Dams that minimise erosion 3

Farm dams are important water sources for stock, irrigation and domestic use on rural properties. Well-designed and constructed dams are farm assets and require little maintenance. Poor design and construction methods can lead to excessive construction costs, severe downstream erosion and a short-lived dam.

All farm dams must comply with NSW Government's Farm Dams Policy. Unlicensed dams may only be built off-stream, or on first or second order streams, and their water storage capacity must fall within the harvestable rights for the property. All other dams require a licence. Water contained in dams licensed for erosion control does not have to be included in a property's harvestable rights storage volume.

You can get more information about the regulations for farm dams from the NSW Department of Water and Energy at http://www.naturalresources.nsw.gov.au/water/dams.shtml

When estimating the size of the dam required, land managers need to consider the purpose of the dam and how much water the particular land use/enterprise will require and over what period. Information in this chapter applies only to small earth dams, and may not be appropriate for major structures or large catchments. Professional advice should be sought where the catchment area is greater than 5 ha, where the dam will store more than 4 m depth of water against the wall, where more than 5,000 m^3 of earth is used in the dam wall, or where material to be used for construction is unsuitable (see page 73).

Dam structure

All dams have three essential features.

- The **excavation** (borrow pit) provides a source of soil for the embankment and becomes the storage basin for the water.
- The **embankment** (dam wall) prevents excessive water seeping through or underneath. All farm dam embankments should have a core trench below the wall that extends into the ground the wall is built on. The embankment needs to be strong enough to hold the water resting against it. A wider embankment is stronger than a high narrow wall. The outside batter slope should be no more than 2.5:1.

A newly constructed gully dam, showing the excavation, embankment, spillway and a trickle pipe for low flows.

- The **spillway** allows excess water to pass through the dam without overtopping or causing damage to the embankment, and discharges excess water from the dam without causing erosion of the area onto which it flows. The spillway width depends on the rainfall intensity of the area, and the peak discharge likely from the catchment. The table below gives minimum spillway widths for locations around the region. A dam with a catchment area of 5 ha should have a spillway of at least 3 m for low rainfall intensity areas (eg Guyra) and up to 9 m for the highest rainfall intensity sites (eg Coffs Harbour, Murwillumbah).

The worksheets (page 165) at the end of this book can help you estimate the peak discharge for your dam.

Minimum spillway widths (in metres) required for dams with catchments up to 5 ha, based on a 1 in 20 year risk interval. These spillway widths assume that the spillway is well grassed, and discharges water onto a well-vegetated area.

Table developed from information provided by Graeme Goldrick, NSW Dept of Environment and Climate Change.

Location	2.5 ha catchment area	5.0 ha catchment area
Armidale	3.0 m	4.5 m
Casino	3.0 m	4.5 m
Coraki	3.0 m	4.5 m
Coffs Harbour	5.0 m	9.0 m
Comboyne	3.0 m	6.0 m
Coopers Shoot	5.0 m	9.0 m
Dorrigo	3.0 m	5.0 m
Drake	3.0 m	4.5 m
Guyra	3.0 m	3.0 m
Legume	3.0 m	3.0 m
Macksville	3.0 m	4.5 m
Maclean	3.0 m	6.0 m
Mallanganee	3.0 m	6.0 m
Murwillumbah	5.0 m	9.0 m
Nimbin	3.0 m	6.0 m
Nymboida	3.0 m	4.5 m
Tenterfield	3.0 m	4.5 m
Tyringham	3.0 m	3.0 m
Uralla	3.0 m	4.5 m
Walcha	3.0 m	3.0 m

