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Federal Emergency
Management Agency

Mitigation Directorate

NATIONAL
DAM SAFETY
PROGRAM

October 1998

Federal Guidelines for Dam Safety:

Hazard Potential Classification Systems for Dams

FEDERAL GUIDELINES FOR DAM SAFETY: HAZARD POTENTIAL CLASSIFICATION SYSTEM FOR DAMS

prepared by the
INTERAGENCY COMMITTEE ON DAM SAFETY

FEDERAL EMERGENCY MANAGEMENT AGENCY
OCTOBER 1998

PREFACE

In April 1977, President Carter issued a memorandum directing the review of federal dam safety activities by an *ad hoc* panel of recognized experts. In June 1979, the *ad hoc* interagency committee on dam safety (ICODS) issued its report, which contained the first guidelines for federal agency dam owners. The Federal Guidelines for Dam Safety (Guidelines) encourage strict safety standards in the practices and procedures employed by federal agencies or required of dam owners regulated by the federal agencies. The Guidelines address management practices and procedures but do not attempt to establish technical standards. They provide the most complete and authoritative statement available of the desired management practices for promoting dam safety and the welfare of the public.

To supplement the Guidelines, ICODS prepared and approved federal guidelines in the areas of emergency action planning; earthquake analysis and design of dams; and selecting and accommodating inflow design floods for dams. These publications, based on the most current knowledge and experience available, provided authoritative statements on the state of the art for three important technical areas involving dam safety. In 1994, the ICODS Subcommittee to Review/Update the Federal Guidelines began an update to these guidelines to meet new dam safety challenges and to ensure consistency across agencies and users. In addition, the ICODS Subcommittee on Federal/Non-Federal Dam Safety Coordination developed a new guideline, Hazard Potential Classification System for Dams.

With the passage of the National Dam Safety Program Act of 1996, Public Law 104-303, ICODS and its Subcommittees were reorganized to reflect the objectives and requirements of Public Law 104-303. In 1998, the newly convened Guidelines Development Subcommittee completed work on the update of all of the following guidelines:

- Federal Guidelines for Dam Safety: Emergency Action Planning for Dam Owners
- Federal Guidelines for Dam Safety: Hazard Potential Classification System for Dams
- Federal Guidelines for Dam Safety: Earthquake Analyses and Design of Dams
- Federal Guidelines for Dam Safety: Selecting and Accommodating Inflow Design Floods for Dams
- Federal Guidelines for Dam Safety: Glossary of Terms

The publication of these guidelines marks the final step in the review and update process. In recognition of the continuing need to enhance dam safety through coordination and information exchange among federal and state agencies, the Guidelines Development Subcommittee will be responsible for maintaining these documents and establishing additional guidelines that will help achieve the objectives of the National Dam Safety Program.

The members of all of the Task Groups responsible for the update of the guidelines are to be commended for their diligent and highly professional efforts.

Harold W. Andress, Jr.
Chairman, Interagency Committee on Dam Safety

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HAZARD POTENTIAL CLASSIFICATION SYSTEM FOR DAMS TASK GROUP

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I. PURPOSE

Common practice among federal and state dam safety offices is to classify a dam according to the potential impact a dam failure (breach) or mis-operation (unscheduled release) would have on upstream and/or downstream areas or at locations remote from the dam. The existing classification systems are numerous and vary within and between both the federal and state sectors. Although differences in classification systems exist, they share a common thread: each system attempts to classify dams according to the potential impacts from a dam failure or mis-operation, should it occur. The most significant problem with these various systems is the use of terms that lack clear definition. In addition, the various systems use different terminology to define similar concepts. This precludes consistency between the various federal and state agencies and understanding by the public.

This document sets forth a hazard potential classification system for dams that is simple, clear, concise, and adaptable to any agency's current system. The intent is to provide straightforward definitions that can be applied uniformly by all federal and state dam safety agencies and can be readily understood by the public. It does not establish how the system will be used, such as prescribing specific design criteria or prioritizing inspections. Those responsibilities belong to the responsible regulatory authority.

II. DEFINITIONS

For the purpose of this system, the following terms are defined:

HAZARD POTENTIAL: The possible adverse incremental consequences that result from the release of water or stored contents due to failure of the dam or mis-operation of the dam or appurtenances.

ADVERSE CONSEQUENCES: Negative impacts that may result from the failure of a dam. The primary concerns are loss of human life, economic loss (including property damage), lifeline disruption, and environmental impact.

INCREMENTAL: Under the same conditions (*e.g.*, flood, earthquake, or other event), the difference in impacts that would occur due to failure or mis-operation of the dam over those that would have occurred without failure or mis-operation of the dam and appurtenances.

PROBABLE: Likely to occur; reasonably expected; realistic.

HAZARD POTENTIAL CLASSIFICATION: A system that categorizes dams according to the degree of adverse incremental consequences of a failure or mis-operation of a dam. The hazard potential classification does not reflect in any way on the current condition of the dam (*e.g.*, safety, structural integrity, flood routing capacity).

III. CLASSIFICATION SYSTEM

Three classification levels are adopted as follows: **LOW**, **SIGNIFICANT**, and **HIGH**, listed in order of increasing adverse incremental consequences. The classification levels build on each other, *i.e.*, the higher order classification levels add to the list of consequences for the lower classification levels, as noted in the table on the following page.

This hazard potential classification system should be utilized with the understanding that the failure of any dam or water-retaining structure, no matter how small, could represent a danger to downstream life and property. Whenever there is an uncontrolled release of stored water, there is the possibility of someone, regardless of how unexpected, being in its path.

A primary purpose of any classification system is to select appropriate design criteria. In other words, design criteria will become more conservative as the potential for loss of life and/or property damage increases. However, postulating every conceivable circumstance that might remotely place a person in the inundation zone whenever a failure may occur should not be the basis for determining the conservatism in dam design criteria.

This hazard potential classification system categorizes dams based on the probable loss of human life and the impacts on economic, environmental, and lifeline interests. Improbable loss of life exists where persons are only temporarily in the potential inundation area. For instance, this hazard potential classification system does not contemplate the improbable loss of life of the occasional recreational user of the river and downstream lands, passer-by, or non-overnight outdoor user of downstream lands. It should be understood that in any classification system, all possibilities cannot be defined. High usage areas of any type should be considered appropriately. Judgment and common sense must ultimately be a part of any decision on classification. Further, no allowances for evacuation or other emergency actions by the population should be considered because emergency procedures should not be a substitute for appropriate design, construction, and maintenance of dam structures.

1. LOW HAZARD POTENTIAL

Dams assigned the low hazard potential classification are those where failure or misoperation results in no probable loss of human life and low economic and/or environmental losses. Losses are principally limited to the owner's property.

2. SIGNIFICANT HAZARD POTENTIAL

Dams assigned the significant hazard potential classification are those dams where failure or mis-operation results in no probable loss of human life but can cause economic loss, environmental damage, disruption of lifeline facilities, or can impact other concerns. Significant hazard potential classification dams are often located in predominantly rural or agricultural areas but could be located in areas with population and significant infrastructure.

3. HIGH HAZARD POTENTIAL

Dams assigned the high hazard potential classification are those where failure or mis-operation will probably cause loss of human life.

Hazard Potential Classification	Loss of Human Life	Economic, Environmental, Lifeline Losses
Low	None expected	Low and generally limited to owner
Significant	None expected	Yes
High	Probable. One or more expected	Yes (but not necessary for this classification)

IV. DISCUSSION

This Hazard Potential Classification System for Dams is based on the probable loss of human life and the potential for economic losses, environmental damage, and/or disruption to lifelines caused by failure of mis-operation of a dam or its appurtenances. This Hazard Potential Classification System for Dams recognizes that the failure or mis-operation of any dam or water-retaining structure, no matter how small, represents a potential danger to downstream life and property. Whenever there is an uncontrolled release of stored water, there is always the possibility, regardless of how unexpected, of someone being in the path of the discharge. However, postulating every conceivable circumstance that might remotely place a person in the potential inundation zone should not be the basis for determining the appropriate classification level. This system considers improbable loss of life to exist where persons are only temporarily in the potential inundation area.

The difference between the significant and high hazard potential classification levels is that a high hazard potential dam includes the probable loss of human life. The failure of a dam that is classified as a high hazard potential structure may or may not include adverse incremental consequences that would otherwise justify a significant hazard potential classification.

The hazard potential classification assigned to a dam is based on consideration of the effects of a failure or mis-operation during both normal and flood flow conditions. The classification assigned should be based on the worst-case probable scenario of failure or mis-operation of the dam, *i.e.*, the assigned classification should be based on failure consequences that will result in the assignment of the highest hazard potential classification of all probable failure and mis-operation scenarios. Each element of a project must be evaluated to determine the proper hazard potential classification for the project. However, there is only one hazard potential classification assigned to the entire project. Individual elements are not assigned separate classifications.

The probable scenarios considered should be reasonable, justifiable, and consistent with the *Federal Guidelines for Dam Safety: Selecting and Accommodating Inflow Design Floods for Dams* (FEMA). For example, assuming reasonable breach parameters and a failure during normal operating conditions ("sunny day" failure) may result in the released water being confined to the river channel and no probable loss of human life, indicating a low hazard potential classification. However, if the dam were assumed to fail in a similar manner during a flood condition, and the result would be probable loss of human life (excluding the occasional passer-by or recreationist) but minor economic losses, a high hazard potential classification would be appropriate. Once a project is placed in the high hazard potential classification, additional probable failure or mis-operation scenarios need only be considered if there is a need to determine if they would likely induce higher adverse incremental impacts.

In most situations, the investigation of the impact of failure or mis-operation of a dam on downstream human life, property damage, lifeline disruption, and environmental concerns is sufficient to determine the appropriate hazard potential classification. However, if failure or mis-operation of a dam contributes to failure of a downstream dam(s), the hazard potential classification of the dam should be at least as high as the classification of the downstream dam(s) and should consider the adverse incremental consequences of the domino failures.

APPENDIX A - BACKGROUND

CHARTER

On September 12, 1994, a Task Group was chartered to review existing hazard potential classification systems, identify ambiguous terminology, and propose a modified or new system for the hazard potential classification of dams.

METHOD

The Task Group met on five occasions. Minutes of each meeting were recorded. The Task Group assembled copies of various Federal agency hazard potential classification systems, a copy of the Canadian Dam Safety Association Classification System, and a summary of state dam safety agency classification systems. Copies of these documents are included in Appendix B. The Task Group reviewed these documents, considered several options, and developed the Hazard Potential Classification System for Dams. The draft Hazard Potential Classification System for Dams was submitted to the ICODS for review and comment. Comments were received in April 1996 and incorporated in the final Task Group report.

DISCUSSION

An early decision of the Task Group was to limit the work to the classification system and associated definitions. The Task Group would not consider issues related to future uses of the classification system, such as to establish design criteria, remediation schedules, inspection schedules, emergency action plan requirements, and/or spillway inflow design flood criteria. The work would be aimed at developing simple, unambiguous definitions for the proposed classification system.

The Task Group reviewed existing classification systems and the history of their development. The existing systems generally evolved from the U.S. Army Corps of Engineers' Appendix D, "Recommended Guidelines for Safety Inspections of Dams" (ER 1110-2-106), dated September 26, 1979. Although the original 1979 classification system was intended for limited use, *i.e.*, primarily to prioritize inspections for the 1979-1982 inspection program, it had evolved into multiple systems with various nomenclatures and specific design criteria. The resulting hodgepodge of systems has led to confusion in the dam safety community when dealing with multiple agencies and across state boundaries.

The confusion begins with the names of the major classification categories that include: High-Significant-Low Hazard Potential, A-B-C, C-B-A, 1-2-3, and 3-2-1 for the corresponding names. In addition, various High Hazard Potential definitions contain an allowance for zero, few, 1 or more, or up to 10 human lives lost. This variety of terms, systems, and criteria leads to confusion in the dam safety community and, more importantly, to a lack of understanding by the general public.

The Task Group reviewed existing systems for a number of categories. Although a few have up to nine categories, the great majority have three, as in the original 1979 system. In view of the long history of the basic 1979 three-category system, the associated regulatory base, and the various associated data bases, the Task Group decided to retain the existing three-category system. It was further decided that the original category titles of High, Significant, and Low Hazard Potential would be retained so that the resulting system would be applied uniformly by all regulatory agencies.

The next issue was to discuss the factors to be considered in each category. The Task Group decided that the four key risk factors are loss of human life; economic losses; environmental damage; and lifeline disruption.

Hazard potential categories would consider increasing levels of loss. However, probable loss of human life would designate a High Hazard Potential Structure regardless of the magnitude of other losses. If no loss of life is probable as the result of dam failure or mis-operation, the dam would be classified as Low or Significant Hazard Potential. This is a major change from prior systems. In an effort to clarify ambiguities in prior classification systems, the probable loss of human life is defined to signify one or more lives lost. The term "probable" is specifically included to indicate that the scenario used to predict the loss of human life must be reasonable and realistic, not contrived. In the definition for High Hazard Potential, the probable loss of human life is further clarified to exclude the casual user of the downstream or upstream area in determining the potential for loss of human life. It is also stated that potential public response to the emergency should not be used to reduce the calculated probable loss of human life.

The terms failure and mis-operation of a project are used by the Task Group to define the causes of the hazard to upstream and downstream interests. Failure of a dam is meant to include any cause that breaches the structure to release the stored contents (water, hazardous liquid wastes, slurries, or tailings). Mis-operation is meant to include any cause related to accidental or deliberate unscheduled release of the stored contents, such as a gate being opened more than planned but which does not result in full release of the reservoir contents.

It is the intent of the Task Group that each project would be periodically re-evaluated and reclassified as appropriate. The frequency of review should be each time the project is scheduled for inspection, or at least once each 5 years. This allows for periodic changes in the assigned hazard potential category based on changed reservoir or downstream development.

