Dam Safety Reviews Manual
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**Acronyms**

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AEP</td>
<td>Annual Exceedance Probability</td>
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<tr>
<td>CSP</td>
<td>Corrugated Steel Pipe</td>
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<tr>
<td>DSR</td>
<td>Dam Safety Review</td>
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<td>EDGM</td>
<td>Earthquake Design Ground Motion</td>
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<td>EPP</td>
<td>Emergency Preparedness Plan</td>
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<td>ERP</td>
<td>Emergency Response Plan</td>
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<td>HFMM</td>
<td>Hazards and Failure Modes Matrix</td>
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<td>IDF</td>
<td>Inflow Design Flood</td>
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<td>JCR</td>
<td>Jump Creek Dam</td>
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<tr>
<td>LCR</td>
<td>Lower Chase River Dam</td>
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<td>LLO</td>
<td>Low Level Outlet</td>
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<tr>
<td>KPI</td>
<td>Key Performance Indicators</td>
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<tr>
<td>MCE</td>
<td>Maximum Credible Earthquake</td>
</tr>
<tr>
<td>MDE</td>
<td>Maximum Design Earthquake</td>
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<tr>
<td>NDS</td>
<td>Nondestructive Testing</td>
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<tr>
<td>OMS</td>
<td>Operations, Maintenance and Surveillance (Manual)</td>
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<td>PAR</td>
<td>Population at Risk</td>
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<td>PBS</td>
<td>Performance Based Surveillance</td>
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<td>PMF</td>
<td>Probable Maximum Flood</td>
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<tr>
<td>PMP</td>
<td>Probable Maximum Precipitation</td>
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<tr>
<td>SCADA</td>
<td>Supervisory Control and Data Acquisition</td>
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</table>
This manual, for the production of Dam Safety Reviews, has been prepared to assist dam owners and their registered professional engineering consultants. It is offered as a guide and is not a required methodology for preparing Dam Safety Reviews (DSR). The dam owners might create their own templates for DSRs.

1. Classification of dams

BOAD recommend to dam owners who will submit a project to the Bank financing, to classify their dam according to the International Commission of Large Dams (ICOLD) classification system.

2. Dam Owner Responsibility

Dam owners are responsible and liable for any damage caused by the failure or mis-operation of their works. Therefore, dams must be constructed to engineering standards which exceed the standards applied to most other infrastructure.

The owner will be assisted by a Dam Safety Review Engineer (DSR engineer) to review the dam safety. The Dam Safety Review Engineer must:

- Hold current registration as a Professional Engineer;
- Have at least 10 years of experience in the design, construction, performance evaluation and operation of dams;
- Be familiar with the Bank Dam Safety operational policy, procedures and Guidelines;
- Have not participated in the design, construction or safety management (including deficiency investigations and capital improvement projects) of the specific dam. Note: it may be appropriate for the same company to do the DSR but the Dam Safety Review Engineer should not have participated in the design, construction or safety management of the dam(s).

If additional support, such as technical specialist consultation, quality assurance and word processing from others is required, these shall be indicated in the Letter of Proposal with their corresponding fees and disbursements.

The Dam Safety Review Engineer is expected to direct and be involved throughout the Dam Safety Review process.

For large dam projects (large according to the ICOLD classification system), the dam owner will appoint a panel of experts to review all the criteria, data, design and dam safety assessments to provide recommendations in conformity with the BOAD Dam safety procedures. The recommendations of the panel will be implemented during the overall process of design, construction and operation of the dam. The panel shall
be involved in assessing and tracking the project from feasibility studies to the first filling of the dam reservoir.

3. Dam safety review recommended phases

A Dam Safety Review is a significant but necessary investment for the owners of dams. The cost can be substantially reduced by having a well documented Dam Safety Program (a dam safety management system) in place prior to starting the process of commissioning a DSR. This section is written for large dam owners, but the basic principles apply to all dams.

If they have not already done so, dam owners should assemble all of the available design and construction information as well as records of inspections, operation, maintenance and any past problems at the dam.

