Uncertainty in Environmental Compliance Decisions

CE Steyn[1], L Bredenhann[2], and AJ Botes[3]

[1]Beal Consulting (Pty) Ltd, Tijgervallei Office Park, Silverlakes Road, Hazeldeen.

[2]IQS Holdings (Pty) Ltd 64 Halepensis Street, Lynnwood Ridge, Pretoria, 0081

[3]GreenGAB (Pty) Ltd, Persequor Office Park, Eulophia Corner Building 1, Pretoria

"The most important questions of life are, for the most part, really only problems of probability."
Pierre-Simon, marquis de Laplace

SUSTREM 2021
ECONOMY • SOCIETY • ENVIRONMENT

Key Discussion Point

"*The most important questions of life are, for the most part, really only problems of probability. Strictly speaking one may even say that nearly all our knowledge is problematical; and in the small number of things which we are able to know with certainty, even in the mathematical sciences themselves, induction and analogy,* ***the principal means for discovering truth, are based on probabilities****, so that the entire system of human knowledge is connected with this theory*."

(Pierre-Simon Laplace, "Theorie Analytique des Probabilités", 1812)

Setting sustainable remediation targets – when are we done?

***“Important questions of life”*?**

- *“Risk of Ruin” problems: outcomes of risks that have a non-zero probability of resulting in unrecoverable losses.*
- *Risk decisions require more rigor than other applications of statistical inference.*
- *Policy should depend at least as much on uncertainty concerning the adverse consequences as it does on the known effects.*

Nassim Nicholas Taleb

Complex System

- Push a complex system too far and it will not come back.
- In complex systems with many unknowns, harm is typically in the dose and not only in the nature of the substance, increasing nonlinearly to the level of ruin making them fragile systems.
- While some amount of contamination is inevitable, high quantities of any contaminant results in exponentially increasing risk of destabilising the system.

Uncertainty

- Uncertainty is implicit in every decision on compliance although rarely explicitly expressed and even less quantified.
- Underlying every decision, we hold a degree of belief in the truth that includes mainly two types of uncertainty:
  - Epistemic – Lack of knowledge;
  - Aleatory – Randomness, observation error
- Epistemic uncertainty can only be reduced by gaining knowledge which requires cause and effect studies and not as is traditional, additional data required for randomness.

Risk

- "Expert" conclusions are generally overconfident and underestimate risk.
- "Experts" are better at narrating what we know than what we don't know. Risk is about what we don't know.
- We follow a so called "Risk Based Approach" that do not quantify the likelihood of occurrence and uncertainty in the consequence (Thresholds).
- ISO 31000 Definition of Risk: "*Effect of **uncertainty** on objectives*". Uncertainty is implicit in the definition of risk.
- People are poor judges of probability and risk. Therefore, the standardisation of numerical methods and terminology for compliance and risk estimation is important.
- Although the philosophical basis for coherent reasoning under uncertainty has a long history it has only now, with improvements in computing power, been developed into practically implementable tools to numerate uncertainty.

The Approach

- In a statistical-evidentiary approaches to risk, the existence of a risk or harm occurs when we experience it. In the case of ruin, by the time evidence comes it will be too late. Thus, standard evidence-based approaches cannot work.
- Risk events are outliers and have extreme effects, but we have an over reliance on the central tendency such as the median.
- Normal statistical approaches give a false impression of understanding of variability, especially due to limited sampling.
- Risk is in the future, expressed in probabilities and is relative.

"Absence of evidence does not equal evidence of absence."

The Approach

- Today we use better statistical models that include different kinds of “outlier” possibilities and run Monte-Carlo simulations that have randomness built-in.
- We should develop a common language of probability, rather than predictions.
- We need to adjust to existence of risk. Focus on what we do not know.
- We should not only learn facts but rules to follow.
- We need to develop a system that identifies extreme events, so we can prepare for them.

