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# Modelling and Managing Uncertainties in Natural Hazards

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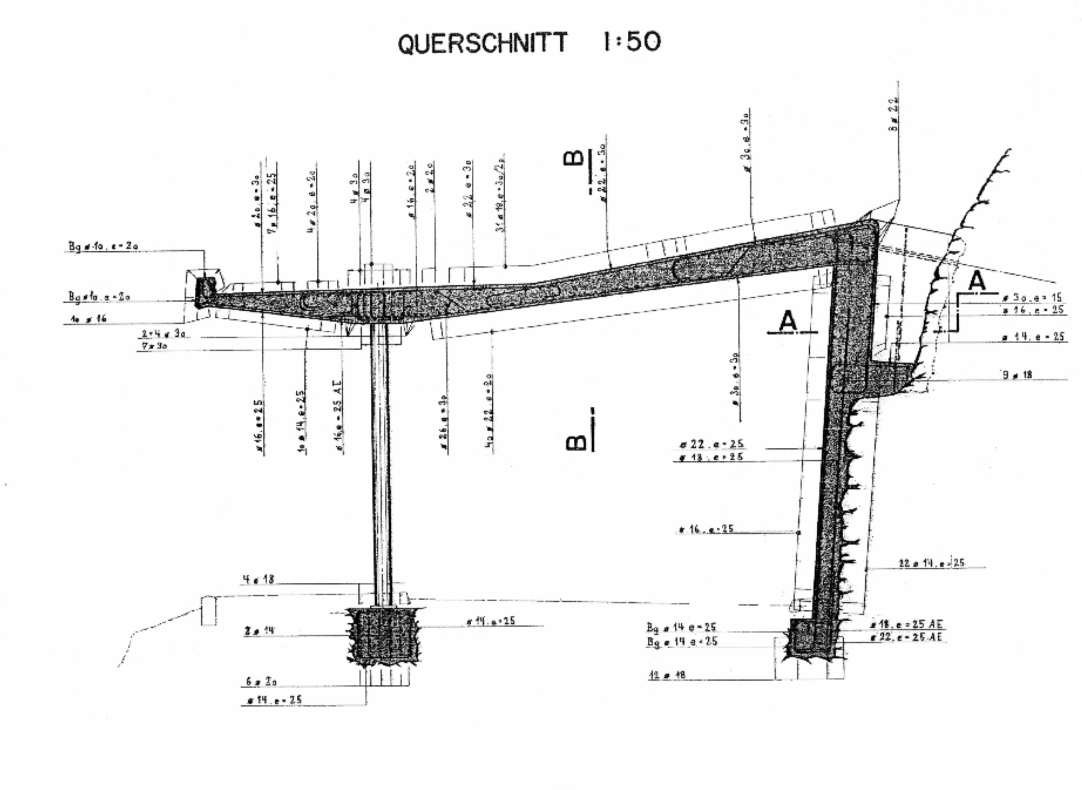
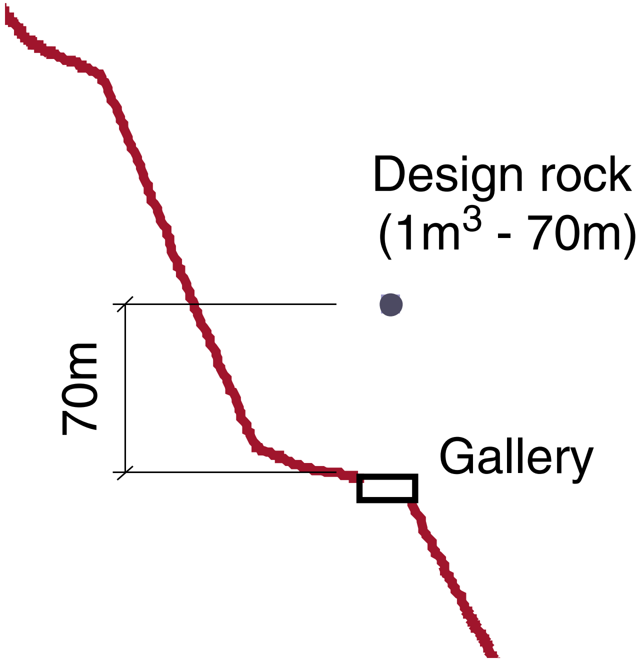
# Natural hazards and the engineer: example rockfall

- Rockfall protection gallery:

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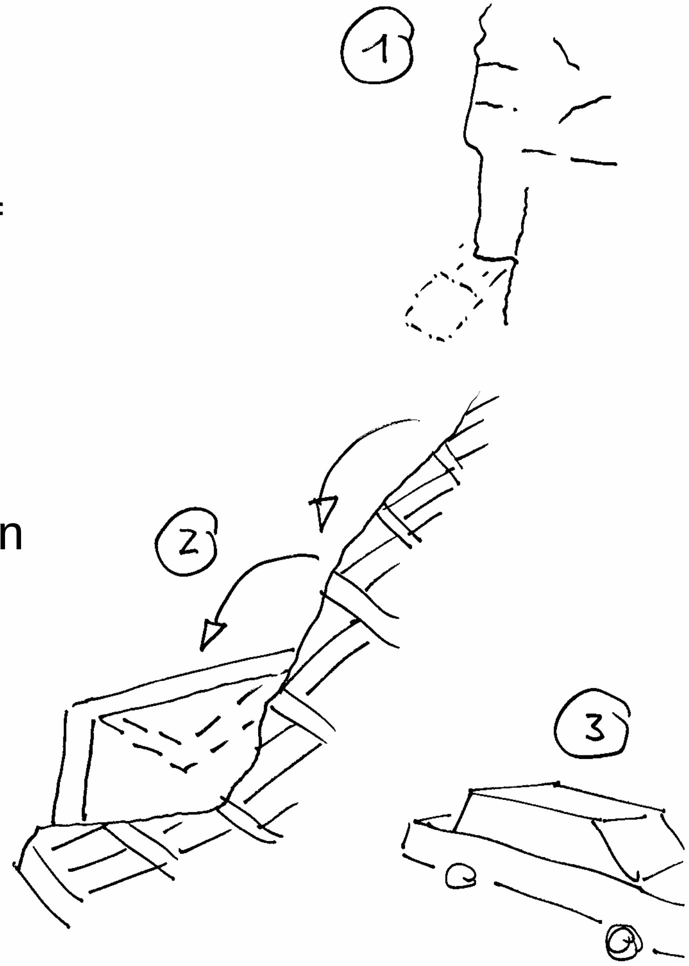
# Outlook

