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Advisory



# Development of Methodology and Visual Audit for Urban Levees

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## AGENCY TERMINOLOGY

Where referred to throughout this document:

- Public Works Advisory of the Department of Regional NSW (PWA) was formerly known as NSW Public Works (NSWPW).
- Environment, Energy and Science of the Department of Planning, Industry and Environment (EES) was formerly known as the Office of Environment and Heritage (OEH).
- Resilience NSW was formerly known as Ministry of Police and Emergency Services.

## EXECUTIVE SUMMARY

This document supersedes the original first edition outlined in the PWA document DC130004 of October 2013. This update considers lessons learnt, improved practices and changes in technology since the previous version of the methodology was released.

Maintenance of flood mitigation structures is key to ensuring their effective operational function during flood events. Urban communities protected by levees can be particularly vulnerable where asset management including maintenance is neglected. Maintenance issues become especially important in the more remote inland areas of the State where the climate is typically hot and dry and / or where the levee owners may have limited financial and technical resources.

Levees systems generally involve an earthen and / or concrete structure in combination with other operational assets, including gravity and/or pumped drainage systems, floodgates and temporary panels.

Levees play a vital role in reducing the risk and impacts of flooding on the community for floods up to their design event. Where considered safe to do so, levees can enable towns to function reasonably effectively and act as a base for supplying surrounding rural communities during long duration floods, such as occurred in inland NSW in early 2011.

The failure of a levee has significant implications for the protected communities. For example, the flooding of Nyngan in 1990, whilst not due to maintenance issues but rather a flood larger than the levee design flood, resulted in \$50M in damage (1990 dollars) and evacuation of the whole town for weeks.

The potential for failure can be reduced through effective and regular monitoring, maintenance and reporting on the condition of a levee system. This is essential to realising the benefits of this investment for the design life and to negate the potential liability resulting from failure of an under-performing structure. Effective monitoring, maintenance and reporting of levee condition are important so their condition is understood and where warranted it also enables:

- Specific defects to be monitored and rectified so the levee remains fit for purpose for its design life.
- The reliability of the levee and key issues affecting this reliability to be understood and monitored as condition deteriorates or rectification works are undertaken.
- Rectification works to be completed as early as practicable to limit further deterioration, repair costs and additional risk exposure of the community.
- The levee owner to develop contingency plans to deal with defects where repairs may not be completed before the next flood.
- Relevant government agencies including flood risk managers (Environment, Energy and Science of the Department of Planning, Industry and Environment (EES)) and emergency services (NSW State Emergency Service, NSW SES) to be kept up to date on the levee condition and the owner's contingency plans to deal with defects so that effective emergency planning for response and recovery can consider the likely ramifications of a flood event.

Levee systems require significant upfront investment from communities and government. They are generally designed to provide protection for an extended period with earthen levees expected to have a design life of at least 40 years. The establishment and resourcing of an effective inspection and maintenance regime as part of good asset management practice is important to achieve this design life. Levees should also be incorporated as a key community asset in the levee owner's Integrated Planning and Reporting Framework.

Floods of the magnitude of a levee design flood may occur relatively infrequently and as a result the need to keep such valuable community assets in good condition may not be considered a high



priority by the owner, particular when drought conditions may be experienced and/or financial and/or technical resources may be limited.

In addition, depending on the location of the levee within a catchment, large floods can occur with little advance warning and a levee may be expected to perform its design function with limited opportunities for the owner to attend to defects or develop and implement contingency plans before the flood threat eventuates.

Decisions to ignore or postpone the maintenance demands of a levee and supporting infrastructure can turn out to be very costly strategies for the local and wider community. Physical failure of the levee and hence the flooding of the protected area can put lives at risk, create major operational problems and threaten the viability of the local community and the wider community normally serviced by the flooded town. Clean up and recovery is likely to impose a significant cost burden on the local and wider communities and all levels of government.

Early identification of developing maintenance and structural issues is necessary to minimise the potential for failure and the associated impacts, and to reduce the potential for significant degradation requiring major rehabilitation. It can also limit the scale and cost of rectification works required. Regular and frequent visual inspections and audits undertaken by suitably qualified and experienced engineering (but not necessarily tertiary qualified) staff are seen as the most cost effective way of identifying potential problems.

