Exploration Program Evaluation at ARCO International - A Case Study in Techniques and Pitfalls

Bath Conference

May 2001

Outline

Measuring exploration success
AIOGC exploration evaluation methods
AIOGC results
- *Geologic and Economic Chance Factors*
- *Reserves Estimation*

Performance Reporting pitfalls
- *Post-discovery reserves uncertainty*

Project economic evaluation issues
- *Drilling Cost Estimation*
- *Country Risk and other evaluation pitfalls*

Early portfolio management issues
- *Risk-Adjusted Value pitfalls*

Concluding observations

Program evaluation involves quantifying risk and reward, reconciling outcomes with predictions, monitoring overall performance against goals

Evaluating individual opportunities

*EPW = PWs*ECF – PWf*(1-ECF)*

*EPW = PWd*ECF – PWx*

- *Minimum criterion is EPW > 0*
- *Under capital constraints, use additional criteria (IE, etc)*
- *Note that reward combines reserves and unit value*

"Finding oil is easy, it's making money that's difficult"
– Marlan Downey, former President, AIOGC, on numerous occasions

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Program success

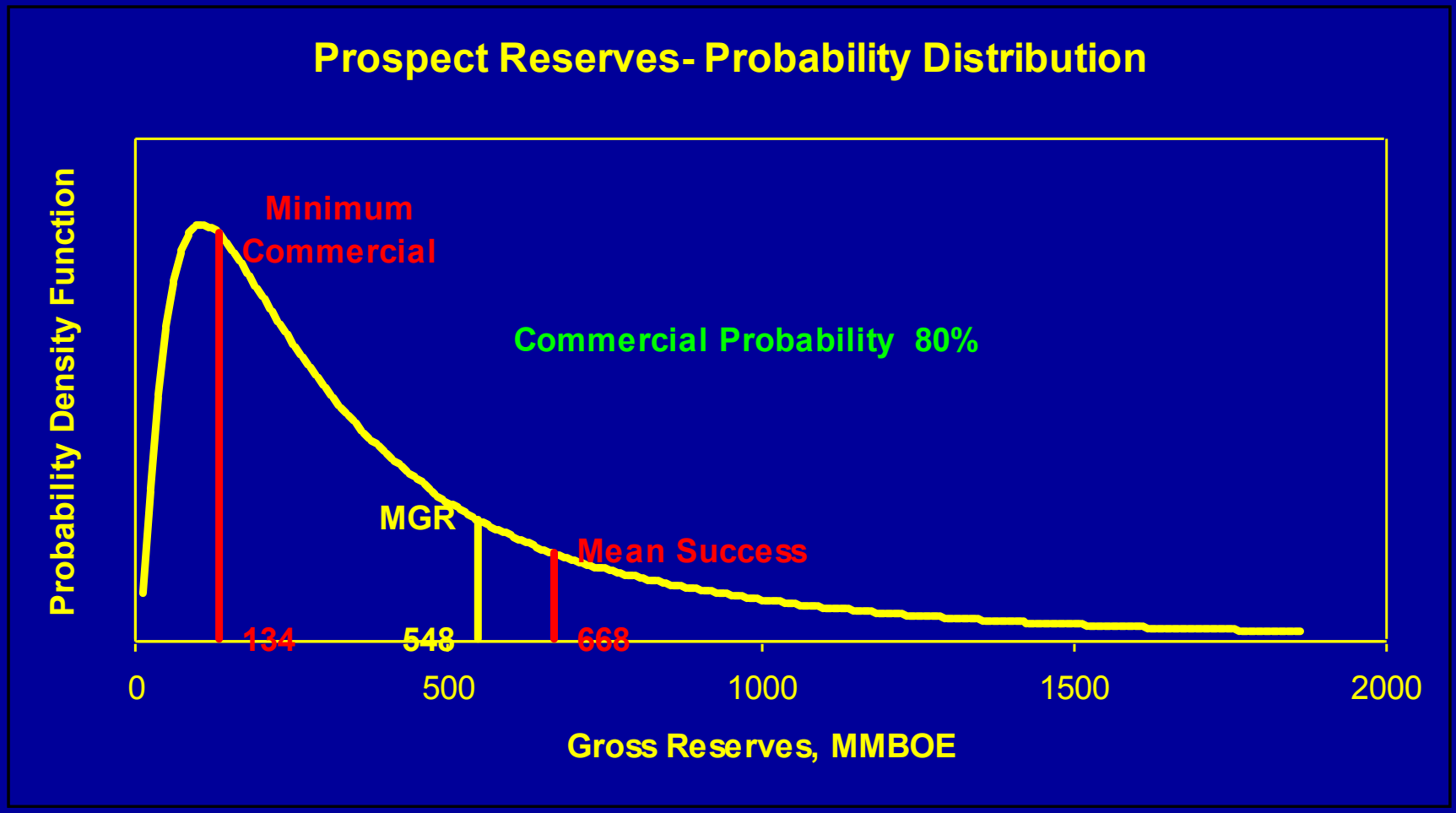
$\Sigma PWd > \Sigma PWx$

$\Sigma PWd / Q > \Sigma PWx / Q$

(Unit value of reserves found > finding cost)

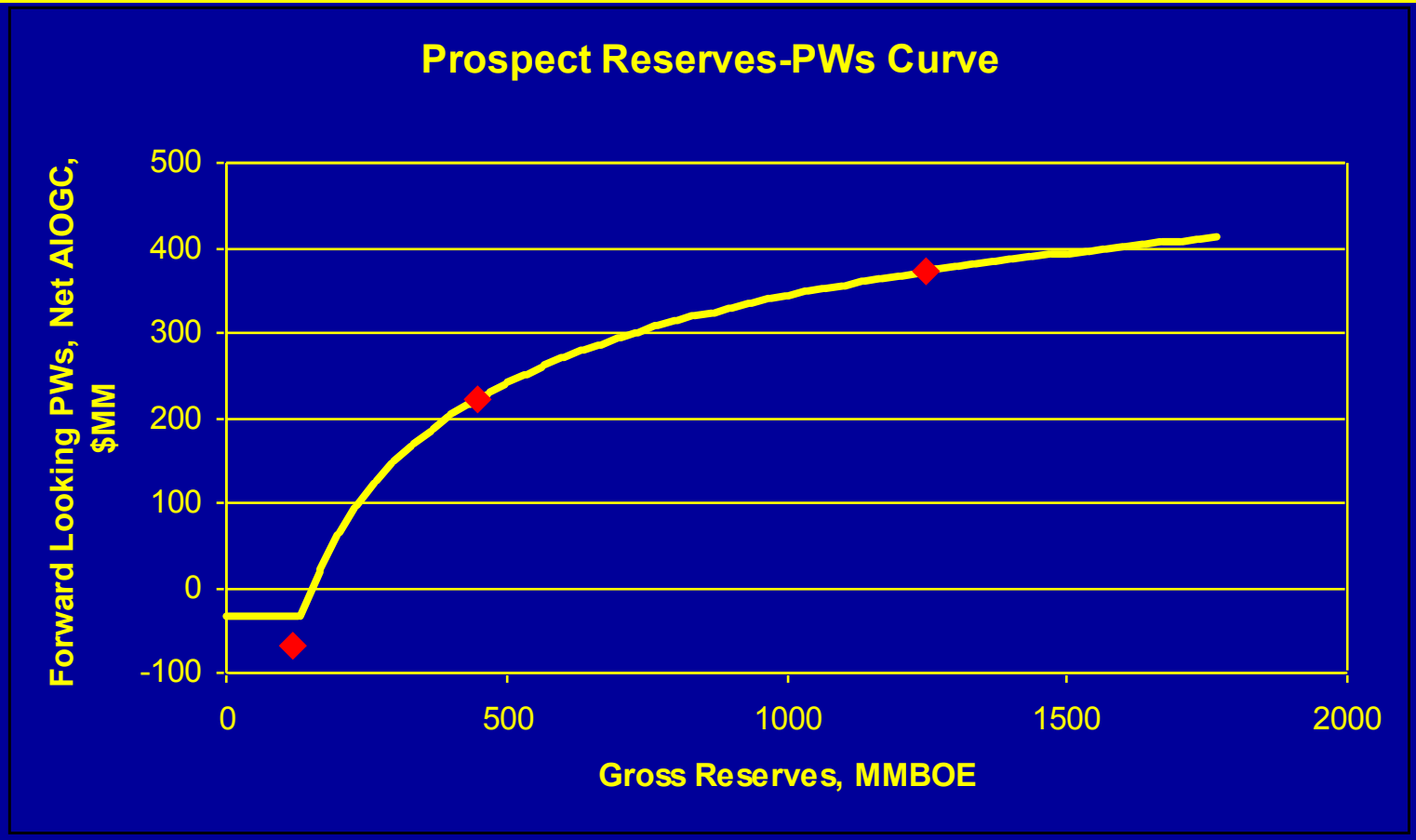
- *Need quantitative goals to measure success*
- *Reserves additions, finding costs*
- *Rate of return, financial targets (income impact, etc)*

ARCO used the two-step approach to deriving an economic chance of success, after evaluating the probability distribution of reserves



Economic Chance Factor = Geologic Chance Factor X Commercial Probability

A three-point curve fit of Upside, Best Estimate and Downside success cases was used to capture the non-linearity of most international projects