Types of dams

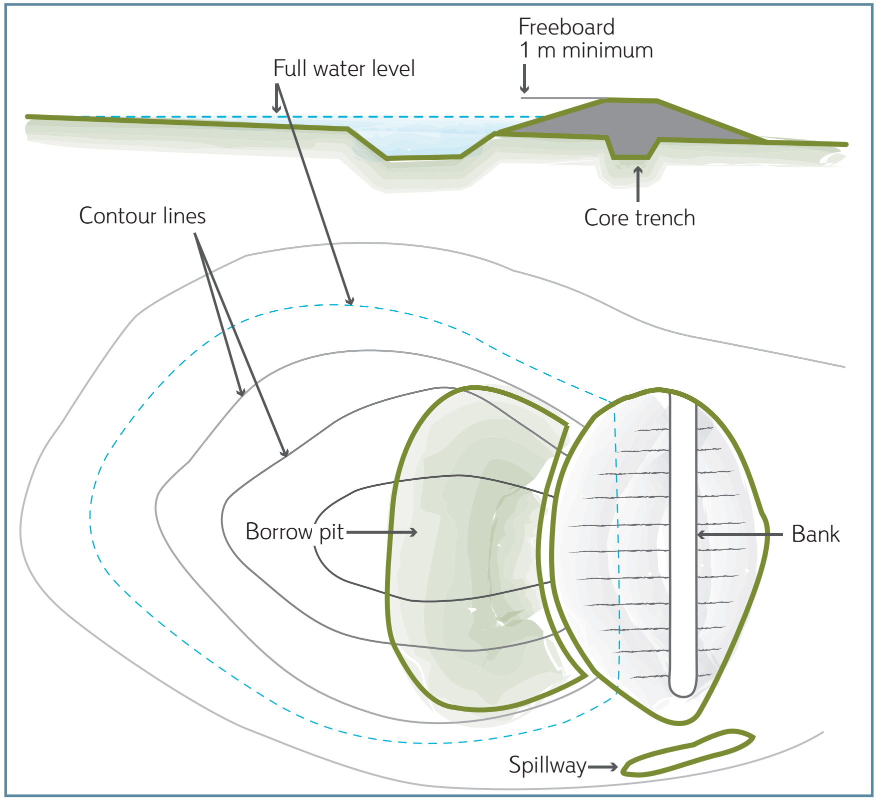
There are three types of dams commonly used on the north coast. The type of dam depends on site conditions.

Gully dam

A gully dam is an earth embankment built across a natural drainage line. These are generally the cheapest dams to build to store a large volume of water. The natural catchment above the dam channels runoff to the dam site.

Gully dam

Adapted from Farm dams – planning, construction and maintenance, Barry Lewis, Landlinks 2002.

