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Developing Reserve Estimates for CO2 EOR Residual Oil Zone Projects

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Presented to SPEE
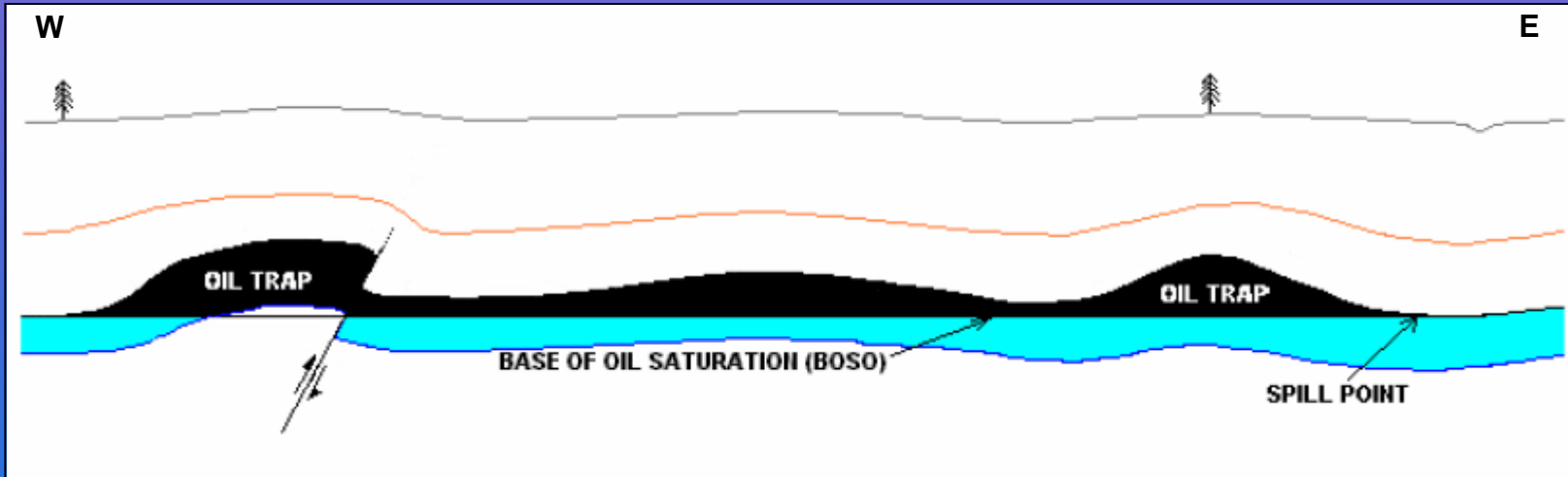October 5th, 2011

Houston, Texas

What is a Residual Oil Zone

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"Previously highly oil saturated zone from which the oil is displaced by water through tectonic tilting and/or hydro-dynamic flooding."

Typical ROZ Traits

- Lower "Swept" Part of productive interval

- Same Rock

- Good stain, oil shows on cores

- "Wet" tests on initial completion (1-5% Oil Cut)

- Oil saturations similar to end of life waterflood 25-45%

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Model for ROZ Formation

Original Oil Accumulation Under Static Aquifer Conditions

W   E

OIL TRAP

OIL TRAP

BASE OF OIL SATURATION (BOSO)

SPILL POINT

Change in Hydrodynamic Conditions, Sweep of the Lower Oil Column, Oil/Water Contact Tilt, and Development of the Residual Oil Zone

W   E

OIL TRAP

ROZ

ROZ   ROZ   ROZ

OIL TRAP

AQUIFER

BASE OF OIL SATURATION (BOSO)

SPILL POINT
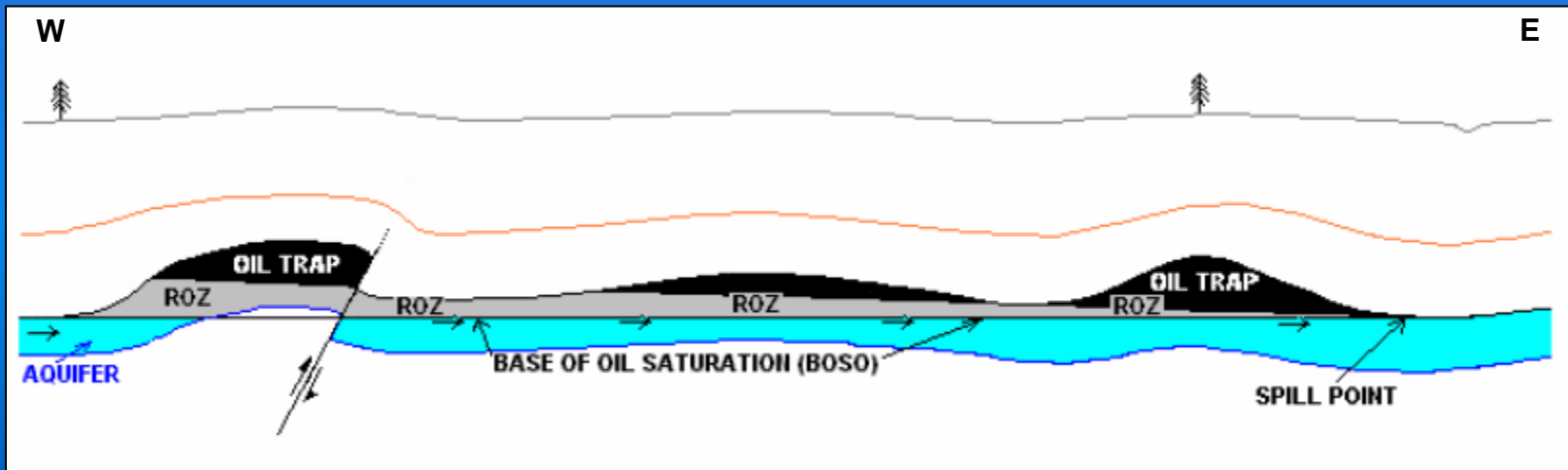
Why are ROZs Important?

ARI estimates 30 BBOOIP are sitting in ROZ zones in the Permian Basin alone.

- Large opportunity for EOR
- Big impact on West Texas Oil Industry
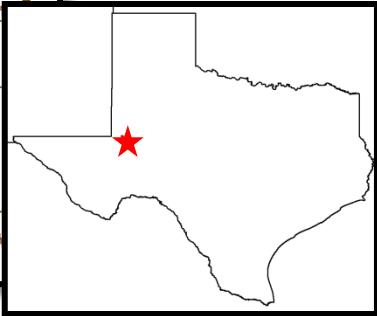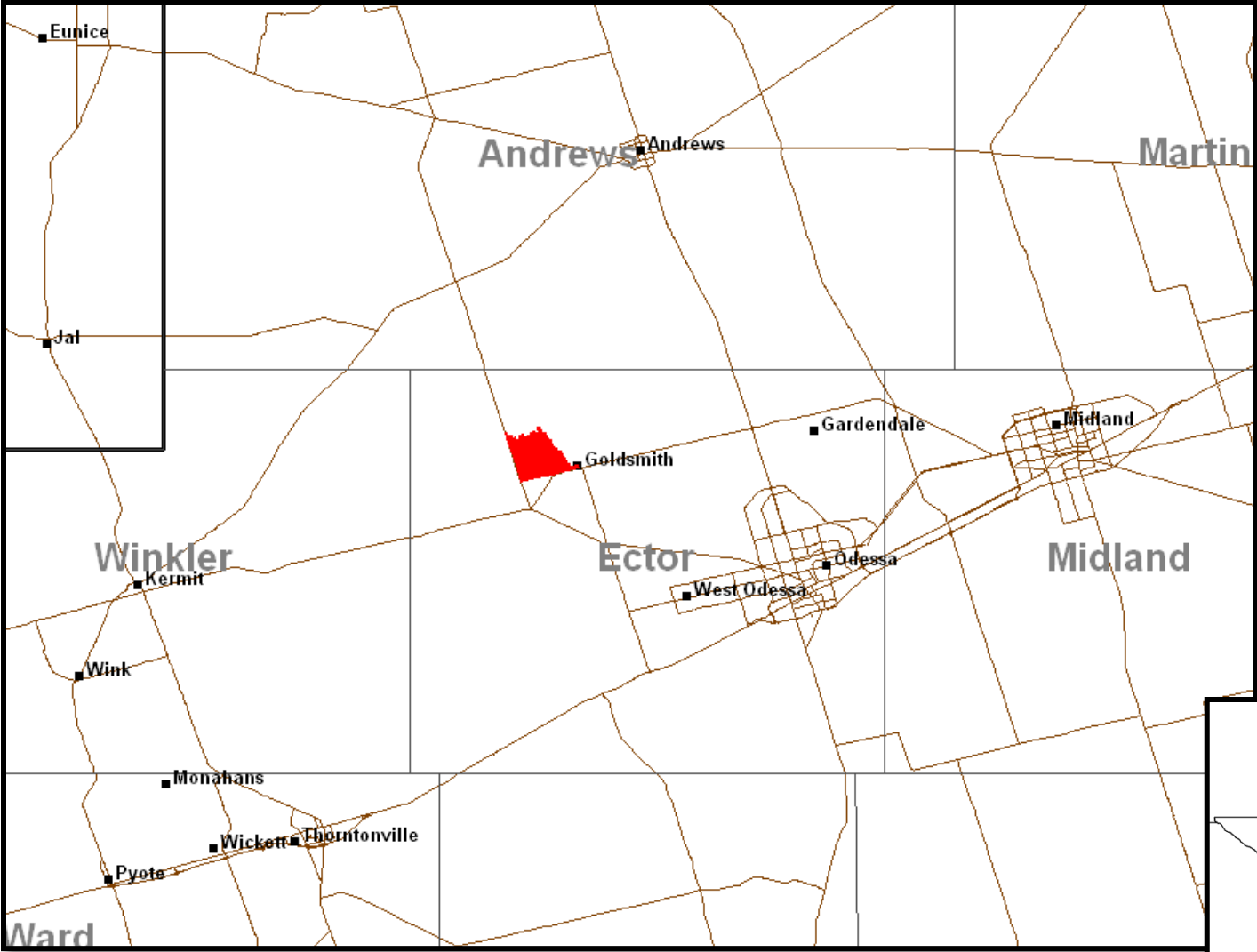- Huge Potential Energy Resource for America

