Uncertainties and its Treatment

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Composition

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Preface

Often-mentioned concerns

A) In the case of natural phenomena, uncertainties in risk information are not necessarily quantifiable in many cases.

B) Using risk results of external hazard assessment for decision making has large uncertainties, which makes it even more difficult.

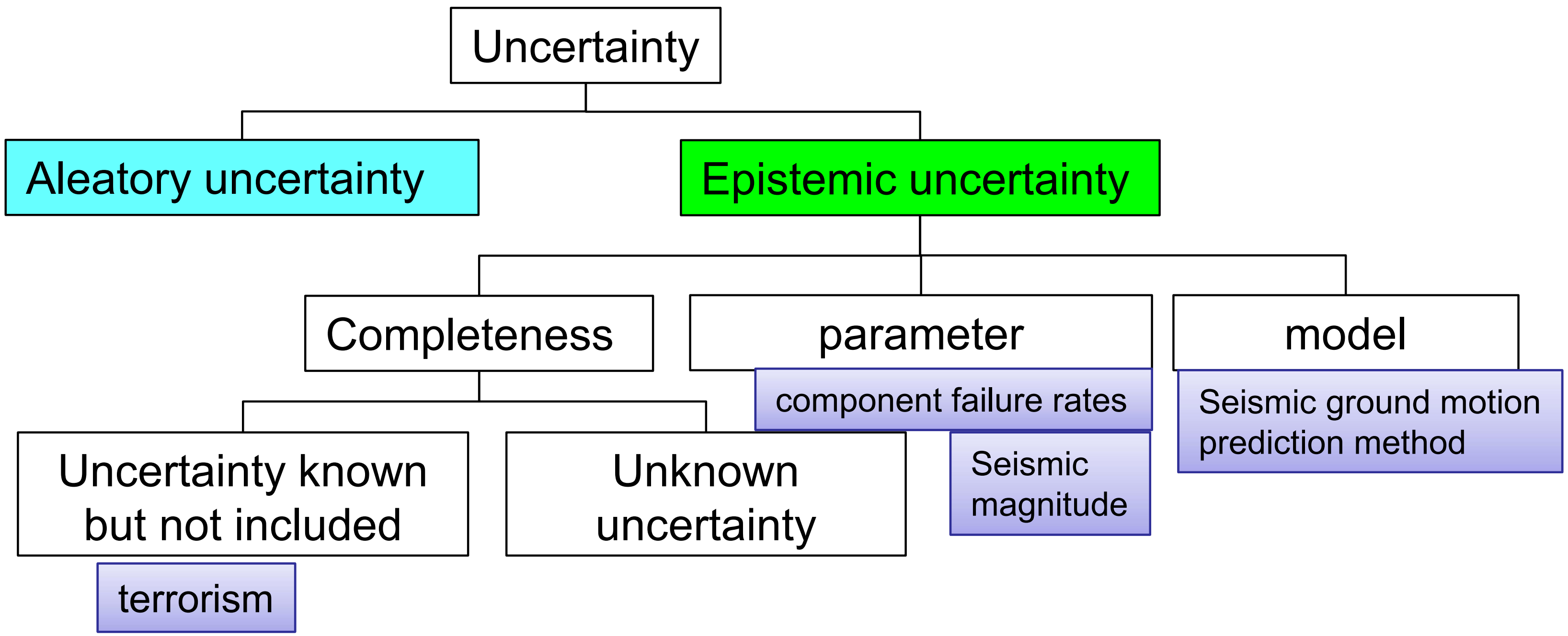
Purpose of this presentation

- The first and most common approach to quantifying uncertainty is through probabilistic methods (PRA).
  - ➢ PRA could be more accurately described as an uncertainty quantification method.
  - ➢ PRA maximizes the utilization of current data and knowledge to perform quantitative analysis.

Uncertainties and its treatment

- **Guidance: NUREG-1855, AESJ-SC-TR011**
- Understand and quantify the uncertainties at each evaluation stage.