Three stages in natural hazards risk assessment:

1. Evaluation and description of the uncertainties related to the occurrence of hazards (natural scientist)
2. Propagation of the uncertainties in the (engineering) model
3. Combining the uncertainties with consequences: Appraisal of risks (decision theory)

→ The uncertainties can be and MUST be addressed explicitly in each stage



# Sources of uncertainty

Two fundamentally different types of uncertainty:

- Aleatory uncertainties (random processes)
- Epistemic uncertainties (related to incomplete knowledge)

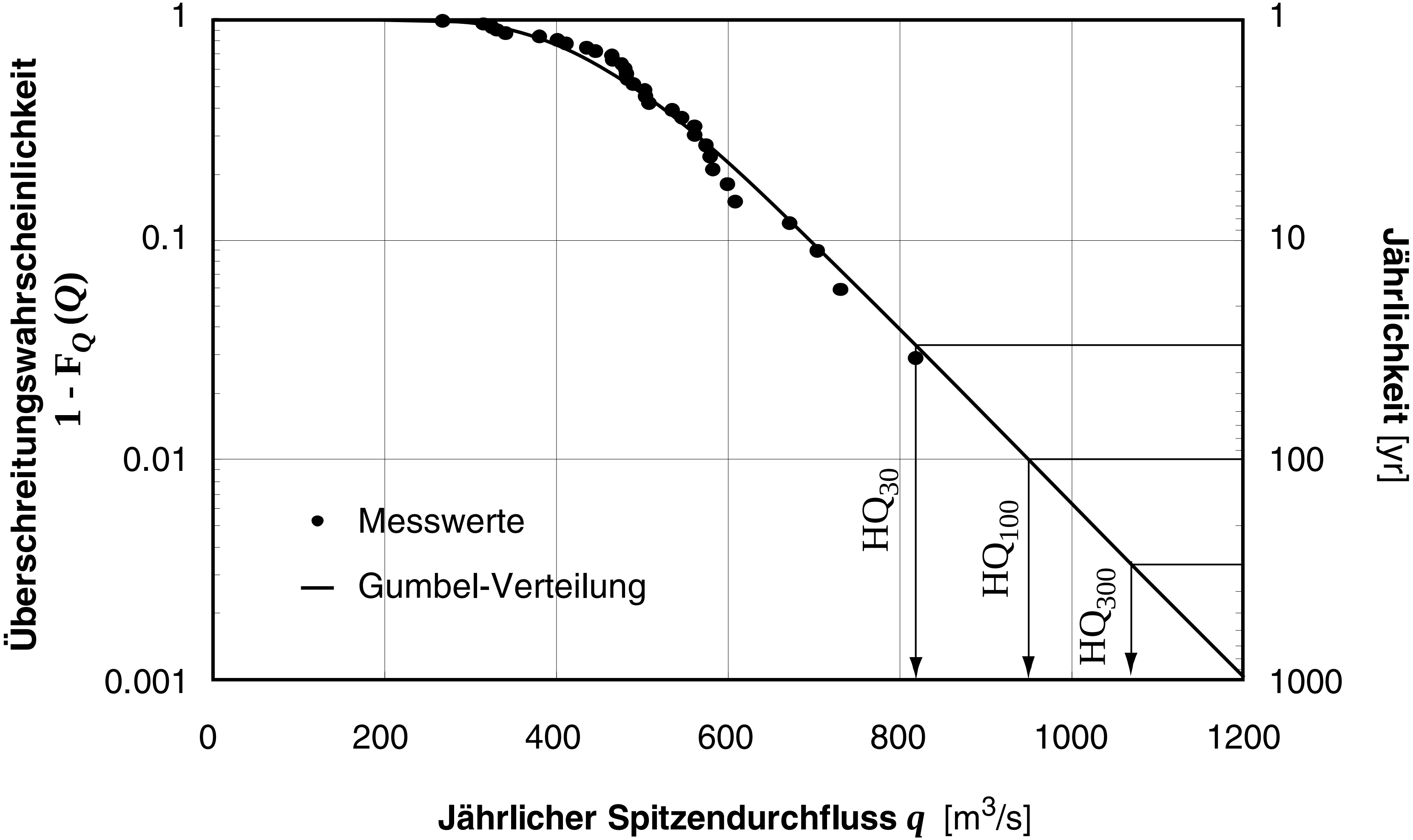
Aleatory uncertainties

- Some processes are subject to inherent randomness (e.g. the detachments of rocks)
- The prediction of future developments (such as climate)

Epistemic uncertainties in natural hazards:

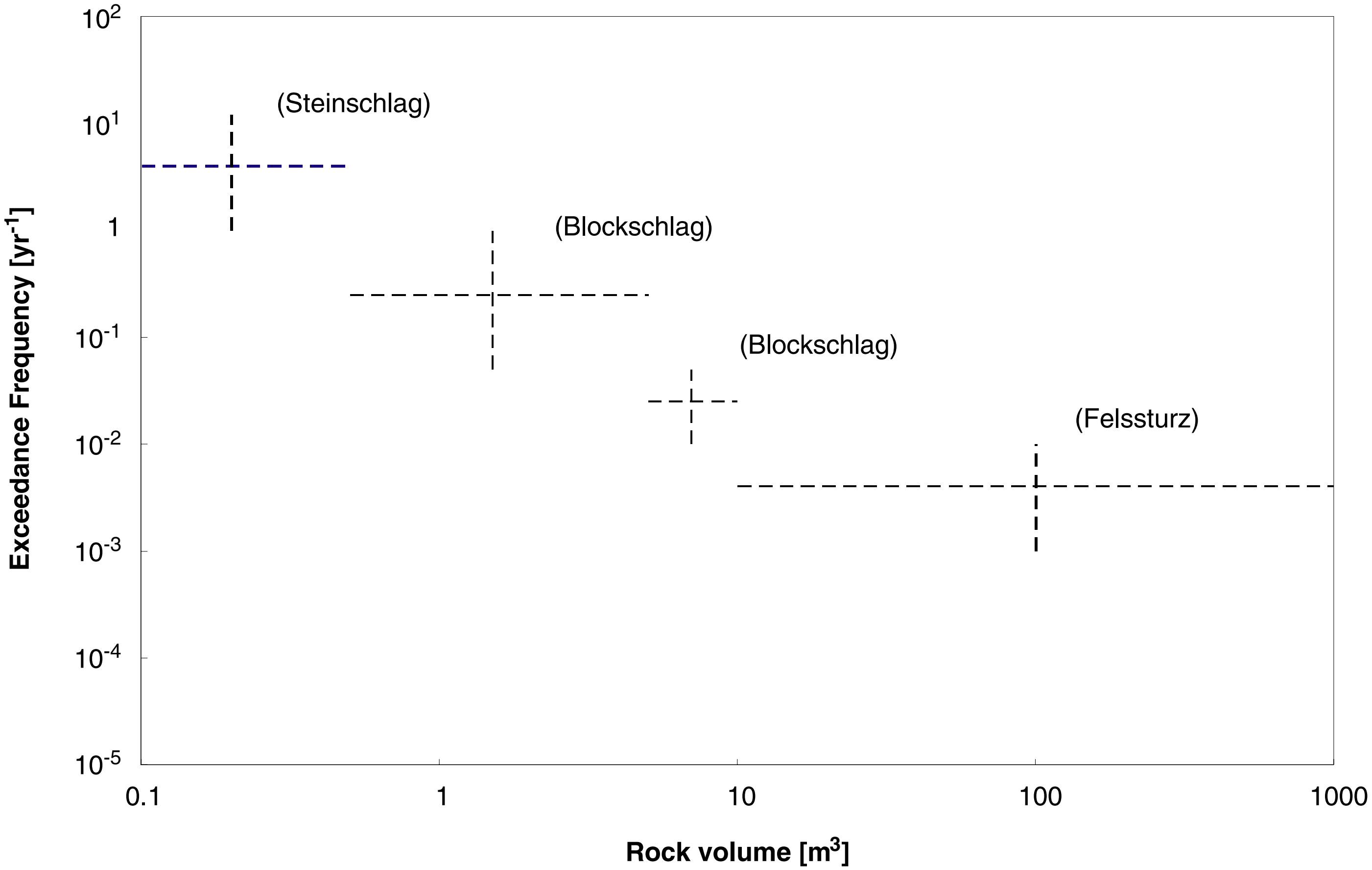
- The (empirical) models are not perfect and thus subject to scatter
- Model parameters are subject to statistical uncertainty
- Incomplete knowledge of site specific characteristics

# Representing uncertainties by exceedance probabilties & frequencies: Example maximum annual discharge



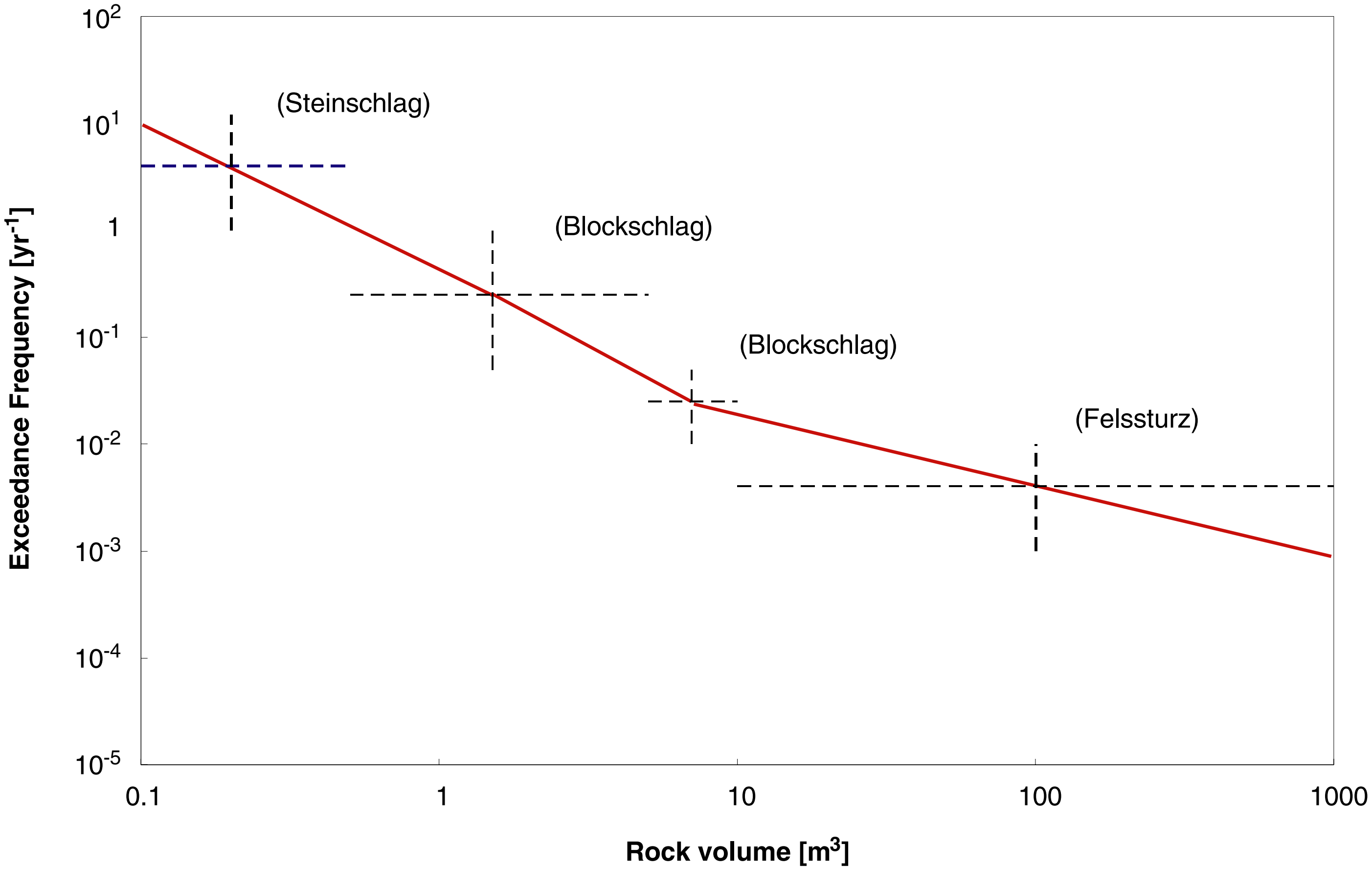
# Example rockfall: Representing uncertainty in the detachment process

