



Petroleum Engineers Club of Dallas

My Own Worst Enemy:

-- A Journey Toward Taming Overconfidence in Reserves Estimates

Presented by Rob Quigley

August 11, 2023



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Imagine, It Was January 2006...

**REPSOL
YPF**



Disclosure of reserves revisions



- Reserves revisions
 - Proved reserves at end-2005 expected to be revised downward by 1,254 Mboe, representing 25% of end-2004 proved reserves

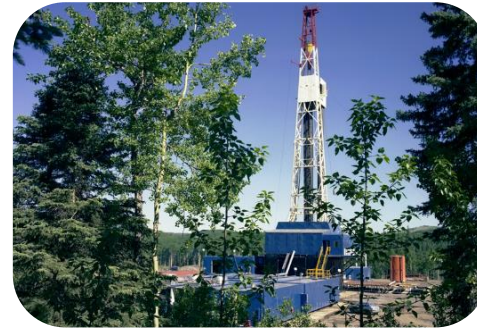
| Mboe | <u>Argentina</u> | <u>Bolivia</u> | <u>RoW</u> | <u>Total</u> |
|------------------------------|------------------|----------------|--------------|------------------|
| December 31, 2004 (c) | 2,364 | 1,309 | 1,253 | 4,926 (a) |
| Expected Revisions | (509) | (659) | (86) | (1,254) (b) |

1. Image: https://commons.wikimedia.org/wiki/File:Sede_central_de_Repsol_YPF_%28Madrid%29_06.jpg
2. Modified from Repsol YPF. 2006.

Why Do We Miss Reserves Estimates?



Poor Estimating Practices



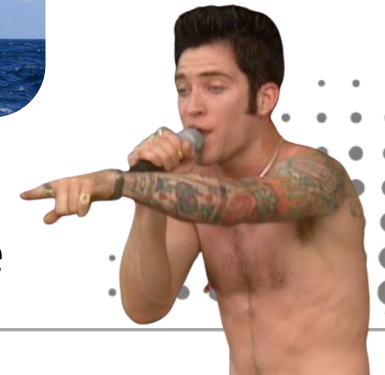
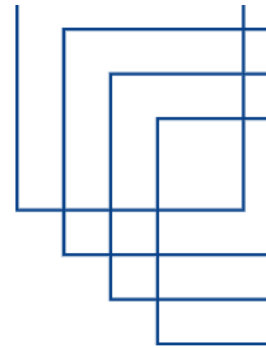
Misguided Incentives



Lack of Professionalism



Human Bias/
Overconfidence



My Own Worst Enemy – Human Psyche in Reserves

1. Overconfidence is an Issue in Reserves Estimation

2. Quiz Time!

3. Bias Exists and Is Hard to Conquer

4. Proving Bias with Public Reserves Disclosures

5. Proposed Solutions to Improve on Bias

6. How Did We Do on the Quiz?

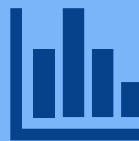
Quiz Time: Test Your Ability to Handle Uncertainty



Scan the QR Code.



Provide your answers
to the 10-question
quiz.

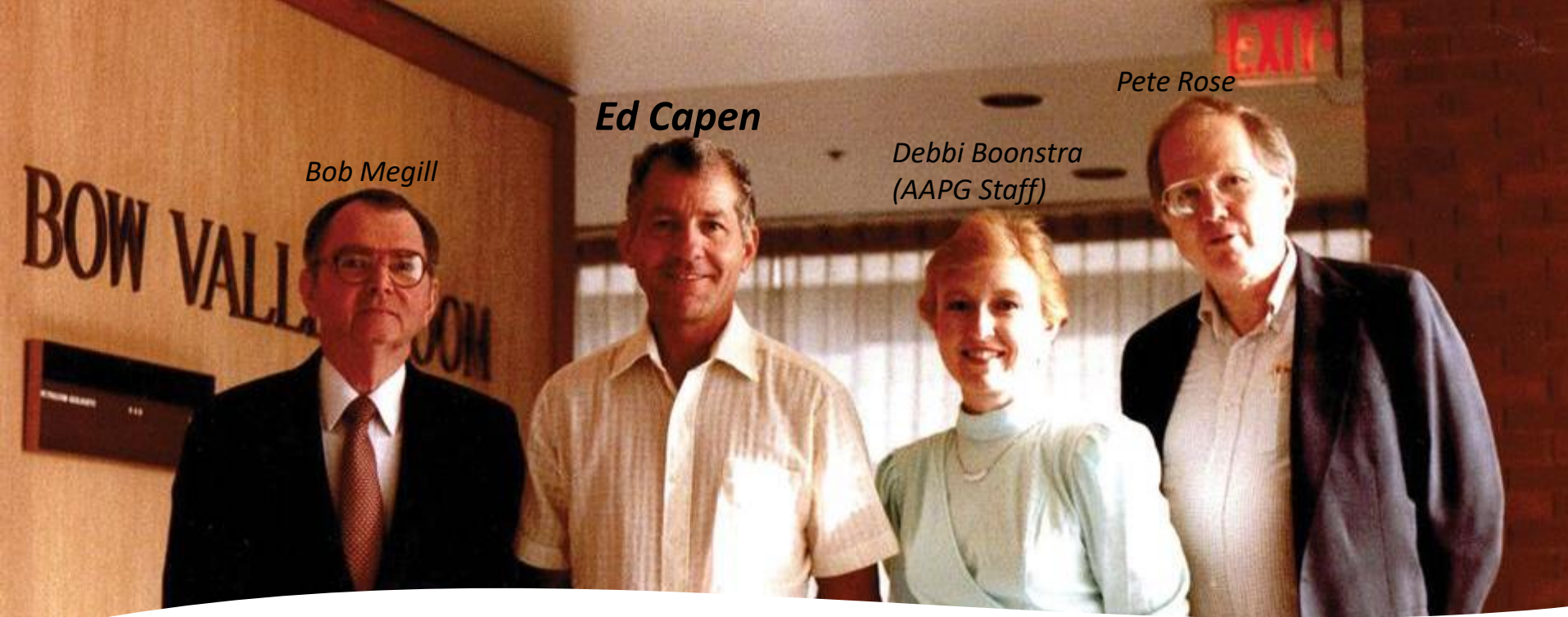


Results will be
summarized at the end
of the presentation.

My Own Worst Enemy – Human Psyche in Reserves

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4. Proving Bias with Public Reserves Disclosures
5. Proposed Solutions to Improve on Bias
6. How Did We Do on the Quiz?





Bob Megill

Ed Capen

*Debbi Boonstra
(AAPG Staff)*

Pete Rose

Capen, Rose, and the E&P Risk Kings of the 1970's

The Difficulty of Assessing Uncertainty (SPE-5579-PA)

- Technical people have little grasp of uncertainty.
- Universal tendency to understate it
- Leads to overestimation of the precision of their knowledge.

1. Image: <https://explorer.aapg.org/story/articleid/50083/a-player-in-the-emergence-of-e-p-risk-analysis>
2. Modified from Capen, E. C. 1976.

Capen's Famous 10 Questions...

