Private dam maintenance and management in emergencies

Guidelines

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Information provided in this guideline is for general advice only.

This guideline is not intended to replace the need for appropriate professional engineering advice, particularly in areas concerning dam condition where the failure of the dam may endanger life, property or important environmental assets.

Professional consulting engineers should be engaged in such circumstance

This guideline is based on a previous guideline produced for DEW by Coffey Services Australia Pty Ltd “Small Dam Emergency Guideline”, 22 June 2017 and a guideline developed by the Victorian Government “Your Dam, Your Responsibility”.

Download this document at www.environment.sa.gov.au/topics/water/hazard-management

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1 Introduction

1.1 Purpose

This guideline applies to earth dams typically encountered in South Australia, particularly farm dams. It is estimated there are in excess of 30 000 privately owned dams in South Australia, some of which would pose significant safety threats to downstream communities if they were to fail. Private dam owners often overlook their responsibility to maintain their dams which increases the risk to downstream communities.

This guideline is intended to assist dam owners and emergency responders better prevent and respond to potential dam safety incidents. A dam safety incident is a situation where a sudden uncontrolled release or excessive controlled release of water from a dam happens or threatens to happen. The release may be caused by damage to, or failure of, the structure, flood conditions unrelated to failure, or any condition that may affect the safe operation of the dam. The release of water may or may not endanger human life, downstream property, or the operation of the structure.

Owners of large public dams have emergency action plans. Owners of private dams should still have planning in place to know what to do.

The South Australian State Emergency Service (SES) is the control agency for flood in South Australia and have the responsibility for responding to flood emergencies and ensuring the public is adequately informed and warned. In the case of dam safety incidents which may threaten community safety, the SES are able to issue emergency warnings to residents (including through the media, mobile and telephone systems, door knocking), direct evacuations and close roads, and coordinate with other agencies including police. The SES also have resources which can assist dam owners with managing dams at threat, including pumps and sandbagging.

The Department for Environment and Water (DEW), as the Flood Hazard Leader has developed these guidelines to assist dam owners and emergency responders better prevent and respond to dam safety incidents.

The objectives of this guideline are to assist dam owners and emergency responders to:

- Better understand dams and the risk they pose;
- Better understand surveillance and maintenance requirements of dams;
- Better understand their responsibilities and liability;
- Be better prepared in the event of an emergency such as extreme rainfall which could trigger dam safety incidents;
- Be able to recognise signs indicating potential dam failure, plus how and why this may be happening;
- Know what to do when an issue arises, including what mitigation actions may be taken;
- Know who to contact, and which tasks they can assist with;
- Know when to seek professional advice.

1.2 Responsibilities of dam owners

Dam owners are responsible for the safety of their dams and accountable for the damage these dams may cause if they fail. Dam performance and maintenance is the responsibility of the dam owner, even if the dam was built by someone else. Even small dams have the potential to cause damage, not only to property and the environment, but to persons, even resulting in death.

Having a dam built by someone else or taking on ownership of an existing dam does not necessarily clear the owner of responsibilities. Insurance does not prevent failure; it is merely a means of managing financial risk. The failure of a dam could trigger the failure of the neighbour’s dam, plus subsequent damage downstream, which the owner may be liable for. Likewise, dams can be impacted by the failure of an upstream dam, so regular maintenance can help lower the risk. Even if a failure does not cause damage of property, the cost of remedial work can easily exceed the original construction cost of the dam.

Often, dams were constructed a long time in the past, by a previous owner, and records may not exist. Owners should recognise that dams, even if well designed and constructed initially, may no longer meet current design standards due to degradation from lack of maintenance, subsidence and more stringent design requirements (such as increases in extreme rainfall predictions).

It is important that dam owners:

- have their dam designed and construction supervised by a suitably qualified and experienced professional;
- establish a program of regular inspections (surveillance) and periodic maintenance, including the keeping of appropriate records;
- carry out repairs when necessary;
- are able to recognise the signs of potential problems and imminent failure;
- are aware of potential downstream impacts from failure of their dam;
- know appropriate remedial actions that can be undertaken if signs of potential problems appear;
- know how and when to seek advice from a professional dam or geotechnical engineer; and
- are aware of their obligation to advise emergency services if there is a risk to property or public safety, and how to do so.

This guideline refers to seeking the advice of a suitably qualified and experienced professional. For small and low risk dams, an experienced dam construction contractor may be appropriate.

For higher risk dams that may endanger life, property or important environmental assets, the advice of a suitably qualified and experienced professional dam engineer should be sought. These may be found by enquiring with consulting engineers that provide design services in dam, civil or geotechnical engineering.

1.3 Resources in this document

Information presented in the document will assist owners and emergency responders alike recognising the signs and causes of a dam safety incident, assessing the risk, and effectively communicating with others regarding the incident.

Section 2 contains common terminology to assist with communicating with emergency services, engineers and other qualified professionals.

Section 3 describes the different types of dam that are encountered in South Australia.

Section 4 provides advice on ongoing maintenance and surveillance for dam owners to assist in preventing dam safety incidents.

Section 5 describes the hazard posed by dam failure, including common risk factors and how to estimate the potential extent of dam break inundation.

Section 6 contains information for dam owners and emergency responders on types of dam failures, their cause and common warning signs.

Section 7 describes the Rapid Risk Assessment tool for both dam owners and emergency services to assist in determining whether further action is needed if it is suspected that a dam safety incident may occur. The Rapid Risk Assessment tool is contained in Appendix A.

Section 8 provides guidance to both dam owners and emergency services on actions they should take during a dam safety incident, including remedial works for dams which may prevent or reduce the impact of failure. An Emergency Action Plan template is provided in Appendix B.

This guideline is not intended to provide design advice for dam repair or upgrade works. Advice should be sought from a suitably qualified and experienced professional. Some works may require a water affecting activity permit or development approval. Contact the local Natural Resources Centre or Local Council in your area if you need more information on approvals and permits.

2 Definitions

The following terms, definitions and Figure 2.1 will assist in communicating with engineers, the SES and other qualified professionals. Not all terms are pictured.

The international convention for 'left' and 'right' sides are determined by facing downstream with the flow direction.

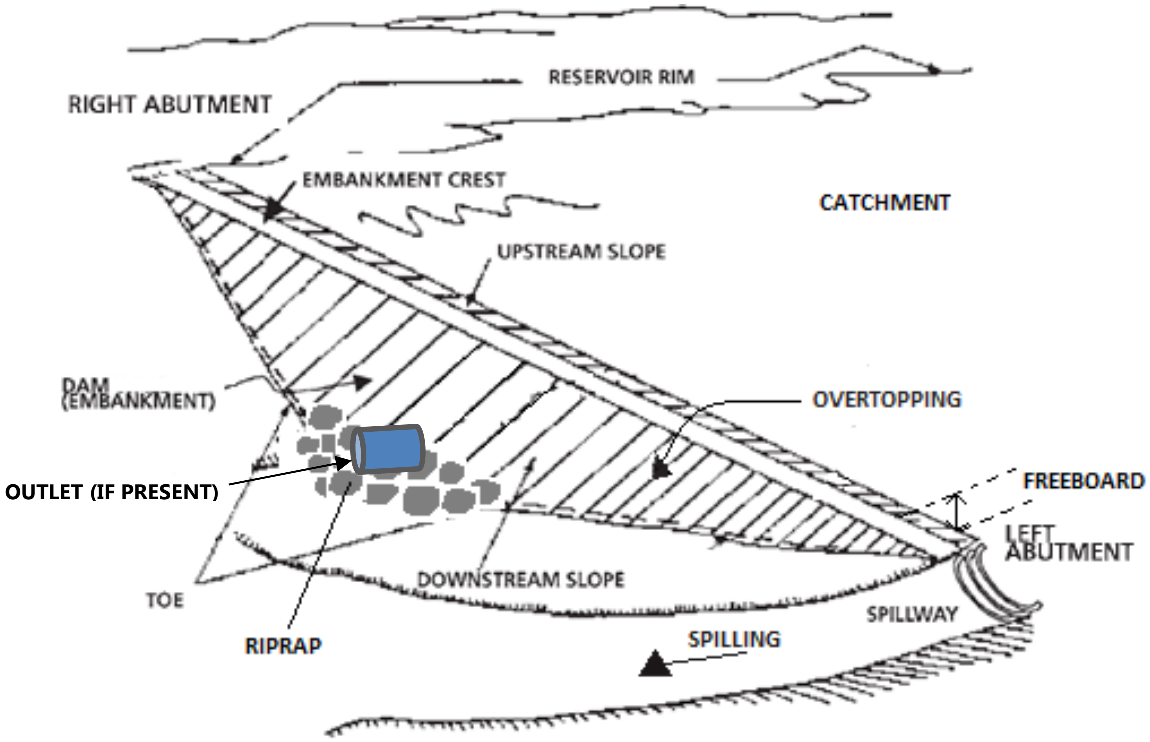

Figure 2.1. Dam with terms

- **Dam** or **embankment** - the constructed wall of the dam
- **Embankment crest** - the top of the wall of the dam
- **Abutment** - the (left or right) side of the gully where the dam 'connects' or 'butts' to the gully looking downstream; that part of the gully side against which the dam is constructed.
- **Upstream slope** - the water storage side of the embankment slope
- **Downstream slope** - the non-water storage side of the embankment slope
- **Batter** (also referred to as 'slope gradient') - the sloping bank of the embankment. Upstream and downstream batters are referred to separately.

