IDENTIFICATION OF RESIDUAL OIL ZONES (ROZS) IN THE WILLISTON AND POWDER RIVER BASINS

DE-FE0024453

Mastering the Subsurface Through Technology Innovation & Collaboration: Carbon Storage & Oil & Natural Gas Technologies Review Meeting

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Critical Challenges. **Practical Solutions.**

PRESENTATION OUTLINE

- Benefit to the program
- Project overview
- Technical status
- Accomplishments to date
- Synergy opportunities
- Summary

BENEFIT TO THE PROGRAM

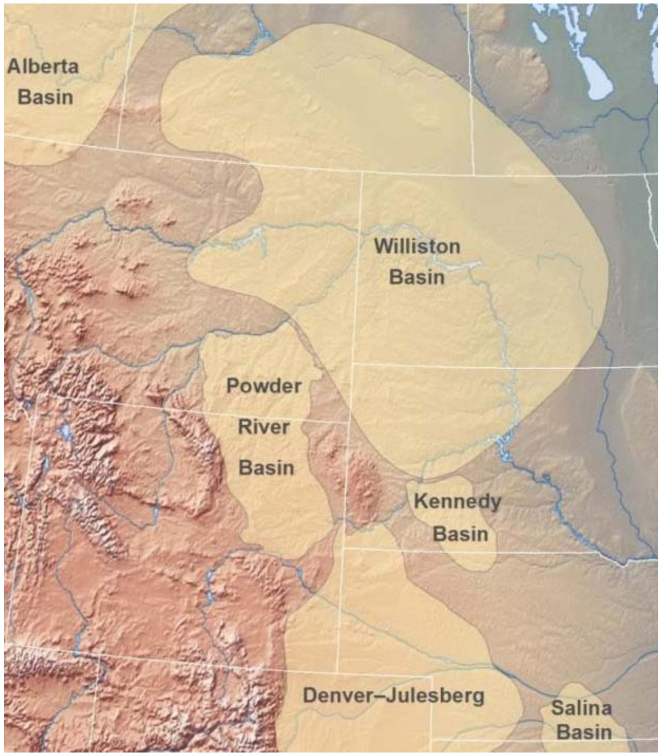
- Second and fourth goals of Carbon Storage Program:
  - Improve reservoir storage efficiency while ensuring containment effectiveness.
  - Develop best practices manuals (BPMs).

- Potential ROZs will be identified and evaluated for oil recovery and CO_2 storage resource potential.
  - CO_2 storage efficiency is improved through CO_2 enhanced oil recovery (EOR).
- A repeatable methodology will be developed and presented in a BPM.

PROJECT OVERVIEW
GOALS AND OBJECTIVES

Objectives:

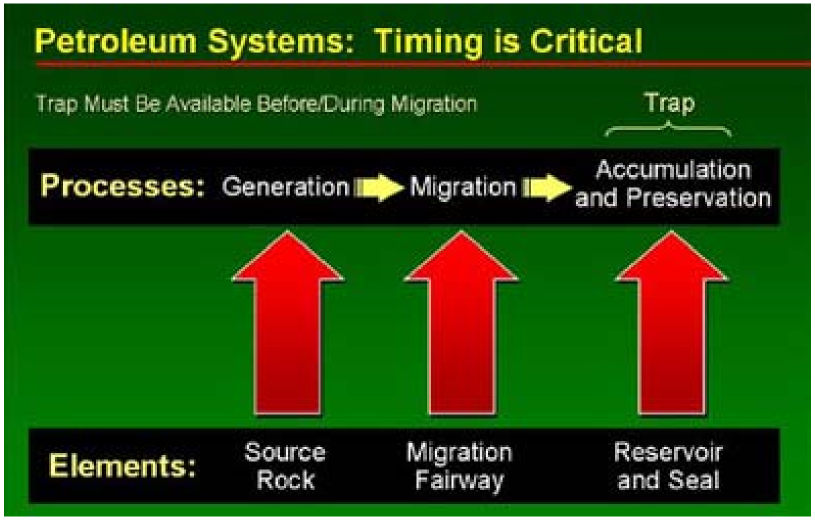
- Identify and characterize the presence and extent of potential ROZs in the Williston Basin (WB) and Powder River Basin (PRB).
- Estimate residual oil in place and CO_2 storage potential (Goal 2).
- Determine potential for CO_2 EOR in identified ROZs (Goal 2).
- Develop repeatable methodology for sedimentary basins to be included in a BPM (Goal 4).



TECHNICAL STATUS: BASIN MODELING

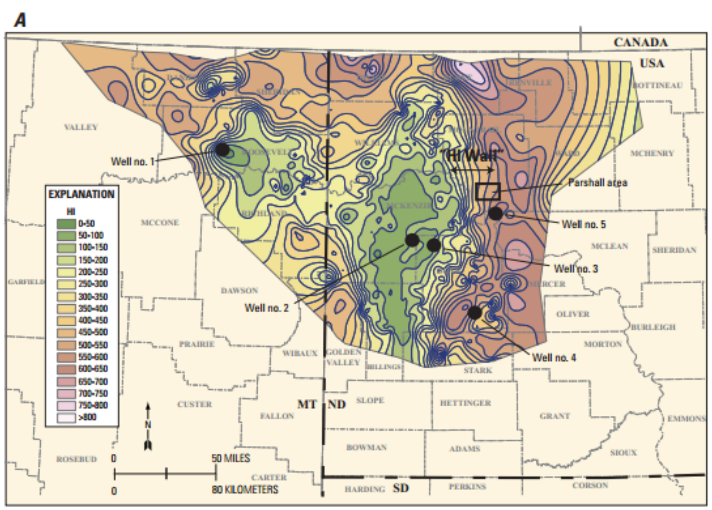
Provides a complete record of the evolution of a petroleum system, including:

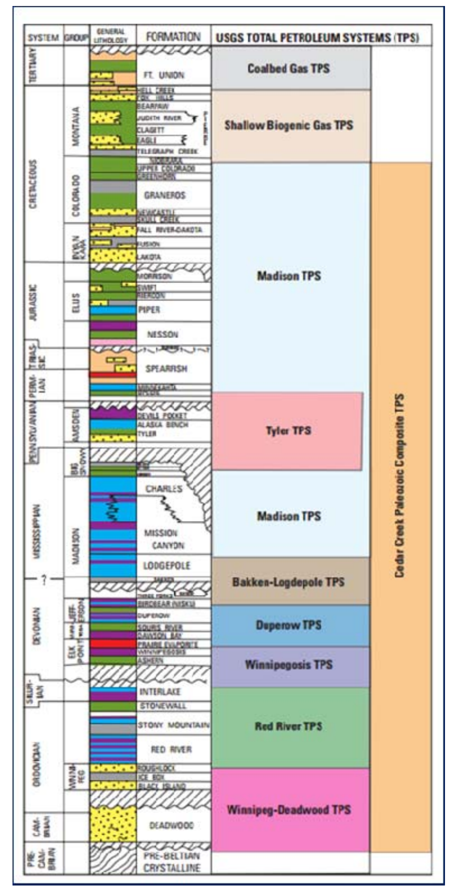
- Deposition and erosion.
- Pressure and compaction.
- Heat flow analysis.
- Petroleum generation.
- Fluid pressure, volume, temperature analysis.
- Reservoir volumetrics.
- Structural evolution.
- Generation, migration, and accumulation of hydrocarbons.



APPROACH

- Understand ROZs and previous work in basin modeling, both local and abroad.
- Translate geologic history of basins into an input for modeling.
- Gather data required for model construction.