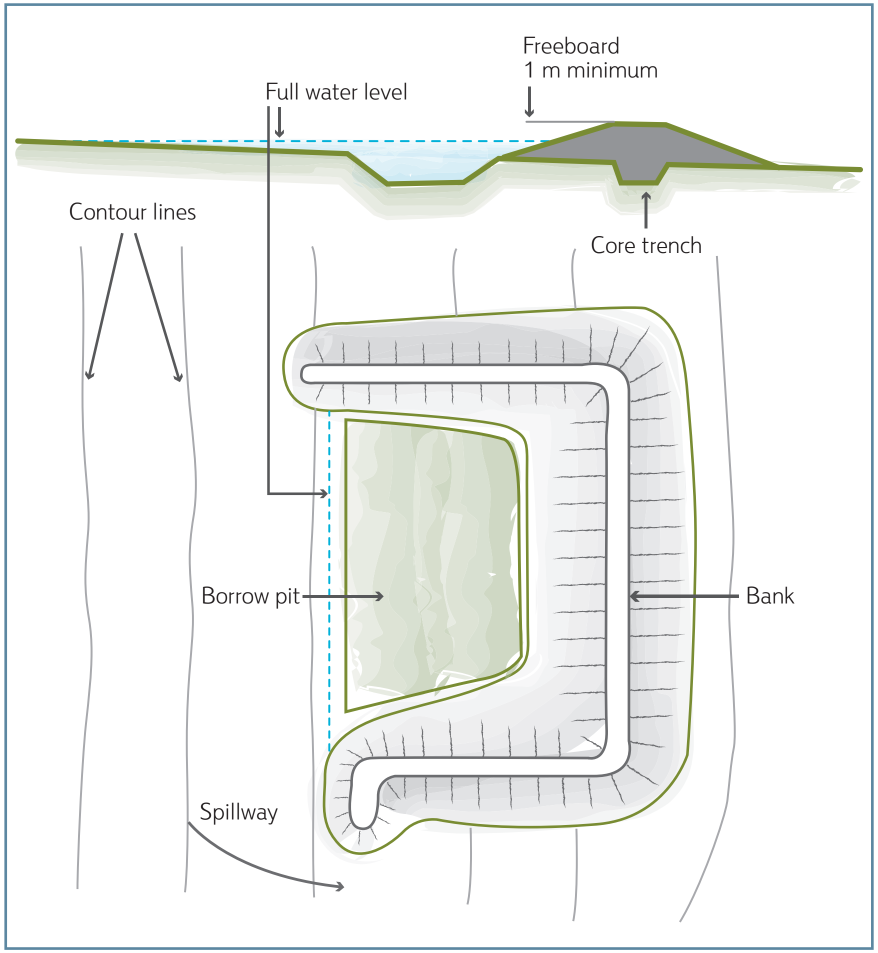


Hillside dam

A hillside dam is built on a low to moderate slope without a significant natural depression. It will generally have a three-sided or curved bank and will often have catch drains to ensure sufficient runoff makes its way to the dam. Hillside dams are also built to capture flows from natural springs.

Hillside dam

Adapted from Farm dams – planning, construction and maintenance, Barry Lewis, Landlinks 2002.



Excavated tanks

Excavated tanks are used on flat or low sloping country. The dam is dug below the natural ground surface and filled by runoff collected by catch drains or by groundwater seepage if the watertable is near the surface. When the dam excavation intercepts the watertable the dam is considered to be a well, and a groundwater use licence is required. These dams are generally the most expensive to build by volume of water stored and are uncommon in the region.

Excavated tank Source: Graham Johnson NSW DPI

Site selection

Slope

Ground slope is important in the selection of dam sites as it determines how large the embankment will need to be, and how much earth will be available from the excavation for the embankment. On flat sites, the excavation volume is the same as the water storage volume, so there is usually soil available for the embankment. As the slope increases, excavation provides less material for the embankment.

Where the slope is greater than 5%, there may not be enough earth to construct the embankment with sufficient freeboard, crest width and batter grade for stability and strength. In this case professional advice is needed.

Use the worksheet at the end of the book (see page 175) to assess slope.

Runoff

Dams fill with runoff and/or groundwater seepage. If the dam depends primarily on surface runoff, it will come from the catchment area upslope of the dam. The amount of runoff depends on the area of the catchment, rainfall, and infiltration rates, the latter determined by groundcover and soil type. To estimate runoff water available for a particular dam site you need to know:

- the average annual rainfall for the area (page 167)
- the size of the catchment (page 168)
- the annual runoff of the catchment (page 171)

Groundwater

Approval to construct any dam that intercepts groundwater is required from the NSW Department of Water and Energy. Groundwater-fed dams will only fill as far as the watertable level. The watertable must remain high enough to keep water in the dam when needed, particularly during dry spells. If the dam has a porous bottom, water will drain away when the watertable drops.

If the watertable is near enough to the surface to fill a dam, groundwater movements need to be monitored with a piezometer for some time before building the dam. These records will show how the watertable moves over the seasons and when groundwater is available to supply the dam.

A piezometer is a perforated pipe dug vertically into the ground. The height of the watertable relative to the ground surface can be measured using a tape measure and a torch.

Slotted pipes for use as piezometers. In the ground only the top of the pipe is visible. Source: Keith Bolton

Spring-fed dams are built so that the top water level of the dam is below the level of the spring. These dams do not need a licence as they do not intercept groundwater. When the spring is flowing, the dam will fill from the surface runoff from the spring. All spring-fed dams should be constructed with a trickle pipe to carry low flows, to avoid persistent wet soil on the spillway (see page 84).

Soil

Not all soils are suitable for dam embankments so soil at potential dam sites must be assessed to determine whether it will hold water (see page 155). A test hole is needed to evaluate the subsoil, as topsoil is not suitable for embankments. Formal soil tests are strongly recommended if there are no nearby dams, or existing dams in the area have unstable walls or spillways.

