Offshore Storage Resource Assessment
DE-FE0026392

Project Update

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Pittsburgh, PA

Project Objective

The objective of this project is to provide quantitative estimates of CO_2 volumes that may be sequestered in Federal offshore GOM depleted oil and natural gas reservoirs at some time in the future. This field by field assessment will likely be used for strategic planning as the U.S. moves forward with options for CO_2 emissions mitigation.

Presentation Outline

Phase 1 (Milestone No. 3 – Feb. 10, 2016)

- Task 2.0 - Identify and rank depleted fields
- Task 3.0 – Validate field OOIP/OGIP
- Task 4.0 – CO_2 sequestration volume calculation (DOE equation)

Phase 2 (Work in Progress)

- Task 5.0 – CO_2 sequestration volume validation and refinement
- Task 6.0 – CO_2 Oil Production Assessment
- Task 7.0 – Document Project

Task 2.0 Purpose and Goals

Purpose: Acquire and access the BOEM public Reserves database and the commercial IHS well and production database

Goal: Identify depleted fields from BOEM, rank depleted fields by OOIP and OGIP, and create a project database for depleted fields

Task 2.0 Executive Summary

- ✓ BOEM Reserves database (12/31/2013) downloaded
- ✓ IHS GOM well and production database leased
- ✓ 675 depleted fields identified and extracted from the BOEM database and a project database created
- ✓ 675 fields contain 3514 individual sands
  - ✓ 8 contain only oil reservoirs
  - ✓ 573 contain only gas reservoirs
  - ✓ 94 contain oil reservoirs with gas cap

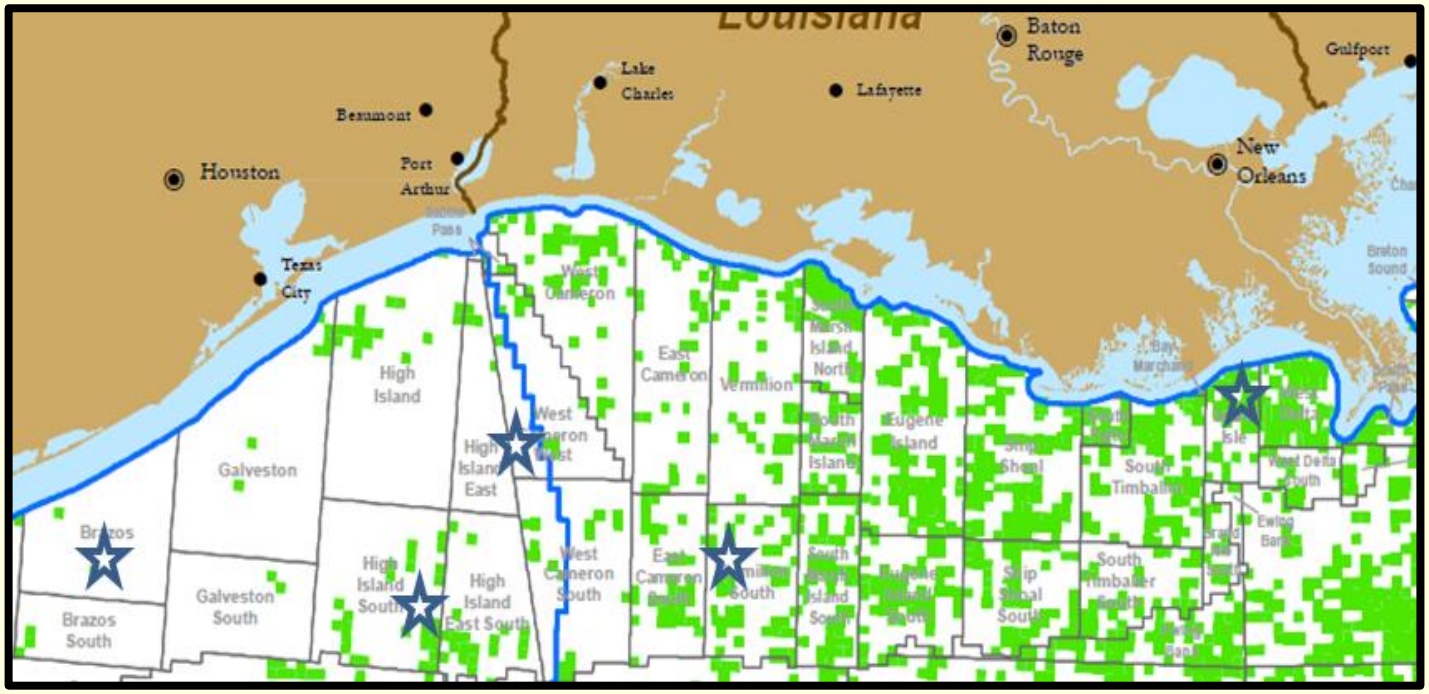
Task 3.0 Purpose and Goals

Purpose: Independently evaluate OOIP and OGIP from the BOEM Reserve Database depleted field list using publically available data for five fields

Goal: Validate the BOEM reported OOIP and OGIP values such that they can reliably be used in subsequent analyses

Task 3.0 Executive Summary-1

Five fields containing 16 productive sands selected for OOIP/OGIP validation



Task 3.0 Executive Summary-2

- ✓ An industry standard evaluation process was followed to integrate geological, petrophysical and engineering data
- ✓ Very limited **data** available from BOEM public records or public domain
- ✓ Significant well location, well log, well production, completion reports, perforation records, etc. available from commercial IHS databases
- ✓ No seismic data was available to assist structural mapping

Task 3.0 Executive Summary-3

- ✓ Well logs (digital format) used to develop stratigraphic cross-sections
- ✓ Structural control assisted by commercial structure maps in area (limited number of wells in each sand)
- ✓ Petrophysical analysis (2 wells per field) and resistivity correlations (other wells) used to estimate net pay
- ✓ Net pay mapped for each sand; acre-feet determined for each sand
- ✓ Porosity and Sw resulting from petrophysical analyses combined to calculate OOIP or OGIP

Task 3.0 Executive Summary-4

- ✓ Total difference for 14 “matched” sands is +2.5%
- ✓ Difference is consistent for oil and gas sands
- ✓ Variance is well within the error associated with the individual properties involved in the evaluation

- ✓ NITEC believes the BOEM reported values for OOIP and OGIP are reasonable based on this validation process.

