GUIDELINES FOR THE CONSTRUCTION OF EARTH-FILL DAMS

Water Resources Policy
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Tasmania
Explore the possibilities

Department of Primary Industries and Water

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The *Water Management Act 1999* ('the Act') provides for the sustainable management and allocation of Tasmania's water resources. Amongst other things the Act provides for the promotion and fostering of social and economic benefits from the development of the State's water resources.

With the commencement of the Act in 2000, a new process for assessing dam permit applications was established. Under the Act, a dam permit is generally required for all dams except in circumstances such as:

- a dam that is not on a watercourse and that holds less than one megalitre of water; or
- a dam constructed for the primary purpose of storing waste as defined in the Act.

In addition to a barrier across a watercourse, a "dam" includes an excavation in a watercourse and a flood levee, both of which also require a permit under the Act.

Under the Act, a statutory committee, the Assessment Committee for Dam Construction (the Assessment Committee), was established as the body responsible for assessing applications for the construction of dams. The Assessment Committee members have expertise in the management of water resources; the use and economic development of water resources; engineering and safety matters relating to dams; integrated natural resource management; and best practice environmental management.

The *Guidelines for the Construction of Earth-Fill Dams* detail the specifications for the construction of earth-fill dams, and outline the precautions and methods which should be employed in order to obtain the soundest possible structure. These guidelines will provide an overview for dam permit holders and existing dam owners of the major matters to be considered in the construction of such dams.

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1. INTRODUCTION

1.1 Purpose of the Guidelines

These guidelines detail the specifications for the construction of earth-fill dams*, including precautions which should be taken and methods which should be employed in order to obtain the soundest possible structure.

A dam permit may prescribe higher requirements for the construction of an earth-fill dam. Therefore, unless otherwise specified in the dam works permit, the works should be undertaken, as far as relevantly possible, in accordance with the following specifications. If in doubt, specific advice should be sought from contractors, engineers or expert consultants.

The specifications relate to general planning and management requirements as well as specific engineering and construction specifications.

Construction and all future safety management and maintenance of any dam must also be carried out in accordance with the *Water Management (Safety of Dams) Regulations 2003*[1].

It should be noted that the soundness of the dam depends also on factors inherent in the site itself, the materials used and the methods of construction. Although every reasonable precaution may be taken faults may yet develop. The Assessment Committee and DPIW and its officers accept no responsibility for anything which may occur during the building of the dam or afterwards.

Some of the terms mentioned in these Guidelines is marked with an asterisk (*), these are defined in the “Definitions and Acronyms” Section of this document.

1.2 Classification of earth-fill dams

Dams under the Australian National Committee on Large Dams (ANCOLD) have specific hazard category ratings. The hazard category* of a dam is based on the risk to the downstream community and environment if the dam failed. In general terms, the higher the hazard category assigned to a dam means that more work will be required to assure that the risk to the downstream community in a dam breach situation is mitigated to an acceptable level.

[1] The conditions on a dam works permit are based on the determination of a dam’s hazard category, which is assessed generally in accordance with guidelines published by the Australian National Committee on Large Dams (ANCOLD).

The specific level of work required to be undertaken to address the hazard category of a dam is detailed in:

- Various ANCOLD Guidelines, as amended from time to time[2].
- *Water Management (Safety of Dams) Regulations 2003*.
- *Dam Works Code 2007* (DPIW 2007).
- Dam permit conditions.

There are seven hazard groups defined within the ANCOLD Guidelines, which range from 'Low' to 'Extreme'. In general, there are three broad categories of dams based on the hazard category, reflecting the amount of work required for the operation of a safe dam:

Category 1. Dams that have a 'Very Low' and 'Low" hazard category. These still require a permit to undertake dam works, but in general, require the least amount of detail to satisfy statutory planning, construction, maintenance and reporting requirements.

Category 2. Dams that fall into a hazard category of 'Significant' and 'High C', or all dams that are over 10 metres but less than 25 meters in height and are not in Category 3 below. These require considerably more detail to satisfy planning, construction, maintenance and reporting requirements compared to those dam in Category 1 above.

Category 3. Dams that are at the higher end of the hazard category scale. These dams include 'High B', 'High A', Extreme hazard category dams and dams that are over 25 metres in height. These generally require the services of an expert dams team.

