

Probabilistic Fault Displacement
Hazard Analysis
Krško Site
Presentation to
Slovenian Nuclear Safety
Administration

April 26, 2013

Engineering & Construction Management
Hydro-Nuclear-Fossil
Geotechnical Engineering
Seismic & Structural Engineering
Hydrological & Hydraulic Engineering
Tunnel Engineering
Environmental Engineering & Permitting

Overview - PFDHA

- Introduction
- Probabilistic Fault Displacement Hazard Analysis
 - Methodology
 - Inputs
 - Results
 - Sensitivity Analysis
 - Peer Review
- Conclusions

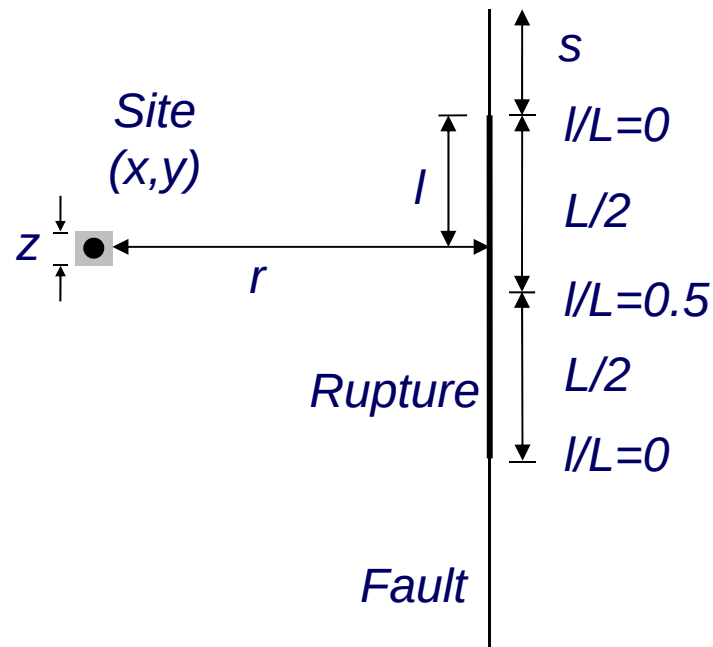
PFDHA Project

- Purpose
 - If any faults are capable, what would be the impact for nuclear safety?
 - Probabilistically evaluate fault displacement hazard to support utility and regulatory decision-making following IAEA SSG-9
- Scope
 - Phase 1 – Base-Case PFDHA
 - Phase 2 – PFDHA sensitivity analyses