A fundamental requirement of any dam safety program is dam inspection and maintenance. The “Inspection and Maintenance of Dams”

At least, three phases approach will ensure that the dam owner is included in the process at all the key times during the review and is in control of the scope and cost. A Professional Engineer “qualified in dam safety analysis” must directly supervise the Dam Safety Review project.

3.1. Reconnaissance & Document Review

The project will commence with a start-up meeting (teleconferencing is possible) to scope the particular areas to be covered or excluded under this review.

The DSR Engineer (and other Engineering support) is expected to:

- Identify performance expectations, including flood and earthquake criteria...;

- Review available documents\(^1\) for evidence of conformance with dam safety requirements. Documents include but may not be limited to:
  - Dam Safety Management Manual;
  - Dam Safety Program Manual;
  - Operation, Maintenance & Surveillance (OMS) Manual for Dam Safety;
  - Emergency Preparedness and or Emergency Response Plans;
  - Surveillance reports and memos;
  - Past Dam Safety Review Reports;

\(^1\) The Dam Safety Review Engineer can include any of the following documents available from Dam Owner and remove those that are not.
- Previous Hazards and Failure Modes Studies;
- Previous Dam Safety Expectations Studies;
- Past Deficiency Investigation and Capital Improvement reports;
- Current outstanding dam safety issues;
- Completed dam safety issues;
- Other available documents related to design, operation, maintenance, improvement, condition and performance of the dam or appurtenant works.

☑ Discuss the chosen hazards and failure modes methodology with Dam Owner.
☑ Discuss the methodology to be used to summarize and prioritize the dam safety deficiencies and non conformances (see definition and identification in appendix 1) from a list of all potential dam safety deficiencies. (A “Sample Check Sheet of Dam Safety Expectations” is provided in Appendix 2) The DSR Report should be based on this list and should indicate whether or not the dam conforms to each dam safety expectation. If the available information is not adequate to draw such a conclusion, then the inadequacy of information should be noted.

At the end of Phase 1, the DSR Engineer (and other Engineering support) is expected to:
☑ Have acquired sufficient knowledge and understanding of the dam(s) to identify the hazards and failure modes applicable the dam(s) in question;
☑ Submit a draft “Hazards and Failures Modes Matrix” (or equivalent) specific to the dam(s), documenting the reasons why certain hazards and failure modes would not apply;
☑ Be technically ready to conduct technical review meetings with Dam Owner staff.

3.2. Detailed Work (including Site Visit)

This is the most intensive phase of the project. In Phase 2, the DSR Engineer (and Other Engineering support) is expected to:
☑ Determine the dam's conformance with the set of dam safety expectations, including:
  - Evaluate, review and audit Dam Owner’s knowledge base by meeting with Dam Owner personnel involved in dam safety management, operation, maintenance, surveillance, performance evaluation or other relevant activities;
  - Conduct a site visit to inspect each dam and review on-site documents;
☑ Identify any additional dam safety requirements to enhance risk management;
☑ Review past reports and studies to ensure that all past recommendations and issues have been properly documented;
✓ Identify and document deficiencies and non-conformances in safety management of the dam and any deficiency in the safety of the dam, using the Dam Safety Expectations check sheet (or equivalent analysis) as a guide. Deficiencies are to be characterized as Actual, Potential or Non-Conformance (as defined in Appendix 2) and prioritized in order of importance;
✓ Make significant progress in the preparation of a Draft Report;

In addition to addressing the foregoing requirements, the report should also include recommendations for dam safety improvements, further investigation of deficiencies, further studies to correct information gaps, and any other appropriate actions to improve dam safety.

At the end of Phase 2, the DSR Engineer (and Other Engineering support) is expected to:
✓ Have obtained all information required to complete the DSR Report;
✓ Be at least 75% complete on the Draft Report;
✓ Hold a verbal presentation session summarizing findings to the Dam Owner staff.