1. In what year was St. Augustine established as a European settlement?

2. How many motor vehicles were registered in California in 2022?

3. What is the air distance from San Francisco to Hong Kong in miles?

4. How far is it from Los Angeles to New Orleans via major highways in miles?

5. What was the census estimate of U.S. population in 1900?

6. What is the span length of the Golden Gate Bridge in feet?

7. What is the area of Canada in square miles?

8. How long is the Amazon River in miles?

9. How many earth years does it take the planet Pluto to revolve around the sun?

10. The English epic poem "Beowulf" was composed in what year?

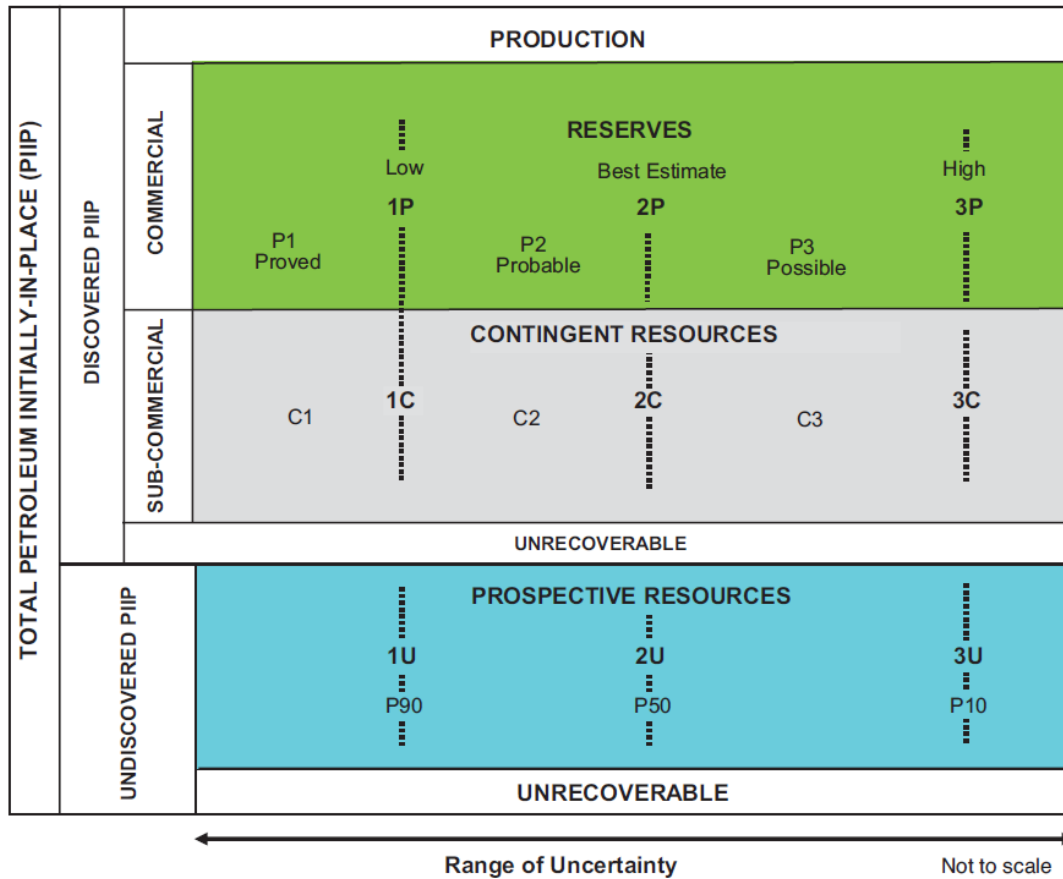
All SPE Section Demonstrated Dramatic Overconfidence

| Requested Confidence Interval | SPE-AIME Section | Response Count | Expected # of Misses | Actual Avg # of Misses | Implied Confidence Interval | Implied Probabilistic Range |
|-------------------------------|------------------------|----------------|----------------------|------------------------|-----------------------------|-----------------------------|
| 98% (P1 to P99) | Hobbs Petroleum | 34 | 0.2 | 6.3 | 37% | P31 to P69 |
| | Oklahoma City | 111 | 0.2 | 7.0 | 30% | P35 to P65 |
| 90% (P5 to P95) | Los Angeles Basin | 28 | 1 | 6.0 | 40% | P30 to P70 |
| | San Francisco | 61 | 1 | 6.4 | 36% | P32 to P68 |
| | Oxnard | 26 | 1 | 7.4 | 26% | P37 to P63 |
| | Long Beach | 28 | 1 | 6.0 | 40% | P30 to P70 |
| | New York | 29 | 1 | 6.5 | 35% | P33 to P67 |
| | Bridgeport ,Charleston | 16 | 1 | 7.6 | 24% | P38 to P62 |
| | Anchorage | 63 | 1 | 6.5 | 35% | P33 to P67 |
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| | Lafayette | 79 | 1 | 6.5 | 35% | P33 to P67 |
| | Shreveport | 41 | 1 | 6.8 | 32% | P34 to P66 |
| 80% (P10 to P90) | Vernal | 13 | 2 | 7.2 | 28% | P36 to P64 |
| | Denver | 129 | 2 | 6.5 | 35% | P32 to P68 |
| | Cody | 42 | 2 | 7.3 | 27% | P37 to P63 |
| 50% (P25 to P75) | Columbus | 27 | 5 | 7.0 | 30% | P35 to P65 |
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| | Long Beach | 28 | 7 | 7.4 | 26% | P37 to P63 |
| | Bridgeport ,Charleston | 15 | 7 | 7.8 | 22% | P39 to P61 |
| All C.I.'s | Grand Total | 965 | - | 6.7 | 33% | P34 to P66 |

Modified from Capen. E. C. 1976.



Contextualizing Capex in PRMS Reserves

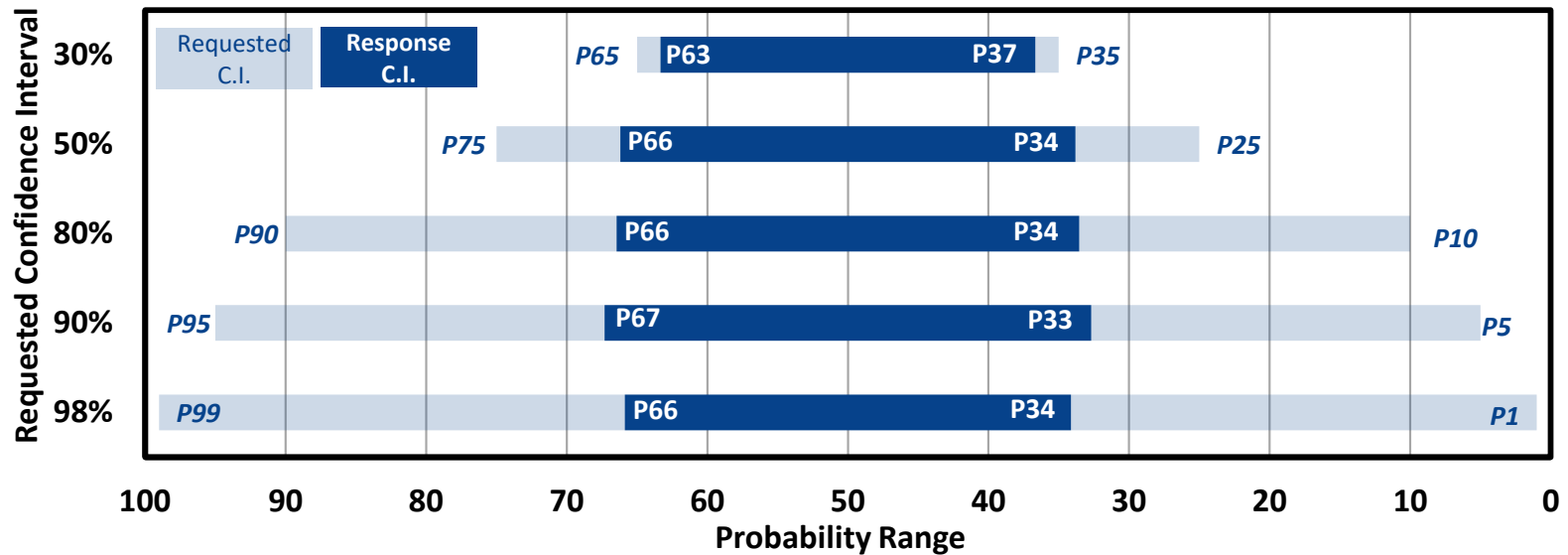


| Reserves Categories | Probability | Confidence Interval |
|-------------------------------------------------|-------------|---------------------|
| 1P - Low Estimate (Proved) | 90% | 80% |
| 2P - Best Estimate (Proved+ Probable) | 50% | |
| 3P - High Estimate (Proved+ Probable+ Possible) | 10% | |

PRMS 2018: 2.2.1.2 When the range of uncertainty is represented by a probability distribution:

- There should be at least a 90% probability (P90) that the quantities will equal or exceed the low estimate.
- There should be at least a 50% probability (P50) that the quantities will equal or exceed the best estimate.
- There should be at least a 10% probability (P10) that the quantities will equal or exceed the high estimate.

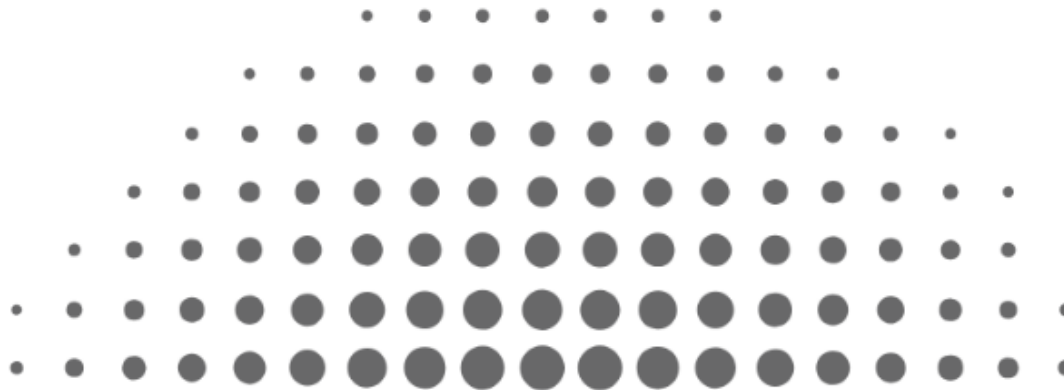
We Can't Handle the Concept of Confidence Intervals



Capen's Hypothesis: Estimators will miss an average 68 percent of the questions, no matter what probability ranges they are asked for (33% CI).