Methodology

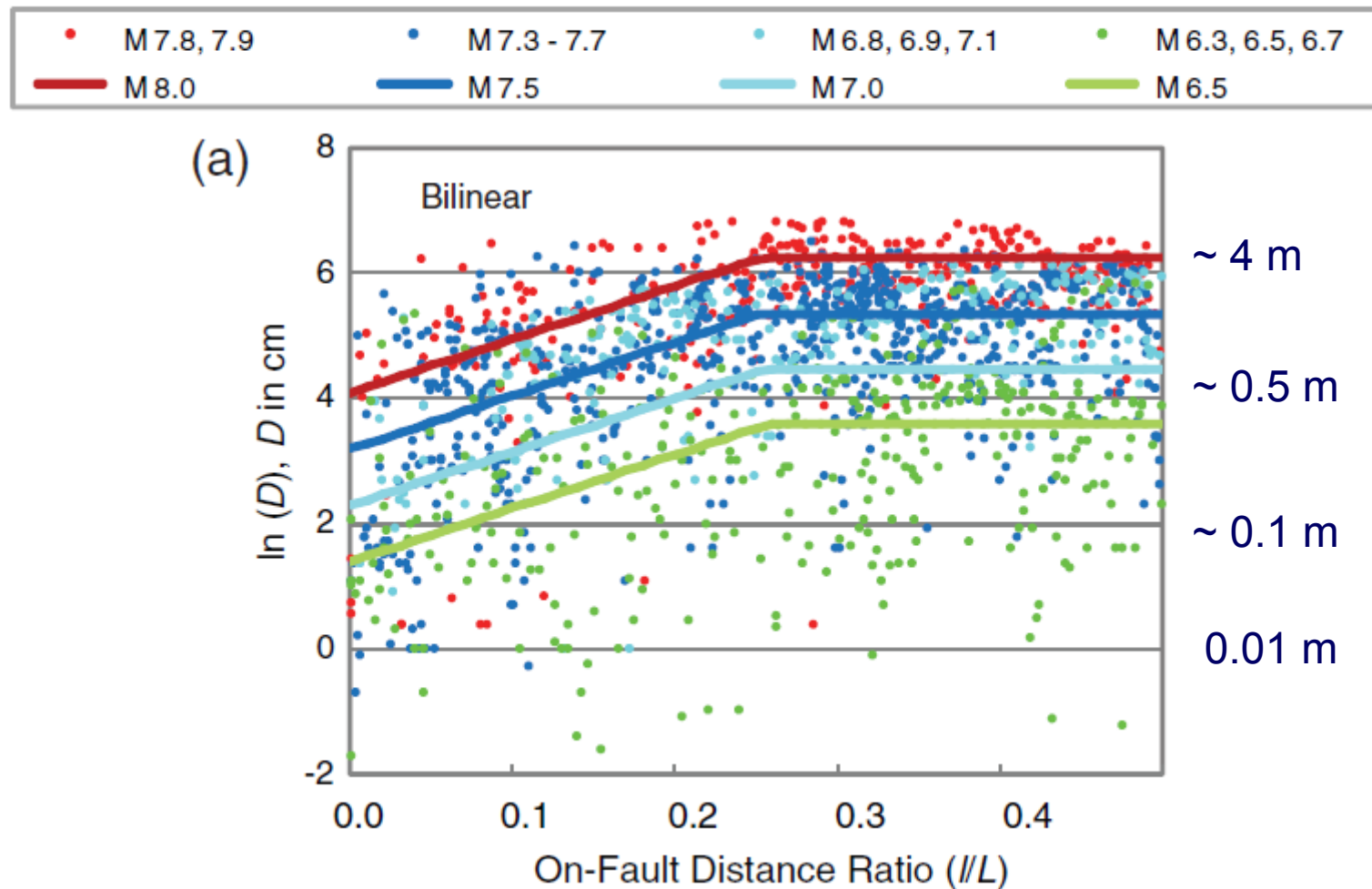
- Use approach of Petersen et al. (2011)
 - Treats displacement occurring both on-fault (principal) and off-fault (distributed)
 - Accounts for uncertainty related to fault mapping accuracy & fault complexity
 - On-fault and off-fault displacement probability distributions developed from database of strike-slip ruptures

