

Queensland Dam Safety Management Guidelines

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1 Introduction

Currently, there are an estimated 300 referable dams in Queensland. These dams fulfil an important role in our society including water supply, hydroelectric power generation, process water management, flood control, sediment and water control and recreation.

The failure of these dams can have significant consequences ranging from loss of life or injury to economic loss and damage to property and the environment. Queensland has had a good dam safety record. However, continuing incidences of dam failures around the world highlight the need and importance of dam safety management programs.

In Queensland, under the *Water Act 2000* and common law, responsibility for the safety of a dam rests with the dam owner. Dam owners may be liable for loss and damage caused by the failure of a dam or the escape of water from a dam. Consequently, dam owners need to be committed to dam safety and have an effective dam safety management program. A dam safety management program is intended to minimise the risk of a dam failing and to protect life and property from the effects of such a failure should one occur.

1.1 Purpose

The aim of this guideline is to describe practices dealing with the construction and management of referable dams and assist dam owners to safely manage their dams and protect the community from dam failure.

It is to be used by:

- owners of referable dams
- operators of referable dams
- employees of referable dam owners and operators
- consultants for referable dam owners and operators.

This guideline outlines best practice in dam safety and is primarily advisory in nature. However, development permit conditions imposed on individual dams under the provisions of the *Water Act 2000* and the *Integrated Planning Act 1997*, may “call up” or reference relevant sections of these guidelines as a way of undertaking particular activities (eg preparing an emergency action plan). To assist users of these guidelines a brief overview of Queensland’s regulatory arrangements for referable water dams is given in section 3.

1.2 Scope

This guideline has been developed specifically for referable dams. However, it may be used by owners of dams which are not referable to develop a dam safety management program.

1.2.1 What is a referable dam?

A dam is referable if:

- a failure impact assessment is required to be carried out under the *Water Act 2000*, and
- that assessment states that the dam has or will have a Category 1 or Category 2 failure impact rating. And
- the chief executive has, under the *Water Act 2000*, accepted the assessment.

2

In addition, some dams may be made referable by:

- a regulation made under the *Water Act 2000*, or
- the transitional provisions in the *Water Act 2000*.

A failure impact assessment is required when a dam is or will be:

- more than 8 metres in height and have a storage capacity of more than 500 megalitres or
- more than 8 metres in height and have a storage capacity of more than 250 megalitres, and a catchment area that is more than 3 times the surface area of the dam at full supply level.

Additionally, the chief executive may give a dam owner a notice to have a dam failure impact assessed (regardless of its size), if the chief executive reasonably believes the dam will have, a Category 1 or Category 2 failure impact rating.

Referable dams are classified according to categories which are based on the population at risk if the dam fails.

Dams with a Category 1 failure impact rating have between 2 and 100 people at risk.

Dams with a Category 2 failure impact rating have over 100 people at risk.

If less than 2 people are at risk by the dam failing then the dam is not referable under the *Water Act 2000*.

The following are also not referable dams under the *Water Act 2000*:

- a dam containing, or a proposed dam that after its construction will contain, hazardous waste
- a weir, unless the weir has a variable flow control structure on its crest.

The following are not dams under the *Water Act 2000* and therefore cannot be referable dams:

- a rainwater tank
- a water tank constructed of steel or concrete or a combination of steel and concrete
- a water tank constructed of fibreglass plastic or similar material.

The Guidelines for Failure Impact Assessments of Water Dams published by the Department of Natural Resources and Mines (NR&M) provide additional information on undertaking a failure impact assessment to determine the population at risk for a dam.

1.2.2 Replacing old guidelines

This guideline comes into force with the commencement of the dam safety provisions of the *Water Act 2000*. This guideline replaces the 1994 guidelines known as the Queensland Dam Safety Management Guidelines 1994.

2 What is a Dam Safety Management Program?

A dam safety management program is a system that incorporates dam safety values as part of the culture of the organisation and the day-to-day operation of a referable dam. A dam safety management program comprises policies, procedures and investigations which minimises the risk of dam failure.

A dam safety management program includes:

- site investigation
- design
- construction
- operation and maintenance
- surveillance
- remedial action and modification
- abandonment and removal of dams.

Its benefits are that the:

- owner is aware that the dam complies with current engineering standards for safety
- owner is assured that the dam is operated in a safe manner
- owner has the condition of the dam assessed on a regular basis
- owner is prepared for an emergency situation at the dam
- risk of dam failure is minimised.

2.1 Documentation for a safety management program

A dam safety management program should ultimately result in six levels of documentation being available for each dam. These are:

1. Investigation, Design, and Construction Documentation including Data Book, Design Report and As-Constructed Details (or Construction Report)¹
2. Standing Operating Procedures (SOPs)
3. Detailed Operating and Maintenance Manuals (DOMMs)
4. Inspection and Evaluation Reports
5. Dam Safety Review Report ²
6. Emergency Action Plan (EAP).

Dam owners should securely store these documents.

Dam owners should ensure that each of the levels of documentation is identified for inspection and auditing purposes. The documentation could either be combined into a single document or left as groups of documents.

Details on the preparation of these documents and issues to be addressed are outlined in the following sections of this guideline.

- 1 ¹ Where appropriate. For example, the As-Constructed Details (or Construction Report) and Design Report for an older dam may not have been prepared or retained.
- 2 ² Where appropriate. For example, a new dam is unlikely to have had a safety review as these are generally undertaken every 20 years.

2.2 Training of personnel engaged in dam safety

Dam owners should ensure personnel engaged in dam safety related investigations and studies have adequate experience and training relevant to the type of dam and the facilities being managed.

Dam owners should ensure that the operating personnel involved in the day-to-day dam safety activities (as outlined in SOPs and EAPs) are experienced and/ or trained in aspects of operation of the owners dam.

Dam Owners should develop a program for keeping the skills of their dam operation staff up to date through training programs, courses and 'on the job' training.

2.3 Quality management of dam safety management programs

The Australian Standard for Quality Systems AS/NZS ISO 9001-3:1994 (Lam) [Quality Systems - Model for quality assurance in design, development, production, installation and servicing] can be used as a model for the quality assurance required for dam safety.

Developing and maintaining comprehensive documentation for a dam safety management program as described in these guidelines and quality management audits provide elements of a quality management system. Audit points should be identified within the dam safety management program to allow measurement of the effectiveness of the program and its components.

The dam owner, an internal auditor or a third party should conduct quality management audits on a systematic basis. When an internal auditor is used, it may be necessary to establish a management structure in which the dam safety functions are independent of the dam operator.

A quality management audit of documentation should establish:

- adequacy of the policies and the dam safety management program as a whole (systems audit)
- adequacy of the process and the necessary studies used to establish the documentation (process audit)
- adequacy of specific procedures, documentation or a specific investigation (validation audit).

Some of the specific issues, which should be examined in a quality management audit, include:

- the authority for performing activities
- allocation of responsibilities for particular activities
- actions to be undertaken and circumstances for such action.

3 Regulation of Referable Dams

Dam safety of referable dams is regulated to protect the community from dam failure. The chief executive of the Department of Natural Resources and Mines (NR&M) is responsible for regulating referable dams. Dams are regulated by the chief executive through:

- safety conditions imposed on referable dams under the *Water Act 2000* (which are partly based on the failure impact rating of the dam)
- development permits containing conditions imposed under the *Integrated Planning Act 1997*, issued to approve the development of a dam (which are partly based on the failure impact rating of the dam)
- auditing of compliance with dam safety conditions (ie safety conditions imposed under the *Water Act 2000* and development permit conditions imposed under the *Integrated Planning Act 1997*)
- emergency action provisions contained in the *Water Act 2000*.

3.1 Development permits

3.1.1 General

Dam safety conditions attach to development permits and incorporate requirements specific to each individual dam. The safety conditions must be relevant to, but not an unreasonable imposition on, the dam or reasonably required for the dam. Dam owners can appeal against dam safety conditions imposed or changed by the chief executive.

Part of the intention of these conditions is to ensure a dam owner develops a dam safety management program for their dam. These guidelines provide advice on how to develop a dam safety management program. Dam safety conditions may require a dam owner to develop specific plans, procedures and reports that will form part of the dam safety management program. If the specific plans, procedures and reports have already been developed by the dam owner (in accordance with these guidelines), those documents will generally be cited in the conditions for that dam.

For example, each dam will generally be issued with a dam safety condition dealing with Emergency Action Plans. Where a dam already has an Emergency Action Plan, the condition might state:

The current Emergency Action Plan for the dam is Document XX as updated from time to time.

The dam owner must provide one copy of the current Emergency Action Plan to the Chief Executive, Department of Natural Resources and Mines by date.

The contact details contained in the Emergency Action Plan must be reviewed prior to DATE each year.

The Emergency Action Plan must be reviewed at least every five years from (date).

The dam owner must ensure that the current (and changed?) Emergency Action Plan is provided to the following parties

- *Specific local government(s) eg Esk Shire Council*
- *Local counter disaster agencies affected by emergency events .eg Ipswich Counter Disaster Coordination Committee*
- *NR&M - Dam Safety*

- *Any additional group specific to this dam*

In all emergencies, the dam owner must respond in accordance with the Emergency Action Plan.

In the event of an emergency, the dam owner must also, within 7 days of the event, prepare an Emergency Event Report and provide a copy of the report to the Department of Natural Resources and Mines. .

The Emergency Event Report must contain:

- *a description of the event;*
- *instrumentation readings (where appropriate);*
- *description of any observed damage;*
- *photographs;*
- *details of communication which took place during the emergency; and*
- *comment on the adequacy of the EAP*
- *any recommendations or suggested changes to the EAP.*

3.1.2 New Dams and Works that Increase Storage Capacity

A development permit is an approval under the *Integrated Planning Act 1997* which allows “assessable development” to occur according to conditions stated in the permit. The construction of a new referable dam and carrying out work that will increase the storage capacity of a referable dam by more than 10% is “assessable development”. The chief executive has the power under *Integrated Planning Act 1997*, to impose and change dam safety conditions on development permits issued approving these types of development.

A development permit will attach to the land where the referable dam is located. This means it will bind:

- the current owner of the land
- future owners of that land
- any occupier of that land (eg a tenant).

A person wanting to construct a new referable dam under the *Water Act 2000* must apply for and obtain a development permit before starting construction. A dam owner must also obtain a development permit to carry out works that will increase the storage capacity of a referable dam by more than 10%, before that work commences. The *Water Act 2000* requires a development application for these types of assessable development to be supported by evidence that the chief executive has accepted a failure impact assessment of the dam.

Prior to submission of a development application, owners and their consultants should consult with officers of the Dam Safety Group in NR&M to discuss technical details of the development and potential dam safety conditions. The Dam Safety Group provides advice to the chief executive on dam safety conditions to be attached to development permits. Dam owners should ensure that they use relevant guidelines prepared by the chief executive when designing and constructing their dam.

Prior to construction of any referable dam, the chief executive will overview each proposal and may require changes to be made to the proposal prior to granting a dam development permit. Where conflicts of opinion exist, the chief executive may seek advice from independent experts before making a decision.

3.1.3 Development Permits for Existing dams

For existing licenced dams which are referable under the *Water Act 2000* the previous licences for the dams will be taken to be a development permit³ which has dam safety conditions attached. Dam safety conditions applied to this development permit for existing licenced dams will therefore initially originate from the dam's waterworks license under the *Water Resources Act 1989* (Qld). The chief executive also has the power under the *Water Act 2000* to impose and change additional safety conditions on the dams.

These safety conditions are taken to be development permit conditions for the purposes of enforcement.

For existing unlicenced dams, which are referable under the *Water Act 2000*, the chief executive will develop and apply safety conditions under the *Water Act 2000*.

The chief executive also has the power to change those safety conditions if satisfied changes should be made in the interests of dam safety. The safety conditions are taken to be development permit conditions for the purpose of enforcement.

3.2 Auditing

The chief executive, to identify shortfalls in a dam safety management program and areas of non-compliance, may carry out audits of compliance with development permit conditions.

There are two Acts in Queensland which deal with enforcement of dam safety. The *Water Act 2000* contains provisions to enable the chief executive to issue a compliance notice if that Act is contravened (eg fail to carry out a failure impact assessment when one is required). Additionally, as dam safety conditions are development permit conditions for the purpose of enforcement, penalties apply under the *Integrated Planning Act 1997* (Qld) for failing to comply with a development permit condition.

3.3 Emergency action provisions

The chief executive has the power to issue a direction to take emergency action under s.494 of the *Water Act 2000*. This notice is only issued if the chief executive is satisfied or reasonably believes that:

- there is a danger of the failure of the referable dam and
- action is necessary to prevent or minimise the impact of the failure.

If a person fails to comply with a notice without a reasonable excuse, action may be taken. The compliance provisions of the *Water Act 2000* will allow any person to bring an enforcement order proceeding in the District Court and seek a Court order forcing a person to comply with the notice.

In addition, the chief executive has power under the *Water Act 2000* to act to prevent or minimise the impact of a dam failure, if a notice is not complied with. The chief executive can recover any reasonable expenses incurred when taking such action and may also make the expenses incurred a charge on the land.

Emergency action notices also attach to the land where the referable dam is located, binding the owner of the land at the time it is issued and any future owners.

³ Defined under the *Integrated Planning Act 1997*.



4 Investigation, Design and Construction

4.1 Introduction

Dams engineering is not an exact science as it frequently involves uncertainties beyond prevailing knowledge. It relies heavily on mathematical principles, physical laws, experienced judgement and known safe practices.

Dam safety management requires that critical uncertainties are recognised, investigated and resolved to acceptable risk levels. Consequently, the investigation, design and construction phase of dams engineering plays an important role in dam safety.

At time of writing philosophies of risk assessment and management were starting to influence the design, management and operation of water dams throughout Australia. This guideline embraces those philosophies as far as they have been incorporated in published ANCOLD Guidelines. Dam owners are encouraged to utilise those philosophies to develop management and operation programs. However, this guideline will await broader dam community assessment of the methodologies before incorporating risk management as a recommended approach to management.

4.2 Issues concerning the dam owner

No two dams are the same. There are many issues including safety issues, which a dam owner should consider when developing a dam. Issues that are specific to dam safety include:

- the failure impact rating of the dam (that is whether the dam will have a Category 1 or Category 2 failure impact rating)
- the resources required to adequately address the technical issues associated with the investigation, design and construction of a dam
- the resources required to adequately manage the dam in a safe manner
- dam safety statutory requirements
- the consequences of potential dam failure.

Other issues, while possibly having dam safety implications, are primarily asset ownership issues. These include:

- environmental or downstream impacts which need to be considered
- the economic viability of the dam
- long-term maintenance management implications of dam ownership.

4.3 Consequence assessment

The regulation of referable dams under the *Water Act 2000* is based solely on the population at risk in the event of a dam failure. However, dam designers, on behalf of dam owners, may also wish to consider other potential consequences to determine design standards for a dam. These other consequences may include:

- economic loss of the asset
- commercial losses and social impacts
- impacts due to loss of water supply
- damage to property and infrastructure
- environmental damage.

If the owner wishes to take these factors into account he or she could undertake an assessment of the consequences of dam failure. A methodology for undertaking a consequence assessment can be found in the Australian National Committee on Large Dams (ANCOLD) Guidelines on the Assessment of the Consequences of Dam Failure.

The effort and resources a dam owner should put into a dam safety management program and the scope of the program is related to the consequences of the failure of a dam on life and property, as well as the complexity and novelty of the dam.

Some of the more common scenarios to be considered in consequence assessments include:

- dam break - the uncontrolled release of pondage for 'sunny day' conditions and a range of flood events
- remote floods - flood surges well downstream of dam which can coincide with storage release
- upstream floods - backwater effects of the dam during floods
- water supply loss - failure of pumps, outlet facilities, reservoir pollution etc
- operational problems - accidental opening of flood gates, equipment malfunction etc.

A consequence assessment should provide a profile of the potential damage of dam failure. In cases where failure does not impact on population and is of economic consequence only to the owner, a case may exist for a minimal dam safety management program. In contrast, where the potential for substantial damage costs exist and significant impact on others is likely, dam safety management should be more rigorous.

Dam owners should periodically review the consequence assessment to monitor any change in circumstances such as development downstream. Such developments can make non-referrable dams 'referable' and can cause changes to the required design standards.

4.4 Investigation

Many investigations are undertaken when developing a dam. Most focus on comparing alternate sites and determining the viability of a particular site, rather than focussing on dam safety issues. Examples of these investigations include:

- economic assessment of a dam, including water pricing studies
- land use studies
- impact assessment studies, including social, cultural heritage, and environmental studies.

Two areas of investigation predominantly relate to dam safety issues. These are:

4.4.1 Geological and geotechnical investigations

These include geological and geotechnical assessments of the site and materials. They are generally carried out in stages ranging from broad scoping levels to more detailed investigations depending on the findings of each stage. Each stage should be thoroughly planned to ensure that all matters, which may affect dam safety, are identified, investigated and appropriately resolved by the designer.

Investigations should not be limited to the dam site alone. The geology, topography and the depth of water held in the storage area should be considered. This ensures that major leakages, slope instabilities and significant reservoir-induced seismic activities, which may jeopardise the safety of the dam, are considered in the design.

All work undertaken in the geological and geotechnical investigation stage should be properly recorded and presented in a comprehensive report. This will enable the designer to define the extent of any further work required prior to finalising the design. Investigations are generally on going through the construction period as the foundations become fully exposed or the extent of any foundation work, such as grouting, is recognised. Consequently, investigative reports need to be updated and amended as construction proceeds. When construction is complete, a full and comprehensive report should be available as a reference for on-going surveillance of the dam and subsequent safety reviews.