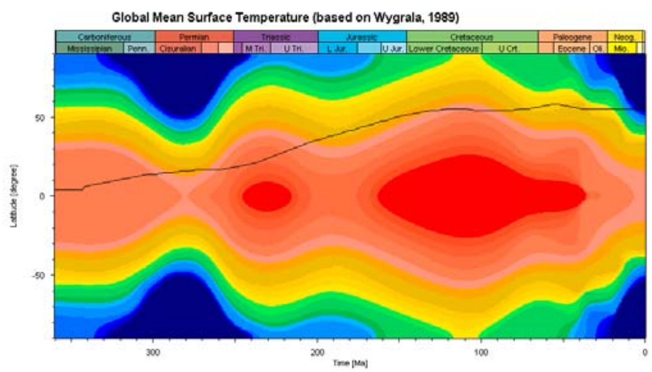




1-D AND 2-D MODELING

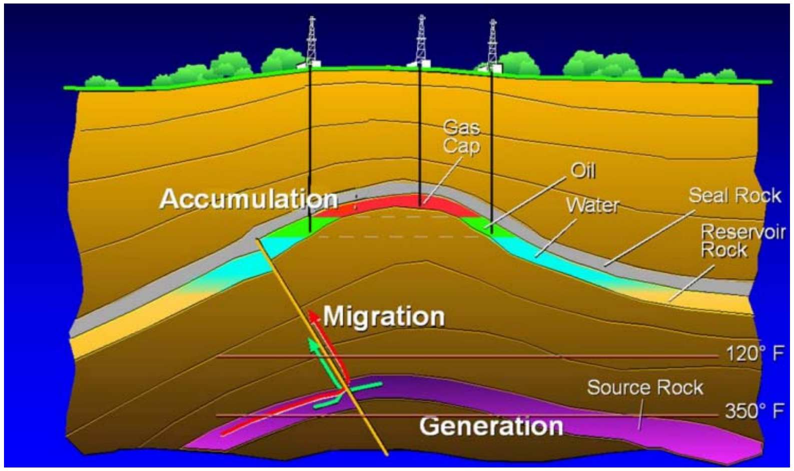
1-D Models

- Point location examination of:
  - Burial history.
  - Temperatures.
  - Boundary conditions.
  - Generation.



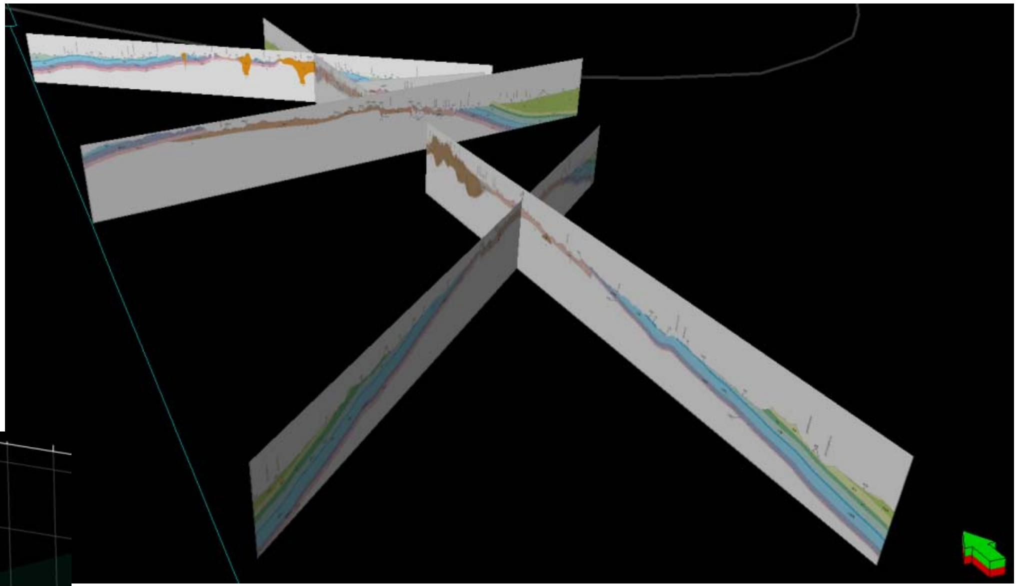
2-D Models

- Investigate generation and lateral migration.
- Faster simulation times than 3-D.

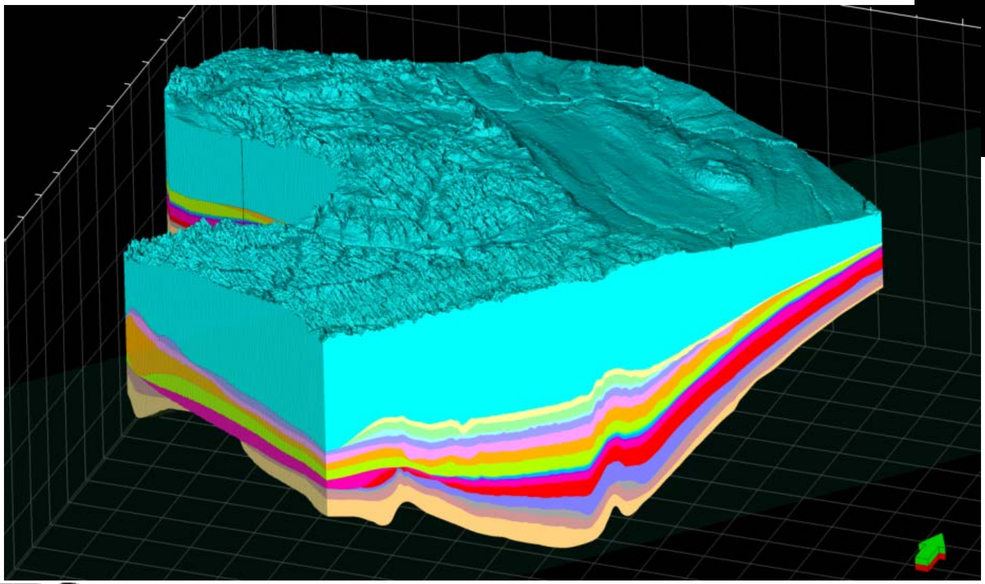


3-D MODELS – STATIC

- Provides more detail than a simplified 2-D model.
- Structural models have been developed.
- Generation and migration calibration ongoing.