The majority of farm dams fall into Category 1, but occasionally fall into Category 2. Larger dams such as some of the Hydro Tasmania dams and other water utility dams may fall into Category 3.

[2] For example *Guidelines on Assessment of the Consequences of Dam Failure* (2000); *Guidelines on the Selection of Acceptable Flood Capacity for Dams* (2000); and *Guidelines on Dam Safety Management* (2003).

2. PLANNING AND MANAGEMENT SPECIFICATIONS

2.1 Introduction

Many farm dams and other earth-fill dams fail because of:

- poor planning;
- poor investigation;
- poor design;
- unsatisfactory siting;
- faulty or poor construction practices; or,
- poor or lack of maintenance after construction.

It should be noted that the majority of dams that do fail, fail on first filling. Research undertaken to date suggest that 1 in 60 earth-fill dams will experience some form of leakage that will generally require some form of expensive remedial work to be carried out during the life of the dam.

It cannot be overstated that the ultimate responsibility for the construction and ongoing operation of a dam lies solely with the permit holder who is generally the dam owner, and the general success of the dam starts in the planning stage when all the pre-construction work is undertaken.

Neither the Department of Primary Industries and Water ('the Department') nor the Assessment Committee for Dam Construction ('Assessment Committee') undertake any design or planning for the construction of a dam.

Some tips for the dam owner to think about:

- In the planning stage if an issue is not clear, the owner should seek the services of an appropriately qualified and experienced professional. This may save a considerable amount of money and time in the long run.
- Properly read and understand the conditions of a dam works permit when granted. If it is not understood seek advice from an appropriately qualified and experienced professional. For dam safety reasons, dams must be built in accordance with the dam works permit conditions. The Department has the power under the *Water Management Act 1999* to take various actions and to impose fines when dam permit conditions are not adhered to.
- The dam works permit holder must supply the contractor with relevant drawing and plans that have been prepared for the dam works proposal. The level of detail in these drawing and plans should commensurate with the size and complexity and hazard category of the dam, as outlined in the appropriate ANCOLD documentation, and be prepared by an appropriately and suitably qualified person. This requirement is contained within the permit conditions.
- Only use a suitably qualified contractor who has experience with building dams of a similar size and complexity. Look around and ask other people who

have had dams recently constructed by the contractor and ask the contractor for a CV listing relevant job experience and qualifications.

Other key matters for consideration by a permit holder are discussed below.

2.2 Risk downstream of a dam

It is the permit holder's responsibility to ensure a dam is constructed so as to be in a safe condition at all times. This requires a risk assessment of downstream impacts of the potential for dam failure to be developed in the planning stage and submitted with the application to the Assessment Committee for permit approval.

It also needs to be recognised that the situation downstream of the dam may change over time and place the dam into a higher hazard category during the life of the dam. For example, downstream changes may include the development of new infrastructure, such as housing development where the Population at Risk (PAR) and the severity of damage and loss becomes greater than when the dam was first built. Hence this may make the dam deficient in its safety requirements, such as the size of the spillway and a higher safety risk. A suitably qualified and experienced dam engineer should be consulted if it is apparent that this may occur.

Population at Risk (PAR) is defined in the *ANCOLD Guidelines on Assessment of the Consequences of Dam Failure* (May 2000):

> *'Includes all those persons who would be directly exposed to flood waters within the dam break affected zone if they took no action to evacuate'.*

and considers:

> *'Flood depths and velocities are relevant in estimating PAR (generally, an inundation depth of 0.3 metres or more can be used as an indication of the area where the population is at risk)'.*
>
> *When estimating the PAR the following issues should be taken into account:*
>
> - *Groupings of dwellings.*
> - *Roads and railway lines.*
> - *Camping areas and occupancy times.*
> - *Allowance for itinerants (fisherman, bushwalkers, birdwatchers, and picnickers).*
> - *River crossing and bridges.*
> - *Occupation of schools, factories, retirement homes, hospitals, institutions, commercial and retail areas.*

2.3 Contract

As a further step towards obtaining a satisfactory structure, it is recommended that the permit holder enter into a contract with the person who is to construct the storage works, to ensure they do so according to the details on the permit and in accordance with the requirements of these Guidelines.

