State of Colorado

Department of Natural Resources
Division of Water Resources
Office of the State Engineer
Dam Safety

GUIDELINES FOR HAZARD CLASSIFICATION

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A. Introduction

This guidance document has been created to provide a technical guide for dam safety engineers and the engineering community involved with the design of dams and safety evaluation of existing dams under the Colorado Revised Statutes and the "Rules and Regulations for Dam Safety and Dam Construction (SEO, anticipated 2020)", referred to collectively herein as "Rules" and individually as a "Rule". The considerations and guidelines described herein are intended to establish consistency in the analysis and review of dam safety projects in Colorado. The Hazard Classification Guidelines should not be considered a design standard, but should be adopted for determining the hazard classification for each specific project and provide justification for the applicable design requirements and standards contained in the Rules. *The State Engineer will make the final determination of the appropriate hazard classification for a given dam.*

B. Scope and Purpose

1. Rule 4.13 states the "Hazard Classification of a Dam" is the placement of a dam into one of four categories as determined by analysis of potential consequences from a sunny day failure of the dam.

2. The purpose of a Hazard Classification Study is to evaluate the potential consequences of the subject dam failure on persons and property below the dam and to identify the standards for the investigation, design, and construction which apply to an existing or proposed project (SEO, 1994).

3. The purpose of these Hazard Classification Guidelines is to provide guidance and methods for performing a Hazard Classification Study, provide guidance and criteria for identifying downstream hazards, and bring objectivity and consistency in assigning the hazard classification of a dam.

C. Criteria for Hazard Classification

1. General Considerations

   a. Procedures for evaluating the behavior of a dam break flood in the downstream channel and floodplain can vary from engineering judgment to state-of-the-art analytical engineering models. These Hazard Classification Guidelines explicitly presume that an engineer performing or reviewing a Hazard Classification Study will understand the limitations of the available analytical tools and procedures and will apply engineering judgment on a case-by-case basis to account for modeling inaccuracies.

   b. The hazard classification of a dam is based on the probable occurrence of property damage and/or the loss of human life resulting from failure or improper operation of a dam. For any dam, a situation can always be imagined that would result in life loss regardless how remote the location of the dam and/or how little the chance of persons being affected by its failure flood (USBR, 1988). 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 selecting the dam design criteria and standards required by the hazard classification (FEMA, 2004).

   c. A Hazard Classification Study is performed for the purpose of determining the adverse impacts of a dam failure flood at critical downstream locations where hazards may exist.

   d. The hazard classification of a dam does not consider the potential impacts of future downstream or upstream development or changes in land use and should be based on current downstream conditions.

e. The hazard potential evaluation should also consider the consequences from the improper operation of the dam such as failure to operate gates or valves to control the reservoir level, or failure to operate or maintain appurtenant structures such as outlet works and spillways.

f. For purposes of determining the hazard classification of a dam, the following terms are defined (adapted from FEMA, 2004):

   i. Adverse Consequences: negative impacts that may result from the failure of a dam. The primary concerns are loss of human life, property damage, and lifeline disruption.

   ii. Incremental: Under normal conditions, the difference in impacts that would occur due to failure or improper operation of the dam over those that would have occurred without failure or improper operation of the dam and appurtenances.

g. Potential failure or improper operation of upstream dams should not be considered in selecting the hazard potential classification of the subject dam; however, potential impacts of the subject dam's failure on downstream dams should be considered.

h. The hazard classification of a dam is based solely on the potential effects of the hydraulic forces exerted by the dam failure flood wave, and does not consider the impacts of environmentally harmful or toxic substances released by failure of the dam.

i. A presumptive determination of the hazard classification of a dam can sometimes be accomplished. For example, if a dam from which a large dam failure flood wave could be released is located immediately upstream of a community, a developed subdivision, or an industrial complex, then a presumptive determination of High Hazard classification may be obvious. Per Rule 6.8.4, a Hazard Classification Study is not required for dams that are declared High Hazard.

j. If failure of the subject dam can cause the failure of another dam or series of dams located downstream, the cumulative dam break flood wave must be considered in the Hazard Classification Study.

k. The worst-case probable scenario of failure of the dam should be the basis of the hazard classification assigned, i.e., the assigned classification should be based on failure consequences that will result in the assignment of the highest hazard classification of all probable failure modes (FEMA, 2004).