Fields with Active ROZ EOR Projects

Third Order Residual on top of Wolfcamp Formation

ENTIRE PERMIAN BASIN

Active ROZ Projects

Seminole - Hess

Wasson - Oxy

Hanford - Fasken

Vacuum – Chevron

Means – Exxon

East Seminole – Tabula Rasa

Goldsmith – Legado
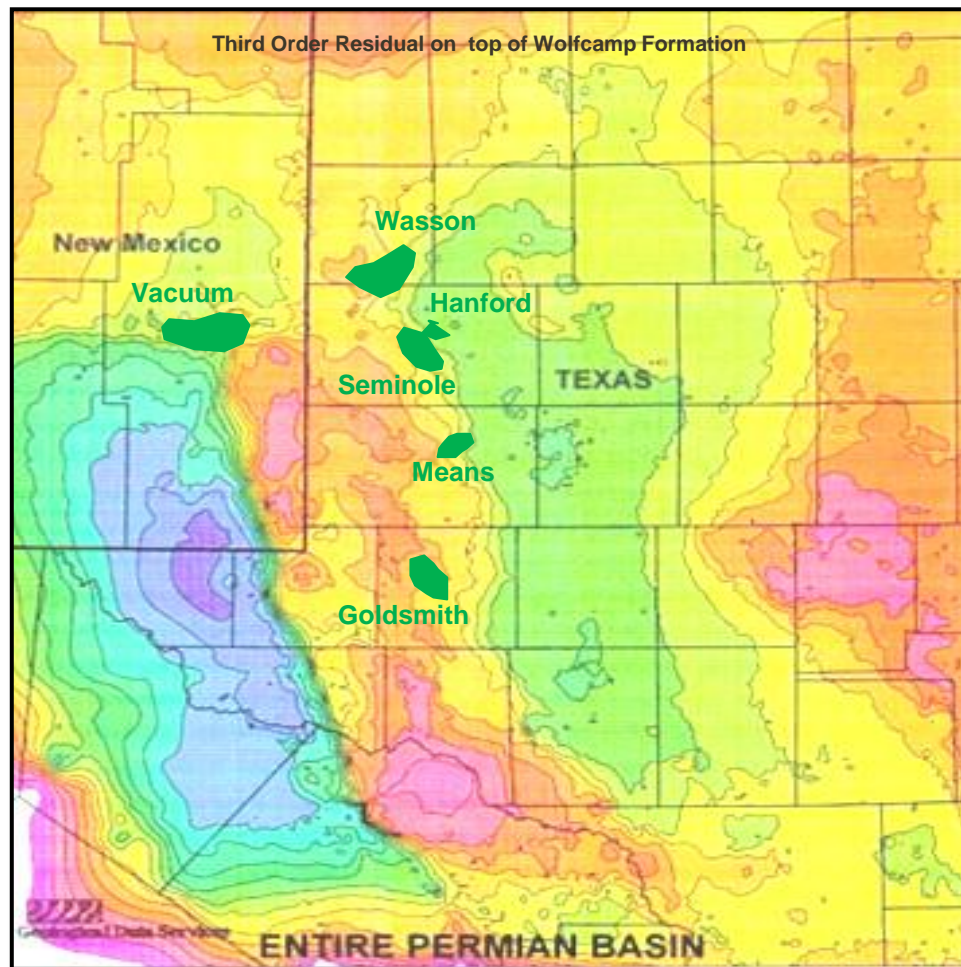
Goldsmith Field, Ector County, Texas

Determining The Reserve Base

Tools

Analogy
- Project Placement
- Known Formation
- Historical Results

Reservoir Characterization
- Log Density
- Extensive Coring Program
- ROZ Saturations
- Petrophysics
- Mapping (Continuity)

Pilot – Response

Answers

Size of Resource
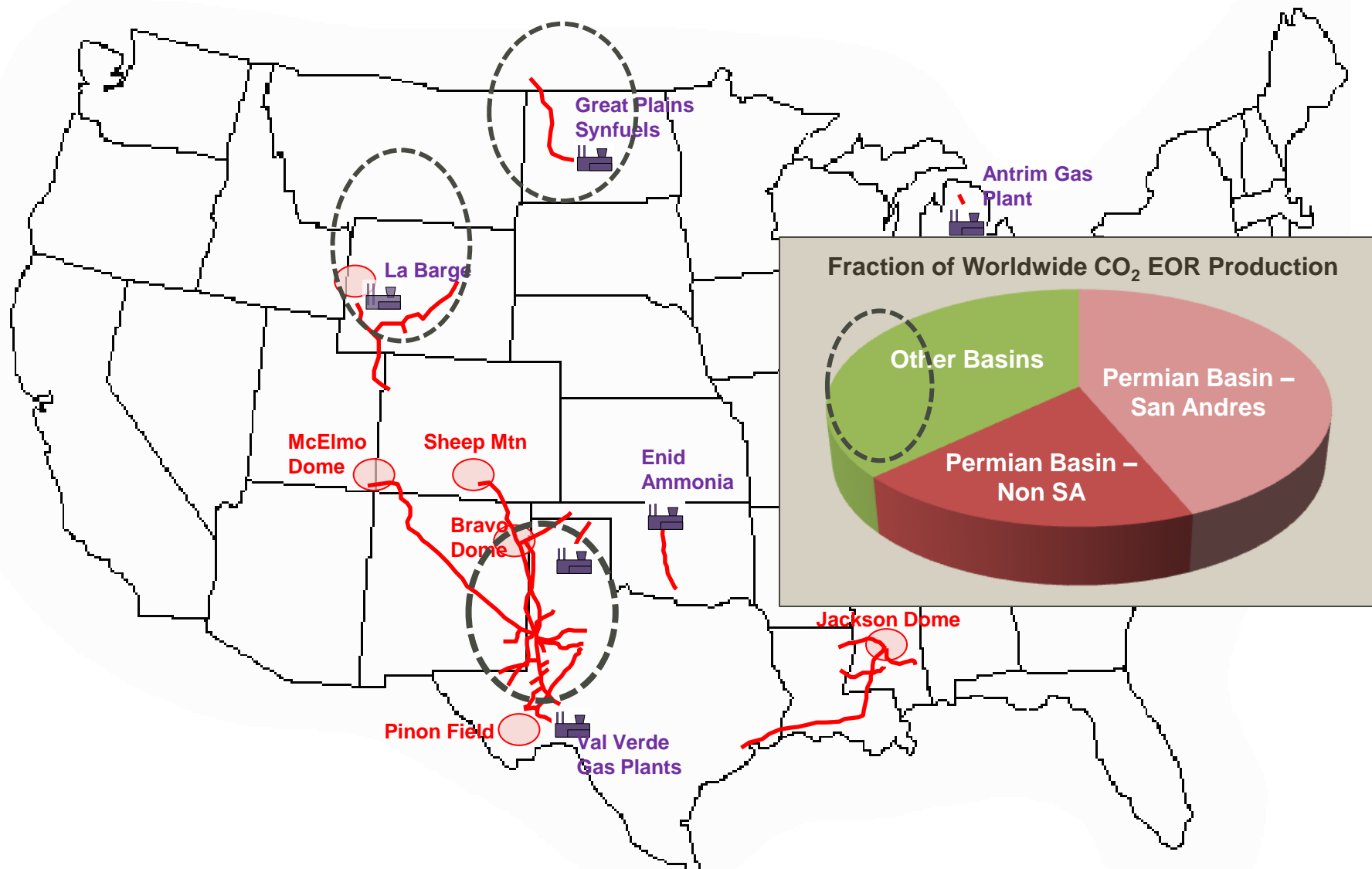- OOIP

Test Mechanism of Recovery
- CO_2 Flood Response
- Oil Cut

Classify Reserves
- PDP, PUD, PRB, POSS
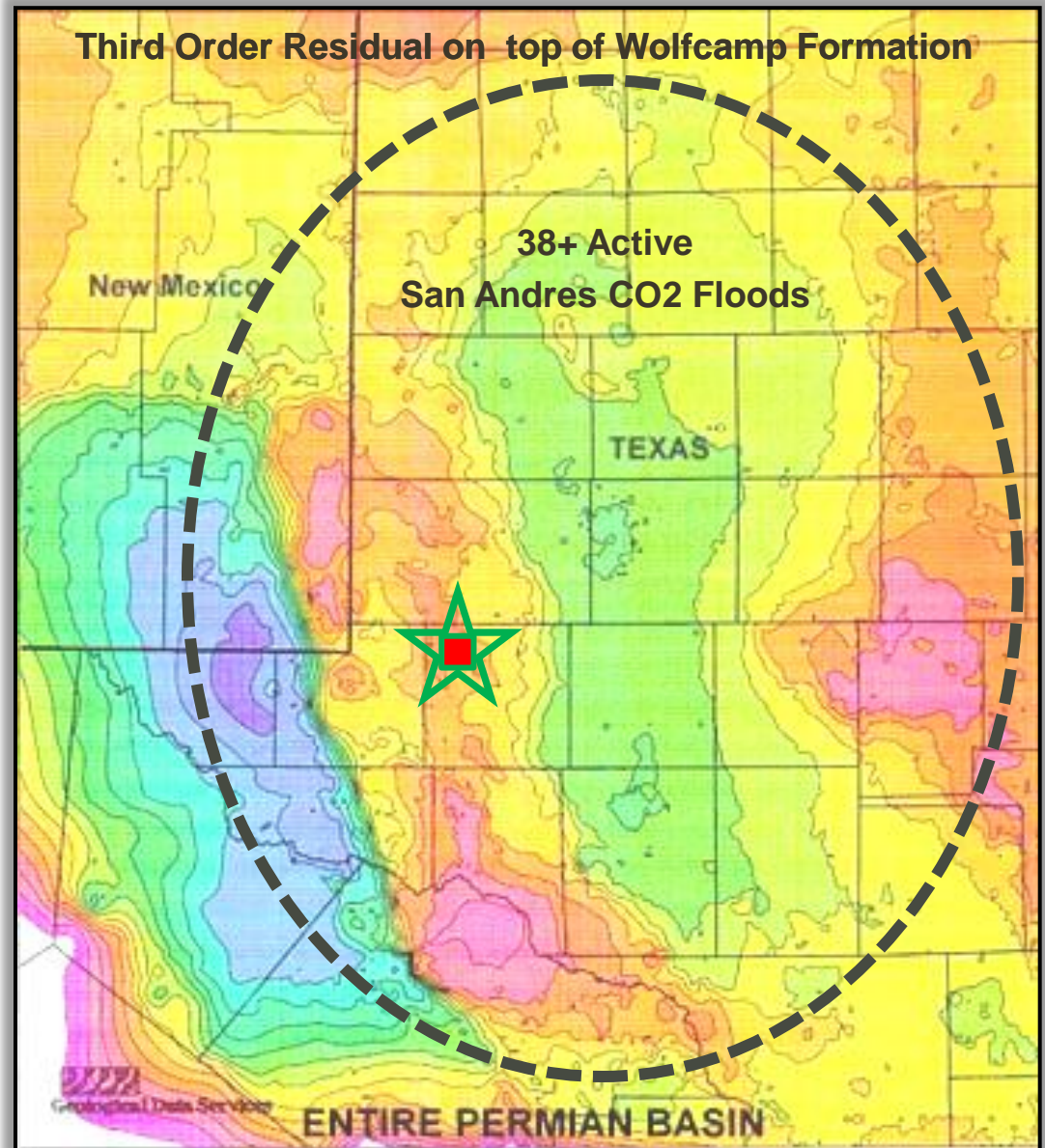
Analogy: Project Placement & Reservoir Type