3.3. Finalize Report

In Phase 3, the DSR Engineer (and Other Engineering support) is expected to:
✓ Complete the Draft Report;
✓ Within 2 weeks of completing Phase 2, submit 2 hard copies or one electronic copy of the Draft Report to Dam Owner Inc for review;
✓ Consider Dam Owner Inc comments for inclusion in the Final Report;
✓ Prepare electronic and hard copies of the Final Report.
✓ At the end of Phase 3, the DSR Engineer is expected to:
✓ Submit the required numbers of Final Reports in both hard copies and CD-ROM’s (see Section TR4).
✓ Provide comments, if any, on improvements of the DSR process.

4. Dam Safety Review Process

The following are the recommended, but not required, chronological steps for the DSR Engineer to follow while undertaking a Dam Safety Review.
✓ Meet with dam owner;
✓ Review Dam Consequence Classification – Is the dam definitely a High Consequence Classification or higher? Is a dam break model study required to
determine if it could be a “Significant or Low” Classification dam, in which case a Dam Safety Review is not required;

✓ Records Search (if necessary) – Design and Construction records, inspections, etc.
✓ Comprehensive Dam Inspection
✓ Dam Assessment
  - Based on Consequence Classification identify IDF and EDGM required
  - Identify hydraulic capacity of spillway and outlet works
  - Identify static stability and seismic stability of dam components
  - Would the dam withstand IDF and EDGM?
  - Hazards and Failure Modes Assessment and Analysis
  - Dam Safety Expectations – Deficiencies and Priorities
✓ Review and assess OMS & EPP for completeness and effectiveness
✓ Review and assess Dam Safety Management System

5. Scope and Content of the Dam Safety Review

The scope of a Dam Safety Review may vary from dam to dam, depending on the consequence classification, complexity of design, previous assessments, age, etc. However, it should cover all aspects required to demonstrate that: (i) the dam is safe, operated safely, and maintained in a safe condition; and (ii) surveillance is adequate to detect any developing safety problem. If safety cannot be demonstrated, the DSR engineer should identify the deficiencies. The review generally includes site inspection, review of all relevant documentation, and interviews with operating and maintenance staff. Records of any dam safety incidents since the previous review and records of follow-up actions should be reviewed. The flow discharge equipment should be tested at this time as well if appropriate.

If a previous Dam Safety Review was conducted, the DSR engineer may elect to structure the DSR as an audit of the previous information, ensuring that it is complete and up to date.

5.1. Site Inspection and Dam Owner Interview

All Dam Safety Reviews should include a site inspection. The inspection should include all works at the dam site, an assessment of the reservoir, in particular reservoir debris and a tour of the downstream area to re-assess the downstream consequence classification. If the dam is exposed to conditions other than those on the day of the inspection (full or drawn down reservoir, extreme cold, wind storm, etc.) the review engineer should review inspection records or speak to the owner
about any anomalies which may have occurred during those conditions. The dam owner should be interviewed about the following: operating and maintenance issues or incidents, equipment or system issues, dam performance, and any issues involving integration with other dam owners or stakeholders. An evaluation of the overall dam management system should be made.

5.2. Data and Records

Ideally, a Dam Safety Review will include an assessment of the construction methodology, conditions and practices used for construction of the dam. Every effort should be made to find all available information about the dam, unfortunately, construction reports, design plans and records are not available for many older dams. The dam owner should keep complete records as part of an effective Dam Safety Program and should ensure that all available information is collected before the Dam Safety Review is started.

The dam owner should keep complete Dam Safety Issues Database (see table in appendix 3)

5.3. Consequences of Failure

During the Dam Safety Review, the potential consequences of dam failure need to be reviewed. The primary reasons for a change in the consequences are new development downstream, re-evaluation of the inundation area or identification of environmental or socioeconomic consequences previously unaccounted for.

5.4. Dam Safety Analysis

Safety analysis of the dam system should include the internal and external hazards, failure modes and effects, operating reliability and dam response. A Hazard and Failure Mode analysis process with instructions is provided in the Dam Safety web site to assist the review engineer to analyse the safety of the dam.

