ENGINEERING AND CONSTRUCTION BULLETIN

US Army Corps of Engineers

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SUBJECT: Interim Approach for Risk-Informed Designs for Dam and Levee Projects

CATEGORY: Guidance

1. **References.** References for this Engineering and Construction Bulletin (ECB) are provided in Appendix A.

2. **Definitions.** Definitions for terms used in this ECB are provided in Appendix B.

3. **Purpose.** This ECB provides interim guidance for incorporation of risk-informed design into on-going and future projects across all phases of work, including those in the FY18 Disaster Relief Supplemental Appropriations, for dam and levee projects.

4. **Background.** Risk assessments have been completed for most of the existing levee systems and dams within the USACE portfolio. The results of those risk assessments have been used extensively to help inform risk management and project designs; however, comprehensive guidance has not been formally provided that requires risk assessments be completed as part of design. Several key USACE guidance documents are currently under development that will incorporate risk assessments into the planning, design, and construction of projects that include dams and levees. The inclusion of risk assessments into the design and construction phases is the natural progression of risk-informed policies to more comprehensively achieve project objectives by identifying all risk drivers and understanding how to efficiently reduce incremental risk to life safety (structurally and non-structurally) within the limits of the authorized project.

5. **Applicability.** This ECB is applicable to all Headquarters USACE (HQUSACE) elements, Divisions, Districts, laboratories and field operating activities related to Civil Works projects. The actions and policies in this ECB will also be applied in the execution of all design projects, including those funded by the 2018 Disaster Relief Supplemental Appropriations (P.L. 115-123).

6. **Principles.** A risk-informed approach will be used for all dam and levee designs for new projects, modifications, improvements, rehabilitation or repairs. Risk assessments are the cornerstone for application of a risk-informed decision making approach. The following are the overarching principles to follow:

a. Hold life safety paramount. While seeking to manage risk to people, property, and the environment, USACE will consider risk to life safety as priority. Tolerable Risk Guidelines (TRGs) will be used as the risk-informed decision goal for life safety. Paragraph 9 and Appendix C of this ECB defines the application of TRGs for risk-informed decision making. Below is a summary of the four TRGs and they are described in greater detail in Appendix C.

(1) TRG 1 – Understanding the Risk. The first tolerable risk guideline involves considering whether society is willing to live with the risk associated with the dam or levee to secure the benefits provided by the dam or levee.

(2) TRG 2 – Building Risk Awareness. The second tolerable risk guideline involves determining that there is a continuation of recognition and communication of the risk associated with a dam or levee, because the risk associated with the dam or levee are not broadly acceptable and cannot be ignored.

(3) TRG 3 – Fulfilling Daily Responsibilities. The third tolerable risk guideline involves determining that the risks associated with the dam or levee are being properly monitored and managed by those responsible for managing the risk.

(4) TRG 4 – Actions to Reduce Risk. The fourth guideline is determining if there are cost effective, socially acceptable, or environmentally acceptable ways to reduce risks from an individual or societal risk perspective.

b. Risk-Informed Decision-Making. Decisions for risk management actions will be commensurate with the level of risk that exists when a dam or levee is present to ensure wise federal investments.

c. Ensure open and transparent engagement. USACE will engage project sponsors in all design activities related to their dams and/or levees.

d. Learn and adapt. Risk assessments will be used to evaluate if designs must be up-scaled (i.e. use more stringent design criteria) or downscaled (i.e. use less stringent design criteria) using a risk-informed approach as compared to solely considering traditional standards.

e. Do no harm. Risk-informed designs should not increase the risk to the population and property above the risk the population currently experiences.

7. **Process.**

a. A Technical Lead should be assigned to each project in accordance ECB 2015-18. The Technical Lead, also referred to as Lead Engineer, should be a senior level professional engineer or engineering geologist with experience in design and construction of dams or levee systems and have an understanding of the risk framework. The Lead Engineer should ensure construction and engineering and design staff are engaged throughout the planning, design, and construction of the project, including reviews. The design intent, including risk reduction objectives, should be clearly defined and communicated to the Project Delivery Team (PDT) at the onset of the project, so it remains integrated through the design phase, specification development and construction implementation. Involvement of construction expertise in the design phase will help maintain constructability of the project, assure construction activities are appropriately incorporated into the cost estimates, and allow construction staff to maintain awareness of design philosophies, intent and assumptions.