My Own Worst Enemy – Human Psyche in Reserves

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Lee, McVay, & Gomez: Reserves Uncertainty in the 21st Century

Technical Revisions Reveal Overconfidence in US and Canadian Reserves (SPE-201116-PA)

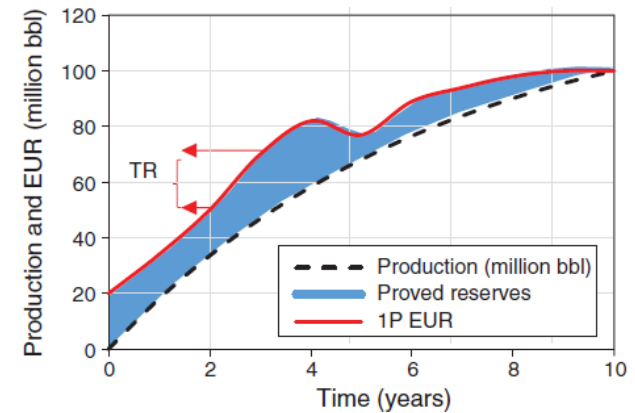
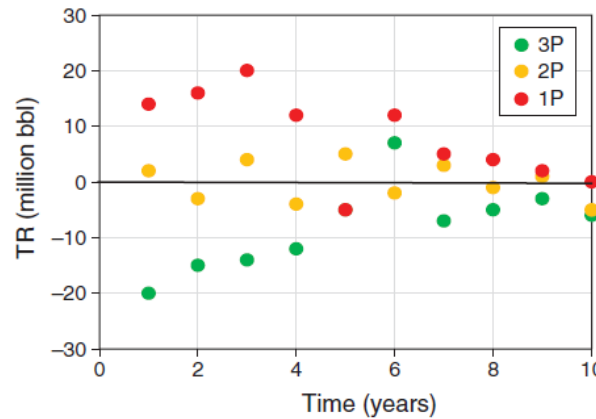
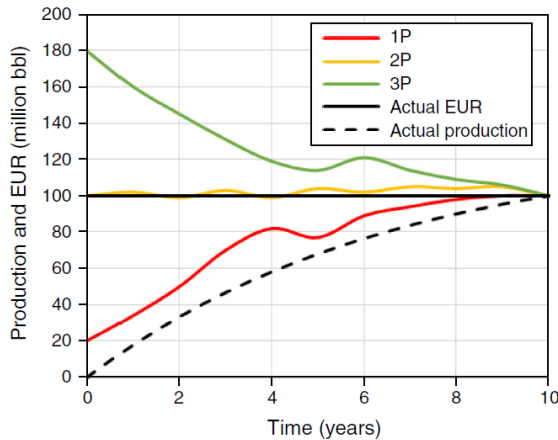
- ❑ Filers overestimated proved (1P) reserves.
 - US filers: 51 % positive TRs instead of 90%
 - Canadian filers: 72% positive TRs instead of 90%
- ❑ Canadian filers underestimated proved-plus-probable (2P) reserves slightly (54% positive TR, instead of 50%).



Idealized Reserves Scenario – Technical Revisions (TRs)

| Year | Actual (mmbbl) | | | 1P (mmbbl) | | | 2P (mmbbl) | | | 3P (mmbbl) | | |
|------|----------------|----------|----------|------------|------|----------|------------|------|----------|------------|-------|----------|
| | Yearly Prod | Cum Prod | Reserves | EUR | TRs | Reserves | EUR | TRs | Reserves | EUR | TRs | Reserves |
| 0 | - | - | 100.0 | 20.0 | - | 20.0 | 100.0 | - | 100.0 | 180.0 | - | 180.0 |
| 1 | 18.0 | 18.0 | 82.0 | 34.0 | 14.0 | 16.0 | 102.0 | 2.0 | 84.0 | 160.0 | -20.0 | 142.0 |
| 2 | 15.5 | 33.5 | 66.5 | 50.0 | 16.0 | 16.5 | 99.0 | -3.0 | 65.5 | 145.0 | -15.0 | 111.5 |
| 3 | 13.3 | 46.8 | 53.2 | 70.0 | 20.0 | 23.2 | 103.0 | 4.0 | 56.2 | 131.0 | -14.0 | 84.2 |
| 4 | 11.4 | 58.2 | 41.8 | 82.0 | 12.0 | 23.8 | 99.0 | -4.0 | 40.8 | 119.0 | -12.0 | 60.8 |
| 5 | 9.8 | 68.0 | 32.0 | 76.9 | -5.1 | 8.9 | 103.9 | 4.9 | 35.9 | 113.9 | -5.1 | 45.9 |
| 6 | 8.5 | 76.5 | 23.5 | 88.9 | 12.0 | 12.4 | 101.9 | -2.0 | 25.4 | 120.9 | 7.0 | 44.4 |
| 7 | 7.3 | 83.8 | 16.2 | 94.0 | 5.1 | 10.2 | 105.0 | 3.1 | 21.2 | 114.0 | -6.9 | 30.2 |
| 8 | 6.3 | 90.1 | 9.9 | 98.0 | 4.0 | 7.9 | 104.0 | -1.0 | 13.9 | 109.0 | -5.0 | 18.9 |
| 9 | 5.4 | 95.5 | 4.5 | 100.0 | 2.0 | 4.5 | 105.0 | 1.0 | 9.5 | 106.0 | -3.0 | 10.5 |
| 10 | 4.5 | 100.0 | 0.0 | 100.0 | 0.0 | 0.0 | 100.0 | -5.0 | 0.0 | 100.0 | -6.0 | 0.0 |

of Positive TR's>>> 9 5 1
 # of Negative TR's>>> 1 5 9

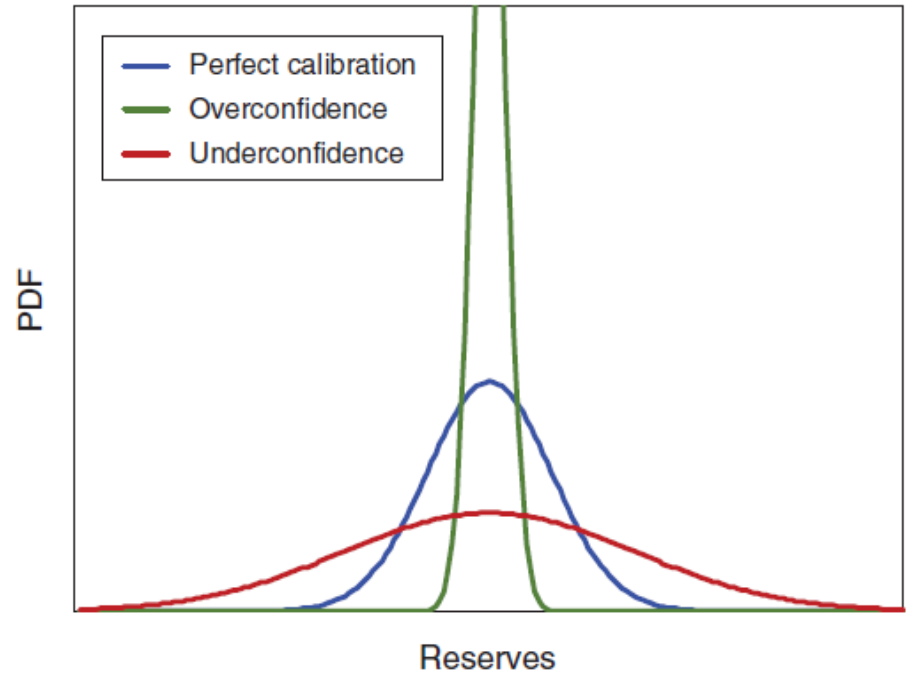
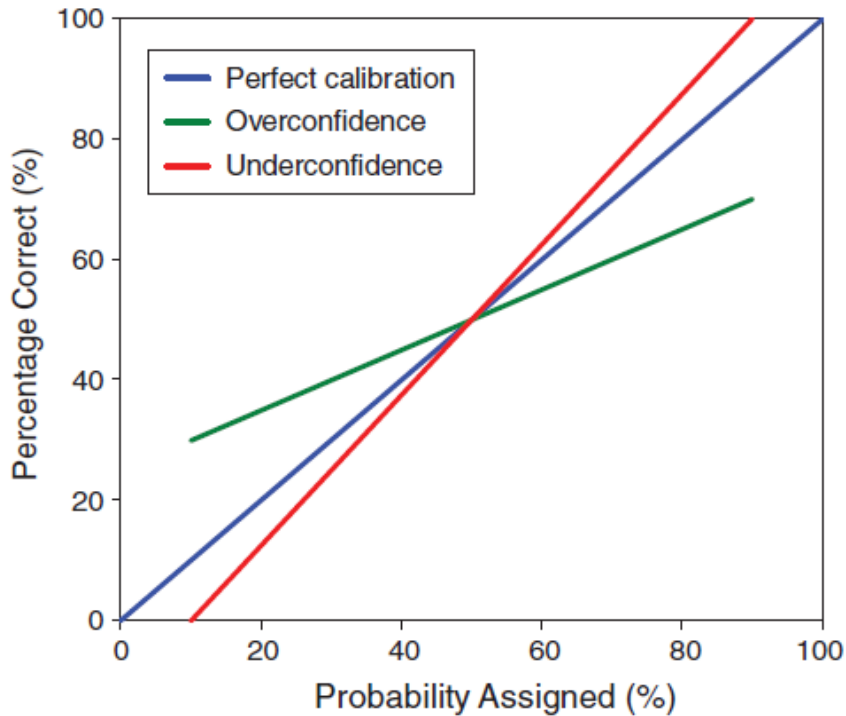


