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Buoyant storage in the western portion of the Gulf of Mexico

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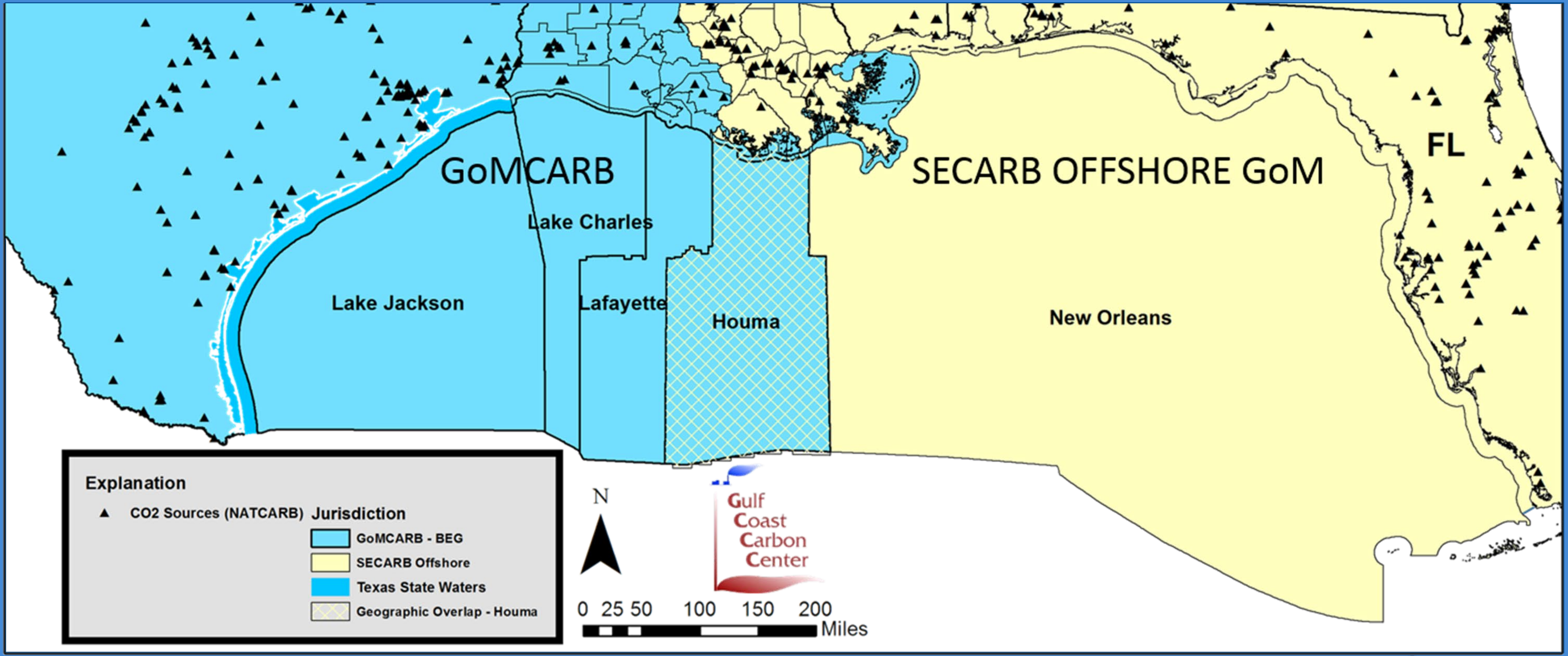
GoMCarb Project Area



Map courtesy of Tip Meckel

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Project Overview

- The goal is to assess the buoyant CO_2 storage resource for the western portion of the Gulf of Mexico.
- The plan is to use a modified version of the U.S. Geological Survey CO_2 storage resource assessment methodology.
- The method was first applied to lower Miocene strata as a test using real data where available and gross estimates where work is ongoing.

- The buoyant storage resource is small relative to the residual storage resource.
  - Pore volume within traps are orders of magnitude less than pore volume of saline formations
  - However more CO_2 will be stored in a smaller region during buoyant storage relative to residual storage within the same saline formation or region.