b. Project Delivery Teams (PDTs) will ensure the district Dam Safety Officer (DSO) and/or Levee Safety Officer (LSO) and Dam Safety Program Manager (DSPM) and/or Levee Safety Program Manager (LSPM) are appropriately engaged throughout the design process. The DSO/LSO and DSPM/LSPM will assign appropriate dam and levee safety personnel to the team in order to ensure the quality of the risk assessment used and ensure that the dam and levee safety data and information is presented correctly in the implementation documents. In addition,

depending on the type of risk assessment required for the project, the LSO/DSO and LSPM/DSPM will assign a trained risk facilitator endorsed by the Risk Management Center (RMC) to lead the risk assessment. If a trained risk facilitator is not available within the District or Division, the RMC will help identify an appropriate resource. The PDT will ensure risk assessment team members have been incorporated into the scheduling, design, and review processes at the appropriate times in a manner to ensure risk information is utilized as part of the design considerations for the project.

c. Reformulation. The USACE process allows for the continued consideration of the federal interest, and decision makers need to be aware that reformulation is a possibility. Risk informed design changes must be evaluated to determine if the changes stay within the Chief of Engineers' discretionary authority and if those changes alter the scope of the project beyond what is defined in ER 1105-2-100 (Planning Guidance Notebook) without additional evaluation. Changes in scope that require additional evaluation are those that result in increases or decreases to the outputs for the authorized purposes of the project. Outputs are the project's physical effects which usually have associated benefits. For example, change in the degree of reduction in flood stages is a change in project outputs. Actions or decisions resulting in formulation or design changes are potential changes in project scope. Project costs must not exceed the maximum cost limits in accordance with Section 902 of the Water Resources Development Act of 1986 without seeking additional project authority. If the risk assessment demonstrates reformulation is necessary or the costs will exceed the Section 902 limits, the process and procedures in ER 1105-2-100 (Planning Guidance Notebook) will inform the path forward. Any increase in project costs, including those that do not exceed the Section 902 limit, may require coordination and approval from the USACE Change Control Board.

8. **Objectives.**

a. Work within Current Authorizations. Reformulation is not the goal when incorporating risk into the design of projects with an approved decision document. As an example, when evaluating overtopping, options do not have to result in designing taller levees, but may result in inclusion of resilient features such as superiority or a splash pad that consider the exceedance event in a cost-effective manner. However, the results of a risk assessment may indicate reformulation is necessary as noted in 7.c above.

b. Use Risk Assessment to Guide Improved Design Decisions. This requires leveraging existing risk assessments and sometimes conducting new risk assessments. Note, these risk assessments would focus on the incremental risk associated with the dam or levee.

(1) A risk-informed design approach does not replace the need for traditional deterministic analysis and criteria (e.g., factors of safety), but rather informs where designs must be up-scaled (e.g. use a factor of safety higher than the minimum) or downscaled (e.g. use a factor of safety lower than the minimum). Using a risk-informed approach, each dam or levee design should provide a reasonable level of assurance that the structure will perform adequately over the full range of loading. The risk-informed design approach will include documenting exceptions to traditional standards, if warranted.

(2) All factors driving the risk (hazards, performance, and consequences) of the dam or levee system must be clearly understood and considered within project designs. The initial step is

to conduct a Potential Failure Mode Analysis (PFMA) combined with a risk assessment that evaluates the dam or levee as designed with traditional standards. Combining the PFMA with a risk assessment allows designers to verify that known potential failure modes are being adequately addressed or identify any risk-driving potential failure modes that were not previously considered for the project. Reformulation may be needed as specified in paragraph 7.c.

(3) Use the most recently completed risk assessment (or conduct a risk assessment if none exists) of the project to evaluate, compare, and select the risk-reduction measures that effectively reduce the incremental risk and deliver the project benefits. The nature of the efforts should be done so in a cost-effective manner, however, reducing cost should not be the sole factor for conducting risk assessments. The measures should also include actions that reduce exposure and vulnerability of people and property, which can be incorporated into the project sponsor's floodplain management plan. Design modifications to new or existing projects are not to be used to compensate for floodplain management practices that are less than state-of-the-practice. See PGL 52 (Flood Plain Management Plans) for additional information.

(4) The objective of risk-informed design is for risks to be tolerable for the final project, including the associated floodplain management practices. The four TRGs are not mutually exclusive and therefore each TRG will be considered individually and collectively. The risk-informed design will evaluate if the risks are commensurate with the benefits to society (TRG 1) and determining if it is cost-effective to further reduce the risk (TRG 4). This is done by satisfying one of the two following outcomes:

(a) Societal and individual incremental life safety risks will be reduced in a cost-effective manner to tolerable levels, including deciding whether further risk reduction is warranted until such actions are impracticable or not cost effective; or

(b) An exceptional circumstance exists that makes reducing risks to tolerable social, economic, or environmental levels impractical (i.e. costs exceed the benefits) or impossible. In this case, the estimated risks for potential failure modes associated with prior to overtopping should be at least an order of magnitude lower than risks for overtopping with breach.

