An Auditor's View of Booking Reserves in CO_2 EOR Projects and the ROZ

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DISCLAIMER:

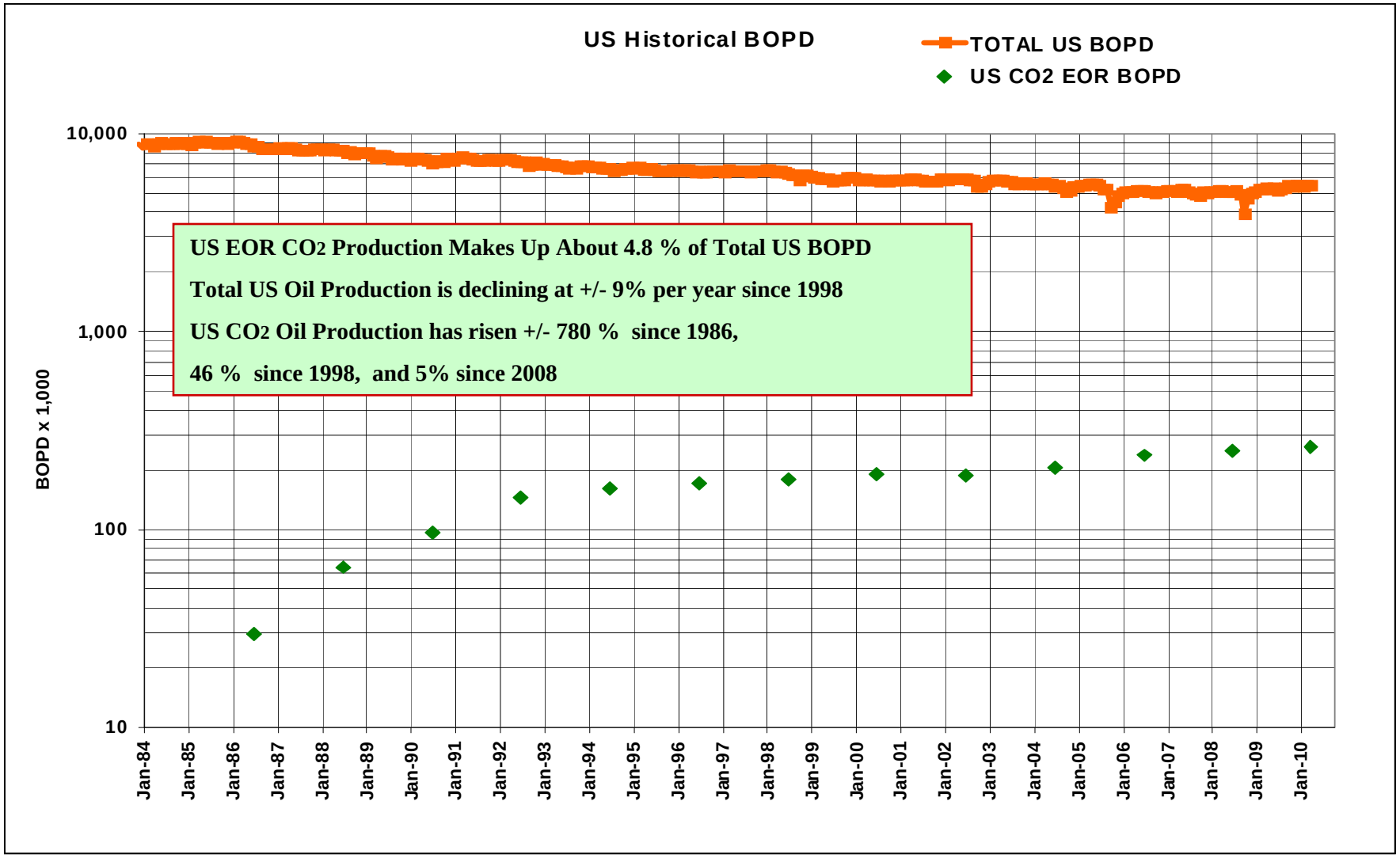
- The information presented herein represents informed opinions about US SEC reserves reporting regulations but does not purport to be identical to advice or rulings that may be obtained from the SEC.

- The SEC interprets each case individually & may alter interpretations based on facts particular to each case.

Outline: *An Auditor's View of Booking Reserves in CO2 EOR Projects and the ROZ*

1. What do the SEC and SPE-PRMS have to say about booking reserves in an EOR project?
2. Which methods are acceptable to book CO_2 projects?
3. Should the Main Pay and the ROZ be handled together or separately? Are they viewed as analogs?
4. What makes a good CO_2 EOR Project PUD?
5. What hurts our case in booking Proved EOR reserves?
6. What else should we consider?

How Significant Are CO_2 EOR Reserves?



Data Source: Melzer Consulting

SEC – Modernization of Oil and Gas Reserves Reporting Proved Oil & Gas Reserves

- *(iv) "Reserves which can be produced economically through application of **improved recovery techniques** (including, but not limited to, fluid injection) are included in the **proved** classification when:*

  *(A) **Successful testing by a pilot project** in an area of the reservoir with properties no more favorable than in the reservoir as a whole, **the operation of an installed program** in **the reservoir or an analogous reservoir**, or **other evidence using reliable technology** establishes the reasonable certainty of the engineering analysis on which the project or program was based; and*

  *(B) The project has been **approved** for development by all necessary parties and entities, including governmental entities"*

Source: Federal Register / Vol. 74, No. 9 / Wednesday, January 14, 2009 / Rules and Regulations page 2192

SEC – Modernization of Oil and Gas Reserves Reporting
Proved Oil & Gas Reserves

- *(31) "Undeveloped oil and gas reserves:*

  (iii) Under no circumstances shall estimates for undeveloped reserves be attributable to any acreage for which an application of fluid injection or other improved recovery technique is contemplated, unless such techniques have been ***proved effective by actual projects in the same reservoir or an analogous reservoir,*** *as defined in paragraph (a)(2) of this section, or by other evidence* ***using reliable technology*** *establishing* ***reasonable certainty****."*

Source: Federal Register / Vol. 74, No. 9 / Wednesday, January 14, 2009 / Rules and Regulations page 2192

SEC – Modernization of Oil and Gas Reserves Reporting
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What is Reliable Technology?