Strobel et al. (1999) Black Hills cross-sections in context

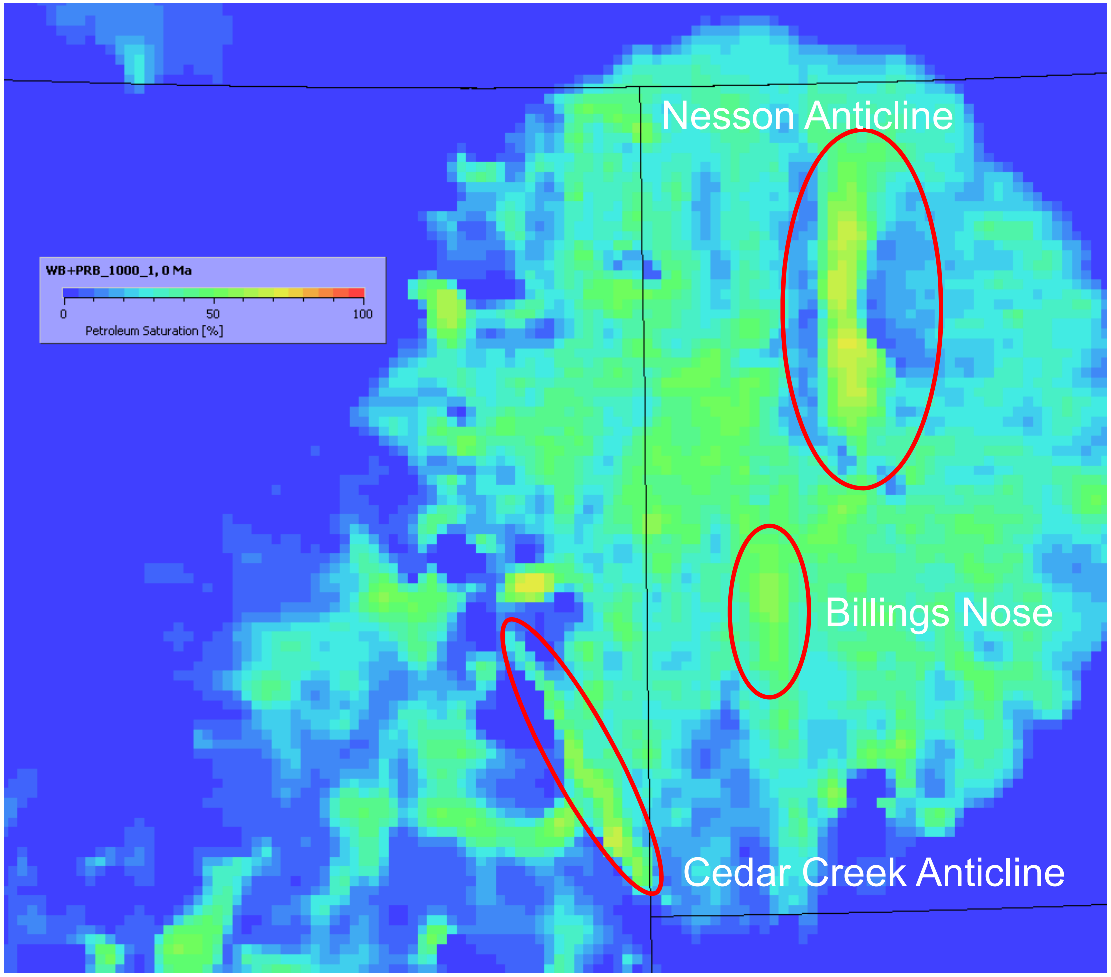


Williston Basin Structure Model
50x Vertical Exaggeration

3-D MODELS – SIMULATION

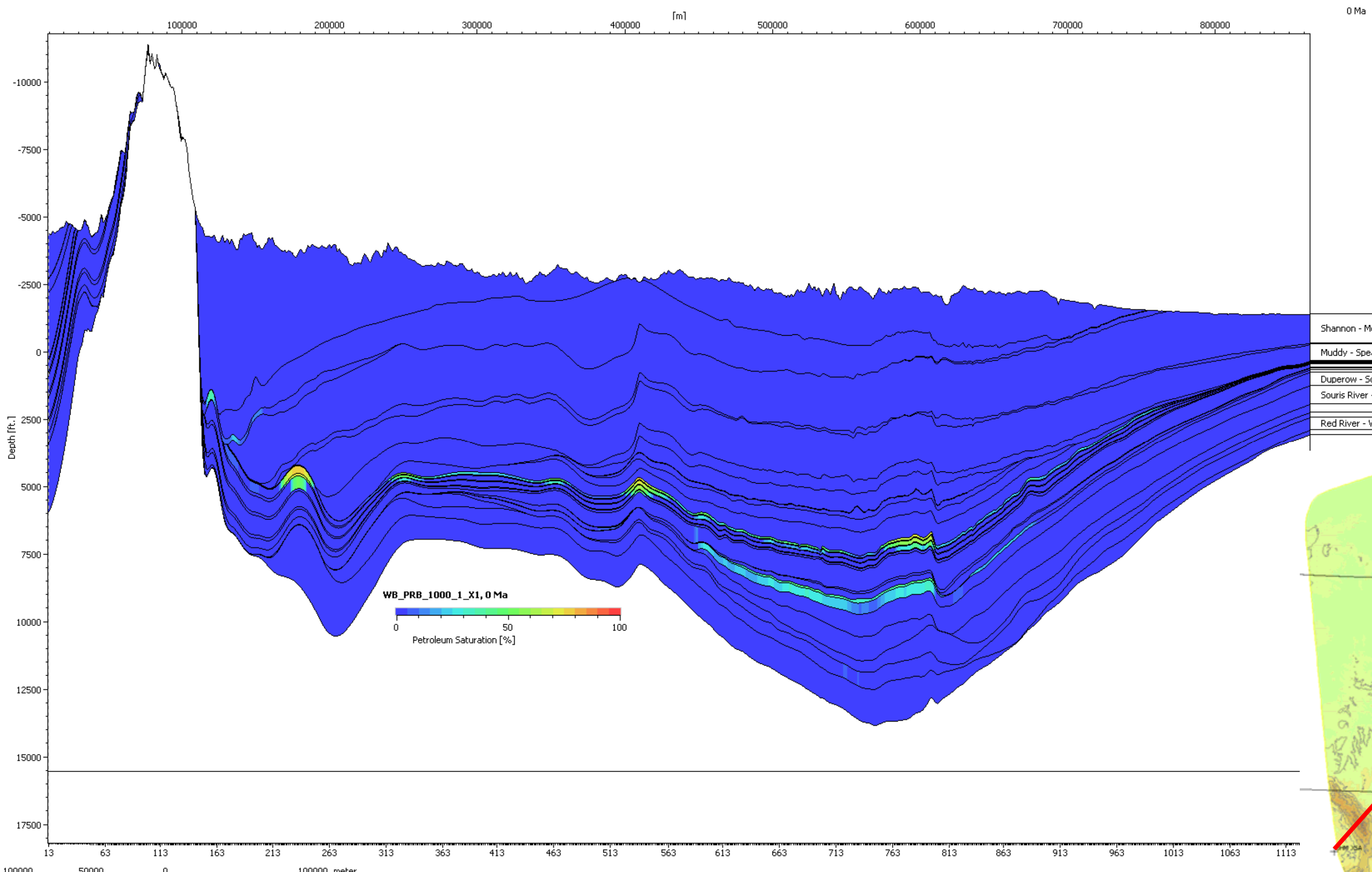
By simulating the entire history of the stratigraphic package, models produce outputs that largely agree with known accumulations of hydrocarbons.

- Produces most accurate pressure history.
- Has a long run time.