  Slopes are always described in terms of horizontal distance to vertical distance. For example, a 3:1 slope means three horizontal units to one vertical. A 1:2 slope means one horizontal to two vertical.
- **Cut-off trench** - the part of the embankment built below the natural surface, to prevent water seepage underneath the embankment.

- **Toe** - the line where edge of the embankment touches the surrounding ground (upstream and downstream toes are referred to separately).
- **Reservoir** - the water that is stored behind the dam. Sometimes called storage.
- **Reservoir rim** – the boundary of the reservoir including all areas along the natural ground located at the same elevation of the embankment crest
- **Catchment** - the area in which rain that falls discharge to the storage (may include other dams on same waterway)
- **Riprap** – rock or other material used to protect the slope of the embankment toe from eroding. May also refer to rock or other material placed on the upstream slope of the embankment to protect against erosion from wave action in the reservoir.
- **Outlet** (if present) – a pipe or other infrastructure used to release and regulate water flow from a dam from upstream to downstream; or, the point at which water exits a pipe or spillway.
- **Inlet** (if present) – the point at which water enters a pipe or spillway.
- **Freeboard** – the vertical distance between the top of the dam (the embankment crest) and the maximum or full water level of the reservoir, which is typically at the level of the spillway inlet. It must be of sufficient height to prevent overtopping of the dam, even under the most adverse conditions such as a maximum flood flow, together with a maximum wave action. The freeboard should also allow for settlement of the dam.
- **Spillway** - a purposely designed and built channel that discharges flood water through a dam once it has reached its full capacity. For earth dams, it is usually an earth excavation cut near the dam abutment. A spillway is needed to discharge flood flows safely to avoid overtopping of the dam embankment.
- **Spilling** – the discharge of water through the spillway of a dam which has been designed for this purpose. Note: compare with definition for "overtopping".
- **Overtopping** – overflowing of water over the dam embankment, rather than through the spillway, such as might occur if the capacity of the spillway has been exceeded or has become blocked. Overtopping or overflow of an earth embankment dam will cause its eventual failure due to erosion of the downstream slope Note: compare with definition of "spilling".
- **Borrow pit** – a site from which soil is excavated to build an earth embankment.
- **Natural Surface (N.S.):** The ground surface prior to embankment construction.
- **Full Supply Level (F.S.L.):** The maximum water level reached when the dam is full and not spilling. Typically equal to the level of the spillway inlet.
- **Dam breach:** An opening or breakthrough of a dam sometimes caused by rapid erosion of a section of earth embankment by water.
- **Turbidity:** The cloudiness or haziness of water, typically caused by silt, sand and mud, but can also be caused by chemicals and bacteria/other germs.
- **Topography –** the natural shape of the land
- **Low flow device –** a device installed on a dam in order to pass smaller inflows through the dam for catchment health benefits downstream. A number of different designs are in use in South Australia. *Not pictured in figure 2.1*

3 Types of dams

Types of earth dams that are typically found in South Australia are described below.

3.1 Gully dam

A gully dam is built across an existing flow path of either a temporary gully or permanent stream, as shown in Figure 3.1 below.

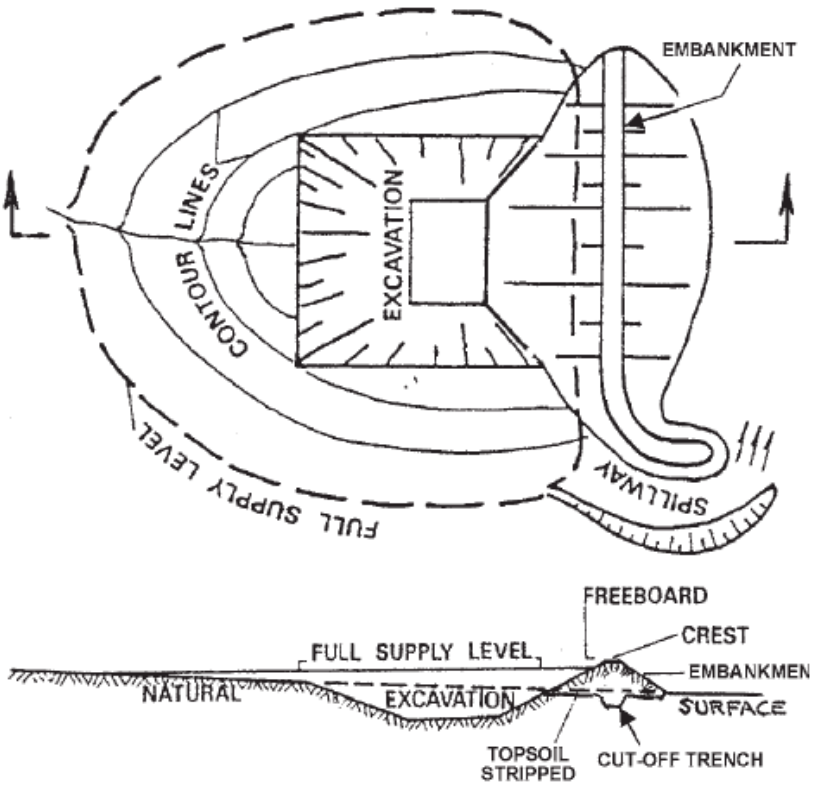

Figure 3.1. Gully dam plan view and cross section

The material used to construct the embankment is typically sourced from within the storage.

It sometimes presents difficulties in design and construction but is the most favoured because of its good storage ratios. The dam is highly susceptible to rapid filling, and potential overtopping during times of high rainfall as it is located on a concentrated flow path. Gully dams shown always incorporate a suitably designed spillway to allow the discharge of water during times of high flow. Dams may also incorporate a low flow device (such as a low flow pipe) to allow a volume of water to continue flowing down the stream.

3.2 Hillside dam

A hillside dam is not built across a stream, but as the name suggests - on the side of the hill. Localised depressions on hillsides are generally chosen, as they intersect with the natural flow direction. A hillside dam would typically have three constructed side embankments, as shown in Figure 3.2 below, however this is based on the topography of the hillside.

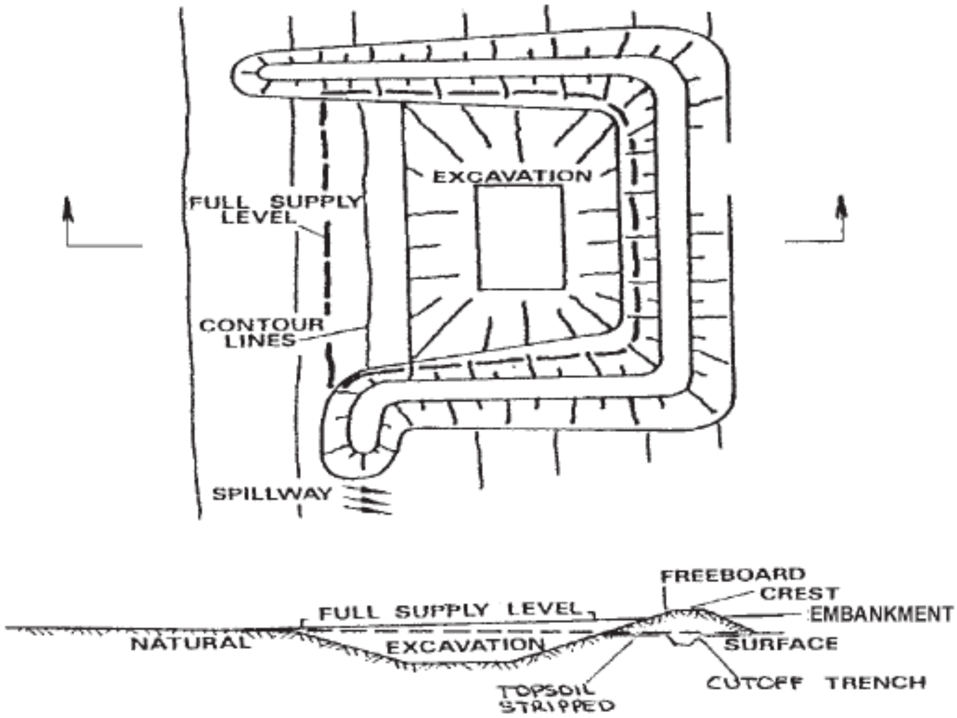

Figure 3.2. Hillside dam plan view and cross section

The material for embankment construction would typically be excavated from within the storage to allow for greater water volume.

The hillside dam is generally not as susceptible to overtopping during times of extreme rainfall, compared to the gully dam, as it is not located on a concentrated flow path.

3.3 Ring dam/tank

A ring dam is a typical dam constructed in flat terrain, where the clayey material required for the embankment construction is sourced from within the storage, as shown in Figure 3.3.

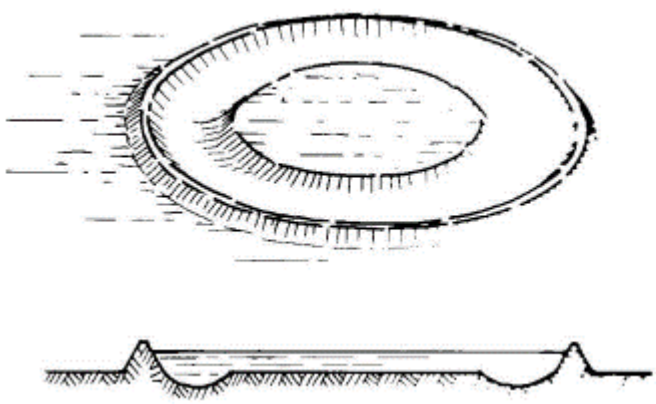

Figure 3.3. Ring dam plan view and cross section

If a ring dam fails the uncontrolled discharge is generally not channelled to a stream system, however it can still result in impacts therefore should be routinely inspected and maintained.

