NORTH DAKOTA DAM SAFETY STANDARDS

POLICY | REG_05.2023

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NORTH Dakota Be Legendary. | Water Resources

Effective Date XX/XX/XXXX

STANDARDS OUTLINE

1 STANDARDS OVERVIEW

The North Dakota Department of Water Resources (Department) regulates the safe design, construction, and operation of dams and other water control structures that are intended to retain, obstruct, or divert water that are located throughout the state.

Throughout the Standards, ponds, lagoons, dugouts, and other similar facilities are referred to as “dams.” “Dam” also includes embankments and appurtenant structures such as spillways, principal spillways, outlets, gates, operational controls, monitoring equipment, and similar facilities.

The Standards outline the administrative and technical requirements necessary to obtain a construction permit that complies with the Department’s dam safety focus. All dams and other water control structures that are capable of retaining, obstructing, or diverting water as specified in North Dakota Century Code (N.D.C.C.) that come before the Department for a construction permit must meet the minimum requirements identified in the Standards. The Standards can also provide useful information for the design of dams that do not require a construction permit from the Department.

The Standards aim to align the Department’s dam safety practices with federal recommendations and the current state of the dam safety practice. Engineers are expected to be familiar with the current state of the practice in dam design and construction and to apply sound engineering judgment and experience.

When issuing a construction permit, the goal of the Department is to minimize the risk to lives and property. The intent of the Dam Safety Standards (Standards) is to ensure that all dams in North Dakota are classified, designed, and permitted in a technically-sound, publicly-responsible, and consistent manner.

The Standards do not cover “safety at dams” issues such as the dangers of low-head dams or appropriate signage. The Association of State Dam Safety Officials addresses public safety concerns on their website.

Owners ultimately bear the full responsibility to construct and maintain a safe dam. A Department-issued construction permit does not reduce, lessen, or absolve the Owner in any way of the full burden and responsibility of ownership or relieve the Owner’s liability for damages caused by releases of impounded water.

The Standards were developed in consultation with RJH Consultants and funded by FEMA’s National Dam Safety Program’s State Assistance Grants.

1.1 STANDARDS AUTHORITY OR IMPLEMENTATION

The Standards garner authority from N.D.C.C. ch. 61-03, § 61-16.1-38, and North Dakota Administrative Code (N.D.A.C) art. 89-08 and will be implemented through the Regulatory Division Dam Safety Program’s construction permit application and review process.

1.2 ACCEPTANCE OR ENFORCEMENT

The Department reserves the right to change the Standards as necessary to ensure the Department fulfills its statutory duties.

The Department reserves the right to return any application submitted under the Standards to the applicant for correction if it does not comply with the Standards' intent or is insufficient for the Department to make an informed decision.

The Department reserves the right to enforce the Standards per the process outlined in N.D.C.C. §§ 61-03-21.2, 61-16.1-38, and N.D.A.C. § 89-08.

1.3 APPEALS

Decisions may be appealed per the process outlined in N.D.C.C. § 61-03-22.

1.4 STANDARDS DEVIATIONS

The Department reserves the right to deviate from the Standards as deemed appropriate and within requirements outlined in N.D.C.C. or N.D.A.C.

A permit applicant may request a Standards Deviation from the Department. The request must justify why requirements of the Standards are not necessary, applicable, or if a suitable replacement to a requirement is desired. Such a deviation will not be granted without significant justification. Additionally, a deviation request does not guarantee that a deviation will be granted.

1.5 ENGINEERING JUDGMENT

The Department recognizes that dam design is complex and requires nuance. When a design decision is based on best engineering practices under site-specific conditions, it is acceptable for the Engineer to design a dam in a way that does not detract from the dam safety focus.

This judgment is subject to review by the Department, and all decisions made under this section will need to be fully documented, supported, and justifiable. The Department reserves the right to overrule decisions made under this section as a part of the permit review and approval process.

Engineering Judgment under this section may only be executed when explicitly noted below.

1.6 DEPARTMENT CONTACT

Please contact the Department's Regulatory Division at (701) 328-4956 or dwrregpermits@nd.gov for questions regarding the Standards or the ND Dam Safety Program.

2 CONSTRUCTION PERMIT NECESSITY

Construction permits are required to construct or modify any water retention structure meeting the requirements laid out in N.D.C.C. § 61-16.1-38. The Standards apply to all water retention structures including dams, ponds, and lagoons that need a construction permit from the Department. Figure 2.1 depicts the process for determining if a dam or other water retention structure requires a construction permit:

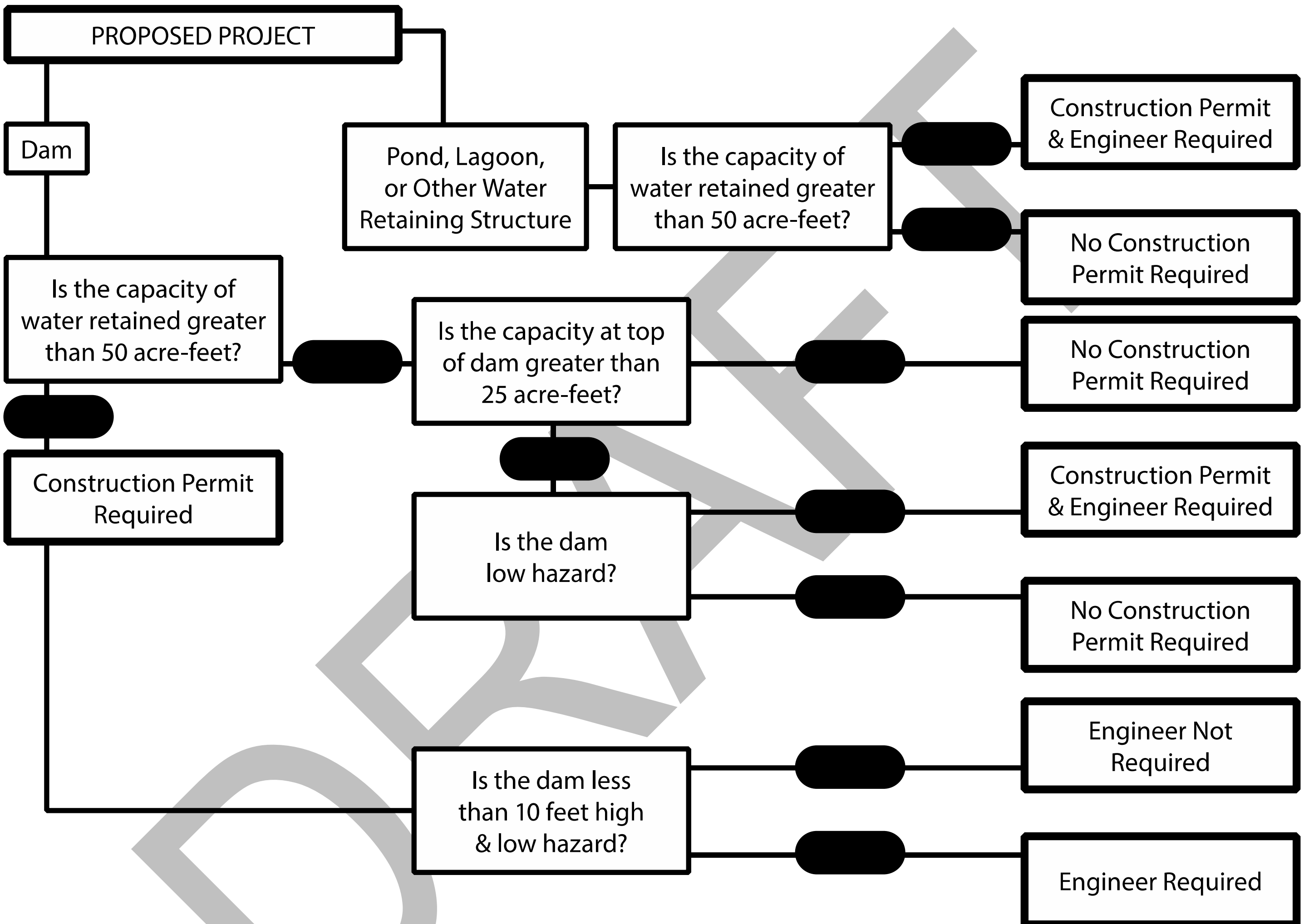


Figure 2.1

As shown in Figure 2.1,

a. Dams that impound more than 50 acre-feet (ac-ft), regardless of hazard classification require a construction permit.

b. Any high hazard or medium hazard dam that impounds more than 25 ac-ft. requires a construction permit.

c. Dams that store less than 25 ac-ft do not require a construction permit.

d. An Engineer is required except for low hazard dams less than 10 feet high.

e. Ponds, lagoons, and other water retaining structures require a construction permit if they store more than 50 ac-ft. above grade, regardless of hazard classification, and must be designed by an Engineer.

2.1 COMMENCEMENT OF WORK

For dams requiring a construction permit, an Owner must obtain the permit prior to commencing any construction activities. The application package must meet the requirements outlined in Section 4. Construction activities may commence once the Department has reviewed the design, found it acceptable, and issued a construction permit. Other permits may be required and have differing timelines.

Other permits that may be required include a water permit for the beneficial use of water, sovereign lands permit if the dam would impact North Dakota's sovereign lands, local zoning or building permits, stormwater discharge permits, dewatering permits, wetland permits, clean water act permits, and various others required by local, state, or federal regulators. Contact the appropriate agencies for every project to determine which permits are required and the timelines needed for review.

2.2 ROUTINE MAINTENANCE AND REPAIRS

The Department does not specifically monitor or permit routine maintenance and minor repairs on dams. It is the Owner's responsibility to carry out routine maintenance and repairs such as vegetation maintenance and removal, sediment removal, or minor concrete repair. Document the requirements for maintenance and repair activities in the dam's O&M Manual (Section 14.5).

a. If a repair restores a dam to its originally permitted design, it is considered routine maintenance and does not require a construction permit. If the dam is being modified from its originally permitted design, it does require a construction permit.

b. If the repair creates a period where the dam cannot provide its intended function safety (i.e., excavation of the embankment, blockage of the spillway, etc.), the Owner is required to notify the Department.

c. Grading and surfacing of a dam crest can be performed as routine maintenance provided there are not cumulative changes to the top of dam or permitted minimum freeboard.

d. The Department will assist Owners if there is a question regarding the significance of maintenance activities or repairs.

2.3 EXISTING DAMS STANDARDS COMPLIANCE

Existing dams designed and constructed under previous guidance will not be required to comply with the Standards unless a permittable action takes place.

The Department details procedures regarding dam repairs and modifications in response to Department-initiated updates to N.D.C.C. and N.D.A.C in Department Policy REG_04.

2.3.1 COMPLIANCE DEVIATION REQUEST

If an Owner needs to apply for a construction permit for dam modification, but full compliance with the Standards isn't feasible, the Owner may request a Standards Deviation under Section 1.4. The Owner will need to submit one of the following options with their request. Both Assessments are required to be completed by an Engineer.

a. **Feasibility or Alternatives Assessment:** This assessment must include a review of known project deficiencies and provide justification of how the proposed modification will improve the overall safety of the project. If the proposed modification will not address all deficiencies, the assessment must include a plan of how and when the Owner intends to correct the other deficiencies or justification of why it is not necessary or feasible to address them.

b. **Risk Assessment:** This assessment may provide insight and assistance with evaluating the severity of a deficiency or prioritizing multiple deficiencies. The submittal must use risk-informed decision making (See Appendix B).

2.4 PUBLIC RISK

If the Department determines an existing dam is unsafe and poses an unacceptable risk to the public, the Owner will be required to either repair the dam and bring it into compliance with the Standards, modify the dam such that it no longer meets the permitting thresholds described in Section 2, or breach the dam such that it no longer holds water at a regulated level per Section 2. If the Owner is unable to repair or modify the dam to the satisfaction of the Department, the Department will order the dam be breached or removed.

3 DEPARTMENT PERMIT REVIEW PROCESS

3.1 PRE-APPLICATION CONSULTATION

The Department strongly encourages pre-application consultation prior to application submittal. Early consultation between the Owner, the Engineer, and the Department will provide early understanding and compliance with the Standards and limit unexpected project costs or delays at the expense of the applicant.

As engineering studies are performed and designs are developed, the Department will perform a courtesy review to ensure results of foundational studies are in line with the Standards. The Department highly recommends the following to be submitted for early review:

- Draft Hazard Classification Analyses (Section 5)
- Draft Hydrology Study (Section 6)
- Draft Geological and Geotechnical Evaluation (Section 7)
- Other documents or studies that will inform the design of the dam.

Discussions may be informal during this phase of the project and include phone calls, emails, and/or meetings, as appropriate for the project.

3.2 PERMIT APPLICATION (UNSEALED DOCUMENTS)

The Owner must submit their entire application package as detailed in Section 4 to the Department when the design is nearing 95% completion. The design criteria must be adequately supported and documented. Label the documents "for DWR Review" and include the date of submittal. The Engineer should not sign and seal the design documents at this stage. This submission initiates the Department's 45-day comment period.

Incomplete or inadequate design submittals will be rejected and returned to the Owner. Submittal of the application and design documents before the documents are ready for a thorough review will result in multiple cycles of review and resubmittal. The Department has the ultimate authority to accept or reject the permit application, in part or as a whole, including supporting analyses and recommendations.

The Owner must address and resolve Department comments, provide additional information requested by the Department, and review the corrected documents with the Department before resubmitting the application package. Note all Department-approved changes to documents by sequentially naming them "Revision 1 (date)", "Revision 2 (date)", etc.

The review and revision process does not indicate official acceptance and Department approval of the entire application package or the permit.

3.2.1 DESIGN REVIEW EXPIRATION

If resolution of the Department's review comments and resubmittal of a final application package by the Owner does not occur within a reasonable timeline as determined by the Department, the application is considered expired. The timeline may be adjusted in consultation with the Department.

3.2.2 RESUBMITTAL OF REJECTED DESIGNS AND EXPIRED APPLICATIONS

If the Owner desires to resume the permit application process after design rejection or application expiration, the Owner is required to submit a revised and complete application package. The new application will be reviewed and re-evaluated relative to the Standards at the time of updated application submittal.

3.3 FINALIZED DESIGN DOCUMENTS

Following resolution of all Department comments, the Owner must submit a final application package that includes the final design documents, signed and sealed by the Engineer. Official acceptance of a report can only be provided upon review of the entire final application package with the final designs.

The Department will review the final application package including the project design reports, construction drawings, and construction specifications. The Department reserves the right to require additional information as deemed necessary to make sound permitting decisions. Once the Department finds the package acceptable and all requirements have been met, the Department will issue a construction permit.

Changes made to the design after final issuance of the construction permit require a Change Order accepted by the Department as detailed in Section 13.2.2.

