Risk Assessment in CCS

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NZ Resource Consortium

Supporting participants: Department of Resources, Energy and Tourism | CANSYD | Meiji University | Process Group | University of Queensland | Newcastle University | U.S. Department of Energy | URS

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CO2CRC

Outline

- What's the risk?
  - Specific hazards in CCS, unusual nature of some, relationship to other risks and public perceptions
- What do we know about it?
  - Related experience in EOR, gas storage, other natural hazards, expert opinion
- How do we use these measurements?
  - Qualitative and quantitative risks, probabilities and consequences, tools for propagating probabilities
- An example – the Otway geological risk assessment
- Some personal conclusions

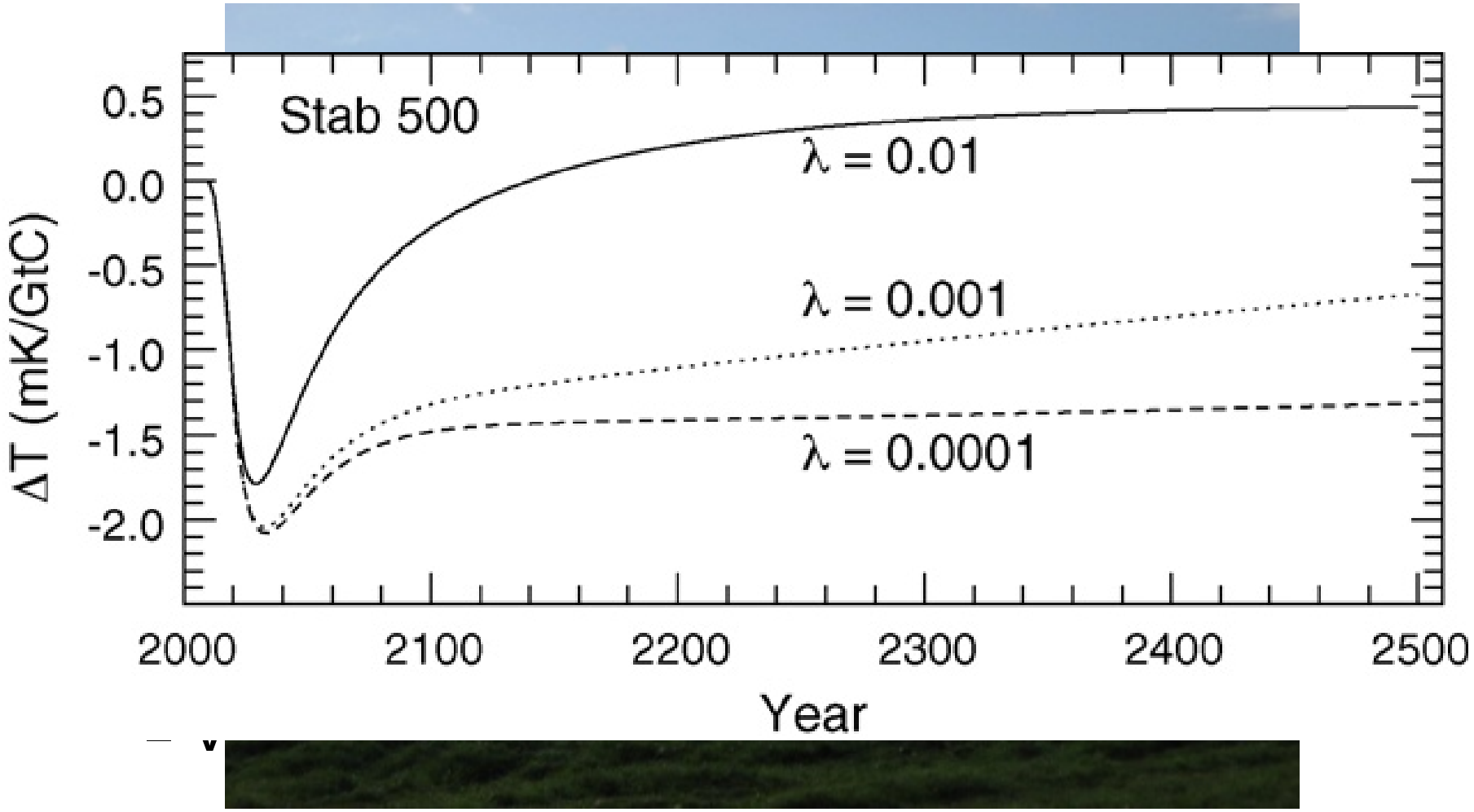
What's the risk?

- Large-scale fatal release of CO_2 – the Lake Nyos scenario
  - Least unlikely during injection phase, perhaps borehole or pipeline failure
  - Limited evidence is that ruptures "freeze over" rapidly
- Migration over tens of years to unforeseen locations
  - Damage to other assets, e.g. groundwater
  - Possible slow release at an outcrop or through faults
  - Consequent dislocation of carbon market, loss of credits, litigation
- Leakage over centuries
  - Greater damage to climate than would have occurred without bothering with CCS; economically damaging
  - Very tight limits – less than 0.1% per annum required

What's the risk?