3.4 Turkey nest dam

A turkey nest dam is similar to a ring dam, with the exception being that the material for embankment construction is sourced from outside of the storage, as shown below in Figure 3.4.

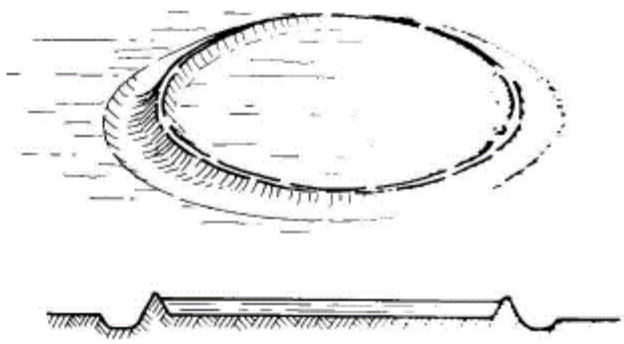

Figure 3.4. Turkey nest dam plan view and cross section

If the ground is too sandy for the embankment to hold water, a lining of clay at the base may also be required.

4 Surveillance and maintenance

4.1 Overview – know your dam

It is vital that dam owners undertake regular inspections (surveillance) of their dam. The benefits of regular surveillance and maintenance are:

- It enables the identification of minor defects which can repaired cost effectively before major damage occurs;
- It prolongs the life of the dam and protects against deterioration; and
- It ensures that the owner is familiar with the condition of the dam so that they can observe any changes that occur, particular during times of stress on the dam (flood, earthquake). For example, without regular surveillance, the dam owner would be unable to tell if a seepage condition is worsening or represents the normal condition of the dam.

The following guidance is provided to dam owners for undertaking regular dam surveillance. Monitoring related to specific dam failure issues are covered in Section 8.

These surveillance techniques are also useful for undertaking a systemic inspection of dam components during a dam safety incident by dam owners and emergency responders. However, a high degree of caution should be exercised and observers should stay well clear of the embankment and downstream area if there is a potential for failure.

4.2 Surveillance (walkover)

"Walk your dam to own it"

- Walk and inspect the dam at the peak of summer, to observe lowest ground water level and inner embankment batter.
- Walk and inspect the dam before winter; check critical dam elements such as spillway, embankment.
- Walk and inspect the dam before major rainfall. Check water level is appropriate to contain excessive rain. Spillway must be clear and embankments in good condition.
- After major rainfall (observe the dam from a safe distance and record any physical changes).
- Walk the dam in spring, and compare with pre winter conditions.

The dam should also be inspected:

- Within 24 hours of expected rainfall
- At least daily during rainfall
- Within hours of a significant rainfall event
- After an earthquake or tremor.

Observers should at all times be mindful of safety. Steep banks may be slippery following rainfall. Standing on the embankment or the downstream area should be avoided if the embankment is showing any signs of instability. If there are any concerns or signs of failure, a Rapid Risk Assessment (Appendix A) should be completed.

It is best to follow a specific sequence when conducting and recording an inspection, since this will lessen the chance of an important component being overlooked, for example (illustrated by Figure 4.1):

1. Upstream slope;
2. Crest (top of bank);
3. Downstream slope;
4. Seepage areas;
5. Outlet and/or low flow device (if present); and
6. Spillway

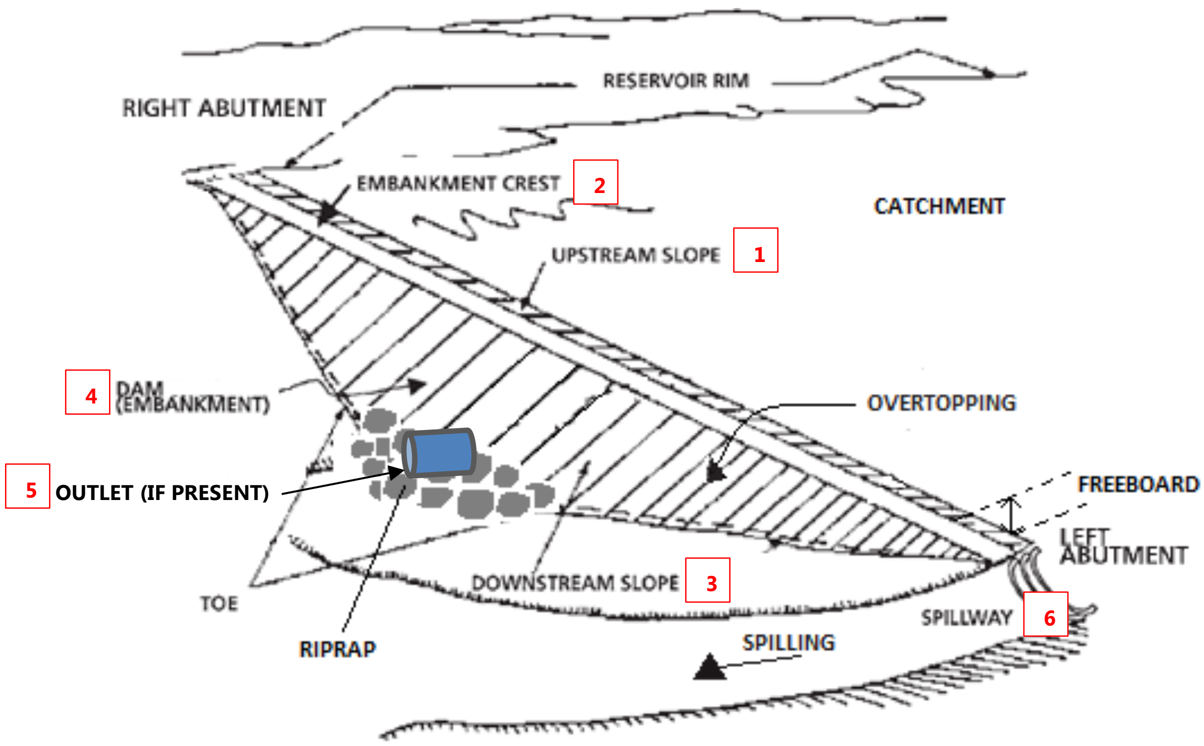

Figure 4.1. Proposed sequence when conducting inspections

The inspection is conducted by walking along and over the dam as many times necessary to survey every square metre. A person can usually obtain a detailed view from any given spot for a distance of three to ten metres in each direction, depending on the smoothness of the surface or the type of material on the surface, i.e. grass, concrete, rock, brush (Figure 4.2).

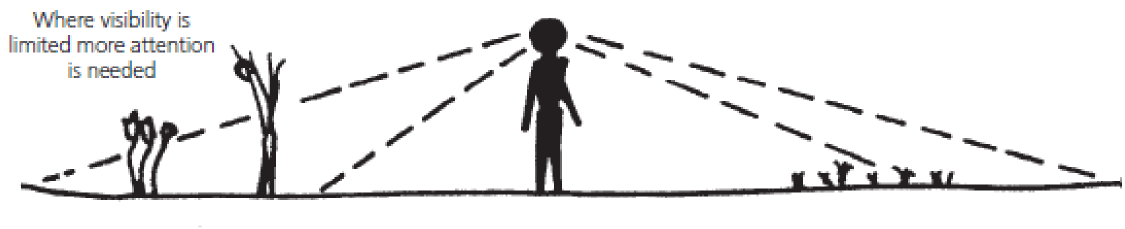

Figure 4.2. Proposed distance of 3 metres to 10 metres for a more detailed inspection

Adequate coverage can be achieved using parallel or zigzag paths (see Figure 4.3). On the downstream slope a zigzag path is recommended to ensure that any defects are detected.

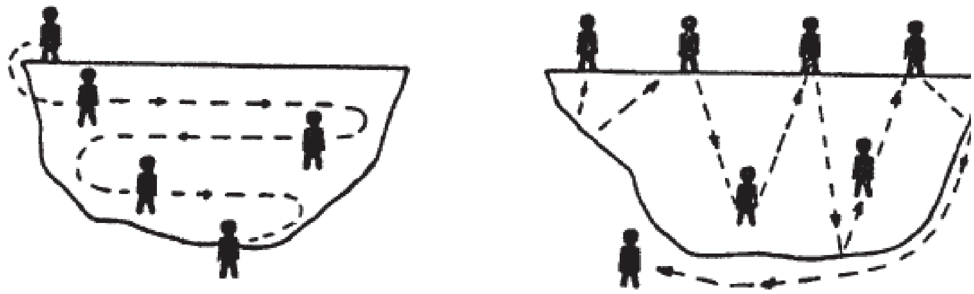

Figure 4.3. Proposed walking paths for dam inspection

Items to be inspected on a regular basis are shown in Table 4.1. Photographs and records should be kept of anything of note.

Checking the histories of any other dams in the area may also highlight potential issues.