(5) In addition, the resulting risk-informed design should evaluate and determine the likelihood that the risks associated with the dam or levee will be properly monitored and managed by those responsible for managing the risk (TRG 3). For example, if relief wells are recommended as a feature of a dam or levee, the ability for the project sponsor to operate and maintain those features for the life of the project should be considered during the risk-informed design process. A resulting outcome from the risk assessment may be detailed O&M recommendations for inclusion in the final project operations and maintenance manual.

c. Scale risk assessments to the magnitude of the decision. Risk assessments are scalable and range from a screening level to semi-quantitative (SQRA) to quantitative (QRA) (see ref. 14). The level of detail required depends on the decision to be made and what is necessary to address uncertainty in the results. Risk assessments will be scheduled and budgeted to be a part of all planning studies involving levees and dams, and pre-construction engineering and design (PED) activities going forward. Requirements for risk assessments for planning studies are outlined in ER 1105-2-101 (Risk Assessment for Flood Risk Management Studies). Since the formal

application of risk-informed design is a new requirement, the risk assessments must be scaled to fit within the constraints of current schedules and budgets.

9. **Engineering Considerations.** Details of how to efficiently apply the overarching principles of risk-informed design are applied as follows:

a. Exceedance Events. Feasibility studies will evaluate a range of water surface elevations and consider alternatives to incorporate resiliency features that can address overtopping exceedance events per ECB 2019-8. Generally the design water surface elevation of a new levee is determined in project authorization and cannot be changed in PED; however, there are opportunities to incorporate resiliency features during PED. Designs will consider, refine, and evaluate structural and nonstructural measures to manage overtopping resilience in order to reduce the likelihood of a catastrophic breach during an overtopping event and to reduce potential life safety consequences over a range of overtopping events. Risk-informed design allows for the proper cost-effective resilient features to be considered and incorporated into designs to accommodate overtopping to improve performance and effectiveness of warning/evacuation procedures.

b. Feasibility Studies. One goal of studies that include an existing dam or existing levee system is to achieve all four Tolerable Risk Guidelines through the formulation, recommendation, and implementation of cost effective alternatives that reduce the risk posed by the infrastructure. Studies including existing dams and levees will include specific objectives regarding achieving the four TRGs. The extent to which the goal and objectives can be met will vary based on conditions in the study area and the efficiency and effectiveness of measures that contribute to meeting the objectives. At a minimum, there should be at least one alternative that addresses both TRG 1 and TRG 4 identified during any study that includes an existing dam or levee. In cases where evaluation reveals the formulated alternatives do not reduce risk below the societal life risk line or individual life risk line, the PDT must describe what factors drive the remaining societal or individual risk, whether revisions to the formulated alternatives can be made to lower the societal or individual life risk, and if additional formulation is required. The PDT must present the information at an in-progress review with the vertical team or at the next study milestone to gain vertical team concurrence on either carrying forward the modified or new alternative that addresses TRG 1 and 4 for additional evaluation or screening the alternative. Tolerable Risk Guidelines (TRG 2 and 3) will primarily be met through life-cycle Operation, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) requirements and the required floodplain management plan. Risk assessments can provide the necessary data to evaluate whether study objectives are likely to be met after construction. Risk assessments completed during the feasibility study will provide the data to evaluate whether the OMRR&R requirements and floodplain management plan included in the studies align to satisfy all four TRGs. The risk assessments will also be used aid in the development of an Emergency Action Plan (EAP) for inclusion in the floodplain management plan required by Section 202(c) of the Water Resources Development Act (WRDA) 1986 and PGL 52 (Flood Plain Management Plans). Coordination with the entity in the local or state government responsible for evacuation planning and implementation is required. See Planning Bulletin PB 2019-04 for the most recent guidance related to life safety considerations for flood and coastal storm risk management studies.

c. Risk-Informed Design Documentation. Risk informed design decisions and supporting documentation, such as risk assessments, will be included in the decision document or implementation document, as appropriate. Risk assessments completed during design phase will be included as an appendix to the Design Documentation Report (DDR).

d. Review Plans. Review of feasibility reports and DDRs will comply with the EC 1165-2-217 (Review Policy for Civil Works). In compliance with this policy, the project review plan submitted to the Review Management Organization (RMO) will integrate required reviews for risk assessments. The district DSO/LSO will be part of the district Quality Control team. The RMC serves as the RMO for all projects whose failure would pose a significant threat to human life and for all dam and levee modification studies. The RMO will coordinate with the appropriate Planning Center of Expertise, DSOG, and LSOG as needed for decisions, when appropriate. In general, DSOG/LSOG members from the relevant disciplines will participate as members of the vertical team, technical review or policy review, as appropriate.