A contractor should only be engaged who is experienced in dam construction. The *Water Management (Safety of Dams) Regulations 2003* require that the contractor must have relevant experience in the construction of dams of a height, type and hazard category similar to the dam being constructed.

2.4 Easements & boundaries

It is the responsibility of the permit holder to ensure that the site which is chosen for the dam is well clear of all easements, rights of way, reserves, and for all purposes such as access, pipelines, cables, power lines. Where property of neighbours will be affected by a dam, the permit holder will need to make all necessary arrangements with the neighbours. It is a requirement that written permission from any neighbours affected by the permit be provided to the Assessment Committee with the application.

A useful organisation to contact before commencement of the construction of the dam is Dial Before You Dig on telephone number 1100 or visit http://www.dialbeforeyoudig.com.au/

It is generally the permit holder's responsibility to ensure that no utilities such as electricity, natural gas, water and sewage infrastructure can be damaged during the construction of their dam. It can be a very expensive exercise to have these repaired and the permit holder is generally responsible.

2.5 Site investigations

Before construction commences the permit holder may need to get their engineer to make a thorough investigation of the site to establish the nature of the foundation and to locate sufficient suitable clay material to use in the embankment.

Depending on the size of the dam, test pits may need to be excavated and soil tests carried out by qualified geotechnical engineers. This may also include a thorough investigation of the foundation of the dam to ensure that it will not fail and cause the embankment to fail.

This is especially important where existing dams are to be raised, if this is not addressed the Assessment Committee cannot make a decision on whether to issue a dam works permit.

2.6 Filling of the dam

Once construction of the dam is complete, the permit holder must submit a Work-as-Executed (WAE) Report to the Regional Water Management Officer (RWMO). After the WAE Report has been submitted, filling of the dam may commence. The dam should be filled as slowly as possible, preferably not more than 0.3 metres depth per day to let the new embankment adjust to the increasing water loads.

The need for caution cannot be overstated because breaching of the dam and the resulting wave of water may cause considerable damage downstream or loss of human life, and it is most likely that the dam owner will be held responsible.