Task 4.0 Purpose and Goals

Purpose: Provide initial estimates of CO_2 storage volumes utilizing the DOE volumetric equation for all Federal GOM depleted fields

Goal: Establish a range of CO_2 storage volumes for the depleted fields based on the reported OOIP and OGIP values and estimated storage efficiency factors, $E_{oil/gas}$

$$G_{CO2} = A\ h_n\ f_e\ (1\text{-}S_w\ )B\ \rho\ E_{oil/gas}$$

OOIP or OGIP

Task 4.0 Executive Summary

- ✓ Depleted field database “created” in Task 2.0 utilized
- ✓ Contained 675 fields and 3514 sands
- ✓ Honored the BOEM reported OOIP and OGIP for each sand
- ✓ Applied the DOE CO_2 storage volume equation
- ✓ Computed CO_2 storage volumes (tons) based on
  - ✓ CO_2 volumetric efficiencies of 10%, 20%, 50%
  - ✓ **Total CO_2 storage at 10% volumetric efficiency**
  - ✓ **471.496 million tons**
  - ✓ Oil sands ranged from 0.001 to 1.351 million tons
  - ✓ Gas sands ranged from 0.001 to 4.229 million tons

Task 5.0 Purpose and Goals

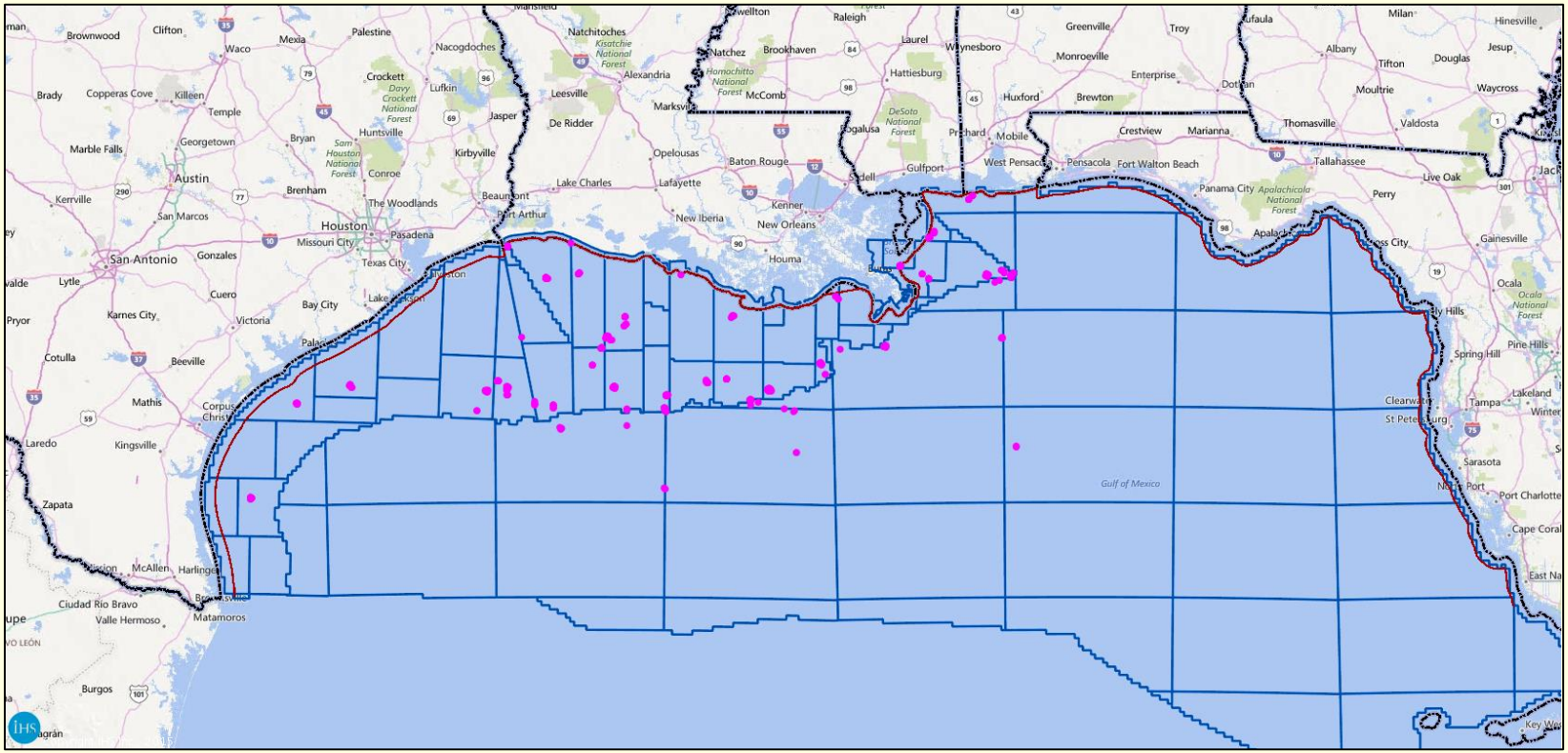
Purpose: Refine CO_2 storage volume estimates using DOE funded CO_2-EOR and sequestration reservoir simulator, COZ

Goal: Determine maximum CO_2 storage volumes for the depleted fields based on simulation of CO_2 injection into the individual "depleted" sands (reservoirs)

Task 5.0 Executive Summary-1 (WIP)

- ✓ Three reservoir simulation engineers working full-time
- ✓ 60 fields from 675 depleted fields identified for possible modeling; 264 sands (27 oil only, 207 gas only, 30 oil/gas)
- ✓ Utilizing NITEC developed COZ simulator funded by DOE
- ✓ **120 sands have been simulated to date; 29 fields**
  - ✓ **5 oil only, 109 gas only, 6 oil/gas**
- ✓ Each sand modeled separately
  - ✓ Utilized proprietary map data from BOEM under an NDA
  - ✓ Sand model calibrated to BOEM reported OOIP (OGIP) and cumulative production at depletion (OIP or GIP)
  - ✓ Depletion pressure estimated based on IHS pressure test data
  - ✓ Calibrated model used to investigate multiple CO_2 injection scenarios to maximize CO_2 storage

Task 5.0 Executive Summary-2 (WIP)



- OOIP 1.6 to 44.8 MMSTB per field; 455.4 MMSTB total (34% all depleted fields)
- OGIP 1.2 to 1,259 BSCF per field; 14.2 TSCF total (19% all depleted fields)
- 1 to 20 sands per field

Task 5.0 Executive Summary-3 (WIP)

86 columns per sand

SN_FORMSAND	SAND_NAME	ASSESSED	SDDATE	SDYEAR	SDDATEH	SDYEAREH	WELLAPI
2	1761_BA001A_6500_1M	Y	09/02/1970	1970	09/02/1970	1970	427043003600