The Task Group considers it important that the term "Potential" be incorporated in each classification system name. This term helps the public understand the significant difference between hazards that "may" become real and any current actual safety concerns for the dam.

It is the Task Group's conclusion that the classification system should be a universal system for all regulatory agencies. The classification system category names should be adopted in lieu of any existing numerical or alphabetical system for consistency in the dam safety community and to properly educate the public on the need to properly maintain this component of the Nation's infrastructure.

TASK GROUP CONCLUSIONS

1. The proposed Hazard Potential Classification System for Dams provides a clear, simple, concise, and adaptable system to classify the hazard potential for dams.

2. The hazard potential rating does not reflect in any way on the current safety, structural integrity, or flood routing capability of the project water retaining structures.

3. The proposed classification system should be submitted to ICODS with a recommendation for peer review by ASDSO, USCOLD, ASCE, and the Canadian Dam Safety Association.

4. Future task groups should be established to consider design criteria associated with the various hazard classification systems.

5. The proposed Hazard Potential Classification System should be adopted in lieu of existing numerical and alphabetical systems. This is necessary to eliminate confusion in the dam safety community and to educate the public on the importance of dam safety.

APPENDIX B - EXISTING CLASSIFICATION SYSTEM INFORMATION

Federal Energy Regulatory Commission

USDA, Natural Resources Conservation Service (formerly Soil Conservation Service)

DOI, Bureau of Reclamation

U. S. Army Corps of Engineers

Canadian Dam Safety Association

Summary of State Systems (compiled April 1995)

FEDERAL ENERGY REGULATORY COMMISSION

FERC 0119-2

ENGINEERING GUIDELINES FOR THE EVALUATION OF HYDROPOWER PROJECTS

FEDERAL ENERGY REGULATORY COMMISSION

OFFICE OF HYDROPOWER LICENSING

APRIL 1991

1-2 Project Classification

1-2.1 Hazard Classification

The hazard potential classification of a project determines the level of engineering review and the criteria that are applicable. Therefore, it is critical to determine the appropriate hazard potential of a dam, because it sets the stage for the analyses that must be completed to properly evaluate the structural integrity of any dam.

1-2.2 Downstream Hazard Potential - Definitions

The hazard potential of dams describes the potential for loss of human life or property damage in the area downstream or upstream of the dam in event of failure or incorrect operation of a dam. Hazard classification does not indicate the structural integrity of the dam itself, but rather the effects if a failure should occur. The hazard potential assigned to a dam is based on consideration of the effects of a failure during both normal and flood flow conditions.

Dams conforming to criteria for the low hazard potential category generally are located in rural or agricultural areas where failure may damage farm buildings, limited agricultural land, or township and country roads. Low hazard potential dams have a small storage capacity, the release of which would be confined to the river channel in the event of a failure and therefore would represent no danger to human life.

Significant hazard potential category structures are usually located in predominately rural or agricultural areas where failure may damage isolated homes, secondary highways or minor railroads; cause interruption of use or service of relatively important public utilities; or cause some incremental flooding of structures with possible danger to human life.

Dams in the high hazard potential category are those located where failure may cause serious damage to homes, agricultural, industrial and commercial facilities, important public utilities, main highways, or railroads, and there would be danger to human life.

The hazard potential evaluation includes consideration of recreational development and use and socio-economic matters. Included in the high hazard potential category are dams where failure would cause serious damage to permanently established or organized recreational areas or activities. Also included in the high hazard potential category are dams where failure could result in loss of life of people gathered for an unorganized recreational activity (such as salmon fishermen and kayakers) where concentrated use of a confined area below the dam is a common annual occurrence during certain times each year.

1-3 Study Requirements

1-3.1 General

The following guidance shall establish the basic requirements for reviews and studies conducted by both the Washington and Regional offices. It is recognized that unique situations may require deviations from these guidelines, however, they are considered flexible enough to be followed for most of the basic types of reviews and studies anticipated. Any engineering study which is conducted, shall be consistent with the applicable sections of these guidelines.

1-3.2 Regional Office Inspections and Studies

The operating manual, prepared by the Division of Dam Safety and Inspections (D2SI), establishes minimum requirements for reports and field inspections of hydroelectric projects conducted pursuant to the Federal Power Act.

1-3.3 Washington Office Studies

1-3.3.1 License Applications

Review for Deficiencies - All license applications shall be reviewed for compliance with the engineering requirements of FERC regulations. Application deficiencies should be documented so the applicant can be appropriately and timely notified. A preliminary review should then be conducted to preliminarily assess economic feasibility and to ensure that the project's power output can be utilized. These preliminary studies should be conducted prior to the acceptance of the application. Items which should be examined include: the need for project power; the existence (or absence) of an agreement or memorandum of understanding for sale of project power; the impact of changes in fish habitat preservation flow releases on power generation; and the reasonableness of the project construction cost estimate. This study should resolve any basic questions concerning the ability of the Applicant to build the project and/or sell the project power.

Safety and Design Assessment - The safety and design assessment report shall include a summary of the conclusions and recommendations resulting from the engineering data in the license applications and technical review and studies based on such data.

that would otherwise not be developed without the dam. Consequently, **evaluation of the consequences of dam failure must be based on the dam being in place, and must compare the impacts of with-failure and without-failure conditions on existing development and known and prospective future development. Comparisons between existing downstream conditions with and without the dam are not relevant.**

2-3.1.2 Defining the Hazard Potential

The hazard potential of a dam pertains to the potential for loss of human life or property damage in the area downstream of the dam in the event of failure or incorrect operation of a dam. Hazard potential does not refer to the structural integrity of the dam itself, but rather the effects if a failure should occur.

The hazard potential classification assigned to a dam (see Section 1-2.2, Chapter I, of these Guidelines) should be based on the worst-case failure condition. That is, the classification is based on failure consequences resulting from the failure condition that will result in the greatest potential for loss of life and property damage. For example, a failure during normal operating conditions may result in the released water being confined to the river channel, indicating a low hazard potential. However, if the dam were to fail during a floodflow condition, and the result would be a potential loss of life or serious damage to property, the dam would have high hazard potential classification.

In many cases, the hazard potential classification can be determined by field investigations and a review of available data, including topographic maps. However, when the hazard potential classification is not apparent from a field reconnaissance, detailed studies, including dambreak analyses, are required for various floodflow conditions to evaluate the incremental effects of a failure of a dam in order to identify the flood level above which the consequences of failure become acceptable--that is, the floodflow condition above which the additional incremental increase in elevation due to failure of a dam is no longer considered to present an unacceptable threat to downstream life and property.

The selection of the appropriate IDF for a dam is related to the hazard classification for the dam. The IDF for a dam having a low hazard potential is selected primarily to protect against loss of the dam and its benefits should a failure occur. The IDF for high and significant hazard potential dams is the maximum flood above which there are no significant incremental impacts on downstream life and property.

2-3.1.3 Evaluating the Consequences of Dam Failure

The possible consequences resulting from a dam failure include loss of human life; economic, social, and environmental impacts; damage to national security installations; and political and legal ramifications. Estimates of the potential for loss of human life and the economic impacts of damage resulting from dam failure are the usual bases for defining hazard potential. Social and environmental impacts, damage to national security installations, and political and legal ramifications are not easily evaluated, and are more susceptible to subjective or qualitative evaluation. Therefore, these other considerations do not usually affect decisions on hazard potential. Because their actual

USDA, NATURAL RESOURCES CONSERVATION SERVICE
(FORMERLY SOIL CONSERVATION SERVICE)

United States Department of Agriculture
Soil Conservation Service
Federal Building, Room 393
100 Centennial Mall North, Box 82503
Lincoln, NE 68501

July 9, 1981

TSC TECHNICAL NOTE - ENG LI-43

From: Wendell B. Moody, Head, Engineering Staff, CTS, MTSC

Re: Hazard Classification of Dams

Objectives

The purpose of this technical note is to provide guidance in determining the hazard classification of dams. It also contains working tools that may be used in arriving at the proper classification.

National Engineering Manual, subpart C, Dams, gives definitions, design criteria, and responsibility for dam classification.

Hazard Classes

National Engineering Manual §520.21 and Technical Release No. 60 give the definitions for hazard classification. Exhibit No. 1 summarizes the relationships between hazard classification, damage to properties, and loss of life.

Exhibit No. 2 gives general definitions of properties and damage that are useful in evaluating hazards. These definitions are to be used with sound judgment consistent with the particular site conditions and damage potential. For example, a township road with a gravel surface may be the only access to homes or communities. Under these conditions, it may be considered a main highway. A very expensive bridge on a township or county road or railroad that would sustain severe damage should result in upgrading hazard classification.

Normally loss of life is associated with people being trapped in temporary or permanent residences. However, the potential for loss of life should be considered when schools, churches, commercial establishments, recreational areas, roads, and railroads are involved. The ability to warn people of a dam failure and to remove them from the hazard should influence hazard classification.

Documentation

National Engineering Manual §520.23 outlines when the hazard classification of dams is to be made, who has responsibility for the classification, and documentation.

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Hazard classification is the beginning of the design process. It establishes the criteria by which the dam will be designed, constructed, operated, and maintained. Hazard classification documentation is a part of the design documentation.

Exhibit No. 3 is a worksheet showing the types of information needed about a dam and the downstream flood plain in order to determine and document hazard classification. The exhibit is not intended to be all inclusive nor is the format intended to be the only method of presenting the information and classification. It is intended as a guide showing minimum documentation needs.

Breach Routing

Technical Release No. 66, Simplify Dam-Breach Routing Procedure, provides a tool for predicting flood stages downstream from a breach dam. Two site parameters required in the analysis are the depth of water in the reservoir and total volume of flow.

National Bulletin No. 210-1-12, dated February 23, 1981, transmitted draft policy and tentative guidelines on the requirements for making inundation maps and emergency action plans. The planned location of the proposed policy is NEM, subchapter C, part 520, subpart C. The proposed policy states that inundation maps are to be made assuming a sudden dam failure with the reservoir surface at the top of the dam. For simplicity, spillway flow at the time of breach and local inflow from areas downstream of the dam are not considered. In TR-66, the depth of water will be that created at the top of the dam. The volume of flow to be routed downstream will be the reservoir volume created at the top of the dam. The depth of water at the dam may be measured from the general flood plain elevation if the dam is long and if the cross sectional area of the stream channel is small compared to that available for flow in the flood plain.

Appendix A is a commentary on the selection of the volume of storage and the depth of water to be used in TR-66 and proposed in the draft policy expressed above.

Downstream Water Surface Profiles Resulting From Dam Failure

Appendix B consists of charts titled "Downstream Water Surface Profiles Resulting From Dam Failure." They provide an insight into the relationship between maximum breach discharge, volume, valley shape, and downstream flooding. TR 66 was used to route the discharges and volumes. If the shape of a natural valley approximates that in the charts, the charts may be used as a first estimate of the downstream water surface profile.

Wendell Moody

WENDELL B. MOODY
Head, Engineering Staff

Attachments

EXHIBIT NO. 1
POTENTIAL HAZARDS FOR DAM
CLASSIFICATION - NEM §520.20 & TR-60

DAMAGE TO:	HAZARD CLASSIFICATION (a)	(b)	(c)
LOCATION	Rural or Agr.	Predominately Rural or Agr.	Developing or Urban
ROADS			
Township & County	May Damage		
Main Highways		May Damage	Serious Damage
RAILROADS			
Minor		May Damage	
Main			Serious Damage
BUILDINGS			
Farm	May Damage		
Homes		May Damage Isolated	Serious Damage
Industrial			Serious Damage
Commercial			Serious Damage
Public			Serious Damage
UTILITIES			
Relatively Important		May cause Interruption	
Important			Serious Damage
LOSS OF LIFE	No	No	Yes

EXHIBIT NO. 2
POTENTIAL HAZARDS FOR DAM CLASSIFICATION
NEM §520.20 & TR-60

DAMAGE TO:	HAZARD CLASSIFICATION (a)	(b)	(c)
LOCATION	Rural or agricultural-- Areas of mostly farming or ranching. Urban housing developments do not exist and none expected during structure design life. Agricultural land--used for agricultural production.	Predominantly rural or agricultural.	Developing or urban.
ROADS Township and county-- All rural area roads without concrete or bituminous surfacing.	May damage-- Damage may occur when road surface acts as weir and d > 2 ft.		
Main highways-- U.S., interstate, and turnpike highways, and any concrete or bituminous surfaced township, county or state road that serves as the only access to a community.		May damage-- Damage may occur when road surface acts as weir and d > 2 ft.	Serious damage-- Interruption of service for more than 1 day.
RAILROADS Minor-- Interstate railroads used as frequently as one time per day. Materials carried are relatively nonperishable, agricultural products, or products if disrupted would not adversely affect local economy, safety, or general well-being of area.		May damage-- Damage may occur when road surface acts as weir and d > 2 ft.	

EXHIBIT NO. 2
POTENTIAL HAZARDS FOR DAM CLASSIFICATION
NEM §520.20 & TR-60

DAMAGE TO:	HAZARD CLASSIFICATION (a)	(b)	(c)
RAILROADS (con.)			
Main-- Intrastate or interstate railroads used more frequently than one time per day. Disruption would adversely affect economy, safety, and general well-being of area.			Serious damage-- Interruption of service for more than 1 day.
BUILDINGS			
Farm-- Farm buildings--On farm buildings not occupied by people or having potential for occupancy.	May damage Damage may occur when $D > 3$ and $DV > 15$.		
Homes-- Single family residences, apartments, nursing homes, motels, hotels, and hospitals.		May damage-- Any flooding above ground floor level.	Serious damage-- Damage may occur when $D > 3$ and $DV > 15$.
Isolated-- Single family dwellings on farms and ranches. Does not include homes in developing areas.			