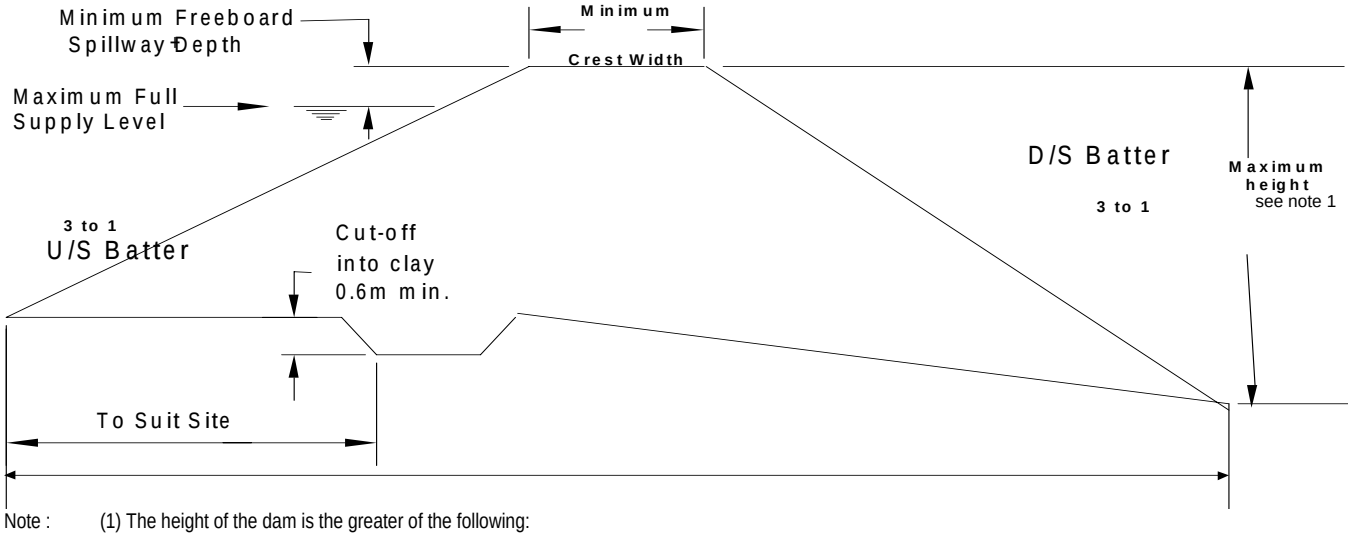
2.7 Dam permit conditions

It is a legal requirement that once a dam permit is issued for the construction of a dam, the permit conditions must be adhered to. A copy of the permit must also be given to the contractor who is engaged to construct the dam. Ultimately it is the sole responsibility of the permit holder to ensure that the construction of the dam complies with the permit. It is in the permit holder's best interest to read and understand the conditions of the permit.

3. ENGINEERING AND CONSTRUCTION SPECIFICATIONS

Figure 1 is a schematic of the major components of an earth-fill dam as detailed in the following specifications.

Figure 1. Earth-fill dam specifications.



Note : (1) The height of the dam is the greater of the following:

a) the height from the natural bed of the stream at the downstream edge of the dam wall to the top of the dam; or

b) the height from the lowest elevation of the outside limit of the dam to the top of the dam. (top of the dam means the uppermost part of the dam excluding any settlement camber or structures such as parapets and guard rails that are not part of the main water retaining structure).

(2) The cut-off trench is required to be taken down a minimum of 600 mm into impervious soil and backed filled with good quality clay that is thoroughly compacted.

(3) A crest settlement allowance for the total length of the crest of 5% of embankment height is required unless otherwise recommended by a person with Class A Competence* & agreed to by the Assessment Committee.

3.1 Engineering

Depending on the scale and size of the dam, specialised engineering supervision may be required at critical stages of construction. The level of specialised engineering supervision required is generally proportional to the hazard category of the dam. In any case, an appropriately qualified and experienced engineer should be consulted to help the future owner with the requirements for the construction of the dam. Engineering expertise can be used during the planning, and construction of the dam, as well as throughout the life of the dam.

3.2 Clearing

The area to be covered by the embankment* should be pegged out prior to commencement of any works. The embankment and the area to be excavated should be cleared and grubbed.

Topsoil should be heaped in areas outside of the area to be covered by the embankment and all trees, scrub and roots removed. Topsoil should be placed in layers not exceeding 200 mm and planted with grass if it is to be left for a considerable time (more than 6 months). This will conserve the integrity of the topsoil.

All saturated material in the embankment area must be pushed well clear of the site and must not be used in the embankment.

*3.3 Foundation**

The base of the embankment should be stripped of all topsoil, silt, loose material, vegetable matter, and then scarified over its whole area.

3.4 Cut-off trench or keyway*

Dams lose water through evaporation and seepage. Little can be done for evaporation losses, but with good construction methods seepage losses can be reduced.

One critical aspect is the construction of the cut-off trench. A cut-off trench or keyway should be 1½ times the height of the dam at the bottom of the trench. This keyway will minimise seepage under the embankment and increase the stability of the dam. It should be taken down to a minimum of 600 mm into impervious soil and rock and backfilled with the appropriate quality clay that is thoroughly compacted. It should extend for the length of the embankment including the hillside flanks, but does not need to be extended under the spillway where the spillway is cut into rock.

3.5 When to use filters

Filters in embankment dams and their foundations are required to perform two basic functions:

1. Prevent erosion of soil particles from the soil they are protecting.
2. Allow drainage of seepage water (Fell *et. al.*, 2005).

Concentrated leaks commonly develop in well-designed and constructed dams, and an important element to deal with such leaks is the filter zone. By providing a conservative downstream filter, risks associated with possible concentrated leaks through the core should be reduced.

There are generally no guidelines contained within the ANCOLD Guidelines on where filters should or should not be used in a dam. Manufactured filters are generally expensive. As a guide, the Department recommends that filters are to be use in the following instances:

- Where it has been recognised that there is a real chance that in a dam break situation there will be a loss of life; or
- Where there will be considerable damage to the community downstream and the environment in a dam breach situation; and or
- That the loss and damage severity will be 'Major'[3].

