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Incorporating Numerical Simulation Into Your Reserves Estimation Process: A Practical Perspective

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Outline

- Introduction
- A Look at Reserves
- Combining Reserves and Simulation
  - Immature Reservoirs
  - Mature Reservoirs
- Examples
- Conclusions

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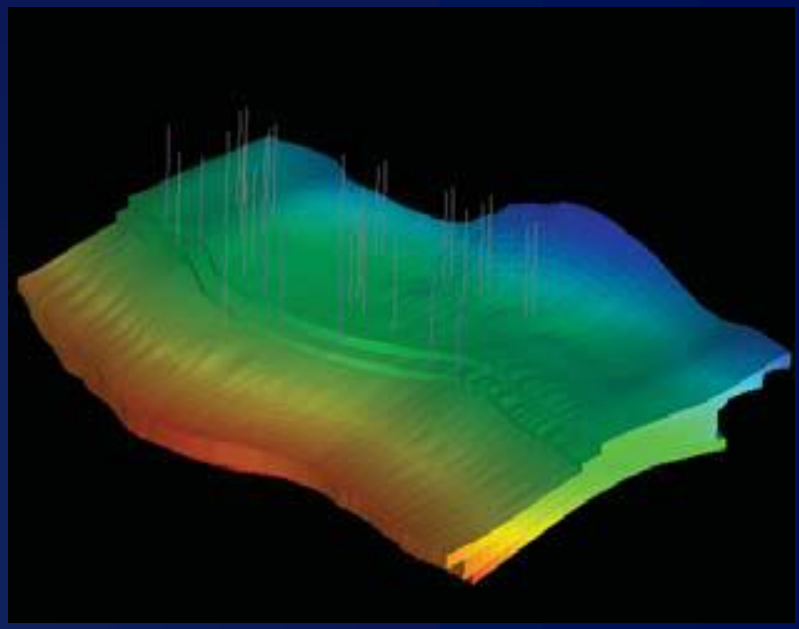
Introduction

- Any estimate of future recovery does **not** necessarily qualify as an estimate of reserves.
- Specific criteria must be met to qualify estimated recoverable volumes as reserves.
- These criteria are generally defined in the form of “reserves definitions.”