Table 4.1. List of dam features for inspection

Dam component	Observation
Earth embankment	• Condition of erosion protection (riprap, rock fill) • Evidence of failure or potential failure mode: slip, slump, erosion, crack, hole, subsidence (caving in/sinking) • Vegetation on embankment grass cover, trees • Seepage through embankment: increase in rate, colour of water (turbidity, which could be indication of internal erosion within the dam). Also note any correlation with rainfall. • Pooling of water downstream of dam wall. • Damage by livestock • Damage by pest animals • Subsidence/settling of dam crest

Abutment and foundations	• Flows from natural springs • Slips / rock movements in natural material • Erosion, holes, piping (may be indicated by presence of sand boils) • Deposition of sediment in drainage paths
Spillway and outlet structures	• Erosion or silting of spillway channel (banks or bed), particularly if continued erosion could endanger the dam wall • Stability of spillway channel batter • Presence and condition of riprap (erosion protection) • Presence of vegetation or debris in spillway or channel • Capacity of the spillway – the spillway must be capable of carrying flood flows from the full supply level of the dam to the natural watercourse. • Condition and operation of outlet structures (e.g. pipes, low flow devices) • Erosion or silting around inlet/outlet of outlet structures (e.g. pipes)
Storage base and rim	(best inspection is achieved at time of low water level or emptying) • Seepage holes • Unusual cracking • Debris accumulation which may interfere with spillway operation • Evidence of landslips or failures within the storage • Seepage through rim • Presence of whirlpools just upstream of embankment
Downstream areas	• Silting up of channel downstream • Erosion / scour immediately downstream • Evidence of seepage downstream • Identify any life or property which are within the flood zone from dam failure, and any changes which have occurred (such as new development).

4.3 Common maintenance examples

Examples of dam maintenance may include but are not limited to:

- Removing and mowing vegetation; establishing desirable vegetation cover
- Replacing deteriorated riprap and erosion protection
- Restoring settled crest and freeboard
- Repairing seepage-induced slumping
- Cleaning the spillway and outlets, including pipes and low flow devices
- Controlling surface erosion
- Controlling burrowing animals

Whenever possible, earthworks operations, particularly those along drainage lines, should be confined to months which have least average rainfall and hence, the lowest risk of soil erosion. Work should be undertaken in staged sections so that no more than a specified area of soil is disturbed or exposed at any one time.

The advice of a suitably qualified and experienced professional should be sought if there is any concern for the condition of the dam. Whilst not all issues will require design aspects to be checked, maintenance which may appear to be small and insignificant may have significant ramifications if undertaken incorrectly.

Specific notes for some common maintenance issues are provided in sections 4.4-4.9.

Modifications to a dam may have water licensing implications, or require a water affecting activity permit.

Maintenance activities generally do not require a water affecting activity permit or development approval if the activity does not involve constructing, altering or removing a dam (provided the storage volume remains unaltered).

Emergency works to a dam during a dam safety incident do not require a permit.

Contact the local Natural Resources Centre or Local Council in your area if you need more information on approvals and permits.

4.4 Excessive settlement of the embankment

Over time, the dam wall may settle, lowering the crest height of the dam. This reduces the freeboard available between the spillway inlet height and the crest of the dam, meaning that overtopping is more likely to occur during a high rainfall event.

If necessary, the freeboard can be restored by placing sandbags along crest of dam so that water is directed to flow through spillway. The water level should be lowered to a safe level by releasing it through the outlet or by pumping, siphoning or a controlled breach until repairs can be made.

4.5 Cracks

Cracks can appear in a dam due to drying out, settlement and shrinkage. These types of cracks can, in some cases, eventually lead to seepage paths through the dam and therefore should be repaired before they compromise the stability of the dam. As a preventative measure, owners should maintain a good coverage of top soil and grass over the dam to minimise drying of the clay core and erosion damage to the dam.

However, the sudden appearance or enlargement of cracks, particularly when the dam is under stress (for example, higher water level than usual) can also be a sign of bank instability. In this case, refer to Section 6 for indicators of failure and Sections 7 and 8 for emergency actions.

General advice is provided below for the identification and repair of stable cracks which are not indicating an immediate dam instability issue. Advice from a suitably qualified and experienced professional should be sought for any significant repairs.

Design and Construction of Small Earth Dams (K.D Nelson, 1985) contains the following advice on crack repair:

> *Any cracks should be filled immediately with well compacted clay. There are three main kinds of cracks: transverse, longitudinal and shrinkage (sometimes called desiccation). Transverse cracks are those that run straight through the dam from the upstream to the downstream side and consequently are very dangerous. One kind of transverse crack is found in the too-dry dam which, when it fills, becomes saturated below the seepage line, and slumps. Unfortunately the material above the seepage line stays dry and firm; it forms a bridge over the saturated material while a crack develops along the seepage line. This is sometimes called a horizontal crack. Such cracks are difficult to handle because they cannot be easily filled. One line of action is to reduce the water level in the storage by pumping. The pumped water should then be sprayed over the crest in an attempt to induce a saturated settlement of the bridged crest. If successful, the crest develops a settlement corresponding to that of the slumped section, thus closing the crack. To prevent the crest from drying out again it should be covered with a 150 to 225 millimeter layer of sandy soil.*
>
> *Longitudinal cracks develop parallel to the crest length and are therefore not so serious, though they should be treated. They should be filled with clay to prevent rain from collecting in them. This rainwater could act as a lubricant to activate a potential slide.*
>
> *Shrinkage cracks are dangerous; they develop in a random pattern of both transverse and longitudinal defects. In very heavy clays they have been known to reach depths of two metres, so those located on the crest could extend well below the full supply level of the storage. Cracks can also lead to another kind of failure - piping.*

Cracks can be backfilled with appropriate fill material (for example, clay, bentonite powder/pellets for small cracks). This should be compacted in multiple layers until the repaired zone is level with the surrounding surfaces (if it is safe to do so).

Dress the area with well-compacted material to keep the material moist and minimise erosion from surface water.

4.6 Spillway and outlet works maintenance

A spillway is needed to discharge flood flows safely though the dam. If inflow to the dam is more than the spillway can handle, water will start flowing over the dam embankment (the dam will 'overtop') and this is a significant risk to the structure of the dam. All dams with a catchment should have a defined spillway, even if the dam is small and/or only fills rarely.

The spillway dimensions (the width and the vertical distance between the spillway crest and the top of the dam wall) will determine the maximum flow rate of water that can be spilled before the dam overtops. Spillways need to be large enough to pass a very large flood – the size of which is dictated by the importance of the dam and the risk downstream.

For dams that may endanger life, property or important environmental assets, it is recommended that professional engineering advice is sought to confirm that the dimensions of the spillway are sufficient to safely pass a large flood through the dam without failure. This may require detailed hydrological calculations.

Spillways require regular surveillance and maintenance to ensure their operability and integrity to safely discharge large flows during floods.

Spillway maintenance requirements may include, but not be limited to, the following:

- Clearing of debris; removal of vegetation from the spillway approach and outlet channels and from the reservoir (where it may migrate and block flow)
- Repair of erosion damage after spill events

The spillway should be kept clear of debris at all times. Trees, branches, vegetation and other objects can block the spillway or outlet of a dam. Each flood will bring down logs and other floating rubbish, which, if held up in the spillway, could reduce its carrying capacity. This could, in turn, lead to overtopping of the dam.

If a blockage is observed, it should be removed to avoid the possibility of overtopping, which could lead to a dam failure. Typically, appropriate maintenance should help prevent blockages. Debris should be removed as soon as possible, to deter problems during an event.

Other outlet works, such as pipes, should also be checked to ensure they remain unblocked.

Another hazard can result from the placing of sandbags across the spillway to give additional storage. If they are not removed before a flood arrives, there can be disastrous consequences. The removal operation can be both difficult and dangerous if attempted at night under flood conditions.

Modifying the spillway to increase storage capacity (for example, by raising the level of the spillway inlet with sandbags or dirt mounds) will greatly increase the likelihood of the dam overtopping and failing. The increased water pressure loading on the dam wall may also cause embankment instability.

If any erosion is observed, maintenance should be undertaken and consideration given to protection or redesign since erosion is likely to be far worse during a larger flood event.

Erosion may indicate that the spillway needs to be redesigned to minimise water velocity. This can be achieved by re-grading the spillway to ensure the spillway slope is as gradual as possible along its length, and remains as level as possible across its entire width to avoid flow concentration.

Erosion protection may be required at the spillway inlet or where the spillway returns to the watercourse downstream. Flow through the spillway should not be allowed to erode the downstream toe of the dam.

Erosion protection may also be required around outlet pipes.

4.7 Trees and vegetation

Dam walls should be covered in topsoil and grasses as protection from surface erosion and drying of the clay material. Grass cover should be encouraged to grow right up to the water's edge to prevent seepage.

Woody vegetation should not be allowed to grow on the dam wall or near the embankment toe. If young shrubs and trees are present, they should be eradicated. Woody vegetation has large root systems that can penetrate into the wall structure, then shrink and die over time. This leaves internal gaps where water can seep through and soil can collapse, leading to dam failure. Trees can also die or fall over during storms, leaving holes in the dam wall which can cause failure.

If large deep-rooted trees and heavy vegetation are already present on or near the dam, advice should be sought from a suitably qualified and experienced professional whether they should be removed and the appropriate method. In some cases killing the tree may worsen the situation as the decayed roots in the dam wall could act as seepage paths. Repair works may be necessary.

Landholders are also subject to laws regarding the removal of significant trees.

Heavy vegetation can also hinder visual inspections which can conceal potential issues with the dam (Figure 4.4). The dam embankment should be kept mown or slashed to control vegetation and enable proper observation of the dam wall (e.g. leakage, instability).

Figure 4.4. Vegetation hindering inspection of downstream slope of dam

4.8 Livestock

Excluding stock from the dam will prevent erosion, in addition to improving water quality and allowing the establishment of native vegetation.

