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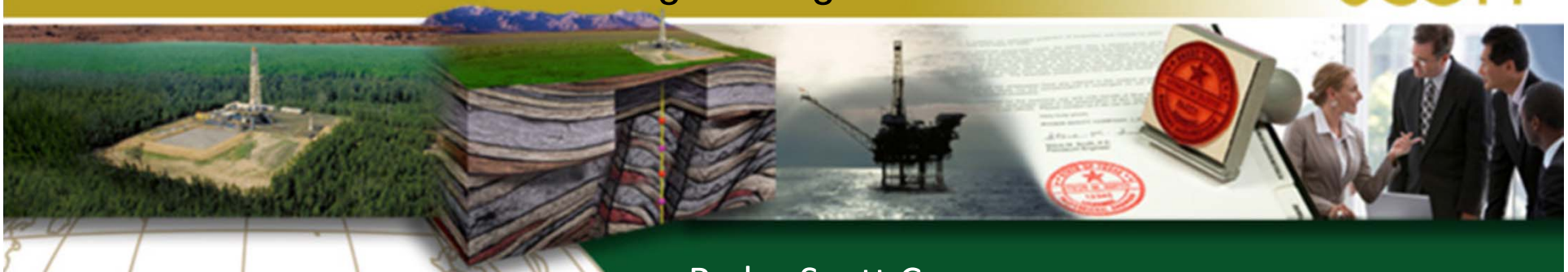
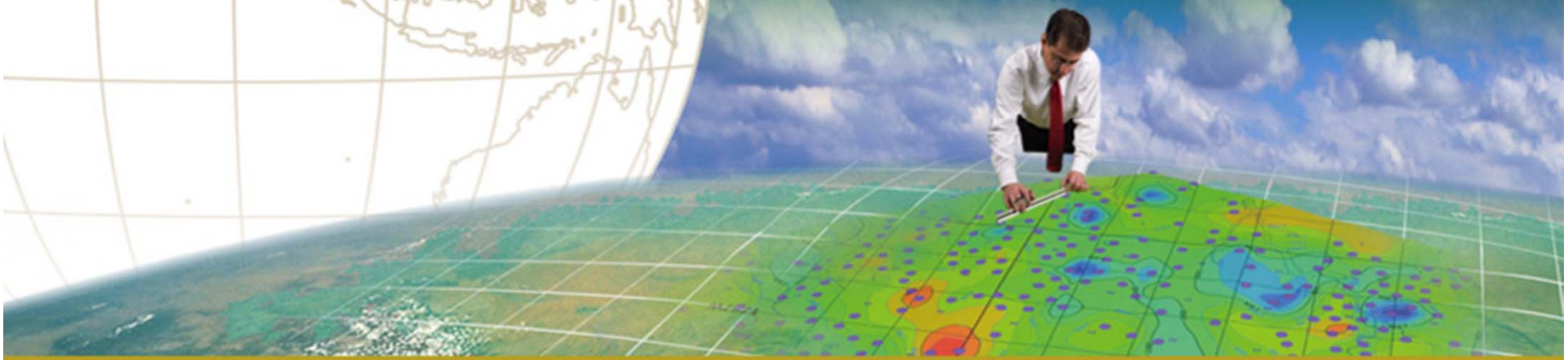
RYDER SCOTT



Ryder Scott Company
Introduction to
Incorporating Uncertainty in Resource Estimates

Larry Connor

May 5, 2016



Uncertainties in the Oil and Gas Industry

Geology & Engineering

- Volumes in Place
- Recovery of in Place Volumes
- Production Rate/Volume forecasts
- Cashflow Projections

Product Market

- Volatility in oil and gas prices
  - Lower project revenue
  - Longer development period
  - Higher economic limits and lower reserve volumes
  - Lower shareholder value and return on investment
- Operations
  - Blowout, casing or tubing collapse, loss of wellbore
  - Equipment breakdown, availability
  - Weather delays
- Monetary Risk
  - Inflation / Foreign currency exchange rates
  - Capex
  - Opex
  - Creditors

Uncertainties in the Oil and Gas Industry

- With lower oil prices it is critical to incorporate the uncertainties into business decisions
- Of all decisions that executives make, choosing between optional investment opportunities is often the most difficult
- Important to use consistent evaluation techniques that provide a better understanding of potential outcomes of investment decisions
  - Which one provides the greatest return for the amount of risk?
  - How do you determine how much risk is in an opportunity?
  - How can you determine the most critical elements?
- **Deterministic** or **Probabilistic** method

