Guidelines for the design, construction, maintenance and safety of small detention dams

Bay of Plenty Regional Council
Guideline 2022/01

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Foreword

The volcanic ash soils of the Bay of Plenty are versatile and provide a good basis for farm production, but they are also very susceptible to erosion by flowing water. Erosion contributes large amounts of sediment to our waterways and estuaries and affects natural habitats and communities by lowering water quality and soil quality.

Overland flowpath

Figure 1 Overland flowpath in pastoral farmland in the Waitetī Stream Catchment (a sub-catchment of Lake Rotorua) after an intense rainfall event. Photo: D.Clarke 2012

There are a number of sustainable land management options aimed to minimise erosion risk, including small flood detention dams.

The function of a small flood detention dams is to moderate peak flow rates during high intensity rainfall events, by impounding floodwaters and release it at a controlled flow rate through a small diameter outlet pipe.

Irrespective of whether the small flood detention dam is compliant with the permitted activity rules of our Regional Water and Land Plan or requiring resource consent, it needs to meet a minimum standard to ensure that the construction:

- Minimises the risk of failure.
- Avoids flooding or drainage problems on neighbouring land upstream.
- Avoids bed scour or bank erosion in the channel downstream
- Minimises adverse impacts on productive land, aquatic habitat or riparian vegetation.

Any small flood detention dam will be unique to an individual site; although special emphasis will have been given to local conditions, certain guidelines and generalities can be applied to all earthfill dams.

The information contained in this document is intended to help engineering practitioners, existing and potential owners, and Bay of Plenty Regional Council (Regional Council) staff to design, construct, maintain and monitor the safety of small flood detention dams in rural areas.

This guideline essentially provides a comprehensive and pragmatic means for the practical understanding of the principles and procedures used in small flood detention dam (earthfill dam) construction. It guides the users to safely and competently construct and maintain the small dams without complex design and costly recourses and construction techniques associated with dams on larger catchments.

This is a major review of the 2006 guidelines prepared by Steve Everitt and takes into consideration changes made to Regional Council's policy, plans and other guidelines as well as knowledge gained during the design and construction of small flood detention dams managed on behalf of the Regional Council in the last decade.

A concise protocol is provided in Appendix 1 to guide the user of this document through the small detention dam process.

Contents

Part 1: **Introduction**

1.1 Setting the scene

These guidelines outline the design process for small flood detention dams (earthfill dams), that do not require specific structural or geotechnical design. A small dam is classified as one that is less than 4 m in height from the base of the foundation to the crest at the highest point and impounds less than 20,000 cubic metres of water (NZSOLD, 2015).

Small flood detention dams are generally constructed in order to control high intensity, short duration rainstorms in catchments prone to erosion. As such, they are usually full only once or twice a year and only for a period of no longer than three days. They are to be used in conjunction with other methods of soil conservation such as land retirement and re-vegetation to reduce the loss of soil through erosion and the formation/worsening of gully heads.

Small Detention Dam

Figure 2 An example of a small detention dam in the Wainui Te Whara Catchment above Whakatane.

1.2 Objective

The objective of this document is to provide direction to designers/owners of small flood detention dams who wish to ensure their earthfill dams are reliable at detaining floodwaters without posing risk to people and property.

This document is for use by anyone who owns and/or is responsible for designing, constructing and maintaining small flood detention dams. The document covers the general fundamentals of the use of small flood detention dams including planning and site investigation, design, construction, maintenance, emergency works and safety review requirements.

1.3 About this document

The layout of this guideline follows a simple process that might typically be employed by someone who wishes to build a new, small flood detention dam. However, owners of existing small flood detention dam, who need to check the design standard of their structure or carry out maintenance, may also find specific parts useful.

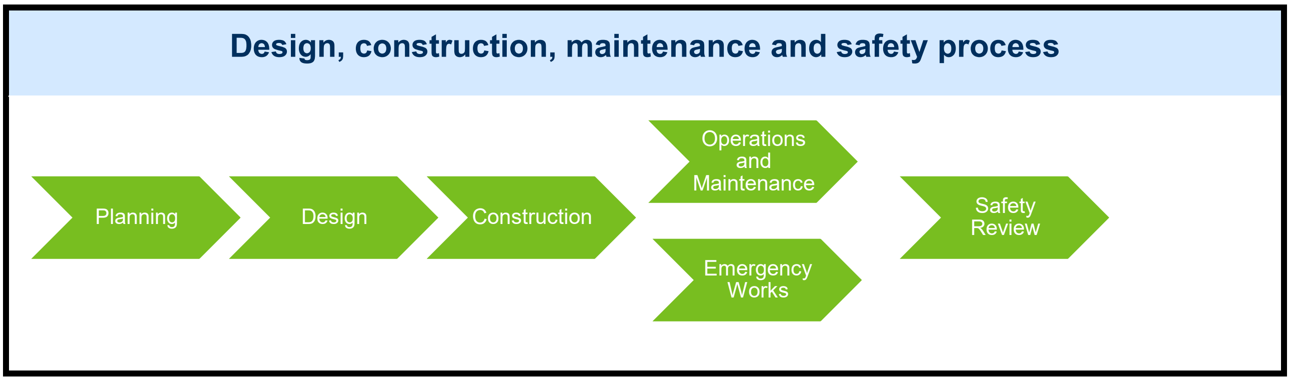


Figure 3 Design, construction, maintenance and safety process

More information is provided within the appendices to aid in planning, design and construction.

1.4 Role of the Regional Council

The purpose of the Resource Management Act 1991 (RMA) is to promote sustainable management of natural and physical resources. Under the Act regional councils have the functions of managing the use of land, air, water and coastal resources to give effect to the purpose of the Act within their regions. The Regional Council provides a limited advisory service to applicants undertaking activities, whether these require consents or not.

Another of the Regional Council's functions is to provide land management advice and promote soil conservation in the Bay of Plenty under the RMA and the Soil Conservation and Rivers Control Act 1941. Over the years, the Regional Council has gained knowledge of small flood detention dams during the design and construction managed on behalf of the Regional Council. This knowledge is reflected in these guidelines and is made available for the use of other existing or potential small flood detention dam owners to ensure a consistent approach for the management of these assets throughout the region.

1.5 Relationship to other Regional Council plans and guidelines

This guideline must meet the environmental standards contained in the RMA and Regional Natural Resources Plan (RNRP) (2018).

Rule WQ R16 of the RNRP permits the damming of water that is from an ephemeral flowpath or gully, an artificial watercourse, or surface runoff subject to the following requirements:

- It must not change, damage or destroy and existing wetland.

- It does not cause or increase flooding or ponding on any land or property owned or occupied by another person.
- It does not cause erosion or instability of any land or stream banks.
- The maximum storage capacity of a 2.5 m high dam is 5,000 m^3 and that of a 1.5 m high dam is 10,000 m3 where the height is taken at the centre of the dam structure to the spillway invert.
- It is designed by or under the guidance of a Chartered Professional Engineer.
- It shall have a functioning and maintained spillway for the one in 100 year (1% annual exceedance probability) flood.
- It shall, at all times, be maintained in a sound condition.

Measurement of dam height (RNRP Rule WQ R16)

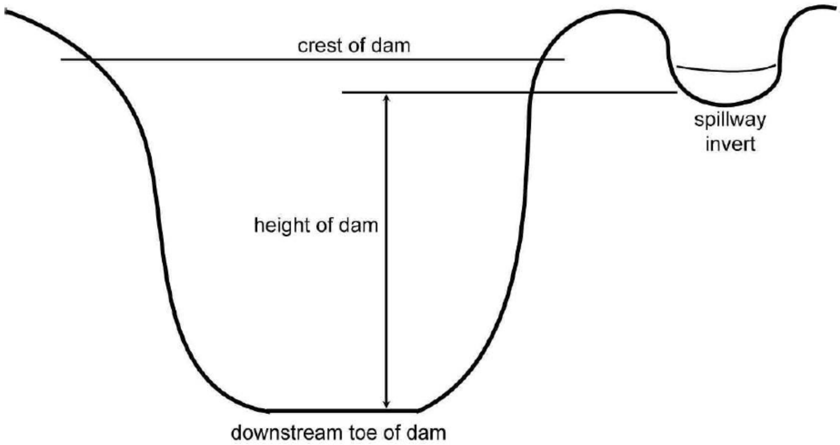


Figure 4 Measurement of dam height (RNRP Rule WQ R16)

Rule WQ R17 Restricted Discretionary and **Rule WQ R21** Discretionary allows Regional Council to assess any damming or diversion activity that will have greater adverse effects on a case by case basis through the resource consent process.

These small flood detention dam guidelines add to the list of guidelines listed in Figure 5 and are to be used in conjunction with Regional Council's Hydrological and Hydraulic guidelines.

Figure 5 below shows the relationship between the New Zealand statutes, Regional Council's policy, plans and other guidelines in relation to this guideline.

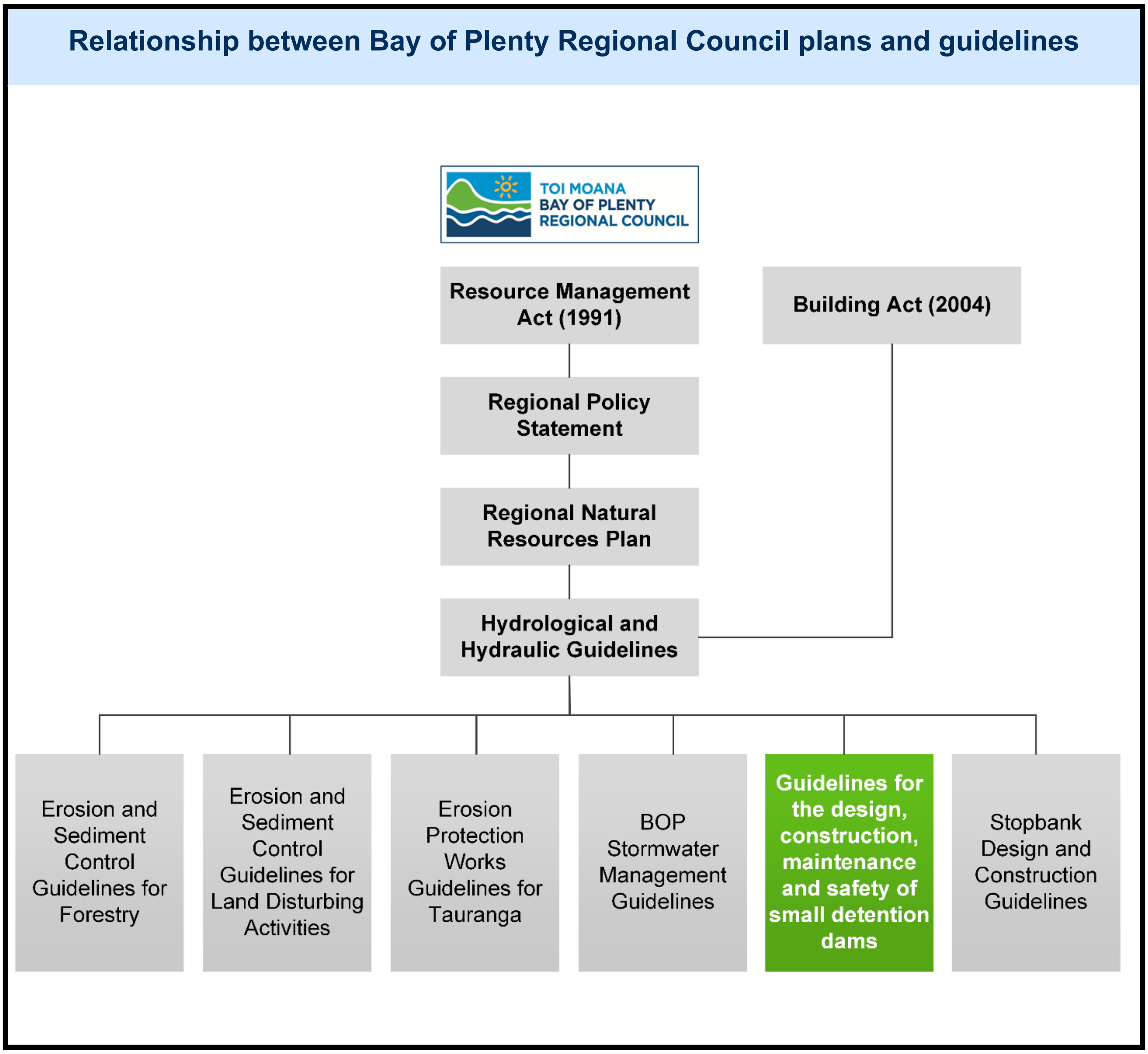


Figure 5 Relationship between New Zealand statutes, BOPRC policy, plans and guidelines.

Part 2:
Design standard

The two primary considerations in the design of any small flood detention dam are safety and economy. These are the criteria by which all structures should be assessed.

This document provides mainly guidance on the design standard to be applied to ensure the safety of the detention dam. Some comments providing economic consideration have been supplied where relevant.

In addition to these design standards, designers shall integrate sound engineering judgment, the most recent applicable national codes and design standards, site-specific technical considerations, and project-specific considerations to ensure suitable designs are produced that protect public safety and the community's investment.

The minimum storage requirement of the reservoir behind all small flood detention dams is the 10 year (10% annual exceedance probability) 24 hour storm volume. The maximum catchment area behind each small flood (earthfill) detention dam shall be capped at 45 hectares (ha), if the catchment area is greater than this it can be spilt into smaller areas by adding more dams on tributaries and in series.