- Information provided originally by the geologist



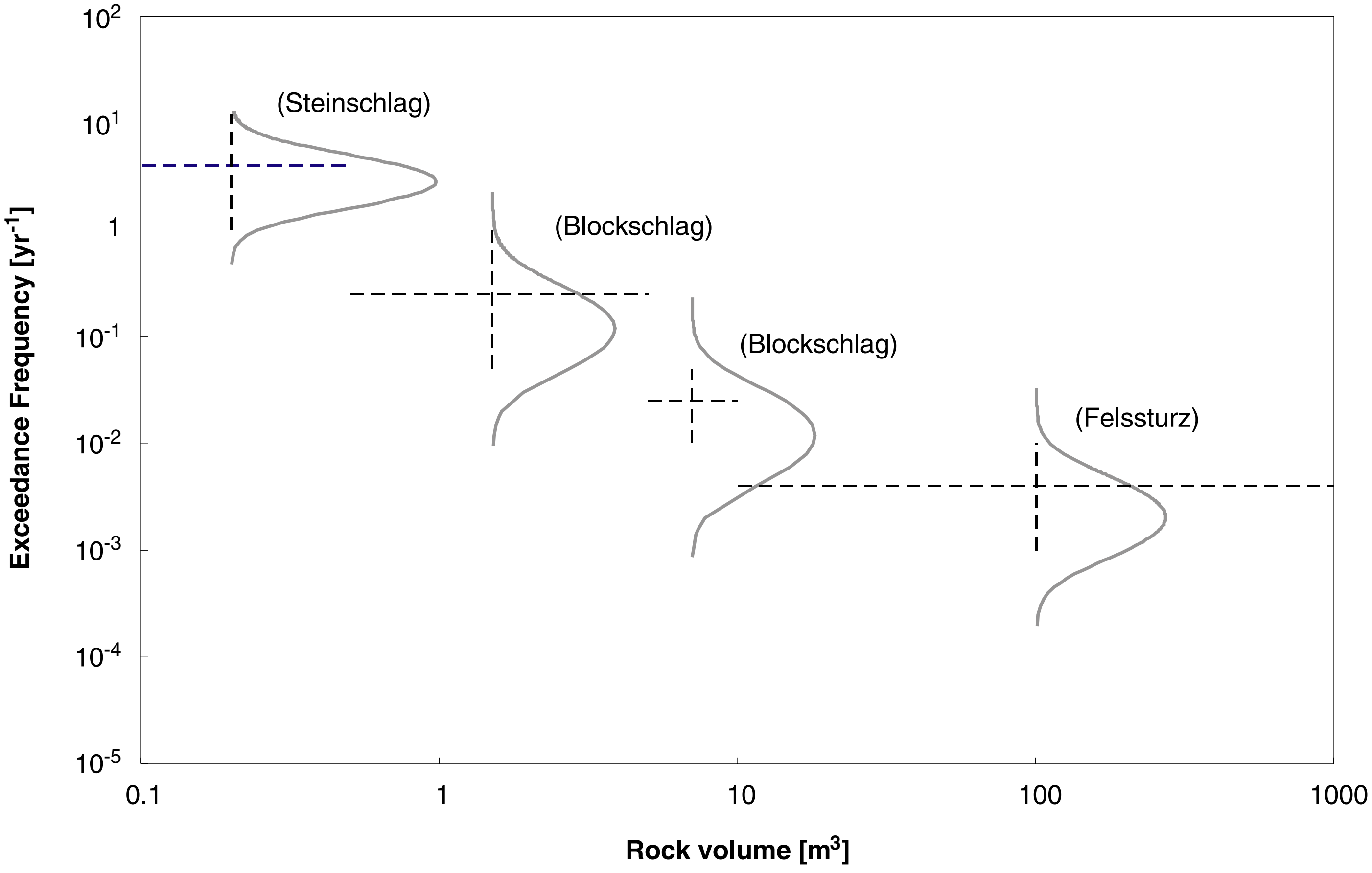
# Example rockfall: Representing uncertainty in the detachment process

- A simple model (not considering the uncertainties in the estimate)