4.4.2 Hydrological investigations

A suite of hydrological investigations should be undertaken to develop dam safety data for the proposed dam. These hydrological investigations, which are independent of yield hydrology⁴, involve:

- developing an appropriate run-off model for the catchment
- calibrating this run-off model with historical flood data where possible
- assessing any operating limitations and criteria, which are to apply to spillway discharges
- assessing the consequences of potential failure of the dam:
 - particularly the population at risk - see NR&M Guidelines for Failure Impact Assessment of Water Dams
 - for best practice purposes to determine other consequences of failure (eg economic and environmental costs) using the ANCOLD Guidelines on Assessment of the Consequences of a Dam Failure (May 2000) if appropriate
 - determining the spillway design standard, spillway design flood and, if the spillway is a gated structure, determining any operating rules which are to be applied.

All work (including documentation of mathematical models) undertaken in hydrological investigations should be properly documented and presented in a comprehensive report. This will enable the designer to finalise the design and will assist subsequent reviews of this aspect of the design.

⁴ Yield hydrology is a major issue for the dam owner but has minor significance to dam safety.

4.5 Design

4.5.1 General

Factors which should be considered during the design of a dam, include:

1. Physical characteristics

- dam type
- location and alignment
- size and shape
- appurtenant works.

2. Geotechnical information

- material properties and availability
- foundation properties and treatment
- geological characteristics
- seismic loadings.

3. Hydraulic aspects

- type of spillway, means of flow control and energy dissipation
- hydrological characteristics
- hydraulic design and water loadings
- stream diversion requirements
- flood mitigation capacity.

4. Stability

- structural capacity of principle elements

5. Construction methods and sequencing

- including watercourse diversion requirements during construction

6. Operational aspects

- operational complexity and reliability
- requirements for ongoing monitoring
- technical capability and availability of operations personnel.

7. Environmental aspects

- environmental impacts including the effects of storage and barriers
- effect on upstream and downstream areas
- magnitude of downstream releases.

4.5.2 Specific Design Requirements

While the way in which these aspects are applied to a particular dam depends on its dam failure impact rating, size, importance, complexity and consequences of a dam failure, the key principles are:

- all dams structures should be designed to suit the loads to be applied to them in accordance with:
 - ANCOLD guidelines
 - relevant Australian Standards
 - notices (compliance and information) issued from time to time by the chief executive
 - generally accepted engineering practices

- in particular, dams must be able to withstand seismic loadings, flood loadings, normal operating loadings, construction loadings, post construction loadings.
- the regional and site geology must be understood and engineering geology models developed to form the basis for design
- the foundations must be capable of supporting the dam structure and controlling seepage
- the reservoir basin and rim must be sufficiently impermeable to prevent excessive losses of water (Any seepage must be controlled and instability must not occur at any stage of reservoir operation.)
- construction materials must be identified to meet site and design requirements
- the spillway size must be established on the basis of accepted engineering standards–ANCOLD Guidelines on Selection of Acceptable Flood Capacity for Dams, 2000 (Hydrological and meteorological information used in the design must be appropriate for the dam locality and dam use)
- the cut-off design must be established on the basis of the loadings, strength of the available materials and the need to control the seepage (For embankment dams, the designer must incorporate adequate lines of defence including properly designed drains and properly designed filters to ensure the long-term integrity of the seepage control system)
- the outlet works must meet the requirements for the reservoir operation and must have provisions for safe operation and maintenance
- provision must be made for the long-term monitoring of the structural performance of the dam and its components
- an appropriate dam safety management program must be developed and adhered to through the investigation, design and construction processes to ensure all matters are properly attended to and adequately recorded.

Some of these factors may have a direct impact on dam safety, while others may have an indirect impact. The dam designer should be a registered professional engineer, highly experienced and with a good knowledge and understanding of dams. In some cases, dam owners may want to establish a review board of experts to provide guidance on the design of the dam. For large projects, dam owners may wish to engage a project design engineer who is assigned technical coordination responsibility for the dam during its design and construction.

These factors influence the construction cost of a dam. The designer should develop a design, which meets accepted safety standards and the needs of the owner (including budget). The designer should be aware of new technology and methods being adopted elsewhere, which may provide cost savings. Such savings should be critically evaluated in terms of possible long-term costs, which may occur should safety and operational problems be experienced with the dam. The more that is known about the site conditions and foundation materials the less conservative the design has to be, resulting in lower construction costs.

The designer should establish specific onsite construction and operational inspection programs for review by appropriate design personnel and technical specialists. These programs should include frequent inspections during construction to confirm that site conditions conform to those assumed for design or to determine if design changes may be required to suit the actual conditions. A major requirement is inspection and approval by the dam designer of the dam foundation and foundation treatment before the placing of dam materials. The final design inspection of the construction should include a complete review of the surveillance undertaken and testing of any operating equipment.

The designer should determine surveillance requirements for the dam including:

- inspections - operational design inspections should continue throughout the life of the project, in accordance with a formal inspection program covering all project features. The inspection program should meet the regulatory requirements specified in the dam safety conditions in the development permit



- instrumentation - as part of the surveillance requirements, there may be a need for instrumentation (eg settlement and foundation pressure). The designer should identify the need for, and position of instrumentation and include a schedule for timely reading, collecting, reducing, and interpreting the data. The design should include an advance determination of critical instrument observations or rates of data change and a plan of action if observations indicate a critical condition may occur. These critical instrumentation figures should be based on the design assumptions.

4.6 Construction

The supervising constructing engineer(s) should be experienced in dams engineering and be able to detect when variations to specified procedures are necessary, or when special attention is required in relation to:

- foundation treatment
- material selection and placement
- material manufacture (eg filters)
- material testing
- stream diversion
- concrete manufacture
- construction equipment selection
- other issues which can affect the safety of the dam.

The constructing engineer should have:

- a comprehensive understanding of the design
- responsibility for technical coordination between design and construction engineers
- responsibility for managing the construction staff to assure compliance with specifications.

One of the most important aspects of dam construction is the foundation inspection. It is seldom possible to fully identify all the characteristics of the foundations of a dam during the investigation stage. Once the foundations have been fully exposed and prepared, there may be a need to amend the design requirements. Inspections by the designer are necessary to confirm any amendments. If unanticipated conditions such as geological features are encountered, the designer must be involved in determining appropriate design changes.

Regular site visits and inspections by the designer and review engineers (where appropriate) are recommended.

4.7 Design and construction documentation

4.7.1 Data Book

Dam owners should compile and maintain a Data Book. A Data Book is a convenient source of information summarising all pertinent records and history. It should encompass the documentation of investigation, design, construction, operation, maintenance, surveillance, remedial action as well as monitoring measurements. A Data Book may be large and consist of several documents eg drawings, electronic data files and printed reports or smaller depending on the type and complexity of the dam.

4.7.1.1 Data Book Checklist

Data Books should include the following information:

General

Table of Contents

Background Information

- Statistical Summary of the main features of the dam
- Aerial Photograph of the Dam (if available)
- Historical Events (prior to construction, during construction and subsequent operation)
- Record of incidents at the dam
- Relevant Correspondence

Geological Information

- Regional Information
- Site Information
- Seismicity
- Relevant Correspondence

Hydrologic Information

- Design Floods
- Current Inflow Design Flood
- Relevant Correspondence
- Failure Impact Assessment
- Consequence Assessment

Foundation Information

- Description
- Design and Analysis
- Treatments
- Construction Records, Changes, and Modifications
- Instrumentation
- Known deficiencies (eg seepage, etc)
- Relevant Correspondence

Dam Structure

- Description
- Design and Analysis
- Treatments
- Construction Materials
- Construction records, changes, and modifications
- Instrumentation
- Deficiencies (eg cracking, etc)
- Relevant Correspondence
- as constructed drawings

Other Features -Spillway, Outlet Works, Mechanical Systems

- Description
- Design and Analysis
- Details of relevant control systems and operating principles
- as constructed drawings



4.7.2 Design Report

On most projects, a Design Report should be compiled once the design and construction stages are completed. However, on major projects, this may have to be staged. The designer should document the design and construction of the dam including:

- Designer's Operating Criteria (DOC), eg gate operating rules and cone valve operation protocols
- design parameters adopted and assumptions made (and their bases)
- methods of analyses
- results of analyses and investigations (numerical and physical)
- hydraulic model testing of final spillway arrangements
- complete set of drawings and specifications
- summary of As-Constructed documentation and other construction information (see 4.7.3).

The Design Report must contain sufficient information so that in the event of any safety problems relating to the dam, information can be quickly and easily obtained to resolve the problem.

When preparing a design report, the designer should consult the checklist of dam technology issues included as Appendix 3 - Checklist of Dam Technology Issues.

4.7.3 As-Constructed documentation

The constructing engineer should provide a complete record of the construction to assist in determining solutions to any safety problem, which may arise during the life of the dam. As a minimum, this record should include:

- decisions to adapt the design to actual field conditions
- as-constructed drawings indicating the actual lines, levels and dimensions to which the structure is built
- construction processes
- systematically compiled and comprehensive photographs and, where appropriate, videos of the construction, with particular coverage of significant events which include:
 - foundation treatment
 - material preparation and placement
 - filters, cut-offs
 - core materials
 - joint preparation
- foundation surface mapping of rock defects
- material test results and comparison with assumed design parameters
- instrumentation data including precise instrument locations and initial instrument readings
- construction inspection reports.

The As-Constructed documentation should be summarised and either incorporated into the Design Report or produced as a separate Construction Report.

5 Operations and Maintenance

5.1 Introduction

Proper operation and maintenance is essential for the continued viability and safety of a dam and its associated structures. Improper operation of a dam may result in dam failure, and poor maintenance can result in abnormal deterioration of the dam, reduced life expectancy of the dam and increase the possibility of dam failure.

Dam owners should have in place an operation and maintenance program, which is described by the following documentation:

- Standing Operating Procedures
- Detailed Operating and Maintenance Manuals
- Recording and Work Assignment system.

5.2 Standing Operating Procedures

Dams are normally designed to operate within a range of operating criteria. A good dam safety management program will ensure that:

- these operating criteria are known
- the dam is operated within these criteria
- the dam is maintained so that it can perform within the established criteria.

This should be done through Standard Operating Procedures (SOPs). These procedures should:

- define responsibilities for actions critical to the safety of the dam
- identify procedures for particular daily activities, which ensure that these activities are done safely, in the same way each time and in accordance with development permit conditions
- ensure appropriate people are notified when unforeseen or unusual events occur.

Dam owners should ensure they operate their dam in accordance with the SOPs.

SOPs are beneficial as they provide information on procedures for a dam (including responsibilities and timings). They help to:

- ensure long term adherence to operating procedures and across changes in ownership and operating personnel
- ensure that a task is completed in the correct, repeatable manner. They reduce the probability of dam threatening situations by providing operating protocols for personnel to follow. Examples of situations, which may be avoided by using appropriate SOPs, include:
 - 'out of date' procedures being applied to activities such that the dam is not operated in the manner expected by others
 - problems not being fixed because dam safety inspections are not performed or are not carried out by appropriate people
 - critical equipment not being checked so that it is not operational when needed
 - the incorrect operation of flood mitigation dams which may result in decreased flood mitigation capability or the amplification or extension of flooding
 - failure to open gated spillways at the appropriate time, which can cause overtopping of the gates and subsequent failure of the dam
 - failure to close gated spillways or outlet works which may empty a reservoir.

SOPs provide documentation of the way in which various tasks are performed and provide a permanent record of actions taken to operate the dam. If action results in an undesirable outcome, SOPs may assist in determining the reason and amendments can be made to the SOP. SOPs enable reviews of an organisation's operations to improve efficiency.

Dam owners should develop SOPs for their dam and operate the dam in accordance with these SOPs. This guideline concentrates on those SOPs, which deal with dam safety issues such as:

- personnel training and procedural issues
- emergency action and incident reporting
- critical operating procedures
- monitoring and surveillance.

When developing SOPs, a dam owner should consider issues, which may affect the complexity of the SOPs including:

- the complexity of dam operations (The more complex the operation is, the more detailed and comprehensive the SOPs should be. For example, detailed SOPs will be required for a dam with a spillway, which is controlled by large, high capacity gates, which could release damaging flood flows downstream in the event of maloperation.)
- degree of backup required
- complexity of spillway arrangements
- simplicity of flow release regimes.

The location of SOPs is critical to their effectiveness. At least one copy of the SOPs should be located where dam operations are controlled and operational decisions are made. This is particularly important for structures with variable flow control.

In addition, to ensure that SOPs remain effective over time, dam owners should ensure each SOP is reviewed annually.

5.2.1 Developing SOPs

There are a number of tests that can be applied to determine whether a SOP needs to be developed for a task. Before writing a procedure for a task, you should consider what the consequences would be if the task was performed incorrectly. That is:

- What costs would be incurred as a result of the task being performed incorrectly?
- What resources would be required to remedy the situation?
- What time would it take to remedy the situation?
- What are the safety implications?
- What are the environmental implications?
- If today was my first day in the job, would I know:
 - Enough about the organisation and its different functional areas to perform the required tasks?
 - With whom I should communicate and what inputs I need, where they come from, how I access them, and whether I need someone's assistance?
 - What to do with the output of my job and to whom I should direct it?
- If the adverse consequences of performing the task incorrectly are minimal, the task may not need to be documented.

5.2.1.1 Comprehensive Checklist of SOPs

Not all of the following SOPs will be applicable to each dam. The requirement for individual SOPs needs to be decided case-by-case. Where applicable, SOPs should be prepared to deal with the following issues.

ISSUE	REASON FOR INCLUSION
Personnel Training and Procedural Issues	
Operator Training	To ensure suitably qualified and experienced people are available to operate the dam
Documentation control and review	To ensure SOPs and other controlled documents are properly updated and only the current version of the procedures is used for dam operations
Undertaking of a Failure Impact Assessment every five years	For compliance with the requirements of the <i>Water Act 2000</i>
Setting of Normal Operation Criteria	To ensure the dam is operated and maintained in accordance with known operating limits eg gate operating limits or restricted FSL's due to stability limits
Emergency Action and Incident Reporting	
Accident and Incident Reports	To ensure incidents which may affect dam safety are documented so that they can be considered in future inspections and safety reviews
Emergency Action Plan (EAPs)	Liaison with affected population, local government and counter disaster organisations
Verification of Emergency Contact Numbers	To ensure EAPs are kept up to date and ready for use
Communication procedures and procedures covering the Loss of Communication during an Emergency Event	To ensure adequate triggering of Emergency Action Plans and to ensure dams are operated properly when communications are restricted
Attendance at dam	To address levels of attendance corresponding to operational states of the dam

ISSUE	REASON FOR INCLUSION
Critical Operating Procedures	
Test operation of critical equipment	To reduce the risk of the equipment not operating as planned. Such a procedure should provide for: <ul style="list-style-type: none"> • an annual pattern of test operation of gates or other crest control devices⁵ • regular testing of backup power supplies • regular testing of sump pumps • regular testing of communications
Pump operation plan for water harvesting that includes monitoring	To minimise the risk of overtopping of the dam through over-pumping
Notification of Spillway Discharge	To ensure emergency planners are aware of significant spillway discharges during flood events
Spillway Gate flood operations including: <ul style="list-style-type: none"> • water level monitoring procedures • discharge Control and flood release protocols including monitoring and warning of areas of impact prior to releases (for campers etc) as required in the Emergency Action Plan • coordination of releases with other dams or downstream tributaries (where appropriate) • communication security and failsafe procedures 	To ensure spillway operations proceed in accordance with agreed procedures which maximise the safety of the dam and minimise disruption to flood affected communities
Bulkhead Gate Installation, Penstock drainage, Trash screen removal and installation	To ensure the safety of operations and maintenance personnel
Confined Space Access	To maximise the safety of people in and around the dam
Monitoring and Surveillance	
Water level monitoring procedures and the monitoring of inflow events	To ensure dam hydrology and spillway performance can be reviewed
Instrumentation surveillance and data recording	To ensure monitoring and surveillance is carried out and the data are rapidly analysed and reviewed
Owners routine dam safety inspection including checklists and reporting requirements	To ensure routine dam safety inspections are carried out consistently and to appropriate standards

5 This SOP must include cracking gate under full load, and raising and lowering gate under no load over full travel

ISSUE	REASON FOR INCLUSION
Monitoring and Surveillance (continued)	
Dam Safety Annual inspections (if annual inspections are required by development permit conditions)	To ensure the inspections are carried out consistently and to appropriate standards
Dam Safety 5 yearly comprehensive inspection (if required by development permit conditions)	To ensure the inspections are carried out consistently and to appropriate standards
Requirement for inspection during and after flood events and after seismic events	To ensure the emergency action plan and any remedial works are triggered during and after such events
Inspection, testing and maintenance of mechanical and electrical equipment	To ensure mechanical equipment can be operated as designed whenever necessary
Log Book	
Maintenance of Dam Log Book	To ensure operations and maintenance activity and associated decisions are recorded
<p>Log book should include major events such as:</p> <ul style="list-style-type: none"> • equipment testing • major planned and unplanned maintenance and special one off jobs at the dam • testing of gate functions • painting programs • flood discharges and reservoir levels • incident details • reports dispatched and received • notification of receipt of changes to documentation (eg SOPs) 	To record major and exceptional events and conformance with procedure

5.2.2 SOPs Checklist

The following comments are suggested to assist in the preparation of SOPs:

- Preliminary pages of the combined SOPs should include:
 - cover sheet
 - title page
 - table of contents
 - revision sheet
 - any necessary certification and/or verification required by the dam owner
 - an aerial photo of the dam if possible.
- In terms of formatting, it is recommended to:
 - bind SOPs in loose-leaf folder so that it is easy to make revisions, additions and updates
 - start each procedure on a new page
 - use a standardised format for each procedure
 - the title of each procedure should be short and adequately identify the task
 - use lists rather than narration to outline instructions and information whenever possible.
- All areas of responsibility in the administration, operation and maintenance of the dam should be clearly indicated in the SOPs. Some of the operational aspects of dam ownership and operation that should be addressed include:
 - operation of equipment at the dam
 - reservoir inflow and flood forecasting
 - authorising spillway flood releases
 - authorising irrigation releases
 - recording reservoir data
 - routine inspection
 - maintenance
 - modification
 - correct method of opening and closing guard gates
 - dam safety and surveillance.
- The operating personnel responsibilities should be specifically identified and should include regularly scheduled duties personnel are required to perform.
- Administrative and operational relationships between the various operating and end user organisations should be detailed. (Both formal and informal agreements should be referenced.)
- Organisational arrangements in the form of flow charts can be beneficial. For example, agreements on allocation of responsibility for operation.
- Write procedures clearly and concisely. Avoid using vague words (for instance use a specific word such as “annually” rather than the word “periodically”).
- Each procedure should identify the step-by-step actions or groups of actions in sufficient detail to describe the task in a logical manner.
- Where appropriate, include drawings, sketches, graphs, manufacturer’s instructions, photographs etc in appendix or text to increase understanding.
- Where appropriate, if a SOP requires a form or forms to be filled out to confirm that a task described in the SOP was undertaken copies of the form should be appended to the SOP.
- Where appropriate, the use of drawings, marked photographs, colour coding and numbering of valves and switches are recommended to supplement step-by-step operation or maintenance instructions. These aids simplify instructions and reduce the chance of error in their use.