- Large
  - L
  - L
- Migra
  - D
  - P
  - C
- Leak
  - G
  - V

What's the risk?



What's the risk - II

- Wider context of risks (maybe more important!)
  - Public opposition
  - Not economically viable
  - Inadequate or vague regulations
  - Who is liable in the long run?
- The risk assessments are themselves a risk
  - "uncertainties in the uncertainties"
  - Mere discussion of risks and probabilities can be hi-jacked for politcal ends
- Humans are bad at assessing small risks
  - Risks have to be set against other risks; relative risk is what affects decisions more reliably

What do we know?

- Sleipner
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- …and of course several other smaller/younger projects
- Enhanced Oil Recovery (EOR) with CO_2 flooding
  - Studied for the CCP by Grigg (2005)
  - In progress for about 50 years in the Permian Basin
  - About 40 Mt per annum being injected (but not stored)
  - Significant body of experience
  - Typically 70% of the injected gas is retained
  - Excellent safety record
- Same applies for acid gas storage in Canada (Bachu & Haug 2006)
- …and Weyburn

What do we know II

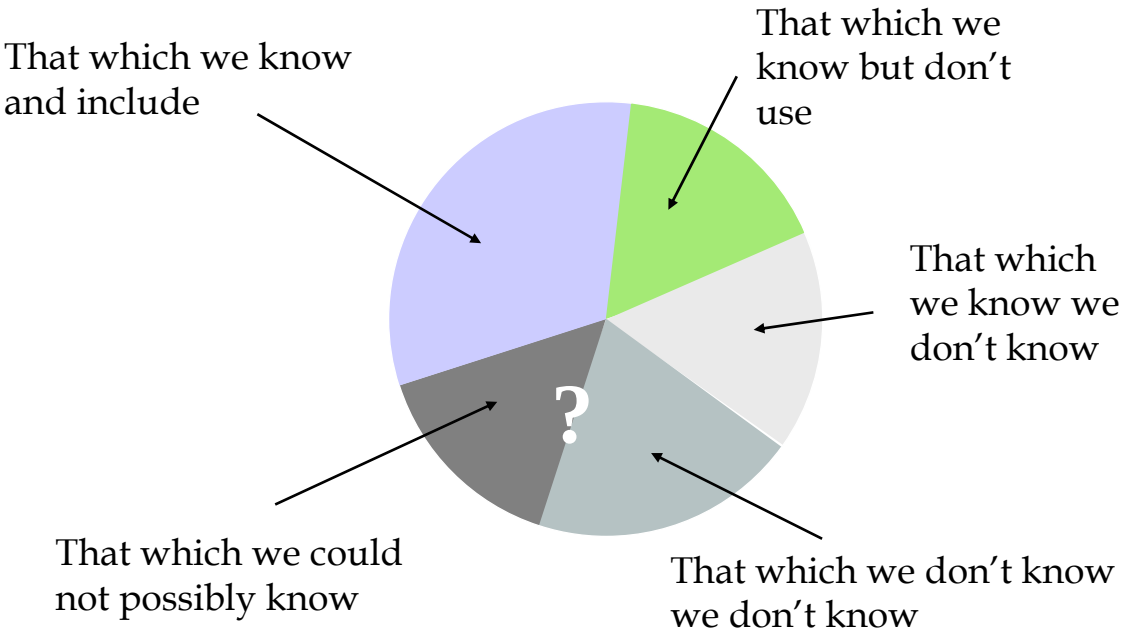
- Natural analogues
  - Plenty of these but difficult to know how good the analogy actually is
  - Would we know about natural CO_2 accumulations that had leaked?
- Gas Storage
  - Very extensive experience – 90 years
  - Studied by Perry (2006) for CCP
  - Only 10 of approximately 600 storage reservoirs have ever experienced leakage
  - Mostly wellbore problems

What do we know III

- We know a great deal but
  - Much of the information is “by analogy”
  - Much is qualitative
  - Little can be turned into probabilities
  - Some key things have never happened (e.g. a real carbon market)
- However
  - The logical structure is well understood (Features Events Processes)
  - We can make sensible rankings of probabilities and consequences
  - We can construct traditional risk matrices right now in a reasonable way
- Is this enough when the ultimate metric is strictly quantitative – the net climate benefit?