e. Deviations from Mandatory Design Standards. Justifications for deviations from mandatory design standards must include a risk assessment that demonstrates adherence to the principles in paragraph 6. All deviations must be clearly identified in the decision documents/design reports and must be deliberately called out, within the review plan, as a specific charge for the review. All proposed deviations from mandatory design standards, including rationale, must be documented in a memorandum approved by the district and division DSO or LSO and concurred by the DSOG or LSOG, whichever is appropriate. The DSOG or LSOG will ensure the appropriate Community of Practice (CoP) leaders or their designated representatives are included in the concurrence process. Review documentation will account for all decisions and rationale for deviations, including the memorandum documenting approval and concurrence. It is highly recommended that districts coordinate with appropriate CoP leaders and/or national centers when considering a deviation. In order to maintain adherence to TRG 3, deviations from mandatory design standards may necessitate specific and unique requirements in the project operation and maintenance manual.

f. Construction Considerations. Involvement of construction expertise in the design phase will help maintain constructability of the project, assure construction activities are appropriately incorporated into the cost estimates, and allow construction staff to maintain awareness of design philosophies, intent and assumptions. The construction team is responsible for ensuring the district LSO/DSO and LSPM/DSPM are appropriately engaged throughout the construction process. The LSO/DSO and LSPM/DSPM will assign appropriate dam and levee safety personnel to be engaged on the construction team in order to ensure appropriate use of risk assessments and full consideration of components to maximize resiliency, reliability, and operability. It may be appropriate to also engage the RMC or other national centers. Monitoring of risks associated with the project throughout construction activities should be informed by on-going or as-needed risk assessments. Changes during construction are likely to occur as the contractor executes the work and site conditions are better understood. As new information is gathered, the Lead Engineer is responsible for assuring consideration and evaluation of the potential for risks to be increased, transferred or transformed by construction activities and by changes made during the construction phase. The Lead Engineer and the PDT will evaluate the changes to the project caused by circumstances such as unexpected foundation conditions, unexpected differences in installed utilities, environmental conditions, hydraulic conditions, or contractor proposed project changes and consider the impacts these changes will have on the

project's risk assessment. Changes to risk both during construction and post-construction should be communicated vertically as appropriate and documented in the Final Project Documents and Records.

10. **Risk-Informed Design Support.** Headquarters, in coordination with the national centers that support Dam and Levee Safety (RMC, Dam Safety Modification Mandatory Center of Expertise (DSMMCX), Levee Safety Center (LSC), and Modeling Mapping and Consequences Production Center (MMC)), has designated a risk-informed design coordinator and a risk-informed design cadre to support districts in implementation of risk-informed design. Additionally, this team can assist evaluating or coordinating any consideration of deviations from mandatory design standards with the appropriate community of practice.

a. Specific support that the risk-informed design coordinator and cadre will provide includes:

(1) Facilitate District's request for project support with the risk-informed design process, including development of work plans.

(2) Ensure a project's risk-informed design process follows guidance/policy, including coordination with appropriate CoP leaders as needed.

(3) Coordinate with RMC for risk assessment policy/guidance, review, and support.

(4) Coordinate with MMC for consequence evaluation in support of risk assessments, risk communication, and development of EAPs.

(5) Ensure personnel with the necessary expertise/experience/skill sets are available to support the District's risk-informed design, including facilitators, risk cadres, and other subject matter experts as needed.

(6) Ensure risk-informed design processes are included in an appropriate Project Management Plan (PMP) and review plans.

(7) Coordinate with the DSOG and LSOG for members and decisions, when appropriate.

b. The risk-informed design coordinator is Brad Arcement, P.E., Levee Safety Branch Chief, Levee Safety Center (CEMVK-EC-PC), 601-631-5899, email: Brad.J.Arcement@usace.army.mil.

c. Funding for risk-informed design support will be provided by District's project funds. Since initial budgeting for existing projects likely did not include the additional effort required for risk-informed design, it is understood that the scope of risk assessments in support of risk-informed design may have to be scaled to fit within existing budgeting constraints to the maximum extent possible. All future PED and feasibility study efforts will be budgeted to fully fund activities in support of a scalable, decision-relevant, risk-informed design.

d. The overarching schedules for FY2019 regular program projects and the 2018 Supplemental Program are already established. The risk-informed design process will be incorporated into the existing project schedules so as not to delay any projects.