5.2.3 Level of Attendance

The owner should ensure that the level of operator attendance for the dam is appropriate for the failure impact rating of the dam as well as the:

- consequences of the dam failure
- proximity of the population at risk and the available warning time
- remoteness of the dam and ease of access during flood events
- reliability of remote sensing and transmission of warning trigger data to offsite control centres
- availability of backup operations personnel
- other activities conducted at or near the dam by the dam operator
- need to trigger Emergency Action Plans
- complexity of gate operations and associated need for skilled operators
- preparedness of operations staff
- inspection post seismic or flood events compared with monitoring as flood event evolves.

For example, the level of attendance for a particular dam with a Category 1 failure impact rating which has simple operating requirements, a distant population at risk and a long warning time, may involve regular visits and inspections (eg daily visits and inspections). In contrast, a dam with a Category 2 failure impact rating with complex operating requirements and a high population at risk in close proximity, may require qualified dam operators in residence and/or an appropriate electronic surveillance, control and communication system. The reliability of electronic systems should be considered in determining the level of attendance during flood events.

Further, a dam owner may wish to assign the operation of a dam to a nominated operator (the dam owner still retains responsibility for dam safety). If this occurs, the dam owner should ensure the nominated operator:

- is aware of the potential damage which could result from the different modes of failure relevant to the dam
- is aware of the Designers Operating Criteria and what constitutes an abnormality
- operates the dam in accordance with SOPs
- participates in dam safety inspections and the surveillance program
- is empowered to initiate Emergency Action Plans should the need arise
- is empowered to communicate directly with the relevant parties (eg advise chief executive of NR&M) should there be a need to operate the dam outside a SOP.

5.3 Detailed Operating and Maintenance Manuals

While a SOP outlines the protocols for operation of a system in the dam (eg water releases by gate operation), Detailed Operations and Maintenance Manuals (DOMMs) address how to operate, maintain and overhaul individual pieces of equipment for a dam and its associated structures (eg the operation, maintenance and replacement of valves and motors for the gates). The dam owner should operate and maintain the dam in accordance with the DOMMs.

The DOMMs are important as equipment, which is operated or maintained in an incorrect or inappropriate manner, can affect the safety of a dam. Significant work should not commence on equipment for a dam and its associated structures without proper authorisation from the dam owner.

The information in the DOMMs should be complete, accurate and up to date and cover all facilities and equipment. Further, for those issues which are critical to the safety of the dam, the dam owner should ensure the DOMMs are reviewed annually so that the manuals remain accurate and up to date.



The manuals should contain the following:

- Work Instructions, which detail the way in which equipment should be operated and outline the steps involved in performing a task. For example, a work instruction may be developed for the use of the gantry crane for placement of bulkheads gates.
- Maintenance Schedules, which detail the asset, description of task, frequency of maintenance and special requirements for servicing and maintaining the equipment. For example, a maintenance schedule should be developed for maintaining and servicing all mechanical and electrical equipment.
- Equipment data sheets or Manufacturer's Manuals, which comprise technical information needed for maintenance, repair and overhaul of equipment. For example, an equipment data sheet or manufacturer's manual should exist for the operation, maintenance, repair and overhaul for the emergency generating set.

Dam owners should ensure that DOMMs developed for their dam reflect the operating complexity, location of the dam and distribution of responsibilities between maintenance and operational personnel. The DOMMs should be located on site at the dam at least for day-to-day use. For procurement and administrative reasons, it may be advisable to hold a second copy in the dam owner's office. This is particularly important for structures with variable flow control.

The DOMMs or at least their drafts should be available prior to the initial filling of the reservoir.

5.4 Recording and Work Assignment system

The Recording and Work Assignment system issues detailed work orders for operational staff (and others such as consultants) and records the outcomes of the order. Work orders originate from requirements of the SOPs and DOMMs. These work orders set out who is responsible for work, supervising responsibilities, recording details of the work and the date of the work. Dam owners should have a Recording and Work Assignment system which is capable of issuing and tracking work orders.

The Recording and Work Assignment system can consist of:

- checklists
- logs
- card files
- computerised systems.

This system plays an important role in verifying work undertaken on the dam for dam safety purposes.

6 Surveillance

6.1 Introduction

Surveillance is the continual examination of the physical condition and operation of a dam. Surveillance programs should be capable of detecting problems or unsafe conditions at an early stage so that corrective measures can be taken and dam safety is not compromised. To obtain a historical context for defects, surveillance should commence as early in the life of the dam as possible to detect the development of any problem or unsafe trends and to provide full background information on a dam's performance.

A dam safety management program begins with the initial investigation of the dam foundation and continues through its design, construction and operation. While many problems may occur and need to be overcome during these phases, there is always a risk that not all problems have manifested themselves or been detected by the time the dam has reached its operational phase.

Any unusual behaviour, regardless of how seemingly insignificant, should be identified and recorded because this may be the forewarning of a newly developed unsafe condition.

The causes and processes of dam failure are varied and the knowledge gained from previous dam failures has contributed to the advancement of specialised knowledge essential to the prevention of further failures. Case histories of dam incidents reveal many remarkable similarities in antecedent conditions and processes of deterioration.

Each dam should have its own surveillance program. The scope of a surveillance program should be appropriate to the size of the dam and storage, the population at risk and other consequences of dam failure, the level of risk at the dam, and the value of the dam to the owner.

A surveillance program should include:

- monitoring of instrumentation
- collection of information or data relating to dam performance (eg investigation, design and construction reports)
- evaluation and interpretation of the data
- a range of inspections, from routine inspections by operational staff through to comprehensive inspections by engineers.

Each of these is considered in more detail in the following sections.

Experienced dams engineers should be consulted on the nature and extent of suitable surveillance programs. Generally, larger more complex structures with novel design features require more detailed and comprehensive surveillance programs. These should be instigated during the design and construction phases and in response to emergent problems.

6.2 Monitoring

Monitoring is the collection, presentation and evaluation of information from measuring devices installed at or near dams. Monitoring is needed:

- to detect deterioration in performance of the dam
- to detect trends or behaviour to establish compliance with design expectations (If the trends

indicate non-compliance with design expectations, remedial action should be initiated.)

- to rectify dam design issues which could not be resolved to high reliability during the design and construction stages (Such issues can only be addressed with a monitoring strategy, which can substantiate design expectations by establishing a correlation with actual behaviour. Some behaviour responds slowly over many years while some may not become evident for many years.)

The designer, review engineer, or inspection engineer should identify the issues that need to be monitored and incorporate appropriate instrumentation into the dam. For instance, for a farm dam, it may be concluded that there is no need for any instrumentation. Forms of monitoring include:

- deformation surveys
- water level measurements (including rainfall)
- seepage and pore pressure measurements
- measurements to confirm design parameters
- foundation pressure management
- stresses in embankments or structural components
- spillway performance and condition
- monitoring of deficiencies (eg cracking or erosion)
- seismic monitoring
- level of surveillance data.

The preferred frequency of monitoring varies over time. Factors influencing the frequency of monitoring include:

- the consequences of a dam failure
- the nature of the behaviour being monitored
- the stage of maturity of the dam (eg monitoring should be more intense during the construction and initial filling stages than during the operational phase)
- the existence of any problems or events (eg special events, such as record floods and earthquakes, will require more intense monitoring).

Dam owners should ensure that dam monitoring programs are reliably executed and that all instrumentation is maintained in a reliable condition and provides accurate readings throughout the life of the dam. Instrumentation available varies according to complexity, robustness and cost. Regardless of the instruments used, the dam owner must be able to ensure that the appropriate standard of monitoring is achieved.

The designer of the dam should determine the monitoring program, instrumentation used and frequency of observations initially in the design and construction phase. Dam owners should have a dams engineer review the appropriateness of the monitoring program, the instrumentation used and the frequency of observation as part of each comprehensive dam safety inspection. Instrumentation may need to be retrofitted if potential problems are identified.

There may be potential for remote monitoring and automation of data collection. However, malfunctions of remote monitoring and automatic data gathering during times of extreme weather conditions suggest that careful consideration be given to the reliability of such systems, especially when some form of operational control relies upon the monitoring. Owners should ensure that backup facilities are available for checking remote monitoring and accessing operational data for the dam during critical periods.

As the design and installation of instrumentation systems is a specialised area of dams engineering, dam owners should engage engineers experienced in this field.

The inclusion of accelerometers in dams in cooperation with wider seismic networks (state or national)

should be considered. This is important in seismically active areas or for large dams where reservoir induced seismicity could occur. Interpretation of data and maintenance of systems should be undertaken by a seismologist.

6.3 Data collection and management

Dam owners are responsible for the collection, storage and presentation of all data associated with the operation and maintenance of a dam. There are two types of data:

- Static data does not change with time. Such data will normally be stored in the data books, dam safety reviews and reports. Static data usually encompasses all design and construction investigations, including the Designers Operating Criteria. Much of this information is found in the Design Report and As-Constructed documentation.

As much of the static data will never be changed, it may be reduced and stored on microfilm or some electronic storage medium. Sufficient, easily accessible information should be kept on hand in Data Books to provide information for any situations which could arise.

- Dynamic data changes with time. It includes data derived from dam safety surveillance, monitoring, operations and maintenance activities. This data is accumulated in the Dam Safety Inspection and Surveillance Reports. Much of the dynamic data is suitable for computer storage and presentation, particularly that arising from monitoring.

For data collection and management purposes, dam owners should be aware of:

- the strengths and limitations of computer storage and retrieval systems (eg ease of access for retrieval of information)
- issues associated with compatibility of computer systems.

Dam owners should ensure that the system used to collect and process the data has facilities to detect the occurrence of “obviously different” data, which can be caused by:

- data recording and transfer errors
- instrumentation malfunction
- abnormal behaviour of the dam.

These situations should be investigated immediately. If the change is attributed to abnormal behaviour, the owner should initiate further investigations to explain the abnormality and ensure that it is not indicative of a worsening dam safety situation. These abnormalities can be a trigger for remedial action.

6.4 Surveillance evaluation

Not all dam deficiencies can be detected by visual inspections. There are many cases where an analysis of surveillance data has detected problems not evident by other means. Surveillance evaluation is an assessment of the safety of a dam in terms of its condition and operation based on data obtained from dam safety inspections and monitoring.

Data is accumulated during the course of surveillance, monitoring and operation of a dam. For ease of understanding, it may be beneficial to reduce this data into graphical form. Dam owners should ensure this data is evaluated on a regular basis to monitor the continued safety of each dam. Data evaluation should be assigned to an experienced dams engineer who should make recommendations based upon their interpretations.

Some examples of how areas of dam performance are considered in a surveillance evaluation include:



- assessment of the available pressure, movement and seepage monitoring data by analysis of the impact (if any) of all monitoring results
- assessment of the seepage from the storage (A plan should be provided showing position, quantity and quality of seepage.)
- the recent movement survey for the dam
- the foundation and embankment pressures being experienced by the dam. A plan showing the position and purpose of the individual piezometers should be provided.

Surveillance evaluation is conducted as part of a periodic dam safety inspection (at five yearly intervals), although evaluation may be undertaken at more frequent intervals or at times of concern.

Following evaluation, a Surveillance Report should be prepared. Experienced dam engineers familiar with the entire history of the dam should prepare this report. The Surveillance Report should:

- review all dam safety inspections and surveillance data for a dam
- identify any anomalous trends
- make recommendations on any actions required to ensure the continued safety of the dam
- summarise and extend previous reports to provide a clear picture of long-term trends.

Anomalies and concerning trends identified in the Surveillance Report should be considered as deficiencies. It is the responsibility of the dam owner to ensure that appropriate remedial actions are taken and documented. Further guidance on surveillance evaluation can be found in Appendix 3.

6.5 Dam safety inspections

One of the most important activities in a dam surveillance program is the frequent and regular dam safety inspection for abnormalities in conditions and deterioration of the dam.

Dam safety inspections are conducted to determine the status of the dam and its features relative to its structural and operational safety. Different types of dam safety inspections should be undertaken for different purposes:

6.5.1 Routine inspections

Purpose:	To identify physical deficiencies of the dam.
Reporting:	There is no standard report for these inspections as they can vary from a short weekly check for a small farm dam to a twice daily dam check using a checklist.
Undertaken by:	The dam owner or field and operating personnel as part of their normal duties at the dam.
Discussion:	Routine Inspections are best carried out by someone involved in the day to day running of the dam. Much of the inspection and observation should be incorporated in the daily work routine of such officers. The Standing Operating Procedures (SOP) should outline the requirements regarding: <ul style="list-style-type: none"> • the timing and frequency of the inspections • who should be involved (In some cases electrical expertise may be needed to inspect some elements of dams.) • the reporting requirements.

6.5.2 Periodic inspections

- Purpose:** Generally carried out by a dams engineer with the purpose of identifying physical deficiencies of the dam by visual examination and review of surveillance data against prevailing knowledge.
- Reporting:** The report should fully document the status of the dam and all defects or unsafe conditions and outline a strategy for taking remedial action (including preliminary costing and, if several defects or conditions are found, prioritisation of actions).
- Undertaken by:** An experienced dams engineer who is a Registered Professional Engineer (RPEQ).
- Discussion:** The inspection should assess all physical aspects of the dam. A periodic inspection requires preparation of checklists, preparation of mechanical equipment, and preparation of access (confined and difficult areas). These inspections are generally carried out on a five yearly basis. However many dam owners may opt to undertake a less extensive periodic inspection more regularly (eg annually). This inspection may exclude aspects of five yearly inspections such as:
- a test operation of all equipment
 - evaluation of all surveillance data
 - major function checks and maintenance inspections. For example:
 - flip bucket dewatering
 - conduit dewatering
 - diver inspection of intake works
 - conduit video inspection.

The timing of the inspection depends on the regional weather pattern. For example, if a distinct wet season exists inspections are best carried out immediately after the wet season, to allow remedial work to be planned and undertaken prior to the next wet season. Guidance on these inspections follows in Appendix 4.

6.5.3 Special inspections

- Purpose:** The examination of a particular physical feature or operational aspect of a dam for some special reason. For example, a special inspection may be carried out on a particular feature of a dam that has been identified as having a possible deficiency or has been subject to abnormal loading conditions.
- Reporting:** The report should fully document the status of the particular physical feature or operational aspect of a dam subject of the investigation as well as any other defects or unsafe conditions and outline a strategy for taking remedial action (including preliminary costing and, if several defects or conditions are found, prioritisation of actions).
- Undertaken by:** A specialist dams engineer.
- Discussion:** These inspections are often carried out with a degree of urgency. It requires some insight into the nature of the feature or defect being investigated to determine what specialist needs to be engaged to carry out the inspection. The inspection will address only issues that relate to the subject feature and is in addition to the regular and periodic inspections. Guidance on these inspections follows in Appendix 4.

6.5.4 Comprehensive inspections

- Purpose:** A periodic inspection of the dam and a review of the owner's whole dam safety management program.
- Reporting:** The report should assess all aspects of the dam safety management program and fully document:
- deficiencies identified in the dam safety management program and its documentation
 - a strategy for overcoming the deficiencies (including prioritisation of actions if several deficiencies are identified).
- Guidance on these inspections follows in Appendix 4.
- Undertaken by:** An experienced dams engineer who is a RPEQ.
- Discussion:** This inspection should incorporate:
- a periodic inspection
 - an assessment of the appropriateness and adequacy, the effectiveness and application (including the owner's response to inspection report and Safety Review recommendations) of the dam safety management program and documentation for the dam including:
 - SOPs
 - DOMMs
 - Emergency Action Plan
 - Data Book
 - Design Report/Safety Review
 - Surveillance and inspection program and records.
- (This assessment should take into account applicable development permit conditions for the dam and the requirements outlined in this guideline.)

6.5.5 Regulatory audits

- Purpose:** Independently, NR&M in its role as Regulator may audit dam safety management programs for referable dams in Queensland. These audits will generally examine compliance with development permit conditions dealing with dam safety and the outcomes of inspections and Safety Reviews. Such audits assist dam owners to compare their practices with industry standards.
- Undertaken by:** NR&M
- Reporting:** The report may indicate:
- deficiencies in the dam safety management program and its documentation
 - non-compliance with development permit conditions
 - proposed actions by NR&M and the dam owner
 - comments on the efficiency and the effectiveness of the dam safety management program.
- Discussion:** Generally the audit will be carried out on dams at random. Dams with a questionable management performance record are more likely to be audited. The outcome of these audits will assist NR&M to assess the effectiveness of their regulation program throughout the state.