For many small older dams there was no sophisticated analysis done when the dam was designed and constructed. The review of the design as it relates to the present condition of the as-constructed, as-operated dam must include the Dam Safety Expectations (or equivalent analysis).

5.5. Hazards and Failure Modes (HFM) Analysis

Dam failures are usually tragic events. Competent and independent investigations must serve at least the following purposes to:

- determine the cause(s) of failure
- understand contributing factors including organizational and cultural factors.
- learn what went right and recognize efforts/successes
- better support communication with the public and the press
- identify lessons learned
- recognize deficiencies and advance design/construction practices
- improve understanding of warning signs of dam distress
- improve dam safety regulation and dam engineering
- prevent future failures
- increase awareness of dam safety and civil infrastructure

External hazards are beyond the control of the dam owner, and originate outside the boundary of the dam and reservoir system. Internal hazards are errors and omissions in the design, operation and maintenance of the dam and water conveyance structures. A failure mode describes how element or component failures must occur to cause loss of the system function.

The interactions between hazards and failure modes can be related through a matrix representation (see appendix 5). The matrix is designed to be used for larger complex dams, but it can be used effectively for smaller dams. This matrix allows the DSR engineer to examine only the failure modes that apply to each specific dam. Analysis of failure modes for smaller dams will be reduced considerably. The hazards and failure modes matrix (HFMM) provides a simple means of summarizing the considerations that, in principle must be embodied in every dam safety program. In general, hazards may be related to failure modes in different ways, including combinations of hazard contributing to an individual failure mode and individual hazards contributing to all several failure modes. It is only through understanding of the number and nature of the hazards and failure modes that must be addressed by dam safety activities that meaningful comparative analysis can be carried out. The HFMM is a simplified representation of this understanding, but it is not the means to generate the understanding.

The most convenient way to use the matrix to identify the hazards and failure modes that must be managed at a dam is to fill out the matrix by assuming that all 104 combinations of hazards and failure modes apply, and then eliminating those that don't apply. The reasoning for the elimination of the hazard-failure mode pairs should be documented.

A simple dam such as a concrete dam wedged in a narrowing canyon, and designed to operate as a weir for flood passage purposes would be expected to have a small number of hazard-failure mode pairs. On the other hand, an earth fill dam on a poor foundation with a gated spillway on a rapidly responding reservoir in a seismic area also prone to unpredictable large floods would be expected to have a large number of hazard and failure mode pairs. Careful thought is required when de-populating the matrix as it is necessary to consider external hazards and internal hazards.
separately and together. As a result, a functional failure characteristic may be vulnerable to external hazards and to internal hazards and to combinations of external hazards and internal hazards that interact. Similarly, external hazards can combine such as a reservoir landslide that can occur naturally, or as triggered by a meteorological or seismic event.

The HFMM will be used slightly differently for surveillance activities than for design reviews, dam safety reviews or deficiency investigations, in that surveillance activities comprise “proactive activities” around internal hazards and “reactive activities” for external hazards. In general, surveillance activities for the purposes of intervention will not focus on external hazards that alone exceed the design basis as in the absence of an intervention plan, any surveillance activity is for information not for active risk management. On the other hand the point at which the design basis is exceeded is fundamental to design reviews, dam safety reviews or deficiency investigations. However, while the uses may be different, the surveillance engineer should know when the design basis is exceeded even if no intervention action is to be taken.

5.6. Operation, Maintenance and Surveillance

The effectiveness and adequacy of the operation, maintenance, and surveillance, along with compliance, must be reviewed. The review of the operation, maintenance, and surveillance should be undertaken using the Dam Safety Expectations (or equivalent analysis).

The Dam Safety Review should address the testing of equipment required to operate discharge facilities (including backup equipment and emergency power supply) needed for safe passage of the IDF and any other flood that could endanger the dam. If the discharge gates and equipment have been tested or operated within a year and adequate documentation is available, a review of such testing or operation records may be adequate. Otherwise, the testing can be carried out during the Dam Safety Review.

