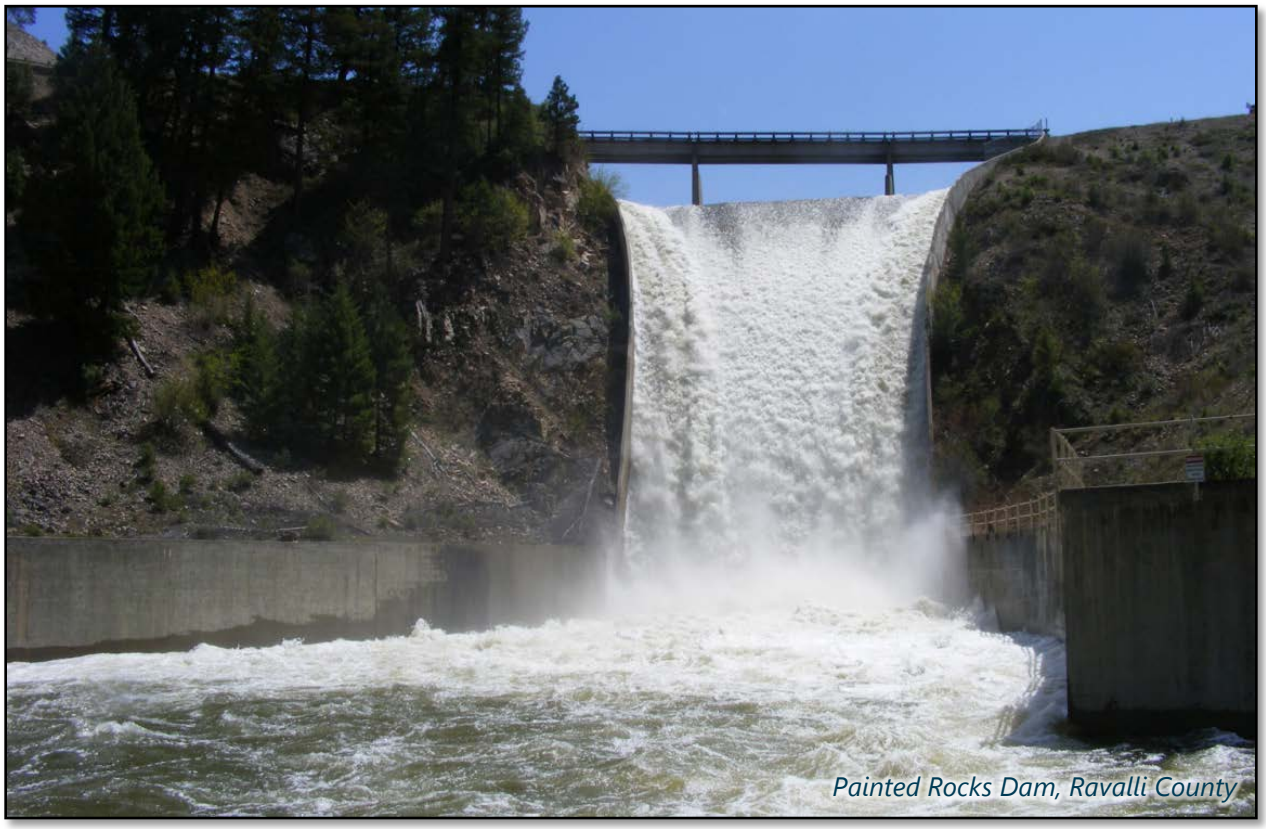
GUIDELINES FOR FIVE-YEAR DAM EVALUATIONS

Montana Department of Natural Resources and Conservation

Version 1.2 (revised January 2023)



Painted Rocks Dam, Ravalli County

These guidelines are consistent with Administrative Rule 36.14. This document was initially prepared by Gannett Fleming, Inc. (Versionn 1.0) under contract with the Montana Department of Natural Resources & Conservation. Periodic updates to the guidelines and corresponding templates will be made by Montana Department of Natural Resources & Conservation as needed.

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1.0 INTRODUCTION

The Five-Year Dam Evaluation is a critical part of the High Hazard Dam Operating Permit Renewal Process. This guidance document (Guidelines) was created by the Montana Department of Natural Resources and Conservation (DNRC) Dam Safety Program (herein referred to as Montana Dam Safety) to help both Engineers and Dam Owners complete and document the Five-Year Dam Evaluation. The Guidelines are intended to clearly explain what is required by the Administrative Rules of Montana (Rules) for dam safety. The Guidelines present a graded approach to the 5-Year Evaluation process, by allowing for less rigorous evaluation and reporting requirements for dams lower consequence potential. .

1.1 Regulatory Framework of Dam Evaluation and Operating Permit Renewal Process

The Administrative Rules of Montana (ARM) regarding Dam Safety are contained in ARM 36.14. There are two types of dam inspections or evaluations that are required in the Rules. These include:

- *Operation & Maintenance Inspection:* This consists of a detailed visual inspection of the dam by the Dam Owner (or their representative) at least once each year as part of regular operation and maintenance activities in accordance with ARM 36.14.407. Montana Dam Safety staff will often assist Owners and participate in these inspections when possible. These guidelines do not address this type of inspection.
- *Five-Year Dam Evaluation:* This consists of a visual inspection and safety evaluation of the dam by a qualified engineer at least once every five years in accordance with ARM 36.14.601 and MCA 85-15. The Five-Year Dam Evaluation is required for the Montana Dam Safety Program to renew or issue an operating permit. These Guidelines address the documentation requirements specific to this type of inspection and evaluation.

A third type of evaluation is not required by the Rules but is becoming the industry standard of care for dams with high downstream hazard potential in case of a failure:

- *Comprehensive Dam Evaluation:* As the name implies, this is the most thorough assessment of a dam and typically includes a wide-ranging search and review of design, construction, operation, modification, and other available records; a performance evaluation with respect to original design and construction; potential failure modes analysis; and other detailed studies to identify risk drivers and deficiencies at an existing dam. This type of evaluation is not required by Montana Dam Safety but is encouraged within the dam safety industry, especially for aging dams that may not meet current standards. These guidelines do not address comprehensive dam evaluations.

Subchapter 6 of the Rules describes the general requirements of Five-Year Dam Evaluations and the associated Engineer's Report. A summary of provisions from the Rules that are most meaningful to these guidelines are summarized below.

1.1.1 Five-Year Dam Evaluations – General Requirements (ARM 36.14.601)

This subchapter states that a Five-Year Dam Evaluation must be completed by a qualified engineer at least once every five years or within the period stated in the terms of an operation permit. The Five-Year Dam Evaluation must include both a ***visual inspection*** of the dam and a ***safety evaluation*** of the dam.

1.1.2 Five-Year Dam Evaluations – Visual Inspection and Safety Evaluation Items (ARM 36.14.602)

The Five-Year Dam Evaluation must include:

Preparation

- Review of previous evaluation reports and available data on the design, construction, operation, and maintenance of the dam and its appurtenances

Visual Inspection

- Visual inspection of the dam, its appurtenances, the downstream area, and all other areas affected by the structure
- Review and documentation of condition of surfaces and vegetation
- Review and documentation of condition of spillway and water level control structures

Safety Evaluation

- Evaluation of operation, maintenance, emergency, and inspection procedures employed by the Owner
- Analysis of instrumentation data
- Review and analysis of seepage rates
- Assessment of hydrologic and hydraulic capabilities
- Assessment of structural stability
- Assessment of other conditions that could constitute a hazard to the integrity of the structure
- Review of maximum operating water surface elevation and the amount of freeboard
- Other items as needed

What constitutes an "assessment" is not defined in the rules. Montana Dam Safety, many dam owners & their engineers have historically interpreted an "assessment" to be a detailed engineering analysis. However, a detailed engineering analysis may not be appropriate for all dams. One goal of these Guidelines is to provide owners of dams with lower downstream consequences the option to conduct less rigorous analyses, while still meeting the intent of the Administrative Rules.