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United States CO_2 Pipeline Infrastructure

Map labels: Great Plains Synfuels, La Barge, Antrim Gas Plant, McElmo Dome, Sheep Mtn, Enid Ammonia, Bravo Dome, Pinon Field, Val Verde Gas Plants, Jackson Dome

Pie chart — Fraction of Worldwide CO_2 EOR Production:
- Other Basins
- Permian Basin – San Andres
- Permian Basin – Non SA

Project Placement – GLSAU Location

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Reservoir Type and Location support Reserve Bookings

✓ **Permian Basin Location**

✓ **San Andres Reservoir**

✓ **Cost – Nearby Access to Worlds Most Extensive PL Network. Top Quality Service Infrastructure.**

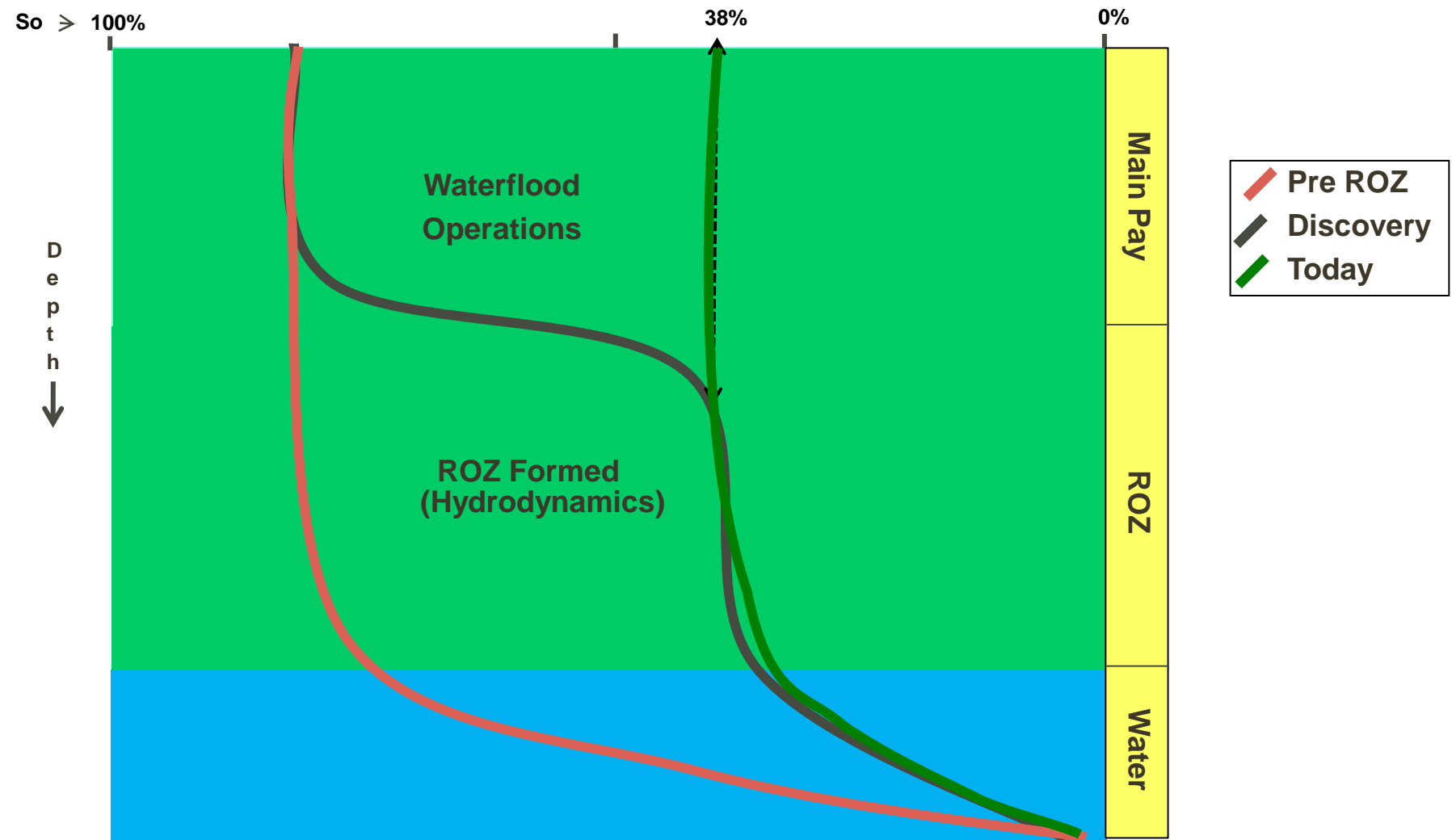✓ **Performance – Vast Array of Analog Information. Highly Refined Range of Outcomes.**
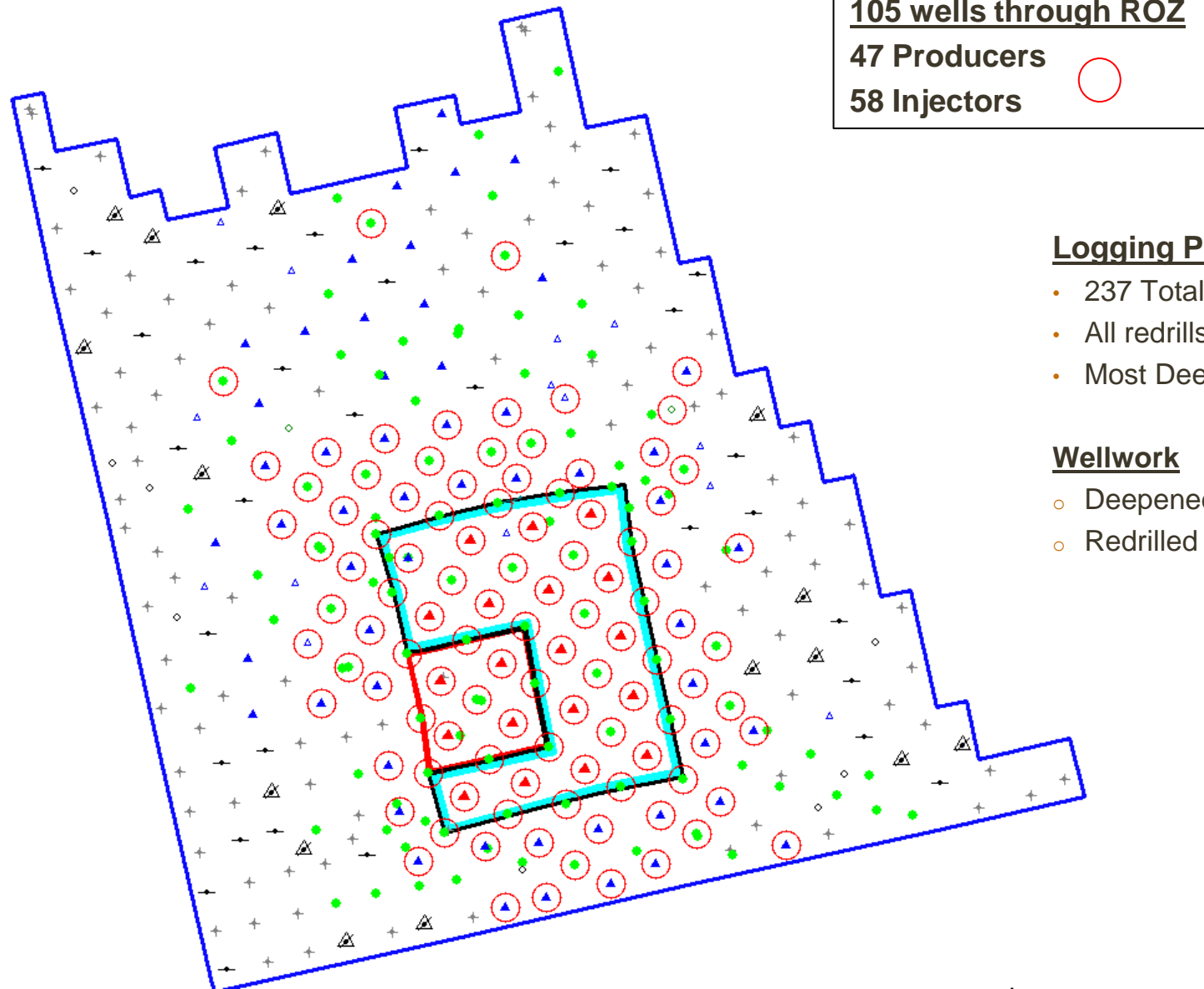

