Retarding Basin Design and Assessment Guideline

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Introduction

Melbourne Water currently manages over 235 flood retarding basins within the drainage system. These basins have been constructed over many years by various authorities including the Melbourne and Metropolitan Board of Works, Dandenong Valley Authority, Local Government Authorities and land developers.

This guideline aims to formalise Melbourne Water's general requirements for the design, construction, operation and maintenance of drainage retarding basins. Where designers believe that a departure from the normal requirements set out in this guideline is warranted, Melbourne Water will assess each proposed departure on its own merits. It is the designer's responsibility to ensure they are referring to the latest version of this guideline.

This guideline will be reviewed to determine ongoing relevance when the DRAFT ANCOLD Guidelines for Retarding Basins (which is expected to be published in 2017) is released.

Melbourne Water is currently undertaking risk assessments of its existing retarding basins to develop a prioritised program of upgrades. This program aims to reduce risk and bring existing retarding basins progressively into line with current industry practice.

Background

Flood retarding basins are water impoundments designed to temporarily store stormwater runoff from small to moderate flood events and allow downstream flow rates to be kept within the design capacity of the drainage system. Such basins are constructed to reduce downstream flooding impacts, reduce the need for downstream drainage upgrade works or to protect natural waterways. These basins are usually designed to mitigate floods up to a 1 in 100 Annual Exceedance Probability (AEP) flood event.

These basins may also provide considerable benefits, other than flood control, for the community (e.g. stormwater quality improvement, recreational areas, gross pollution control etc.).

When these basins store water they become reservoirs, potentially storing significant volumes of water, and therefore they impose dam safety risks on communities downstream. As a result, the design must have regard for ANCOLD (Australian National Committee on Large Dams) guidelines, comply with Melbourne Water's 'Statement of Obligations' to the Minister for Water and have regard for Melbourne Water's due diligence obligations as owners of potentially hazardous infrastructure.

A dam, for the purposes of this document, is defined as anything in which by means of excavation or other works, a bank or barrier is created where water is collected, stored or concentrated. This includes water supply dams, retarding basins, levees and wastewater lagoons with a maximum height of 0.5 metres or more above the downstream natural surface level.

Design Requirements

As a minimum, Melbourne Water requires any engineer providing advice, design or engineering input on our existing or future dam assets to satisfy the ANCOLD definition of a Dams Engineer (ANCOLD, 2003):

A professional engineer who is suitably qualified and recognised by the engineering profession as experienced in the engineering of dams and its various subfields.

Melbourne Water takes this to include an individual who has a broad understanding of all aspects of dam design, construction, operation and maintenance including:

- Demonstrated experience in the use and application of ANCOLD Guidelines; and,
- An appreciation of the sub-fields of dams engineering including:
    - Risk assessments;
    - Consequence assessments;
    - Flood Hydrology;
    - Failure mode and likelihood assessments;
    - Design and construction of dams, spillways and outlet works; and,
    - Dam operations including flood routing, surveillance and instrumentation.

In addition to a general understanding of dams engineering, an individual must have up-to-date knowledge, as well as relevant and recent experience in the specific area for which they are providing advice.

Melbourne Water relies on the knowledge, skill and diligence of the designer for aspects of detailed analysis, design and conformance with current industry practice. However, Melbourne Water may require further assessment of any aspect of design to ensure adequate protection of the community and environment.

As examples, Melbourne Water considers the following organisations as having suitably qualified Dams Engineers:

SMEC
Contact: Elliot Hannan, Delivery Manager – Dams

GHD
Contact: Paul Maisano, Principal Dams Engineer

Jacobs
Contact: Kelly Maslin, Director of Operations: Water

AECOM
Contact: Dr Gavan Hunter, Technical Director – Dam Engineering

Richard Rodd & Associates
Contact: Richard Rodd, Principal

If a third party would like to use a different organisation or individual on a specific project that they are completing for Melbourne Water, they must submit a case that the individual meets the criteria outlined above, which includes referees. The submission will be reviewed and decided upon by a panel headed by Melbourne Waters Principal Dams Engineer.

Note that on a case-by-case basis Melbourne Water also may engage an independent peer reviewer who will assist in reviewing works proposals, designs and risk assessments.