What do we know IV

- **Faced with this disparate mass of data we often turn to "expert panels"**
- **Best we can do but they have a mixed record**
- **Prone to over-rate their own reliability**
- **Tetlock (2005) concluded in a careful study that expert political judgement is very poor; financial experts seems recently to have done no better**
- **Generous error bounds on expert opinion are needed and it can then be very useful**



Rumsfeld Diagram

(Quintessa)

Using the data

- Risk matrix, based on rankings: a risk management tool
- Based on the statistical concept of expectation:

$$\sum_i p_i C_i$$

- The *p*'s are very uncertain
- Some *C*'s may matter much more than others; some may be unacceptable at any *p*
- Better to simulate the whole process by Monte Carlo methods; look at probability distribution of consequences

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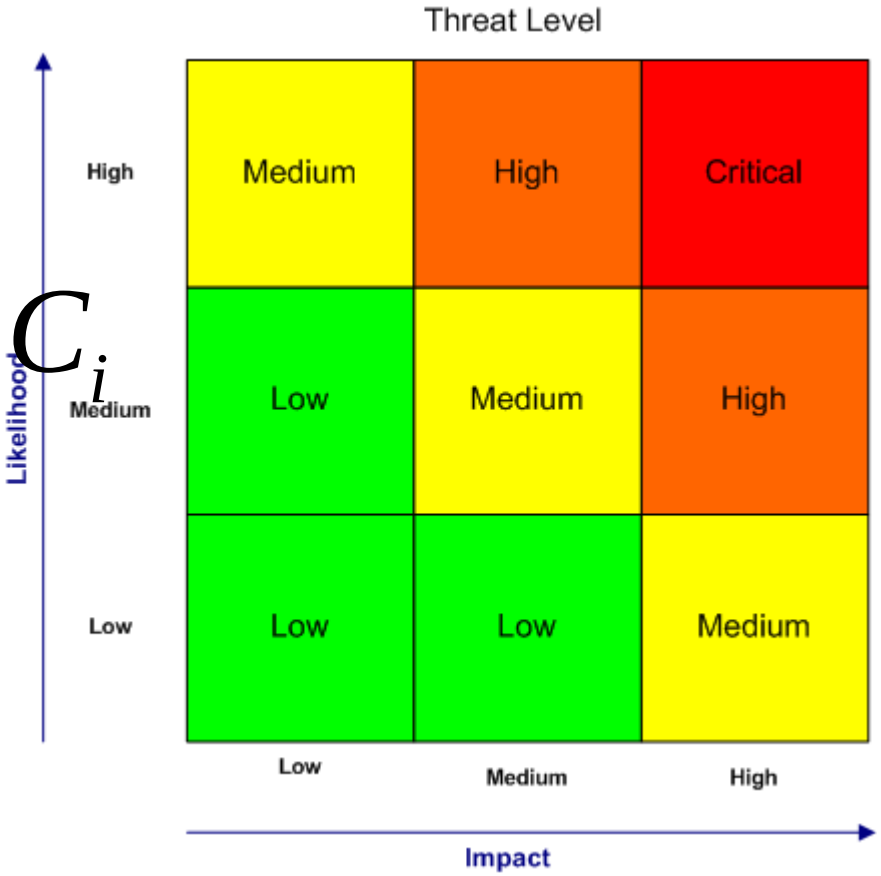
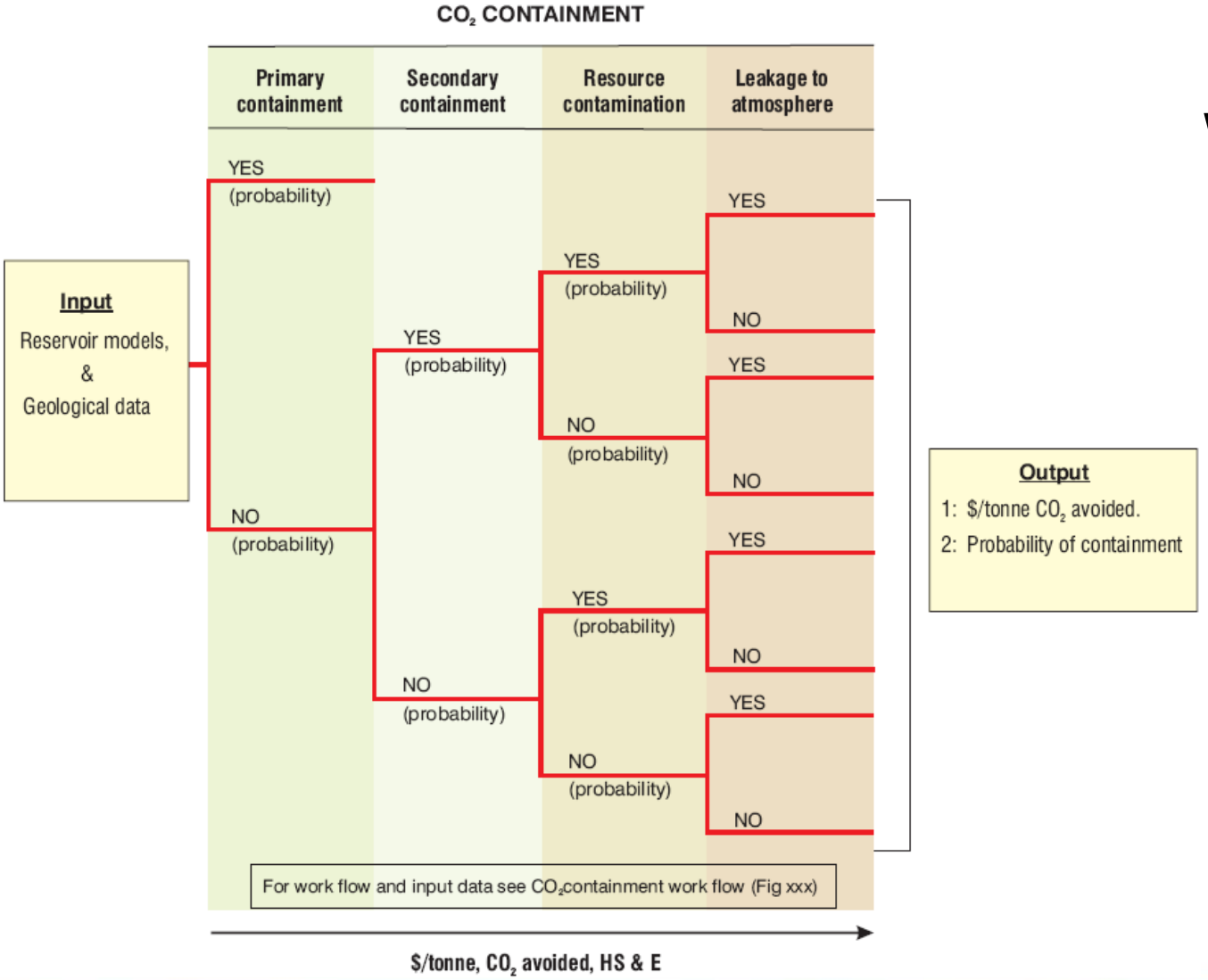


