

# Liquefaction at Depth Initiative

Technical Director  
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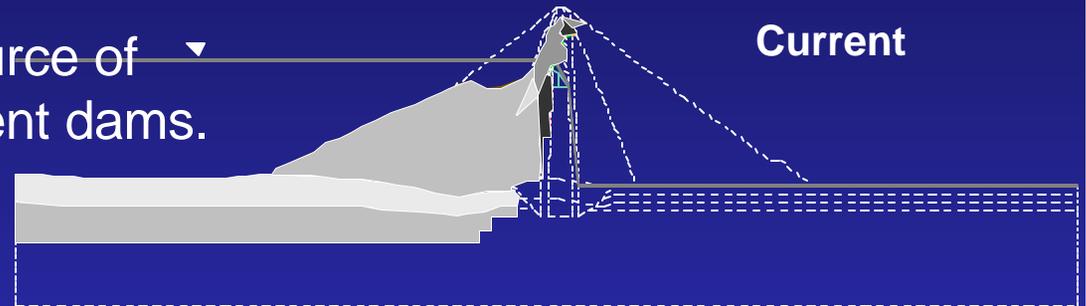
Michael K. Sharp



# Basic R&D Program Thrust

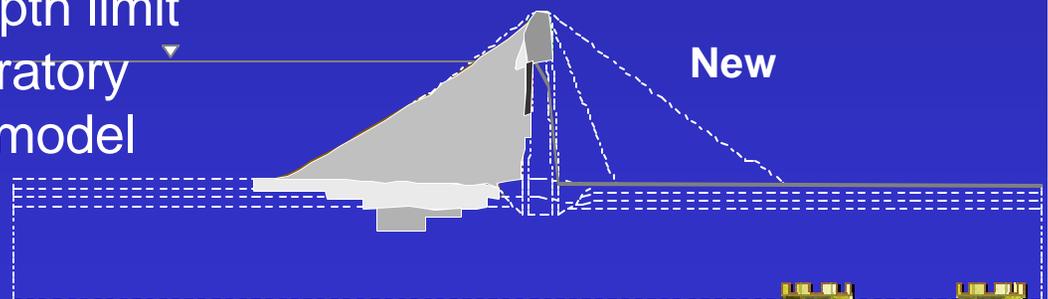
## *Issue*

- Liquefaction is the primary source of seismic damage to embankment dams. ▼



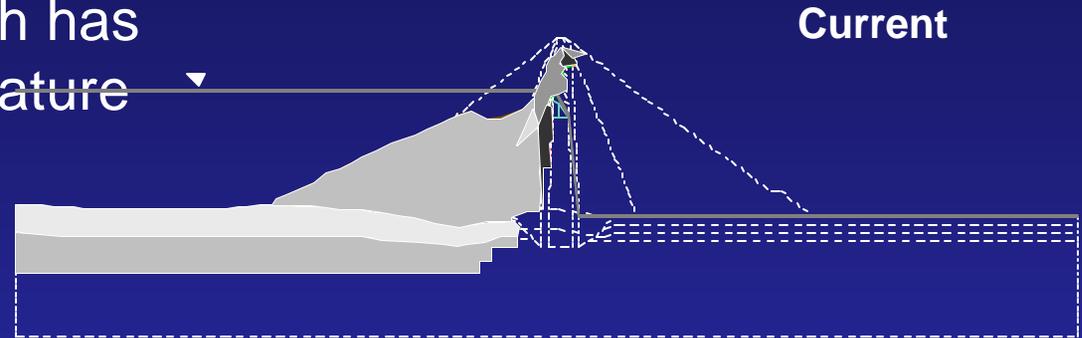
- Can liquefaction occur at great depths or beneath large embankment dams?