1.1.3 Engineer's Report of Five-Year Dam Evaluation (ARM 36.14.603)

The written and photographic report of the Five-Year Dam Evaluation must include:

- Date and findings of inspection
- Assessment of the conditions of the dam
- Recommendations for critical or emergency measures or actions
- Recommendations for corrective measures or actions related to design, construction, operation, maintenance, and inspection of the structure

- Recommendations for time schedule of emergency or corrective measures
- Recommendations for additional detailed studies, investigations, and analyses
- Recommendations for the safe storage level of the dam or reservoir
- Recommendations for the next time of evaluation

1.1.4 High Hazard Dam Operation Permit Renewal Process

A flow chart that summarizes the High Hazard Dam Operation Permit Renewal Process is presented in Figure 1. This flow chart documents four major steps in the permit renewal process. Key parts to each step as they relate to the Five-Year Dam Evaluation are summarized below.

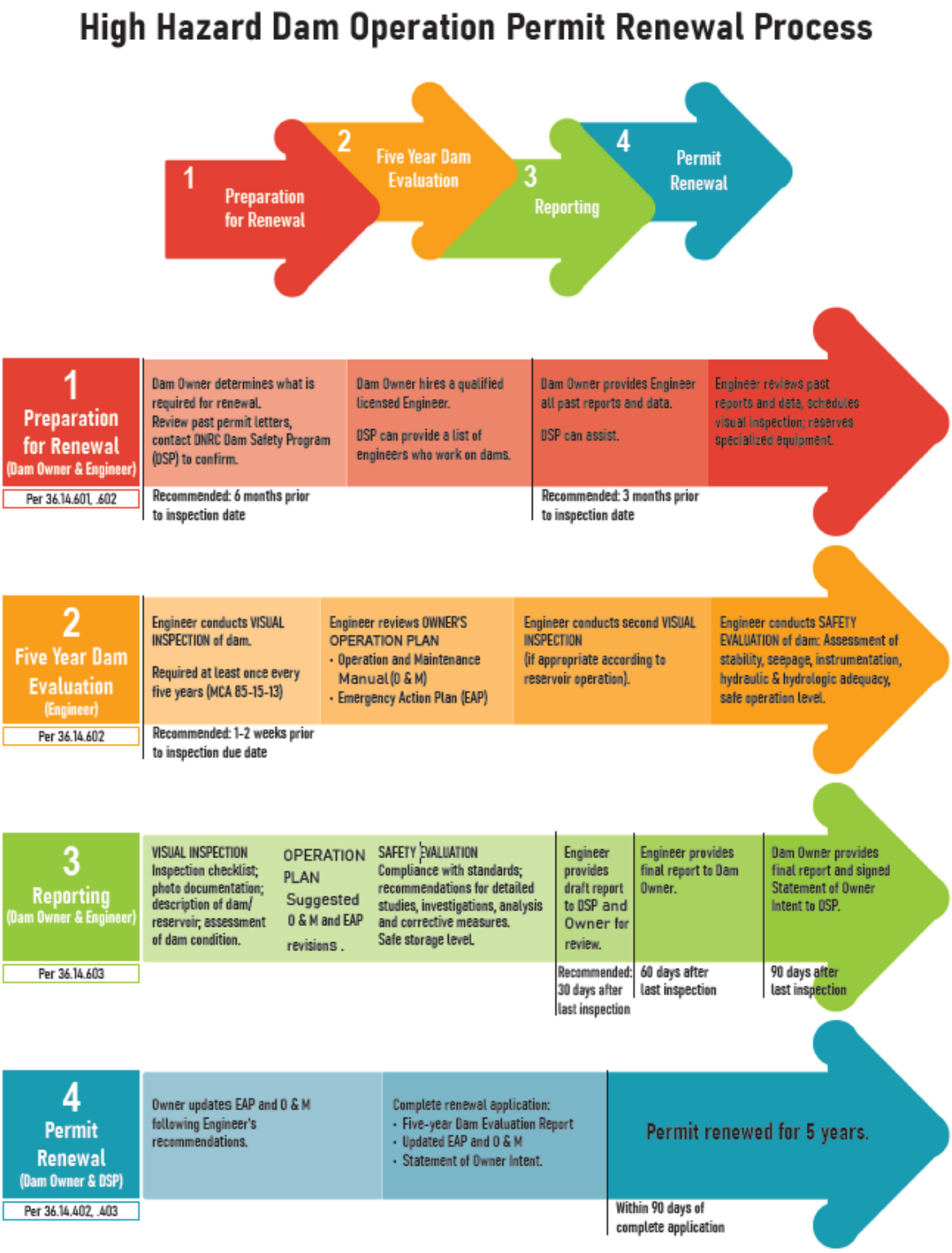

Figure 1 High Hazard Dam Operation Permit Renewal Process Flow Chart

Step 1: Preparing for Renewal

At least six months prior to the evaluation, the Owner should begin preparing for renewal. During this step, the Owner reviews available data, documents the performance of the dam during the past five-year period, and evaluates what is needed for the renewal. A brief Dam Owner Questionnaire has been developed by Montana Dam Safety to facilitate this process.

The Owner should provide the completed questionnaire and associated information to engineers being considered for the Five-Year Evaluation. This will help the engineers develop a scope of work and accurately estimate the level of effort necessary to complete the evaluation. Providing organized, clear information to engineers is important. Uncertainty or lack of information may lead to changes and cost escalation during the evaluation.

Information the Owner should provide to the Engineer to assist with scoping and cost proposals includes:

- Past Five-Year Evaluation Report
- Operation Permit renewal letter and subsequent correspondence from Montana Dam Safety
- Summary of work completed on the dam and progress made in meeting Montana Dam Safety requirements described in the renewal letter
- Documentation of Owner's Annual Operation and Maintenance Inspections
- Operation and Maintenance Manual
- Emergency Action Plan
- Instrumentation Records
- Contact person at Montana Dam Safety in case the Engineer has any questions

After hiring an Engineer and agreeing on a scope of work, the Engineer will likely need more information including previous dam evaluation reports, construction records, and past engineering analyses. Montana Dam Safety can help provide these records.

Step 2: Dam Evaluation

The Five-Year Dam Evaluation (visual inspection and safety evaluation) is completed by the Engineer and includes a visual inspection of the dam; review and assessment of the Operation and Maintenance Manual (O&M) and Emergency Action Plan (EAP); and evaluation of available design, construction, inspection, and monitoring records. The evaluation is completed according to the requirements in ARM 36.14.601 and ARM 36.14.602, discussed in more detail below.

Step 3: Reporting

As part of the evaluation process, the Engineer prepares a Five-Year Dam Evaluation Report that includes recommendations pertaining to the safe operation of the dam and meets the requirements in ARM 36.14.603. Report templates and checklists have been prepared to facilitate the reporting process and outline Montana Dam Safety expectations. Use of these templates is optional but encouraged.

The Engineer delivers the report and discusses it with the Owner within 60 days of completion of the visual inspection. At this time, Dam Owners are encouraged to share an electronic draft of the Five-Year Dam Evaluation Report with Montana Dam Safety for initial review.

Based on findings of the Five-Year Dam Evaluation, the Dam Owner is responsible for developing a plan to address recommendations arising from the Engineer's evaluation. Within 90 days of completion of the visual inspection associated with the Five-Year Dam Evaluation, the Owner delivers a copy of the report to Montana Dam Safety, together with the owner's statement of the intent regarding any deficient or unsafe items identified in the report, and a time schedule to remedy the items. Electronic submittals are encouraged.

Step 4: Permit Renewal

Montana Dam Safety reviews and accepts the Dam Evaluation Report and associated Dam Owner's Statement of Intent. Before the permit can be renewed, the Owner must update the EAP and O&M Manual in accordance with the Engineer's recommendations. Once an updated EAP and O&M Manual have been received, Montana Dam Safety renews the permit. The process is the same for a newly constructed dam except that the final construction inspection may serve as the Dam Evaluation discussed above.

NOTE: ***An Operation Permit is a statement by the State of Montana that the dam poses a reasonable and acceptable level of risk to life and property downstream.*** If this statement cannot be supported, Montana Dam Safety cannot issue or renew an Operation Permit.

No dam is perfect, even newly constructed dams. Montana Dam Safety often issues an Operation Permit with the following types of provisions requiring action by the owner to mitigate risk:

Operation Permit *Condition*

- Significant actions are needed to minimize risk to life and property downstream.
- Failure to comply with a Condition impedes Montana Dam Safety's ability to offer reasonable assurance that the dam poses an acceptable risk to the public. As a result, the Operation Permit may be revoked. Revocation of the permit could involve a reservoir level restriction, notification of local officials and downstream public, increased emergency planning, intervention planning, a civil penalty, and/or breach of the dam.