Modified from Gomez Et. Al., 2020



Measuring Reserves Reliability – Calibration Plots

Confidence Bias



$$\text{Confidence Bias (CB)} = 1 - m$$

$m = \text{slope}$

* equation only for overconfidence

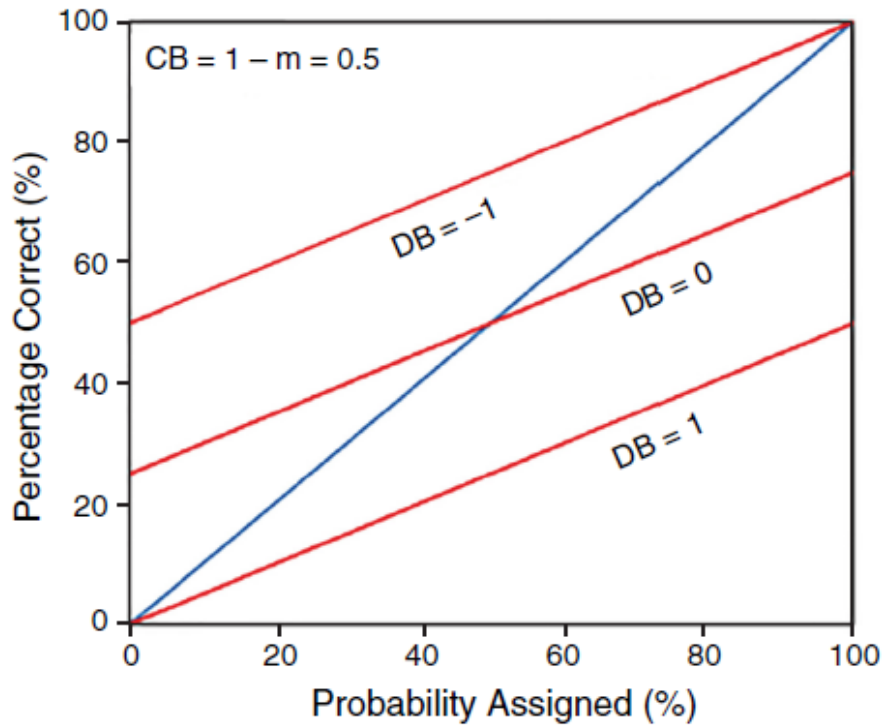
CB = 1 (Complete Overconfidence)

CB = 0 (Neutral, Perfect Calibration)

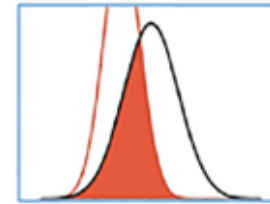
CB = -1 (Complete Underconfidence)

Measuring Reserves Reliability – Calibration Plots

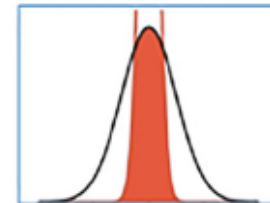
Directional Bias



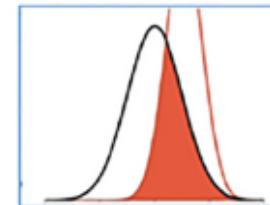
All with CB = 0.5



DB = -1
Complete
pessimism



DB = 0
Neutral



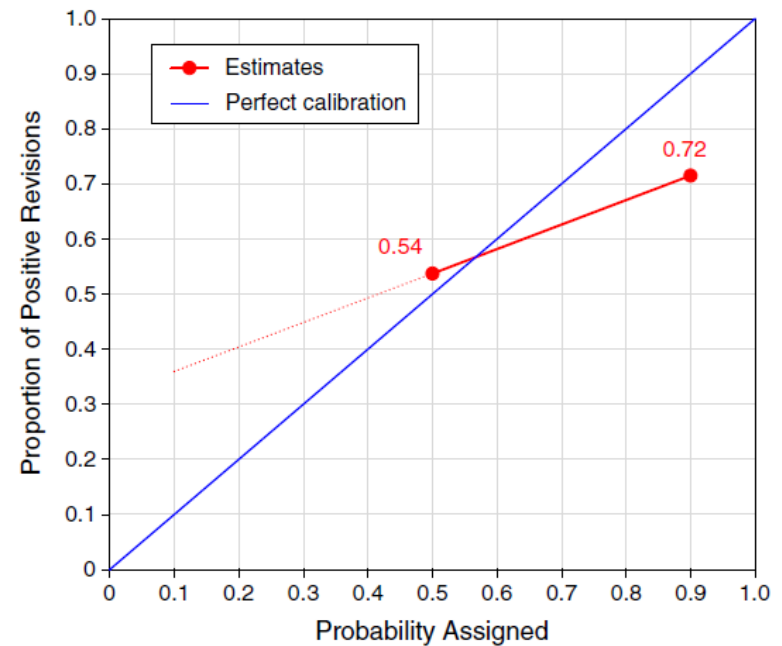
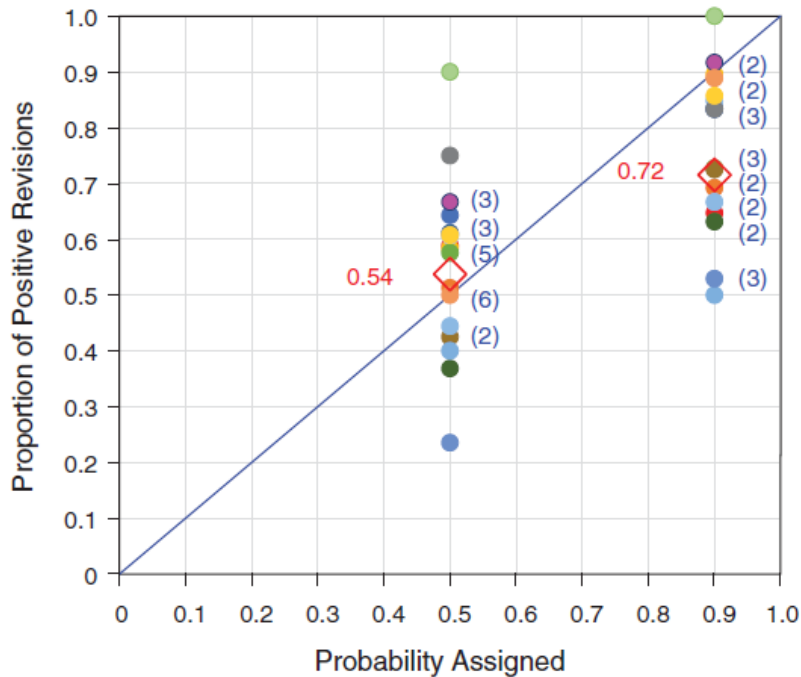
DB = -1
Complete
optimism

$$\text{Directional Bias (DB)} = 1 - \frac{2a}{1 - m}$$

m = slope

a = intercept

Technical Revisions Calibration

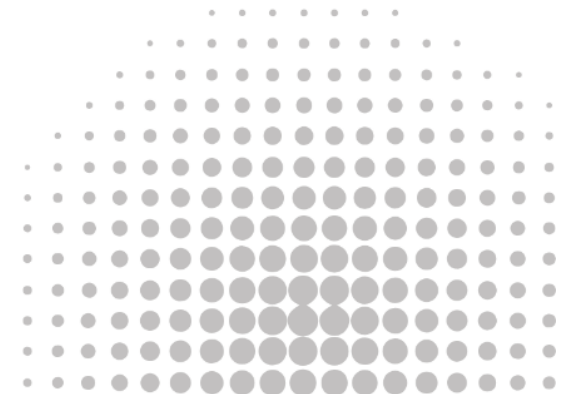


Canadian Annual Information Forum (CAIF) Disclosures Used for Revision Calibrations

- 1P and 2P reserves reported by public companies in Canada.
- Used Technical Revisions (“TR’s”) reported in Canada.

