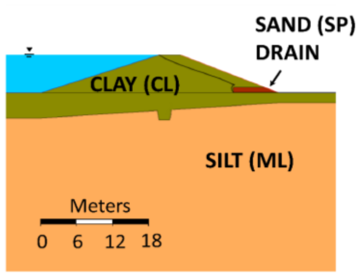
DEVELOPING SYSTEM RESPONSE CURVES TO CHARACTERIZE LEVEE RELIABILITY

US Army Corps of Engineers
Engineer Research and Development Center

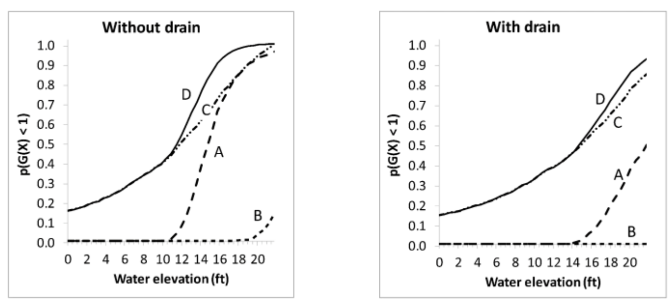
Need There is a need for objective, quantitative, and broadly applicable tools and techniques for characterizing the reliability of levees and estimating the probability of unsatisfactory levee performance. These probabilties are needed to support risk-informed design and assessment of levee infrastructure, flood risk assessment, and asset-management decisions. This need will be addressed by developing efficient tools and techniques for uncertainty analysis of geotechnical simulation models.

Approach Probabilities are derived from uncertainty analysis of two mechanistic models that simulate four common levee failure modes. SEEP2D-HPC is a steady-state finite element model that simulates underseepage and through-seepage. SLOPE2D-HPC locates the circular failure surface and performs slope stability analysis using the simplified Bishop method, incorporating the phreatic surface and pore pressures from seepage analysis. Probabilities of unsatisfactory performance are derived using Monte Carlo simulation treating the geometry and classification of each soil layer in the two dimensional levee cross section as fixed and eleven soil properties as correlated random variables. A system response curve is produced by varying flood loads. Future work will address transient seepage models, non-homogenous soil layers and new failure modes, including backward erosion, piping, and overtopping erosion.

Outcomes The output of the procedure is a system response curve that describes the probability of unsatisfactory performance over the range of potential flood loads and serves as a more efficient surrogate for the mechanistic models used to simulate each failure mode. In the demonstration below, the procedure is used to estimate the reliability benefit of a sand drain in a section of Wabash River levee. Using an analytical approach such as this to derive system response curves will make levee reliability assessments more objective, more defensible, and more efficient. This research will also improve our understanding of levee failure modes and the sources and implications of uncertainty in models of failure modes. A website will make these techniques accessible to USACE districts on demand.



A cross-section of Wabash River levee near Lyles, Indiana.



System response curves, showing how the sand drain reduces the probability of unsatisfactory performance, $p(G(\mathbf{X}) < 1)$, with respect to A) underseepage, B) through-seepage, C) slope stability, and D) an aggregate failure mode.

More Information

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For more information on FRM R&D, see the ERDC FRM wiki:
https://wiki.erdc.dren.mil/Flood_and_Coastal_Storm_Damage_Reduction_Research_Program