Evaluation Methodologies under SPE-PRMS

Deterministic

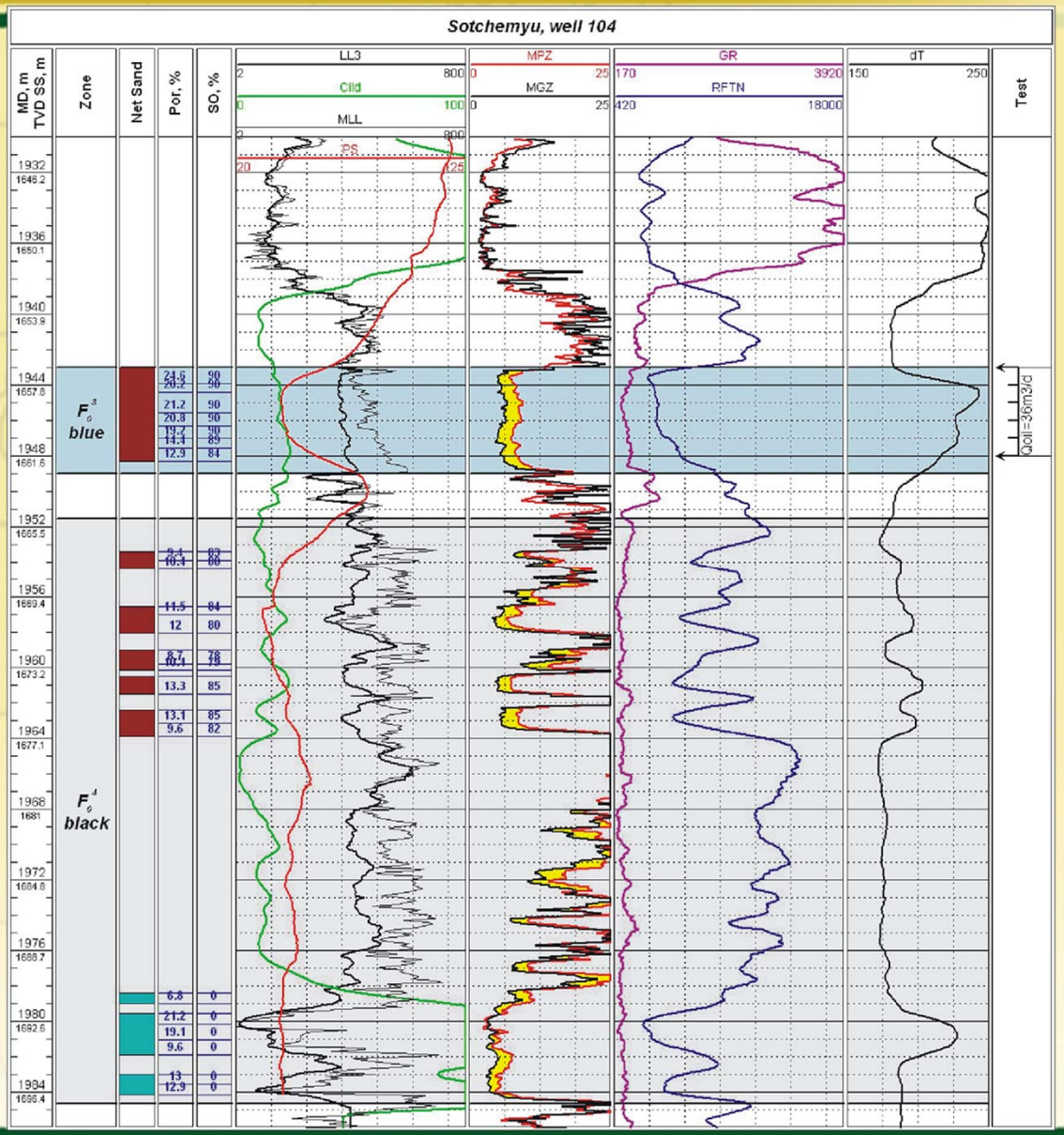
Most common method used in the industry

- Evaluate petrophysical attributes (porosity, thickness, saturations, permeability, skin, etc.)
  - Logs, core
  - Pressure transient analysis
  - Flow tests
- Evaluate geophysical data (reservoir size and limits)
  - 2D, 3D seismic
  - Other prospecting data
- Construct structure and isopach/isochore maps
- Planimeter volumes
- Assign Recovery Factor

