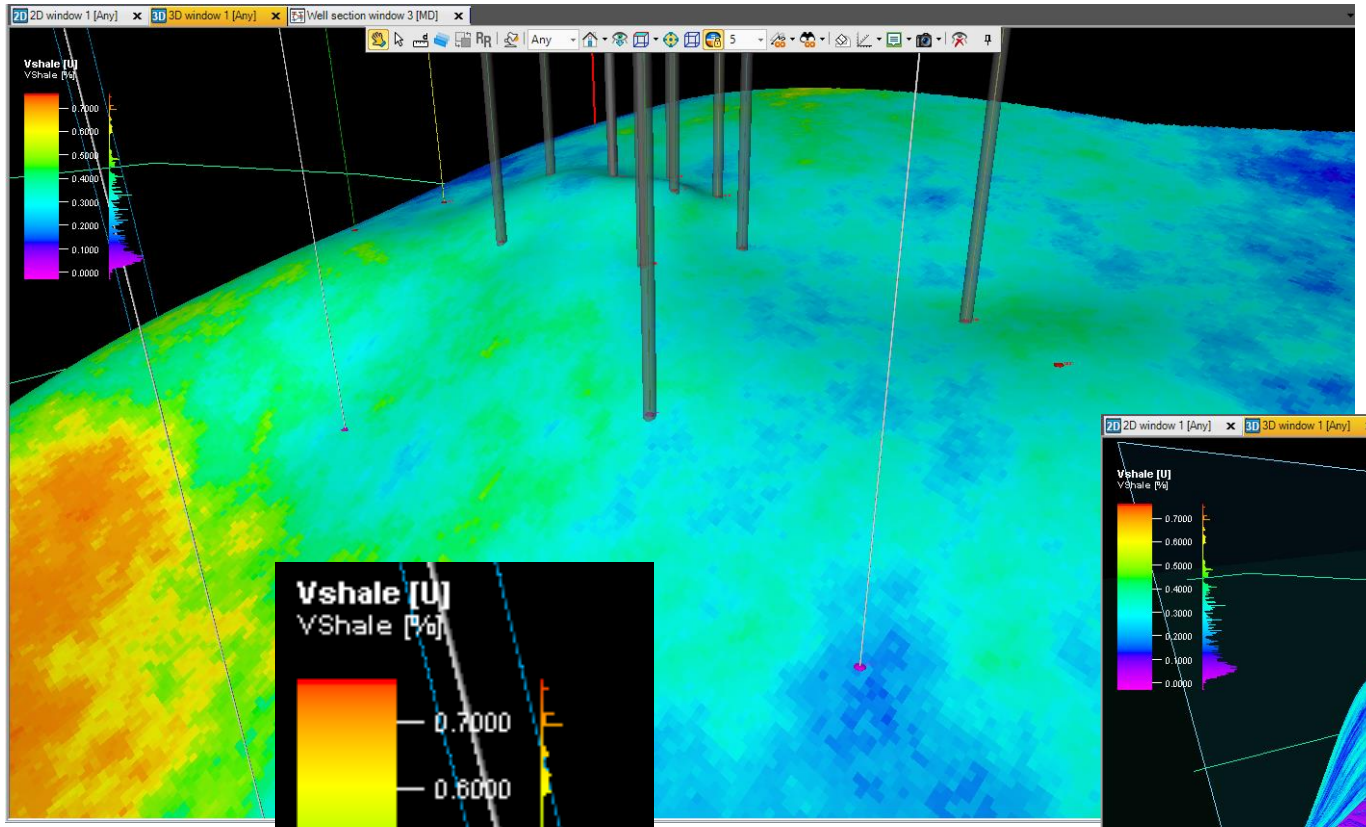


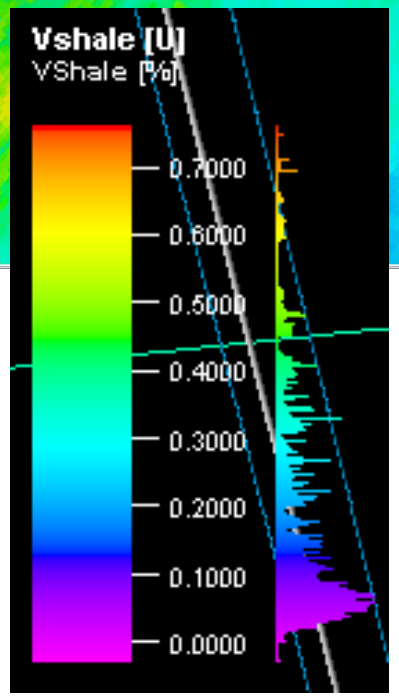
View of water saturation distribution of the Tensleep Formation. Wells observed are cluster of wells of interest for CO2 injection.