EXHIBIT NO. 2
POTENTIAL HAZARDS FOR DAM CLASSIFICATION
NEM §520.20 & TR-60

DAMAGE TO:	HAZARD CLASSIFICATION (a)	(b)	(c)
BUILDINGS (con.)			
Industrial/Commercial--			Serious damage-- Kind, construction, and contents of building must be evaluated. General serious damage can occur at a depth of 3 ft or less and at a velocity of 5 ft/second or less.
Public-- Schools, churches, libraries, etc.			Serious damage-- Kind, construction, and contents of building must be evaluated. General serious damage can occur at a depth of 3 ft or less and at a velocity of 5 ft/second or less.
UTILITIES			
Relatively important--		May damage-- Damage may occur when buried lines can be exposed by erosion and when towers, poles, and above ground lines can be damaged by undermining or by debris produced from the flood plain.	

EXHIBIT NO. 2
POTENTIAL HAZARDS FOR DAM CLASSIFICATION
NEM §520.20 & TR-60

DAMAGE TO:	HAZARD CLASSIFICATION (a)	(b)	(c)
UTILITIES (con.) Important-- Interstate and intrastate power and communication lines serving towns, communities, and significant military and commercial facilities in which disruption of power and communication would adversely affect the economy, safety, and general well-being of the area.			Serious damage-- Interruption of service for more than 1 day.
LOSS OF LIFE Potential for loss of life-- Flood depths greater than 1 ft in living quarters; such as residences, apartments, nursing homes, motels, hotels, and hospitals, and on escape routes from such living quarters. Potential of loss of life should be considered for schools and recreational areas where adequate warning systems are not available.	No	No	Yes

DOI, BUREAU OF RECLAMATION

ACER TECHNICAL MEMORANDUM NO. 11
ASSISTANT COMMISSIONER - ENGINEERING AND RESEARCH
DENVER, COLORADO

DOWNSTREAM HAZARD CLASSIFICATION GUIDELINES

U.S. DEPARTMENT OF THE INTERIOR
Bureau of Reclamation
1988

DOWNSTREAM HAZARD CLASSIFICATION GUIDELINES

I. INTRODUCTION

A. Definition of Downstream Hazard

A downstream hazard is defined as the potential loss of life or property damage downstream from a dam and/or associated facility (e.g., dike) due to floodwaters released at the structure or waters released by partial or complete failure of the structure [1].[1]

Downstream hazard classification is not associated with the existing condition of a dam and its appurtenant structures or the anticipated performance or operation of a dam. Rather, hazard classification is a statement of potential adverse impact on human life and downstream developments if a designated dam failed.

The cost of the dam, related facilities (e.g., pump stations, canals, pipelines, etc.), and project losses are not considered in downstream hazard classification. Also, the consequences of a rapid reservoir drawdown, due to a dam failure, on persons upstream from the dam are not considered in downstream hazard classification. Only the direct effects of a dam-break flood on persons, property, or outstanding natural resources at officially designated parks, recreation areas, or preserves downstream from the dam are considered.

B. Purpose of Downstream Hazard Classification

Dams are given a hazard classification for two reasons:

1. The Department of the Interior (DOI) Departmental Manual, Part 753 [2], establishes that a hazard classification is to be assigned to every DOI dam.

2. Hazard classification serves as a management tool for determining which dams are to undergo the full SEED (Safety Evaluation of Existing Dams) process. Dams having a low downstream hazard classification are excluded, whereas those having a significant or high downstream hazard classification are included.

---

[1] Numbers in brackets identify references listed in section VI.

For large dams, hazard classification guidelines may seem superfluous; almost all large dams are obvious high-hazard facilities. Although it is with the smaller structures that these guidelines become most useful, all dams are given the same depth of analysis if needed. The hazard classification of small dams is often uncertain and requires detailed technical analysis, good engineering judgment, and a good "feel" for the impacts of dam failure floods (app. A).

For any dam, a situation can always be imagined that would result in loss of life regardless how remote the location of a dam and/or how little the chance of persons being affected by its failure flood. Thus, guidelines can be very useful in these situations to avoid being unduly conservative and to provide consistency to hazard classification as much as possible.

C. Purpose of the Downstream Hazard Classification Guidelines

The purpose of this document is:

1. To define the SEED method for assigning a dam's hazard classification (secs. I and II);

2. To provide guidance and present methods, for the purpose of downstream hazard classification, for estimating the downstream area susceptible to flooding due to a dam failure (sec. III and app. A);

3. To provide guidance and criteria for identification of downstream hazards (sec. IV); and,

4. To bring objectivity and consistency into downstream hazard classification.

Section III on estimating inundated area is included to present state-of-the-art methodology and a systematic approach that can be used by analysts not familiar with dam-break/inundation study techniques. A discussion of other accepted methods is included in appendix A.

Identifying downstream hazards is often controversial and/or nebulous. Due to this, section IV on identification of hazards is presented in order to bring objectivity and consistency, as much as can be reasonably expected, into the identification of downstream hazards. New concepts that equate flood depth and velocity relationships to hazard identification have been developed and are presented in section IV.

It is very important to note that these guidelines are intended for hazard classification purposes, but not for preparation of inundation maps for Emergency Preparedness Plans (EEPs) or hazard assessments.

Dam-break/inundation studies are not an exact science, and guidelines and criteria for performing these studies will vary depending upon the intent. Although studies for hazard classification and EPPs have some similarities, there are still major differences; these differences are explained in subsection III.A.

Dam-break/inundation studies performed for hazard assessments (as opposed to hazard classification) pose still another set of criteria. Such studies focus upon risk analysis which uses expected values. Thus, guidelines and criteria for these studies are based upon the highest probability of what is expected to occur [3].

II. DOWNSTREAM HAZARD CLASSIFICATION SCHEME

The system presented in table 1 is used by the SEED Program for classifying Bureau of Reclamation (Reclamation) and other DOI dams.

Table 1. - Downstream hazard classification system

Classification	Lives-in-jeopardy	Economic loss
Low	0	Minimal (undeveloped agriculture, occasional uninhabited structures, or minimal outstanding natural resources)
Significant	1-6	Appreciable (rural area with notable agriculture, industry, or worksites, or outstanding natural resources)
High	More than 6	Excessive (urban area including extensive community, industry, agriculture, or outstanding natural resources)

A. Lives-in-Jeopardy

Lives-in-jeopardy is defined as all individuals within the inundation boundaries who, if they took no action to evacuate, would be subject to danger commensurate with the criteria in section IV.

Lives-in-jeopardy is limited to direct downstream impacts resulting from the dam failure flood. Thus, lives-in-jeopardy does not consider situations such as persons in the reservoir or vehicle accidents due to a washed out highway crossing (after the flood wave has passed).

Lives-in-jeopardy is divided into permanent and temporary use. Permanent use includes:

> Permanently inhabited dwellings (structures that are currently used for housing people and are permanently connected to utilities, including mobile homes; three residents per dwelling are assumed based on 1980 National Census)
>
> Worksite areas that contain workers on a daily (workweek) basis. Commonly affected worksites include:
>
> - Public utilities and vital public facilities (powerplants, water and sewage treatment plants, etc.)
> - Private industrial plants or operations including materials production (sand, gravel, etc.)
> - Farm operations
> - Fish hatcheries

Temporary use includes:

- Primary roads along the channel, on the crest of the dam, or crossing the channel
- Established campgrounds and backpacker campsites
- Other recreational areas

The values in table 1 ("1-6" and "more than 6" for significant and high, respectively) are purely arbitrary. Previous downstream hazard classification criteria used lives-in-jeopardy of "few" and "more than few" for the significant- and high-hazard categories, respectively. The values in the table are presented for the intent of quantifying "few" and "more than few." It seemed reasonable to consider all occupants of two average households as "few." According to the 1980 census, the average U.S. household has three occupants; thus, "few" was quantified as six persons, and "more than few" was considered "more than 6." The lives-in-jeopardy for low-hazard classification, which had been "none expected," was quantified as "zero."

It is important to note that hazard classification deals only with lives in jeopardy, as opposed to "estimated loss of life". Estimated loss of life is the likely number of fatalities that would result from a dam failure flood event and is a forecast based on warning time that the population at risk would receive of dangerous flooding, and also on the use of historical relationships between warning time and loss of life. Details of the "estimated loss of life" are included in ACER Technical Memorandum No. 7 [3].

Determining the estimated loss of life involves many uncertainties and good judgment by the analyst. Analyses may indicate catastrophic flooding of a permanently occupied area, thus, indicating obvious loss of life to any occupants, or indicate as little as only shallow flooding (e.g., 1 to 2 feet (0.3-0.6 m)) with low velocities in areas of temporary use. In the latter case, it is difficult to determine the extent of loss of life, if any, that will occur to occupants affected by the flood. People may be safe if they remain in buildings, automobiles, move to high ground, etc. Flooding may be little more than just wetting of an area such that a person is safe to wade, but it is conceivable that a small child could fall into a ditch or depression or be drowned by locally fast moving water. Persons commuting to work may be unaware of a current dam failure, residents may not receive warning or may ignore warnings, residents may not be able to safely evacuate, etc.

Other factors to consider regarding estimating loss of life are proximity of the hazard and time of day. A community may be susceptible to catastrophic flooding but be located far enough downstream to allow ample warning and evacuation of its occupants. A dam could fail during the most inopportune time of day (11:00 p.m. to 6:00 a.m.), thus, allowing for little or no warning to downstream residents.

Due to these many uncertainties and unknowns with regard to estimated loss of life, a conservative approach of using lives-in-jeopardy (versus estimated loss of life) in the hazard classification system (table 1) is adopted by the SEED Program.

B. Economic Loss

Economic loss is that loss resulting from damage to residences, commercial buildings, industries, croplands, pasturelands, utilities, roads and highways, railroads, etc. Consideration should also be given to economic loss resulting from damage to outstanding natural resources within officially declared parks, preserves, wilderness areas, etc. Also, if a toxic or harmful substance is known to be present in significant quantities in the impoundment, the effect of its dispersion on downstream areas (with respect to economic loss only) should be considered in the downstream hazard classification. Because the dollar value of real property changes over time and varies according to the uses of the property, no attempt is made to assign dollar values as guidelines.

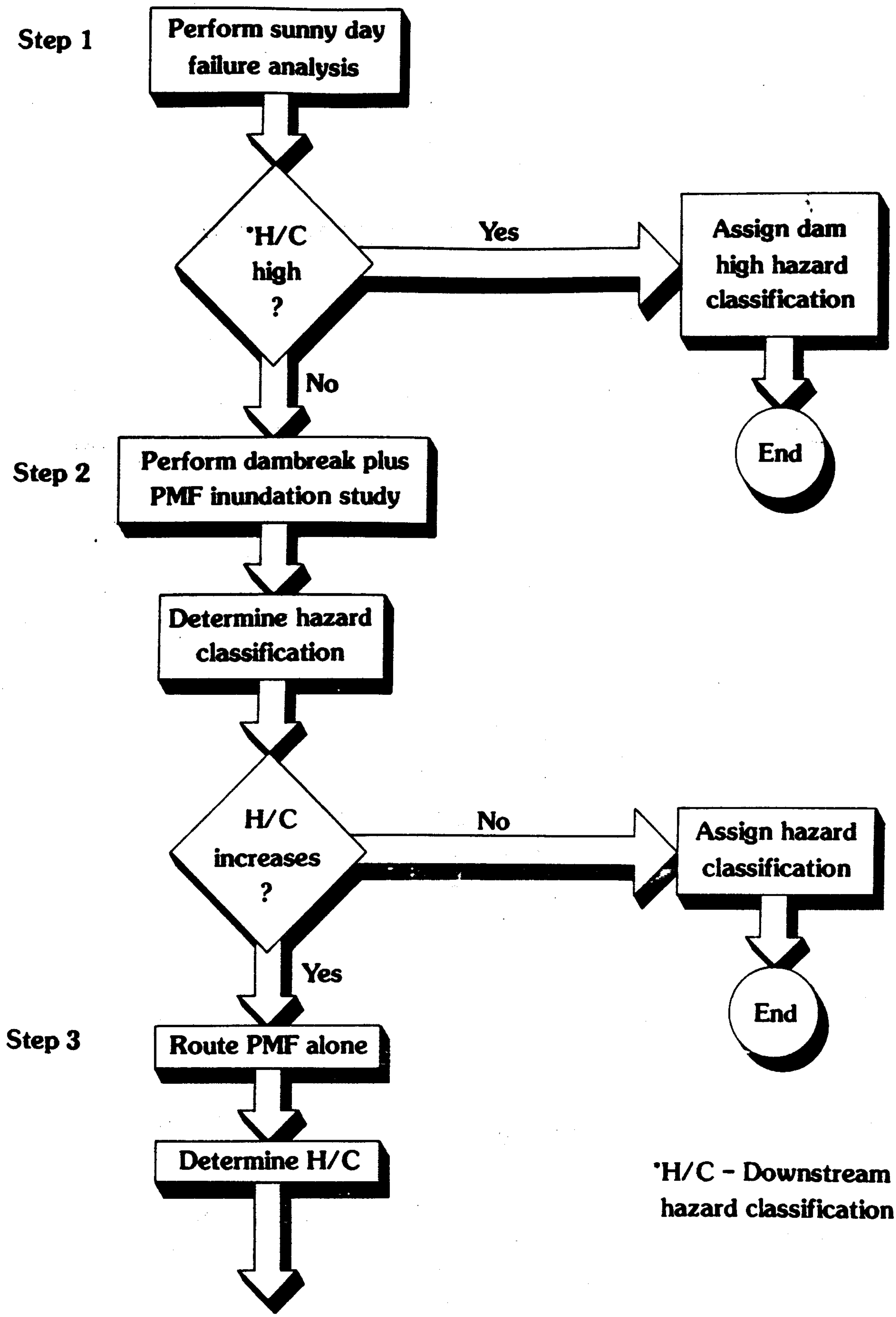
Economic loss does not include the loss of the dam and associated project facilities.