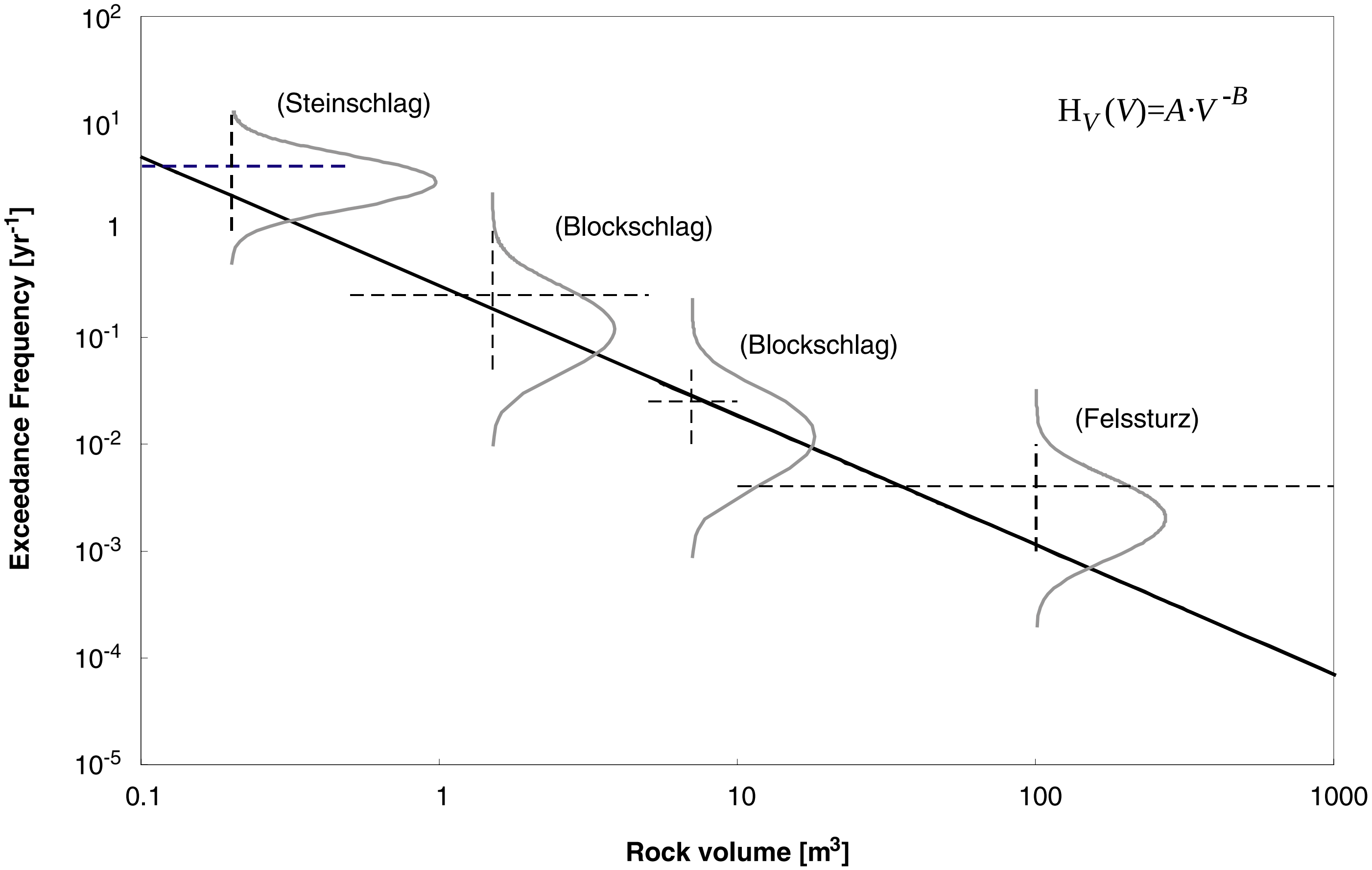
# Example rockfall: Representing uncertainty in the detachment process

- Modelling the uncertainties in the original estimation



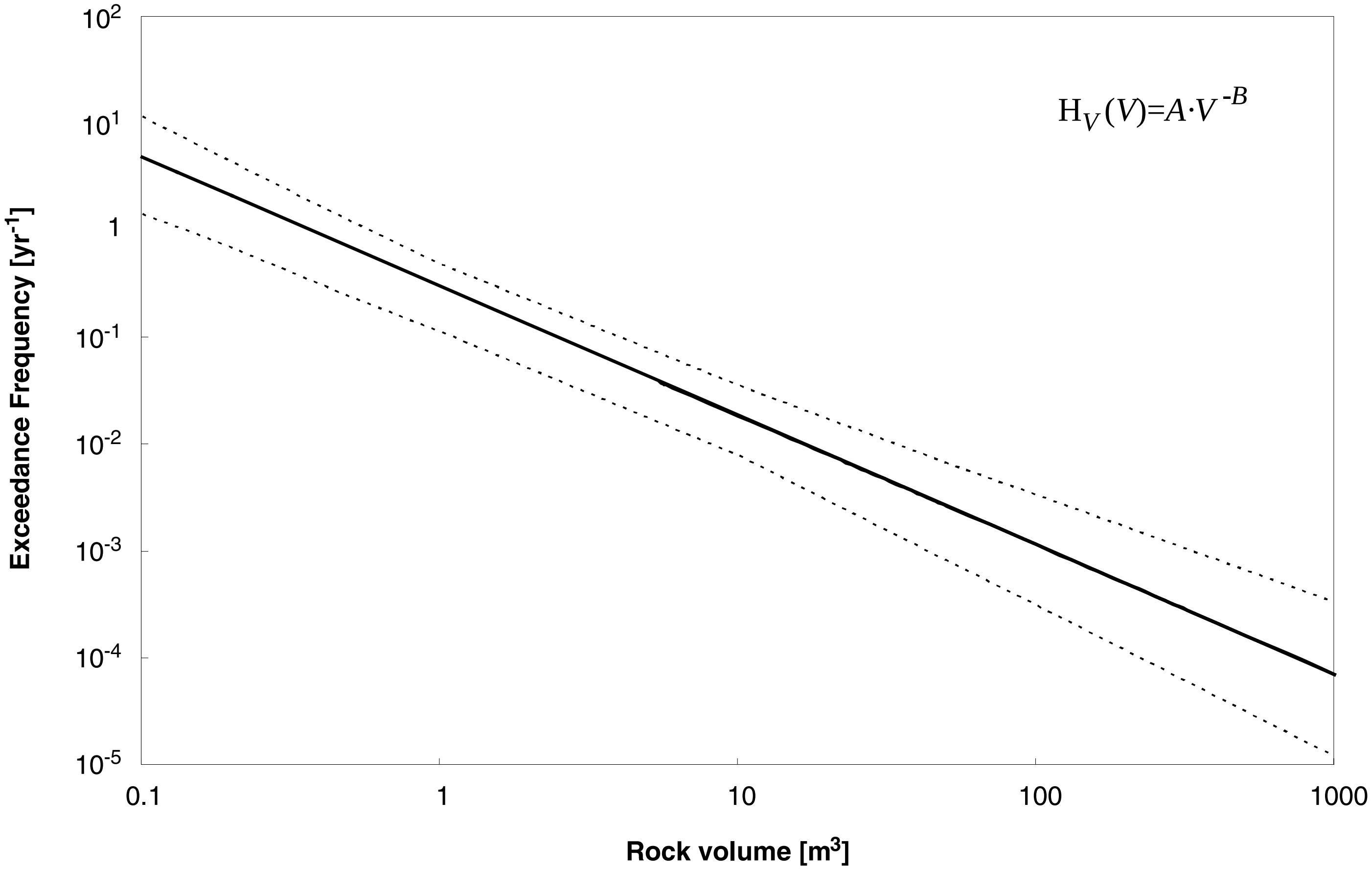
# Example rockfall: Representing uncertainty in the detachment process