Top of Tensleep Formation

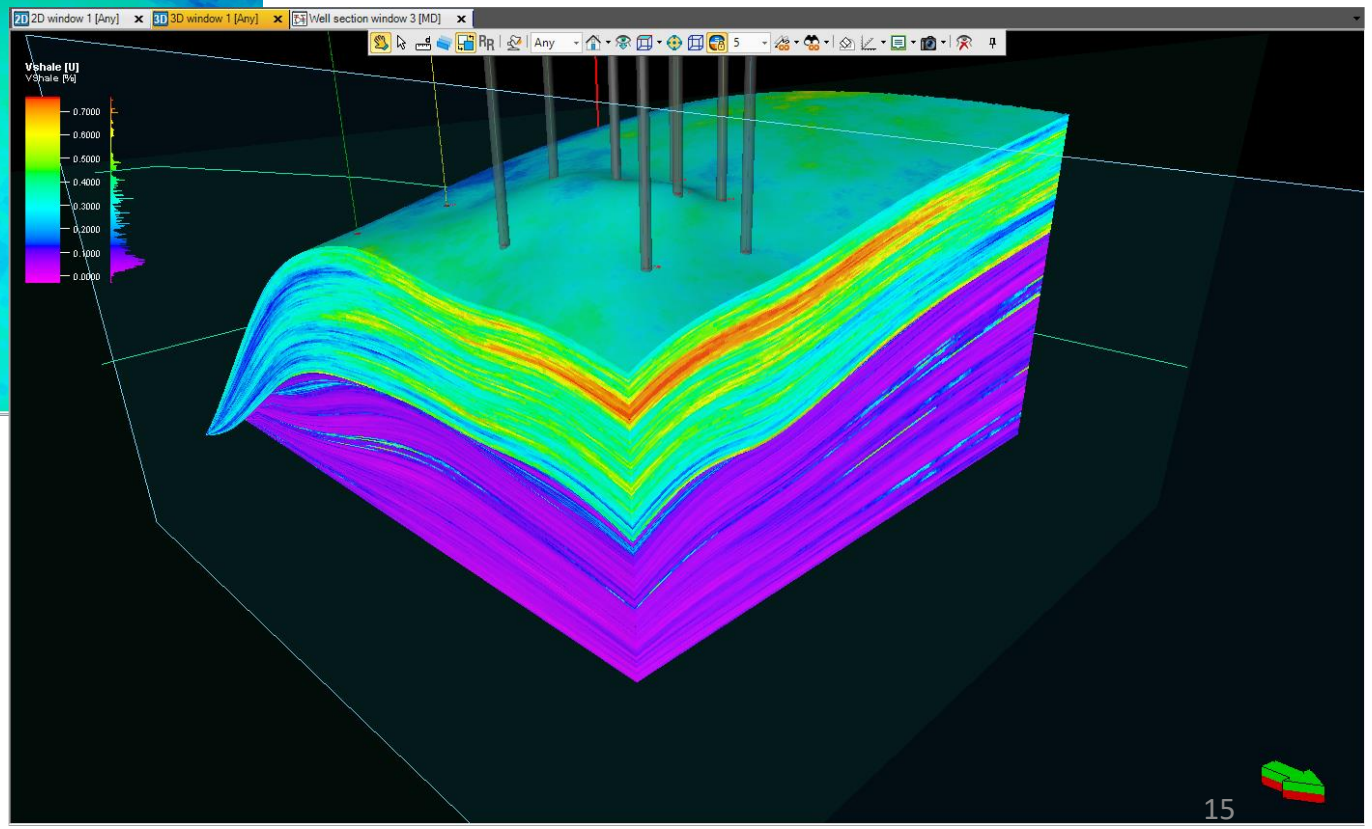
Top of Tensleep A Sand

Petrel Static Model: *Vshale Distribution*

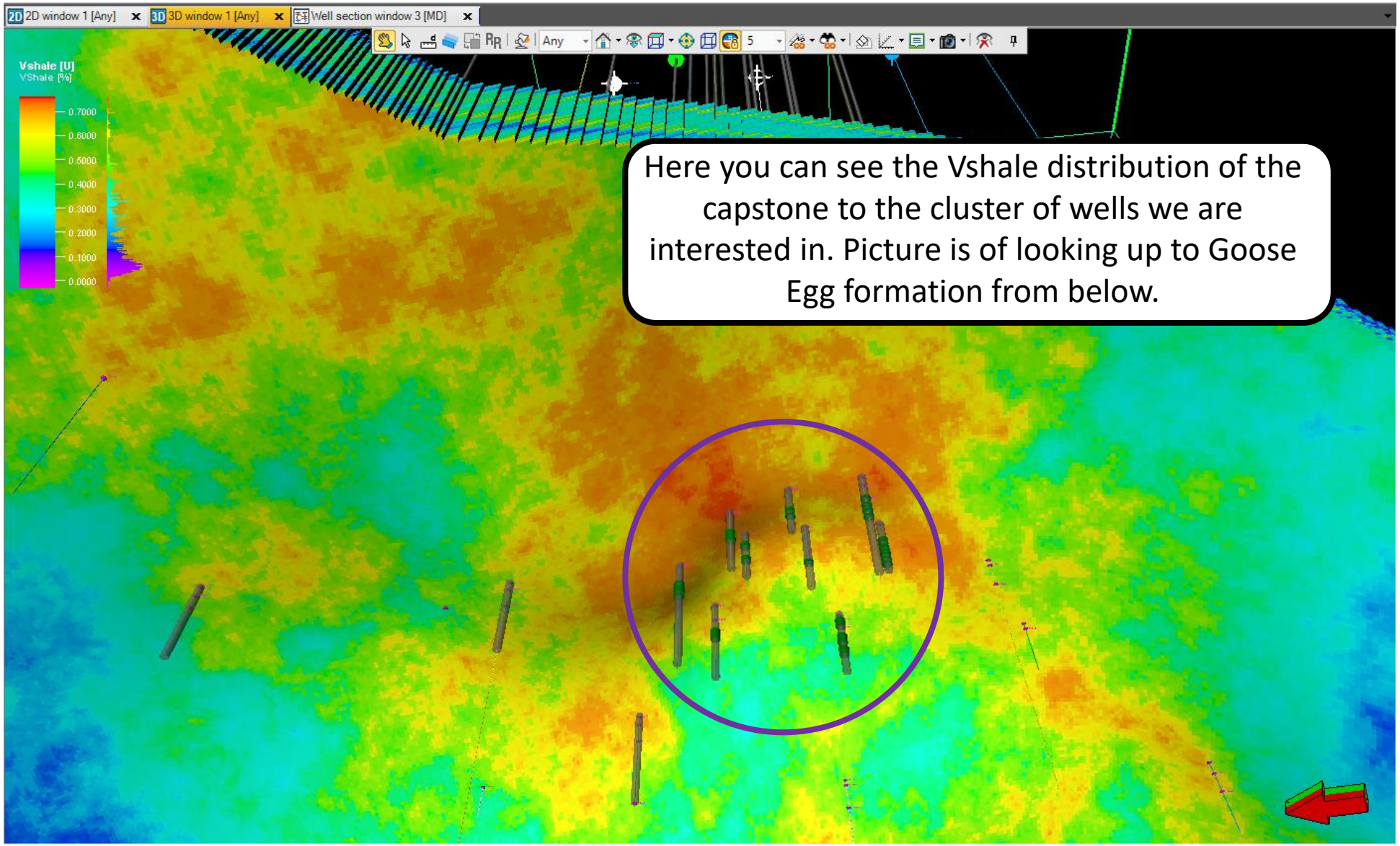




View of Vshale distribution in the Goose Egg Formation (blue/green) and Tensleep Formation (purple). Wells observed are cluster of wells of interest for CO2 injection.