Fences and gates should be maintained to allow access for emergency responders.

4.9 Pest animals

Dams can be an important water source and habitat for many animals, however, animals should not be allowed to dig in or around the dam wall and spillway. Burrowing animals within dams can cause substantial and costly damage if left unmitigated. The burrows created by animals can create seepage paths through the dam, leading to internal erosion and failure.

In South Australia, pest animals such as rabbits and foxes generally prefer soft ground such as a dam wall. Any holes in the wall or spillway will need reparation by filling the hole(s) with soil or small rocks, then grass to provide cover. Extensive burrows will need to be assessed by a suitably qualified and experienced professional.

Your local Natural Resources Centre can advise on native creeping grasses suitable for covering dam walls to protect from erosion and drying.

Further advice on pest animal control can be provided by the Natural Resources Centre.

5 The hazard posed by dams

5.1 Hazard and risk factors

There are tens of thousands of dams in South Australia. For the majority of these, failure would not be particularly harmful, either because the dam is too small to generate a sizable flood wave, or there is nothing of value that could be damaged downstream.

However, the failure of some dams could lead to disastrous consequences. Even relatively small, privately-owned dams can cause considerable losses to individuals, communities and environments downstream if they are poorly managed. Without appropriate design, construction, maintenance and surveillance, dams will age, deteriorate or malfunction, posing a risk that they will release sudden, dangerous flood flows.

The impact will depend on the following:

- **Size and type** – The height and width of the dam wall, and the volume lost if the embankment fails.
- **Location** – Location of the storage relative to other hydrological features, such as other dams upstream which could release water into this dam if it fails, and capacity of the watercourse downstream. Presence of residences, businesses, roads or any other public infrastructure downstream which could be impacted by the uncontrolled release of water.
- **Type and speed of failure –** Shape and size of the dam breach, and the speed at which it forms. These are in turn dependent on the mode of failure (e.g. overtopping, piping) and the construction materials used in the dam.

To the untrained eye a dam may appear to be in reasonable condition, and it may take an experienced professional in geotechnical engineering or hydrology to identify weaknesses in design or condition. The following risk factors may contribute to poor dam condition and an increased risk of failure:

- **Construction methodology / materials** – Whether the dam was designed by a suitably experienced engineer and constructed under engineering supervision. The use of unsuitable material and incorrect placement are a major cause of dam failures.
- **Geological conditions** - While the dam embankment itself may be sound, the material supporting it may be unsuitable; either possessing insufficient strength, or by allowing water to 'pipe' beneath or around the embankment.
- **Inadequate inspection and maintenance** - Regular inspection and maintenance is imperative to assist with the identification and resolution of issues before they escalate.
- **Modifications -** Some dam owners try to modify the spillway on a dam to achieve an increase in storage capacity. If a spillway is filled in or obstructed the chances of overtopping the dam are greatly increased. Water pressure loading on the dam wall will also increase due to the added height of water and this may cause instability in the bank and embankment slips.
- **Storage capacity and spillway capacity** - While the dam may appear to have sufficient storage volume, the capacity of the spillway is also of critical importance, otherwise in a high rainfall event the dam may overtop. A spillway needs to be appropriately designed for the size of the upstream catchment.

If there is any uncertainty regarding any of the above conditions, the dam may be hazardous, and it is important to have it assessed by a suitably qualified and experienced professional.

5.2 Downstream area of consequence

An awareness of the potential consequences of dam failure is essential for dam owners and emergency services so that they understand the risks from dam failure and can initiate the appropriate response to an emergency situation. The actions taken for a potential dam failure in an uninhabited region with few downstream consequences is vastly different to the emergency response that would be required for a failing dam upstream of an urban area.

The downstream area that will be inundated from the dam failure and the consequences will depend on:

- The maximum outflow from the dam breach
- Routing and attenuation of the flood wave (how it "flattens out" as it travels down the valley)
- Depth and velocity at the location of the impacted property or people

It is difficult to accurately assess the dambreak area without computer modelling, and even then, assumptions need to be made regarding the size and speed of development of the dam breach. In the case of earth embankment dams, it is common to assume that the dam could fail rapidly once erosion has begun.

Flood waves from dam failure also commonly carry a large amount of debris which can further exacerbate the consequences (for example, by blocking bridge openings) and making survivability of the flood wave by people caught in flood waters very difficult.

If there are dams located downstream, it is possible that the flood wave could also cause those dams to fail as well. For example, if a downstream dam has an earthen embankment that would be significantly overtopped due to the upstream dam failure, then the predicted inundation zone should also reflect the additional flooding from failure of the downstream dam. There have also been cases where road and rail bridges and embankments have acted as temporary dams – holding up the floodwaters before failing – which have caused renewed surges.

The guide *Consequence Screening Tool for Small Dams* (Department of Environment and Primary Industries (Victoria), 2014) provides the curves shown in Figure 5.1 to provide guidance on the distance downstream where a flood wave from a dambreak could potentially result in significant consequences.

Assessment of the consequences of dam failure would also need to consider the relative proximity of people or property to the natural channel of the watercourse (how close, how high above the bank) and roads or railway lines that may cross the watercourse.

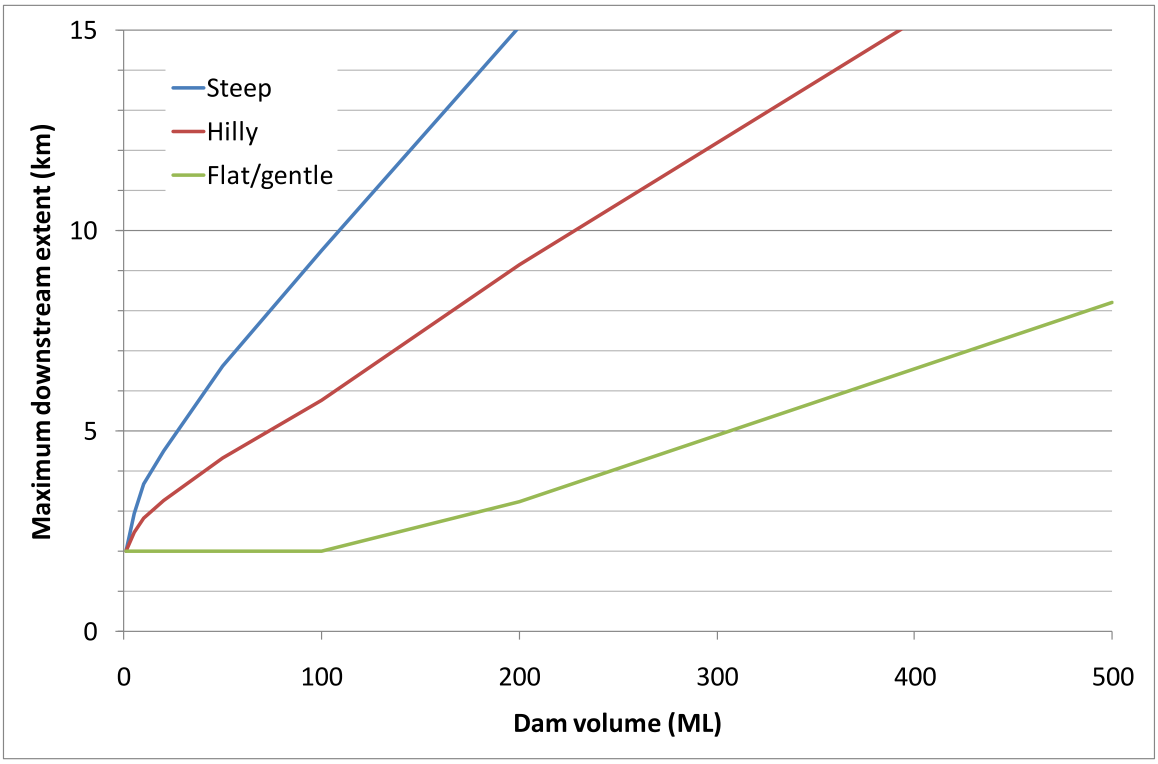

Figure 5.1. Indicative maximum downstream extent of dambreak impact (DEPI 2014)

Three variations in terrain related to the slope of the downstream valley were considered in developing the extent curves: ‘Steep’, ‘Hilly’, ‘Flat/gentle’. The curves were derived assuming slopes of up to 0.002% for the lower limiting ‘Flat/gentle’ curve and 0.02% for the upper limiting ‘Steep’ curve (DEPI 2014).

6 Types of dam failures

Earth dams can fail in a number of ways. Failure types typically fall within two main categories: overtopping by a flood of greater magnitude than what the dam was designed for, and structural failure caused by inadequate design or construction or by deterioration of the structure itself over time.

Farm dam failures are not often reported in the media but are relatively common. In 1992, the Australian National Committee on Large Dams (ANCOLD) reported a 23% failure rate for farm dams in NSW. Additionally, a high percentage fail during their first filling, usually because of poor design or construction.

6.1 Overtopping

Overtopping is the uncontrolled release of water over the dam embankment following a major rain event (see . Overtopping can occur:

- If the capacity of the spillway is too small to discharge flood flows safely though the dam
- If the dam was constructed without a spillway and the dam storage is insufficient to contain all of the inflow
- If the spillway is not properly maintained, has become blocked or has been temporarily or permanently raised
- If the crest of the embankment has settled (become lower) relative to the inlet height of the spillway

Figure 6.1. Overtopping of dam at maximum storage capacity (prior to failure)

In the United States, overtopping due to inadequate spillway design, debris blockage of spillways, or settlement of the dam crest accounts for approximately 34 per cent of all dam failures.