- Fitting a parametric model to the estimates



# Example rockfall: Representing uncertainty in the detachment process

- Including the uncertainties in the estimate as obtained by a MLE



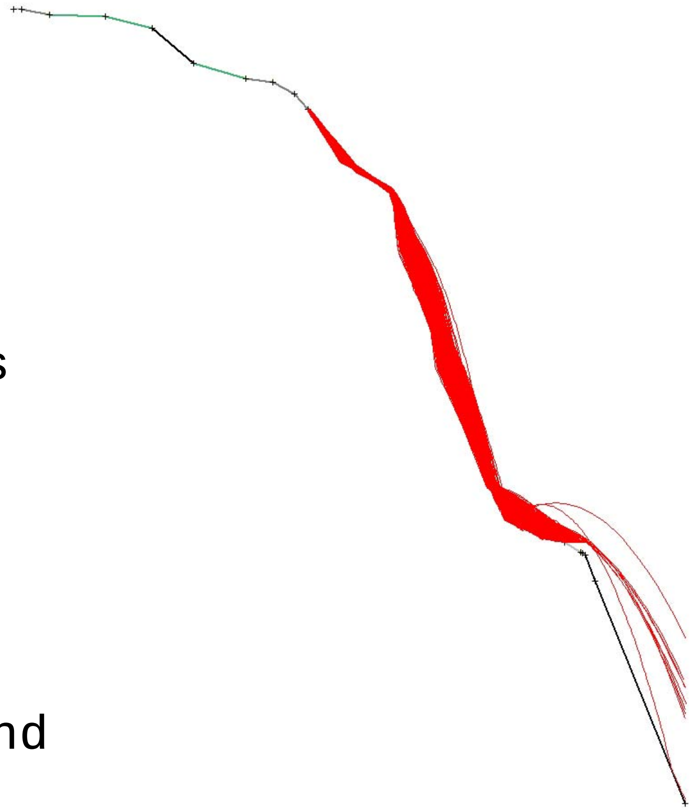
## Propagation of uncertainties

- Using stochastic tools such as

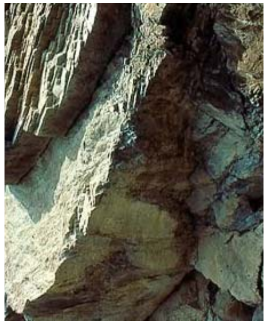
  - Structural Reliability Analysis
  - Monte Carlo Simulation
  - Direct integration

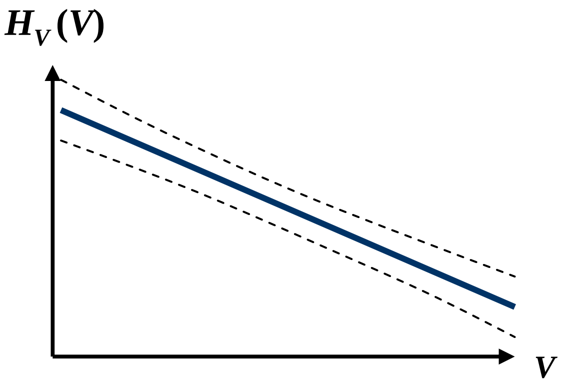
  the estimated exposure probabilities can be combined with the models describing the hazard propagation and the performance of defence structures.

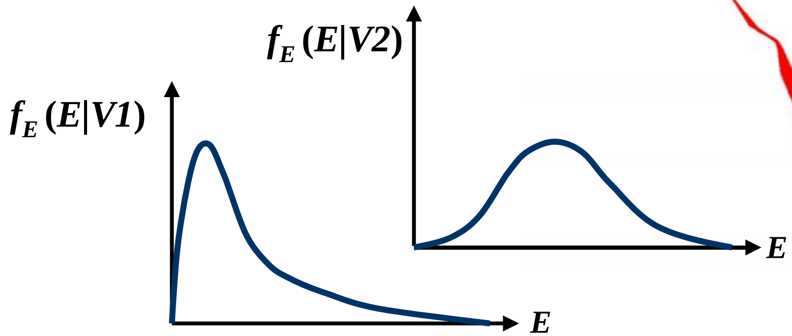
- The uncertainties in these models and their parameters can also be accounted for

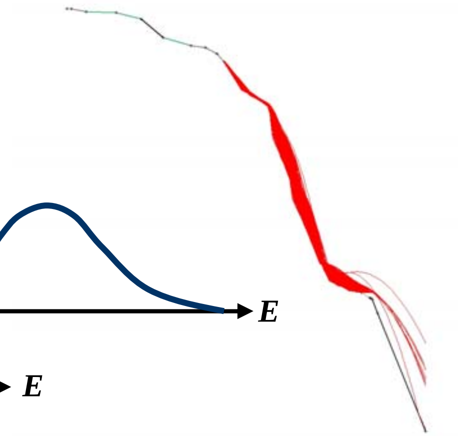


## Propagation of uncertainties: rockfall

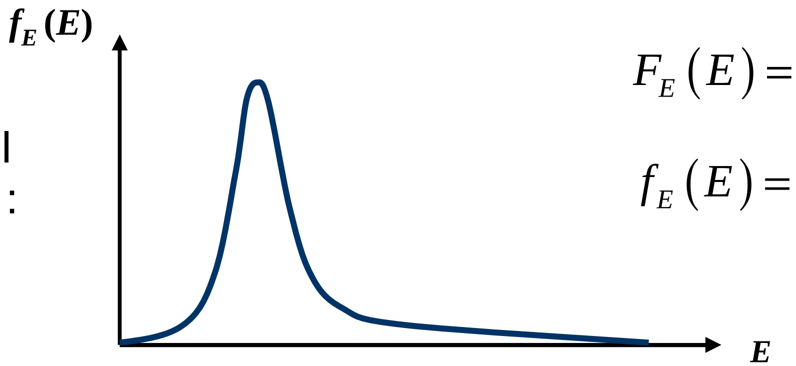




Distribution of the annual maximum impact energy:



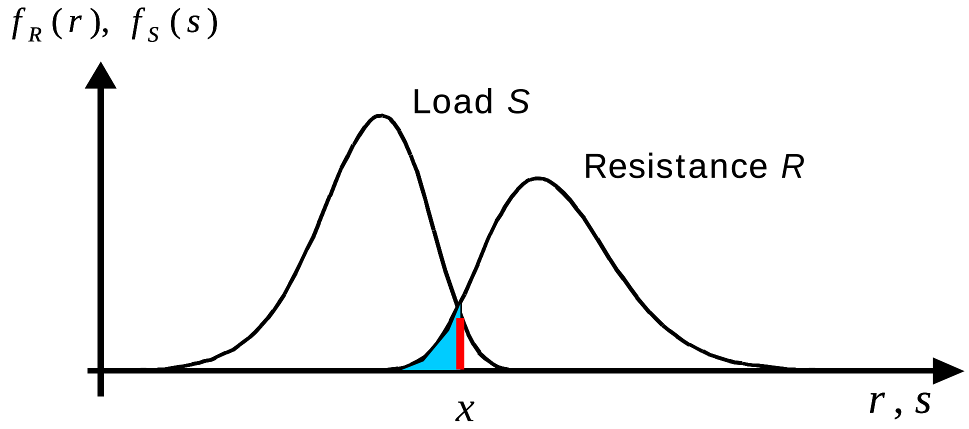

$$F_E(E) = 1 - e^{-\int_0^E \int_0^\infty f_E(E|V) h_V(V) \, \mathrm{d}V \, \mathrm{d}E}$$

$$f_E(E) = \frac{\mathrm{d}F_E(E)}{\mathrm{d}E}$$

## Propagation of uncertainties: protection gallery

- The risk is related to the probability of failure of the gallery, P(*F*)
- P(*F*) is determined by the fundamental structural reliability problem:

$$P(F) = P(R \leq S)$$




- For the rockfall case, *S* is represented by the distribution of *E*
- *R* is represented by a stochastic model of the gallery resistance

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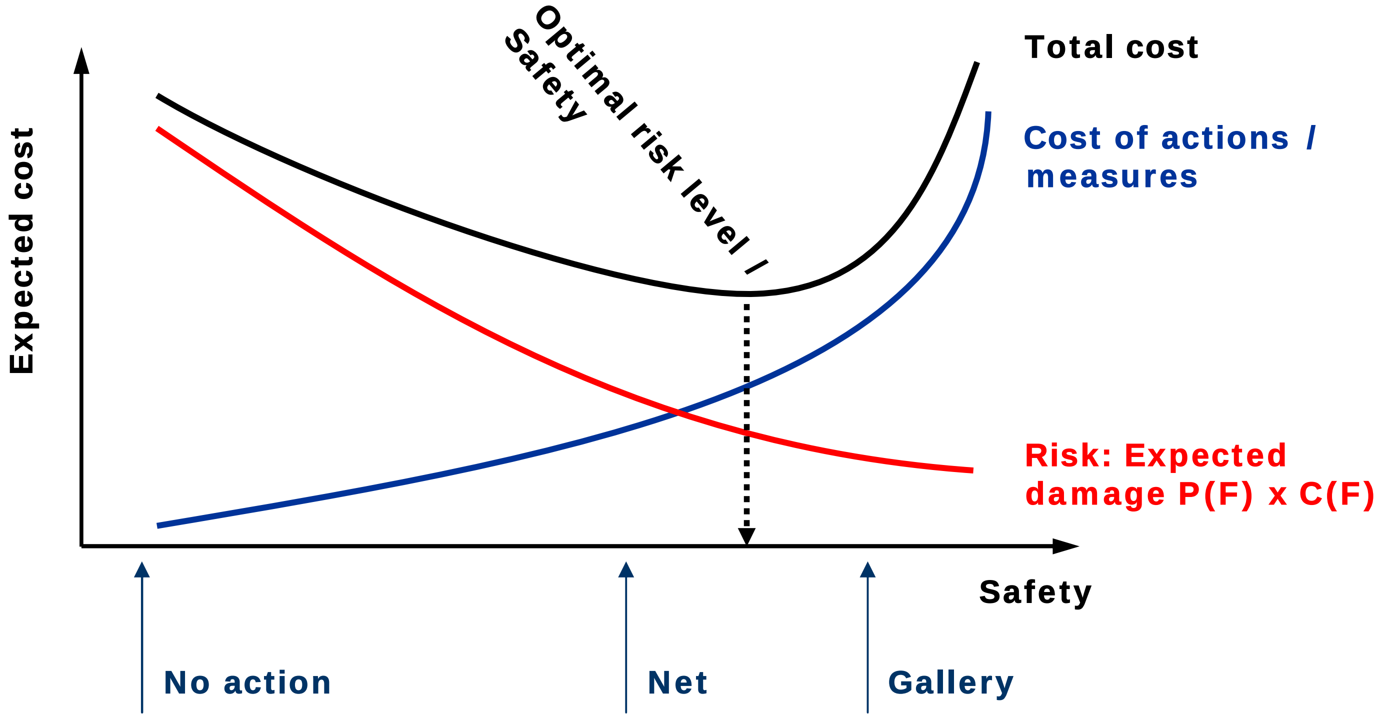
## Risk & Optimisation

- The risk is determined by combining (multiplying) the consequences with the probabilities of occurrence, here the failure of the gallery
- Taking into account the number of people and objects exposed
- The risk is decisive for the decision on the optimal measure/action to take

