ENERGY NAVIGATOR

A better way.

Boyd Russell P.Eng. and Randy Freeborn P.Eng.

Statistical Analysis of P50 Forecasts Leads to Realistic Values for P10/P90

The Concept

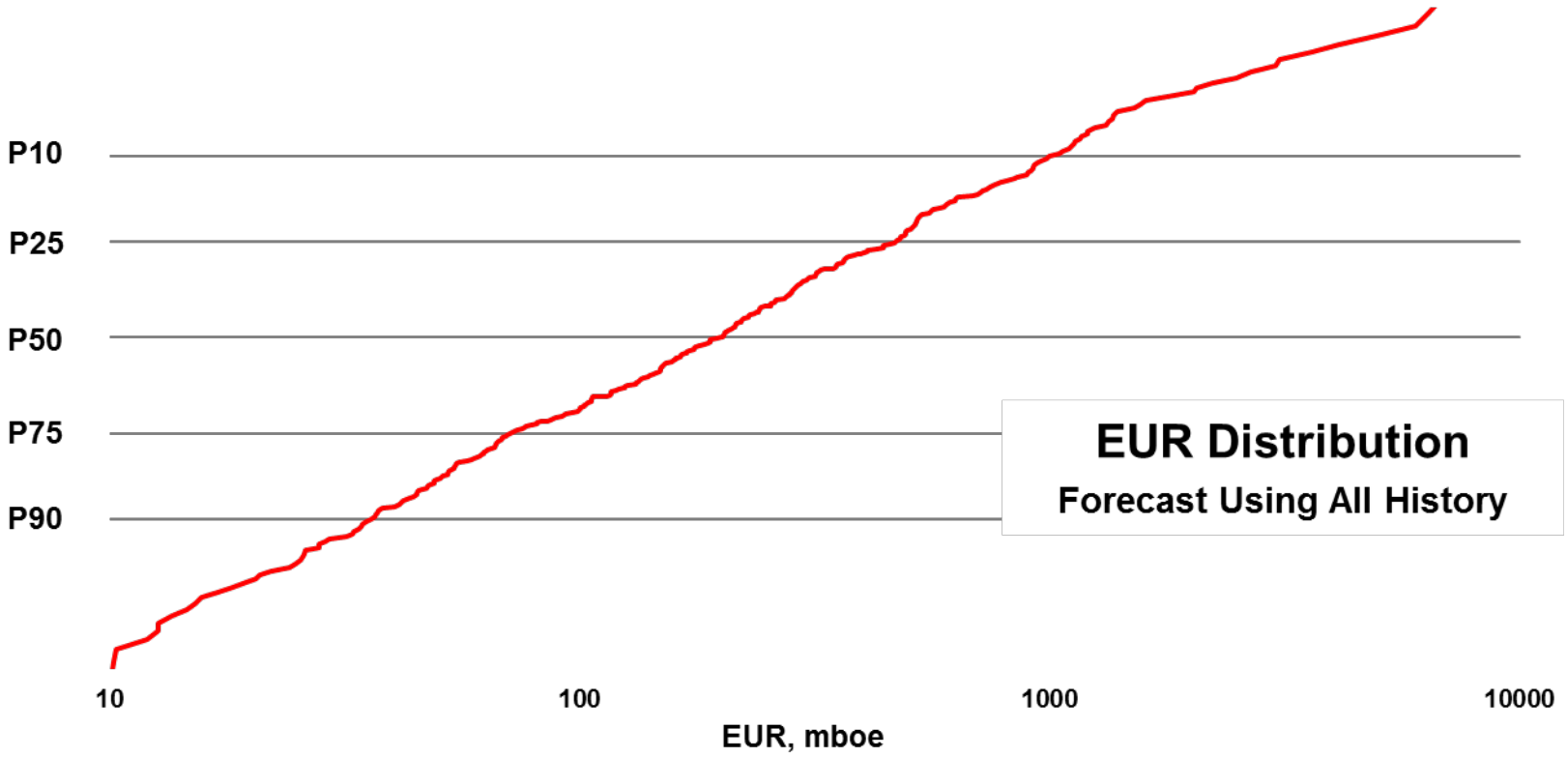
- Calculate the accuracy of EUR forecasts over time by comparing historical EUR estimates to current.
- Make sense of the data by looking at the statistical distribution of the errors.
- Use the statistical error distribution to determine P10/P90 EURs from a P50 forecast.
- Combine aggregation and error distribution.