11. **Point of Contact.** HQUSACE point of contact for this ECB is Ms. Phoebe Percell, P.E., CECW-EC, (202) 761-7662.

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Encl.
Appendix A – References
Appendix B – Definitions
Appendix C – USACE Tolerable Risk Guidelines for Dams and Levee Systems

APPENDIX A – References

1. Engineer Regulation (ER) 1105-2-101, Risk Assessment for Flood Risk Management Studies, 17 July 2017

2. Engineer Regulation (ER) 1100-2-1156, Safety of Dams – Policy and Procedures, 31 March 2014

3. Engineer Regulation (ER) 1105-2-100, Planning Guidance Notebook, 22 April 2000

4. Engineer Regulation (ER) 1110-2-1150, Engineering and Design for Civil Works Projects, 8 August 1999

5. Engineer Circular (EC) 1110-2-6074, Guidance for Emergency Action Plans, Incident Management and Reporting, and Inundation Maps for Dams and Levee Systems, 31 Jan 2018

6. Engineer Circular (EC) 1165-2-217, Review Policy for Civil Works, 20 Feb 2018

7. Director's Policy Memorandum FY2019 (2019-02), Employing MSC and District Technical Expertise and Professional Judgment to empower enhanced delivery of the 2018 Emergency Supplemental Program, 24 January 2019

8. Engineering and Construction Bulletin (ECB) 2015-18, Technical Lead for E&C Deliverables, 29 February 16, Rev 1

9. Engineering and Construction Bulletin (ECB) 2019-3, Risk Informed Decision Making for Engineering Work During Planning Studies, 06 March 2019

10. Engineering and Construction Bulletin (ECB) 2019-8, Managed Overtopping of Levee Systems, 24 April 2019

11. Planning Bulletin, PB 2019-04, Incorporating Life Safety into Flood and Coastal Storm Risk Management Studies, 20 June 2019

12. Policy Guidance Letter (PGL) No. 52, Flood Plain Management Plans, 8 December 1997

13. U.S. Army Corps of Engineers, Institute for Water Resources 2010. Institute for Water Resources, "Proceedings of the Workshop, Exploration of Tolerable Risk Guidelines for the USACE Levee Safety Program," 17 - 18 March 2010, Washington, DC. Institute for Water Resources, 10-R-8. http://www.iwr.usace.army.mil/docs/iwrreports/10-R-8.pdf

14. Best Practices in Dam and Levee Risk Analysis
http://www.usbr.gov/ssle/damsafety/Risk/methodology.html

15. Health Service Executive 1999. HSE (Health and Safety Executive, United Kingdom), Reducing Risks, Protecting People, Discussion Paper, Risk Assessment Policy Unit, 1999, Her Majesty's Stationary Office, London

APPENDIX B – Definitions

Annual Exceedance Probability (AEP) – AEP represents the probability that flooding from dam or levee breach or overtopping will occur in any given year considering the full range of possible annual floods. Sometimes also referred to as annual probability of inundation or annual probability of failure.

Incremental risk – The risk of inundation posed by a dam or a levee system for the following three inundation scenarios: prior to overtopping, overtopping with breach, and component malfunction/mis-operation.

Individual life risk – The increment of flood risk imposed on a single individual posed by a dam or levee system. Individual life risk is influenced by location, exposure, and vulnerability.

Potential Failure Mode (PFM) – A potential failure mode is a mechanism that once initiated potentially could progress to breach of a dam or levee system. It is noted that overtopping without breach is not called a potential failure mode.

Potential Failure Modes Analysis (PFMA) – The process for which potential failure modes are identified and examined for a dam or levee system, conducted by a team of persons who are qualified either by experience and\or education to evaluate dams or levee systems.

Quantitative risk assessment (QRA) – A risk assessment that results in numerical calculations for probability of breach and consequences combined to quantify a numeric risk estimate.

Project sponsor – A public entity that has responsibility for operation and maintenance for all or a certain portion of a dam or levee system.

Risk Assessment – A systematic, evidence-based approach for quantifying and describing the nature, likelihood, and magnitude of risk.

Risk Cadre – A multidisciplinary team of experts trained in conducting risk assessments

Risk-driving PFM – Potential Failure Mode that has been determined as having the most influence on incremental risk and is carried through to determine its associated risk estimate in a risk estimate.

Risk Estimate – The combination of the probability of inundation due to a dam or levee breach and the associated consequences and portraying the results as a combined risk estimate typically portrayed in a risk matrix.

Risk Facilitator – A licensed engineer or geologist with experience in leading multidisciplinary teams through risk assessments.