To help ensure that such inspections and audits are undertaken to a reasonably consistent standard across NSW, visual inspections / auditing regime, monitoring and reporting system, and associated tools have been developed. The Levee Owner's Guideline presents a general overall guidance for the implementation of such regime and systems with supplementary operation and maintenance (O&M) tasks. This provides engineering staff with the basis for future inspections and audits. It enables effective tracking of changes of levee conditions and rectification works, and facilitates communication with other stakeholders such as EES and the SES. In terms of the suggested overall O&M package for NSW levee systems, the following, as presented in the Guideline, are considered the minimum required items / tasks:

1. Levee Crest Level Survey – inclusive of locations and invert levels of floodgates, road crossings, etc. if not already known.
2. Operational Inspections – annual visual inspection of the entire levee system performed by the levee owner.
3. Visual Audits – 5 yearly comprehensive visual audit and inspection of the entire levee system performed by an independent specialist dam / levee engineer. The reporting includes the comparison of the CLS data with the levee's original Design Crest Level (DCL) data.
4. Levee Owner's Manual – O&M manual.

This report presents the current visual audit methodology. The Methodology and the associated tools provide a sound basis for the visual audits, monitoring and reporting on the condition of levee systems. This will aid the management of levees and the knowledge of levee condition prior to flood events to facilitate effective contingency, response and recovery planning. For further information and guidance on other levee O&M aspects, as suggested in the list above, levee owners are encouraged to obtain knowledge provided in the Levee Owner Guideline.

The Methodology will continue to be refined as parts of future audits, experience and lessons learnt and the associated tools will be made available through a relevant website.

## **ACKNOWLEDGEMENTS**

PWA has worked closely with key technical staff at the EES in the scoping and development of this project.

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Valuable information from the USACE website contributed to the preparation of the Methodology.

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## 1. INTRODUCTION

This document (the Methodology) provides general information and guidance for the Visual Audit of levees within New South Wales. It was instigated by the EES to support the development of a methodology to:

- Collate all available information of the levee system to assist with inspections, operation and maintenance (O&M) procedures.
- Support frequent auditing;
- Support monitoring of levee conditions;
- Support timely rectification of significant issues where found; and
- Promote the availability of up to date information on levee condition across government.

This report has been prepared with:

- Section 2 outlining the aims of the Methodology.
- Section 3 giving a background on levees.
- Section 4 discussing the need for a system for monitoring levees.
- Section 5 outlining an audit regime for levees.
- Section 6 breaks levees down into different zones for assessment.
- Section 7 outlines a rating system for the levee.
- Section 8 outlines the audit methodology.
- Section 9 provides guide notes.
- Section 10 outlines common issues encountered.
- Section 11 introducing WHS issues associated typical O&M tasks (newly added in this 2020 Edition)
- Section 12 outlines tracking and reporting systems.

The template for audits is provided in Appendix A. A field data collection tool (e.g. smart device app) could be utilised to undertake the audit with the results extracted for reporting of the inspection. NSW Government uses the [Fulcrum](#) app / database.

Within the audit methodology, a rating system is provided to help identify the risk levels associated with observed issues within the levee. Such risk assessment is used to identify potential consequences and prioritisation of actions. Guide notes are provided to assist with specific issues and use of the template.

## 2. PROJECT AIM

This project aims to update the methodology for monitoring levee condition to support the effective management of levees to fulfil their intended function over their design life. It involves facilitating the early rectification of issues that may compromise levee performance or design life and the protection provided to the community and the availability of information on condition across government. To achieve this, this project provides:

- A consistent methodology for undertaking visual audits, considering the significant variation in levee types and purposes. This can be supported by guidance on the type of problem, its importance and the course for corrective action. Visual audits are the domain of suitably qualified engineering professionals. However, it is possible for suitably qualified and experienced engineering staff to undertake general visual inspections, such as an Operational Inspection (operational inspection) or even more frequent, to highlight where problems may be present so that additional advice could be sought. These general visual inspections may be undertaken more frequently than visual audits enabling the identification, reporting and rectification of potential problems in a timely manner. Detailed audits are generally undertaken with a survey of the levee crest. They do not include geotechnical or any other types of specialist investigation (e.g. ground penetrating radar, EM Surveys). However, visual audit reports for individual levees may recommend further investigations of this nature where warranted.
- A methodology and associated aids for collecting information on levee condition in the field and tracking and reporting on changes to condition over time. This includes references to relevant reports, Work-As-Executed (WAE) drawings, levee owner manual etc and set out in the Levee Owner Guideline. This would feed information into levee condition reports to provide essential information to the levee owner for maintenance and rectification decisions.
- A system of monitoring and reporting that identifies, tracks and reports on individual defects, the seriousness of these defects and their condition, and where relevant their rectification, over time.
- A system for developing and documenting contingency plans (where necessary) to deal with significant defects, if these are not able to be rectified before a flood.
- A system that supports the provision of advice across government on the reliability of a levee and any works necessary to improve reliability. This aims to provide an effective way of ensuring that up to date information on levee conditions, deficiencies and associated contingency planning, are available to those within government whose operations or decision making may be affected by any change in condition. This includes both the council and State Government (in particular, EES and the SES).

The methodology outlined through Sections 5 to 12 requires someone to complete the information, to provide details of what they find and to take measurements and record their observations. It considers the importance of understanding the information available on the levee and previous audits. The methodology has been adapted to digital field apparatus to improve efficiencies in information gathering and reporting and to reduce the potential for information to be lost and previous defects to be overlooked.

The Methodology attempts to cover the general aspects of all levees. However, there will be details that are not covered in particular situations. The Methodology and associated tools will continue to develop to cover additional issues and will be available through an appropriate website. The principles and examples give aim to provide enough information for the auditor to make an informed and reasonable decision in those circumstances. This decision may involve the need to seek more expert advice, which should be the default position where the auditor has significant doubts or concerns.

### 3. BACKGROUND ON LEVEES

Flood mitigation works, such as levees, perform a vital role in reducing the flood risk exposure of many communities in NSW. Levees aim to reduce impacts on the community up to their design flood event.

Urban levees are typically an earthen structure or a combination of earthen and concrete structure. They are a protection system made up of a number of key components. These may include:

- Temporary panels which are placed in the lead up to a flood. These enable the levee system to accommodate key transport links through it to operate efficiently in non-flood times. During flood times the temporary panels cut these routes through the levee to enable it to protect the community.
- Drainage paths through the levee. These are essential to prevent localised flooding behind the levee in the protected area. These are generally culverts or pipe systems which would generally have flood gates to stop the back flow of water from the flooded river through the levee. In some cases, these gravity systems may be supplemented by parallel pumped drainage systems to enable discharge of water from the local catchment in the protected area when the river is in flood and the gravity drainage system is not able to operate effectively.

They may also be supported by flood gauging and information networks and prediction systems that provide flood warnings to emergency services, levee operators, the community and emergency management planning for the community. This along with appropriate exercising and testing, community engagement and awareness, enables effective response actions to be undertaken relative to the flood threat.

Levees themselves are therefore part of a whole system that needs to be maintained between floods and operated during a flood. Without effective operation and maintenance, the levee may not be capable of performing its design function of reducing flood risk within the protected area during a flood.

Levees are generally constructed to reduce the frequency of exposure of vulnerable communities to flooding and the associated impacts. The benefits of a levee can be significant as it can remove or at least significantly reduce the impacts of flooding up to the design event. Lismore levee, for example, whilst only designed to provide protection for a 10% annual exceedance probability (AEP) flood, has since its completion in 2005 reduced the impacts of a number of floods on the protected community. This has saved the community millions of dollars and the significant emotional and physical impacts of flooding on the affected community. However, in 2017 a rarer flood did overtop the levee.

Levees also have significant community benefit as they enable towns to function reasonably effectively during major floods and act as a base for supplying surrounding rural communities during long duration floods, such as occurred in inland NSW in early 2011 and again in early 2012.

Levees involve a major financial investment by the local community in their investigation, design, construction, operation and maintenance. Investment in investigation, design and construction may be subsidised by the State and sometimes the Commonwealth Government. However, the operation and the maintenance of a levee remains the financial responsibility of the owner, often local government.