Third Order Residual on top of Wolfcamp Formation

New Mexico

38+ Active San Andres CO2 Floods

TEXAS

Geological Data Service

ENTIRE PERMIAN BASIN

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Analogous Fields and Log Section
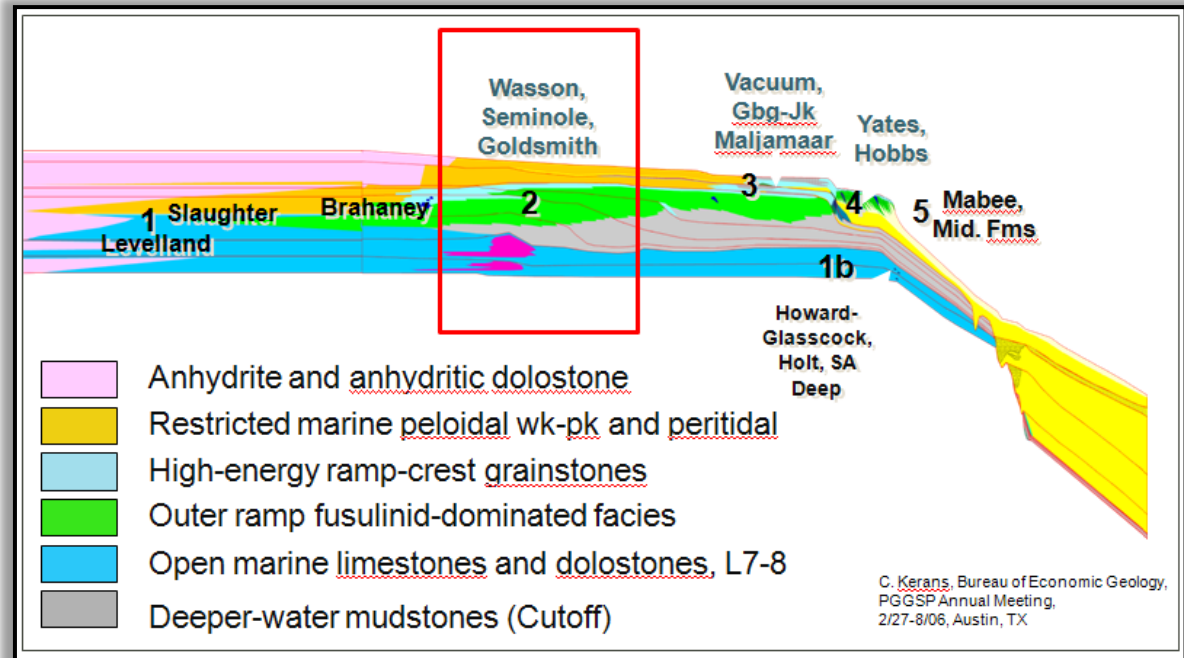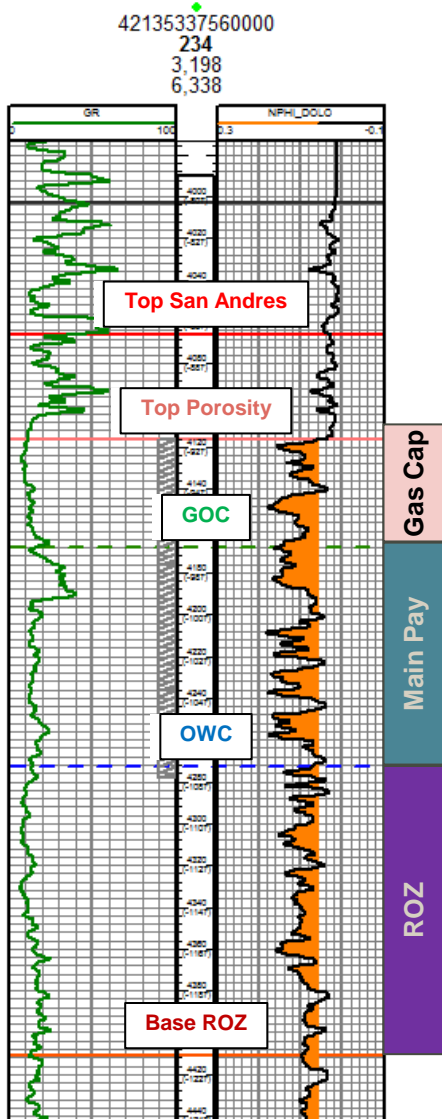
|		Goldsmith	Wasson	Seminole
Formation		San Andres	San Andres	San Andres
Discovery	(Yr)	1935	1936	1936
Depth	(Ft)	4,200	4,900	5,200
Pinit	(psi)	1,712	1,850	2,020
Temperature	(Deg)	95	107	108
API Gravity	(Deg)	34	33	35
MMP	(psi)	1,150	1,280	1,300
Porosity	(Frac)	0.11	0.11	0.12

ROZ Field Saturation Progression

Technical Data Density

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105 wells through ROZ

47 Producers

58 Injectors

Logging Program

- 237 Total OH Logs used
- All redrills have Triple Combo
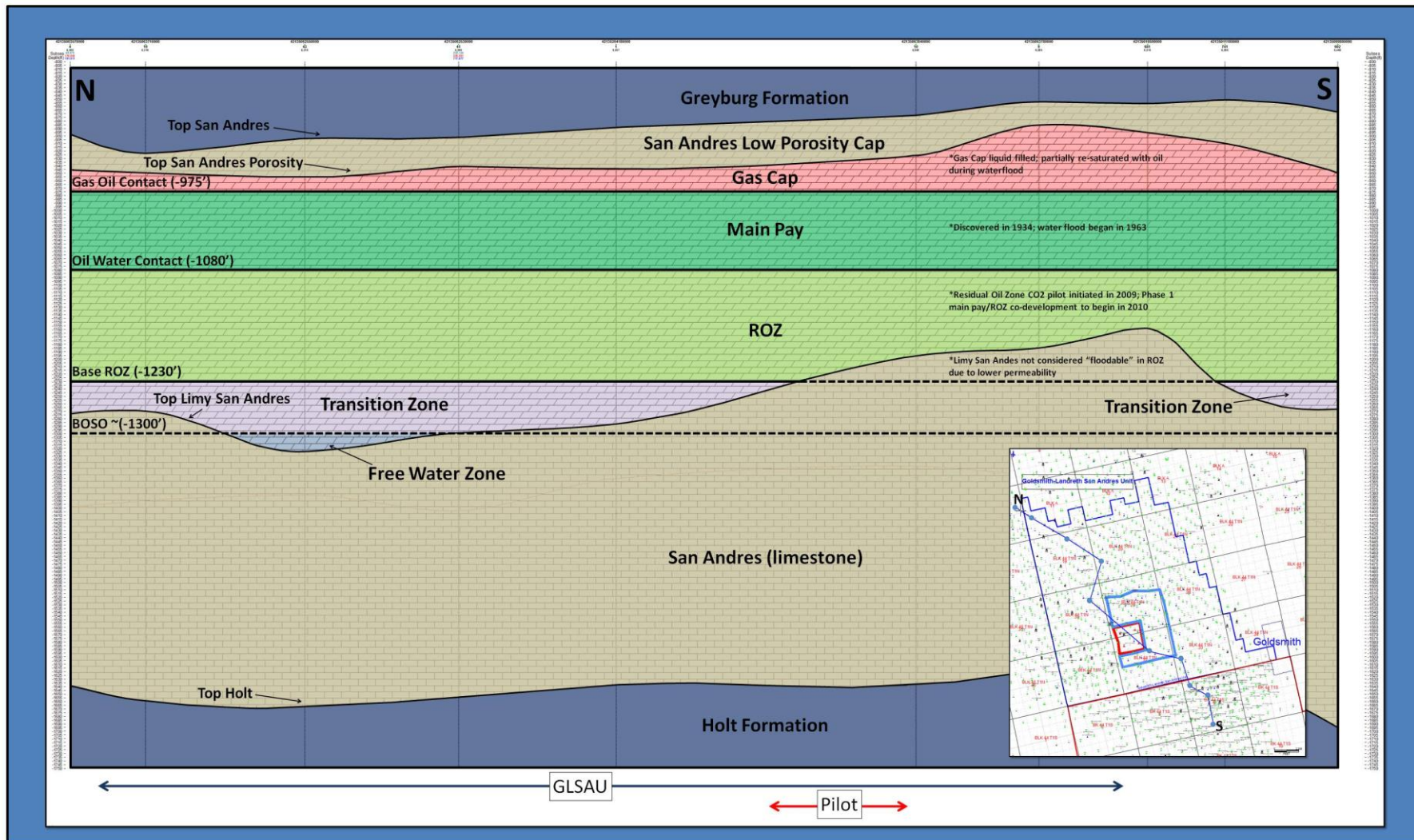- Most Deepenings GR/Neutron