Many overtopping failures are due to insufficiently designed or constructed spillways. The design of many spillways has been determined largely by a few simple rules based on catchment area and some empirical factors, or the experience of the dam building contractor, which may not always be appropriate for the risk posed by the dam. Furthermore, over time, changes to the land use of the catchment, stricter design criteria and increased flood estimates may lead to old dam spillway designs becoming outdated.

If overtopping occurs, it can rapidly erode the downstream embankment and cause dam failure (see Figure 6.2).

Figure 6.2. Overtopping dam failure

The process of overtopping failure is usually:

1. Reservoir is full and the excess water flows down the batter of the dam
2. Dam toe starts to scour
3. Slumping of the bank above the scouring
4. Process (scouring and slumping) repeats itself until the slumping reaches the top of the embankment and a dam break occurs.

Some earth dams, particularly those with a good even cover of grass, can withstand overtopping for short periods. However, once erosion is started, it can progress rapidly. The risk of erosion increases with increasing steepness of the downstream batter, height of the dam and poor quality grass cover.

Actions to manage overtopping include:

- Lowering the water level of the dam
- Raising the embankment crest to direct more flow to the spillway
- Increasing the capacity of the spillway
- Managing the rate of erosion

These actions are described in Section 8.

6.2 Seepage and piping

Seepage (or leakage) is the migration of water from within the storage area through the dam embankment. It can occur through the dam wall or the foundations. A small amount of clear seepage is common for earth dams.

However, an increase in seepage or discoloured discharge will generally indicate a more serious problem (shown in Figure 6.3). Seepage causing internal erosion through and under embankments poses one of the greatest threats to the structure of the dam and can readily result in failure. A study conducted by the University of New

South Wales (Foster et al. 1998) shows that 54 percent of the world-wide embankment dam failures post-1950 were the result of internal erosion.

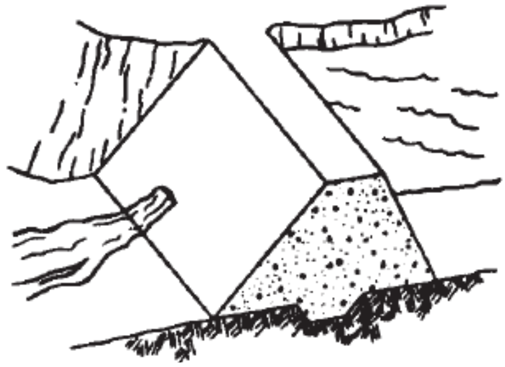

Figure 6.3. Seepage escaping downstream of an embankment

Excessive seepage can lead to internal erosion. This is often referred to as piping. Particles of soil are carried away by the seepage until eventually a tunnel, or pipe, is formed from the downstream exit point to the reservoir.

The point where seepage emerges from the embankment is typically referred to as a seep or boil. A seep is a wet spot or area where seepage is discharged on the downstream slope, toe, abutment or location downstream of the embankment. If the seepage forces are large enough, soil particles will be eroded from the embankment or foundation and deposited in the shape of a cone around the discharge point. This is known as a boil. Boils are an indicator of internal erosion which is a potentially serious condition that could lead to failure of the dam.

Once internal erosion initiates, it could develop rapidly into a dam breach within a few days or even hours. It is also possible for the erosion to only occur episodically, possibly taking many decades to manifest into a problem. It could be that erosion only occurs when the reservoir reaches a threshold elevation, which might only exist for a short period annually, or perhaps might not be reached except during flood events.

Observation of clear seepage does not necessarily mean that there is no internal erosion concern. Sediment transport could be occurring, but it might not be visible if materials are eroding slowly, or it could be that the observation was made during a period of no active erosion.

Initially, seepage can be minimal and clear, with the flow gradually increasing and becoming visibly turbid, and rapidly escalating into a very threatening situation.

In addition to seeps and boils, other indicators of seepage include:

- A soft wet area on the dam embankment or downstream, which may initially be evident as an area where the vegetation is more lush and green
- A continuous or sudden unexplained drop in water level of the reservoir
- Appearance of sinkholes (localised depressions caused by the collapse of surface and near-surface materials into an underground void)
- Other surface deformations such as slumps and cracks
- A whirlpool in the reservoir upstream of the embankment, indicating water is being sucked through the embankment

Seepage problems can rapidly escalate and it is therefore recommended to consult a suitably qualified and experienced professional for advice immediately if concerns arise.

Actions to manage seepage include:

- Lowering the water level of the dam
- Monitoring the rate of seepage
- Monitoring the cloudiness of seepage
- Monitoring the condition of the dam, including shape and cracks
- Seepage / leakage repair methods

Refer to Section 8 for further information on how to safely undertake these actions.

6.3 Longitudinal/Transverse cracking

During dry periods, drying and shrinkage of surface material can cause cracking in the dam as it dries out. Over time, cracks can lead to the development of preferential seepage paths and internal erosion can occur. Cracks can also be an indicator of slope instability (see Section 6.4 Slide, slump or slip).

Cracking in both the longitudinal direction and transverse direction can occur (see Figure 6.4, Figure 6.5 and Figure 6.6).

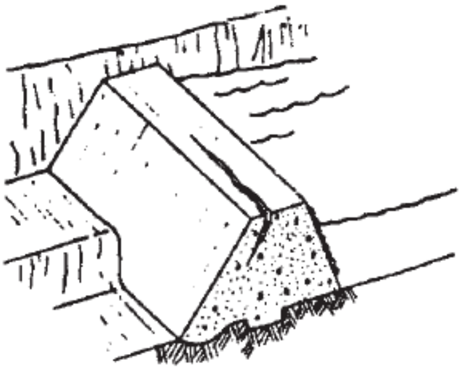

Figure 6.4. Longitudinal cracking

Figure 6.5. Example of longitudinal cracking

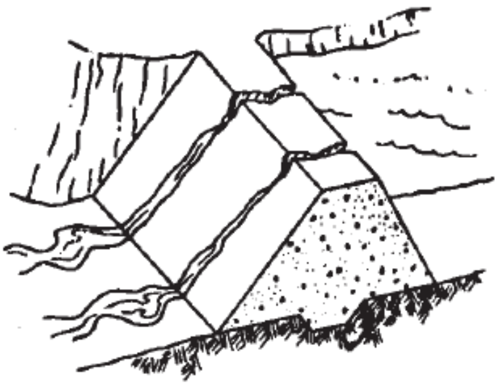

Figure 6.6. Transverse cracking

If longitudinal or transverse cracking is identified, and there is no immediate concern of slope instability, the cracks should be backfilled (see Section 4). If the cracking is too large to repair safely, are growing in length or number, or there is a concern of instability, it is recommended to consult a suitably qualified and experienced professional for advice.

Actions to manage cracking include:

- Lowering the water level of the dam

- Crack repair methods (if cracks are from drying)

Refer to Section 8 for further information on how to safely undertake these actions, or Section 4 for repairing cracks due to drying.

6.4 Slide, slump or slip

Slides, slumps or slips are localised failures due to the lack of strength of the material (shown in Figure 6.7 and Figure 6.8). This may cause entire failure of the dam. The cause of the localised failure could be due to heavy rain, seepage or poor construction of the embankment. Batters that are too steep for the material characteristics can cause slipping of material. They can occur on either side of the dam.

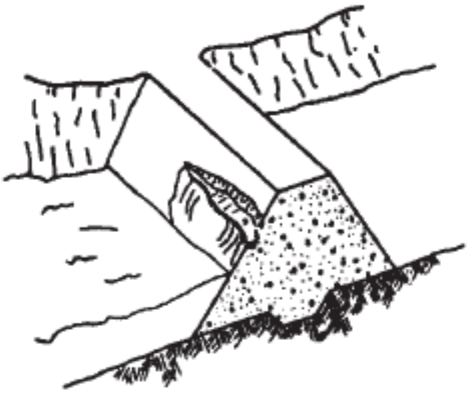

Figure 6.7. Slumping of material on upstream slope

Figure 6.8. Example of localised failure on downstream slope

If sliding, slumping or slipping occurs, it is recommended to consult a suitably qualified and experienced professional for advice.

Actions to manage slides, slumps or slips include:

- Lowering the water level of the dam

Refer to Section 8 for further information on how to safely undertake these actions.

6.5 Erosion on crest and downstream slope

Erosion on the crest and the downstream slope is usually caused by heavy rainfall, wind, or by poor construction and/or maintenance (see Figure 6.9). As it continues to rain, the damage will continue from the surface to the internal structure, downstream to upstream, causing dam failure. This is a different failure mechanism to erosion caused by overtopping, which is discussed in Section 6.1.

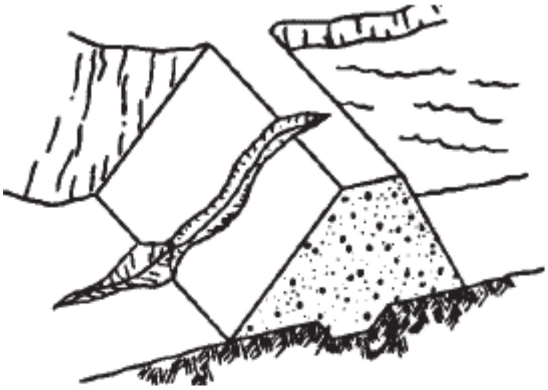

Figure 6.9. Erosion on crest and downstream slope

Dams constructed of dispersive soils can be susceptible to infiltration of rain, leading to development of erosion tunnels and shafts through the dam and subsequently failure. If erosion is observed during an inspection, and it does not threaten the safety of the dam, it should be repaired immediately (if safe to do so).