*(25) "**Reliable technology** is a grouping of one or more technologies (including computational methods) that has been **field tested** and has been demonstrated to provide reasonably certain results with **consistency and repeatability** in the **formation being evaluated or in an analogous formation.**"*

Source: Federal Register / Vol. 74, No. 9 / Wednesday, January 14, 2009 / Rules and Regulations page 2192

SPE-PRMS
2.3.4 IMPROVED RECOVERY

- Includes incremental recovery resulting from:
  - Waterflooding
  - Secondary Recovery
  - Tertiary Recovery
  - Pressure Maintenance

- May be Proved, Probable, or Possible Reserves or Contingent Resources. **Depending upon the available data and level of reasonable certainty.**

Source: SPE-PRMS

SPE-PRMS
4.0 Estimation of Recoverable Quantities

Acceptable Analytical Procedures

- Performance Based Methods
  - Production Decline Analysis
  - Material Balance
  - Simulation Modeling
- Analogy
- Volumetric Estimates

Source: SPE-PRMS

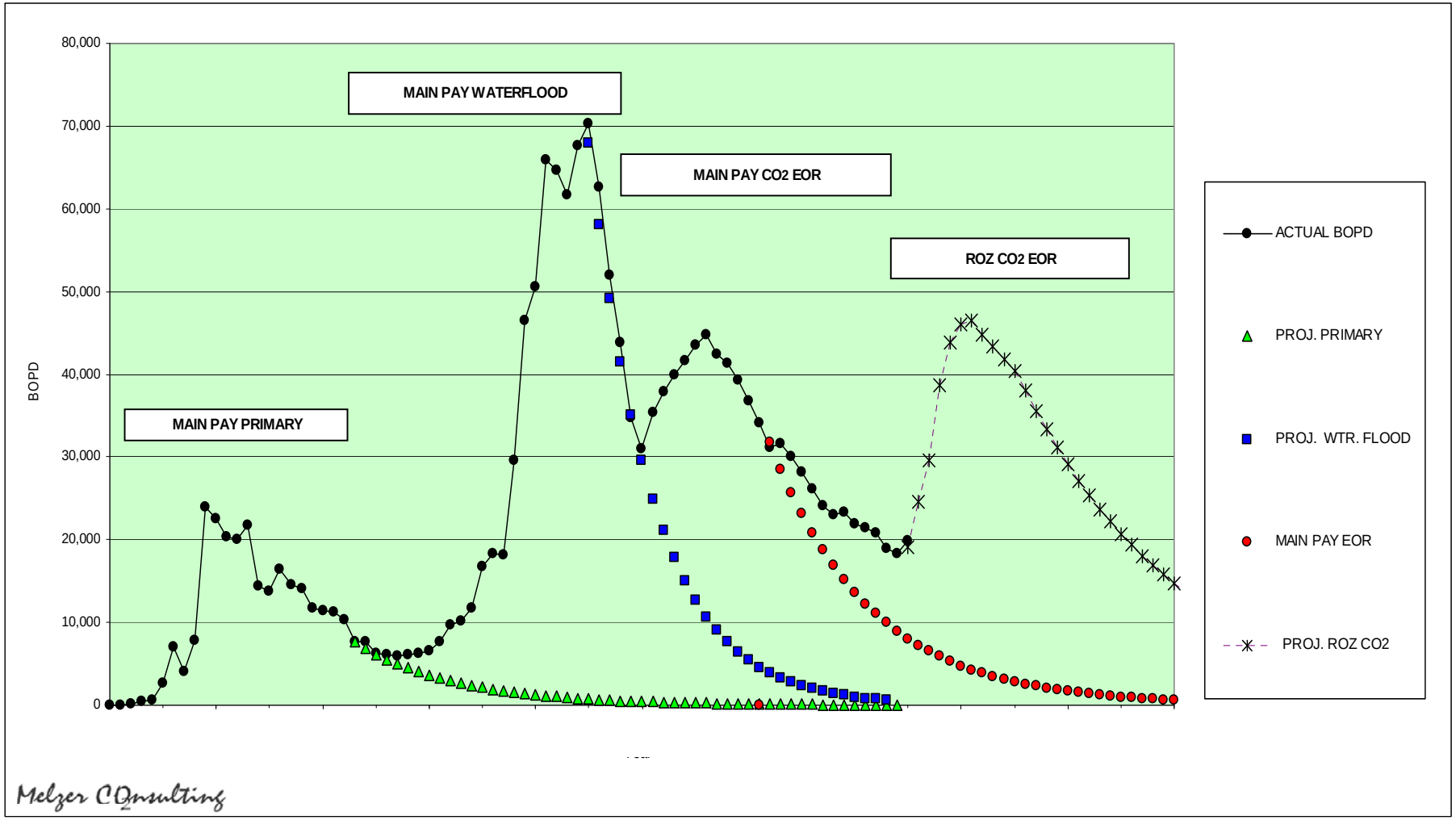
Various Performance Techniques (DCA) to Estimate Oil EUR for each *Definitive* trend

- Log of oil rate vs. time (semi-log plot)
  - Most often takes a hyperbolic shape
- Oil rate vs. cumulative oil (co-ordinate plot)
- Log % oil cut vs. cumulative oil
- Log % water cut vs cumulative oil
- Log WOR vs. cumulative oil

- Summation of individual well or injection pattern plots generally provide a more repeatable estimate than a field level (group) plot, unless the field is in a static (no change) mode of operation.

  - Meaning no change in which wells are active, same project phase, no mechanical changes, no injection changes, no zone changes, no new infill wells, no wells shut in to limit water production.....

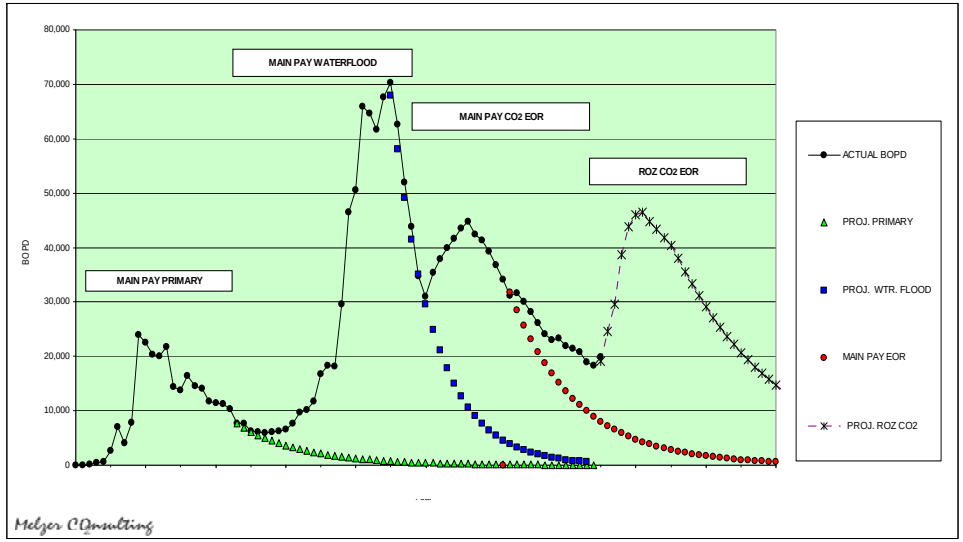
In a Mature Reservoir, You may Observe 4 distinct trends



In a Mature Reservoir, You may Observe 4 distinct trends

By subtracting the projected EUR of one phase from the total EUR of next phase you can estimate :

- Primary Recovery
- Secondary Recovery
- Tertiary Recovery in the Main Pay
- Tertiary Recovery from the ROZ with CO_2 Project



Well by well performance estimates are hard to beat if you have a definitive trend for a given phase.