Types of uncertainty



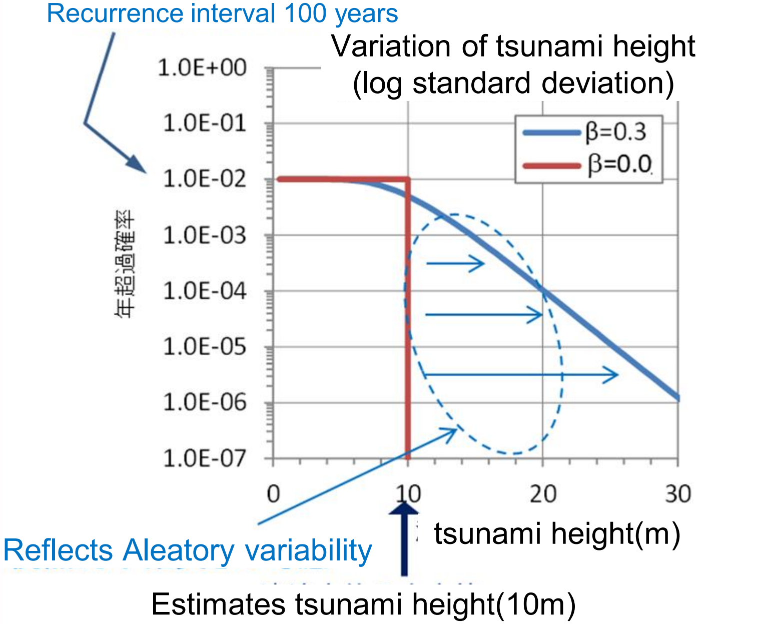
- USNRC、NUREG-1855(2017):Guidance on the Treatment of Uncertainties Associated with PRAs in Risk-Informed Decision Making
- AESJ, AESJ-SC-TR011(2015):To understand risk assessment

Example of treating uncertainty: Tsunami

Tsunami height of a certain wave source (earthquake): 10m
Average interval of earthquakes: 50 years (weight 0.25), 100 years (0.5), 200 years (0.25)

①偶然的不確実さ(aleatory variability)

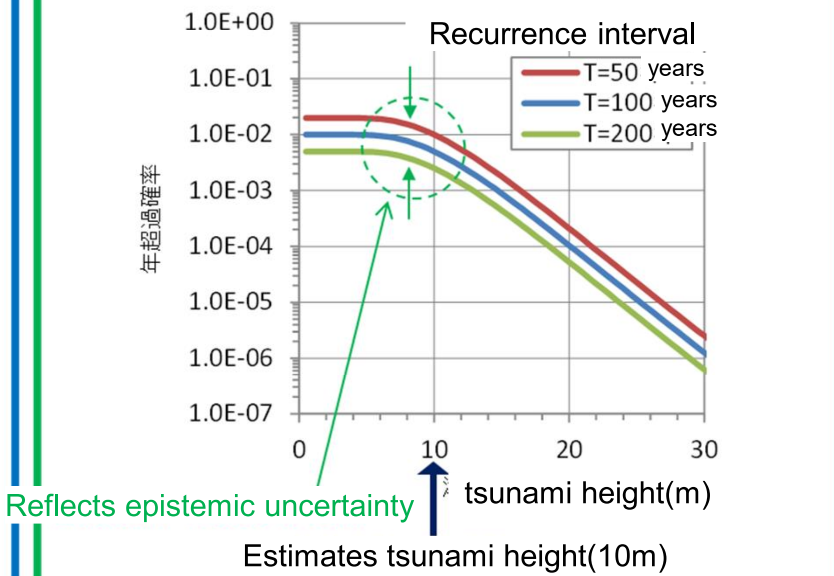
- Due to the inherent randomness of physical phenomena.
- Unpredictable
- Considered within a single tsunami hazard curve



Quantify as a probability distribution

②認識論的不確実さ(epistemic uncertainty)

- Uncertainty due to lack of knowledge
- Unpredictable at present, although it can be determined with the progress of research
- Considered as a branch of the logic tree and expressed in multiple tsunami hazard curves