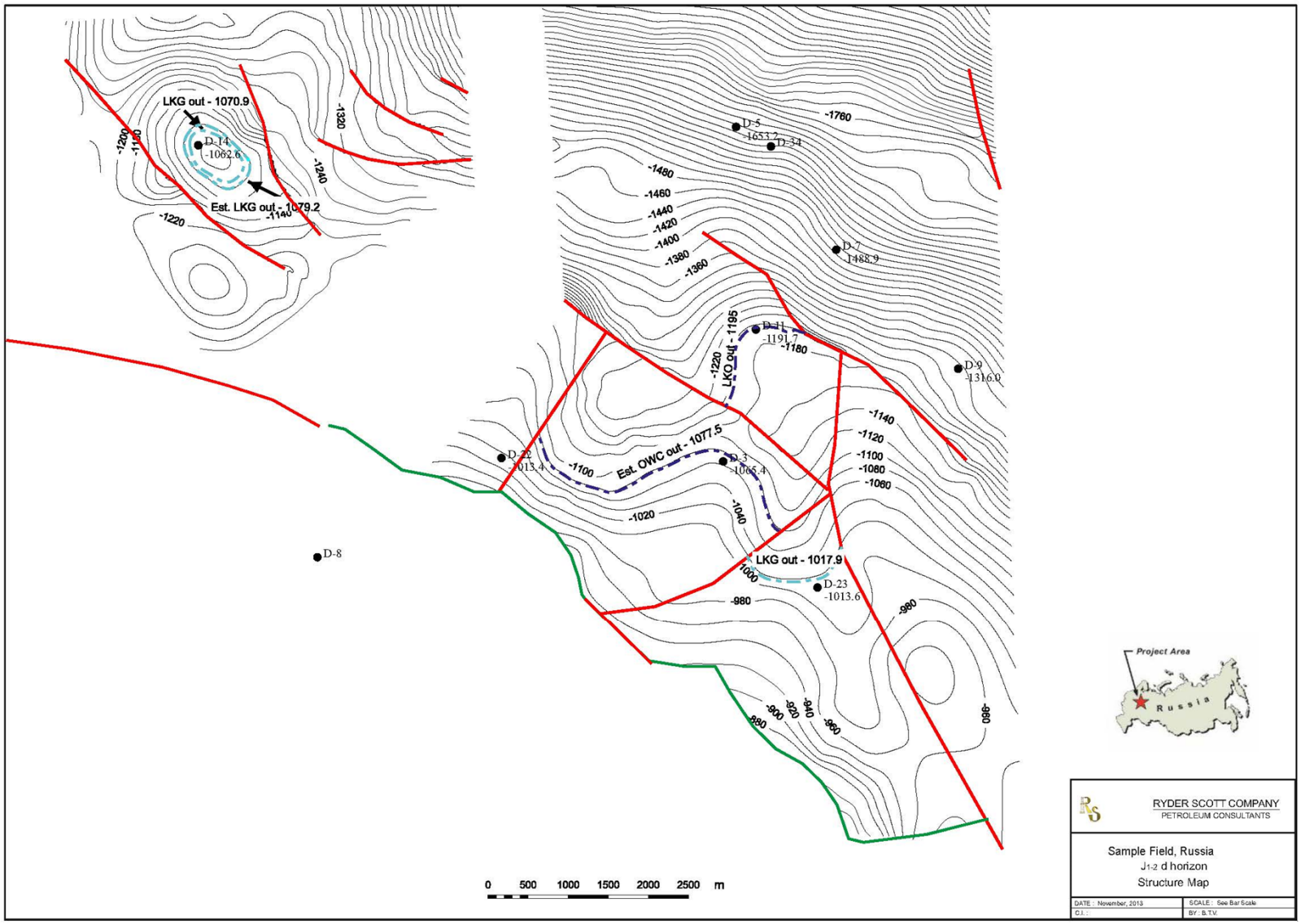
Easily understood and widely accepted.

Does not incorporate uncertainty, only presents a single potential outcome based on fixed input variables.