- Current practice indicates *no* depth limit exists, based on traditional laboratory tests, and simplifying analytical model assumptions. ▼

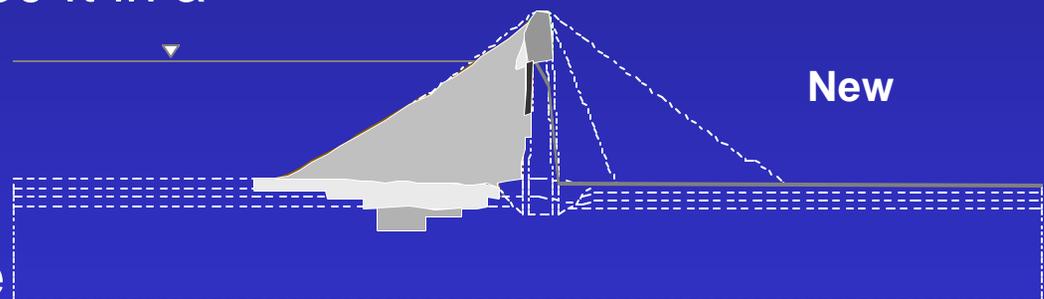


## ***Issue*** (continued/concluded)

- Liquefaction at great depth has *never* been observed in nature from an earthquake