4 APPLICATION REQUIREMENTS

As of the effective date listed, the Standards apply to all new dams and modifications to existing dams that require a construction permit.

For structures that do not require design by an Engineer, follow the submittal procedures and design requirements outlined in Appendix A.

Permit applications must be submitted electronically as a PDF unless otherwise agreed to by the Department and the Owner. Further, the following considerations need to be taken:

a. Efforts must be made to minimize digital file size while still allowing for clear printing of both full-size and half-size drawings without losing clarity, quality, or scalability.

b. Document security settings must allow for the required digital review and approval process.

c. The finalized design documents submitted in the final application package must be sealed and signed by the Engineer.

4.1 PERMIT APPLICATION PACKAGE CONTENTS

The application package for a construction permit must include the following items:

a. Executive Summary: Include a brief narrative and overview of the project.

b. Table of Contents: Including document names, document descriptions, and document formats of all materials included within the application package.

c. Completed Application Form (SFN 51695) found on the Department's website.

d. Proof of Property Rights: Documentation must be included with the application package to demonstrate that the Owner has complied with the Department's Construction Permit Water Management policy (REG-2020-1) regarding property rights. This includes the lands on which the dam and reservoir will be located, lands within the impoundment reservoir, and any other lands impacted by the project.

e. List of all permits required for a project including local, state, and federal permits and their status.

f. Construction drawings that adhere to the formatting requirements in Section 4.2.1 and content requirements in Section 4.2.2.

g. Construction specifications that adhere to the formatting requirements in Section 4.2.3 and the content requirements in Section 4.2.4.

h. Design Report(s) must be submitted as a comprehensive report. The report must adhere to the formatting requirements in Section 4.2.5 and the content requirements in Section 4.2.6.

4.1.1 CONSTRUCTION DRAWINGS FORMAT

The set of digital construction drawings must meet the following format requirements:

a. Drawings must be clear and legible when printed.

b. Drawings must be scaled to a common engineering ratio, fully dimensioned, and have bar scales to allow scaling of reduced-size drawings.

c. Each sheet must be numbered sequentially, with the first sheet being sheet number one along with the total number of sheets (e.g., sheet 1 of 6). This can be in addition to other sheet designations.

d. Each drawing sheet must be dated and include a title block that clearly indicates it is part of a drawing set. The title block must also include a place to identify what the drawing set is being issued for (i.e., 95 Percent Design, Issued for Department Review, etc.), and a space to track revisions.

4.1.2 CONSTRUCTION DRAWINGS CONTENT

The construction drawings must depict the design of the dam and all appurtenant structures and features in sufficient detail. The set of construction drawings must include the following:

a. The Engineer's seal and signature on every sheet.

b. A cover sheet showing the following minimum information:

- The name of the dam.
- The county in which the dam is located.
- A project location map.
- The township, range, and section in which the dam is located.
- The latitude and longitude of the point where the centerline of the dam crest intersects with the tallest section of the dam (or alternatively, the intersection with the primary outlet conduit).

- A space for a future signature block for the Engineer's approval of as-built drawings and a statement that the project was constructed as depicted on the as-built drawings.

- Other information that can be included in the coversheet—but that is not required--is the stream name on which the dam is built, the watershed size, and a map of the watershed.

c. A list of the drawings with a brief description or sheet title (i.e., Table of Contents).

d. Where applicable, include stage-discharge curves and tables for spillways and outlets on the drawings. Include the rating data on the drawings and reference it to gage height and the elevation datum.

e. Area-capacity and stage-capacity curves and tables must be provided for all new dams and enlargements and when otherwise required by the Department.

f. Reference elevations and horizontal control to the currently-accepted datums by the Department: North American Vertical Datum of 1988 (NAVD88); and North American Datum of 1983 (NAD83). Provide correction factors or equations for other datums used for past projects at the same dam.

g. Source all references used to support design requirements with title, year, and author.

4.1.3 CONSTRUCTION SPECIFICATIONS FORMAT

Construction specifications shall be provided as a separate document from the drawings. In some limited cases, as approved beforehand by the Department, construction notes (included on the drawings) may be developed instead of separate specifications.

The construction specifications must meet the following format requirements:

a. Specifications must be submitted as a PDF file suitable for printing.

b. Specifications must be organized to facilitate referencing and locating information. Typical organization schemes are outlined by the Construction Specification Institute and others.

c. Following Department acceptance, the specifications are not allowed to be modified without the Department's approval.

4.1.4 CONSTRUCTION SPECIFICATIONS CONTENT

The construction specifications must provide a sufficient description of requirements and constraints to build the project in accordance with the intent of the design. The specifications must incorporate current dam safety construction practices.

Only technical specifications should be submitted. Contract documents or other specifications not directly pertaining to the project design or construction should only be included if requested. The construction specifications must include the following:

a. The Engineer’s seal and signature on the cover page.

b. The cover sheet must show the following information at a minimum:

   - The name of the dam
   - The county in which the dam is located
   - Date
   - The Engineer's certification statement and seal
   - A placeholder for the revision number
   - An “Issued for:” placeholder

c. A table of contents

d. On each page, in either the header or footer:

   - Page number
   - Date
   - An “Issued For:” placeholder
   - Revision number

e. Address, at a minimum, the following:

   - Change Orders
   - Construction inspections and monitoring
   - Quality of materials used in construction.

- Acceptable quality of workmanship.
- References to applicable standards as appropriate.
- Required tests and estimated frequency of testing to demonstrate conformance of construction to specified requirements.
- Actions to be taken if unsatisfactory materials or workmanship are discovered in the construction.

f. Source all references used to support design requirements with title, year, and author.

4.1.5 DESIGN REPORT FORMAT

The Design Report can be one compiled document, or the Engineer may summarize and compile multiple topic-specific reports such as a Hydrology Report, Geotechnical Report, Hazard Classification Report, etc. These topic-specific reports may be completed as separate documents during the development of the project design and receive an unofficial review from the Department under Section 3.1.

If the Design Report summarizes multiple topic-specific reports, information from the topic-specific reports should be integrated and summarized in the comprehensive Design Report. The topic-specific reports should be included as appendices to a final comprehensive Design Report.

Follow these formatting requirements:

a. Display the Engineer's seal and signature on the cover or cover page.

b. Include the date and revision number on each page in either the header or footer.

c. Detailed model output and computation worksheets should be included as appendices to the reports. This requirement also applies to topic-specific reports.

d. All reports must be free of typographical errors and other incorrect numbers or references. The report must be written to provide a straightforward narrative that is organized and easy to quickly find information.

4.1.6 DESIGN REPORT CONTENT

All items submitted as a part of the Design Report must include support for design decisions, engineering analyses, and engineering investigations. The

Department requires that engineering assumptions, design parameters, and the decision rationale be fully documented in a comprehensive report.

Descriptions and summaries of all computational methods, inputs, assumptions, and results (including computer models and software used in developing design) must be detailed throughout the report. All data, results, and conclusions must be consistent throughout the entirety of the report and appendices.

The items listed below must be included in the Design Report. More detail on what should be included in specific sections of the Design Report is provided in Sections 5–12.

a. An Executive Summary

b. Design objectives and criteria

c. Components and key features of the project.

d. Hazard Classification Report as detailed in Section 5. This report may be submitted as a part of Section 3.1 Pre-Application Consultation with the Department.

e. Hydrology Report as detailed in Section 6. This report may be submitted as a part of Section 3.1 Pre-Application Consultation with the Department.

f. Hydraulic Design. This section must explain how the proposed spillway(s) have been designed to protect the dam from overtopping damage during the IDF, to meet flood control requirements, and how the proposed outlets will comply with downstream delivery and reservoir evacuation requirements.

g. Geological and Geotechnical Evaluation and Conditions as detailed in Section 7. This report may be submitted as a part of Section 3.1 Pre-Application Consultation with the Department.

h. Geotechnical Design. This section must explain geotechnical and engineering geology considerations for the project. Geotechnical data can be documented in a separate Geotechnical Report. All geologic and geotechnical data should be interpreted with sufficient rationale to understand the subsurface characterization, foundation conditions, and geotechnical designs.

i. Structural Design. This section must describe the design and supporting analyses for structural components detailed in Sections 8, 9, 10, and 12.

j. Instrumentation Plan. This section must describe the objectives, scope, and details of the proposed instrumentation discussed in Section 11. Rationale must be provided to support a decision not to provide instrumentation.

k. Mechanical and Electrical Design. This section must include a discussion of designs and analyses for all mechanical and electrical systems, including but not limited to gates, valves, motorized trash racks and mechanical systems, systems for operating gates and valves, electrical power requirements, and emergency backup power or manual override features. Mechanical and Electrical Design is also discussed in Section 12.

l. Site Considerations. This section must describe any site-specific issues that result in unusual or unique design and construction considerations, including but not limited to land use limitations, special environmental or archaeological circumstances, past development at the site, etc.

h. Source all references used to support design requirements with title, year, and author.

5 HAZARD CLASSIFICATION

The hazard classification of a dam is based on the potential downstream effects if the dam were to fail and unexpectedly release the impounded water. Hazard classification does not refer to the condition of the dam or the likelihood that the dam will fail.

Dam hazard classification is primarily determined by evaluating the potential to cause loss of human life in the event of a dam breach downstream of a dam. This, along with additional considerations that can be applied to determine hazard classification are outlined below.

The outlined model requirements are intended to represent the minimum dam breach model requirements for the purpose of determining the hazard classification only and is not intended to represent a precise prediction of property damage or loss of life that would be experienced in a dam breach. The Emergency Action Plan (EAP) discussed in Section 15, and the inundation mapping contained in it, are the most appropriate place to convey a detailed representation of the potential impacts anticipated from a failure of the dam.

The hazard classification of a dam establishes minimum design requirements, but Owners may elect to design a dam at a more restrictive hazard classification. Owners should consider the potential for upstream or downstream development, the impact of such development on the hazard classification of their dam, and the resulting impact on the design and performance requirements for their dam.

All work done under this section must be overseen by an Engineer. Alternate methods may be used if requested by the Owner and are subject to Department approval under Section 1.4.

5.1 HAZARD CLASSIFICATION ANALYSES

Hazard classification can be analyzed in several ways. In most cases, a Dam Breach model will be appropriate, however alternate methods may be used by the Department and Owner to inform a hazard classification review, as appropriate and within the parameters described below. An Owner may elect to complete more detailed dam breach modeling than what is described as long as the intent of these Standards are met, as determined by the Department.

5.1.1 2-DIMENSIONAL DAM BREACH MODEL

The use of a 2-Dimensional hydraulic model is used where flow path is not known and spread is likely.

The following metrics apply for Department and Owners modeling a dam breach to inform a hazard classification review.

a. Assume a starting water surface elevation at the top of dam, or at the maximum reservoir level reached by the Probably Maximum Flood (PMF), whichever is less.

b. Assume no additional reservoir inflow.

c. Assume no coincident flooding downstream of the dam.

d. Either assume an internal erosion breach where the failure mode is due to piping or sediment moving with flowing waters out of the dam creating a void within the dam or use NRCS TR-60 methods to derive the breach hydrograph.

e. Use survey or Light Detection and Ranging (LiDAR) topographic information.

f. Dam breach model limits must extend downstream to a point where there are no additional impacts from the dam failure that would affect the hazard classification of the dam.

5.1.2 1-DIMENSIONAL DAM BREACH MODEL

In the case where a 2D dam breach model is not feasible, the Engineer may use Engineering Judgment under Section 1.5 and use a 1D model as described below:

a. Use survey or LiDAR information

b. The other requirements described in Section 5.1.1 apply.

c. The presence of people is evaluated as described in Section 5.2.1.

d. Flooding lethality is evaluated based on flooding depth only.

e. For homes and other habitable structures, loss of human life is assumed if the inundation depth is greater than 2 feet. Inundation at any depth is assumed to result in economic losses.

f. For roads and railroads, loss of human life is assumed if the road or railroad meets the criteria outlined in Sections 5.2.1.2 and 5.2.1.3.

5.1.3 SIMPLIFIED HAZARD CLASSIFICATIONS

The hazard classification of a dam can be determined in some cases by field investigation and a review of available data, such as recent aerial imagery and topographic data. Basic engineering calculations may also be used in some cases.

A simplified analysis is generally only applicable to situations where the hazard classification is obvious and indisputable. If downstream consequences are not clear, a more detailed analysis must be performed. No breach model is required for determining hazard classification if the dam is concluded to be high hazard (i.e., a dam immediately upstream of a neighborhood). However, the inundation map produced from a breach analysis will still be required for the EAP detailed in Section 15.

The use of this simplified option to justify anything other than a high hazard classification is limited to dams with a maximum storage capacity at the top of the dam of less than 200 ac-ft.

5.2 FAILURE CONSEQUENCES

This section provides guidance on how to apply the results from Section 5.1 to hazard classification definitions based on the potential impacts due to dam failure.

5.2.1 LOSS OF HUMAN LIFE

The potential to cause loss of human life in the event of a dam breach downstream of a dam is a primary factor in determining a dam's hazard classification. Loss of human life is based on the following:

- Potential presence of people at the time of a dam breach, and
- Presence of lethal conditions based on depth and velocity of flooding

It is assumed that if people are reasonably expected to be present at locations where potentially lethal flood conditions are expected, then loss of life is probable.

Downstream hazards must be analyzed to identify the presence of people at risk during a dam failure. The following hazards include most areas where people are present in the downstream floodplain where loss of life would be probable:

5.2.1.1 HOUSES AND RESIDENTIAL STRUCTURES

All habitable structures including single- and multi- family dwellings, trailers, and mobile homes; commercial, industrial, and agricultural buildings regularly occupied by workers or the public; and recreational facilities with overnight stays possible are assumed to be occupied. This excludes out-buildings or facilities that are occupied on an occasional or inconsistent basis.

Evaluate potential flooding lethality of occupied houses and residential structures with the following metrics:

a. Inundation of one or more habitable structures will result in a high hazard classification if it is determined that potentially lethal flood conditions occur based on the flow depth and velocity at each structure.

b. The evaluation is based on outputs from the breach model completed in Section 5.1 and selected lethality charts for structures contained in *ACER Technical Memorandum No. 11 – Downstream Hazard Classification Guidelines (ACER 11)*, U.S. Bureau of Reclamation, 1988. See Figures 5.1 and 5.2.

c. The depth-velocity-flood danger relationships in ACER 11 are divided into three zones: a low danger zone where loss of life is improbable, a high danger zone where loss of life is probable, and a judgment zone where engineering judgment must be used to determine if loss of life is probable.

d. Flooding lethality is evaluated based on flooding depth only if a 1D hydraulic model is used for the dam breach analysis, inundation of one or more habitable structures to a depth greater than 2.5 feet will result in a high hazard classification.

e. Inundation of habitable structures at any depth is assumed to result in economic losses. If lethal conditions as defined above are not present, then the dam may be classified as medium hazard if there are no other hazards to be considered. A dam may be classified as low hazard if the only impacts are to uninhabited buildings.

f. A dam may be classified as low hazard if it may cause potential damage to agricultural land, uninhabited buildings, or isolated unoccupied oil well pads.