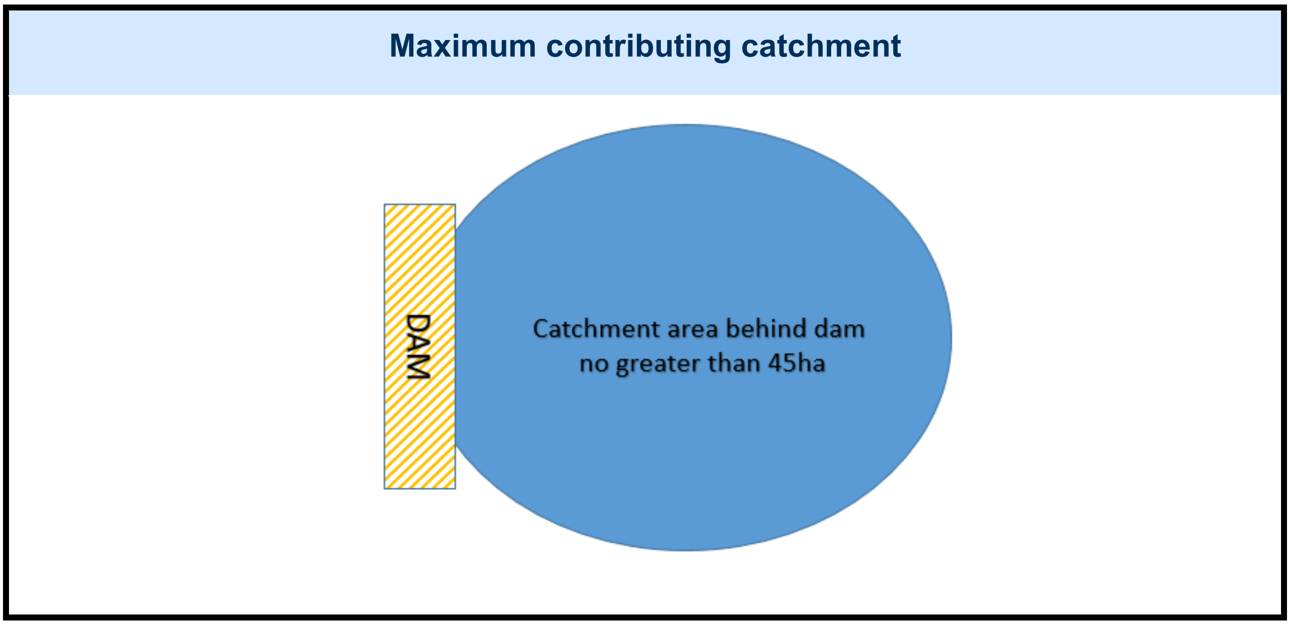


Figure 6 Maximum contributing catchment

- A minimum capacity of 60 cubic metres per hectare of catchment is required. Flood routing, allowing for the discharge from the outlet pipe, can be carried out to refine the required volume.
- If the runoff from the catchment contains a high sediment load, the design of the dam could make allowance for the settlement of most of the sediment out of the water before discharge. Details for the calculation of the required storage time and volume are given in the Regional Council's Stormwater Management Guidelines for the Bay of Plenty region.
- For catchments greater than 45 ha earthfill dams using local material may not be appropriate. Imported earthfill, rockfill or concrete dams may be more suitable, but require economic considerations. A detail design should be provided for any dam servicing a catchment bigger than 45 ha.

Part 3: Planning

3.1 Dam location

Although the selection of a suitable dam location is essentially a field exercise, the use of available GIS data (e.g., historic aerial photographs, waterways, property boundaries, soil class, contours) can provide a useful assessment of the local topography and hydrological conditions before any field visit takes place.

Field time can be saved by allowing the poorest sites to be excluded and a list of the more promising sites to be drawn up.

Small flood detention dams on steep slopes are rarely economic as embankments give limited storage. Areas that appear to have flatter gradients (i.e., less than 5%) should be prioritised.

Once the aerial photography interpretation has been completed and possible dam locations identified, a field visit is essential.

Small detention dam site assessment

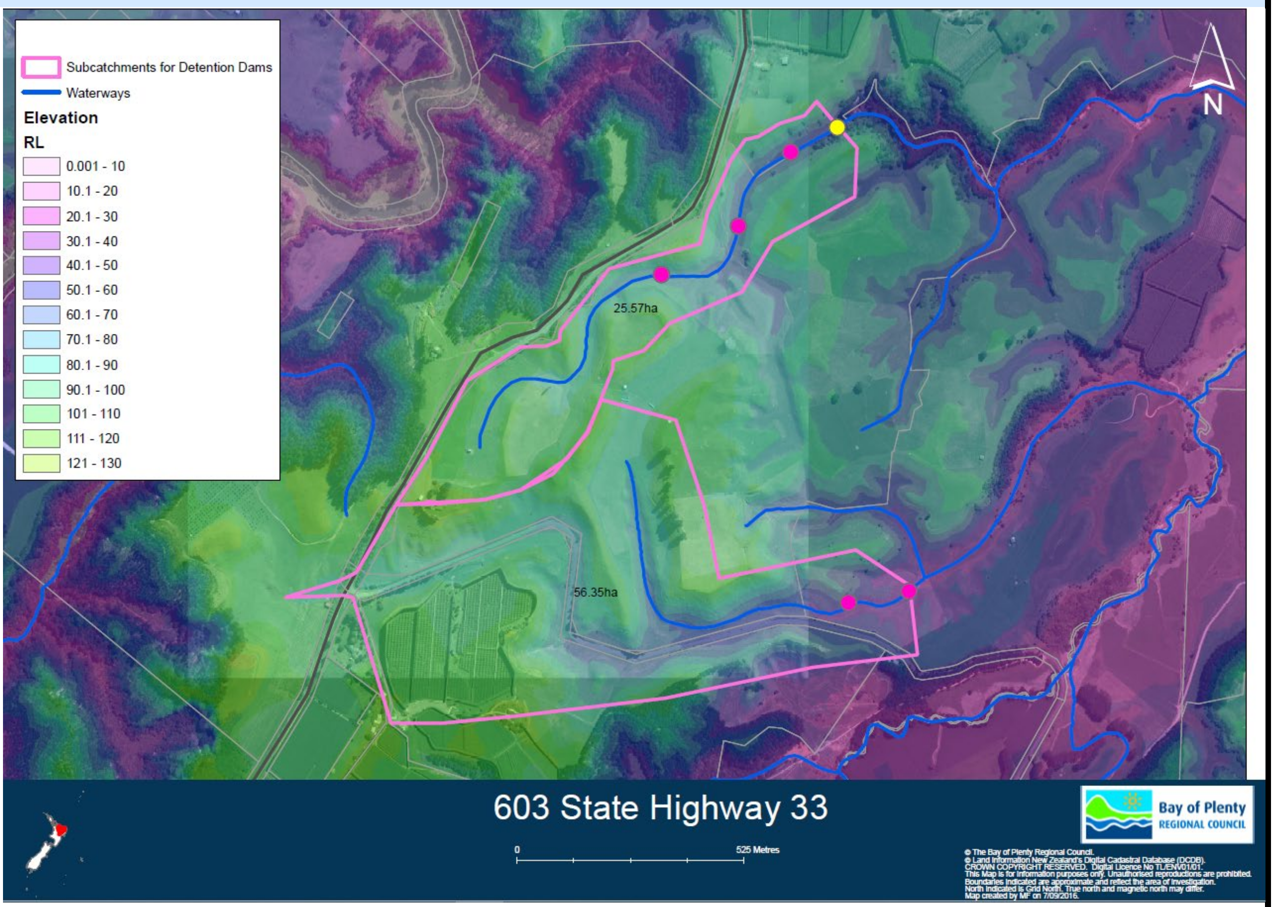


Figure 7 Example of assessment for small detention dam sites

The purpose of this site visit is to identify potential dam locations which may provide adequate storage with minimal earthworks. If the required storage capacity cannot be achieved with the restriction on dam height, it may be necessary to build a series of small dams in tributaries.

If the small flood detention dams are to become part of a Riparian Management Plan then the Land Management Officer (LMO) is to meet with the property owner and discuss Regional Council processes prior to a site visit with the Engineers. Refer to Appendices for design considerations.

Once the dam locations have been narrowed down a survey shall be undertaken either via a laser level and a handheld GPS location tracker to identify the ponded area extent assuming the desired dam height or by cross-section survey using accurate GPS equipment.

Assessing the ponding area

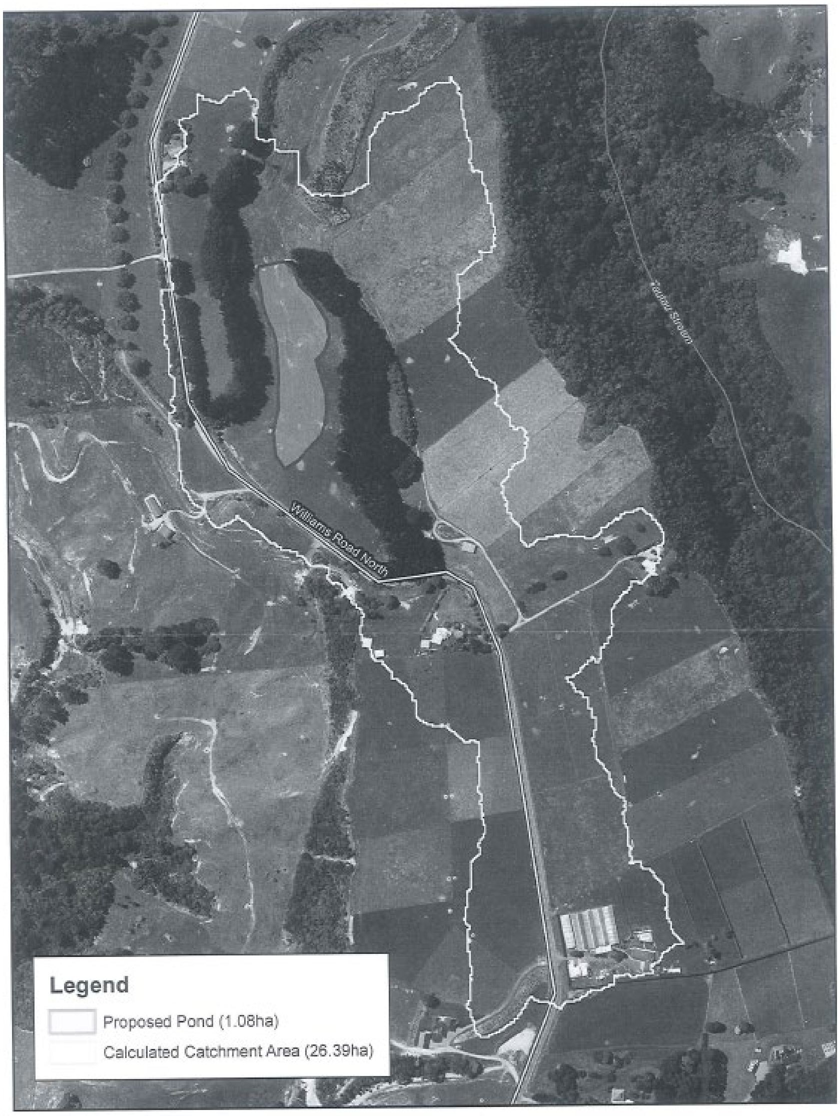


Figure 8 *Plotted extent of ponded area for detention dam at 150 Williams Road North, Pyes Pa*

Part 4:
Dam design

Small flood detention dams consist of a number of components which must be designed accordingly to ensure safe operation of the dam structure over its lifetime. The interface and interaction between the natural and different manmade components are the weak points within the dam structure and need consideration.

The principal components are as follows:

- Reservoir/Storage Area
- Foundation
- Cut-off Trench and Core
- Embankment Structure
- Spillway
- Culvert and Energy Dissipater
- Borrow Area.

The Bay of Plenty Regional Council has developed a standard design and specification for small detention dams. Refer to the Appendices for design considerations and standard design details.

Components of dam structure

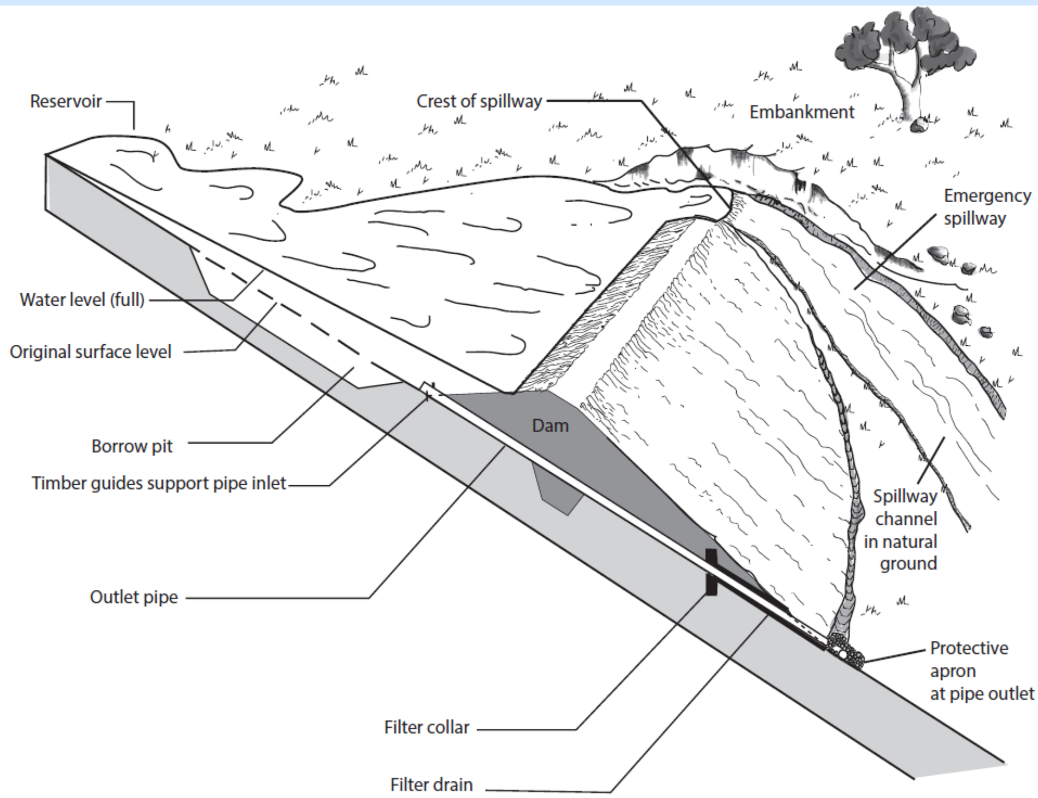


Figure 9 Components of dam structure

Part 5:
Dam construction

5.1 Construction planning

Construction planning is a fundamental activity in the management and execution of the dam construction project. It involves the definition and sequence of work tasks, the estimation of the required resources (labour, plant and materials), and durations for individual tasks.

The planning should include as a minimum the tasks outlined below and shall specify hold points for Engineers inspection. Refer to Appendices for a detailed outline of each task.

An outcome of the planning process is a programme for the construction and a cost estimate.

- Preliminary and general planning
- Site preparation
- Foundation
- Borrow area
- Cut-off trenches
- Culvert and energy dissipater
- Embankment structure
- Construction records and as-builts.

It is important to recognise, that hazards and risks apply during construction of the dam. A suitable contractor needs to have skills in evaluating and managing construction risk, particularly floods during construction.

Construction of dam structures

Figure 10 Construction of dam structures

The contractor needs to establish a flood management procedure to ensure a low probability of rupturing, weakening or collapsing of the embankment during construction.