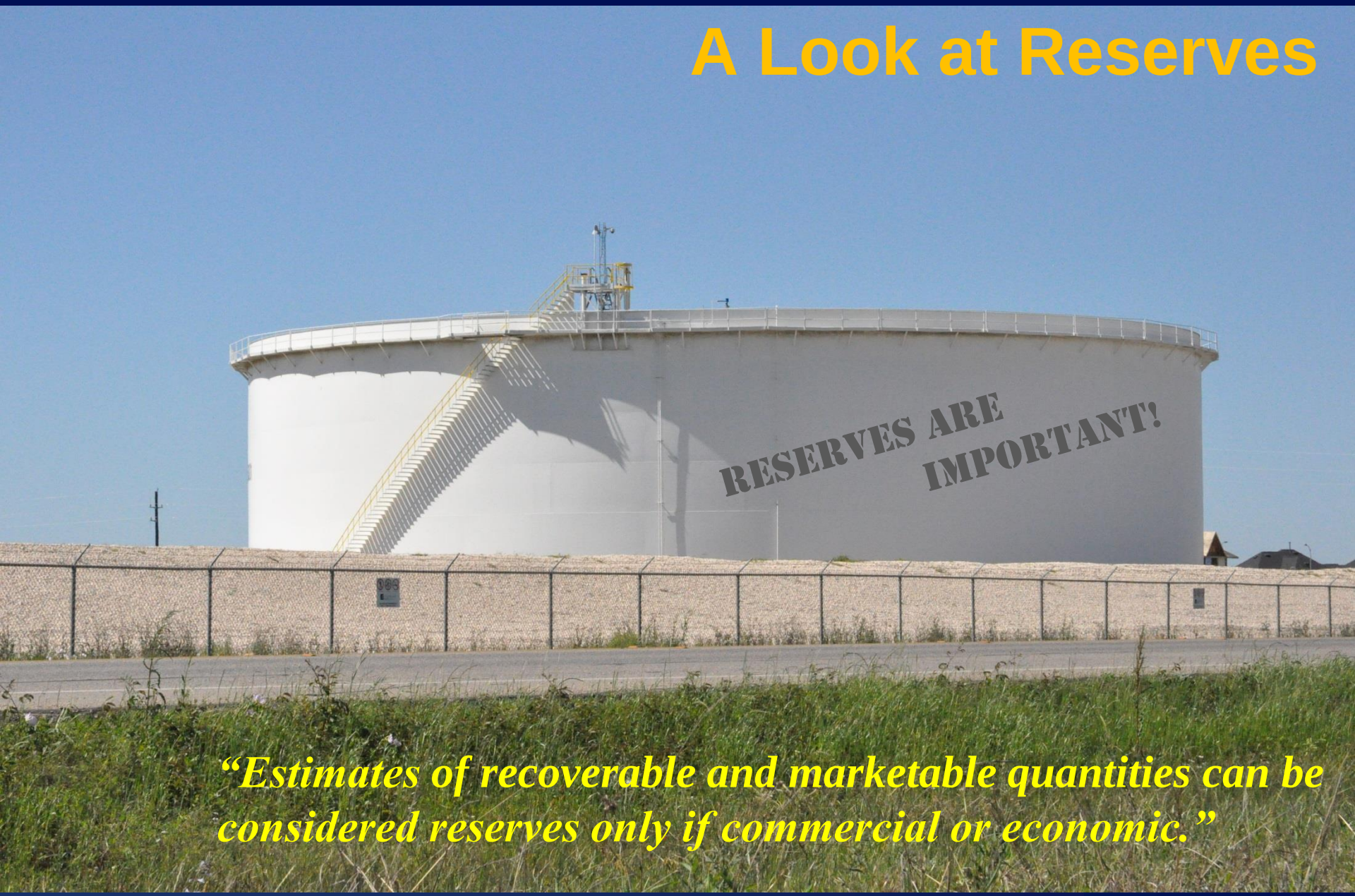
Background on the Subject

- SPE 71430 (2001)
  - Intended to start a dialog
- SPE 96410 (2005)
  - Reviewing History Matches
- SPE 110066 (2007)
  - Case Study Examples



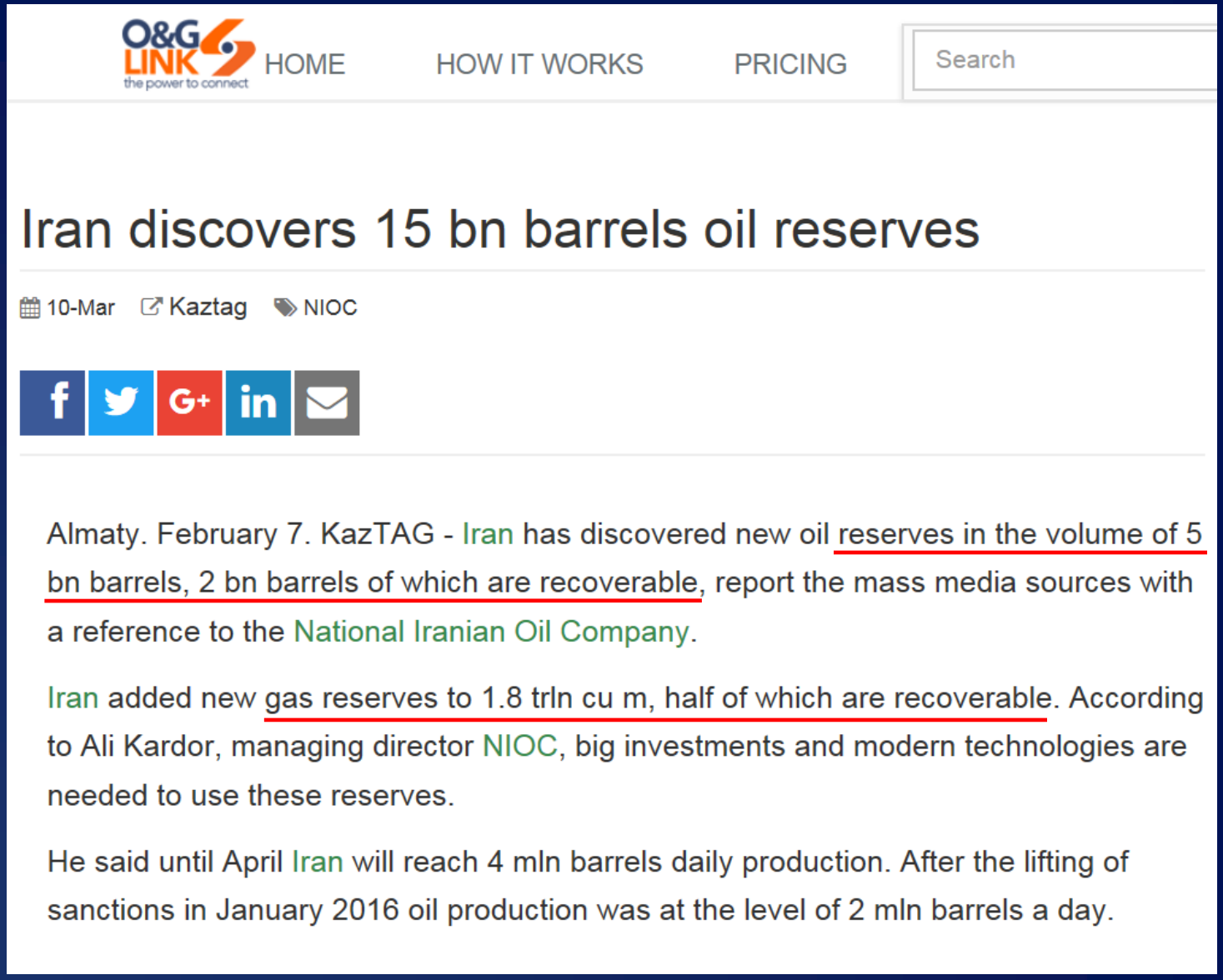
- *SPE 71430 "The Adaptation of Reservoir Simulation Models for Use in Reserves Certification Under Regulatory Guidelines or Reserves Definitions"*
- *SPE 96410 "Reservoir Simulation and Reserves Classifications – Guidelines for Reviewing Model History Matches to Help Bridge the Gap Between Evaluators and Simulation Specialists"*
- *SPE 110066 "Case Studies Illustrating the Use of Reservoir Simulation Results in the Reserves Estimation Process"*