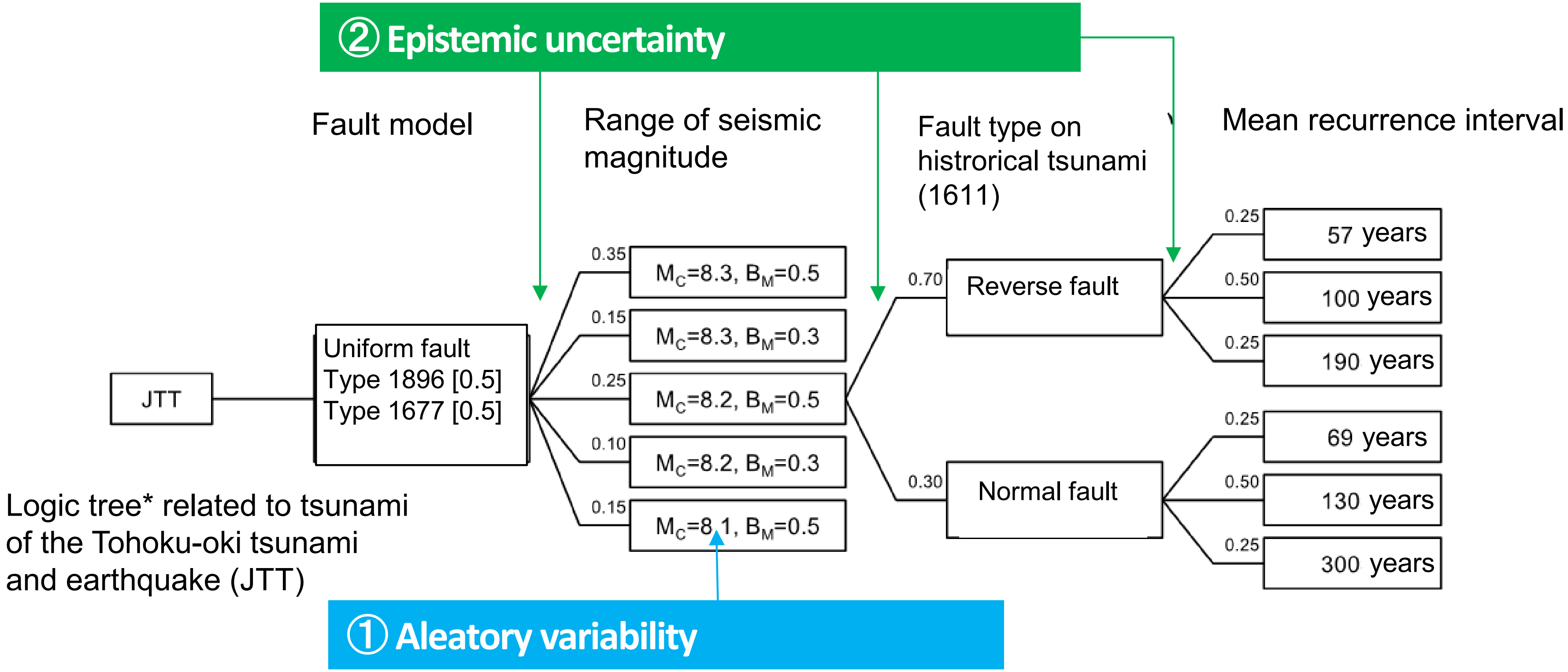
Quantify the weights distribution of logic tree branches

Epistemic uncertainty

- Three uncertainties: NUREG-1855
  - Completeness Uncertainty
    - Tsunami due to meteorite impact → Not considered as frequency is small.
  - Parameter Uncertainty
    - Mean recurrence interval of earthquakes
    - Maximum seismic magnitude (scale)
  - Model Uncertainty
    - Multiple fault models proposed for earthquake
    - Seismic PRA (not tsunami): Many kinds of seismic motion prediction methods

