

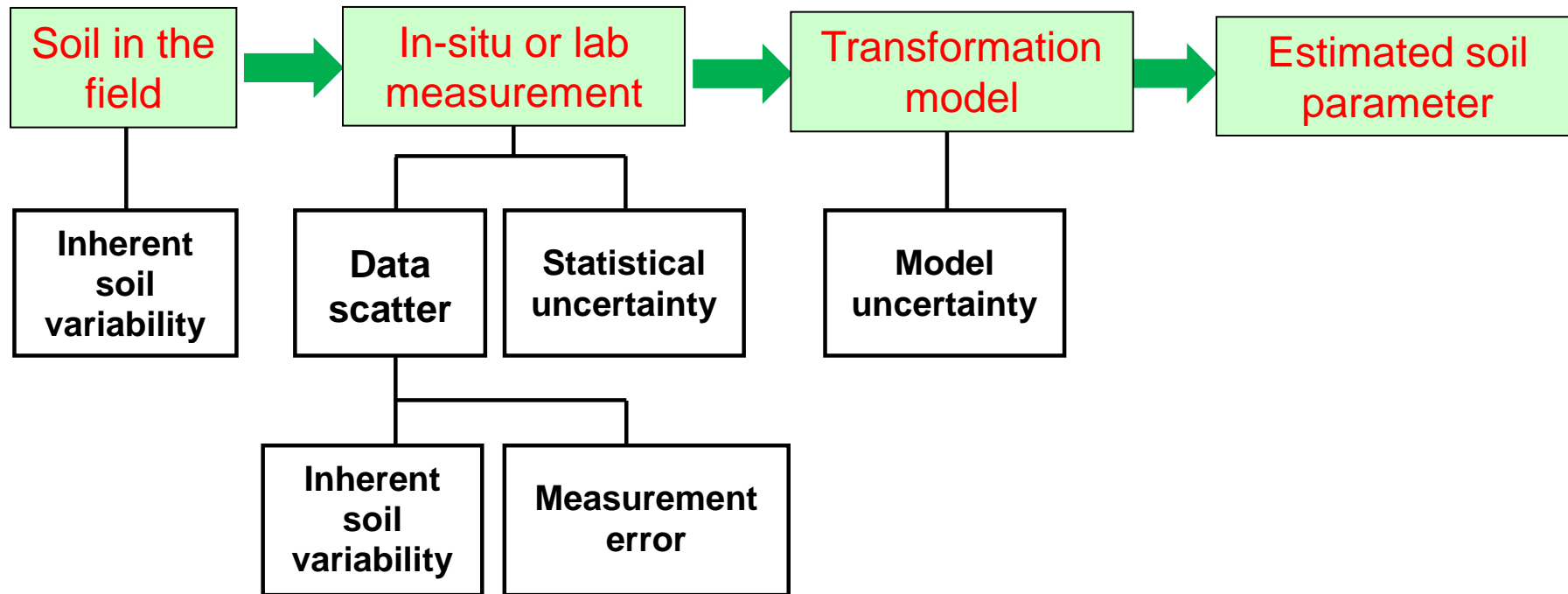
# “Risk based Framework for Geo-hazards”



## WE'LL DISCUSS...

1. Basic risk/reliability design concepts (i.e., LRFD)
2. Risk examples
3. System-based risk examples
4. Summary

# Uncertainties Involved in Estimating Soil Parameters



(Kulhawy and Phoon 2002)