BOEM_FIELD	FCLASS	FSTAT	FSTRU	FTRAP1	FTRAP2	FDDATE	FDYEAR
BA001A	PDN	E	K	C		09/01/1970	1970

EIAID	PLAREA	SAND	PLAY_NUM	PLAY_NAME	POOL_NAME	CHRONOZONE	PLAY_TYPE
805001	WGM	6500_1M	1761	MLU_P1	1761_BA001A	MLU	P1

P_J	SD_TYPE	WDEP	P_RECOIL	P_RECGAS	P_RECBOE	P_CUMCOIL	P_CUMGAS
P	G	113	347,911	21,585,148	4,188,685	347,911	21,585,148

P_CUMBOE	P_REMOIL	P_REMGAS	P_REMBOE	J_RECOIL	J_RECGAS	J_RECBOE	DISCOIL
4,188,685	0	0	0	0	0	0	347,911

DISCGAS	DISCBOE	SS	THK	TAREA	TVOL	OTHK	OAREA
21,585,148	4,188,685	6,457	10.4	1,283	13,325		

OVOL	GTHK	GAREA	GVOL	DRIVE	RES_TYPE	POROSITY	SW
	10.4	1,283	13,325	WTR	N	0.32	0.23

PERMEABILITY	PI	TI	SDPG	SDTG	RSI	YIELD	PROP
576	3,941	175	0.608	1.655		16.1	0.0000

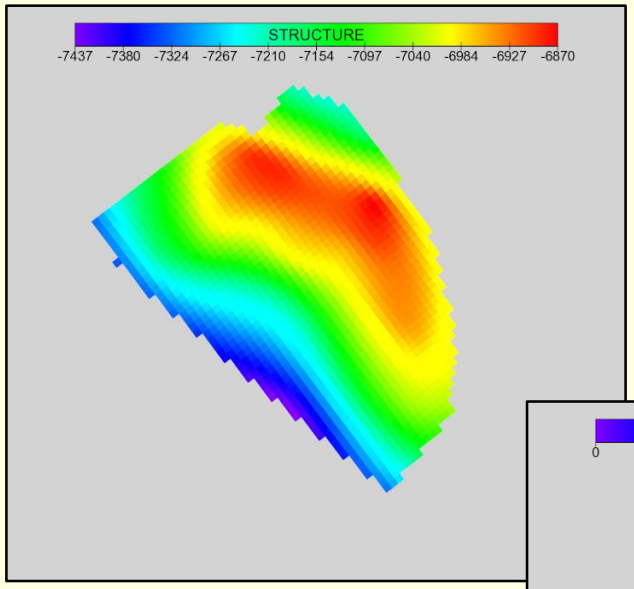
GOR	SPGR	API	BGI	BOI	RECO_AF	RECG_AF	OIP
62	0.63		235.30			1,619.899	

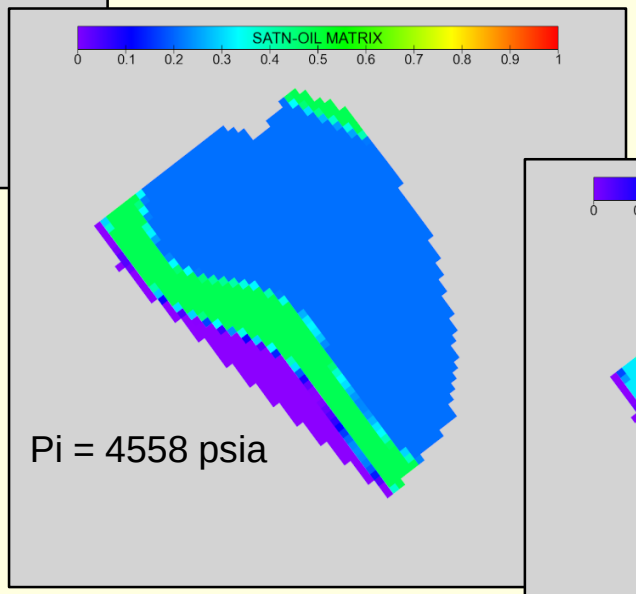
GIP	ORF	ORECO	ORECG	ORP	GRF	GRECO	GRECG
33,652,530					0.64	347,911	21,585,148

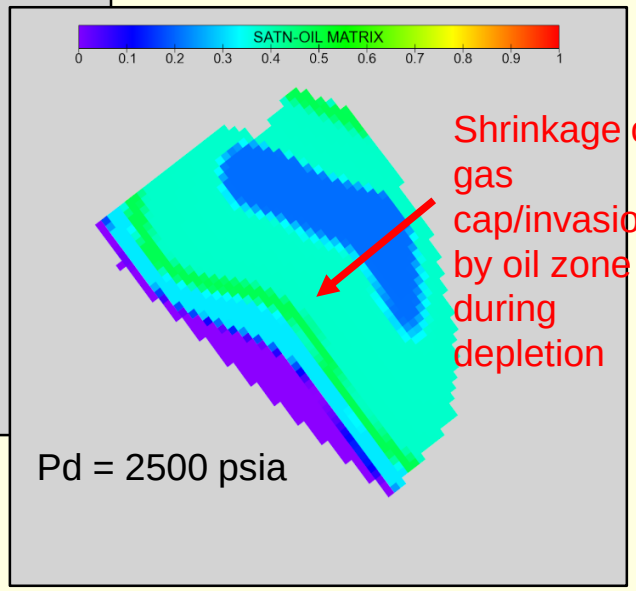
GRP	NCNT	UCNT	SCNT	TCNT	BHCOMP
62.00	1	0	0	1	3

Task 5.0 Executive Summary-4 (WIP)

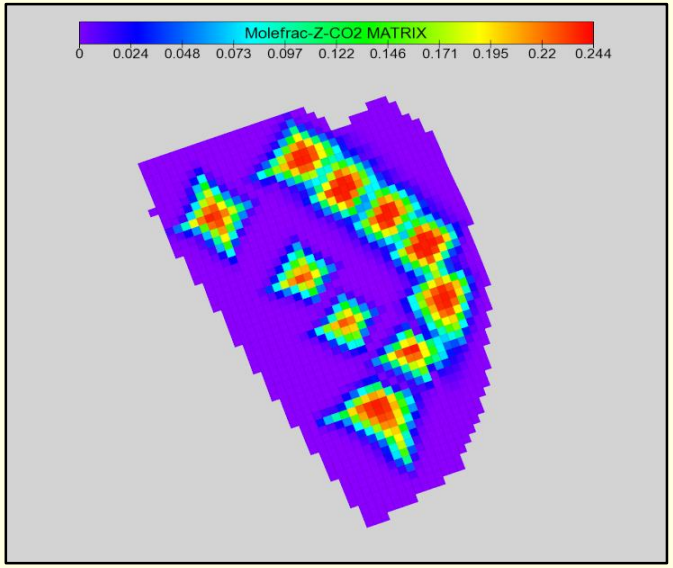
Property	BOEM	Model	Difference	% Difference
OOIP,MMSTB	10.011	10.07	-0.059	-0.59
OGIP,BSCF	54.021	54.029	-0.008	-0.01
P_CUMOIL,MMSTB	1.401	1.424	-0.023	-1.64
P_CUMGAS, BSCF	32.847	32.291	0.556	1.69
P_CUMWAT, MMSTB	1.970	1.880	0.090	4.57
Current OIP,MMSTB	8.610	8.546	0.064	0.74
Current GIP,BSCF	22.197	21.738	0.459	2.07