Risk Informed Decision Making – The process of using qualitative, semi qualitative or quantitative risk information in conjunction with other considerations to lead to more complete, transparent, and informed decisions.

Screening Level Risk Assessment (or screening) – A simplified semi-qualitative risk assessment that relies on existing data, historical performance, engineering judgment, and consequence estimation to quickly characterize the relative risks posed by dams and levee systems in terms of a relative probability of breach and potential risk to life and property.

Semi-Quantitative Risk Assessment (SQRA) – A risk assessment that uses a combination of limited numerical estimates with qualitative descriptions that result in risk estimates based on orders of magnitude.

Societal life risk – The risk of widespread or large-scale catastrophes posed by a dam or levee system that would result in a negative socio response.

Tolerable Risk (related to dams or levee systems) – Incremental risk that meet all of the following: (1) Society is willing to live with the risk associated with the dam or levee system to secure the benefits of living and working in the leveed area or downstream of the dam; (2) There is a continuation of recognition of the dam or levee related risk, because the risk associated with dams and levee systems are not broadly acceptable and cannot be ignored; (3) Risks associated with the dam or levee system are being properly monitored and managed by those responsible for managing the risk; and (4) Those responsible for managing the risk associated with a dam or levee system continue to reduce the risk still further as practicable.

APPENDIX C – USACE Tolerable Risk Guidelines for Dams and Levee Systems

1. **Background.** This appendix defines the application of Tolerable Risk Guidelines (TRGs) for risk-informed decision making within the U.S. Army Corps of Engineers (USACE) Dam and Levee Safety Program. USACE has chosen to use the "tolerability of risk" framework with associated TRGs, originally developed in the United Kingdom and adapted elsewhere. The concept evolved from the recognition that absolute safety is not practical and that managing risks needs to reflect how people and society view risk. The tolerability of risk approach is a framework for reaching decisions by focusing on the most serious risks in a consistent, efficient, and transparent manner.

2. **USE of TRGs.** USACE will make risk-informed decisions, including the development of recommendations, related to dams and levee systems with the goal meeting all four TRGs. USACE's judgment will be based from the perspective of the federal interest, not an individual's or community's perception of tolerability. The four TRGs are not mutually exclusive and therefore each TRG will be considered individually and collectively. There is no prescriptive list of criteria to each of the guidelines and often, actions and recommendations will overlap between guidelines. USACE will make a tolerability determination based on basic considerations outlined in paragraph 9 and this Appendix and in combination with risk assessment data and evidence, knowledge, experience, and judgment. Because risks are dynamic, meeting TRGs for dams and levee systems requires continuous assessment, management, and improvement. Risks can be considered tolerable by identifying and making progress towards risk management recommendations or by determining that no further risk reduction is justifiable. Risks would be considered unacceptable if no progress or action is being accomplished. For additional information on the basis of USACE's TRGs, refer to Institute for Water Resources "Proceedings of the Workshop, Exploration of Tolerable Risk Guidelines for the USACE Levee Safety Program," 17 - 18 March 2010 and Health Service Executive "Reducing Risks, Protecting People, Discussion Paper, Risk Assessment Policy Unit, "1999.

a. USACE will use TRGs for the following purposes:

(1) To inform the degree and priority of federal investments and actions, as well as, make recommendations on non-federal investment to others on the same basis; and

(2) To determine if the risk associated with a dam or levee systems is "tolerable," which is a judgment of the appropriateness of collective federal and non-federal efforts to manage that risk.

3. **Life Safety Risk.** USACE will consider risk to life safety related to the TRGs from two perspectives.

a. Societal Life Risk. Societal life risk is the risk of widespread or large-scale catastrophes from the inundation of a leveed area or area downstream of a dam that would result in a negative societal response. In general, society is more averse to risk if multiple fatalities were to occur from a single event. In contrast, society tends to be less averse to risks that result from many events resulting in only one or two fatalities, even if the total losses from the small events is larger than that from the single large event.

b. Individual Life Risk. The individual life risk is represented by the probability of life loss for the identifiable person or group by location that is most at risk of loss of life due to a dam or levee breach. Individual life risk is influenced by location, exposure, and vulnerability.

4. **Economic Risk.** As part of TRGs, USACE will consider economic risk associated with the likelihood of direct and indirect economic losses associated with a dam or levee breach. Direct economic risk can include damage to private and public buildings, contents of buildings, vehicles, public infrastructure such as roads and bridges, public utility infrastructure, agricultural crops, agricultural capital, erosion losses to land, and costs associated with cleaning up contaminates. Indirect economic risks are those associated with the destruction of property, loss of ability to work, loss of regional economic activity, and the displacement of people due to inundation.