Forecast and Error Calculation

Generate Forecasts

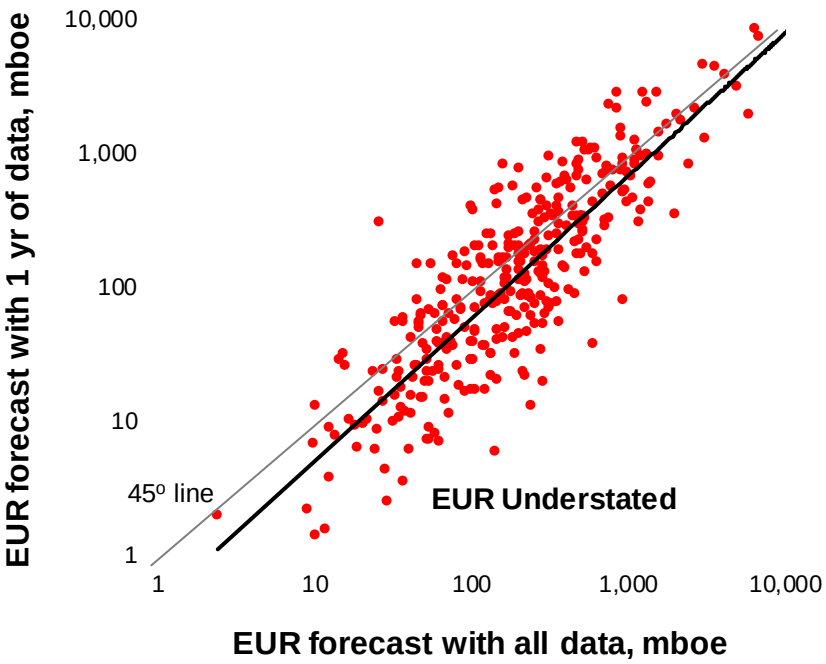
- 357 random wells.
  - Uniformly distributed across Western Canada.
  - Uniformly distributed product and producing horizon
- Each well started production between January 2000 and December 2002.
- Each well is still producing (11-13 years history).
- Each well was auto-forecasted and individually corrected if necessary (~1% were adjusted manually).
- Eight additional forecasts were created using only a portion of the available production history.
  - 0.5 / 1 / 2 / 3 / 4 / 5 / 6 / 7 years

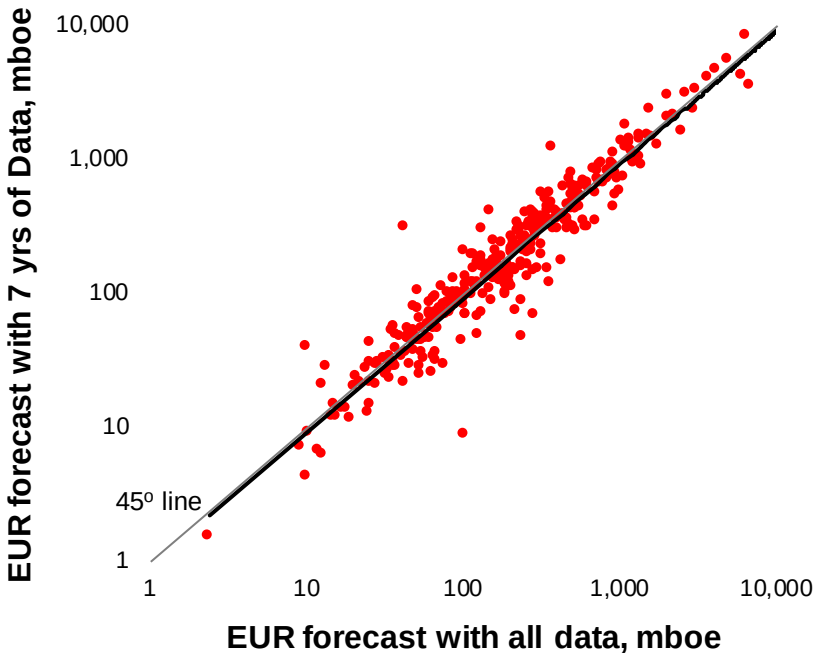
Distribution of Forecast Results



- Log normal distribution.
- Broad data sampling indicated by range in EUR: P10/P90 = 28.