# Deterministic (FS) vs. Reliability-Based Design

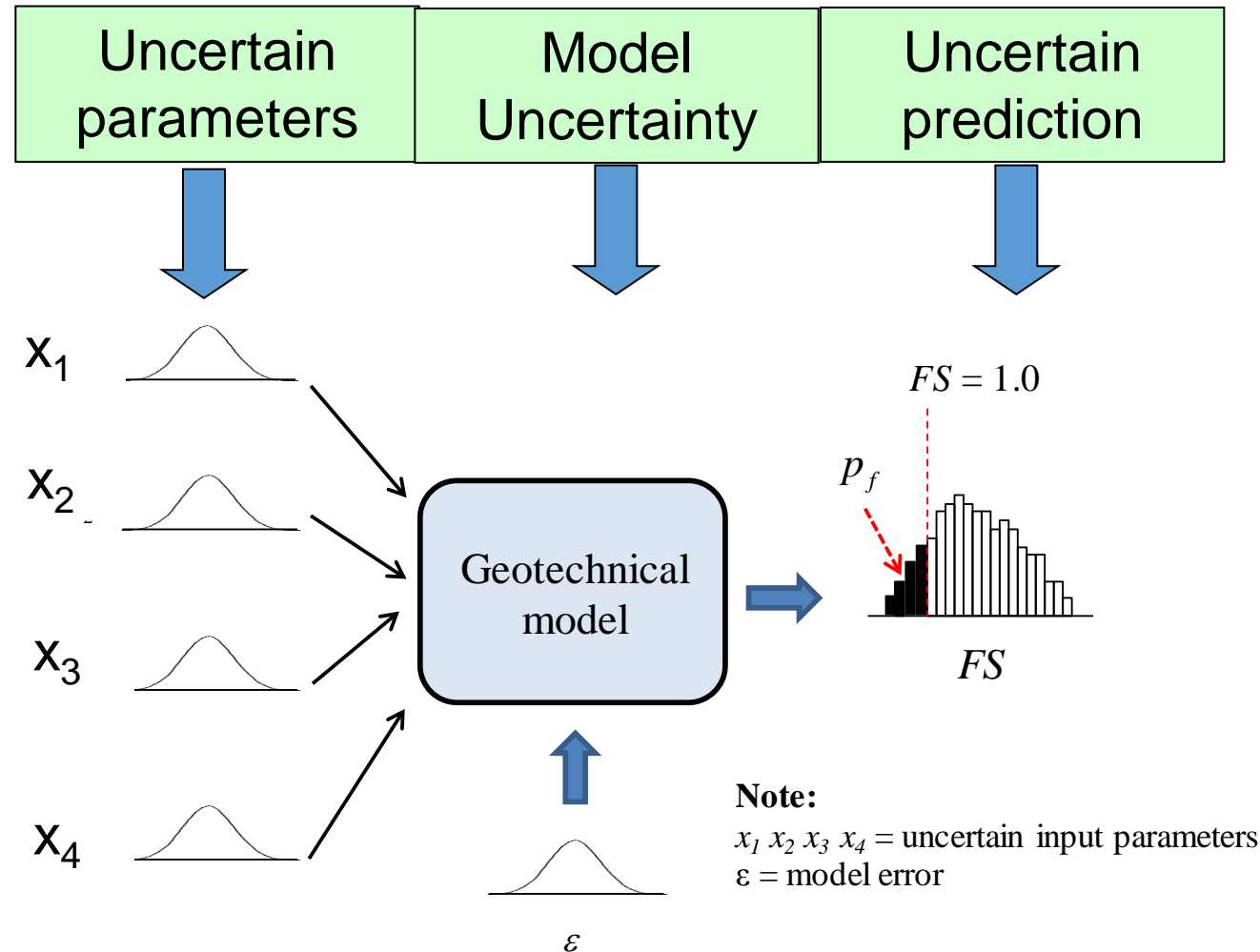
## Deterministic Design

- $F_s > F_{S,Target}$
- $F_{S,Target}$  is logically based on experience
- The same FS is applied to conditions with varying degrees of uncertainty; which is not logical