Key Concepts/Misinterpretations

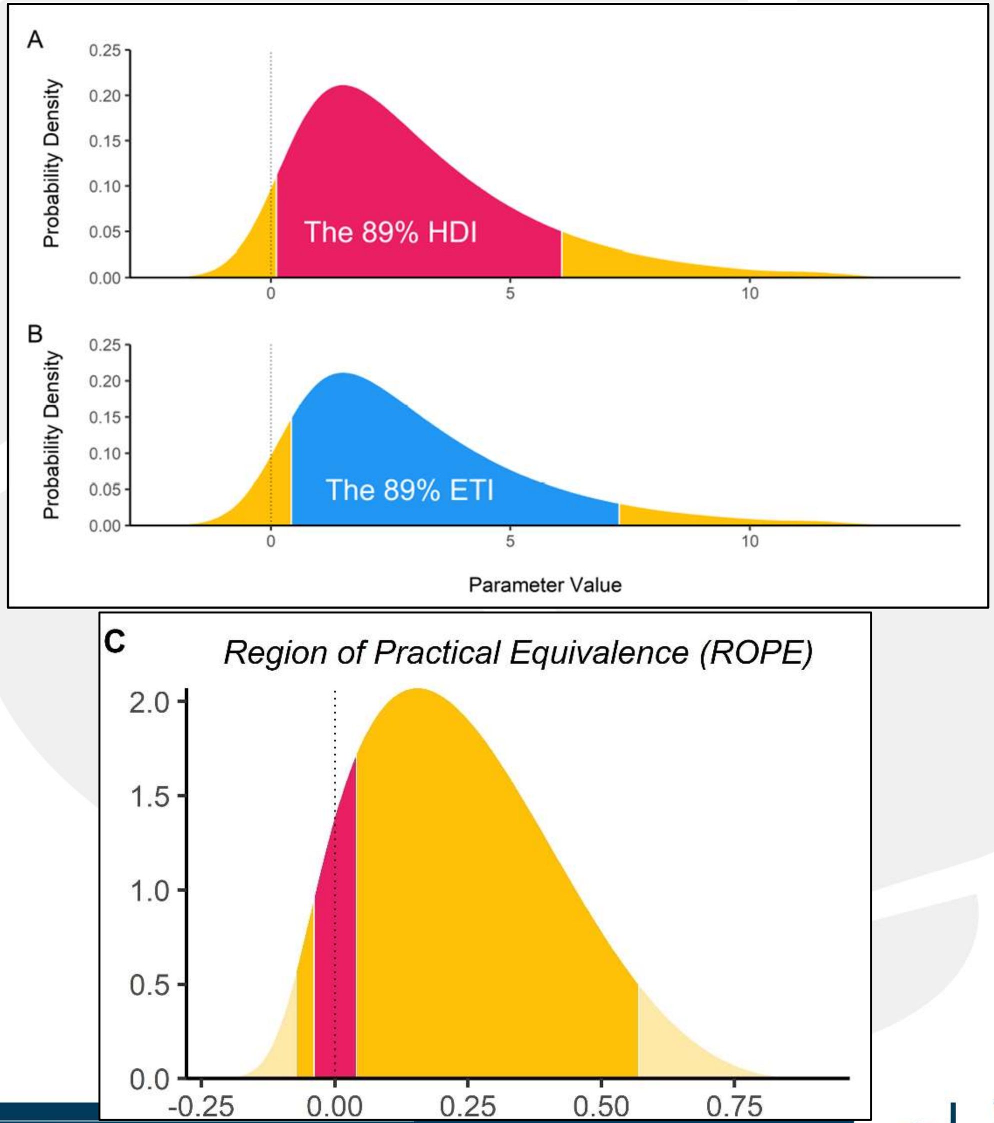
- The first step in developing a coherent approach is to get a common acceptance, understanding and language of uncertainty.
- For example, uncertainty is mostly equated to inherent variability or randomness in natural phenomena, also called aleatory uncertainty. Aleatory uncertainty/variability cannot be reduced but it can be better characterised. However, epistemic uncertainty (lack of knowledge) should also be numerated and require cause and effect studies.

Key Concepts/Misinterpretations

- Numerically misinterpretations are also common. For example, significance is expressed as a probability that your results (data) have occurred by chance, commonly defined as a p-value (usually either 0.05 (5%) or 0.01 (1%)).
- A confidence interval is a range of values that have a probability that the true value of a point estimate such as the mean falls within it. This interval is stochastic and changes with repeat data sets.
- However, evaluating compliance requires an estimate of the population distribution. Not the chance that your estimate has missed the true mean.