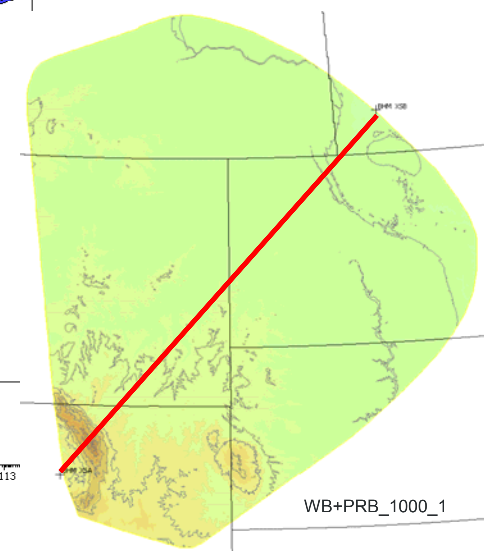


Mission Canyon, WB+PRB_1000_1

2-D MODELS – SIMULATION

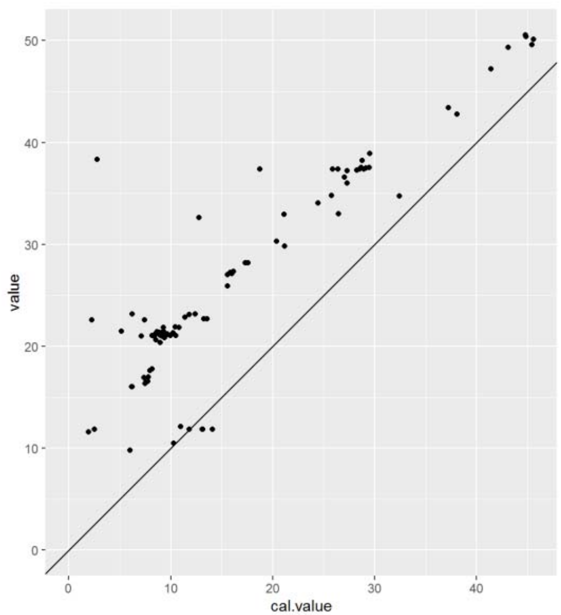


- Extracted 2-D models depict expulsion and migration throughout the Williston and Powder River Basins.



CALIBRATION – MOTIVATION

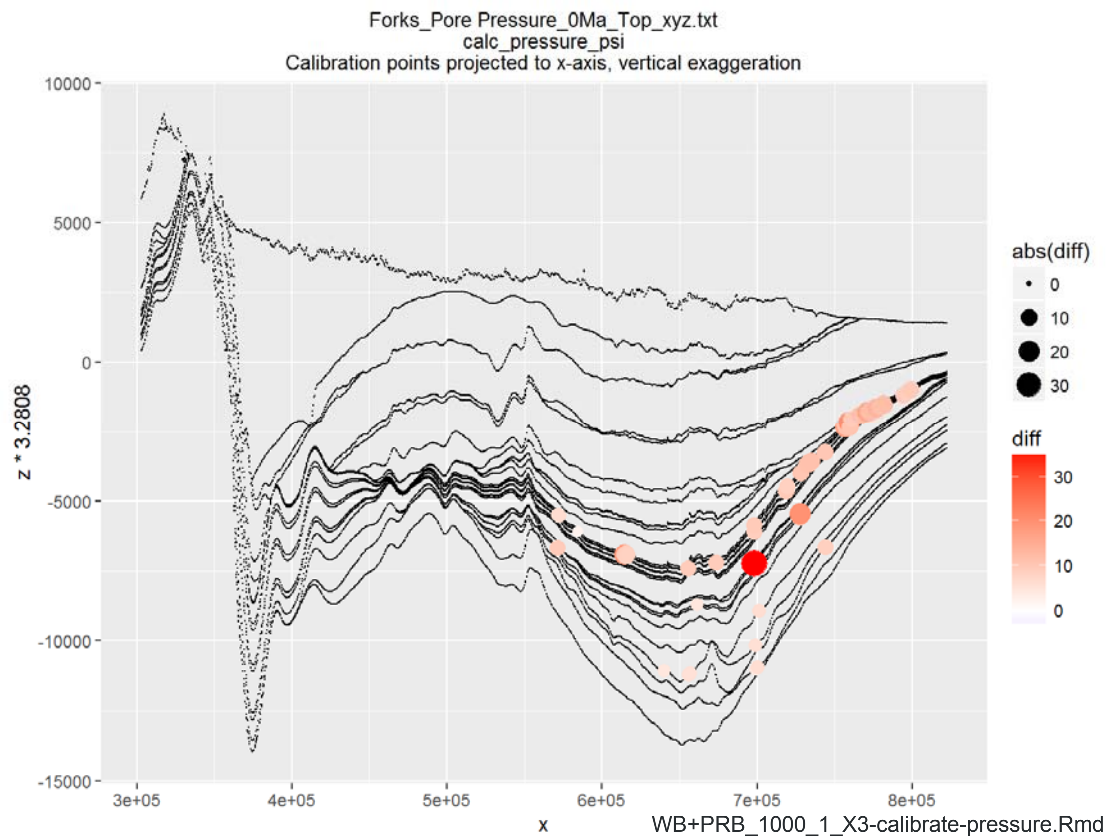
1. Compare model outputs (overlays) to known values (calibration database).
2. Adjust model inputs so model produces more accurate output.



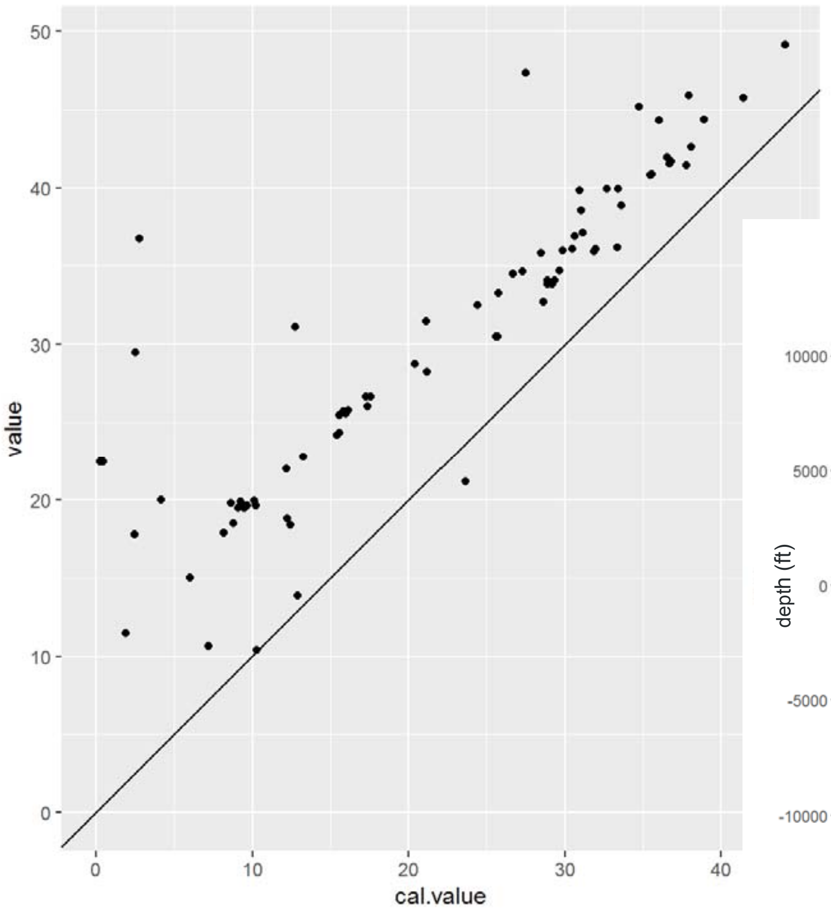
- PetroMod software does not include calibration tools—all comparison and input adjustments are manual.
- The use of scripting in R for the comparison step of calibration results in more rapid iteration.
- Comparing all known values can identify:
  – Systematic errors.
  – Trends with a systematic solution.
- Comparing all known values eliminates issues with piecemeal changes to model inputs.
  – Local changes may have many effects.
  – Multiple simulations increase confusion.