If the opening is too large to repair safely, it is recommended to consult a suitably qualified and experienced professional for advice.

Actions to manage erosion on the crest and downstream slope include:

- Lowering the water level of the dam
- Repair of erosion

Refer to Section 8 for further information on how to safely undertake these actions.

6.6 Spillway or outlet pipe erosion

Scouring and gullying associated with high velocity spillway flows have been known to undercut embankments and cause major failure. Erosion may also occur around damaged or deteriorated outlet pipes, which may significantly erode the embankment and lead to failure.

[insert picture of outlet pipe erosion at Strathalbyn dam from September 2017 – follow up with SES]

Actions to manage erosion on or around the spillway or outlet pipe include:

- Lowering the water level of the dam
- Managing erosion

Refer to Section 8 for further information on how to safely undertake these actions.

7 Rapid risk assessment (RRA)

The intent of the Rapid Risk Assessment (RRA) is to provide dam owners and emergency responders with a rapid and simple assessment to determine if further action when they think there is a possibility that a dam failure will occur.

The RRA is presented in **Appendix A**. It is recommended that dam owners pre-complete the first section of the RRA, which includes information about the dam's size and downstream impacts of failure, before any potential issues arise. The dam owner should be able to answer the questionnaire to their best knowledge prior to contacting emergency services and/or a suitably qualified and experienced professional (who may not be familiar with the dam and site) and will assist them to quickly evaluate the current state of the dam.

The second section should be filled out when there is a concern for a dam safety incident prior to contacting a qualified professional and/or the SES.

The RRA will trigger Emergency Actions if an emergency situation has been identified. The RRA will also enable dam owners and emergency services to rapidly convey critical information should an emergency situation arise.

8 Emergency Actions

8.1 Emergency planning

Dam owners are responsible for the ongoing safety of their dam, and may be held liable for any damage that the dam causes due to failure. In general, the dam owner is responsible for the ongoing maintenance of the dam, detecting and evaluating dam safety incidents, notifying emergency management authorities if there is a risk to public safety, and taking appropriate actions to mitigate the likelihood or consequences of an incident where they are able to do so.

It is recommended that dam owners be prepared with an emergency action plan so they are ready to execute it immediately when an emergency situation is identified. This should be reviewed and updated annually. Preservation of human life is always the first priority.

A template for a dam emergency action plan is provided in **Appendix B**. This should be followed if the RRA identnfies the need to activate the dam emergency action plan.

When a significant concern exists it is strongly recommended that the SES be informed at the earliest opportunity so that appropriate emergency responses can be instigated. Seeking help with a developing problem needs to be done quickly before the problem progresses into something serious. SES is the emergency service responsible for warning and evacuation for floods, which may include notifying any downstream residents who may be in danger if a dam failure occurs. The SES may also be able to assist with action to mitigate dam failure, such as pumping and placement of sandbags.

Dam owners also should immediately seek the advice of a suitably qualified and experienced professional.

Information contained in the RRA will assist the SES and a suitably qualified and experienced professional to assess the incident and whether an emergency response is required. The dam owner should be able to advise or explain:

- the type of dam, its size and location;
- the nature of the problem, including the type of defect and the extent;
- how quickly it is changing;
- the current status of inflows and water level;
- possible downstream consequences of failure.

The completed RRA form, a site plan, drawings/sketches and/or photos should also be ready to be sent by e-mail or mobile phone message. Remember that it will take time for emergency services and/or a qualified professional to come onto the site to provide assistance or advice and depending on the rate of incident development, it may be too late or inappropriate.

Emergency planning should also take into consideration that the dam may be inaccessible or access restricted during times of heavy rain (when most dam safety incidents occur). For example, this may occur due to access roads being inundated, or surrounding paddocks being too wet for vehicles to approach the dam site.

It is important to remember that in most cases the risk of failure and the impact of a failing dam will be significantly reduced if it contains less water. Safely reducing the water level of the dam is always a sensible action if a serious problem develops or is developing.

8.2 Advice on what not to do

1. **DO NOT** do anything that will put the owners, workers, downstream residents or general public at risk. There have been incidents resulting in death involving people trying to 'save' a dam.
2. **DO NOT** drive on the embankment where the dam integrity has been compromised, as unexpected failure may occur, as well as personal injury.
3. **DO NOT** walk upstream, downstream or on the embankment if you see cracks on the embankment increasing in width, as unexpected failure may occur.
4. **DO NOT** walk upstream, downstream or on the embankment if you see seepage increasing or if the water is muddy at the toe of the embankment. Stay away from the embankment and dam downstream flood zone, as rapid failure may occur (as quickly as 30 minutes).
5. **DO NOT** excavate a new spillway in the dam embankment to evacuate the water. A spillway should only be excavated in the natural soil and should be protected from erosion (unless designed otherwise by a qualified professional).

Caution should be exercised if the embankment even has partial failure and a suitably qualified and experienced professional should be contacted for advice.

8.3 Monitoring

Monitoring is an essential part of managing any dam safety incident. Monitoring should be undertaken regularly to identify any changes that might occur to:

- Reservoir level
- Rate and turbidity (cloudiness) of any seepage, including whether any sediment is being deposited
- Location and width of cracks
- Erosion, and whether further erosion is occurring
- Changes to the shape of the embankment
- Rate of inflow to the reservoir

Photographs and records should be kept. The use of markers (for example, sticks placed on the reservoir edge, painted lines on the embankment) are useful for assessing changes over time. Caution should be exercised that the observer doesn't place themselves in danger.

The surveillance walkover and checklist in Section 4.2 provides a systematic approach to monitoring.

8.4 Lowering the water level by pumping

Some important considerations when determining if pumping is an appropriate option to lower the water level are:

- Rate of drawdown possible with available pumping resources. If the pump capacity is small relative to the volume of the dam and/or continuing inflows, pumping may not be worthwhile.
- Access to the site
- Availability of equipment and power sources available

- Dam embankment stability
- Inlet and outlet conditions. Pipe inlets and outlets need to be able to be placed safely and without causing further erosion.
- The risk of the dam safety incident and the rate at which the defect is worsening. Pumping can take several hours to lower the water level sufficient to reduce the load on the dam embankment. Resources may be best directed towards alternative actions.

If using pumps to lower the water level:

1. **DO NOT** place pipe connections (if any) at the crest of the dam. If the pipes aren't properly connected, they may leak which in the worst case may cause dam failure.
2. If possible, place pumps and pipe connections on natural ground; a flat easily accessible area by an all terrain vehicle.
3. **DO NOT** place pump at the top of dam embankments.
4. **DO NOT** place the hose outlet on the downstream slope of the dam or near the toe of the dam. This may cause erosion at the toe of the dam which may lead to dam failure. If possible, place the hose outlet on natural ground.

Pumps, vehicles and other equipment should be placed away from the dam embankment in case of sudden failure. The natural ground surrounding the reservoir may also be soft following heavy rainfall and/or inundation, which should be taken into consideration when placing vehicles and equipment.

Siphons are an alternative option to lower the water level. Siphons are typically a pipe or conduit that have been primed (filled with water) to allow atmospheric pressure to force water over an embankment dam and out the other end of the pipe. A pump may be required to initially prime the siphon, but after that no further power source is required. A key limitation on whether a siphon will work is the vertical distance between the reservoir water level and the dam crest (the vertical lift). If the vertical lift is too great, the vacuum pressure within the pipe might be too low and could collapse the pipe. Notching the dam crest (excavating a small transverse trench for the siphon) can be used to reduce the vertical lift provided it doesn't introduce risks of erosion. The inlet of the siphon also needs to be adequately submerged to prevent formation of a vortex in the reservoir and entrainment of air in the siphon. Advice should be sought from a suitably qualified and experienced professional whether a siphon is an appropriate option for lowering the water level of the dam.

8.5 Lowering the water level by enlarging the existing spillway or excavating a new spillway

A new spillway should never be excavated in the dam embankment itself, as the flow of water will rapidly erode the dam material and lead to failure of the dam.

If a new spillway is to be excavated, it should be cut through the dam abutment (natural surface), well away from the dam embankment. The spillway channel should be cut so that it is as gently sloping as possible, so as to minimise erosion from flowing water. The location of the spillway channel should also ensure that water is discharged well away from the downstream toe of the embankment to avoid erosion of the embankment. The excavation should be undertaken so that the water level is lowered in a controlled manner, without causing a sudden surge of high velocity water which may result in excessive erosion or a floodwave in the downstream watercourse.

Similar principles apply to the widening and/or lowering of the inlet level of an existing spillway. Excavations should only occur through the abutment and be as gently sloping as possible to manage erosion from flowing water.

The dam embankment and surrounding natural surface may be soft from heavy rainfall and/or inundation and more susceptible than usual to erosion.

Extreme caution should be exercised when removing blockages from spillways or outlet pipes due to the risk of sudden suction.

8.6 Managing overtopping by raising the dam crest

Sandbags may be placed along the crest of the dam to mitigate the risk of overtopping, particularly for dams where settlement of the crest has occurred and it has become lower compared to the inlet height of the spillway. This will direct more water through the spillway.

8.7 Managing erosion

Erosion can occur in the spillway channel or on the embankment due to overtopping, erosion around the outlet pipe, or from spillway discharge).