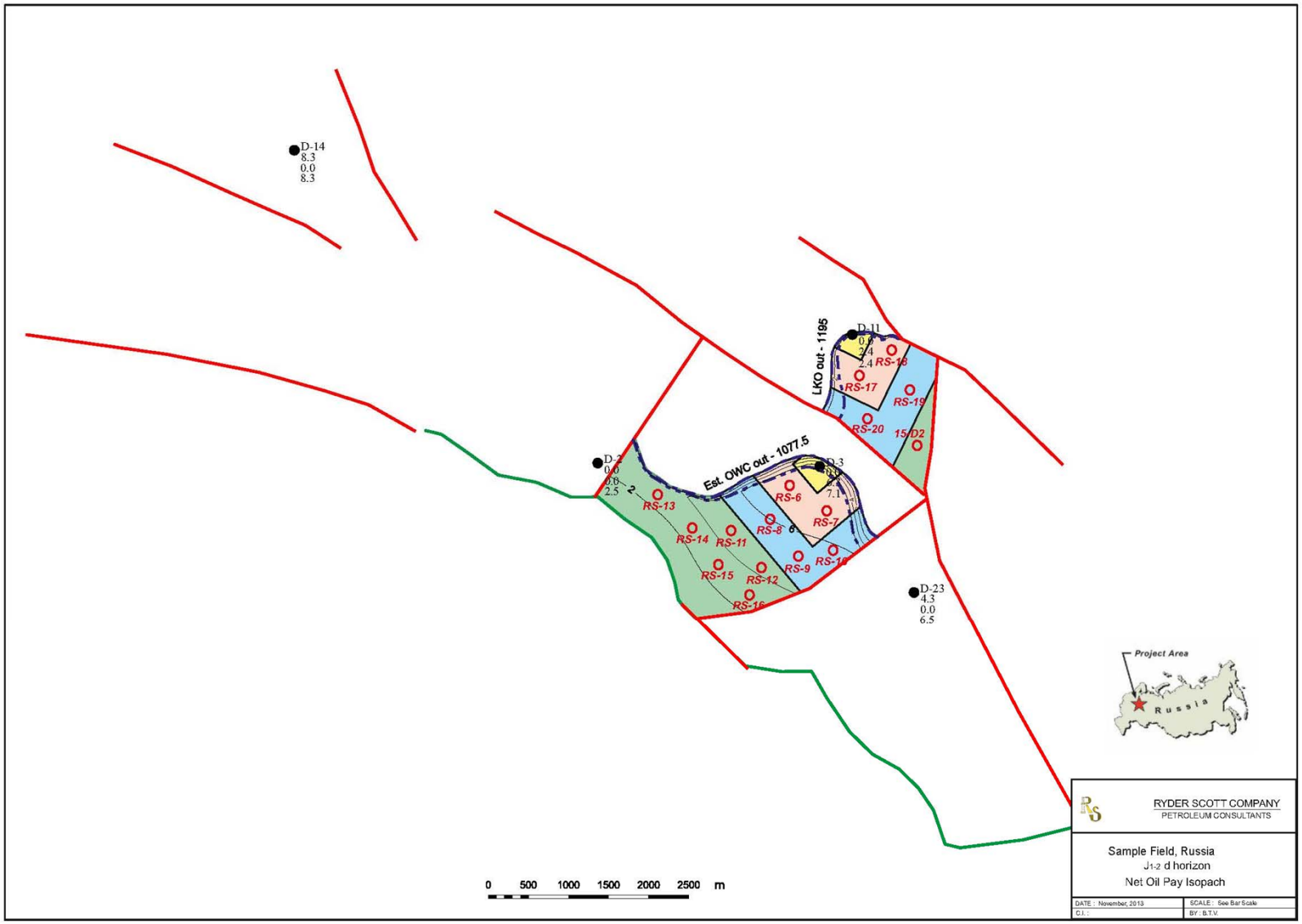
Evaluation Methodologies under SPE-PRMS



Evaluation Methodologies under SPE-PRMS



Evaluation Methodologies under SPE-PRMS



Evaluation Methodologies under SPE-PRMS

Advantages of Deterministic Methodology

- Well known methodology
- Widely accepted
- Easy to apply and understand

Disadvantages

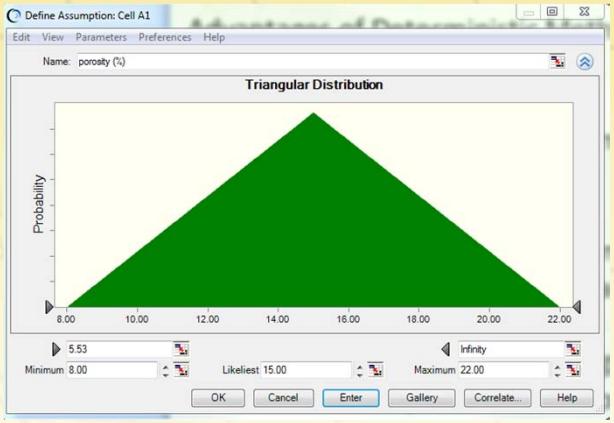
- Does not fully or correctly incorporate uncertainty
  - Could create high case and low case using different input parameters
    - too optimistic on high case
    - Too pessimistic on low case
    - **Just not correct**