Wellwork

- Deepened 86 Wells Through ROZ
- Redrilled 19 Wells Through ROZ
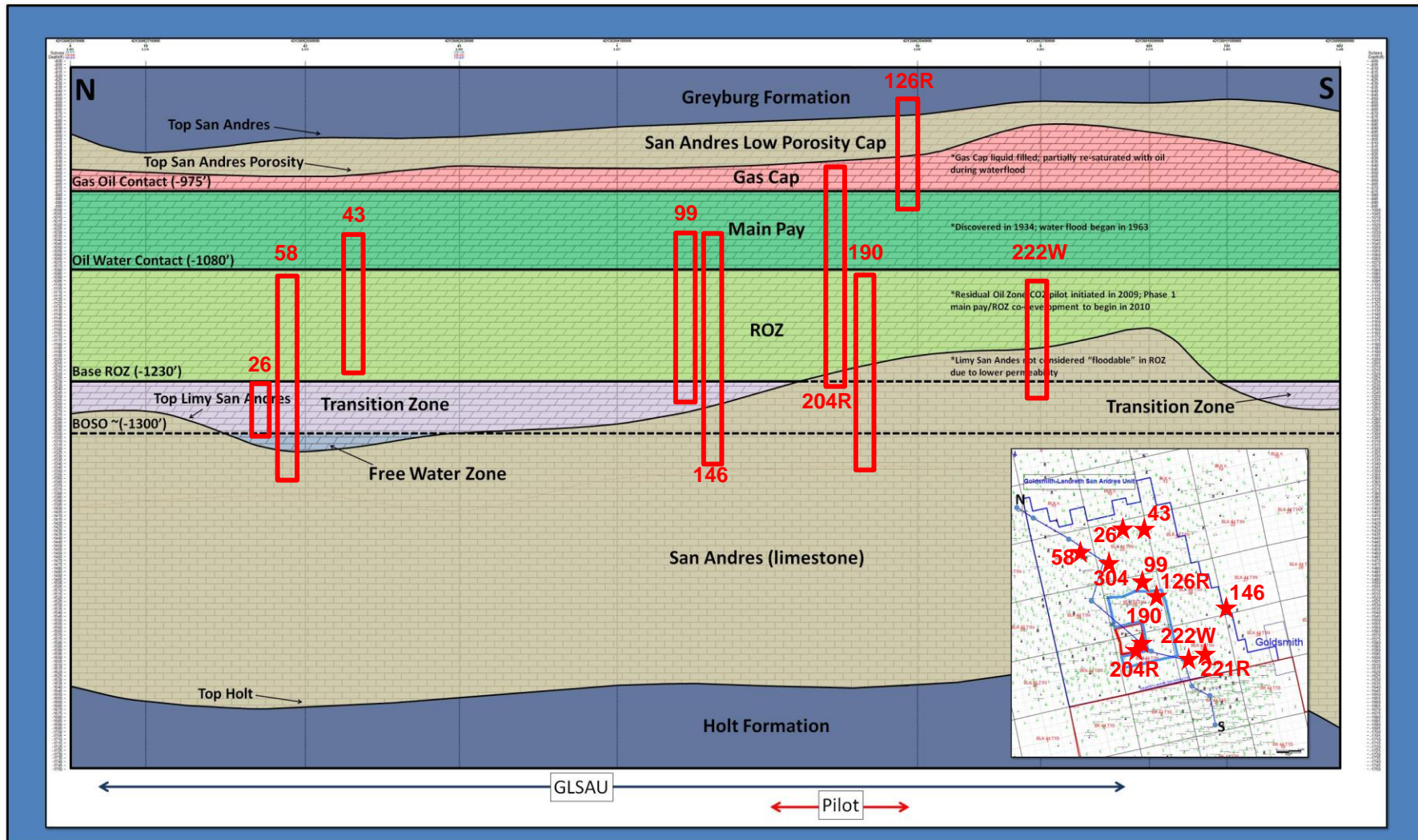
Technical Evaluation – Legado Coring Program
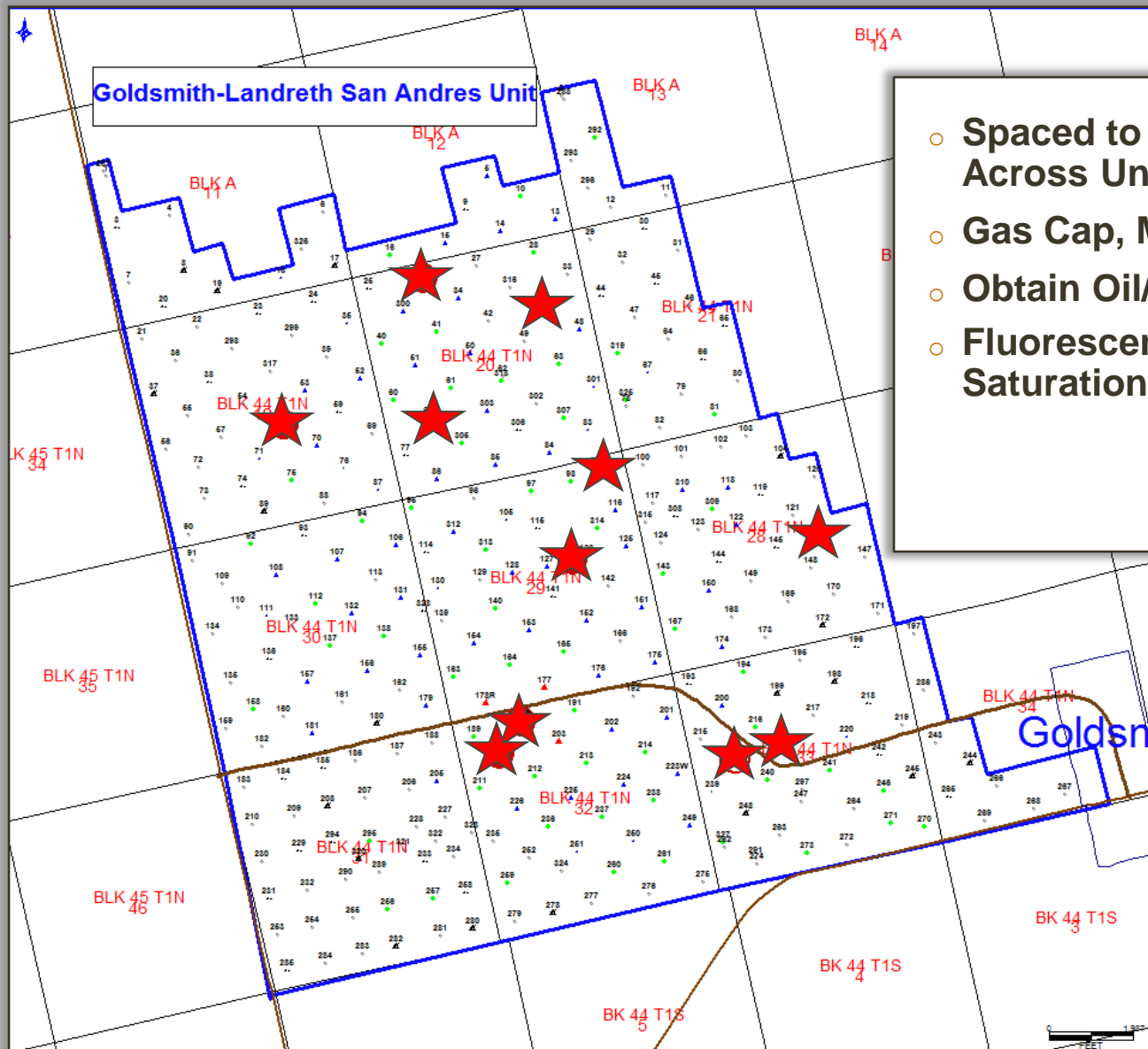
- Spaced to Investigate Distribution Across Unit
- Gas Cap, Main Pay, ROZ
- Obtain Oil/Fluid Sample
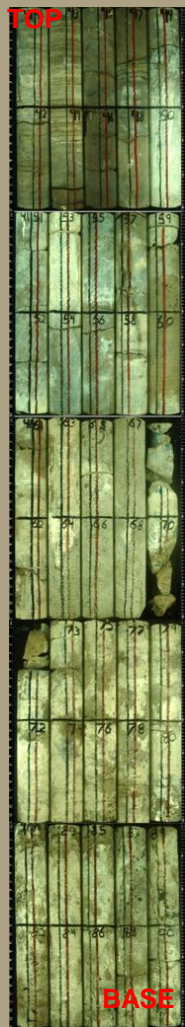- Fluorescence Photos and Saturation Measurements