Hazard classification due to economic loss is based on the judgment of the analyst. However, judging economic value is, in most cases, not a problem because it is rarely addressed. The reason for this is that if economic loss is involved, then usually lives-in-jeopardy is a factor and the downstream hazard classification will be based solely on that. Thus, if a dam is classified as low or significant hazard based on lives-in-jeopardy, only then is economic loss evaluated to determine if a higher hazard classification is justified.

C. Multiple Dams

If failure of an upstream dam could contribute to failure of a downstream dam(s), the minimum hazard classification of the upstream dam should be the same as the highest classification of the downstream dam(s).

Figure 1 - Downstream hazard classification procedure flow chart



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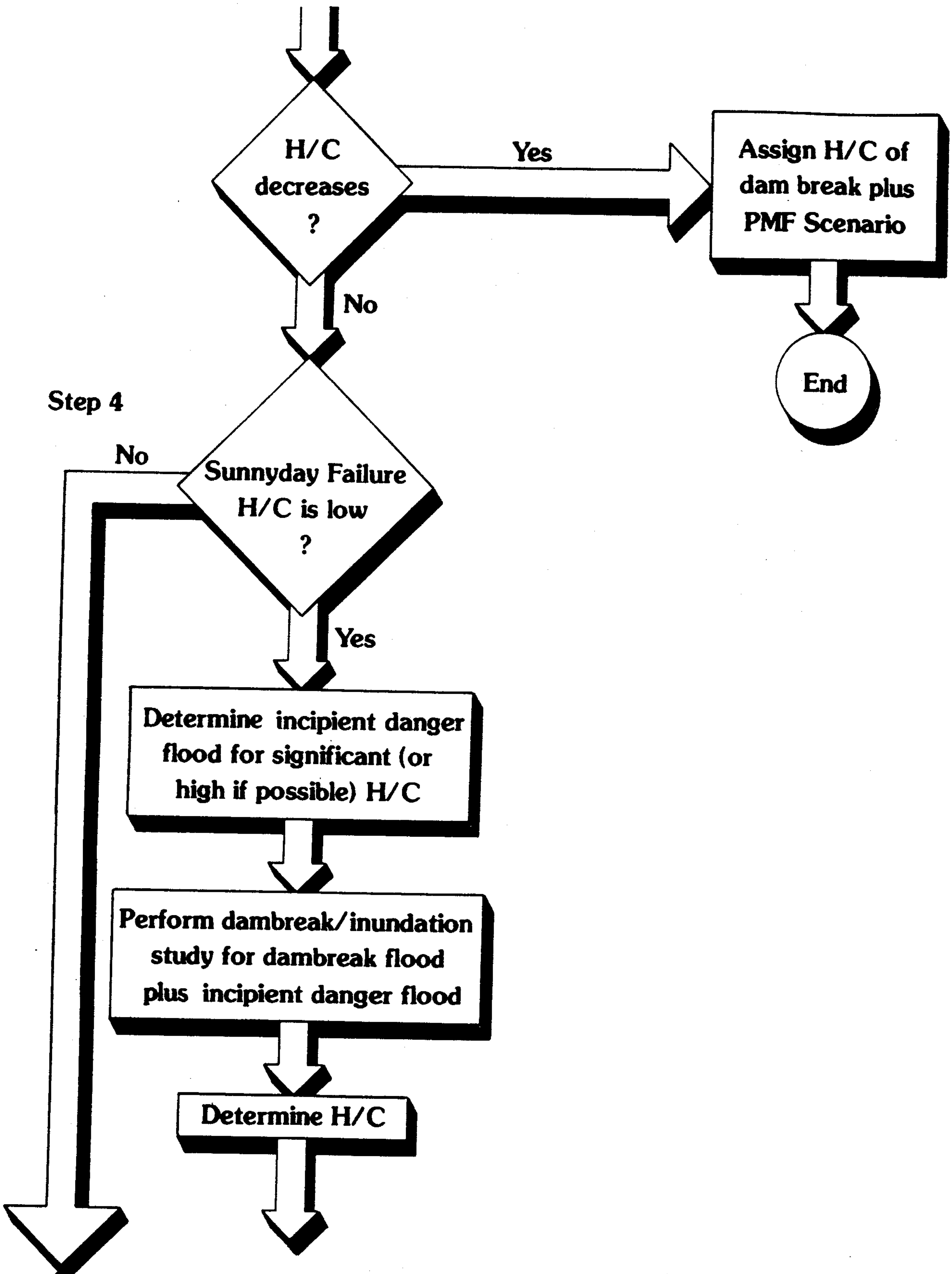

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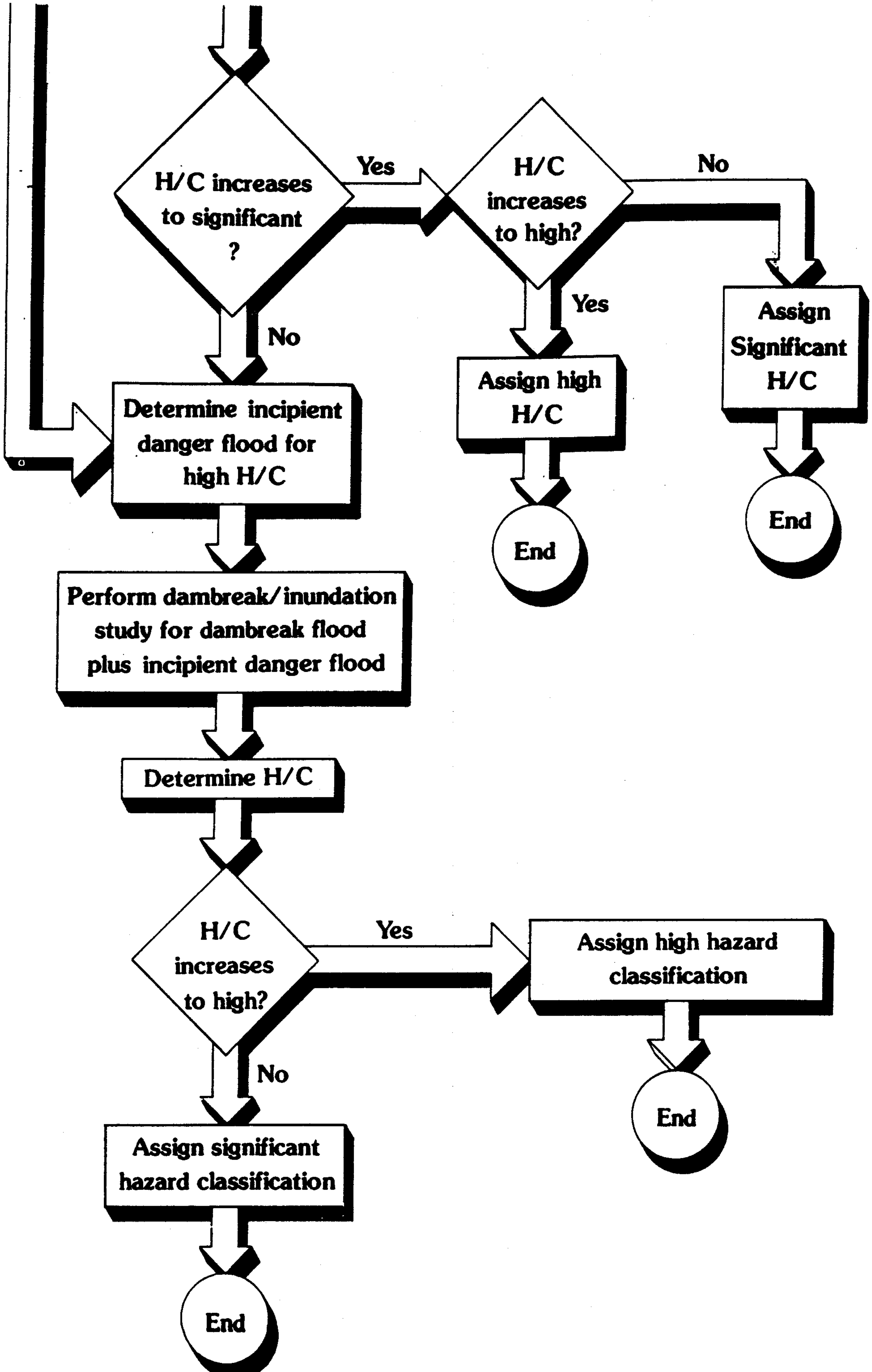
H/C increases to significant ?
Yes
No
H/C increases to high?
No
Yes
Assign Significant H/C
Assign high H/C
End
End
Determine incipient danger flood for high H/C
Perform dambreak/inundation study for dambreak flood plus incipient danger flood
Determine H/C
H/C increases to high?
Yes
No
Assign high hazard classification
End
Assign significant hazard classification
End

U. S. ARMY CORPS OF ENGINEERS

CECW-EP

DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, DC 20314-1000

ER 1110-2-1155

Regulation
No. 1110-2-1155

31 July 1995

Engineering and Design
DAM SAFETY ASSURANCE PROGRAM

1. Purpose

This regulation provides guidance and procedures for the investigation and justification of modifications for dam safety assurance at completed Corps of Engineers projects, under the authority of Section 1203 of the Water Resources Development Act of 1986 (P.L.99-662).

2. Applicability

This regulation applies to HQUSACE elements, major subordinate commands (MSC), districts, and field operating activities having responsibility for civil works projects.

3. References

See Appendix A for references.

4. Program Parameters

a. The Dam Safety Assurance Program provides for modification of completed Corps of Engineers dams and related facilities, when deemed necessary for safety purposes due to new hydrologic or seismic data or changes in the state-of-the-art design or construction criteria.

b. In order to qualify, the modifications must be within the Chief of Engineers discretionary authority to rectify plus meet the eligibility requirements described below. Projects approved under the Dam Safety Assurance Program will require a Dam Safety Assurance Program Evaluation Report, budget justification and other supporting data in accordance with the annual budget Engineer Circular as described in ER 5-7-1(FR). Generally, existing project authorities are considered sufficient to permit improvements to the project for safety purposes, if such improvements do not alter the scope or function of the project or substantially change any of its specifically authorized purposes.

c. Project modifications requiring additional authorization may be studied under the authority of Section 216 of the Rivers and Harbors Act of 1970, following the guidance in Chapter 2 of reference 6. Modifications to project features, which do not qualify under this regulation, will continue to be accomplished under the programs funded by the Operations and Maintenance, General, or Flood Control, Mississippi River and Tributaries (FC,MR&T) appropriations, respectively.

5. Eligibility

a. Examples of project features eligible for modification under this program follow:

(1) Modifying existing or constructing new facilities to provide stable and adequate discharge capability to contain the Inflow Design Flood (IDF). The IDF is the level of the Probable Maximum

This regulation supersedes that portion of ER 1130-2-417, 30 November 1980, pertaining to the Dam Safety Assurance Program

APPENDIX D
CONTENT OF DESIGN MEMORANDUM

The content of the design memorandum shall be as outlined below, in accordance with ER 1110-2-1150. Guidance included here is supplemental and shall be complied with, as appropriate to the project.

1. **General**

2. **Syllabus**

3. **Table of Contents**

4. **Project Description**

Cite the authority for the preparation of the design memorandum, referring to the approved evaluation report prepared in accordance with Appendix C. Provide a description of the design as originally constructed, and the present condition of the dam and related facilities. Include a discussion on the suitability of the feature or structure as constructed, and whether the design and/or construction has proven sufficient in serving the authorized project purposes. Also discuss the necessity for the proposed modification for dam safety and summarize any information in the evaluation report on the potential risk, damage and economics of the proposed work. Explain required real estate acquisitions. If the cost estimate of the work has increased since the evaluation report to the point that it now exceeds $10 million or is greater than 25% of the replacement cost of the total project, and there is no detailed economic analysis in the evaluation report, present such an analysis here. An Acquisition Plan is also required when a project cost exceeds $10,000,000 and should be accomplished in accordance with applicable Federal Acquisition Regulations.

5. **Pertinent Data**

Include a brief description of the feature(s) to be rehabilitated or modified for dam safety, why the modification is required, and a summary of the estimated cost.

6. **References**

7. **Project Cooperation Agreement**

If there will be no non-Federal sponsor for the project, this section can be omitted.

8. **Engineering Studies, Investigations, and Design**

The results of special investigations completed following the preparation of the evaluation report should be summarized in this section. Any additional studies or investigations accomplished as part of the design process should be described to the level of detail set forth in ER 1110-2-1150.

9. **Environmental Engineering**

10. **Plates**

11. **Project Cost Estimate and Associated Sponsorship**

Include a brief summary of the cost sharing information contained in the evaluation report, and a revised estimate of costs. Provide the sponsor(s) views and willingness to provide the required cooperation.

12. **Economic Analysis**

Projects accomplished under the authority of this Dam Safety Assurance Program do not need a benefit-cost ratio calculated. However, the cost and benefits from the proposed modifications need to be set forth.

13. Post-Authorization Changes

Modifications requiring new authorization may be recommended in the evaluation report. However, preparation of the design memorandum will not commence until such authorization is obtained.

14. Recommendations

15. Real Estate Appendix

If real estate acquisitions or relocations are required, then the real estate appendix contained in the evaluation report should be revised and updated as appropriate. A separate Real Estate DM may be appropriate, based on the complexity of the project.