Using the Data -II

- **We have quite a good idea of the logical structure we are dealing with**
- **May be hierarchical (logic tree)**

Using the Data -II



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- **Or network-like (Bayesian Belief Network)**

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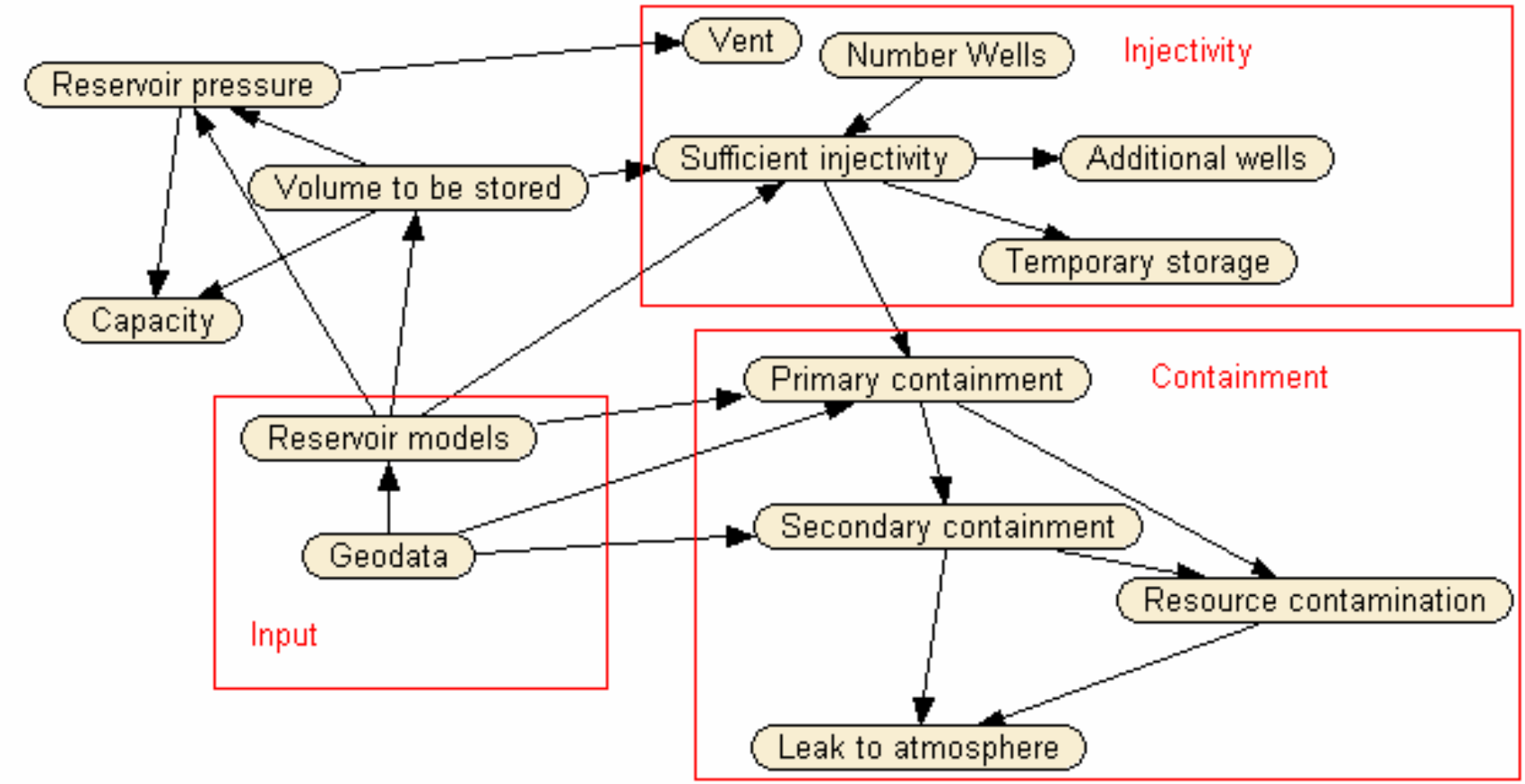