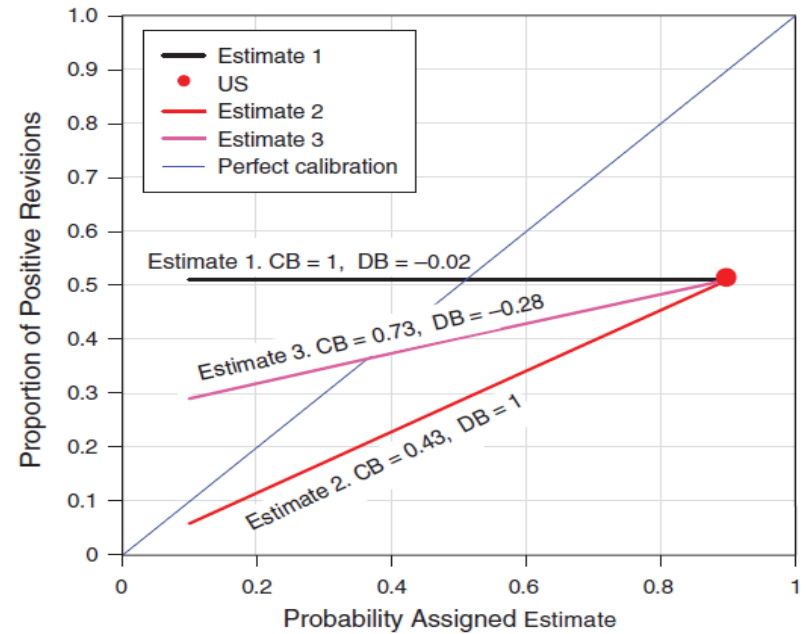
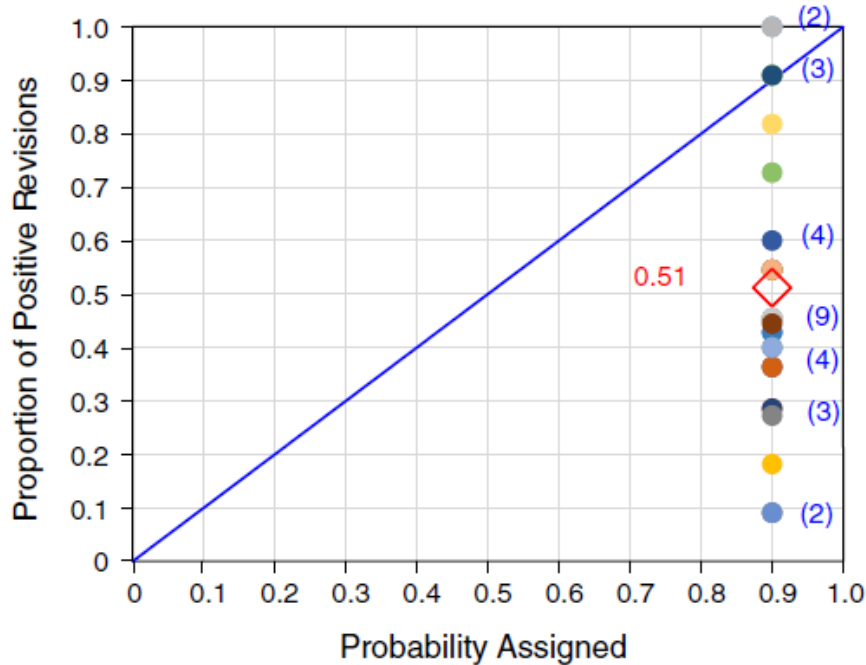
Summary of Canadian Estimators:

- 75% positive TR’s for 1P (instead of 90%)
- 54% positive TR’s for 2P (instead of 50%)
- 37% CI instead of 80% (in line with Capen universal 33% CI hypothesis).
- CB 0.56 (Moderate Overconfidence)
- DB -0.14 (Slight Pessimism)

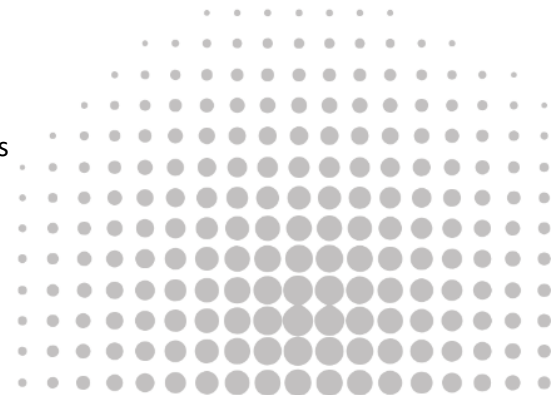


Modified from Gomez Et. Al., 2020

Technical Revisions Calibration



- **SEC Disclosures Used for Revision Calibrations**
 - Only 1P required in USA instead of 2P in Canada.
 - Instead of TR's reported in Canada, identifying performance-related revisions is more difficult in the US.
 - Used Revisions Other Than Price ("ROTP"). Calculated by subtracting price-related revisions from "revisions of previous estimates".
- **Summary of Canadian Estimators:**
 - 51% positive TR's for 1P (instead of 90%)
 - No 2P/3P report, so Gomez estimated 3 scenarios for US reporters:
 - Est 1: Max CB (extreme overconfidence with negligible optimism) (0% CI vs 80%)
 - Est 2: Max DB (Moderate overconfidence and maximum optimism) (46% CI vs 80%)
 - Est 3: Middle Est. (21% CI vs 80%)

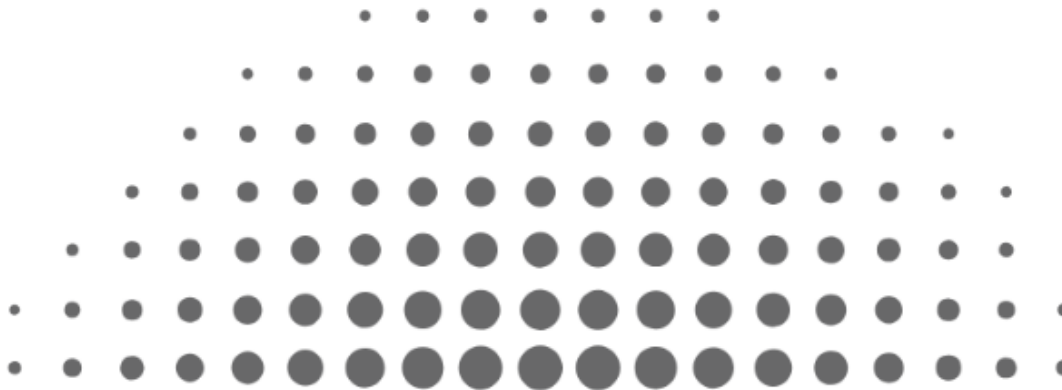


Modified from Gomez Et. Al., 2020

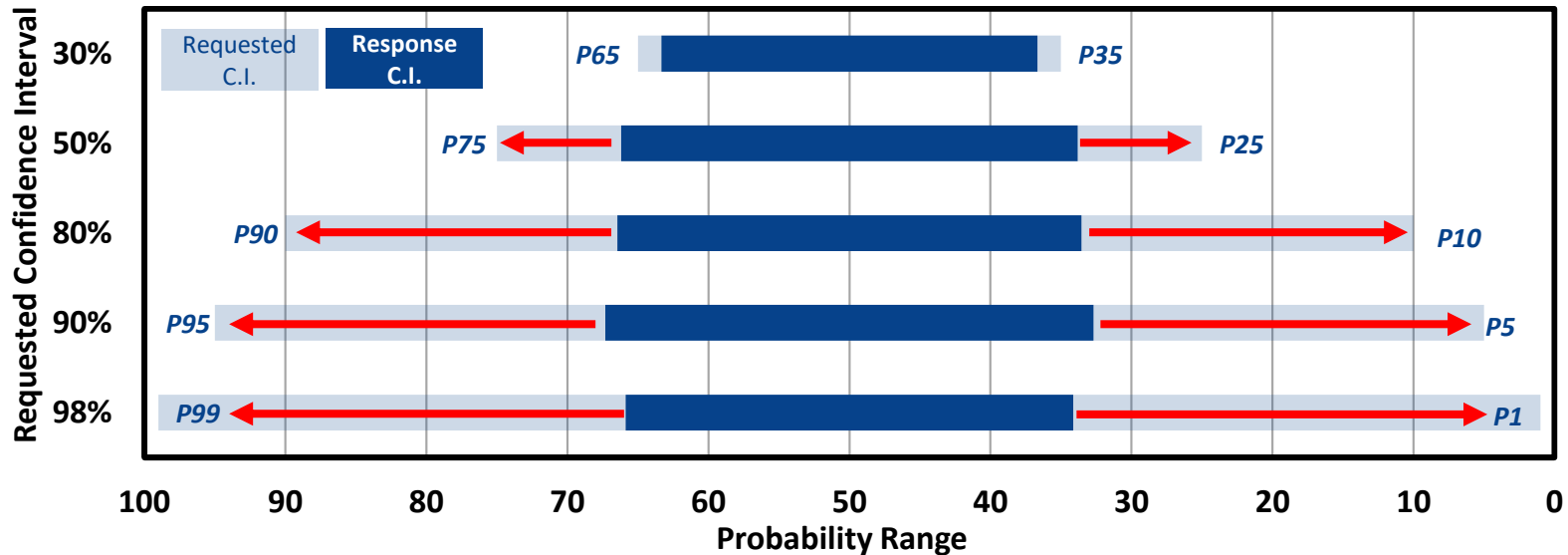


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Proposed Methods to Overcome Human Bias



Capen's Hypothesis: Estimators will miss an average 68 percent of the questions, no matter what probability ranges they are asked for (33% CI).