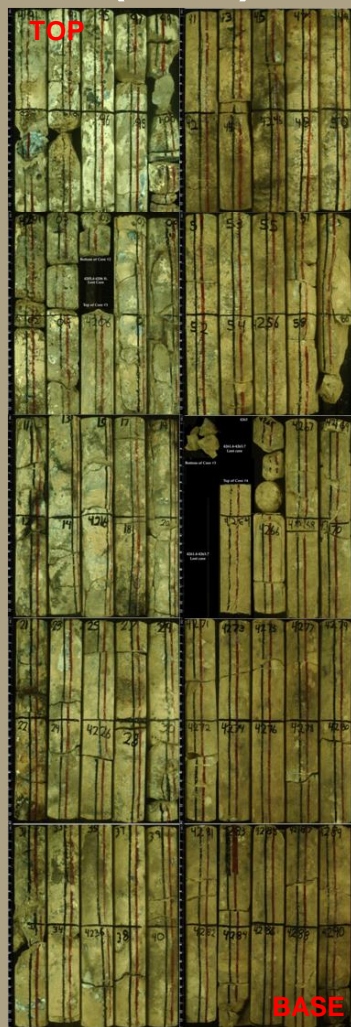# GLSAU Reservoir Model

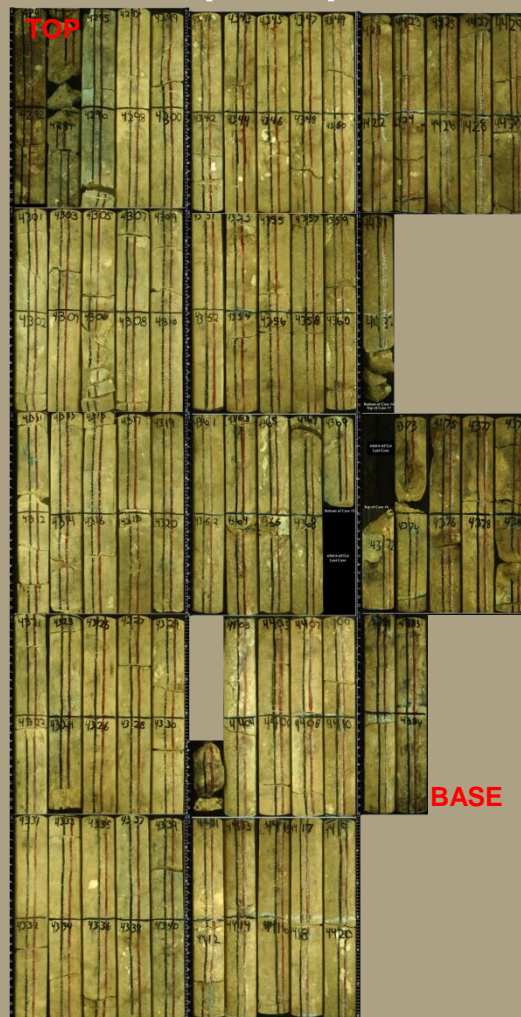# GLSAU Cored Intervals

Technical Evaluation – Core Fluorescence
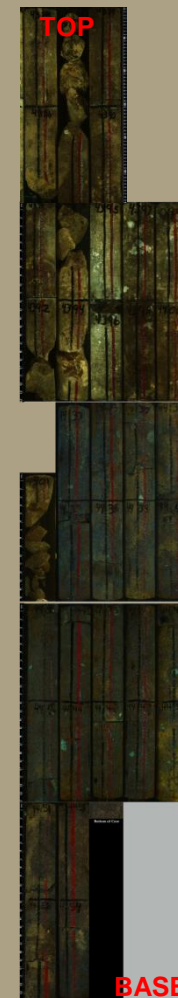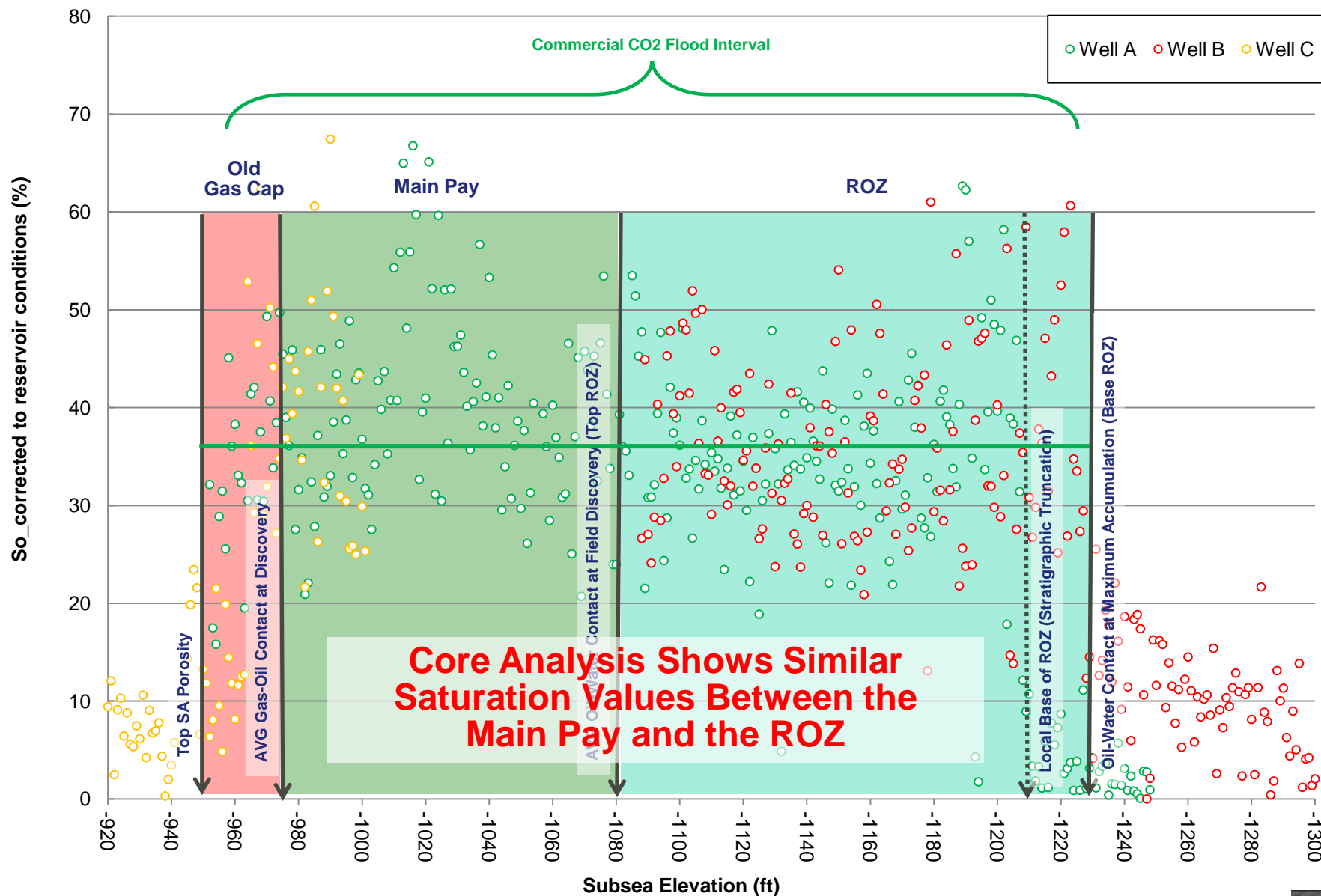

Gas Cap (Resaturated)

Main Pay Oil Zone (MPZ)
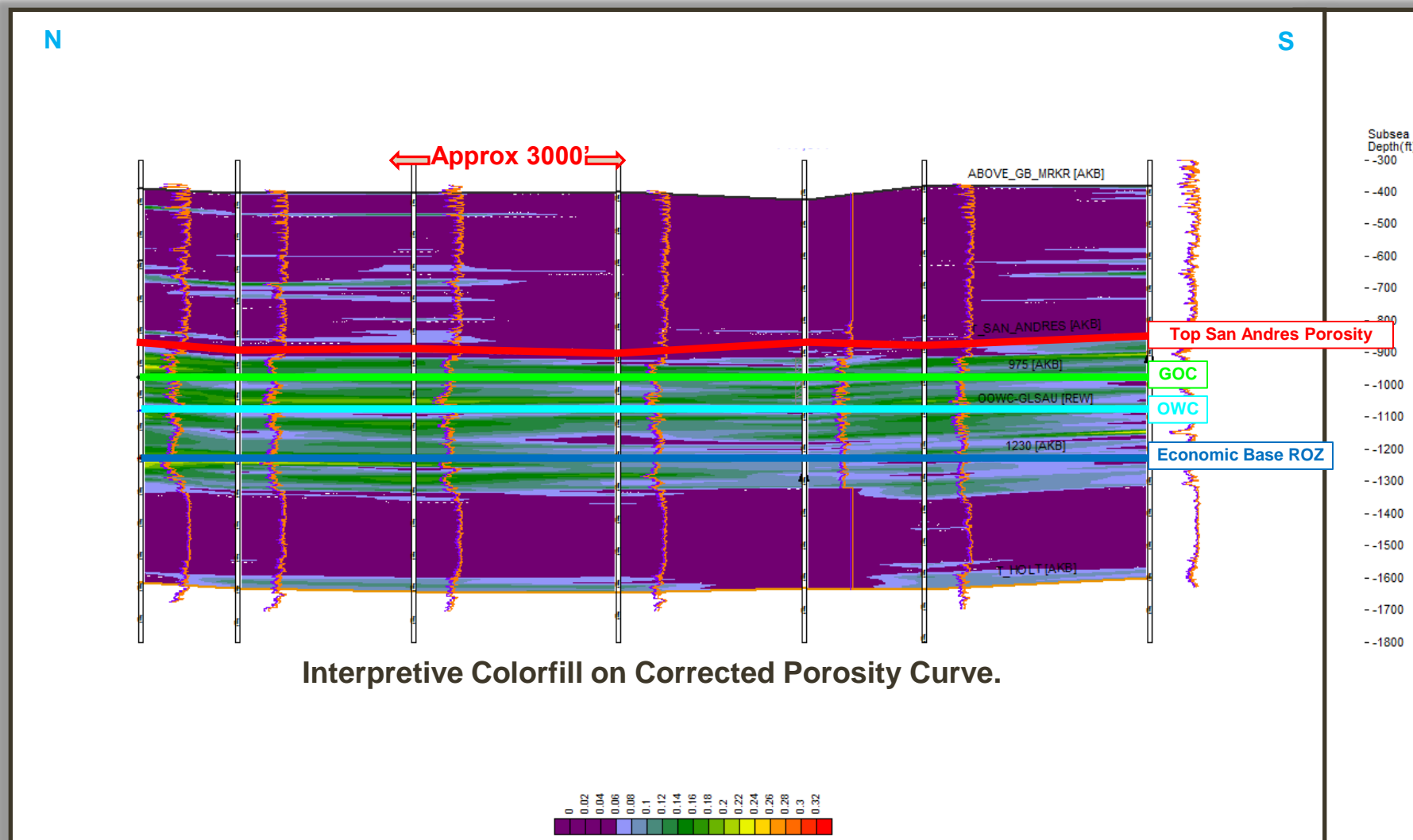
Residual Oil Zone (ROZ)

Below ROZ

Technical Evaluation – Core Saturation

Technical Evaluation – Characterization

Interpretive Colorfill on Corrected Porosity Curve.

Reservoir Continuity Good Even at 3000' Spacing (320 Acres)

Determining The Reserve Base: OOIP

Main Pay OOIP

Detailed OOIP Knowledge from 1930s

- So = 80%, Swc = 20%

At Sorw

- Over 400 wells drilled
- Produced over 85 years total
- Waterflooded 45 years
- Oil cut 0.5-2%

- *Volumterics and Matl Bal*
  - **MP OOIP ~ 250 MMBO**

ROZ OOIP

- Extensive work to determine ROZ fluid contacts
- *Floodable* ROZ Excludes Much of TZ

- OOIP Convention
- At 1934 Field Discovery So = 38% (Current)
- Before ROZ was created it was "Main Pay"

- Taking back to pre ROZ formation
- So = 80% (Same as Main pay, same Swc = 20)