The Department judges on where filters should be used on a case by case basis. But stipulates if filters are to be used then they must meet modern filter design criteria, such as Sherard and Dunnigan of the United States Soil Conservation Services (Fell *et. al.*, 2005).

3.6 Rock

If rock is encountered under the embankment, appropriate measures should be taken to cut off seepage along the rock/soil contact and to prevent seepage in the rock joints coming into contact with the embankment soil. Such measures might involve the use of bentonite and a mortar or shotcrete blanket over the rock.

3.7 Outlet pipe

An outlet pipe will need to be installed in the base of the dam. The outlet pipe is required to enable the permit holder to pass inflows during summer and winter, as required by water licence conditions. It is also required to allow water in the stream, upstream of the construction work to be bypassed during construction. The minimum size outlet pipe is specified on the permit, however if the permit holder wishes to install larger diameter pipe then this is allowable. Should the permit holder wish to have a specific size pipe to suit the pump/irrigation plant it is recommended that dedicated pipe work also be installed for that purpose.

[3] As per the ANCOLD *Guidelines on Assessment of the Consequences of Dam Failure* (May 2000) – severity of dam and losses hazard category spreadsheet.

3.8 Outlet pipe materials and installation

High Density Polyethylene (HDPE) is a suitable material for pipework in earth-filled dams. However no less than Class 9 rating (90 kPa should be considered, based on Australian Standard: AS/NZS 4130:2003: *Polyethylene (PE) pipes for pressure applications*. The Class number should be marked on the pipe as per the above Australian Standard.

Every precaution should be taken with the installation of the pipe, given the fact that a large percentage of dam failures are associated with poor installation of outlet pipes. The following applies to outlet pipes:

1. A separate trench should be dug through the foundations of the dam and the outlet pipe installed in the trench.
2. Installation of the outlet pipe should only be undertaken after clearing and grubbing of the foundation and installation of the cut-off trench. It must however, be done before construction work starts on the embankment.
3. Under no circumstances should the outlet pipe be placed in the embankment. This can lead to cracking of the embankment through poor installation and compaction and result in failure of the dam. It is generally recognised that dams that do fail, fail on first filling and often around the outlet pipe.
4. Under no circumstances is the outlet pipe to be closed before the Work-as-Executed (WAE) Report is received by the Regional Water Management Officer (RWMO). To do this is a breach of dam permit conditions and also a safety issue and may result in the embankment overtopping, leading to dam failure before the construction of the dam embankment is finished.

HDPE pipe lengths (they generally come in 12 metre lengths) are joined by either fusion welding or if they need to be disassembled can be joined by Victaulic joints or depending on the application, a mixture of both.

3.9 Baffle plates on outlet pipes

HDPE baffle plates 600mm x 600mm x 20mm thick should be placed over the pipe at regular intervals and sealed to prevent seepage along the pipe.

Clay should be hand-tamped with an appropriate hand held tamping machine such as a ‘Wacker Packer’ up to slightly above the top of the pipe so as not to damage or crush the pipe before compacting successive layers with an appropriate machine such as a CAT 815 sheeps foot roller.

Pipes of other materials such as concrete or steel, if proposed, may require more careful installation and testing. Steel pipe will need to be treated to resist corrosion and may have a shorter life than the preferred HDPE pipes.

The upstream end of every outlet pipe should be fitted with a screen and the downstream end with a stop tap and marker. The screen and pipe inlet should also be encased in a concrete anchor block.

3.10 Borrow pits

The full excavation for embankment material, wherever possible should be kept as much as possible below the full supply level (FSL)* of the storage area. Excavating suitable materials within the wetted perimeter of the storage will maximise the total storage potential. Otherwise suitable material to construct the dam may have to be sourced outside the wetted perimeter.

Great care should be taken when obtaining borrow materials from steep bank areas that may be prone to instability. A person should never enter an excavation that is deeper than chest level unless the excavation has been made safe from collapse. If the excavation collapsed it can bury a person leading to a possible fatality or permanent injury. In order to avoid permanent injury or fatal incidents, excavations deeper than chest level where it is intended that a person will enter:

- should either be shored up by using an appropriate method such as steel shoring; or
- all sides of the excavation should be battered back and should not be steeper than 2:1 horizontal to vertical slope.