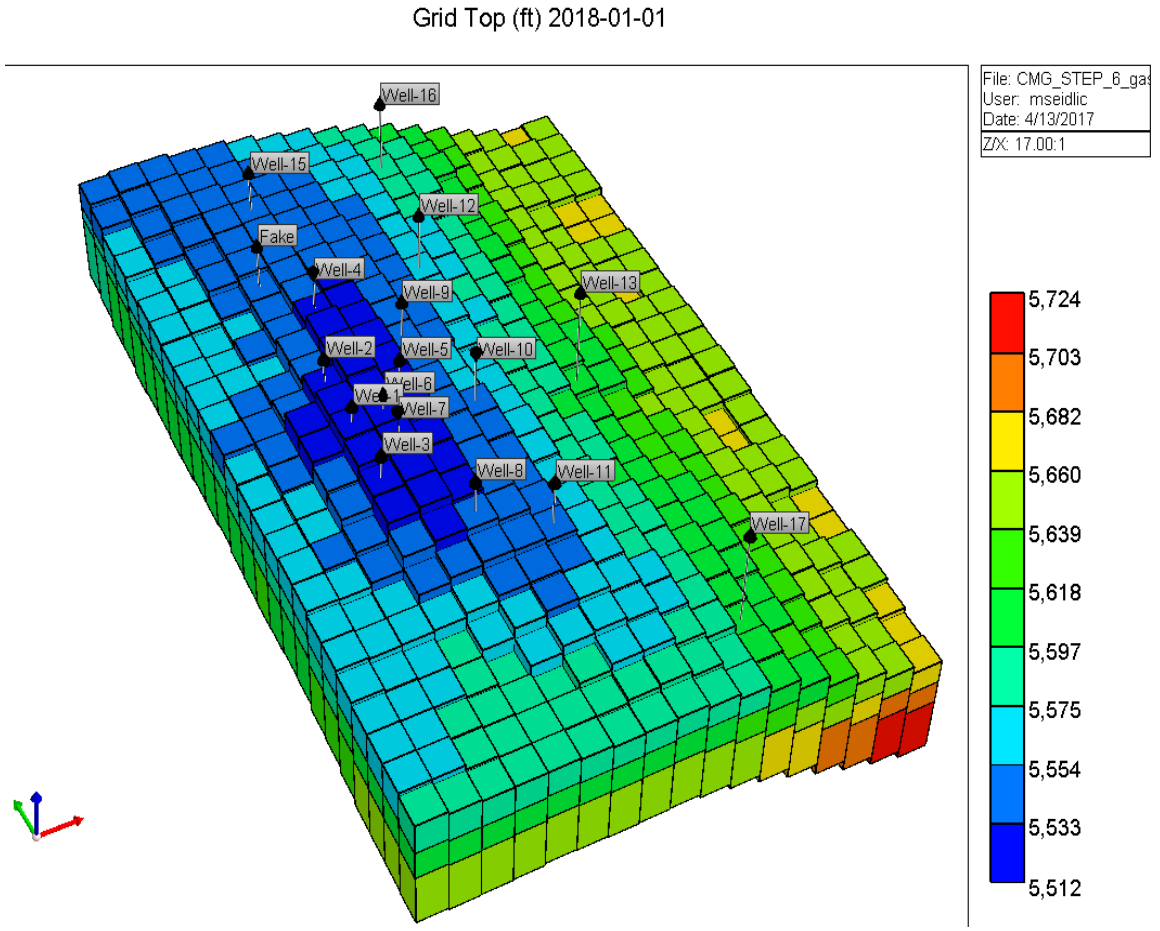


Petrel Static Model: *Vshale Distribution*



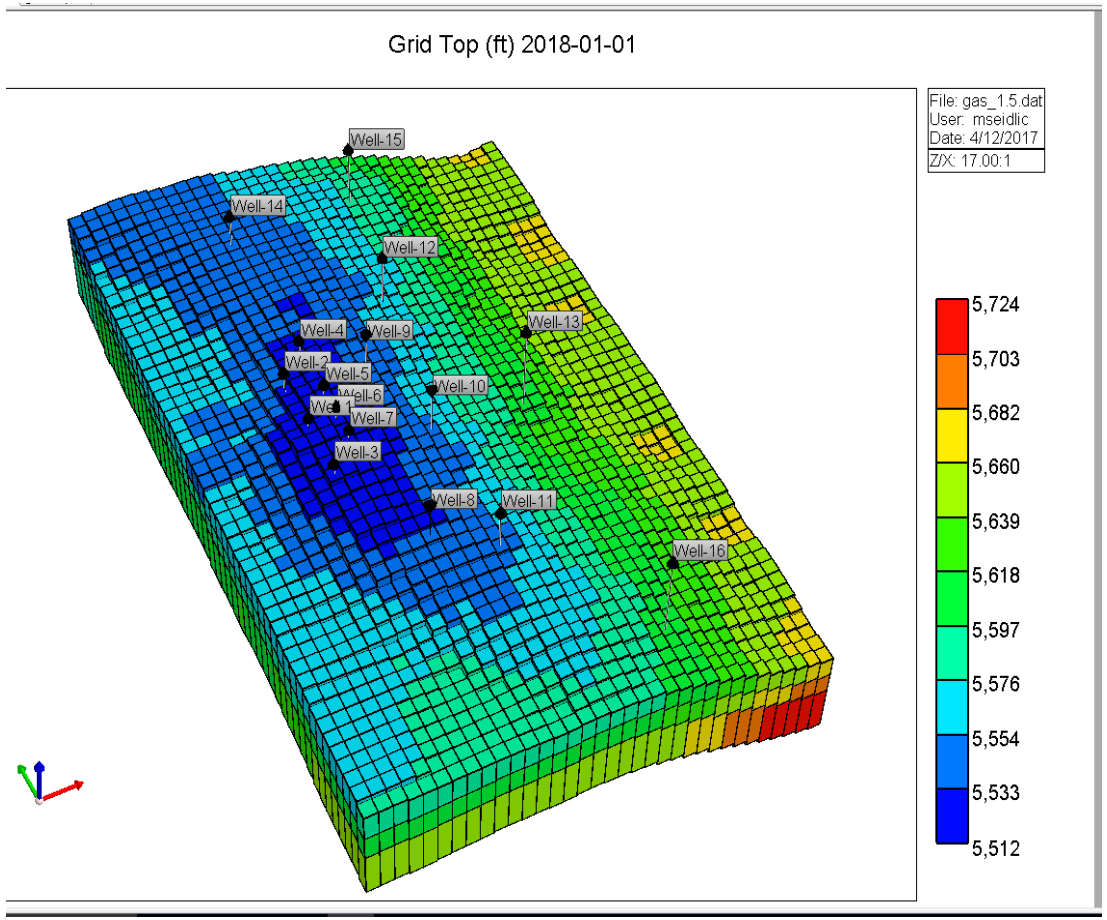
Basic Reservoir Platform

- CMG's software package
- User friendly
- User guide and troubleshooting
- Initial model
- Physical size



Advancing the Reservoir Model

- 5100 Grid Blocks
- More accurate
- Better representation of the static model
- Wells used as reference datum
- Maps



Production History Match

- Wyoming Oil and Gas Commission
- 90 day production
- Running the field through CMG under real-world conditions
- Correction of percent error

Well	API	oil BBL/ month	water BBL/month	Operation
1	2510439	120	66000	Feb-17
2	2522843	20	73	May-09
3	2522770	59	38481	Jul-96
4	2522847	4	25167	Nov-02
5	2510869	20	73	May-09
6	2510778	20	67263	Jul-15
7	2510610	217	116774	Feb-17

Injection Strategy

- Base line for Injection Strategy
- 4 producing wells
- 3 injectors
- Increased oil production, gas breakthrough and amount of CO_2
- Oil Production Increase of 18%
- WAG

Injection Strategy			
Well	API	Status	CO2 (Mscf/d)
1	2510439	Producer	
2	2522843	Injector	350
3	2522770	Producer	
4	2522847	Producer	
5	2510869	Injector	350
6	2510778	Producer	
7	2510610	Injector	300

WAG Strategy

- Water and gas injection recovery mechanism.
- Better sweep efficiency
- Improves oil and CO_2 contact time
- The CO_2 being pressurized by the water will get the CO_2 to the minimum miscible pressure to dissolve into the oil.

