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 unforseen 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  - 'out of date' procedures being applied to activities such that the dam is not operated in the manner expected by others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 *Water Act 2000*
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

Comprehensive Checklist of SOPs (cont.)

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: • an annual pattern of test operation of gates or other crest control devices[5] • 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: • 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
Log book should include major events such as: • 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.