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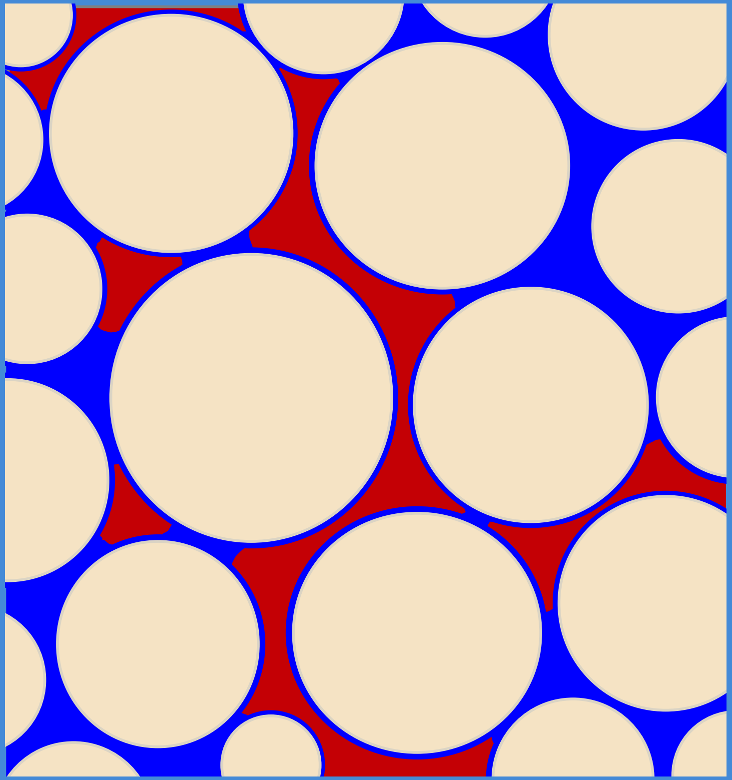
Buoyant Storage

Buoyant Trapping

CO_2 fills pore space, held in place by top and lateral seals



Beige = sand grains
Blue = water
Red = CO_2

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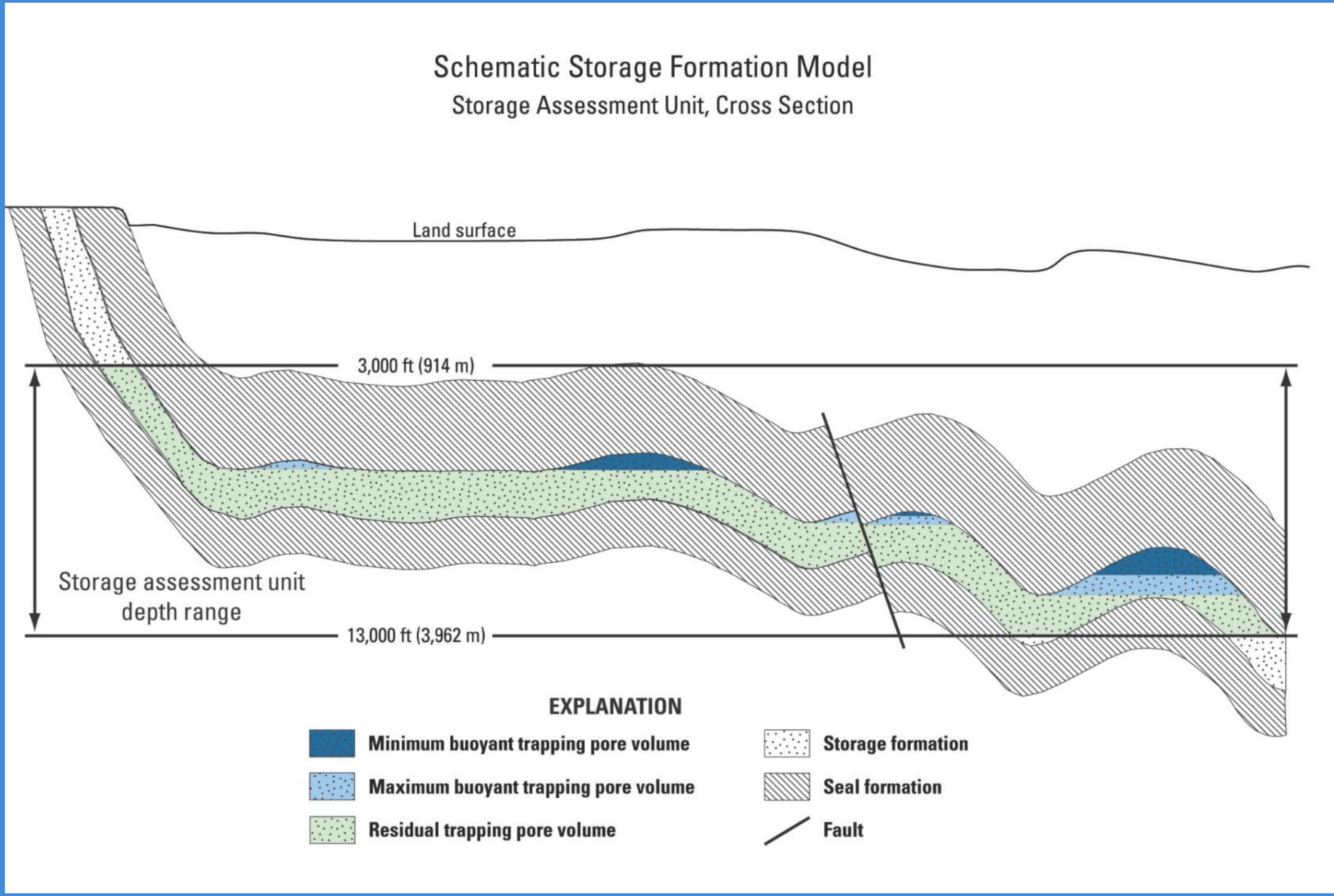