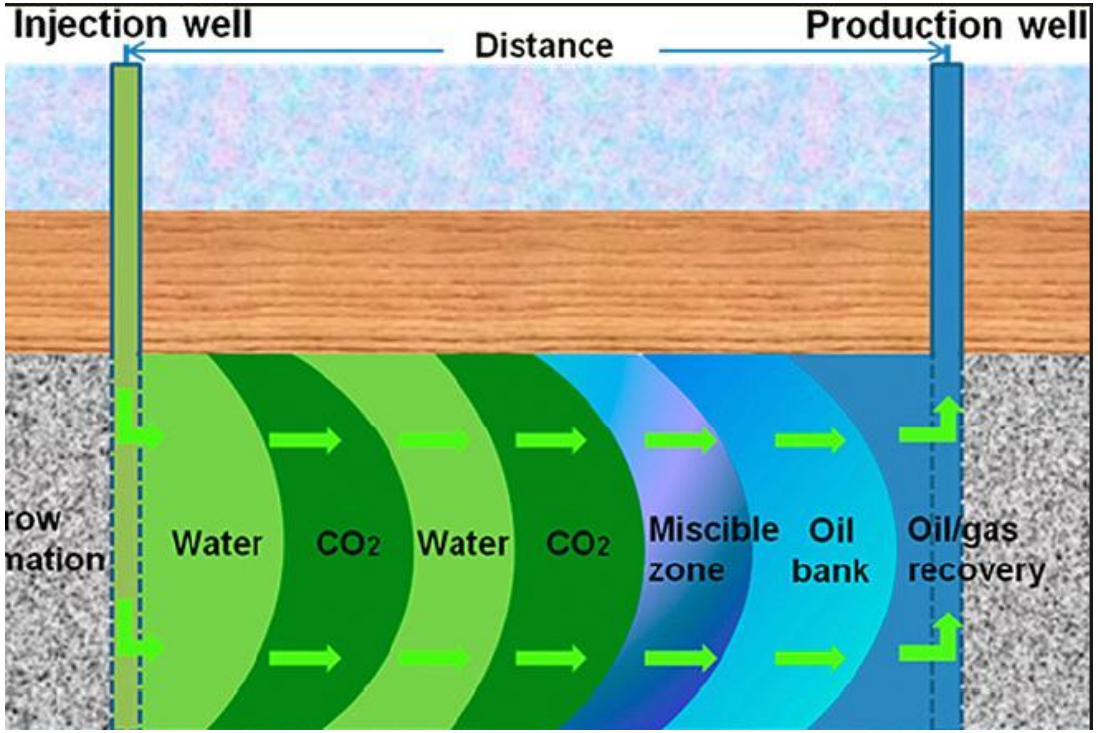
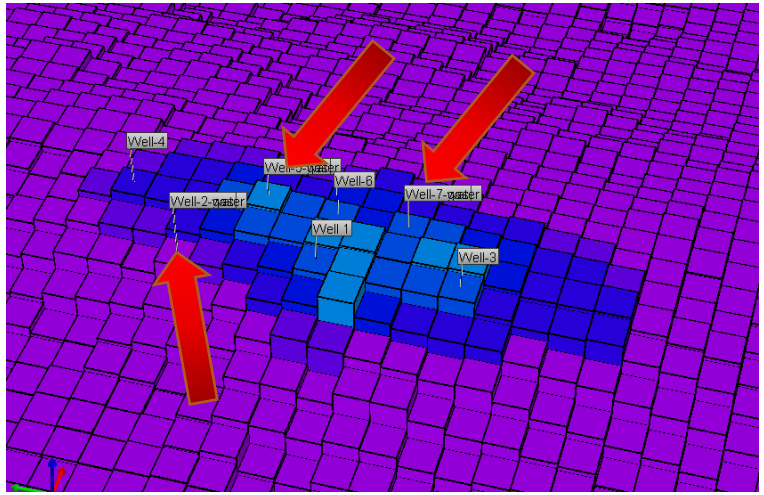
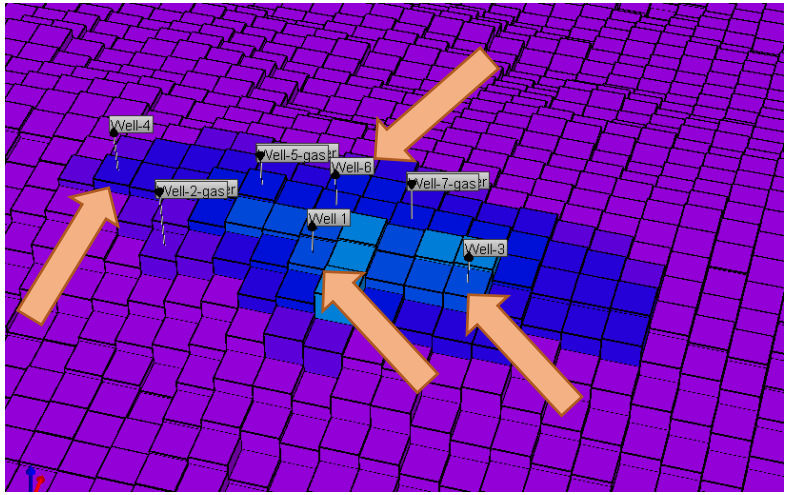


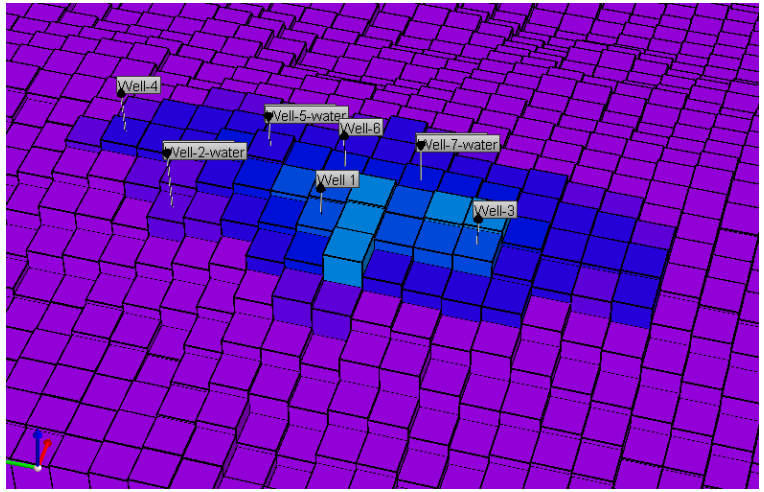
Image only (uaf.edu 2017)

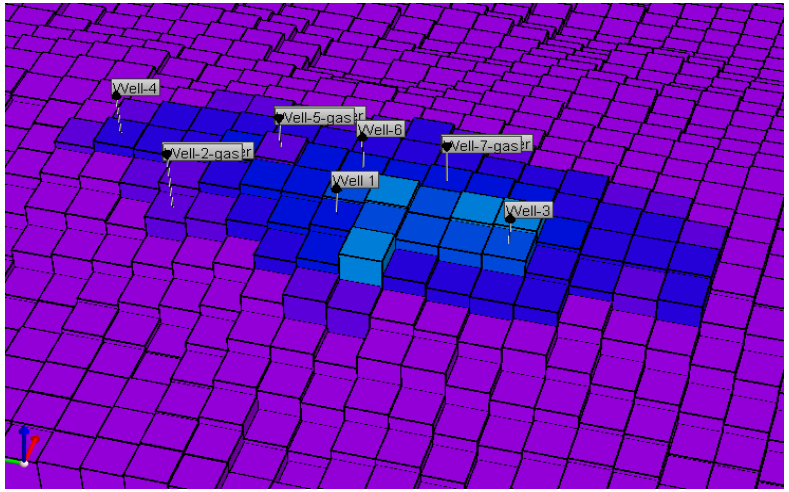
Water and Gas Cycle Injection

- CMG Injection Group
- Breakthrough on Water at 62 Days
  - Water at 4500 STB/D
  - Gas at 1 MMCF/D