CALIBRATION – METHODS

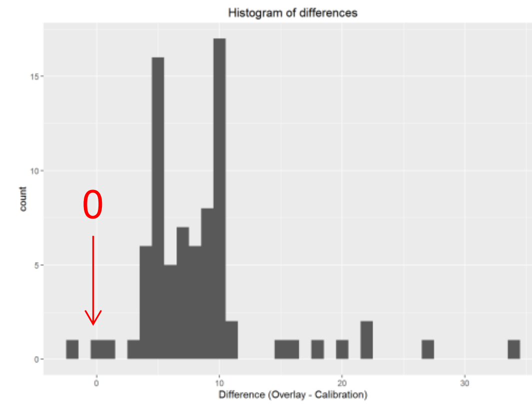
- Three calibration comparison scripts were built using R:
  - “2-D Calibration”
  - “2-D Compare Calibration”
  - “2-D Compare Overlay”
- Comparisons performed in the same way.
  - Simulate models with same structure
  - Overlay data as (x,y,z,value)
  - Calibration data as (x,y,z,value)
  - Compare closest overlay point with each calibration point (within bandwidth)

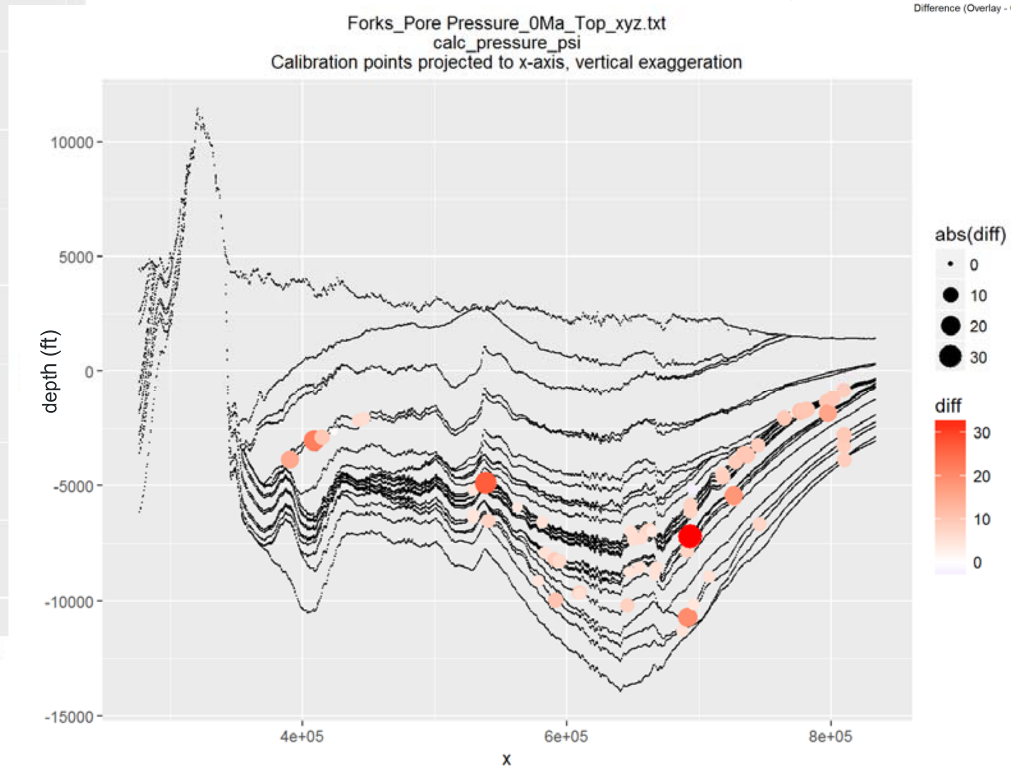


CALIBRATION – EXAMPLE RESULTS