The plan needs to involve:

- An active monitoring programme of any weather-related conditions.
- Provisions for diverting the catchment flows past the dam during construction.
- Protection of bare surfaces during construction.
- Provision of Erosion and sediment controls as per Regional Council’s Erosion and Sediment Control Guidelines for Land Disturbing Activities.

Part 6:
Dam maintenance

A dam owner is responsible to maintain their dam in a safe manner and could be found liable should the structure fail and cause loss of life or damage to other properties and the environment.

Understanding potential failure modes for a dam and early warning signs for a particular failure mode is an important step to improve dam safety, prevent a dam failure and/or minimise the effects of dam failure.

Failures of earthen embankment dams can generally be grouped into three classifications:

- Hydraulic Failures – erosive action of water on or adjacent to the embankment
- Seepage Failures – concentrated flow of water through the embankment (piping)
- Structural Failures – separation of the embankment material and/or the dam foundation.

Figure 11 shows the common failure modes that can lead to hydraulic or seepage failures.

Common failure mode of dam structures

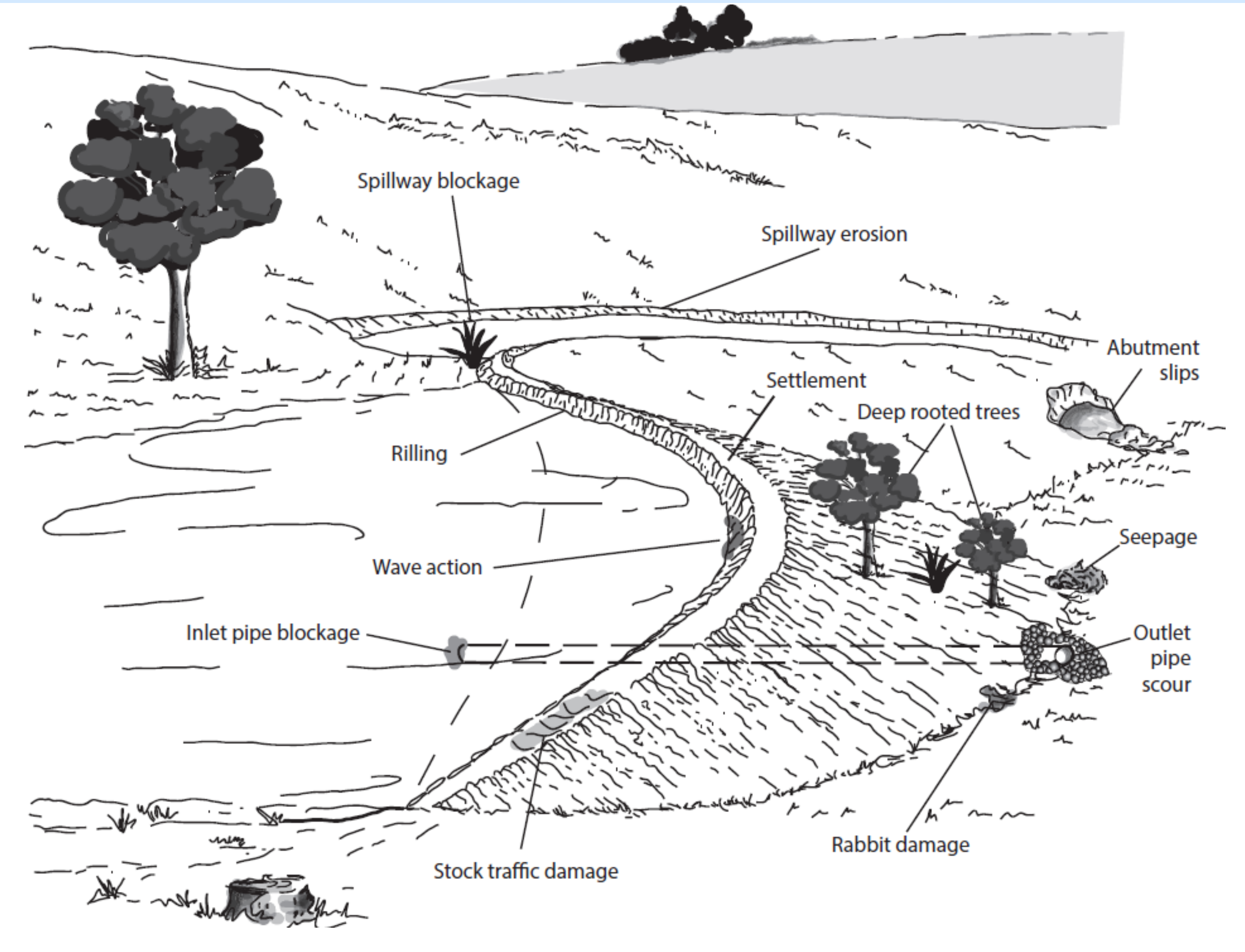
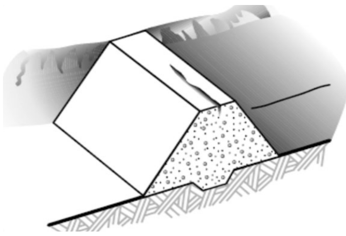


Figure 11 Common failure mode of dam structures

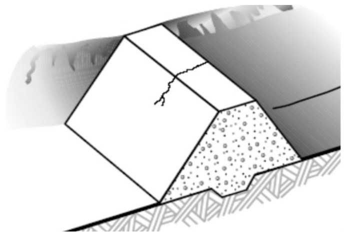
Targeted dam inspections and timely maintenance activities can assure safety during normal (designed) operation.

However, wide deep cracks that are parallel or perpendicular to the dam crest or other deformations of the embankment as well as sand boils or heaves downstream of the dam are signs of serious instability and may indicate structural failure.

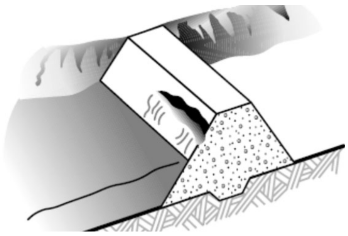
Serious failure mode of dam structures



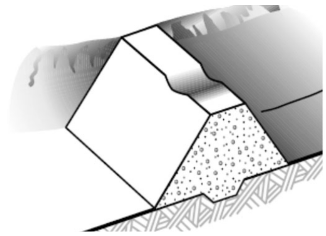
Longitudinal Cracking (parallel to the dam crest)



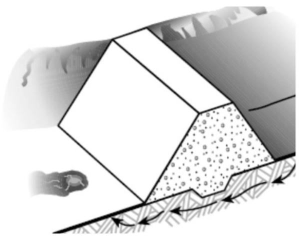
Transverse Cracking (perpendicular to the dam crest)



Slide, slump or slip on either embankment face



Depression on the crest of a dam.



Seepage path through the foundation exiting as a sand boil or heave downstream of the dam

Figure 12 Serious failure mode of dam structures (FEMA, October 2016)

If signs of such failure are observed, a professional engineer should be called to the site to assess the situation and evaluate remediation options. Any embankment or foundation sliding often requires the removal and re-construction of the affected section of the dam.

6.1 Inspections

The minimum inspection requirements are as follows:

- Immediately after and preferably during the first filling.
- Prior to and immediately after significant rainfall. This is defined as a one in 10 year event.
- After a significant earthquake (say larger than Magnitude 5.5).

- Annually including a review of upstream watershed and catchment characteristics.
- Annually to confirm no modifications have been made to the small flood detention dam and the spillway and culvert are still clear and operational.
- Annually to confirm that the potential downstream impact of a dam failure remains the same i.e., no increase in risk to life or damage to property.

6.2 Maintenance requirements

All stock is to be kept off the small flood detention dam until the fill is well consolidated and the vegetation/grass has established. It is also important that stock is kept off in wet weather to avoid pugging and consequential surface erosion.

If any rills and gullies develop as a result of rain or flows over the dam, fill these and resew. Grass is to be maintained on the dam at all times.

The dam and spillway shall be kept clear of large vegetation that will obstruct flow, prevent visual inspections or encourage burrowing animals. Debris such as tree logs or stumps shall also be removed from the storage area and if possible from the upper catchment to prevent them washing against and damaging the detention dam in large storm events.

6.3 Inspection and maintenance records

An effective method and system of record keeping is an essential contribution to the safety of a small flood detention dam. Inspection records and associated maintenance records shall be kept by the property owner. The checklist in Appendix 6 can be used to document and maintain a log of all inspections undertaken. The maintenance records are best to be done as soon as work has occurred and shall contain a description of works and pre- and post-photographic evidence. Records shall be provided as per Resource Consent requirements or shall be made available to Land Management Officer or Manager Pollution Prevention on request for non-consented structures.

Part 7:
Emergency works

Natural hazards such as earthquakes, large floods and landslides could result in dam incidents that require emergency works to be undertaken.

Earthquakes can lead to structural failures. An inspection following a significant event shall be undertaken to identify any required remedial works.

Large floods and landslides can lead to dam overtopping. Earth embankments are not designed to be overtopped and therefore are particularly susceptible to erosion. Once erosion has begun during overtopping, it is almost impossible to manage (Gannett Fleming Inc., July 2016).

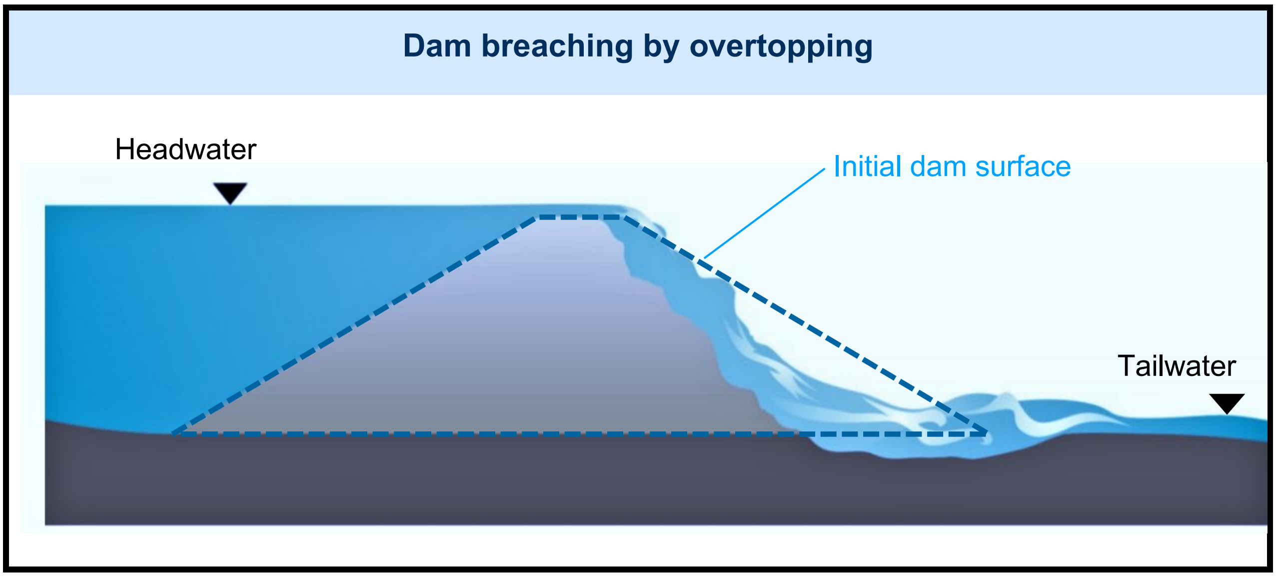


Figure 13 Overtopping dam breach erosion on the downstream face (adapted from FEMA, July 2013)

For this reason, monitoring of weather forecast and reservoir levels as well as emergency intervention is important. Any obstruction to the emergency spillway should be cleared if it is safe to do so and the embankment and emergency spillway be protected from erosion. Temporarily armouring of the embankment could be provided by placing polyethylene sheeting and riprap or sandbags.

If overtopping is imminent, intervention actions should focus on preventing overtopping of the dam crest through lowering the reservoir via pumping, raising the embankment by placement of sandbags or constructing a second bypass channel. Care must be taken when lowering the reservoir level as sudden draw down can lead to slumping failures.

In the event of failure, small flood detention dams should only cause minor incremental damage to the stream channel downstream and its immediate surroundings. The failure should not threaten people, buildings, other infrastructure or prime agricultural land.

Part 8:
Dam safety review

If the catchment, dam or downstream land use changes, then the dam owner should report this to the Regional Council. Changes such as these can increase the potential hazard posed by a small flood detention dam failure and as such may require the dam owner to carry out a more comprehensive dam safety review and to undertake a surveillance monitoring programme. According to the Building Act 2004 and the NZSOLD Guidelines 2015 small detention dams are classed as, very low potential impact dams. This means that the potential incremental consequences of a dam failure are expected to comprise minimal damages beyond the owner's property and no fatalities. If however, overtime the potential impact to life and property increases then the owner is responsible for reducing, mitigating or avoiding the increase in detrimental consequences. The potential impact could increase for a number of reasons including:

- Increase in dam inflow as a result of upper catchment changes (e.g., deforestation, urbanisation).
- Increase in dam size resulting from increase dam height and storage capacity.
- Landuse change downstream resulting in an increase to risk to life and property.

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Appendices

Appendix 1
Process

Detention Dam Construction Sequence (BOPRC internal)

November 2016

The following sequence/checklist outlines the steps to be followed when constructing small detention dams.

- ☐ LMO identifies possible detention dam site in conjunction with landowner
- ☐ Engineering visit site in conjunction with Geotechnical Engineer
- ☐ Undertake a survey as required. Either using laser level or Survey Team.
- ☐ Geotechnical Engineer undertakes site investigation testing
- ☐ Engineering undertakes hydrology and sizes spillway
- ☐ Engineering produces drawings and specifications based on geotech report and hydrology
- ☐ LMO arranges contractor and supervises work
- ☐ Engineering (and Geotechnical Engineer) inspect periodically
- ☐ Work completed and LMO advises Engineering for final inspection
- ☐ Chartered Professional Engineer provides sign off following final inspection

Appendix 2
Planning and investigation

Dam location

The Design Engineer is to visit in conjunction with a Geotechnical Engineer. During this site visit the Engineers shall identify the following:

- Areas of instability at the proposed abutments.
- Potential for erosion of the abutments due to surface flow from upslope.
- Areas of potential instability in the reservoir area in which failure could be triggered by raised water levels.
- Any narrow ridges around the perimeter of the reservoir that would act as a dam when the reservoir is full.
- Evidence of sand layers, tunnel gulley erosion or tomos.
- Jointing in any exposed rock.
- A suitable site for a spillway with no adjacent slope instability.
- The condition of the dam foundation. Thick layers of organic material containing stumps etc. are not ideal.