Key Concepts/Misinterpretations

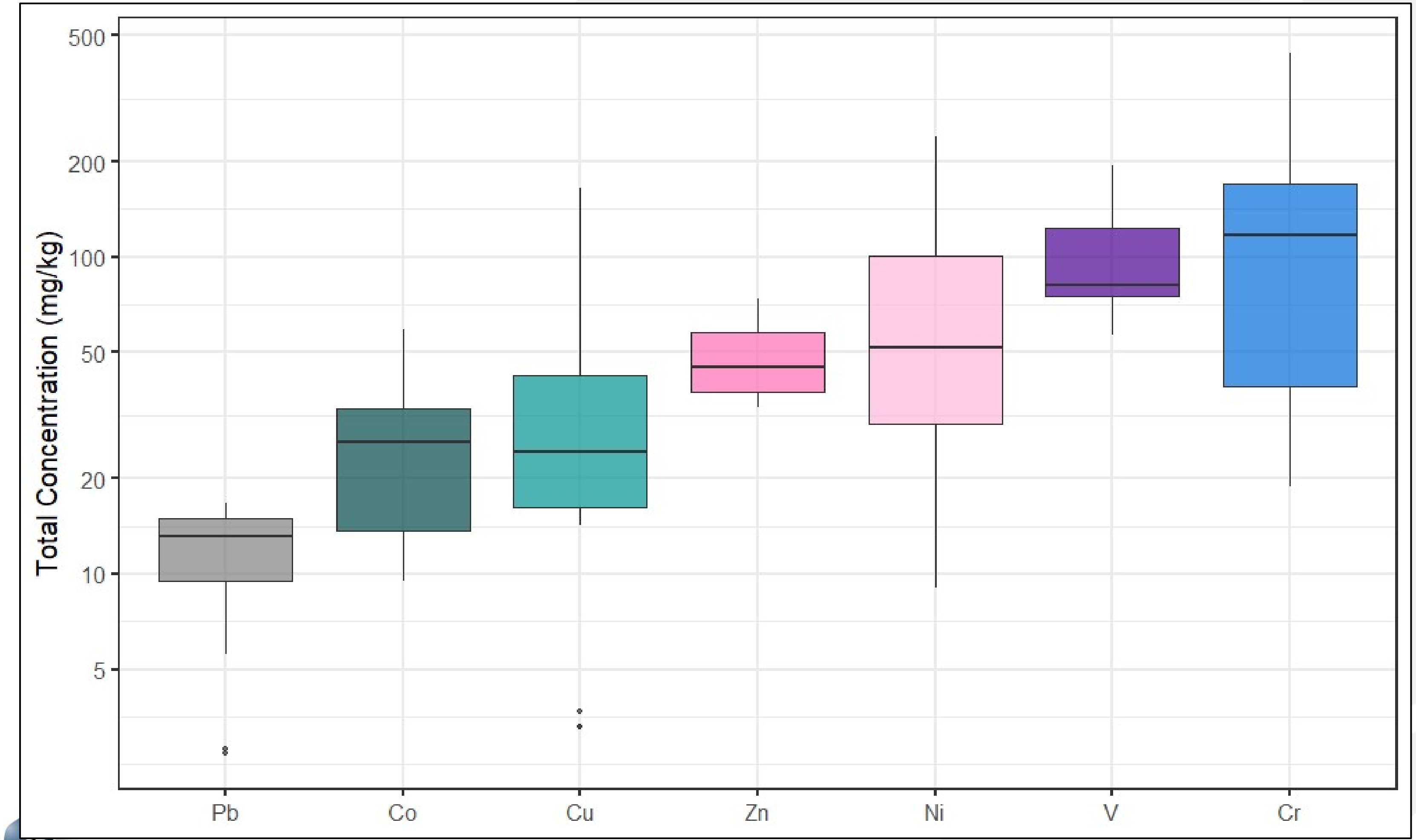
- Develop definitions associated population estimates so that we do not get confused with the traditional use of the terms e.g., “confidence interval” replace with concepts such as Highest Density or Equal-Tailed Credible Interval, Region of Practical Equivalence (ROPE).