Figure 5.1

Depth-Velocity-Flood Danger Level Relationship for Houses Built on Foundations (Bureau of Reclamation, 1988)

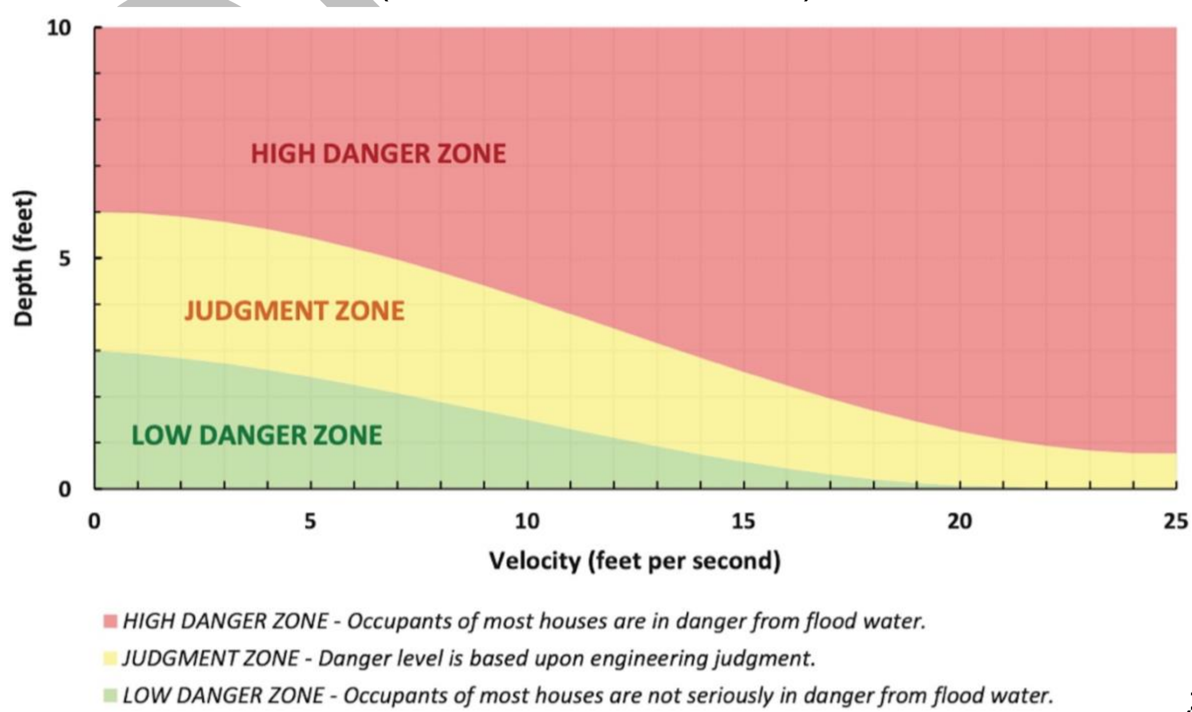
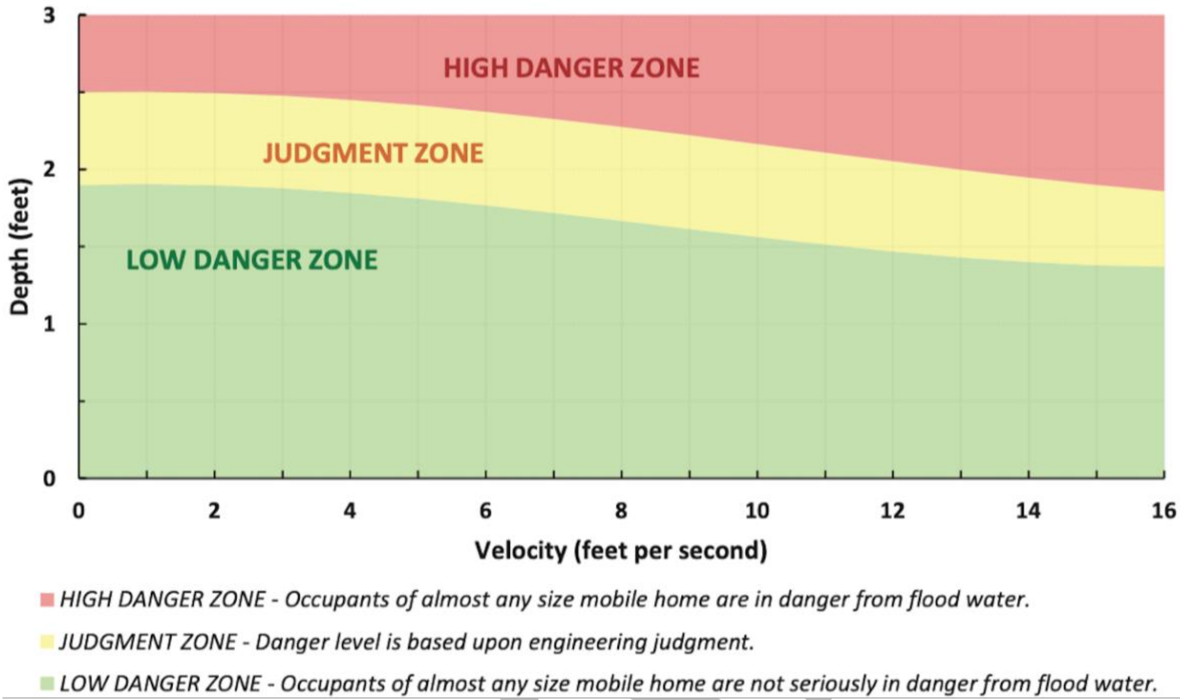


Figure 5.2
Depth-Velocity-Flood Danger Level Relationship for Mobile Homes
(Bureau of Reclamation, 1988)



5.2.1.2 ROADS

Consider any road crossing the dam, or downstream of the dam in the hazard classification. The likelihood of people being present is based on a roadway's Annual Average Daily Traffic (AADT) count.

AADT information can be obtained from the North Dakota Department of Transportation's website.

Use the most recent traffic count data available. If the traffic level of a particular roadway is in question and AADT data is unavailable, reasonable assumptions may be made based on the best available data, or an Owner may perform a traffic count to facilitate a hazard classification decision.

Roads are assumed to be impacted if overtopped at any depth. The potential for roads to be overtopped is based on the analysis completed in Section 5.1.

If the road is determined to be impacted, use following criteria to determine loss of human life and evaluate the hazard classification:

a. Private roads and roads with AADT< 500 vehicles: No probable loss of human life. Dams that impact roads in this category will be classified as low hazard if there are no other hazards to be considered.

b. U.S. Highways, State Highways, or roads with AADT 500–2,000 vehicles: Transportation disruptions, potential economic impacts, but loss of human life unlikely. Dams that impact roads in this category will be classified as medium hazard if there are no other hazards to be considered.

c. Interstates or roads with AADT > 2,000: Probable loss of human life. Impacts to these roads would result in a high hazard classification.

d. Impacts to a road that provides the only access to a residence, business, or another type of occupied location would result in a medium hazard classification.

5.2.1.3 RAILROADS

Consider any railroad downstream of the dam, or crossing the dam, in determining the hazard classification. The likelihood of people being present is based on the rail line's freight or passenger designation and the average number of trains per day.

Determine the average number of trains per day and the type of rail line (passenger, freight, etc.) using U.S. Department of Transportation Railroad Crossing Inventory Forms (Part II, 1.a & 1.b), which can be obtained from the Federal Railroad Administration's website.

Railroads are assumed to be impacted if overtopped at any depth. The potential for a railroad to be overtopped is based on the analysis completed in Section 5.1. If the railroad is determined to be impacted, use the following criteria to determine loss of human life and evaluate the hazard classification:

a. If any railroad is impacted, the dam will be classified as at least medium hazard.

b. Freight Line: Probable loss of human life if 10 or more trains per day. Impacts to lines with 10 or more trains per day would result in a high hazard classification.

c. Passenger Rail Line: Probable loss of human life if active line. Impacts to these lines would result in a high hazard classification.

5.2.2 ECONOMIC LOSS AND LIFELINE FACTILITIES

Where a dam has no probable loss of human life associated with its failure, economic losses and lifeline facility impacts are the metrics used to determine if a dam is classified as low or medium hazard.

Economic losses are assumed to occur if occupied structures are inundated to any degree, or roads or railroads are overtopped by any amount. This includes inundation of homes, commercial or industrial facilities (including large oil and gas facilities), roadways as described in Subsections (b) and (d) of Section 5.2.1.2, and railroads as described in Section 5.2.1.3.

Consider lifeline facilities such as public utilities and emergency response facilities in this analysis. Any dam breach impacts to lifeline facilities that reduce the effectiveness or prohibit access to such facilities will result in a medium hazard classification.

The Engineer may use Engineering Judgment under Section 1.5 to ascertain if a dam classifies as low or medium hazard.

5.3 ADDITIONAL CONSIDERATIONS

The following points provide further discussion and interpretation of the division between the hazard classification categories:

a. Downstream Consequences: The hazard classification of a dam is based solely on the potential downstream consequences of the failure of the dam itself.

b. Imminent Future Development: The hazard classification must be based on current downstream conditions and any imminent future downstream development. Imminent future development includes planned land use for which a development plan has been approved by the local zoning jurisdiction, approved development permits, and active development.

c. Cascading Failures: If failure or misoperation of a dam could contribute to failure of a downstream dam, the hazard classification of the dam should be at least as high as the classification of the downstream dam and should consider the adverse incremental consequences of the cascading failures (FEMA, 2004).

d. Emergency Actions: No allowances for evacuation or other emergency actions by the downstream population should be considered in the hazard classification (FEMA, 2004).

e. Above-Grade Impoundment Embankments: Evaluation of the hazard classification must consider the consequences of failure of the impoundment embankment at various locations. The scenario resulting in the most severe consequences must be considered when evaluating the appropriate classification.

f. Borderline Classifications: The hazard classification must be conservative; if a classification is borderline, the higher classification must be assigned.

5.4 HAZARD CLASSIFICATION REPORT

The Owner or Owner's representative must submit a Hazard Classification Report with a construction permit application for a new dam or for modification of an existing dam. The Department will review the Hazard Classification Report and make the final determination of the appropriate hazard classification for a given dam.

Hazard Classification Reports may be submitted as a part of Section 3.1 Pre-Application Consultation with the Department. The Department may request additional information or more detailed analysis if the hazard potential needs to be clarified based on the information provided by the Owner.

The Hazard Classification Report must confirm the existing classification or propose a new hazard classification for the dam and must provide a written description of the rationale for the proposed classification and be supported by engineering analyses where appropriate. In the case of an existing medium or low hazard classification dam, adopting the previously-assigned hazard classification without supporting documentation is not permissible.

The Hazard Classification Report must identify the hazard classification for the dam. A detailed analysis is not required for dams declared as high hazard; however, a dam failure inundation map is required for the EAP (Section 15.3).

The Hazard Classification Report must include the following minimum information:

a. **Downstream Breach Inundation Zone:** Describe the inundated areas including the location of the dam and the extents of the flooding. The description also needs to include a discussion of the land uses within the breach inundation area.

b. **Dam Breach and Flood Channel Discharge Parameters:** Include procedures for dam breach analysis, breach discharge routing, and estimation of hydraulic conditions at critical locations. Provide backup for hydraulic analyses including computer models, spreadsheets, and other computational aids. The submittal must include the full analysis models. Include any sensitivity analyses performed.

c. **Dam Failure Inundation Map:**
For a 1D model, include the location and alignment of the cross-sections used in the analysis, flow depth in feet, average flow velocity in feet per second, and flood wave arrival time at each cross-section. Mark the limits of inundation on each cross-section. Critical sections should illustrate any features discussed in Section 5.1.2 impacted by the dam failure flood wave.

For a 2D model, include the locations of identified hazards according to Section 5.1.1 and include annotations for flow depth, flow velocity, and flow wave arrival time at each critical feature. Not every feature requires annotations, but as many features as can clearly be shown (ranked by a priority of human life safety) should be marked on the map. 2D models must show the limits of inundation with a raster of flood depths.

d. **Conclusions and Statement of the Recommended Hazard Classification:** The recommended hazard classification for the dam must be clearly stated. The dam is classified or reclassified once the Department accepts the findings of the report and determines the official hazard classification.

5.5 HAZARD CLASSIFICATION REPORT (SIMPLIFIED ANALYSIS):

When doing a simplified hazard classification analysis as detailed in Section 5.1.3, include the following in the Hazard Classification Report:

a. A map of the dam and surrounding area.
   - Clearly label nearby structures, waterways, streams, and other features that may impact the dam classification.
   - Show the direction of downstream flow.

b. Topographic data, either from a survey or from best available LiDAR data.

c. Photographs of the site and aerial photographs.

d. Any engineering calculations used in the analysis.

e. Discussion of why the consequences meet hazard criteria.

f. A statement of the recommended hazard classification.

6 HYDROLOGY STUDY

Hydrology for dam design is based on frequency precipitation events and surface flow through a watershed. In combination, these two data sets result in a site-specific flood hydrograph, Inflow Design Flood (IDF), and principal spillway design events. The IDF is used to size the auxiliary spillway and establish the elevation of the dam crest.

The IDF must be developed by evaluation of precipitation estimates and rainfall-runoff modeling. Once rainfall has been established, perform rainfall-runoff modeling to complete the analysis of the IDF. The IDF must include the runoff from the precipitation event plus runoff from snowmelt, as appropriate.

The reservoir volume may be small in comparison to the volume of the hydrologic event to which the reservoir and dam may be subjected. In these cases, the incremental damages from the failure of the dam may be relatively minor, and the IDF may be reduced through incremental damage analysis (IDA) as discussed in Section 6.4.

All work done under this section must be overseen by an Engineer. Alternate methods may be used if requested by the Owner and are subject to Department approval under Section 1.4.

6.1 DRAINAGE BASINS

The makeup of the basin is critical to forming the IDF hydrograph. The movement of water though a basin includes many parameters, but is not limited to basin size, basin topography, soil permeabilities, and vegetative covers. Because basins are not always homogeneous in these variables, basins can be divided into sub-basins to perform detailed analysis. Basins that are generally homogenous may be analyzed without sub-basins. Include the entire drainage area when developing the IDF, including non-contributing sub-basins or areas. The Engineer may use Engineering Judgment under Section 1.5 to allow for the exclusion of non-contributing sub-basins if there is clear rationale to support the decision.