A Look at Reserves



"Estimates of recoverable and marketable quantities can be considered reserves only if commercial or economic."

“Reserves” in the Press



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Iran discovers 15 bn barrels oil reserves

10-Mar Kaztag NIOC

Almaty. February 7. KazTAG - Iran has discovered new oil reserves in the volume of 5 bn barrels, 2 bn barrels of which are recoverable, report the mass media sources with a reference to the National Iranian Oil Company.

Iran added new gas reserves to 1.8 trln cu m, half of which are recoverable. According to Ali Kardor, managing director NIOC, big investments and modern technologies are needed to use these reserves.

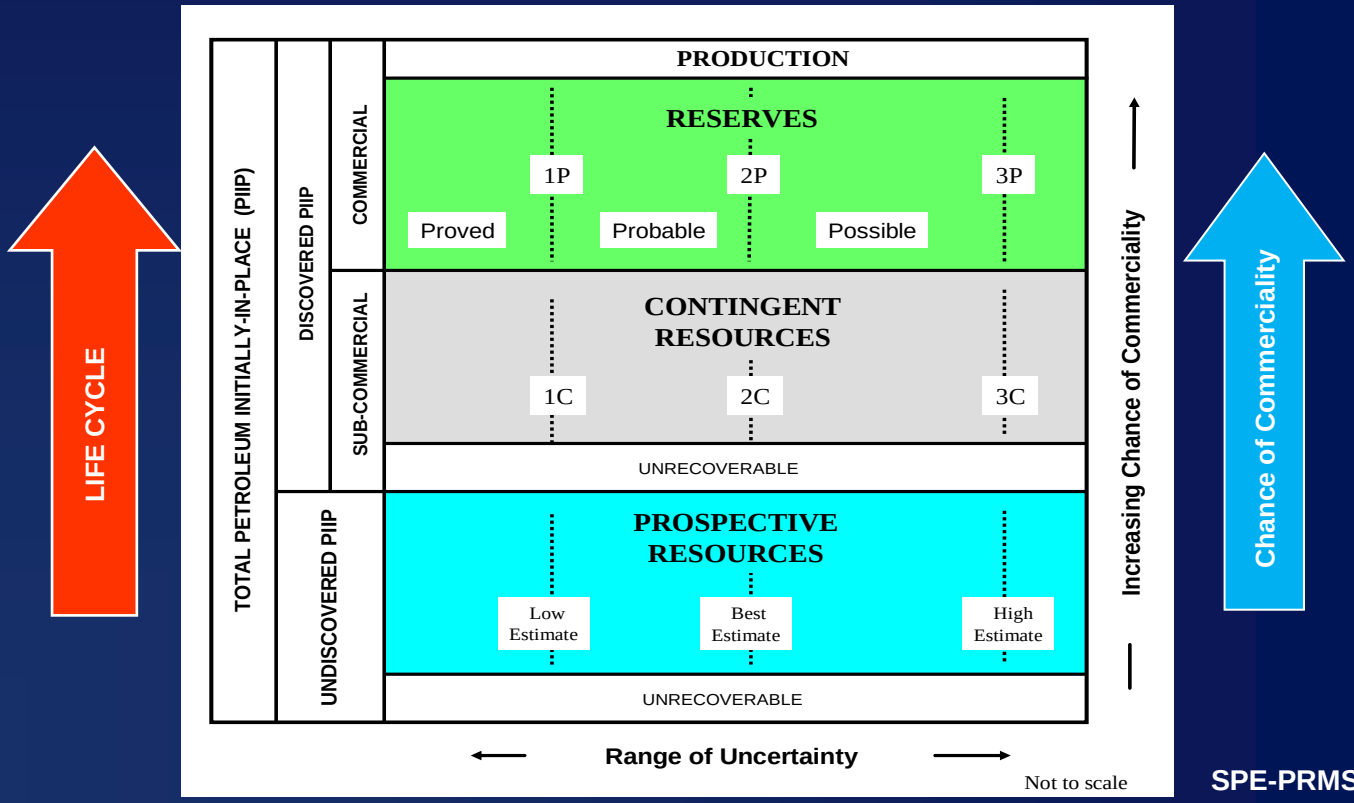
He said until April Iran will reach 4 mln barrels daily production. After the lifting of sanctions in January 2016 oil production was at the level of 2 mln barrels a day.