Brennan et al., 2010

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Approach

- The USGS buoyant CO_2 storage assessment methodology is fully probabilistic.
- This means that we use ranges for all inputs and use those ranges to create probability distributions.
- These distributions are then sampled using a Monte Carlo simulation that chooses values from those distributions for inputs into the storage equation, which is then run for thousands of iterations to generate a distribution of buoyant storage values.

The equation that is used here is basic:

Buoyant CO_2 storage = pore volume x storage efficiency x CO_2 density

- To get to these input values, we use existing (e.g., petroleum production fields, structural maps, well logs, and seismic).

Buoyant Storage Calculation

- Buoyant CO_2 Pore Volume
- Buoyant CO_2 Storage Efficiency
- Buoyant CO_2 Storage Volume
- Density of CO_2
- Buoyant CO_2 Storage Resource

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Data Required

- To follow that flow chart and equation, data are compiled from various sources.
- The main data source for the 2013 USGS CO_2 storage resource assessment was the Nehring dataset of significant oil and gas reservoirs of the United States.
- This dataset contains:
  - *production data from reservoirs, and*
  - *field average values of: porosity, depth, thickness, temperature, and pressure.*
- Produced petroleum, and reserves, serve as the minimum value for the buoyant pore volume.
- For the 2013 USGS CO_2 storage resource assessment, the “most likely” value which defined the mode of our buoyant pore volume distribution, was the sum of produced, reserve, and undiscovered petroleum within our assessment unit.
  - *Undiscovered petroleum estimates came from the USGS oil and gas assessments. In this GoMCarb assessment we will rely on the Bureau of Ocean Energy Management’s undiscovered oil and gas assessments of the federal offshore.*
- The maximum value is purposefully large. In this case we used the area of all extant petroleum reservoirs and assumed that the average thickness and porosity from the USGS onshore lower Miocene assessment would hold buoyantly trapped CO_2.
  - *This value is just for informational purposes to complete the buoyant pore volume distribution and run the Monte Carlo model.*

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Storage Efficiency Rationale

- For the USGS CO_2 storage assessment (2013), we used different storage efficiencies for residual and buoyant storage (Blondes et al., 2013).
- We also assumed that the buoyant storage efficiencies could be relatively high due to the lack of mobility of the CO_2 within a trap (Blondes et al., 2013).
- Natural gas reservoirs, which commonly have 80% of the reservoir pore volume originally filled natural gas, can serve as a proxy for how much pore volume that CO_2 fills with buoyant storage.
- However, CO_2 can only fill the pores that is can enter.
- *Results from CO_2-Enhanced Oil Recovery (CO2-EOR) processes can be a proxy for understanding the pore volume that CO_2 can enter, this term is known as "sweep efficiency".*
- *Typically, the maximum sweep efficiency in CO2-EOR projects* is *50% of the pore volume.*
- Therefore, we assumed a maximum storage efficiency in buoyant storage of 40%.
- The minimum was assumed to be 20% with a mode value of 30%.