Operation Permit *Requirement*

- Action needed to maintain a dam in acceptable operating condition with proper emergency notification procedures.
- Requirements includes minor repairs, increase in monitoring, annual inspections, annual EAP updates, and studies to evaluate concerns at the dam.
- Failure to comply with a Requirement could result in elevation to a Permit Condition.

Operation Permit *Recommendation*

- General maintenance, monitoring, communication, and other activities important for continued safe operation of dam.
- Failure to comply with a Recommendation could result in elevation to a Permit Requirement.

1.2 Risk-based Approach

Risk is a function of both consequences and the likelihood of dam failure. To incorporate risk-based principles into evaluation requirements, all DNRC-regulated High Hazard Potential dams in Montana are

classified as either *Higher Consequence Dams* or *Lower Consequence Dams*. For the purposes of these guidelines, risk categorization is primarily based only on the consequences of failure, represented by the population at risk (or referred to in the Rules as proximity to population centers). *Lower Consequence Dams* may complete a less rigorous assessment as part of the Five-Year Dam Evaluation than what has been required in the past.

While the likelihood of failure is not quantitatively used in the categorization, risk pertaining to the likelihood of failure may be addressed qualitatively. All dams are required to follow the Administrative Rules, but for dams that are identified as Lower Consequnce Dams, Montana Dam Safety will accept less rigorous analysis for certain requirements. The Owner or the Engineer may still choose to complete the more detailed assessment required for Higher Consequence Dams for some or all dam components based on specific knowledge or observations at the dam. If specific deficiencies or observations at the dam could indicate an increased likelihood of dam failure (e.g., changes in seepage, inadequate spillway capacity, inoperable gates), certain requirements may be elevated to a more detailed assessment through recommendations in the evaluation report. Montana Dam Safety can also require any high hazard potential dam to meet Higher Consequence requirements if significant risk factors other than persons at risk are identified (e.g., poor maintenance, deficient construction, inadequate/deficient design). This is consistent with the Rules which provide for consideration of the condition of the dam, current design technology, and type of construction.

1.2.1 Population at Risk

In 2022, Montana Dam Safety evaluated the potential consequences associated with a credible dam failure for all 94 high hazard potential dams in the DNRC-regulated inventory. Each dam was assigned a category of either Lower Consequence or Higher Consequence. A credible dam failure was defined as a sunny day breach scenario with a breach volume equivalent to the dam's normal storage. It is important to note that a credible dam failure event and the risk categorization analysis differs from the failure event and analysis required by Montana Dam Safety to determine the hazard potential classification. Therefore, the population at risk (or lack thereof) that is the basis for the risk categorization should not be used as justification to change a dam's hazard potential classification. Also note that EAPs commonly contain evacuation maps based on a dam failure during an extreme flood event. This conservative approach is intended to identify all of the road crossings and structures that could potentially be impacted by a dam failure flood, acknowledging the uncertainty in predicting dam failure flooding. EAP maps should not be interpreted as a precise prediction of flooded areas due to dam failure.

The 2022 dam breach analyses consisted of two-dimensional unsteady flow models that were developed using the U.S. Army Corps of Engineers' HEC-RAS computer program. The highest resolution, publicly available terrain data at the time of study was used in these models. The inundation extents predicted by the models were screened such that they were reduced to regions where any of the following three criteria were met: depth greater than 2 feet, velocity greater than 6.5 feet per second, or depth multiplied by velocity greater than 6.5 $feet^2$ per second. The consequences of a credible dam failure were evaluated by estimating the population at risk within the screened inundation area.

Population at risk (PAR) was estimated by evaluating the number and type of inundated structures and roadways. The population at risk associated with inundated structures and roadways was estimated by totaling the number of each structure/roadway type within an inundation area and multiplying each total by a PAR factor. The PAR factor was commensurate with the number of people that would typically reside within the structure type or be exposed to hazardous conditions on the roadway based on its functional classification.

Montana Dam Safety will notify the dam owner if their dam fits into a lower consequence category at renewal time. HEC-RAS model files and other information used to estimate the population at risk can be requested from Montana Dam Safety. Of course the dam owner can choose to conduct their own analysis of population at risk below their dam and submit to Montana Dam Safety for consideration.Risk Categorization

For the purposes of these guidelines, population at risk is used as the primary indicator of consequences. Each dam is categorized as Lower Consequence or Higher Consequence according to the estimated population at risk during a credible dam failure event. Dams with a total population at risk less than or equal to 100 are categorized as Lower Consequence Dams, and dams with population at risk higher than 100 are categorized as Higher Consequence Dams.

Population at risk is also a good indicator of potential damage to infrastructure during a dam failure. Areas with higher population at risk commonly have water and wastewater treatment plants, and a higher density of roads, bridges, natural gas/oil pipelines and power transmission lines.

2.0 GENERAL REQUIREMENTS FOR THE FIVE-YEAR DAM EVALUATION

These guidelines are organized to step the Dam Owner and the Engineer through the Five-Year Dam Evaluation process. The guidelines cite pertinent references and include instructions to facilitate the development of recommendations and documentation of the evaluation.

Template report files and checklists are available to assist the Dam Owner and Engineer in completing the evaluation. These templates include the Dam Owner Questionnaire, a Visual Inspection Checklist, a 5-Year Dam Evaluation Report template, and a template for the Owner's Statement of Intent. These template files provide further clarification of Montana Dam Safety expectations and, if used, will promote consistency in the evaluations across the state's entire high hazard potential dam inventory. Use of these templates is encouraged by Montana Dam Safety but not mandated. Note that Montana Dam Safety will be using the templates as review aids. Engineers are encouraged to reference the templates to assure their submittal meets all requirements outlined in the Rules. Templates can be modified or supplemented as needed to be tailored to specific dams.

2.1 Evaluation Requirements (Lower vs. Higher Consequence Dams)

Some components of the Five-Year Dam Evaluation listed in ARM 36.14.602 and ARM 36.14.603 are required regardless of the dam categorization (Lower or Higher Consequence). These components include the visual inspection, an evaluation of downstream development, an instrumentation data review, an assessment of recent performance, a review of the operation and maintenance manual, and a review of the emergency action plan. These are considered ***core requirements***. For the required assessments listed in the Rules, it is reasonable to allow Lower Consequences Dams the option to complete a less rigorous analysis. The differences between the requirements for Higher Consequence Dams and Lower Consequence Dams are identified in Table 1 and discussed further in Section 4.0.

If specific deficiencies or observations at a Lower Consequence dam could indicate an increased likelihood of dam failure (e.g., changes in seepage, inadequate spillway capacity, inoperable gates), then there is a potentially higher risk than previously believed (i.e., risk is probability times consequence) and Montana Dam Safety can require that a specific section or sections of the Detailed Safety and Design Evaluation be completed to address those concerns. Montana Dam Safety can also require any high hazard potential dam to meet Higher Consequence requirements if significant risk factors other than persons at risk are identified (e.g., poor maintenance, deficient construction, inadequate defensive measures against potential failure modes). Dam Owners are always encouraged to exceed the minimum evaluation requirements.

In all cases, Five-Year Dam Evaluations should be thorough and utilize all available design, construction, and operation information available. Overreliance on past evaluations may result in "normalization of deviance" in which unexpected conditions are overlooked or incorrectly perceived as "normal" based on repeated observations. Several recent dam failures and incidents within the United States could have been avoided had it not been for this human tendency. As such, Five-Year Dam Evaluation Reports that include significant carryover or "copy and paste" from previous reports will not be accepted by Montana Dam Safety. The Engineer must be prepared to support observations, conclusions, and recommendations based on evaluation efforts from the current Five-Year Dam Evaluation cycle.