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- **May use standard Kolomogorov probabilities (e.g. RISQUE)**
- **…or a three valued calculus (e.g. TESLA)**

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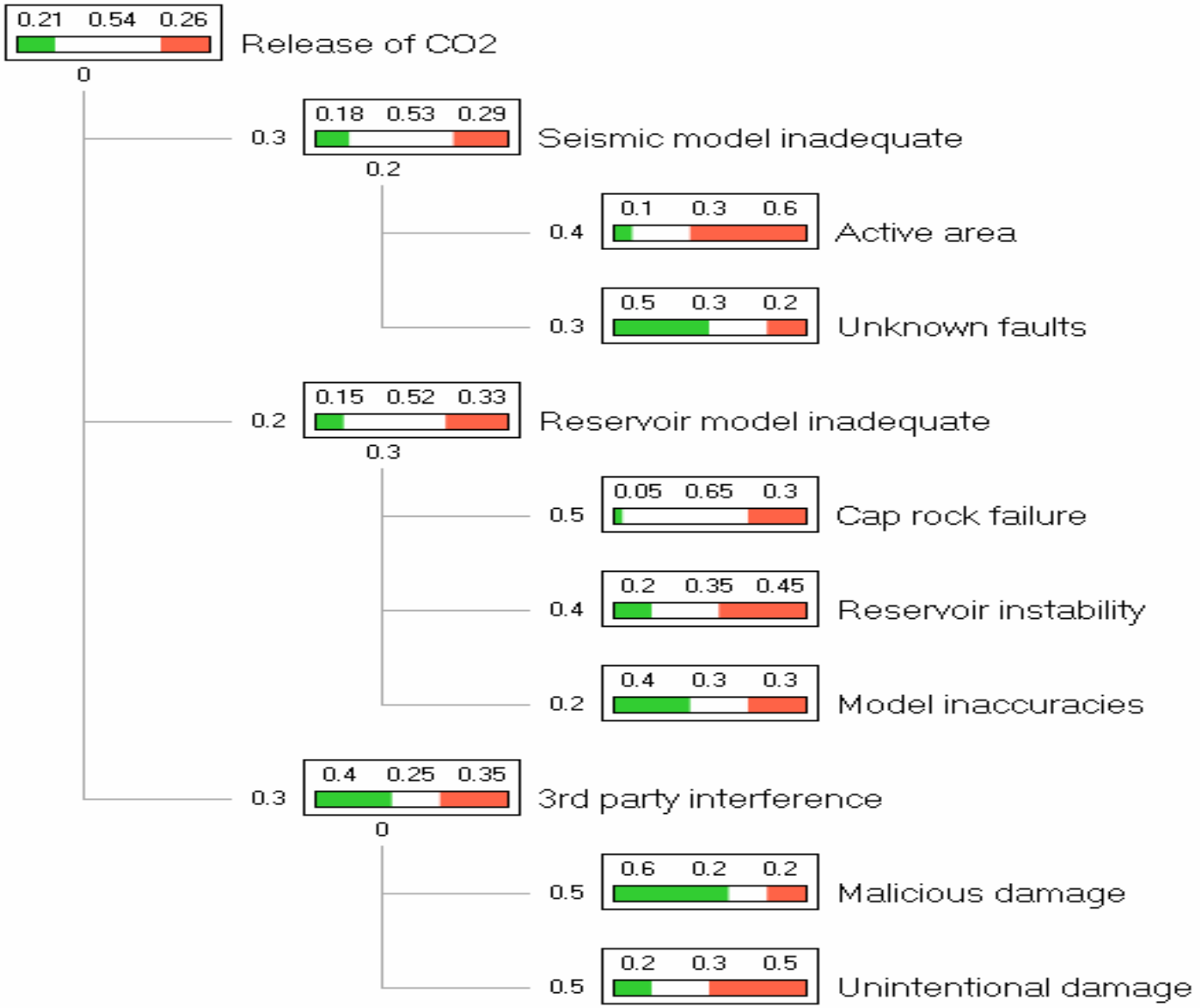