When rock is exposed in the excavation area, no attempt should be made to excavate into the rock. All exposed areas of gravel, jointed rock or other porous material in the storage area and under the embankment shall be covered with 300mm of compacted clay to ensure water tightness.

3.11 Embankment compaction

Leaks in earth-filled dams that lead to dam failures are often the result of inadequate compaction levels. Therefore it is important that effective compaction is achieved. This can be undertaken by applying the required compaction effort to high clay content materials.

Compaction should be undertaken by using a tamper foot roller, commonly referred to as a sheepsfoot roller. As a rule of thumb to obtain the required compaction effort, the following should be undertaken as a minimum for all dams greater than approximately 3 metres in height and 3 Megalitres in capacity:

1. All fill material for the embankment should be placed in layers (or lifts) no greater than 150mm thick.
2. The largest size particle should not be greater than 1/3rd the height of the lift, that is, 50mm.

3. Each layer should be thoroughly compacted before the next layer is placed. A minimum of 6 passes to achieve the required compaction effort is generally required by a suitable machine (see below).
4. The compaction effort achieved should be on average 98% Standard Maximum Dry Density (MDD) (non-structural fill) as in context to Modified MDD (structural fill) as per Australian Standard: AS1289.0-2000 *Methods of testing soils for engineering purposes.*
5. The minimum compaction effort should be 95% Standard MDD. If the range of compaction effort varies throughout the dam, then it can lead to the dam embankment settling to different degrees (differential settlement) causing the embankment of the dam to crack. This may ultimately lead to leakage and dam failure.
6. The material forming the embankment should be placed with sufficient moisture to ensure proper compaction. The moisture content should be in the range of –1% to + 3% of optimum moisture content (OMC). If the material is too dry, water should be added. If the material is too wet it should be spread and mixed.
7. Before each additional 150mm lift is added to the embankment, the preceding lift should be scarified to ensure that the two lifts are properly joined so that no natural paths for seepage are present that may result in dam failure.
8. A wheeled scraper or truck should be used for placing the clay on the dam site. The clay should then be spread by the use of the blade on a tamper foot roller or from a bulldozer towing a tamper foot roller (sheepsfoot roller). Vehicles with crawler tracks are not suitable, as high compaction levels are not achieved. Likewise, compaction using a scraper tyre should not be used as the required compaction effort will not be achieved.

In general, a sheepsfoot roller kneads the clay in the core. When compacting a loose lift of clay, its feet will sink deeply into the soil during the first pass. Upon successive passes, the roller will sink less deeply if proper compaction is being achieved. The roller is said to “walk out” compacting from the bottom up. Loaded scraper or dozer tracks **do not** undertake this function and should not be used for compaction of the dam’s core.

3.12 Compaction testing requirements

Dams that require engineering input during the construction stage require specific geotechnical testing to be undertaken, for example, density tests to ensure that the compaction specifications are met. This includes:

- all dams with Low hazard category greater than 5 metres; and
- all dams that are greater than 10 metres in height regardless of the hazard category; and
- all dams with a Significant hazard category or greater as defined by the *Water Management (Safety of Dams) Regulations 2003*.

It is critical that the supervising engineer selects a qualified technician with relevant NATA accreditation for the type of test being undertaken. As a minimum 6 visits should be carried by the technician. This includes undertaking 3 density test per visit on the embankment, around the outlet pipe, with the filter etc. The technician should also accompany the engineer in their routine inspections.

The test certificates need to be included in the Appendix of the Work-as-Executed Report to be submitted to the Department.

*3.13 Batter slope**

Special care shall be taken to ensure that the upstream and downstream batters are well compacted and trimmed to a slope batter of 3:1 horizontal to vertical slope or designed by an appropriate qualified person (eg a professional geotechnical engineer). Failure to comply with this requirement may greatly affect the stability of the embankment.

3.14 Settlement of the embankment

Settlement of soil banks is common and an allowance must be made for settlement of the dam embankment. The embankment may settle to a level where it is overtopped by water and failure will result. Or overtime settlement may result in the height of the embankment becoming lower than the spillway.

Clay soil can settle in excess of 10% of the dam's height, but well constructed and compacted clay dam embankments are not likely to settle more than about 5%. An allowance of 5% of the height of the embankment (along its length) to cater for settlement is necessary. For example, if the design height of the dam is 5 metres, the embankment should be built to 5.25 metres (+5%) to allow for settlement.