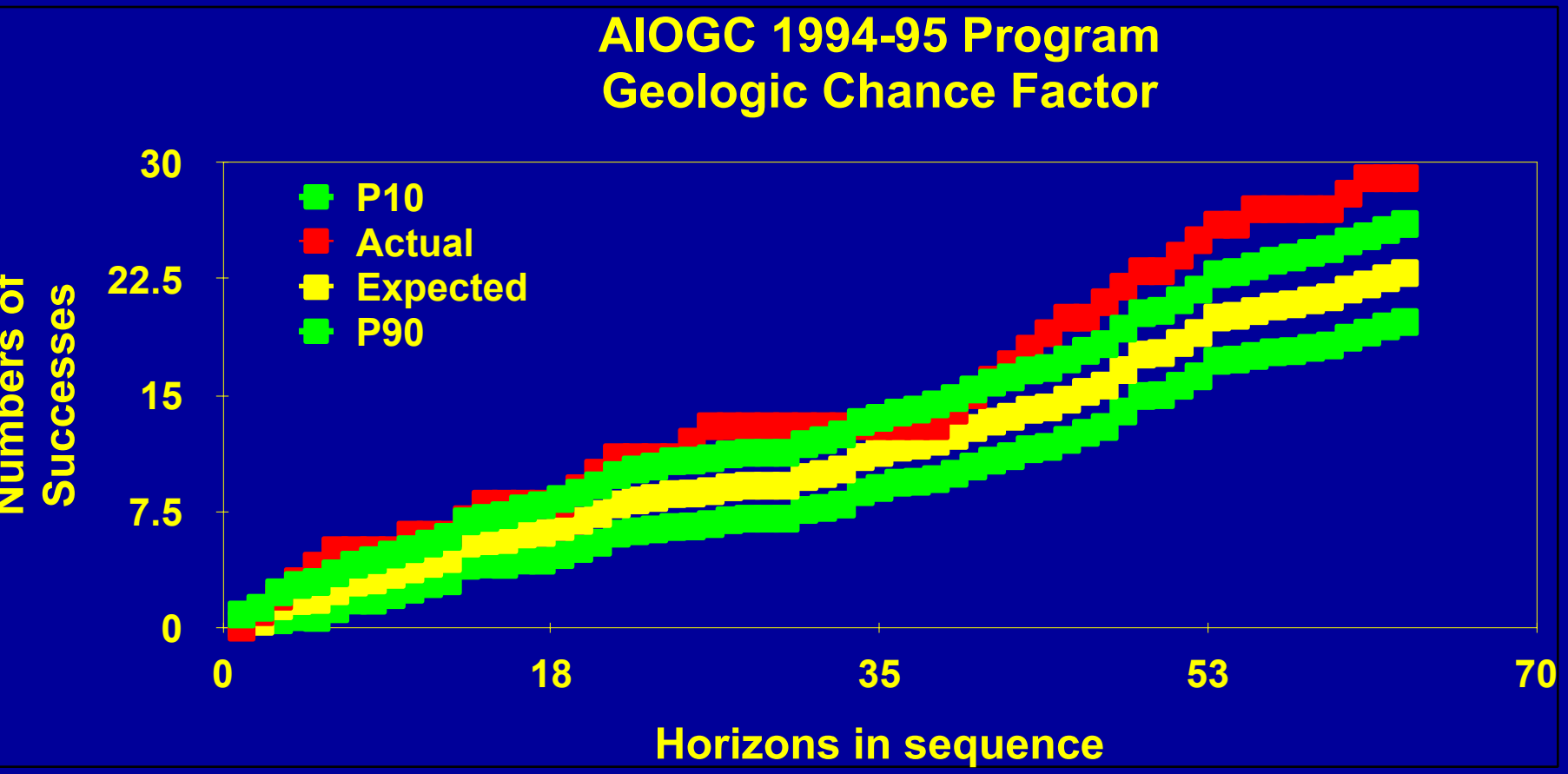


Functional form of fit is PWs = $AQ^k + B$, where Q is Reserves

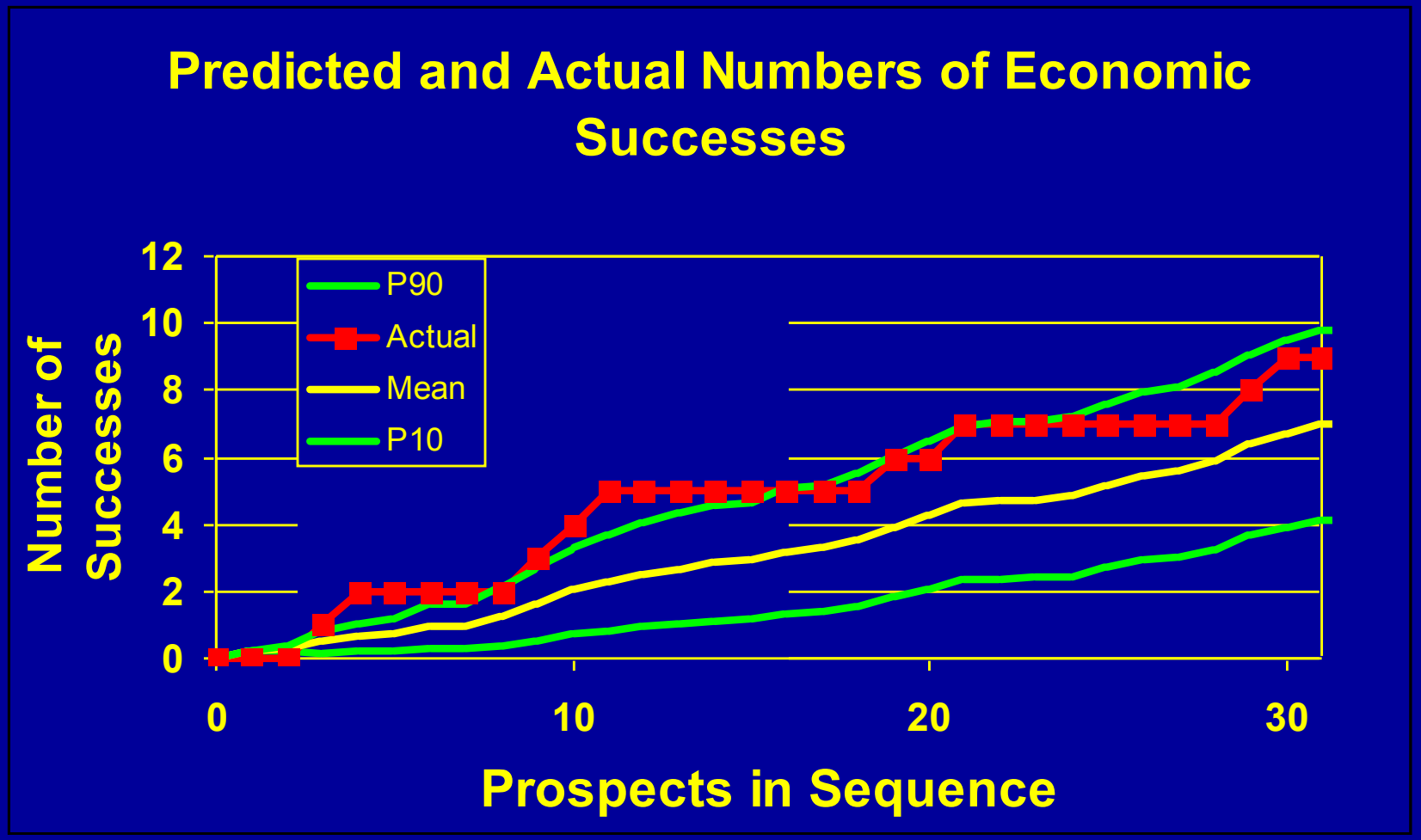
Minimum Commercial defined where PWd = 0, PWs = - PWf