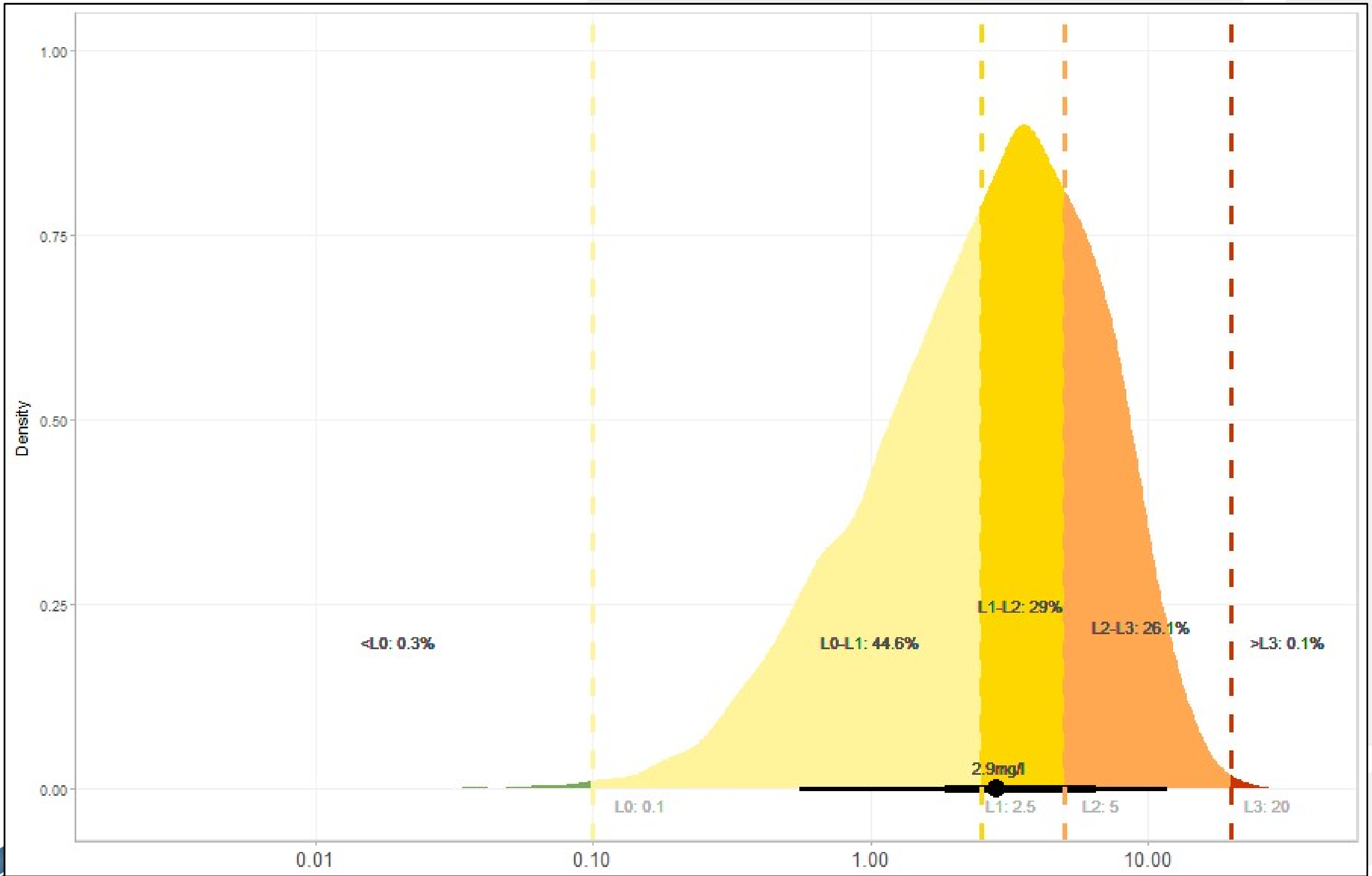
Key Concepts/Misinterpretations

- It has been shown that natural systems often are "scalable" or have fat tail (power law distributions) behaviors associated with the propagation of impacts in a complex system.
- In fat tailed domains of risk, harm comes from the large events. Examples of statistical distributions include Pareto, Levy-Stable distributions with infinite variance, Cauchy, and power law distributions.
- When evaluating appropriate distributions for risk quantification the underling uncertainty generating mechanism should be considered and appropriate distribution selected and not automatically default to normal or lognormal distributions.