Reserves Definitions

- **SPE/WPC/AAPG/SPEE**
  - **Petroleum Resources Management System 2007**, pp. 20 and 21 (PRMS Document)
  - Proved, probable, and possible reserves
- **SEC**
  - **17 CFR Part 210.4-10**
  - Recent revisions effective January 1, 2010
  - References:
    - "Modernization of the Oil and Gas Reporting Requirements," Conforming Version No. 33-8935, pp. 134-147, found at: *http://www.sec.gov/rules/proposed/2008/33-8935.pdf*
    - Federal Register Final Rule, January 14, 2009, pp. 2190-2192, found at: *http://www.sec.gov/rules/final/2009/33-8995fr.pdf*

SPE-PRMS Combines Both Resource Classification and Categorization

*"... projects are **"classified"** based on their chance of **commerciality** (the vertical axis) and estimates of recoverable and marketable quantities associated with each project are **"categorized"** to reflect **uncertainty** (the horizontal axis)."*



SPE-PRMS Page 5

Reference to Simulation with Reserves (SPE-PRMS)

- SPE-PRMS and Reservoir Simulation
  - Recovery can be based on analog field or simulation studies.
  - Reservoir simulation is a “sophisticated form of material balance.”
  - Most reliable when validated with a history match.

PRMS Document – SPE/WPC/AAPG/SPEE, pp. 20-21
(Petroleum Resources Management System 2007)

Reference to Simulation with Reserves SEC (2009)

{2008} ***(25) Reliable technology. 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.***

Combining Reserves & Simulation

Reliable results from models can be used for reserves.