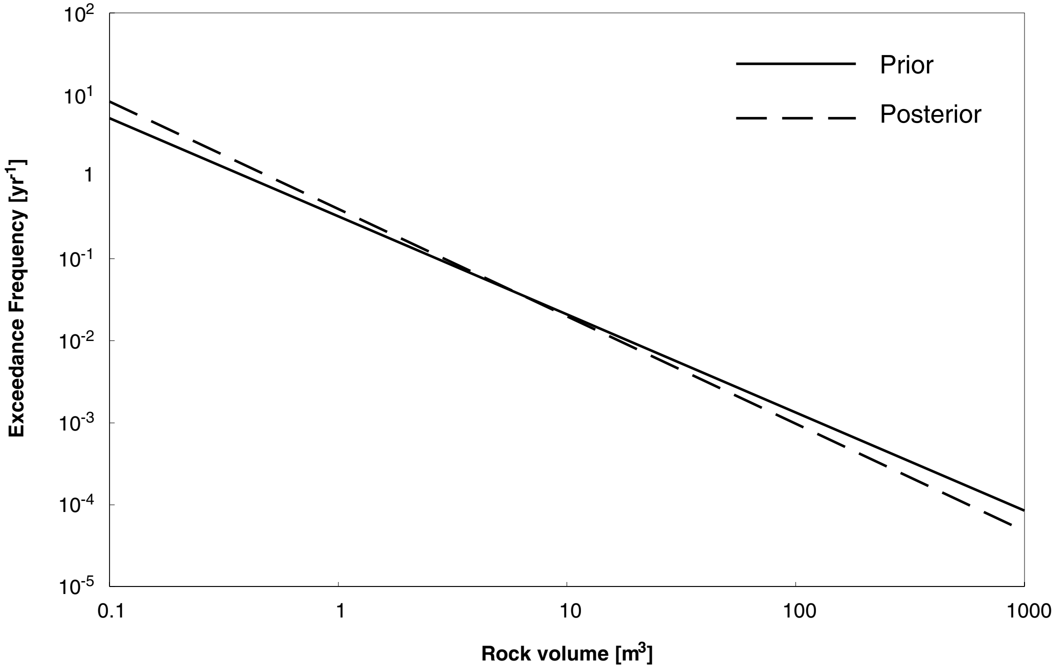


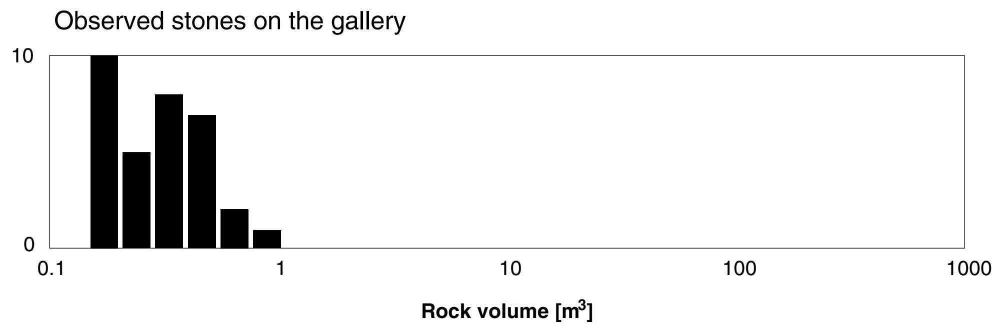
# Including additional information in the analysis

- When additional information (evidence) is available, this will reduce the uncertainty in the model.

- This additional information can be accounted for by updating the probabilistic model according to Bayes' rule.

- Example: The number of stones observed on and below the gallery at T=10yr.



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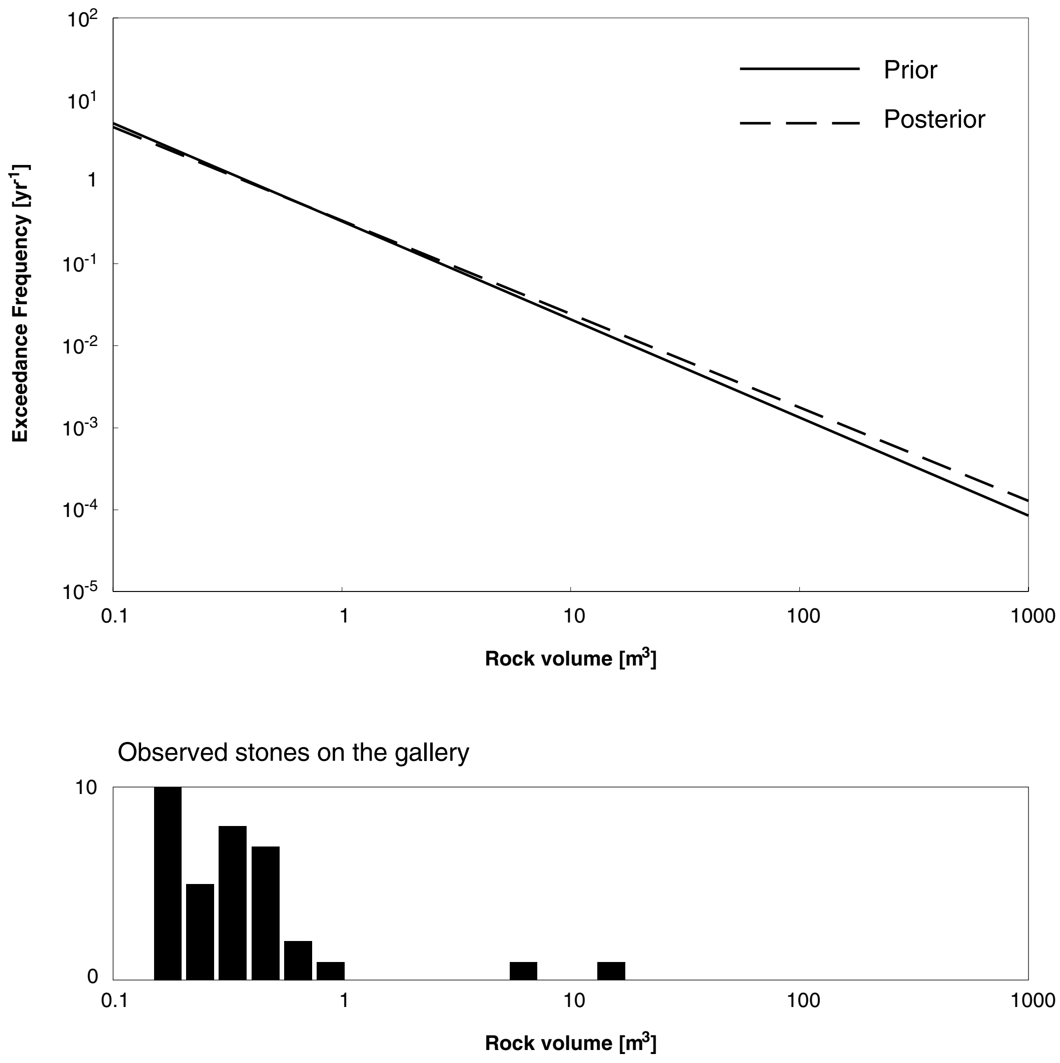
- Example: The number of stones observed on and below the gallery at T=10yr, modified



## Conclusions

- Uncertainties must be addressed to identify optimal decision in natural hazards management
- The outlined procedures allow for dealing with the uncertainties in a consistent and formalised manner
- All available information can be integrated in the model by means of Bayes' rule
- Care is needed when choosing the probabilistic models: Are the models really representing the considered (physical or other) processes?

## The end

Thank you for your attention!