APPENDIX E
HAZARD POTENTIAL CLASSIFICATION

1. **Discussion.** The current classification system used to evaluate the hydrologic hazard potential of dams was established in response to several dam failures in the early 1970's which resulted in significant loss of life and property damage. This classification system while useful for the evaluation of hazard to life and property, is deficient in that it does not consider the indirect losses of critical lifelines due to a dam failure. These losses, such as the loss of water supply, loss of key transportation or medical facilities, loss of power generation capability, or loss of navigation and environmental damage can have a significant impact on the public after a major hydrologic or seismic event. Some attempt has been made in the past to consider lifeline and environmental losses as economic losses, however a standard classification system has not been established.

An additional deficiency in the existing classification system is in the potential loss of life posed by the significant and high classifications. The terms "few" under the significant category, and "high potential" under the high category are too vague and subject to interpretation. The following is an attempt to quantify the loss of life associated with each level of hazard.

2. **Classification System.** The attached table establishes a classification system which groups losses into four general categories: loss of life, property, lifeline and environmental losses. This hazard classification is related to the functional integrity of the project, not the structural integrity of project features or components. Direct loss of life is quantified as either none, certain (one or more) or uncertain. Economic indirect losses are classified as either direct property, environmental or lifelines losses. Hazard ratings are based entirely upon the proximity of the project to population which would be at risk due to project failure or operation, and the impact upon life and property of the loss of essential services. A more detailed discussion on each of the four categories follows:

a. **Loss of Life.** If there is certainty that one or more lives will be lost due to failure or incorrect operation of the project, the project should be classified as <u>high</u> hazard. This certainty should be due to extensive residential or industrial development in the flood plain downstream of the project, and should be confirmed by inundation mapping which considers population at risk, time of flood wave travel and warning time. If the loss of life potential is uncertain because the downstream flood plain development is predominately rural or agricultural, or is managed so that the land usage is for transient activities such as with day-use facilities, then a <u>significant</u> hazard rating should be appropriate. Only those projects with no permanent downstream development located in rural or agricultural areas with no expected loss of life can be considered to have a <u>low</u> hazard potential.

b. **Property Losses.** Property losses are classified as either: direct economic losses due to flood damaged homes, businesses, infrastructure; or indirect economic losses due to the interruption of services provided by either the failed facility or by damaged property or infrastructure downstream.

Examples of indirect losses include:

(1) Loss of power generation capability at the failed dam (or at an inundated powerhouse downstream)

(2) Loss of navigation due to evacuation of the navigation pool at a failed reservoir (or due to direct damage to a lock)

(3) loss of water supply due to a reservoir emptied by a failed dam

c. Lifelines Losses. Disruption of essential lifeline services or access to these services during or following a catastrophic event can result in indirect threats to life. The loss of key transportation links such as bridges or highways would prevent access to medical facilities at a time critically injured people need access the most. Another example would be the loss or damage to medical facilities.

d. Environmental Losses. Damage to the environment caused by project failure or operation can result in the need for mitigative measures, or can cause irreparable damage to the environment. Environmental damage estimates should consider the damage which would normally be caused by the flood event under which the project failure occurs. Only the incremental damage caused by the project failure should be attributed to project failure or operation. Some other examples of environmental impacts are:

(1) Environmental damage caused by the release of a reservoir contaminated by toxic or hazardous mine waste

(2) Environmental damage caused by sediment released by a reservoir

3. See Table E-1 for classifying Civil Works projects as low, significant, or high hazard.

TABLE E-1: HAZARD POTENTIAL CLASSIFICATION FOR CIVIL WORKS PROJECTS

CATEGORY[1]	LOW	SIGNIFICANT	HIGH
Direct Loss of Life[2]	None expected (due to rural location with no permanent structures for human habitation)	Uncertain (rural location with few residences and only transient or industrial development)	Certain (one or more extensive residential, commercial or industrial development)
Lifeline Losses[3]	No disruption of services - repairs are cosmetic or rapidly repairable damage	Disruption of essential facilities and access	Disruption of critical facilities and access
Property Losses[4]	Private agricultural lands, equipment and isolated buildings.	Major public and private facilities	Extensive public and private facilities
Environmental Losses[5]	Minimal incremental damage	Major mitigation required	Extensive mitigation cost or impossible to mitigate

Notes:

1. Categories are based upon project performance and do not apply to individual structures within a project.

2. Loss of life potential based upon inundation mapping of area downstream of the project. Analyses of loss of life potential should take into account the extent of development and associated population at risk, time of flood wave travel and warning time.

3. Indirect threats to life caused by the interruption of lifeline services due to project failure, or operation, i.e., direct loss of (or access to) critical medical facilities or loss of water or power supply, communications, power supply, etc.

4. Direct economic impact of value of property damages to project facilities and down stream property and indirect economic impact due to loss of project services, i.e., impact on navigation industry of the loss of a dam and navigation pool, or impact upon a community of the loss of water or power supply.

5. Environmental impact downstream caused by the incremental flood wave produced by the project failure, beyond which would normally be expected for the magnitude flood event under a without project conditions.

recommended guidelines for safety inspection of DAMS

DEPARTMENT OF THE ARMY • OFFICE OF THE CHIEF OF ENGINEERS

WASHINGTON D C 20314

CHAPTER 2 - GENERAL REQUIREMENTS

2.1. <u>Classification of Dams</u>. Dams should be classified in accordance with size and hazard potential in order to formulate a priority basis for selecting dams to be included in the inspection program and also to provide compatibility between guideline requirements and involved risks. When possible the initial classifications should be based upon information listed in the National Inventory of Dams with respect to size, impoundment capacity and hazard potential. It may be necessary to reclassify dams when additional information becomes available.

2.1.1. <u>Size</u>. The classification for size based on the height of the dam and storage capacity should be in accordance with Table 1. The height of the dam is established with respect to the maximum storage potential measured from the natural bed of the stream or watercourse at the downstream toe of the barrier, or if it is not across a stream or watercourse, the height from the lowest elevation of the outside limit of the barrier, to the maximum water storage elevation. For the purpose of determining project size, the maximum storage elevation may be considered equal to the top of dam elevation. Size classification may be determined by either storage or height, whichever gives the larger size category.

TABLE 1

SIZE CLASSIFICATION

Category	Impoundment Storage (Ac-Ft)	Height (Ft)
Small	< 1000 and ≥ 50	< 40 and ≥ 25
Intermediate	≥ 1000 and < 50,000	≥ 40 and < 100
Large	≥ 50,000	≥ 100

2.1.2. <u>Hazard Potential</u>. The classification for potential hazards should be in accordance with Table 2. The hazards pertain to potential loss of human life or property damage in the area downstream of the dam in event of failure or misoperation of the dam or appurtenant facilities. Dams conforming to criteria for the low hazard potential category generally will be located in rural or agricultural areas where failure may damage farm buildings, limited agricultural land, or township and country roads. Significant hazard potential category structures will be those located in predominantly rural or agricultural areas where failure may damage isolated homes, secondary highways or minor railroads or cause interruption of use or service of relatively important public utilities. Dams in the high hazard potential category will be those located where failure may cause serious damage to homes, extensive agricultural, industrial and commercial facilities, important public utilities, main highways, or railroads.

TABLE 2

HAZARD POTENTIAL CLASSIFICATION

Category	Loss of Life (Extent of Development)	Economic Loss (Extent of Development)
Low	None expected (No permanent structures for human habitation)	Minimal (Undeveloped to occasional structures or agriculture)
Significant	Few (No urban developments and no more than a small number of inhabitable structures)	Appreciable (Notable agriculture, industry or structures)
High	More than few	Excessive (Extensive community, industry or agriculture)

2.2. Selection of Dams to be Investigated. The selection of dams to be investigated should be based upon an assessment of existing developments in flood hazard areas. Those dams possessing a hazard potential classified high or significant as indicated in Table 2 should be given first and second priorities, respectively, in the inspection program. Inspection priorities within each category may be developed from a consideration of factors such as size classification and age of the dam, the population size in the downstream flood area, and potential developments anticipated in flood hazard areas.

2.3. Technical Investigations. A detailed, systematic, technical inspection and evaluation should be made of each dam selected for investigation in which the hydraulic and hydrologic capabilities, structural stability and operational adequacy of project features are analyzed and evaluated to determine if the dam constitutes a danger to human life or property. The investigation should vary in scope and completeness depending upon the availability and suitability of engineering data, the validity of design assumptions and analyses and the condition of the dam. The minimum investigation will be designated Phase I, and an in-depth investigation designated Phase II should be made where deemed necessary. Phase I investigations should consist of a visual inspection of the dam, abutments and critical appurtenant structures, and a review of readily available engineering data. It is not intended to perform costly explorations or analyses during Phase I. Phase II investigations should consist of all additional engineering investigations and analyses found necessary by results of the Phase I investigation.

2.4. Qualifications of Investigators. The technical investigations should be conducted under the direction of licensed professional engineers experienced in the investigation, design, construction and operation of dams, applying the disciplines of hydrologic, hydraulic, soils and structural engineering and engineering geology. All field inspections should be conducted by qualified engineers, engineering geologists and other specialists, including experts on mechanical and electrical operation of gates and controls, knowledgeable in the investigation, design, construction and operation of dams.

CANADIAN DAM SAFETY ASSOCIATION

DAM SAFETY GUIDELINES

Canadian Dam Safety Association
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Tel. (403) 422-1356; Fax. (403) 427-6334

1.4 CLASSIFICATION OF DAMS

Requirement: **Each dam shall be classified in terms of the reasonably foreseeable consequences of failure. Each water retaining structure, including water passages, shall be classified separately.**

Each dam should be classified in accordance with the consequences of failure. The classification constitutes the basis for analysing the dam's safety and setting appropriate levels of surveillance activities. Table 1-1 represents a commonly-accepted classification system which is based on the potential loss of life and economic damages associated with dam failure. This classification system is used to link the consequences of failure to the requirements contained in Sections 2 through 10.

Alternative classification systems may be adopted for interpreting and addressing the requirements for dam surveillance and dam safety reviews, as set out in Sections 2 and 3 of these Guidelines. Such classification systems may incorporate the physical characteristics of the dam, its condition and the perceived risk of its failure, as well as the consequences of failure.

Appurtenances may be classified and evaluated separately. Thus the water passages could be in a different category from the dam, depending on the consequences of failure. If warning systems are considered to reduce the potential loss of life, the reliability of such warning systems must be incorporated into all analyses and evaluations.

The consequence categories listed in Table 1-1 are based on the incremental losses which a failure might inflict on downstream or upstream areas or at the dam. "Incremental losses" are those over and above losses which might have occurred for the same natural event or conditions, had the dam not failed.

The distinction between consequence categories, and the link with safety requirements, is intended to reflect society's values and priorities in allocating and distributing resources and funds to be used for protecting and saving lives, and for safeguarding property.

The incremental consequences of dam failure should be evaluated in terms of:

- Loss of life
- Economic value of other losses and/or damage to property, facilities, other utilities and dam, as well as loss of power generation or water supply. Where appropriate, costs are assigned to social, cultural and environmental impacts.
- Other less quantifiable consequences related to social, cultural and environmental damages.

The most severe consequences should prevail - if economic losses are Very High and loss of life is High, the dam would be classified as a Very High Consequence dam.

Evaluation of potential losses, both with and without dam failure, should be based on inundation studies and should consider existing and anticipated future downstream development and land uses. At the same time, the appropriate study level of inundation would depend on the potential consequences of failure. For dams where there is uncertainty about the consequences of a dam break, a simplified and conservative analysis should be used to make a preliminary assessment. If this analysis demonstrates a potential hazard, a more sophisticated analysis should then be undertaken. In the case of dams where the consequences of failure clearly fall within the "Very Low" category, a formal inundation study is not required.

A dam may be in one category for flood hazard and a different category for earthquakes, depending on the incremental damage attributable to dam failure from each cause.

A screening level estimation of the incremental consequences of failure may be appropriate for a dam to be classified in the Low Consequence category. However, if a dam is likely to be classified in the High or Very High Consequence categories, the evaluation of incremental consequences of failure should be based on site-specific analysis, and may require detailed site investigation.

Consequences of dam failure due to earthquakes should be based on average discharge conditions and maximum normal operating levels. Consequences attributable to reservoir slope failure or slope-failure-induced waves should be based on average discharge and maximum normal operating levels, unless the slide would have been induced by extreme rainfall associated with an extreme flood.

TABLE 1-1
CONSEQUENCE CLASSIFICATION OF DAMS

CONSEQUENCE CATEGORY	POTENTIAL INCREMENTAL CONSEQUENCES OF FAILURE [a]	
	LOSS OF LIFE	ECONOMIC, SOCIAL, ENVIRONMENTAL
VERY HIGH	Large increase expected [b]	Excessive increase in social, economic and/or environmental losses.
HIGH	Some increase expected [b]	Substantial increase in social, economic and/or environmental losses.
LOW	No increase expected	Low social, economic and/or environmental losses.
VERY LOW	No increase	Small dams with minimal social, economic and/or environmental losses. Losses generally limited to the owner's property; damages to other property are acceptable to society.

[a] Incremental to the impacts which would occur under the same natural conditions (flood, earthquake or other event) but without failure of the dam. The type of consequence (e.g. loss of life, or economic losses) with the highest rating determines which category is assigned to the structure.

[b] The loss-of-life criteria which separate the High and Very High categories may be based on risks which are acceptable or tolerable to society, taken to be 0.001 lives per year for each dam. Consistent with this tolerable societal risk, the minimum criteria for a Very High Consequence dam (PMF and MCE) should result in an annual probability of failure less than 1/100,000.

1.5 SELECTION OF SAFETY CRITERIA

Requirements: **The dam, along with its foundation and abutments, shall have adequate stability to safely withstand extreme loads as well as the normal design loads.**

The selection of loading criteria for extreme loads shall be based on the consequences of failure of the dam.