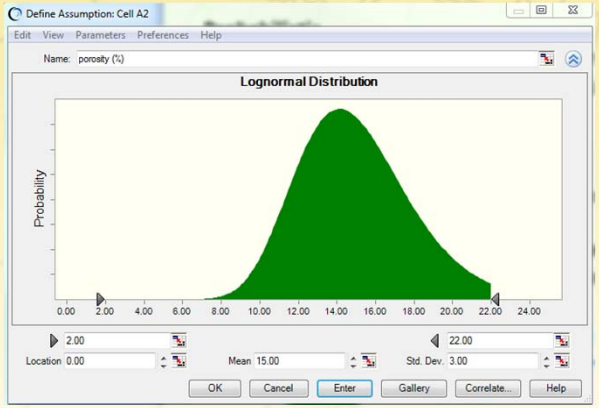
Evaluation Methodologies under SPE-PRMS

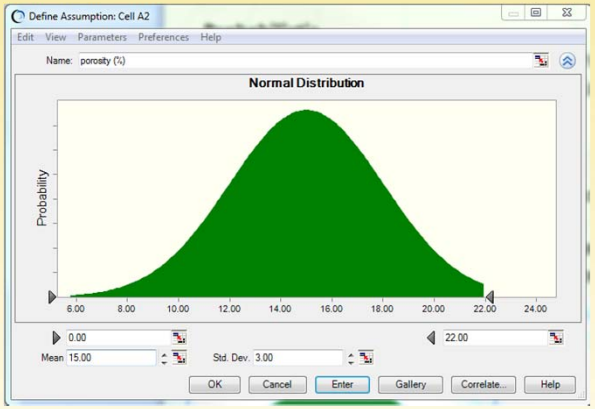
Probabilistic

Used in the industry but not as common in conventional, very popular in unconventional

- Evaluate petrophysical attributes (porosity, thickness, saturations, permeability, skin, etc.)
  - Logs, core
  - Pressure transient analysis
  - Flow tests
- Evaluate geophysical data (structure size)
  - 2D, 3D seismic
  - Other prospecting data
- Construct distributions for each variable
  - More common: triangular, normal, lognormal







Evaluation Methodologies under SPE-PRMS

Probabilistic

- Calculate volumes using stochastic volumetric model
- Assign distribution to Recovery Factor
- Calculate the Geologic Chance of Success