PFDHA Methodology



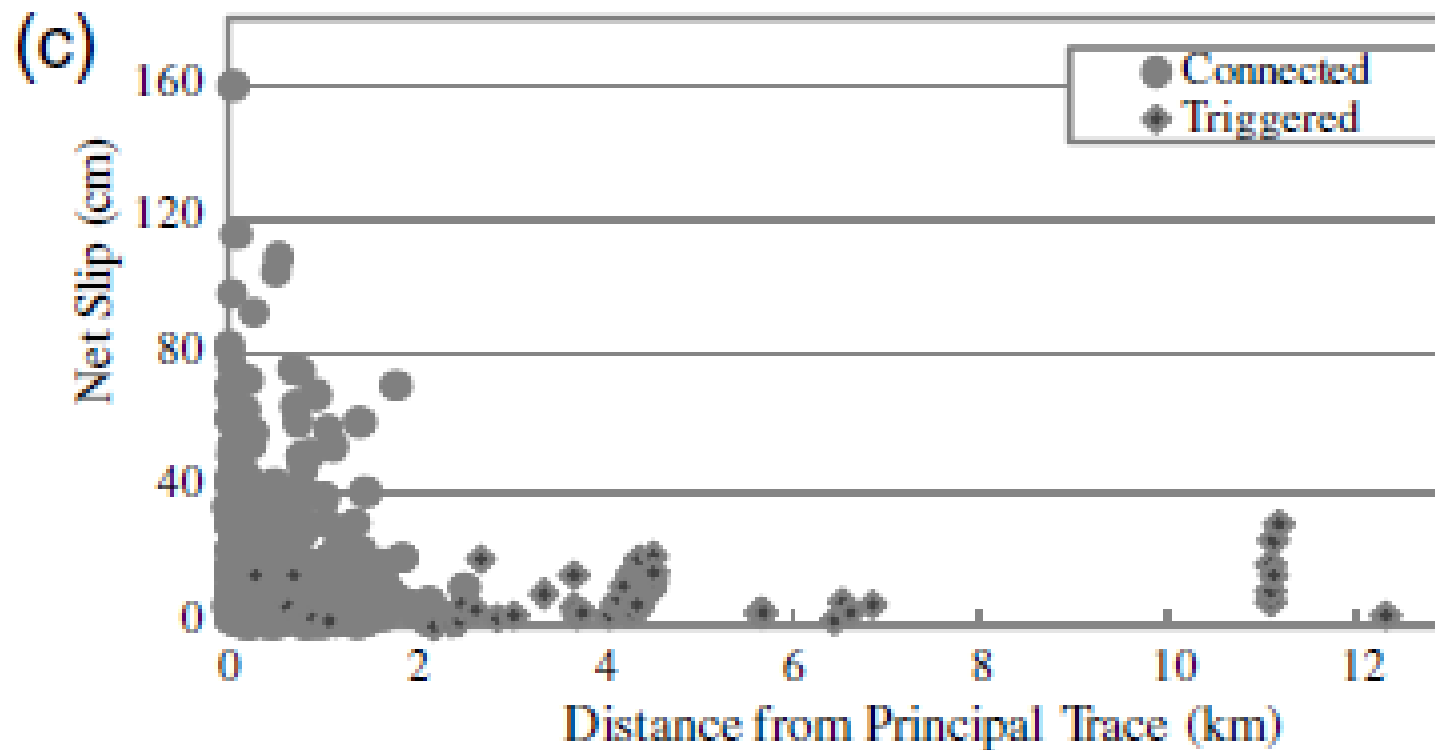
- Site located at (x, y)
- Footprint area of z^2
- Site is located at distance r from the fault rupture
- Distance l is measured from the nearest point on the rupture to the closest end of the rupture of length $= L$

On-fault Displacement



Petersen et al. (2011)