Also, whilst meeting with the property owner the Engineer should enquire about site history and suitable fill material such as, clayey or silty gravel, clayey or silty sand, clay or silt. It may be possible to increase storage capacity by winning fill from within the ponding area, provided this does not create any instability. For each site, the survey must be sufficiently accurate and detailed to enable comparative estimates.

Site Investigations

Once a dam site has been identified some basic subsurface investigations should be carried out to determine if the dam will hold water without subsurface flow channels developing over time, to confirm that 3H:1V batters will be stable and to estimate possible dam settlements.

The investigations could be carried out by excavating test pits with a small excavator or by hand augers. The following is considered the minimum amount of investigation:

- One hand auger or pit at each abutment to twice the retained water depth or a stiff cohesive soil layer.
- One hand auger or pit to twice the retained water depth or a stiff cohesive soil layer at maximum 20m intervals along the dam centre line.
- One hand auger or pit in each potential borrow area to the likely depth of borrow.
- One hand auger in the spillway location to the depth of the reservoir or stiff soil if the spillway is over natural ground. Further hand augers should be carried out if it appears there is a change in soil type along the spillway. It is considered that pits should not be carried out in the spillway if it is in natural ground as these will cause significant disruption to the integrity of the covering vegetation.

If it appears that the foundation conditions could change upstream or downstream of the dam centreline, additional hand augers should be carried out at the estimated locations of the toes of the dam.

The investigations should be logged in accordance with the New Zealand Geotechnical Society “Guideline for the Field Classification and Description of Soil and Rock for Engineering Purposes” (Burns, D., Farqhuar, G., Mills, M. and Williams, A., 2005). Particular care should be taken with the description of the grading of granular soil layers as this is provides an indication of their permeability. If granular layers are found beneath a dam site within 1m of the ground surface a low permeability soil cut off can be constructed through these layers. If the granular layers are deeper professional advice should be sought. In situ constant head or falling head permeability tests may be carried out to help determine if seepage beneath the dam could cause problems during the short duration the dam is full of water.

Within the dam footprint Scala penetration tests should be carried out in granular soils and shear vane tests in cohesive soils in conjunction with the augers or pits. One shear vane test should be carried out in each cohesive layer and at a minimum of 300mm depth intervals. These tests provide an indication of how much a dam could settle and whether the foundations have adequate strength for the batters to be stable. Samples from each cohesive layer should be sealed in a plastic bag for laboratory testing if required.

Geotechnical investigation

Figure 14 Soil sampling and in situ testing

A bulk soil sample should be taken from potential borrow sites so that compaction, water content and shrinkage testing can be carried out if appropriate.

The investigation results should be reviewed by a Chartered Geotechnical Engineer, who shall recommend further in situ or laboratory testing if necessary.

Cultural investigations

When investigating potential sites, the designer needs to recognise and protect sites of significance to tangata whenua and need to comply with the provisions of the Heritage New Zealand Pouhere Taonga Act 2014 (the HNZPTA 2014).

The HNZPTA 2014 makes it unlawful for anyone to damage an archaeological site without prior authority from Heritage New Zealand (HNZ).

An archaeological site is herein defined as any place associated with pre-1900 human activity, where there is evidence relating to the history of New Zealand that can be investigated using archaeological methods.

The designer shall research whether any archaeological sites have been recorded in close proximity of the small flood detention dam site. Records of these sites are hold by the New Zealand Archaeological Association (http://www.archsite.org.nz). Some Local Authorities also show the sites on their online map system.

If any work may affect an archaeological site than a professional archaeologist shall be engaged to undertake an archaeological assessment and an HNZ authority must be sought prior to works starting.

If there are no known archaeological sites in close proximity to the small flood detention dam sites than an Accidental Cultural Discovery Protocol shall be established. This Accidental Cultural Discovery Protocol outlines the steps to be taken in the event of the accidental discovery of cultural or historic artefacts and/or koiwi tangata (human remains), as the result of any physical disturbance to the existing ground surface.

If the project is led by BOPRC staff then the “Te Kawa Tuhura Regional Council Discovery Protocol Operations Guidelines” shall be followed. Te Kawa Tūhura includes a Practice Guide, which offers guidance for the project planning phase and identifies steps to take in the event of discovery of a site of Māori origin. It contains Planning Flowcharts, Referral Flowcharts, a Discovery Protocol Template and handy cards with tips for first respondents at a discovery site.

Hydrological investigations

The 10 year 24 hour storm detention volume should be calculated using standard hydrological techniques such as those given in the Regional Council’s Hydrological and Hydraulic Guidelines. In addition to these guidelines, a standard method is outlined below:

- Create a map of the proposed dam site including the location of the dam, the topographic survey, most recent aerials and as accurate contours as are available.
- Use the contours to delineate the catchment draining to the flowpath behind the proposed dam and calculate the area.
- Create a profile graph of the streamline from the top of the catchment to the dam and use the Equal Area Method to calculate the average slope.
- Identify the length of the longest flowpath.
- Measure the direct length of the flowpath from the furthest point on the catchment to the outlet point at the dam.
- Export the rainfall data for the site using the HIRDS software provided by NIWA, including 2.5°C temperature rise for climate change.
- Calculate the expected flow for the 10 year 24 hour storm using the Rational Method.

- Determine the 10 year 24 hour flood volume using Equation 1 below.

$$V_{10} = \frac{4}{3} \times Q_p \times t_c.$$ **Equation 1**

Where:

- V_{10} is the 10 year 24 hour flood volume
- Q_P is peak flow during a 10 year 24 hour flood
- T_C is the time of concentration

The volume available at a hypothetical 1 m high dam can then be determined by using equally spaced cross sections drawn perpendicular to the flowpath across the potential ponding area.

The area under the cross-section can be calculated using the Mid-ordinate Rule (Equation 2 and Figure 15) below.

$$A = \left(\frac{D_0 + D_1}{2}\right) \times \Delta L$$ **Equation 2**

Where:

- A is the area between each point along the cross section.
- $D_{0,1,2,\ldots n}$ are the iterative depths
- ΔL is the distance between each point along the cross section.

Cross-section area calculation

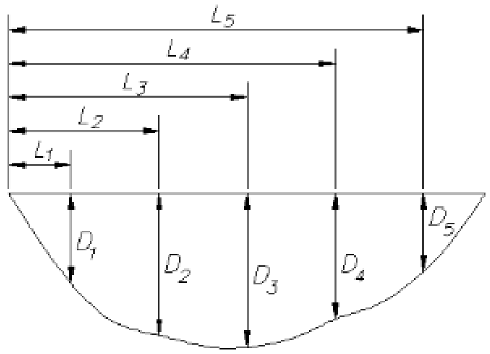


Figure 15 Schematic area calculation using Mid-ordinate rule

This is calculated for each point and then summed to give the total area under the cross section.

The total volume is then found using Simpson's Rule showing in Equation 3 and Figure 16 below.

$$V = \frac{y}{3} \times (A_o + 4A_1 + 2A_2 + 4A_3 + \cdots + 2A_{n-2} + 4A_{4n-1} + A_n)$$ **Equation 3**

Where:

- V is the storage volume.
- A is the area under each line.
- y is the distance between the cross sections.

Volume calculation of reservoir area

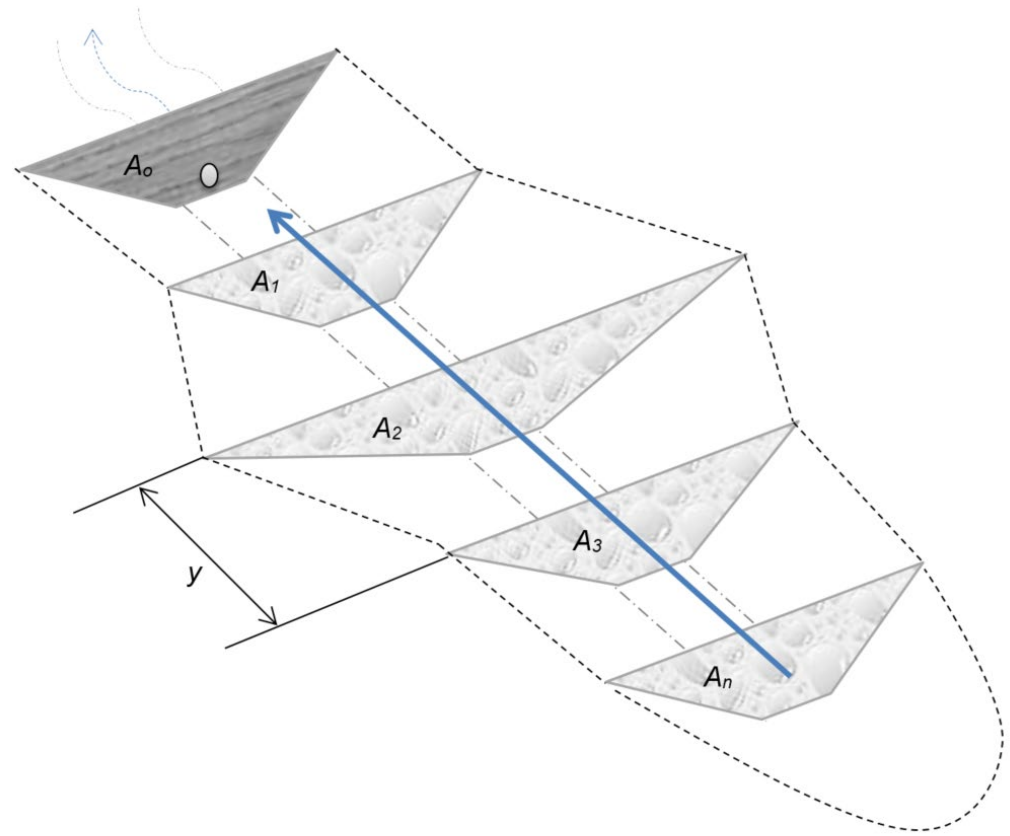


Figure 16 Schematic volume calculation using Simpson's Rule

Alternatively for less complicated shapes the ponded volume can be approximated by using the simplified methodology included in the Department of Building and Housing (DBH) publication "Dam Safety Scheme, Guidance for Regional Authorities and Owners of Large Dams" (DBH, 2008), summarised in Figure 17 below.

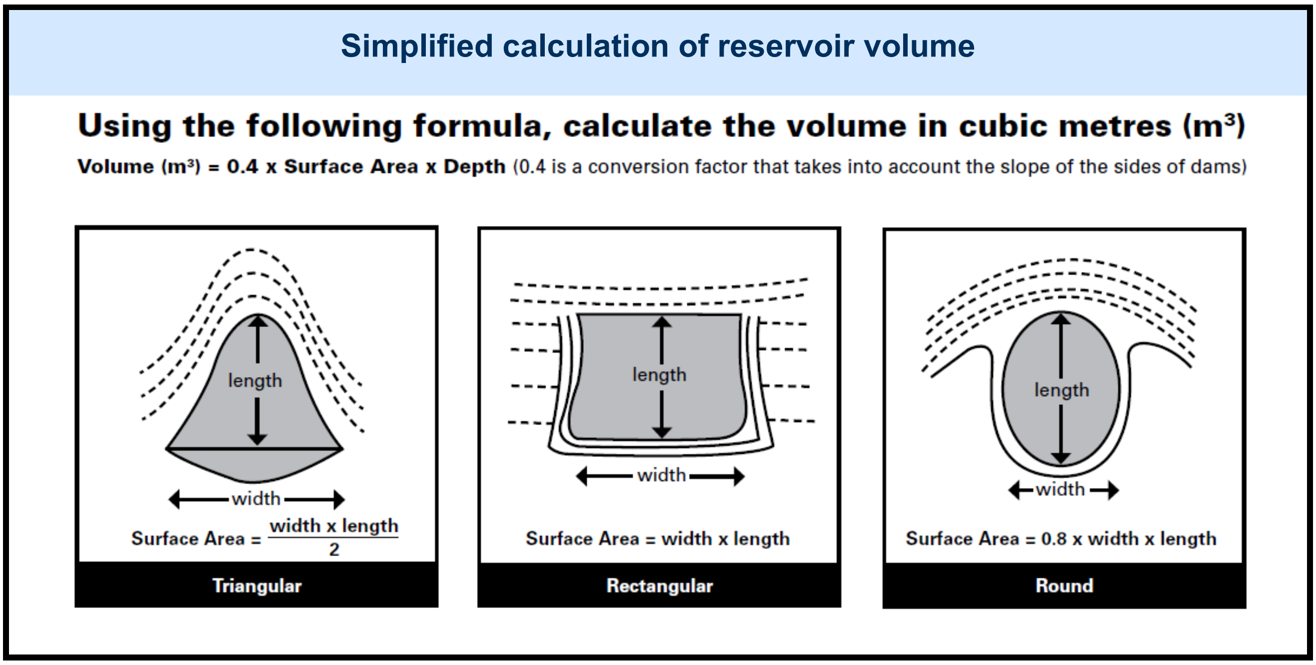


Figure 17 Simplified calculation of reservoir volume, Source: (DBH, 2008)

Appendix 3
Dam design

Reservoir/Storage area

The reservoir rim may be subject to slope failures, precipitation erosion and in extreme cases landslides due to natural events such as earthquakes and extreme weather.

These can trigger impulse waves that could be big enough to overtop and possibly damage the earthfill dam.

This risk can be mitigated by limiting the contributing catchment area above the small flood detention dam, inspecting the rim prior to construction and after each rain event resulting in ponding longer than 24h.

Foundation

The term “foundation”, as used in these guidelines, includes both the floor of the valley and the abutments upon which the embankment structure will be built. The excavated surface or undisturbed material upon which the dam is placed must be strong enough to bear the weight of the dam and the pressure of the impounded water.

A poor foundation can lead to settlement, which can cause cracking in the embankment fill, potentially dislocate the culvert that passes through the embankment or foundations and a reduced freeboard. It can also create points of weakness that are prone to high seepage flows, internal erosion and uplifting pressures, which can cause dam failure.

The loose structure of saturated sands and gravels are susceptible to liquefaction during earthquakes. **Some silt and clay soils may also be subject to loss of strength during earthquake loading.**

Although the foundation is not actually designed, certain provision for soil investigation and associated treatment options of the foundation needs to be provided to ensure safety requirements are met.

Subsurface investigations in the vicinity of the dam must identify that the ground can support the load being placed upon it. However, it must be noted that foundation conditions determined during the design stage investigation may vary from what can be found during the construction stage. If weak soils are geologically possible below the planned foundation level then a comprehensive investigation should be undertaken during construction. Any weaker soil layers found on site have to be removed and replaced with stronger materials.