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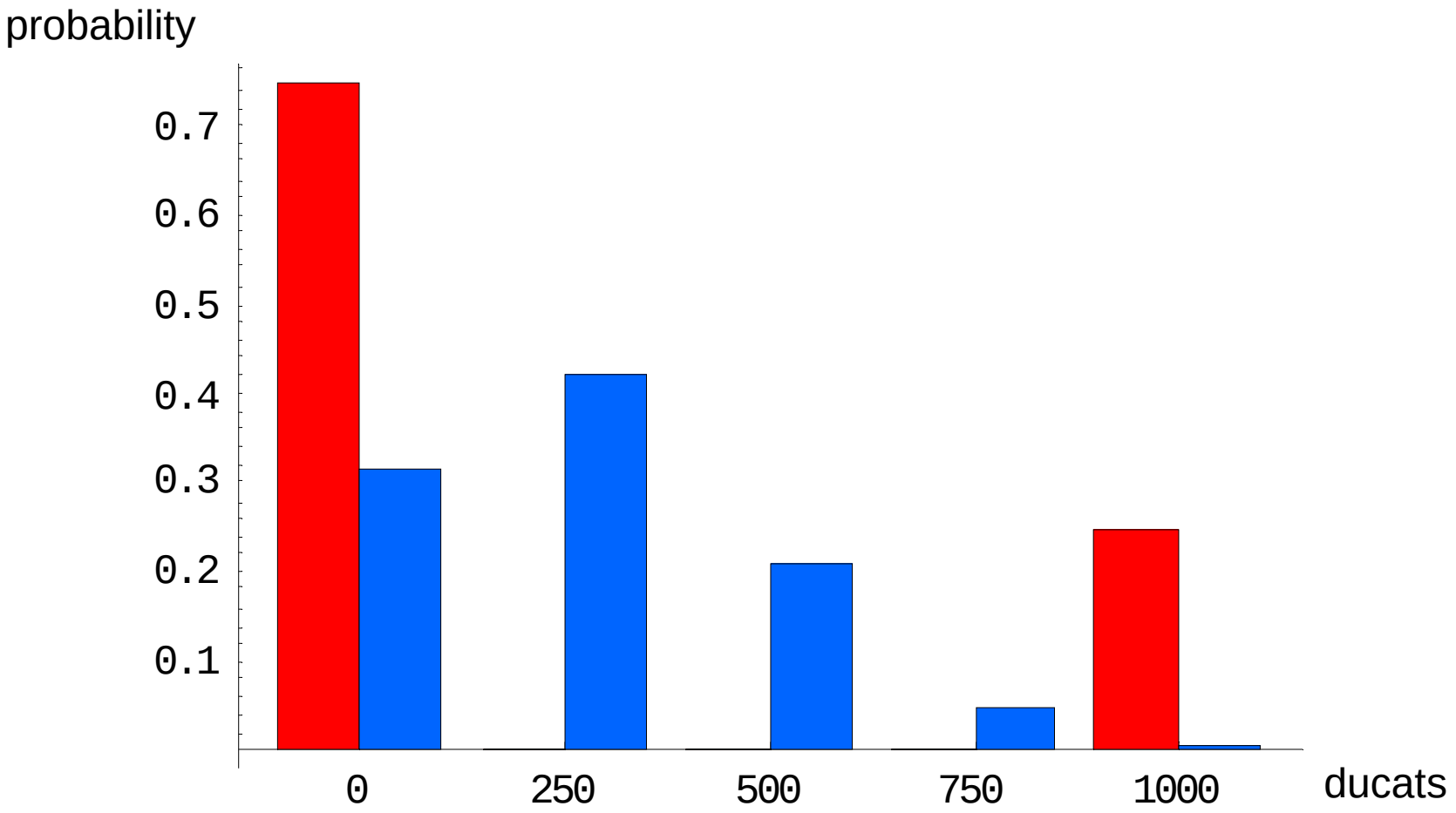
- …or a three valued calculus (e.g. TESLA)
- Each of these can be used in simulation mode to give a distribution of outcomes
- Adding a probability distribution to the assigned probabilities is very instructive (RISQUE)

Sempronius' problem

- **Sempronius has 1000 ducats in the bank in Venice, but he needs to ship another 1000 ducats worth of goods from a distant port (*from Daniel Bernoulli, "A new theory on the measurement of Risk, 1738*).**
- **There is a one in four chance that the ship will be lost on the journey.**
- **Should Sempronius risk all his goods to one ship (expected loss= probability of loss x amount at risk =250 ducats)?**
- **Or, should he divide his goods amongst four ships (expected loss = probability of loss x amount at risk x number of ways of losing ships = 250 ducats)?**