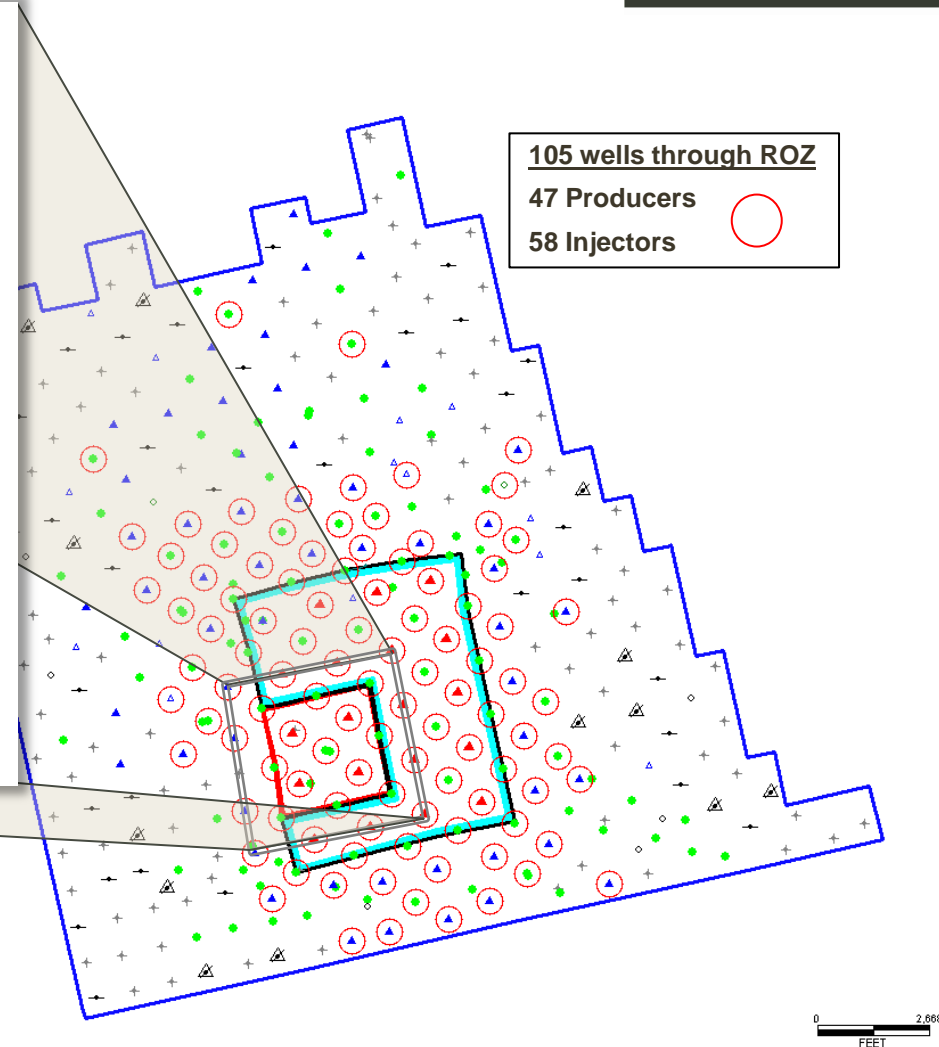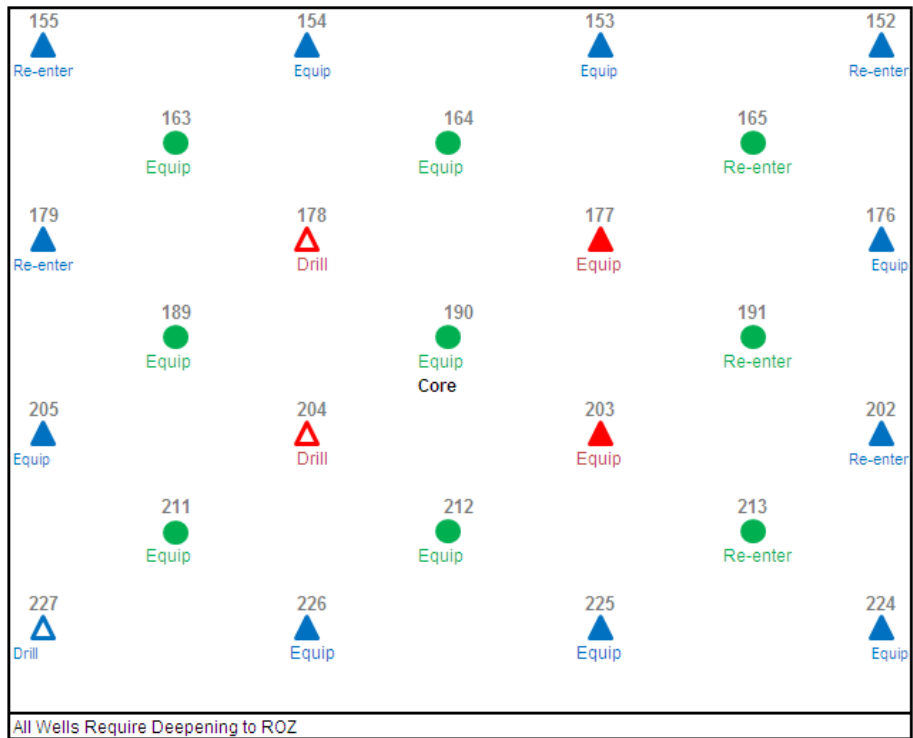 - **ROZ OOIP ~ 300 MMBO**

OOIP ~ 550 MMBO

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CO2 Reserves – Bulk of Reserve Value

- ✓ Characterization of Reservoir
- ✓ Continuity of Interval
- ✓ So in the MP and ROZ
- ✓ Good analogs at Wasson and Seminole
- • Prove Mechanism of Recovery (Pilot)

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Recovery Mechanism : Pilot Design

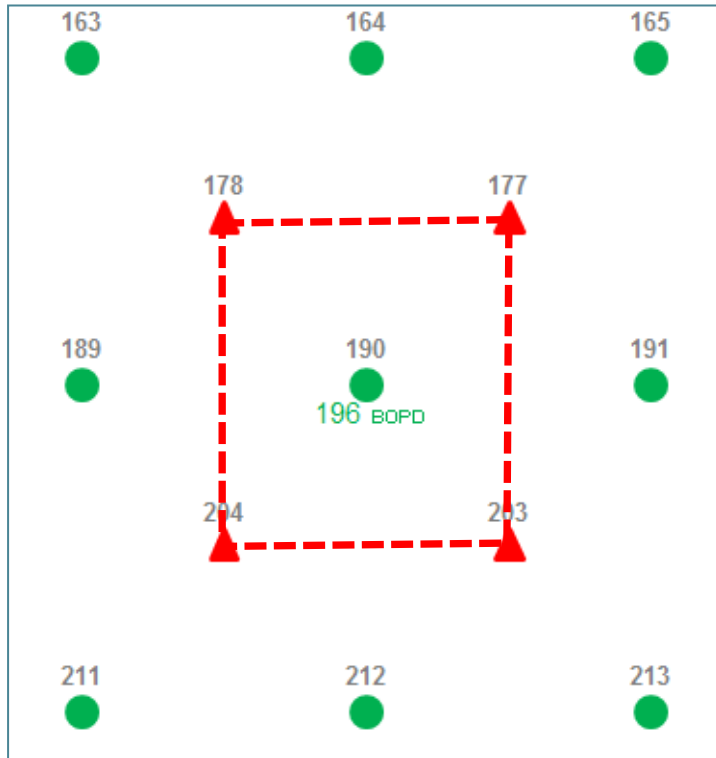**105 wells through ROZ**

47 Producers

58 Injectors

o **Well Utility ($3.8 MM)**
- 15 Deepen and Equip
- 7 Re-entry and Deepen
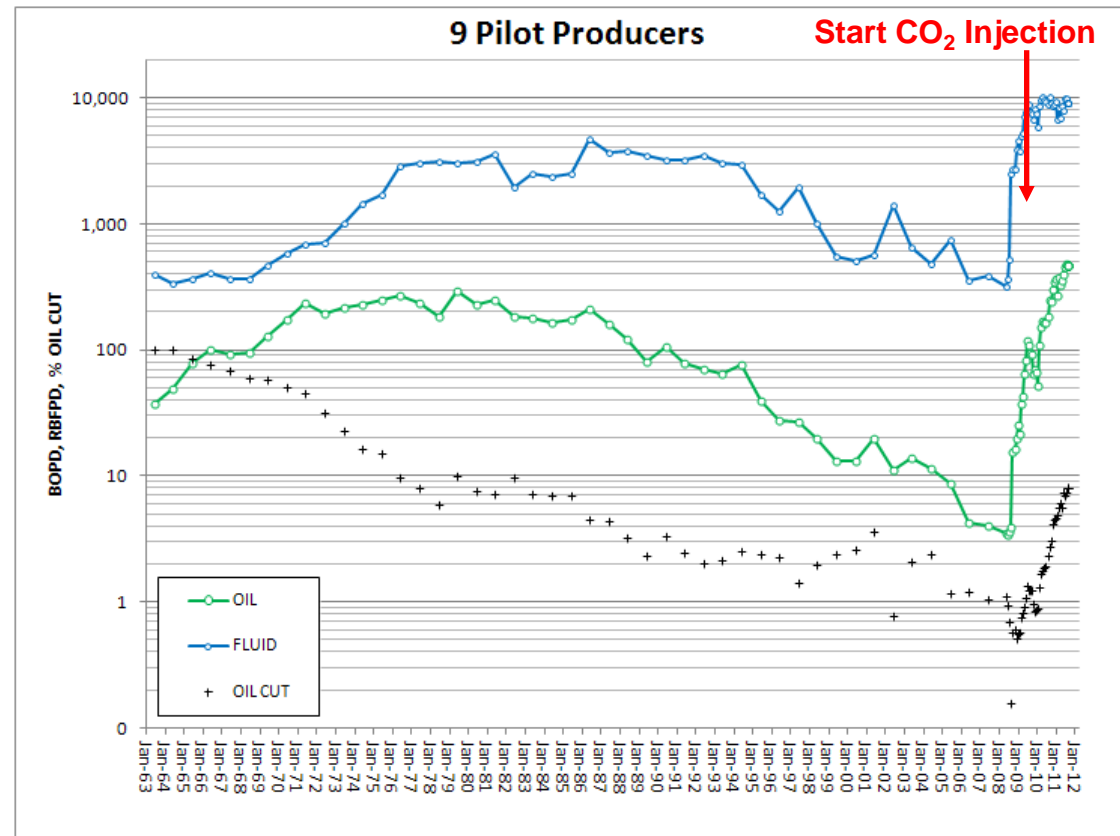- 3 Drill Wells