Foundation preparation

Figure 18 Photo showing excavation of weaker soil below a new detention dam

Cut-off trench and core

The cut-off trench is designed to resist lateral movement of the dam resulting from water pressure and to prevent seepage under the dam. As such the trench shall extend down to low permeability material and is to be keyed into the banks on either side. If low permeable material is not found on site, then the trench should be sufficiently deep founded to ensure that the length of the flowpath under the dam is long enough to eliminate piping problems.

The cut-off trench is backfilled and compacted to form a solid core. Generally, soils containing a significant percentage of clay are ideal for the core.

Cut-off trench and core

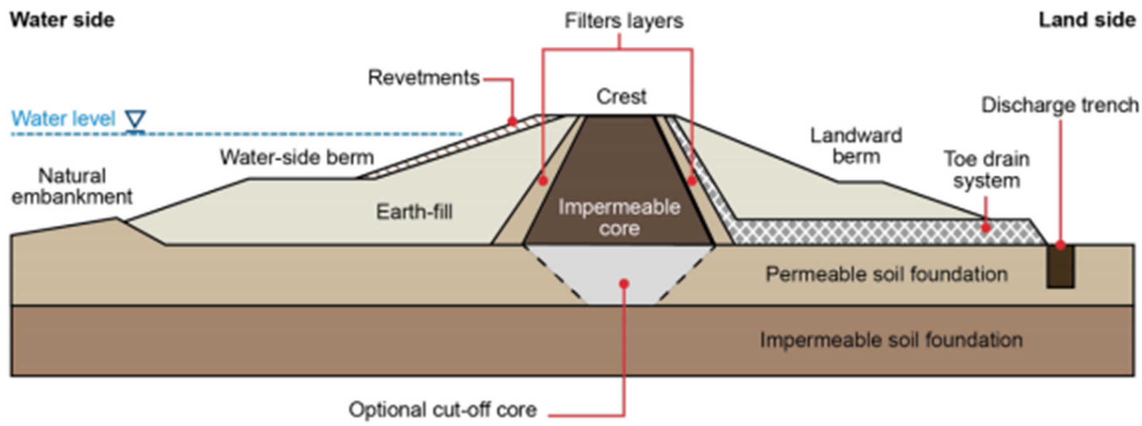


Figure 19 Cut-off trench and core schematic for a stopbank. Detention dams similar to this.

Embankment structure

Earthfill embankment structures are structures made of highly compacted soils.

The type of embankment is dependent on the properties of the available soil material for construction. There are two general types, homogeneous embankments and the zoned embankments.

Types of embankments

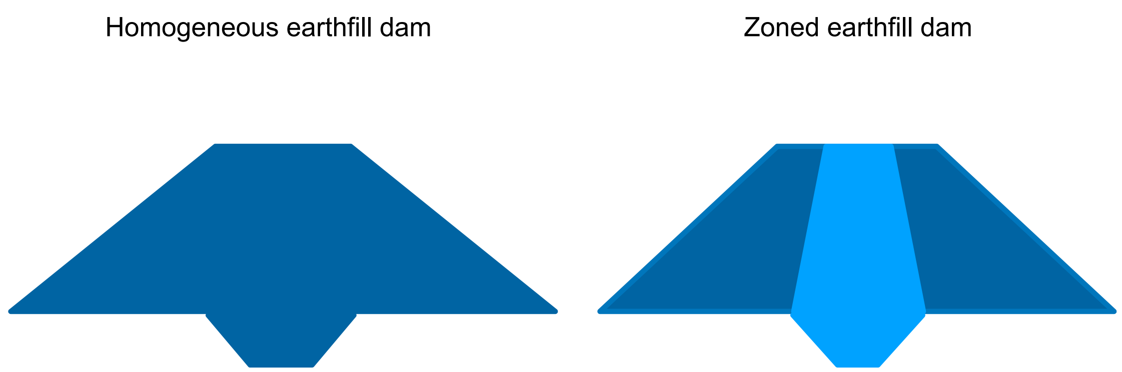


Figure 20 Types of embankments

Embankment material should be well mixed cohesive soil types (e.g., clay, silty sand or clayey sand). Do not use earthfill materials susceptible to piping. Earth materials susceptible to piping ranges from non-cohesive silts (i.e., D_{50} = 0.02 mm) to fine sands (i.e., D_{50} = 0.20 mm).

steeper than 3H:1V, and at least 4H:1V if it is likely that stock will be allowed access to the embankment face. For all slopes vegetation must be encouraged and maintained on both side of the embankment.

The minimum crest with is set at 3 m and can be increased where required such as for vehicle access. Seepage flow through the embankment must be controlled in order to minimise internal erosion, and to prevent softening and collapse where the seepage emerges from the downslope face. A filter drain and filter collar shall be designed to intercept this water and to safely carry it out of the embankment. The filter drain shall extend from the toe of the dam to within H + 1.5 m of the dam centreline where H is the dam height. The drain shall encompass the proposed culvert and shall have a square cross section with the dimension being 2 x D where D is the culvert diameter.

To prevent the sediment to migrate into and clogging the filtration media a heavy duty geotextile filter fabric, Bidim A34 or equivalent is to be wrapped around the filter drain with a minimum overlap of 400 mm to prevent the ingress and leaching of fines from the embankment. The filter collar is to be positioned near the centre of the dam at the end of the filter drain. It is to be a cube with dimensions 3 x D. The top of the filter collar must not extend within 2/3 x H of the top of the dam.

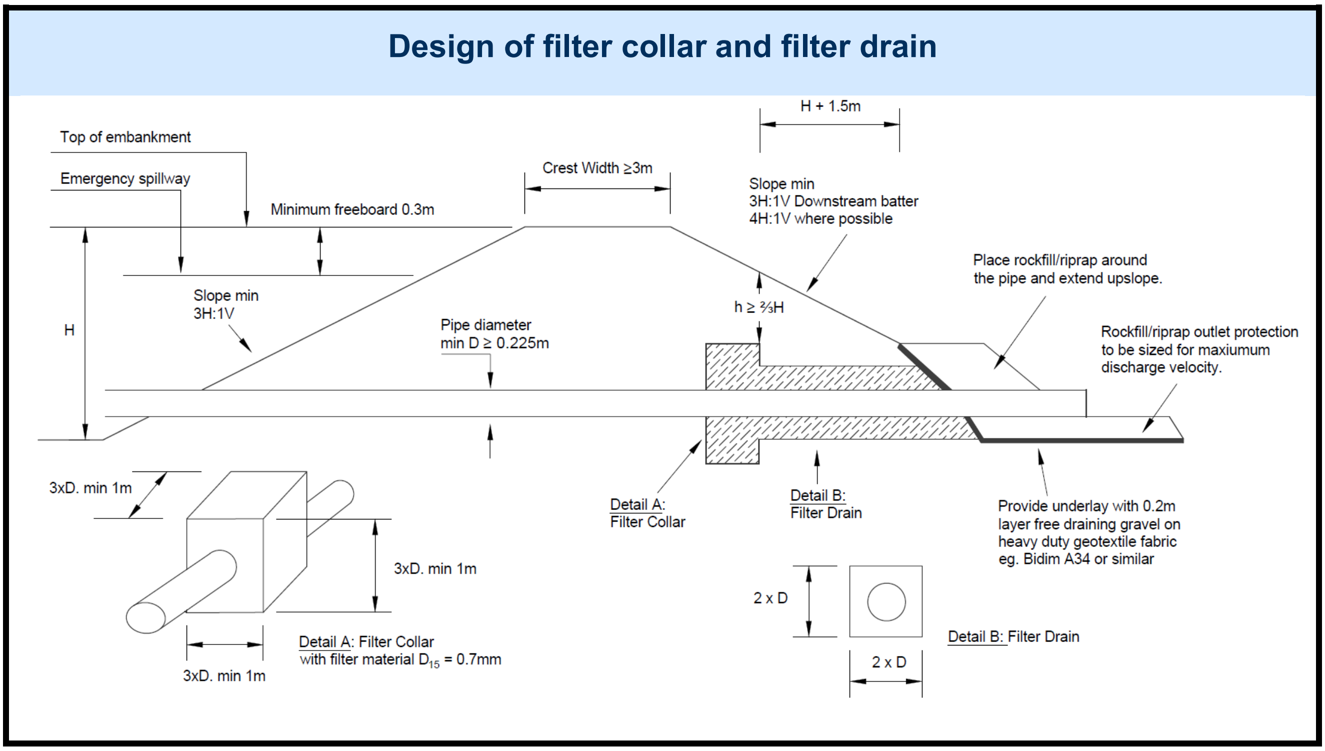


Figure 21 Filter collar and filter drain design

Cut-off collars are not accepted as a seepage control measure.

Spillway

The purpose of the flood spillway is to safely carry flood flows past the dam.

The spillway is to be positioned so that it can naturally follow ground contours, and such that it directs water away from the toe of the dam. Trees, vegetation and fences can pose a risk of blockage of the spillway and their position in relation to the spillway should be considered.

The dam spillway should normally be capable of passing a 100 year flood whilst maintaining a minimum freeboard of 300 mm to crest level.

Three types of flood spillway are permitted: grassed, reinforced grassed, and rock lined spillways. If the spillway is to be located on the dam embankment and not on adjacent natural ground, the velocities over the crest and the downstream slope should be kept low enough to prevent erosion.

If there are dams in series, each downstream dam spillway shall be designed for the cumulative catchment of the dams above it.

The spillway section is normally designed as a trapezoidal channel. The sizing is based on trial and error using Equation 4.

$$Q_{100} = 0.57\, x\, (2g)\, x\, {}^{1}/_{2} ({}^{2}/_{3}\, L\, x\, h^{3/2}\, + {}^{8}/_{15}\, Z\, x\, h^{5/2}$$ **Equation 4**

Where:

- Q is the discharge through the spillway.
- L is the horizontal bottom width of the spillway.
- h is the depth of flow at design flow.
- Z is the horizontal/vertical side slope (recommended to be 3).

Design of Spillway

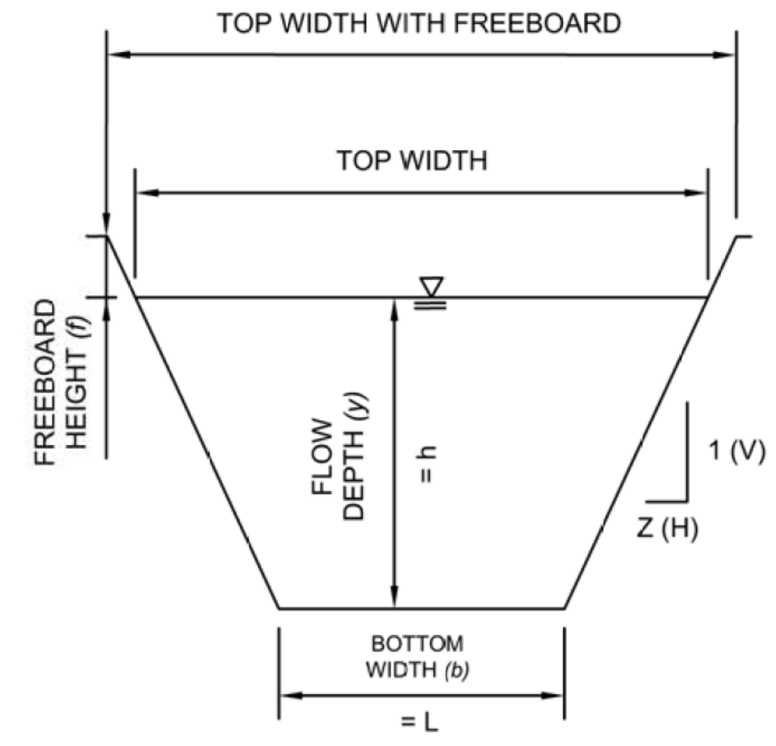


Figure 22 Spillway design

Alternatively, this can be calculated as a broad-crested weir using Equation 5 for approximation. This approximates the depth of water at the entrance to the spillway on the crest and is conservative as it assumes square sides; the spillway over the downslope of the dam can then be designed by Manning's Equation.

$$Q_{100} = 1.7 \times L \times h^{2/3}$$ **Equation 5**

Where:

- Q_{100} is the 100 year flood flow.
- L is the width of the spillway.
- h is the height of water at the spillway.

The height of the dam shall be determined such that there is sufficient storage for the 10 year 24 hour flood behind the dam considering a 100mm freeboard to the spillway, the height of water over the dam at the 100 year flood and a 300mm freeboard from this water level to the crest. The minimum storage behind the dam was approximated in Section 3, this can be adjusted for the height calculated (100mm below spillway) here to determine if there is sufficient volume. See Figure 23 below for further clarification.

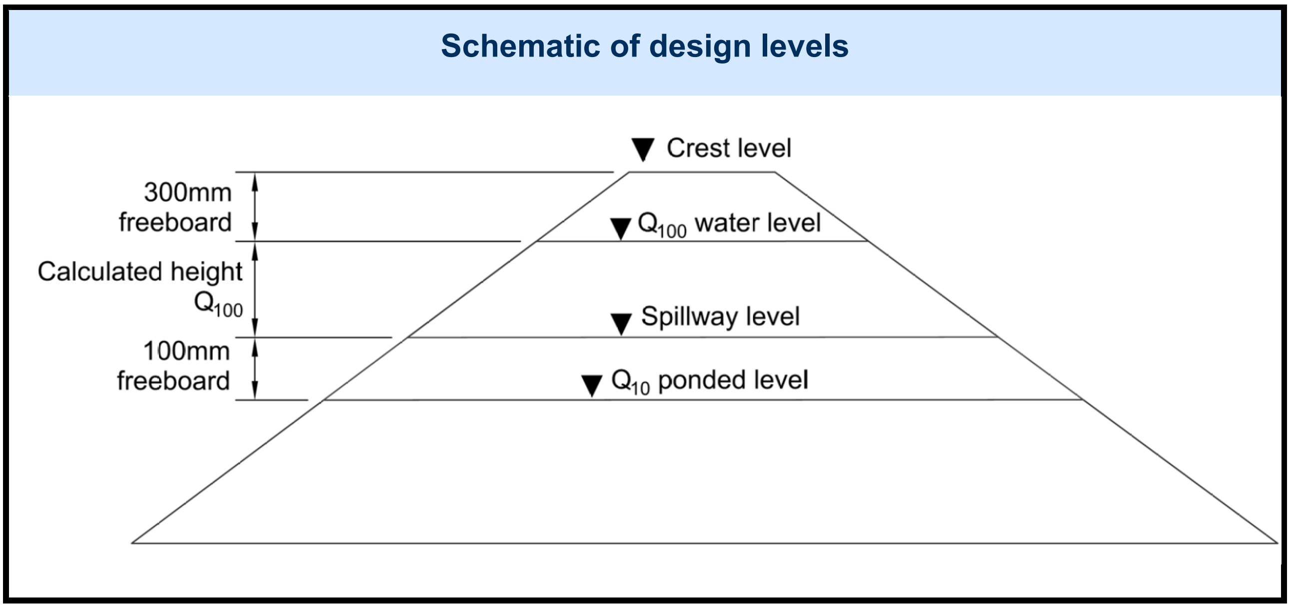


Figure 23 Schematic of design levels

Mannings Equation (Equation 6) is then used to size the spillway over the rear of the dam and to determine whether the flow may cause erosion as a result of a high velocity.

$$Q_{100} = \frac{1}{n} \times A \times R^{\frac{2}{3}} \times S^{\frac{1}{2}}$$ **Equation 6**

Where:

- Q_{100} is the 100 year flood flow.
- n is mannings number.
- A is the cross sectional area of the spillway.
- R is the hydraulic radius
- S is the spillway slope (minimum 10H : 1 V).

