SPEE Panel on Unconventional Reserve Estimation

• Rod Sidle – Moderator, SPEE Reserves Definitions Committee Chair
• Gary Gonzenbach, P.E. – SPEE 2015 President (co-author Monograph 3)
• Paul McDonald, P.E. – (co-author Monograph 3)
• John Seidle, Ph.D., P.E. – Monograph 4 Committee Chair (co-author Monograph 4)
• John Lee, Ph.D., P.E. – (co-author Monograph 4)

13 August 2015
SPEE Panel Format

Opening remarks/presentation

• Who is “SPEE”?
• What is Monograph 3?
• How has Monograph 3 been used?
• What is Monograph 4 (General Summary)?
• What are key features of the Monograph 4 workflow?

Panel Discussion – Q&A
Recognizing that Petroleum Evaluation Engineering is a specialized field, the Society is dedicated to

- the promotion of professional growth of the membership

- and to the advancement of the profession of Petroleum Evaluation Engineering by demonstrating by example the highest standard of ethics,

- by promoting continuing education of our membership and by education of the public in the area of oil and gas reserve definitions, reserve evaluations, and fair market value.
Qualifications

Full Membership
1. Bachelor or advanced degree in Engineering, Geology, or Equivalent
2. 10 years experience in Evaluation of Oil & Gas properties
3. Professional License if offering engineering services to public

Associate Membership
1. Bachelor or advanced degree in Engineering, Geology, or Equivalent
2. 5 years experience in Evaluation of Oil & Gas properties
3. Professional License if offering engineering services to public
Monograph 3 – Guidelines for the Practical Evaluation of Undeveloped Reserves in Resource Plays

1. Published December 2010
2. Reasonable and Practical method for determining Proved Undeveloped Reserves

Monograph 4 – Estimating Developed Reserves in Unconventional Reservoirs

1. Expected publication year end 2015
2. Reasonable and Practical methods for estimating Developed Reserves
SPEE Monograph 3 –
Guidelines for the Practical Evaluation of Undeveloped Reserves in Resource Plays

Purpose – To provide a reasonable guideline for estimating Undeveloped Reserves and Resources in a Resource Play.
SPEE Monograph 3 -- Committee Members

- Russell Hall – Russell K. Hall and Associates - Chairman
- Robin Bertram – AJM Deloitte
- **Gary Gonzenbach** – CG Petroleum Consulting
- Jim Gouveia – Rose and Associates
- Brent Hale – William M. Cobb and Associates
- Paul Lupardus – Chesapeake Energy
- **Paul McDonald** – Pioneer Natural Resources
- Bill Vail – DeGolyer and MacNaughton
- Marshall Watson – Texas Tech University
Workflow for Evaluation of *Undeveloped* Reserves in Resource Plays

From SPEE Monograph 3

1. Determine whether the reservoir is a Resource Play
2. Identify Analogous Wells (completion & production characteristics) & determine EUR
3. Create a log normal distribution of Analogous well EURs
4. Determine the Proved Areas using the distribution model
5. Adjust Deterministic EURs to Statistical EURs
Characteristics of a Resource Play

1) Tier 1 Criteria (always)
   1) Repeatable Statistical EUR Distribution
   2) Offset performance is not a reliable performance predictor
   3) Continuous hydrocarbon system (regional)
   4) Hydrocarbons are not held in place by hydrodynamics

2) Tier 2 Criteria (common)
   1) Requires stimulation to produce economically
   2) Produces little in-situ water (except for CBM)
   3) No obvious seal or trap
   4) Low perm

Is it a Resource Play?
Observations of a Resource Play and Well Count

1) It is not possible to determine if a reservoir is a Resource Play early in the exploration process

2) A Resource Play must include substantially more than 100 minimal risk locations

3) A Resource Play should encompass at least 50 to 100 drilled wells.

Is it a Resource Play?
Analogous Wells

Identify Analogous Wells

Are these in Common?

- Geology
- Lithology
- Completion Method
- Lateral Length
- Line Pressure
- Spacing

*SPEE Monograph 3: Guidelines for the Practical Evaluation of Undeveloped Reserves in Resource Plays, Chapter 1, @Copyright 2010 by the Society of Petroleum Evaluation Engineers*
Determine EUR on Individual Producing Wells

1) See Monograph 4
Example: Log Normal Distribution of Analogous producing Well EURs

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What is the Proved Area? – Anchor Wells

1) Select a random set of “Anchor Wells”
2) Re-calculate the distribution
3) Compare Reference Values
4) Is it repeatable?