Methods to determine appropriate normal design loadings and factors of safety are covered in Sections 5 through 9 of this document. Sections 5 and 6 address earthquake loadings and floods, respectively.

To select criteria for extreme events, a risk-based approach may be used. The principle is that a dam whose failure would cause excessive damage or the loss of many lives should be designed to a proportionately higher standard than a dam whose failure would result in less damage or fewer lives lost. In assessing the safety of an existing dam, probabilistic risk analysis (PRA) methods can help verify that qualitative factors such as internal erosion and spillway debris blockage are not overlooked and that they receive attention commensurate with their contribution to the failure probability. The level of safety of a dam can sometimes be improved by addressing conditions less severe but more likely than those associated with such extreme events as the Maximum Credible Earthquake (MCE) and the Probable Maximum Flood (PMF).

Criteria for extreme events other than floods and earthquakes should be consistent with the levels required for flood and earthquakes.

1.4 CLASSIFICATION OF DAMS

Inundation Studies

For Very Low Consequence dams, dam failure would cause no inundation of populated areas, or no inundation leading to appreciable damage to property not belonging to the dam owner. Such dams do not require inundation studies. For all other dams, inundation studies must be carried out (see Section 4.3). These studies must include inundation resulting from both cases, **with and without dam failure**, in order to calculate the incremental consequences.

For the purpose of estimating the potential loss of life, the following items are required from each inundation study:

- Maps showing the inundated area
- Detailed flood arrival times shown on the inundation maps in the form of 15 minute interval isochrones (up to a minimum of 3 hours)
- Flood depth and velocity at various key locations in the inundated area. Depths should be representative of those experienced by inhabitants, not the depth above the low point on the river cross section
- Plots of flood discharge and depth versus time for various key locations in the inundated area

Tabulations should be used as a supplement to the information depicted on the maps. These should provide information on depths, velocities, flow rates, maximum rates of rise, and flood arrival times.

Potential Loss of Life

The factors affecting possible loss of life due to dam failure, and methods for estimating potential loss of life, are discussed thoroughly in three U.S. Bureau of Reclamation (USBR) documents (1986, 1988, 1989).

The first level of assessment requires determination whether there is any probable loss of life associated with a dam failure. USBR (1986) provides graphs of "high danger zone", "judgement zone" and "low danger zone" relating depth and velocity of flooding to the potential danger to vehicles, pedestrians, houses and mobile homes.

Depending on the definitions of High and Very High consequences (i.e. maximum loss of life allowed in the High category as indicated in Table 1-1 of the Guidelines), and whether risk analysis is used to determine extreme loading criteria, a more detailed estimate of the number of lives lost may be necessary.

In USBR (1989), "baseline" loss of life is related to the size of the population at risk (PAR) and the warning time before inundation, by empirically-derived equations. The baseline loss of life is then modified by correcting for the average exposure time of the population and for site-specific circumstances which differ substantially from the historic average conditions on the formulae were based.

A more recent methodology is described by DeKay and McClelland (1993), as outlined below. They propose an empirical equation for estimating the potential loss of life due to severe flooding, derived from the historical record of dam failures and flash flood cases. The calculated estimates of loss of life depend on:

- Population at risk
- Warning time
- Forcefulness of flood waters

Population at Risk (PAR)

DeKay and McClelland suggest that the "PAR should reflect the population at risk of "getting their feet wet" rather than the population at risk of experiencing treacherous flood waters". Also, they suggest that "no one who is more than 3 hr (flood) travel time below the dam be included in the PAR". Because of the limited data, the logistic model developed by DeKay and McClelland is statistically valid only for a population at risk of less than 100,000. Care should be taken when extrapolating the loss of life for a PAR greater than 100,000.

Similarly, the USBR define the PAR as the population which, if they took no action, would be exposed to any depth of inundation.

Various sources may be used for estimating the population at risk, including:

- Census data (for an entire region only if it is completely inundated, or census data based on postal codes for smaller areas)
- Local planning officials, real estate professionals, and chambers of commerce
- "Windshield surveys" of inundated area
- Ownership maps
- Topographic, planimetric, and cadastral maps, if relatively current
- Discussions with dam operators or other personnel familiar with the local area
- Multiplying number of houses by average number of people per house
- House-to-house survey

Once the number of residents in the area is estimated, the population at risk is found by multiplying the number of residents by an annual exposure factor. This is the fraction of a year that a typical individual would spend at home. A typical exposure factor for residents is usually in the range of 0.6 to 0.8.

The population at risk for facilities other than residences (such as schools, parks, shopping centres, etc.) should be found by multiplying the estimated average number of people within the facility by an exposure factor, which may reflect the fraction of the year that the facility is open. If the number of people and/or exposure factor can not accurately be found, then estimates should be made using the best overall judgement.

Warning Time

There is no single method for estimating warning time. USBR (1989) states that:

> "Specifically, the time to be estimated is the time at which the public warning process has been officially set in motion and the first individuals for each PAR are being warned to evacuate. Again, this time is expressed as the number of hours prior to the arrival of flooding at the location of the PAR".

In other words, warning time is equal to the difference between the time the public evacuation warning is initiated and the actual flood arrival time for the population at risk. The most conservative estimate of warning time would be the flood arrival time as shown on the inundation maps. DeKay and McClelland point out that:

> "Such assumptions may be reasonable for earthquake-induced failures (and perhaps terrorist acts), but other modes of failure will typically allow for longer WTs and greater evacuation benefits. We assume that the case in which an evacuation is ordered at the time of dam failure represents the *worst*-case scenario and the most reasonable baseline for assessing the benefits of additional WT".

If the population at risk covers a large area, the average warning time for the PAR should be used.

Warning of impending flooding can greatly reduce and even eliminate the threat to life. If a warning system is relied on to reduce the expected loss of life from potential dam failure, its effectiveness must be carefully evaluated. Warning systems include a wide range of actions that may be initiated either prior to or immediately following a dam failure. An effective warning system must include five elements: detection, evaluation, notification, warning and evacuation.

Force

DeKay and McClelland describe "force" as flooding lethality indicated by variations in the depth and velocity of the flood waters. Force is treated as a dichotomous (two-valued) variable with values of one for high force and zero for low force.

The term high force refers to flood waters that are likely to be very deep and swift. This would be typical in a narrow valley or canyon area. The term "low force" refers to flood waters that are likely to be shallow and slow. This would be typical in a level plateau or plain area.

For cases where the population at risk is located partly in a canyon area and partly in a plain area, it may be necessary to divide the PAR. However, because the loss-of-life equations vary nonlinearly with PAR and WT, this may lead to an overestimation of the potential loss of life. Division of the total population at risk into more and more groups can easily lead to significant overestimates of the potential loss of life.

The population at risk may be divided into two groups, but only when there is a significant difference in forcefulness or warning time. Any situations that may call for a greater division of the population at risk should be considered for a more in-depth study of the potential loss of life.

The USBR method (USBR, 1989) does not incorporate a "force" variable into its equations, but allows for adjustment factors to be applied to the baseline loss of life, depending on site-specific situations.

Economic Losses

An economic assessment is made of the economic, social, cultural and environmental tangible damages which are attributable to the failure of the dam facility. The damages due to flooding which would have existed without failure must be separately identified and subtracted from the total damages to give the incremental damages.

Economic consequences include loss and or damage to all property, including transportation facilities, public utilities, and the dam, as well as generation and transmission systems and loss of generation. Damage costs are to be computed by either establishing replacement costs (such as for the dam and associated structures, and which include generation outage costs) or loss of future benefits.

Economic costs are also assigned, where appropriate, to social and cultural impacts. Environmental impacts include damage to recreation, wildlife, fish habitat and areas of scenic value.

As discussed in USBR (1989), the following types of property should be considered:

- Residential Areas: Damage to homes (total or partial), costs of displacement (temporary rental elsewhere) during the recovery period, damage to personal property (insurance information may be helpful).
- Commercial and Industrial Businesses: Employment and income losses; capital losses.
- Public Facilities: Government buildings and offices, police and fire stations, libraries, health care facilities, transportation and associated structures, utilities, recreation sites and structures. Costs of providing temporary services during the recovery period should be included.
- Farmlands: Capital losses to farm structures, equipment or permanent plantings; crop losses and crop inputs such as seed and fertilizer; lost productive capacity of land from erosion.

Estimating Intangible/Environmental Consequences

Damages may exist which are very difficult to quantify, especially related to social, cultural and environmental values, including the following:

- Physical and mental health of individuals
- Social interaction (poverty, crime, community "spirit")
- Damage to irreplaceable historic and cultural features
- Reduction of business and community development
- Reduction of scenic beauty
- Long-lasting pollution of land, air and water
- Long-lasting or permanent changes to the ecology, including fish habitat
- Damage to irreplaceable personal effects

Environmental impacts are assessed and expressed in terms of appropriate environmental units. Some of the environmental losses (tangible losses) can be expressed in monetary terms, whereas others (intangibles) cannot. Those losses to which a dollar value can be assigned are included with the economic losses.

Intangible losses should be considered on a site-specific basis with site-criteria applied if necessary.

SUMMARY OF STATE SYSTEMS (COMPILED APRIL 1995)

STATE	CLASS	HAZARD CLASSIFICATION	HAZARD CRITERIA: LOSS OF LIFE (extent of development)	HAZARD CRITERIA: ECONOMIC LOSS	SIZE OF DAM	SIZE CRITERIA: HEIGHT (ft)	SIZE CRITERIA: RESERVOIR VOLUME (ac-ft)	SIZE CRITERIA: DRAINAGE AREA	FLOOD DESIGN CRITERIA	FREEBOARD
Alaska	I		Probable loss of life	Serious hazard to public health, or serious damage to homes, high-value industrial or commercial properties, or major public utilities		10 - 40 40 - 100 100	50 - 1000 1,000 - 50,000 50,000		1/2 PMF - PMF PMF PMF	
	II		No loss of human life	Possible health hazard, probable loss of high-value property, probable damage to major highways, railroads, or other public utilities, or probable damage to or loss of important salmon spawning habitat as identified by the commissioner of the Department of Fish and Game		10 - 40 40 - 100 100	50 - 1000 1,000 - 50,000 50,000		100 yr - 1/2 PMF 1/2 PMF - PMF PMF	
	III		No loss of human life	Result in property losses restricted mainly to rural land and buildings and local roads, and would not result in hazard to human health		10 - 40 40 - 100 100	50 - 1000 1,000 - 50,000 50,000		50-100 yr freq 100 yr - 1/2 PMF	
Arizona		High	More than a few	Excessive (extensive community, industry, or agriculture)	Small Medium Large	Size Classification Height (ft) 6-24 25-30 40-59 60-79 80-99 100+	Reservoir Capacity 15-499 500-999 1,000-2,999 3,000-9,999 10,000-24,999 25,000+	Rating Factors 0 1 2 3 4 5	1/2 PMF 1/2 PMF to PMF PMF	
		Significant	Few (no urban developments and no more than a small number of inhabitable structures)	Appreciable (notable agriculture, industry, or other structures)	Small Medium Large				100 yr to 1/2 PMF 1/2 PMF 1/2 PMF to PMF	
		Low	None expected (no permanent structures for human habitation)	Minimal (undeveloped to occasional structures or agriculture)	Small Medium Large				100 yr 100 yr to 1/2 PMF 1/2 PMF	
Arkansas	1 2 3 4		Spillway design must include sufficient capacity and freeboard to prevent overtopping of the dam, have sufficient strength to prevent structural failure, and an adequate energy-dissipating device at the outlet. The following minimums will apply (PM--The flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions.				10,000 5,000 1,000 20	10 sq mi 1000 ac 100 ac 0	0.75 PMF 0.50 PMF 0.25 PMF 100 year	

California

As a matter of policy, California does not publish standards or criteria so information provided has been compiled from several internal documents.
Hydrology - spillway capacity. "The size and type of dam and its vulnerability to failure because of an inadequate spillway shall be considered in the selection of the magnitude of the spillway design flood, and consequently the spillway capacity."

Minimum design flood required is a one in 1,000 year flood and the maximum is a PMF as derived from the PMP determined from Hydrometeorological Report No. 36 (U.S. weathr Bureau, 1961a) or Technical Paper No. 38 (U.S. Weather Bureau, 1960) as appropriate for drainage area. The return period for the flood is selected by using a rating system that considers (1) reservoir capacity, (2) dam height, (3) estimated number of people that would have to be evacuated in anticipation of dam failure, and (4) potential downstream damage.
Maximum design flood required - PMF

The system is such that only remote farm dams qualify for the one in 1,000 year floods. Typically PMF's required to impound 1000 acre feet or more, are at least 50 feet high, the estimated evacuation is is at least 1,000 people, and damage potential is $20,000,000 or greater. The scale for floods between the 1,000 year and PMF is continuous; so a dam with a slightly lower rating in one of the four factors than the example would require a statistical flood equal to about 90% of a PMF.