## Reliability-Based Design

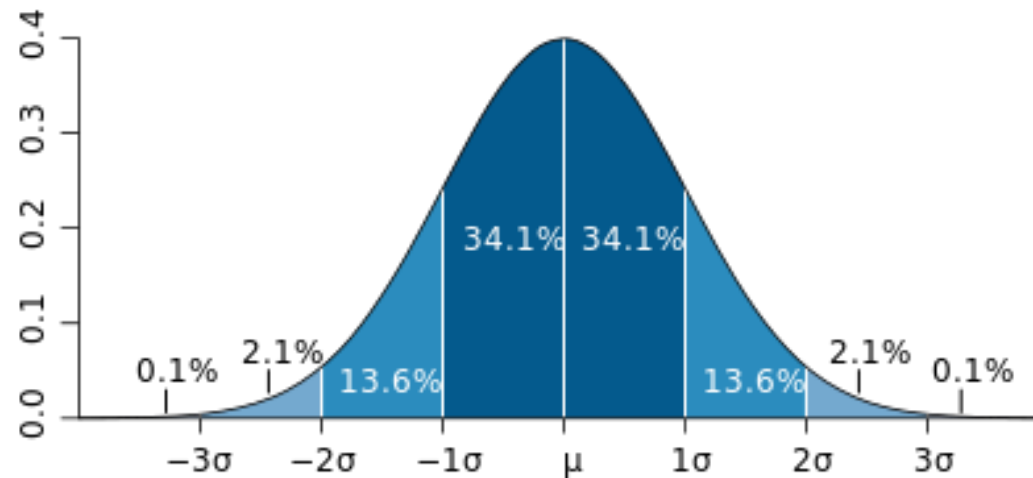
- $\beta > \beta_{Target}$  (or  $P_f$ )
- Provides a means of evaluating combined effect of uncertainties
- Requires more data, time and effort, and is not as familiar to most geotechnical engineers

# Geotechnical Reliability Analysis



## The less uncertainty, the better

- The greater the scatter (or COV), the higher the probability of failure ( $p_f$ )



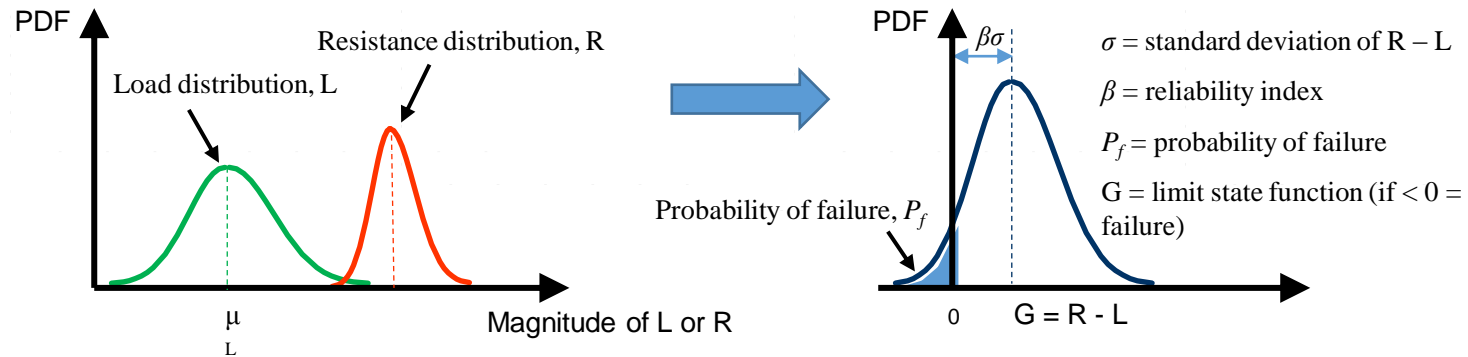
$$\text{COV} = \sigma / \mu$$

where, COV = coefficient of variation

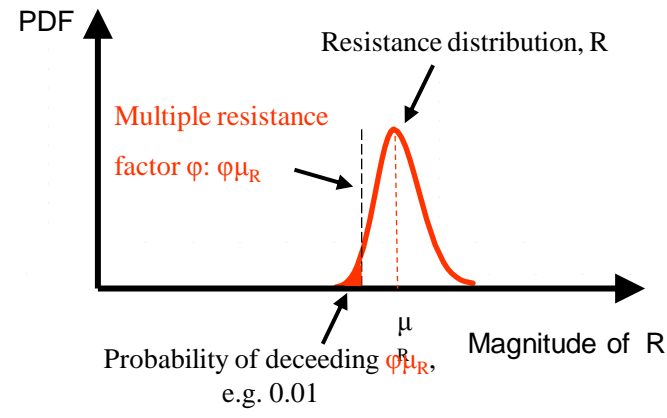
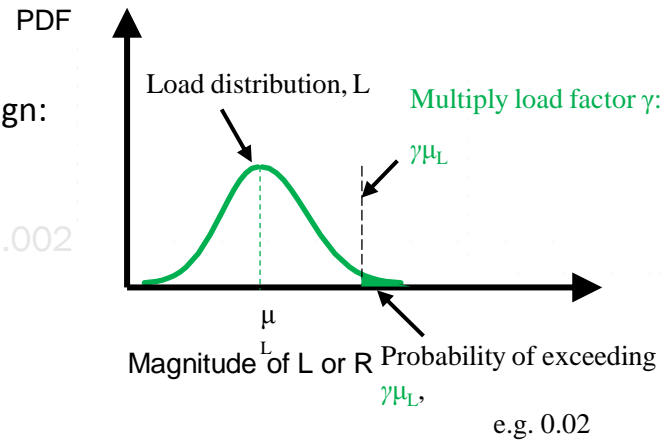
$\sigma$  = standard deviation, and  $\mu$  = mean