Off-fault Displacement

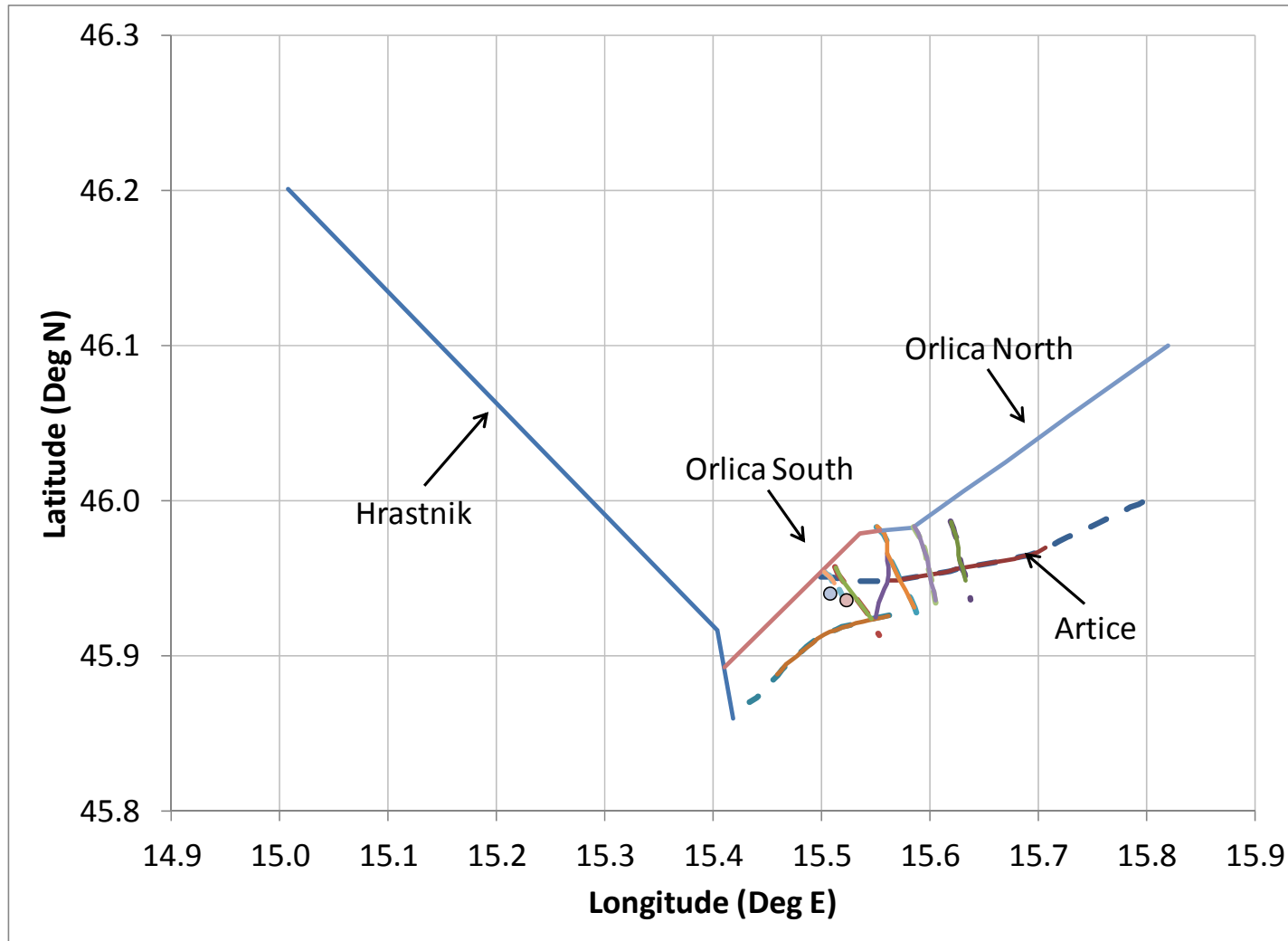


Petersen et al. (2011)

