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Toward improved risk assessment of internal erosion-induced embankment failure: a new neural network approach

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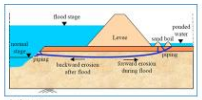
Abstract: Current internal erosion risk assessment techniques for levees, tailings dams and other embankments tend to be limited and non-constitutive bringing their accuracy into question. Since *Turnbull and Mansur's (1961)* pioneering work to characterize and assess failure risk for levees along the Mississippi valley 70 years ago, little progress has been made to adequately quantify risk beyond blanket theory and critical exit gradients, which have been demonstrated to be incomplete indicators of potential problems in certain cases. Clearly, present understanding of the role of significant factors in internal erosion including *hydraulic gradients*, *seepage paths*, insitu *stresses*, and *soil mechanics* is incomplete at best. This research presents a **new data-driven modeling approach toward prediction of initiation of internal erosion** using artificial neural networks (ANNs) in embankments. The **focus is on initiation** because both deterministic and probabilistic assessment tools rely on the factor of safety concept, and it makes sense to focus on preventing the initiation. **ANNs** are an important computational technique whose functionality is based on the human nervous system. Major advantageous features of ANNs over both purely analytical models and purely statistical models include adaptation with presence of fresh data (i.e. "learn"), ability to implicitly detect nonlinear parametric relationships without prior assumptions, and ability to function when data are limited. Because the ANN technique is empirically derived, it provides both a systematic and **quantitative basis for internal erosion initiation assessment** without ignoring key underlying seepage theory and associated constitutive laws.

1. Overall Objectives

TO DEVELOP IMPROVED METHODS FOR RISK ASSESSMENT OF LEVEES, TAILINGS DAMS & OTHER EARTHEN DAMS



RISK = PROBABILITY X CONSEQUENCE

LIKELIHOOD

2. Research Approach: a focus on initiation

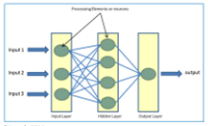
Current standard procedures:

1) determine blanket thickness
2) determine the hydraulic *gradient* near land-side toe
3) assess risk

Estimated accuracy of current standard seepage analysis procedures

Identified	Actually Critical	Actually NON-Critical	Total
Critical	19%	21%	40%
Non-Critical	1%	59%	60%
Total	20%	80%	100%

*(Wolff, 2002)



*Kaunda 2014

Soil mechanics and seepage paths may be more important indicators of internal erosion than just hydraulic gradients and blanket thickness

*Van Beek et al., 2010; Richards and Reddy 2014

3. Results and Applications to Assess Initiation

A) ANNs as a Classification Tool

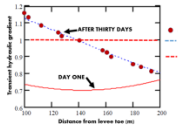
*Kaunda, 2013

$$FS = \frac{F_{hcrit(lab)}}{F_{havailable(field)}}$$

*Richards and Reddy 2014

*Kaunda, 2015

B) ANNs as a Prediction Tool



ANN approaches which incorporate both soil mechanics properties and hydraulic characteristics, have great potential to assess risk for internal erosion in tailings dams, levees and other earthen embankments. The methodology is meant to be complementary, and not a replacement of existing field or numerical modeling techniques. As in other types of ANN modeling, it is important to be conversant with applicable boundary conditions, constraints and limitations of this approach.

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