7 Safety Reviews

7.1 Introduction

A safety review is a procedure for systematically assessing the safety of a dam after its original construction. It is a fresh engineering assessment of the integrity of all elements of a dam. It usually incorporates a:

- current failure impact assessment
- detailed review of structural, hydraulic, hydrologic and geotechnical design aspects
- review of historical operational performance
- review of surveillance reports
- comprehensive inspection of the dam
- comparison of the standards used for building and upgrading the dam against current design standards.

7.2 Steps involved in a Safety Review

The steps involved in a safety review include:

- Collect background information on the dam. This includes all relevant historical investigation, design, construction, remedial, operation and maintenance, monitoring and inspection data.
- Compare the performance of the dam with the standard set by the original design engineers (if known) and the relevant standards and guidelines existing at the time of the review. The review must include a prediction or assessment of the theoretical performance of the dam against current standards and guidelines.
- Where design aspects are based on assumptions or are incomplete, the Safety Review should include basic investigations and detailed analysis to substantiate the design.
- In the case of incomplete documentation, further investigations may be required, particularly in the case of an initial safety review. Where insufficient plans or data exist of critical elements, additional investigation activities should be undertaken to resolve uncertainties. Typical investigation activities include:
 - survey to establish lines and dimensions
 - testing of materials in the dam and its foundation
 - geological drilling and mapping
 - calculation of revised flood estimates
 - updating of earthquake forces.

Particular attention should be given to changes in land use that may have occurred since construction of the dam which may affect design and operation criteria. This includes such activities as mining, urbanisation or clearing of the catchment area both upstream and downstream of the dam.

The design assumptions and standards used should be reviewed and compared with current best practice, eg

- the foundation integrity (bearing, seepage) applied should be reviewed and compared with current best practice
- the spillway adequacy should be reviewed and compared with current accepted engineering standards, ie ANCOLD–Guidelines on Selection of Acceptable Flood Capacity for Dams
- the embankment and outlet structure should be reviewed and checked as to whether it can withstand appropriate loadings (including seismic) in accordance with current engineering practice.

Conclusions should be developed regarding the adequacy of the main elements of the dam (ie foundations, main wall, spillway, outlet works, associated equipment and monitoring system).

Comments should be made regarding adequacy of the dam safety surveillance and inspection program and operation and maintenance procedures. Such comments and conclusions should reflect prevailing knowledge in hydrology, hydraulics, soil mechanics, geology, structural analysis and design criteria relating to dams.

Further guidance in the issue to be addressed when undertaking a Safety Review can be obtained from Appendix 3 - Checklist of Dam Technology Issues.

The level of sophistication of Safety Reviews varies depending on the complexity of the dam. For example, a Safety Review for a large gated structure requires a greater range and depth of studies than for a small grassed bywash earth dam. In addition, Safety Reviews are not necessarily completed when the Safety Review Report is finalised. Subsequent investigations recommended in the Report are often required and may take years to finalise.

7.3 Frequency of Safety Review

The frequency of dam safety reviews is generally based on the age of the dam and the appropriateness of the technology used on that dam. Safety reviews are generally conducted on a maximum twenty-year cycle but may also be initiated in response to issues such as:

- an absence of design and construction documentation
- a regulatory requirement
- detection of abnormal behaviour
- changes in acceptable design and construction standards
- proposals to raise or modify a dam
- changes in Standing Operating Procedures.

7.4 Safety Review personnel

the Safety Review of a dam can be quite complex and personnel engaged in safety reviews should be experienced in dam technology. Where necessary, the services of suitably experienced geologists, hydrologists and other specialists should be utilised. Consideration should also be given to independent review by engineers other than those who carried out the original design of the dam.

7.5 Safety Review Reports

A Safety Review Report should be produced to document the safety review and should include:

- a statement on the safety of the dam indicating whether or not the dam is in a satisfactory condition and capable of meeting current design criteria
- report on comprehensive inspection
- parameters adapted and assumptions made (and their bases) for review analyses)
- methods of review analyses and results (numerical and physical)
- identification of any deficiencies in the dam including criticality ratings for these deficiencies⁶
- recommendations for remedial work, emergency action and/or further studies which should be undertaken and timings for these.

⁶ A deficiency may be insufficient knowledge about a particular aspect of a dam.

Whilst dam owners may engage consultant engineers to carry out the Safety Review and prepare the report, the recommendations contained in a Safety Review Report will be considered as originating from the dam owner. The dam owner will be responsible for implementing the recommendations. Comprehensive inspections and ultimately audits undertaken by the Regulator, will evaluate the dam owners response to Safety Review Reports.

When preparing a Safety Review Report the reviewer should consult the checklist of dam technology issues included as Appendix 3—Checklist of Dam Technology Issues.

8 Deficiencies, Incidents, Failures and Remedial Action

8.1 Introduction

There are a number of situations that may require remedial action at a dam. These situations can vary from a minor deficiency in the dam, to a major incident or even dam failure.

A deficiency threatens the safety of a dam and may be detected by surveillance inspections and evaluations or dam safety reviews. Deficiencies include:

- inappropriate or deficient design or construction
- changes to design criteria
- changes in the failure impact rating of the dam (for example an increase from a category 1 failure rating to a category 2 failure impact rating)
- time based deterioration or breakdown of material;
- maintenance related problems
- deficiencies in the dam safety management program
- inappropriate operating techniques
- inadequate surveillance procedures
- damage to dam (eg landslides, erosion, earthquake etc).

An incident is an event, which could deteriorate to a very serious situation or endanger the dam.

Examples of incidents include:

- rapid change in seepage
- overtopping of earth embankment
- excessive beaching
- excessive embankment erosion
- spillway or bywash erosion or blockage
- excessive cracking or displacement in concrete dams and spillways
- sliding, rotation or settlement of the dam
- malfunction of gates or crest bags.

The failure of a referable dam means the physical collapse of all or part of the dam or the uncontrolled release of any of its contents. Causes of failure include:

- overtopping of embankment dams
- collapse or erosion of spillways
- internal erosion or piping through earth embankments or abutments
- failure of release conduits
- overturning of concrete dams
- deterioration of maintenance deficiencies.

8.2 The need for remedial action

Remedial action is required in response to a deficiency, incident or dam failure. The type of remedial action required and its urgency is determined by the nature of the event.

Remedial action may include:

- preventative measures to stop situations worsening;
- short term actions such as activation of Emergency Action Plans (including evacuations), installation and operation of warning systems, modification of operating procedures including lowering of reservoir levels by controlled release and increased surveillance;
- long term actions such as structural changes to a dam;
- changes to operating procedures;
- decommissioning of a dam.

In life threatening situations, remedial actions may involve short-term actions including the removal of persons at risk, modification to operations, controlled release of storage, increased surveillance and provision of alarm systems.

8.3 Remedial action review

There may be a number of remedial actions which can be undertaken in response to an incident, deficiency or failure. A Remedial Action Review should be undertaken which methodically evaluates the various options.

The Remedial Action Review should include:

- determination of the risk of failure of the dam
- preparation of a failure impact assessment to determine the current population at risk and a consequence assessment to determine other consequences such as economic and environmental damage
- development of possible solutions
- quantitative risk analysis
- estimation of the benefits and implementation costs of each solution
- justification for the adoption of the preferred remedial action.

8.4 Communication of incidents and failures

All dam incidents and failures, either actual or suspected, should be documented. If the dam owner is not already aware of the incidents and failures, such information should be conveyed by the dam operator (or consultants) to the dam owner for consideration and action⁷. Dam owners should ensure that permanent records of such events are kept in the dam safety inspection and evaluation reports.

⁷ Information on dam deficiencies is provided to the dam owner as a part of periodic and comprehensive inspections.

9 Emergency Action Planning

9.1 Introduction

An Emergency Action Plan (EAP) is a formal plan that:

- identifies emergency conditions which could endanger the integrity of the dam and which require immediate action;
- prescribes procedures which should be followed by the dam owner and operating personnel in the event of an emergency;
- provides timely warning to appropriate emergency management agencies for their implementation of protection measures for downstream communities.

The standards used for design, construction, operation, maintenance and inspection of dams are intended to minimise the risk of dam failure. However, as unusual circumstances could result in dam failure, dam owners need to identify conditions which could lead to failure situations and which may require dam safety emergency planning.

Emergency planning takes place at two levels:

- to prescribe activities at the dam - known as the Emergency Action Plan which is prepared and operated by the dam owner, and
- to prescribe activities below or beyond the dam - known as the Counter Disaster Plan, which is prepared and operated by the appropriate local Disaster District Co-ordination Committee (DDCC) with significant input from the dam owner.

An EAP should indicate who is responsible for undertaking particular actions under emergency circumstances and must be tailored to the conditions at each dam.

9.2 Dam owner's role

A dam owner should:

- develop and maintain an EAP
- in all emergencies, respond in accordance with the EAP
- determine the area of potential inundation or other impact from dam failure
- establish and maintain a communication system for the timely notification of impending and actual emergencies
- provide the Disaster District Co-ordination Committee (DDCC) with details of emergency response actions at the dam (eg, flood releases) and estimates of their downstream impacts
- develop a test schedule to ensure the EAP is functional and staff are familiar with the EAP.

9.3 Process for developing an EAP

When developing an EAP, the following steps should be taken by, or on behalf of, the dam owner:

- determine and identify those conditions that could forewarn of an emergency and specify the actions to be taken and by whom under what circumstances
- in consultation with the District Disaster Coordinator (DDC) for the impacted area (or the Disaster District Manager from the Department of Emergency Services), identify all jurisdictions, agencies and individuals who should be involved in the EAP (for example, local governments, the Queensland Police Service and downstream residents)
- identify response actions to be taken in response to potential emergencies

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- identify any necessary resources, special tools, equipment, keys and indicate where they can be located if required in an emergency
- list and prioritise all persons and entities (including contact details) involved in the notification process and the roles and responsibilities assigned to them (eg a flow chart may be used)
- identify primary and secondary communication systems, both internal (between persons at the dam) and external (between dam personnel and outside entities)
- develop a draft of the EAP
- hold meetings with all parties (including emergency management agencies) included in the notification list, to review the draft EAP
- make any revisions, obtain the necessary plan approval and disseminate the EAP to those who have responsibilities under the EAP
- test and revise the EAP at regular intervals.

9.4 Issues To Be Considered In Emergency Action Plans

An Emergency Action Plan (EAP) needs to be easily identified. Consequently, it is recommended that the EAP is contained in a hard covered A4 sized folder, colour coded red.

The issues to be included in an EAP should be as follows.

1. Distribution control sheet (which is page 1)

It is important that the current EAP is issued to a number of parties including:

- Dam Operator
- Specific dam personnel with roles in the EAP
- Chief executive NR&M
- Local counter disaster groups (eg Disaster District Co-ordination Committee (DDCC) and local Government Counter Disaster Committee (LGCDC))
- Local governments which may be affected by the emergency.

Details of these parties should be listed on the distribution control sheet.

2. Title Page/Cover Sheet

3. Table of Contents

4. Notification listing or flowchart

This listing or flow chart should clearly summarise the following:

- Who is responsible for notifying each dam owner representative(s) and/or emergency management official(s) and others (eg residents located immediately downstream of a dam)?
- What is the prioritised order in which individuals are to be notified?
- Who is to be notified?

The listing or flowchart should include current individual names, position titles, office and home telephone numbers, alternative contacts and means of communication. Where applicable, radio frequencies and call signs should be detailed.

The number of persons to be notified by each responsible individual on the flowchart should be governed by what other responsibilities the person has been assigned. It is usually recommended that any one individual not be responsible for contacting more than three or four other parties.

The following parties should be considered for inclusion in the notification listing or flowchart:

- dam owner
- local emergency management officials (DDCC and LGCDC) and other organisations
- appropriate state emergency management agencies
- residents and property owners located immediately downstream of the dam within the boundary of potential inundation where available warning time is very limited
- local governments which may be affected
- operators of other dams or water-retention facilities which may be affected



- managers and operators of recreation facilities which may be affected
- Bureau of Meteorology.

The decisions as to who needs to be contacted will depend on the scale and timing of the potential impacts.

5. Roles and Responsibilities

The responsibilities of the following parties should be specified:

- dam owner
- dam operator
- other dam personnel with a role to play in the EAP (including standby officers where appropriate).

Specific roles, which should be addressed in terms of responsibilities, include:

- notification of local counter disaster agencies (such as DDCC and LGCDC) and dissemination of information to the media and public
- notification of evacuation (eg in the case of a resident located just downstream of the dam the dam owner may need to notify that person directly)
- on-site monitoring of the situation at the dam and keeping parties informed of developing conditions at the dam from time to time
- other actions (eg opening of gates etc where appropriate)
- follow-up evaluation after the emergency (including an Emergency Event Report).

6. Area map

This map should show access routes to the storage during fair and adverse weather conditions, identifying travel times and distances.

7. Drawing of the Storage Catchment Area

8. Emergency Events and action list

Typical emergency or potential problem identification includes but is not limited to:

Problem	General characteristics	When and what to check
Overtopping imminent	Storage full and water level rising - check water levels	During periods of excessive rainfall
Wave erosion	Beaching or notching of the upstream face of embankments by waves generated over long periods of strong wind	During or after periods of strong wind - inspect upstream face of embankment
Toe erosion	Erosion of embankment toe by spillway discharge or diversion flows	During and after large rainfalls - inspect embankment toe

Problem	General characteristics	When and what to check
Gullyng	No armouring or vegetation cover on embankment batters or poor drainage	During and after large rainfalls inspect embankment batters for damage to armouring or vegetation cover
Loss of storage contents	Excessive loss from the storage and/or occasionally increased seepage or increased groundwater levels near the storage	During routine monitoring - look for environmental changes such as vegetation damage, salt scalds, etc
Seepage erosion or piping	Progressive internal erosion of the embankment or foundation to form an open conduit or pipe	During routine inspection or after unaccountable increases in seepage flows, look for an emission point
New springs, seeps or boggy areas	Evidence of internal changes in seepage control (could be initial signs of piping failure)	During routine inspection, look for “evergreen” spots, boggy ground or pools of water
Rapid increases or cloudy appearance of seepage	Seepage flow through the storage embankment is cloudy and increasing (piping failure has started)	After detection of cloudy water at seepage monitoring points - look for the source of cloudy water
Increase in gallery seepage	Increase in the normal rate of gallery seepage	After detection - check for differential movement or cracking in concrete components
Foundation failure	Sliding, rotation or settlement of part or entire dam	During routine inspection or immediately after earthquakes - inspect for evidence of foundation movement or displacement immediately adjacent to dam
Slide in downstream slope	Slide in the downstream face	During routine inspection - look for cracks or scarps near the crest and bulges at the toe
Flow slide	Collapse and flow of soil around the storage periphery	During routine inspection and especially with sedimentary/ colluvial soils - look for material displacement around the storage rim



Problem	General characteristics	When and what to check
Landslide	Mass movement of soil or rock from slopes and valley walls around the storage	During routine inspection - look for material displacement
Movement or cracking in structural concrete work	Failure of mechanical components such as pipes, gates etc	During routine inspection or when mechanical problems such as a burst pipe or a jammed gate occur - look for any movement or cracking of the structural concrete work to determine the cause
Failure of appurtenant structures or operating equipment	Loss of ability to supply water or discharge floods safely	After detecting an operational anomaly - identify and investigate the cause
Abnormal instrument readings (if installed)	A sudden change in the values of instrument readings	On detection - check for equipment malfunction and investigate the cause
Algal blooms	Blue green opaque nature of near surface and shallow water	During routine inspections particularly in the summer months - look for rapid colour change of the storage to a blue green opaque nature
Chemical spills	Dead fish and other aquatic life in storage, or a strange odour or colouration	On detection - identify and investigate the cause

In the event of such problems occurring it may be appropriate for more detailed inspections by properly qualified dams engineers. If the problems are likely to cause failure of the dam and loss of storage, the Emergency Action plan should be activated.

9. Dam Failure Inundation Map

- Dam failure inundation maps should be developed at a scale sufficient to be used for identifying downstream-inhabited areas within the area subject to possible danger.
- Inundated areas should be clearly identified.
- It may be appropriate to supplement the inundation on the maps with water surface profiles showing the elevation before failure, the peak water surface elevation after failure, and the location of structures at critical locations.
- A narrative description of the areas affected by the dam break can be included to clarify unusual conditions.
- The best available topographic map should be used. The expected inundation following the assumed failure should be delineated on the map.

- The accuracy and limitation of the information supplied on the inundation maps and how best to use the maps should be described.
- Inundation maps should be updated periodically to reflect changes in downstream areas.
- Include any other pertinent information as a result of coordination with the appropriate emergency management authorities.

10. Any other charts, rating tables, considered by the dam owner as necessary

Other charts and rating tables may include charts developed in the hydrological analysis for the dam or during spillway design.

9.5 Emergency Event Report

Following an emergency, an Emergency Event Report should be completed which contains:

- a description of the event
- instrumentation readings (where appropriate)
- description of any observed damage
- photographs
- the EAP
- details of communication which took place during the emergency
- comment on the adequacy of the EAP
- any recommendations or suggested changes to the EAP.

Dam owners have the responsibility for implementing the recommendations contained in the Emergency Event Report. Comprehensive inspections and ultimately audits undertaken by the Regulator, will evaluate the dam owners response to Emergency Event Reports.

9.6 Counter Disaster Plan

The Department of Emergency Services controls counter disaster coordination and planning in Queensland. If an emergency occurs with a dam which will constitute a disaster, the State Emergency Service will be in charge of the community response including the evacuation of residents. Counter Disaster Plans should be linked to the EAPs prepared for each dam. Dam owners should co-operate with the Disaster District Agencies (DDCC and LGCDC) and the community when preparing Counter Disaster Plans.