5.7. Emergency Preparedness

The emergency preparedness plans and emergency response procedures must be reviewed. The review of the emergency preparedness plans and emergency response procedures should be undertaken using the Dam Safety Expectations (or equivalent analysis).

5.8. Public Safety and Security

The DSR engineer should verify that public safety hazards at the dam have been identified and addressed. The DSR engineer should verify that the operating
equipment is secured against vandalism or operation by unauthorized individuals. The dam owner has the right to secure the works of the Dam Safety Regulation.

5.9. Dam Safety Management System

For the purposes of this guideline, the review of the management of the dam may be limited to a review of the OMS & EPP from the perspective of overall management of the dam & reservoir. The figure in appendix 4 provides an overview of a dam owner’s Dam Safety Management System.

6. Dam Safety Review Report

At the completion of the Dam Safety Review, the review engineer should present the dam owner with a formal report containing the conclusions of the review and recommendations that will help the owner fulfill the responsibility for dam safety and comply with regulations. This report should:

✓ Document the review².
✓ Quantify deficiencies and non-conformances in the structures (Appendix 1) and/or owners dam safety program using the “Checklist of Dam Safety Expectations” (or equivalent analysis) in Appendix 2.
✓ Draw attention to any non-compliance with policies, guidelines, or standards and to any other issues requiring follow-up so that priorities can be readily established for safety improvement, remedial measures, or additional investigations (Appendix 3).
✓ Identify any additional steps needed for safe operation, proper maintenance, and adequate surveillance of the dam.
✓ Report on information gaps in past documentation, identify potential deficiencies, and suggest further actions or investigations that may be needed to confirm conformance with dam safety requirements.
✓ List all records reviewed and location of records.

The initial methods of analysis used in the review, or the data available, may be insufficient to clearly demonstrate an acceptable level of safety for the dam, discharge facilities, or reservoir slopes. If additional work is needed to evaluate and document dam safety, the Dam Safety Review report should include recommendations for more extensive analysis or investigations to provide adequate data for analysis.

Therefore, the essential output of the safety review is one or more of the following conclusions:

✓ The dam clearly meets all safety requirements;

² For example see Appendix 5
The dam clearly does not meet some safety requirements (list the deficiencies or non-conformances and recommended actions);

It is uncertain whether or not some requirements are met (list the areas of doubt and the actions needed to reach a firm position.

It is the responsibility of the dam owner to review the Dam Safety Review Report and forward a copy to the BOAD Dam Safety Officer. This report is then reviewed for completeness and accuracy by the Dam Safety Officer.
APPENDIX
Appendix 1: Deficiencies and Non-Conformances Definition and Identification

1. Deficiencies:

1.1. Actual Deficiencies

1.1.1. Definition

An unacceptable dam performance condition which has been confirmed based on current dam safety standards and applied criteria. The two types of Actual Deficiencies include those under normal loads expected during the life time of the dam and those under unlikely loads that are not expected to occur.

1.1.2. Identification

Identification of an actual deficiency generally leads to an appropriate corrective action or directly to a capital improvement project:

- (An) Normal Load – Load which is expected to occur during the life of a dam;
- (Au) Unlikely Load – Load which could occur under unusual load (large earthquake or flood).

1.2. Potential Deficiencies

1.2.1. Definition

A potentially unacceptable performance condition which has not yet been confirmed. These potential deficiencies are separated into those which, upon a more detailed assessment, are expected to be confirmed as Actual deficiencies or those that are not including deficiencies which are difficult to prove.

1.2.2. Identification

There is a reason to expect that an unacceptable condition might exist, but has not been confirmed. Identification of a potential deficiency generally leads to a Deficiency Investigation:

- (Pn) Normal Load – Load which is expected to occur during the life of a dam.
- (Pu) Unlikely Load – Load which could occur under unusual load (large earthquake or flood)
- (Pq) Quick – Potential deficiency that cannot be confirmed but can be readily eliminated by a specific action.
✓ (Pd) Difficult - Potential deficiency that is difficult or impossible to prove or disprove.