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Gulf of Mexico – Lower Miocene

- To start, we are looking at the lower Miocene strata in the state waters of Louisiana and Texas, and the Federal Offshore.
- This interval is a prolific gas producer, and has the potential for significant, relatively near shore, CO_2 storage.

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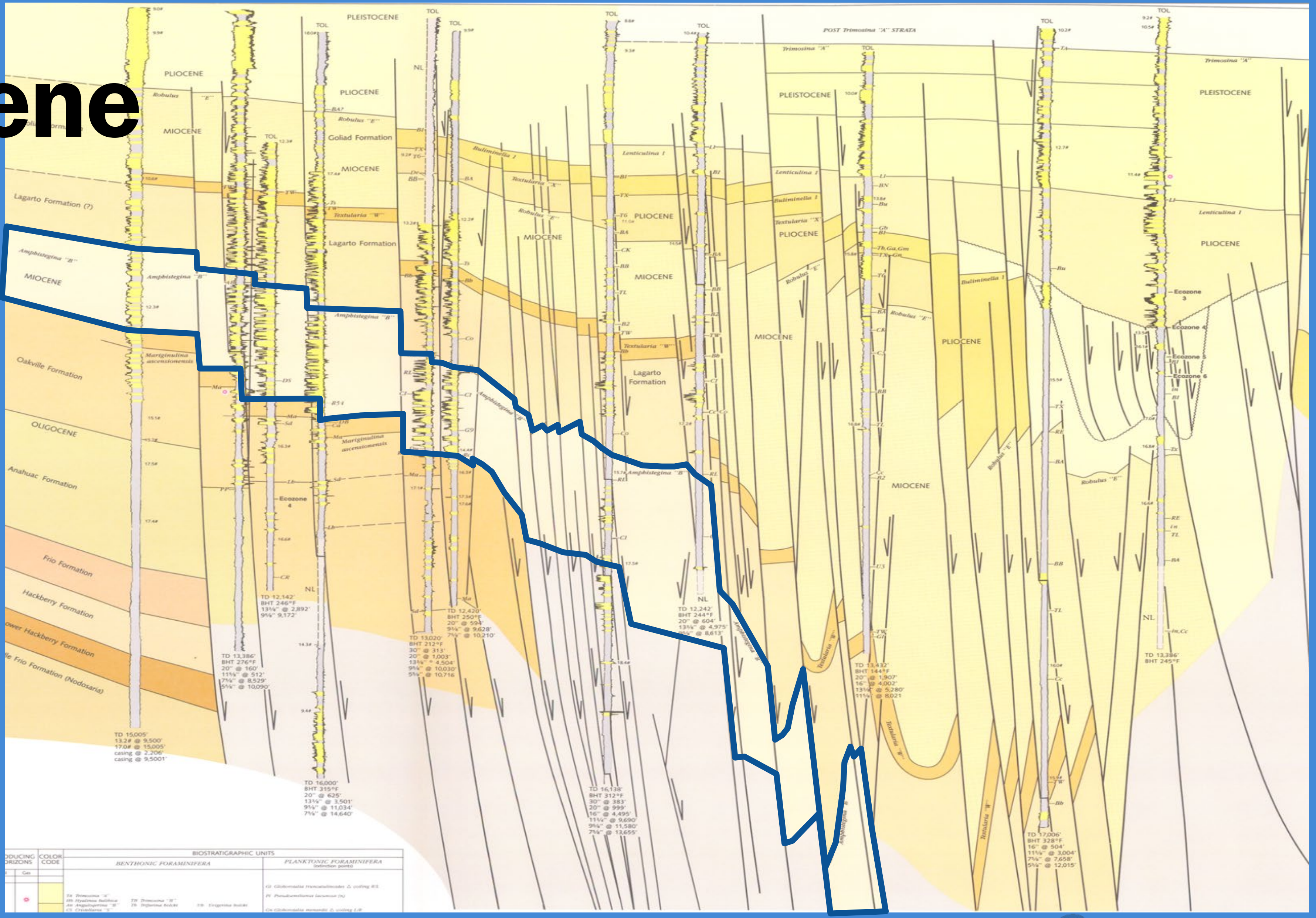
Lower Miocene

- This north-south cross section is from the Texas/Louisiana border at the shoreline and extends approximately 80 miles offshore. The lower Miocene is outlined in blue.