Distribution of Forecast Results





- The forecast quality improves with time
- The error band has the same width over the full data range
- Error is biased with fewer years of data
  - more likely to understate EUR
  - greater bias at low EURs

How to Determine Error

Error Calculation

- Used error, rather than EUR difference in order to normalize data and make it universally applicable.
- Typically, error is calculated by dividing EUR difference by the correct EUR.

$$Error = \frac{EUR - correct\ EUR}{correct\ EUR}$$

- Because this method results in a non symmetrical error distribution, it was not used.
- For example:

  For 5 times greater value $Error = \frac{50-10}{10} = 5$

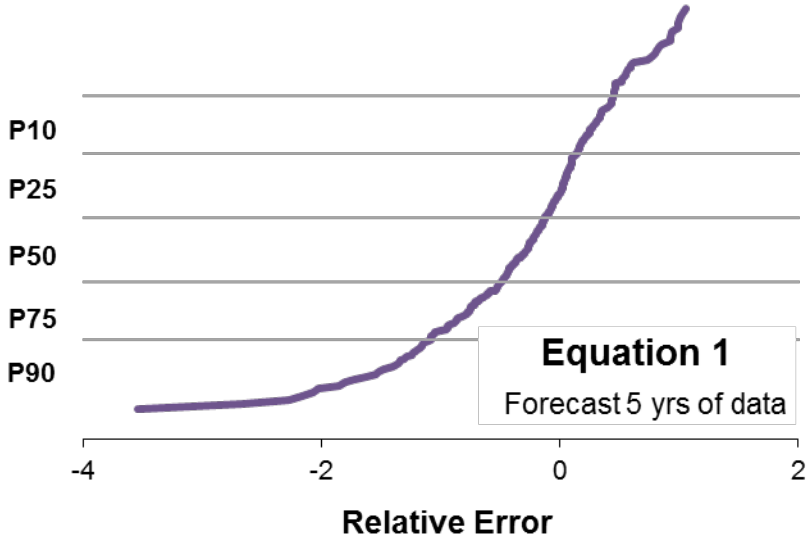
  For 5 times less value $Error = \frac{2-10}{10} = -0.8$

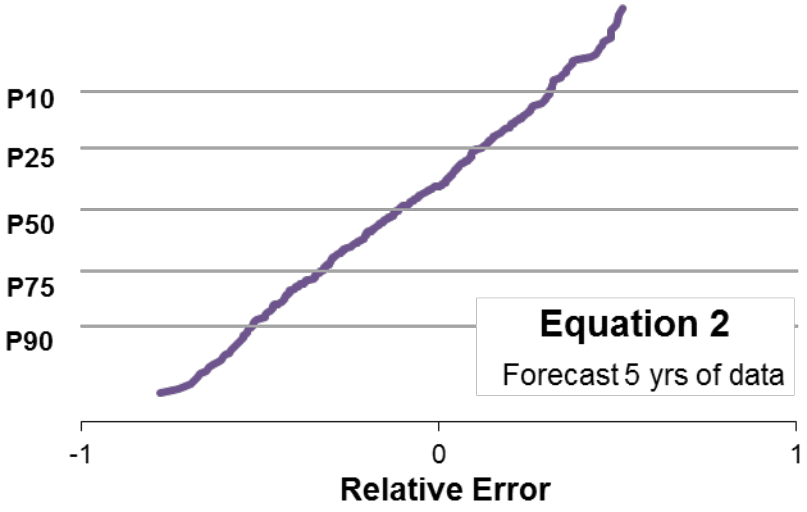
Error Calculation Methodology

- Two error calculation methods were evaluated:

Eqn. 1 $$Error = \frac{EUR - correct\ EUR}{min(EUR, correct\ EUR)} \qquad -\infty > Error < \infty$$

Eqn. 2 $$Error = \frac{EUR - correct\ EUR}{max(EUR, correct\ EUR)} \qquad -1 \geq Error \leq 1$$