The following areas, in particular, require detailed consideration by designers:

Embankment Location

The ownership of the embankment and ancillary assets i.e. roads, paths, bridges, pipes etc. must be determined before assets are constructed. Where a retarding basin asset does not belong to Melbourne Water or there is shared responsibility between Melbourne Water and Council a maintenance agreement must be entered into.

Where an embankment forms part of another structure, e.g. road or railway or drainage channel embankment and is expected to perform the function of a retarding basin embankment, the embankment must be designed as a retarding basin embankment.

Flood Capacity

The consequences of a storm event exceeding the design capacity of the structure should be considered in the design of a retarding basin. Although such an occurrence may be unusual, it is possible, and the consequences of the sudden failure of a basin could be extreme because of their proximity to populated areas.

Accordingly, Melbourne Water requires that basins be designed to pass appropriate extreme storms safely in accordance with the guidance provided by the ANCOLD Acceptable Flood Capacity and/or Risk Guidelines as is the case for conventional dams.

Consequence Assessment

In Australia, it is standard industry practice that the consequences of the failure of a dam structure should inform:

- The flood event that the structure must safely pass; and,
- How often the structure must be inspected and its safety reviewed.

For this reason, MW requires that all retarding basins have a consequence category assigned to them, so that the risk associated with them is understood and managed.

The guidance in this area is contained in the ANCOLD consequence assessment guidelines, which outline a process for assessing the consequences of failure in order to assign a consequence category. MW requires that the latest version of these guidelines is followed when assessing the consequence category for a retarding basin.

The current version of these guidelines (ANCOLD, 2012) outlines three different standards for completing consequence assessments:

- Initial Assessment
- Intermediate Assessment
- Comprehensive Assessment

For structures that, in the event of a dam breach event, will not pose a risk to any people or private property downstream, an "initial assessment" is adequate. It should be noted that in the assessment, the dam breach case that results in the largest Population at Risk (PAR) or Potential Loss of Life (PLL) (either total or incremental based on the level of assessment adopted) must be used to determine the consequence category.

Melbourne Water requires that the consequence assessment considers;

- the impact of future development downstream; and,
- the impact on other basins in the catchment.

Irrespective of the level of assessment adopted, the assessment must be documented and certified by one of the suitably qualified engineers listed under the Design Requirements section of this document and then submitted to Melbourne Water. This documentation must include a detailed description of the site, Population at Risk, Potential Loss of Life (if required), severity of damage and loss, and recommended consequence category. The acceptable flood capacity for the retarding basin must also be recommended, based on the latest ANCOLD guidelines on acceptable flood capacity.

Downstream Development

The extent of existing and future development in an urban catchment should be considered during design of a retarding basin as future extensive development within the catchment could significantly alter catchment inflow response at the basin. In addition, future development downstream of the basin could significantly increase the consequences of failure presented by the basin (affecting Melbourne Water's requirements) and affect Melbourne Water's risk profile. The construction of a new retarding basin may require subsequent upgrades of downstream basins.

The flood capacity of a basin should be designed to take into account future downstream development based on the expected density of population.

Multiple Basins within a Catchment

With increasing urbanisation there are now many catchments in Melbourne Water's drainage area which contain a series of retarding basins. This introduces two further aspects which must be considered. The consequences of one basin failure cascading downstream into lower basins should be evaluated. In addition the effect of long period releases from upper basins superimposing flows through lower basins may require a revision of the operation of basins throughout the catchment. Overall each basin within a catchment should be investigated and modelled, not only individually, but also collectively within the catchment.

The Design Process

Site Investigation

Site investigations must be undertaken as part of the overall design process. Such investigation shall include but not be limited to:

- Geological assessment of the site (report to be submitted to Melbourne Water);
- A program of geotechnical investigations to assess the retarding basin and spillway foundations and any preferred borrow pits and material sources (report to be submitted to Melbourne Water);

Embankment Design

Retarding basin embankments are to be designed as dams. Structural vulnerabilities that can be present in retarding basin embankments should be avoided. These are associated with different construction materials and techniques and also the hazards posed by trees, large shrubs and their root systems. Embankment protection should take into account long term maintenance of the structure.