2. Non-Conformances

2.1. Definition

While non-conformances are related to the subject item, but are not generally rated for prioritization and do not necessarily indicate unacceptable dam performance, a priority level has been provided in Appendix I. Non-conformances are generally identified for consideration to improvements of policies, procedures, operations, maintenance, or surveillance plan.

2.2. Identification

Established procedures, systems and instructions are not being followed, or, they are inadequate or inappropriate and should be revised.

✓ Operational (NCo);
✓ Maintenance (NCm)
✓ Surveillance (NCs)
✓ Information (NCi) – information is insufficient to confirm adequacy of dam or physical infrastructure for dam safety;
✓ Other Procedures (NCp) – other procedures, to be specified.
# Appendix 2: Sample Check Sheet for a Dam Safety Expectations

<table>
<thead>
<tr>
<th>DAM SAFETY EXPECTATIONS</th>
<th>Yes</th>
<th>N/A</th>
<th>No</th>
<th>Au/An</th>
<th>Pu/Pu</th>
<th>NCs/NCm/NCi/NCp</th>
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<tbody>
<tr>
<td>1 Dam Safety Analysis</td>
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<tr>
<td>1.1 Records relevant to dam safety are available including design documents, historical instrument readings, inspection and testing reports, operational records and investigation results.</td>
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<td>1.2 The Dam is classified appropriately in terms of the consequences of failure including life, environmental, cultural and third-party economic losses</td>
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<td>1.3 Inundation study adequate to determine consequence classification Flood and “sunny day” scenarios assessed</td>
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<td>1.4 Hazards external and internal to the dam have been defined</td>
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<td>1.5 The potential failure modes for the dam and the initial conditions downstream from the dam have been identified</td>
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<td>1.6 All other components of the water barrier (retaining walls, saddle dams, spillways, road embankments) are included in the dam safety management process</td>
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<td>1.7 The MDE selected reflects current seismic understanding</td>
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<td>1.8 The IDF is based on appropriate hydrological analyses</td>
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<td>1.9 The dam is safely capable of passing flows as required for all applicable loading conditions (normal, earthquake, flood)</td>
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<td>1.10 The dam has adequate freeboard for all applicable operating conditions (normal, earthquake, flood)</td>
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<td>1.11 The analyses are current</td>
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<td>1.12 The approach and exit channels of discharge facilities are adequately protected against erosion and free of any obstructions that could adversely affect the discharge capacity of the facilities</td>
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<td>1.13 The dams, abutments and foundations are not subject to unacceptable deformation or overstressing</td>
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<td>1.14 Adequate filter and drainage facilities are provided to intercept and control the maximum anticipated seepage and to prevent internal erosion</td>
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<td>1.15 Hydraulic gradients in the dams, abutments, foundations and along embedded structures are sufficiently low to prevent piping and instability</td>
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<td>1.16 Slopes of an embankment have adequate protection against erosion, seepage, traffic and burrowing animals</td>
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<td>1.17 Stability of reservoir slopes are evaluated under all conditions and unacceptable risk to public safety, the dam or its appurtenant structures is identified</td>
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<td>1.18 The need for reservoir evacuation or emergency drawdown capability as a dam safety risk control measure has been assessed</td>
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<tr>
<td>2 Operation, Maintenance and Surveillance</td>
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<td>2.1 Responsibilities and authorities are clearly delegated within the organization for all dam safety activities</td>
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<td>2.2 Requirements for the safe operation, maintenance and surveillance of the dam are documented with sufficient information in accordance with the impacts of operation and the consequences of dam failure</td>
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<td>2.3 The OMS Manual is reviewed and updated periodically when major changes to the structure, flow control equipment, operating conditions or company organizational structure and responsibilities have occurred</td>
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<tr>
<td><strong>DAM SAFETY EXPECTATIONS</strong></td>
<td><strong>Yes</strong></td>
<td><strong>N/A</strong></td>
<td><strong>No</strong></td>
<td><strong>An/Au</strong></td>
<td><strong>Pu/Pu/Pg/Pd</strong></td>
<td><strong>NCs</strong></td>
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<tr>
<td>2.4 Documented operating procedures for the dam and flow control equipment under normal, unusual and emergency conditions exist, are consistent with the OMS Manual and are followed</td>
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</table>