Suitable materials for managing erosion include riprap (rockfill), sandbags, plastic sheets weighted with sandbags, geotextile fabric and hay bales.

Suitably-placed erosion protection can assist in managing the rate of erosion so that dewatering of a dam occurs over several hours rather than a sudden failure creating a damaging floodwave.

8.8 Managing cracks

Cracks can be due to drying and shrinkage of the embankment material, or may be an early warning sign of bank instability. Refer to Section 4.5 for advice on repairing cracks from drying.

If the cracking is too large to repair safely, the cracks are growing in width, length or number, or there is a concern regarding embankment instability, advice should be sought from a suitably qualified and experienced professional and other emergency actions should be undertaken (such as lowering the water level).

8.9 Repair of seepage/leakage

Excess seepage and erosion by piping is very difficult to repair. Examples of remediation used, subject to consultation with a suitably qualified and experienced professional, may include but not be limited to:

- Use very silty water so that the fines get drawn into the pores and hopefully block the piping
- Cover the upstream face with clay or plastic/polyethylene liner or bentonite liner
- Jet grouting
- Dig out the affected area and replace with appropriate material.

Extreme caution should be exercised while attempting to repair a leak on the upstream face of a dam since there is a risk of sudden embankment failure or being sucked into an erosion hole.

8.10 After the event

Following the dam safety incident, it is the responsibility of the dam owner to seek the advice of a suitably qualified and experienced professional and ensure that all necessary repairs are undertaken as soon as reasonably practical.

It is also recommended that the dam owner review the RRA and emergency action plan and update if necessary to improve future response actions.

9 References and further reading

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10 Appendices

Rapid risk assessment (RRA)

Always fill out the general section. If there is concern for a dam safety incident, complete section 2 as well.
This form is to be filled out to the best of the dam owner's knowledge prior to contacting a qualified professional

IF ANY RED BOXES ARE CHECKED OFF, PROCEED TO THE EMERGENCY ACTION PLAN AFTER COMPLETING THIS QUESTIONNAIRE

SECTION 1: GENERAL INFORMATION

NAME:

ADDRESS:

SITE LOCATION / DESCRIPTION / ACCESS

1. What is the approximate height of the dam?	☐ <1m	☐ 1-3m ☐ >3m
2. What is the maximum approximate volume of water contained by the dam?	☐ <1 ML	☐ 1 ML-5 ML ☐ >5 ML
3. Does the dam have a spillway?	☐ YES	☐ NO
a. If yes, does the spillway have enough capacity to allow flood overflow?	☐ YES	☐ NO
b. If yes, is the spillway protected from erosion?	☐ YES	☐ NO
c. If yes, is the spillway located on natural ground?	☐ YES	☐ NO
4. If a dam failure occurs, who/what will be affected downstream of the dam?	☐ WATER CHANNEL ☐ OPEN PADDOCK	☐ RESIDENT(S) ☐ ANOTHER DAM ☐ PUBLIC ASSET (ROAD, BUILDING) ☐ I DON'T KNOW ☐ OTHER:__________

SECTION 2: IF THERE IS CONCERN FOR A DAM SAFETY INCIDENT

DATE:

WEATHER:

5. Are there any landslips along the dam?	☐ NO	☐ YES
6. Is there an increasing flow of seepage?	☐ NO	☐ YES
7. Is the colour/turbidity of the seepage muddy (ie. not clear)?	☐ NO	☐ YES
8. Is there a progression of erosion along the dam?	☐ NO	☐ YES
9. Is the dam overtopping?	☐ NO	☐ YES
10. What is the likelihood of immediate failure (including timeframe)? ☐ UNLIKELY ☐ POSSIBLE ☐ LIKELY →	☐ >24HRS	☐ 1-24 HRS ☐ <1 HR ☐ I DON'T KNOW
11. Can maintenance work be done safely to minimise risk of failure?	☐ YES	☐ NO
12. Can the water level be lowered safely without increasing risk of failure? i.e. pumping, siphoning, modifying spillway	☐ YES	☐ NO

SITE PLAN / SKETCH (PLEASE HIGHLIGHT AREAS OF CONCERN)

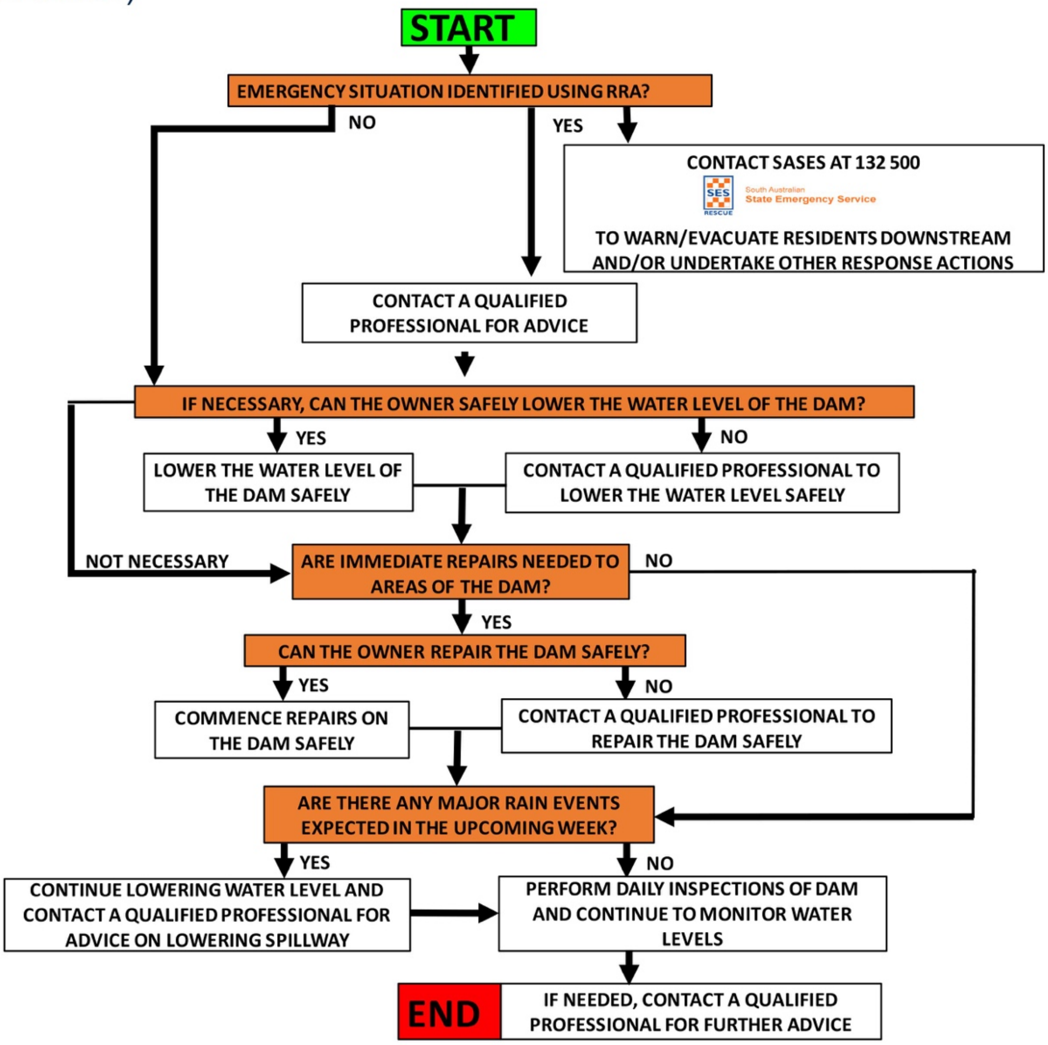
- include approximate dimensions and distances in metres
- include cross-sections, if possible
- include photos, if possible

RRA CHECKLIST

QUESTIONNAIRE (GENERAL)	☐ COMPLETED
QUESTIONNAIRE (IF CONCERN)	☐ COMPLETED
SITE PLAN / SKETCH	☐ COMPLETED
PHOTOS TAKEN	☐ COMPLETED

Emergency action plan flow chart

(For dam owner)



CONTACT LIST FOR EMERGENCY RESPONSE (PRE-COMPLETED BY DAM OWNER)

POLICE: Ph: ______________________

SOUTH AUSTRALIAN STATE EMERGENCY SERVICES: Ph: ______________________

DOWNSTREAM RESIDENTS:
Name: ____________________ Ph: ______________________
Name: ____________________ Ph: ______________________
Name: ____________________ Ph: ______________________
Name: ____________________ Ph: ______________________

CONSULTING ENGINEER:
Company: ______________________
Name: ______________________
Phone: ______________________
E-mail: ______________________

GEOFABRIC, PLASTIC, SANDBAGS & OTHER MATERIAL
Company: ______________________
Name: ______________________
Phone: ______________________
E-mail: ______________________

EQUIPMENT PROVIDER:
Company: ______________________
Name: ______________________
Phone: ______________________
E-mail: ______________________

LOCAL NATURAL RESOURCE MANAGEMENT CENTRE (NRM):
Company: ______________________
Name: ______________________
Phone: ______________________
E-mail: ______________________

FILL MATERIAL (CLAY, SAND, GRAVEL OR ROCK):
Company: ______________________
Name: ______________________
Phone: ______________________
E-mail: ______________________

OTHER:
Company: ______________________
Name: ______________________
Phone: ______________________
E-mail: ______________________

SOUTH AUSTRALIA

Government of South Australia

Department for Environment and Water

SES RESCUE