Proposed Methods to Overcome Human Bias

The Value of Feedback: Capen Monthly Uncertainty Quiz

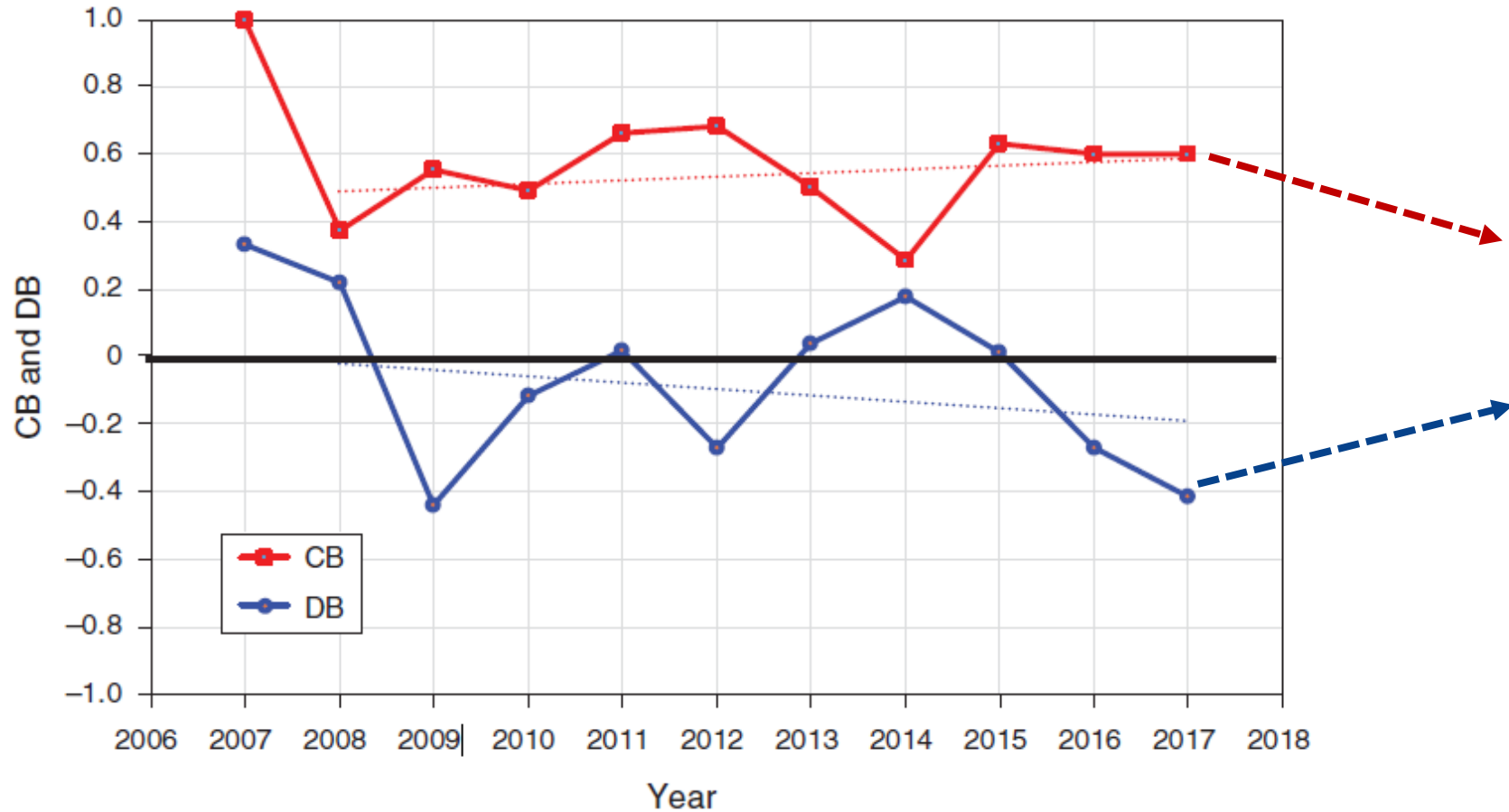
- ❑ We need feedback to overcome our biases.
- ❑ Feedback Improves Reserves Estimation
 - New Orleans SPE
 - Stanford Research Institute (SRI)
 - [Some] Meteorologists Are Least Bias
- ❑ Capen's Proposed Monthly Training Program
 - Make prediction about the future.
 - Assign probabilities to your predictions.
 - Religiously check your results.



Modified from Capen. E. C. 1976.

Proposed Methods to Overcome Human Bias

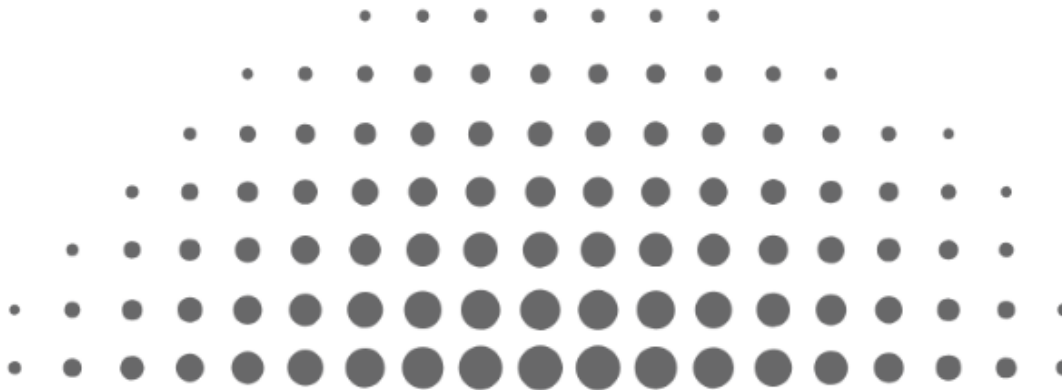
The Value of Feedback: Tracking Confidence/Directional Bias Over Time



$$\text{Confidenc Bias (CB)} = 1 - m \quad \text{Directional Bias (DB)} = 1 - \frac{2a}{1 - m}$$

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PECD Survey Results

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2. How many motor vehicles were registered in California in 2022?

3. What is the air distance from San Francisco to Hong Kong in miles?

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5. What was the census estimate of U.S. population in 1900?

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6. What is the span length of the Golden Gate Bridge in feet?

7. What is the area of Canada in square miles?

8. How long is the Amazon River in miles?

9. How many earth years does it take the planet Pluto to revolve around the sun?

10. The English epic poem "Beowulf" was composed in what year?

PECD Survey Results

Comparison to Capen 1976 Study Results

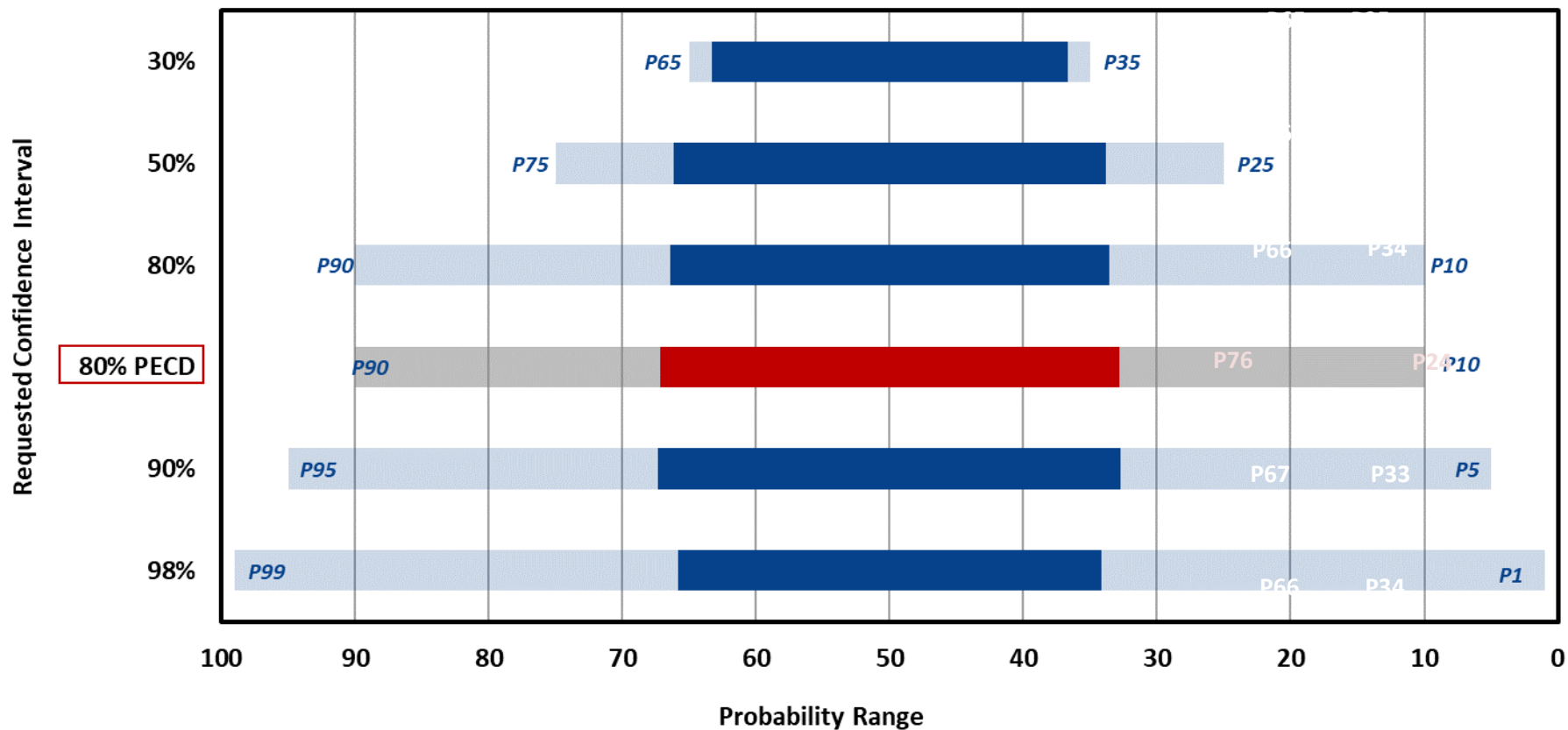
| Requested Confidence Interval | SPE-AIME Section | Response Count | Expected # of Misses | Actual Avg # of Misses | Implied Confidence Interval | Implied Probabilistic Range |
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| | Denver | 129 | 2 | 6.46 | 35% | P32 to P68 |
| | Cody | 42 | 2 | 7.31 | 27% | P37 to P63 |
| | Dallas PECD 2023 | 31 | 2 | 6.56 | 34% | P33 to P67 |
| 50% (P25 to P75) | Columbus | 27 | 5 | 6.96 | 30% | P35 to P65 |
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| | Chicago | 41 | 5 | 6.54 | 35% | P33 to P67 |
| | Tulsa | 53 | 5 | 6.79 | 32% | P34 to P66 |
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Modified from Capen. E. C. 1976.