Mean Success PW by combining curve with reserves distribution

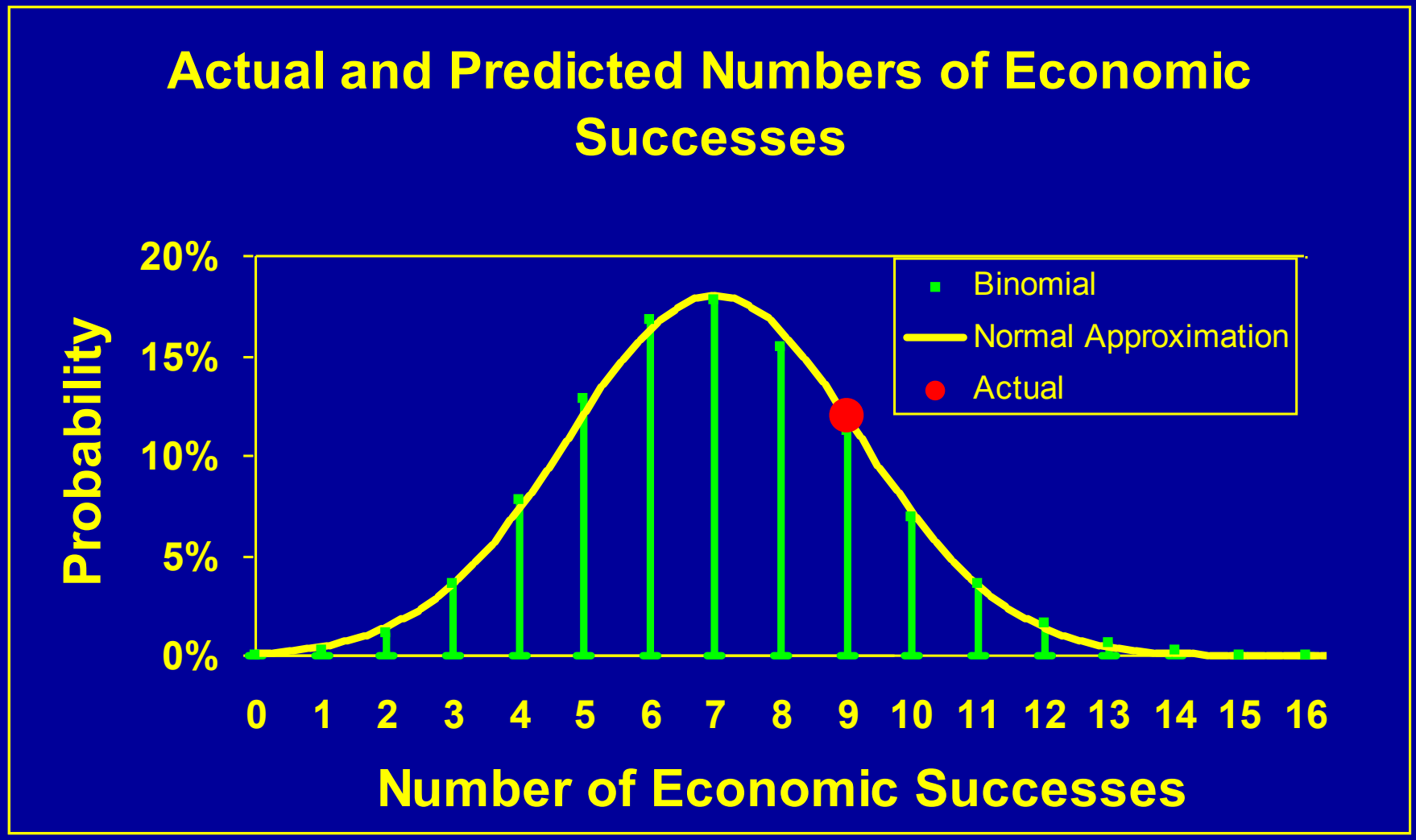
Geologic Chance Factors now show a tendency to underestimate the number of geological successes by horizon, especially in wildcat wells



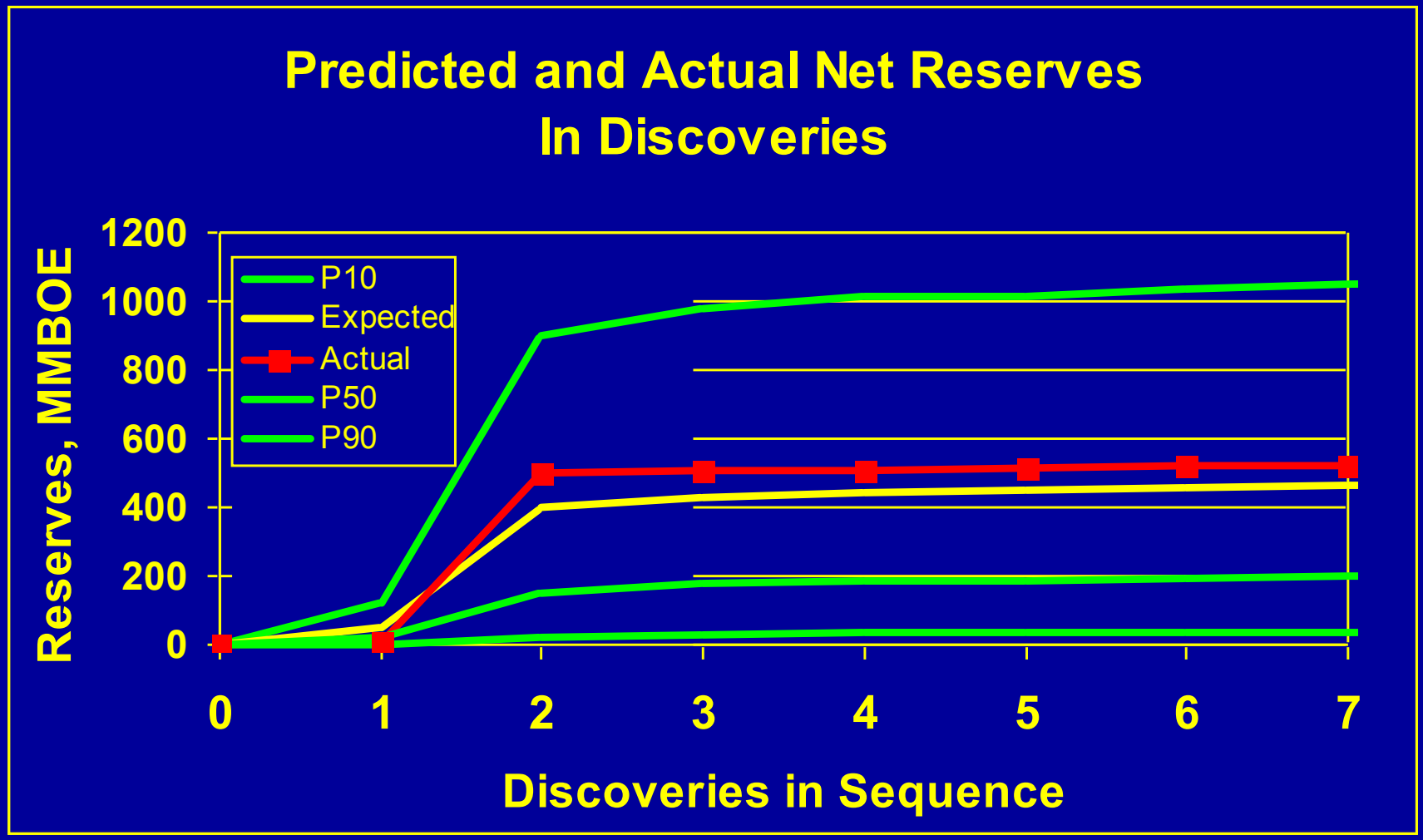
After combining horizons (incorporating dependency) and adjusting for commercial probability, Economic Chance Factors looked acceptable



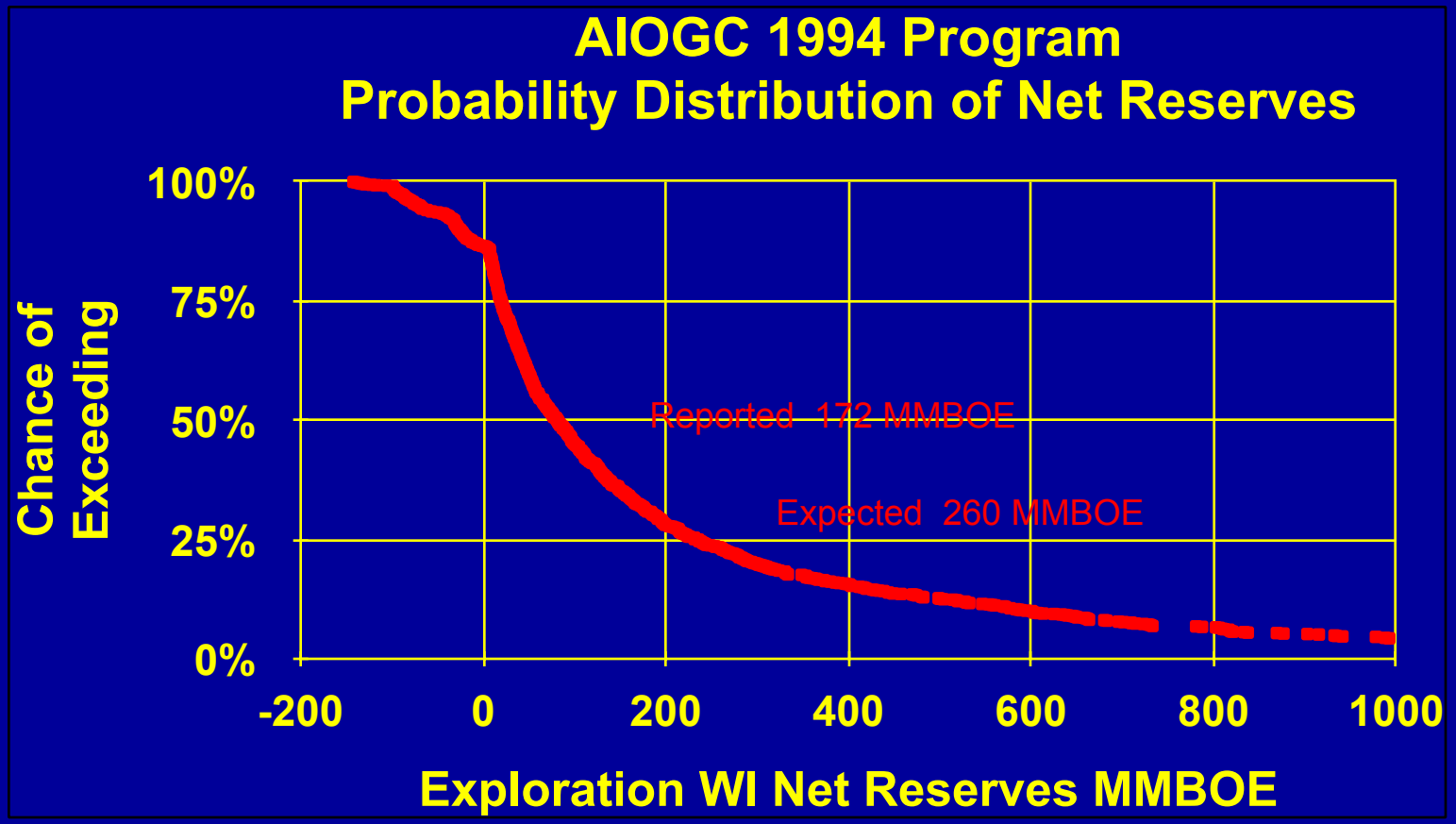
We can display the full range of possible numbers of successes; note that the normal approximation works well for portfolios this size or larger