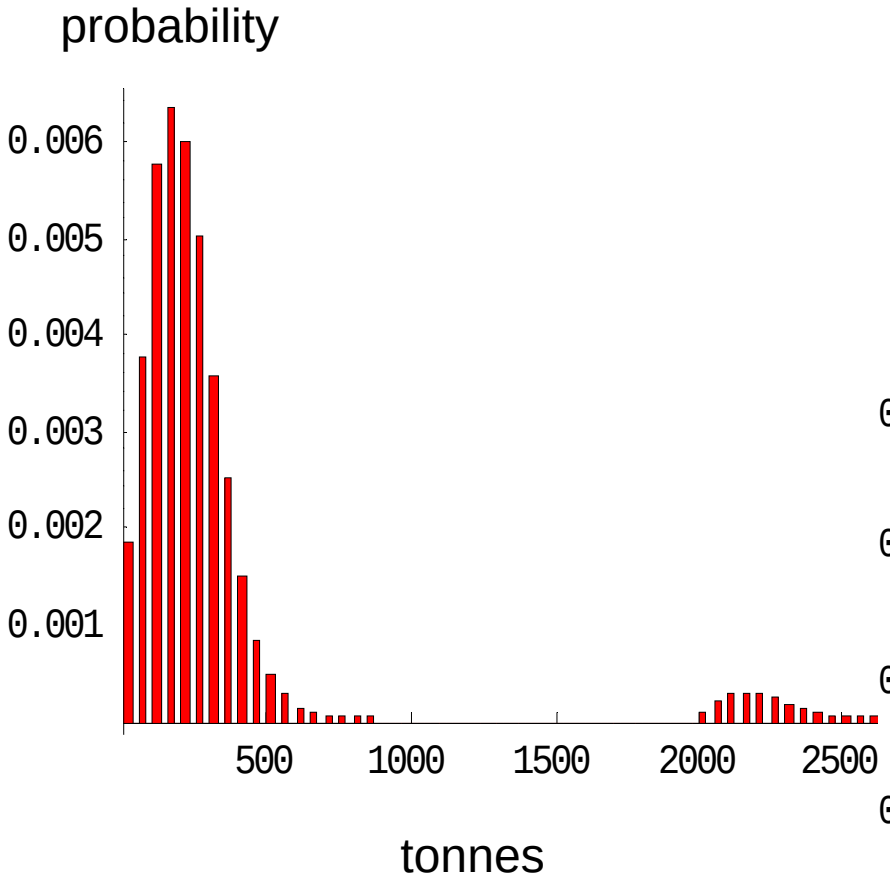
The probability distribution of losses

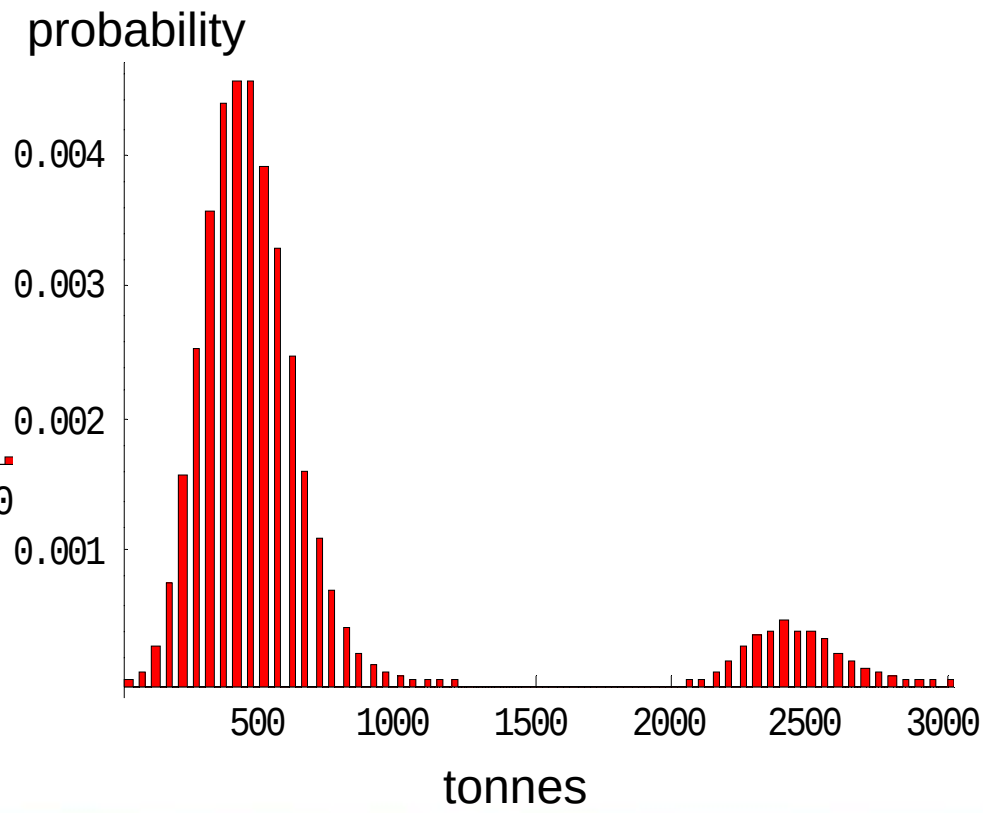


A “toy” example for storage

- We have three loss mechanisms:
- Mechanism A, probability 1/100 per year of losing 100 tonnes
- Mechanism B, probability 1/50 per year of losing 50 tonnes
- Mechanism C, probability 1/2000 per year of losing 2000 tonnes
- Let's look at the distribution of losses over say 100 years.
- e.g. we could lose 200 tonnes by 50 tonnes four times, 50 tonnes twice and 100 tonnes once, or 100 tonnes twice. And so on for other loss combinations.
- Look at effect of uncertainty in a factor of 8 on the probabilities