Aleatory variability

- Epistemic uncertainty is organized in the following logic tree as an example



Uncertainties are quantitatively assessed to prepare many tsunami scenarios

Scenarios can be developed for a massive earthquake

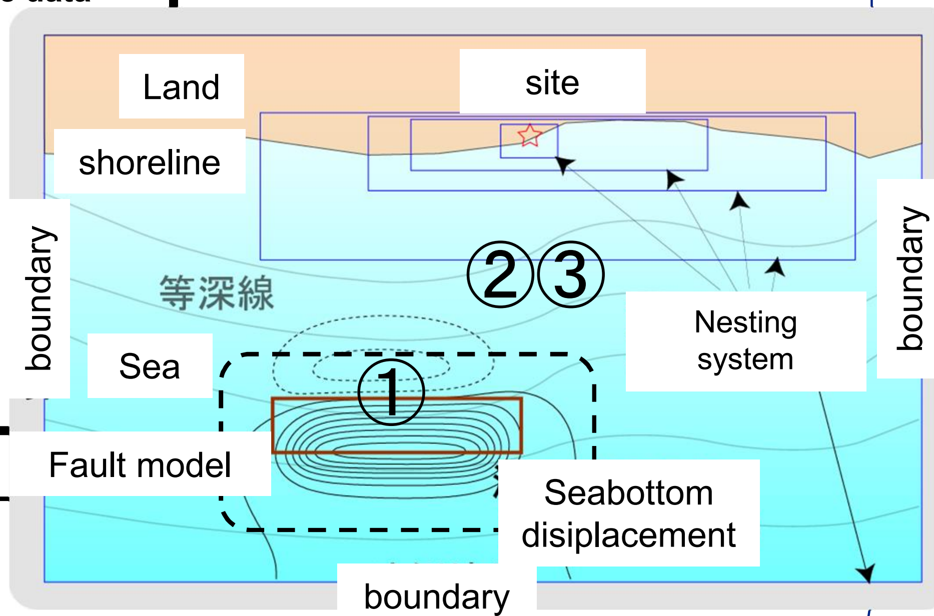
*Tsunami Assessment Method for Nuclear Power Plants in Japan 2016 (Japan Society of Civil Engineers)

Uncertainties considered in tsunami hazard assessment

- Quantification of uncertainties in the analysis of propagation from tsunami source

Mean recurrence interval

① Uncertainty of earthquake (tsunami source)	② Uncertainty in numerical analysis	③ Uncertainty of data
･fault position ･Strike angle ･Depth of fault ･rake angle ･Slip angle ･Combination of fault segments ･Maximum siemic maginituide ･Scaling rule ･Slip heterogeneity, etc.	･Fundamental equation ･Calculation scheme ･Initial conditions ･Boundary conditions ･Computational grid partitioning ･Various coefficients ･Reproduction time	･Errors in submarine and coastal topographic data



Dominant and carefully modeled

Quantitative assessment considering uncertainty of tsunami height for the optimum wave source model

Consideration of variation from measured records of reproduction models of existing tsunami