Unfortunately, Definitive Performance Trends May Not Be Available Because:

- The project is too immature to have established a definitive trend for the current or planned development phase.
- The project is still undeveloped due to either:
  - The amount of unspent capital remaining or,
  - No favorable response from the producing wells for a new waterflood, CO_2 project, or development of the ROZ.
- In these cases Analogy is often the most appropriate method of analysis

SEC – Modernization of Oil and Gas Reserves Reporting
Proved Oil & Gas Reserves

- *"**Analogous reservoirs**, as used in resources assessments, have **similar** rock and fluid properties, reservoir conditions (depth, temperature, and pressure) and drive mechanisms, but are typically at a more advanced stage of development than the reservoir of interest and thus may provide concepts to assist in the interpretation of more limited data and estimation of recovery."*

Source: Federal Register / Vol. 74, No. 9 / Wednesday, January 14, 2009 / Rules and Regulations page 2190

SEC – Modernization of Oil and Gas Reserves Reporting
Proved Oil & Gas Reserves

- *"When used to support proved reserves, an **analogous reservoir** refers to a reservoir that shares the following characteristics with the reservoir of interest:*
  - *(i) Same geological formation (but not necessarily in pressure communication with the reservoir of interest);*
  - *(ii) Same environment of deposition;*
  - *(iii) Similar geological structure; and*
  - *(iv) Same drive mechanism."*

- *Instruction to paragraph (a)(2): Reservoir properties must, **in the aggregate**, be no more favorable in the analog than in the reservoir of interest.*

Source: Federal Register / Vol. 74, No. 9 / Wednesday, January 14, 2009 / Rules and Regulations page 2190

SPE-PRMS
4.1.1 Analogs

- *Analogs are widely used in resources estimation, particularly in the exploration and early development stages, when direct measurement information is limited.*
- *The methodology is based on the assumption that the analogous reservoir is comparable to the subject reservoir regarding reservoir and fluid properties that control ultimate recovery of petroleum.*
- *By selecting appropriate analogs, where performance data based on* ***comparable development plans*** *(including* ***well type****,* ***well spacing*** *and stimulation) are available, a similar production profile may be forecast.*

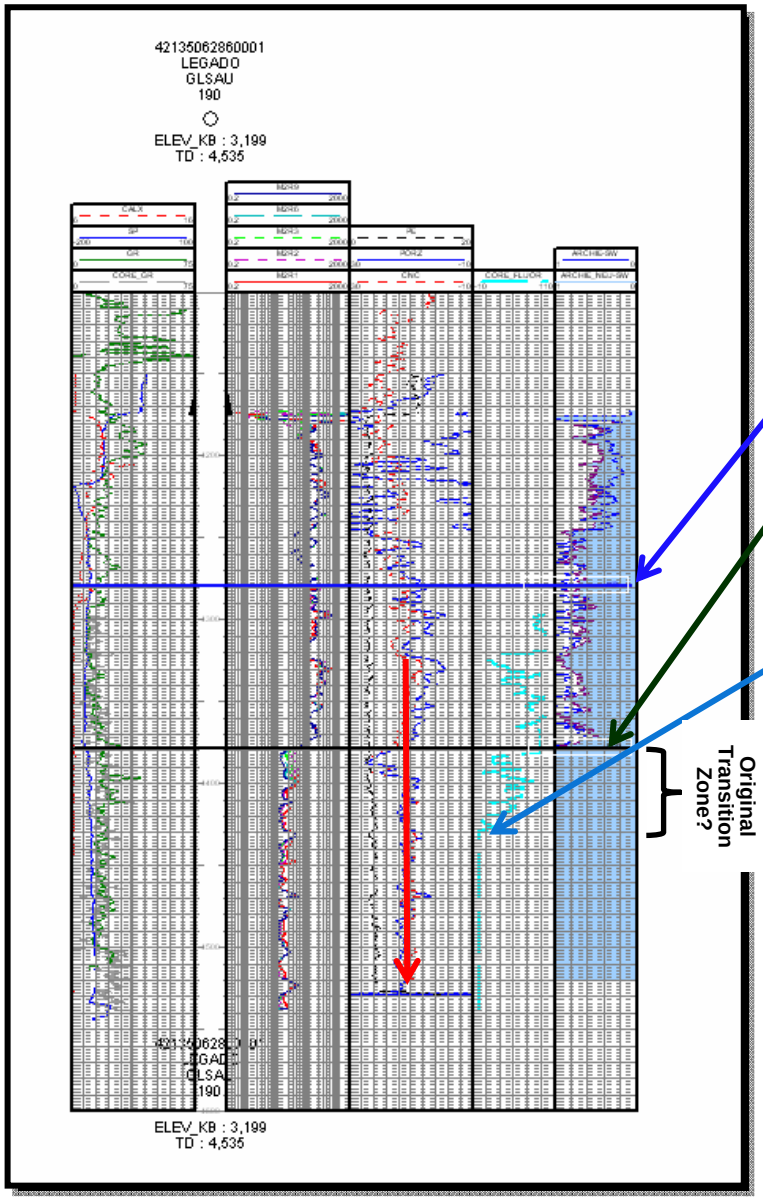
Source: SPE-PRMS

From a Practical Viewpoint, What Should We Consider to Justify an Analogy?

- Critical parameters for comprehensive review

Geoscience	Engineering	Operational
Structural configuration	Pressure and temperature	Well spacing
Lithology and stratigraphy	Fluid properties	Artificial lift methods
Principal heterogeneities	Recovery mechanism	Pattern type and spacing
Reservoir continuity	Fluid mobilities	Injector to producer ratio
Average net thickness	Fluid distribution	Annual injection volumes
Water saturation	Reservoir maturity	Fluid handling capacity
Permeability	Well productivity	Stimulation design
Porosity	EOR specifications	Areal proximity
Areal proximity	Areal proximity	

The Main Oil Pay & The ROZ



Main Pay OWC at Discovery (-1080')

Base ROZ from Log Calculations
(this is the Base ROZ marker used for volumetric mapping)