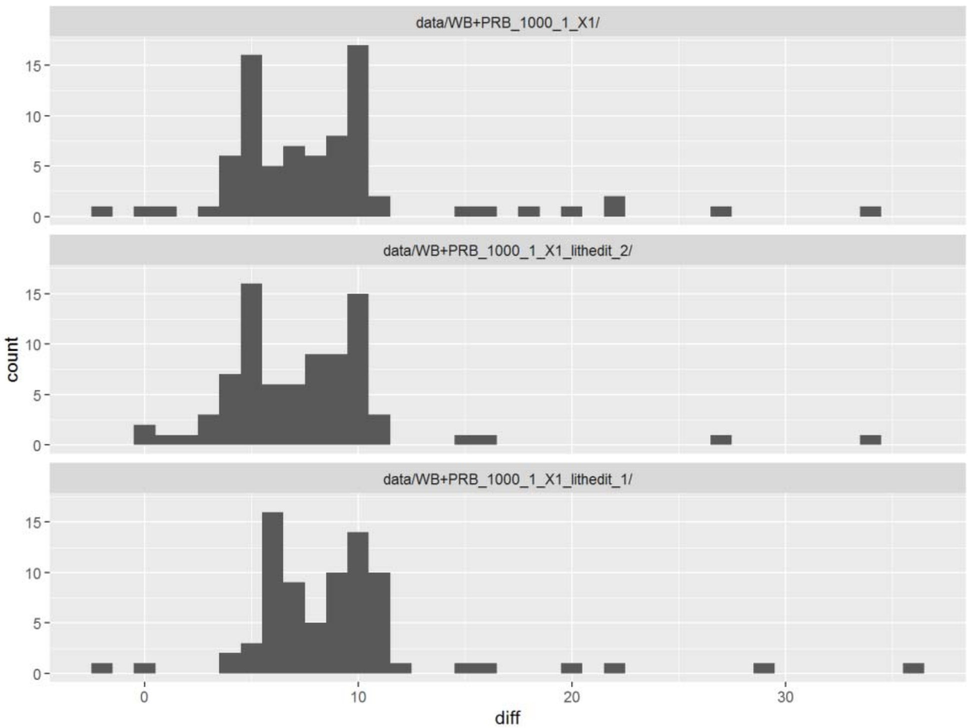


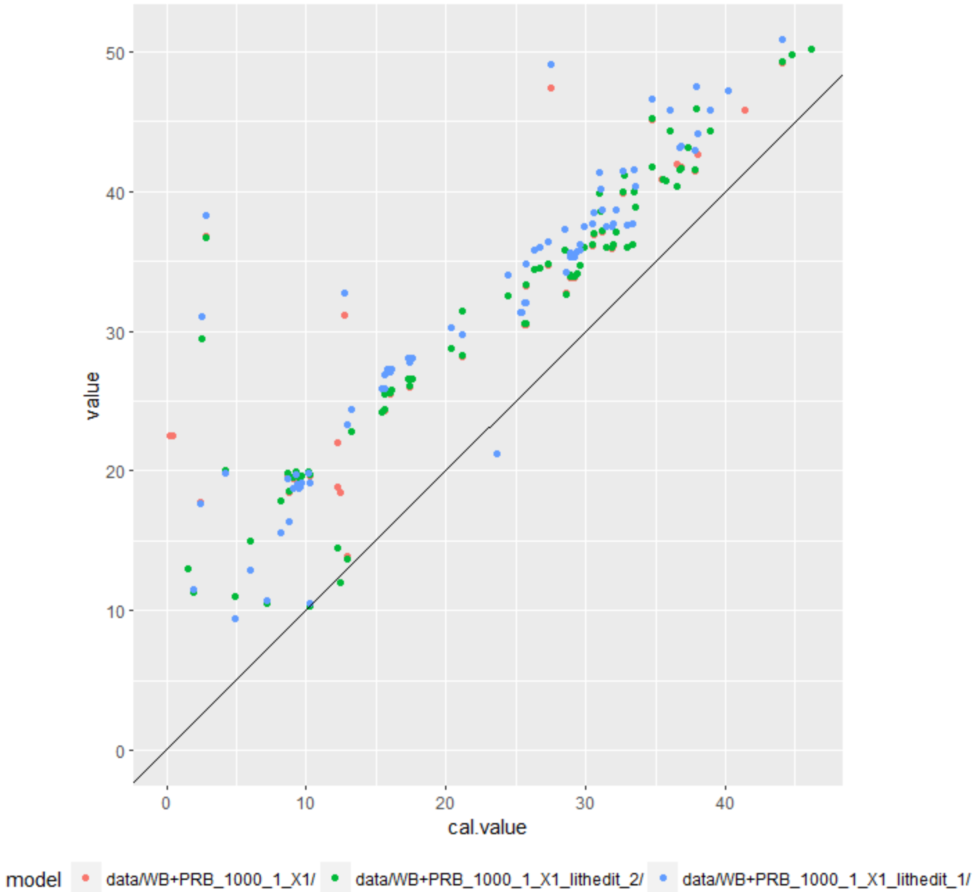
WB+PRB_1000_1_X1 Pressure



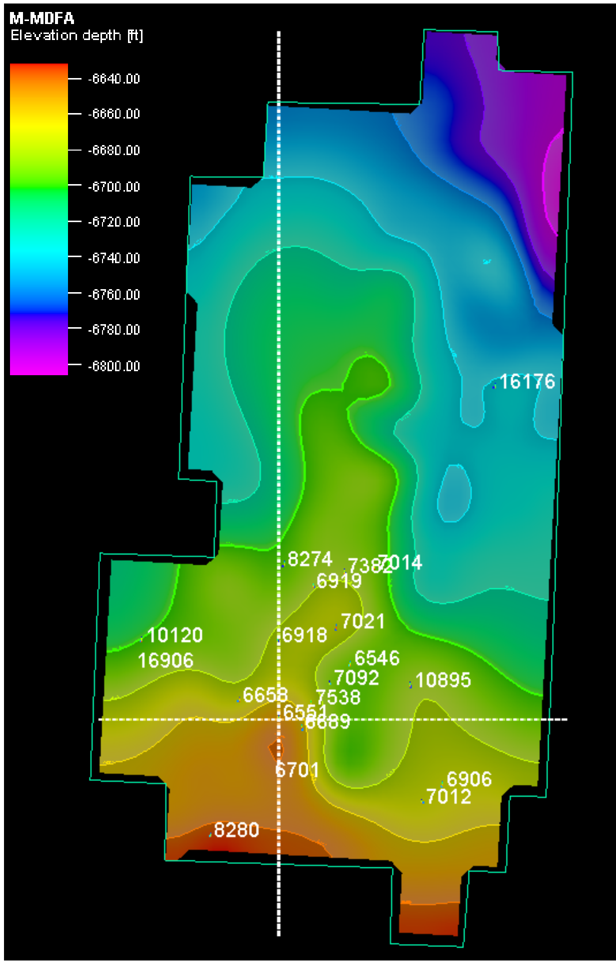


CALIBRATION – EXAMPLE RESULTS

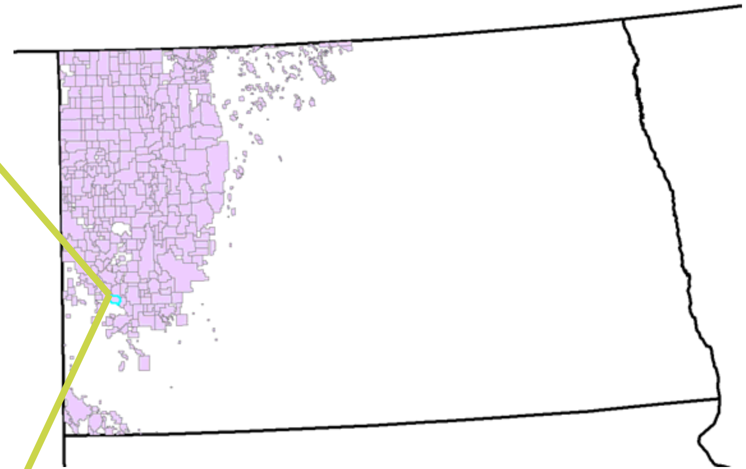




PETROPHYSICAL APPROACH



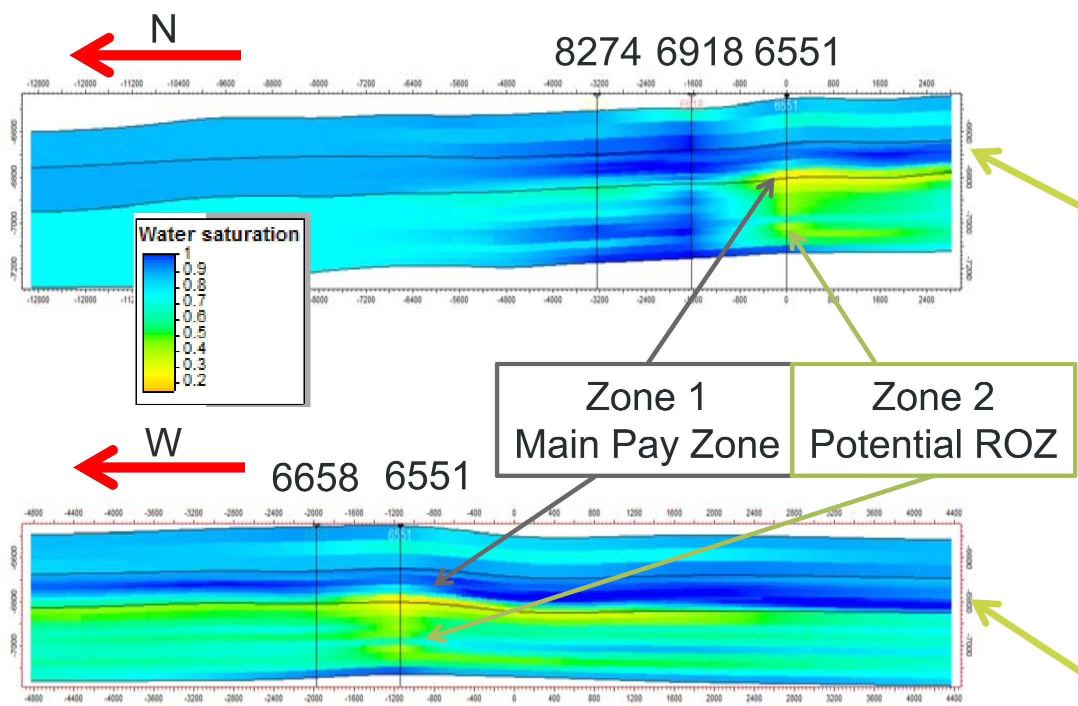
Depth to top of Mission Canyon Formation



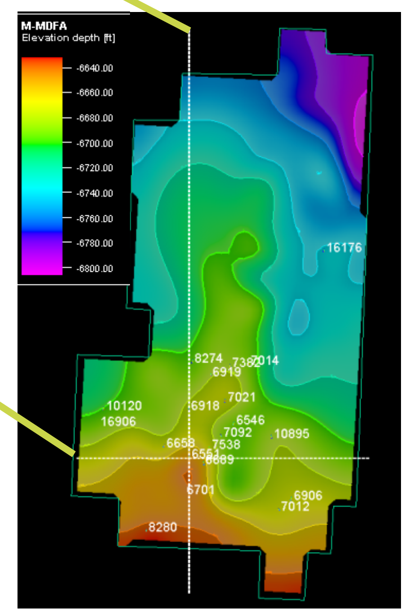
Petrophysical workflows analyzing oil and water saturations from existing logs in areas of known tilted oil–water contacts will support modeling efforts.