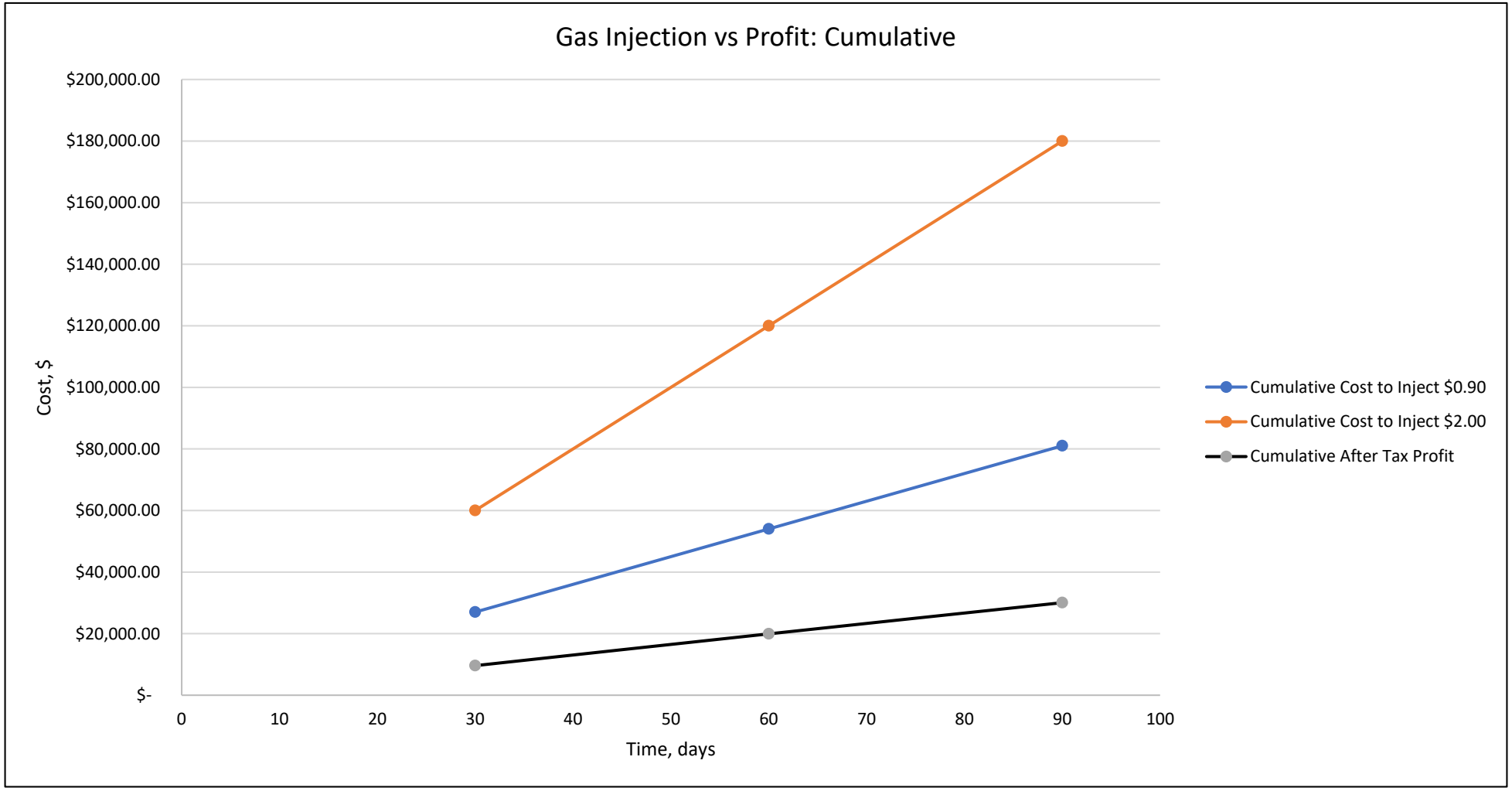
Economic Analysis

- Present Value
  - Production Taxed at 37%
  - Interest Rate at 5% (5% I)
  - Inflation
- Gas Value
  - $0.90-Reinjection
  - $2.00-Off the Line
- Water Value
  - $1.00 - Fresh
- Cumulative Injection
  - 1,000 MCF/Day Gas or 4500 STB/Day Water

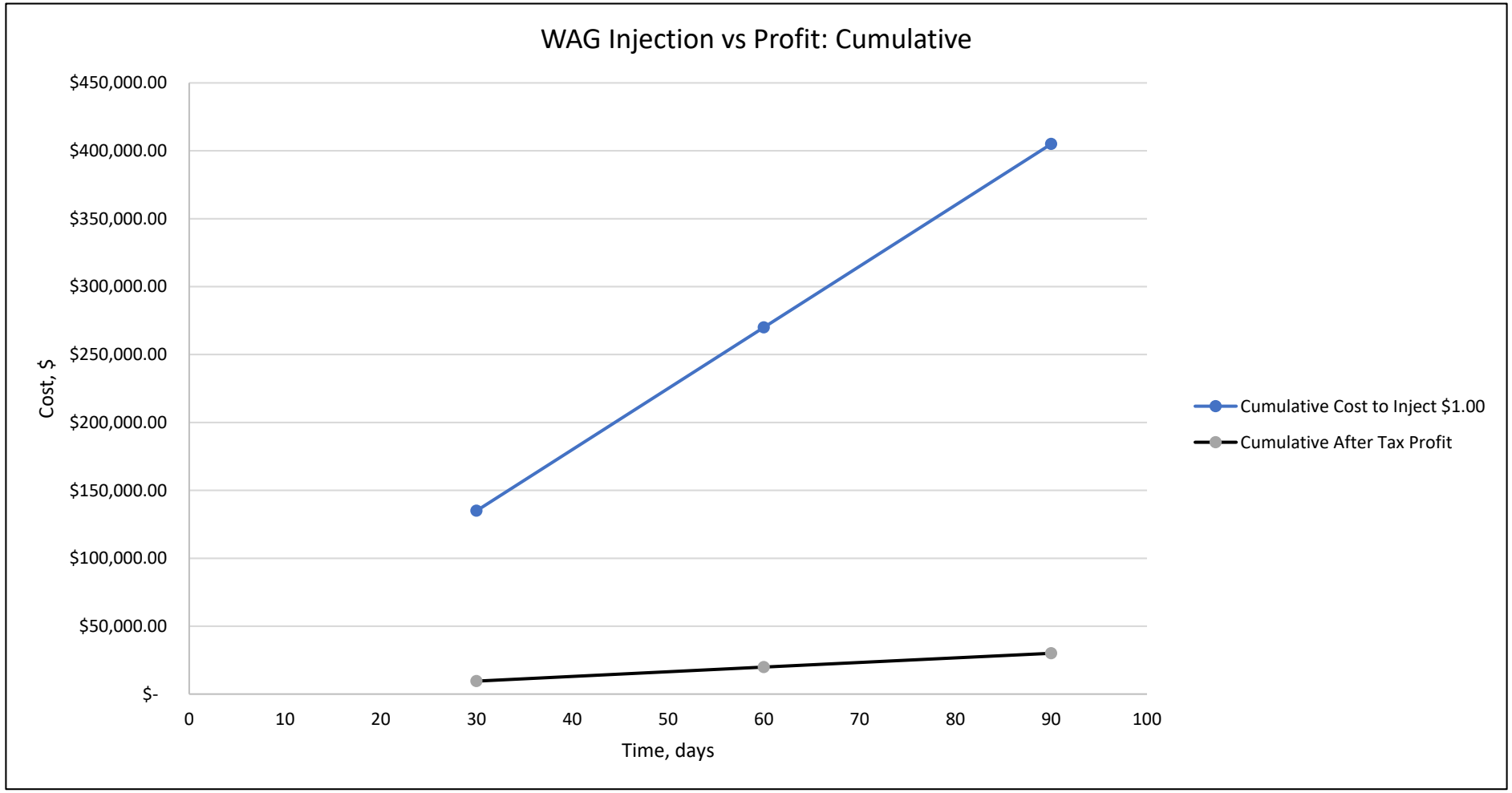
Net Cost to Inject (5% I) $0.90	$73,527.70
Net Cost to Inject (5% I) $2.00	$163,394.88
Net Cost to Inject (5% I) $1.00	$367,638.48

Net Cash Flow Before Tax (5% I)	$43,253.42
After Tax Net Cash Flow (5% I)	$27,249.65

Cost Analysis of Gas Injection (90 Days)