Initial results also suggested an improvement in reserves prediction, although both predictions and results are dominated by one giant prospect



Pitfalls in assessing total program performance stem from the fallacy that reserves outcomes can be accurately assessed post-drill



Attempts to resolve this problem led to some interesting but inconclusive studies on a number of related issues

Reserves Uncertainty

- ***Improving understanding of volumetric uncertainty***
- ***Failure to incorporate multiple interpretations***

Reserves Growth

- ***Testing applicability of USGS results***

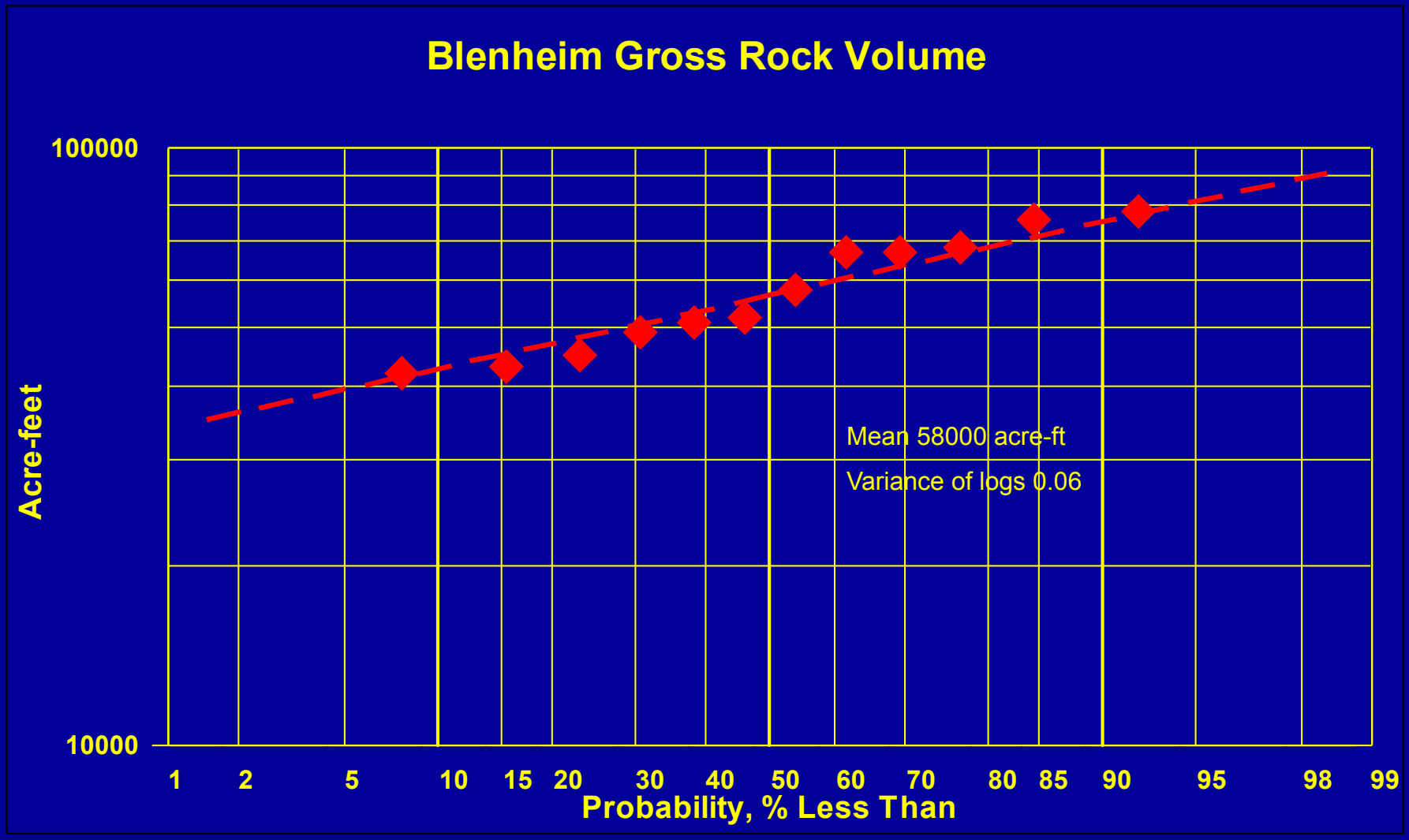
Reserves Definitions

- ***Relating probabilistic results to Proven and Potential***

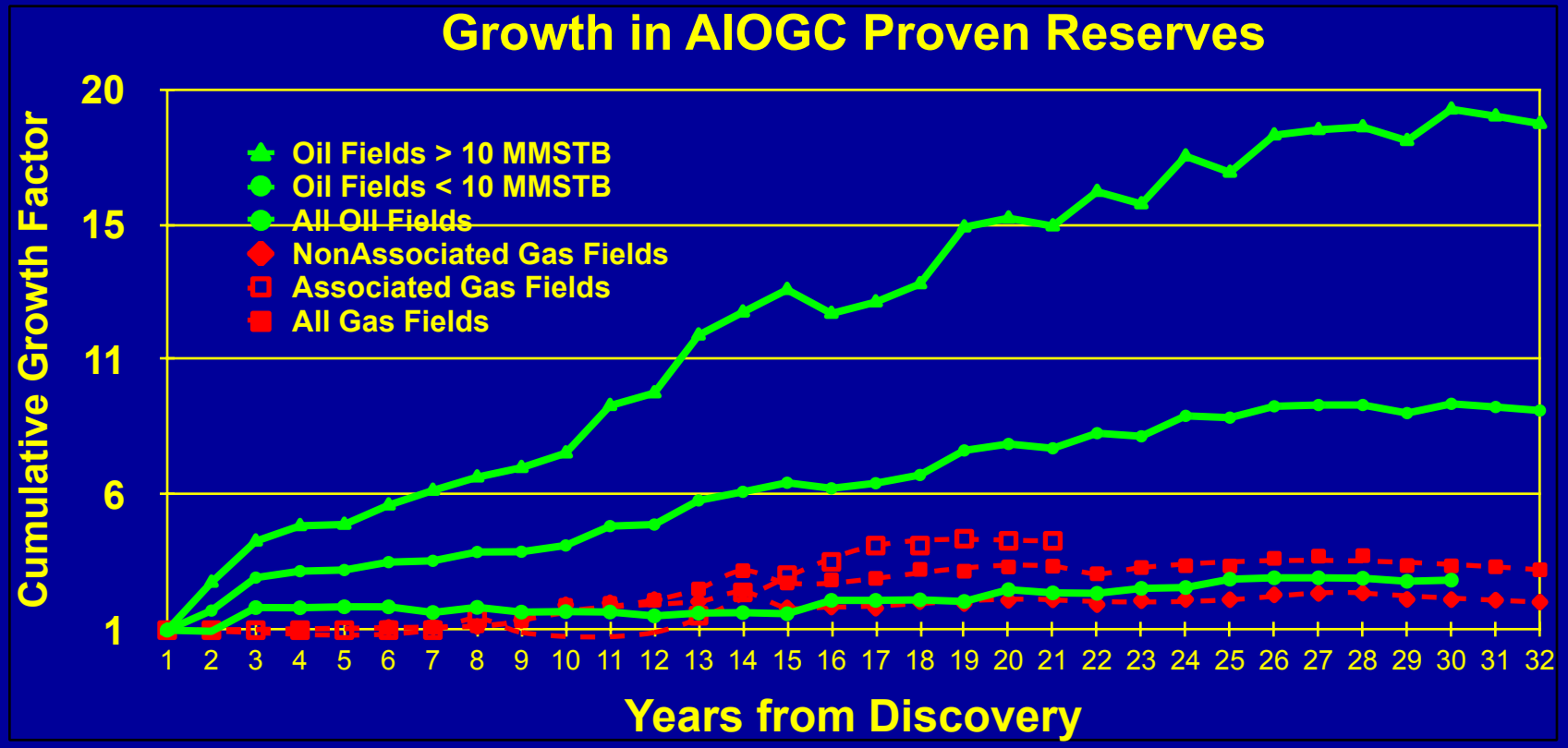
Alternative Performance Metrics

- ***Include reserves revisions from prior discoveries***
  - ***Attempts to incorporate growth***
  - ***Not adopted due to lack of focus on current program***