6.2 PRECIPITATION

Dam design is informed by both hazard classification and associated precipitation magnitudes. A higher hazard classification will be required to pass a larger precipitation event, as shown in Table 6.1. The values in Table 6.1 are based on FEMA’s “Selecting and Accommodating Inflow Design Floods for Dams” (FEMA, 2013) and the dam’s hazard classification. For sizing a principal spillway, use runoff from a storm duration of at least 10 days and inflow amounts from the storm events as stated in Table 6.1. For determining the IDF, high hazard dams require development of the Probable Maximum Flood (PMF), the flood resulting from the PMP.

TABLE 6.1
MINIMUM INFLOW DESIGN FLOOD REQUIREMENTS

Hazard Classification	Inflow Design Flood (IDF)	Minimum Principal Spillway Capacity
High	Probable Maximum Flood (PMF)	1 Percent AEP (100-year Flood)
Medium	0.1 Percent AEP Flood (1,000-year Flood)	2 Percent AEP (50-year Flood)
Low	1 Percent AEP Flood (100-year Flood)	4 Percent AEP (25-year flood)

Data for the required precipitation events can be found in the following locations:

- Obtain the Probable Maximum Precipitation (PMP) from the North Dakota Statewide PMP Study, found on the Department's website and explained in Section 6.2.1.

- Obtain the 0.1 percent Annual Exceedance Probability (AEP) storm and 1 percent AEP precipitation depth from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 "Precipitation-Frequency Atlas of the United States," Volume 8, Midwestern States, (2013).

6.2.1 NORTH DAKOTA STATEWIDE PMP STUDY

The North Dakota PMP Study (June 2021) has statewide PMP estimates that incorporate snowmelt, and both temporal and spatial distributions of PMP rainfall events. The PMP study includes three GIS-based tools to allow evaluation of the PMPs for individual basins: a PMP Tool, a Snowmelt Tool, and a Spatial Distribution Tool and supersedes previous guidance provided by Hydrometeorological Reports 48 and 51. The toolset and detailed documentation can be downloaded from the Department website.

The PMP Tool can analyze three types of storms: the warm season general, warm season local, and cool season. A general storm is a storm covering a large area with a longer duration. The cool season storm is a general storm occurring during the late winter/early spring, this is in combination with a snowmelt parameter. A local storm is a thunderstorm, short duration within a small area.

Based on the basin size, evaluate which storm is appropriate to use in developing the PMF. Use the PMP tool and Snowmelt Tool when applicable, to find the most severe storm event possible.

Use the parameters below when performing PMP analysis using the PMP Tool:

a. Basins greater than or equal to 100 square miles:

- Analyze the cool season storm, local storm, and general storm to determine which produces a more critical IDF. For the cool season analysis, follow the steps noted in the cool season section below.
- Evaluate the local storm separately from the general storm.
- Evaluate 2-hour, 6-hour, 24-hour, and 72-hour storm events as appropriate for the specific basin.
- Analyze alternative spatial patterns or break up the PMP analysis on a sub-basin level.

b. Basins less than 100 square miles:

- Analyze the local storm and general storm.
- Evaluate the local storm separately from the general storm.
- Evaluate 2-hour, 6-hour, 24-hour, and 72-hour storm events as appropriate for the specific basin.
- Do not use the general storm for basins 20 square miles or smaller.
- No alternative spatial patterns are required for basins less than 100 square miles.

c. Temporal Distributions

- The critically stacked temporal distribution pattern is the most conservative temporal distribution. The Engineer may use Engineering Judgment under Section 1.5 to determine for the most applicable temporal distribution.
- Results from other temporal patterns associated with each storm type within the PMP Tool may be used for design as appropriate, provided the results in the checking file for that storm indicate, “PASS”. The precipitation results based on other temporal distribution patterns may be more realistic than the critically stacked pattern and can be used to refine the PMP analysis.

d. Spatial Distributions:

- The Engineer may use Engineering Judgment under Section 1.5 to determine the location of the storm.
- Consider that a smaller, more intense local storm over only a portion of the basin could be controlling for any basin size.

- Consider multiple locations including centered over the basin and those closer to the dam which may result in more severe runoff.

e. Cool Season Storms:

The cool season hydrograph, derived using cool season rainfall values from the PMP Tool, must be modeled in conjunction with results from the Snowmelt Tool. Snowmelt results are given in depth of runoff per day. Model the snowmelt as baseflow when developing the basin response. The input variables in the Snowmelt Tool are as follows:

- Melt Start and End Date: Snowmelt can begin between March 1 and June 1, depending on the basin's size and location. Use an iterative process to identify start and end dates that maximize the volume of snowmelt based on snow water equivalent and the temperature time series. Iterating through the snowmelt coefficients over the season (March 1 to June 1) will narrow the start date search. The date that snowmelt begins can be determined by looking for the first date that snowmelt occurs in the Snowmelt Tool output table.

- Rain-on-Snow Event Duration: To model a rain-on-snow event for determining the cool season PMP, add a rain-on-snow event using the Snowmelt Tool, which increases snowmelt for the duration of the event. The snowmelt end date should be late enough to ensure all snowmelt accumulation is accounted for.

- Melt Coefficient: Larger coefficients ripen the atmospheric and snowpack conditions to yield a higher melt rate. The "clear sky" melt coefficient is not applicable for modeling a rain-on-snow event.

6.3 RAINFALL-RUNOFF AND BASIN RESPONSE

Once the IDF precipitation hyetograph has been established, develop a hydrologic model to route the runoff to the reservoir. The IDF must be determined considering basin size, basin elevation, soil permeabilities, vegetative covers, and other factors related to the routing of the storm event. Antecedent conditions for the PMF should consider a saturated basin.

To verify Table 6.1 parameters, the reservoir should be routed with a starting water surface at the auxiliary spillway crest. The reservoir can be routed as part of the rainfall-runoff program, or other options, such as a spreadsheet, may be used.

6.4 INCREMENTAL DAMAGE ANALYSIS (IDA)

If it can be shown that the flood event, including dam failure, would not cause additional downstream damage as compared to a flood event without dam failure, a flood of lesser magnitude can be analyzed in the same manner. The IDF is selected as the flood above which there is a negligible increase in the consequences due to dam failure, as compared to the same flood without dam failure. Figure 6.1 depicts this comparison.

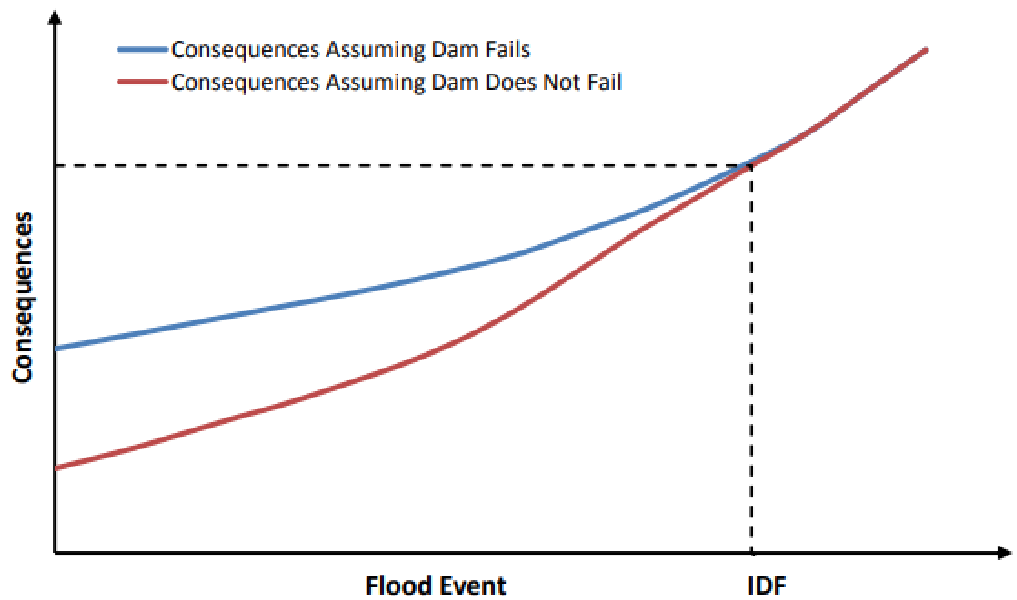


Figure 6.1: Conceptual Comparison of Incremental Damages

Note:
Reference: FEMA, 2015

An IDA may be used to justify a reduction to the IDF for medium and high hazard dams. The IDA will not be used to reduce the hazard classification. In situations where an IDA is justified, the IDF is the flood with a magnitude such that the failure of the dam simultaneously with the peak of the IDF hydrograph does not contribute to any additional flood damage downstream.

To evaluate if an IDA is appropriate, compare the following floods:

- A base flow flood in which the dam does not fail.
- A dam failure flood in which failure occurs due to overtopping, and the dam breach hydrograph is routed downstream along with the peak of the base flow flood.

All dams for which an IDA establishes the IDF must be capable of passing the inflow generated by a 24-hour, 500-year rainstorm event.

6.4.1 IDA DOCUMENTATION

The following information is required for the IDA:

a. A figure or set of figures showing the breach inundation areas for each flood event analyzed based on outputs from a 2D hydraulic model.

   - Clearly label structures, roads, streams, and other features that may impact the analysis.

- Show the differences between the depth and velocity of base flow and the base flow plus dam breach flood on topographic maps of the affected areas.

b. Summary of all assumed hydraulic parameters.

c. Table of potential failure consequences as discussed in Section 5.2, comparing the results for each flood event. No new structures should be inundated, and the potential life loss should be the same.

d. Table summarizing the results of the IDA at the various downstream cross sections comparing the two floods.

e. Documentation may also include channel profiles with the various flood stages; aerial photographs of the affected areas; and computer printouts showing flood discharges, stages, and velocities with respect to time.

6.5 HYDROLOGY REPORT

The Owner or Owner's representative must submit a Hydrology Report with a construction permit application for a new dam or for modification of an existing dam.

Hydrology Reports may be submitted as a part of Section 3.1 Pre-Application Consultation with the Department. The Department may request additional information or more detailed analysis as necessary.

The purpose of the Hydrology Report is to document the IDF for a dam and the corresponding minimum principal spillway capacity. The report must also document any engineering assumptions, modeling parameters, and decision-making processes in the development of the IDF.

The report must also include all pertinent design analyses and assumptions necessary to determine the minimum principal spillway capacity.

The Hydrology Report must include the following minimum information:

a. **Sub-Basin Characteristics:**

- Delineation of the basin or sub-basins

- A topographic map of the basin and sub-basins.

b. **Precipitation**

- PMP study rainfall results (as appropriate).

- NOAA Atlas 14 results.

- Calculation of the IDF precipitation hyetographs.

- Justification for all selections made while using the PMP study, such as storm type, temporal distribution, and any other assumptions.

c. **Rainfall-Runoff Model:**

- Rainfall-runoff model and all input parameters including maps of input parameters (i.e., soil groups, vegetation or land use characterizations across the basin, etc.).

- Justification for input parameter assumptions and choices.

- Routing method and modeling parameters.

- All computer models, spreadsheets, and other computational aids. The submittal must include the full analysis.

- Any sensitivity analyses performed on the runoff parameters.

d. **Conclusions:**

- Identify the controlling storm and IDF hydrograph. Justify the selection of the controlling storm.

- Identify the minimum principal spillway capacity.

e. **IDA:**

- Hydrology Reports relying on IDA must also include all IDA-specific requirements from Section 6.4.

7 GEOLOGICAL AND GEOTECHNICAL EVALUATION

A geological and geotechnical evaluation is required for all new dams. Dam modifications may require a geotechnical evaluation depending on the scope of the project.

The geotechnical evaluation must include all pertinent geotechnical considerations for a given project. Documentation and interpretation of all appropriate field and laboratory investigation and testing programs must be sufficiently comprehensive to support the basis of design for the dam, the foundation, and the foundations of appurtenant structures. The extent of the required investigation, testing, and evaluation varies with the hazard classification, size, and complexity of the dam; however, it is intended that an adequate level of investigation and analysis must be conducted for every dam in accordance with accepted standards of engineering practice.

Feasibility level investigations and reports are not sufficient to support designs of medium and high hazard dams.

All work done under this section must be overseen by an Engineer. Alternate methods may be used if requested by the Owner and are subject to Department approval under Section 1.4.

7.1 SITE CHARACTERIZATION

Geologic and geotechnical investigations must be conducted to appropriately characterize the subsurface conditions and support design parameters for all new, repaired, or modified dams.

7.2 GEOLOGICAL ASSESSMENT

Provide a geological assessment of the dam and reservoir site, including evaluation of the geologic suitability of the dam foundation and reservoir area, and other potential geological hazards posed by the site and proposed construction. The assessment needs to include the following as a minimum:

a. Site-specific geologic map based upon published records and field observations. The map must cover the reservoir area, dam, spillways, abutments, and the locations of all appurtenant structures.

b. Potential for unstable slopes around the reservoir perimeter

c. Potential for adverse changes to the groundwater or surface water regime in the area

d. Location of faults and historic earthquakes (greater than a magnitude 3.0) within a radius of 62 miles (100 kilometers)

e. The peak ground acceleration and spectral response accelerations appropriate for use in design. Seismic design parameters must adhere to the guidance provided in *Technical Release 210-60 Earth Dams and Reservoirs (NRCS, 2019).*

f. Approximate Depth to Bedrock (published or observed): If bedrock is shallow (relative to the size of the project), provide descriptions of the predominate fractures, faults, and joints in bedrock within the reservoir basin, at the dam abutments, or in the dam foundation.

g. The presence of unsuitable soils, karst, or other conditions that could adversely affect the safety of the dam.

h. For low hazard dams, geologic assessment should include at least a consideration of published geology, depth to bedrock, locations of published faults, and seismic loading information available from the US Geological survey.

7.3 SUBSURFACE INVESTIGATIONS

Subsurface geotechnical investigations must be conducted to adequately characterize and understand foundation conditions (including the subsurface materials below all parts of the dam and appurtenances) and earthen materials to be used for construction.

7.3.1 ADEQUATE CHARACTERIZATION

Adequate characterization must include sufficient coverage of the site, depth, details, and quantities to provide a reliable and statistically meaningful representation of the subsurface earth materials. Subsurface investigation requirements will vary based on project-specific needs.

Develop a subsurface investigation plan to plan a field program that will provide the geotechnical and geologic data needed to support design and mitigate risks.