Presents a range of expected outcome
Incorporates uncertainty

Evaluation Methodologies under SPE-PRMS

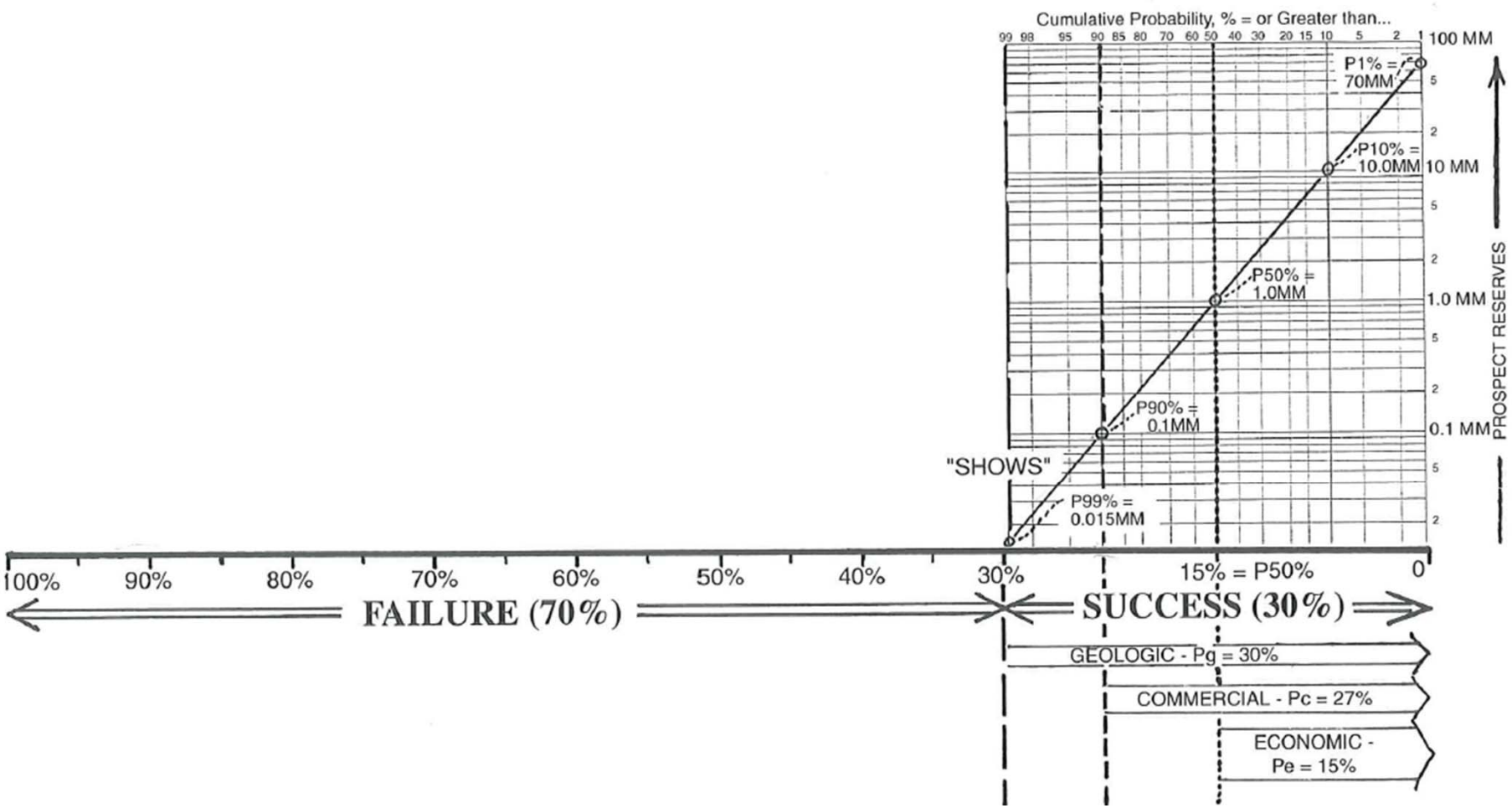
Probabilistic

- Estimate the Geologic Chance of Success
  - Conventional reservoirs
    - Source Rock = .85
    - Timing and Migration = .8
    - Trap = .7
    - Reservoir = .62
    - Total COS = 30%
  - Unconventional reservoirs
    - Presence of shale = 1.0
    - Organics – proper Total Organic Content = 1.0
    - Thermal Maturity – vitrinite reflectance = .7
    - Brittle Lithology – low clay content – high silica = .8
    - Continuity of oil shale = .8
    - Total COS = 45%