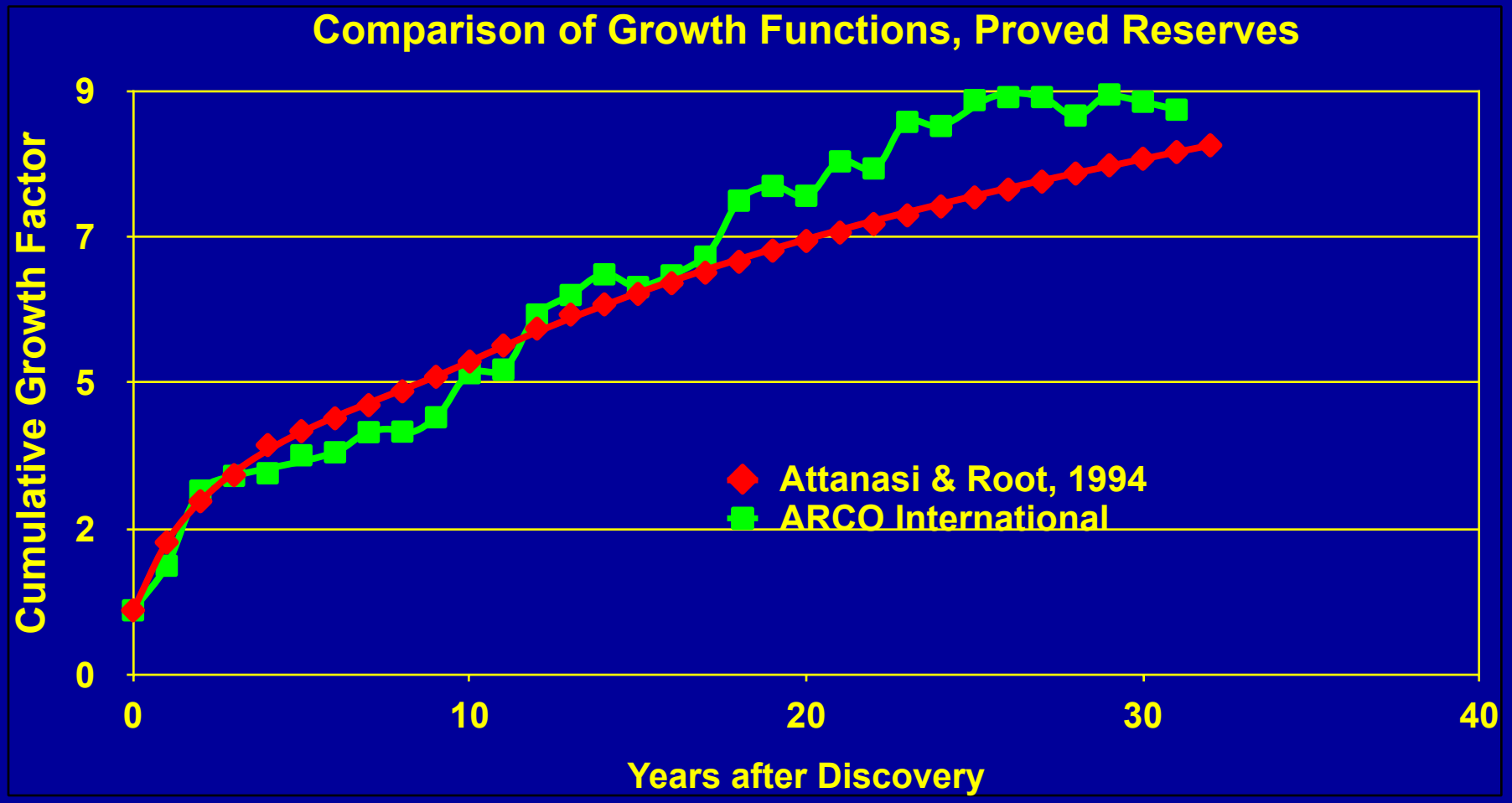
GRV from twelve interpretations in the two years prior to development sanction demonstrate the uncertainty in measuring undeveloped reserves



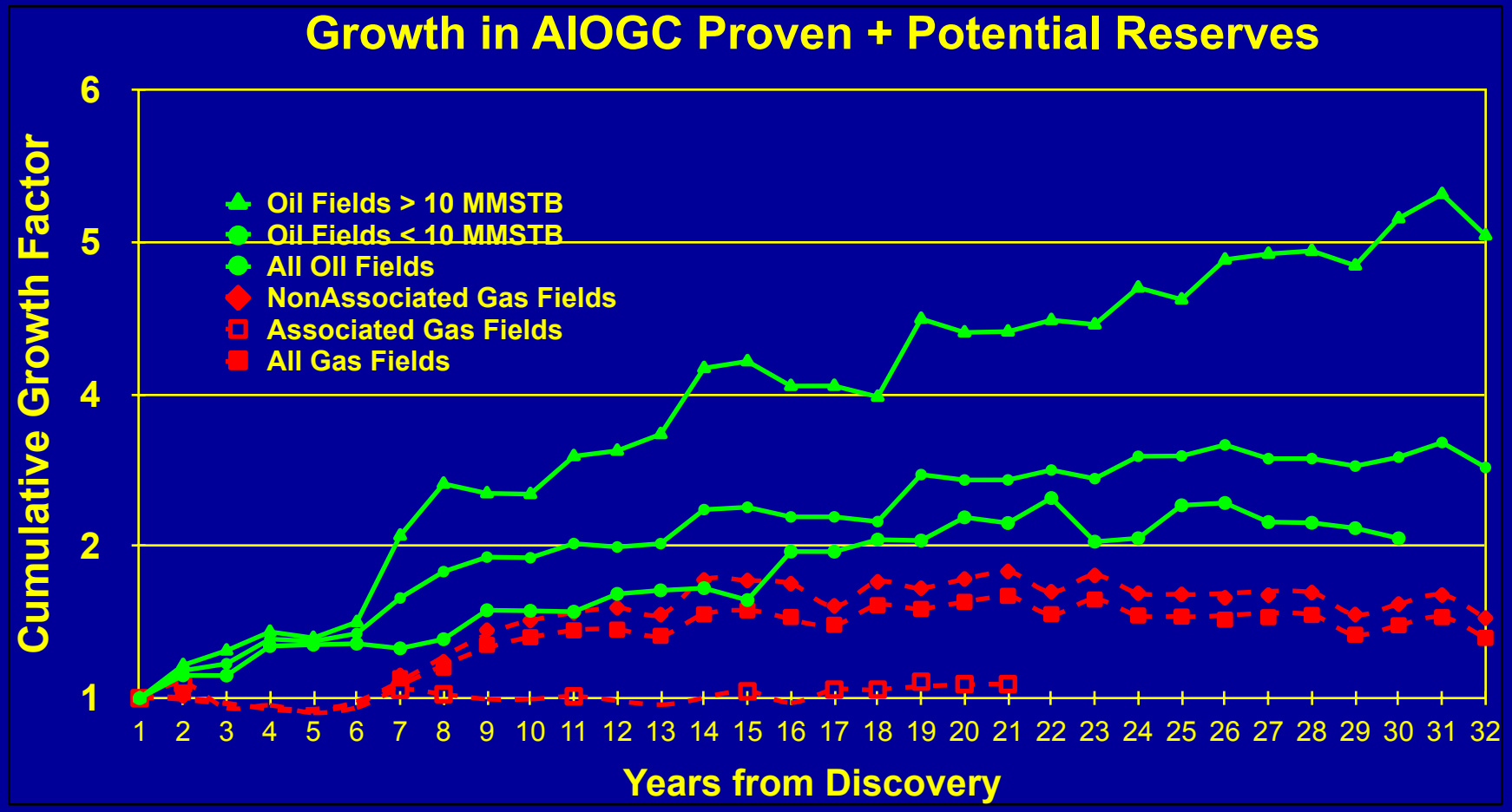
Reserves growth was quoted as evidence that exploration performance was being systematically under-stated; it appeared to be true for oil but not gas



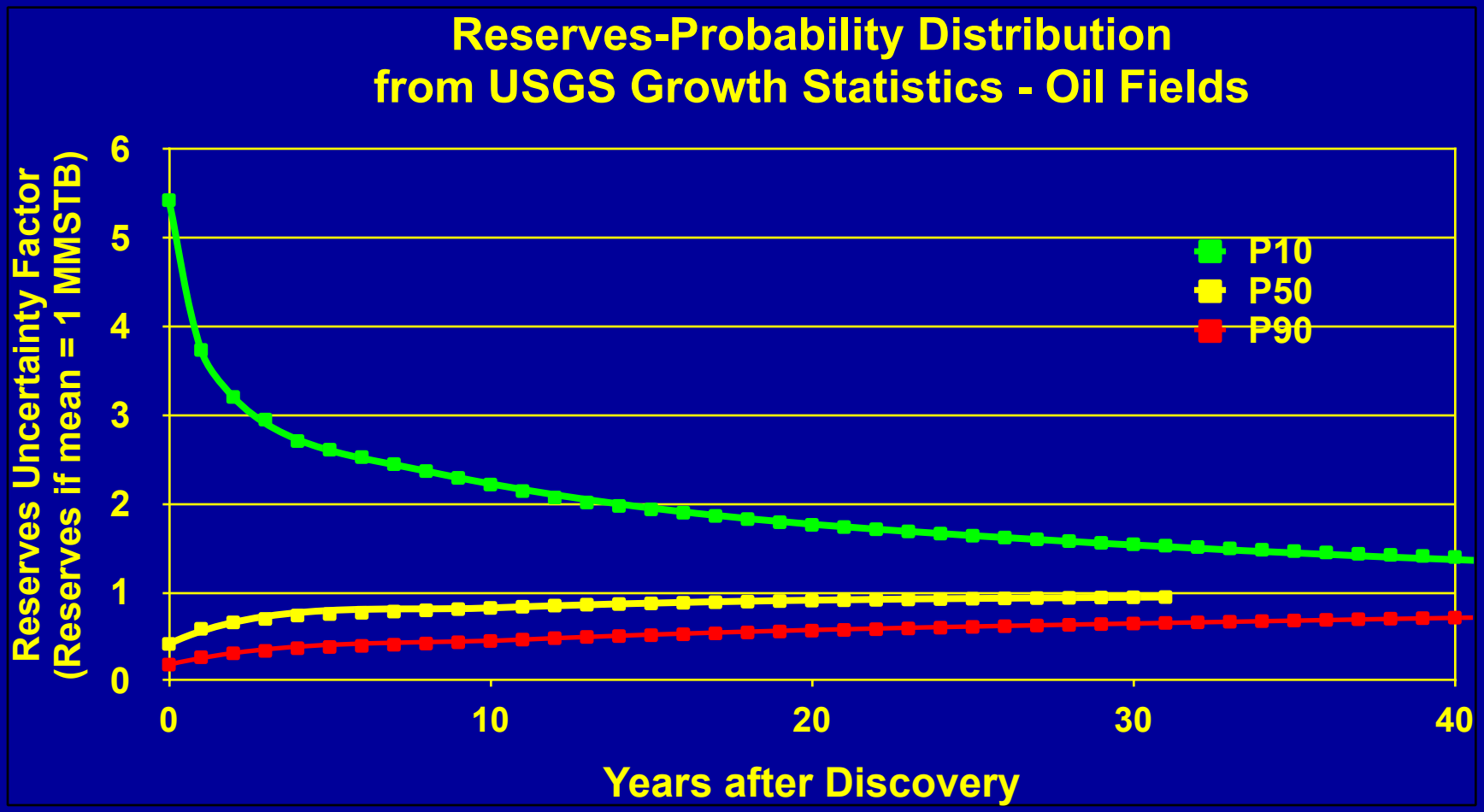
The results for Proved Reserves for All Oil Fields were strikingly similar to those published by the USGS, despite small sample sets beyond 20 years