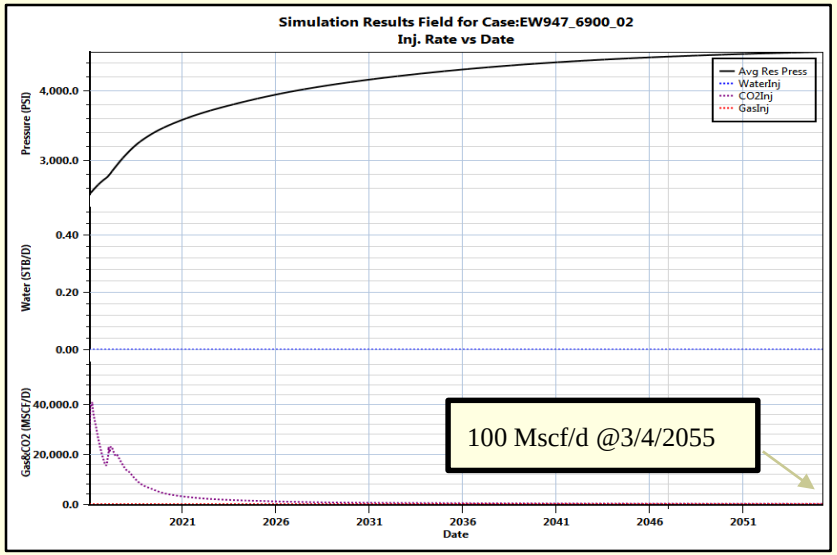


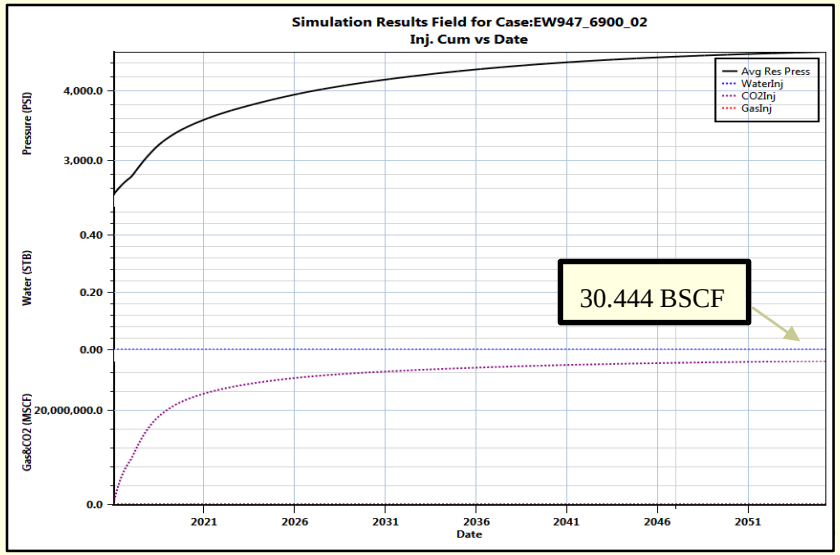




Task 5.0 Executive Summary-5 (WIP)

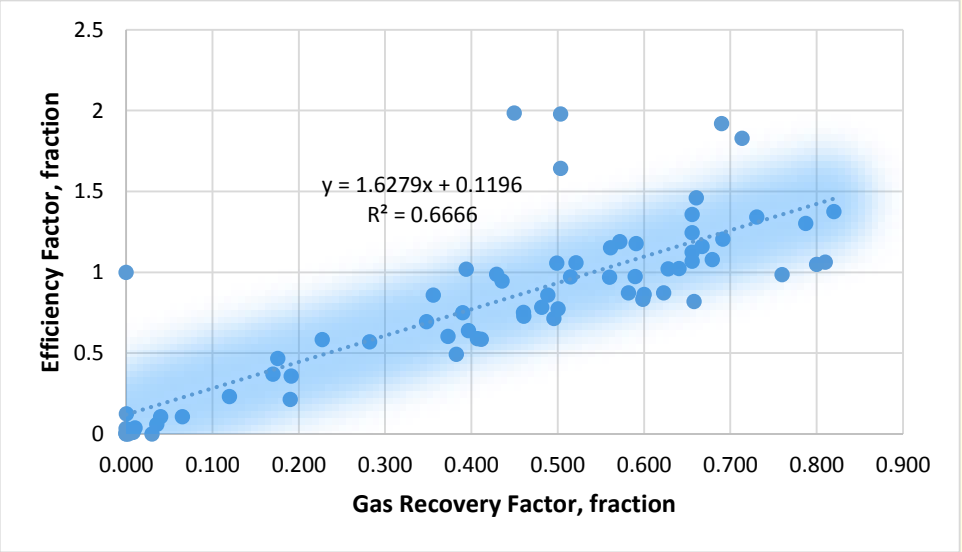






Task 5.0 Executive Summary-6 (WIP)

- ✓ Results indicate much higher $E_{oil/gas}$ in gas sands than estimated in Task 4.0
- ✓ $E_{oil/gas}$ appears to correlated well with gas recovery factor.
  - ✓ This will be useful in better estimating gas storage volumes in non-simulated gas sands.