2. Failure Mode

a. The chosen mode of failure should be the one that produces the largest dam break flood reasonably possible. The failure mode is not limited to erosion of embankment materials initiated by piping or internal erosion, nor is the high water line limited to the emergency spillway crest.

b. Internal erosion and piping are mechanisms by which the uncontrolled flow of water through and under embankments removes soil particles, leading to failure. The majority of failure scenarios under this failure mode will likely produce the largest dam break flood if it is assumed that failure occurs at the maximum section of the dam with the reservoir at the emergency spillway crest.

D. High Hazard Dam

1. Rule 4.13.1 defines a High Hazard Dam as a dam for which life loss is expected to result from failure of the dam.

2. The determination of a High Hazard dam classification shall be based solely on the potential for loss of human life, regardless of other damages or effects of the dam failure. The expected loss of one human life as a consequence of the dam failure is sufficient to require a High Hazard classification.

3. Criteria for determining expected loss of human life

   a. No life loss is expected to occur if the depth of flow is two feet or less and the product of the flow depth and the flow velocity at the critical location is less than seven.

   b. If the flow velocity cannot be calculated with confidence at the critical location, then the average cross-section flow velocity may be used in calculating the product of depth and velocity.

   c. Judgment and sound reason must be used in determining the potential for life loss at locations where the flow depth is less than two feet and the product of depth and velocity is greater than seven, or where the depth of flow is greater than two feet and the product of depth and velocity is less than seven. An example location may be the basement of a habitable structure.

4. When roads with heavy traffic such as Interstate Highways, main arterial highways, and any other roads with a normally high traffic volume are within the dam break flood inundation zone, the dam may be considered for a High Hazard rating. Situations where a road passes through the dam break flood channel or a road parallels the flood channel in a valley or canyon may also be considered. The traffic volume should be high enough such that the potential for life loss exists if the dam fails at any given time of day and the product of flow depth and velocity is greater than seven.

5. Designated campgrounds and recreational areas

   a. Designated recreational sites located downstream within the bounds of possible inundation should also be evaluated for potential loss of human life.

   b. Designated recreation areas are considered specially designated areas promoted in order to attract people for recreation activities. Some designated recreation areas along streams and rivers feature man-made improvements and structures such as boat ramps, restrooms, buildings, and large established campgrounds, which sometimes include camper hookups. Other designated recreation areas along streams and rivers may be promoted by featuring the absence of man-made improvements or large established campgrounds. These designated recreation areas attract people by providing activities such as gold medal fishing, canyon rock climbing, rafting, kayaking, etc. (SEO, 1998).

   c. For estimating the potential for life loss, the number of people likely to use the site during a heavy use period should be considered (SEO, 1998). Use of the floodplain by the occasional camper or fisherman is not controlling, since these individuals are expected to be warned by rising waters and flee from danger (SEO, 1983).

6. Consideration of warning time

   a. Technologies are available that can provide early warning and notification to emergency personnel and people downstream of dams in the event of a dam failure. Early warning systems can be a valuable component of an Emergency Action Plan; however, they should not be considered when evaluating the hazard classification of a dam.

b. Situations can always be imagined where the physical warning of rising flood waters may be available to people in harm's way. The ability to escape in the early stages of a flood is greatly dependent on the floodplain configuration and shape of the routed dam break flood hydrograph. If the floodplain has gentle side slopes, escape may be possible during the early stages of a flood, even though the depths and velocities during the peak of the hydrograph may be sufficient to cause life loss. For escape to be assumed the dam break has to be relatively slow or the attenuation of the dam break flood sufficient to slowly increase flood depths in the critical area (i.e., a gradual increase in the rising limb of the routed dam break hydrograph). Conversely, if the dam break is rapid with little attenuation in a canyon with steep side slopes, escape may not be possible.

7. If failure of the subject dam can cause failure of a High Hazard dam located downstream, the dam is automatically considered High Hazard (SEO, 1994).

E. Significant Hazard Dam

1. Rule 4.13.2 defines a Significant Hazard Dam as a dam for which significant damage is expected to occur, but no loss of human life is expected from failure of the dam.