This provided some comfort that the results for Proved + Potential Reserves were also valid. The apparent low growth for gas has not been fully explained.



If Proved and P90 Reserves are the same, the USGS curve can be used to derive an uncertainty distribution through time for fixed mean reserves



Despite meeting goals for Reserves Added and Finding Costs, concerns remained over financial performance

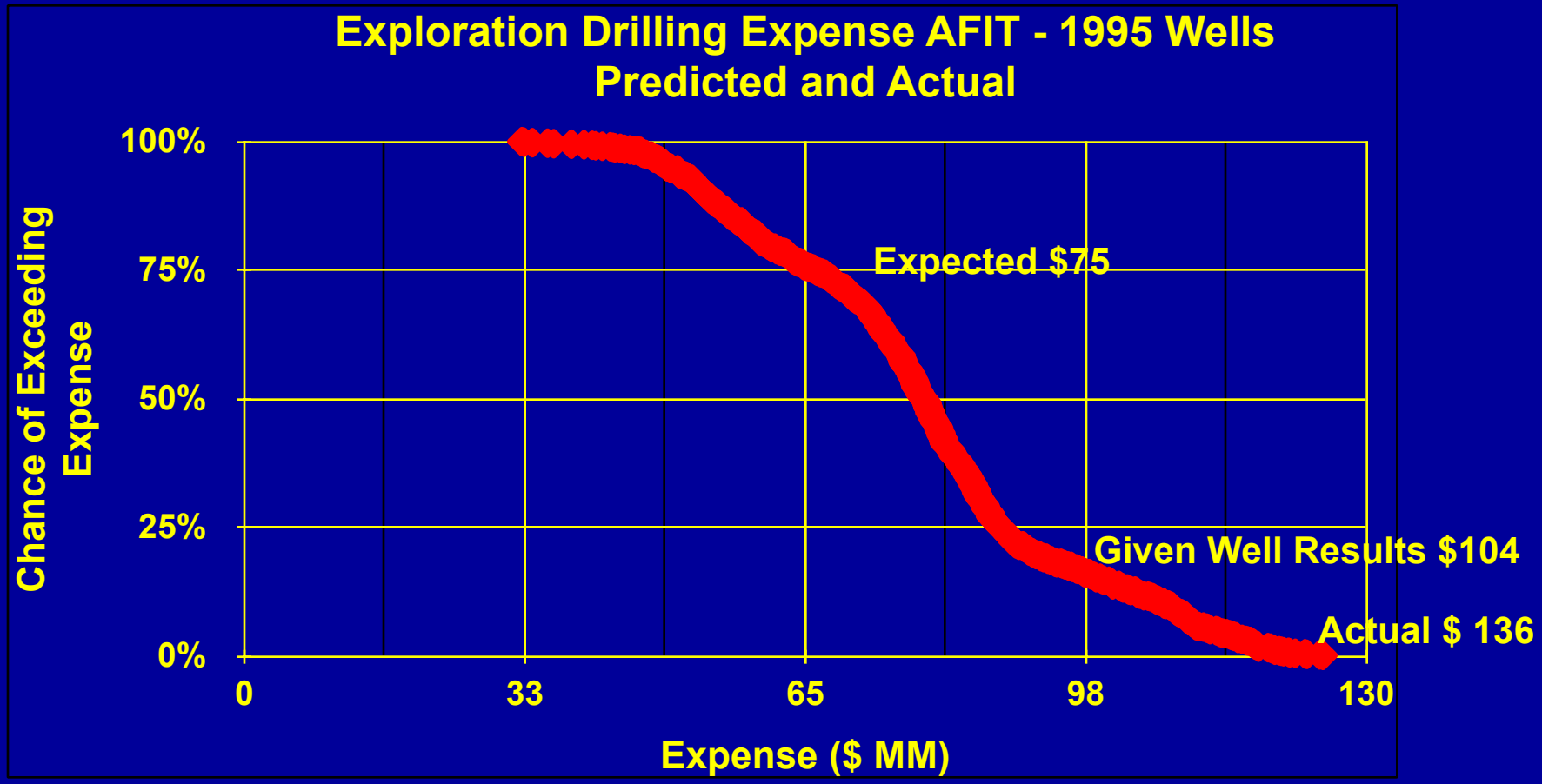
Exploration Expense too high given actual success rates

- ***Focused attention on drilling cost estimation***

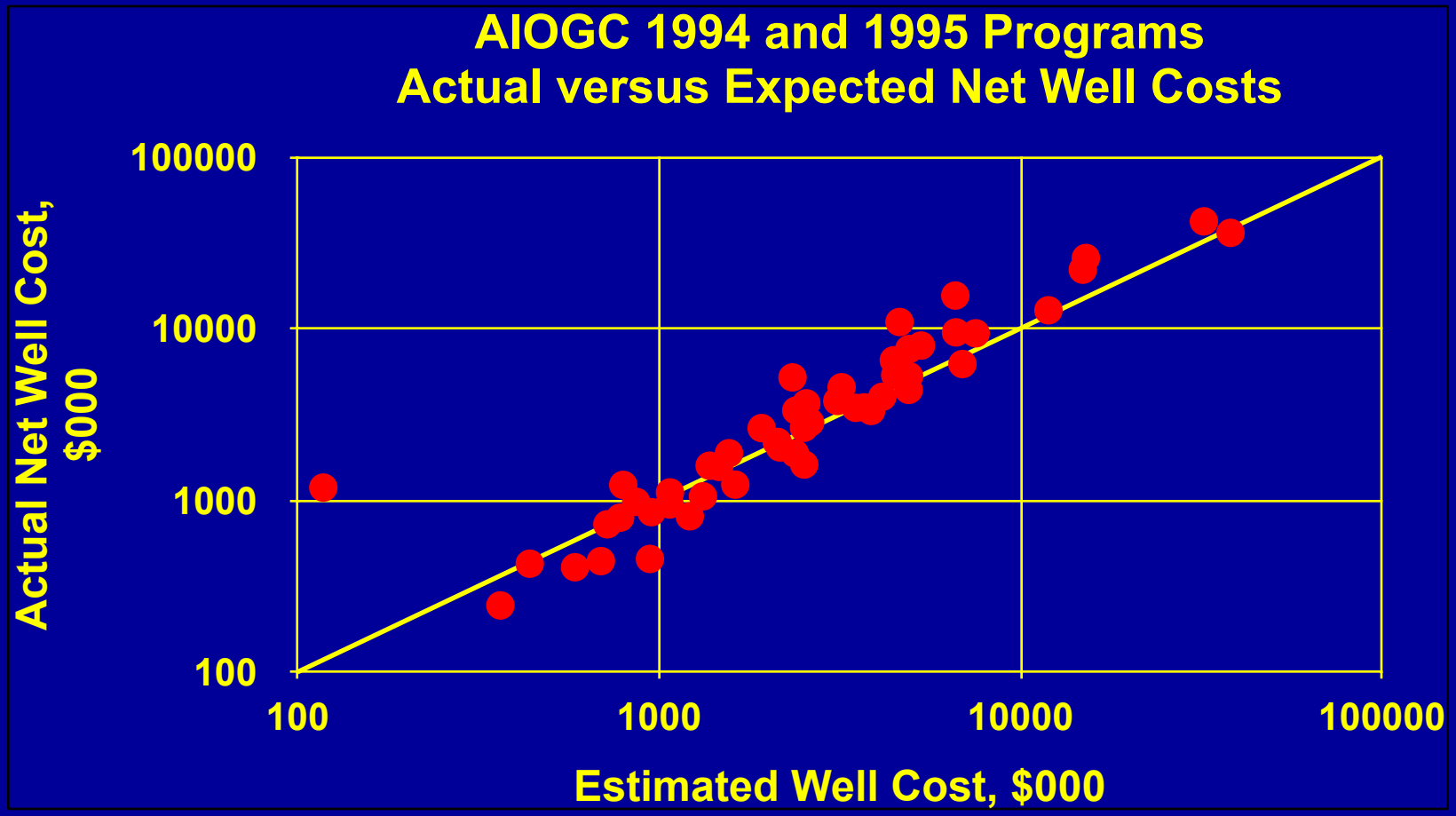
Rate of Return study results inconsistent with evaluations

