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Development of a reliability-based early-warning framework for toe erosion induced dike failure in steep channel

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The major cause of dike failure in a steep channel is the sliding or overturning of dike fundation due to the serious erosion at the toe of dike. This study developed a framework to numerically derive the threshold curves for toe erosion induced dike failure early-warning under stipulated lead-time and forecast reliability. The forecast reliability is defined as the probability that the type II error (i.e. dike collapsed without issuing alarm) does not occur. The Chiu-She Dike located on the middle stream of Dajia River, Taiwan was the study site. Firstly, a comprehensive stability analysis of dike fundation based on numerical simulation was performed. The results indicate that the scouring depth (DS) at the toe of dike and the difference in elevation (DE) between the water table inside the dike and the water surface in the channel are the major factors that highly correlated with the stability of dike. Secondly, 60 realizations of hydrograph were randomly generated according to the characteristics of historical flow data. Then, the Monte Carlo Simulation was adopted which consists of series analyses including the channel flow routing, the seepage simulation, and the safety factor calculation of dike fundation. We used the results of Monte Carlo Simulation along with the frequency analysis to obtain the approximate probability distribution functions of DE under various scouring depths (DS) and lead-times, from which the threshold curves under stipulated lead-time and forecast reliability can be derived. The horizontal and vertical axes of the threshold curve are the DS and the DE, respectively. Besides the proposed framework, we also installed an automatical dike monitoring system on the study site which including: (1) vertical distributed pore water pressure sensors inside the dike; (2) Time Domain Reflectometry (TDR) to measure the displacement of dike; (3) wireless floating device to measure the scouring depth at the toe of dike; and (4) water level gauge. The early-warning of dike failure during a rainstorm event can be accomplished by the conjugation of derived threshold curve and real-time monitoring data. Furthermore, a guideline for how to decide the lead-time and forecast reliability is also presented in this study.