Some soils can cause problems or increase the costs of dam construction. If a dam has to be built in these soils, expert advice is needed in both the design and construction of the dam.

Sodic soils

Sodic soils occur in clay soils where a high percentage of sodium cations are attached to each clay particle. The cations make the particles separate and disperse when wet. This characteristic means the soils are highly erodible in water, which can lead to tunnel erosion and dam wall failure. Sodic soils are often a bleached grey or yellow in colour and should be avoided when building dams. If a dam has to be constructed in these soils professional advice is needed. The following precautions reduce the risk of dam failure in sodic soils.

- Keep the dam as small as possible, with a maximum wall crest height of 3 m.
- Increase the effort and time taken to compact the wall during construction.
- Keep soil at optimum moisture content during construction.
- Reduce batter grades to less than 3:1.
- Increase the amount of freeboard in the dam.
- Incorporate gypsum in the soil during wall construction.
- Use a dam liner.

For more information on sodic soils go NSW Department of Primary Industries website.
http://www.dpi.nsw.gov.au/agriculture/resources/soils/sodic

Well-aggregated soils

Well-aggregated soils such as the volcanic red ferrosols found on the Alstonville, Dorrigo and Comboyne plateaus have the opposite problem to sodic soils. The soil clods are so stable when wet that they retain their porous texture and do not form a good seal despite a high clay content. A dam liner or soil ameliorant may be required.

Cracking clay soils

Cracking clays such as the heavy black clays found on the Richmond River floodplain swell when wet and shrink as they dry out which leads to large cracks in the soil profile. If the cracks extend far enough into a dam wall, they can cause the dam to fail.

Low clay soils

Dam soils need a high level of clay to seal the soil from water infiltration. Clay content can be assessed by wetting a handful of soil, rolling it into a thread about 5 mm thick, and bending the thread into a 5 cm diameter ring. If the thread forms a ring without breaking it may have enough clay to form a suitable seal for the dam. If the thread breaks, the soil may be unsuitable for dam building and should be investigated further with laboratory tests.

Gravel and sand seams

Gravel and sand seams occur in the ancient flowlines of old river beds. If these seams are encountered they need to be dug out and plugged with at least 60 cm of clay material.

Rocky soils

Rocky sites can make construction of the dam more difficult. If the rocks are porous or fractured, seepage may occur through the rocks or along the soil rock interface.

Acid sulfate soils

Acid sulfate soils (ASS) produce sulfuric acid when they are excavated below the watertable and allowed to dry. This acid can affect water quality in a dam and downstream. ASS are most common in low lying coastal areas, and acid sulfate hazard maps identify areas of risk. In addition to the environmental concerns, works in ASS areas are regulated by councils under Local Environmental Planning provisions (LEPs), and may require consent and special precautions.

Soil ameliorants

When alternative dam sites are not available, soil ameliorants can be applied during dam construction to improve the performance of a problem soil.

- Gypsum and hydrated lime (NOT ag lime) reduce tunnelling in sodic soils.
- STPP (sodium tripolyphosphate) induces dispersion in well-aggregated soils that will not form a seal.
- Bentonite (engineering grade) is used in soils with insufficient clay content.

Other things to consider

When building a new dam, it is important to recognise that it will become a long term part of the infrastructure of the property and will influence how the property is managed on a day to day basis.

The following factors will influence the size and location of the dam.

- impact on access for vehicles, heavy farm machinery and stock
- impact on fencing and other infrastructure
- safety considerations (ie the location in relation to roads and houses)
- requirements of the Dam Safety Committee http://www.damsafety.nsw.gov.au
- how the water will be extracted and used (ie pumping, reticulation, troughs)

Troubleshooting

Lack of groundcover

Embankments need a good vegetative cover to protect them from erosion. Grasses, either native or introduced, are best because tree roots can create channels that cause dam walls to leak. Trees should not be planted on embankments and must be removed if they establish naturally. When dams are constructed, topsoil is stockpiled and then spread over disturbed areas that will not be covered by water when the dam is full.