The following failure modes are to be considered during the design:

- Flood Overtopping
- Piping along outlet conduit
- Piping through embankment due to Desiccation Cracking
- Piping through embankment due to Poorly Compacted Layer
- Foundation piping - Upstream wetland with permanent shallow pool
- Foundation piping due to defects in foundation material or surface cracking prior to construction of embankment.

In addition:

- Appropriate stability analyses and practices should be used.
- Appropriate foundation treatment should be specified in the report and drawings submitted to Melbourne Water. This may include stripping all organic topsoil matter and removal of unsuitable foundation material, etc.
- Suitable compaction and moisture standards should be specified in the report and drawings submitted to Melbourne Water and protection provided to cater for cracking or dispersive soils. Typical values for earthfill embankments are a minimum dry density ratio of 96% of Standard Maximum Density and moisture content between 2.0% dry and 1.0% wet.
- Embankment batter slopes shall not be steeper than 1V in 5H. This provides accessible embankment slopes to enable maintenance such as mowing.
- A 3m runout area at a maximum grade of 1V in 12H shall be incorporated at the toe of the embankment for mowing access. The runout area shall be clear of rocks, trees and fences to allow for mowing.
- Trees and woody shrubs shall not be planted on the embankment slopes or within 3m of toe of embankment (including canopy). Trees and woody shrubs have large root systems which can create potential piping paths through the embankment.
- Impervious zones of the embankment should preferably take the form of a centrally located 'core' rather than an upstream face zone to reduce the effects of drying which may lead to cracking.
- The crest must be capped to reduce the likelihood of desiccation cracking.
- Seismic hazards should be considered where retarding basins are expected to retain permanent or semi-permanent water bodies.

For embankments considered to have a consequence category of 'Significant' or higher, chimney filters and filter blankets must be provided for the entire length of the embankment, from abutment to abutment and to a depth determined sufficient for the material type and embankment configuration, irrespective of the assigned consequence category, embankments constructed using dispersive soils (categorised as Pinhole Dispersion Classification D1 or D2 or categorised as Emerson Class 1 or 2) or erodible soils (Plasticity Index of less than 7) must be constructed with a chimney filter and filter blanket for the entire length of the embankment from abutment to abutment. Refer to Melbourne Water Standard Drawings 7251/11/001 and 7251/11/002 for the design of chimney filter and filter blankets.

Spillway Design

Melbourne Water does not permit designs that envisage the overtopping of earthen embankments at flood frequencies greater than the *"Fallback" Spillway Annual Exceedence Probability (AEP)* as defined by ANCOLD unless it can be justified. In such cases the design submission is to be accompanied by a full risk assessment undertaken by a suitably qualified dams engineer listed under the design requirements section of this document.

The design capacity of spillways should be set with the outlet blockage based on the recommendations of the Australian Rainfall and Runoff guidance on blockage Book 6, Chapter 6. A sensitivity analysis of impacts of different levels of blockage of the outlet can be used as part of designing the spillway capacity.

Where a concrete spillway (or other concrete structure) is specified to be constructed through the embankment, filter protection should be provided adjacent to the structure irrespective of the assigned ANCOLD consequence category.

Where the spillway is a grass depression excavated into the abutment of an embankment, the spillway crest level should be defined by a concrete control weir. Spillway flows should be directed such that they do not impact upon the integrity of the embankment and minimise the effect on surrounding properties and other assets. Spillway flow velocities must be within recognised limits to avoid erosion on the floor and sides of the grassed channel or if necessary erosion protection should be provided.

Conduits below or through embankment

Locating conduits through or under embankments should be avoided where possible. The preferred location of conduits is through the abutment, to reduce the potential for embankment failure due to piping.

Irrespective of the assigned consequence category of the embankment, a filter diaphragm is required to be constructed around all conduits that pass through or under the embankment or where the potential for piping exists, including conduits through abutments that 'daylight' downstream. For embankments requiring full filter protection, the filter diaphragm is to be incorporated into the chimney filter zone and the filter protection is to extend below the conduit, consistent with the requirements for a filter diaphragm. Melbourne Water Standard Drawings 7251/11/001, 7251/11/002, 7251/11/003 and 7251/11/004 provide the recommended design requirements for filter protection around conduits. Where concrete pipes are to be used, the joints should be rubber-ring type within the embankment footprint. The joints of butt jointed pipes and culverts shall be sand sealed and fully encased with a concrete bandage.