**Operation**

2.5 Critical discharge facilities are able to operate under all expected conditions

a. Flow control equipment are tested and are capable of operating as required
b. Normal and standby power sources, as well as local and remote controls, are tested
c. Testing is on a defined schedule and test results are documented and reviewed
d. Management of debris is carried out to ensure operability of discharge facilities

2.6 Operating procedures take into account:

a. Outflow from upstream dams
b. Reservoir levels and rates of drawdown
c. Reservoir control and discharge during an emergency
d. Reliable flood forecasting information
e. Operator safety

**Maintenance**

2.7 The particular maintenance needs of critical components or subsystems, such as flow control systems, power supply, backup power, civil structures, drainage, public safety and security measures and communications and other infrastructure have been identified

2.8 Maintenance procedures are documented and followed to ensure that the dam remains in a safe and operational condition

2.9 Maintenance activities are prioritized and carried out with due consideration to the consequences of failure, public safety and security

**Surveillance**

2.10 Documented surveillance procedures for the dam and reservoir are followed to provide early identification and to allow for timely mitigation of conditions that might affect dam safety

2.11 The surveillance program provides regular monitoring of dam performance, as follows:

a. Actual and expected performance are compared to identify deviations
b. Analysis of changes in performance, deviation from expected performance or the development of hazardous conditions
c. Reservoir operations are confirmed to be in compliance with dam safety requirements
d. Confirmation that adequate maintenance is being carried out

2.12 The surveillance program has adequate quality assurance to maintain the integrity of data, inspection information, dam safety recommendations, training and response to unusual conditions

2.13 The frequency of inspection and monitoring activities reflects the consequences of failure, dam condition and past performance, rapidity of development of potential failure modes, access constraints due to weather or the season, regulatory requirements and security needs.

2.14 Special inspections are undertaken following unusual events (if no unusual events then acknowledge that requirement to do so is documented in OMS).
2.15 Training is provided so that inspectors understand the importance of their role, the value of good documentation, and the means to carry out their responsibilities effectively.

2.16 Qualifications and training records of all individuals with responsibilities for dam safety activities are available and maintained.

2.17 Procedures document how often instruments are read and by whom, where the instrument readings will be stored, how they will be processed, how they will be analyzed, what threshold values or limits are acceptable for triggering follow-up actions, what the follow-up actions should be and what instrument maintenance and calibration are necessary.

3 Emergency Preparedness

3.1 An emergency management process is in place for the dam including emergency response procedures and emergency preparedness plans with a level of detail that is commensurate with the consequences of failure.

3.2 The emergency response procedures outline the steps that the operations staff is to follow in the event of an emergency at the dam.

3.3 Documentation clearly states, in order of priority, the key roles and responsibilities, as well as the required notifications and contact information.

3.4 The emergency response procedures cover the full range of flood management planning, normal operating procedures and surveillance procedures.

3.5 The emergency management process ensures that effective emergency preparedness procedures are in place for use by external response agencies with responsibilities for public safety within the floodplain.

3.6 Roles and responsibilities of the dam owner and response agencies are defined.

3.7 Inundation maps and critical flood information are appropriate and are available to downstream response agencies.

3.8 Exercises are carried out regularly to test the emergency procedures.

3.9 Staff are adequately trained in the emergency procedures.

3.10 Emergency plans are updated regularly and updated pages are distributed to all plan holders in a controlled manner.

4 Dam Safety Review

4.1 A safety review of the dam (“Dam Safety Review”) is carried out periodically based on the consequences of failure.

5 Dam Safety Management System

5.1 The dam safety management system for the dam is in place incorporating:

a. policies,
b. responsibilities,
c. plans and procedures including OMS, public safety and security,
d. documentation,
e. training and review,
f. prioritization and correction of deficiencies and non-conformances,
g. supporting infrastructure.