When earthworks are finished, these areas are sown with heavy applications of seed (and fertiliser if required), at up to ten times the normal rate of seed application recommended for pasture establishment. In high rainfall areas, turf can be laid in strips to protect the soil until seeds shoot. Turf is most effectively used in spillways or drainage lines, where the cost of turf is less than the cost of erosion repairs.

If groundcover fails to establish, it may be due to nutrient deficiencies or pH imbalance in the soil. Soil testing can help identify these conditions. Other actions that may help include:

- sow and fertilise suitable grass species for the locality and season
- exclude stock until good cover is established
- remove trees, saplings or shrubs.

Overtopping

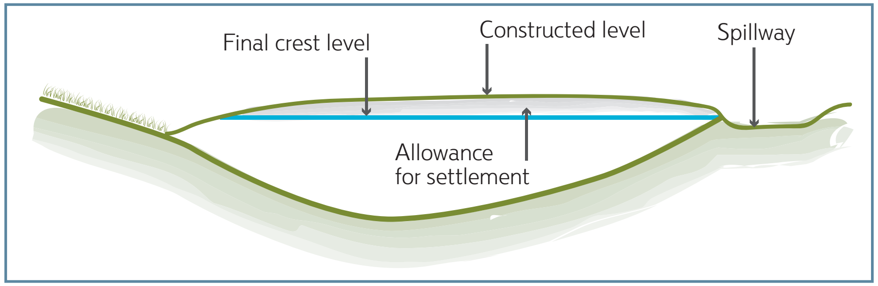
Water overtopping a dam wall is a serious problem that often results in dam failure. A newly constructed farm dam is most vulnerable to overtopping when groundcover has not established. Overtopping can occur for four reasons.

Insufficient freeboard

There may be insufficient freeboard between the height of the wall and the spillway to allow for wave action and storm surcharge. Ideally, a new dam embankment is constructed of adequately compacted soil with enough freeboard to allow for settling while maintaining sufficient freeboard between the height of the embankment and the height of the spillway (see diagram below). If the wall is too low to allow sufficient freeboard, it may be more effective to widen or lower the spillway height than to raise the level of the entire embankment.

A dam wall needs to be initially constructed to a higher level than required to allow for settlement.

Adapted from Farm dams – planning, construction and maintenance, Barry Lewis, Landlinks 2002.



Slumping

All new embankments settle to some extent, but excessive or uneven settling can lead to slumping of parts of the embankment. This can happen when the material at the bottom of the wall is unable to support the weight of the material above. This most commonly happens where the embankment material is poorly consolidated, is excessively wet due to seepage, or is high in organic matter, for example when topsoil is accidentally incorporated. If a large proportion of a dam embankment is affected by slumping, professional advice is needed. If only a small section is affected, it can be built up to provide at least 1 m freeboard height between the lowest point of the embankment and the spillway.

This embankment has overtopped because of insufficent freeboard between the embankment crest and the spillway (to left). Source: Mark Stanton-Cook NSW DPI

Inadequate spillway

If there is sufficient freeboard between the height of the embankment and the spillway and overtopping still occurs, it indicates that the spillway is too small to carry the peak discharge required. If the spillway is too small you may need to widen it to prevent further overtopping of the embankment.

Use the worksheet to estimate peak discharge of your catchment (see page 172).

Blocked spillway

If the spillway is obstructed by vegetation, fallen timber or other material, less water can flow over it, which may cause overtopping elsewhere on the dam wall.

Several options are available to remedy overtopping.

- Remove large debris from the spillway.
- Maintain vegetation height at 10–30 cm on the spillway.
- Check that all parts of the embankment are high enough to allow 1m freeboard between the height of the embankment and the spillway.
- Remove topsoil from low sections or breaches of the embankment, fill with clay and compact before respreading with topsoil and revegetating.
- Lower the spillway level if necessary to provide adequate freeboard.

Embankment collapse

The usual causes of collapse of an embankment are slumping and overtopping. If the damage is severe, the entire dam wall needs to be reconstructed.