$E_{oil/gas}$ = CO_2 storage volume/OGIP

$$G_{CO2} = A\ h_n\ f_e\ (1\text{-}S_w\ )B\ \rho\ E_{oil/gas}$$

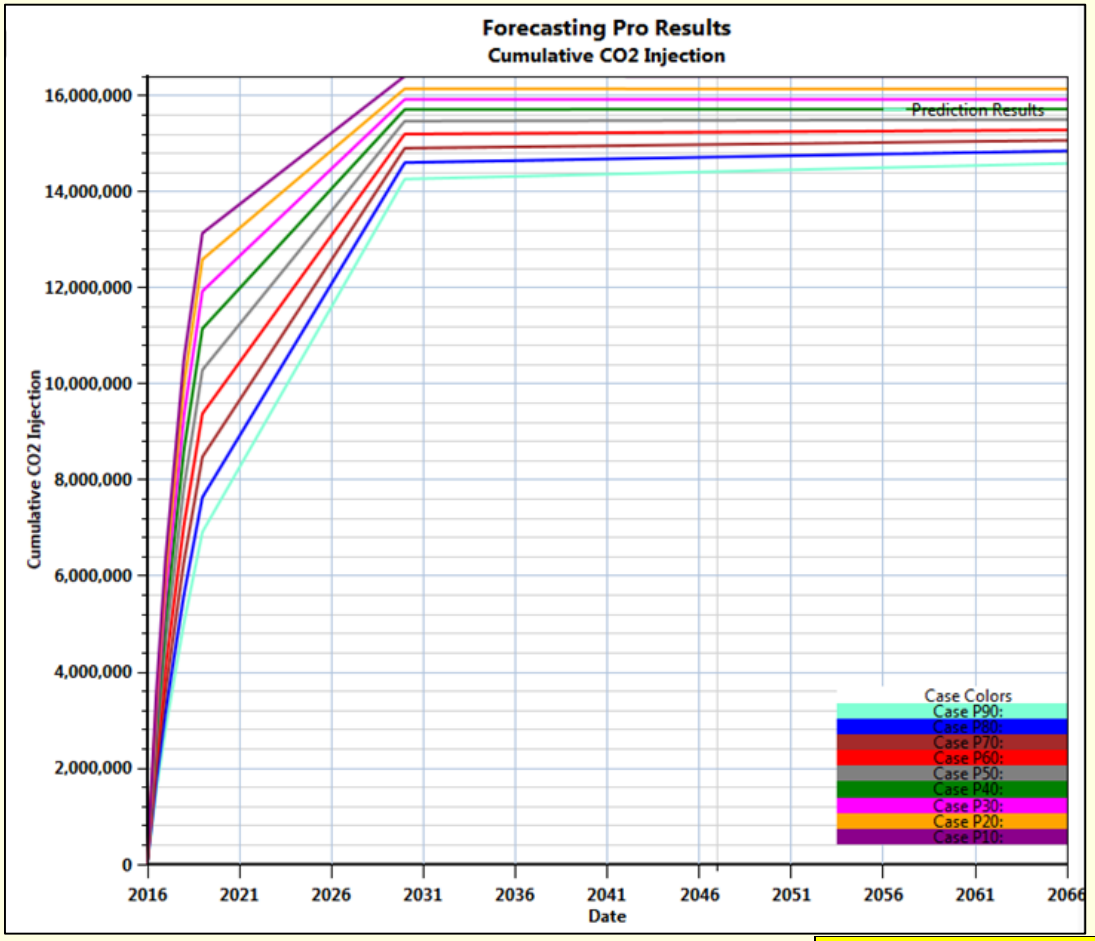
Task 5.0 Executive Summary-7 (WIP)

Uncertainty Analysis

Parameter	Uncertainty, %
Porosity, fraction	+/- 5
Permeability, mD	+/- 50
Bottom-hole Injection Pressure, psia	+/- 10
Maximum Well CO_2 Injection Rate, Mscf/d	+/- 50
Maximum Field CO_2 Injection Rate, Mscf/d	+/- 50
SORM, fraction (oil sands only)	+/- 50

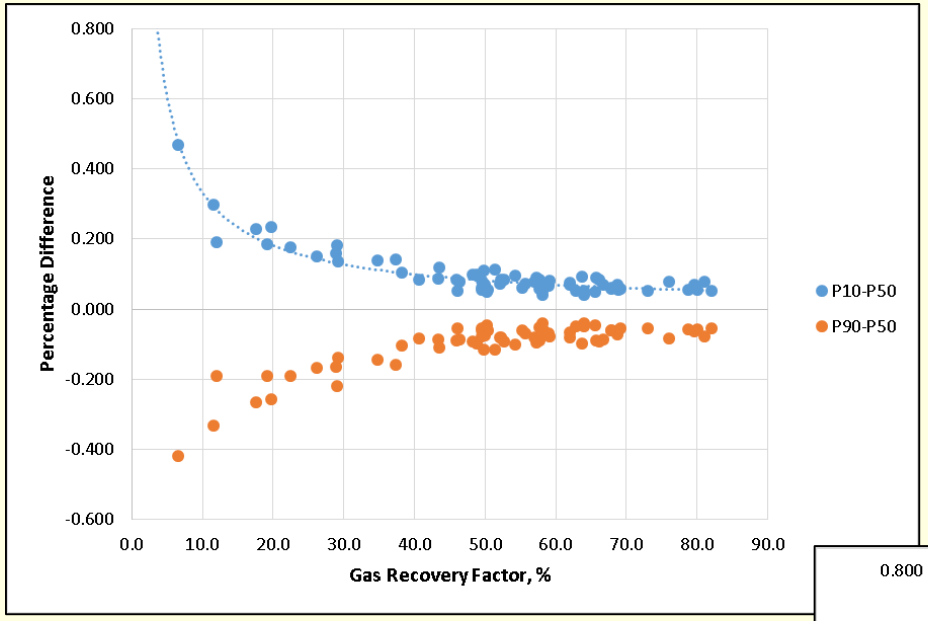
Parameter	Base case	Minimum	Maximum
Porosity, fraction	0.27	0.2565	0.2835
Permeability, mD	15.00	7.50	22.50
Bottom-hole Injection Pressure, psia	5,033	4,530	5,536
Maximum Well CO_2 Injection Rate, Mscf/d	20,000	10,000	30,000
Maximum Field CO_2 Injection Rate, Mscf/d	80,000	40,000	120,000