- Verify commerciality

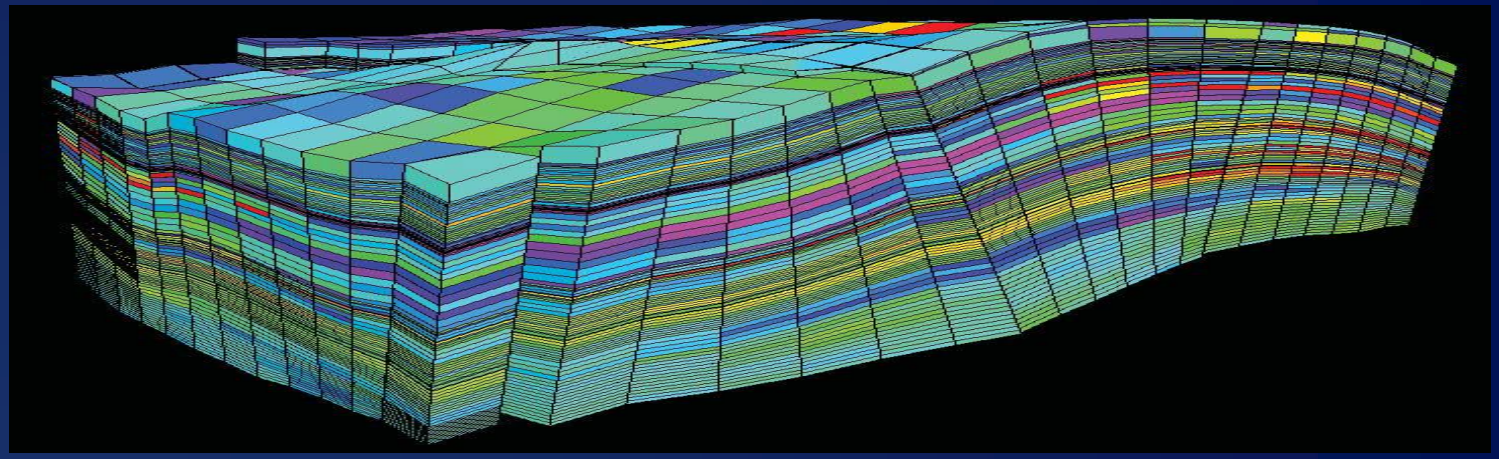
- Comply with guidelines

Applying Simulation Results for Estimating Proved Reserves

- Usually, the primary objective of a simulation study is to better understand the reservoir to improve recovery (Proved + Probable – 2P or “most likely”).
- Development plans should be based on 2P or even 3P (Proved + Probable + Possible).

Applying Simulation Results for Estimating Proved Reserves

- It is common that results from a simulation model cannot be directly applied to the proved reserves category, even if they are passed through a cash flow analysis to demonstrate economic viability.



Applying Simulation Results for Estimating Proved Reserves

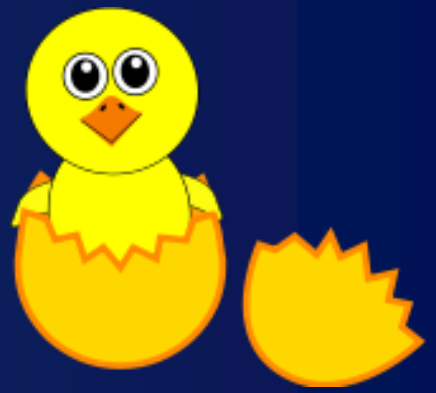
- Typical models might not be consistent with “proved” guidelines due to:
  - Original oil-in-place (OOIP) beyond “proved”
  - Pressure support or energy
  - Other parameters

Immature and Mature Reservoirs

- Mature reservoirs contain a period of production history that is modeled or “history matched.”
- Immature reservoirs contain little or no production history and the simulation models have not yet been verified by actual field performance.

Immature Reservoirs

- Description relies primarily on geophysical and geological data.
- A “history match” of the model to the reservoir is easy to obtain.
  - Few performance points
  - Not very reliable



Immature Reservoirs

- Unlikely to be acceptable for proved reserves.
  - “Most likely” OOIP
  - Not reliable
- Models helpful in estimating hydrocarbon recovery efficiency.
  - Sensitivity studies
  - Unless contradicted by analogy data (or experience)

Mature Reservoirs: Validating with a History Match

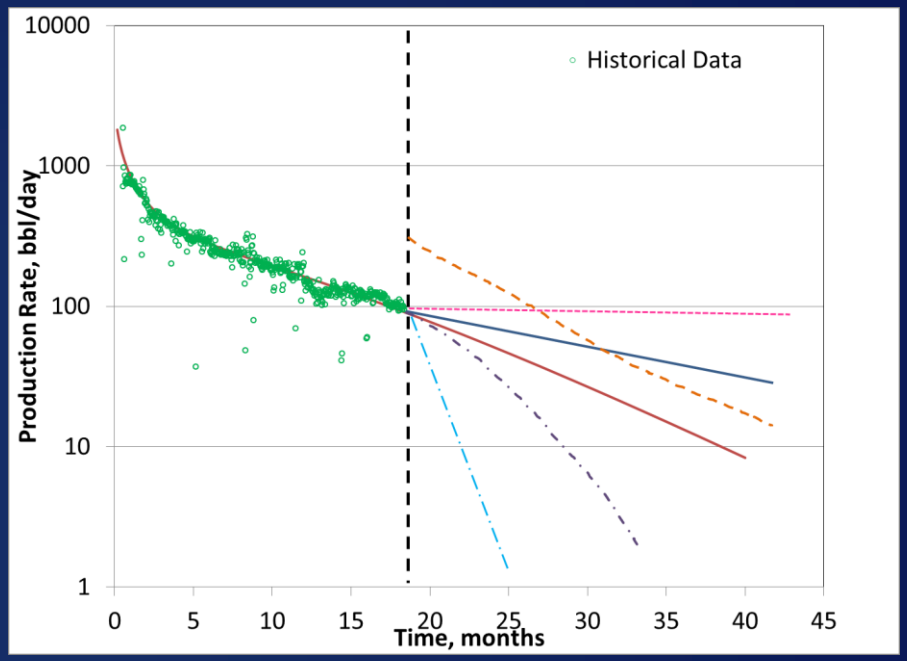
- Model parameter adjustment
  - Reasonable
  - Non-contradictory
  - Consistent with known geological and engineering evidence
- Sensitivity studies can investigate uncertain parameters.