Leaking, seepage and tunnelling

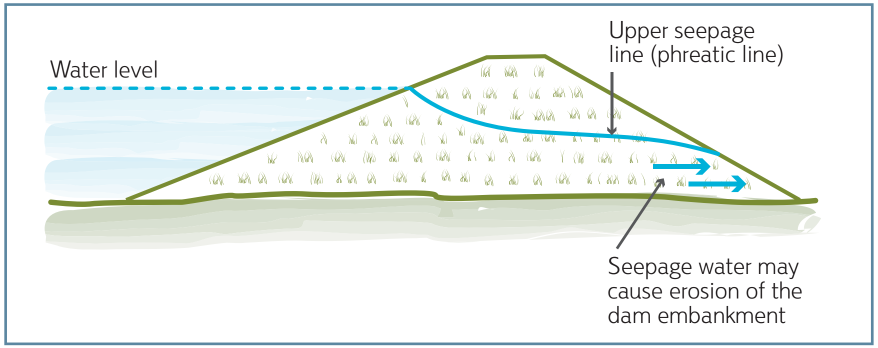
All dams leak to a degree but excessive seepage through a dam wall can lead to slumping or collapse of the wall. Indicators of excess seepage are damp spots or greener areas of vegetation in the downstream wall or below the dam. A trickle of muddy water could mean a tunnel is forming. Leakage in the bottom or upslope sides of the dam is not a structural danger to the embankment, or likely to cause soil erosion. The decision to treat the problem depends on the economic value of the stored water and the reliability of runoff to refill the dam.

The following section presents options for resolving leaking dam walls, in order of increasing cost and effort. If the leakage is not easily resolved, it is worth weighing up the cost of fixing the problem compared with the cost of building another dam in a more suitable location.

Check around the waterline for tunnels

Seepages and tunnels usually start just below the waterline. A large tunnel will be obvious by a whirlpool forming in the dam. Other tunnelling can be checked by probing the soil around the waterline with a steel bar to a depth of 40 cm. Any soft spots need to be filled and rammed with suitable clay to seal the leak.

Seepage occurring on the downstream side of dam wall.
Adapted from: http://www.worldagroforestry.org/sites/relma/relmapublications/PDFs/TH%2029%2080-140.pdf



Compact the soil

If the dam continues to leak, further compaction may break up the soil aggregates and compact the finer particles to form a better seal. The dam will need to be emptied and then stocked heavily with cattle, or rolled with a sheepsfoot roller or, if very dry, ripped, scarified, watered and rolled.

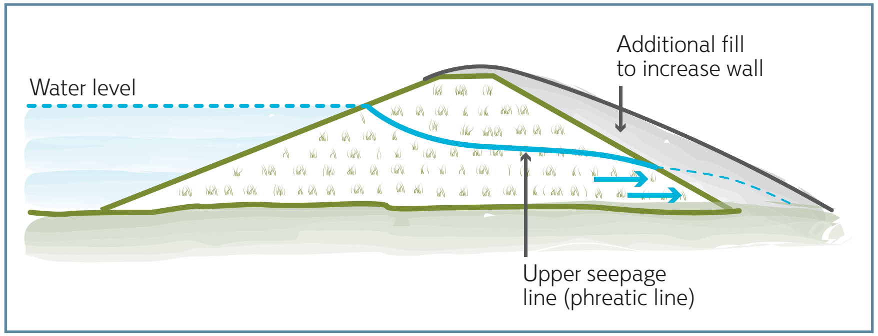
Broaden the embankment

When an embankment holds back water, a line of seepage can be imagined running through the embankment from the top water line. This line of seepage is called the phreatic line. It needs to reach natural ground level within the embankment or a zone of seepage will emerge in the face of the dam wall, making it vulnerable to erosion. This may be occurring if seepage is observed where the slope of the downstream side of the dam wall is steeper than 2.5:1.

If it does occur:

- remove and stockpile topsoil from the embankment
- add and compact more suitable earth to increase the width of the embankment and reduce the slope of the outer dam wall
- respread topsoil and revegetate.