Adequate characterization includes generally understanding:

a. The stratigraphy and variability of soil and rock layers or deposits (including the variability of depths and thicknesses)

b. The depth to and geologic classification of generalized soil types and bedrock units (if applicable)

c. Excavatability

d. The strength and deformation characteristics when subjected to anticipated loads

e. Permeability of native earthen materials that will be relied upon for seepage control

f. Groutability or ability to receive other ground improvements

g. Compaction characteristics at various moisture contents of earthfill materials

h. Strength, permeability, erodibility, and compressibility characteristics of earthfill materials.

7.3.2 DRILLING METHODS

Drilling methods in all dams and dam foundations must be chosen to minimize the risk of hydraulic fracturing or otherwise damaging the strata or formations being drilled. All drilling through or within 200 feet of existing dams in North Dakota should be performed in accordance with the U.S. Army Corps of Engineers (USACE) requirements outlined in Engineer Regulation 1110-1-1807, “Drilling in Earth Embankment Dams and Levees” (USACE, 2014).

7.3.3 MINIMUM REQUIREMENTS

Subsurface geotechnical investigations must include the following:

a. Minimum of three borings along the dam centerline to a depth 1.5 times the height of the dam, with one of the boreholes located on the alignment of the principal spillway

b. Additional borings or test pits within or near the dam and spillway footprint, as appropriate, including at least one borehole along the proposed alignment of the principal spillway

c. Logs of borings and test pits

d. Standard Penetration Testing

e. Field density tests, as appropriate

f. Field classification of subsurface materials in accordance with published standards

g. Measurement of the water level in each drill hole

h. In-situ permeability tests

i. Evaluation of the site’s suitability to accommodate the principal and auxiliary spillways and their associated structures

j. Field classification of soils along the alignment of spillways and below hydraulic structures (i.e., intakes, control weirs, stilling basins, etc.)

k. Profile of materials along the spillway channel extending to a depth of at least 5 feet below the bottom of the proposed channel invert

l. Characterization of borrow sources including the availability, suitability, and quantity of all earth and rock materials proposed for construction of the dam as designed. Borrow areas must be located so they do not negatively impact the dam stability or foundation seepage. Locate borrow areas at least 200 feet outside the dam footprint.

m. Subsurface geotechnical investigations for low hazard dams may not need to include all items noted above and can be revised if justified by the simplicity of the geology and proposed design.

7.4 LABORATORY TESTING

Laboratory testing must be performed to provide engineering justification for the selected parameters used to support design. Perform a sufficient number of laboratory tests for each material used to construct the dam and support the selected properties used in analyses.

a. Use independently-defined and commonly-accepted standards (i.e., ASTM, American Association of State Highway and Transportation Officials, etc.).

b. Include gradation and index testing for adequate classification of all soils, including hydrometer tests on clay soils as needed to confirm filter design and permeability correlations.

c. Include in-situ moisture content and dry density of each soil strata identified in the subsurface investigation.

d. The test program, as appropriate, should provide a direct measurement of the drained and undrained shear strength parameters needed for slope stability and bearing capacity analyses.

e. Perform a consolidation/swell test on undisturbed and remolded samples, as appropriate, of all soils or rock that could affect the dam or appurtenant structures through settlement or heave. Test conditions should reflect the loading conditions anticipated for the soils.

f. Test foundation soils and soils to be used for embankment fill to evaluate the potential for dispersive behavior.

g. Test foundation soils for corrosivity and aggregate for alkali-aggregate reaction, as appropriate.

h. Evaluate foundation rock, if present, for intact strength and joint/bedding strength.

i. Conduct permeability tests for foundation, abutment, and embankment materials under laboratory conditions that represent the anticipated loading conditions for the materials. Use undisturbed and remolded samples, as appropriate, for the dam design.

7.5 GEOTECHNICAL REPORT

The Owner or Owner's representative must submit a Geotechnical Report with a construction permit application for a new dam or for modification of an existing dam.

The Geotechnical Report may be submitted as a part of Section 3.1 Pre-Application Consultation with the Department. The Department may request additional information or more detailed analysis as necessary.

The purpose of the Geotechnical Report is to document the geologic, geotechnical and groundwater conditions in the foundation, and the geotechnical conditions of earthen materials to be used to construct the dam. The Department may reject a report for insufficient detail or justification.

This report must explain the geologic, seismic, and foundation conditions and considerations for the project.

The Geotechnical Report must include the following minimum information: and considerations for the project, and include, at a minimum:

a. Geotechnical Investigations as detailed in Section 7.3.3.

b. Engineering assumptions

c. Modeling parameters

d. Design rationale for the geotechnical design of the dam.

e. Results for each test with respect to the dam element or material zone represented by the test.

8 EMBANKMENT DESIGN REQUIREMENTS

All work done under this section must be overseen by an Engineer. Alternate methods may be used if requested by the Owner and are subject to Department approval under Section 1.4.

The following design and construction requirements are the minimum considerations to promote dam safety.

8.1 DAM GEOMETRY

An earth or rockfill dam of any size must be designed to be safe and stable during its entire life, including during construction. Designs must consider the need to provide perpetual access to the dam for maintenance, inspections, and repairs.

Include dam geometry analyses as supporting design information in the Design Report.

8.1.1 FREEBOARD

a. Medium and High Hazard Dams: Freeboard must be designed in accordance with Design Standard No. 13, Chapter 6 “Freeboard” (Reclamation, 2021), or a similarly accepted design standard, except as follows:
   - Minimum normal freeboard must be greater of 3 feet or a 100 mile per hour wind-generated setup and runup.
   - Minimum residual freeboard must be the greater of 1 foot or a 10 percent AEP wind-generated setup and runup.

b. Low Hazard Dams: Freeboard must be at least 3 feet.

c. Design crest elevation for all dam hazard classifications must be post-settlement.

8.1.2 EMBANKMENT CRESTS

a. Medium and High Hazard Dam requirements:
   - Minimum crest width must be equal to 10 feet plus 20% of the dam height, or 25 feet, whichever is less.
   - Crest must have a longitudinal camber sufficient to maintain the design freeboard based on the anticipated magnitude of crest settlement. The anticipated magnitude of a crest settlement must be based on engineering analyses. In no case can the camber be less than 0.5 feet.
   - Crest design must include details to protect impervious cores from desiccation or frost penetration.

- Crest must have adequate cross slopes to the upstream edge to prevent ponding and facilitate surface drainage.

- Roads located on the dam crest must have appropriate surfacing to provide a stable base that resists rutting and provides adequate traction for safety in wet conditions. Unless specifically approved by the Department, roadways including any structural section of the roadway, are not considered part of the dam (including the freeboard).

b. Low Hazard Dam requirements:

- Minimum crest width is 12 feet.

- Grade the surface of the crest to provide positive drainage toward the reservoir.

- Place a durable surface as the top-wearing surface on the dam crest to prevent rutting and other erosion.

8.1.3 SLOPES

a. Stability analyses must be performed for all medium and high hazard dams to demonstrate that embankments are stable during construction and under all conditions of reservoir operation.

b. The required safety factors for stable slopes under various loading conditions are published in Engineering Manual 1110-2-1902 (Table 3-1) (USACE, 2003).

c. All dams must be designed with upstream slopes no steeper than 3 horizontal to 1 vertical (3H:1V) and downstream slopes no steeper than 2H:1V. Include slope stability as supporting design information in the design report.

8.2 EMBANKMENT SEEPAGE CONTROL

Controlling the phreatic surface within an earth or rock dam is essential to limiting seepage and ensuring embankment stability. Seepage through the dam must be adequately controlled to mitigate slope instability and prevent seepage from exiting with sufficient energy to initiate internal erosion.

Dams should include a cutoff trench under the central portion of the dam. Extend the cutoff to an erosion-resistant strata or impervious soil to prevent seepage beneath the dam. When a sufficiently deep cutoff trench is not feasible, other foundation treatment methods may be required.

Seepage through the embankment, abutments, foundation, and under and around appurtenances must be analyzed for the design of seepage controls to prevent internal erosion, piping, and external sloughing; and to provide for adequate stability of the dam. Results of the seepage analyses will form the basis for the design of the filters, drain blankets, toe drain, uplift resistance, and other drainage features. Geotechnical analyses should include filter compatibility analysis between all material zones within the dam and foundation that are subject to seepage flows. Unfiltered seepage or seepage that exits the dam or foundation uncontrolled is not permissible.

Include seepage analyses and filter analyses as supporting design information in the Design Report.

8.2.1 SEEPAGE CONTROL

For low hazard dams, if there is a concern about foundation or embankment seepage, install a suitable filter zone or toe drain. The toe drain must meet the design requirements for high or medium hazard dams.

Seepage control for medium and high hazard dams must meet the following requirements:

a. Steady state seepage must be analyzed using numerical modeling. Document and justify all modeling input parameters.

b. Filter protect all seepage exit points

c. Filter protect all penetrations through embankments against concentrated leakage along the conduit.

d. Evaluate the filter compatibility of the drain, transition zone, and embankment materials utilizing methods accepted as the current state of the practice (i.e. FEMA, NRCS, USACE, etc.). Granular filter materials must be self-healing and free of cementitious properties.

e. Drains must collect and convey seepage to designated monitoring points. Drains must consist of slotted or perforated pipe surrounded with free-draining gravel that is filter-compatible with the surrounding filter material and will not pass through the drain pipe perforations.

f. Drains and pipes to collect and route seepage flows from internal filters must meet the following minimum requirements:

- 6 inches in diameter

- Be comprised of material that is non-corrodible and non-collapsible for the estimated overlying earth pressures and anticipated settlement or ground movement associated with dam construction.

- Be designed to convey the estimated seepage with a flow depth no greater than 1/4 of the diameter of the pipe.
- Be provided with cleanouts and access points for internal camera inspection, cleaning, and repair of the drain system.
- Discharge freely into locations where flow rates can be measured, such as galleries, manholes, vaults, or headwalls.
- Extend beyond headwalls to facilitate discharge measurement.
- Have elbows with no more than 45 degrees of bend to facilitate inspection, cleaning, and repair.
- Be equipped with removable protective screens to prevent access by rodents and other animals.

8.3 DEFORMATION AND CRACKING

All dams must be analyzed and designed to prevent deformation or instability caused by movement as a result of settlement, consolidation, seismicity, or collapse.

All dams must be analyzed and designed to prevent excessive settlement and the formation of cracks due to differential settlement or the creation of low stress zones that could lead to hydraulic fracturing. Seismic deformation analysis, stress analysis, or consolidation analyses may be needed.

Include settlement, deformation and stress analyses in the Design report.

8.4 FOUNDATION AND ABUTMENTS

The dam foundation and abutments must be analyzed, and design criteria selected to ensure sound performance for the life of the structure must meet the requirements of this section.

Include foundation and abutment analysis as supporting design information in the Design Report.

8.4.1 UNSUITABLE MATERIALS

Remove unsuitable materials from the dam foundation and abutments or treat to mitigate adverse effects to dam safety. Unsuitable materials include, but are not limited to, liquefiable, dispersive, weak, organic, expansive, and collapsible soils. Some soluble rock or soils or weak shales may also be considered unsuitable.

8.4.2 FOUNDATION GEOMETRY:

Design the dam foundation and abutments to prevent the creation of low stress zones in the embankment that could cause differential settlement and cracking of the dam. Avoid abrupt transitions within the prepared foundation (i.e., steep excavation slopes, vertical steps, etc.).

8.4.3 FOUNDATION TREATMENT:

The foundation may need to be treated to prevent deformation or instability of the dam as a result of heave, swell, rebound, settlement, or collapse within the foundation or abutment materials.

8.4.4 FOUNDATION SEEPAGE CONTROL

For medium and high hazard dams, the anticipated seepage volume beneath and around the dam must be quantified in the design. Minimize seepage through the abutments and foundation through adequate treatment. To prevent internal erosion, embankment, foundation, and abutment seepage must be controlled through filtered exits.

The design for all dams must demonstrate acceptably-low exit gradients.

8.4.5 FOUNDATION DRAINAGE DESIGN CRITERIA

Provide foundation drainage to reduce or control uplift pressures that would affect the stability of the dam. The design of the drainage system must consider specific conditions within the dam foundation such as general permeability, risks of highly-concentrated seepage paths, and general groundwater conditions. The ability to inspect and maintain the drainage system to meet the requirements assumed for the design of the dam must be provided.

8.5 MATERIAL PLACEMENT AND COMPACTION

Effective practices that should be followed for the placement of earthfill in dams:

a. Prior to placing any fill materials, strip all topsoil and organic materials from the entire surface of the ground on which the fill will be placed. The bottom of the cutoff trench and the other foundation soils beneath the embankment must be scarified (roughened by plowing, etc.) to a minimum depth of 6 inches, and any oversized rock or other unsuitable material must be removed. The surface must then be moisture treated and compacted.

b. Construct the embankment in nearly horizontal lifts that avoid transverse joints. Limit loose lifts of earthfill to a maximum of 12 inches before being compacted to a minimum specified density.

c. Place coarser, more pervious embankment materials towards the exterior of the embankment slopes and place finer, less permeable materials closer to the center of the dam.

d. Minimum compacted density for embankment materials must be 95 percent of maximum dry density according to ASTM D698 (Standard Proctor).

e. Place impervious zones with clay fines at near optimum moisture content to prevent overcompacted, brittle zones.

f. The density for cohesionless filter and drain materials must range between 65 and 75 percent relative density as determined by ASTM D4253 and D4254.

g. Construct filter and drain zones with sufficient thickness to prevent contamination or loss of continuity that would adversely impact their performance.

h. Base construction of filters and drains on placement procedures developed through a test fill program to verify acceptable density and avoid excessive particle breakdown.

8.6 EROSION PROTECTION

When designing the dam embankment, the Engineer must consider the need to protect the embankment from erosion. Consider the following in the design.

Include any erosion protection analysis as supporting design information in the Design Report.

a. The upstream slope must be protected against erosion from wave action.

b. Rock riprap must be well-graded, durable, sized to withstand the design wave action, and placed on a well-graded pervious sand and/or gravel bedding or acceptable geotextile fabric that is filter-compatible with the underlying embankment zone.

c. Soil cement slope protection design and construction specifications must be based on the principles provided in Soil Cement Slope Protection (Reclamation, 2013).

d. The Engineer may use Engineering Judgment under Section 1.5 to determine if other types of erosion protection in addition to riprap, vegetative cover, and soil cement are justified.

e. Design the upstream and downstream slopes to resist erosion from precipitation runoff.

8.7 UTILITIES IN DAMS

Buried utilities within a dam or within 100 feet of the toe of a dam are prohibited.

If utility burial is approved under a Section 1.4 Standards Deviation request, the design of buried utilities must include adequate provisions for protecting the dam and foundation from damage by the failure of the utility and allow for repair or removal of the utility without adversely affecting the safety of the dam or its appurtenant structures.