For further information on Counter Disaster Plans, refer to Guide 7 of Emergency Management Planning for Floods Affected by Dams published by Emergency Management Australia.

9.7 Testing and Reviewing

To ensure EAPs are kept up to date and effective, they need to be maintained by:

- Testing

EAPs should be tested periodically by conducting a drill simulating emergency conditions (exercises). Such tests can be either field or desk top exercises and are used to refresh and train

those likely to be involved if an event occurs.

Operational staff at dams should participate in exercises annually. Larger scale exercises involving coordination between the Counter Disaster Agencies and other authorities should be conducted at least every five years.

- Updating the EAP

A periodic review of the overall plan should be conducted to assess its workability and efficiency (ie timeliness), and to plan for the improvement of weak areas. For example, telephone contact details should be reviewed and updated at least on an annual basis.

The EAP should be reviewed for adequacy at least every five years as part of the comprehensive 5 yearly inspection.

Once the EAP has been revised, the updated version (or the affected pages) should be distributed to all involved parties. The distribution of copies of the EAP and the notification flowchart (if issued separately) must be controlled and documented to ensure simultaneous updating of all copies. Updates should be made promptly. In addition, it is recommended that the entire EAP is reprinted and distributed to all parties at least every 5 years.

10 Decommissioning

10.1 Introduction

When a dam is no longer needed, the dam owner may:

- arrange for the transfer of ownership and associated responsibilities to another party
- decommission the dam.

10.2 Decommissioning

A decommissioned dam is a dam where parts of the structure are removed or otherwise modified to make it incapable of storing water, either temporarily or permanently.

The extent of modification required for the safe decommissioning of a dam should be assessed by an experienced dams engineer and may include:

- effective removal of part of the main wall
- permanent enlargement or opening of the outlet works
- lowering of the spillway crest
- removal of spillway, control gates or stopboards
- excavation of a diversion channel through an abutment.

10.3 Dam Safety Decommissioning Plan

When decommissioning a dam, owners should prepare a dam safety decommissioning plan, which outlines the proposed action to be taken to decommission the dam. The dam safety decommissioning plan should:

- include a time sequence of studies and works associated with the decommissioning
- address all dam safety issues associated with the decommissioning including:
 - show impacts of sudden loss of remaining embankments or other dam sections for a range of flood events in compliance with the Guidelines for Failure Impact Assessments of Water Dams
 - provision for safe release of stored water
 - assessment of altered hydraulic character of spillways and streams
 - provision to minimise impact on downstream residents
 - provision for consultation with downstream residents and landholders.

In addition to dam safety issues there are numerous environmental, economic and social issues to be considered when decommissioning a dam. The owner should determine the requirements of the Environment Protection Agency (EPA) when planning the decommissioning of any dam.

Appendix 1

Abbreviations and Definitions

Abbreviations

ANCOLD	Australian National Committee on Large Dams
AFC	Acceptable Flood Capacity
DDC	Disaster District Co-ordinator
DDDC	Disaster District Co-ordination Committee
DOC	Designer's Operating Criteria
DOMM	Detailed Operating and Maintenance Manual
EAP	Emergency Action Plan
FSL	Full Supply Level
IFF	Imminent Failure Flood
LGCDC	Local Government Counter Disaster Committee
NR&M	Department of Natural Resources and Mines
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RPEQ	Registered Professional Engineer (Queensland)
SOP	Standing Operating Procedures

Definitions

Abutment: That part of the valley side against which the dam is constructed.

Annual exceedance probability: The probability of a specified event being exceeded in any year.

Appurtenant Works: All ancillary structures of a dam including, but are not limited to, spillways, inlet and outlet works, tunnels, pipelines, penstocks, power stations and diversions.

Catchment: The land surface area, which drains into a dam or to a specific point.

Category 1 failure impact rating: A category of referable dam under *Water Act 2000*. The population at risk has been determined as between 2 and 100 persons inclusive.

Category 2 failure impact rating: A category of referable dam under *Water Act 2000*. The population at risk has been determined as greater than 100 persons.

Chief Executive: Chief executive of the Government Department (Qld) responsible for administering the dam safety provisions of the *Water Act 2000*. At the time of writing this was NR&M.

Collapse: The physical deformation of a structure to the point where it no longer fulfils its intended function.

Controlled Document: A document subject to managerial control over its contents, distribution and storage.



Dam:

- (a) works that include a barrier, whether permanent or temporary, that does or could or would impound, divert or control water and
- (b) the storage area created by the works. The term includes an embankment or other structure that controls the flow of water and is incidental to works mentioned in (a).

The term does not include the following -

- A rainwater tank
- A water tank constructed of steel or concrete or a combination of steel or concrete
- A water tank constructed of fibreglass, plastic or similar material

Dams Engineer: An engineer who is suitably qualified and experienced and who is recognised by the engineering profession as experienced in the engineering of dams.

Decommissioned Dam: A dam that has been taken out of service and which has been rendered safe in the long term.

Designers Operating Criteria (DOC): Comprehensive operating criteria, which stress the designers, intended use and operation of equipment and structures in the interest of safe, proper, and efficient use of the facilities.

Emergency: An emergency in terms of dam operation is any condition, which develops unexpectedly, endangers the integrity of the dam and requires immediate action.

Emergency Action Plan (EAP): A continually updated set of instructions and maps to deal with emergency situations or unusual occurrences at dam.

Failure (Dam):

- the physical collapse of all or part of the dam or
- the uncontrolled release of any of its contents.

Flood Control Dam: A dam which temporarily stores or controls flood runoff and includes dams used to form flood retarding basins.

Foundation: The undisturbed material on which the dam structure is placed.

Freeboard: The vertical distance between a stated water level and the lowest level of the non overflow section of the dam.

Full Supply Level (FSL): Means the level of the water surface when the water storage is at maximum operating level when not affected by flood.

Height of Dam: Means the measurement of the difference in level between the natural bed of the watercourse at the downstream toe of the dam or, if the dam is not across a watercourse, between the lowest elevation of the outside limit of the dam and the top of the dam.

Imminent Failure Flood (IFF): The flood event which when routed through the reservoir just threatens failure of the dam. The reservoir is assumed to be initially at maximum normal operating level.

Incident: An event which could deteriorate to a very serious situation or endanger the dam.

Inspection (Dam): A careful and critical examination of all physical aspects of a dam.

Inspector: A technical person suitably trained to undertake dam safety inspections

Maintenance: The routine work required to maintain existing works and systems (civil, hydraulic, mechanical and electrical and computer hardware/software) in a safe and functional condition.

Monitoring: The collection and review of data to assess the performance and behavioural trends of a dam and appurtenant structures.

Operator: The person, organisation, or legal entity which is responsible for the control, operation and maintenance of the dam and/or reservoir and the appurtenant works.

Outlet works: The combination of intake structure, screen, conduits, tunnels and valves that control discharge.

Owner: The owner of land on which the dam is constructed or proposed to be constructed.

Probable Maximum Flood (PMF): The flood resulting from PMP and, where applicable, snowmelt, coupled with the worst flood-producing catchment conditions that can be realistically expected in the prevailing meteorological conditions.

Probable Maximum Precipitation (PMP): The theoretical greatest depth of precipitation for a given duration that is physically possible over a particular drainage basin.

Referable Dam: A dam is a referable dam if:

- a failure impact assessment is required to be carried out for the dam and
- the assessment states the dam has a category 1 or 2 failure impact rating and the chief executive accepts the assessment.

Registered Professional Engineer (RPEQ): A registered professional engineer, a professional engineering company or a registered professional engineering unit as defined under the Professional Engineers Act 1988 (Qld).

Remedial Work: Any work required to rectify a deficiency to an adequate safety standard.

Reservoir: An artificial lake, pond or basin for storage, regulation and control of water, silt, debris or other liquid or liquid carried material.

Reservoir Capacity: The total or gross storage capacity of the reservoir up to full supply level excluding flood surcharge.

Risk: The probability of an adverse event. The likelihood of a dam failure occurring with adverse consequences (“chance of failure to perform” or “chance of harm” are alternative definitions).

Safety Review: The assessment of dam safety by methodical examination of all design and surveillance records and reports, and by the investigation and analysis of matters not addressed previously or subject to new design criteria.

Spillway: A weir, conduit, tunnel or other structure designed to permit discharges from the reservoir when pondage levels rise above the full supply level.

Spillway Crest: The uppermost portion of the spillway overflow section.

Surveillance: Ongoing monitoring and review of the condition of a dam and its appurtenant structures; and the review of operation, maintenance, monitoring procedures and results in order to determine whether a hazardous trend is developing or is likely to develop.

Tailwater Level: The level of water in the discharge channel immediately downstream of the dam.

Toe of Dam: The junction of the downstream (or upstream) face of dam with the ground surface (foundation); sometimes 'Heel' is used to define the upstream toe of a concrete gravity dam.

Top of Dam: The elevation of the uppermost surface of the dam proper, not taking into account any camber allowed for settlement, kerbs, parapets, guardrails or other structures that are not a part of the main water retaining structure. This elevation may be a roadway, walkway or the non-overflow section of the dam.



Appendix 2

Further reading

Legislation and Australian Guidelines

Water Act 2000 (Qld)

Water Resources Act 1989 (Qld)

(To be repealed on commencement of relevant sections of *Water Act 2000*)

Environmental Protection Act 1994 (Qld)

Integrated Planning Act 1997 (Qld)

Department of Primary Industries (Water Resources), Queensland, “Queensland Dam Safety Management Guidelines - Dam Safety Course Version”, 1994. (Superseded by this document)

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Australian National Committee on Large Dams (ANCOLD), “Guidelines on the Assessment of the Consequences of Dam Failure”, 2000.

Australian National Committee on Large Dams, “Guidelines on Selection of Acceptable Flood Capacity for Dams”, 2000.

Australian National Committee on Large Dams, “Guidelines on Tailings Dam Design, Construction and Operation”, 1999.

Australian National Committee on Large Dams (ANCOLD), “Dam Safety Management Guidelines”, 1994.

Australian National Committee on Large Dams (ANCOLD), “Guidelines on Risk Assessment”, 1994.

Australian National Committee on Large Dams, “Guidelines on Strengthening and Raising Concrete Gravity Dams”, 1992.

Australian National Committee on Large Dams, “Guidelines on Design Criteria for Concrete Gravity Dams”, 1991.

Australian National Committee on Large Dams, “Guidelines on Concrete Faced Rockfill Dams”, 1991.

Australian National Committee on Large Dams, “Roller Compacted Concrete for Gravity Dams”, Guidelines Supplement, Bulletin No 75, 1991.

Australian National Committee on Large Dams, “Guidelines on Design of Dams for Earthquakes”, 1988.

Department of Natural Resources & Mines, “The Guidelines for Failure Impact Assessments for Water Dams”, 2002.

The Australian Standard for Quality Systems AS/NZS ISO 9001-3:1994.

Emergency Management Australia, “Emergency Management Planning for Floods Affected by Dams” Guide 7, 2002.

Useful Web Sites

Australian National Committee on Large Dams (ANCOLD)
<http://www.ancold.org.au>

U.S. Bureau of Reclamation, “Training Aids for Dam Safety”, July 2001.
<http://www.usbr.gov/dsis/tads.html>

Queensland Government Legislation
<http://www.legislation.qld.gov.au/legislation.htm>

US Army Corps of Engineers
<http://www.usace.army.mil/inet/usac-docs/eng-manuals/em.htm>

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U.S. Bureau of Reclamation, ‘Design of Gravity Dams’, U.S. Department of the Interior, Bureau of Reclamation, 1976.

U.S. Committee on Large Dams, “Dam Safety Practices and Concerns in the U.S.A.”,

U. S. Federal Emergency Management Agency, “National Dam Safety Program - A Progress Report”, FEMA, No 103, 1986.

U. S. Federal Emergency Management Agency, “Dam Safety: An Owners Guidance Manual”, FEMA, No 145, 1987.

U.S. National Research Council, “Safety of Existing Dams - Evaluation and Improvement”, National Academy Press, 1983.

U.S. National Research Council, “Safety of Dams - Flood and Earthquake Criteria”, National Academy Press, 1985.

The Australian National Committee on Large Dams produces a “Bulletin” as a periodical with 2 or 3 editions being published each year. These bulletins present papers on all aspects of Australian dam design, construction and ongoing operation and management of dam safety. Further details are available from the ANCOLD website (<http://www.ancold.org.au>)



United States Bureau of Reclamation - Training Aids for Dam Safety (July 2001).

Dam safety inspection training modules⁸:

- Preparing to Conduct a Dam Safety Inspection.
- Documenting and Reporting Findings from a Dam Safety Inspection.
- Inspection of Embankment Dams.
- Inspection of Concrete and Masonry Dams.
- Inspection of the Foundation, Abutments, and Reservoir Rim.
- Inspection of Spillways and Outlet Works.
- Inspection and Testing of Gates, Valves, and Other Mechanical Systems.
- Instrumentation for Embankment and Concrete Dams.
- Identification of Material Deficiencies.
- Evaluation of Facility Emergency Preparedness.

Dam safety awareness, organization, and implementation modules: ⁹

- Dam Safety Awareness
- How to Organize a Dam Safety Program.
- How to Organize an Operation and Maintenance Program.
- How to Develop and Implement an Emergency Action Plan.
- Identification of Visual Dam Safety Deficiencies.

Data review, investigation and analysis, and remedial action for dam safety modules: ¹⁰

- The Dam Safety Process.
- Evaluation of Hydrologic Adequacy.
- Evaluation of Hydraulic Adequacy.
- Evaluation of Concrete Dam Stability.
- Evaluation of Embankment Dam Stability and Deformation.
- Evaluation of Seepage Conditions¹¹.

International Commission on Large Dams (ICOLD), Publish Bulletins and Transactions on a range of aspects of dam design, construction and ongoing operation and management of dam safety.

In Australia these are available through :-

- the ANCOLD Publications Officer. (In January 2002 the position was held by Mr Len McDonald [len@damsafety.nsw.gov.au].)
- or through the ANCOLD web site <http://www.ancold.org.au>

A list of the ICOLD publications available at 1 January 2002 follows:-

- No. 15 Frost Resistance of Concrete (1960)
- No. 18 Guide and Recommendations on Aggregates for Concrete for Large Dams (1965)
- No. 20 Surface-active Admixtures for Concrete for Large Dams (1968)
- No. 22 Guide and Recommendations on Pozzolans and Slags for use in Concrete for Large Dams (1972)

⁸ These modules are for engineers with little or no inspection experience and technicians with some familiarity with dams.

⁹ These training modules are primarily for dam owners and operators.

¹⁰ These modules are for dam safety program managers, dam owners and operators, and experienced engineers.

¹¹ Available from United States Bureau of Reclamation, Engineering and Research, D-3000, P.O. Box 25007, DFC, Denver, Colorado 80225-0007.

- No. 24 Accelerating and Retarding Admixtures (1973)
- No. 25 Extensibility of Concrete for Large Dams (1976)
- No. 29 Report from the Committee on Risks to Third Parties from Large Dams (1977)
- No.30a Finite Element Methods in Analysis and Design of Dams (2nd Edition, 1978)
- No.32a Bituminous Concrete Facings for Earth and Rockfill Dams (1977-82)
- No. 33 Compendium of Dam Symbols (1979)
- No. 34 ICOLD Guide for the International System of Units (IS)
- No.36a Cements for Concrete for Large Dams
- No. 37 Dam Projects and Environmental Success (1981)
- No. 38 Use of Thin Membranes on Fill Dams (1981)
- No. 39 Upstream Facing Interface with Foundations and Abutments (1st Supplement to Bulletin 32a)
- No.40a Fibre Reinforced Concrete (1988)
- No. 42 Bituminous Cores for Earth and Rockfill Dams (1982)
- No. 44a Bibliography - Mine and Industrial Tailings Dams and Dumps (1982, 1989)
- No. 46 Seismicity and Dam Design (1983)
- No. 47 Quality Control of Concrete (1983)
- No. 48a River Control During Dam Construction (Reprinted 1986)
- No. 49a Operation of Hydraulic Structures of Dams (Reprinted 1986)
- No. 50 Dams and the Environment. Notes on Regional Influences (1985)
- No. 51 Filling Materials for Watertight Cut-Off Walls (1985)
- No. 52 Earthquake Analysis Procedure for Dams- State of the Art (1986)
- No. 53 Static Analysis of Embankment Dams (1986)
- No. 54 Soil-Cement for Embankment Dams (1986)
- No. 55 Geotextiles as Filters and Transitions in Fill Dams (1986)
- No. 56 Quality Control for Fill Dams (1986)
- No. 57 Materials for Joints in Concrete Dams
- No. 58 Spillways for Dams (1987)
- No. 59 Dams Safety Guidelines (1987)
- No. 60 Dam Monitoring - General Considerations (1988)
- No. 61 Dam Design Criteria-Philosophy of Choice (1988)
- No. 62 Inspection of Dams after Earthquakes - Guidelines (1988)
- No. 63 New Construction Methods (1988)
- No. 64 Registration of Dam Heightening (1988)
- No. 65 Dams and Environment - Case Histories (1988)
- No. 66 Dams and Environment - The Zuiderzee Damming (1989)