The decision to build a levee is generally due to a desire to reduce the impacts of flood on an existing community. Levees may bring substantial financial and social benefits to the community but these must be weighed up against any potential environmental and social costs. The benefits flowing from the levee are only realised whilst the levee can perform its design function to reduce flood risk up to the design event.

Levees are generally designed to provide protection for an extended period. Earthen levees would be expected to have a design life of at least 40 years. During this period, they need to have ongoing maintenance to ensure that they are fit for purpose, i.e., they can manage the impacts of the design flood for their full design life.

A key element of levee ownership is the development and implementation of a Levee Owner's Manual which includes advice on the levee and its operation and maintenance. These manuals provide an important ongoing tool to assist with ensuring that levees are effectively understood, maintained and operated. These manuals should include or reference work-as-executed (WAE) drawings for the levee and connect to the most recent advice on the levee condition to ensure that these are available when needed. If used in this manner they can enable tracking of modifications, improvements, and monitoring of problems or deficiencies, to be readily retrievable at short notice in the lead up to a flood event.

The consequences of levees failing in floods less than or equal to their design flood has significant implications for the protected communities. The benefits provided by a levee will be partially or potentially even fully negated, depending upon the individual circumstances and the degree of failure. Sudden failure could also put the community at an increased risk to life than if the levee did not exist.



## 4. DEVELOPING A MONITORING SYSTEM

### 4.1 Why is a System for Monitoring Levee Condition so Important?

Floods of the magnitude of a levee design flood generally occur relatively infrequently. As a result, the need to keep such valuable community assets in good condition is often not considered to be a high priority. This can be a particular issue when drought conditions may be experienced for a prolonged period and/or resources may be limited. The protection provided by earthen levees may deteriorate quickly if they are not effectively maintained, especially where drier climatic conditions prevail, and the resources of levee owners are limited.

It is therefore important to monitor their condition, undertake regular maintenance and investigate and implement rectification works for particular problems, where this is warranted, by their condition. Such works can maximise the life over which the levee can perform its design function. Early intervention can also reduce rectification costs. This maximises the benefit of the asset and the return on investment to the community. It is worth noting that in general where levees have been constructed with funding assistance from the Government (State and / or Commonwealth) a condition of the funding assistance is that the completed works are maintained by the levee owner.

Depending on the location of the levee within a catchment, large flood events can occur with little advance warning. As such a levee may be expected to perform its design function with limited opportunity for the levee owner to attend to defects. An asset management schedule that includes regular maintenance, rectification of defects and upgrade is essential to maintain levees and useful life of the structure. Fixing the levee in the lead up to any flood event is not an emergency response function of the SES.

Inadequate routine maintenance of urban levees and / or a failure to identify and promptly attend to developing defects in the levee structure and/or foundations in a timely manner may lead to the failure of the levee to perform its design function for its design life. A levee is just like a chain, it only takes one weak link for it to fail. It is desirable that the levee be in a “state of readiness” for when a flood threat occurs and does not have to rely on the owner attempting temporary or rapid repair / maintenance work “at the last minute” as has sometimes occurred.

It is recognised that for levees on the broad inland floodplains of NSW, away from the western influence of the Great Dividing Range, there can be weeks, or even months, notice of an impending flood. However, the above principle of preparedness should also be applied in these instances as specific circumstances, such as weather conditions, immediately prior to the arrival of a flood may prevent or at least hinder repairs to a levee leaving the community exposed.

Early identification of developing maintenance and structural issues, particularly those with significant ramifications to levee performance, is advisable to minimise the potential for failure and the associated impacts, and to reduce the potential for significant degradation requiring major rehabilitation at significant cost to the community, well in excess of the cost of ongoing maintenance.

An urban levee that has deteriorated to the point that it is no longer able to fulfil its design function can also have major liability implications for the levee owner, and planning and operational implications for those with a role in emergency response and recovery. It may be that robust emergency management planning developed in consideration of the protection provided by the levee could be compromised by levee failure leading to additional risk to life.

Decisions to ignore or postpone the maintenance demands of a levee can turn out to be very costly strategy for the local and wider community. Physical failure of the levee and subsequent flooding of the protected area can put lives at risk, create major operational problems and threaten the viability of the local community and the wider community normally serviced by the flooded town. Clean up and recovery is likely to impose a significant cost burden on the local and wider communities and all levels of government.