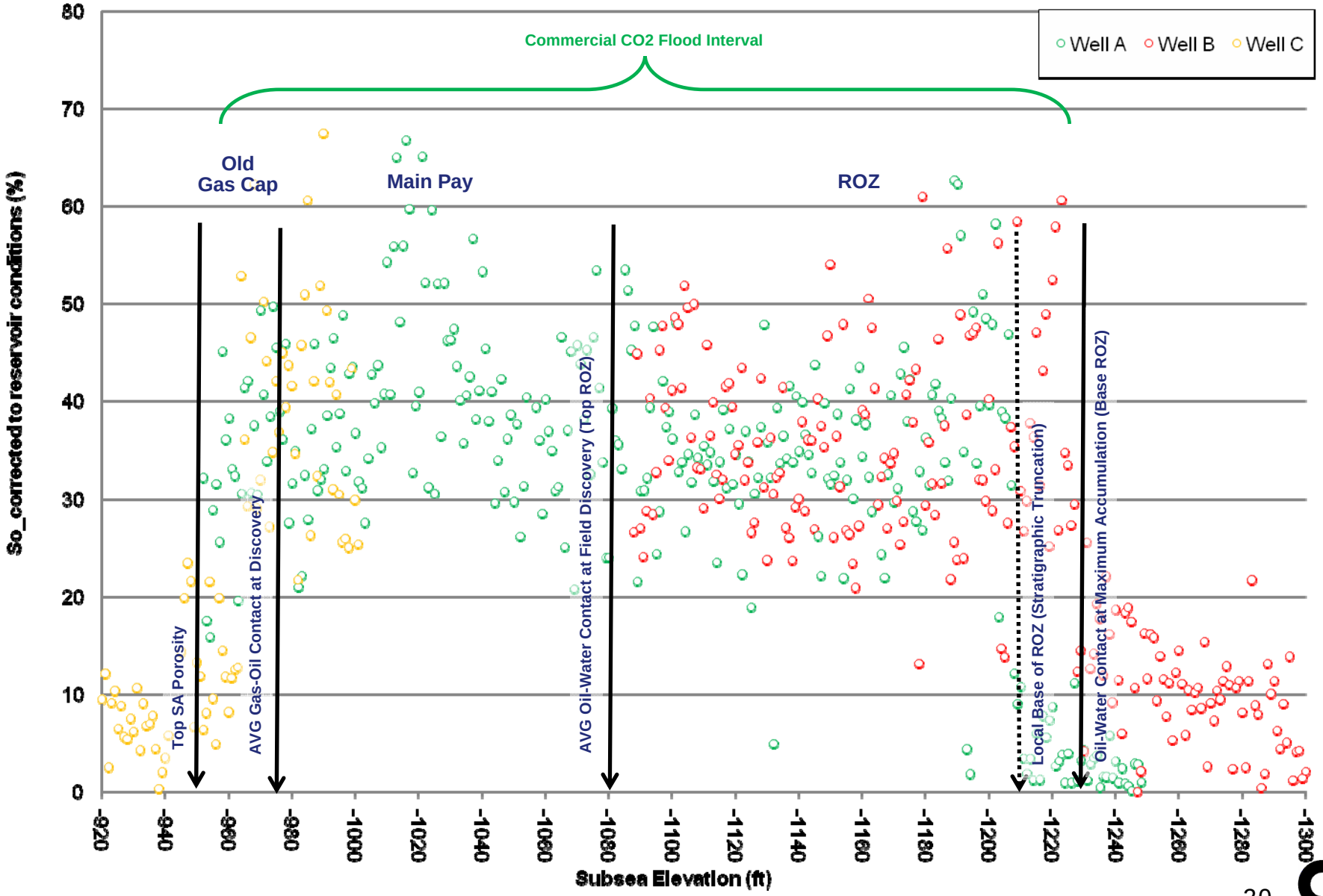
Base ROZ from Core Data
(oil saturation extends additional 40-50', but is weaker)

- **Induction/Resistivity log response correlates to higher water saturation**
- **Porosity/GR/SP logs remain constant**
- **Indicates Induction/Resistivity log influenced by fluid resistivity**
- **Therefore, use Induction/Resistivity to map Base of ROZ (confirmed log response with several cores)**

Can the Main Pay Zone and the ROZ be considered as Analogies For CO_2 Reserves?

- **Main Pay**
  - K = 9 md average
  - Initial So = 84%
  - Development Timeline
    - Primary Production
    - Water Injection (So after water = 35%)
    - CO_2 Injection
- **ROZ**
  - K = 12 md average
  - Initial So = 32%
  - Development Timeline
    - Planned CO_2 Injection – no water injection – no pilot
- Are Other Parameters close enough to be considered analogous?

Full Core Taken After Waterflood in the Main Pay Zone Shows Sor Similar to ROZ So



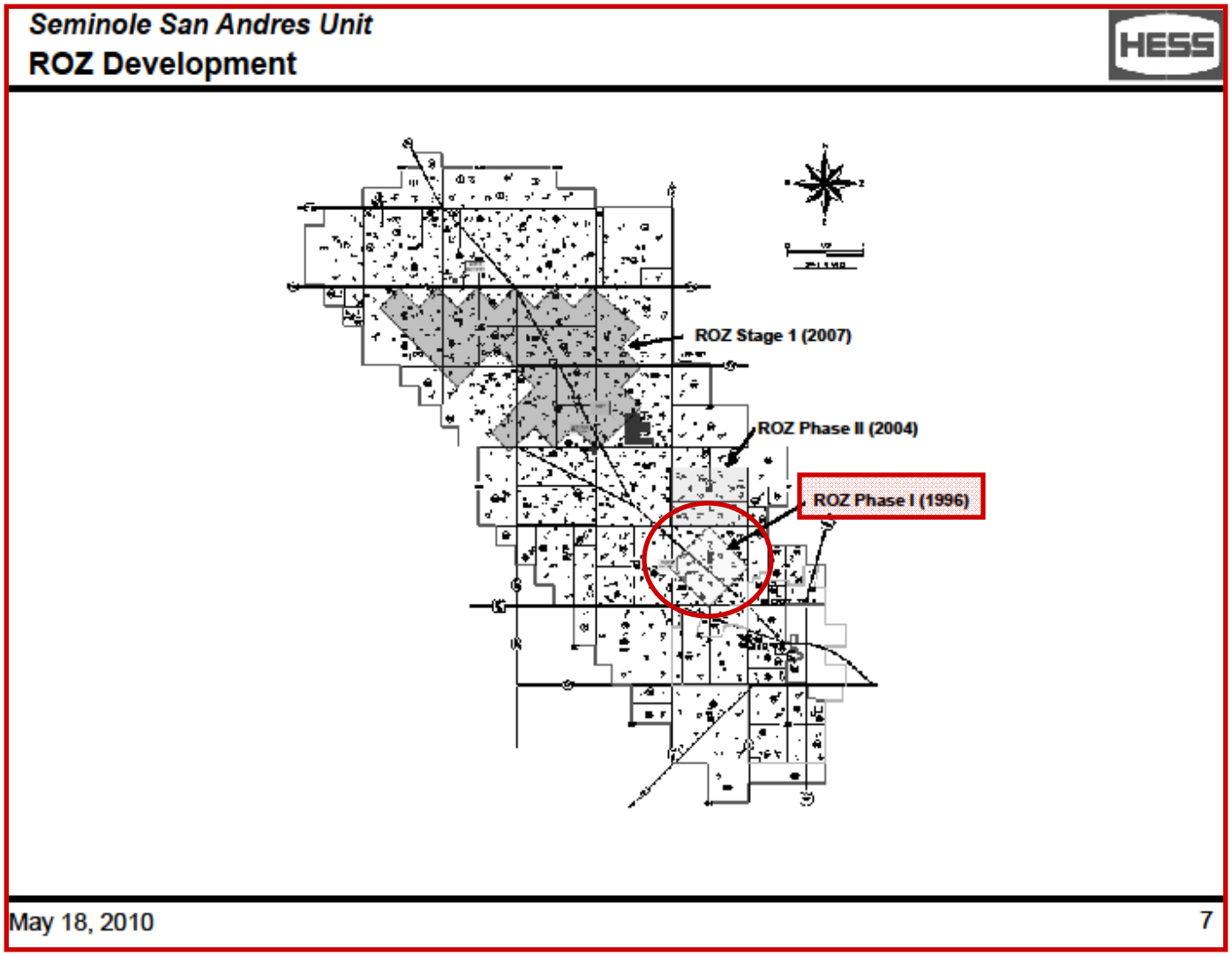
Can the Main Pay Zone and the ROZ be considered as Analogies For CO_2 Reserves?