2. Significant damage is defined as damage to structures where people generally live, work, or recreate, or public or private facilities. Guidelines for defining these structures and facilities are provided below:

   a. Habitable residences attached to foundations and connected to utilities (USBR, 1988).

   b. Habitable mobile homes not attached to foundations (USBR, 1988).

   c. Habitable industrial or commercial facilities where people live, work, or recreate that are attached to foundations and connected to utilities.

   d. Farm structures including barns or other work places attached to foundations and connected to utilities. Miscellaneous farm outbuildings/sheds are not included (Van Sciver, 1983).

   e. Water, gas, or power lines that are considered to be major lifeline utilities.

   f. Large irrigation structures. Small irrigation structures do not need to be considered for a Significant Hazard rating (Van Sciver, 1983).

   g. Railroads, roadways, or driveway embankments and crossings that provide sole access to improved or developed areas.

      i. Unimproved dirt roads or seldom used improved roads that access undeveloped areas are not included.

      ii. Similarly, roads that are flush with the surrounding floodplain where overtopping and flooding would cause only temporary disruption of traffic are not included.

      iii. Improved or unimproved roads that are not the sole access routes to improved and developed areas are not included.

   h. Downstream dams that could be overtopped by failure of the upstream subject dam (Van Sciver, 1983). An exception may be small ponds with embankments that could easily be repaired if overtopped.

3. Rule 4.13.2 defines significant damage to the aforementioned structures as damage sufficient to render structures or facilities uninhabitable or inoperable. In general, significant damage is expected to occur when a structure is in more than two feet of water, or the product of the water depth and the flow velocity at the structure is greater than seven (SEO, 1994). A detailed analysis of the damage to each structure may be made as an alternative to this presumption.

   a. As a rule of thumb, significant damage is expected to occur if the maximum flood depth renders the structure uninhabitable or inoperable. It should be noted that if the water depth at these structures cannot be predicted with confidence, then a conservative approach should be used that assumes any possible hazard in the path of a dam break flood is in danger (USBR, 1988).

   b. If failure of the subject dam causes overtopping and failure of a downstream dam, the failure of the downstream dam should be considered significant damage. Failure is presumed to occur if overtopping of the lower dam exceeds six inches in depth (Van Sciver, 1983), unless a detailed analysis (such as a separate overtopping failure analysis of the lower dam) shows otherwise. For example, if the duration of overtopping exceeding six inches is relatively short or if the embankment is small enough to allow tail-water effects to inhibit erosion, then a determination can be made that failure would likely not occur. The same presumption can also be made for railroad and roadway embankments. In cases where failure of the subject dam does not cause failure of a downstream dam, impacts of the flood wave below the downstream dam should be evaluated.

4. Significant damage is expected to occur if failure of the dam causes extensive and widespread destruction of and damage to multiple minor improvements.

F. Low Hazard Dam

1. Rule 4.13.3 defines a Low Hazard Dam as a dam for which loss of human life is not expected, and significant damage to structures and public facilities as defined for a Significant Hazard dam is not expected to result from failure of the dam.

2. To assign a Low Hazard classification, the flood due to failure of the dam may cause damage less than that defined as significant damage to man-made improvements, other than the dam itself, without expected life loss. Minor damage to unimproved roads and small irrigation structures is considered within the class of Low Hazard, as is sheet flooding of agricultural lands and farm out-buildings (Van Sciver, 1983).

3. A Low Hazard classification may be considered for a dam that fails into a downstream reservoir without causing it to fail, and there are no man-made improvements located between the two reservoirs. In this case, the lower reservoir is expected to fully attenuate the flood hydrograph (Van Sciver, 1983). Impacts of the flood wave below the downstream dam should be evaluated.

4. A Low Hazard classification may be considered where damage is expected to occur only to natural resources such as National Forests, fishing areas, natural attractions, meadowlands, wetlands, etc., in the event of failure of the dam (Pearson, 1986).

G. No Public Hazard (“NPH”) Dam

1. Rule 4.13.4 defines a No Public Hazard (NPH) Dam as a dam for which no loss of human life is expected, and for which damage only to the dam owner's property will result from failure of the dam.

2. The Hazard Classification Study must adequately show that damage would not occur to adjacent properties beyond the point where the flood exits the dam owner's property.

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