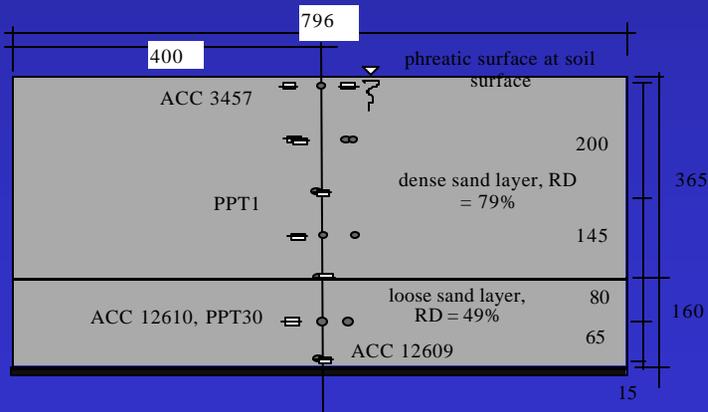
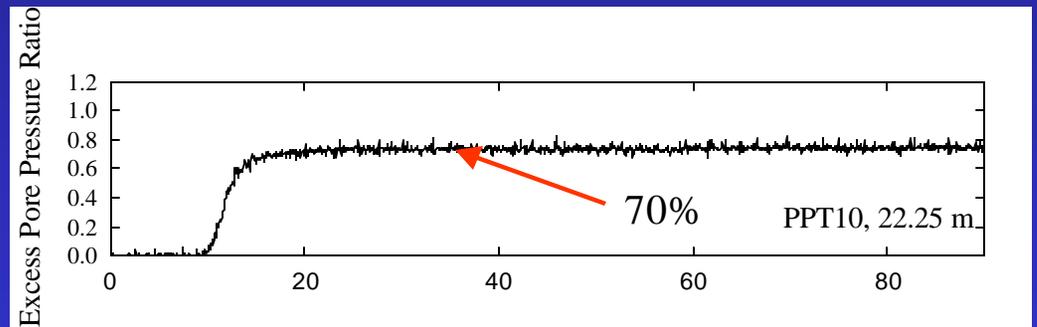
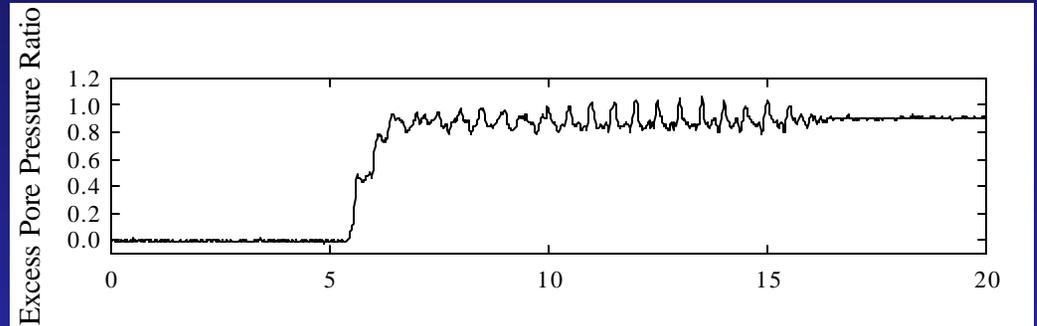
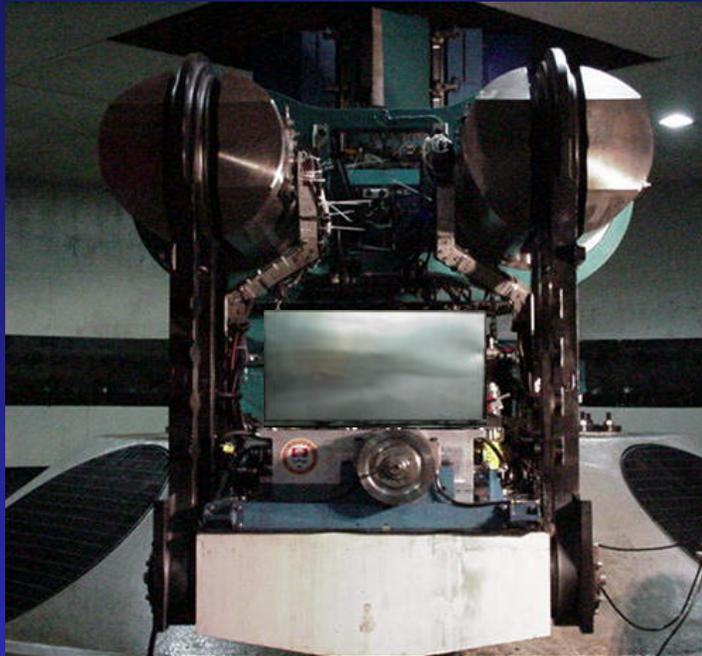
- Centrifuge tests show that for level ground, liquefaction cannot occur at depths greater than about 80 ft in a sandy soil deposit



