Well Spacing and Reserves Impacts

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NSAI's Role and Point of View

• Typically engaged by an E&P company or investor

• Product: independent evaluation or audit of resources
  • For company-internal assurance purposes
  • For external disclosures (e.g. SEC reporting)
  • For investment due diligence
  • For financial purposes (e.g. reserves-based lending)

• Typical technical data received and analyzed
  • By well: production data, completions details, location
  • Geologic information, including well logs
  • Forward development plan
How are Well Interactions Defined?

- Producing Horizontal Well (PDP)
- Initial Infill Drilling Horizontal Location
- Second Infill Drilling Horizontal Location
"Tolerate" interference while capturing profitable incremental hydrocarbons

Similar Impact: True infill vs Close proximity step-outs
Downspacing – Unconventionals

Similar outcome, but more variance in spacing and timing of development

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Potential Determinants of Performance

- Completed lateral length
- Reservoir Sw
- Permeability
- Production strategy
- Initial pressure
- Frac hit management
- Completion sequence
- Well orientation
- Operator
- Extent of SRV
- Frac stage count
- Fluid flow regimes
- OOIP
- Artificial lift type
- Reservoir thickness
- Downspacing strategy
- Landing zone
- Perf clusters/stage
- Extent of natural fractures
- Porosity
- Offset Interference
- Downspacing timing
- Offset maturity
- Restimulation strategy
- Horizontal inclination
- Proppant/stage
- Fluid type/character
- Proximity to faulting
- Fluid/stage
- OGIP
- Spatial geologic variation
- Extent of SRV
- Proportant/stage
- Production drawdown
- Proximity to faulting
- Fluid type/character
Well Interference

- Optimization controls for well economics
  - Well length
  - Completion / stimulation
  - **Well spacing / Wells per section**
- Particularly with well spacing: Maximum value usually achieved at stage of diminishing returns per well
- Goal - "Tolerate" interference while capturing profitable incremental hydrocarbons
Toolbox for Unconventional Analysis

• Performance analysis
  • Performance / Decline Curve Analysis
  • Analogy / Type well profiles
  • Transient versus Boundary Dominated Flow (BDF)
    • BDF Analysis
    • Transient Flow Analysis
  • Analytical models
  • Flowing Material Balance
  • Productivity Index

• Volumetrics

• Numerical simulation

Material Balance Equation
\[
C_t = \frac{1}{V} \times \frac{\Delta V}{\Delta p}
\]

\[
p_i - \bar{p} = m_{pss} N_p
\]

\[
\bar{p} - p_{wf} = b_{pss} \times q_{oil}
\]

\[
q = q_f (1 + b D_f t)^{-1/b}
\]

\[
\frac{m(p_i) - m(p_{wf})}{q_g} = \frac{1.632 \times 10^6 T}{kh} \left[ \log\left(\frac{kt}{\phi \mu B r_w^2}\right) - 3.23 + 0.87s \right] \quad \text{... gas}
\]
Dealing with Well Interactions
The Evaluators' Approach

- Boundary conditions/limitations
  - Existing development
  - Operator's plan of future development (POD)
  - OHIP/Recovery factor
- Levers available
  - Reserves categorization
  - Volume adjustment – degradation factors against “parent” well
- Timing
  - Pre-drill - Parents kept whole, volume adjustment to undrilled children
  - Some Time Post-drill – Impact inherent in performance of parent and child
- Complications
  - Frac hits on parents
  - Pad/Batch drilling
  - POD more dense than analog spacing
  - Public allocated data

In between – transition to shared impact
Spacing Tests – Delaware WCA

- Demonstrated results to assign EURs at operator’s planned development spacing – single zone
- Adjust for local well performance and geology
- Confirm total section EUR increases as well count increases with assigned degradation factor
Impact of Well Location – Utica

- Expect unbounded or exterior well to have higher EUR than well interior to development
- Assign undeveloped reserves based on position relative to other wells
Multi-Zone Development – Midland Basin

- Consider inter-zone interference for areas with multiple landing zones
- Projections at lease level can help mitigate allocation errors
- Assign reserves category based on data density and consistency
Early Time Can Be Deceiving

2018 Pattern Results Degraded Over Time

Summary of 2018 Drilling Program
- Drilled 175 wells and completed 174 wells in 2018
- At year-end 2018 we had 17 patterns with 6-10 wells per section density with meaningful production results
- While early pattern well results appear strong vs. the type curve, they have consistently degraded over time
- Oil EUR for the average 2018 pattern well is ~120 MBO in the YE 2018 reserve report
- 2018 results driving management focus in 2019 on improved infill economics through:
  - Upspacing and lateral placement
  - Lowering D&C costs
  - Lowering LOE and overhead

16 of 17 Patterns Above 250 MBO TC at 30 days

4 of 17 Patterns Above 250 MBO TC at 120 days

Alta Mesa
Dealing with Parent/Child and Well Spacing
Incorporating Technology & Geology

• Know the play – no substitute for having seen many wells
• Be cognizant of completion types and lateral lengths
• Statistical analysis may be valuable, but
  • "Close-ology" and EUR trends are meaningful, and
  • Honoring geology (and volumetric in-place) is critical
• Analogy can be highly useful but verify applicability; every well is still unique
• Expect decreased EUR once density reaches some point, but it may not be immediately apparent
• Reasonableness check (and upper limit) involves OHIP/Recovery factor
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