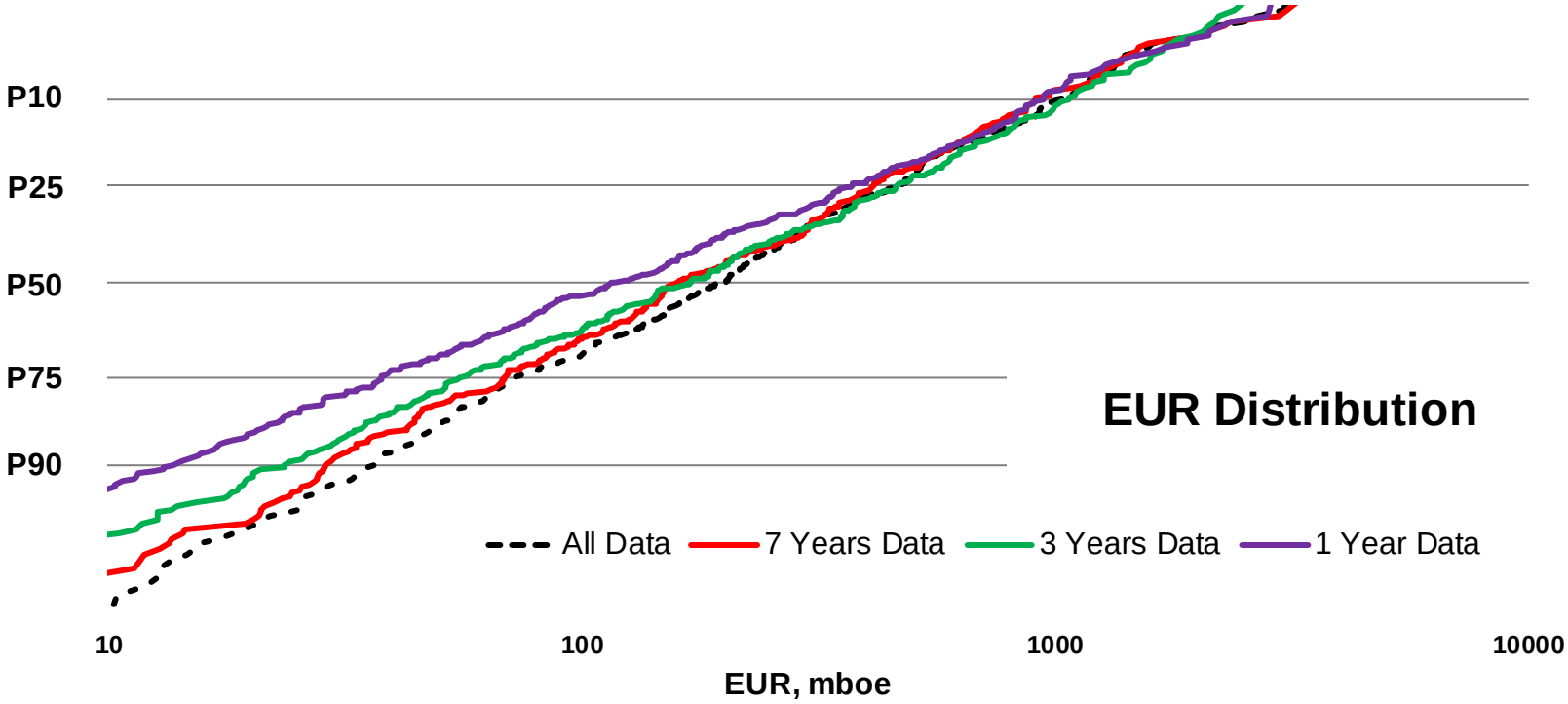
- Equation 2 was used because it was normally distributed.