8.8 GEOSYNTHETICS IN DAMS

Do not use geotextiles for applications where the geotextile is buried within the embankment and relied upon for critical dam safety functions (i.e., geotextile as the filter). The use of geotextile within dams may be appropriate for other applications. The Engineer may use Engineering Judgment under Section 1.5 to determine those applications.

Geotextile is not permissible as the sole separation between riprap and embankment fill unless the riprap and embankment fill are filter-compatible. Geosynthetic liners (i.e., high-density polyethylene [HDPE] or polyvinyl chloride [PVC], etc.) may be considered with appropriate design.

8.9 EMBANKMENT DESIGN REPORT REQUIREMENTS

Fully describe the embankment design within the structural section of the Design Report.

The Design Report for embankment design must include the following minimum information:

a. Analysis used to determine dam geometry design (Section 8.1)

b. Analysis used to design seepage control features (Section 8.2)

c. Analysis used to inform deformation and cracking prevention design (Section 8.3)

d. Analysis used to inform foundation design (Section 8.4)

e. Analysis used to inform erosion protection design (Section 8.6)

9 SPILLWAY DESIGN REQUIREMENTS

Spillways are critical to both the normal and flood operations of a safe dam. Often, dams are designed with two spillways: the principal spillway for maintenance of the normal pool and the auxiliary spillway for passing large flood flows. In some cases, having only one spillway that serves both functions is appropriate.

At a minimum, design spillways to protect the structure from overtopping and provide a minimum principal spillway capacity in accordance with the design criteria for the dam's hazard classification.

All work done under this section must be overseen by an Engineer. Alternate methods may be used if requested by the Owner and are subject to Department approval under Section 1.4.

9.1 PRINCIPAL SPILLWAY DESIGN CONSIDERATIONS

a. If included as an appurtenance, design principal spillways to maintain the intended normal reservoir pool while safely and routinely conveying water through the dam during typical hydrologic conditions.

b. Design the principal spillway to provide the minimum capacity shown in Table 6.1 without activating an auxiliary spillway.

c. Design principal spillways hydraulically to avoid surging, vibrations, and cavitation.

d. Principal Spillways must be able to withstand all anticipated loads, including hydrodynamic, ice, lateral earth pressures, and seismic loads.

e. In most cases, the principal spillway must be designed in accordance with the requirements for outlets in Section 10.

f. Consider public safety if recreation near the auxiliary spillway is anticipated.

g. The specific requirements to design the principal spillway will depend upon the purposes and intended functions of the dam. The hydraulic section of the Design Report should contain design information about the principal spillway.

9.2 AUXILARY SPILLWAY DESIGN CONSIDERATIONS

Minimum design considerations for the auxiliary spillway must include the following:

a. The starting water surface elevation when routing the IDF must be the auxiliary spillway crest, unless gated or designed with a fuse plug.

b. The spillway must safely route the IDF as defined in Section 6.2 back to the natural channel.

c. Design the auxiliary spillway channel to withstand the anticipated flow velocity of all anticipated flows up to and including the design event.

d. Consider the potential for ice jams and include mitigation, as appropriate.

e. Consider public safety if recreation near the auxiliary spillway is anticipated.

f. Design must allow for access for inspection, operations, and maintenance of the auxiliary spillway.

9.3 LINED SPILLWAY CHANNELS AND CHUTES

a. If a spillway channel consists of soil, grass lining is permissible only if maximum flow velocities will be less than 6 feet per second (fps). A hardened lining is required when anticipated velocities are expected to be greater than 6 fps.

b. Hardened channel linings must be designed to withstand erosion when subjected to the anticipated flow velocities of the design storm event. Hardened channels can consist of various erosion resistant materials including riprap, grouted riprap, articulated concrete blocks, soil cement, roller-compacted concrete, reinforced concrete, and various other materials. Chute spillways are a type of hardened channel.

c. For spillways that consist of material that is not susceptible to erosion, the channel may be unlined. The Engineer must provide information to the Department demonstrating that the unlined channel will resist erosion during the design event.

d. Use the routed inflow design hydrograph to determine spillway velocities and ensure that the spillway lining will protect against erosion that could lead to failure. The Engineer must provide justification to the Department that the lining is suitable for the design storm and that the spillway will not fail.

9.4 FILTER ZONES

Filter zones or drains to relieve hydrostatic pressure below the spillway are required if the potential uplift pressure exceeds the resisting pressure of the spillway chute.

a. Spillway filters and drains must daylight outside the spillway chute and be terminated so that the flow can be measured.

b. Provide backflow prevention if the terminal end of the filter or drain is inundated.

c. Provide protections, such as screens or similar devices, to prevent animals from entering and hinder vandalism to the drain systems.

d. Filter design must follow the requirements in Section 8.2.

9.5 ENERGY DISSIPATION

Spillway discharges must be conveyed to natural drainageways without threatening the safety of the dam. Design stilling basins to contain hydraulic jumps with a minimum of 1.0-feet of freeboard.

9.6 PIPE AUXILIARY SPILLWAYS

Pipe auxiliary spillways are not allowed unless the likelihood for plugging and blocking is demonstrated to be low, or otherwise mitigated. Pipes may be oversized so that blocking or clogging potential is reduced. Inlets should be protected from debris, and frequent maintenance to remove blockage may be necessary.

Auxiliary spillways consisting of multiple pipes are not permitted.

9.7 OVERTOPPING PROTECTION

Route flood flows around the embankment (i.e., auxiliary spillways).

Overtopping protection must be designed using materials that resist erosion forces from the design flows calculated. Overtopping materials must be hardened surfaces (i.e., grouted riprap, articulated concrete blocks, roller-compacted concrete, concrete, etc.).

The Engineer may use Engineering Judgment under Section 1.5 for dams with inadequate spillways. Protecting the embankment against erosion from overtopping flows may be considered. The Engineer must provide documentation to the Department that overtopping of the dam by floods that exceed the spillway capacity up to the IDF will not cause the failure of the dam.

9.8 DEBRIS

Provide protection for the spillway from logs and other debris that may block spillway flow or damage the spillway structure.

9.9 SPILLWAY DESIGN REPORT REQUIREMENTS

Fully describe the spillway design (including both principal spillways and auxiliary spillways) within the hydraulic section of the Design Report.

The Design Report for spillway design must include the following minimum information:

a. Discharge table(s) showing the discharge for each foot of head between the spillway crest and crest of the dam.

b. The equation(s) and model(s) used for determining spillway discharge.

c. Subsurface geotechnical information, including the following minimum information:

- A soil/rock profile along the spillway channel. A geologic description of the foundation rock, including the bedding and jointing patterns.
- Density or bearing capacity of foundation soils beneath structures in the spillway conduits and channels.
- Erodibility of spillway channel materials if natural materials are exposed.
- Provisions to mitigate uplift, lateral earth, and stagnation pressures (if applicable).

10 OUTLETS

All work done under this section must be overseen by an Engineer. Alternate methods may be used if requested by the Owner and are subject to Department approval under Section 1.4.

10.1 LOW-LEVEL OUTLET REQUIRED

Controlled low-level outlets capable of evacuating the impounded reservoir must be included in all dams intended to store water permanently.

- The minimum diameter required for a low-level outlet is 12 inches.
- The low-level outlet must be capable of releasing the entire reservoir in a reasonable period of time, as determined by the Department.
- Low-level outlet design should consider emergency drawdown of the reservoir during both normal and unusual inflow conditions. In most cases, design the low-level outlet to release the top 5 feet of the reservoir within five days, and evacuate the entire reservoir within 1 to 2 months.
- In combination with the principal spillway, the outlets must be capable of releasing water to meet the demands of downstream senior water rights and the Owner's release requirements.

10.2 OUTLET DESIGN

Outlet design should consider all gated and ungated outlets, including the low-level outlet(s) and principal spillway.

Minimum design considerations for all outlets from the dam, whether low-level, principal spillway, or other must include the following:

10.2.1 CONDUIT MATERIALS

a. Outlet conduit material must be durable and structurally capable of withstanding all loading conditions applied by the embankment and outlet flows.

b. All new or repaired outlet conduits, whether or not they are designed as pressurized conduits, must be watertight and pressure tested to 150 percent of the maximum anticipated operating pressure once they are securely in place to verify that they have been installed and joined appropriately.

c. Outlet conduit materials must be selected for the unique conditions of the specific application.

d. Corrugated metal pipe, vitrified clay pipe, pre-stressed concrete cylinder pipe, and wood are not permissible for use in medium and high hazard dams. If proposed for use in small, low hazard dams, the Engineer must demonstrate the need to use the material and the safety measures that will be included to mitigate dam safety concerns associated with outlet conduits constructed with this material.

10.2.2 CONDUIT JOINTS AND FITTINGS

a. Joints and fitting must be watertight and meet the pressure requirements noted in Section 10.2.1.

b. Avoid bends in the alignment of outlet conduits. If bends cannot be avoided, design thrust restraint as appropriate and use large-radius fittings to facilitate inspection and maintenance.

c. The anticipated movement (i.e. settlement, extensions, etc.) at joints must be within tolerances specified by the conduit manufacturer.

10.2.3 CONDUIT ENCASEMENT

a. Outlet conduits must be encased in reinforced concrete for medium and high hazard dams. For low-hazard dams, conduits should be partially encased (i.e., cradle) For some low-hazard dams, full encasement may be needed depending on the conduit material and height of the dam (i.e. external loading)

b. A concrete encasement must be designed to withstand the external forces exerted on the outlet conduit by all overburden loads and the internal impact forces exerted by outlet discharges.

c. Vertical sides of a concrete encasement are not permissible. Appropriate batter of side walls (10V:1H or less steep) is required.

10.2.4 CONDUIT BEDDING

a. Support the outlet conduit on firm material. The specifications must provide for the preparation of a stable foundation for the outlet conduit to avoid sagging, differential settlement, and/or spreading that could lead to damage to the conduit or separation of joints.

b. Seepage control must be considered when designing pipe bedding.

c. The use of washed aggregates is unsuitable bedding in dams, except near the downstream end of the conduit with appropriate filter protection.

10.2.5 TRASH RACKS

a. All intakes to outlets must have a trash rack. Design trash racks to consider the size of the conduit, the need to provide sufficient hydraulic capacity, and to avoid clogging, clogging of the conduit, or clogging from ice jams.

b. Design trash racks to have as large an opening as reasonable to protect the conduit from clogging and to maintain a velocity through the open area of less than 2.5 feet per second.

10.2.6 OUTLET GATES AND OPERATORS

a. Locate the control structure for the outlet gate upstream of the impervious zone in the embankment.

b. Design outlet gates, operating structures, and equipment to withstand the forces generated during the opening and closing of the gate under all design loading conditions anticipated for the dam.

c. Design outlet gates and controls to facilitate maintenance and replacement.

d. Protect outlet gate controls against damage by the elements and vandals.

10.2.7 CLOSED OUTLET SYSTEMS

All outlets connected directly to a downstream pipeline or other closed system must have a bypass valve or other suitable connection near the dam to allow video camera access for inspecting the interior of the outlet conduit.

10.2.8 ENERGY DISSIPATION

All principal spillways and outlets, including low-level outlets, must have energy dissipaters, plunge basins, and/or adequate riprap channel protection at the discharge point to prevent unsafe erosion or damage to the dam embankment, nearby structures, or facilities.

10.2.9 AIR VENTING

Air vents may be necessary on the outlet conduit to prevent a collapse of the conduit or prevent the formation of low pressures, which can lead to cavitation damage.

10.2.10 SEEPAGE PROTECTION FOR CONDUITS

a. Design outlet conduits through embankment dams to avoid the development of preferential seepage paths along the conduit.

b. Design conduits to avoid allowing seepage from within the embankment or foundation to exit into joints, holes, or other openings in the conduit.

c. Design outlet conduits with filter diaphragms, filter collars, or other systems to prevent the development of piping and erosion along the outside of the conduit, designed in accordance with the current state of the practice.

d. Anti-seep collars are not allowed.

10.2.11 PRESSURIZED CONDUITS

Pressurized conduits in embankment dams are permissible only when approved by the Department and if features are included to mitigate dam safety issues inherent with pressurized conduits. This may include a thick concrete encasement, filter and drain zones, or others.

10.2.12 CLOSED SECTIONS

Avoid installing the outlet conduit within a closure section of the dam where possible due to the increased potential for differential settlement and hydraulic fracturing of the embankment.

10.2.13 CONDUIT LINING AND REPLACEMENT

10.2.13.1 CONDUIT LINERS

The Engineer must provide documentation to the Department that the proposed lining is suitable to accomplish the design objectives for a given project. Key considerations in the design of outlet conduit lining projects include:

a. Structural capacity of the liner. The Engineer must provide documentation that the selected pipe lining products have the structural capacity to carry embankment load without any support from the host (carrier) pipe.

b. Discharge capacity of the lined conduit with reduced diameter.

c. Sealing the annulus between the liner and the carrier pipe.

d. Selected material can sustain the anticipated velocities and scour potential of the expected sediment.

e. Verifying prior to construction that the selected liner can be installed in the existing conduit.

10.2.13.2 CONDUIT REPLACEMENT

Cut-and-cover replacement of outlet conduits should follow the requirements for the construction of new conduits. Trench side slopes must be flat enough to effectively connect with compacted backfill. Trench side slopes steeper than 3H:1V are not permissible in areas below an overlying dam embankment.

10.2.13.3 INSTALLATION OF FILTER DIAPHRAGMS

Owners must install a filter diaphragm (i.e., filter collar) as part of conduit replacement or lining projects if one is not present or if the existing filter does not meet current design criteria.

10.2.13.4 CONDUIT REMOVAL OR ABANDONMENT

When a conduit can no longer be used, there are two options:

a. Removal: Completely remove the conduit from the embankment. The replacement conduit must follow the new conduit design and construction procedures described in Sections 10.2.1–10.2.12 and have sufficiently flat excavation slopes as described for conduit replacement in Section 10.2.13.2.

b. Abandonment: Where removing conduit is not feasible, abandon the existing conduit in-place by completely filling the entire conduit with non-shrink grout or concrete. The downstream end of the conduit should be removed and appropriately protected with a buried filter zone.

10.2.14 TUNNEL OUTLETS

a. Tunnels driven through the dam embankment are not permitted.

b. An experienced soft-ground tunneling specialist must design tunnels driven through dam abutments.

c. Directional drilling, microtunneling, “pipe jacking”, and “boring and jacking” are not allowed within or under dams.

10.3 OUTLET DESIGN REPORT REQUIREMENTS

Fully describe the outlet design within the hydraulic section of the Design Report including the hydraulic, structural, mechanical, and other analyses that form the basis of the design for the outlet.