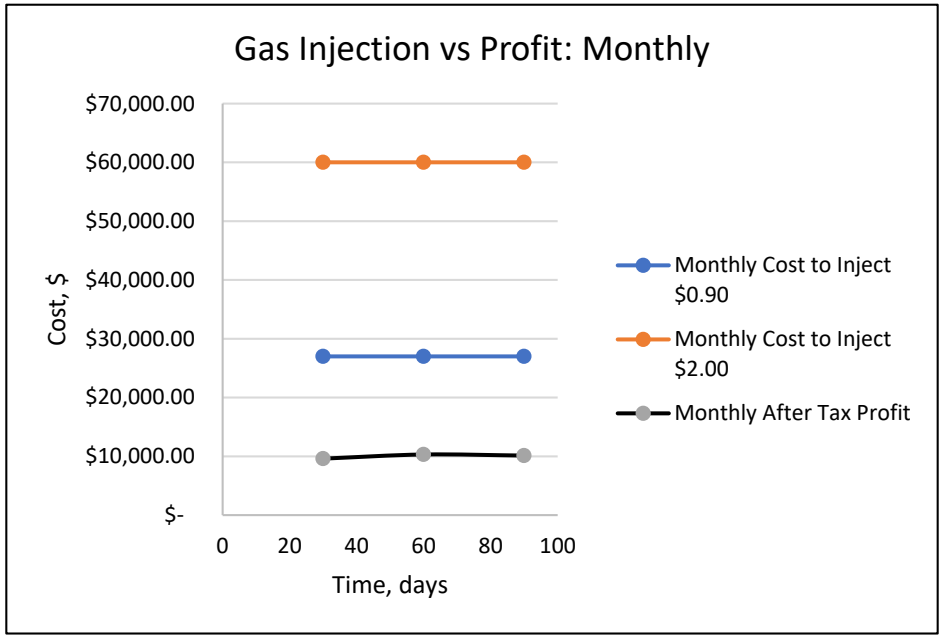
Cost Analysis of WAG

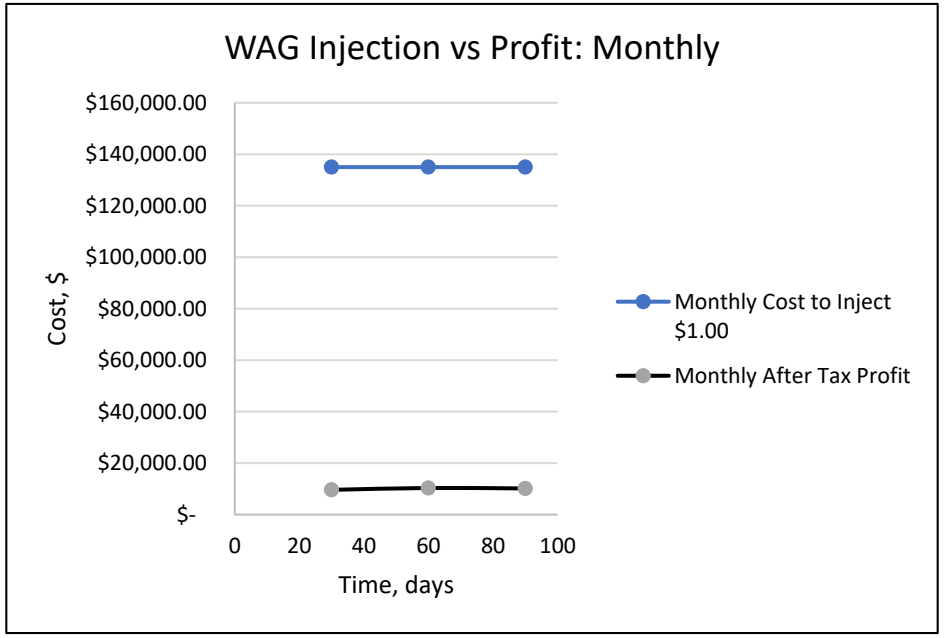


Economic Results

- Loss of Profit
- Change in Injection Costs versus After Tax Profit

Gas to Profit at $0.90	($46,278.04)
Gas to Profit at $2.00	($136,145.23)
Water to Profit at $1.00	($340,388.83)





Permeability Model

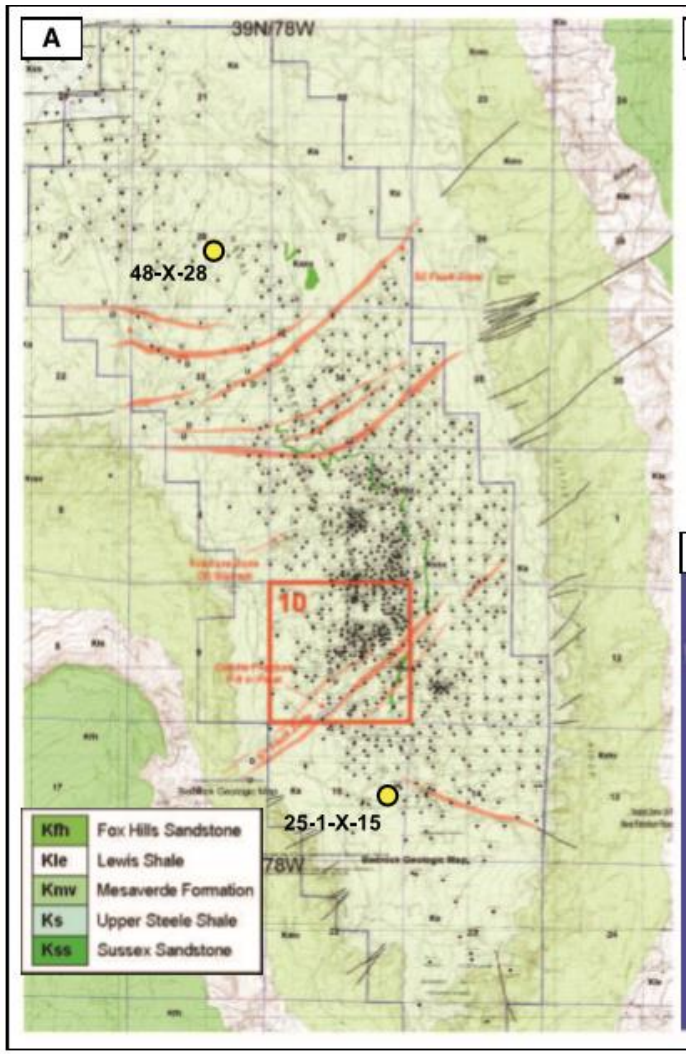
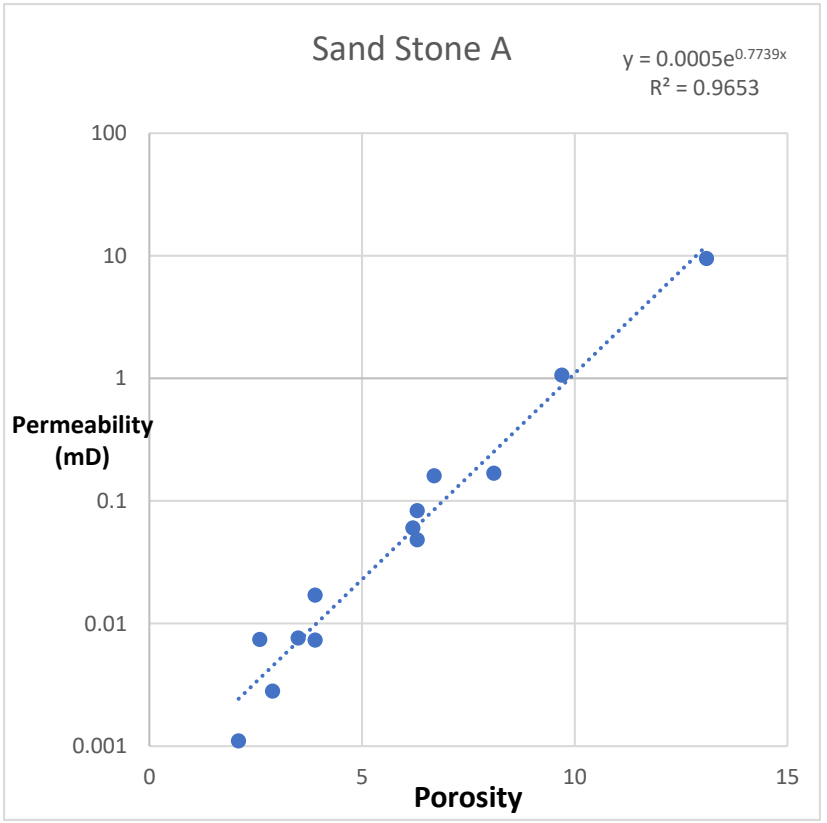
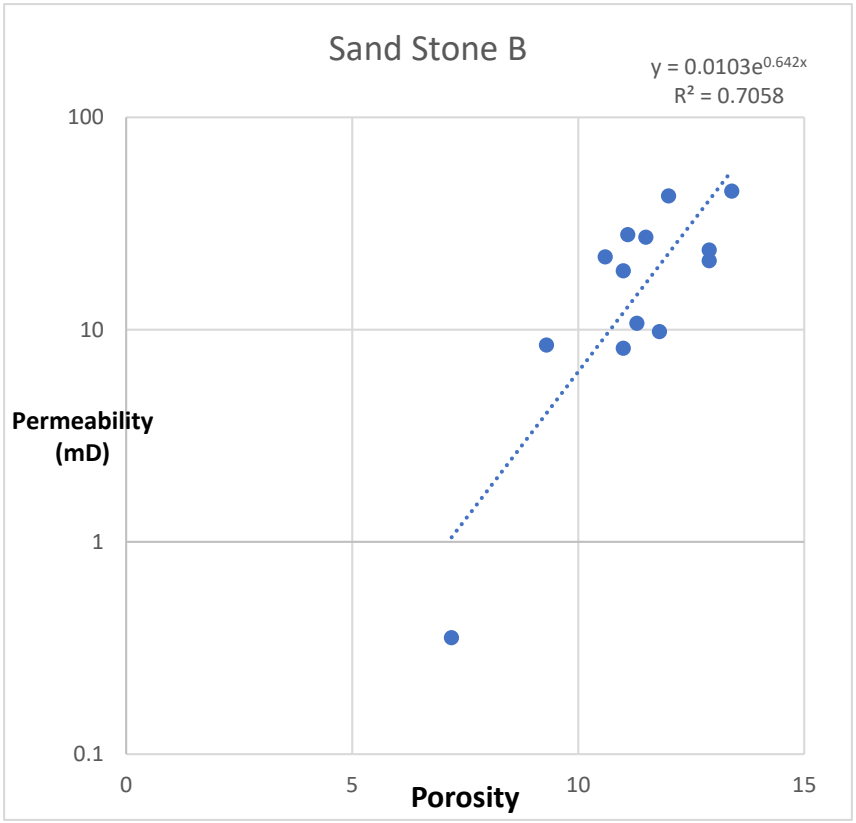