Evaluation Methodologies under SPE-PRMS

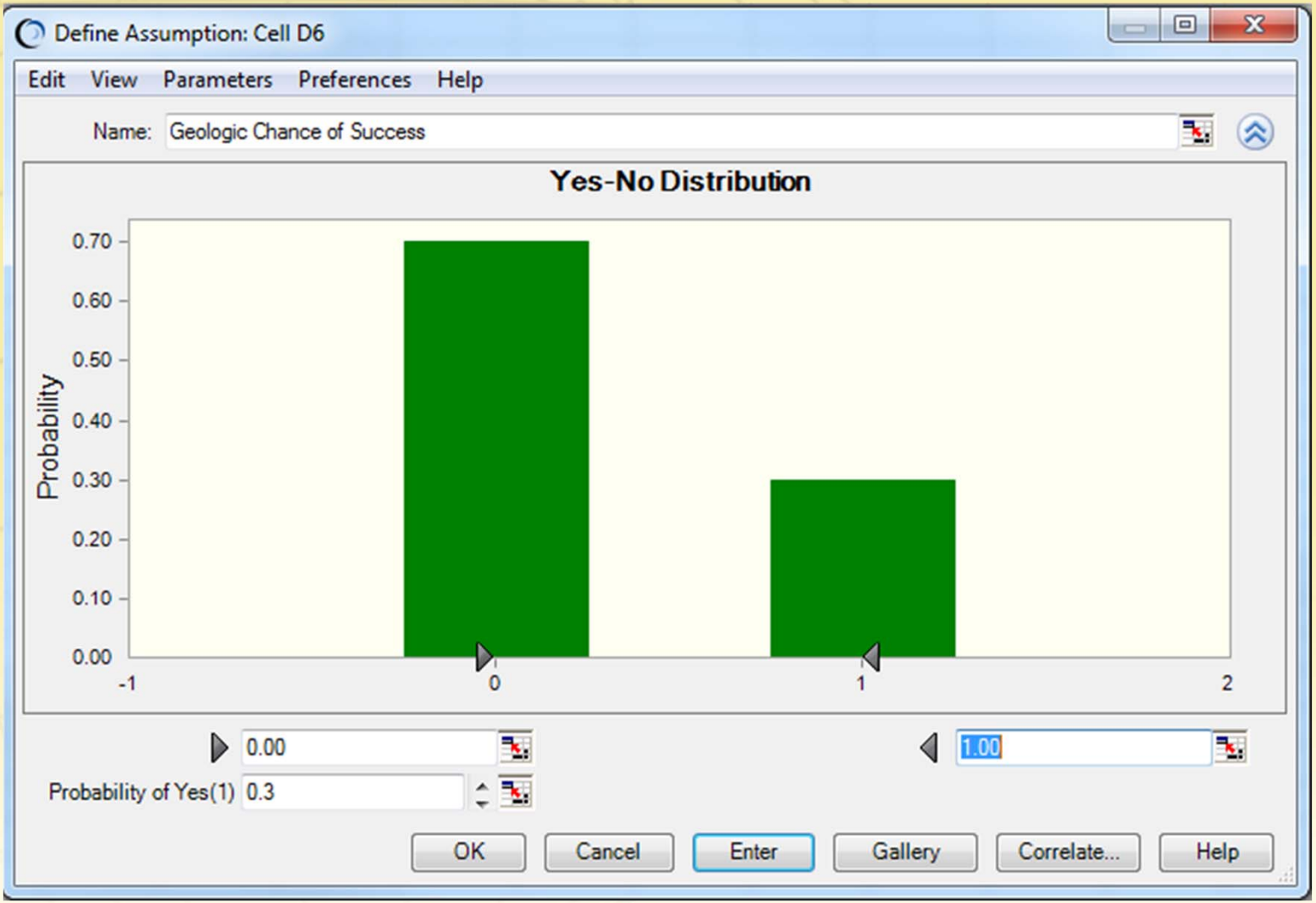
Probabilistic – incorporating the Chance of Success

32 **Risk Analysis of Exploration Prospects**



Evaluation Methodologies under SPE-PRMS

Probabilistic – incorporating the Chance of Success



Evaluation Methodologies under SPE-PRMS

Probabilistic

- Calculate volumes using stochastic volumetric model
  - Distributions assigned for input parameters:
    - Area
    - Gross Thickness
    - Net to Gross Ratio
    - Porostity
    - Fluid Saturation
    - Formation Volume Factor
    - Recovery factor
  - Covariance between variables
    - Porosity ~ Water saturation
    - Area ~ Net thickness
    - Recovery Factor ~ Net to Gross thickness

Evaluation Methodologies under SPE-PRMS

Probabilistic

- Project Recoverable Volumes using Arps decline equations
  - Distributions assigned for input parameters:
    - Initial rate
    - Decline rate
    - Hyperbolic b factor
    - Minimum decline rate
    - Secondary product yields (Gas – Oil ratio) or (condensate – gas ratio)
  - Covariance between variables
    - Initial Rate ~ Decline Rate
    - Initial Rate ~ Net Thickness
    - Initial Rate ~ Pressure

Evaluation Methodologies under SPE-PRMS

Probabilistic

- Calculate economic value using stochastic model
  - Distributions assigned for input parameters:
    - Product prices
    - opex
    - capex
  - Covariance between variables
    - Product prices ~ opex
    - Product prices ~ capex
    - Capex ~ Initial Rate

Evaluation Methodologies under SPE-PRMS

Probabilistic

- Results in a range of outcomes
  - Original Volumes in Place
  - Recoverable Volumes
  - Economic Value – Net Present Value
    - Opex
    - Capex