STATE	CLASS	HAZARD CLASSIFICATION	HAZARD CRITERIA: LOSS OF LIFE (extent of development)	HAZARD CRITERIA: ECONOMIC LOSS	SIZE OF DAM	SIZE CRITERIA: HEIGHT (ft)	SIZE CRITERIA: RESERVOIR VOLUME (ac-ft)	SIZE CRITERIA: DRAINAGE AREA	FLOOD DESIGN CRITERIA	FREEBOARD
Canada (Proposed)										
Consequence Classification of Dams: Consequence categories are based on the potential incremental losses which a failure might inflict on upstream or downstream areas or at the dam, over and above any losses that might occur for the same event without failure of the dam. The incremental consequences of dam failure should be evaluated in terms of: Loss of life; Economic costs of other losses, covering loss and/or damage to property, facilities, other utilities and dam, aswell as loss of power generation or water supply. Where appropriate, costs are assigned to social, cultural and environmental impacts; Other less quantifiable consequences such as social, cultural and environmental damages.										
Colorado	I	High	Loss of human life is expected		Large	>100 feet in vertical height, or > 50,000 acre feet in capacity				
	II	Moderate	No loss of human life is expected	Significant damage to structures where people generally live, work, or recreate, or public or private facilities exclusive of unpaved roads and picnic areas. Damage means rendering structures uninhabitable or inoperable	Intermediate	> 40 feet in vertical height but = to or < than both 100 feet and 50,000 acre-ft in capacity, or is > than 1,000 acre-ft in capacity and 100 feet in vertical height.				
	III	Low	No loss of human life is expected	Damage to structures and public facilities as defined for a "Class II" dam is not expected	Small	> 20 ft in vertical height but = to or < than both 40 ft and 1000 acre-ft in capacity, or is > than 100 acre-ft but = to or < both 1,000 acre-ft in capacity and 40 ft in vertical height.				
	IV		No loss of human life is expected	Damage will occur only to the dam owner's property	Minor	Does not exceed 20 ft in vertical height and 100 acre-ft in capacity.				
Georgia					Very Large Large Medium Small	100 35-100 25-35 25	50,000 1,000-50,000 500 - 1,000 500		100% of PMF 50% of PMF 33% of PMF 25% of PMF	
Hawaii		High	More than a few	Extensive community, industry or agriculture	Large	≥ 100	≥ 50,000			
		Significant	Few (no urban developments and no more than a small number of inhabitable structures	Appreciable (Notable agriculture, industry or structures)	Intermediate	≥ 40 and < 100	≥ 1000 and < 50,000			
		Low	None expected (No permanent structures for human habitation	Minimal (Undeveloped to occasional structures or agriculture	Small	≥ 25 and < 40	≥ 50,000			
Illinois	I	High	High probability for loss of life	Substantial economic loss, damage to structures (home, hospital, nursing home highly travelled roadway, shopping center, or similar type facilities	Large Intermediate Small	≥ 100	≥ 50,000		PMF PMF 1/2 PMF to PMF	
	II	Moderate	Moderate probability for loss of life	Damage to such structures such as a water treatment facility, sewage treatment facility, power substation, city park U.S. or Illinois Route highway, railroad or similar type facilities	Large Intermediate Small	≥ 40 to < 100	≥ 1,000 to < 50,000		PMF 1/2 PMF to PMF 100 yr to 1/2 PMF	
	III	Low	Low probability for loss of life	Damage to agricultural fields, timber areas, township roads or similar areas where people are seldom present and few structures	Large Intermediate Small	< 40	< 1,000		1/2 PMF to PMF 100 yr to 1/2 PMF 100 yr	

STATE	CLASS	HAZARD CLASSIFICATION	HAZARD CRITERIA: LOSS OF LIFE (extent of development)	HAZARD CRITERIA: ECONOMIC LOSS	SIZE OF DAM	SIZE CRITERIA: HEIGHT (ft)	SIZE CRITERIA: RESERVOIR VOLUME (ac-ft)	DRAINAGE AREA	FLOOD DESIGN CRITERIA	FREEBOARD
Indiana										
Data furnished did not include any criteria for dams										
Iowa		High	Serious threat of loss of human life	Serious damage to residential, industrial or commercial areas, important public utilities, public buildings, or major transportation facilities						
		Moderate	Without substantial risk of loss of life	May damage isolated homes or cabins, industrial or commercial buildings, moderately traveled roads or railroads, interrupt major utility services						
		Low	Loss of human life is considered unlikely	Limited to loss of dam, livestock, damages to farm out-buildings, agricultural lands, and lesser used roads						
Multiple Dams - Where failure of a dam could contribute to failure of a downstream dam or dams, the minimum hazard class of the dam shall not be less than that of any such downstream structure.										
					Effective Height (ft)	Size factor*	Effective storage (acre-ft)			
Kansas	C	High	Extensive loss of life	Serious damage to homes industrial and commercial facilities, important public utilities, main highways or railroads	>30,000 Between 3,000 and 30,000 Between 1,250 and 3,000		> 50 > 50 > 50			
	B	Significant	May endanger few lives	Predominantly rural or agricultural area, damage isolated homes, secondary highways or minor railroads or cause interruption of use or service of relatively important public utilities	< 1,250	<25	> 50			
	A	Low	No loss of life expected	Rural or agricultural areas, may damage farm buildings, limited agricultural land, or county, township and private roads						
*Size Factor - the product of the Effective Height of Dam (in feet) by the Effective Storage (in acre-feet)										
Louisiana		High			Large				PMF*	3 feet
					Intermediate				PMF*	1 foot
					Small				1/2 PMF to PMF	0 foot
		Significant			Large				PMF*	3 feet
					Intermediate				1/2 PMF to PMF	1 foot
					Small				100 yr to 1/2 PMF	0 foot
		Low			Large				1/2 PMF to PMF	3 feet
					Intermediate				100 yr to 1/2 PMF	1 foot
					Small				50 to 100 yr	0 foot
*Primary spillway may be sized to accommodate not less than 1/2 of the total PMF with the remainder of the total PMF accommodated by an emergency spillway.										
Maine										
Currently, the State of Maine uses the same standard of dam hazard classifications as the U.S. Army corps of Engineers.										

STATE	CLASS	HAZARD CLASSIFICATION	HAZARD CRITERIA: LOSS OF LIFE (extent of development)	HAZARD CRITERIA: ECONOMIC LOSS	SIZE OF DAM	SIZE CRITERIA: HEIGHT (ft) Norman Depth (Ft)	SIZE CRITERIA: RESERVOIR VOLUME (ac-ft) Normal Pool (Acre-ft)	DRAINAGE AREA	FLOOD DESIGN CRITERIA	FREEBOARD
Maryland	1	High	Probably more than 2 (Lives in jeopardy > 6)	Serious damage to residential, commercial, industrial, buildings, major public roads, railroads or public utilities (i.e., water supply reservoirs)		≥ 50	≥ 20,000			
	2	Significant	Possible 1 to 2 Habitable (Lives in jeopardy 1 to 6)	Predominantly rural or agricultural areas; damage to isolated residence or cause interruption of use or service to public utilities or roads or significant natural resources		25 to 50	1,000 to 20,000			
	3	Low	Very unlikely (Lives in jeopardy 0)	Damage is isolated to the dam itself and floodplain		< 25	< 1,000			

Michigan

The State of Michigan does not quantify losses as a result of dam failures in designating a hazard classification. Michigan's dams are listed as low, significant and high, and were originally rated based upon the Corps of Engineers classification in the National Dam Safety Program from 1977 through 1981. Those lists have been used in the administration of Michigan's Dam Safety Act, Act 300, PA 1989, as amended.

"Significant hazard potential dam" means a dam located in an area where its failure may cuase damage limited to isolated inhabited homes, agricultural buildings, structures, seconday highways, short line railroads, or public utilities, environmental degradation may be significant, or where danger to individuals exists.

STATE	CLASS	HAZARD CLASSIFICATION	LOSS OF LIFE	ECONOMIC LOSS
Minnesota	I		Any loss of life	Serious damage or damage to health; damage to main highways, high-value industrial or commercial properties, major public utilities, or serious direct or indirect economic loss to the public
	II		Possible health hazard	Loss of high-value property, damage to secondary highways, railroads or other public utilities, or limited direct or indirect economic loss to the public other than that descirbed in Class III
	III			Property losses restricted mainly to rural buildings and local county and township roads which are an essential part of the rural transportaion system serving the area involved

Minnesota does not have a well developed set of quantitative criteria for hazard classification. As regards loss of life in residential structures, consider the reasonable possibility of occurrence to begin after an inundation of 3 feet; Will consider the time from dambreak to inundation, the rate of rise of the inundation, the numbers of people, regional topography, presence of special needs persons such as elderly, and whatever other concerns that become obvious during an investigation. For probability of loss of life on highways, Minnesota starts with the State Department of Transportation functional classification. Generally roads classified as minor collectors or smaller are associated with low hazard classification. Major collector, minor arterial, and principal arterial highways are generally associated with a significant hazard classification. Interstate highways are associated with a high hazard classification. Consideration is also given as regards speed limits, sight distance, stationary lighting, flow velocity in the channel, and other concerns that may be relevant to a specific site.

In assigning a hazard value to a site, also consider social, cultural, and environmental implications of failure.

Mississippi

The State Dam Safety Coordinator has stated: "We basically follow the criteria and standards of the Soil Conservation Service as published in their Technical Release No. 60 -- Earth Dams and Reservoirs. For new dams classified as high hazard, we require that they pass the full PMF. For existing high-hazard dams, we require them to pass 50% of the PMF."

STATE	CLASS	HAZARD CLASSIFICATION	HAZARD CRITERIA: LOSS OF LIFE (extent of development)	HAZARD CRITERIA: ECONOMIC LOSS	SIZE OF DAM	SIZE CRITERIA: HEIGHT (ft)	SIZE CRITERIA: RESERVOIR VOLUME (ac-ft)	SIZE CRITERIA: DRAINAGE AREA	FLOOD DESIGN CRITERIA	FREEBOARD

Missouri

Environmental Class I-Contains 10 or more permanent dwellings or one or more public buildings
Environmental Class II-Contains 1 to 9 permanent dwellings; or one or more camp grounds with permanent utility service; or one or more roads with average daily traffice volume of 300 or more; or one or more industrial buildings.
Environmental Class III-Everything else.

Dam Type	Construction	Conditions	I	II	III
Conventional or industrial	Completed	Two or more dams in a series	0.75 PMP	0.5 PMP	0.5 PMP
		Storage x height > 30,000 ac-ft	0.75 PMP	0.5 PMP	0.4 PMP
		Storage x height < 30,000 ac-ft	0.75 PMP	0.5 PMP	0.3 PMP
Industrial	Starter	Any	0.5 PMP	0.2 PMP	0.1 PMP
	After starter dam is finished and before final dam if completed	Any	0.75 PMP	0.5 PMP	0.2 PMP

Montana

CRITERIA FOR DETERMINATION:

(1) Hazard determination shall be based on the consequences of dam failure--not the condition, probability, or risk of failure. A dam must be classified high-hazard if the impoundment capacity is 50 acre-feet or larger and it is determined that a loss of human life is likely to occur within the breach flooded area as a result of failure of the dam.

(2) The breach flooded area, for the purpose of this classification only, is the flooded area caused by a breach of the dam with the reservoir full to the crest of the emergency spillway.

(3) The evaluation of the effects of flood inundation, for the purpose of classification, will continue downstream until the flood stage is equal to that of the 100-year floodplain.

(4) The breach flow hydrograph and downstream routing of the breach flows, for the purpose of classification, will be estimated by the department either by visual determination or dam breach modeling techniques.

(5) Loss of life is assumed to occur if the following structures are present or planned for as a matter of public record or notice in the breach flooded area: occupied houses and farm buildings, stores, gas stations, parks, golf courses, stadiums, ball parks, interstate, principal, and other paved highways, and including railroads, highway rest areas, RV areas, developed campgrounds; and excluding unpaved county roads and all private roads.

Nebraska

Department of Water Resources is principally a regulatory agency of the water resources in the State of Nebraska

STATE	CLASS	HAZARD CLASSIFICATION	LOSS OF LIFE	ECONOMIC LOSS	SIZE OF DAM	HEIGHT (ft)	RESERVOIR VOLUME (ac-ft)	DRAINAGE AREA	FLOOD DESIGN CRITERIA	FREEBOARD
Nevada		High	Reasonable potential for loss of life and/or	Excessive economic loss	Large Medium Small Very Small		 < 50		PMF PMF PMF 1/2 PMF	
		Significant	No reasonable potential for loss of life	Appreciable economic loss	Large Medium Small Very Small		 < 200		PMF or 1/2 PMF PMF or 1/2 PMF 500-year events	
		Low	No reasonable potential for loss of life	Minor economic loss	Very Large Large Medium Small		> 1,000 > 1,000		500-year events 500-year events 100-year events* 100-year events*	

* 100 year-events may be allowed as design criteria for some tailings facilities but will be assessed on an individual basis.

STATE	CLASS	HAZARD CLASSIFICATION	HAZARD CRITERIA: LOSS OF LIFE (extent of development)	HAZARD CRITERIA: ECONOMIC LOSS	SIZE OF DAM	SIZE CRITERIA: HEIGHT (ft)	SIZE CRITERIA: RESERVOIR VOLUME (ac-ft)	SIZE CRITERIA: DRAINAGE AREA	FLOOD DESIGN CRITERIA	FREEBOARD
New Jersey	I	High*	Probable loss of life	Destructive loss of industrial or commercial facilities, essential public utilities, main highways, railroads or bridges						
	II	Significant	Loss of life not envisioned	Significant damage to property and project operation. Predominantly rural, agricultural areas; damage to isolated homes, major highways or railroads or cause interruption of service of relatively important public utilities						
	III	Low	No loss of life	Rural or agricultural areas, damage to farm buildings other than residences, agricultural lands or non-major roads						
	IV				Small	<15	<15	150 acres or < in extent		

*A dam may be classified as having a high hazard potential based solely on high projected economic loss. Recreational facilities below a dam, such as a campground or recreation area, may be sufficient reason to classify a dam as having a high hazard potential.

