# QUANTIFYING RISKS FOR COASTAL LEVEE DESIGNS ALONG THE U.S. GULF COAST

Alexander Nelson, US Army Corps of Engineers, alexander.g.nelson@usace.army.mil
Brad Arcement, US Army Corps of Engineers, brad.j.arcement@usace.army.mil
Brad Burrows, US Army Corps of Engineers, brad.l.burrows@usace.army.mil
Andrew Hill, US Army Corps of Engineers, andrew.d.hill@usace.army.mil

## DESIGN CRITERIA AND TOLERABLE RISK

For all U.S. Army Corps of Engineers (USACE) dam and levee designs for new projects, modifications, improvements, rehabilitation, or repairs, a risk-informed design approach is taken (ECB 2019-15). Risk-informed design ensures that risks and uncertainties are evaluated and estimated to be tolerable. This approach occurs in parallel to the typical design approach, which primarily focuses on ensuring the project is commensurate with available policies, guidance, and criteria as specified in USACE publications (regulations, manuals, etc.) as well as project-specific criteria. These criteria result in designs that achieve adequate factors of safety for levees, floodwalls, or other structural features across a full range of hydraulic, seismic, and other types of hazards. The risk-informed design approach allows for adaptability to identify cases where a lesser factor of safety may still result in tolerable risks, or conversely, where proposed criteria may not be sufficient to reduce risks to an acceptable level. These type of assessments are performed while ensuring that the project holds life safety paramount, and the design and risk teams are open and transparent in their engagement with local partners.

## SABINE PASS TO GALVESTON BAY PROJECT

The Sabine Pass to Galveston Bay (S2G) Coastal Storm Risk Management (CSRM) Project consists of $4B in construction costs to replace existing floodwalls, raise existing levees, construct new navigation and drainage structures, and complete environmental restoration at two existing levee systems near Freeport and Port Arthur, Texas and one new system near Orange, Texas. The risk-informed design approach for these systems has included performing baseline system-wide risk assessments for each system, performing ongoing semi-quantitative risk assessments (SQRAs) and quantitative risk assessments (QRAs) for major design decisions, and participating in the review of criteria and submittals with a focus on understanding and reducing project risks.

## UNDERSTANDING AND REDUCING RISKS

Dam and levee safety risks are a product of hazards exposed to a system, the system response to the hazard, and the associated life safety and economic consequences of a system response failure. Each of these aspects have associated uncertainties that contribute to the overall uncertainty of the risk estimate. The USACE Risk Management Center (RMC) has developed a Beta version of the new quantitative risk analysis software RMC-TotalRisk (Smith, Fields and Snorteland, 2021) to aide in quantifying risk for dam and levee systems. The software can be used to setup 'Risk Analyses' that quantify the risk from the hazard, response, and consequence estimates. For the design of the S2G project, some of the assessed risks include risks of temporary flood protection, foundation seepage related failures, and interior ponding loading of levees. The most prominent risk assessed for these systems is the risk of a levee breach due to overtopping, which is driven by both still-water level exceedance and from wave overtopping. In this risk analysis framework, hazards are estimated in the form of wave overtopping rate frequencies which are estimated from coastal hazard modeling outputs. The system response, or failure probability, is estimated by the risk team eliciting a probability estimate for each "node" in the event tree. For example, the overtopping breach event tree includes four nodes: flaw/failure of the cover material, initiation of headcut erosion, continuation of erosion through the levee crown, and downcut and widening of a breach. The life loss and economic consequences are estimated by modeling the breach and non-breach inundation in a hydraulic model and applying the dynamic inundation scenarios in the agent-based, spatially distributed LifeSim modeling software (Risk Management Center, 2021). The direct life loss model results and associated uncertainties are then linked with the hazard and response estimates in RMC-TotalRisk. Figure 1 shows the risk analysis diagram for a wave overtopping failure mode (a) along with the event tree nodes that make up the overtopping system response probability (b).

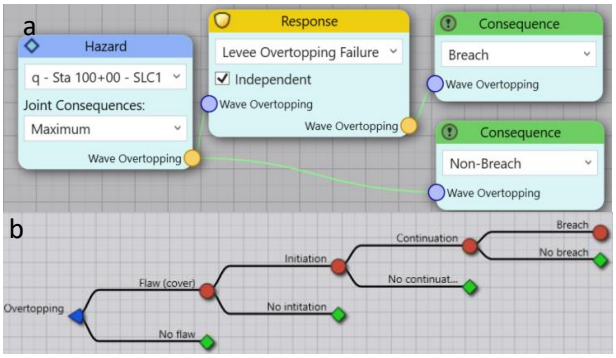


Figure 1 – RMC-TotalRisk setup for wave overtopping showing: a) the 'Risk Analysis' framework and b) the nodal event tree used to estimate the 'Response'

## SUMMARY

Utilizing the RMC-TotalRisk beta software in parallel with legacy USACE risk estimation tools for risk-informed design of coastal levee systems provides a greater understanding of the risks of proposed project alternatives being considered during design. Risks can be assessed for both at the end of construction condition and for future conditions considering the impacts of sea level change to identify changes in risk over time. In comparing these risks and showing the full range of uncertainties surrounding

the risk estimates, design teams can document and communicate decisions in ways that the project reduces risks for life safety and economic damages. By ensuring the risk is understood and reduced to tolerable levels, decisions to make wise investments in structural and non-structural measures can be made to lower risk for many vulnerable communities exposed to coastal hazards.

## REFERENCES


ECB, 2019-15, Interim Approach for Risk-Informed Designs for Dam and Levee Projects (08 October 2019). https://www.wbdg.org/ffc/dod/engineering-and-construction-bulletins-ecb/usace-ecb-2019-15

Risk Management Center, 2021. LifeSim, Life Loss Estimation, User's Manual, Version 2.0, CPD-97, U.S. Army Corps of Engineers, Lakewood, CO. https://www.rmc.usace.army.mil/Software/LifeSim/

Smith, Fields, and Snorteland, 2021. A New Suite of Risk Analysis Software for Dam and Levee Safety. The Journal of Dam Safety, (Summer 2021), pp.36-46.