PECD Survey Results

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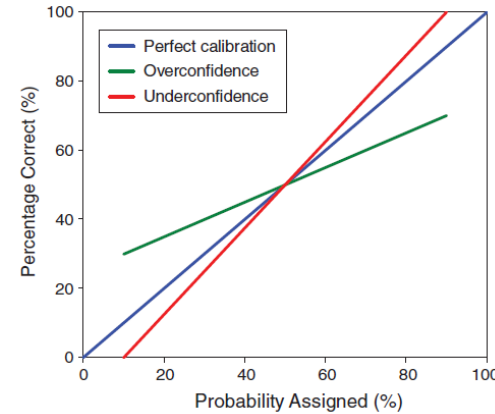
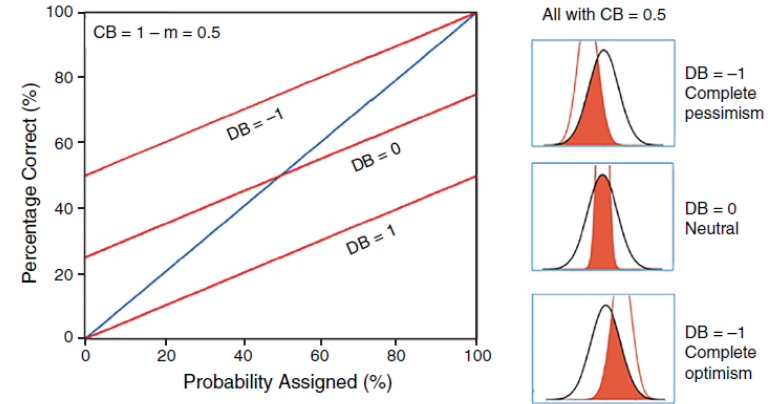
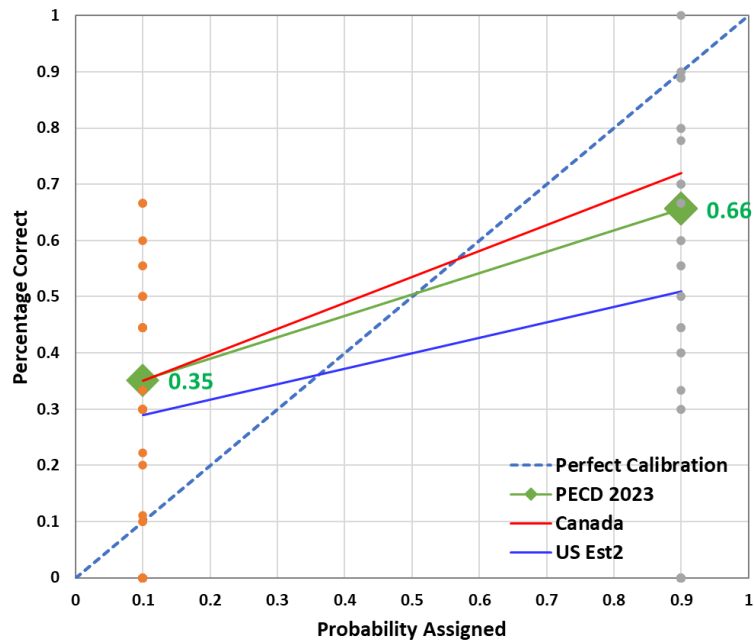


Modified from Capen, E. C. 1976.



PECD Survey Results

Reserves Calibration Plots



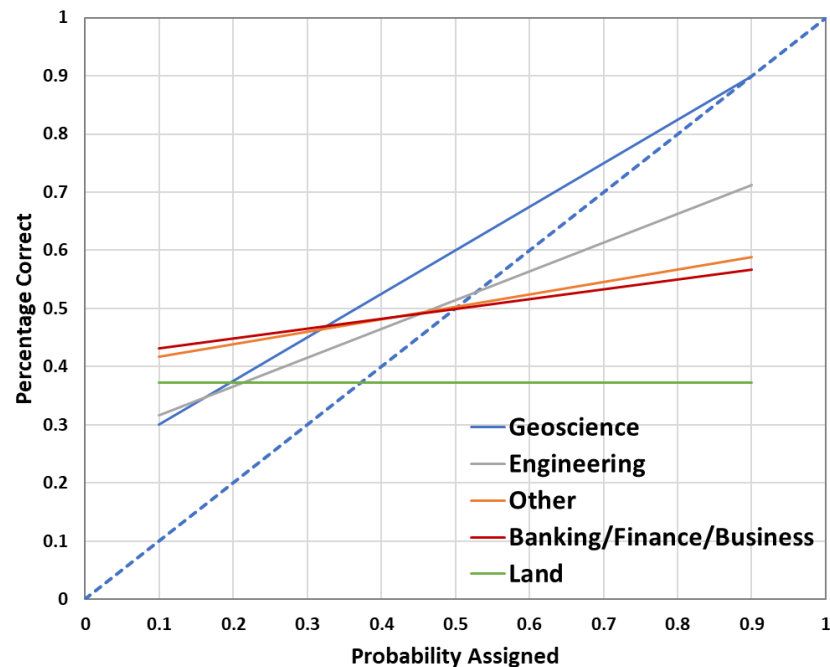
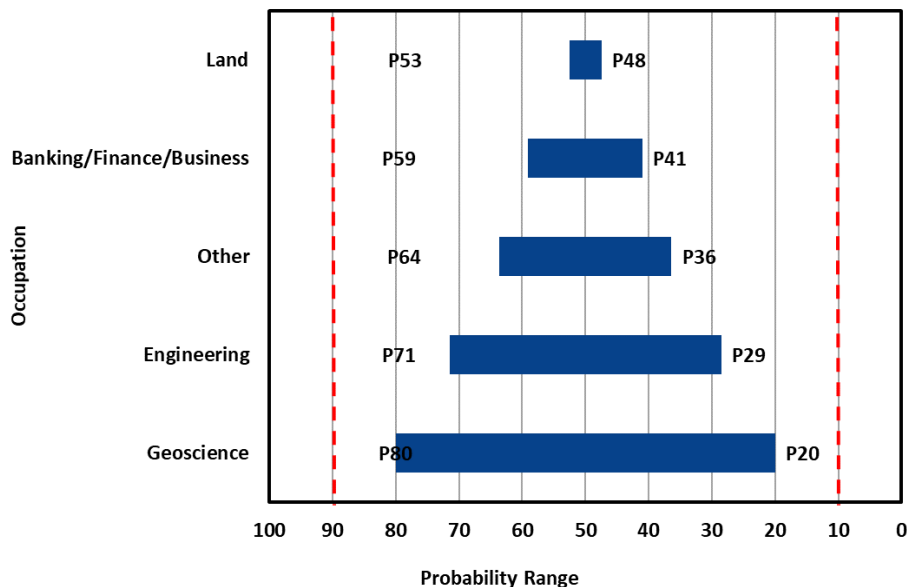
| | PECD 2023 | Canada | USA Est2 |
|--------------------------|-----------|--------|----------|
| Avg. Actual # of Misses | 6.6 | - | - |
| Avg. P90 # of Misses | 3.4 | - | - |
| Avg. P10 # of Misses | 3.5 | - | - |
| Avg. Implied CI (vs 80%) | 34% | 37% | 46% |
| Avg. Confidence Bias | 0.62 | 0.56 | 0.43 |
| Avg. Directional Bias | -0.11 | -0.14 | -0.28 |