Seepage controlled by additional fill placement.
Adapted from: http://www.worldagroforestry.org/sites/relma/relmapublications/PDFs/TH%20 29%2080-140.pdf



Line the dam

Another option is to line a leaking dam wall with an impermeable material. If suitable clay is available within the dam site, a 30–50 cm thick layer can be applied in a sequence of thin layers over the inside surface of the dam wall, rolling and watering each layer to ensure good compaction. This treatment is only viable if suitable clay can be obtained from within the dam site. Otherwise plastic membranes can be used but expert advice is needed as to which material is appropriate for the particular situation.

More detailed information on dealing with a leaking farm dam can be found in NSW DPI's Agfact AG 24 Leaking Farm Dams. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/164038/leading-dams.pdf

This eroding spillway needs repair.

Spillway erosion

Spillways need a dense cover of grass to prevent the water scouring the soil and changing the shape of the spillway, making it less effective in disposing of excess water without damage.

Spillways are designed to carry occasional large flows of water spread over a wide level sill. Prolonged low flows, such as those that occur in spring-fed dams will cut a channel in the spillway. When high flows occur, the force of the water will scour out this channel and over time this will lower the top water level or cause dam failure. Stock or vehicle traffic on the spillway will accelerate the problem. The following actions will fix an eroding spillway.

- Reshape the spillway to form a level sill.
- Establish dense cover of a local grass.
- Clear out existing trickle pipes.
- Install a trickle pipe to carry low flows through the dam wall.
- Exclude stock and vehicles until dense groundcover is established and prolonged water flow across the spillway surface is redirected.

Trickle pipes

Trickle pipes discharge small flows through the dam wall. Installed during dam construction, they are commonly 150–300 mm pipe, with the inlet installed 300 mm below the height of the spillway. The outlet for the trickle pipe is extended to the floor of the downslope flowline, as if the pipe extends through the dam wall out into the air, it is likely to create an erosion problem in the 'drop zone' below, potentially undermining the dam wall. The area at the outlet of large pipes may need to be lined with rocks to prevent erosion.

Trickle pipes can be fitted with an anti-seepage or cut-off collar, or set of collars along their length to stop water seeping or tunnelling through the dam wall along the outside of the pipe. Seepage can reduce the strength of the dam wall and should be fixed immediately if seen. Trickle pipes often become blocked by debris. A coarse screen over the entrance to the pipe can prevent this.

To maintain trickle pipes:

- check and clear out pipes annually
- repair leakage around pipes by excavating near the inlet and installing additional collars on the pipe. Before replacing soil add ameliorants to improve its seal, and compact it strongly into place.

Exposed subsoil of the back batter is difficult to revegetate.

Back batter erosion

When a dam is built on a steep slope, the excavation may be extended beyond the area covered by water to obtain enough material to build the embankment. The excavated face, known as the back batter, is usually a steep slope of exposed subsoil and prone to erosion, so deep-rooted vegetation should be established as soon as possible, using imported soil if necessary.

Stock should be kept off the batter. It is also important that concentrated water flow does not enter the dam across an excavated batter. Where this could occur, the water needs to be diverted around the batter, or the flowline armoured with rock or concrete.

Dam cleaning

Sediment eroded from the catchment area of a dam often accumulates in the dam and reduces its storage capacity, so periodic desilting is required to maintain the storage volume. Desilting is carried out with earthmoving equipment. Bulldozing is impractical because the silt is often wet and heavy, if not submerged.

For small dams an excavator is positioned beside the dam, where it buckets out sediment onto the dam wall. On larger dams, a combination of dozer and excavator may be used to bucket out and spread the silt. Silt from dams is prone to erosion as it is a fine material easily transported by water so must not be stored or spread in drainage lines. When spread thinly across grassed areas below the dam's catchment, grass will grow through it quickly and surrounding grass will catch any moving sediment. Mounded silt can be sown to grass or planted with other vegetation.

To manage a silted dam:

- reduce erosion from upslope
- remove silt from the dam
- spread the removed silt away from flowlines
- establish groundcover.

Silt spread across pasture will quickly revegetate.