Making Sense of the Data

Data Analysis: Forecast Bias

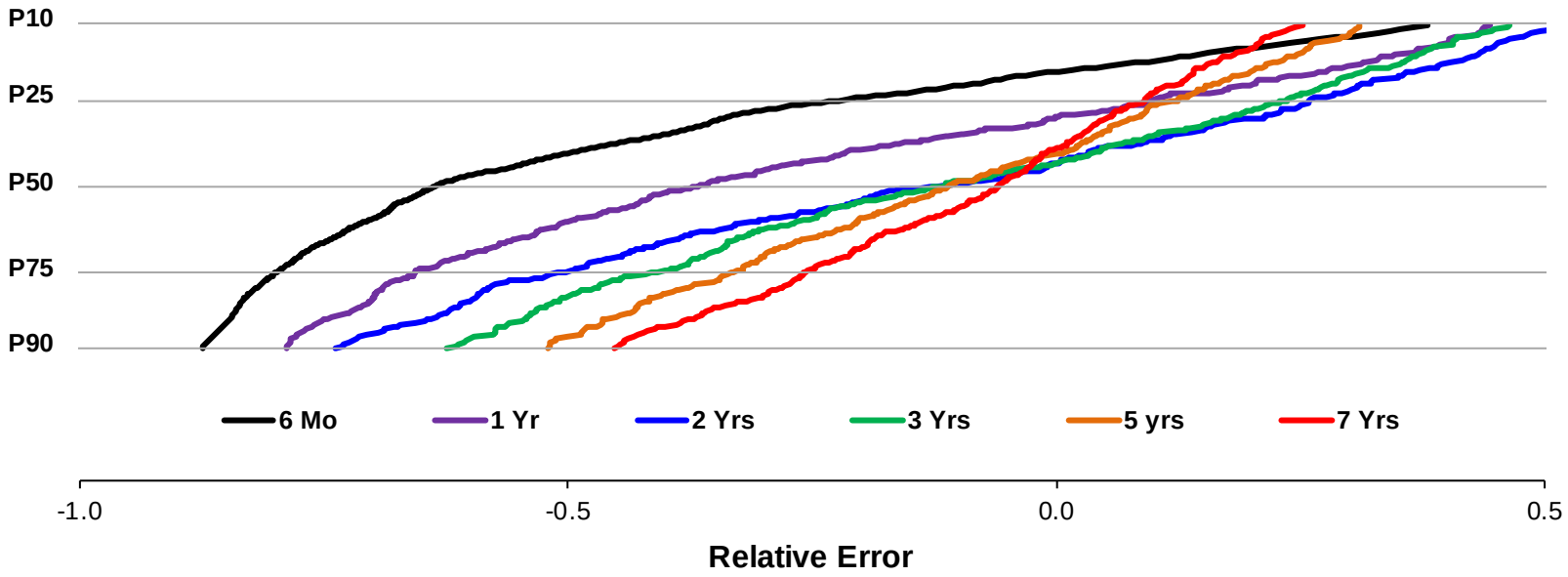
- The error is normally distributed.
- Best estimate forecast: the error at P50 should be zero.
- **Question**: Should forecasts be increased by 6% to adjust for bias?

Data Analysis: Forecast Bias



- Log normal distribution for all forecast groups.
- Error bias for all forecast groups:
  - More likely to understate EUR
  - Greater bias at low EURs

Data Analysis: Multi-Year Distribution



Observations:

- For the six month and one year case, distribution deviates from normal.
- With more production history
  - The distribution the P10/P90 ratio decreases (reduced error range).
  - The error becomes more balanced (P50 is closer to zero).
  - In all cases there is a bias to under-estimate the P50 EUR.

Obtaining P10 and P90 EURs:

- For individual wells, obtain P10/P90 EURs by adjusting the P50 EUR using the error taken from the chart.

Aggregation: Proposed

Aggregation

- Individual well forecasts are unreliable.
- Aggregation of multiple wells improves accuracy because individual errors tend to cancel out. (SPE 158867).
- SPEE Monograph 3 provides a method to calculate aggregated EURs.
  - Specify the P10/P90 ratio and well count to obtain the EUR correction factor.
  - The correction only accounts for the range of possible EURs, not the accuracy of the EUR estimate.
- We have expanded on the SPEE method by including an adjustment for forecast accuracy.

Description of Proposed Aggregation

- Example: **5 years of data** Drill: **10 wells**
  - Randomly select 10 wells from the single well probability distribution.
  - For these 10 wells, calculate the error:

$$\mathrm{Error} = \frac{[\sum 5\ yr\ EUR - \sum correct\ EUR\ ]}{max[\sum 5\ yr\ EUR, \sum correct\ EUR]}$$

  - Repeat the 10 well process for thousands of trials.
  - Plot the probability distribution (normal) of the trials to find the error at selected probabilities (P10/P50/P90).
- From the single well distribution find the probabilities that correspond to the selected errors.