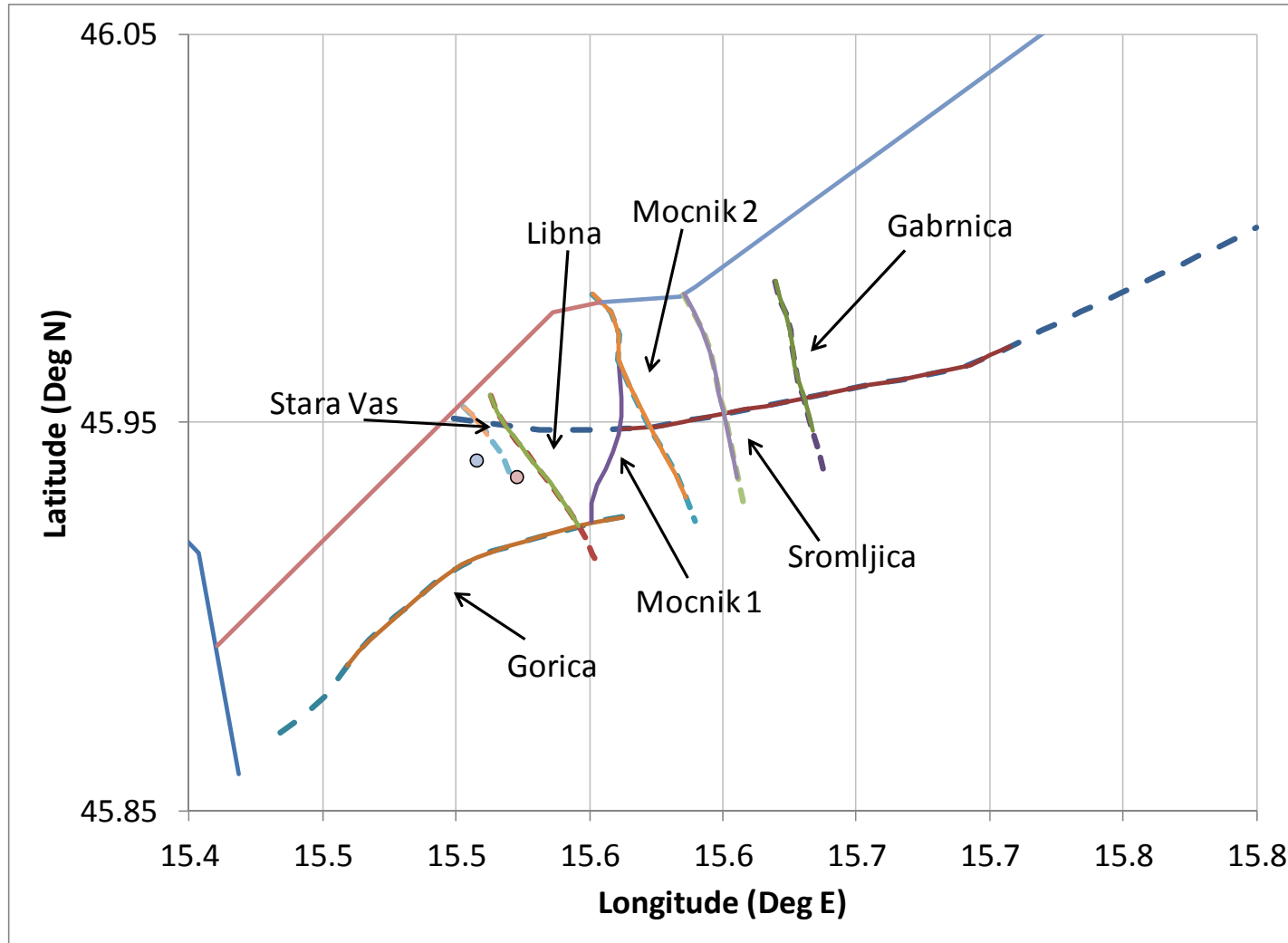
Inputs

- Characterize fault sources
 - Goal: Represent center, body, and range of technically defensible interpretations
 - Logic tree accounts for epistemic uncertainty
 - Inputs are based on knowledge as of May 2011
 - Account for results of Consortium's work
- Results comprise the “base-case”

Source Faults



Source Faults



Characterization

- Probability of activity
- Fault/rupture length
- Frequency-magnitude distribution
 - Slip-rate based, using b-value and Mmax
 - Slip-rates range from 0.001 to 0.25 mm/yr
 - Mmax based on regression relations between magnitude and rupture characteristics
 - b-value taken from existing PSHA