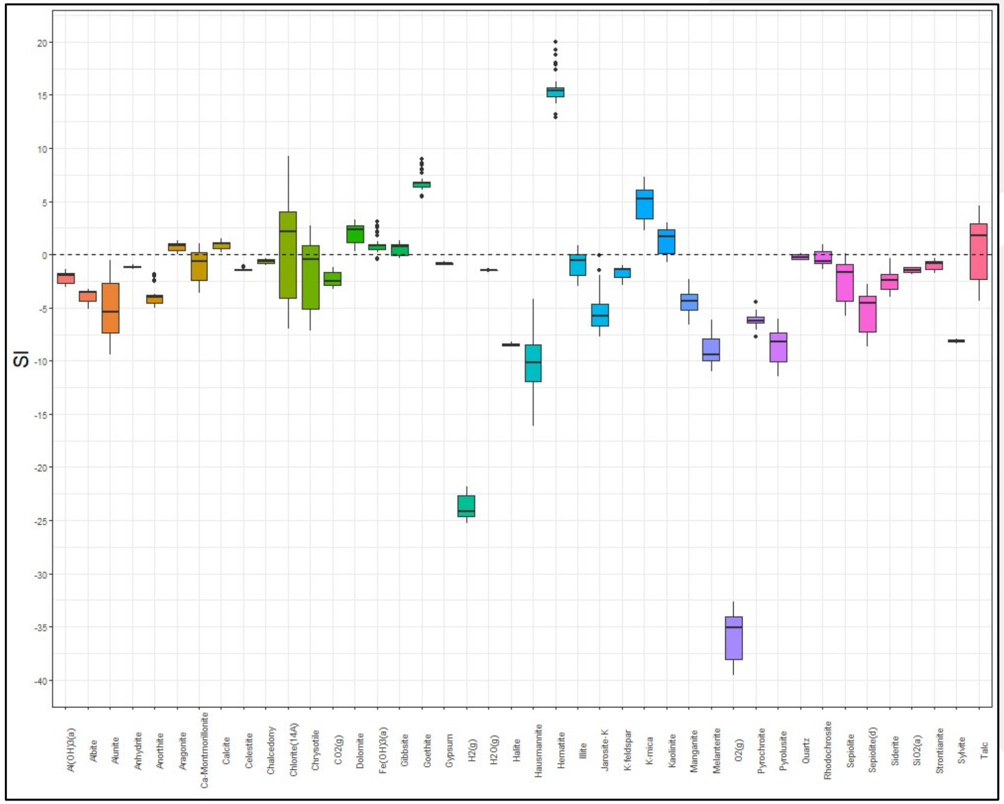
Example: Establish ROPE

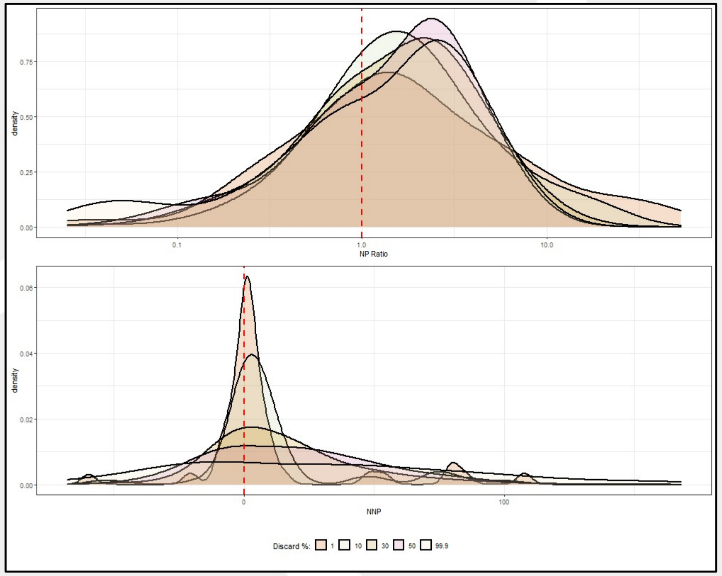


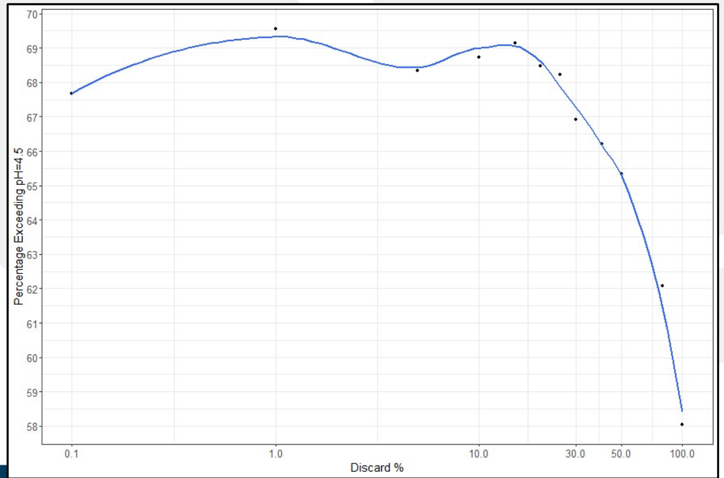
Example: Population Exceedance



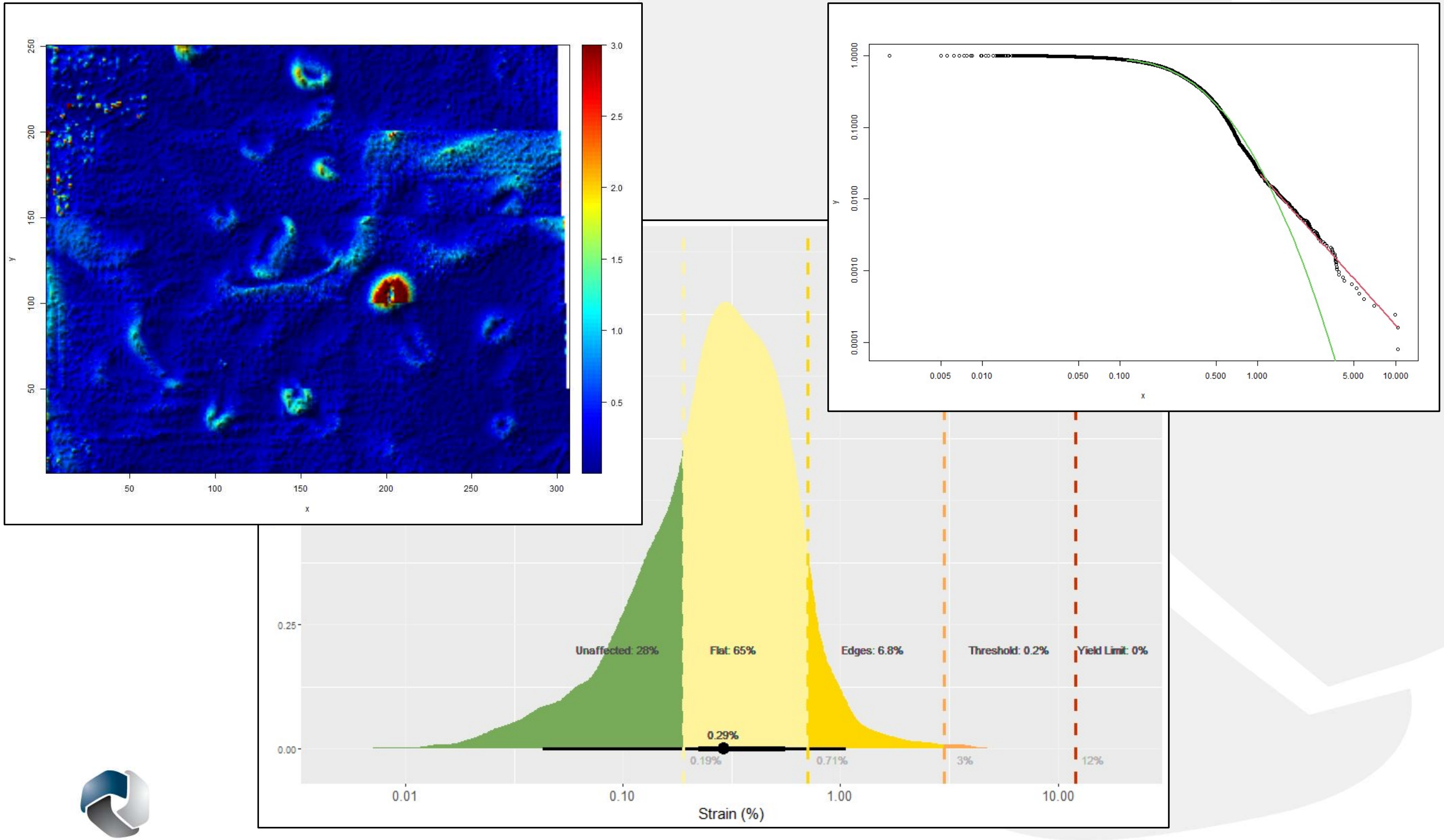
Example: Integration with Modelling







Example: Power Law Distribution



Conclusions

- *"Setting sustainable remediation targets"* we should have a probabilistic mindset.
- Developing rules to follow rather than targets.
- We should use a *"real risk based approach"* methodology.
- If we do not change the approach we will never be done setting targets and they will continually change based on *"evidence"* of risk of ruin events.
- This presentation focuses on the scientist role but bring this into the legislative/legal realm we also need to consider "**Cause and Effect**".

carl@beal.co.za