Proposed Aggregation – Step 1

- Select 10 wells at random.
- Calculate the Mean EURs:
  Five Years and Correct.
- Calculate the mean error the formula.
- Repeat for many trials (50,000)

Method incorporates

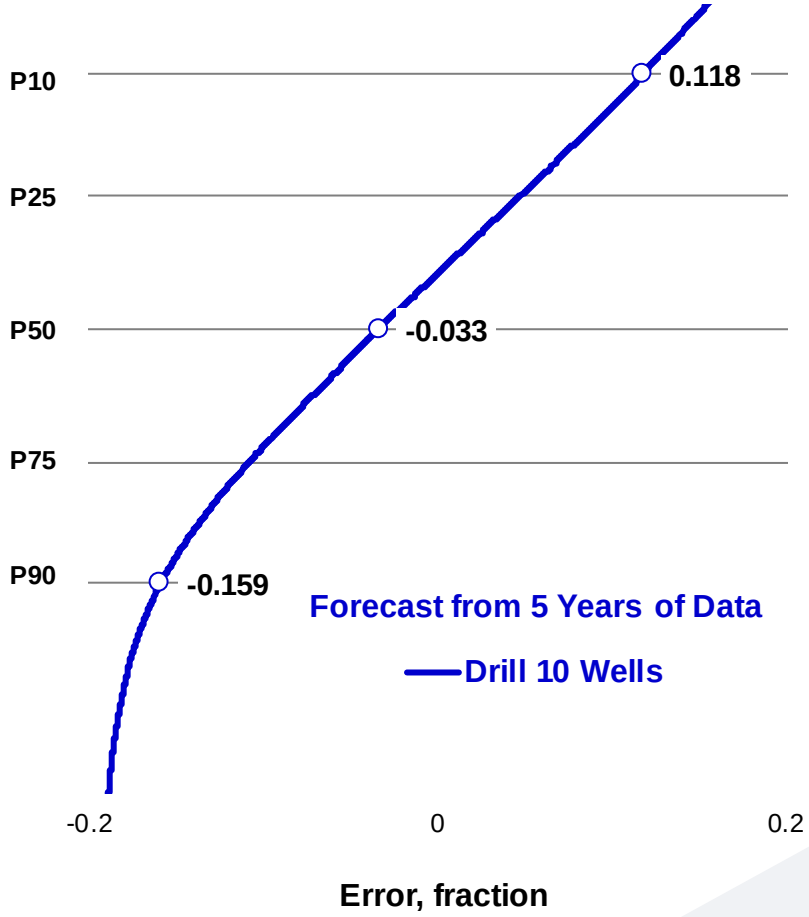
- Well aggregation
- Accuracy of EUR estimate

	EUR	
Well	5 Year	Correct
1	181	206
2	134	145
3	355	429
4	494	374
5	439	545
6	726	1296
7	468	603
8	1209	2000
9	537	709
10	1383	2171
Total	5927	8478
Mean	593	848

$$\boldsymbol{Error} = \frac{(\mathbf{593} - \mathbf{848})}{\mathbf{848}} = -\mathbf{0.301}$$