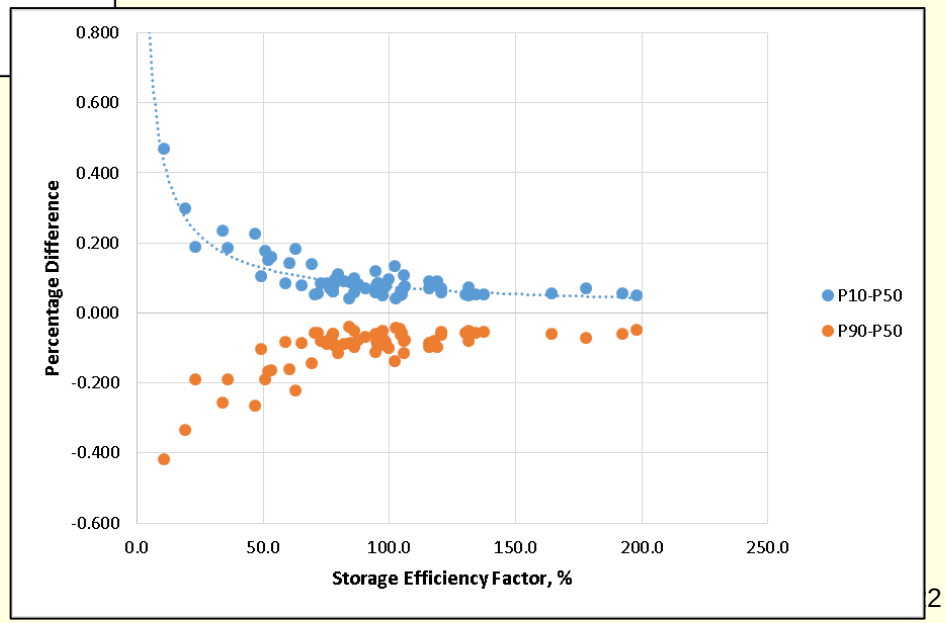
Task 5.0 Executive Summary-8 (WIP)



Probability	Cumulative CO_2 injection, BSCF
Base case	15.52
P10	16.13
P50	15.50
P90	14.58

Task 5.0 Executive Summary-9 (WIP)





Task 6.0 Purpose and Goals

Purpose: Evaluate CO_2 storage in conjunction with CO_2-EOR

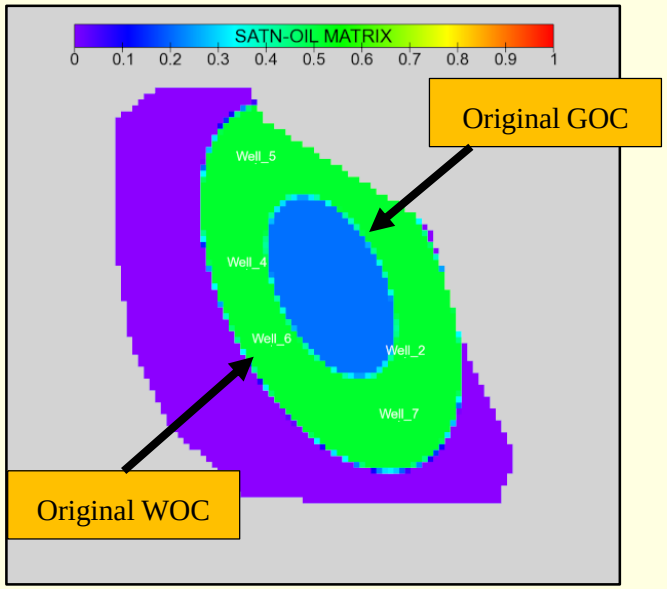
Goal: Determine impact on maximum CO_2 storage volumes for depleted sands when CO_2 storage injection is preceded by CO_2-EOR operations.

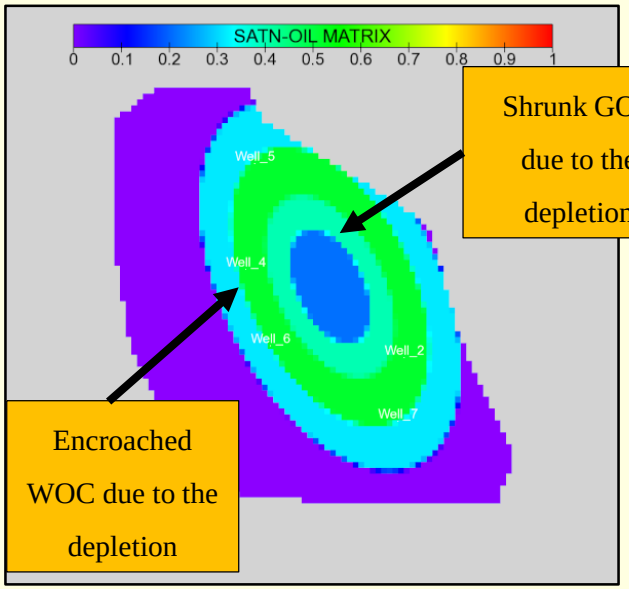
Task 6.0 Executive Summary-1 (WIP)

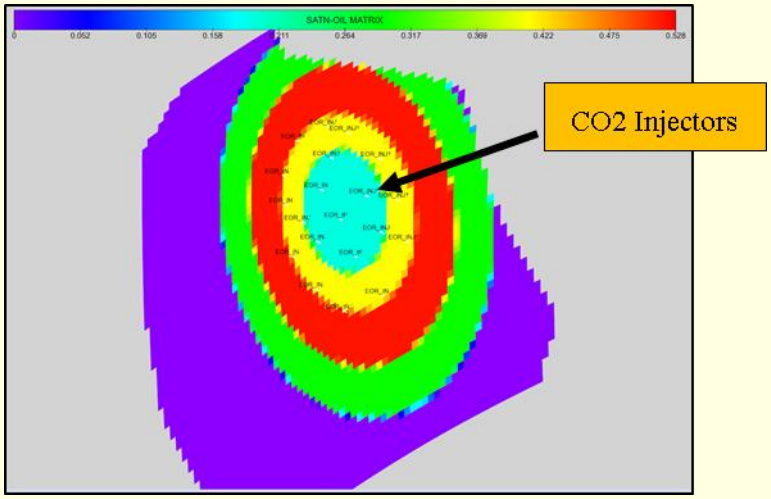
- ✓ Selected 5 oil sands for CO_2-EOR evaluation

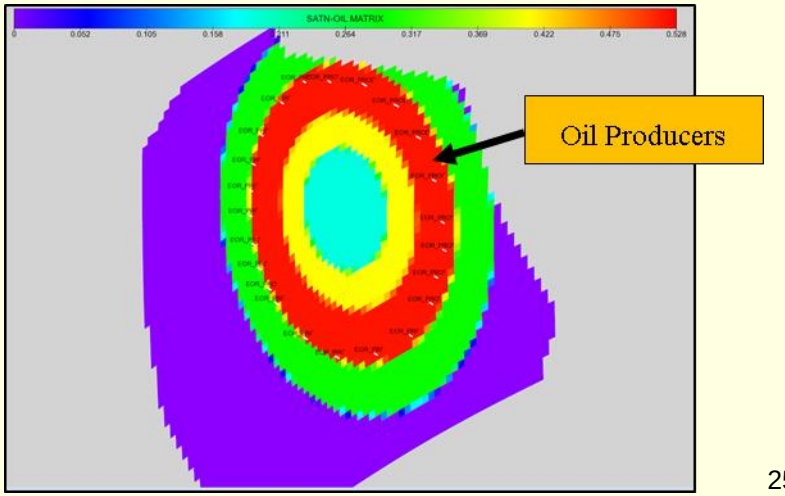
Field_Sand Name	OOIP	OGIP	Cumulative Oil Production	Primary Oil Recovery	Initial Pressure	Depletion Pressure	Depth
	MMSTB	BSCF	MMSTB	%	psia	psia	ft ss
EW947_8100L	33.6	17.3	1.4	4.1	5,443	3,200	8,350
GI020_X	19.3	NA	7.4	37.0	9,565	3,750	12,631
MP253_LK1	30.8	2.4	0.05	0.2	4,040	4,020	8,656
VR348_AB4	14.2	NA	0.42	2.9	2,480	1300	5,300
MP306_K10	17.0	NA	3.8	22.0	2,395	950	5,117