- No. 67 Sedimentation Control of Reservoirs
- No. 68 Monitoring of Dams and Their Foundations - State of the Art (1989)
- No. 69 Moraine as Embankment and Foundation Material - State of the Art (1989)
- No. 70 Rockfill Dams with Concrete Facing (1989)
- No. 71 Exposure of Dam Faces to Aggressive Water (1989)
- No. 72 Selecting Seismic Parameters (1989)
- No. 73 Savings in Dam Construction (1989)
- No. 74 Tailings Dam Safety (1989)
- No. 75 Roller Compacted Concrete for Gravity Dams (1989)
- No. 76 Conventional Methods in Dam Construction (1990)
- No. 77 Dispersive Soils in Embankment Dams (1990)
- No. 78 Watertight Geomembranes for Dams (Supersedes No. 38) (1991)
- No. 79 Alkali - Aggregate Reaction in Concrete Dams (1991)
- No. 80 Dam Construction Sites Accident Prevention - Review and Recommendations (1992)
- No. 81 Spillways; Shockwaves and Air Entrainment (1992)
- No. 82 Selection of Design Flood (1992)
- No. 83 Cost Impact on Future Dam Design - Analysis and Proposals (1992)
- No. 84 Bituminous Cores for Fill Dams - State of the Art (1992)
- No. 85 Owners, Consultants and Contractors - How to improve relationships (1992)
- No. 86 Dams and the Environment - Socio economic impacts (1992)
- No. 87 Improvement of Existing Dam Monitoring - Recommendations and Case Histories
- No. 88 Rock Foundations for Dams (1993)
- No. 89 Reinforced Rockfill and Reinforced Fill for Dams - State of the Art (1993)
- No. 90 Dams and Environment - Geophysical Impacts (1993)
- No. 91 Embankment Dams - Upstream Slope Protection - Review and Recommendations (1993)
- No. 92 Rock Materials for Rockfill Dams Review and Recommendations (1993)
- No. 93 Aging of Dams and Appurtenant Works - Review and Recommendations (1994)
- No. 94 Computer Software for Dams - Comments and Proposals (1994)
- No. 95 Embankment Dams - Granular Filters and Drains - Review and Recommendations (1994)
- No. 96 Dams and Environment - Water Quality and Climate (1994)
- No. 97 Tailings Dams - Design of Drainage - Review and Recommendations (1994)
- No. 98 Tailings Dams and Seismicity - Review and Recommendations (1995)
- No. 99 Dam Failures - Statistical Analysis (1995)
- No.100 Dams and Environment Ridracoli - A Model Achievement (1995)
- No.101 Tailings Dams - Transport, Placement and Decantation (1995)

- No.102 Vibrations of Hydraulic Equipment for Dams (1996)
- No.103 Tailings Dams and Environment - Review and Recommendations (1996)
- No.104 Monitoring of Tailings Dams - Review and Recommendations (1996)
- No.105 Dams and Related Structures in Cold Climates - Design Guidelines and Case Studies (1996)
- No.106 A Guide to Tailings Dams and Impoundments - Design, Construction, Use and Rehabilitation (1996)
- No.107 Concrete Dams - Control and Treatment of Cracks (1997)
- No.108 Cost of Flood Control in Dams - Review and Recommendations (1997)
- No.109 Dams Less than 30m High - Cost Savings and Safety Improvements (1998)
- No.110 Cost Impact of Rules, Criteria and Specifications - Review and Recommendations (1998)
- No. 111 Dam-break Analysis - Review and Recommendations (1998)
- No. 112 Neotectonics and Dams - Guidelines and Case Histories (1998)
- No. 113 Seismic Observations of Dams - Guidelines and Case Studies (1999)
- No. 114 Embankment Dams with Bituminous Concrete Facing - Review and Recommendations (1999)
- No. 115 Dealing with Reservoir Sedimentation - Guidelines and Case Studies (1999)
- No. 116 Dams and Fishes - Review and Recommendations (1999)
- No. 117 The Gravity Dam: A Dam for the future - Review and Recommendations (2000)
- No. 118 Automated Dam Monitoring Systems - Guidelines and Case Histories (2000)
- No. 119 Rehabilitation of Dams and Appurtenant Works - State of the Art and Case Histories (2000)
- No. 120 Design Features of Dams to Resist Seismic Ground Motion - Guidelines and Case Histories (2000)
- No. 121 Tailings Dams: Risk of Dangerous Occurrences - Lessons Learnt from Practical Experience (2001)
- No. 122 Computational Procedures for Dam Engineering - Reliability and Applicability (2001)

Proceedings of the X Congress, Montreal 1970, 6 Vols

Proceedings of the XII Congress, Mexico 1976, 5 Vols

Proceedings of the XIII Congress, New Delhi 1979, 5 Vols

Proceedings of the XIV Congress, Rio de Janeiro 1982, 5 Vols

Proceedings of XV Congress, Lausanne 1985, 5 Vols

Proceedings of the XVI Congress, San Francisco 1988, 5 Vols.

Proceedings of the XVII Congress, Vienna 1991, 5 Vols

Proceedings of the XVIII Congress, Durban 1994, 5 Vols

Proceedings of the XIX Congress, Florence 1997, 5 Vols

Proceedings of the XX Congress, Beijing 2000, 5 Vols

Appendix 3 - Checklist of Dam Technology Issues

Issues that should be considered when preparing a Design Report or a Safety Review Report

1. General

- Report on any specific investigations and analyses carried out.
- Report on design methods, standards and loads adopted and the design data gathered and developed (ie plans, reports of investigations).
- Report on the proposed and actual construction methods (including results of testing).
- Report on operational and maintenance intentions used in developing the design or necessitated by the constraints of the design.
- Describe the expected performance and condition of the structure.
- Describe the instrumentation and monitoring requirements for the dam.

2. Drawings

- Plan of the dam and appurtenant works drawn on a contour plan of the site.
- Arrangements, elevations and sections showing details of the structures, the proposed foundation levels and sub-surface geological features.

3. Summary of Principal Data

- Type of dam.
- Type of foundation cut-off (if any).
- Type of spillway.
- Height of dam (as defined in the *Water Act 2000*).
- Length of (as applicable) embankment(s) or non-overflow structure(s).
- Spillway crest(s).
 - Type, number and dimensions of spillway and any crest or sluice gates.
- Elevations of (as applicable):
 - original stream bed or lowest natural surface at toe
 - base of cut-off
 - spillway crest(s)
 - top of dam
 - full supply level
 - top of flood control storage (if any)
 - maximum flood level.
- Volumes of (as applicable):
 - excavation for foundations, cut-off and spillway
 - fill in each embankment zone and total
 - concrete in spillway, if separate
 - concrete in dam wall and appurtenance.
- Reservoir storage capacity:
 - to full supply level
 - in flood control storage
 - in surcharge storage.
- Reservoir surface area at full supply level.
- Catchment area.

- For the maximum design flood:
 - estimated recurrence interval
 - peak inflow rate
 - peak spillway discharge.
- For outlet works:
 - number and dimensions of outlet pipes and conduits
 - number, sizes and types of guard and regulating valves and gates
 - discharge capacity of each outlet with reservoir at full supply level.
- List of reports prepared by any person or organisation in the course of investigation and design.

4. Hydrological and Hydraulic Data and Analyses

- Failure impact assessment (including dam break analysis) and consequence assessment.
- Topographic map of the catchment or description of the terrain including elevations.
- Area of the catchment and of each sub-area controlled by other storages or lakes.
- Summary of stream flow, flood flow or rainfall records on which the hydrological analyses are based.
- Adequacy of spillway and means of assessment.
- Tables or curves of reservoir area and storage capacity versus water surface level.
- Summaries, as applicable, of hydrological analyses leading to the determination of flood frequencies, probable maximum flood, reservoir capacity, outlet capacity, spillway capacity and freeboard above maximum flood level.
- Recurrence interval of maximum flood adopted for the design of spillway and outlets, as applicable.
- Particulars of proposed reservoir operation including operation of outlets and spillway crest gates during floods.
- Tailwater rating curve(s) for spillways and outlets.
- Hydraulic data including formulae and co-efficients used in determining capacity of spillways and outlets.
- Discharge rating curves for spillways and outlets.
- Summary of assumptions and methods adopted for the design of energy dissipaters for spillways and outlets.
- Results of any physical or numerical hydraulic model studies.
- Fetch of reservoir and estimated wave height and run-up.

5. Foundation conditions and treatment

- Map and description of the general geology of the dam site and reservoir area showing major faults and identifying any other potentially hazardous features requiring special consideration.
- Report on any underground mine workings in the vicinity of the dam or reservoir and any provisions considered necessary to accommodate these workings.
- Records of foundation exploration holes, pits, excavations and other sub-surface investigations indicating:
 - nature and depth of material on which the dam, spillway, outlets and other appurtenant works are proposed to be founded
 - summaries of results of laboratory and in-situ tests for determining the engineering properties of the foundation materials indicating the number of tests, sampling locations and extreme as well as average values.
- Nature and extent of any proposed foundation treatments such as:
 - cut-off through pervious strata
 - provisions for drainage
 - curtain, blanket or consolidation grouting;
 - measures to consolidate, decrease permeability or otherwise modify the properties of the foundation or remedy defects.

6. Properties of construction materials

- For earthfill, filter materials, pervious materials, transition materials and rockfill:
 - approximate locations of the borrow areas and quarries and estimated volumes of reserves of each material
 - numbers of exploration holes, pits and excavations in each proposed borrow area and quarry
 - summaries of results of laboratory tests for determining the engineering properties of each type of material, and of results of geological examinations and tests on rock materials, indicating the number of test samples and extreme as well as average values.
- For concrete aggregates, if not obtained from sources of materials previously described:
 - approximate locations of proposed sources and estimated volumes of reserves of aggregates
 - number of exploration holes, pits and excavations in each proposed source
 - summaries of results of laboratory tests for determining the engineering properties of each type of material, and of results of geological examination and tests on rock materials, indicating the number of test samples and extreme as well as average values.

7. Embankment Design and Stability Analyses

- Details of each design case considered.
- Summaries of the properties of the material in each zone of the embankment and the foundation adopted for the stability analyses including density and shear strength parameters both as placed and saturated as appropriate and the justification for the adopted properties.
- Basis for the estimates of the pore pressures in the impervious zones adopted for each design case examined.
- Particulars of the methods of stability analyses used, formulae used in the analyses or references in technical literature, and the upstream and downstream water levels used in each design case.
- Minimum values of the factor of safety obtained for each design case and the locations of the critical slip surface for each case drawn on a cross-section of the embankment or results of any other method of assessment of the stability of the embankment.
- References in technical literature to design rules if used to determine dimensions of a small embankment without analyses.

8. Stress and Stability Analysis of Concrete Structures & other structural components

- Details of each design case considered.
- Summaries of the properties of concrete and foundation materials adopted for the analyses.
- Assumptions as to loads, including combinations of loads due to water, dead weight, uplift, earthquake, silt or other solids and temperature change when appropriate.
- Limiting stresses.
- Methods of analysis.
- Results of any structural model studies.
- Results of analyses including safety factors and stresses in the structure and foundation or the results of any other method of assessment of the stability of the structure.

9. Instrumentation

- Layout and description of embedded instruments and other devices installed to observe the behaviour of the works including, as applicable, pore pressures and uplift, leakage, embankment settlements, foundation deformations, alignment, deflections, stresses, strains, temperatures, contraction joint openings, seismic and mechanical vibrations.
- Pore pressure and uplift values assumed for the design of the associated structures at instrument locations
- Recommended for frequency of observations/readings

10. Construction specifications

- Clauses dealing with:
 - foundation treatment and grouting
 - sources of construction materials
 - methods of treatment and placement of materials
 - acceptability criteria.
- Construction schedule and sequence of construction operations, if specified.
- Stream diversion plan with respect to safety during construction.

Appendix 4 - Checklist Of Details For Consideration When Undertaking A Surveillance Evaluation¹⁶

1. General Interpretation

All new data should be thoroughly examined in context with existing data.

Situation “Normal”

Generally the latest set of observations can be quickly scanned as numbers in a table or points on a plot and be seen to be as expected. In simple cases such as settlement or horizontal deflection of fill or gravity dams the reading should be within a millimetre or two of expectation, for a well-planned observation schedule.

For high thin arch dams, reservoir water level and seasonal temperature variations can justify statistical regression checks, and the observation should be within a few millimetres of a well-organised prediction from regression.

Leakage and piezometric data, when notionally cleared of local runoff effects, should generally follow any significant reservoir head changes. Seasonal opening and closing of joints or cracks in concrete dams can be reflected in gallery or toe drain flows, but after allowing for such influences, there should be negligible long term change.

Anomalies - Real or Not?

Sometimes an isolated instrument reading, or a survey observation, will indicate some severe distress or a strain, deformation or pore pressure which, if valid, would represent a real threat to the dam.

Every effort should be made to urgently assess such a situation, with repeat readings, repair of blown fuses, or extra instruments, targets or reference pillar checks.

If the dam has not failed and the adjacent parts are not indicated as behaving abnormally, that instrument reading or survey observation must be taken as anomalous, however carefully it purports to have been checked “correct”.

Typical Assessment of “Overall Picture”

In foundations with piezometers upstream and downstream of grout and drainage curtains, and flow measurement of drains or drainage adits, it is possible to develop a good picture of the water table.

Ideally the piezometers will continue to indicate a roughly linear head drop along the seepage path. Rises and falls can be expected to follow corresponding reservoir level changes.

If tightening of foundation joints by creep causes a slow reduction in the long-term mean leakage flow, the head pattern described above should still apply.

¹⁶ Taken from ANCOLD Dam Safety Management Guidelines (1994)



If pressures build up downstream of the drainage curtain in dry weather, consideration of some extra drainage drilling is indicated.

Emergency Action “Triggering”

The surveillance engineer should be familiar with the designs, recent performance and possible failure mechanisms of all dams for which the engineer has surveillance responsibility.

Immediate personal access should be available to senior management in a perceived Dam Safety emergency. Senior management should not usurp the authority of the Dams Safety Engineer unless they are appropriately qualified and experienced.

Staff at the dam should be sufficiently trained to recognise an emergency and have the authority to trigger emergency action in the event of a disruption in communication.

Dam owners, particularly in relation to initiating, testing or upgrading Emergency Action Plans should maintain close regular liaison with those responsible for emergency services.

2. Factors For Consideration

The evaluation of a dam’s performance usually requires a close inspection of the dam and its appurtenances, examination of water pressures and seepage records and the various movements relative to the abutments or of differential movement within the dam. These data are then compared with design assumptions, predictions and historical behaviour patterns to fully evaluate the existing situation.

Seepage

Seepage through, around or under a dam is expected. The quantity and nature of seepage, the seepage paths, and the velocity of the seepage waters are issues to be considered when analysing the dams’ structural behaviour.

The quantity and nature of seepage is important for several reasons:

- **Leaching:**
seepage may dissolve some of the chemical constituents of the concrete, rock or soil. Leaching may provide an enlarged seepage path resulting in increasing seepage. Dams founded on limestone are subject to this problem. Evaluation of the composition of the seepage water (eg turbidity, dissolved salt content) can provide a further insight into dam behaviour.
- **Weakening:**
seepage water may completely saturate soils and rock, and cause excessive uplift (pore pressures) as well as softening and weakening of soil and rock.
- **Loss of Storage:**
excessive leakage may, in extreme cases, compromise the storage capability of the reservoir.
- **Indication of Behaviour:**
increases in seepage quantity with time may indicate the onset of internal erosion, and decreases may indicate infilling of seepage paths, with build up of internal pressures in dams and their foundations.

The location of a seepage path is of concern because:

- **Piping:**
if seepage is confined to a few discrete paths and the velocity becomes sufficiently high to move soil particles, progressive erosion may occur resulting in a “piping” failure.
- **Leaching:**
seepage waters may result in concentrated dissolution.
- **Drainage:**
if discrete seepage paths are present and are not intercepted by drains, then drains should be installed. Seepage (or pore) pressures if above design values may compromise the stability of a dam.

Movements

Some movement of all or part of a dam can be expected eg seasonal movements, changes in water level. Movements may be in the vertical plane, the axial plane (along the dam’s axis), and the upstream-downstream plane, or rotational. It is common for more than one direction and mode of movement to be present in a dam.

Vertical movements occur as a result of consolidation of the foundations or the embankment. Such settlement is typically greater along the crest of the dam than along the heel or toe and is also usually greater near the centre of the dam than near the abutments. Such settlement can result in cracking. Minor upward vertical movement (heave) can also occur at the toe of an embankment dam due to fill creep or excess uplift pressures.

Vertical movement of the centre of a fill dam with respect to the abutments is generally associated with horizontal movement toward the centre of the dam. This axial movement results in tension, which can involve cracking of the core or face membrane.

Upstream-downstream movements are usually in the downstream direction and are due to hydrostatic forces acting on the upstream face of the dam. These movements can be horizontal or rotational. Upstream movements are usually of a rotational-type and may occur during “rapid drawdown”. These rotational movements may be a deep-seated or a relatively shallow configuration. The slides may extend into the foundation, intersect at the dam’s heel or toe, or may be entirely contained within the dam. The general cause of such movements is deficient shearing resistance along the often saturated failure surface associated with high uplift pressures and reduced effective stresses.

3. Typical Periods for Evaluation

During the life of a dam, from initial planning, through construction, reservoir filling, and operation, an evaluation may be necessary as follows:

Preconstruction

Evaluation of pre-construction conditions using various instruments can be valuable. During the initial planning and design stages several important considerations affecting dam safety should be investigated. They include:

- **Normal ground-water levels:**
the existing ground-water level in the abutments, dam area, reservoir rim, and downstream of the dam and its seasonal variation should be determined.
- **Quality of the ground-water:**
ground-water mineral composition can be compared with later seepage water mineral composition

- to aid in determining if dissolution is occurring.
- Seepage at abutments:
seepage due to natural ground-water at abutments prior to construction will affect the design of the dam and later evaluation of the dam's performance.
 - Landslide scars/faults:
old landslide scars and faults in the vicinity of the dam indicate the potential for additional sliding during reservoir construction and operation.
 - Permeability of existing materials:
for the foundation, abutments, and reservoir floor, treatments such as grouting cut-off walls and upstream blankets can reduce the effect of excessively permeable materials.
 - Foundation consolidation:
knowing the characteristics of foundation materials allows anticipated settlement of the dam to be estimated.
 - Fill and foundation shear strength:
the shear strengths of the relevant materials are needed to determine the stability of the dam.
 - Seismic:
the seismic risk at the dam site is used to design the dam to resist loading up to the Maximum Credible Earthquake. Preparations should also be made to assess the existence of reservoir-induced seismicity.
 - Hydrologic:
catchment conditions, flood potential and the likelihood of changing conditions affecting future flood magnitude are important in determining spillway capacity.