Mature Reservoirs & History Matching Drawbacks

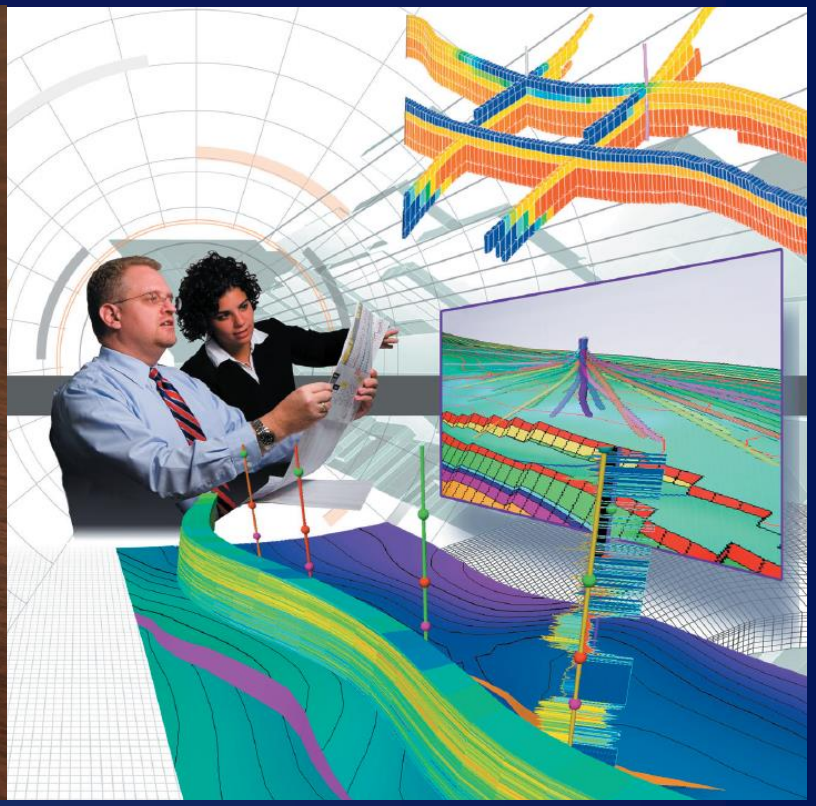
- Non-unique
- Certain parameters may have a limited impact on the history match but may have a dramatic impact on the prediction.
  - Aquifer dimensions
  - Original hydrocarbon in-place!

Mature Reservoirs & History Matching Additional Considerations

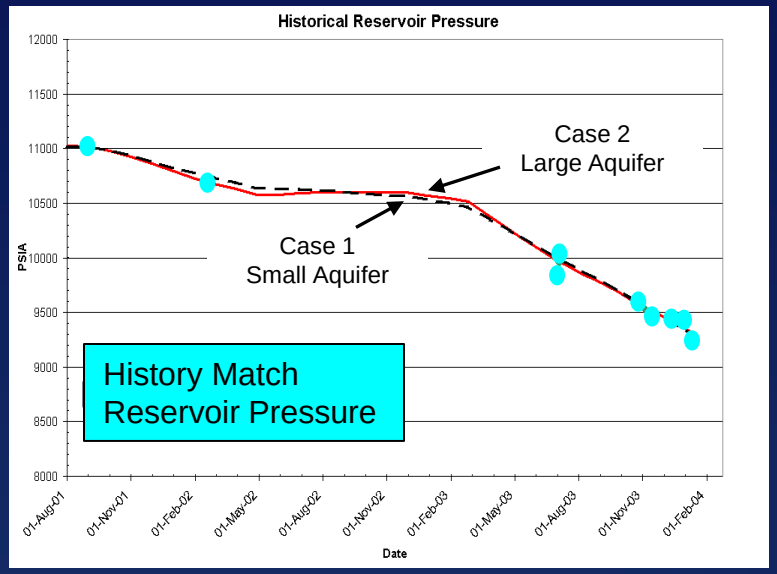
- Recognize situations where there may be changes to the depletion process
- Assess the Transition to Forecast
  - Status quo or “do nothing” case is consistent in rate’s decline