Task 6.0 Executive Summary-2 (WIP)

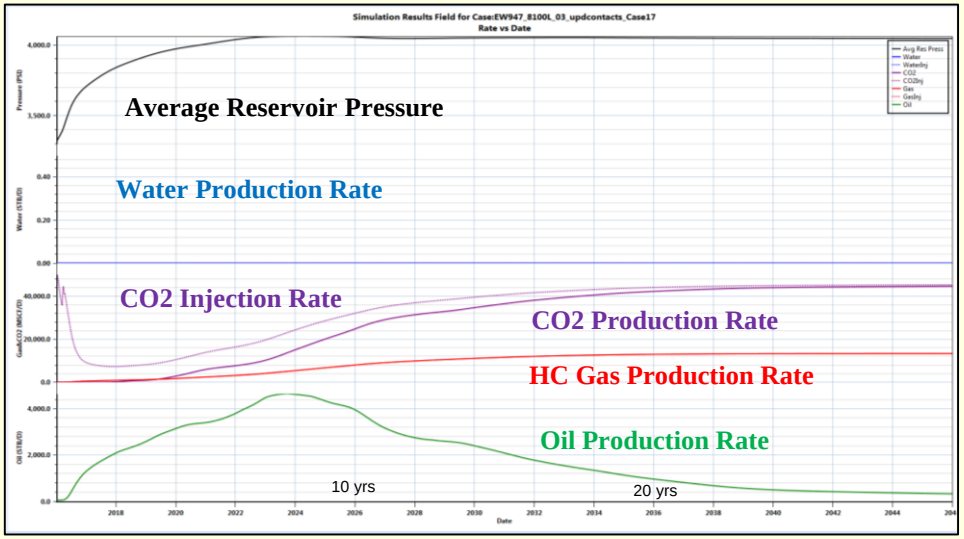


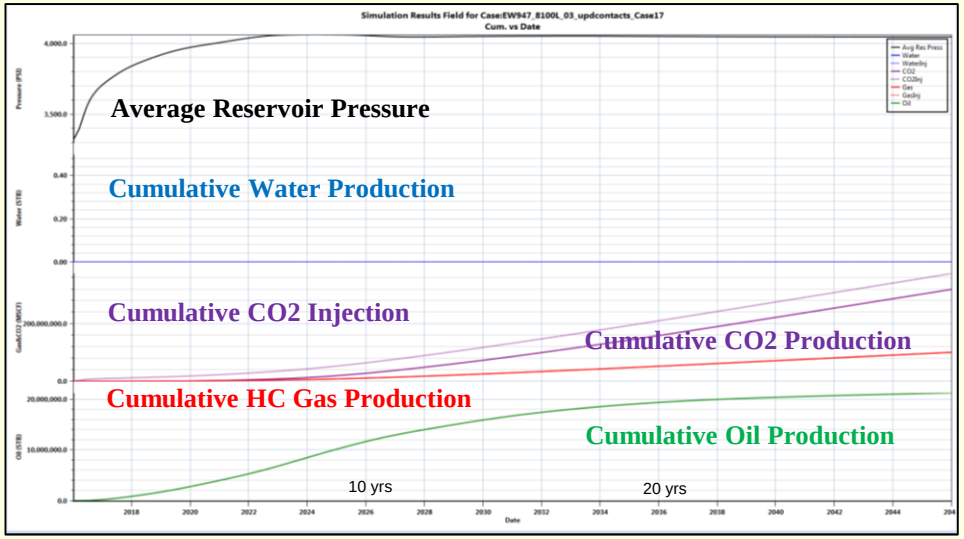




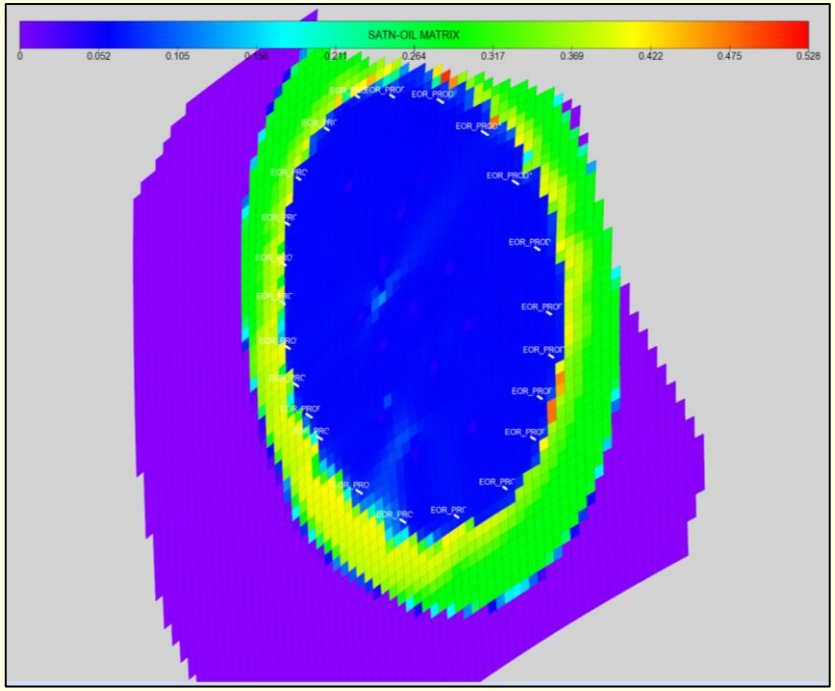


Task 6.0 Executive Summary-3 (WIP)