Image only (science.uwaterloo 2005)

- Well 48-X-28 had a 197 ft. of coring pulled that was in poor condition due its natural fractures.
- Based on the coring from this well is how we built our permeability model for Petrel and CMG.
- However, area of our investigation is calculated to be around 3 miles from this well.
- Our injectors and producers for CO_2 injection can be found in and just outside of the red section.
- Due to the distance we believe we should learn more about the natural fractures that create a dual porosity and permeability in the Tensleep formation in our area of interest.
- To do this we need core within this area.

Property Modelling Permeability (48-X-28)

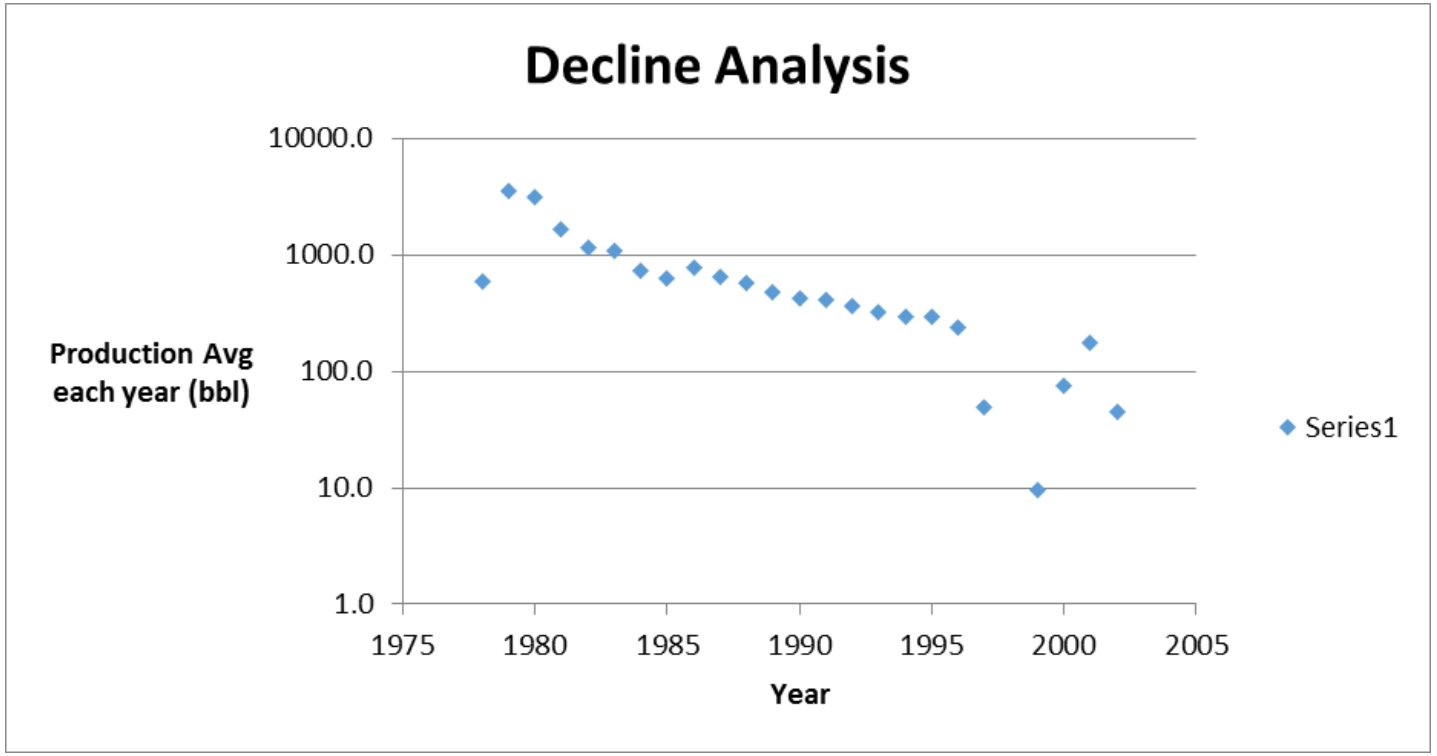




Decline Curve Analysis

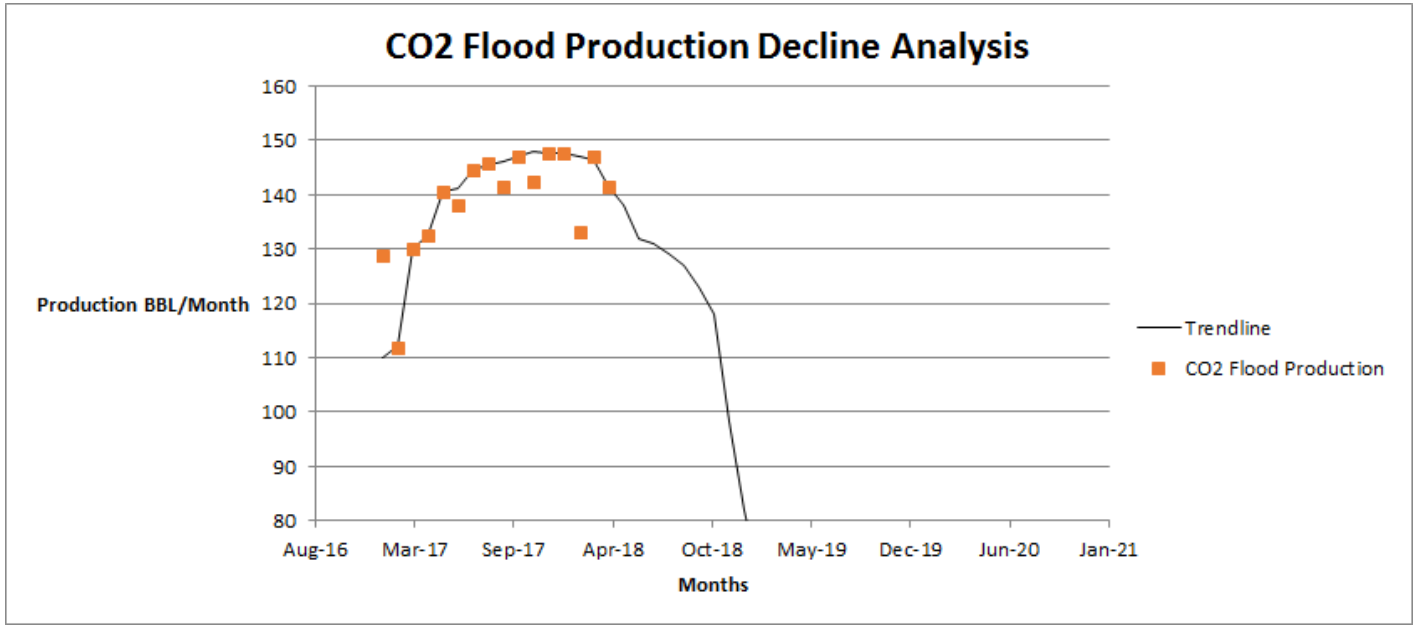
n	1.2
di	0.432
qi	1654

$$qt = qi \div [1 + n * di * t]^{1}/n$$



Year	qt	time	Qp	Calculated qt
	STB/Month			
1978	599.6		599.6	
1979	3583		4182.3	
1980	3092		7274.6	
1981	1654	0	8928.2	1654.0
1982	1169	1	10097.6	1167.8
1983	1080	2	11177.4	914.3
1984	729	3	11906.3	756.9
1985	627	4	12533.3	648.9
1986	781	5	13314.3	569.8
1987	657	6	13971.0	509.3
1988	570	7	14541.2	461.3
1989	475	8	15016.2	422.2
1990	429	9	15445.6	389.8
1991	413	10	15858.3	362.4
1992	366	11	16224.0	338.9
1993	322	12	16545.5	318.5
1994	291	13	16836.4	300.6
1995	291	14	17126.9	284.8
1996	236	15	17362.5	270.7
1997	49	16	17411.2	258.0
1998	0	17	17411.2	246.6
1999	10	18	17420.7	236.3
2000	76	19	17496.5	226.8
2001	178	20	17674.3	218.2
2002	45	21	17719.3	210.2

CO_2 Decline Analysis



$$qt = qi \div [1 + n * di * t]^1/n$$

- Applying the decline exponent “n”, that was calculated from past production history.
- Using the equation from the previous slide.
- This time using it to find the flow rate at a specific month.
- These flow rates were plotted, and hidden except for the trend line to show how we interpretation of the decline.

Leakage Risk Characterization

Image only
archives.datapages.com

- The RMOTC Conducted a study on fluid migration from two faults near the area of study.
- Dug two shallow trenches along these faults and saw no evidence of fluid migration from producing zones or CO_2 from testing the area for CO_2 injection.
- The natural vertical fractures in the Tensleep from theory WAG would increase the vertical sweep of the oil.
- Suggestions find out if there is leakage due to the fractures of the rock.

Environment

- Produced Water Management
- CO_2 Trapping in the Reservoir

Image only (www.fws.gov, 2003)

Recommendations

- Cost Analysis - Gas
- Oil Production - WAG
- CO_2 Sequestration
- More Coring

Image only (http://www.wyohistory.org, 2017)

Conclusion

- Project Schedule
- Where is the Teapot Dome
- Petrel Static Model
- CMG Dynamic Model
- CO_2 Injection
- Economic Analysis