- ***Erosion of value between pre-drill and post-drill evaluations***
- ***Project delays ("country risk")***

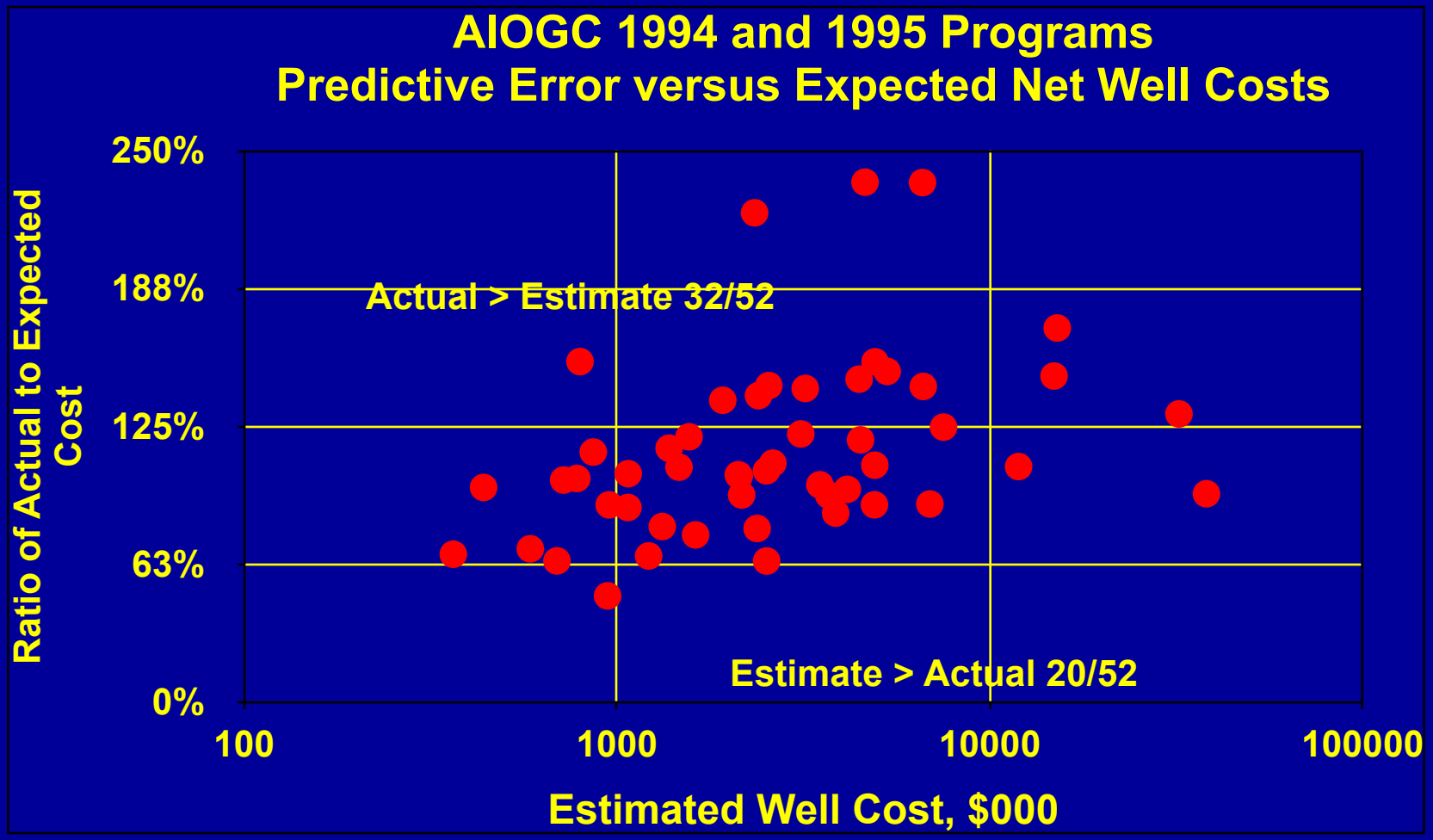
Dry Hole Expense is uncertain even when drill costs are known; significant inaccuracy in predicting drilling cost can lead to nasty surprises



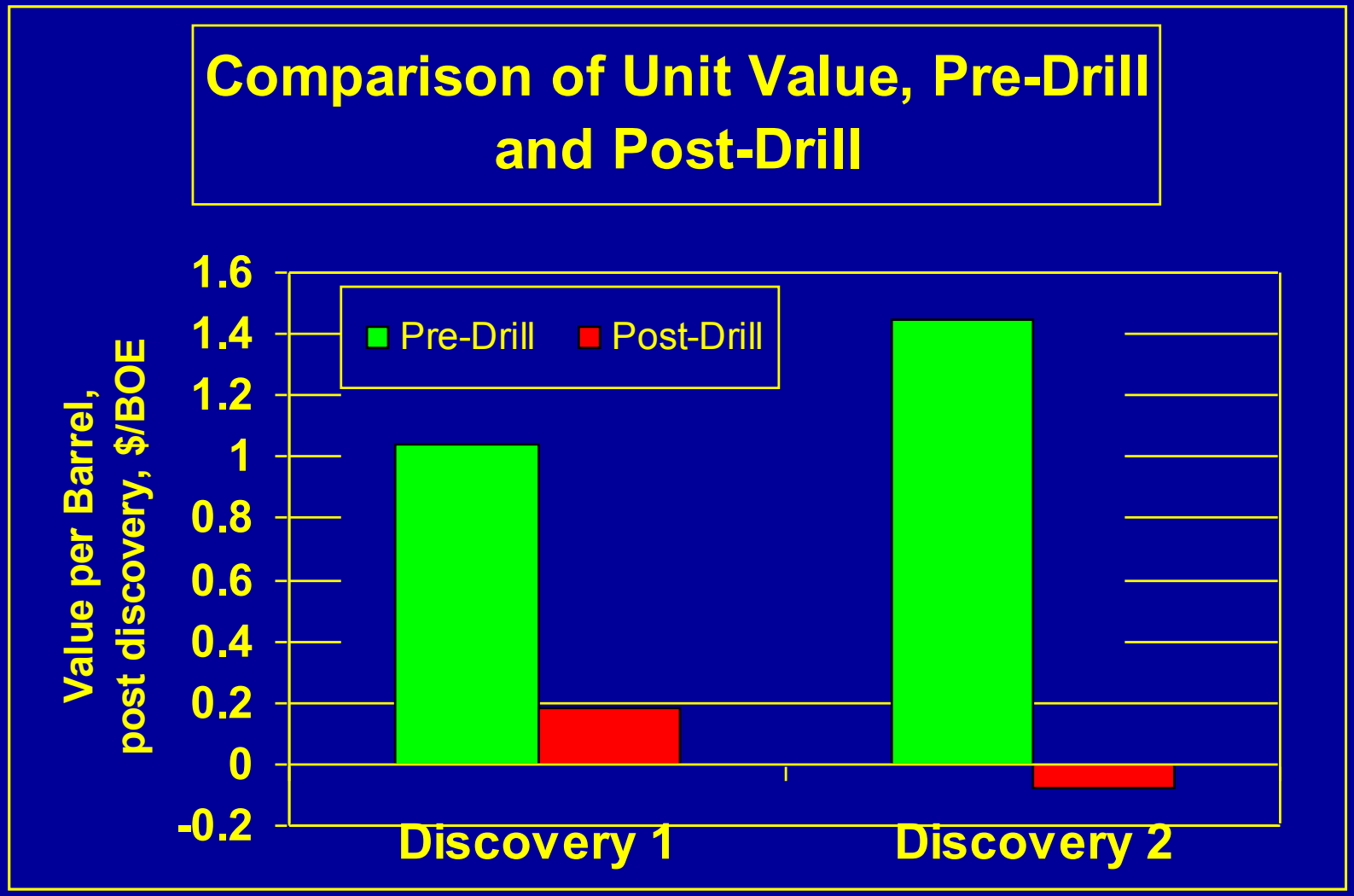
At first glance, accuracy looks O.K., with a tendency to overestimate low cost wells and underestimate high cost wells ….