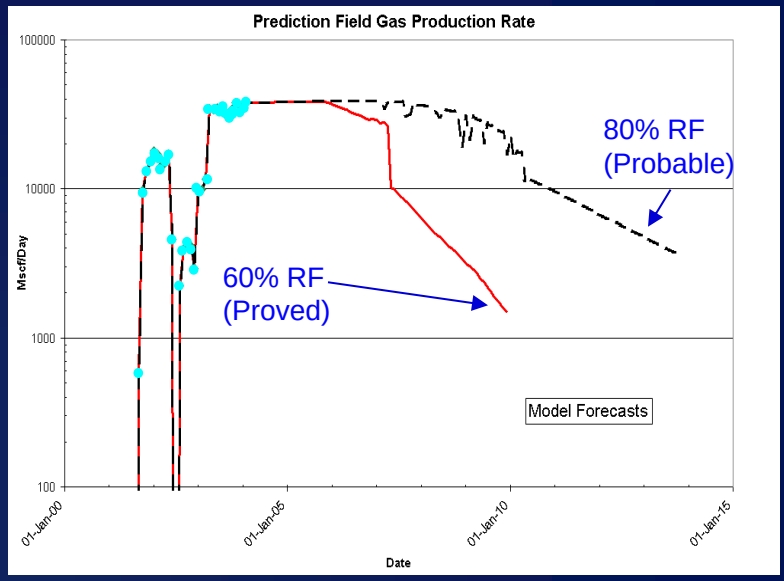


Some Examples



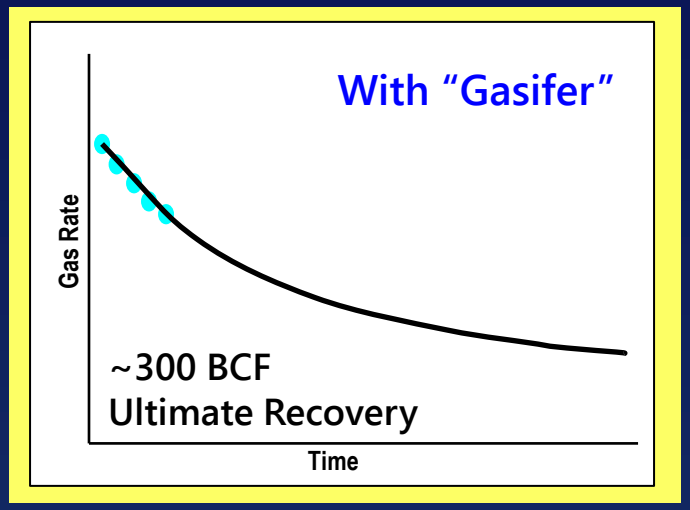
Example 1:
Apply Reservoir Simulation to Assess Geological or Drive Mechanism Uncertainty

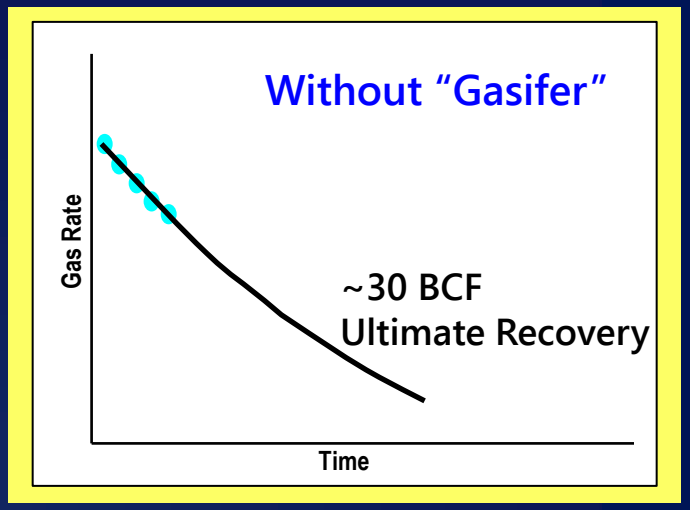




- Two models with different assumptions
- Both have good history match
- Models provide range of expected recovery