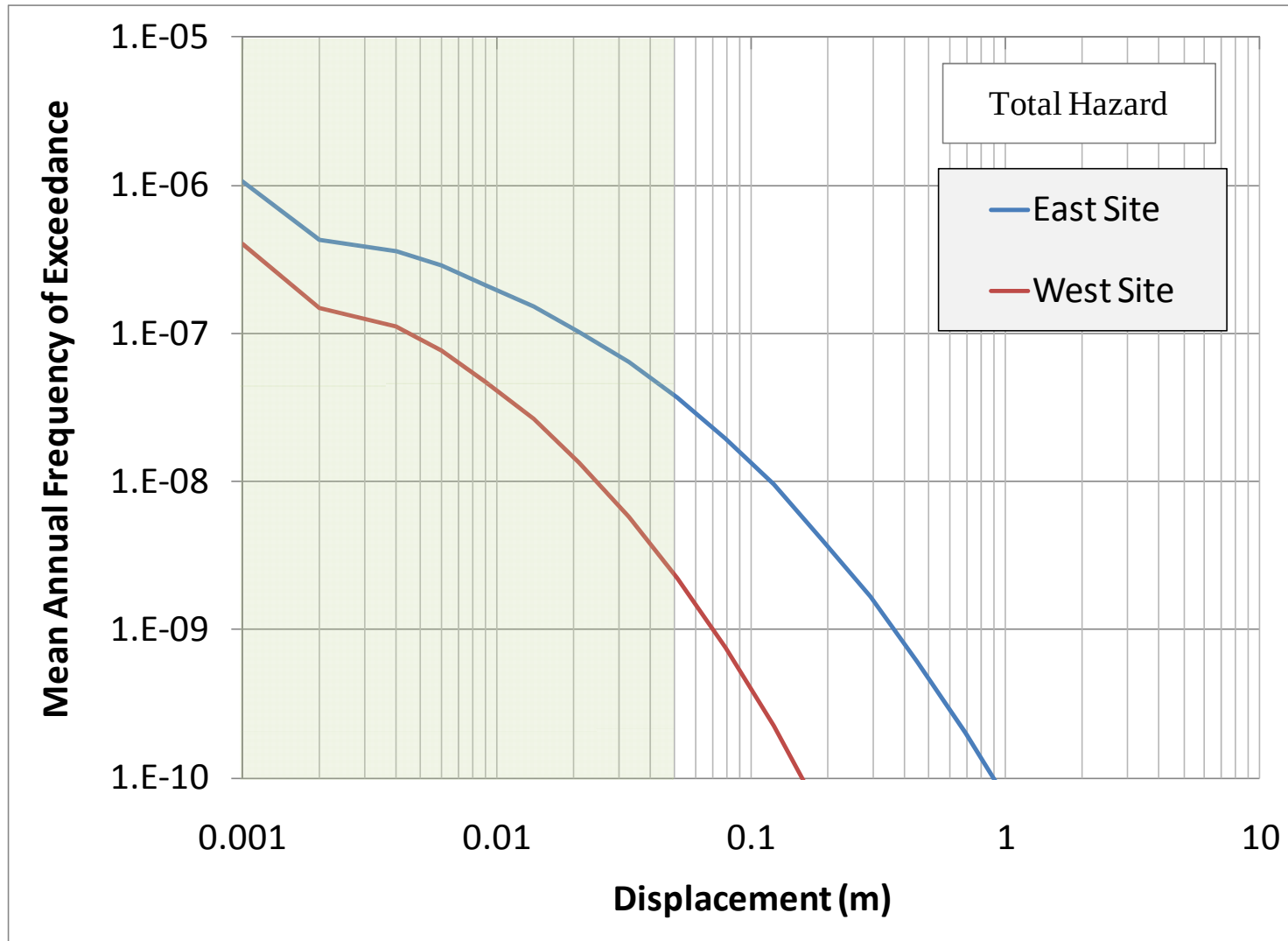
Characterization

- Fault mapping accuracy and fault complexity
 - Inferred and complex ($\sigma = 116$ m)
 - Location distribution is truncated at 2σ
- Hazard calculation cell size (z^2)
 - 200 m x 200 m

Characterization

- Displacement models
 - Multivariate (0.6), normalized (0.4)
 - Three multivariate approaches – 1/3 weight each

Base-case Results



Base-case Results

- For 0.001 m
 - Mean annual frequency of exceedance
 - East Site = 10^{-6}
 - West Site = 3×10^{-7}
 - Both exceedance frequencies are lower than that associated with severe accidents and a LERF
- For 50 to 100 mm – considered to be of engineering significance for an NPP
 - Annual frequency of exceedance is $< 10^{-8}$ & 10^{-9}

Sensitivity Analysis

- Purpose
 - Evaluate robustness: How sensitive are the PFDHA results to variation in the inputs?
 - Understand relation between inputs and outputs: What are the more important inputs?

Sensitivity Analysis

- Inputs for which sensitivity is evaluated
 - Probability of activity (Case A)
 - Fault length (Case B)
 - Fault location (Case C)
 - Slip rate (Case D)
 - Maximum magnitude (Case E)
 - Hazard calculation cell size (Case F)
- Cases are “one-factor-at-a-time”

Sensitivity Analysis

- Summary of sensitivity findings
 - Faults close to the site are important because they contribute on-fault displacement hazard
 - No sensitivity case gave a mean annual frequency of exceedance greater than 4×10^{-6} for a displacement level of 0.001 m (1 mm)
 - For displacement levels of engineering significance (> 5 cm), exceedance frequencies are an order of magnitude lower

Peer Review

- Peer Review Panel
 - Drs. Gurpinar, Serva, Costantino
 - Comments included:
 - Fault displacement not a concern for Krško site
 - Conservative choices made in characterization
 - Site conditions may attenuate displacements

Status

- Hazard calculations being updated to account for Peer Review Panel feedback
- Final results expected in May 2013

Conclusions

- PFDHA takes into account uncertainties in interpretations and provides a basis for assessment of safety significance of capable faults, if any are identified

Questions?