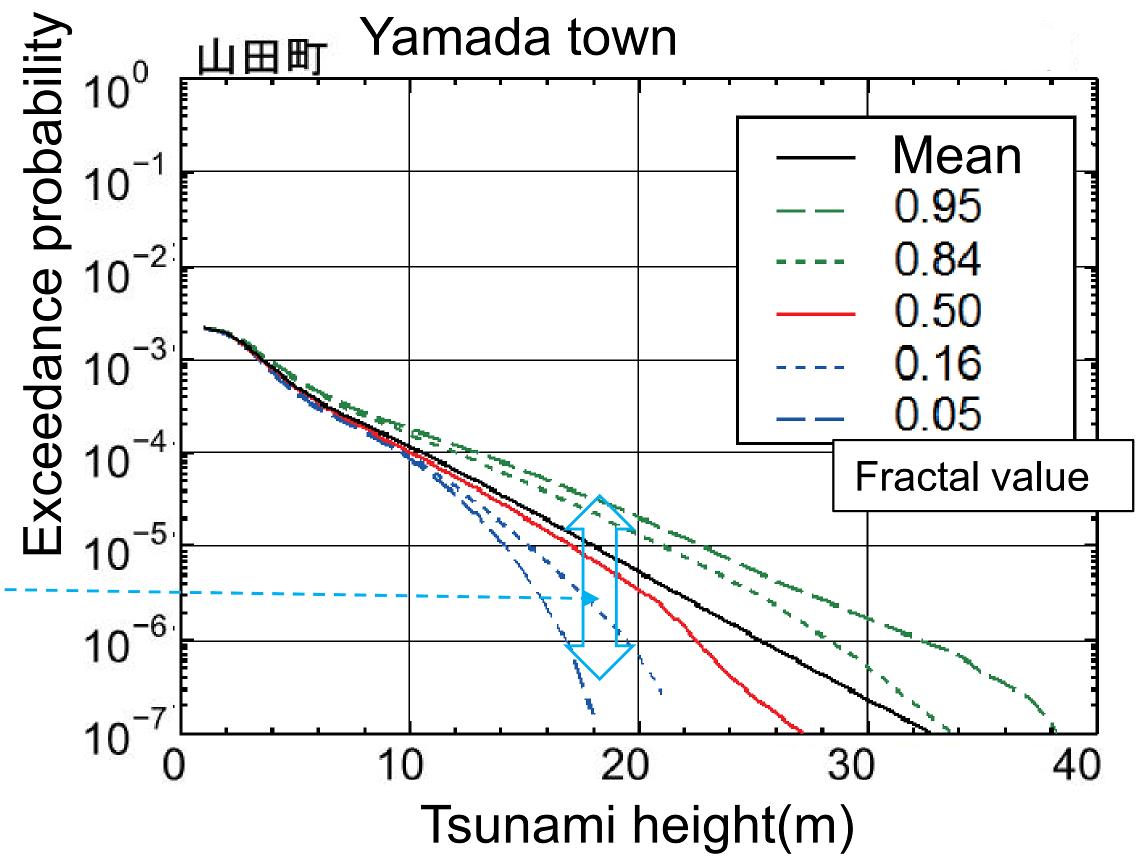
Aleatory
- **Variation κ: ln(κ)**

Epistemic
- **Size of κ**

Example of probabilistic tsunami hazard assessment

- Quantitative assessment of annual exceedance probability of massive tsunami over 20m on the coast
- In PRA, risk assessment is possible by continuously assuming tsunami scenarios exceeding the seawall height
- Spread of the fractal curve indicates the range of epistemic uncertainty → use in RIDM
- There is no rapid expansion of earthquake history data. However, it is possible and important to update data by incorporating new knowledge.