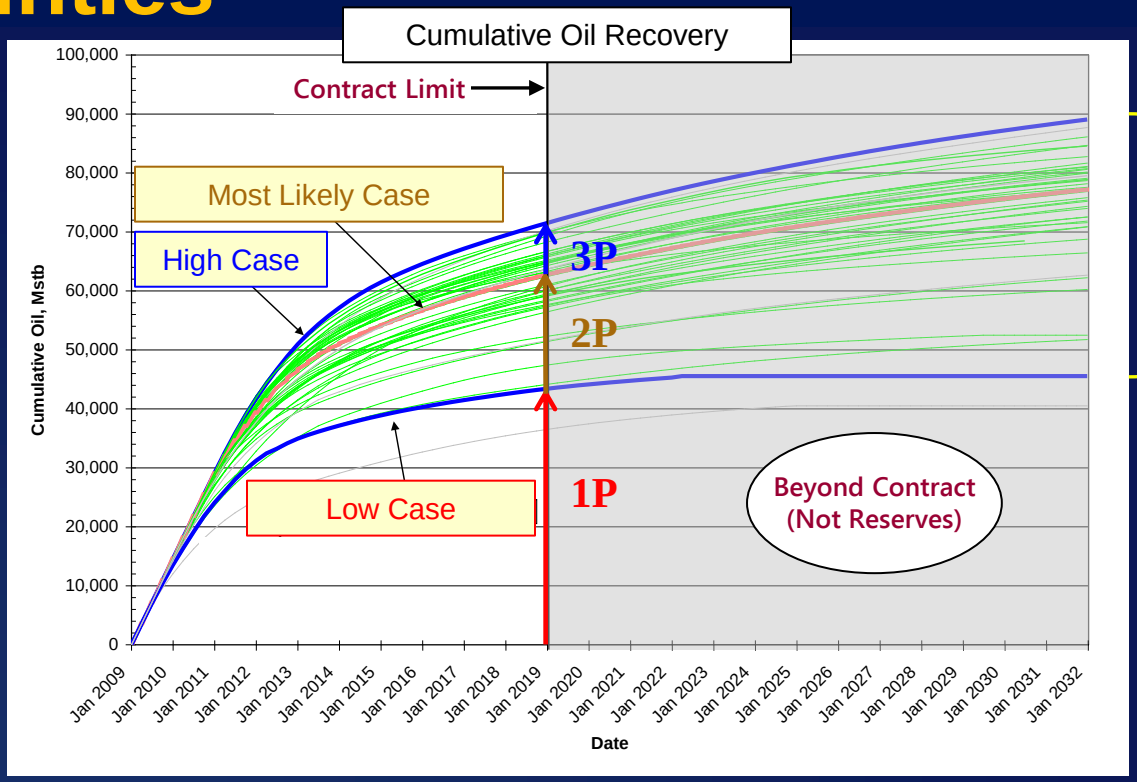
Example 2:
Misuse of Simulation: The "Gasifer"





- Conclusions not supported by model results
- Easily disputed

Example 3: Reserves Assigned Based on Forecast Uncertainties



- Modeling used to assess field recovery under various operating and input parameter assumptions
- All of the above projected volumes must be demonstrated to have economic or commercial viability before being called “reserves.”

Case Studies Illustrating the Use of Reserves (SPE Paper 110066)

- SPE Paper 110066 (2007) was written to provide examples of incorporating simulation results in the reserves process.

Mature

- Case Study 1 - Modify the simulation results (Mature Reservoir).
- Case Study 2 - Modify so model complies with reserves definitions (Mature Reservoir).

Immature

- Case Study 3 – If the field being evaluated is an Immature Reservoir with no sustained production history, then perform a series of sensitivity studies.

Overall Conclusions

- The reliability of the results from a model is strongly dependent on the understanding of the geology and the confidence in all of the parameters used to construct the model.
  - What is needed?
    - Reasonable assumptions
    - Good history match
    - Good/reasonable forecast
    - Sensitivity cases
  - Documentation/Supporting Information

Final Remarks

- Reliable results from models can be used for reserves.
  - Verify commerciality
  - Comply with guidelines
- Provide significant supporting information.
- For proved reserves, detailed analysis and scrutiny should be applied to “typical models.”

Reliable

Consistent

Reasonably Certain

Repeatable


Thank You!
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