Table 1 Five-Year Dam Evaluation Requirements

Item	Responsible Party	Lower Consequence Dams	Higher Consequence Dams
Dam Owner's Questionnaire	**Owner**	Recommended	Recommended
Dam Background & History · **Dam Records** · **Summary Dam Data** · **Dam History** *(ARM 36.14.602(1)(a))*	**Engineer**	**Required**	**Required**
Visual Inspection of Dam · **Current Dam Condition** · **Outlet Works Inspection** *(ARM 36.14.602(1)(b),(g),(i))*	**Engineer**	**Required**	**Required**
Review of Owner's Dam Operation Plan · **Operation & Maintenance Manual** · **Owner Inspection Methods** · **Emergency Planning** *(ARM 36.14.602(1)(d))*	**Engineer**	**Required**	**Required**
Review and Analysis of Instrumentation Data	**Engineer**	**Required**	**Required**
High Level Safety Evaluation · **Visual/Desktop Downstream Hazard Assessment** · **Hydrologic & Hydraulic Evaluation** · **Structural & Geotechnical Evaluation** *(ARM 36.14.602(1)(c),(e),(f),(h))*	**Engineer**	**Required** (if no detailed evaluation) Not applicable (if detailed evaluation completed)	Not Applicable
Detailed Safety & Design Evaluation · **Breach Analysis & Inundation Mapping Review** · **Loss of Life Estimation Review** · **Hydrologic Analysis Review** · **Principal Spillway Assessment** · **Auxiliary Spillway Assessment** · **Total Spillway Capacity Review** · **Low Level Outlet Assessment** · **Drawdown Analysis Review** · **Seepage Analysis Review** · **Slope Stability Analysis Review** · **Structural Stability Analysis Review** *(ARM 36.14.602(1)(c),(e),(f),(h))*	**Engineer**	Optional (but encouraged)	**Required**
Risk Assessment	**Engineer**	Optional	Optional
Engineer's Report · **Urgent/High Priority/Routine Priority Recommendations and Timeline** · **Reservoir Safe Operating Level** · **Timeline for Next Dam Evaluation** · **P.E. Seal and Signature** *(ARM 36.14.603)*	**Engineer**	**Required**	**Required**
Dam Owner's Statement of Intent *(ARM 36.14.402(1))*	**Owner**	**Required**	**Required**

2.2 Qualified Professional Engineer

Per ARM 36.14.601, the Five-Year Dam Evaluation must be conducted by a qualified engineer licensed to practice in the state of Montana. Dam engineering and evaluation requires expertise that is specialized and different from other engineering disciplines. For example, the design and inspection of a highway embankment is very different from the design and inspection of a water-impounding embankment (i.e., dam). Codes of ethics for professional engineers stipulate that an engineer shall only perform services in areas of their competence, where competence in a specific service (i.e., dam safety engineering) is achieved through training and experience.

Montana Dam Safety requires that the evaluation be completed by a licensed Professional Engineer registered in the State of Montana who has the appropriate professional expertise in the safe design, construction, operation, and inspection of the specific type (e.g., earth embankment, concrete arch) of dam to be evaluated.

The Engineer of Record will be required to sign and seal the Five-Year Dam Evaluation Report which implies that:

- He/she is a qualified Professional Engineer with expertise in dam safety,
- The entire report has been developed by and under his/her direction

The Engineer of Record is thus taking responsibility for the Dam Evaluation Report contents as a Professional Engineer.

2.3 Anticipated Level of Effort

For Higher Consequence Dams, it can be expected that the Five-Year Dam Evaluation process will take approximately two weeks (80 hours) of an engineer's time. For Lower Consequence Dams where only a visual inspection and high level safety evaluation are required, the level of effort required by an engineer to complete the Five-Year Dam Evaluation and Report is expected to be a minimum of one week (40 hours) for the simplest and most accessible dams. These estimates do not include travel time, which should be taken into account.

Note that these are generalized estimates, and that the effort required to complete dam evaluations will of course vary based on accessibility of the dam, complexity of design, data availability and other factors. These estimates only include the effort required to complete the visual inspection and safety evaluation, and do not account for supplemental analysis, engineering design effort, or maintenance/repair costs that may be necessary as part of safe and responsible dam ownership for high hazard potential structures.

3.0 GUIDANCE FOR DAM OWNERS

To renew a Dam Operating Permit, the Dam Owner is responsible to initiate the Dam Evaluation, submit the Dam Evaluation Report to Montana Dam Safety, update the Operation and Maintenance Manual and Emergency Action Plan, and submit and follow an owner's Statement of Intent based on the Engineer's recommendations from the Dam Evaluation Report. Key owner responsibilities in this process relating to the Five-Year Dam Evaluation include the following:

- *Dam Record:* Dam Owners should compile and maintain a dam record consisting of data and documents related to the design, construction, modification, monitoring, and operation and maintenance of the dam. Recent performance during the past five-year period should also be documented. A complete dam record may include but is not limited to:
    - Previous Dam Evaluation Reports,
    - Summary of Consequence Category Evaluation,
    - Design Records,
    - As-Built Drawings,
    - Drawings for Modification(s),
    - Historical Inspection Reports,
    - Operational & Maintenance Records,
    - Construction Records,
    - Flood Records,
    - Pool Level Records,
    - Piezometric Levels,
    - Seepage Records,
    - Hydrologic & Hydraulic Analyses,
    - Embankment Stability Analyses,
    - Structural Stability Analyses, and
    - Outlet Works Analyses.
    - Survey Monument Records

  Montana Dam Safety can often assist dam owners in locating this documentation. All available information should be shared with the Engineer to facilitate a complete evaluation. Learn more about best practices related to maintaining a dam record from this online resource (ASDSO, 2022).

- *Engineer of Record:* Dam Owners are responsible to identify a qualified engineer who will perform the Dam Evaluation. If hiring an engineer, Owners should develop a scope of work in coordination with the Engineer and negotiate a contract in advance of inspection season. Owners should also identify any recent or ongoing concerns with the dam and bring these concerns to the attention of the Engineer and/or Montana Dam Safety as part of the evaluation scoping effort. There is always a chance that the Engineer will identify concerns during the evaluation that require additional out-of-scope effort to investigate; however, early identification and coordination regarding known

concerns at the dam will reduce the likelihood that change orders will be required during the evaluation.

- *Owner's Statement of Intent:* After the Engineer's evaluation is complete for the current cycle, the Owner should review the Dam Evaluation Report and develop a statement of intent to address all recommendations stemming from the evaluation.
- *Operation and Maintenance Manual (O&Mand Emergency Action Plan (EAP):* The Owner should review the Engineer's recommendations for the O&M Manual and EAP and develop updated documents as necessary. Many owners also task their Engineer to provide the updates as part of the negotiated scope of work.

A Dam Owner Questionnaire template and a Dam Owner Statement of Intent template have been prepared to help the Dam Owner fulfill these key responsibilities. Instructions relating to these templates are included below. Within 90 days of completion of the visual inspection associated with the Five-Year Dam Evaluation, the Owner shall deliver a copy of the report to Montana Dam Safety, together with the Dam Owner's Statement of Intent, 'regarding any deficient or unsafe items identified by the report, and a time schedule to remedy the items. Electronic submittals are encouraged.

3.1 Dam Owner Questionnaire

Montana Dam Safety recommends that the Dam Owner complete a brief questionnaire about the dam and recent activities concerning the dam. This questionnaire is intended to be completed prior to contracting with an Engineer to complete the Five-Year Dam Evaluation and should be provided to the Engineer during contract negotiations and planning. The questionnaire will help the Owner and Engineer define the scope of the evaluation based on both the consequence category of the dam and known concerns. *This advance planning by the Owner will make the process more efficient, reducing the Engineer's level of effort which translates to a cost savings. In addition, providing clear, organized information to the Engineer reduces uncertainty. Faced with uncertainty, engineers have no choice to but to increase their cost estimate.*

The questionnaire addresses the completeness of the dam record; recent history of the dam including major and minor modifications; inspection and maintenance activities completed by the Owner since the last evaluation; and recent emergencies or other significant events that have occurred at the dam since the last evaluation.

Finally, the questionnaire also provides the Dam Owner the opportunity to share specific concerns relating to the dam that may be cause for more detailed review. If the Dam Owner indicates that there are items of concern, this will not automatically expand the requirements of the Dam Evaluation. Rather, if the Owner expresses concerns on the Questionnaire, then they should discuss these items with the Engineer and Montana Dam Safety during scoping of the evaluation to determine if a more detailed evaluation is warranted.