During Construction

Installation and observation of instrumentation begins during construction. Visual observation is also vital during this period.

- Instrument installation:
many instruments are installed during dam construction. These include piezometers, pressure cells, strain gauges, settlement and movement measuring devices and thermometers. It is absolutely essential that proper care be taken during their installation otherwise no information of value will be obtained from them. Incorrect installation techniques produce information detrimental to interpretation. Instruments must be tested as they are installed. Continuous supervision by specialists with authority to require repair or replacement is vital in the rough construction environment.
- Settlement:
consolidation of foundation and embankment materials result in settlement of the surface of the dam as it is constructed. Settlement measuring instrumentation (such as hydrostatic manometers and cross arms), installed during construction, record such settlement.
- Observation of excavations:
during construction excavations for foundation and core trenches, should remove undesirable materials. Visual observations by experienced personnel during this phase are extremely valuable and should be carefully recorded. Based on these observations, there may be need for instruments to be relocated or added or for design changes. This information can be important in diagnosing subsequent anomalous behaviour.
- Increasing Pore Pressures:
rapid construction of embankments, at high moisture contents, may cause excessive pore pressures, which would result in instability if not allowed to dissipate. Records of such pore pressures can be of long-term significance.
- Slide movements:
slide movements due to high pore pressure building up during construction may be noted either

visually or by instrumentation.

- Temperature:
excessive temperatures from cement hydration in concrete dams may cause subsequent thermal cracking if not controlled.
- Permeability:
filter permeability should be checked as placement can compact a filter more than specified.

During First Reservoir Filling

The first filling of a reservoir is normally a critical event for a dam. At that time, the first true analysis of the behaviour of a dam with reservoir loading can be made. Instrumentation readings and visual observations are conducted very frequently during this period.

- Seepage:
as the water level in the reservoir rises, it is especially important to watch both the dam and abutments for increases in seepage quantities, changes in seepage clarity, new seepage locations and the functioning of drains.
- Pore pressure:
at this time frequent readings should be taken to monitor pore pressure changes and patterns.
- Dam movements:
the increasing load from the reservoir water will cause movements of the dam, particularly in the downstream direction. These require close monitoring, ideally including correlation with movement controlling factors.

During Normal Operations

Dam owners generally aim to have trouble free operation of a dam for many years. The water level in many reservoirs fluctuates each year resulting in seepage quantity and pore pressure fluctuations on a regular, somewhat predictable basis. It is therefore important to establish a regular instrumentation monitoring schedule and a regular visual inspection of the facility and to summarise the findings in regular surveillance reports on the dam. Any significant unusual changes noted should be an immediate cause for further investigation.

During Rapid Drawdown

Occasionally, the reservoir level is lowered rather quickly for some reason. The term “rapid” depends on the type of material in the dam and abutments. In some relatively permeable materials, “rapid” may mean hours or days, while in low permeability materials, a “rapid drawdown” might cover a period of weeks. During drawdown the external reservoir water pressure is removed but the internal pore pressures in the dam and abutments remain, to dissipate more slowly in impermeable materials. This creates a condition where slides may occur in the upstream face of an embankment, the abutments, or anywhere along the reservoir rim. Surface movements and pore pressures in the upstream shoulders require special monitoring at this time.

4. Interpretation Of Data

Data Presentation

The use of graphical presentation of instrumentation data should be undertaken for the evaluation of dams. Graphical presentation by computers is simple and rapid and reduces the chance of plotting errors and enables ancillary computations and data variation checks to be performed.

Data presentation, when properly done, is of very significant value, but incorrect data plotting may cause



errors in interpretation. The characteristics of incorrect plotting include:

- **Improper scale:**
proper and consistent scales must be used. Movements should not normally be shown larger than full-scale (1:1).
- **Excessive data:**
in general, each plot should contain only two variables: (eg water level and time). There may, however, be a large amount of data points on a single instrument or even a number of instruments. The number of instruments shown on a single sheet of plotting is a matter of common sense. Plot lines should not repeatedly cross each other and distinctly different line symbols should be used for each plot.
- **Coloured lines:**
distinguishing plots by colour should be avoided due to the use of black and white photocopying (eg when “quoting” plots in subsequent communications).

Detection of Errors

Data errors can usually be detected either in the field at the time of reading or in the office during processing or reviewing. Often, it has been found that if the instrument reader knows what the previous reading on an instrument was, they can re-check the current reading if it differs significantly. (The risk that the reader will report a reading close to the previous one without actually making an observation, or even where a different reading is actually obtained, has to be considered.)

Normal and Abnormal Conditions

Application of the terms “normal” and “abnormal” depends on the particular characteristics of a dam in question. The behaviour of pressures, strains, movements, and seepage, should be compared to the behaviour anticipated during the design of the dam and any preconstruction data gathered from the dam site. It is important for designers to state acceptable “ranges” in design reports and operating instructions. For dams with limited design data, historical behaviour patterns should be developed.

Correlation of Inspection/Monitoring Data

The recommendation for major remedial works on a dam should not depend on uncorroborated evidence. Ideally any visible anomaly should be confirmed by anomalies recorded on associated instruments.

It is important to compare measured aspects of a dam’s behaviour over identical date ranges. Since observations cannot always be made concurrently, response factors, such as regression coefficients, should be used to determine the most probable values on the chosen comparison date, for movements, which could not be observed on the date.

Reservoir water level, ambient temperature, and age since construction should be included amongst the controlling variables in these studies. In comparing the designer’s predictions and the prototype’s performance, regression can be an important tool in separating the effects of temperature, water load and creep, so that each may be compared in turn.

In general, those responsible for interpreting monitoring results should endeavour to make all possible logical linkages throughout the range of dam data obtained from observations and inspections and be vigilant in the detection of errors and false alarms. Familiarity with the reliability of installations and observers is a great advantage in making a judgement as to whether an “alarm” is false or real as a result of a genuine excessive change in the value of the entity being monitored. In this regard close liaison between operators and surveillance personnel is critical.

Appendix 5

Checklist of Advice Concerning Dam Safety Inspections and the Preparation of Reports

This detailed advice applies to periodic and special inspections for physical integrity in the dam and to comprehensive inspections which assess the overall safety management of the dam. This checklist:

- defines the information about the structure that needs to be gathered during the inspection
- gives examples of the defects and problems that may be encountered
- requires the formulation of recommendations on remediation and repair strategies
- specifies the standard of report presentation that is acceptable to NR&M.

This advice is intended to define a minimum standard of report. It would be expected that engineers experienced in the management and performance of dams would provide a dam owner with comment and insight into the issues that are influencing the safety of a dam and advice on the management of the dam as an asset.

While most of the common causes of dam failure have been included in here, the list is not inclusive. Each dam is different and may present its own unique problems. Anyone who inspects dams should be aware of a wide range of potential problems and look for all potential modes of failure.

Where a dam contains novel or particularly complex features the inspection and report should reflect additional emphasis on these aspects.

Part A - Periodic Inspections

Periodic Inspections focus on the physical defects.

Personnel

For safety reasons it is advisable to have two or more personnel on each inspection. This applies particularly to isolated areas and to inspections where access to confined spaces is necessary.

Equipment

The following items may be useful

- checklist field book and pencils
- recording device (eg dictaphone)
- cameras (still and video)
- hand held levels
- probe
- safety gear: waders, harnesses, hard hats, safety boots, breathing apparatus, flame safety lamp and anything else to comply with safety regulations
- tape measures

- torch (“mine safe” for unventilated conduits, tunnels or adits)
- shovel
- geological hammer
- binoculars
- first aid kit
- stakes and flagging tape.

Recording Inspection Observations

Inspections require the accurate location, recording and photographing of questionable areas. The objective is to permit observation and comparison of the state of a dam through time. It is necessary to record:

- extent of such areas (ie length, volume, width and depth or height)
- a brief description of any anomalous condition eg:
 - quantity/quality of drain outflows, seepage and its source(s)
 - location, type and extent of deteriorated concrete
 - location, length, displacement and depth of cracks
 - extent of moist, wet or saturated areas
 - changes in conditions.

Areas For Inspection

Monitoring

A surveillance evaluation should be integrated into a periodic inspection. The surveillance evaluation report should:

- assess the available pressure, movement and seepage monitoring data by analysis of the impact (if any) of all monitoring results
- assess the seepage from the storage (A plan should be provided showing position, quantity, and quality of seepage.)
- report on the recent movement survey for the dam
- report on the foundation and embankment pressures being experienced by the dam (A plan showing the position and purpose of the individual piezometers should be provided).

An assessment should be made of the appropriateness of seepage, movement and pressure monitoring being carried out at the dam.

Operation

The report should include a review of the way in which the dam has been operating since the last periodic inspection and how it is intended to operate until the next periodic inspection is carried out. The report should comment on the impacts of the operation on dam safety including rainfall records, release records, record of flows in the spillway and maintenance and repairs carried out.

It is appropriate to report on the compliance with Standard Operating Procedures (SOP). It is also desirable to assess the SOP relative to best practice and the Queensland Dam Safety Management Guidelines 2002.

Requirements for specific elements of dams are outlined in Part E.

The following areas may also have to be considered in an inspection;

- a test operation of all equipment
- evaluation of all surveillance data
- major function checks and maintenance inspections. For example:
 - flip bucket watering
 - conduit dewatering
 - diver inspection of intake work
 - conduit video inspection
- the foundations, abutments, and reservoir rim should all be inspected regularly
- an inspection should be made far enough downstream to ensure that there are no problems that will affect the safety of the dam
- the reservoir surface and shoreline should also be regularly inspected to identify possible problems. whirlpools can indicate submerged outlets (Large landslides coming into the reservoir could cause waves overtopping the dam or water quality problems, suspect areas should be quantitatively monitored.)
- upstream development and other catchment characteristics, which might influence reservoir water or silt inflows, should be noted in major inspection reports to anticipate possible problems or modifications in the dam
- downstream development in flood plains should also be regularly assessed.

Part B - Special Inspections

A Special Inspection is recommended in the following cases regardless of the regular inspection schedule:

- whenever a concerning specific defect is observed in the dam
- during and immediately after the first reservoir filling or augmentation
- during and after a rapid draw down
- before a predicted major rainfall, or filling
- during (if possible) and after heavy flooding (or severe windstorm)
- following an earthquake, sabotage or overtopping; immediately and then regularly for several months to detect any delayed effects.

When carrying out a Special Inspection a dam owner should follow the steps listed for Periodic Inspections.

Part C - Comprehensive Inspections

Comprehensive Inspection focuses on the dam safety management program and documentation for the dam. It is an assessment of the appropriateness, the effectiveness and application (including the owner's response to recommendations) of the dam safety management program and documentation for the dam including:

- SOPs
- DOMMs
- EAP
- Data Book
- Design Report/Safety Review
- Surveillance and inspection program and records.

This assessment should take into account the development permit conditions for the dam.

Personnel

An experienced dams engineer who is a RPEQ should carry out Comprehensive Inspections. In assessing and reporting on these aspects of the dam the inspecting engineer needs to assess the current dam safety management program and documentation for the dam against that required firstly, in the development permit conditions and generally in the Queensland Dam Safety Management Guidelines 2002.

Operation

It is appropriate to report on the compliance with SOPs. It is also desirable to assess the SOP relative to best practice and the requirements of the Queensland Dam Safety Management Guidelines 2002

Inspection

Comprehensive Inspections should incorporate a review of the Periodic Inspection program and periodic inspection records for the dam as well as evaluating the dam owner's response to the conclusions and recommendations from inspection reports.

Emergency Preparedness

Comprehensive Inspections should incorporate an assessment of the emergency preparedness of the owners and operators of the dam. The owners EAPs and documentation should be assessed relative to the requirements of the Queensland Dam Safety Management Guidelines 2002.

Part D - Preparation of a Periodic, Special And Comprehensive Inspection Report

General

The aim of the periodic, special and comprehensive inspection reports is to document the findings of each inspection and to detail the required actions to be taken by the owner as a result of the inspection. These reports should be presented in a precise and readable form and be signed by the inspector.

Detailed data that is used to assess aspects of the dam should be attached as appendices and not included in the body of the reports. Captioned and dated photographs should be used extensively in the reports.

Information On The Dam

The report should include the following background information on the storage:

- ownership details including any change of owner
- details of the development permit conditions for the dam
- a brief description of the dam including:
 - location (latitude and longitude)
 - nearest town
 - principal dimensions and design water levels
 - construction type
 - current water levels
 - history, including inspection history.
- a thorough and critical review of:
 - Data Book

- SOPs
- EAPs
- operation and maintenance plans and log books for the dam
- Safety Review status for the dam.

Documenting The Inspection

The report should address the preparation for the inspection in the following areas:

- outline of the preparation for the inspection
- the preparation of checklists
- data gathering
- special provisions (eg drainage of stilling basins or aerial inspection)
- review of previous inspection, including identification of action items
- review of operation and design information.
- composition of the inspection team including:
 - details of the inspecting engineer or consultant including the RPEQ No. as appropriate (RPEQ No. compulsory for comprehensive inspections)
 - details of owner's representative
 - details of operations staff involved in the inspection
- the photographic record of the inspection. All photographs should be dated and annotated to reflect the features recorded

Conclusions And Recommendations

Each inspection report should include an overall assessment of the state of the dam and recommend action to remedy defects or ensure continued appropriate management practices. These should include:

- comments on the implementation of recommendations from previous reports
- conclusions on the safety of the dam
- recommendations on additional evaluation, investigation or testing
- recommendations on rehabilitation, repair and operational modifications relating to issues that were noted during the inspection
- a summary sheet outlining the recommended action, the responsible person and the appropriate time frame
- the dam owner should sign the report and endorse the recommendations.

If observed defects are considered serious, advice from a suitably qualified and experienced engineer should be sought. Depending on the significance of the potential consequences, the advice should be documented in the report.

Circulation

Copies of the periodic inspection report should be circulated to the following:

- the dam owner
- the individual responsible for operation of the dam.

Copies of the comprehensive inspection report should also be circulated in accordance with the development permit conditions for the dam.

Sample Contents Page

- General
- Conclusions and Recommendations
- Information on the dam
- Inspection
- Monitoring
- Review of Data Book, SOPs, DOMMs & EAP *for comprehensive inspections
- Embankment (If Needed)
- Spillway
- Outlet Works (If Needed)
- Concrete (If Needed)
- Weir
- Captioned and Dated Photographs

Part E - Requirements for specific elements of dams for Periodic, Special And Comprehensive Inspections

This section outlines defects observed in each of the following elements of dams.

1. Earth embankments
2. Spillways and bywashes
3. Discharge control structures and outlet works
4. Concrete dams
5. Weirs

Owners should address the requirements for each element of their dam.

1. Requirements for earth embankments

There are several types of dam construction that are included in the earth embankment category. They include:

- homogeneous rolled earth fill dams
- homogeneous rolled earth fill dams with toe drains
- zoned rolled earth fill dams
- diaphragm rockfill dams
- central core rockfill dams.

These dams all include an impermeable zone of clay fill or concrete and a supporting rock or earthfill zone to provide strength. Filter zones provide internal drainage of the structure.

These dams can fail by:

- internal erosion of embankment material by seepage and transport of embankment material through sinkhole cracks, animal burrows, compaction flaws in embankment, compaction flaws in conduit surrounds, flaws in the abutments (known as a piping failure)
- bulk removal of material and loss of height and section through slumping, beaching, tree blow over, and gully and sheet erosion
- overtopping.

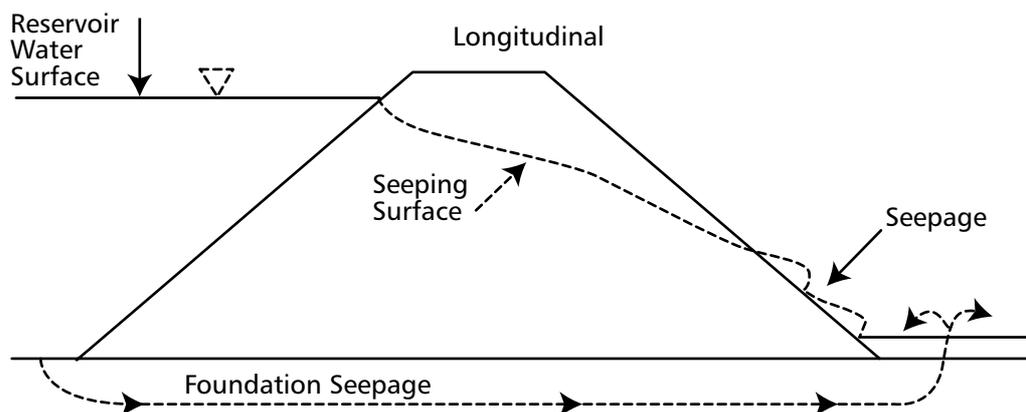
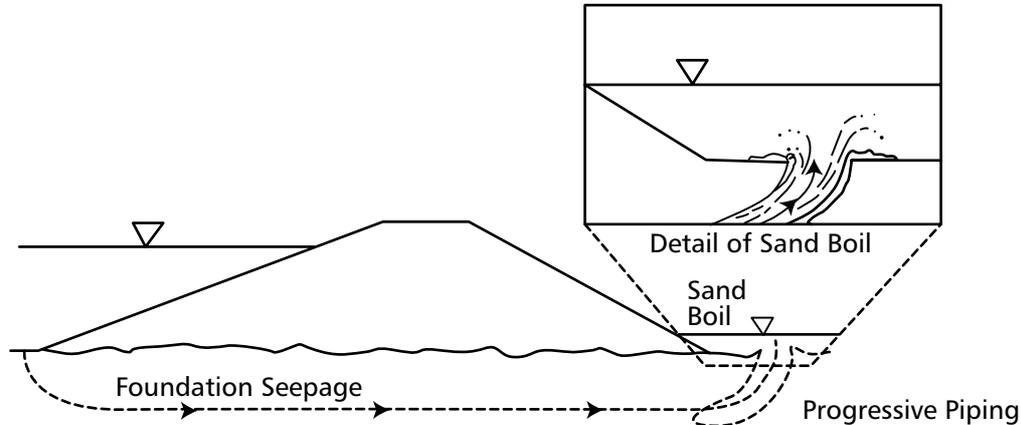
The report should document the inspection by including comments on the condition of the dam embankment with regard to

- erosion
- vegetative growth
- seepage
- slump formation
- beaching
- deterioration of rip rap
- cracking.