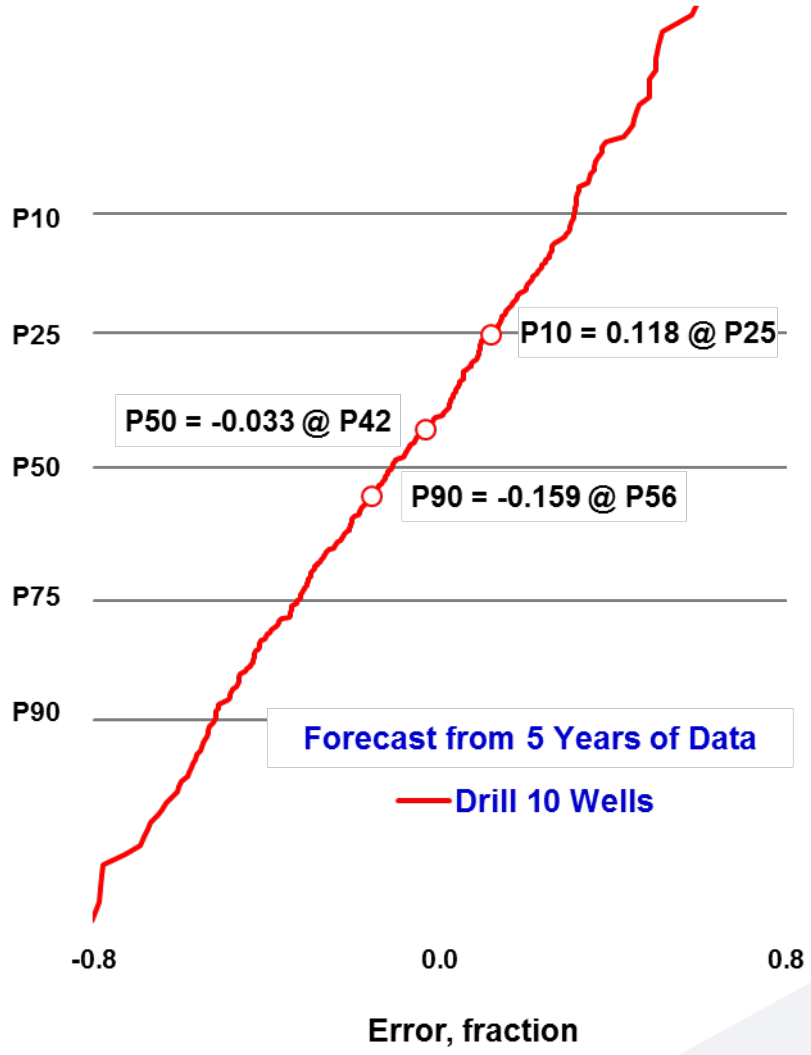
Proposed Aggregation – Step 2

- Sort the mean error from all the trials.
- Assign cumulative probability.
- Plot the distribution of mean error on a probit scale.
- Read the aggregated error at the desired probabilities.
- Determine where the P10, P50 and P90 aggregated errors occur on original error distribution plot.