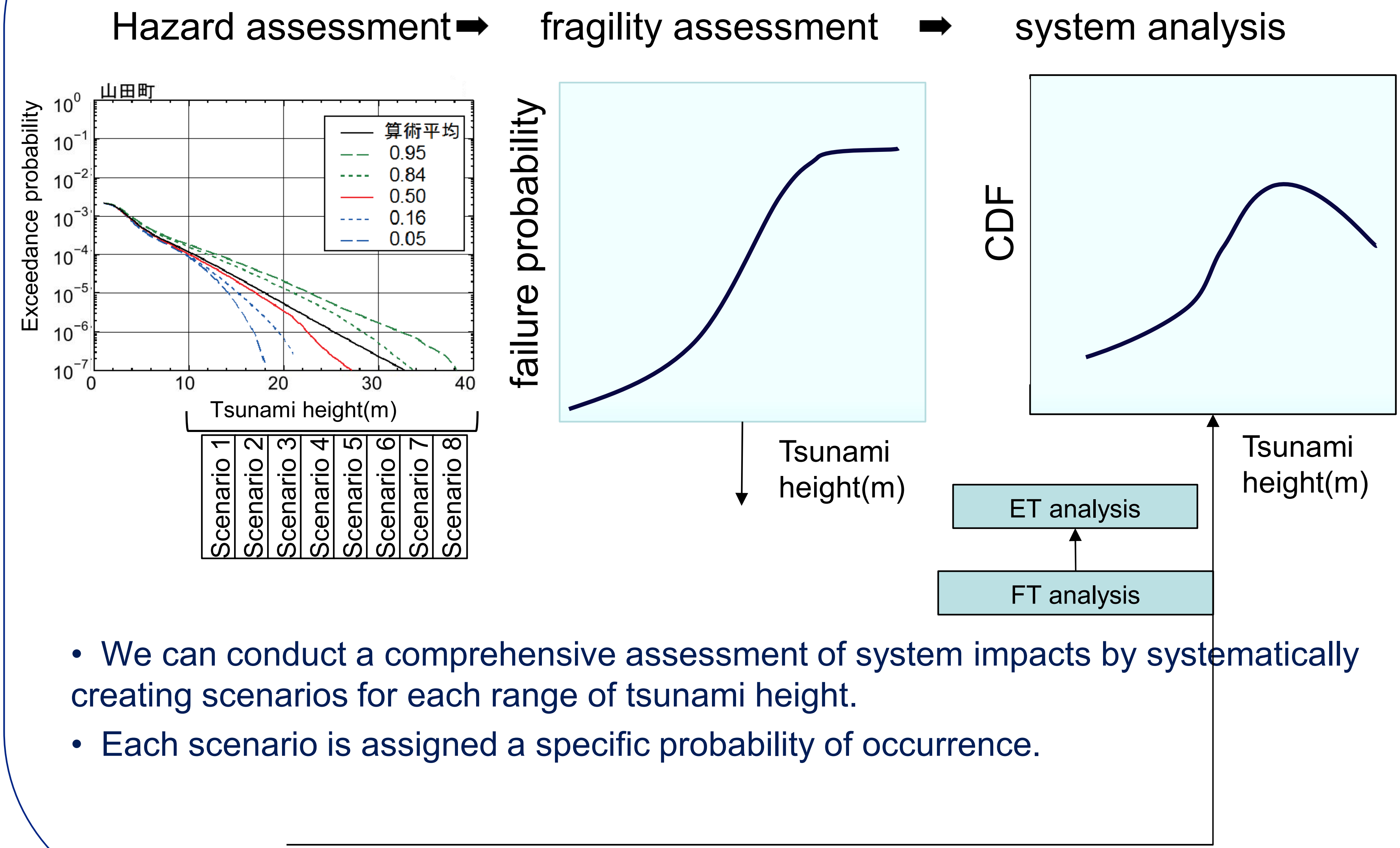
Utilization of SSHAC method



Assessment example* of fractal tsunami hazard curve and arithmetic mean hazard curve

*Tsunami Assessment Method for Nuclear Power Plants in Japan 2016 (Japan Society of Civil Engineers)

Use of hazard assessment for PRA

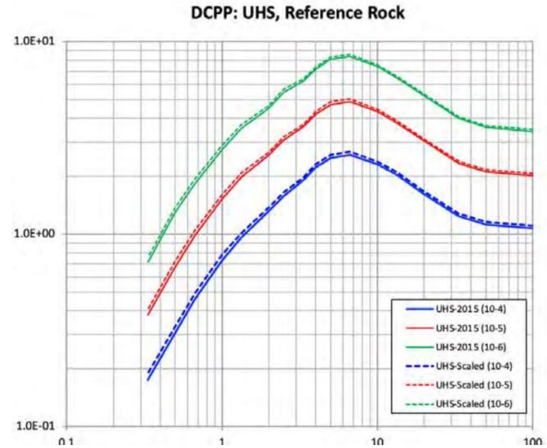


- We can conduct a comprehensive assessment of system impacts by systematically creating scenarios for each range of tsunami height.
- Each scenario is assigned a specific probability of occurrence.

*Tsunami Assessment Method for Nuclear Power Plants in Japan 2016 (Japan Society of Civil Engineers)

Seismic PRA (SPRA) in U.S.

- Diablo Canyon Power Plant(DCPP) Unit 1(1985)、Unit 2(1986)
  - ➢ Long Term Seismic Program(LTSP)
  - ➢ 1988: SPRA Update : Improvements Below
    - Reinforcement of diesel generator (DG) fuel supply system, cooling system, and addition of substation spare parts.
  - ➢ 2018: SPRA report**
    - Following the Fukushima Daiichi accident, deterministic seismic risk assessment was first conducted.
    - Probabilistic seismic hazard re-assessment by SSHAC level3 (2015)
    - Following these results, SPRA have been updated.
      - – There is no increased risk requiring additional seismic hazard mitigation measures.
      - – Improve the vulnerabilities found in the supply air duct during this process
  - ➢ 2024: Diablo Canyon Updated Seismic Assessment ***
    - Seismic Hazard re-assessment by SSHAC level 1
    - SPRA results have been updated →
      - – The total frequency of core damage (CDF) and large early release frequency (LERF) is below the target value.
      - – The changes in ΔCDF and ΔLERF due to the seismic hazard update are also small.
  - ➢ others：Application of probabilistic fault displace assessment



UHS from the 2015 study (solid lines) and the updated results (dashed lines) for hazard levels of 10-4 (blue lines), 10-5 (red lines), and 10-6 (green lines) ***

Enhancements in the quantification of hazard uncertainty, with a focus on incorporating new findings.
Continuously conduct risk assessments that include seismic hazards and take necessary actions.

*D. C. Bley et. al, Enhanced Seismic Risk Assessment on the Diablo Canyon Power Plant, SMiRT10, 1989.
**PG&E Letter DCL-18-027, 2018, https://www.nrc.gov/docs/ML1812/ML18120A201.pdf
*** PG&E, Diablo Canyon Updated Seismic Assessment, 2024.

Conclusion

- PRA can be used to quantify uncertainty, even when uncertainty is high.
  - ➢ The most effective method for quantifying and understanding uncertainty at present
    - In Japan, where uncertainty related to natural external events is significant, this approach should be adopted.
    - It is possible to update this to reflect new findings.
    - In the US, earthquake PRA is used for decision making continuously.