If the expected velocity over the spillway exceeds 1 m/s erosion protection may be required. The most suitable form of erosion protection if the embankment is to be stocked is using reinforced grassed (Enkamat). This can be further refined by meeting with the land owners, LMO, and investigating whether the spillway slope can be softened by using natural land flowpaths.

Culvert and energy dissipater

All small flood detention dams are to have culverts (service pipes) passing underneath to prevent water ponding, and to allow small flows. The minimum culvert diameter size permitted is 225 mm. The pipe shall have a minimum grade of 2 degree. The pipe material chosen must be strong enough to withstand construction loads. Possible options include corrugated HDPE, thick walled PVC or concrete.

The culvert design must be undertaken using the height of the water at the spillway in the 1 in 100 year flood event. This height provides the maximum headwater that will be experienced by the culvert and will result in the greatest exit velocity.

The Hydraulic Engineering Circular No. 14 (HEC 14) "Hydraulic Design of Energy Dissipators for Culverts and Channels" (FHWA, 2006) can be used to size the pipe.

First determine whether the culvert is governed by inlet or outlet control. The majority of these culverts will be under inlet control given the steep nature of the farms, the issue of erosion and the large headwater in a 100 year flood event.

The procedure used to size culverts under inlet control is as follows:

1. Find the headwater depth (HW) using the height of the 1 in 100 year flood.
2. Assume a culvert size and use culvert nomographs (FHWA, 2012) to determine the flow through the culvert.
3. Use the method described in Section 3.2.2 of HEC 14 for culverts under inlet control to calculate the normal depth and outlet velocity. If the parameters cannot be read off the charts, the culvert is full and the flow from it will cause severe erosion at end/hydraulic jump.
4. Next calculate the Froude number Fr. If this is >3 then the pipe is undersized, and if the pipe size is not increased an engineered energy dissipator will need to be designed.
5. If either of the issues in steps 3 and 4 occurs, increase pipe size and repeat step 2 to 4 until a solution can be achieved using the HEC 14 method.

Dams in series

As the largest detention dams will be designed at the base of the catchments, below other dams, they will likely have high HW due to the size of the cumulative 1 in 100 year flood flows. This will result in large diameter culverts. Once the diameter has been selected using the procedure detailed above, the design flow must be compared with the 10 year 24 hour storm flow. If the culvert is no longer detaining this water, a throttle plate can be specified for either the inlet or outlet to reduce flows. A throttle plate can be a gate valve or orifice plate.

If dams are built in series with the lower dam being within an urban area or settlement or within 1 kilometre upstream of an urban area, settlement or regionally significant infrastructure, then a dam-break flood hazard assessment using flood wave routing software shall be undertaken as waves generated by the failure of the upstream detention dam could result in damage to the downstream detention dam.

The upstream slopes of downstream detention dams and their abutments may require structural strengthening and/or protection against erosion by wave action.

Outlet protection

It is highly likely that a concentrated flow will create a scour hole, which in return can undermine the culvert outlet and the dam embankment causing failure and potentially open up a gully head.

HEC 1 (FHWA, 2006) provides in-depth design information for analysing scour problems at culvert outlets and protection options of the downstream open channel.

If the outlet velocity from the culvert have been determined as greater than the maximum permissible velocities for unlined channels as determined by Frontier, S. and Scobey, F.C. (1926), than outlet protection is required. Table 1 provides information on permissible velocities for different channel material.

Table 1 Maximum Permissible Velocities (Frontier, S. and Scobey, F.C., 1926)

Material	Velocity (m/s)
Fine sand (colloidal)	0.46
Sandy loam (non-colloidal)	0.53
Silt loam (non-colloidal)	0.61
Alluvial silt (non-colloidal)	0.61
Ordinary firm loam	0.76
Volcanic ash	0.76
Fine gravel	0.76
Stiff clay	1.14
Graded loam to cobbles (non-colloidal)	1.14
Alluvial silt (colloidal)	1.14
Graded silt to cobbles (colloidal)	1.22
Coarse gravel (non-colloidal)	1.22
Cobbles and shingles	1.52
Shales and hard pans	1.83

Regardless of the velocity, if the designer determined during the field investigation that the soils at the outlet position are vulnerable to erosion, then the designer shall estimate the potential extent of scour (i.e., depth, hs; width, Ws and length, Ls) using the equations provided in HEC 14.

Throughout the selection and design process, the designer should keep in mind the primary objective is to protect the dam structure and adjacent area from excessive damage due to erosion. However, the secondary objective is to keep the structure economically viable.

As such the designer shall assess the following criteria when choosing the appropriate outlet protection, taking into consideration an increase in cost from 1 to 4:

1 If the scour hole dimensions are acceptable and the velocity is smaller than the permissible velocity, then no erosion protection is required. However the designer should document the size of the expected scour hole for maintenance and note the monitoring requirements. Retrofitting of erosion protection might become necessary at a later stage.

2 If the scour hole dimensions are unacceptable, but the velocity is smaller than 6 m/s and the Froude Number is smaller than 1.7, then a riprap apron can be used as erosion protection.

3 If the velocity is smaller than 6 m/s and the Froude Number is greater than 1.7, but smaller than 3, then a riprap basin is required.

4 If the velocity is higher than 6 m/s and/or the Froude Number is greater than 3, then the designer should evaluate the use of engineered energy dissipators, such as stilling basins, hydraulic jump basins or baffled aprons.

HEC 14 provides a method for evaluating the most appropriate riprap size in Section 10.2. Equation 7 below can be used to estimate the minimum riprap size.

$$D_{50} = 0.2 \times D \times \left(\frac{Q}{(g^{0.5}) \times D^{2.5}}\right)^{\frac{4}{3}} \times \left(\frac{D}{TW}\right)$$ **Equation 7**

Where:

- D_{50} is the riprap size (particle size of gradation, of which only 50 percent of the mixture is finer by weight).
- D is the diameter of the culvert.
- Q is the design flow from the culvert.
- TW is the tailwater. If the tailwater is unknown, use 0.4 x D.
- g is the acceleration due to gravity, 9.81 m/s^2

If the flow is supercritical out of the culvert (Fr>1), then an adjusted diameter as calculated in Equation 8 shall be used.

$$D' = \frac{D + y_n}{2}$$ **Equation 8**

Where:

- D' is the adjusted diameter.
- D is the unadjusted diameter.
- y_n is the normal (supercritical depth) at the culvert.

Once the D_{50} is determined the designer should specify the minimum riprap size by using the next larger riprap class shown in Table 2 below (FHWA (2006), Table 10.1).

Table 2 Example riprap classes and apron dimensions from HEC 14 (FHWA, 2006)

Class	D_{50}	Apron Length L_A	Apron Depth D_A
1	125	4D	3.5 D_{50}
2	150	4D	3.3 D_{50}
3	250	5D	2.4 D_{50}
4	350	6D	2.2 D_{50}
5	500	7D	2.0 D_{50}
6	550	8D	2.0 D_{50}

For projects with several detention dams which require riprap aprons, the designer must evaluate the balances between oversizing riprap at some locations in order to gain efficiencies when acquiring bulk quantities.

The apron width W_A can be determined using 1:1 flare or $3D + 2/3L_A$. The width of the apron at the culvert is D either side of the culvert. See Figure 10.4 from HEC 14 below.

Riprap outlet protection (FHWA, 2016)

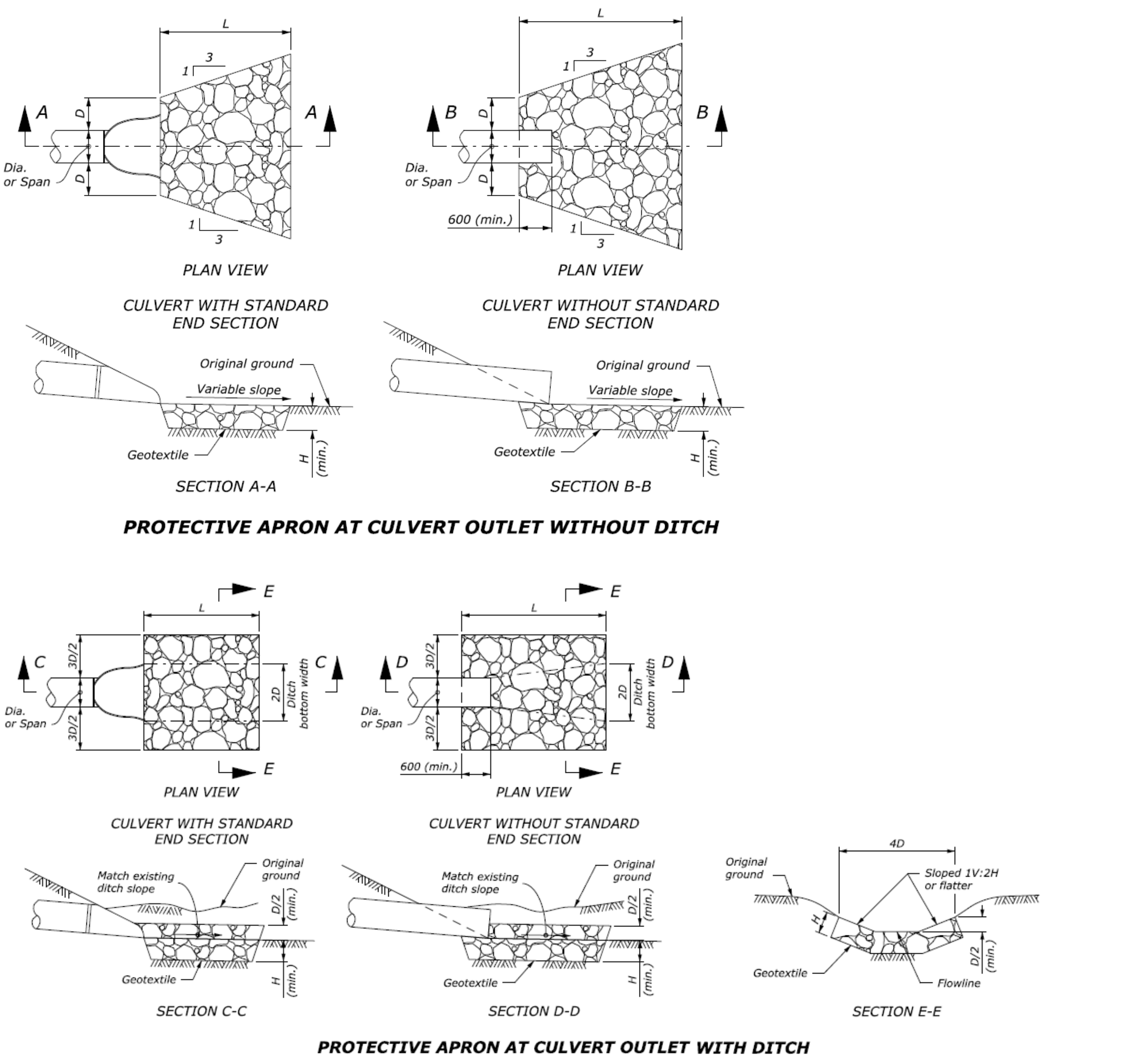


Figure 24 Placed riprap at culverts (FHWA, 2016)

The riprap apron design shown above can be adjusted to tie in with the insitu ground shape at the end of the culvert. The most important parameter to maintain is the D_{50} size. If this is undersized, the rock will be displaced by the force of the water. All rock shall be placed on geotextile or approved equivalent.

Borrow area

Suitable earthfill borrow areas should be identified during the investigation stage. The borrow sites should hold approximate 150% of the required earthfill material for the dam construction to account for any losses and unsuitable material.

To provide for economic benefits the earthfill should be sourced locally to limit excessive haul distances. However, the borrow area should not be located downstream of the dam, as it may destabilise the dam structure.

Fill can be taken upstream from the reservoir/storage area to provide increased storage capacity or close by valley sides. Although borrow areas within the proposed reservoir are desirable, no excavation should occur closer than 8 x the dam height from the upstream toe of the embankment to avoid introducing weak points.

Care must also be taken in using the valley sides for borrow to not create slope failures, particularly due to rapid draw down, as occurs with flood detention dams.

Design records and certification

A Technical Memorandum detailing the specifics of the design should be prepared by the Design Engineer and certified by a suitably qualified Chartered Professional Engineer.

The memo should contain as a minimum:

- **Introduction** – discusses the larger project context and introduces the topic that will be presented in the memo.
- **Purpose** – discusses the general purpose of the memo and the overall project. Be concise and brief - one sentence is sufficient.
- **Site Investigation** – summarises field investigation, laboratory results and the conclusions on site suitability and design constrains.
- **Analyses and Recommendations** – briefly summarise the design criteria, the analysis undertaken and the recommendations.
- **Appendices** – a map containing the dam locations and contributing catchment areas, geotechnical investigation report, hydrological analysis, spillway calculations and Culvert and Energy Dissipater calculations, and design drawings and dam dimensions.

This report forms part of the supporting information for a resource consent application. If the detention dams are within the permitted activity rule 46 of the RWLP a copy of this report should be provided to the LMO of the area and the District Council for inclusion on the property file.

This is to ensure that the evidence of the design information and verification by the CPEng is not lost when properties are changing ownership and that new owners know of the assets on the property and its management requirements.

Appendix 4
Dam construction

Preliminary and general

The site planning also involves the preparation of an Environmental Management Plan (EMP) and a Site Specific Safety Plan to ensure compliance with the provision of the RMA and the Health and Safety at Work Act 2015 (HSWA).

The main focus of the EMP is to identify the principles, practices and procedures to be implemented to prevent and mitigate any potential effects on land and/or water from the site operations. It should include an Erosion and Sedimentation Control Plan, an Emergency Spill Response Plan and a Flood Management Plan.