- Main Pay
  - After Water Injection So = 35%
  - CO_2 Injection was a success, recovering an additional 16% of the OOIP
- ROZ
  - Higher k
  - Initial So = 32%
- Is the S_o similarity prior to CO_2 injection enough to book proved reserves from the ROZ?

Can the Main Pay Zone and the ROZ be considered as Analogies For CO_2 Reserves?

- In this case, you need to ask additional questions…
- The Main Pay Zone was water flooded but the ROZ was not.
- You would need a commercially successful pilot in this ROZ or another field in which an analogous ROZ has produced commercially after CO_2 injection, without a water flood.
- Is the field in question more heterogeneous?

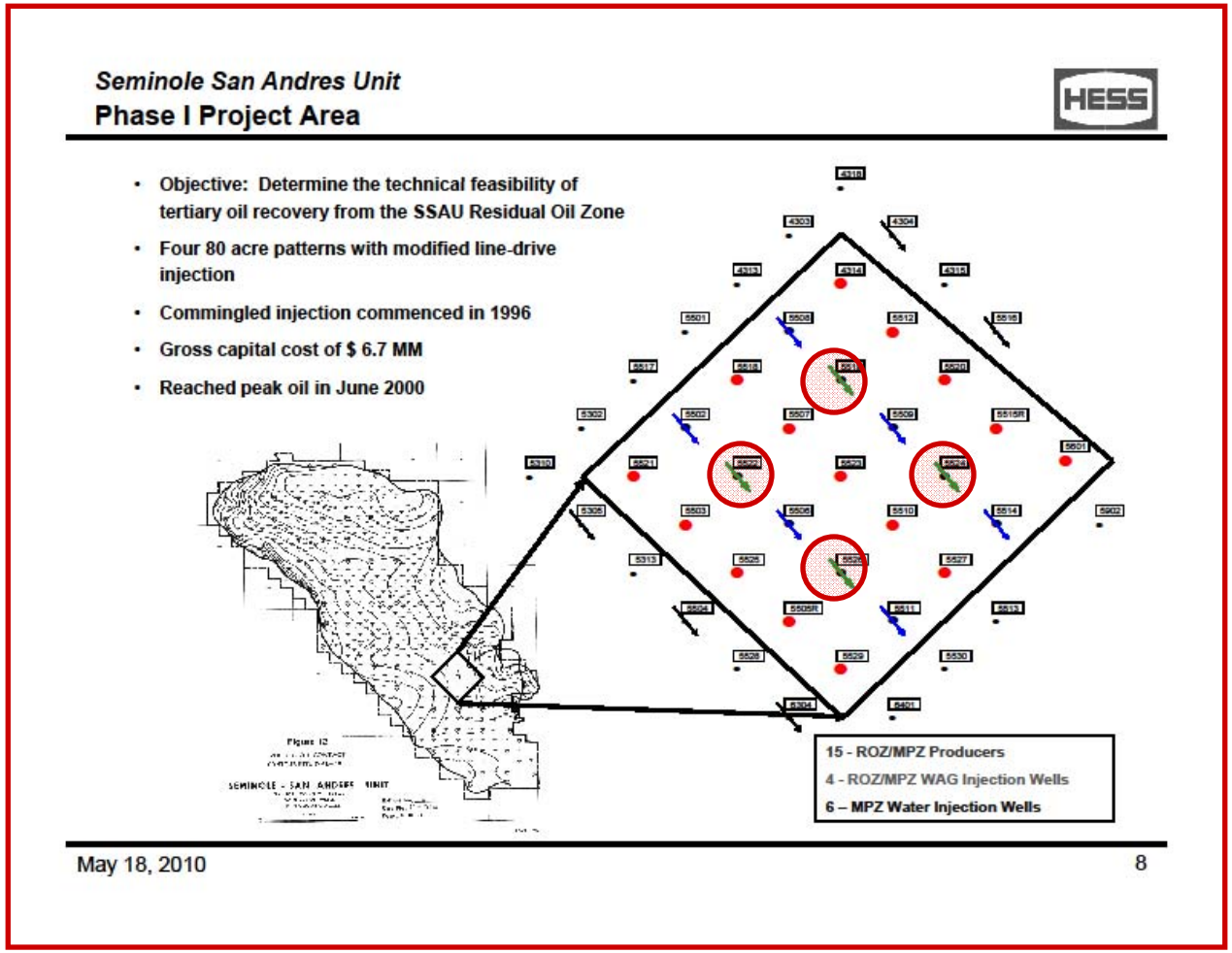
Let's Look At Hess's Phase I Pilot in the Seminole San Andres Unit ROZ



Prior to Full Field Development, Hess Implemented a CO_2 pilot project in 1996

Courtesy of Scott Biagiotti, Hess Corporation – SPE Gulf Coast Permian Study Group – May 2010