The Design Report for outlet design must include the following minimum requirements:

a. Discharge table(s) showing the discharge for each foot of head between the invert of the outlet and crest of the dam

b. The equation(s) and model(s) used for determining outlet discharges

c. Design velocities and justification for material selection

d. Maximum pressures anticipated within the outlet

e. Description of cavitation prevention, including air venting

f. Description of the foundation conditions and methods to support the pipe

g. Description of manufacture's allowable joint movement, and supporting details for methods to maintain watertight joints, if applicable

h. Description and justification for methods for protecting against corrosion of the conduit

i. Calculations demonstrating sufficient structural capacity of the outlet (including ability to resist application of loads applied during construction)

j. Computations supporting the design of the trash rack

k. Computations supporting the design of the stilling basin

11 INSTRUMENTATION

Develop an Instrumentation Plan for all dam and appurtenant facilities instruments. Include the instrumentation plan as part of the Design Report.

The Instrumentation Plan must include the following:

a. Instrument locations
b. Installation details
c. Schedule for reading and monitoring
d. Range of expected readings

All work done under this section must be overseen by an Engineer. Alternate methods may be used if requested by the Owner and are subject to Department approval under Section 1.4.

11.1 MINIMUM INSTRUMENTS REQUIRED

The instruments described below are the minimum instrument requirements. The Owner may include additional instruments for monitoring the dam or appurtenant facilities. If the Owner chooses not to provide instrumentation, rationale must be provided to support the decision.

a. Identify and mark the instruments in the field. The instruments must be accessible.

b. All dams must have a reservoir staff gage to measure the reservoir level. Position the staff gage so it is visible or accessible at all times. The zero mark of the staff gage must be the invert of the low-level outlet for medium and high hazard dams or the low point of the reservoir for low hazard dams. It must extend to within one foot of the dam crest. Mark the gage in feet and tenths.

c. All medium and high hazard dams are required to have a staff gage marking elevation from the auxiliary spillway crest to the dam crest. Locate the staff gage so it is visible during flow events in the auxiliary spillway.

d. All medium and high hazard dams are required to have provisions for monitoring seepage through the dam or foundation. The provisions may include weirs, flumes, or other measuring devices at the terminal end of the internal drainage systems. Provide positive drainage away from the seepage monitoring termination.

e. All medium and high hazard dams with a crest length greater than 100 feet must have station markers every 100 feet along the crest.

f. Medium and high hazard dams must have piezometers to monitor the phreatic surface within the dam or uplift pressures within the foundation. A minimum of one piezometer must be provided at the maximum embankment section in the core (or upstream of the filter) and one piezometer at the maximum section downstream of the filter. For medium and high hazard dams with no filter, install piezometers on the upstream and downstream slopes to facilitate measurement of the phreatic surface in the embankment. Provide visible markers indicating piezometer locations. Protect piezometers from damage by animals and vehicles.

g. Medium and high hazard dams must have monuments to measure the horizontal and vertical movements of the dam and appurtenant structures. At a minimum, a monument must be located at the maximum section of the dam, and at flow or elevation control structures (e.g., intake towers, spillway control sills, etc.). Monument surveys must be accurate to 0.01 feet, and control monuments must be placed off the dam on the natural ground in areas not subject to movement. Monuments must be set below frost depth.

12 OTHER DESIGN REQUIREMENTS

12.1 STRUCTURAL DESIGN

Structural designs must be performed by a qualified engineer, adhere to commonly used codes, and provide for dam safety. Documentation of structural designs must be provided in the Design Report and facilitate peer and regulatory review.

12.2 MECHANICAL AND ELECTRICAL DESIGN

Mechanical and electrical designs must be performed by a qualified engineer, adhere to commonly used codes, and provide for dam safety. Documentation of mechanical and electrical designs must be provided in the Design Report and facilitate peer and regulatory review.

13 DAM CONSTRUCTION

The Department is involved at several key times during the construction of the dam.

All work done under this section must be overseen by an Engineer. Alternate methods may be used if requested by the Owner and are subject to Department approval under Section 1.4.

13.1 CONSTRUCTION INSPECTION AND REPORTING

The Department may visit the project site at any time during construction.

13.1.1 CONSTRUCTION INSPECTION

The Engineer or their representative must observe, inspect, and document construction as needed to ensure that construction is performed in accordance with the intent of the design.

The information obtained during observations and inspections must be documented in a written report.

13.1.2 PRE-CONSTRUCTION MEETING

If there is a pre-construction meeting, the Department must be notified and invited to attend.

13.2 CONSTRUCTION QUALITY CONTROL

Construction quality control must be performed and documented to confirm that the construction was completed in accordance with the approved plans and specifications.

Testing of constructed items at regular intervals is required to demonstrate conformance with the specifications. The specifications should indicate the minimum testing required.

The Department may require that the test types be modified, and the testing frequency be increased.

13.2.1 CONSTRUCTION CRITERIA

a. Medium and high hazard dams require the Engineer to perform construction inspection. The Engineer must observe and record the progress and quality of the construction. The Engineer must disapprove work failing to conform to the approved plans and specifications. The Owner must require the Contractor to correct disapproved work.

b. The Engineer must maintain a record of construction for submittal to the Department in accordance with Section 14, including the following:

   - Daily activity and progress reports

- Photographs of the construction through completion. As a minimum, photographs must be captured weekly and at major construction milestones.

- All field and laboratory materials testing results

- All geologic information obtained for the foundation

- Design change orders

- Documentation of any construction problems and remedies

- Construction-related correspondence

- Submittal documentation

- As-built drawings showing actual field conditions and completed construction

c. Provide at least five (5) days advance notice of any work items for observation by the Department as determined in pre-construction coordination or the preconstruction meeting, to allow for observation by the Department.

d. Provide at least fourteen (14) days advance notice to the Department prior to the project's final construction inspection. The Engineer must document the completion of any punch list items.

13.2.2 CONSTRUCTION CHANGE ORDERS

Major construction changes shall be submitted to the Department in writing by the Engineer, with supporting documentation, and no change shall be implemented until the Department approves the change in writing. The change order must detail the conditions or material availability that significantly requires the construction work to change from the approved plans and specifications. No change shall be executed until the Department accepts the construction change order. All changes to the approved plans and specifications must be reflected in the Construction Completion Report and As-Built Drawings.

Contract change orders and other changes that do not pertain directly to the design of the project and the construction permit should not be submitted to the Department for review and approval.

14 CONSTRUCTION COMPLETION SUBMITTALS

To receive acceptance from the Department, the Owner must provide construction completion documents listed in this section within 6 months of project completion.

Unsatisfactory performance during the first filling or failure to provide these documents may result in a dam being deemed unsafe. An unsafe dam may be ordered to be modified or removed by the Department.

Owners of non-permitted dams are encouraged to maintain a site-specific EAP and an O&M Manual.

All work done under this section must be overseen by an Engineer. Alternate methods may be used if requested by the Owner and are subject to Department approval under Section 1.4.

14.1 COMPLETION FORM AND ENGINEER'S CERTIFICATION

The Engineer must provide the Department with written notification that the project is complete. The notification must be signed and sealed by the Engineer and state that the project conforms with the approved plans, specifications, and change orders; it must also include the Construction Completion Notification form found on the Department's website.

14.2 AS-BUILT DRAWINGS

As-Built Drawings must be submitted in a PDF file to the Department within six months after the completion of the construction and include any changes to the approved plans. The As-Built Drawings must show the final constructed conditions and should not include bubbles, clouds, or cross-outs. They must be signed and sealed by the Engineer.

14.3 CONSTRUCTION COMPLETION REPORT

The Construction Completion Report must contain the following:

a. Summary of construction, including changes to the original approved design, problems encountered and solutions, etc.

b. Copies of all construction change orders, requests for information, and Engineer's directives addressed during construction

c. Photographs documenting the construction of the project

d. Appendices containing all quality assurance reports, quality control reports, progress reports, and daily construction inspection reports

e. Schedule of construction—updated to reflect actual construction sequence.

f. Field and laboratory test summary, including:

- Test type
- Location (relative to known points on the dam [stationing] or appurtenant structure)
- Results (include resolution of failed test results)

14.4 EMERGENCY ACTION PLAN (EAP)

For medium and high hazard dams, Owners must develop and submit an EAP to the Department for approval before completion of the construction of the dam. EAP requirements are laid out in Section 15.

14.5 OPERATION AND MAINTENANCE (O&M) MANUAL

The Owner must prepare and submit an O&M Manual for medium and high hazard dams. Additional guidance can be found on the Department website. Low hazard dam Owners are encouraged to develop an O&M Manual. Maintenance guidance is available on the Department website.

General maintenance activities include the following:

a. Vegetation removal and control

b. Animal control

c. Erosion repair and control. Repair erosion on the dam, spillway, or other areas associated with the dam or appurtenant facilities. Include provisions to reduce or eliminate future erosion.

d. Surface grading. Grade the dam crest to remove low areas, provide a safe traveling surface, and provide proper drainage.

e. Repair riprap and bedding. The repair must return the areas to the original level of protection.

f. Maintenance of mechanical equipment (exercising, painting, caulking, lubricating, etc.). Replacing worn parts or equipment.

g. Concrete repair, including patching, caulking, etc.

h. Remove debris from channels, conduits, trash racks, energy dissipater, structures, etc.

15 EMERGENCY ACTION PLAN (EAP)

An EAP is a formal document that identifies potential emergency situations that could occur at a dam and specifies the course of action to be taken when an emergency situation arises. The purpose of an EAP is to reduce the risk to lives and property in the event of a dam failure. Having a practical, comprehensive, and current EAPs is a critical aspect of owning and maintaining a safe dam. Owners are responsible for developing, testing, and updating an EAP for their dam.

An up-to-date EAP must be on file with the Department for all medium and high hazard dams. An EAP is not required for low hazard dams. However, it is recommended that the Owner of a low hazard dam create a simplified EAP with a notification list of individuals and agencies to contact in case of an emergency situation at the dam.

All work done under this section must be overseen by an Engineer. Alternate methods may be used if requested by the Owner and are subject to Department approval under Section 1.5.

15.1 DEPARTMENT APPROVAL OF EAPS

All EAPs must be approved by the Department before they are considered complete.

Develop the EAP in accordance with these Standards. The Department recognizes that some deviation is necessary in order to meet specific requirements by other Owner agencies. The EAP must be developed in coordination with local emergency managers. Include a completed concurrence sheet with signatures from key emergency response team members shown on the EAP notification list in the EAP.

An electronic copy of the completed EAP must be included in a single PDF file and provided to the Department. Provide a hard copy or an electronic copy of the completed EAP to all emergency response team members shown on the notification list.

15.2 EAP FORMAT

An EAP template is available on the Department website. Owners may modify the format or use their own format to meet specific situations and needs.

An EAP must contain the following basic information:

a. Procedures to assist the Owner in detecting and evaluating an emergency situation at the dam

b. Responsibilities and expected actions of all parties involved in responding to an emergency at the dam

c. Inundation map identifying downstream areas that could be impacted by a dam failure as detailed in Section 15.3.

d. Communications directory and notification flowchart. The appropriate response may differ depending on the level of emergency; prepare a notification flowchart for each of the following scenarios:

- An unusual event that is slowly developing
- A potential dam failure situation that is rapidly developing
- An urgent event with dam failure imminent or in progress

e. Description of emergency remedial measures that can be taken to arrest, mitigate, moderate, or alleviate an emergency at the dam.

f. A list of locally available resources and contractors that can be utilized in the event of an emergency at the dam

g. Site specific information such as access to the dam and alternate access routes in cases where the main access may be flooded during an emergency

15.3 INUNDATION MAPPING

The inundation map must be prepared by an Engineer. The inundation map must be based on a dam breach model, using a hydraulic model such as HEC-RAS that is capable of unsteady flow routing. The use of a 2D hydraulic model, such as HEC-RAS 2D, is permissible and is encouraged in situations where the conditions warrant the use of such a model. Use field surveyed cross-sections or LIDAR data in the model as necessary to adequately define the area downstream of the dam. The flood wave must be routed downstream to a point where the floodwaters no longer present a hazard to life or property.

The inundation map, as used in Section 15, is to assist with emergency preparedness and planning in the generation of the EAP. The inundation maps developed to determine a dam's hazard classification in Section 5 may not be appropriate for EAP preparation.

15.3.1 HIGH HAZARD DAMS

Prepare inundation mapping for a dam failure under both normal "sunny day" operating conditions and flood conditions. The sunny day failure assumes that the dam fails with the reservoir and inflow at normal operating levels. For the flood condition failure, the dam is assumed to fail during a flood event. The inflow to the reservoir is assumed to be the probable maximum flood or other technically justifiable value such as the inflow design flood (IDF). Other assumptions may be based on the judgment of the Engineer, but must be sound, justifiable, and accepted by the Department.

In order to model the flood failure scenario, the reservoir inflow hydrograph must be determined for the flood event to be modeled. This hydrograph must be determined by an updated, or verifiable, hydrologic analysis using a suitable program such as HEC-HMS.

15.3.2 MEDIUM HAZARD DAMS

Inundation mapping may be prepared as described for high hazard dams above. Alternatively, a dam breach model for a simplified scenario as described in Section 3.1.2.1 may be used.

15.3.3 MAPPING FORMAT

The inundation map should identify and label all downstream hazards that are within the inundation zone. The map should also show the estimated travel time and depth at selected locations. Further guidance on preparing inundation maps is available from FEMA (July 2013a), (July 2013b).

A description of the source of the inundation mapping, including the dam breach modeling scenario and assumptions used, must be included in the EAP.

15.4 EAP UPDATES

Owners should review and update the EAP annually. This includes reviewing and updating all information contained in the EAP including contact information, inundation maps, agency responsibilities, etc.

EAP updates must be included in a single PDF file containing the complete EAP and distributed electronically to the Department. Provide either a hard copy or an electronic copy of the updated EAP to all emergency response team members shown on the notification list (depending on the receiving agencies’ preference).

15.5 EAP EXERCISES

The Owner must test the EAP in coordination with local emergency management authorities at least every five years to ensure the effectiveness of the EAP. The test should simulate a dam emergency, and be performed to evaluate and improve the effectiveness of the EAP in reducing potential consequences from a dam failure or incident.

Guidance on testing an EAP is available from FEMA (FEMA, 2013a). While there are various levels of EAP exercises that can be conducted, a simple discussion-based exercise is all that is required to familiarize participants with the dam, the contents of the EAP, and their roles and responsibilities during an emergency at the dam.