It should also cover the requirements of the Resource Consents (if applicable) and the archaeological authority from Heritage New Zealand or an accidental discovery protocol.

The Site Specific Safety Plan should include a Job Hazard and Risk Register, a Task Analysis & Safe Work Method Statement for higher-risk activities, an Emergency Response Plan and Notifiable Works Permits (where applicable). Site Safe New Zealand Inc. (2016) provides templates for the preparation of a Site Specific Safety Plan and a guideline on how to use the templates.

In addition, if the proposal affects the normal operating condition of a public road, than a suitably qualified Site Traffic Management Supervisor (STMS) needs to prepare a Traffic Management Plan (TMP), which shall meet the requirements set out in (NZ Transport Agency, 2012). The TMP needs to be signed off by the Traffic Management Coordinator of the Road Controlling Authority and put into practice prior to work commencing on site.

Site preparation

Traffic control shall be implemented in accordance with the approved TMP.

Erosion and sedimentation control shall be implemented in accordance with the Regional Council's Erosion and Sediment Control Guidelines for Land Disturbing Activities and/or Resource Consent conditions prior to starting dam construction.

All vegetation should be cleared from the dam and borrow sites and disposed of so that it will not be washed into waterways.

Foundation

The minimum treatment for any foundation will require the stripping of the foundation area to remove topsoil (typically 300mm) and other unsuitable (organic or permeable) material. Any soft material identified during the site visit and during construction shall be cut out and replaced with compacted fill.

Foundation preparation

Figure 25 Foundation preparation for a new detention dam site

The topsoil and any other organic material should be stockpiled outside of the reservoir area for later re-spreading over the dam and borrow area. If the dam is to be built on organic material the foundation preparation should be in accordance with the recommendations of the Geotechnical Engineer.

The cleared area should be inspected for any stumps, buried logs or tomos. If any stumps or logs are found they should be dug out and the hole filled with compacted soil. If a tomo is found it should be excavated and chased back to its origin. If the tomo does not appear to have an obvious cause, such as a rotted out log, geotechnical advice should be sought.

Borrow area

Turf and topsoil should be removed and stockpiled outside of the reservoir area, to use for site restoration afterwards.

Following the completion of fill placement, the borrow area should be shaped to blend in with the surrounding ground and ensure surface water does not pond. The stockpiled topsoil should be re-spread and the area seeded and protected until there is a good grass cover.

Cut-off trenches

Where a shallow permeable soil layer (< 2 m) has been identified and/or the general slope of the land is greater than 5 degrees, a cut-off trench should be dug along the dam centreline through to the base of the layer. The trench should be at least 3 m wide and have 1H:1V side batters or flatter to enable machine compaction. Low permeability fill should be placed and compacted in the trench as for main body of the dam.

Cut-off trench construction

Figure 26 Excavation of a cut-off trench

Culvert and energy dissipater

The pipe should be installed as follows:

- Excavate a trench in the prepared dam foundations (and cut-off trench where applicable) so that the top of the pipe will be at least 300 mm below the natural ground surface. If it is not possible to place the pipe in the dam foundation a trench can be excavated in the compacted fill at the base of the dam. The width of the trench should be sufficient to allow compaction of the backfill along both sides of the pipe with a plate compactor or similar.
- Compact the base of the trench.
- Lay the pipe at specified grade. If the dam is to be used to allow sediment to settle out of the water, the inlet to the discharge pipe may need to be modified to lift it above sediment level.
- Place a 200 mm thick layer of loose soil fill along each side of the pipe and hand compact using light hand operated mechanical compaction equipment such as trench rammers (jumping Jack compactors) and trench rollers. Continue placing and compacting soil layers evenly along both sides of the pipe. Test the fill compaction along the pipe at a maximum 5 m interval using a scala penetrometer. The minimum number of blows required per 100 mm penetration is five. Heavy compaction equipment shall not be used until there is at least 1.5 m of hand compacted fill above the pipe. The use of backfill with some cohesion is preferable as this will reduce the amount of seepage along the trench.
- Form the granular filter collar along the downstream section of the pipe as shown in Figure 21.The filter material should be compacted in 200 mm thick loose layers, wet of optimum water content to prevent its collapse when it becomes saturated.
- Place geotextile and rock rip rap over the exposed end of the filter.
- Install outlet erosion protection and/or a box flume or drop structure if necessary.

Mechanical soil compaction

Figure 27 Example of pipe installation with mechanical soil compaction of bedding and surround materials in layers (Photos: Wacker Neuson/Humes)

If the soil in the body of the dam has 40% to 85% of soil particles less than 75 mm in size, the granular filter material around the pipe shall be a medium to coarse grained sand with 15% of particles smaller than 0.7 mm in diameter. If the dam is constructed of finer silts and clays the filter material shall have a TNZ F/2 grading (refer to Table 3 below) or be approved by a Chartered Professional Geotechnical Engineer. The filter material also needs to be compatible with the soils in the dam foundation that it is in contact with.

Table 3 TNZ F/2 filter grading

Test Sieve Aperture	Percentage Passing
26.5 mm	100
13.2 mm	85-100
9.5 mm	80-95
4.75 mm	65-85
2.36 mm	50-70
1.18 mm	35-55

Test Sieve Aperture	Percentage Passing
600 mm	18-40
300 mm	3-25
150 mm	8 max
75 mm	0

Where sand with the required grading for a filter or TNZ F/2 material is unavailable or prohibitively expensive, the filter along the outlet pipe can be formed from geotextile wrapped aggregate. The aggregate should have the grading given in Table 4 and could be Grade 4 sealing chip or road chip sweepings.

Table 4 Geotextile wrapped filter grading

Test Sieve Aperture	Percentage Passing
53 mm	100
13.2 mm	10 max

Where geotextile is used it shall be placed in the excavated trench and wrapped over the compacted filter material around the outlet pipe with a minimum of 300 mm over-laps. The only longitudinal joint should be that where the geotextile is wrapped above the pipe. If significant settlements are expected the overlaps should be increased to 500 mm. The geotextile containing the filter material should be attached to the discharge pipe with three bandit type straps, with the buckles off set around the pipe. The geotextile should not be left exposed to sunlight for more than two weeks.

The geotextile shall be non-woven with the following characteristics:

- flow rate ≥ 50 litres/m2/s
- equivalent opening size ≤ 180 mm
- elongation > 30%
- grab strength 700N

Detention dam outlet

Figure 28 Example of a detention dam outlet with a timber discharge chute

Riprap outlet erosion protection

Figure 29 Example of a detention dam outlet with a riprap erosion protection

Embankment structure

Prior to placement of the embankment fill the dam footprint shall be inspected by the Engineer.

The embankment material is to be well mixed to create a homogenous fill and placed such that no continuous permeable layers are created. Any roots or timber thicker than a thumb should be removed from the fill. The fill is to be placed in 200 mm (loose) thick continuous layers spread in a longitudinal direction along the dam face. Compaction can be by a drum roller, tyres and tracks, with care taken to ensure compaction at the abutments and edges of the fill. A wedge foot roller may be required if the fill is stiff.

The embankment material is to be placed at or near optimum moisture content for compaction. For most suitable soils this will be only slightly damp. The water content of the fill should be adjusted to achieve good compaction by spraying water or allowing it to dry in the borrow area or on the dam if necessary. Where the fill has a moisture content significantly greater than optimum (i.e., close to saturation) the construction shall take place in stages to allow time for the dissipation of pore pressures.

Once the first 500 mm of compacted fill has been placed a compaction test should be carried out for every 10 m length of dam, with a minimum of 6 tests. The aim is to achieve at least 95% of the maximum dry density of the soil. An indication of this is typically a minimum shear strength of 150 kPa, as measured by a shear vane, for highly cohesive soils, and 5 blows/100 mm penetration of a scala penetrometer for other soils. A plateau density test could be carried out by testing after four passes of the compaction equipment and after each following pass until the maximum strength is achieved. This will give the contractor some guidance on the minimum number of passes to achieve the required compaction.

Dust control should be carried out if the dust created by the construction work could affect the workers, neighbours, stock or horticulture. The fill should be shaped and rolled smooth at the end of each day or when rains threatens to prevent surface ponding and construction delays.

Cohesive soils could weave under the compaction equipment if over compacted. If this occurs the soil could be too wet and should be left to dry until optimum water content is reached. This should be tested before another soil layer is placed.

Testing should be carried out for each 500 mm lift of the dam. Any poorly compacted layers should be excavated if necessary, re-compacted and re-tested.

The tests should be located to get a good coverage of the surface area of the fill and pick up areas outside of the highly trafficked paths. The test results should be recorded with the level of the fill and a sketch showing the approximate test location on the fill. This is to ensure there is a good spread of testing throughout the dam.

The dam crest level should be set to allow for the required freeboard and any estimated settlement. If the spillway is not over natural existing ground, once fill has been placed to this level the spillway can be cut to the required shape and depth and enkamat installed where required by the Engineer. The spillway shall be rolled to compact ensuring the shape definition is not removed. The shape and fall of the spillway should be checked such that it will not push water onto the toe of the dam during operation. Additional rock scour protection may be required by the Engineer at the base of the spillway.

Two H4 150 x 100 RS timber guides shall be installed either side of the inlet to the service pipe, driven firmly into the ground so they cannot be moved by hand. These are required so the inlet can be found and cleared in case of a blockage.

Fertilise and sow grass at an optimum time of the year for strike and keep any stock of the grass until well established. First graze with sheep or use mower to encourage grass thickening.

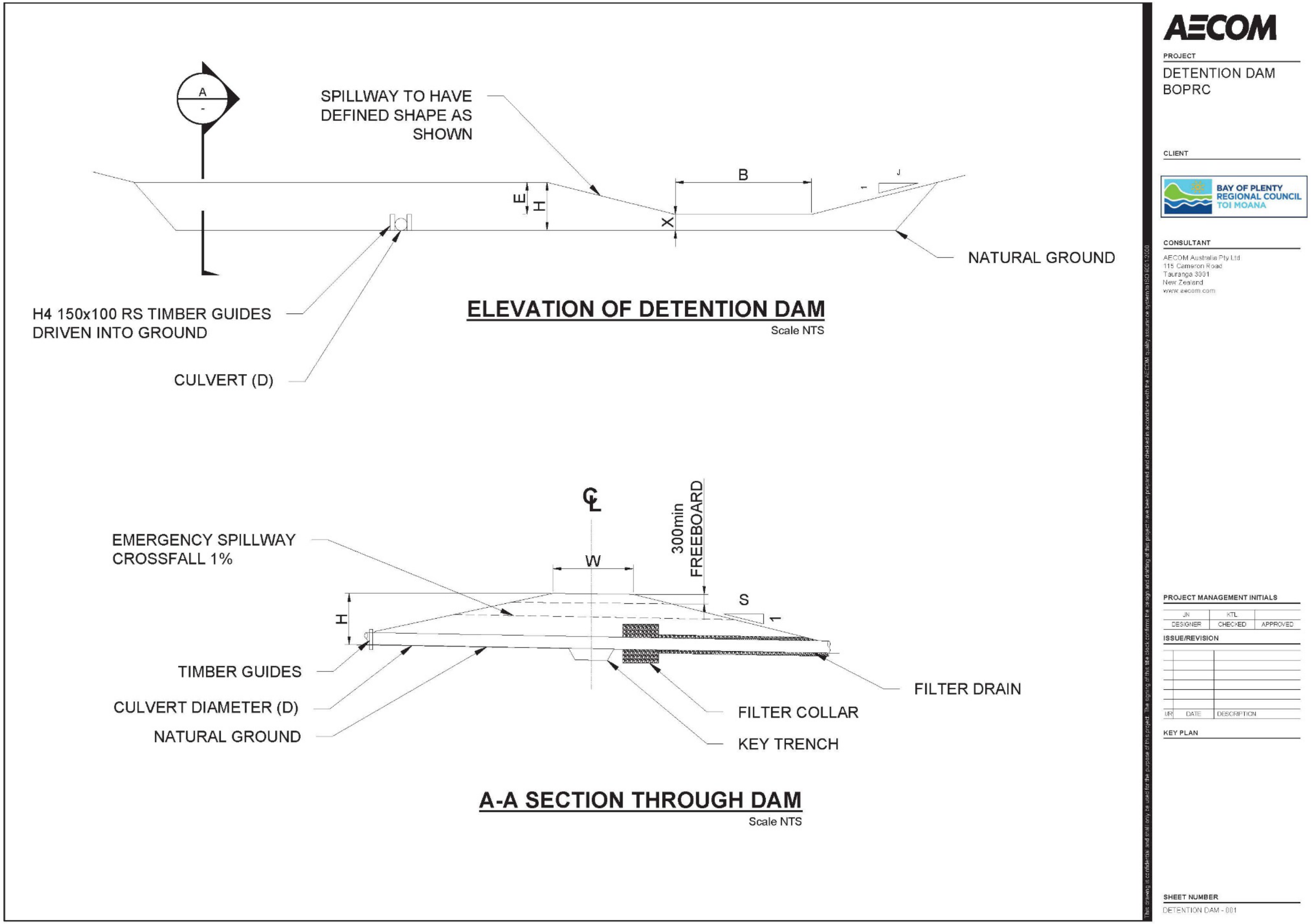
Construction records and as-builts

Maintaining good site records during the construction is important to prove work was done to the required standard. During the construction process, it is critical that the Contractors, LMO and Engineers keep comprehensive records of what happens on site.

At the end of a building project, the Contractor shall compile and provide the owner and the LMO with a report containing, visual evidence, as-built drawings, compaction testing records, material testing records and notes about any particular design changes required, such as the need to drain springs in the foundations.

As-builts could consist of marked up design drawings.