3.2 Dam Owner's Statement of Intent

Within the Dam Evaluation Report, the Engineer will provide recommendations to resolve deficiencies identified during the 5-Year evaluation process. Each recommendation should be classified based on its importance relative to the safe operation of the dam. The Engineer will also assign a due date for each recommendation. In general, recommendations will be classified as one of the following:

- *Urgent:* These recommendations are essential to the safe operation of the dam and time is of the essence. Immediate, and in some cases emergency, actions must be taken to correct a deficient condition or take interim risk reduction actions (e.g., lowering the reservoir pool) until the deficient condition is permanently resolved.
- *High Priority:* These recommendations are important to the continued safe operation of the dam, but do not reflect an emergency condition. Examples include performing repairs that are needed to resolve deficiencies identified during the 5-Year Evaluation process. If major modifications to the dam are needed, these could also be classified as "High Priority" but would likely require multiple years to address.
- *Routine Priority:* These recommendations are are targeted towards performing deferred maintenance or correcting minor deficiencies before they deteriorate/progress into major/severe deficiencies. Such recommendations could also include identifying the need toperform updated analyses to confirm the safety of the dam.

All recommendations made by the Engineer pertaining to the safe operation of the dam must be included in the Dam Owner Statement of Intent. If the templates provided by Montana Dam Safety are used, then the summary of recommendations in Section 7.0 of the Engineer's Dam Evaluation Report can be correlated with Section 2.0 of the Dam Owner Statement of Intent template. Recommendations are sorted based on their priority, and the Owner must specify a plan and schedule to address all recommendations.

4.0 GUIDANCE FOR ENGINEERS

The Engineer of Record is responsible to perform and document the Five-Year Dam Evaluation. Key responsibilities of the Engineer in this process include the following:

- *Data Review:* A dam record consists of data and documents related to the design, construction, modification, monitoring, and operation and maintenance of the dam. Engineers can assist Dam Owners in developing this record but are primarily responsible to review the available documentation as part of the Dam Evaluation. Ideally, the Engineer will complete at least a cursory review of the dam record in advance of the visual inspection. A complete review of the available data is required to perform the safety evaluation.
- *Visual Inspection:* This consists of at least one physical visit to the dam to assess the existing condition and safety of the dam and its associated features. Areas within the watershed and downstream dam breach inundation zone should also be observed concurrent with the site visit to identify new development or changed conditions. For some dams, it may be preferrable to split the visual inspection into two separate visits to better coordinate aspects of the inspection with reservoir operation. This allows flexibility to conduct part of the visual inspection in the spring when the reservoir is full and part of the inspection in the fall when the spillway is dewatered.

  The condition of the dam and its appurtenant structures should be recorded on an inspection checklist and photo log. The Engineer is responsible to make recommendations relating to the condition of the dam based on the findings of the visual inspection. More guidance regarding visual inspections is provided in Section 4.2.

- *Review of Owner's Dam Operation Plan:* This consists of an evaluation of owner processes and preparedness. Specifically, the Engineer must review and assess the Operation & Maintenance Manual, dam owner inspection methods, and Emergency Action Plan. The Engineer is responsible to make recommendations relating to these documents and processes based on the findings of the review. More guidance relating to the owner evaluation is provided in Section 4.3.
- *Safety Evaluation:* A safety evaluation is the assessment of a dam's condition that is typically accomplished through an analysis of instrumentation, stability, seepage, hydraulic adequacy, hydrologic adequacy, and compliance with current standards. All features of the dam should be evaluated to determine if they are consistent with current design and construction practice. If there are variations from current practice, the potential for these features to cause failure of the dam should be assessed. If there is not enough information to evaluate a feature, the Engineer should assess if the potential risk is significant enough to justify further investigations or evaluation. The Engineer is responsible to make recommendations relating to all aspects of dam safety based on the findings of the safety evaluation.

  For Lower Consequence Dams, a High Level Safety Evaluation is allowed. This focuses on key items that are core to assessing the safety of the dam. More guidance relating to a High Level Safety Evaluation is provided in Section 4.4. For Higher Consequence dams, a more thorough evaluation process must be completed. Due to the higher risk posed by these structures, a more extensive review is warranted.

  In completing a detailed review of analyses, the Engineer should gain an understanding of the underlying assumptions and methods used and assess whether the findings of the analyses are valid. Original design and modifications should also be reviewed to evaluate whether they meet

current standards. Documentation of a detailed review must include a brief summary of the parameters, methodologies, and results that document the Engineer's decision regarding the adequacy of the design and analysis. More guidance relating to the requirements of a Detailed Design and Safety Evaluation is provided in Section 4.5.

For Lower Consequence dams, the Owner, the Engineer or Montana Dam Safety can require that a Detailed Evaluation be completed for some or all dam components based on specific knowledge or observations at the dam. If specific deficiencies or observations at the dam could indicate an increased likelihood of dam failure (e.g., changes in seepage, inadequate spillway capacity, inoperable gates), certain requirements may be elevated to a more detailed assessment. In some cases, the Engineer may discover deficiencies or concerns while performing the visual inspection or safety evaluation of the dam. These items may require additional investigation and effort that was not anticipated at the beginning of the evaluation. If such items are identified during an evaluation, the Engineer should alert the Dam Owner. The Owner can then coordinate with Montana Dam Safety to determine whether this new information warrants immediate action or if it can be incorporated as a recommendation in the Dam Evaluation Report to be addressed at a later date.

- *Documentation:* In accordance with ARM 36.14.603, the Engineer must prepare a written report and photographic record of the dam evaluation. This report must also include recommendations for:
    - any critical or emergency measures or actions,
    - corrective measures or actions relating to design, construction, operation, maintenance, and inspection of the dam,
    - additional studies, investigations, or analyses,
    - appropriate time periods for implementation of these required actions,
    - safe storage level of the dam and reservoir, and
    - time of the next inspection by an engineer.

The report should also include a section regarding the status of each recommendation from the prevous inspection report and confirm urgent and high priority recommendations were successfully implemented. If recommendations were not implemented, the report should address why a recommendation is no longer necessary, or identify consequences for failing to implement the recommendation.

Montana Dam Safety has provided a dam inspection report template that has been used by engineers for the past several years to document the visual inspection portion of the evaluation. An optional template for the Safety Evaluation portion of the Engineer's Dam Evaluation Report has also been prepared to assist the Engineer in completing and documenting the Five-Year Dam Evaluation. The template provides basic instructions and a general outline/checklist for the Engineer to follow in completing the evaluation. Comprehensive instructions relating to this template are included in the subsections below. The template is flexible and can be edited and tailored to a specific dam. Additional report sections should be added as needed. Deletion of subsections of the template is discouraged. If a subsection does not apply to a specific dam, the subsection heading should be retained with the statement "Not Applicable". All templates are available on Montana Dam Safety's website.

The Engineer shall deliver the report and discuss it with the Owner within 60 days of completion of the visual inspection. If the visual inspection is split into two visits, then the 60-day period begins after the second site visit when the visual inspection is complete.

4.1 Dam Background and History

4.1.1 Dam Record

In accordance with ARM 36.14.602, the Engineer should obtain and review the dam record from the Owner. This record consists of the available data and documents related to the design, construction, modification, monitoring (including crest and monument surveys), and operation and maintenance of the dam. Recent performance during the past five-year period should also be documented. The availability of documentation can vary significantly for different dams.

Within this section of the Dam Evaluation Report, the Engineer should record what documentation and dam records were obtained and reviewed, and comment on the overall adequacy of the dam record. If there are any data gaps, these should be identified with recommendations to address them. In some cases, the dam record can be improved by researching archives, coordination with other agencies, scanning physical documents to create an electronic record, or performing new analyses to assess the design if original documentation cannot be located. Learn more about best practices related to maintaining a dam record from this online resource (ASDSO, 2022). As part of the data review, the Engineer should also confirm that all recommended actions from the previous Five-Year Evaluation Report and Dam Owner's Statement of Intent have been satisfactorily addressed (either successfully implemented or reasoning for non-implementation).

Pertinent drawings of the structure should be included for reference in Attachment A of the Dam Evaluation Report. The entire dam record does not need to be attached to the report; however, if there are key documents from the dam record that provide critical supporting data to the evaluation or its recommendations, these documents should also be included as additional attachments to the Dam Evaluation Report. Note that a complete set of drawings should be included in every O&M Manual. In lieu of including drawings in Attachment A of the Dam Evaluation Report, engineers can reference pertinent sections of the O&M Manual.