Let's Look At Hess's Phase I Pilot in the Seminole San Andres Unit ROZ



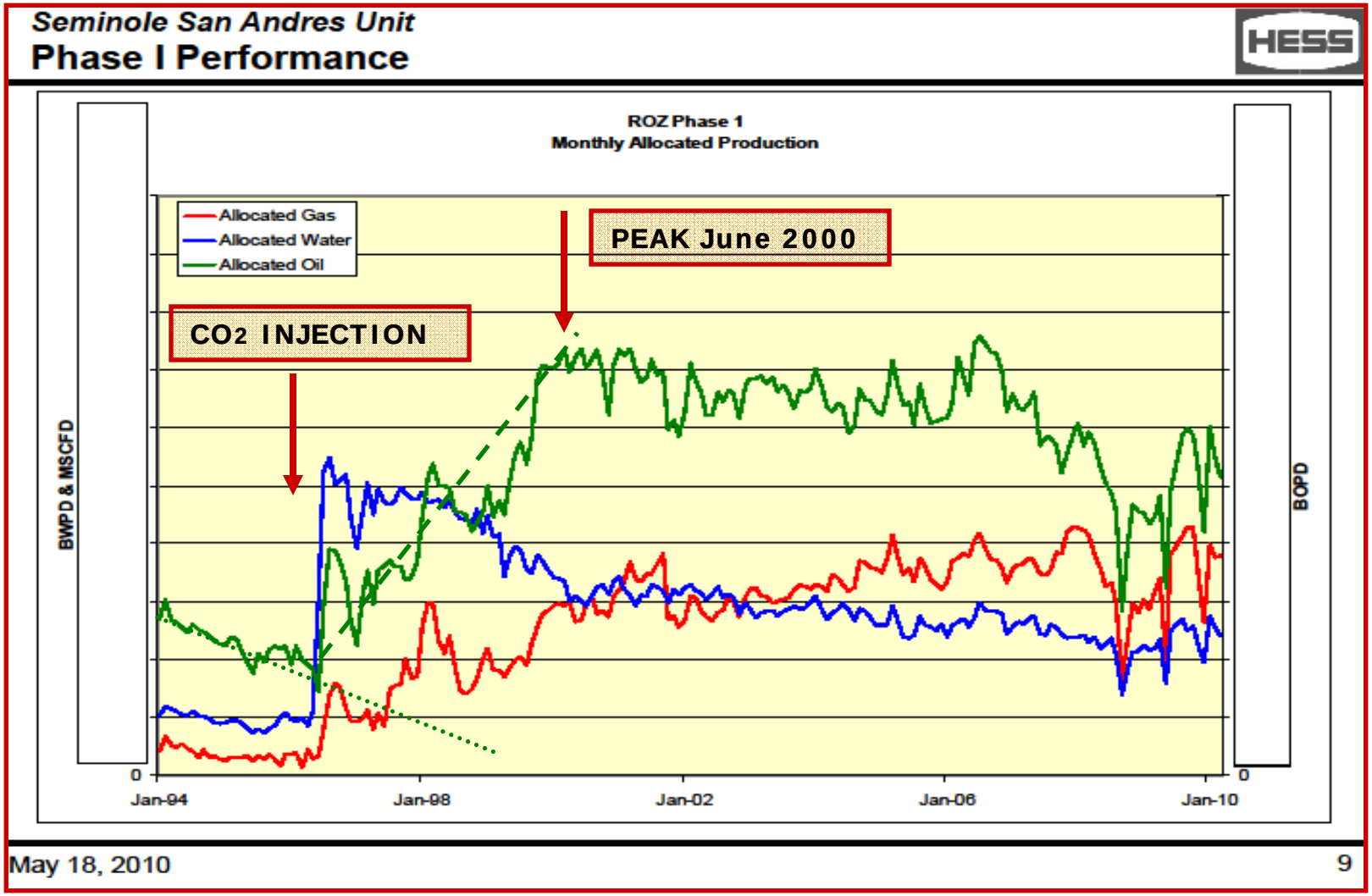
The ROZ pilot consisted of 4 - 80 acre patterns, with modified line drive CO2 injection

4 wells were used to inject CO_2 into the MPZ and ROZ

The MPZ and ROZ produced from 16 wells

Courtesy of Scott Biagiotti, Hess Corporation – SPE Gulf Coast Permian Study Group – May 2010

The Pilot Confirmed A Successful and Commercial CO_2 Flood of the ROZ



Courtesy of Scott Biagiotti, Hess Corporation – SPE Gulf Coast Permian Study Group – May 2010

What is a successful test or pilot?

- No definitive guidance set forth by SEC, but, **historically**,
- SEC has required **production response** or a **successful commercial analogy with a production response**
- PRMS requires “favorable” response
  - May be BHP response
  - May be change in GOR
  - May be confirmation of pre-injection simulation model
- The SEC **may** be open to a combination of “favorable” responses similar to the PRMS, but this is an opinion, document your work and conclusions to present a “compelling case”
- The Seminole San Andres Phase I ROZ pilot clearly demonstrated the favorable production response

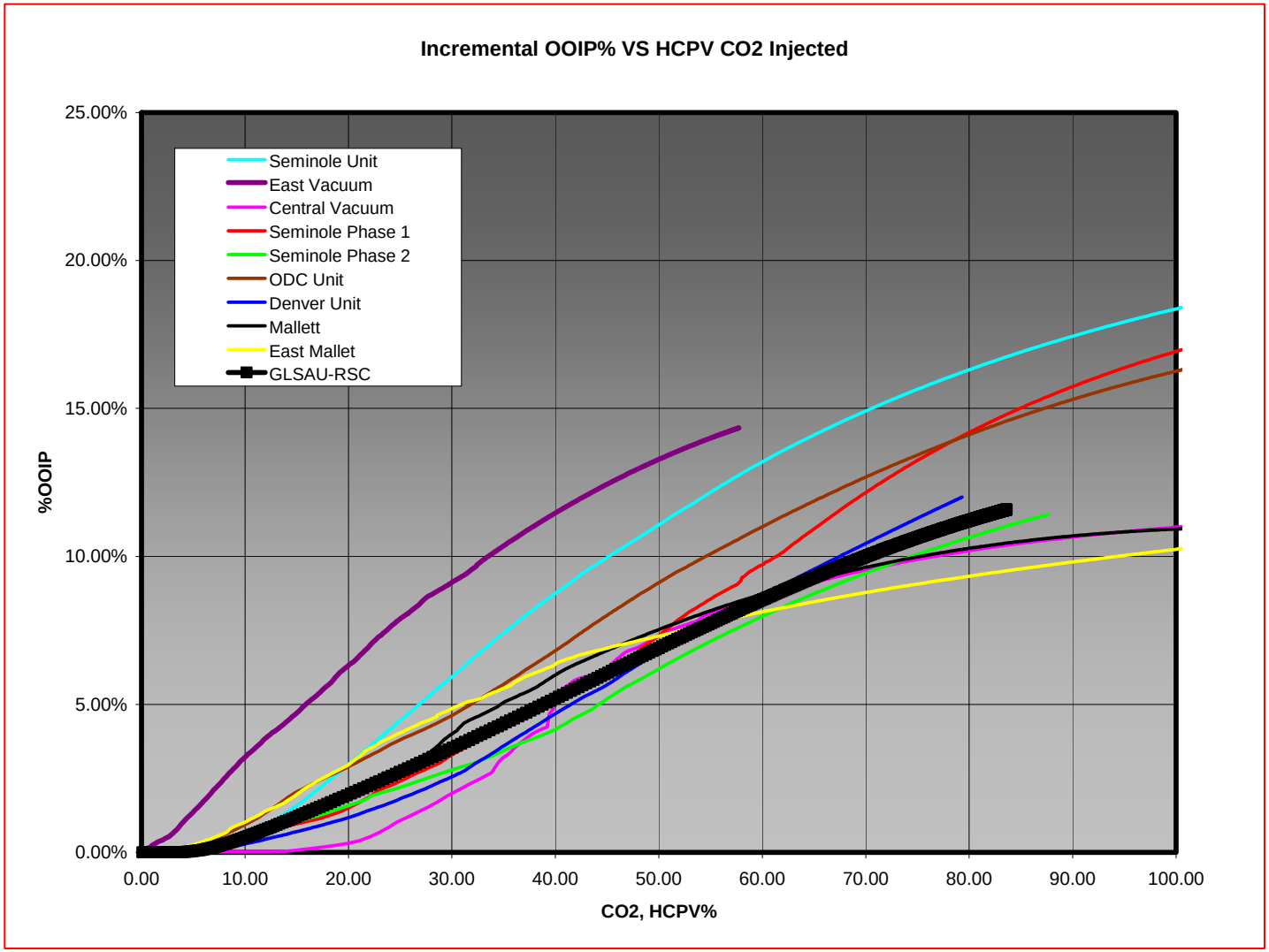
Items Necessary For a Compliant and Strong Proved Reserves Case