5.2 Deficiencies are documented, reviewed and resolved in a timely manner. Decisions are justified and documented.

5.3 Applicable regulations are met.
Appendix 3: Dam Safety Issues Database

<table>
<thead>
<tr>
<th>Issue</th>
<th>Type</th>
<th>Reference</th>
<th>Key Words</th>
<th>Description of Issue</th>
<th>Status</th>
<th>Recommendation</th>
<th>Draft Priority</th>
<th>Updates</th>
<th>Date</th>
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</table>


Appendix 4: Dam Safety Management System

- Dam safety policy

**Reporting**
- Period reporting to management and regulator

**Planning**
- Work program components
- Executive responsibilities
- Standards and procedures
- Resources
- Schedule

**Correctives Actions**
Follow-up to:
- Peer reviews and audits
- Incident investigation
- Deficiencies and non-conformances identified during Dam Safety Reviews, inspection, monitoring, equipment testing or emergency prepared tests

**Implementation**
- Operation
- Maintenance
- Surveillance
- Emergency preparedness

**Checking and Reviewing**
- Dam surveillance and Dam Safety Reviews
- Program peer reviews or review boards
- Program audits
- Incident investigations
- Testing of emergency preparedness

**Supporting Processes**
- Staff training and qualification
- Program communication
- Record keeping and management
## Appendix 5: Hazards and Failure Mode Matrix

<table>
<thead>
<tr>
<th>GLOBAL FAILURE MODES</th>
<th>ELEMENT AND/OR ELEMENT FUNCTION</th>
<th>MOST BASIC FUNCTIONAL FAILURE CHARACTERISTICS</th>
<th>External Hazards</th>
<th>Internal Hazards (Design, Construction, Maintenance, Operation)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Meteorological</td>
<td>Seismic</td>
</tr>
<tr>
<td>DAM COLLAPSE BY OVERTROPPING (erosion or overturning)</td>
<td>DAM COLLAPSE BY OVERTROPPING (erosion or overturning)</td>
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<td></td>
<td></td>
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<tr>
<td>Water elevation high</td>
<td>Inadequate installed discharge capacity</td>
<td>Meteorological &gt; buffer + outflow capacity</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Inadequate reservoir operation (rules not followed)</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Inadequate available discharge capacity</td>
<td>Random functional failure on demand</td>
<td>x</td>
<td>x</td>
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<tr>
<td></td>
<td>Discharge capacity not maintained</td>
<td></td>
<td>x</td>
<td>x</td>
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<tr>
<td></td>
<td>Inadequate freeboard</td>
<td>Excessive elevation due to landslide or U/S dam</td>
<td>x</td>
<td>x</td>
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<tr>
<td></td>
<td>Wind-wave dissipation inadequate</td>
<td></td>
<td>x</td>
<td>x</td>
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<tr>
<td>DAM COLLAPSE BY LOSS OF STRENGTH (External or Internal structural failure and weakening)</td>
<td>DAM COLLAPSE BY LOSS OF STRENGTH (External or Internal structural failure and weakening)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Water elevation too low</td>
<td>Stability under applied loads</td>
<td>Mass movement (external stability-displacement, tilting, seismic resistance)</td>
<td>x</td>
<td>x</td>
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<td></td>
<td>Loss of support (foundation or abutment failure)</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Watertightness</td>
<td>Seepage around interfaces (abutments, foundation, water stops)</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Through dam seepage control failure (fillets, drains, pumps)</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Durability/cracking</td>
<td>Structural weakening (Internal erosion, AAR, crushing, gradual strength loss)</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Instantaneous change of state (static liquefaction, hydraulic fracture, seismic cracking)</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>
REFERENCES

1. Dam Safety Review Guidelines, Dam safety Section, Vitoria, BC, November 2012
2. Federal Guidelines for Dam Safety, FEMA, April 2004;
4. Hazards and Failure Modes Matrix (Revision 8, 11-03-05)
5. Dam Safety Review Report Template – under development, contact Dam Safety Section, Victoria
8. Dams and the World’s Water, International Commission on Large Dams