# Level I and II Reliability-Based Design

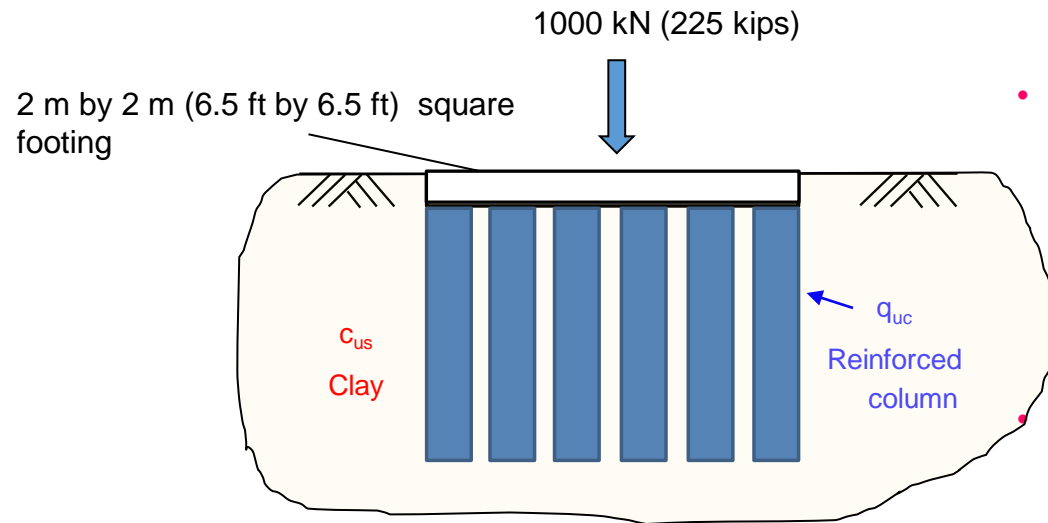
Level II Reliability design  
 $P_f = p(R - L < 0)$



Level I - LRFD design:  
 $\phi\mu_R - \gamma\mu_L > 0$   
 $P_f = (0.02)(0.01) = 0.002$



# PBD Example 1: Soil Mixing in Clay – Square footing bearing capacity



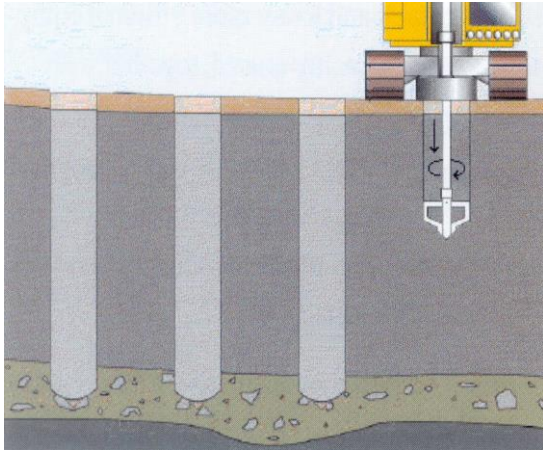
$$q_u = 0.7 q_{uc} \cdot \alpha + \lambda (1 - \alpha) c_{us}$$

(e.g., Brom 2000)