Following are some illustrations of deficiencies to look for when inspecting embankment dams.

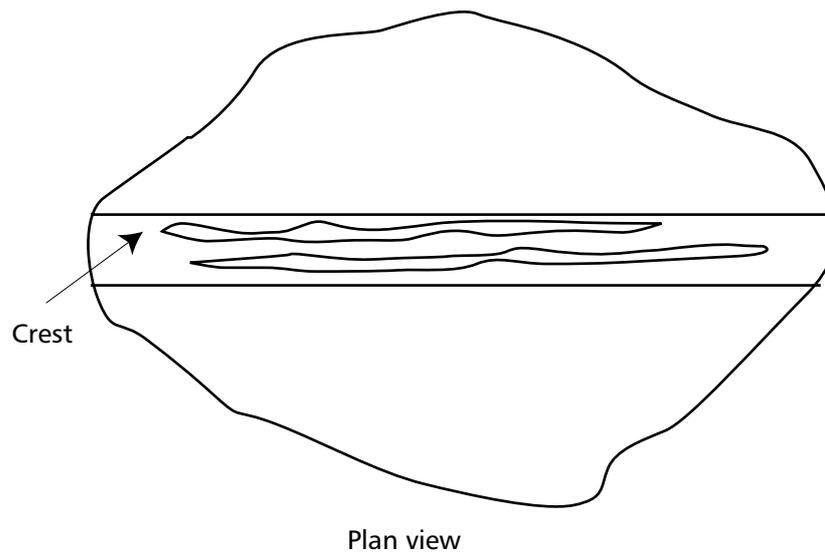
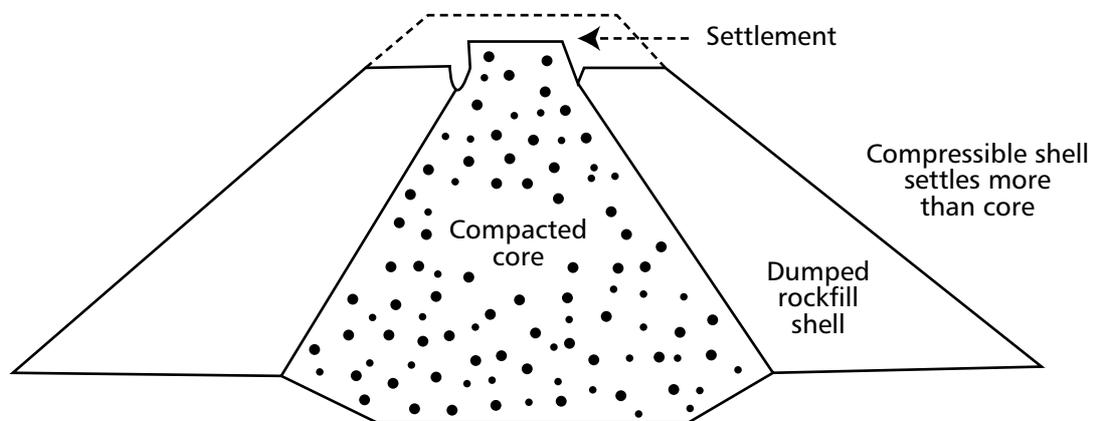
Seepage

- A water flow or sand boil on the lower portion of the downstream slope or toe area, especially at the groins.
- Leakage around conveyance structures such as outlet works, spillway conduits, or penstocks.
- Blocked toe drains and relief wells.
- An increase in the amount of water being released from toe drains and relief wells. (Remember to take into account changes in the reservoir level, or the effects of rainfall on the downstream face and abutments).
- Wet areas or area where the vegetation appears greener or more lush on the embankment slope or toe area.
- Turbidity or cloudiness of the seepage.



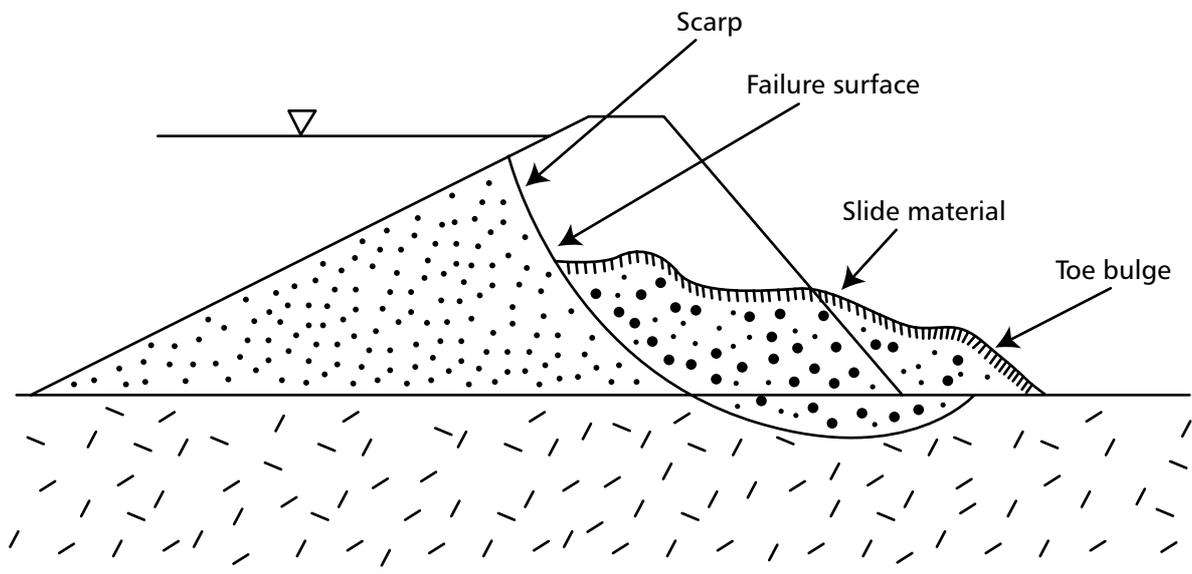
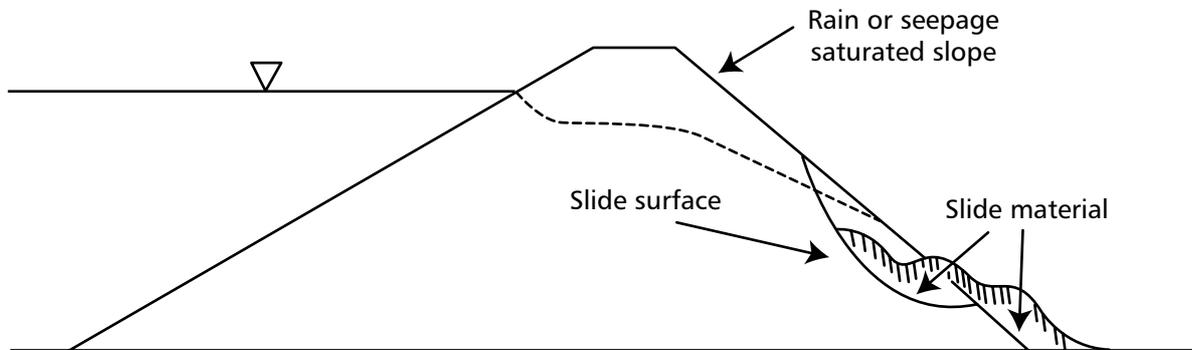
Cracking

- Desiccation Cracking: A random honeycomb pattern of cracks usually found on the crest and the downstream slope.
- Transverse Cracking: Cracks that are perpendicular to the length of the dam usually found on the crest.
- Longitudinal Cracking: Cracks that are parallel to the length of the dam. Longitudinal cracks may be associated with stability problems in the slopes.



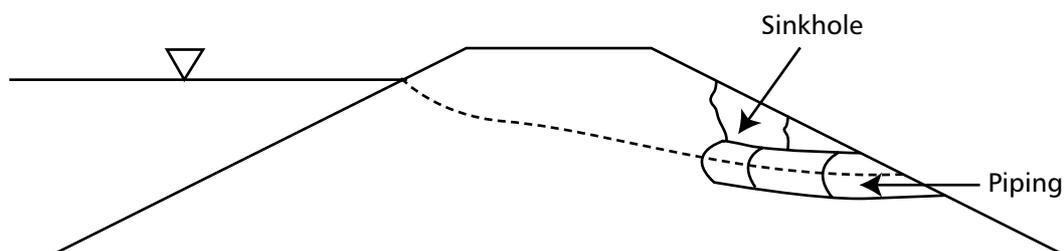
Instability

- Slides on the upstream and downstream slopes.
- Bulging, especially at the toe of the dam.
- Misalignments in the crest and embankment slopes found by sighting along fixed points.



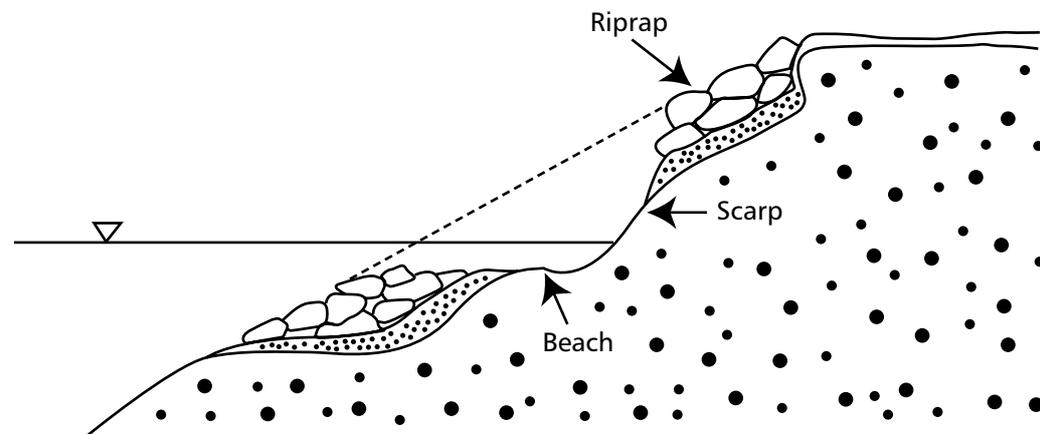
Depressions

- Sinkholes found by checking and probing each depression. Remember, sinkholes have steep, bucket-like sides while minor depressions have gently sloping, bowl-like sides. These are initiated by settlement or migration of materials in the embankment.



Maintenance Concerns

- Inadequate Slope Protection: Check for bald areas or areas where the protection is sparse or damaged.
- Surface Runoff Erosion: Check for gullies or other signs of erosion. Make sure to check the low points along the upstream and downstream shoulders and groins since surface runoff can collect in these areas.
- Inappropriate Vegetative Growth: Check for excessive and deep-rooted vegetative growth, especially trees.
- Debris: Check for debris on and around the dam, especially debris that could clog or choke outlet-works or spillway inlets.
- “Animal Burrows”: Check for damage caused by burrowing animals.



2. Requirements for spillways and bywashes

Spillways are designed to withstand high flows that have the capacity to overtop and erode embankments and to undermine concrete and rockfill structures.

Spillways that are not able to adequately contain the extreme flows through the dam contribute to failure of the dam by overtopping.

Spillways can fail by erosion of the structure from downstream, and by erosion that results from failing to contain the flows within the spillway section and by erosion of support for any structural elements through weaknesses.

Spillway flow needs to be directed back to the stream safely. Poorly directed flows through the spillway can erode the toe of the dam embankment and initiate failure.

Spillways and bywashes should be inspected immediately after spill events to monitor any damage and to determine erosion patterns. Comments on damage sustained after spill events should be included in the surveillance report.

The surveillance report should include an assessment of, and recommendations on the dam spillway or bywash with regard to:

- erosion of the downstream slope
- slumps in sidewalls
- potential for blockages caused by fencing, debris build up, or vegetative growth
- profusion and integrity of grass cover to the downstream slope

- blockages in the underdrainage of concrete spillways.

A recommendation for any remedial works to ensure the spillway and bywash is capable of fulfilling its function.

3. Requirements for discharge control structures and outlet works

Dams with inadequate and failed outlet pipes experience loss of serviceability by emptying or by being unable to release as required. Leaking from the outlet conduit is a common source of internal erosion failure. Deterioration and failure of the outlet structure, collapse or deterioration of the outlet pipework or valves or failure of associated control systems could cause the loss of outlet capability.

Discharge conduit

The discharge conduit should be inspected internally if possible (proper regard for workplace health and safety requirements is essential). If access to the conduit is not possible, video inspection should be carried out. The following aspects of the conduit should be assessed and reported on:

- sources of leakage should be photographed, marked on a plan and the flow rate estimated
- misalignment should be measured, and marked on a plan
- deterioration of pipe and joint material should be photographed
- fouling of the intake structure
- extent of corrosion.

Valves

All valves should be exercised at each inspection and an assessment made on the condition, the ease of operation, maintenance history and ease of access. The report should contain comments on the appropriateness of labelling of valves.

The full range of gate settings should be checked. The person performing the inspection should slowly open the valve, checking for noise and vibration. Certain valve settings may result in greater turbulence. There is a need to also listen for noise like gravel in the system. This indicates cavitation is occurring, and these gate settings should be avoided.

Structures

All structure associated with the dam should be assessed for serviceability. Intake structures may need to be inspected by divers for fouling and deterioration. Valve pits and boxes inspected for concrete deterioration and settlement. Intake structure steelwork inspected for corrosion and misalignment and damage. Baulks and gates exercised and inspected for corrosion and damage. Outlet structures inspected for concrete deterioration corrosion and misalignment and damage.

Dams incorporating mechanical or fabridam gate structures should be reported on by an appropriately experienced mechanical engineer.

Electrical, mechanical and control systems

Mechanical equipment including spillway gates, sluice gates, valves, stoplogs, pumps, flash boards, relief wells, emergency power sources, siphons, and electrical equipment should be operated at least once a year and preferably more often. Testing should cover the full operating range under actual operating conditions. Each operating device should be permanently marked for easy identification, and all



operating equipment should be kept accessible. All controls should be checked for proper security to prevent vandalism. All operating instructions should be checked for clarity and maintained in a secure, but readily accessible location.

All control systems associated with operation of the dam should be reported on by an appropriately experienced electrical engineer. The report should include assessment of the operation of all functions of the control system through the full range of responses and alarms. The report should incorporate an assessment of the condition and the maintenance and operation history of the system and of the existence and appropriateness of the operation plan for the controlled system. The report should make recommendations on the future maintenance requirements.

4. Requirements for concrete dams

Possible causes of concrete dam failure include:

- overturning or sliding due to erosion of the foundation or abutments during overtopping resulting from inadequate freeboard
- abutment or foundation failure due to overstressing
- structural failure of concrete unable to sustain imposed loads.

When inspecting the crest and the faces of concrete dams and weirs any of the following defects should be noted, documented and photographed and an assessment made of any changes in their severity since last inspection:

- seepage and leakage
- cracking concrete deterioration
- disintegration
- spalling
- efflorescence
- drummy concrete
- popouts
- pitting
- scaling
- surface defects
- displacement
- misalignment
- differential movement in cracks
- conditions of joints.

When inspecting the areas upstream and downstream of a concrete dam and weirs any of the following defects should be noted, documented and photographed and an assessment made of any changes in their severity since last inspection:

- cracking, bulges and slides
- sinkholes
- wet areas
- lush vegetation
- erosion of the abutment areas following spills.

5. Requirements for weirs

Weirs are designed to withstand overtopping by all river flows. As a consequence, weirs need to not only be stable and safe against the hydraulic forces applied and to retain water but must also be able to retain integrity in an erosive environment.



Whilst a regular time based inspection regime is appropriate, it is more important to inspect and document the deficiencies and remedial requirements after each river flow event.

Common causes of failure of weirs include:

- excessive and progressive downstream erosion, both from within the stream and through lateral erosion of the banks
- erosion of inadequately protected abutments
- hydraulic removal of fines and other support material from downstream protection (gabions and aprons) resulting in erosion of the apron protection
- deterioration of the cutoff and subsequent loss of containment
- additional aspects specific to concrete, rockfill or steel structures.

Inspection reports should comment on:

- details of any testing of flow control structure
- adequacy of flow control structure
- Mechanical / electrical equipment
- disruption to the downstream banks - as an indication of erosion
- water levels in the downstream pond - as an indication of seepage
- deepening of the downstream pond as a result of erosion
- erosion of abutment protection
- corrosion or other deterioration of the sheetpile or other cutoff material
- cracks and open construction joints in the downstream apron - as an indicator of hydraulic removal of fines.

Inspection reports for weirs should document the:

- magnitude of each river flow event since last report
- comment on the relative upstream and downstream water levels
- any repairs and maintenance resulting from each flow event
- comments on the operation of mechanical equipment (eg gates, bags) during flow events.

Notes

Notes





Queensland
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DEPARTMENT OF NATURAL RESOURCES AND MINES

QUEENSLAND DAM SAFETY MANAGEMENT GUIDELINES

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