- Example: T.R. and Big Stick Fields in southwestern North Dakota.

PETROPHYSICAL APPROACH



Field-scale models and petrophysical analyses will be used to validate and calibrate basin-scale models.



VALIDITY TESTING: CORE ANALYSIS

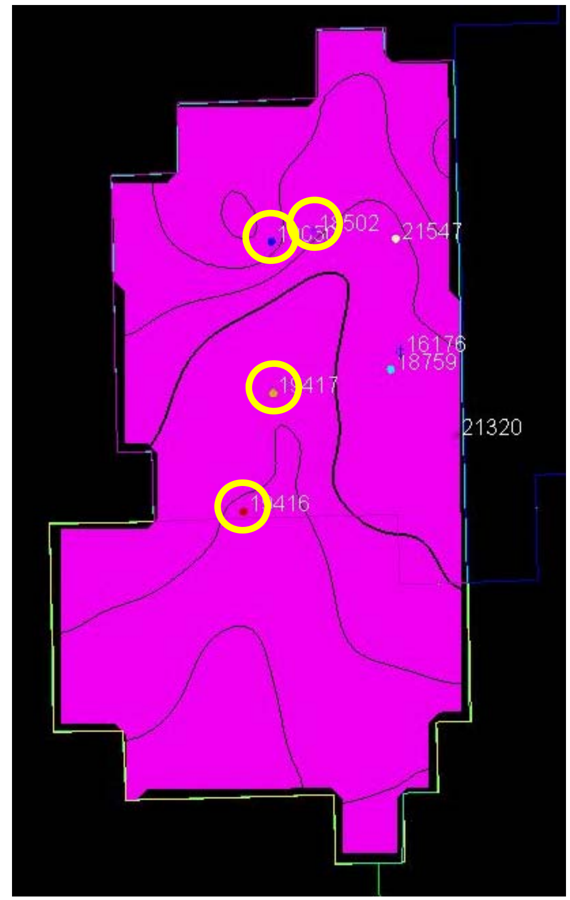
- Data from core will be used to support the modeling effort (e.g., calibration, validation testing).
- Multiple wells will be chosen based on literature review, modeling results, and core availability.

VALIDITY TESTING: PULSED-NEUTRON LOGS (PNLs)

PNLs will be collected near suspected ROZs to support and validate modeling and petrophysical analysis efforts.

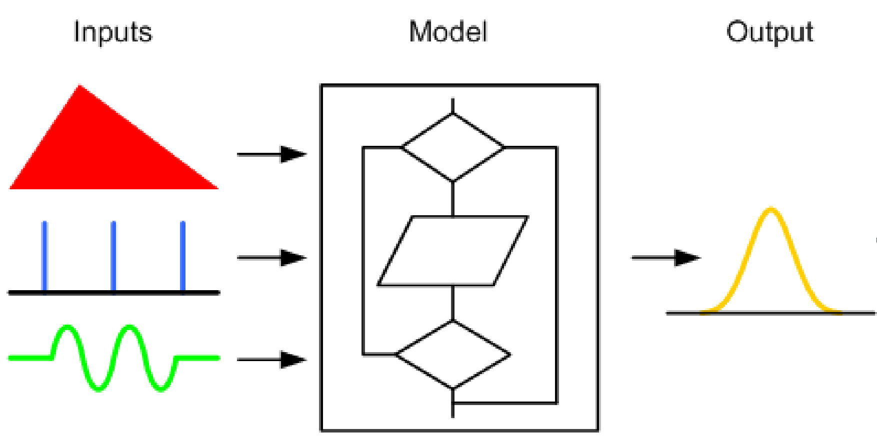
To choose potential locations for PNLs, multiple criteria must be met:

- Currently active well
- Wells penetrate through to the potential ROZ
- Completion specifications



OUTPUT: RISK ANALYSIS

- Uncertainty analysis using Monte Carlo simulations will be performed to better understand the impact of key variables.
- Range of data for each variable will come from literature review database.
- Probabilities, confidence intervals, error bars, correlations, and calibration will be considered to find the best model fit.
- High-, mid-, and low-probability models will be used in fairway mapping.



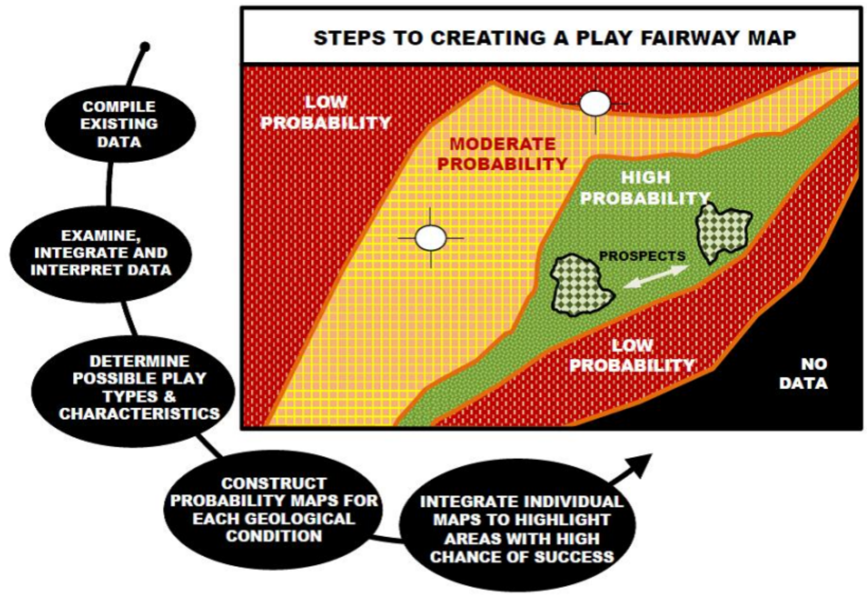
www.brighton-webs.co.uk/montecarlo/simulation.aspx

Analyze

- Histograms
- Tornado plots
- Crossplots
- Distributions

OUTPUT: ROZ FAIRWAY MAPPING

- Create play fairway maps showing potential brownfield (existing fields) and greenfield (new fields) ROZs.
- Display high, mid-, and low probabilities.



OUTPUT: CO_2 EOR FEASIBILITY STUDY

- Analyze potential ROZs to determine feasibility for EOR using CO_2.
- Use published ranges for recovery and utilization factors for conventional CO_2 EOR projects.
- Make high, mid-, and low estimates.

www.aogr.com

ACCOMPLISHMENTS TO DATE

- Literature review has been completed.
- Several 1-D models have been completed, simulated, and calibrated as part of the PetroMod learning process.
- Several 2-D models have been extracted from the Williston Basin + Powder River Basin combined 3-D model and simulated.
- Calibration of lithologic properties and other input data based on 1-D and 2-D simulations is well under way.
- Reservoir simulation of T.R. and Big Stick Field 3-D model is in progress.
- Project overview has been presented in multiple venues.

SYNERGY OPPORTUNITIES

Associated Storage (EOR)

- Basin evolution modeling could be used to identify future unconventional or conventional targets.
- Collaboration between projects investigating CO_2 EOR in unconventional reservoirs and ROZs will help further the understanding of CO_2 storage associated with EOR.