16 DEFINITIONS

Appurtenant Works: Defined in N.D.A.C. § 89-08-01-01 as, "All works incident or attached to a dam, dike, or other device, including:

- A spillway, either in the dam or separate from it;
- The reservoir and its rim;
- A low-level outlet; and
- A water conduit such as a tunnel, pipeline, or penstock, either through the dam, dike or other device and their abutments."

As-Built Drawings: Synonymous with "As-Built Plans". An official record of the project once construction is complete. The permitted and sealed plans and specifications are modified to show all additions, deletions, and other modifications made throughout construction.

Auxiliary Spillway: A spillway that is designed to operate only during large flood events. The purpose of the auxiliary spillway is to safely pass major flows around the dam to prevent overtopping of the dam.

Construction/Construct: Defined in N.D.A.C. § 89-08-01-01 as, **"**Any activity for which a permit is required by North Dakota Century Code section 61-16.1-38, including construction, alteration, enlargement, or modification of a dam, dike, or other device."

Dam: Defined in N.D.A.C. § 89-08-01-01 as, "Any barrier, including any appurtenant works, constructed across a watercourse, or an area that drains naturally to impound or attenuate the flow of water. All structures necessary to impound a single body of water are considered a single dam."

For the purposes of Policy REG_05, ponds, lagoons, dugouts, and other similar facilities are referred to as "dams." "Dam" also includes embankments and appurtenant structures such as spillways, principal spillways, outlets, gates, operational controls, monitoring equipment, and similar facilities.

Dike:

Embankment: Defined in N.D.A.C. § 89-08-01-01 as, "A structure created by an artificial deposit of material upon the natural surface of the land that is designed to act as a water control device, support roads or railways, or for other similar purposes."

Freeboard:

- **Normal Freeboard**: The distance between the maximum normal water surface and the nominal dam crest elevation.

- **Residual Freeboard:** The vertical distance between the maximum water surface in the reservoir during routing of the IDF and the nominal dam crest elevation.

Hazard Classifications:

- **Low Hazard Dam:** Defined in N.D.A.C. § 89-08-01-01 as, "A dam with low-hazard potential where failure or misoperation results in no probable loss of human life and low economic losses."

- **Medium Hazard Dam:** Defined in N.D.A.C. § 89-08-01-01 as, "A dam with medium-hazard potential where failure or misoperation results in no probable loss of human life but can cause economic loss, disruption of lifeline facilities, or can impact other concerns." "Significant Hazard Dam" means the same as "medium-hazard dam" and may be used interchangeably.

- **High Hazard Dam:** Defined in N.D.A.C. § 89-08-01-01 as, "a damwith high-hazard potential where failure or misoperation will probably cause loss of human life."

Height: Defined in N.D.A.C. § 89-08-01-01 as, "the maximum vertical distance from the stream channel bottom or lowest elevation of a naturally draining area to the top of dam."

Holding Pond, Lagoon, or Dugout: Defined in N.D.A.C. § 89-08-01-01 as, "Any artificial, hydraulically disconnected structure, including any appurtenant works constructed to store water."

For the purposes of Policy REG_05, ponds, lagoons, dugouts, and other similar facilities are referred to as "dams."

Inspection: Defined in N.D.A.C. § 89-08-01-01 as, "A visual or mechanical check, a measurement, a boring, or any other method necessary for determination of the adequacy of construction techniques, conformity of work with approved plans and specifications, or the safety and operating performance of a dam, dike or other device."

Low-Level Outlet: An intake structure on a dam situated near the bottom of a dam reservoir such that it is capable of withdrawing water from lower levels of the impoundment and discharging through a conduit within the embankment. Low-level outlets are often constructed with a control mechanism to regulate flow discharge and allow for the complete drainage of reservoir impoundments should reservoir evacuation be required.

Other Device: Defined in N.D.A.C. § 89-08-01-01 as, "water control structure, other than a dam or dike, including diversions and holding ponds, lagoons, and dugouts."

Owner: Defined in N.D.A.C. § 89-08-01-01 as, "Any person who owns, controls, operates, maintains, manages, or proposes to construct a dam, dike, or other device. For the purpose of a construction permit application, "Owner", means the person who owns the property or interest in property where the dam, dike, or other device will be built."

For the purposes of Policy REG_05, "Owner" can also be used to mean the Owner's designee when communicating with the Department.

Permittable Action: Any action to construct a new dam, or modify an existing dam, that requires a construction permit from the Department to be obtained as outlined in N.D.C.C. § 61-16.1-38 and N.D.A.C. ch. 89-08-02. Routine maintenance that restores a dam to its original design is not a permittable action.

Principal Spillway: The lowest ungated spillway designed to convey water from the reservoir at predetermined release rates, with an invert elevation typically established to control the elevation of the maximum normal reservoir water surface.

Top of Dam: Defined in N.D.A.C. § 89-08-01-01 as, "The top of the settled embankment or the elevation of the uppermost surface of a non-embankment dam, excluding accessory features, such as railings."

Unsafe Dam, Dike, or Other Device: Defined in N.D.A.C. § 89-08-01-01 as, "any such structure that threatens harm to life or property or is improperly maintained."

Engineer: Defined in N.D.C.C. § 43-19.0-02 as, "An individual who by reason of special knowledge or use of the mathematical, physical, end engineering sciences and the principles and methods of engineering analysis and design, acquired by engineering education and engineering experience, is qualified to practice engineering, and who has been registered and licensed by the state board of registration for professional engineers and land surveyors" and is further defined in N.D.A.C § 89-08-01-01 as "a person who has been duly registered and licensed as an Engineer by the North Dakota state board of registration for professional engineers." Engineer licensure, registration, ethics, and competency are outlined in N.D.A.C. Title 28.

For the purposes of Policy REG_05, "Engineer" means a registered Professional Engineer under N.D.C.C. and N.D.A.C. in good standing.

17 STANDARDS HISTORY

Policy Adopted: XX/XX/XXXX
Previous Revision(s): No Revisions Available

APPENDIX A

REQUIREMENTS AND PROCEDURES FOR DAMS NOT DESIGNED BY AN ENGINEER

In accordance with N.D.C.C. § 61-16.1.38, the construction or modification of a dam capable of impounding more than 50 acre-feet of water requires a construction permit. However, if the dam is classified as low hazard and is less than ten feet in height, the dam does not need to be designed by a registered Professional Engineer in order to obtain a construction permit. This section outlines minimum requirements for Owners to obtain a construction permit for dams that do not need to be designed by a registered professional engineer.

Note that Appendix A applies only to the construction permit and other permits may be required for the project. See Section 2.1 for further discussion.

A.1 APPLICABILITY

For a project to be exempt from the requirement for design by an Engineer, that the dam must be classified as low hazard as defined in N.D.A.C. and be less than ten feet in height. The Department will review a submittal to verify that the proposed project is indeed exempt from the requirement to have plans and specifications completed by an Engineer.

If the Owner disagrees with the hazard classification assigned by the Department, the Owner will be required to have an Engineer perform and document appropriate analyses demonstrating justification for a different hazard classification in accordance with Section 5.

A.2 SUBMITTAL REQUIREMENTS

The following is a brief list of submittal requirements for Owners to apply for a construction permit for a dam that does not need to be designed by a registered professional engineer.

a. Follow the general minimum design requirements outlined in Section A.3.

b. Complete the construction permit application form (SFN 51695) with the requested information. The application form can be found on the Department website.

c. Attach a brief written explanation of the location, size, purpose, and general physical characteristics of the structure to be constructed or modified.

d. Attach any additional drawings, sketches, or figures that depict the project.

e. Attach documentation demonstrating that the Owner has complied with the Department Construction Permit Water Management Policy (REG-2020-01) regarding property rights for the land on which the dam and reservoir will be located.

f. Prepare a neat, legible, and clear submittal package, and submit it to Department.

A.3 MINIMUM DESIGN REQUIREMENTS

a. Construct the upstream and downstream slopes of an embankment no steeper than 3:1 (horizontal to vertical).

b. The dam crest must have a minimum width of 10 feet.

c. The dam must have a spillway to convey runoff from a large storm event in the drainage basin above the dam.

- The spillway will be evaluated by the Department to verify that it has the capacity to handle an approximate 25-year rainfall event at a minimum.
- Locate the spillway in natural ground, an adequate distance from the dam embankment to prevent the erosion of the embankment. Do not use a spillway over the dam embankment.
- A minimum of 3 feet vertical distance is required from the bottom of the spillway channel to the top of the dam crest.

d. An outlet conduit separate from the spillway may be included to control the reservoir level and allow water releases.

- Minimum pipe diameter is 12 inches
- Any valve to control releases must be located on the upstream end of the pipe.
- A trash rack must be included on the upstream end of the pipe.

e. The dam embankment must be adequately protected from erosion. Rock riprap is permissible on the upstream slope, and other exposed portions may be seeded with grass.

f. Consult an Engineer if there is any question regarding the proper design and construction of the dam, or if unique circumstances are encountered.

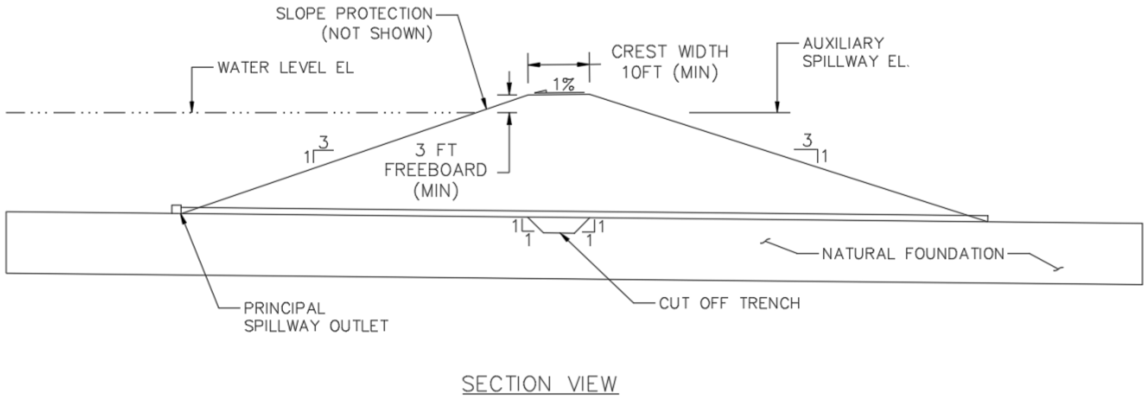


Figure A-1. General depiction of design considerations for a non-engineered dam, section view.

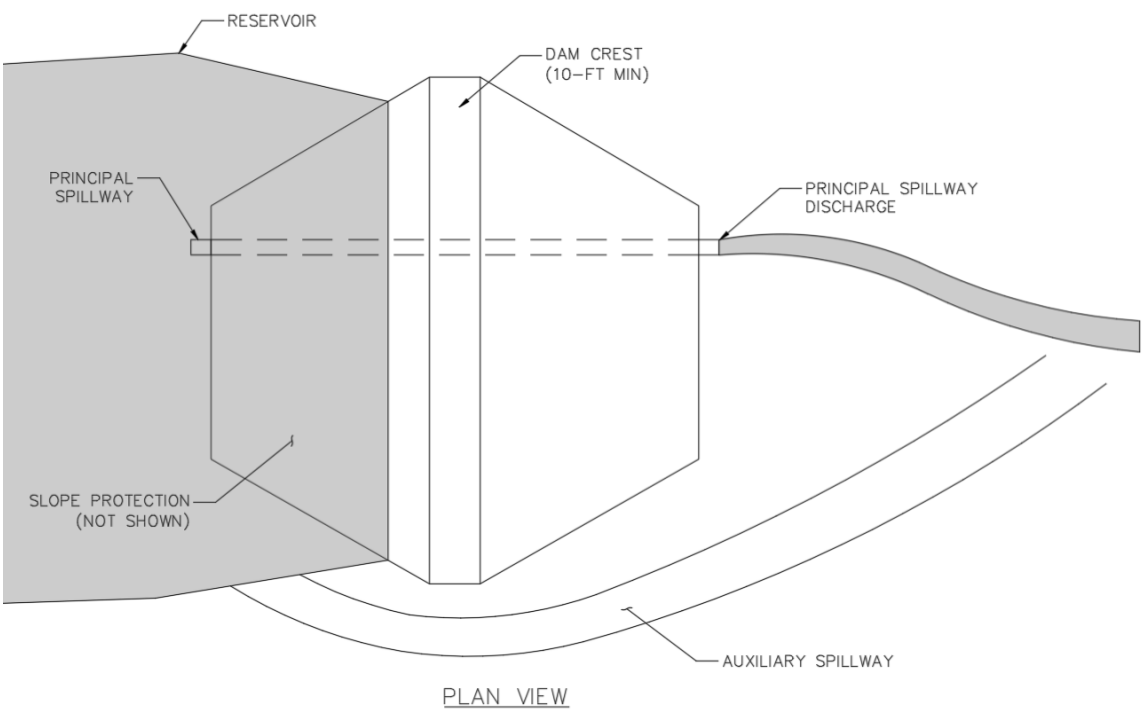


Figure A-2. General depiction of design considerations for a non-engineered dam, plan view.

APPENDIX B

INTRODUCTION TO RISK INFORMED DECISION MAKING FOR DAM SAFETY

Entities that own or regulate dams are required to make various decisions regarding dam safety. Questions that often arise when dams do not comply with dam safety standards include:

- How significant are the items that do not meet state dam safety standards?
- How urgent is it that I address the items that do not meet standards?
- If I cannot address all items at once, what is the priority for addressing multiple items?
- What are the risks of not taking action to comply with standards?

The Department uses a standards-based approach for regulating the safety of dams, however, consideration of ***dam safety risk*** can provide a logical and justifiable approach for Owners wishing to better understand some of the questions noted above.

Risk, in the context of dam safety, is the product of three factors:

- The likelihood that a load will be applied to the dam (e.g., flood, earthquake, etc.),
- Given the applied load, the likelihood that the dam will respond to the load ineffectively (e.g., dam failure, damaging spillway discharge, etc.), and
- The severity of the consequences resulting from the ineffective dam performance (e.g., life loss, economic damages, environmental damages, etc.).

The equation for risk is therefore:

$$R = (P_L) \times (P_{SF}) \times (C)$$

Where:
R is Risk
P_L is probability of load being applied
P_{SF} is the probability of system failure
C is the consequences

An understanding of a dam's risk can be developed from engineering evaluations performed by experienced dam safety professionals who are knowledgeable in the field of dam safety risk. With an understanding of dam safety risks, Owners, Engineers, and regulators can make decisions about the significance, urgency, value, and priority of addressing items that do not meet dam safety standards.

Information on risk-informed decision making for dam safety has been published by The US Army Corps of Engineers, Bureau of Reclamation, and The Federal Energy Regulatory Commission.

APPENDIX C

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