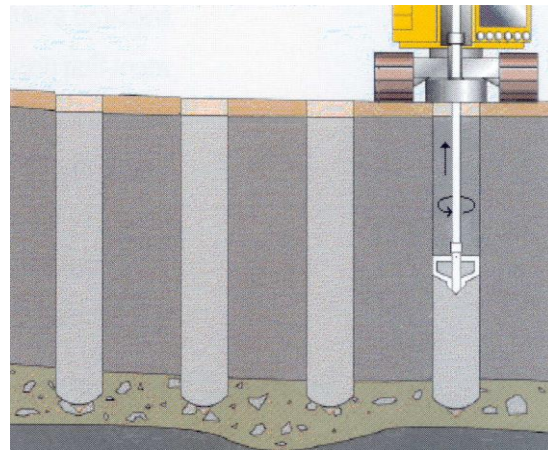
- $q_{uc}$  – unconfined compression strength of column
  - $\mu = 600 \text{ kN/m}^2$  (12.5 kip/ft<sup>2</sup>)
  - COV can be 0.17 – 0.67 depending on the level of quality control (Navin and Filz 2005)
- $c_{us}$  – undrained shear strength strength of soft soil
  - $\mu = 50 \text{ kN/m}^2$  (1.0 kip/ft<sup>2</sup>)
  - COV = 0.3 (Phoon and Kulhawy 1999)
- $\alpha$  – replacement ratio (60%)



## PBD Example 1 - Deep Soil Mixing in Clay



mixing blade rotated  
down to the required  
depth



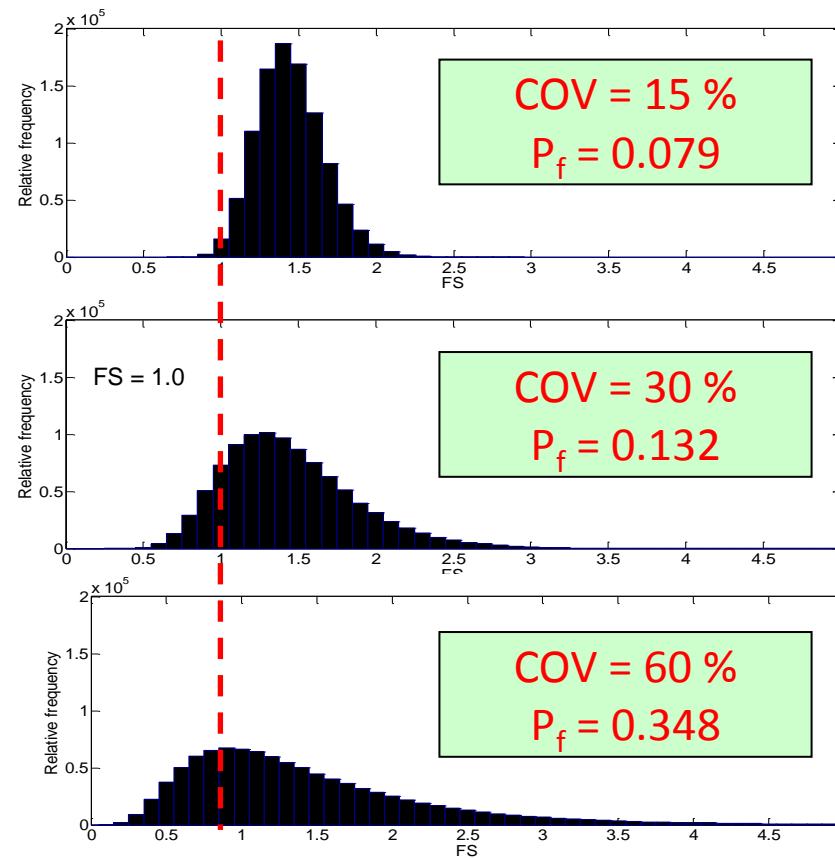
lime or cement supplied while  
retracting the mixing tool