5. **Environmental Risk.** As part of TRGs, USACE will consider environmental risk associated with the likelihood of both direct and indirect impacts on natural, ecological, cultural, and historic resources, as well as impacts on the nation's security that typically cannot be measured in monetary terms.

6. **TRG 1 – Understanding the Risk.** The first tolerable risk guideline involves considering whether society is willing to live with the risk associated with the dam or levee system to secure the benefits of living and working in the leveed area or downstream of a dam. In other words, answering the basic question – are the risks commensurate with the benefits? The process to evaluate this guideline will include a combination of considering the risk estimates from a risk assessment with qualitative factors. USACE will consider life safety, economic, and environmental risk for TRG 1 as described below. However, the first factor to consider is whether there is any additional information or studies needed to improve the understanding of the dam or levee risk.

a. Evaluation of Life Safety Risk. The life safety risk matrix shown in Figure C-1 will be used to guide the decision of whether the life safety risk associated with a dam or levee system meets TRG 1 both from a societal and individual life risk perspective. Consideration of uncertainty in the risk estimates will be a factor in determining if life safety risk meets TRG 1, especially for those risk estimates that plot on or around the individual and/or societal risk lines. When the life safety risk has average loss of life of 1000 or more with an annual exceedance probability of breach of 1.E-06 or less, those situations will be closely scrutinized prior to deciding if the risks are tolerable due to limitations with methods to estimate probabilities that low. For those situations where TRG 1 is met for societal life risk but not individual life risk, further considerations related to identifying the most at risk individuals; verifying the potential for life loss; and considering whether individuals exposed consider the benefits worth the dam or levee risk will be taken into account for TRG 1.

(1) Evaluation of Societal Life Risk. Risks that plot above the societal life risk line are considered unacceptable except in exceptional circumstances. Exceptional circumstances refer to a situation when USACE, acting on behalf of society, may determine that the life safety risks, although high, can be considered meeting TRG 1 based on benefits that the dam or levee system brings to society at large and that additional risk reduction is not justified or feasible. Typically, it takes a feasibility level of effort to determine if this type of exceptional circumstance exists.

Typically, risks that plot below the societal life risk line are considered to have met TRG 1 for life safety risk.

(2) Evaluation of Individual Life Risk. USACE has chosen to use 1 in 10,000 per year (1E-04) for the probability of life loss for an individual or group of individuals most at risk. The goal is to keep the risks associated with USACE program dam and levees from increasing the probability of death for an individual above annual mortality rates. The individual tolerable risk line is shown in Figure C-1.