- Good estimate of OOIP for both the analogous reservoir and the reservoir being studied.
- OOIP For CO_2 Flood Area
- Initial Oil Formation Volume Factor – Boi
- Current Oil Formation Volume Factor – Bo
- Current Reservoir Temperature and Pressure (º F and psia)
- CO_2 Formation Volume Factor – B_{CO2}
- Initial and Residual Oil Saturation - So
- Historical production and injection rates

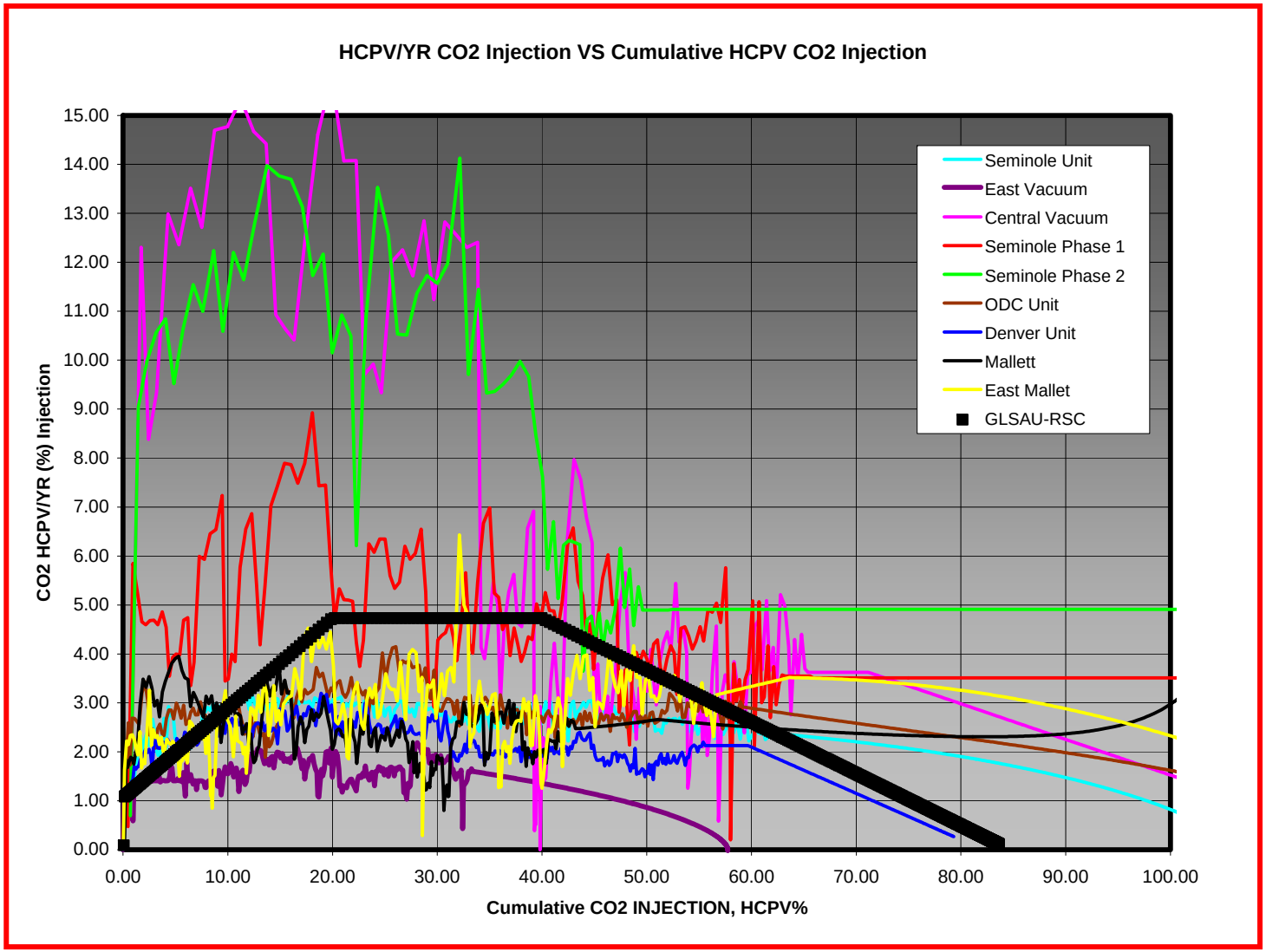
Developing Compliant Analogies: CO_2 Flood Reserves Estimation & Projection

- Document Why the two Reservoirs are Good Analogs
- Determine "Dimensionless" EOR response to CO_2 injection from analogous reservoirs on a Hydrocarbon Pore Volume (HCPV) basis
  - Establish baseline waterflood forecast
    - Performance Trends
    - Original Ershaghi (SPE 6977)
    - Modified Ershaghi
  - Subtract baseline WF from total oil production to determine EOR wedge
  - Plot cumulative EOR/OOIP (%OOIP) versus CO_2 injection on HCPV basis (RB CO_2/(OOIP*B_{oi}))
- Scale results to the reservoir of interest on HCPV basis

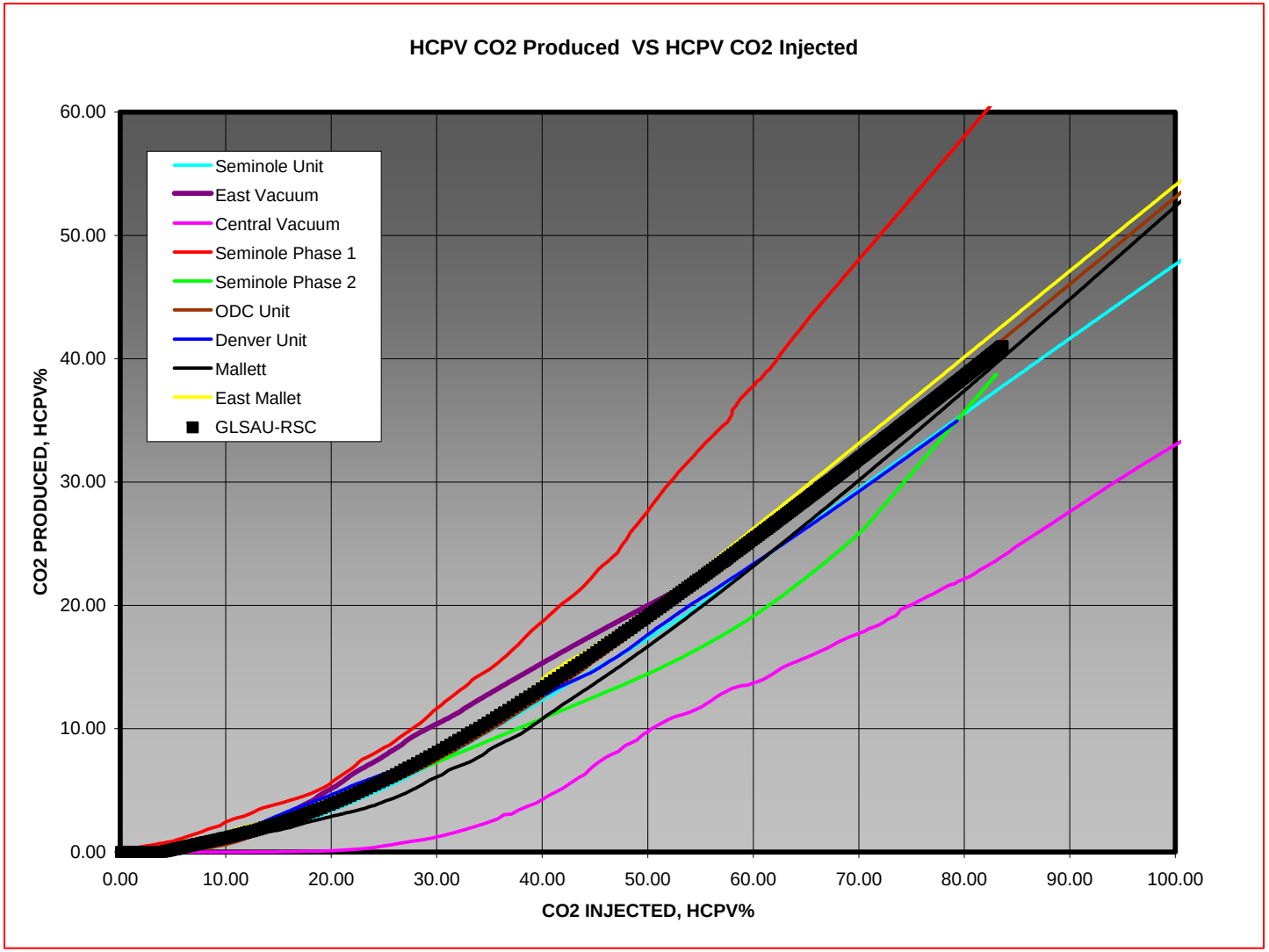
Incremental EOR Recovery vs Injected CO2