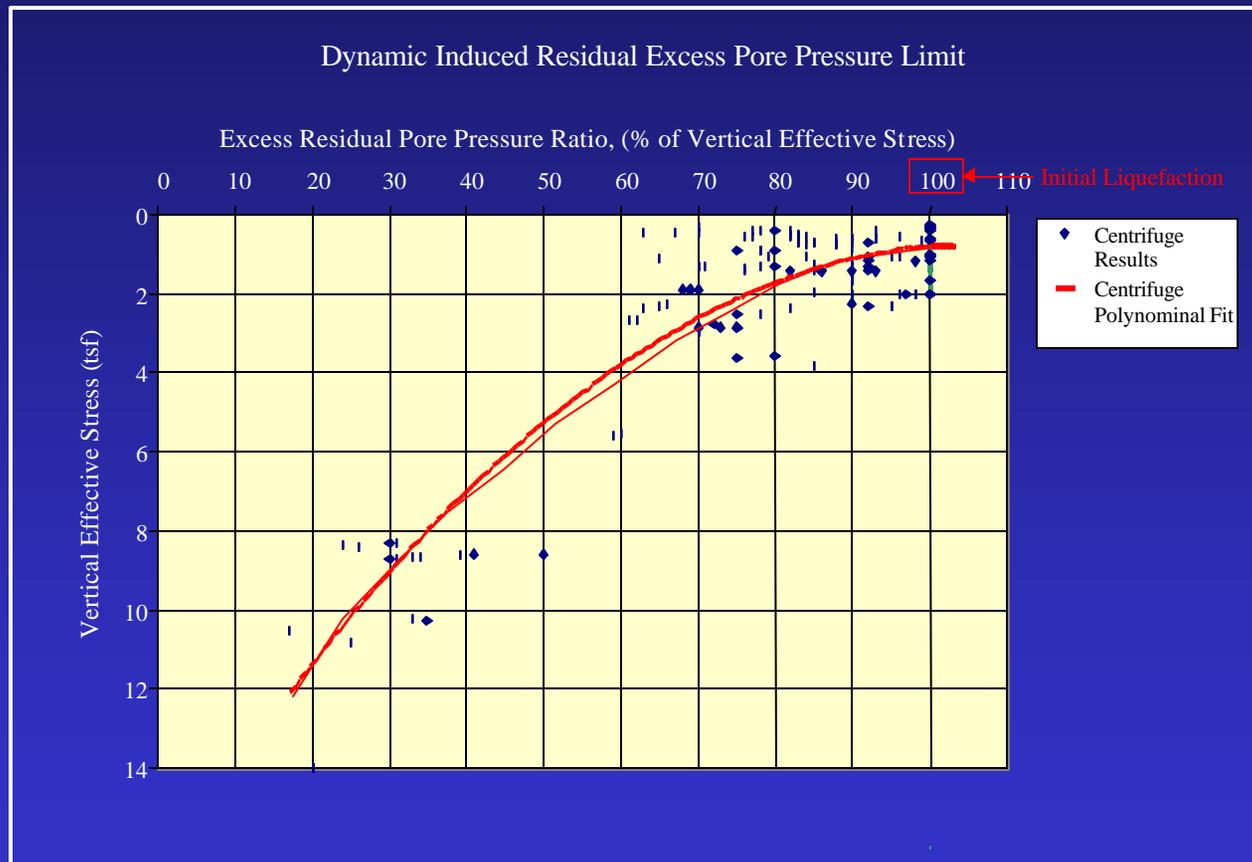
- Research to investigate the applicability of these findings to dams may lead to less costly remedial construction