3.15 Vegetation

Topsoil should be spread over the exposed surfaces of the embankment to a depth of at least 150mm and sown with pasture grass to establish a good cover as soon as possible.

Never allow any vegetation larger than pasture grass to become established on or near the embankment. Tree roots, especially eucalyptus tree roots can cause the core to crack resulting in the failure of the dam. As a rule of thumb, trees and shrubs should be kept to a minimum distance of 1½ times the height of the tree away from the embankment of the dam. This especially applies to eucalypts.

3.16 Spillway or stream return*

The purpose of the spillway is to pass flood flows without overtopping the dam wall. Particular attention must be paid to providing adequate width and depth (or freeboard) of the spillway as per the specifications given in the dam permit. The following guidelines apply to spillways:

1. The absolute minimum width of a spillway is three metres.
2. Minimum spillway dimensions are given on the permit. Alteration of the spillway by the installation of culvert pipes should be treated with great caution. Adequate allowance for the passage of the specified flood flows must be maintained by increasing the amount of freeboard or increased spillway width if culvert pipes, or any other obstruction, is used or required in the spillway. Specific engineering advice must be sought before changing, modifying or obstructing a spillway in any manner.
3. The spillway should be cut in solid material (preferably rock) that will resist erosion. The stream return should be channelled back to the original watercourse and stabilised with a suitable size riprap consisting of rock or other materials such as Reno Mattresses or Gabions that will resist erosion and subsequent deposition of soil materials downstream.
4. In no circumstances should a spillway be blocked by either logs becoming wedged in the spillway or the spillway being purposely filled in to increase the capacity of the dam. The spillway of a dam is purposely designed to pass a very extreme flood. Reducing the size of the spillway increases the risk of the embankment overtopping and ultimately failing because the size of the spillway is limited to only passing smaller flood events than what the dam was originally designed for and the freeboard of the dam is reduced.
5. It is the dam owner's responsibility to maintain the dam in a safe condition at all times including the maintenance of an adequate spillway able to pass the specified flood flows.

*3.17 Freeboard**

Freeboard is the vertical distance from the top of the embankment to the level of the spillway.

It is most important that adequate depth be provided. If the depth is insufficient, floods will overtop the dam and the embankment material will be carried away at a progressively greater rate and extensive damage will be done. Many cases of complete dam failure have resulted from insufficient freeboard.

Freeboard must not be less than the dimensions specified on the dam works permit. The absolute minimum is 0.50 metres, usually with an additional 0.25 metres to take into account potential wave action.

3.18 Protection from wave action

Where the dimensions of the surface of the stored water are such that the prevailing winds will cause wave action on the embankment, protection of the upstream face of the dam should be provided in the form of stone pitching or rip-rap.

As a rule of thumb the wave height can be calculated by Hawksley's formula:

$$\mathbf{H = 0.0138(F)^{0.5}}$$

Where **H** is the wave height in metres; and,
F is the fetch distance over the longest exposed water surface expressed in metres.

Or the minimum depth for wave action is 0.25 metres

3.19 Sedimentation

Over a period of time, sedimentation will decrease the capacity of the dam. Therefore, as part of the planning process, the permit holder should consider the potential for a dam to fill with silt and what measure can be undertaken to reduce the likelihood of this occurring.

The potential for sedimentation can be mitigated by undertaking certain drainage and erosion control measures aimed at stopping large volumes of sediment from entering a dam. For example, limiting the amount of fallow land upstream of the dam.

3.20 Maintenance and inspections

Once the dam has been constructed, regular maintenance and inspections are required to ensure it remains in a good operating condition.

Dams over 10 metres in height and dams with hazard categories of 'Significant' and higher require the following regular inspections to be carried out:

- Weekly or more frequent inspection to be carried out by the owner.
- Biennial or intermediate inspections and surveillance reports carried out by a suitably qualified person (as defined by the *Water Management (Safety of Dams) 2003 Regulations*).
- Comprehensive surveillance reports carried out every 5 years by a suitably qualified person such as a Class A competent Engineer as defined by the *Water Management (Safety of Dams) 2003 Regulations*.