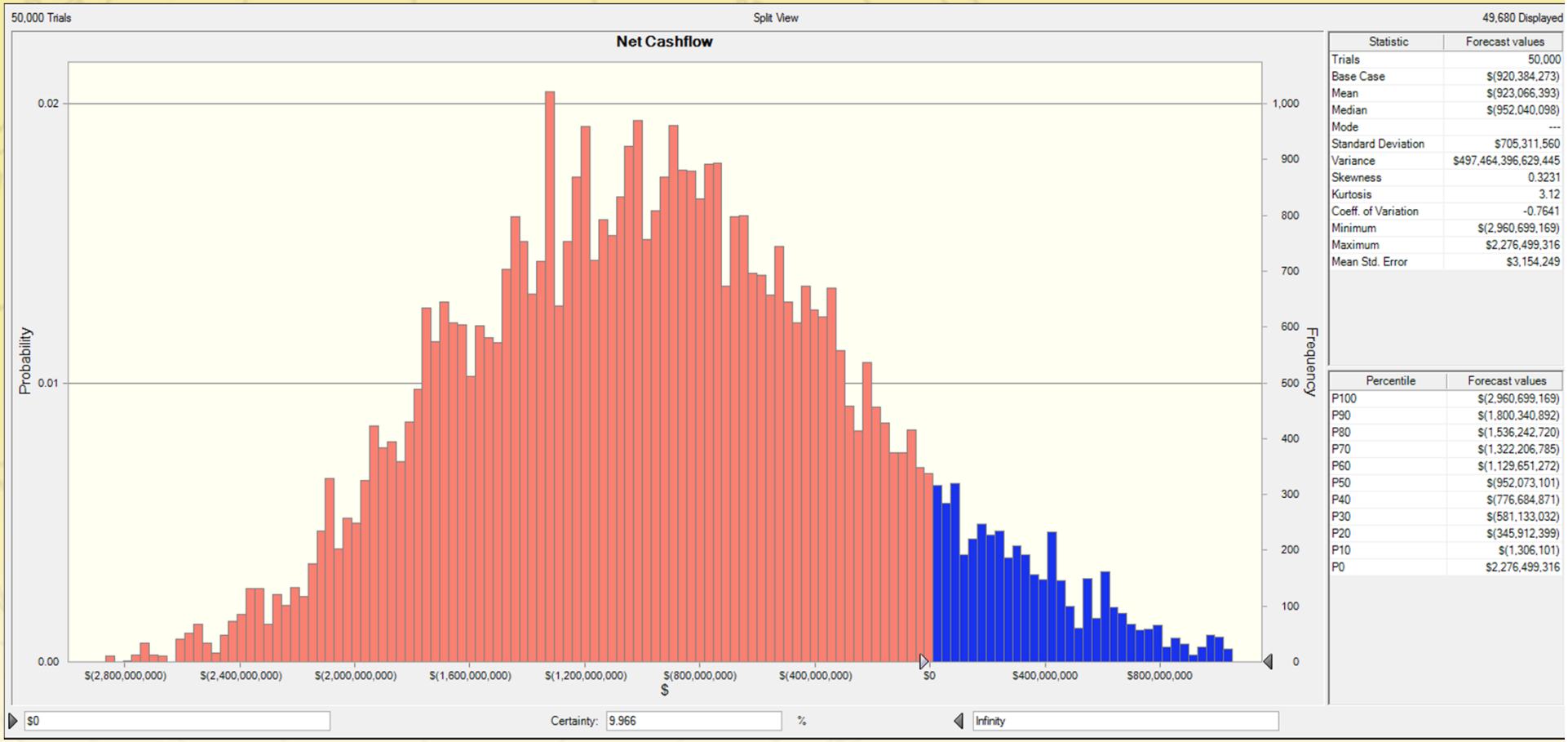
- Allows Managers to understand and incorporate uncertainties
  - Better decisions
  - Positions company for better profitability

Evaluation Methodologies under SPE-PRMS

Probabilistic

- Where can you use it?
  - Determine most likely outcome of a workover campaign
    - Which is the most cost efficient workover
  - Shale Prospect Analysis
  - Undiscovered Conventional Reservoir Prospect Analysis
  - Exploration of Undrilled Acreage
  - Infill drilling

Evaluation Methodologies under SPE-PRMS



Statistic	Forecast values
Trials	50,000
Base Case	$(920,384,273)
Mean	$(923,066,393)
Median	$(952,040,098)
Mode	---
Standard Deviation	$705,311,560
Variance	$497,464,396,629,445
Skewness	0.3231
Kurtosis	3.12
Coeff. of Variation	-0.7641
Minimum	$(2,960,699,169)
Maximum	$2,276,499,316
Mean Std. Error	$3,154,249

Percentile	Forecast values
P100	$(2,960,699,169)
P90	$(1,800,340,892)
P80	$(1,536,242,720)
P70	$(1,322,206,785)
P60	$(1,129,651,272)
P50	$(952,073,101)
P40	$(776,684,871)
P30	$(581,133,032)
P20	$(345,912,399)
P10	$(1,306,101)
P0	$2,276,499,316

Background Info