STATE	CLASS	HAZARD CLASSIFICATION	HAZARD CRITERIA: LOSS OF LIFE (extent of development)	HAZARD CRITERIA: ECONOMIC LOSS	SIZE OF DAM	SIZE CRITERIA: HEIGHT (ft)	SIZE CRITERIA: RESERVOIR VOLUME (ac-ft)	SIZE CRITERIA: DRAINAGE AREA	FLOOD DESIGN CRITERIA	FREEBOARD
New Hampshire	C	High	Probable loss of life	Extensive economic loss to businesses, communities, individuals, agriculture or industry; or major damage to interstate highways						
	B	Significant	Possible loss of life	Appreciable economic loss to businesses, communities, individuals, agriculture or industry; major damage to primary and secondary state highways; minor damage to interstate highways; loss of municipal water supply reservoir which constitutes more than 50% of community's source; release of industrial or commercial wastes or municipal sewage						
	A	Low	No expected loss of life	Minimal economic loss to business, communities, agriculture or industry; major damage to town and city roads; minor damage to primary and secondary state highways; or release of industrial or commercial wastes or municipal sewage if impoundment is less than 2 acre-ft and is located more than 300 ft from a waterbody or water course						
New Mexico		High	More than few	Excessive (Extensive community, industry or agriculture)						
		Significant	Few (No urban developments and no more than a small number of inhabitable structures)	Appreciable (Notable agriculture, industry or structures)						
		Low	None expected (No permanent structures for human habitation)	Minimal (Undeveloped to occasional structures or agriculture)						

STATE	CLASS	HAZARD CLASSIFICATION	HAZARD CRITERIA: LOSS OF LIFE (extent of development)	HAZARD CRITERIA: ECONOMIC LOSS	SIZE OF DAM	SIZE CRITERIA: HEIGHT (ft)	SIZE CRITERIA: RESERVOIR VOLUME (ac-ft)	SIZE CRITERIA: DRAINAGE AREA	FLOOD DESIGN CRITERIA	FREEBOARD
New York		Design of Dams								
	C		Loss of life	Serious damage to homes, industrial or commercial buildings, important public utilities, main highways, and railroads					1/2 PMF PMF	1 foot 2 feet
	B			Damage homes, main highways, minor railroads, or interrupt use or service of relatively important public utilities					225% of 100 yr 40% of PMF	1 foot 2 feet
	A			Damage nothing more than isolated farm buildings, undeveloped lands or township or country roads					100 yr 150% of 100 yr	1 foot 2 feet
		Existing Dams								
	C		Loss of life	Serious damage to homes, industrial or commercial buildings, important public utilities, main highways or railroads and/or extensive economic loss					1/2 of PMF	
	B			Damage isolated homes, main highways, minor railroads, interrupt the use of relatively important public utilities and/or significant economic loss or serious environmental damage					150% of 100 yr	
	A			Damage nothing more than isolated buildings, undeveloped lands, or township or county roads and no significant economic loss or serious environmental damage					100 yr	
North Carolina	C	High	Loss of life	Damage to homes, industrial and commercial buildings, important public utilities, primary highways, or major railroads						
	B	Intermediate		Damage major highways or secondary railroads, interruption of use or service of public utilities, minor damage to isolated homes, commercial and industrial buildings						
	A	Low		Damage to low value non-residential buildings, agricultural land, or low volume roads						
North Dakota		High	Loss of more than a few lives	Serious damage to homes, industrial and commercial buildings and major public utilities						
		Medium	Loss of a few lives	Damage isolated homes, main highways, railroads, or cause interruption of minor public utilities						
		Low	No loss of life expected	Damage to agricultural land, township and county roads, farm buildings other than residences						

Table 4-1. Dam Design Classifications*

Height (ft)	Hazard Categories: Low	Medium	High
< 10	I	II	IV
10 to 24	II	III	IV
25 to 39	III	III	IV
40 to 55	III	IV	V
Over 55	III	IV	V

*Table 4-1 is based on dam height and hazard categories and outlines five classifications for dam design. Each classification will require varying degrees of intensity of investigation for hydrology, foundation and borrow explorations, soil testing, structural design, etc.

STATE	CLASS	HAZARD CLASSIFICATION	HAZARD CRITERIA: LOSS OF LIFE (extent of development)	HAZARD CRITERIA: ECONOMIC LOSS	SIZE OF DAM	SIZE CRITERIA: HEIGHT (ft)	SIZE CRITERIA: RESERVOIR VOLUME (ac-ft)	SIZE CRITERIA: DRAINAGE AREA	FLOOD DESIGN CRITERIA	FREEBOARD
Ohio	I		Probable loss of life Serious damage to homes	Structural damage to high-value industrial property (i.e., homes, industries, major public utilities)		> 60	> 5,000		PMF	
	II		No loss of life envisioned	Damage to homes, businesses industrial structures, state and interstate highways, railroads, only access to residential areas		> 40	> 500		50% OF PMF	
	III		No loss of life envisioned	Damage to low value non-residential structures, local roads, agricultural crops and livestock		> 25	> 50		25% OF PMF	
	IV			Losses restricted mainly to the dam		≤ 25	≤ 50			
Oklahoma		High	Yes (One or more habitable structures with loss of life likely)	Excessive (Extensive community, industrial or agricultural)	Large	Over 100	Over 50,000			
		Significant	None (Potential for future development exists; habitable structures may exist in inflow design flood floodplain)	Appreciable (Notable agriculture, industrial or structural)	Intermediate	Between 50 and 110	Between 10,000 and 50,000			
		Low	None (No probable future development; may be zoned to prevent future development)	Minimal (Undeveloped to occasional structure or agriculture)	Small	< 50	< 10,000			

Oregon

Oregon has an "in-house" policy for determining hazard classification of dams. Presently, attempt to follow U.S. Army Corps of Engineers quantitative guidlines for hazard classification, size, and spillway design requirements . One small distinction between Oregon and the Corps is that any potential for loss of human life in the event of a sudden failure places a dam in the High Hazard category.

STATE	CLASS	HAZARD CLASSIFICATION	HAZARD CRITERIA: LOSS OF LIFE (extent of development)	HAZARD CRITERIA: ECONOMIC LOSS	SIZE OF DAM	SIZE CRITERIA: HEIGHT (ft)	SIZE CRITERIA: RESERVOIR VOLUME (ac-ft)	SIZE CRITERIA: DRAINAGE AREA	FLOOD DESIGN CRITERIA	FREEBOARD
Oregon		High			Large				PMF	
					Intermediate				PMF	
					Small				1/2 PMF to PMF	
					Very Small				100 yr to 1/2 PMF	
		Significant			Large				PMF	
					Intermediate				1/2 PMF to PMF	
					Small				100 yr to 1/2 PMF	
					Very Small				50 to 100 yr freq	
		Low			Large				1/2 PMF to PMF	
					Intermediate				100 yr to 1/2 PMF	
					Small				50 to 100 yr freq	

STATE	CLASS	HAZARD CLASSIFICATION	HAZARD CRITERIA: LOSS OF LIFE (extent of development)	HAZARD CRITERIA: ECONOMIC LOSS	SIZE OF DAM	SIZE CRITERIA: HEIGHT (ft)	SIZE CRITERIA: RESERVOIR VOLUME (ac-ft)	DRAINAGE AREA	FLOOD DESIGN CRITERIA	FREEBOARD

Pennsylvania

Category	Loss of Life	Economic Loss
1	More than 3 lives More than 1 habitable structure	Extensive; heavily used
2	No more than 3 lives No more than 1 habitable structure	Appreciable; public roads or sole access roads over-topping and washing out; loss of sole water supply source
3	No habitable structures	Minimal economic loss, outbuildings, minor road crossings

Size Classification*

Class of Dam	Height (ft)	Storage
A	≥ 100	≥ 50,000
B	< 100 but > 40	< 50,000 but > 1,000
C	≤ 40	≤ 1,000

*Size classification may be determined by either storage or height of structure, whichever gives the higher category.

Hazard Potential Classification

Size and Hazard Classification	Design Flood
A-1, A-2, B-1	PMF
A-3, B-2, C-1	1/2 PMF to PMF
B-3, C-2	100 yr to 1/2 PMF
C-3	50 yr to 100 yr freq

Rhode Island

Does not currently have specific promulgated quantitative criteria relating to the hazard classification of Rhode Island's dams. However, since the inception of the National Program for the Inspection of Non-Federal Dams in 1977, have more-or-less unofficially adopted the criteria as set forth in that program as to our own hazard classifications and size categories.

South Carolina

Size of Dam	Flood Design Criteria
Large	PMF
Intermediate	PMF
Small	1/2 PMF to PMF
Very Small	100yr TO 1/2 PMF
Large	PMF
Intermediate	1/2 PMF to PMF
Small	100 yr to 1/2 PMF
Very Small	50 TO 100 yr freq
Large	1/2 PMF to PMF
Intermediate	100 yr to 1/2 PMF
Small	50 to 100 yr freq

South Dakota

State has no requirements or "in-house" policies regarding "quantitative criteria" for assigning hazard classifications for dams except their Safety of Dams Rules, Chapter 74:02:008 has a section defining classification of dams using loss of life potential and economic loss potential. This section uses a general definition of minimal economic loss for Category 3, low hazard dams and extensive economic loss for Category 2, significant hazard dams. Usually require that a downstream risk assessment accompany applications for dams to help in the hazard classification process.

Texas

The Texas dam safety program does not use quantitative criteria for hazard classification of dams. Current rules track the guidelines of the Soil Conservation Service for hazard classification. This system has proved to be effective and and efficient thus far. The following information was taken from a copy of Chapter 299 (Dams & Reservoirs) of the Commission Rules.

Hazard Classification	Loss of Life	Economic Loss	Size of Dam	Height (ft)	Reservoir Volume (ac-ft)
High	Expected (Urban development or large number of inhabitable structures	Excessive (Extensive public, industrial, commercial or agricultural development	Large	≥ 100	≥ 50,000
Significant	Possible, but not expected (A small number of inhabitable structures	Appreciable (Notable agricultural, industrial or commercial development)	Intermediate	≥ 40 and < 100	≥ 1,000 and < 50,000
Low	None expected (No permanent structures for human habitation)	Minimal (Undeveloped to occasional structures or agricultural improvements)	Small	< 40	< 1,000

Utah

The following material on spillway hydrology is quoted from "Rules and Regulations Governing Dam Safety in Utah." Unless specifically exempted by the State Engineer, the spillway design calculations shall follow the list below. The spillway shall be sized such that the appropriate flood can pass through the structure without overtopping.

STATE	CLASS	HAZARD CLASSIFICATION	HAZARD CRITERIA: LOSS OF LIFE (extent of development)	HAZARD CRITERIA: ECONOMIC LOSS	SIZE OF DAM	SIZE CRITERIA: HEIGHT (ft)	SIZE CRITERIA: RESERVOIR VOLUME (ac-ft)	SIZE CRITERIA: DRAINAGE AREA	FLOOD DESIGN CRITERIA	FREEBOARD
Utah		High Moderate Low							1/2 PMF-PMF 100 yr freq-1/2 PMF 100 yr freq	
Vermont	1	High	More than few	Excessive (Extensive community, industry or agriculture						
	2	Significant	Few (No urban developments and no more than a small number of inhabitable structures)	Appreciable (Notable agriculture, industry or structures)						
	3	Low	None expected (No permanent structures for human habitation)	Minimal (Undeveloped to occasional structures or agriculture						
Virginia	I		Probable loss of life	Excessive, serious damage to occupied buildings, industrial or commercial facilities, important public utilities, main highways or railroads	Large Medium Small	> 100 > 40 and < 100 > 25 and < 40	> 50,000 > 1,000 and < 50,000 > 50 and < 1,000		PMF PMF 1/2 PMF to PMF	
	II		Probable loss of life	Appreciable, damage to occupied buildings, industrial or commercial facilities, secondary highways or railroads or cause interruption of use or service of relatively important public utilities	Large Medium Small	> 100 > 40 and < 100 > 25 and < 40	> 50,000 > 1,000 and < 50,000 > 50 and < 1,000		PMF 1/2 PMF to PMF 100 yr to 1/2 PMF	
	III		No loss of life	Minimal property damage to others	Large Medium Small	> 100 > 40 and < 100 > 25 and < 40	> 50,000 > 1,000 and < 50,000 > 50 and < 1,000		PMF 1/2 PMF to PMF 50 yr to 100 yr	
	IV		No loss of life	No property damage to others						

STATE	CLASS	HAZARD CLASSIFICATION	HAZARD CRITERIA: LOSS OF LIFE (extent of development)	HAZARD CRITERIA: ECONOMIC LOSS	SIZE OF DAM	SIZE CRITERIA: HEIGHT (ft)	SIZE CRITERIA: RESERVOIR VOLUME (ac-ft)	SIZE CRITERIA: DRAINAGE AREA	FLOOD DESIGN CRITERIA	FREEBOARD
Washington	1A	High	More than 300	Extreme, more than 100 inhabited structures; highly developed, densely populated suburban or urban area with associated industry, property, transportation and community life line features						
	1B	High	31 to 300	Extreme; 11 to 100 inhabited structures; medium density suburban or urban area with associated industry, property and transportation features						
	1C	High	7 to 30	Major; 3 to 10 inhabited structures; low density suburban area with some industry and work sites; primary highways and rail lines						
	2	Significant	1 to 6	Appreciable; 1 to 2 inhabited structures; notable agriculture or work sites; secondary highway and/or rail lines						
	3	Low	0	Minimal; no inhabited structures; limited agriculture development						
West Virginia (Proposed)	C		Loss of human life	Serious damage to homes, industrial and commercial buildings, public utilities, primary highways, or main railroads						
	B			Great damage to property and project dominantly rural agricultural areas						
	A			Rural or agricultural areas damage farm buildings, agricultural or secondary highways						
Wyoming (Draft)	I		Loss of human life expected							
	II		No loss of human life	Significant damage to structures where people generally live, work, or recreate, or public or private facilities exclusive of non-primary roads and picnic areas; damage means rendering structures uninhabitable or inoperable						
	III		No loss of human life	Damage to structures and public facilities as defined for a "Class II" dam is not expected						
	IV		No loss of human life	Damage will occur only to the dam owner's property						

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