- The growth faults are identified from seismic interpretations, and the strata are correlated based on microfossils.

- The depth along the left side of the cross section is from essentially sea level to 14,000 feet below sea level.



Morton et al., 1990

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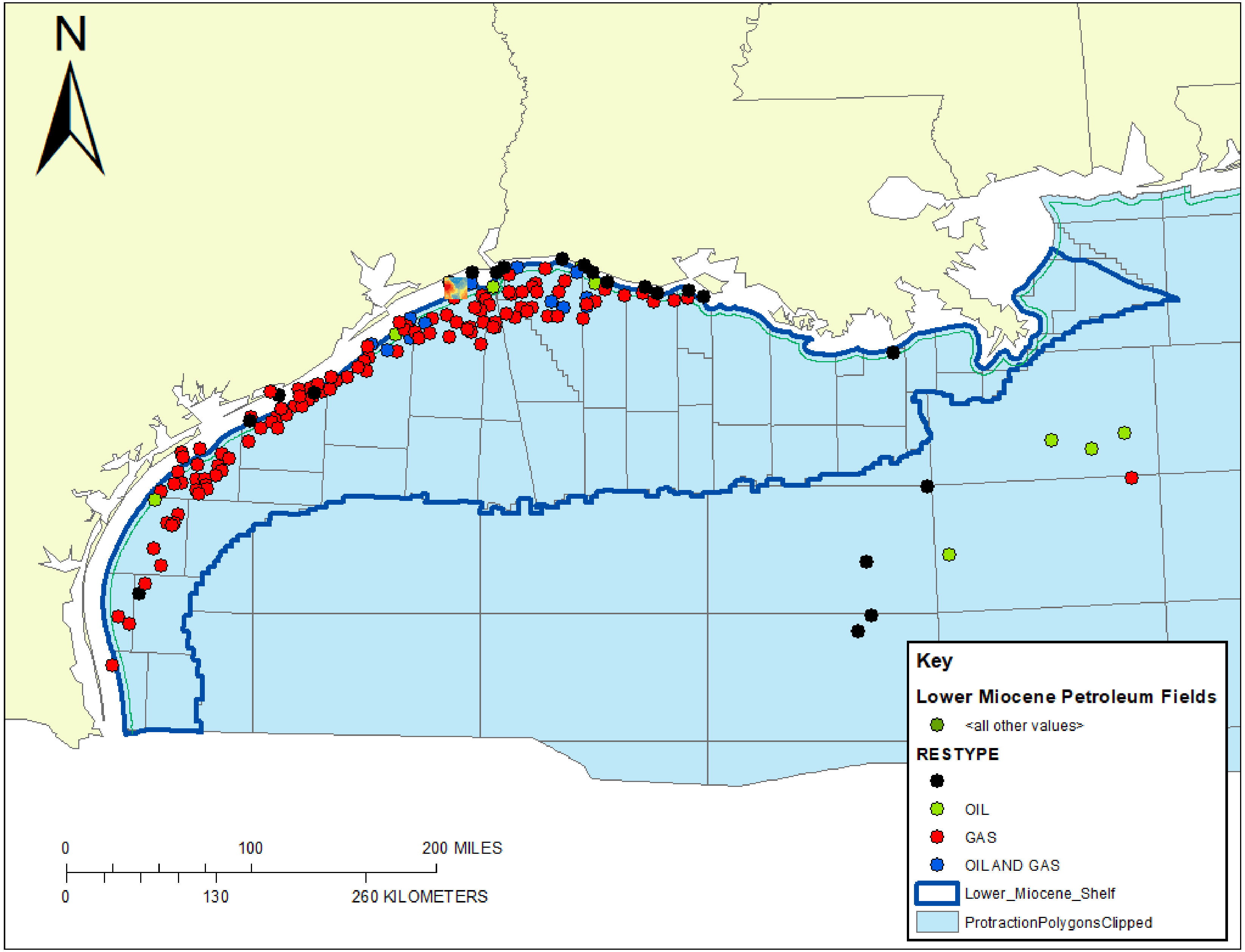

Estimation of Input Values

The initial stage of estimating the buoyant storage is to use data from petroleum reservoirs from the lower Miocene in the assessment area.