Concrete cut-off collars around conduits must not be used through/ under embankments. Deep trenches steep batter slopes greater than 1V in 3H should be avoided due to the difficulty in gaining an appropriate level of compaction. Concrete encasement and concrete footings are required on conduits passing through or under embankments as shown in Melbourne Water Standard Drawings 7251/11/003 and 7251/11/004. The conduit must be designed to resist all applied loads including overburden with a 20% increase in the calculated load, and internal and external water pressures.

The construction of conduits in embankments with dispersive fill (categorised as Pinhole Classification D1 or D2 or Emerson Class 1 or 2) is to be avoided. Where no alternative exists, lime or gypsum is to be added to the back fill material in sufficient quantity to render the soil non-dispersive based on a site specific geotechnical report completed by a recognised engineering geotechnical consultant.

Outlet Structures and Gratings

Outlet structures and grilles/gratings should be designed with self-cleaning grilles/grates that are blockage resistant to allow maximum outlet flow to continue for as long as possible during a storm event. Self-cleaning grilles/grates should be aligned with the direction of flow and not be steeper than 1V to 3H. Refer to MW Standard Drawing 7251/08/423 for details. Grates directly on the pipe should be avoided where possible and other means to provide public safety-such as pools at inlet and outlets to deter entry to the pipe should be considered.

Underground Pipelines

Designers should also be aware of the effects of any service conduits (gas, power, water, sewer etc.) that penetrate retarding basin embankments in respect of initiating piping failures. Gas and high pressure water lines should be re- routed. Sewers and similar pipelines must be treated as conduits through or below the embankment and have appropriate defensive measures such as intercept filter zones, to guard against piping (see Conduits below or through embankment section).Vegetation

Trees and other woody vegetation must not be planted on retarding basin embankments for structural integrity, surveillance and maintenance reasons (refer Appendix B for list of acceptable vegetation species).

Preferably, embankments should be protected by a uniform, robust grass cover that can be easily and safely mown and inspected for defects. This includes around structures such as pits, spillways and pipelines so that the structure will not be damaged by roots and access for maintenance is available.

Vegetation is undesirable on embankments for structural integrity, surveillance and maintenance reasons. It is proposed to reduce the impact of this type of vegetation from high & significant hazard rated assets to ensure the embankments are managed according to their risk rating.

The following items outline the reasons for reducing such vegetation from the retarding basin embankments:

• Potential for loss of freeboard and breaching if trees are blown over during the operation of the assets.

• Potential for significant damage or failure of the embankment through piping, if trees die & root systems rot to become channels for flow and ultimate embankment failure.

• Obstruction of visibility and access to interfere with surveillance and maintenance of embankments. Vegetation on constructed embankment slopes should generally consist only of regularly cut grass.

• Tree roots can also displace and damage concrete structures including spillways, outlet structures and underground pipelines.

• Vegetation and Tree branches can interfere with the normal operation of flood protection structures by obstructing flow path/blocking outlets.

Construction Supervision

Construction supervision, design advice and other activities during the construction of the works must be undertaken by an experienced team with knowledge of dam construction. That team must include the suitably qualified dams engineer undertaking the design and input from an appropriate geologist/geotechnical engineer with Level 1 Geotechnical Inspection and Testing Authority (GITA) accreditation to assess and map the foundation. The suitably qualified dams engineer and the geologist/geotechnical engineer must have access at all times to inspect the works to ensure that the design intent is being met. The suitably qualified dam engineer, the geologist/geotechnical engineer with Level 1 Geotechnical Inspection and Testing Authority (GITA) accreditation and the construction engineer must all accept or reject the foundations, embankment and spillway during the construction works with this acceptance/rejection report submitted to Melbourne Water.

The Contractor will be required to ensure that appropriate control in the handling and placement of filter materials are in place to prevent segregation and contamination of filter zones during construction. The Contractor shall provide a quality control testing and acceptance program (endorsed by the suitably qualified dams engineer and geologist/geotechnical engineer with Level 1 Geotechnical Inspection and Testing Authority (GITA) accreditation) for all embankment materials to confirm that the materials used in the works meet the requirements of the specification.