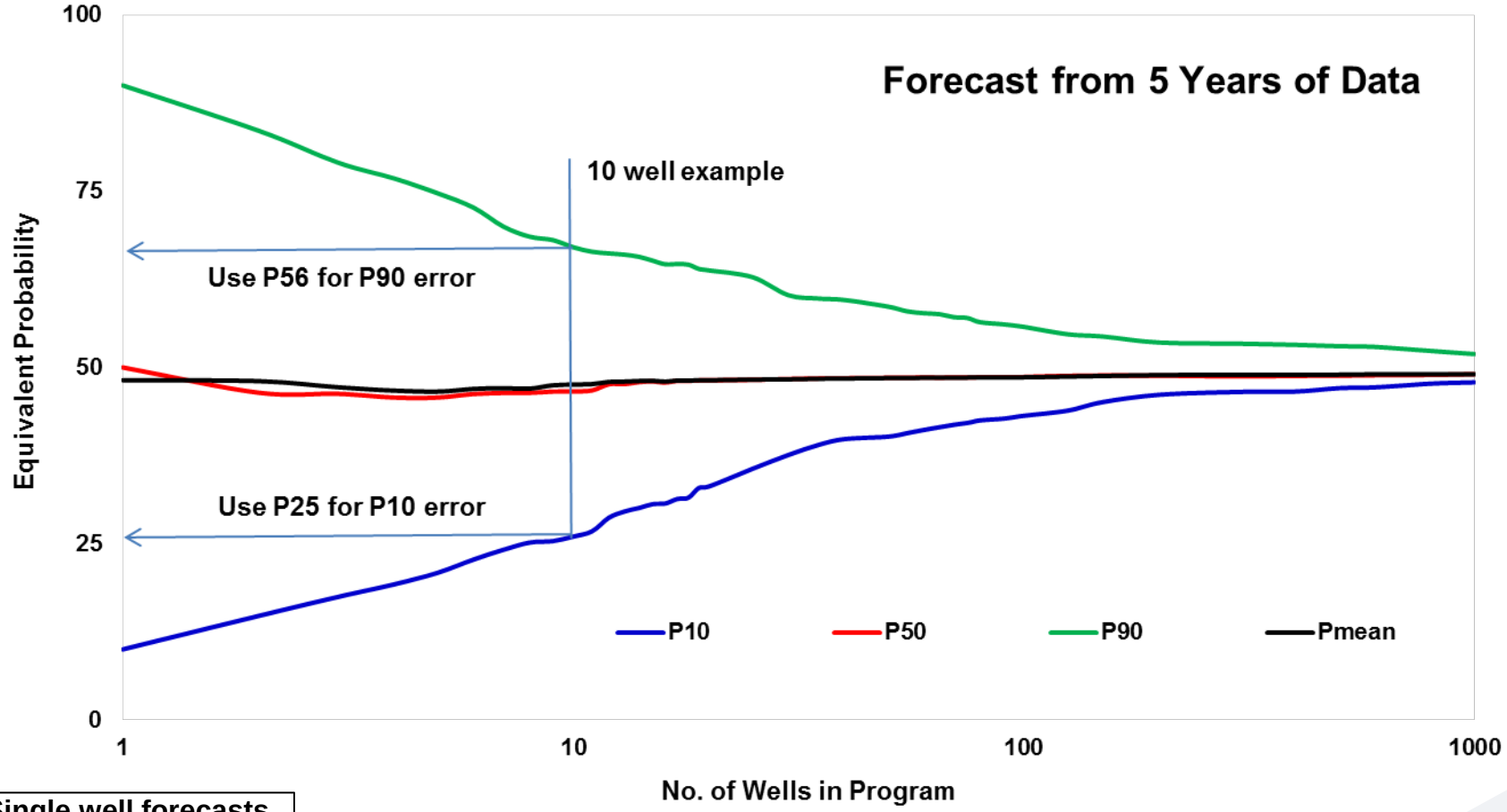


Show Aggregation Result on the Original Error Distribution

- Return to the single well error probability distribution.
- Determine which probability corresponds to the errors determined on previous slide.
- Example for P90 Error.
  - When drilling 10 wells look to P56 on the single well distribution.
- Repeat for various well counts and years of history.
- Selected points represent one slice on a trumpet chart (to be shown on next slide.)



Trumpet Chart – Multi-Well Aggregation



Single well forecasts are unreliable

Calculation Procedure

Example: **5 years of data** Drill: **10 wells**

- Trumpet Plot: Get probability for P50 (P42)
- Original Distribution: Get P50 error (P42) = -0.033
- For each of 10 wells: Get EUR (P50, say 100)
- Error Equation: Solve for correct EUR

$$Error = \frac{[\sum 5\ yr\ EUR - \sum correct\ EUR\ ]}{max[\sum 5\ yr\ EUR, \sum correct\ EUR]}$$

$$-0.033 = \frac{100 - correct\ EUR}{100} \quad correct\ EUR = 103.3$$

- P10 and P90 EUR: Repeat, but now solve for EUR using calculated correct EUR

Workflows

Workflow 1:

- Need a statistically significant sample of wells with enough history to get reliable EUR forecasts.
- Create individual well forecasts at frequent time intervals. Can be done by hand or use prior reserve reports.
- Calculate error and error distribution for all time intervals.
- Conduct aggregation calculations for a number of well count/time interval combinations.
- Aggregation should have sufficient trials to result in uniform and representative distribution. We used 7000 to 75,000 trials per aggregation.
- Create a Trumpet Plot for each time interval to create a working tool to adjust for multiple wells with varying amounts of history.
- Use Trumpet Plot to correct EURs.

Workflow 2:

- Use a representative Trumpet Plot created by others.

Observations

- Individual well forecasts have a bias that needs to be corrected.
- A method is proposed to adjust EUR for both forecast error and well quality (EUR aggregation).
- Forecast accuracy depends on amount of history available. The more the better.
- Overall error can be reduced by aggregating forecasts.
- The distribution of error can be used to estimate P10/P90 from a P50 forecast.
- The P10/P90 error range is influenced by the number of wells and the number of months on production.
- Until now, we have not seen the application of probabilistic methods to estimate deterministic reserves.

Where Do We Go from Here

- Random selection of wells (357) may prove to be universally applicable, but this is not confirmed.
- Method can be easily automated to generate P90/P10 forecasts from best guess (mean) forecasts.
- Need to consider how to implement adjusted EUR (different decline?)
- Need feedback from producers, reserve evaluators and regulators.

Thank You

Questions?