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Estimation of Minimum and Most Likely Buoyant Pore Volume Values

- Buoyant pore volumes are estimated using known petroleum production values, estimates of undiscovered petroleum, and estimates of maximum possible pore volumes.
- The oil and natural gas liquids (NGL) volumes are in thousands of barrels (MBBLS) and the gas volumes are in millions of cubic feet (MMcf)
- Production volumes are reported at surficial conditions typically, so they need to be transformed into subsurface or in situ volumes by multiplying by their respective formation volume factor (FVF).
- This was completed by running a Monte Carlo model to use the FVFs to convert the volumes to subsurface volumes, and then populate minimum and most likely the buoyant pore volume inputs discussed on the next slide.

1) Oil KR	MBBLS	83,600	220,000		
2) Gas KR	MMcf	13,700,000	20,000,000		
3) NGL KR	MBBLS	320,000	480,000		
	Units	Min	Most likely	Max	@Risk F(x)
4) Oil FVF	Dec. Frac	1.05	1.4	1.9	1.27914768
5) Gas FVF	Dec. Frac	0.0037	0.0047	0.009	0.00523316
6) NGL FVF	Dec. Frac	1.5	2.5	5	2.93212245
		Min	Most likely		
	Oil - In Situ Volume (ft^3)	599915143.6	1578724062		
	Gas - In Situ Vol (ft^3)	71694345757	1.04663E+11		
	NGL - In Situ Vol (ft^3)	5263746228	7895619342		
	Total In Situ Volume	77558007129	1.14138E+11		