Results of the grading and durability tests undertaken on filter material are to be submitted to Melbourne Water accompanied by a report from the geologist/geotechnical engineer with Level 1 Geotechnical Inspection and Testing Authority (GITA) accreditation to demonstrate that material properties meet the requirements of the specification.

The records for material placement and compaction shall show compliance of each lift and shall include:

a) For embankment fill zones: the density results, moisture content and confirmation of lift thickness.
b) For filter zones: the records providing confirmation of the filter extent, lift thickness and number of coverages of compaction plant.
c) Sign off by the client representative on site to confirm acceptance and approval of each lift.

The work-as-executed (as constructed) drawings must be prepared; progressively during the works as each construction hold point is completed. An updated design report, complete with detail of changes made and the reasons for them, plus broad information on the construction process, must be presented to Melbourne Water upon completion of construction.

Maintenance

Regular maintenance is a critical factor to ensure the long-term safe operation of retarding basins. Maintenance requirements shall be included as part of the project report and should include a statement on exclusion zones for woody vegetation. Any trees/woody vegetation that appears on embankments should be quickly removed before the lateral and tap roots develop too far.

The design of any retarding basin structure should take into account the ease of maintenance with respect to:-

- Safe access to the structure and assets within for
  - clearing of debris
  - de-silting of sediment/wetland ponds
- Outlet blockages
  - design grille/grates to reduce blockages
- Vegetation management including grass cutting access
  - uniform grass coverage
  - tree planting - location and type (not permitted on embankment or within 3m of embankment toe

Engineering Information

Melbourne Water requires that all information relevant to the design and proposed construction supervision of the retarding basin be presented in the form of a design report. The design report needs to cover all aspects of the retarding basin (Appendix A – Retarding Basin Requirements Guide) included in these Guidelines as well as any other relevant information related specifically to the basin in question.

Glossary

Dam Crest Flood – The flood event which when routed through the reservoir, results in a still water level in the reservoir, excluding wave effects, which:

- For an embankment is the lowest point of the embankment crest.
- For a concrete dam is the uppermost level of the crest, excluding handrails, and normally parapets, unless the parapet is capable of supporting the flood surcharge load.

Spillway Design Flood – is the flow stage selected from site and economic considerations for the hydraulic design of the spillway structure, chute and dissipater, under operational conditions, as distinct from potential, but low probability extreme floods selected for overall dam safety.

"Fallback" Design Flood – Refers to the use of the ANCOLD guidelines as a simplified method for the determination of spillway design flood as opposed to a risk based approach.

Reference

ANCOLD Guidelines on Selection of Acceptable Flood Capacity of Dams (2000)

ANCOLD Guidelines on Risk Assessment (2003)

ANCOLD Guidelines on Dam Safety Management

(2003)

ANCOLD Guidelines on the Consequence Categories for Dams (2012)

Fell, R., MacGregor, P., Stapledon, D., Bell, G. (2005), Geotechnical engineering of dams, Balkema Publishers Leiden

Federal Emergency Management Agency (FEMA) (2011), Filters for Embankment Dams: Best Practices for Design and Construction.

Fell, R., Foster, M., Cyganiewicz, J., Sills, G., Vroman, N and Davidson, R. (2008) Risk Analysis for Dam Safety: A Unified Method for Estimating Probabilities of Failure of Embankment Dams by Internal Erosion and Piping Guidance Document ('Piping Toolbox'), Delta Version, Issue 2.

Foster, M (1999) The probability of failure of embankment dams by internal erosion and piping. PhD thesis, School of Civil and Environmental Engineering, The University of New South Wales.

Foster, M. and Fell, R. (2001), Assessing embankment dams, filters which do not satisfy design criteria, J. Geotechnical and Geoenvironmental Engineering, ASCE, Vol. 127, No. 4, May 2001, 398-407.

Foster, M., Fell, R. and Spannagle, M. (2000). The statistics of embankment dam failures and accidents, Canadian Geotechnical Journal, Vol. 37, No.5, National Research Council Canada, Ottawa, 1000-1024, ISSN 0008-3674.

Sherard, J. and Dunnigan, L. (1985). Filter and leakage control in embankment dams, Seepage and Leakage from Dams and Impoundments. ASCE Geotechnical Engineering Division Conference, 1-30.

The State of Victoria Department of Environment, Land, Water & Planning (2015). Levee Management Guidelines.