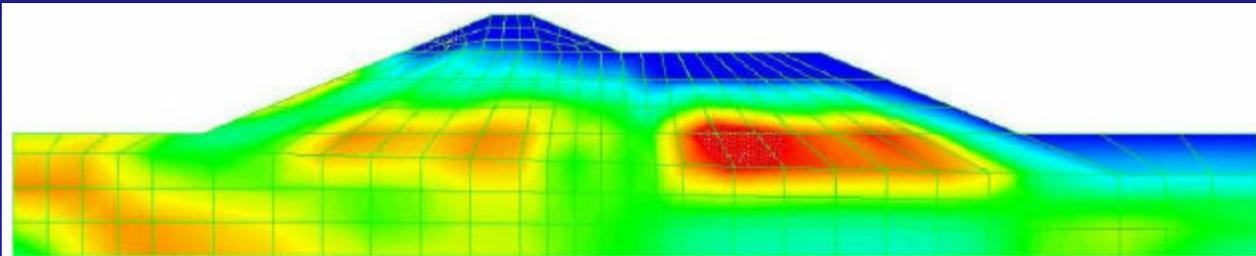
# Current Research



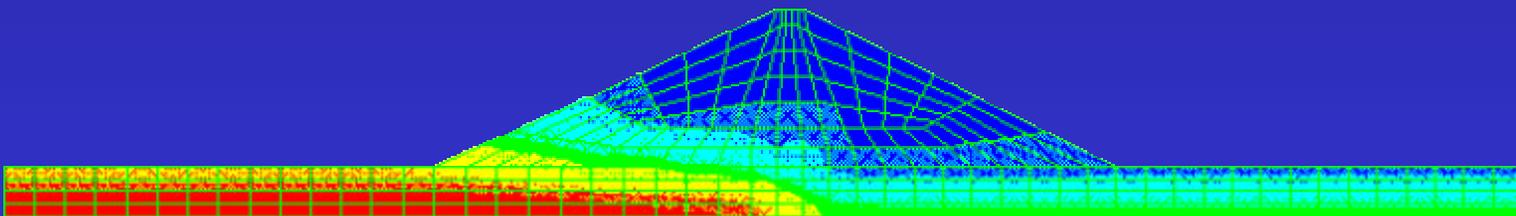
# Over 300 data points and 40 tests



# Numerical Modeling – STUBBS



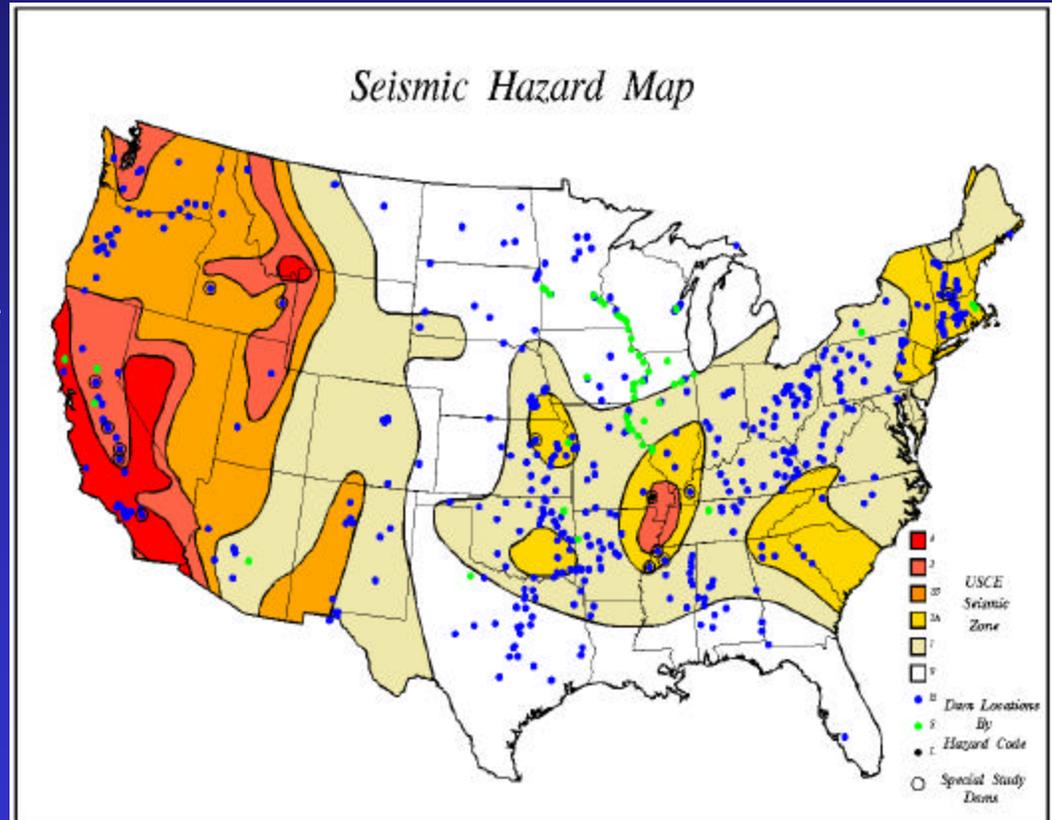
*EQEN: Upper San Fernando Dam, CA*



# Applicability to USACE Business Practices

## Scope of the Problem

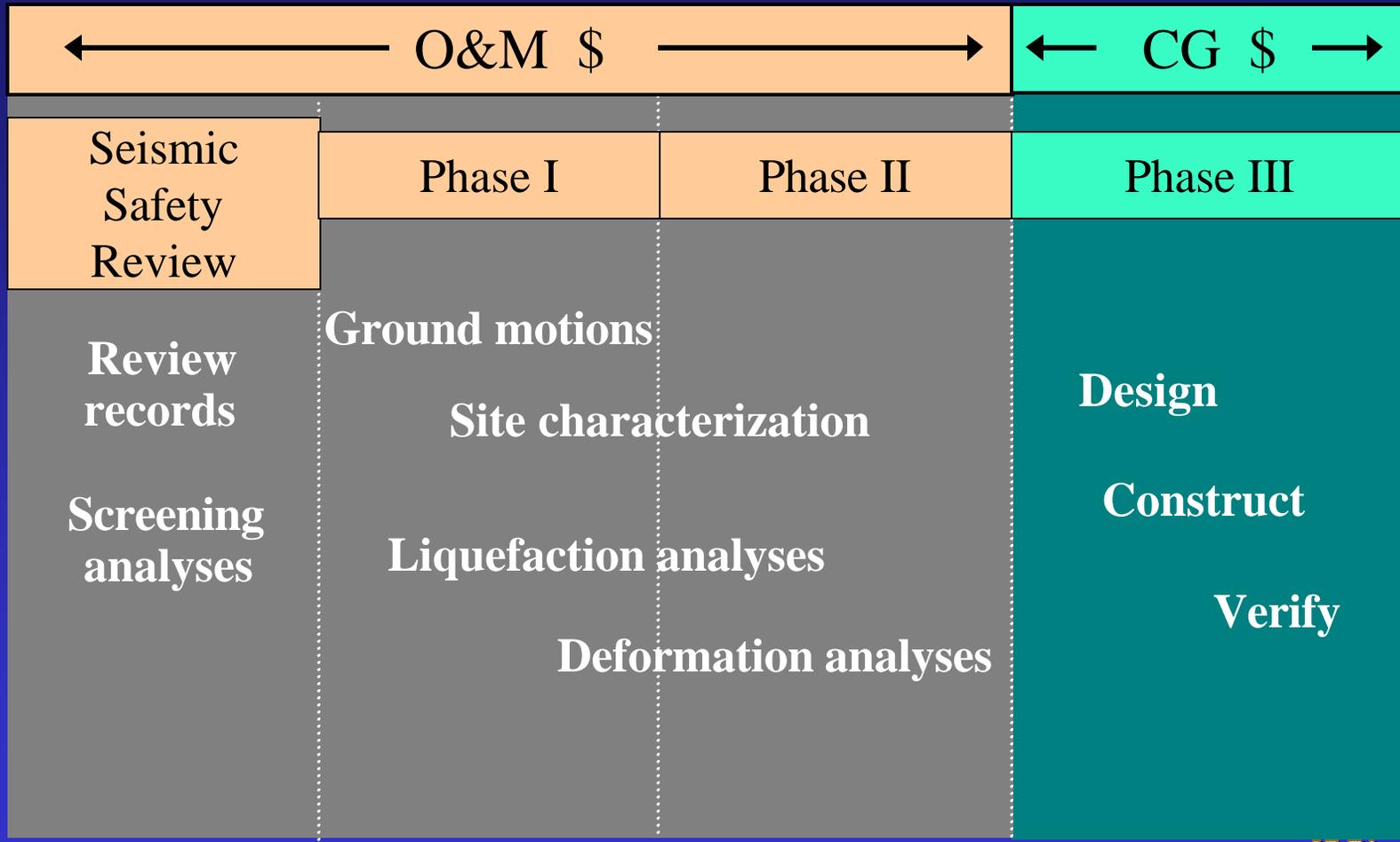
- 391 embankment Corps dams
- Most built before seismic hazards were recognized
- Most built before earthquake engineering was developed
- 162 Corps embankment dams in high seismic zone  $\geq 2$



- Dams are more earthquake resistant than current state-of-knowledge tells us  $\Rightarrow$  *fewer dams need remedial construction*
- More strength is available to resist deformations in the dam  $\Rightarrow$  *less remedial construction*
- More strength is available to buttress the remediated zone  $\Rightarrow$  *remedial zone is smaller*
- Smaller portion of dam and foundation is involved in safety evaluation  $\Rightarrow$  *reduction in O&M funded site investigation and analyses*