… more detailed analysis confirmed significant bias. Work process re-design, and a more rigorous approach to uncertainty, followed in 1996-97



For two major discoveries, the loss of value between the pre-drill and post-drill evaluations for the reserves' size discovered is significant



Global competitor analysis confirmed that international projects typically take longer than best practice (Gulf of Mexico benchmark)

Case Studies from AIOGC and competitors identified specific, quantifiable delays due to different issues

- *Commercial*
- *Political*
- *Logistical*
- *Bureaucratic*

collectively termed "Country Risk"

Different approaches were considered to incorporate country risk; this raised awareness but was not implemented rigorously

Higher hurdle rates

- *Theoretically unsound*
- *Dangerous (favors particular types of projects)*
- *Over-rides investment efficiency yardsticks*

Risk-weighted cash flows

- *Theoretically sound*
- *Difficult to quantify*

Incorporating a distribution of delays

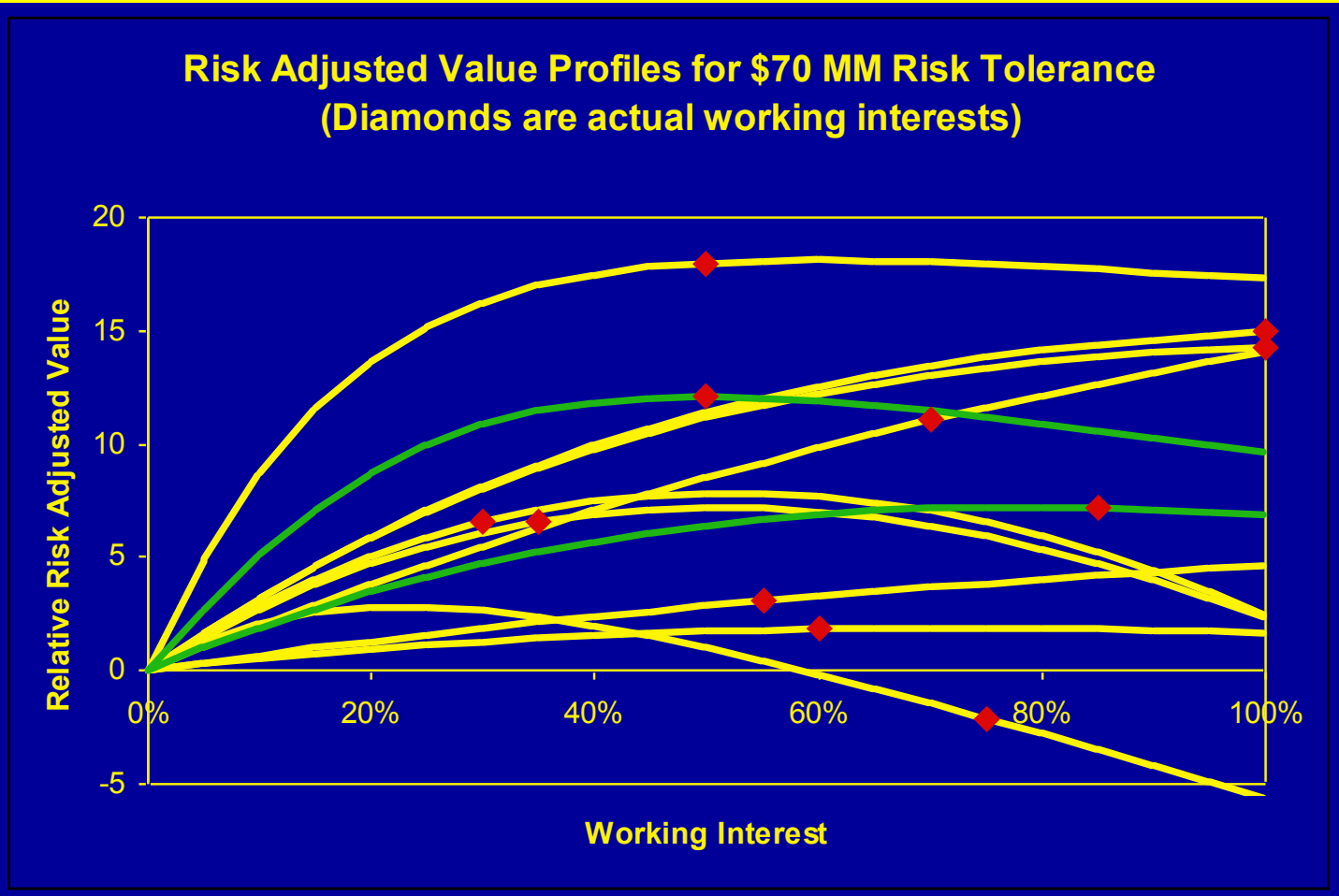
- *Theoretically reasonable*
  - *Delay is the primary effect of country risk*
  - *Reduces effective size of future cash flows due to discounting*
- *Less difficult to quantify*
  - *Empirical data available*

Similar concerns emerged over performance compared to predictions for all projects – appraisal, development, re-development, EOR, stranded gas

Performance predictions tending to decline through time

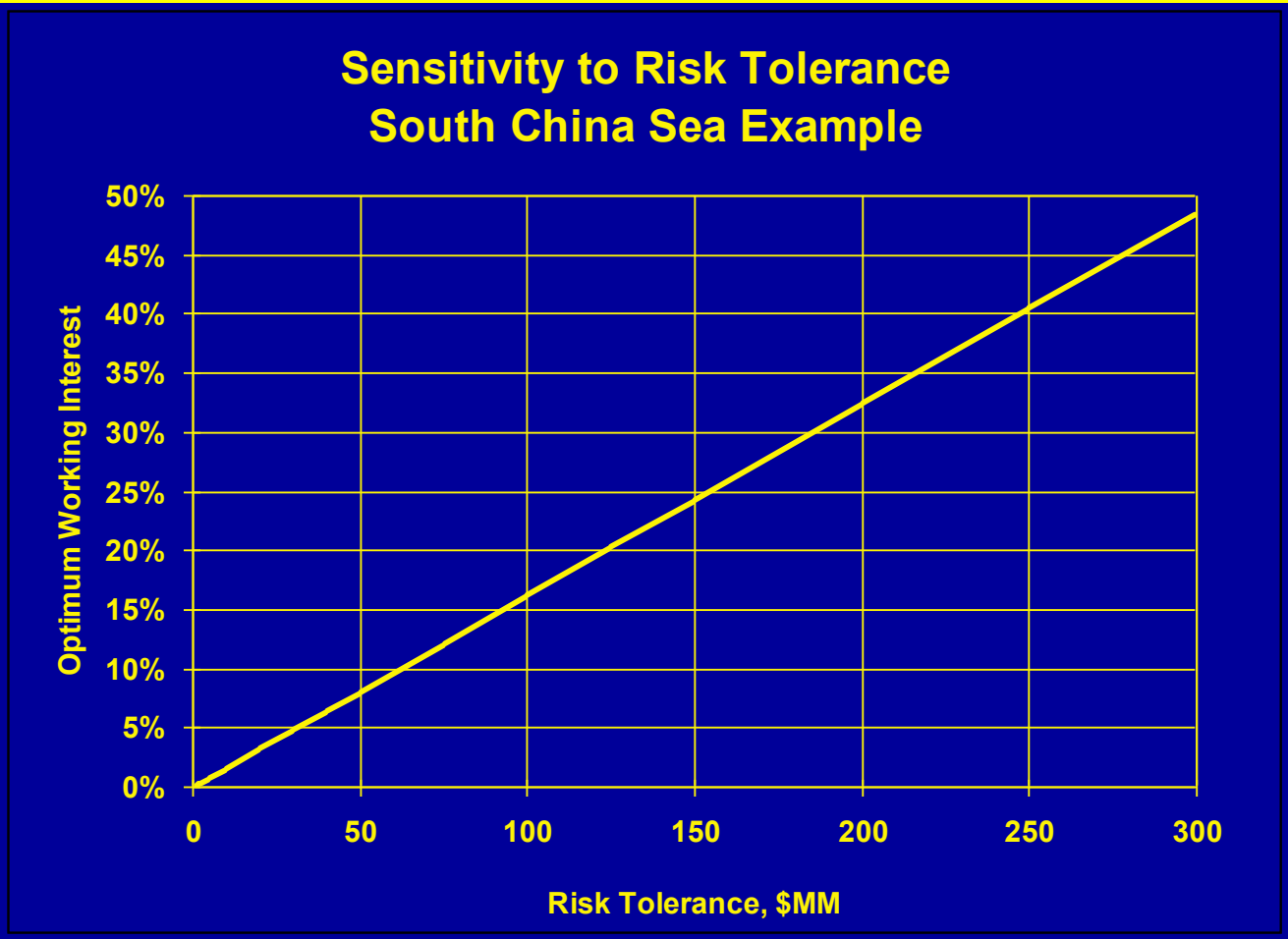
- *Seen in annual Long Range Plan exercise, corrected for price*
- *Implies post-discovery evaluations may also suffer from bias*
- *Concept of "trouble free" or best performance evaluations*
  - *Performance uncertainty distribution strongly skewed*
  - *Low probability of meeting or exceeding performance metrics*
- *Psychological hurdles to making evaluations more realistic*
  - *Requires asset managers to predict sup-optimal performance*
- *Decision-makers compensate by applying unrealistic hurdles*
  - *Project IRR demanded >> WACC or historic E&P ROR*
  - *For some realism, see Capen, 2001 (SPE HEES Proceedings)*

A Preference Theory approach was taken to evaluate WI decisions, with the best fit for historical WI decisions yielding a Risk Tolerance of $70 MM



The recommended WI for two new opportunities (shown in green) were also consistent with this RT, but was this appropriate?

It was not clear that this Risk Tolerance was appropriate for ARCO as a corporation, but rather reflected AIOGC operating as an independent entity



This was an important consideration since the optimum working interest is very sensitive to the choice of RT, but was never pursued

My personal perspective of the AIOGC experience over the period leads me to a number of observations

- *Technical performance prediction (chance of success and reserves) can be achieved through a systematic approach*
- *Accurate real time exploration program performance prediction remains difficult*
  - *Substantial reserves' uncertainty remains post-discovery*
  - *Systematic biases may compromise financial measures*
- *Realistic, unbiased, multi-disciplinary evaluations are needed to inform decision-makers*
  - *Empirical data can provide the necessary "reality check"*
- *Theoretically sound portfolio management approaches provide additional insight*
  - *But are only as good as the quality of the underlying project evaluations*