HCPV % Per Year CO2 Injection



HCPV CO2 Production vs Injection



Items that Limit or Prohibit Booking PUD EOR Reserves

- **No Successful EOR Pilot in Reservoir**
- **No Successful EOR Analog Reservoir**

- **Factors that Increase the Unswept Area :**
  - Discontinuities
  - Low k in the zone to flooded
    - Limits Injectivity
    - Limits sweep and rate
  - Layering with variable k
  - Multiple facies
  - Moderate compartmentalization
  - The higher the free Sg the lower the sweep
  - Lower oil gravity
  - Higher oil viscosity

The Overall Heterogeneity Will Play a Big Role in the Recovery and How an Auditor will View Analogs

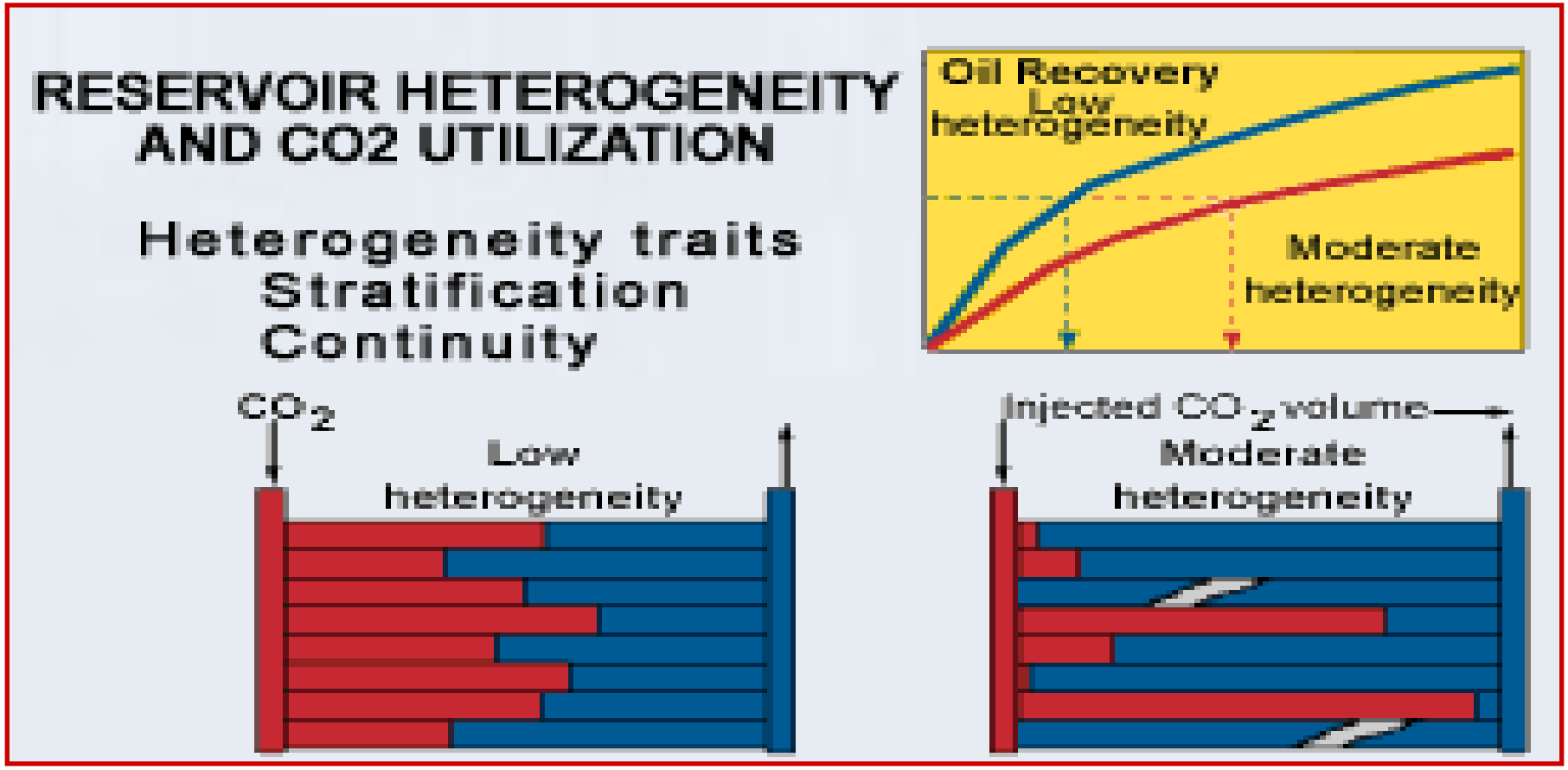


Illustration Taken From Kinder Morgan Website

Other Things to Think About

- CO_2 floods are miscible floods for areas with high residual oil to water. CO_2 must be readily available.
- Waterflood simulation output must always be checked against analogies.
- CO_2 flood simulation must always be checked against analogies.
- Simulation **without a history match for the phase under** evaluation may be used in a PRMS reserves report, but will probably fail an SEC audit
- Best analogs are in same reservoir or pilot in the same reservoir
- Statistical wide area studies of incremental RF by drive mechanism and zone may be the best analogies available
- You must have documented analogy every time the drive mechanism or mechanical configuration changes.

It's time for me to quit.
Any Questions?

ARE YOU AS CONFUSED AS I AM?