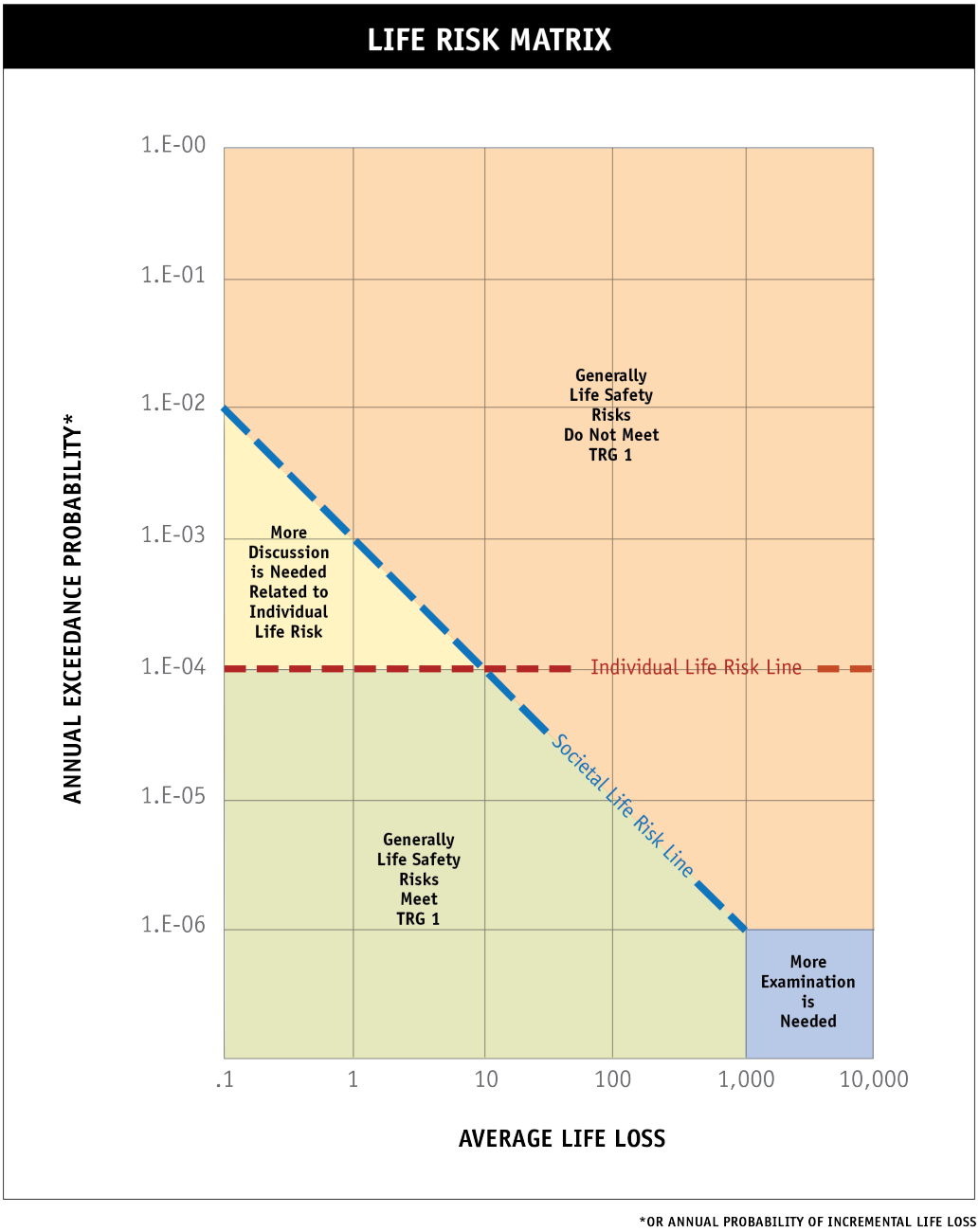

Figure C-1. Life Risk Matrix

b. Evaluation of Economic Risk. After evaluating life safety risks related to Figure 12.1, USACE will consider how economic risks determined from the risk assessment may influence a determination for meeting TRG 1. Similar to risk estimates for life safety, when the economic risk associated with a seemingly remote annual exceedance probability of breach or overtopping with breach of 1.E-06 or less, those situations will be closely scrutinized.

c. Evaluation of Environmental Risk. After evaluating life safety risks related to Figure C-1, USACE will consider through qualitative discussion how non-monetized risks determined from the risk assessment may influence a determination of meeting TRG 1.

7. **TRG 2 – Building Risk Awareness.** The second tolerable risk guideline involves determining that there is a continuation of recognition and communication of the dam or levee related risk, because the risk associated with dams and levee systems are not broadly acceptable and cannot be ignored. The rationale for meeting TRG 2 will be determined qualitatively and may be met through USACE dam and levee safety program activities and/or project sponsor activities, which includes risk communication. The following questions should be considered for TRG 2.

a. Does the project sponsor(s) have access to and aware of the best available levee risk information? Examples of this include participation in screening or higher level risk assessments with USACE and updating and posting the Levee System Summary.

b. Has the community in the leveed area or downstream of the dam been provided the best available risk information associated with the dam or levee system? Examples include public engagement activities, media stories, or a current community website.

c. Have flood risk (residual risk) and potential changes to flood risk over time been communicated to the community? Examples include public engagement activities, media stories, or a current community website.

8. **TRG 3 – Fulfilling Daily Responsibilities.** The third tolerable risk guideline involves determining that the risks associated with the dam or levee system are being properly monitored and managed by those responsible for managing the risk. The rationale for meeting TRG 3 will be determined qualitatively and may be met through USACE dam and levee safety program activities and/or project sponsor activities. TRG 3 can be met through demonstrated monitoring and risk management activities. This would include an active operation and maintenance program, visual monitoring (documented regular inspections), updated and tested emergency plan, instrumentation program, and interim risk reduction measures plan.

9. **TRG 4 – Actions to Reduce Risk.** The fourth guideline is determining if there are cost effective, socially acceptable, or environmentally acceptable ways to reduce risks from an individual or societal risk perspective. If it is determined that there are no acceptable ways to further reduce risks, USACE may consider this an exceptional circumstance and therefore might consider the dam or levee risk to be tolerable even if the life safety risk exceeds the associated tolerability guideline under TRG 1. The following questions should be considered for TRG 4.

a. Have appropriate actions been taken to reduce risks?

b. Could any actions reasonably be taken that would reduce risks further?

c. What is the cost to reduce the risk and how much is the risk reduced?

d. Should actions be evaluated in a detailed study?

e. Is there demonstrated progress towards risk reduction measures?