ANCOLD (2003). Guidelines on Dam Safety Management. Australian National Committee on Large Dams Inc. August 2003.

Appendix A

Retarding Basin Requirements Guide

Note that the below requirements are a guide only and that some parameters may not be applicable to all sites.**Location & Background**	
Location	
Date of Practical Completion / Final Completion	
Melways Map reference	
Council	
Design Intent	
Land Ownership	
Catchment Details (assume fully developed)	
Watercourse Name	
Total Catchment (ha)	
5 Year Flow at Outlet (cumecs)	
100 Year Flow at Outlet (cumecs)	
RORB Model parameters (kc, m etc)	
Physical Details	
Land Ownership	
Storage type ie. wetland/lake/dry	
Other RBs in catchment (incl. those downstream).	
Maximum Embankment Crest Height (m)	
Embankment Crest Level (AHD)	
Top Water Level to Spillway Crest (AHD)	
Capacity to Spillway Crest (ML)	
Capacity at Embankment Crest Level (ML)	
Normal Outlet	
Normal Outlet Type	
Normal Outlet Invert Level (AHD)	
Normal Outlet Size (mm)	
Low Flow or Bypass System Capacity(before RB starts filling)	
Discharge with water at Spillway Crest (assuming no blockage)(m^3/s)	

Discharge with water at Embankment	
Crest Level (without spillway) (m^3/s)	
Primary Spillway	
Spillway Type	
Spillway Crest Level (AHD)	
Spillway Crest Length / diameter (m)	
Spillway Capacity with water at Embankment Crest Level (m^3/s)	
Outlet Pipe Size (mm)	
Additional Spillway/s	
Spillway Type	
Spillway Crest Level (AHD)	
Spillway Crest Length (m)	
Spillway Capacity at Embankment Crest Level (m^3/s)	
Consequence Assessment	
Total Population at Risk	
Incremental Population at Risk	
Incremental Potential Loss of Life (if used)	
Severity of Damage and Loss	
ANCOLD Consequence Category	
ANCOLD ‘fallback’ flood capacity (AEP) (if VL, L or S)	
Probability of Dam Crest Flood (DCF) (AEP)	
Design Requirements	
Embankment Type	
Operational and Maintenance Information	
Security Provision (fencing, appropriate prohibition signage, secure access points etc)	
Agreements / Licenses / Leases	
Monitoring Requirements (e.g an indication of silt, litter and debris build up monitoring, High risk fire prone area monitoring)	
Final Asset Inspection Details (signage, safety, quality	
Asset Information	
As constructed information provided	

APPENDIX B

Embankment Vegetation Guideline

The following table defines acceptable vegetation for embankments subject to the hazard rating classification for the asset.

Embankment Vegetation Guidelines		Established trees (all)	New trees / Bushes	Existing Bushes	Existing bushes (<2m)	Slashed grass (70-250mm)	Ground Cover / Non Slashed grass types
Hazard Rating	**Location**	**Acceptable Vegetation**					
High	Constructed Embankment (top & both faces) including Abutment region					✓	
	Minimum 3m clear of embankment Toe (US & DS)					✓	
	Slope areas in cut (non embankment area)	✓	✓	✓	✓	✓	✓
	Floor of basin (min 3m clear of embankments / spillway structures	✓	✓	✓	✓	✓	✓
	Structures (Min 3m clear of spillway & outlet structures)					✓	✓
Low	Constructed Embankment (top & both faces) including Abutment region	✓*				✓	✓^
	Minimum 3m clear of embankment Toe (US & DS)	✓*				✓	✓^
	Slope areas in cut (non embankment area)	✓*	✓	✓*		✓	✓
	Floor of basin (min 3m clear of embankments / spillway structures	✓*	✓	✓*		✓	✓
	Structures (Min 3m clear of spillway & outlet structures)					✓	✓

* *existing healthy established vegetation to be tolerated and monitored as part of inspection program. No new trees to be permitted on embankments.*

^ *existing ground-cover to remain, no new planting permitted*

- An established tree is either an indigenous, native or exotic species, typically greater than 10 years old that provides habitat of amenity values.
- An established tree is not considered appropriate if the likelihood of failure is great and the impact of failure is also great.
- The high and low hazard rating is based on a case by case assessment and linked to the criticality/consequence assessment