o **Facilities ($4.5 MM)**
- 3.5 Mile 8" CO_2 Service Pipeline
- 700 HP Recycle Compressor (~3.2 MMCFD)
- Separation and Test Satellite
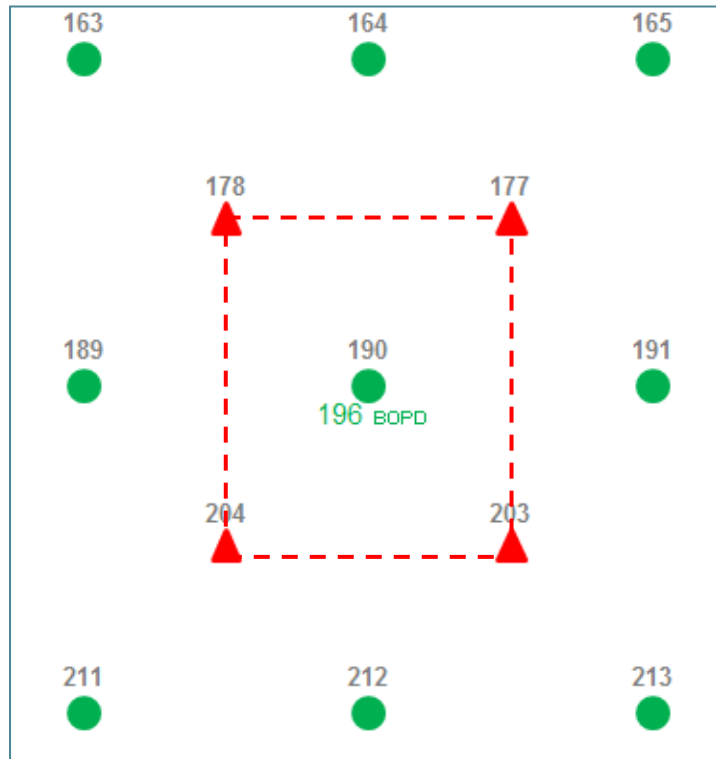
Pilot Operations – Performance

Full Pilot Area

- 500 BOPD Production
- 10 Fold Increase in Oil Cut
- Oil Rate ~2 x Peak from Water Flood
- Fluid Rate ~2 x Peak from Water Flood
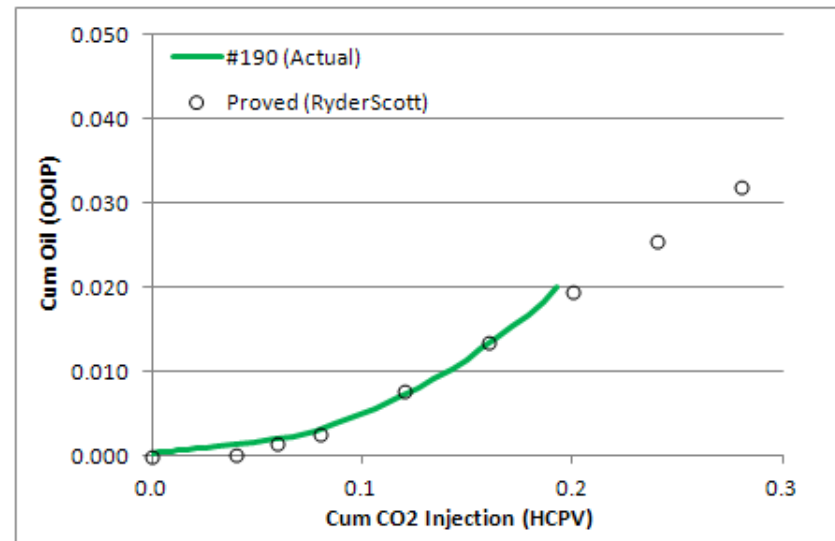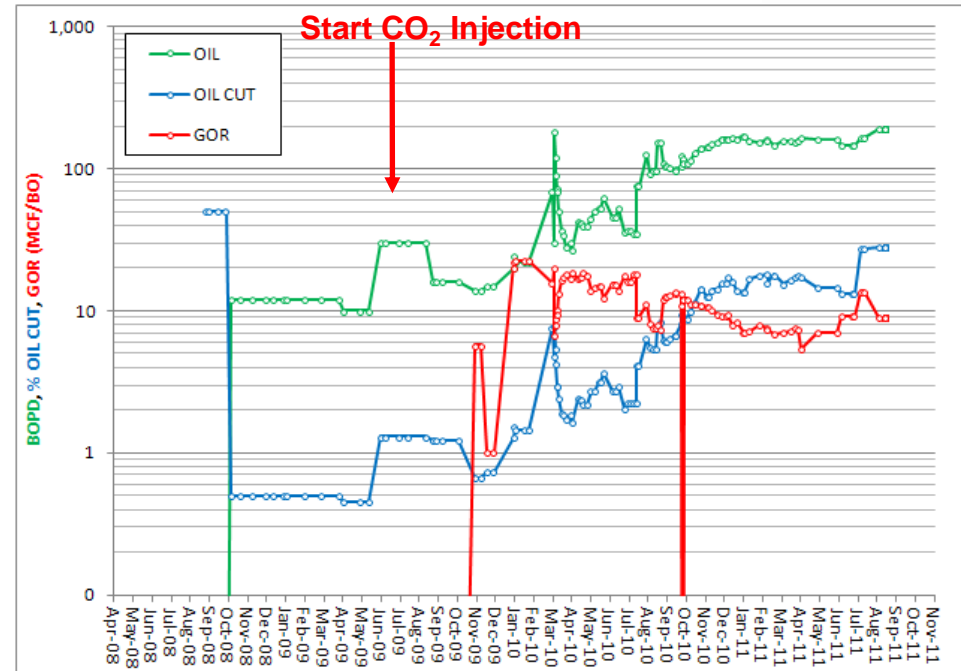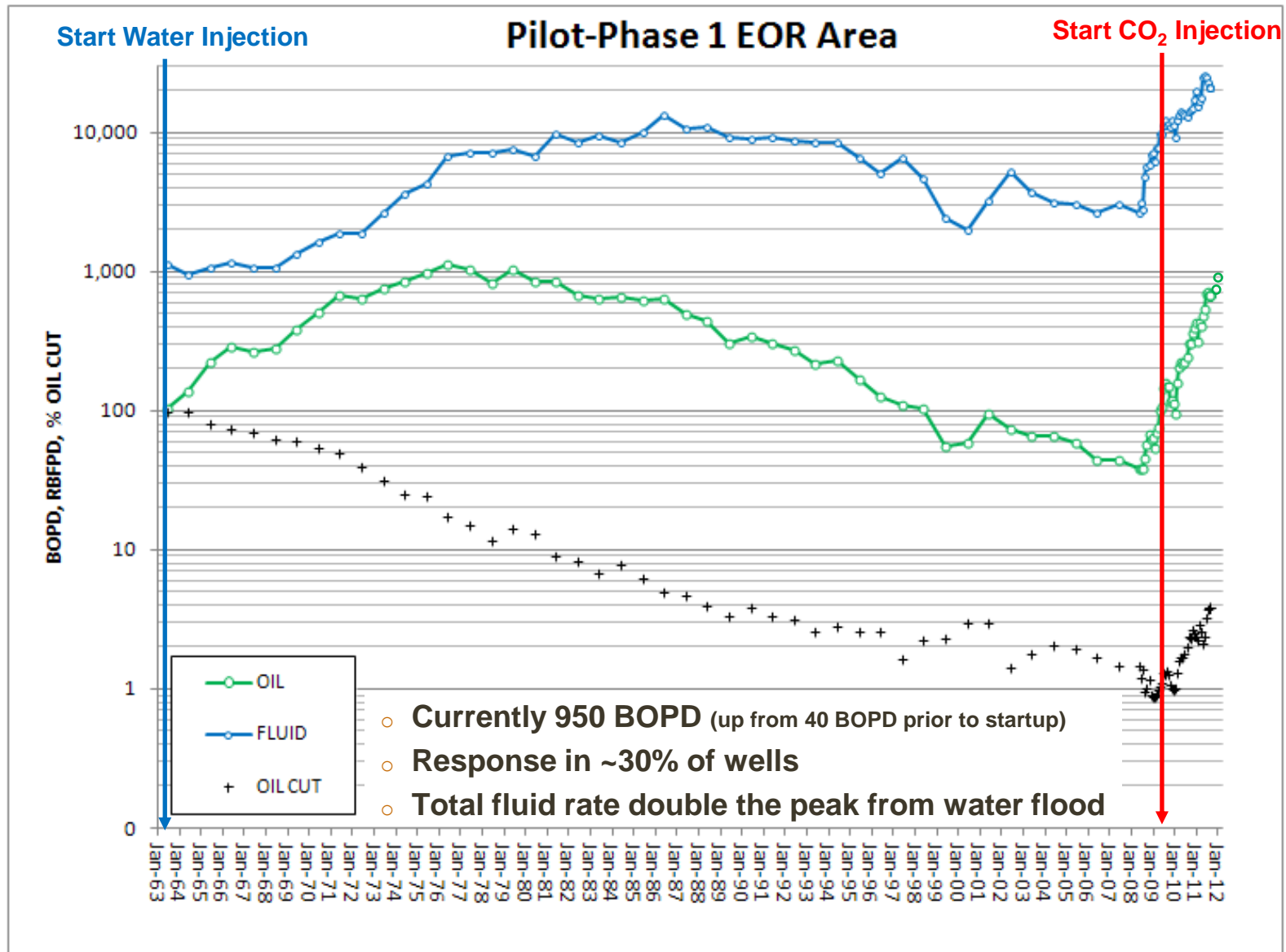- Response Continuing to Increase

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Surveillance Activities

- o **Material Balance & Performance**
- o **Injection Tests and Profiles**
- o **Production Logs**
- o **Pressure Observation**

Total CO2 Flood Area (Pilot - Phase 1)

Pilot-Phase 1 EOR Area

- Currently 950 BOPD (up from 40 BOPD prior to startup)
- Response in ~30% of wells
- Total fluid rate double the peak from water flood

Residual Oil Zone Fields Reserves Estimation – Summary

- **OOIP confidence**
  - Robust Geo Model
  - Extensive Core Density and Analysis
  - Good Log Coverage
  - * Must calculate OOIP properly from pre ROZ formation oil sats
- **Recovery Projection Confidence**
  - Analogy
  - Large Number of San Andres CO2 flood Recovery Curves
- **Response to CO2 Injection**
  - Miscible
  - Strong Oil Response
  - GOR under Control
  - Dramatically Increasing Oil Cut

Questions?