Delta Risk Management Strategy
Seismic Fragility Analysis

Lessons & Questions

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Sacramento-San Joaquin Delta
Delta Levees

Delta Levees Dams

- Imagine a ‘dam’ 1,110 miles long
- Large fraction of the total length has blow counts of 20 or less; 80+ % liquefiable material
- What is the seismic fragility/ reliability of the ‘system’?
- How many ‘breaches’?
  - Number, or
  - Per mile
- How confident are we in the results?
Levee ‘Design’ & Construction
Elements of a Seismic Risk Analysis

- Hazards Analysis
- Fragility Analysis
- Systems Analysis
- Inundation/Hydrodynamic Assessment
- Emergency Response & Repair
- Consequence Assessment

Risk Quantification & Uncertainty Analysis
What We Want to Predict: Breaching
We Also Want to Predict: Non-Breach Damaged

7 feet
Fragility Representation

\[ P(f|\text{Ground Motion}) \]

Ground Motion Characterization
Levee Fragility Analysis

• Fragility analysis estimates the conditional probability of failure as a function of a loading parameter (ground motion; elevation)
• For earthquake and flood (geotechnical) failures there is considerable uncertainty in estimating when failure occurs and how likely it is to occur
• Sources of uncertainty:
  – Defining the failure/performance state
  – Model uncertainties (modeling the ‘real’ world)
  – Estimating model parameters (prior to and at failure)
Fragility Results

Delta

New Orleans

St. Charles - SC1 - pre-Katrina

Orleans Main - OM12 - Pre-Katrina
Defining Failure / Estimating the Fraction of Times It Occurs
(Aleatory Uncertainty)

• Given calculated vertical deformations, when does failure occur?

• What fraction of the time will it occur?

• How certain are we?
One Experts Results
Expert Results

Conditional Probability of Failure vs Vertical Deformation / Initial Freeboard
Probability Distribution in the Displacement Fragility of Levees

(Epistemic Uncertainty)
Sensitivity Evaluation

• Union Island – located in the south Delta

• Modeled as a series of 13 ‘independent’ levee reaches defined by their physical characteristics (vulnerability classes)

• Issue – Looking at the ‘raw’ data, there seems to be different interpretations for the characterization of the levee reaches into different vulnerability classes
Sensitivity Evaluation Results

Union Island - Base: M=6

Conditional Probability of Failure vs. PGA (g)
Lessons & Questions

(from DRMS and Other Experience)
Lessons

- Evaluation of uncertainties; both aleatory and epistemic
  - Require a clear taxonomy of the types of uncertainty and their meaning
  - Experts need to be educated; Ask and you shall get an answer is not an expert elicitation process
  - Typically underestimated (cognitive short-coming; over-confidence)
  - Process should be formal;
    - What is being elicited
    - Expert interaction
    - Expert ‘defense’ of their interpretations
  - Interpretations/evaluations documented
Lessons & Insights (cont.)

• It’s a ‘system’ (ASCE, 2009)
• Fragility analysis provides unique insight to ‘system’ performance
• Risk Analyst Role
  – Modeler, Quantifier (run the numbers)
  – Trainer, Psychologist
Questions

• Probabilistic analysis:
  – Better indexing system (Don’t believe the numbers); a relative measure only, or
  – A more absolute measure of events of interest (chance of breaching), or
  – A framework (rules) for identify and evaluating uncertainties (aleatory & epistemic).

• Believe the numbers?
Questions (cont.)

• ‘Length Effect’ Problem
  – The ‘length’ effect; spatial correlation of properties & performance

• System modeling
  – How does the system really perform
  – As a simple series system
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<tr>
<th>Element</th>
<th>Epistemic</th>
<th>Aleatory</th>
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<tbody>
<tr>
<td>Modeling</td>
<td>Uncertainty about a model and the degree to which it can predict events. Model, epistemic uncertainty addresses the possibility that a model may systematically (but not necessarily predictably), over- or under-predict events/results of interest (i.e., deformations).</td>
<td>Aleatory modeling variability is the variation not explained by a model. For instance, it is variability that is attributed to elements of the physical process that are not modeled and, therefore, represents variability (random differences) between model predictions and observations.</td>
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<td>Parametric</td>
<td>Parametric epistemic uncertainty is associated with the estimate of model parameters given available data, indirect measurements, etc.</td>
<td>This uncertainty is similar to aleatory modeling uncertainty. However, this is variability that may be due to factors that are random, but have a systematic effect on model results.</td>
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