4.1.2 Dam Data

Based on the dam record provided by the Owner, the Engineer should summarize data, including the type, purpose, and geometry of the dam, critical elevations, reservoir storage and surface area information, and dimensions of other key features. Section 1.2 of the template report provides a table to summarize the dam data. This table should be added to or modified to reflect the specific features at the dam being evaluated.

The Engineer should take care to note the source of the data with preference given to the most recent survey/measurement. In general, this information will come directly from existing sources such as prior Dam Evaluation Reports, inspection reports, or as-built drawings. If multiple or conflicting data is observed, this should be noted in the report with a recommendation to resolve the discrepancy. Key elevations should be referenced to an appropriate vertical datum that is noted in the report. If design or other documentation reference a different vertical datum, then the appropriate datum conversion should also be noted.

4.1.3 Dam History

Based on the dam record provided by the Owner, the Engineer should summarize the history of the dam, including the date and description of initial design and construction, any design changes during construction, significant modifications since construction, incidents or failures, and major floods or other

events that impacted the structure. The history should include a summary of any ongoing analyses or design projects. Do not include minor repairs or routine maintenance items.

The flood of record and other significant flood events within the past five-year period should also be documented, including an estimate of peak outflow and reservoir elevation.

4.1.4 Other Items of Note

The Engineer may note other items of concern at the dam that are not addressed in other sections of the Dam Evaluation Report.

4.1.5 Status of Previous Recommendations

The report should also describe the status of each recommendation from the prevous inspection report and confirm urgent and high priority recommendations were successfully implemented. If recommendations were not implemented, the report should address why a recommendation is no longer necessary, or identify consequences for failing to implement the recommendation.

4.2 Visual Inspection

In accordance with ARM 36.14.602, the Engineer is required to conduct a visual inspection of the dam, its appurtenances, the downstream area, and all other areas affected by the structure. Ideally, the Engineer will complete at least a cursory review of the dam record in advance of the visual inspection to be familiar with the dam's history and previously identified areas of concern. The Engineer should also be familiar with common deficiencies and potential failure modes of dams in general. The Association of State Dam Safety Officials regularly provides dam inspection training opportunities including this free webinar titled "Introduction to Inspecting Dams" that provides a basic overview of considerations for inspecting embankment dams.

Per the Rules, the visual inspection includes:

- inspecting the condition of surfaces and vegetation on the crest and slopes of the dam and area beyond the downstream toe of the dam,
- reviewing and analyzing the rate and volume of seepage,
- checking the condition and maximum flow capability of any seepage collection systems, and
- inspecting the condition of spillways and water level control structures, including all conduits exiting the dam.

Areas along the reservoir rim, within the upstream watershed, and in the downstream dam breach inundation zone should also be observed concurrent with the visual inspection to identify new development or changed conditions. For each element of the project, the Engineer should report visual observations of its condition as appropriate. Items to note include, but are not limited to, settlement, movement, erosion, seepage, leakage, wet areas, animal damage, condition of vegetation, cracking, deterioration, operability, evidence of high artesian or uplift pressures, observations of sediment transport, debris within the reservoir, and instability of the reservoir rim. The intent of the visual inspection is to identify changed or concerning conditions at the dam, not to document unimportant or minor details.

An inspection checklist should be used by the Engineer to document the visual inspection. Montana Dam Safety has provided a recommended checklist that has been in use for several years. The template is flexible and can be edited and tailored to a specific dam. Additional sections should be added as needed to address all appurtenant structures. Documentation of the visual inspection should also include photographs of

significant project features and important observations. A photo log template is also provided. At a minimum, each photo should include an identification number, the date taken, and a description of the photo contents. Providing GPS coordinates of the location where each photo was taken (i.e., geotagging) and/or a photo location map accompanying the photo log can also be helpful in locating observed deficiencies during future inspections and dam evaluations.

As part of the visual inspection, Montana Dam Safety requires that the reasonably accessible portions of outlet conduits be inspected on at least a five-year interval. The conduit inspection should coincide with the Engineer's visual inspection if possible. If it is not possible to inspect the conduit at the time of the inspection, documentation and/or video of a recent conduit inspection should be reviewed by the Engineer as part of the Dam Evaluation. If documentation of inspection is not available for review, the Engineer should discuss and evaluate the need for an inspection within the inspection report. If it has been five years or longer since the conduit was inspected, the Engineer should include the requirement to complete a conduit inspection as a High Priority recommendation in the Dam Evaluation Report. Note that Montana Dam Safety has an outlet inspection sled available for small diameter outlets. For inaccessible outlets, the Engineer should propose alternative means for assessing the condition of the outlet conduit. Note that Montana law considers most dam conduits a confined space if they have a large enough diameter to access physically, and that the Engineer should be aware of OSHA requirements for permit-required confined spaces. As such, appropriate air monitoring and associated safety protocol is required before entering. Montana Dam Safety may have air monitoring equipment available for you to borrow.

4.3 Review of Owner's Operation Plan

4.3.1 Operation & Maintenance Procedures

As part of the Five-Year Dam Evaluation, the Engineer is required to review operation and maintenance procedures employed by the Dam Owner as documented in the Operation & Maintenance Manual. Operation requirements relating to the safe operation of the dam are defined in ARM 36.14.404. Maintenance requirements relating to maintenance procedures are defined in ARM 36.14.405.

Additional resources from Montana Dam Safety relating to dam operation and maintenance are available on the DNRC website. This includes template and example Operation & Maintenance Manuals.

4.3.2 Owner Inspection Methods

As part of the Five-Year Dam Evaluation, the Engineer is required to review the inspection methods employed by the Dam Owner. At a minimum, this should consist of an annual Operation and Maintenance inspection of the dam conducted by the Dam Owner, dam tender, or engineer in accordance with ARM 36.14.407. Montana Dam Safety staff will often assist Owners and participate in these inspections when possible.

Documentation of owner inspections must be submitted to Montana Dam Safety. As part of this evaluation, the Engineer should review available records of dam owner inspections and speak with the Owner about the inspection methods they have followed since the previous dam evaluation. The Engineer should determine if the Owner is performing routine inspections, when these inspections typically occur, how the inspections are documented, and if any follow up occurs to address findings from the dam inspections. The Engineer should also verify that instrumentation is being properly measured and recorded. Recommendations may include the need for training or assistance in completing dam inspections, encouraging the Owner to document and act on important inspection findings, or identification of other opportunities for improvement.

4.3.3 Emergency Planning

As part of the Five-Year Dam Evaluation, the Engineer is required to review emergency planning procedures employed by the Dam Owner as documented in the Emergency Procedures and Warning Plan (more commonly referred to as the Emergency Action Plan). Requirements relating to the Emergency Procedures and Warning Plan are summarized in ARM 36.14.406.

Additional resources and guidance from Montana Dam Safety relating to emergency planning are available on the DNRC website. This includes guidelines for developing and updating a dam Emergency Action Plan, a model dam Emergency Action Plan, and a Dam Owner Emergency Intervention Toolbox.

4.4 Instrumentation & Surveillance

Instrumentation is often the most important tool available to monitor the health of a dam. Montana Dam Safety has specific guidelines and examples for how this instrumentation evaluation should be presented that are described in *Technical Note 10 – Analysis of Dam Instrumentation as part of a Five Year Dam Evaluation*.

The Engineer must review all available instrumentation or monitoring data for the dam. This includes review and analysis of piezometric levels, the rate and volume of seepage, and other pertinent data. The Engineer should also assess the condition and adequacy of existing instrumentation as well as the adequacy of current unsafe or watch levels. If available data is limited, and the dam's condition warrants investigation and surveillance, recommendations should be made to design and implement a monitoring program including the installation of additional instrumentation if needed. If data is limited and the dam's condition does not warrant additional instrumentation, then this section of the evaluation will be relatively simple.

An overview of the instrumentation, summary of available historical instrumentation data, and the Engineer's findings, conclusions, and interpretations should be included in the Dam Evaluation Report narrative. When applicable, it is recommended that detailed descriptions of instrumentation and supporting data analyses be documented in an Instrumentation Summary Report as described in *Technical Note 10,* and included as an attachment to the Evaluation Report. Other prior analyses can also be included as attachments if they are thought to be of significance. A summary of all available instrumentation data should be available to Montana Dam Safety upon request.