# CW Seismic Safety Investigation Process O&M and CG Funding



# Research Needs

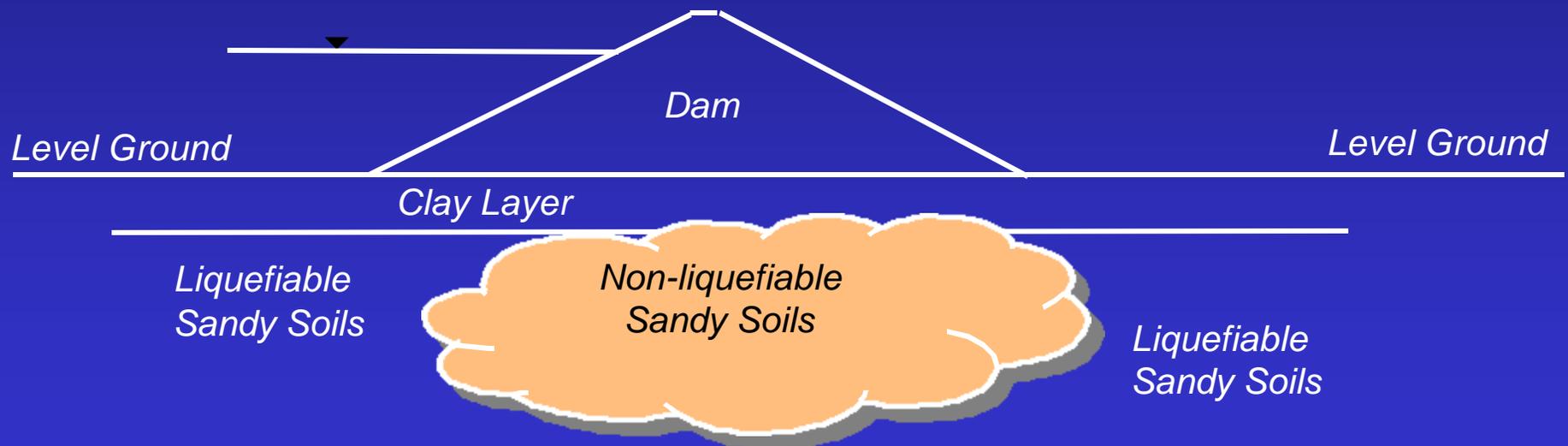
Required  
Immediate  
Product:

Calibrated, reviewed and accepted design procedure for **sandy soils** under slopes with/without clay layers

Expanded  
Scope or  
Future  
Products:

...for gravels

...for silts, silty clays



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...for gravels

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Internal Efforts

Physical Modeling

Numerical Modeling

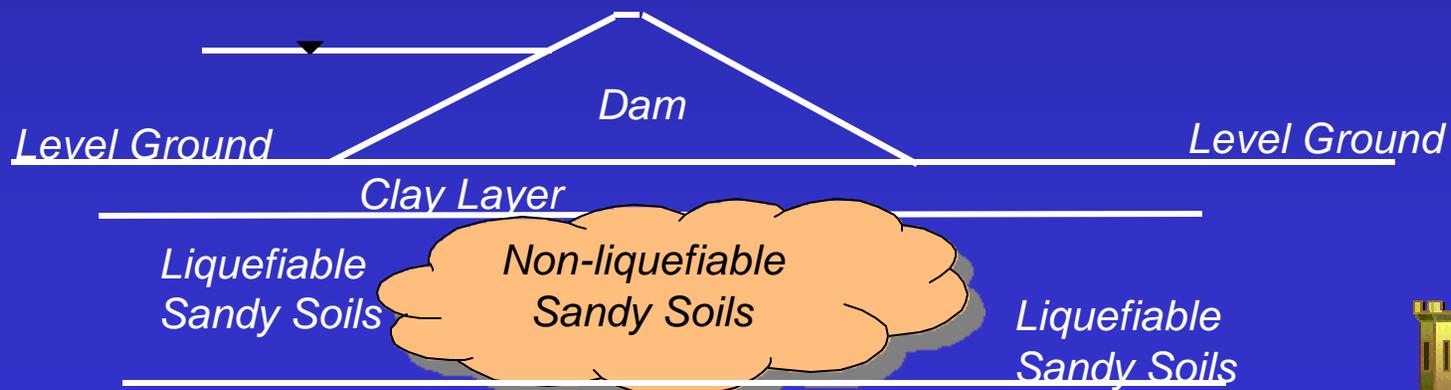
External Efforts

Physical Modeling

Numerical Modeling

Change Practice

Achieve acceptance



# Products

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**1. *The Corps spends less money and does less construction\* to correct seismic safety deficiencies of its embankment dams.***

**\* Less construction is clearly more environmentally friendly**



## 2. New, less conservative technology:

- *peer reviewed & accepted by practice*
- *reduces the number of embankment dams determined to be seismically deficient*
- *reduces the amount of remedial construction needed if a dam is deficient*