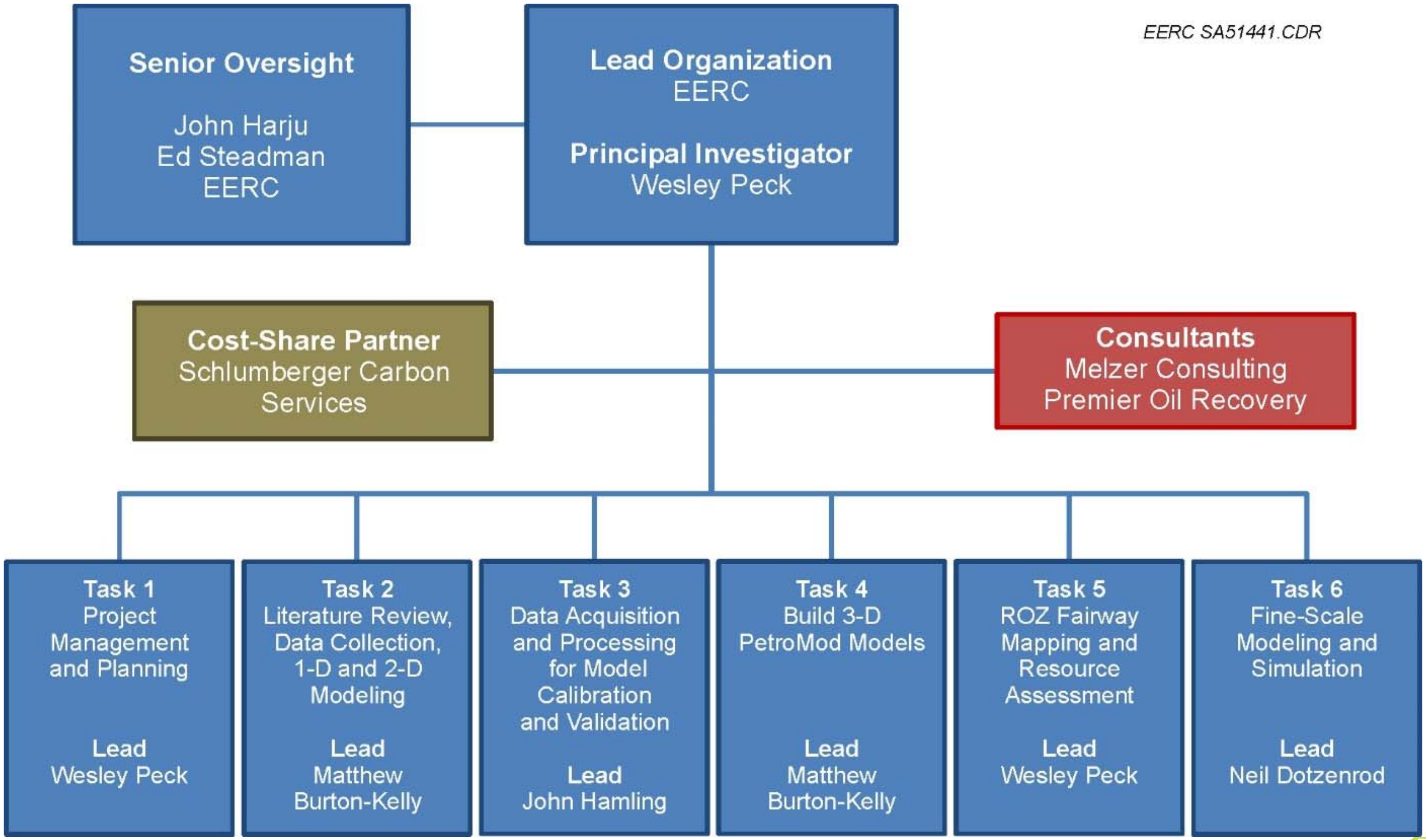
SUMMARY

- Key findings
  – Current PetroMod models predict hydrocarbon accumulations that largely agree with known pools.
- Lessons learned
  – Much greater understanding of PetroMod software and relationships among variables.
  – Improved structural frameworks for the WB and PRB.
  – Delicate balance between not enough detail and too much when collecting data.
- Future plans
  – Streamline and calibrate.

THANK YOU!

Critical Challenges. **Practical Solutions.**

ORGANIZATION CHART



GANTT CHART

	Start Date	End Date
Task 1.0 – Project Management and Planning	**11/1/2014**	**10/31/2017**
1.1 – Perform Project Management	11/1/2014	10/31/2017
1.2 – Project Reporting	11/1/2014	10/31/2017
Task 2.0 – Literature Review, Data Collection, Compilation and Simulation of 1-D and 2-D PetroMod Models	**11/1/2014**	**12/31/2016**
2.1 – Literature Review and Data Collection	11/1/2014	12/31/2015
2.2 – Build Dynamic 1-D PetroMod Models	12/1/2014	9/30/2015
2.3 – Build Dynamic 2-D PetroMod Models	3/1/2015	9/30/2015
2.4 – Recalibrate, History-Match, and Simulate 2-D PetroMod Models Based on Field Logging Interpretations	12/1/2015	12/31/2016
Task 3.0 – Data Acquisition and Processing for Model Calibration and Validation	**6/1/2015**	**12/31/2016**
3.1 – Core Acquisition and Petrophysical Analysis	6/1/2015	10/31/2016
3.2 – Pulsed-Neutron and Temperature Logging	1/1/2016	12/31/2016
Task 4.0 – Build 3-D PetroMod Models	**5/1/2016**	**1/31/2017**
4.1 – Build, Calibrate, and Simulate 3-D PetroMod Models	5/1/2016	1/31/2017
4.2 – Select Submodels for Evaluation of Salt Movement, Hydrogen Sulfide Existence, and Free Sulfide Migration	7/1/2016	1/31/2017
4.3 – Perform Risk Analysis	12/1/2016	1/31/2017
Task 5.0 – ROZ Fairway Mapping, Volumetric Resource Estimates, and Preparation of Methodology to Be Used in Other Basins	**2/1/2017**	**6/30/2017**
5.1 – ROZ Fairway Mapping	2/1/2017	4/30/2017
5.2 – CO_2 EOR Feasibility Study	2/1/2017	6/30/2017
Task 6.0 – Fine-Scale Modeling and Simulation	**11/1/2015**	**9/30/2016**
6.1 – Build Fine-Scale Model(s)	11/1/2015	3/31/2016
6.2 – Conduct Simulation of Fine-Scale Model(s)	4/1/2016	9/30/2016

Summary Task
Activity Bar
Milestone (M) ◆
Deliverable (D) ▼
Critical Path

Key for Milestones (M) ◆	Key for Deliverables (D) ▼
M1 – Project Kickoff Meeting Held	D1 – Updated PMP
M2 – First Cross Section of 1-D Model Completed	D2 – Project Fact Sheet
M3 – Potential ROZ Identified	D3 – Data Submission to EDX
M4 – First Petrophysical Analysis Completed	D4 – Final Report
M5 – PNL Collection Completed	D5 – Literature Review Summary
M6 – Risk Analysis Completed	D6 – Conference Paper
M7 – Resource Assessment Completed	D7 – Peer-Reviewed Journal Article
M8 – Debriefing Meeting with Operators	D8 – Topical Report: Fine-Scale Modeling and Simulation Results

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BIBLIOGRAPHY

- No peer-reviewed literature to date.

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