Determine the Proved Area

Fig. 3.13 – Example 2 - Anchor Wells in Resource Play

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What is the Proved Area? – Radii around Anchor Set

1) Test areas around “Anchors” – vary radius

2) No overlap of wells

3) Compare Reference Values of Distribution

Determine the Proved Area
Final Proved Area

Determine the Proved Area

Fig. 3.21 – Example Problem 2 – Final Proved Area

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Determine Proved EURs

Alternatives:

1. Solve for P90 using Analogous Well EUR distribution in a Monte Carlo Simulator (recommended)
2. Approximate using P^ (midpoint between P50 and mean)
3. Apply Aggregation Factor using Analogous Well EUR distribution

Adjust EURs for Aggregation
Example: Adjusting Deterministic EUR to Statistical EUR based on drilling opportunities - Aggregation
Statistical EUR: $P^\wedge$ Approximation

Fig 4.15 – Ratio of $P_{90}$ to $P^\wedge$ versus Well Count

Example: Adjusting Deterministic EUR to Statistical EUR based on $P^\wedge$ - Aggregation
Case Study of Monograph 3 Methodology

Pioneer Natural Resources

1. Determine whether the reservoir is a Resource Play
2. Identify Analogous Wells (completion & production characteristics) & determine EUR
3. Create a log normal distribution of Analogous well EURs
4. Determine the Proved Areas using the distribution model
5. Calculate proved, probable, possible reserves
6. Results
SPEE Monograph 4 - Estimating Developed Reserves in Unconventional Reservoirs

John Seidle
MHA Petroleum Consultants

13 August 2015
SPEE Monograph 4 – Estimating Developed Reserves in Unconventional Reservoirs

Purpose - Assess current methods to forecast performance of wells in unconventional reservoirs given different reservoir types, different completions, and different well maturities.
What does Monograph 4 cover?

- Light tight oil/shale oil
- Shale/tight gas
- Coalbed methane (CBM)/coalseam gas
- Basin-centered gas

What Is Excluded?

- Oil sands (bitumen)
- Gas hydrates
- Oil shale (kerogen)
SPEE Monograph 4 -- Committee Members

- Jim Erdle (CMG)
- Brent Hale (SPEE, Cobb & Associates)
- Olivier Houze` (KAPPA Engineering)
- Dilhan Ilk (DeGolyer & MacNaughton)
- Creties Jenkins (SPEE, Rose & Associates)
- John Lee (SPEE, Univ of Houston)
- John Ritter (SPEE, Occidental Petroleum)
- **John Seidle** (SPEE, MHA Petroleum Consultants)
- Darla-Jean Weatherford (TextRight, technical editor)
- Scott Wilson (SPEE, Ryder Scott)
Acknowledgements –

Use of images provided by SPEE Monograph 4 Committee Members is gratefully acknowledged.
SPEE Monograph 4 -- Outline

1. Introduction
2. Definition of Unconventional Reservoirs (UCR)
3. Reservoir Characterization Aspects of Estimating Developed Reserves in UCR’s
4. Drilling, Completions, and Operational Aspects of Estimating Developed Reserves in UCR’s
5. Classical Arps’ Decline Curve Analysis (DCA)
6. Fluid Flow Theory & Alternative Decline Curve Methods
7. Model-Based Well Performance Analysis & Forecasting
8. Discretized Models
9. Statistical Methods and Uncertainty in Forecasts and Estimated Ultimate Recovery
10. Example Problems
Geoscience controls in unconventional reservoirs

- Regional geology
- Structural geology
- Stratigraphy
- Lithofacies types
- Depositional system
- Diagenesis
- Organic geochemistry
- Hydrogeology
- Natural fractures
- Geomechanical props.
- Rock properties
- Log properties
- Seismic scale props.
- Fluid properties
Drilling & Completions

- Shale wells are mostly horizontal and completed with slickwater fracs
- Tight sand and CBM wells mostly vertical
- Microseismic data indicate stimulated reservoir volume and influence on production profiles
- Key success driver is cost reduction
Operations

- Reservoir and operating conditions will change
  - Greater drawdown due to larger choke sizes, artificial lift, compression
  - Loss of fracture conductivity
  - Loss or increase in permeability
- Offset wells may impact existing wells
- Costs may escalate (higher water cuts, environmental monitoring, etc.)
Arps basic decline curve equations