Probability distribution of losses

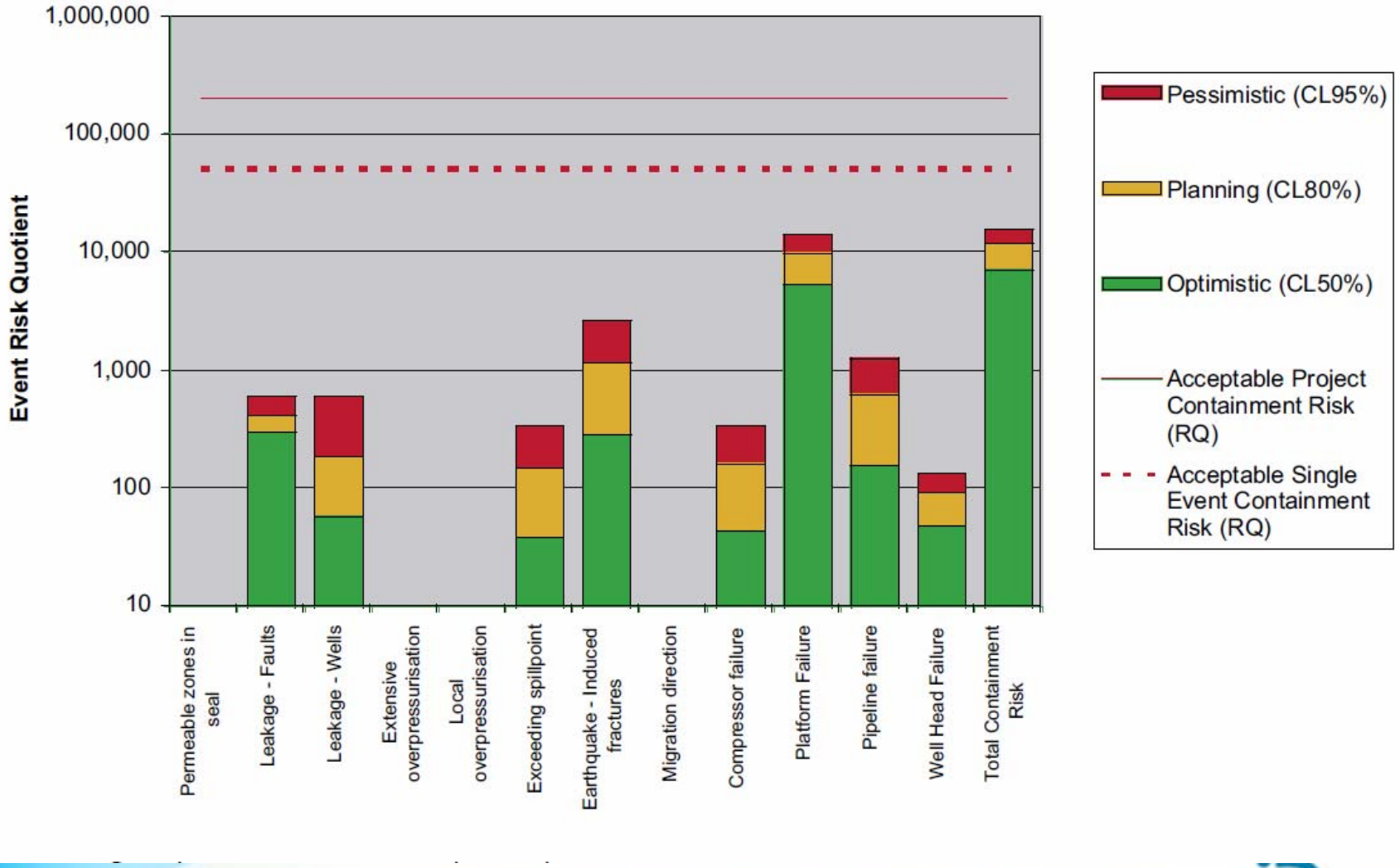




Back to…Using the Data III

- This type of simulation technique is used in RISQUE
- Basis of the two geological risk assessments for Otway Stage 1 and 2 (there were also of course risk assessments for other aspects of the project)
- Based on elicitation of processes and their probabilities from an expert panel
- Processed by Monte Carlo with large statistical spread added to the elicited probabilities

Back to…Using the Data III



Conclusions

- **There is abundant industry experience, in chemical engineering, pipeline technology, and oil & gas that can be turned into reasonable *qualitative* risk assessments for CCS**
- **The *quantitative* nature of the climate problem, the associated economics, and public acceptance issues, are driving risk assessment to a quantitative style of assessment**
- **Lots of interesting and entertaining ways are available for doing this but**
- **objective data for constructing the needed probabilities are very hard to come by!**
- ***Somehow, we have to get started (take some managed risks)* before we have the experience to construct the highly detailed risk quantitative assessments that are often thought to be desireable.**