The maintenance and inspection requirements detailed above do not always apply to Lower hazard category dams. In such cases the dam owner should read their dam permit to verify what maintenance and inspection requirements must be undertaken.

It is good practice for the dam owner to inspect their dam on a regular basis to ensure that the dam is operating in a safe manner. Such inspections should include the following as well as any other matters the dam owner thinks necessary to inspect:

- Inspection of the spillway to ensure it is not blocked by logs or trees growing in the spillway or deliberately blocked to increase the capacity of the dam (section 3.16 provides information on spillways);
- Inspection to ensure that trees have not become established on or near a dam embankment. Tree roots can cause the embankment to crack leading to dam stability problems (section 3.15 provides information on vegetation). The highest plant growth that should be allowed on a dam embankment is pasture grass to protect against erosion.
- Seepage from the dam should be monitored on a regular basis. Seepage is generally normal in all dams and should not be a concern unless it increases over a time or the water becomes turbid (dirty). An increase in turbid water is an indication that the embankment may be eroding internally which may lead to piping failure. If concerned, a suitably qualified and experienced person should be consulted.

It is suggested that the dam owner use a logbook to record observations from any dam maintenance and inspections visits for future reference.

3.21 Your engineer

As the expert, it is the role of the consulting engineer to offer advice to the dam owner throughout the whole dams works process where the dam works permit or the *Water Management (Safety of Dams) Regulations 2003* specifies that an engineer supervises construction.

For Significant hazard category dams or greater, the process works as follows:

1. A pre-construction report is compiled by the consulting engineer.
2. The consulting engineer must be available to supervise the critical stages of construction of the dam. This also applies to all dams over 10 metres in height, regardless of the hazard category and all dams with a Low hazard category.
3. The consulting engineer must compile a Dam Safety Emergency Management Plan for the dam.
4. On completion of the dam a Work-as-Executed (WAE) Report must be completed within 28 days and submitted to the Department of Primary Industries and Water.

5. An additional safety surveillance report must be prepared by the consulting engineer on the first substantial filling.
6. The consulting engineer needs to compile an Operation and Maintenance Manual for the dam and advise the owner of good dams practices such as the use of 'V' notch weirs.
7. The consulting engineer prepares a 5 year comprehensive surveillance report.

The *Water Management (Safety of Dams) 2003 Regulations* will prescribe the competency level required based on the hazard category of a particular dam.

For Low hazard category dams, engineering supervision is required and for all Low hazard category dams over 7 metres in height requires the engineer to prepare a Work-as-Executed Report.

4. ACRONYMS AND DEFINITIONS

4.1 Acronyms

ANCOLD	Australian National Committee on Large Dams
Assessment Committee	Assessment Committee for Dam Construction
Department	Department of Primary Industries and Water
FSL	Full Supply Level
HDPE	High Density Polyethylene
MDD	Maximum Dry Density
mm	millimetre
NATA	National Association of Testing Authorities
OMC	Optimum Moisture Content
RWMO	Regional Water Management Officer
the Act	*Water Management Act 1999*
WAE	Work-as-Executed

4.2 Definitions

"Batter slope" means the upstream or downstream outer surface of a dam wall.

"Class A Competence" means a person who is an engineer with relevant experience in the investigation, design, construction and day-to-day safety management of dams of a height, type and hazard category similar to the relevant dam.

"Cut-off trench" means an excavation later to be filled with impervious material to prevent or reduce seepage under the embankment.

"Earth-fill dam" means an earth-fill embankment dam wall primarily constructed of selected excavated soil materials.

"Embankment" means an artificial bank built across a waterway or off-stream to either protect adjacent land from inundation by flooding or to store water.

"Foundation" means the material of the valley floor and abutments on which the dam is constructed.

“Freeboard” means the vertical distance between the maximum wall height and the full supply level.

“Full Supply Level (FSL)” means the level of the water when the dam is at maximum operating level, excluding times of flood discharge. When a controlled spillway is provided, it is the spillway crest level.

“Hazard category" means a hazard category referred to in the *Guidelines on Assessment of the Consequences of Dam Failure*, published in May 2000 by ANCOLD, as amended from time to time.

"Spillway" means a structure over or through which excess water is discharged from a dam.

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