Hyperbolic \[ q = q_i (1 + bD_i t)^{-1/b} \]

Exponential \[ q = q_i e^{-Dt} \]

Harmonic \[ q = \frac{q_i}{(1+D_i t)} \]

- Simple to get ....
- Adequate empirical match that leads to essentially universal adoption by
  - practicing engineers
  - software manufacturers
  - financial backers
Decline curve recommended practices

• Use well-level, high frequency data
• Plot all phases, all pressures
• No b values higher than customary for well/reservoir type or 2
• Multiple-segment declines for performance-changing events
• Constrain hyperbolic forecasts with $b > 1$ using a terminal decline rate
Rate Transient Analysis (RTA)

• Analytical/numerical models to analyze and forecast well performance

• Objectives
  – Determine well and reservoir properties
  – Evaluate completion effectiveness
  – Forecast well production
  – Assess uncertainties in results and forecasts

• Limitations
  – Single well
  – Single phase
  – Homogeneous reservoirs
Numerical simulation

• Can describe situations where simpler methods fail
  – Multiphase flow
  – Reservoir heterogeneity
  – Well interference
  – Changing reservoir/completion parameters over time

• History matches not unique. Automatic history matching algorithms identify multiple matches.

• Provides multiple production forecasts

• Aids in assessment of uncertainties
Uncertainty in the Estimation of Developed Reserves

• Reserve category uncertainty
  – 90% or P90 or proved
  – 50% or P50 or proved + probable
  – 10% or P10 or proved + probable + possible

• Tools for quantifying uncertainty
  – Log-log, semilog, log-probit plots and histograms
  – Trumpet plot aggregation
  – Cumulative confidence interval plots
  – Sequential accumulation plots
Conclusions

• SPEE monograph 4 addresses developed reserves in unconventional reservoirs

• Geoscience, drilling, completions, and operations all exert strong controls on unconventional reserves

• Current industry practice
  – Modified Arps for most wells
  – Full suite of analyses for high value/problem wells
SPEE Monograph 4: Workflow and Examples

John Lee
University of Houston
13 August 2015
Workflow for Evaluation of Developed Reserves in Unconventional Reservoirs

From SPEE Monograph 4

1. Assess data viability and correlation
2. Construct diagnostic plots
3. Identify flow regimes
4. Analyze and forecast with selected simple models
5. Analyze and forecast with semi-analytical models (RTA)
6. History match with simulator and forecast
7. Reconcile forecasts and estimated ultimate recoveries (EUR’s)
## Comparison of Models to Ideal Model

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Outlier Analysis

Example 1, Denton (Barnett Shale)

Filtered Dataset

- Flowrate
- YM-SEPD

$q$, mmscfd vs. time, days

0 500 1,000 1,500 2,000 2,500 3,000 3,500 4,000 4,500

- RESERVE ESTIMATION
- UNCONVENTIONALS
- SPEE
- REU Houston 2015
Flow Regime Identification

Example 1, Denton (Barnett Shale)

log q vs log t

log q vs MBT

Linear Flow
(Slope -1/2)

End of Transient Linear Flow

Data not in Transient Linear Flow regime

Start of Boundary Dominated Flow

BDF (Slope -1)
Forecast Comparison

Example 1, Denton (Barnett Shale)

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<th>30 year EUR, bcf</th>
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<td>Linear + Arps (b=0.5) + Arps (b=0)</td>
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<td>Linear + Arps (b=0.5) + Arps (b=2)</td>
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**Forecast Comparison**

- Production Data
- Linear + Arps
- Duong + Arps
- YM-SEPD + Arps
- Linear+Arps (b=0.5)+Arps (b=2)
- Linear+Arps (b=0.5)+Arps (b=0)

**Graph Details**

- **x-axis**: time, days
- **y-axis**: $q$, mscfd

**Table Details**

- 30 year EUR, bcf values for different decline models.
End of Presentations – Panel Discussion

What are your questions?
BACKUP
Who is SPEE - Senior Leadership

Career Roles

- Presidents 26%
- Vice Presidents 21%
- Directors 21%
- Owners 11%
- Others 21%

Industry Segment

- Consultants 35%
- Expl & Prod 26%
- A&D 12%
- Other 2%
- Banking 5%

25% of members hold advanced degrees
Average member has 20+ years industry experience