## PBD Example 1 - Soil-Mixed Columns



# PBD Example 1 – Soil Mixing PBD Results



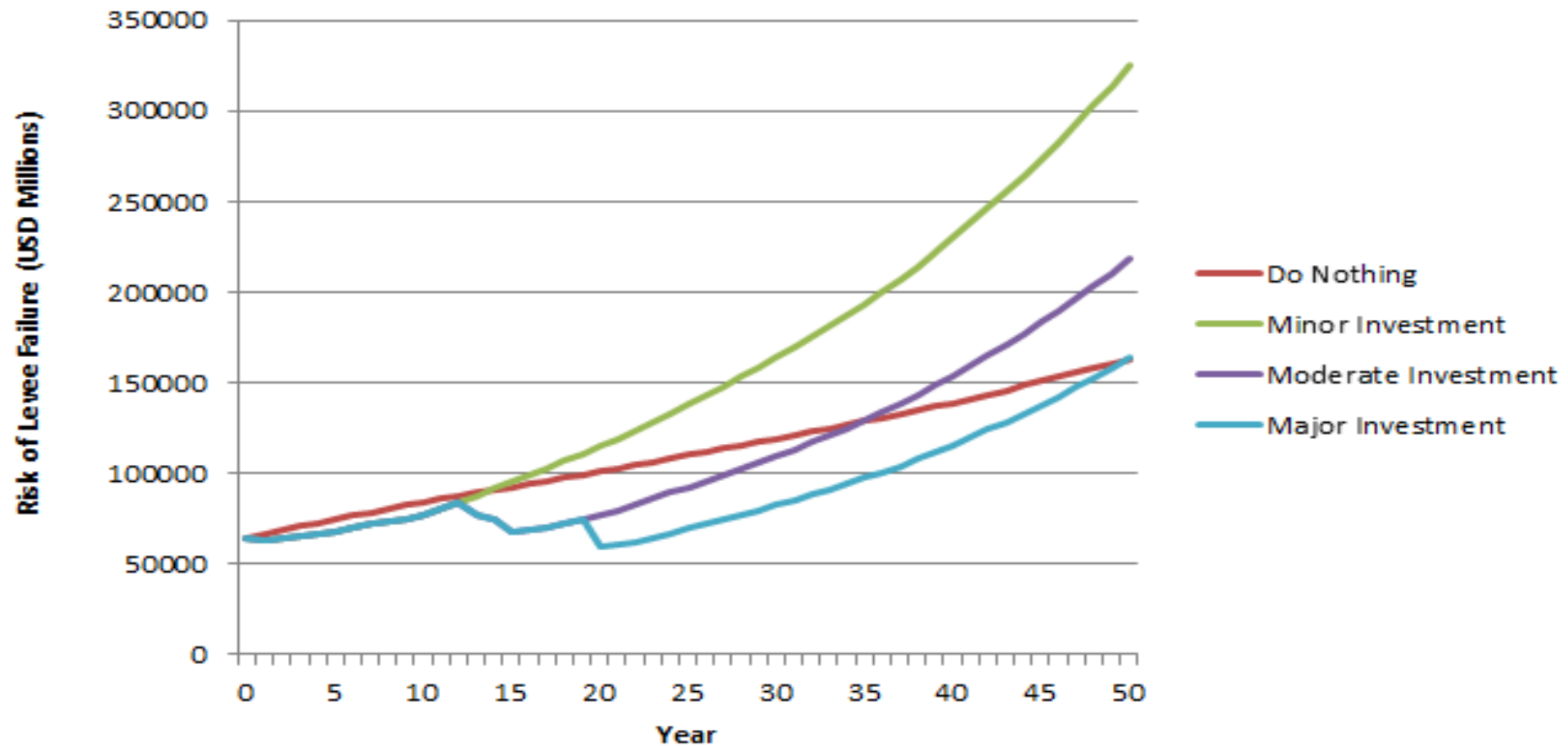
# Levee Failure - Hurricane Katrina



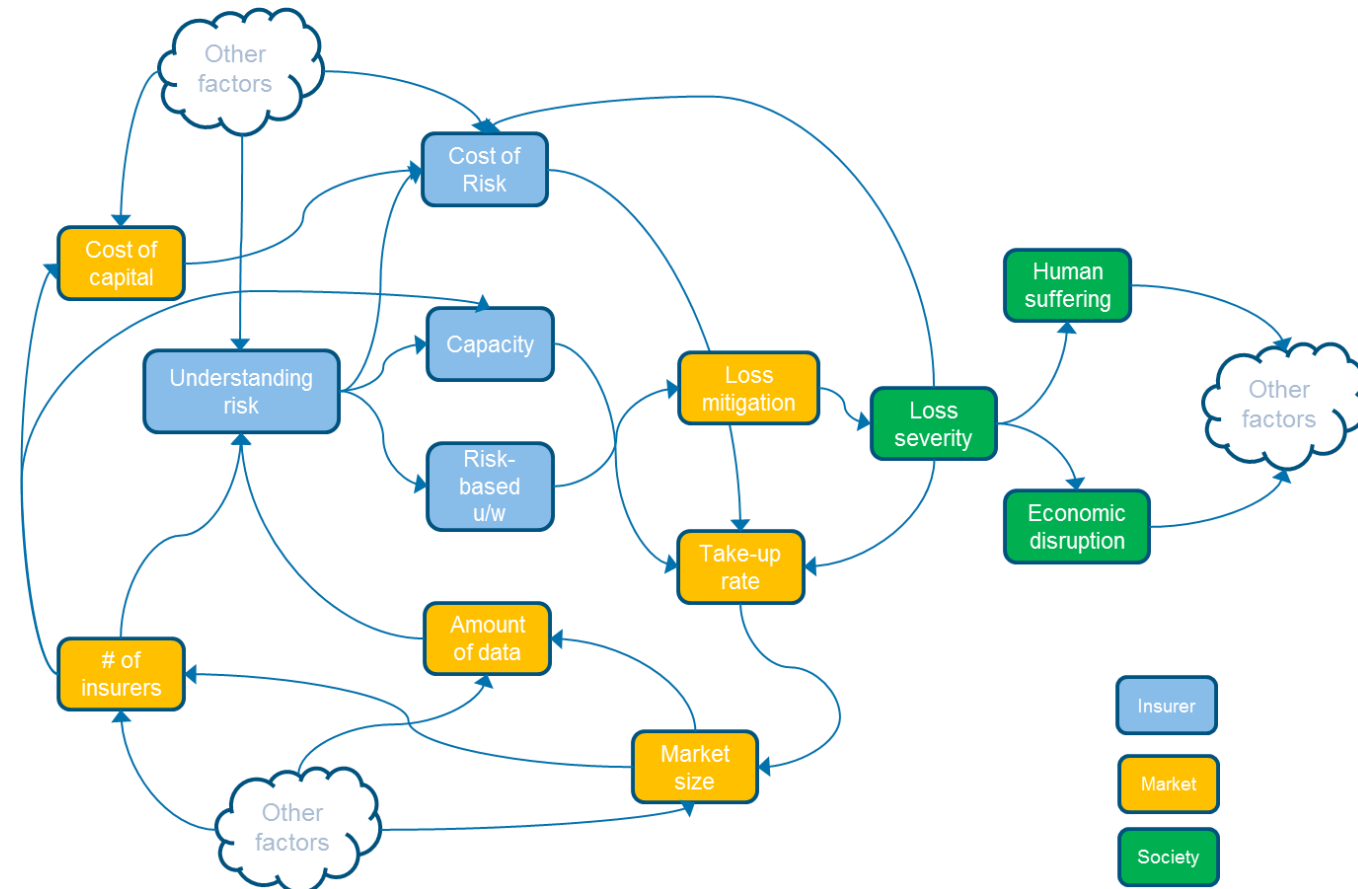


# Levee System Risk Modeling Example

**Behavior of Risk Over Time**



# SYSTEM DYNAMICS (SD) MAP OF HOW INSURANCE AFFECTS BEHAVIOR



# SUMMARY

- Our risks are rapidly evolving;
- Solutions, approaches, tools, and leadership must likewise evolve and adapt...faster
- Risk-based approaches increasingly required, including system-based risk
- *Must shift from silos to systems*
- Our Grand Challenge: How do we take a “fuzzy” concept like risk and distill that down to what we each should do differently each day?