Modified from Gomez Et. Al., 2020



PECD Survey Results

Summary by Occupation



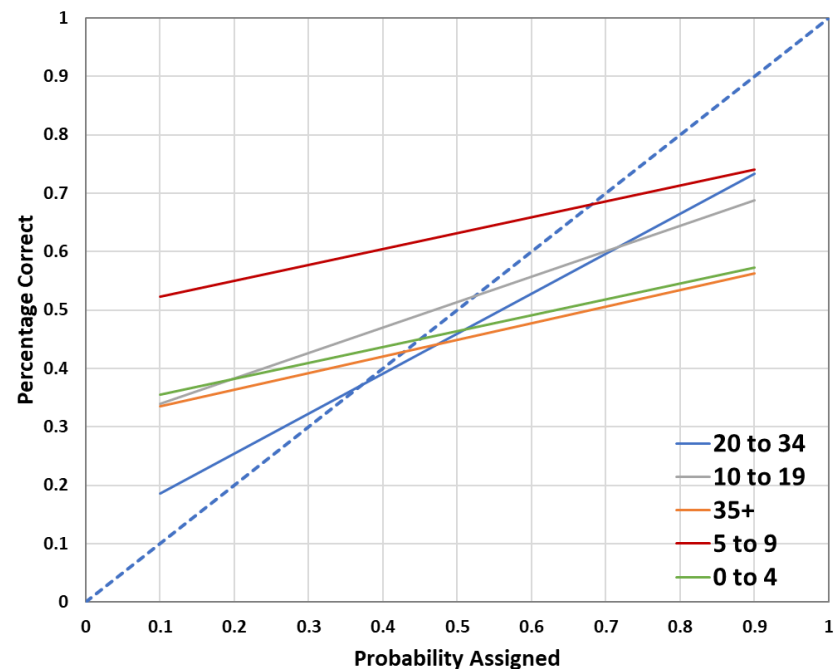
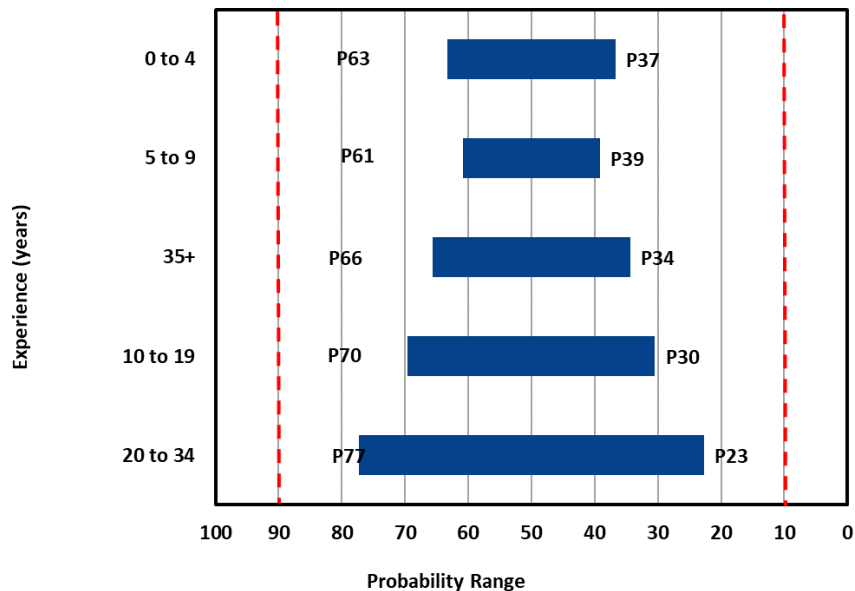
| Rank | Occupation | Responses | Avg # of Misses | Avg # of P90 Misses | Avg # of P10 Misses | Avg Implied CI | Avg Confidence Bias | Avg Directional Bias |
|------|--------------------------|-----------|-----------------|---------------------|---------------------|----------------|---------------------|----------------------|
| 1 | Geoscience | 1 | 4.0 | 1.0 | 3.0 | 0.60 | 0.25 | -0.80 |
| 2 | Engineering | 19 | 5.7 | 2.9 | 3.2 | 0.43 | 0.50 | -0.15 |
| 3 | Other | 2 | 7.3 | 4.1 | 4.2 | 0.27 | 0.78 | -0.08 |
| 4 | Banking/Finance/Business | 8 | 8.2 | 4.3 | 4.3 | 0.18 | 0.83 | -0.02 |
| 5 | Land | 2 | 9.5 | 6.3 | 3.7 | 0.05 | 1.00 | 0.26 |
| | Grand Total | 32 | 6.6 | 3.5 | 3.5 | 0.34 | 0.63 | -0.11 |

Modified from Capen. E. C. 1976 & Gomez Et. Al., 2020



PECD Survey Results

Summary by Experience



| Rank | Experience | Responses | Avg # of Misses | Avg # of P90 Misses | Avg # of P10 Misses | Avg Implied CI | Avg Confidence Bias | Avg Directional Bias |
|------|--------------------|-----------|-----------------|---------------------|---------------------|----------------|---------------------|----------------------|
| 1 | 20 to 34 | 4 | 4.5 | 2.7 | 1.9 | 0.55 | 0.32 | -0.09 |
| 2 | 10 to 19 | 10 | 6.1 | 3.1 | 3.4 | 0.39 | 0.57 | -0.09 |
| 3 | 35+ | 6 | 6.9 | 4.4 | 3.4 | 0.31 | 0.72 | -0.08 |
| 4 | 5 to 9 | 5 | 7.8 | 2.6 | 5.2 | 0.22 | 0.73 | -0.41 |
| 5 | 0 to 4 | 7 | 7.3 | 4.3 | 3.6 | 0.27 | 0.73 | 0.07 |
| | Grand Total | 32 | 6.6 | 3.5 | 3.5 | 0.34 | 0.62 | -0.11 |

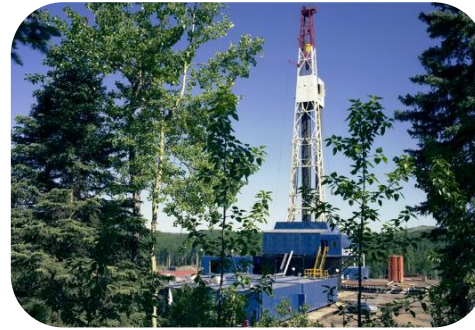
Modified from Capen. E. C. 1976 & Gomez Et. Al., 2020



Why Do We Miss Reserves Estimates?



Poor Estimating Practices



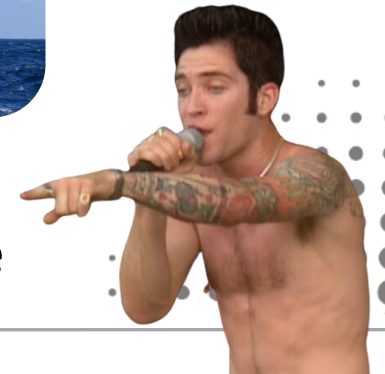
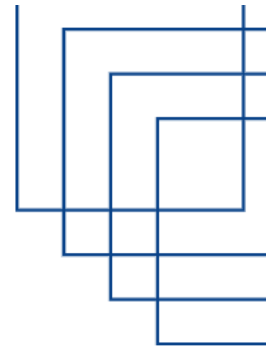
Misguided Incentives



Lack of Professionalism



Human Bias/
Overconfidence



Our Petroleum Advisory Services Include:



Acquisitions /
Divestitures Due
Diligence



Reserves Report



Oil & Gas Supply
Studies



Restructuring Services



Expert Witness
Testimony

Reputation

VSO's reputation is trusted industry-wide by both technical and financial professionals. Every VSO report adheres to the highest standards of technical excellence and reliability.

Attention

We are very responsive to clients and place a high degree of focus on each project. We put in extra effort to be highly attentive and creative for our clients, and to ensure every report relies upon a technically supportable evaluation.

Transparency

All readers of our reports and materials obtain great clarity into our analysis and key asset value drivers. Consumers of our differentiated reports and supporting documentation aren't left guessing; our analysis is transparent and thorough.



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Appendix

My Own Worst Enemy – Taming Reserves Overconfidence

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Proposed Methods to Overcome Human Bias

Capen Compensation Methodology

- Capen's Hypothesis: Estimators will miss an average 68 percent of the questions, no matter what probability ranges they are asked for (33% CI).
- Methodology proposed by Capen to compensate for this phenomenon:
 - Plot your best guess P10 & P90 at the P30 & P70 mark, respectively on a probit plot (blue circles).
 - Assumes your best guess is only a 40% C.I. per survey results instead of an 80% C.I. required for a true P10 & P90.
 - Draw a straight line through you plotted points.
 - Extrapolate to find the bias-compensated P10 & P90 (red stars)