4.5 High Level Safety Evaluation

As described in Section 4.0, a Lower Consequence Dam may choose to complete a High Level SafetyEvaluation. instead of the detailed evaluation that has been required in the past. Specifics are discussed below.

4.5.1 Downstream Hazard Assessment

This is an assessment of downstream development and changed conditions based on observations made in the field during the visual dam inspection. Field observations should be supplemented with a desktop review of the inundation area using recent aerial photography. Available inundation mapping should be reviewed by the Engineer to determine an appropriate downstream and lateral extent for this assessment.

Note that this is not an assessment of the adequacy of available mapping or the hazard potential classification of the dam. Rather, this assessment is intended to identify new development in the downstream inundation area for the purpose of improving emergency planning. New impacts should be noted as appropriate for inclusion in the Emergency Action Plan.

The downstream hazard assessment is also intended to confirm the consequence category used to define the Five-Year Dam Evaluation requirements. If the dam is currently categorized as a "Lower Consequence" structure, the Engineer should evaluate whether a change in the consequence category is warranted, due to increased development downstream

4.5.2 Hydrologic & Hydraulic Evaluation

Key components relating to the hydrologic and hydraulic safety of the dam are the low level outlet works and spillways (e.g., principal spillway, auxiliary spillway). Spillways and outlet works should be designed to perform satisfactorily without endangering the dam during all flows ranging from typical base flows up to the inflow design flood.

The Engineer is responsible to review hydrologic and hydraulic design and performance data that is pertinent to these structures. Detailed review of related analyses (e.g., Inflow Design Flood study) is not required, but a high level review of these studies should be completed to understand the major assumptions and methods used as well as the findings of the analyses. If supporting analyses are unavailable or out-of-date, this should be noted with appropriate recommendations.

Montana Dam Safety requirements relating to hydrology and hydraulics are summarized in ARM 36.14.404 (Operation Plan – Reservoir Operating Procedures), ARM 36.14.501 (High Hazard Dam Criteria), ARM 36.14.502 (Hydrologic Standard for Auxiliary and Principal Spillways), and the following technical guidance documents:

- Technical Note 1: Determination of the Inflow Design Flood for High Hazard Dams in Montana (DOWL, 2019)
- Technical Note 1: References and Additional Information
- Guidance Manual for High Frequency Storm Rainfall Runoff Models (Hydrometrics, 2022)

4.5.3 Structural & Geotechnical Evaluation

For embankment structures, the Engineer is responsible to review pertinent geotechnical design and performance data. Detailed review of related analyses (e.g., slope stability, seepage, foundation conditions) is not required, but a high level review of these studies should be completed to understand the major assumptions and methods used, as well as the findings of the analyses. The Engineer should also conduct a visual assessment of the embankment to assess the adequacy of seepage collection systems and the stability of the embankment. If no stability analyses are available for the dam, the application of "rule of thumb" guidelines that incorporate slope angle and crest width is appropriate for a high level review.

For concrete/masonry structures, the Engineer is responsible to review pertinent structural design and performance data. Detailed review of related design details and analyses (e.g., structural stability, structural design, drainage collection, foundation conditions) is not required, but a high level review of these features and calculations should be completed to understand the major assumptions and methods used as well as the findings of the analyses.

In all cases, if supporting data and analyses are unavailable or out-of-date, this should be noted with appropriate recommendations.

4.6 Detailed Safety & Design Evaluation

As described in Section 4.0, dams that are not Lower Consequence Dams (i.e. Higher Consequence Dams) must complete a detailed evaluation. . Due to the higher risk posed by these structures, a more extensive review is warranted.. A Detailed Safety and Design Evaluation includes in-depth review of past analyses including breach analysis and inundation mapping, loss of life estimation, hydrologic analysis to determine the inflow design flood, drawdown analysis (if available), seepage analysis, slope stability analysis, structural analysis, and any other pertinent studies.

In completing a detailed review of analyses, the Engineer should gain an understanding of the underlying assumptions and methods used and assess whether the findings of the analyses are valid. Original design and modifications should also be reviewed to evaluate whether they meet current standards. Documentation of a detailed review must include a brief summary of the parameters, methodologies, and results that document the Engineer's determination regarding the adequacy of the design and analyses. It is not necessary to redo the analyses; however, the engineer must have sufficient understanding of the analysis to confidently conclude whether they are adequate or need to be revisited.

4.6.1 Hazard Potential & Hydrology

In addition to the high level hydrologic and hydraulic evaluation described in Section 4.4.2, a more thorough review of related studies is required for Higher Consequence Dams. This includes dam breach analyses and the associated inundation mapping, loss of life estimation, and inflow design flood calculations. The evaluation of hazard potential and hydrology will be based on past studies and, if necessary, results in recommendations for additional analysis. It is not appropriate to simply indicate that the analysis was evaluated and previously found to be adequate by others. The Engineer must indicate their concurrence that the analysis is adequate based on review of the assumptions, data, and methods used. In some cases, it may be necessary to recommend that a plan be developed to obtain more information or perform analysis, as insufficient information is available to make a determination.

Dam Breach Analysis, Inundation Mapping

Detailed and up-to-date dam breach analysis is a vital part of the Emergency Action Plan. The Engineer's review should include consideration of the following:

- Adequacy of Dam Breach Analysis
    - Are the assumptions used in the breach analysis reasonable (e.g., starting reservoir water surface, inclusion of spillway releases, accuracy of topographic data, hydraulic modeling approach, downstream extent, etc.)? Note any excessive conservatism.
    - If there isn't a report describing the assumptions used to develop the breach analysis and downstream routings, or if the native model files are not available for review, then the engineer must evaluate whether the mapping is adequate for evacuation needs, and if not, make recommendations for improvement.
- Adequacy of Inundation Mapping
    - Are the data used to develop the maps reasonable and up-to-date (e.g., accuracy of topographic data, scale of mapping, base map selection, etc.)?
    - Is critical infrastructure noted on the maps?
    - Is there additional development downstream of the dam not reflected on the maps?

- Does the mapping extend far enough downstream?
- Is there a need to include non-failure inundation mapping (e.g., a case where the spillway flowing full without a dam failure can cause significant downstream flooding)?
- Are the flooding scenarios included on the maps appropriate (i.e., flood failure or sunny day / fair weather piping)? For high population centers directly below a dam, detailed maps for multiple scenarios may be necessary to avoid excessive evacuation of downstream residents.
- Has the Dam Owner coordinated with emergency managers and adapted mapping based on their preferences? Some local emergency managers prefer to use evacuation zones instead of inundation maps, especially in populated areas.
- In your professional opinion, are these maps adequate for local emergency managers to successfully evacuate the public at risk downstream?

Loss of Life

In Montana, the regulatory Inflow Design Flood for a dam is determined based on the estimated loss of life due to theoretical dam failure. Montana Dam Safety requirements relating to loss of life estimation and the Inflow Design Flood are summarized in ARM 36.14.502 (Hydrologic Standard for Auxiliary and Principal Spillways), and the following technical guidance document:

- Technical Note 2: Estimating Loss of Life for Determining the Minimum Inflow Design Flood Recurrence Interval (DOWL, 2019)

Dam breach analysis and inundation mapping is used to estimate loss of life. The review should also examine if the inundation mapping used to estimate loss of life reflects current downstream development and is appropriately conservative. Loss of life estimation is one area where Montana Dam Safety suggests conservatism.

Inflow Design Flood

The Inflow Design Flood is the primary regulatory requirement for the hydrologic safety of dams. A dam should be able to safely pass the Inflow Design Flood (IDF) with adequate freeboard between the maximum water surface elevation and the dam crest (i.e., the dam doesn't overtop during the IDF). Montana Dam Safety requirements relating to the Inflow Design Flood are defined in ARM 36.14.501 (High Hazard Dam Criteria), ARM 36.14.502 (Hydrologic Standard for Auxiliary and Principal Spillways), and the following technical guidance documents:

- Technical Note 1: Determination of the Inflow Design Flood for High Hazard Dams in Montana (DOWL, 2019)
- Technical Note 1: References and Additional Information
- Guidance Manual for High Frequency Storm Rainfall Runoff Models (Hydrometrics, 2022)

4.6.2 Spillway(s)

The Engineer should perform a detailed evaluation of all spillway structures. This includes an evaluation of the adequacy of spillway capacity and spillway integrity during the Inflow Design Flood and more frequent events. The review should also include detailed review of geotechnical and structural design details as applicable. The spillway should be designed to perform satisfactorily under the full range of loading

conditions (normal, seismic, flood, etc.). The discharge rating curve for each spillway should also be evaluated and confirmed by the Engineer.