Appendix 5
Standard design and specification



SPILLWAY TO HAVE DEFINED SHAPE AS SHOWN
A
B
E
H
X
NATURAL GROUND
H4 150x100 RS TIMBER GUIDES DRIVEN INTO GROUND
CULVERT (D)
ELEVATION OF DETENTION DAM
Scale NTS
EMERGENCY SPILLWAY CROSSFALL 1%
W
300min FREEBOARD
S
1
H
TIMBER GUIDES
CULVERT DIAMETER (D)
NATURAL GROUND
FILTER COLLAR
KEY TRENCH
FILTER DRAIN
A-A SECTION THROUGH DAM
Scale NTS
AECOM
PROJECT
DETENTION DAM
BOPRC
CLIENT
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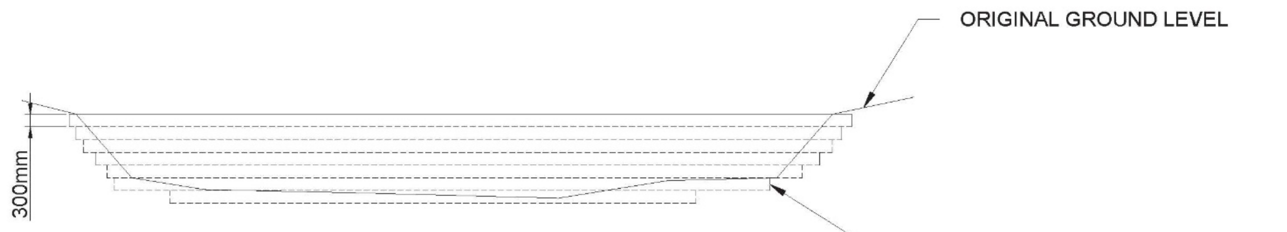
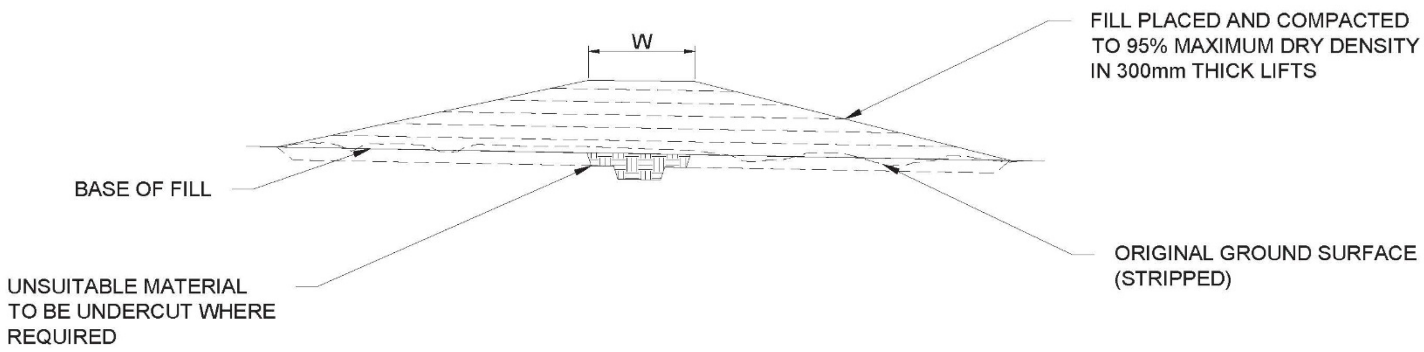
PROJECT MANAGEMENT INITIALS
JN
KTL
DESIGNER
CHECKED
APPROVED
ISSUE/REVISION
DATE
DESCRIPTION
KEY PLAN
SHEET NUMBER
DETENTION DAM - 001



CONSTRUCTION LIFTS

Scale NTS



TYPICAL SECTION SHOWING COMPACTION LIFTS

Scale NTS

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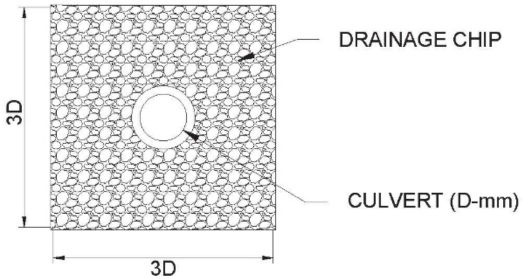
KEY PLAN

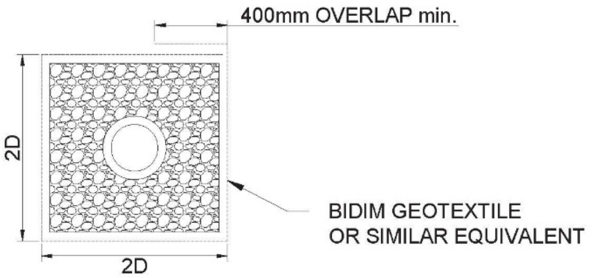
SHEET NUMBER

DETENTION DAM - 002



FILTER COLLAR

Scale NTS



FILTER DRAIN

Scale NTS

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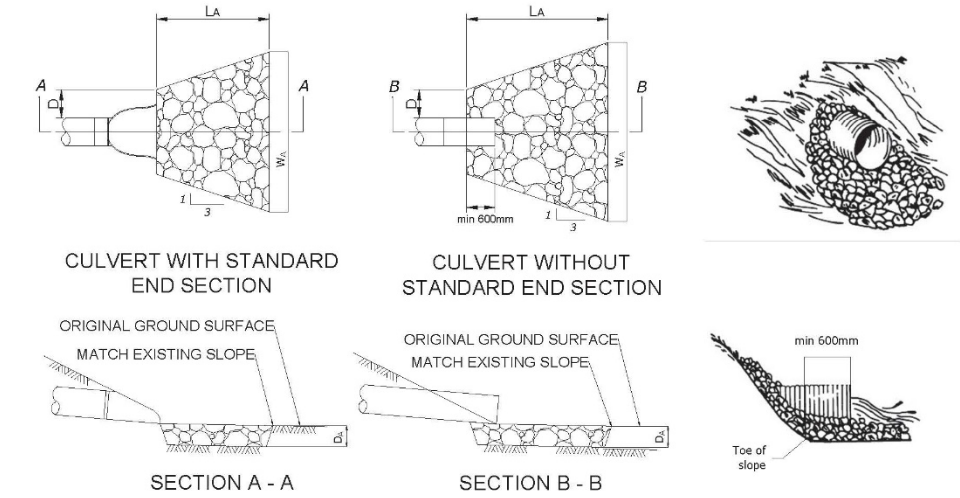
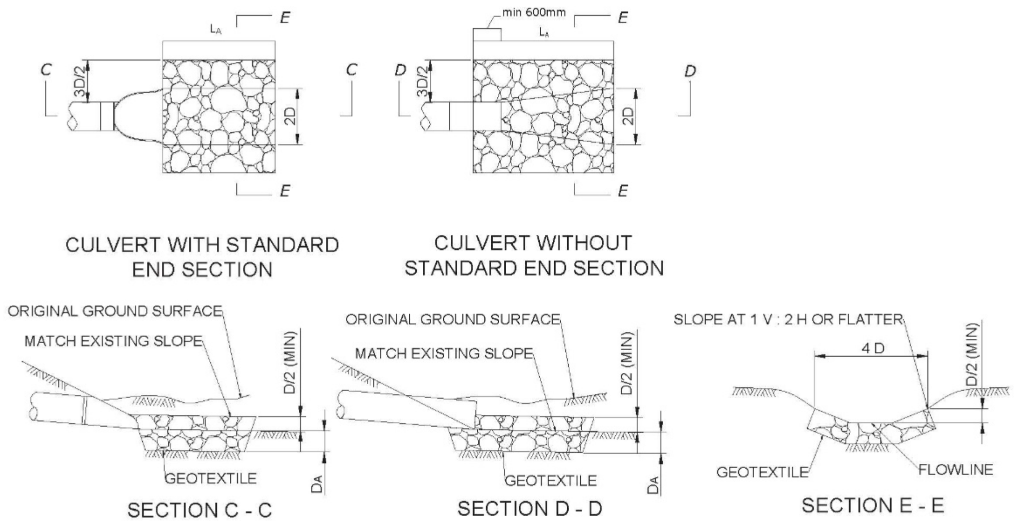
SHEET NUMBER

DETENTION DAM - 003 - FILTER COLLAR DETAILS



PROTECTIVE APRON AT CULVERT OUTLET WITHOUT DITCH

Scale NTS



PROTECTIVE APRON AT CULVERT OUTLET WITH DITCH

Scale NTS

NOTE:

1. *USE FOR APRONS SERVING CULVERTS WITH SLOPES LESS THAN 10%.*
2. *FURNISH SEPARATION AND STABILISATION GEOTEXTILE.*
3. *DO NOT MEASURE RIPRAP PLACEMENT EXCAVATION FOR PAYMENT.*

OUTLET WITHOUT DITCH
PROTECTIVE APRON DIMENSIONS AND QUANTITIES
FOR INFORMATION ONLY

	CULVERT DIAMETER D (mm)	RIPRAP CLASS	APRON LENGTH L_A (mm)	APRON DEPTH D_A (mm)	ESTIMATED RIPRAP QUANTITY (m^3)	ESTIMATED GEOTEXTILE QUANTITY (m^2)
WITH END SECTION	300	2	1200	460	0.7	4
	450	2	1800	460	1.6	7
	600	2	2400	460	2.9	11
	750	3	3750	610	8.0	22
	900	3	4500	610	11.5	30
	1050	4	6300	760	25.1	51
	1200	4	7200	760	32.8	64
WITHOUT END SECTION	300	2	1800	460	1.2	6
	450	2	2400	460	2.4	9
	600	2	3000	460	3.9	14
	750	3	4350	610	9.8	26
	900	3	5100	610	13.7	34
	1050	4	6900	760	28.6	57
	1200	4	7200	760	36.8	70

OUTLET WITH DITCH
PROTECTIVE APRON DIMENSIONS AND QUANTITIES
FOR INFORMATION ONLY

	CULVERT DIAMETER D (mm)	RIPRAP CLASS	APRON LENGTH L_A (mm)	APRON DEPTH D_A (mm)	ESTIMATED RIPRAP QUANTITY (m^3)	ESTIMATED GEOTEXTILE QUANTITY (m^2)
WITH END SECTION	300	2	1200	460	0.7	4
	450	2	1800	460	1.5	7
	600	2	2400	460	2.6	10
	750	3	3750	610	6.9	19
	900	3	4500	610	9.9	26
	1050	4	6300	760	20.1	42
	1200	4	7200	760	26.3	53
WITHOUT END SECTION	300	2	1800	460	1.0	5
	450	2	2400	460	2.0	8
	600	2	3000	460	3.3	12
	750	3	4350	610	8.0	22
	900	3	5100	610	11.2	29
	1050	4	6900	760	22.0	46
	1200	4	7800	760	28.5	57

Based on:

- *FHWA 2016 - Standard Drawing MW251-1*
- *DAF 1994 - Figure 6-46*

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PROJECT MANAGEMENT INITIALS

JN	KTL	
DESIGNER	CHECKED	APPROVED

ISSUE/REVISION

I/R	DATE	DESCRIPTION

KEY PLAN

SHEET NUMBER

DETENTION DAM - 004 - PLACED RIPRAP AT CULVERT OUTLETS

Appendix 6
Dam maintenance

During inspection the following should be looked for:

(a) Reservoir

- Erosion
- Surface failures
- Fallen vegetation.

(b) Foundation (Abutments)

- Cracking
- Surface failures
- Deeper failures
- Damage to vegetation cover
- Seepage
- Soft or greener areas
- Holes or tomos including those due to animal burrows.

(c) Crest, upstream and downstream faces

- Cracking
- Settlement/deformation of the crest
- Surface failures
- Deeper failures
- Bulging at the toe
- Surface erosion/rilling
- Erosion at toe
- Damage to vegetation cover
- Seepage (an effort should be made to collect a sample of seepage water to see whether it contains soil particles)
- Soft or greener areas
- Holes or tomos in either dam face including those due to animal burrows
- The growth of weeds/vegetation.

(d) Spillway

- Scouring/erosion,
- Deformation of crest,
- Damage to erosion protection, and
- Blockage by debris/vegetation.

(e) Outflow drain

- Settlement in the face above inlet or outlet
- Damage to the inlet or outlet structures
- Scour at the outlet
- Flow from the filter drain
- Dislodgement of rip rap protection.

If significant cracking, deformation, or any seepage is observed, professional advice should be sought.

SMALL FLOOD DETENTION DAM INSPECTION REPORT

To:	**BOPRC**	**Date:**
Attn:	Land Management Officer Manager Pollution Prevention	**LMO File No:** **Resource Consent No:**
From:		**Job Tracker No:**
Subject:	Small Flood Detention Dam Inspection Report, dated [Publish Date], Page 1 of x	

Dear xxx,

Consent No: xxx (if applicable)

Consent Holder: xxx (if applicable)

Address: xxx

Detention Dam Name/Number: xxx

Construction Date: xxx

Site Location: xxx

I/We have inspected the Small Flood Detention Dam relating to the above address and enclosed is the completed checklist as required under the Guidelines for the Design, Construction, Maintenance and Safety of Small Flood Detention Dams.

Inspection Date: xxx

Weather: xxx

This inspection is:

☐ Immediately after Construction

☐ After a Significant Storm Event or Other Natural Disaster

☐ Routine Annual

Location Map

"Insert location plan of dam/s here."

FOR USE AFTER CONSTRUCTION – ANNUAL AND POST EVENT

Code Key:

N/A = Not Applicable **M= Monitor (potential for future problem)**

N/P = Not a Problem **WN = Work Needed**

RESERVOIR		
Assessment	**Code**	**Explanation**
Erosion		
Surface Failures		
Fallen Vegetation/debris		
Other (Describe)		
FOUNDATION (ABUTMENT)		
Assessment	**Code**	**Explanation**
Erosion and/or loss of dam material		
Surface failures		
Deeper failures		
Deep rooted shrub/trees present		
Has grass been established/damaged		
Holes/tomos/animal burrows		
Soft spots/boggy areas/seepage		
Other (describe)		
CREST, UPSTREAM AND DOWNSTREAM FACES.		
Assessment	**Code**	**Explanation**
Cracking		
Settlement/deformation		
Surface failures		
Deeper failures		
Bulging at the toe		
Surface erosion/rilling		
Erosion at the toe		
Has grass been established/damaged		
Deep rooted shrub/trees present		

Soft spots/boggy areas/seepage		
Holes/tomos/animal burrows		
Other (describe)		
SPILLWAY		
Assessment	**Code**	**Explanation**
Obstruction: vegetation/debris/sediment		
Damage to erosion protection		
Deformation of crest		
Lack of definition		
Other (describe)		
SERVICE PIPE/CULVERT		
Assessment	**Code**	**Explanation**
Settlement in the face above inlet or outlet		
Damage to the inlet or outlet structure/ loose guide posts		
Scour at the outlet or downstream of riprap protection		
Flow from filter drain		
Dislodgment of riprap protection		
Blockages in pipe		
MISCELLANOUS		
Any changes in downstream risk? i.e. new house		
Any changes in upstream catchment? i.e. land cover change, new culvert/bridge.		
Any change in land ownership?		
Any gully heads open above or below dam?		
Any issues raised by dam owner?		

PHOTOGRAPHS	
Photo One:	**Photo Two:**
Photo Three:	**Photo Four:**
Photo Five:	**Photo Six:**

ADDITIONAL COMMENTS

If you have any further queries, please do not hesitate to contact the undersigned.

Regards

....

Name

Reviewed by:	xx
Chartered Professional Engineer #	xx
Signed:	xx
Date:	xx