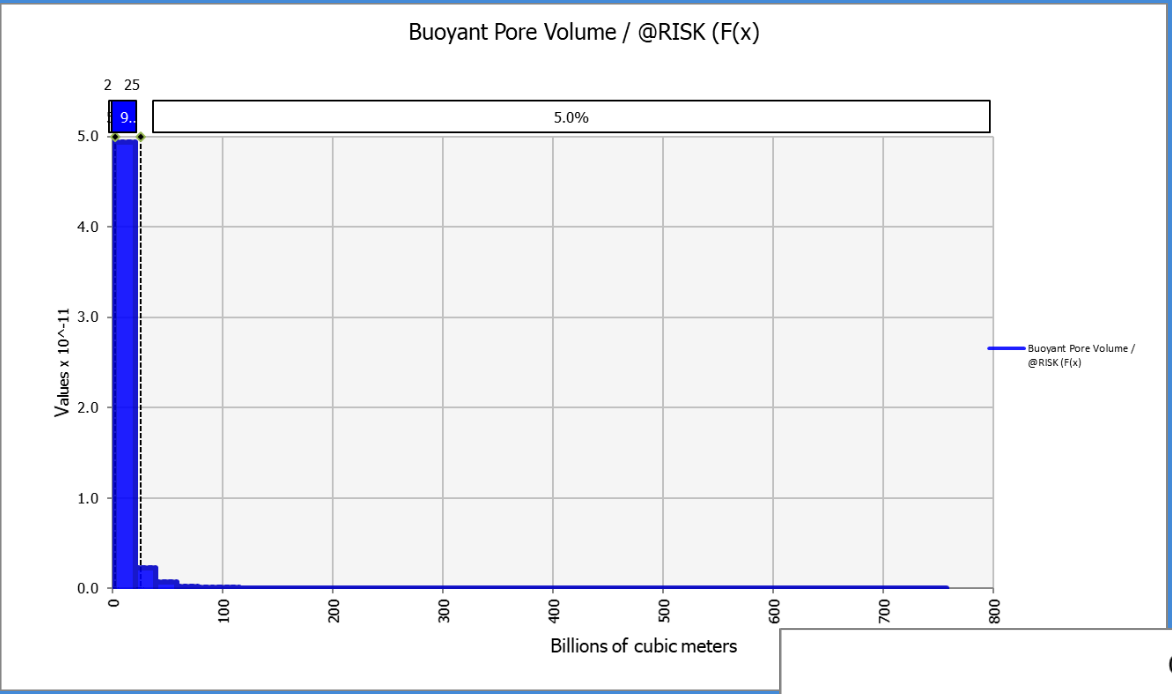
Estimation of Input Values

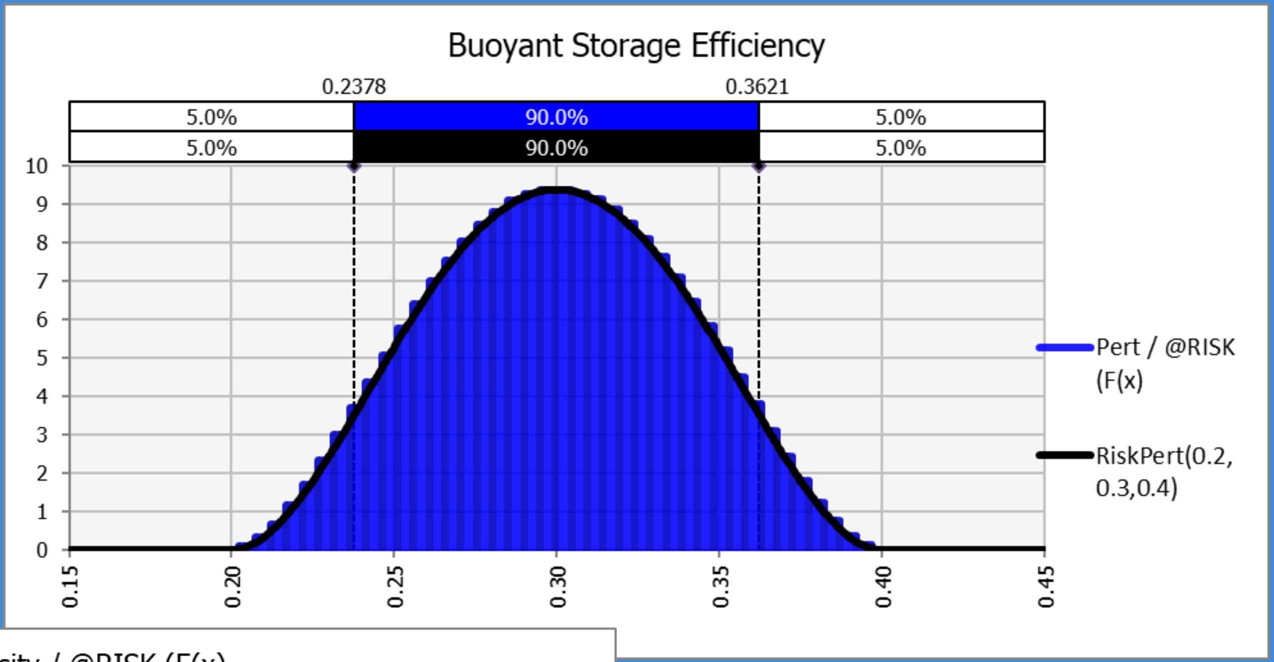
- For each iteration of the buoyant storage resource calculation in the Monte Carlo model, the minimum and most likely pore volumes are calculated using the simulation in the previous slide.
- The maximum value for the buoyant pore volume distribution is fixed, based on the calculation discussed earlier.
- These values create a distribution for each iteration of the Monte Carlo simulation of buoyant storage.
- The storage efficiency and CO_2 density values are chosen from their respective distributions to populate the equation:

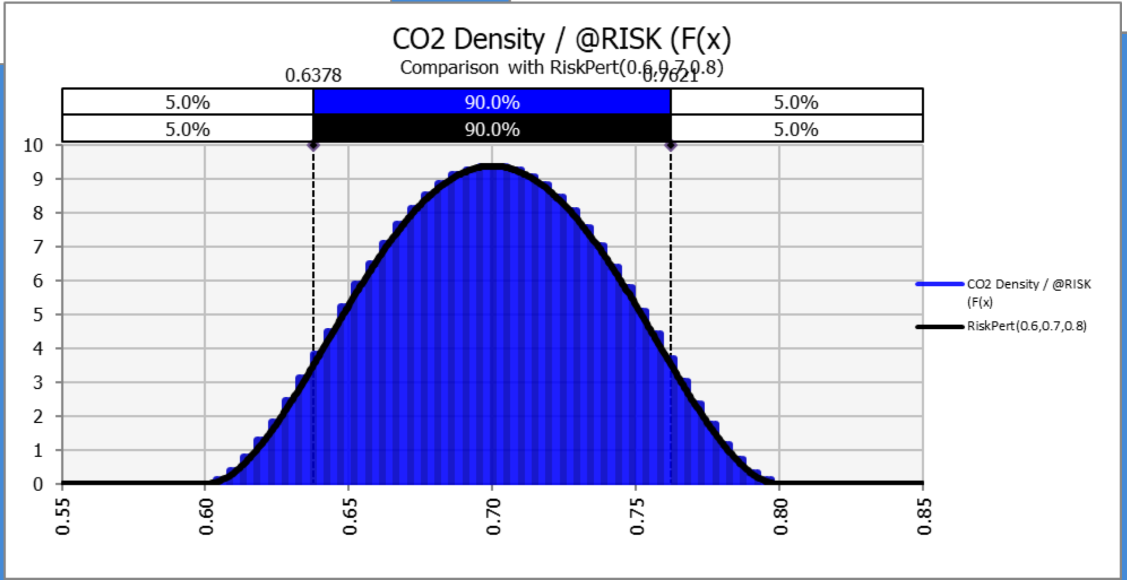
$$\text{Buoyant } CO_2 \text{ storage} = \text{pore volume} \times \text{storage efficiency} \times CO_2 \text{ density}$$

	Titles	Calcs							
	Input	Outputs							
	Min	Most likely	Max	μ	σ	mean	sd	@RISK (F(x)	
Buoyant Pore Volume	2,199,183,568	3,238,521,209	78,000,000,000	21	1	1,039,323,126	6,599,507,223	2,749,754,585	m3
Storage Efficiency	20%	30%	40%					0.351	storage efficiency (fraction)
CO2 Density	0.600	0.700	0.800					0.625	tonne/m3
				P95	P50	P5	mean		
			Buoyant CO2 Storage (Tons)	4.24E+08	9.08E+08	5.35E+09	1.76E+09	602,958,144	

Input Value Distributions







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Monte Carlo Output

Using the known produced and undiscovered petroleum in the assessment area, and an estimate of the maximum buoyant pore volumes the buoyant CO_2 storage resource for the lower Miocene in this assessment area in gigatons (Gt) would be:

Mean	P95	P50	P5
1.76	0.42	0.91	5.35

If the most likely value for the volume of produced, reserves, and undiscovered natural gas is increased from 20 trillion cubic feet (TCF) to 50 TCF, while keeping all the other inputs the same, the buoyant storage resource values (Gt) would be:

Mean	P95	P50	P5
1.69	0.45	1.08	4.82

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These values are informational/provisional only. Only to be used as an example of the model.

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Status and Results

- Currently, for the assessment inputs, we are relying petroleum production, BOEM's estimates of undiscovered volumes, and the input data from 2013 USGS CO_2 storage resource assessment of the lower Miocene.

- We are working on calculating buoyant pore volumes from interpretation of seismic data, which should lead to better defined buoyant pore volume distribution values.

- If we decide to use a method that attempts to capture the total thickness of porous strata within traps, then more data and estimates of buoyant pore volume within specific mapped traps will be required to estimate the most likely and maximum values. Other GoMCarb collaborators will be mapping closures along maximum flooding surfaces based on seismic and cross-sections of well data of the state waters, which should help estimating these pore volumes.

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Next Steps

- A more accurate accounting of most likely buoyant pore volume and estimates for maximum buoyant pore volume are needed to complete the assessment

- Currently we are discussing a more detailed estimate of trap volumes based on interpreted seismic data, which will provide storage within stratigraphic, structural/fault bounded, and salt dome traps.

    - Collaborators within GoMCarb are working on identifying spill points along maximum flooding surfaces along the Texas and Louisiana State waters.

    - The pore volumes within these traps can be used to create a different distribution of buoyant pore volume, more akin to a normal distribution instead of such an extreme logarithmic distribution.

    - The pore volumes can then be used as analogs to assess the areas without detailed mapped trap volumes.

- Once the lower Miocene is assessed, we will assess the other stratigraphic intervals.

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