- Environmental Risks
- Recommendation

Image only (http://editors.eol.org, 2008)

References

- *CMG*. Computer software. Vers. 2016. Computer Modelling Group, n.d. Web.
- Dennen, K. O., & Geological Survey (U.S.). (2005). *Geochemical analyses of oils and gases, Naval Petroleum Reserve No. 3, Teapot Dome field, Natrona County, Wyoming*. Reston, Va: U.S. Geological Survey.
- "Enhanced Oil Recovery." *Denbury Resources - CO2 EOR Enhanced Oil Recovery Carbon Dioxide*. Denbury Resources, 2017. Web. 24 Apr. 2017. <http://www.denbury.com/default.aspx?SectionId=0fd5e3fd-08bc-480b-ac91-ece9dd20240b&LanguageId=1>.
- "Enhanced Oil Recovery Facilities." Pelican Energy, 2016. Web. 24 Apr. 2017. <http://pelicanenergy.com/enhanced-oil-recovery-facilities/>.
- Li, X., Lei, X., & Li, Q. (2016). Injection-induced fracturing process in a tight sandstone under different saturation conditions. *Environmental Earth Sciences, 75*(23), 1-12.
- Martin, D. F., & Taber, J. J. (1992, April 1). Carbon Dioxide Flooding. Society of Petroleum Engineers.
- McCurdy, R. (n.d.). Underground Injection Wells for Produced Water Disposal. Retrieved April 23, 2017, from https://www.epa.gov/sites/production/files/documents/21_McCurdy_-_UIC_Disposal_508.pdf
- Mungan, N. (1981, January 1). Carbon Dioxide Flooding-fundamentals. Petroleum Society of Canada. doi:10.2118/81-01-03
- Ouenes, A., Anderson, T. C., Klepacki, D., Bachir, A., Boukhelf, D., Robinson, G. C., … Stamp, V. W. (2010, January 1). Integrated Characterization and Simulation of the Fractured Tensleep Reservoir at Teapot Dome for CO2 Injection Design. SPE

References

- *Petrel*. Computer software. Vers. 2016. Schlumberger, n.d. Web.
- Project Risk Management Process. (2015, September 20). Retrieved March 19, 2017, from Risk Matrix
- *Search and Discovery*. N.p., n.d. Web. 05 Mar. 2017.
- "Society of Petroleum Engineers -." *Society of Petroleum Engineers* -. N.p., n.d. Web. 05 Mar. 2017. Journal Database
- "Society of Petroleum Engineers -." *Society of Petroleum Engineers* -. N.p., n.d. Web. 05 Mar. 2017. Professional Code of Conduct
- Taxes, Energy and The Economy. (n.d.). Retrieved April 23, 2017, from http://www.api.org/news-policy-and-issues/taxes
- "University of Wyoming Libraries Research Launchpad." *Libraries Research Launchpad @ University of Wyoming*. N.p., n.d. Web. 05 Mar. 2017. Journal and Article Database
- "Wyoming, Continental United States" *World Atlas - Maps, Geography, travel*. N.p., n.d. Web. 05 Mar. 2017.
- "Welcome to NCEES." *NCEES*. 2014. N.p., n.d. Web. 05 Mar. 2017. Model Law
- "§30-5-104. Oil and Gas Conservation Commission; Powers and Duties; Investigations; Rules and Regulations." *Wyoming Oil and Gas Conservation Commission*, n.d. Web. 22 Apr. 2017. <http://wogcc.state.wy.us/db/statutes/s104.html>.