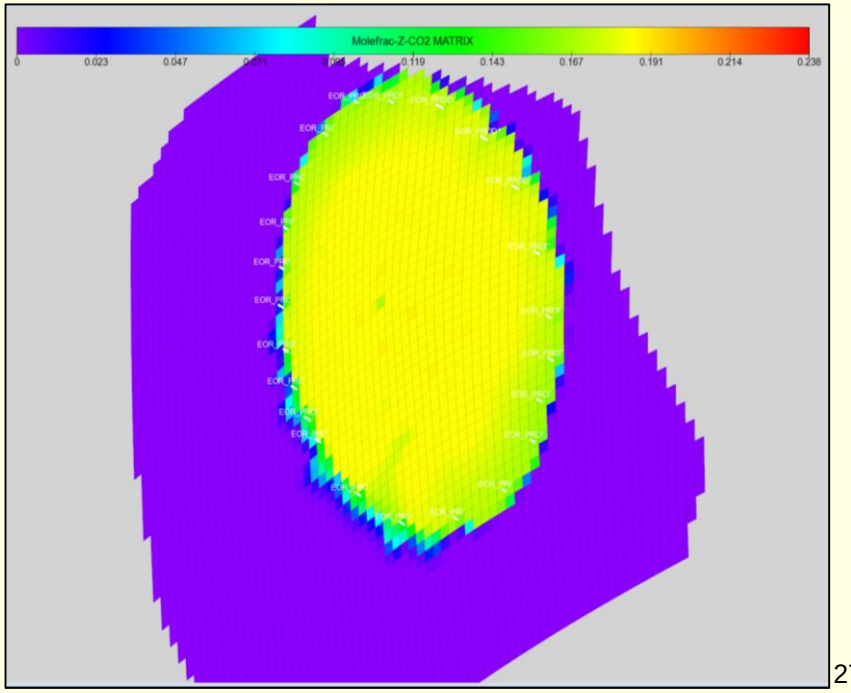


Task 6.0 Executive Summary-4 (WIP)



Oil Saturation at End of CO_2-EOR

CO_2 Concentration at End of CO_2-EOR

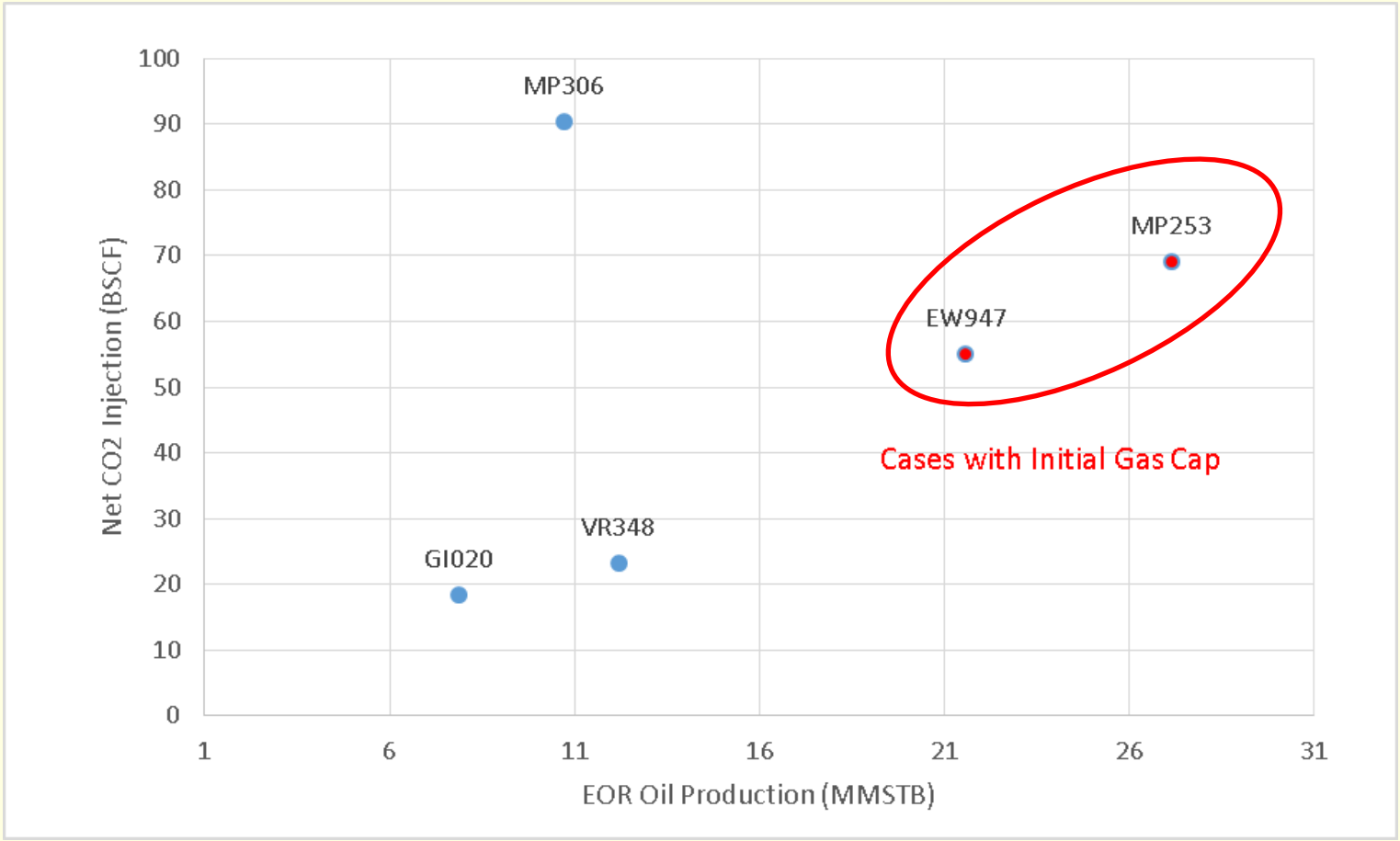


Task 6.0 Executive Summary-5 (WIP)

Field_Sand Name	OOIP	Primary Oil Production	CO_2-EOR Oil Production	CO_2 Storage after Primary	CO_2 Storage during/after CO_2-EOR	Incremental CO_2 Storage
	MMSTB	MMSTB	MMSTB	BSCF	BSCF	BSCF
EW947_8100L	33.6	1.4	21.2	20.6	67.1	46.5
GI020_X	19.3	7.4	7.5	16.5	33.4	16.9
MP253_LK1	30.8	0.05	26.77	0.044	71.6	71.56
VR348_AB4	14.2	0.42	11.8	2.4	25.0	22.6
MP306_K10	17.0	3.8	10.53	16.1	90.4	74.3

Sorm = 6.0%

Task 6.0 Executive Summary-6 (WIP)



The END

Thank you!