The evaluation of spillways will be based past studies and, if necessary, result in recommendations for additional analysis. It is not appropriate to simply indicate that a spillway was evaluated and previously found to be adequate by others. The Engineer must indicate their concurrence that the analysis is adequate based on review of the assumptions, data, and methods used. In some cases, it may be necessary to recommend that a plan be developed to obtain more information or perform analysis, as insufficient information is available to make a determination.

4.6.3 Low Level Outlet

The Engineer should perform a detailed evaluation of the low level outlet system, inclusive of the intake structure, gates/valves, outlet conduit, terminal structure, and energy dissipation structure/features. This includes an evaluation of the adequacy of low level outlet capacity, structural adequacy, operability, and overall performance. Observations from the visual inspection and most recent conduit inspection should be considered. The discharge rating curve for the low level outlet should also be evaluated and confirmed by the Engineer. At a minimum, the discharge rating curve assuming all operable gates and valves are fully open should be considered. If the Dam Owner uses the low level outlet to regulate flows, then rating curves for additional gate openings should be considered.

The low level outlet is the primary means of drawing down the reservoir in the event of an emergency. A dam should be able to safely draw down the reservoir in such situations (see ARM 36.14.404). The Engineer should evaluate the drawdown analysis for the dam, including if appropriate base flow conditions are assumed and if the outlet is adequate to draw down the reservoir in a reasonable amount of time. The Engineer should also evaluate the reasonableness of stage-storage relationship with respect to readily available topographic mapping of the area above the pool elevation.

4.6.4 Dam Embankment/Structure

The dam structure, foundation conditions, and any other appurtenant structures should be evaluated by the Engineer from both a structural and geotechnical standpoint. This includes detailed review of seepage analyses, slope stability analyses, structural stability analysis, and geotechnical and structural design details as applicable. Regardless of dam type, the structure should be designed to perform satisfactorily under the full range of loading conditions (normal, seismic, flood, etc.) and should consider the potential for internal erosion.

In addition to observations during the Visual Inspection, evaluation of the dam embankment/structure will include a detailed review of past analyses and studies and, if necessary, result in recommendations for additional analysis or investigations. It is not appropriate to simply indicate that the dam was evaluated and previously found to be adequate by others. The Engineer must indicate their concurrence that the previous analyses are adequate based on review of the assumptions, data, and methods used. In some cases, it may be necessary to recommend that a plan be developed to obtain more information or perform analysis, as insufficient information is available to make a determination.

Montana Dam Safety requirements relating to geotechnical and structural design are summarized in ARM 36.14.501 (High Hazard Dam Criteria). Technical guidance and trainings are published by multiple federal agencies (e.g., Natural Resources Conservation Service, Bureau of Reclamation, U.S. Army Corps of Engineers) and the Association of State Dam Safety Officials. At the present time, no single reference relating to geotechnical or structural design of dams is recommended by Montana Dam Safety, providing the

Engineer flexibility to determine the design standard most applicable to the situation. Montana Dam Safety has published the following Montana-specific technical guidance documents that should be referenced as part of a dam evaluation where seismic stability is a concern:

- Technical Note 5: Simplified Seismic Analysis Procedure for Montana Dams (HDR, 2020)
- Probabilistic Earthquake Hazard Maps for the State of Montana (Montana Bureau of Mines and Geology,2005)

4.7 Risk Assessment

While not required by Montana laws and rules, risk-informed decision-making is a useful tool for comprehensively evaluating a dam. One key aspect of risk-informed decision-making that is widely used in the dam safety industry and can be applied to dams of any size is Potential Failure Mode Analysis. Potential Failure Mode Analysis is a joint effort between engineers, operators, and dam owners to identify the various ways a specific dam could fail. Results from a Potential Failure Mode Analysis can be used to direct future monitoring, identify weak points in the dam, validate the adequacy of existing structures, and prioritize risk reduction efforts.

If risk-informed analyses have been performed, the Engineer should review these studies and consider the findings as part of the Dam Evaluation process. The Engineer can also recommend that these types of analyses be performed for a dam if a particular need or benefit is identified. Montana Dam Safety has developed simplified tools to help dam owners and engineers cost-effectively complete this type of analysis. This process is summarized in Technical Note 7: Guidelines for Conducting a Simplified Failure Mode Analysis For Montana Dams (Hydrometrics, 2011).

4.8 Engineer's Summary and Recommendations

4.8.1 Summary of Recommendations

Throughout the Dam Evaluation Report, the Engineer will make recommendations specific to the various subtopics within the evaluation to resolve deficiencies identified during the 5-Year evaluation processrestore, repair, or prevent a reduction in dam safety performance. Each recommendation should be classified based on its importance relative to the safe operation of the dam. The Engineer will also indicate a due date for each recommendation. In general, recommendations will be classified as one of the following:

- *Urgent:* These recommendations are essential to the safe operation of the dam and time is of the essence. Immediate and in some cases emergency actions should be taken to address the concern or take interim risk reductions (e.g., lowering the reservoir pool until the issue can be addressed).
- *High Priority:* These recommendations are important to the continued safe operation of the dam, but do not reflect an emergency condition. Examples might include addressing maintenance issues or performing minor repairs that are needed to resolve deficiencies identified during the 5-Year evaluation process. If major modifications to the dam are needed, these could also be classified as "High Priority" but would likely require more than one year to address.
- *Routine Priority:* Recommendations classified as "Routine Priority" are not necessarily less important than "High Priority" recommendations, but they are less urgent. This might include the need to perform updated analyses to confirm the safety of the dam or repairs that would prolong the life of the structure but do not necessarily enhance the safety of the dam.

At the conclusion of the Dam Evaluation Report (Section 7.0 of the template), recommendations should be compiled by the Engineer and summarized in a single table that is sorted based on priority. Recommendations should be specific and actionable so that the Dam Owner can develop an appropriate Statement of Intent to address them.

4.8.2 Reservoir Safe Operating Level

In addition to general recommendations, the Engineer is responsible to review the maximum operating water surface elevation (i.e., the maximum reservoir level that the reservoir should be operated at during normal, non-flood conditions) and amount of freeboard as part of the Five-Year Dam Evaluation (ARM 36.14.602). In evaluating the safe operating level, the Engineer should consider the frequency of spillway use, the presence of concerning seepage or signs of internal erosion, the adequacy of freeboard given the fetch of the reservoir, and if the reservoir is being operated in accordance with the Operation Plan. If the Engineer believes they do not have sufficient information to recommend a safe operating level for the dam, they should clearly explain why and include specific information that must be acquired in the recommendation section of the Evaluation Report.

4.8.3 Recommendation for Next Dam Evaluation

The Engineer must also make a recommendation for the time of the next Five-Year Dam Evaluation by a qualified engineer (ARM 36.14.603). As the name implies, the typical frequency and minimum requirement for dam evaluations is every five years. If there are significant concerns with the performance of the dam and its appurtenances, or if the dam owner is showing signs of negligence with regards to operation, maintenance, or emergency planning, the Engineer can recommend that the next evaluation be completed sooner than the next five-year period. If this is the case, justification for the recommendation of a reduced evaluation period must be provided.

4.8.4 Professional Engineer Seal and Signature

A Professional Engineer licensed in Montana is required to sign and seal the Dam Evaluation Report, thereby indicating that it has been conducted in accordance with the standard of care within the dam safety engineering practice. The Engineer confirms that the entire Dam Evaluation was completed under his/her direction, and that he/she certifies the content of the 5-Year Dam Evaluation Report. The Engineer is thus taking responsibility for the Dam Evaluation Report contents as a Professional Engineer, but the seal does not constitute a warranty or guarantee of facts or conditions.