The flooding of Nyngan in 1990 cost the wider community approximately \$50M at the time and the evacuation of the whole town for a period of three weeks. It is acknowledged that the failure of the Nyngan levee was not due to lack of maintenance, but it does illustrate the costs that may be associated with a levee failure.

#### 4.2 What has Hampered Audits of Levees in the Past?

EES have at times had detailed visual audits of levees undertaken to inform levee owners of the condition of their levee systems and identify any essential rectification or rehabilitation works. Councils have, from time to time, also employed consultants to provide independent advice on the condition of their levees.

A key issue identified in previous visual audit reports is the general lack of available background information (design and WAE drawings, manuals etc) and the ready access to the findings of previous inspections / visual audits. This has hampered achieving the objectives of visual audits such as early response to remedial works and operational difficulties for the levee owner and SES in responding to floods.

Improving the availability of information is part of a complementary Levee Owner's Guideline and document and associated Levee Owner's Manual. This links the information on levee condition, maintenance history and persistent problems (from audit) to form an overall knowledge database of the levee system. It also improves accessibility across government by its placement on the NSW Flood Database.

#### 4.3 What should a System for Monitoring Levee Condition Entail?

Monitoring the condition of a levee system should involve a system of auditing and reporting on condition and rectification works and communicating the status of the levee to relevant parties within government. To be effective, this needs to be supported by easy access to information on the levee design, construction and operations and maintenance through the Levee Owner's Manual.

The outcomes of an audit provide up to date information on the levee condition and any associated deficiencies. Addressing these issues may require a change to the current maintenance regime of the levee or rectification works. Where these deficiencies could take some time to rectify, the levee owner should consider developing contingency plans that they can instigate to deal with these deficiencies in the event of a flood prior to rectification. The levee owner also needs to ensure relevant staff and government agencies are aware of the deficiencies and contingency plans so this can be considered in their planning.

## 5. AUDIT REGIME

### 5.1 Visual Audit Regime

Effective monitoring and reporting on the condition of a levee is essential to identify any issues that may need to be rectified or further investigated, to enable the levee to fulfil its design function for its useful life.

To satisfy this requirement, an audit and reporting regime is recommended that involves survey of the levee crest, more frequent visual audits of the levee which result in a report that outlines the levee condition, rectification work required and / or conducted since the previous audits, issues to be monitored, and communication of outcomes to relevant staff and government agencies who need to consider this in their planning or operations.

An audit is more formal than a visual inspection. It involves a systematic assessment of a levee, not only reporting on the observed conditions (e.g. acceptable, unacceptable, etc.) but interpreting it, highlighting potential underlying issues and consequences, and recommending a course of action. This may include the need to seek additional advice or undertake additional investigations. This may also require more rigour than a visual inspection and the right perspective which considers the potential consequences of flood events to the community and how floodwaters and levee system interact.

A visual inspection is typically undertaken to monitor progress or deterioration of issues identified in previous inspections / visual audits. It may also identify new issues with the levee. visual audit reports are intended to focus on issues that require rectification, categorised into severity ratings.

Carrying on as described in the Guideline, the audit regime recommended in detail in the Methodology involves the following components:

- **Levee Crest Level Survey (CLS) key appurtenant features:** This would generally be undertaken every 5 years preceding the visual audit process so it can be used in its preparation and further analyses where required. This could be undertaken by a qualified surveyor or survey technician. The survey should have access to the WAE plans and any subsequent CLSs so that changes can be compared and identified. The CLS plans and long-section should be included with the visual audit reporting.
- **Detailed visual audit of the entire levee system:** This would normally occur every 5-10 years and may also be undertaken after a major flood event where significant damages to the levee system are identified. visual audits are to be undertaken by an external professional engineer with civil or geotechnical engineering qualifications and appropriate design (e.g. hydrologic / hydraulic modelling, earthworks, concrete works, drainage, mechanical, electrical) and construction experience.

A visual audit does not include detailed geotechnical investigation or other types of specialist investigations. However, the audit may identify defects that warrant further intrusive investigations and make recommendations accordingly. Ideally a detailed visual audit would be available to inform visual inspections of the levee.

Operational Inspection of the entire levee system would normally be undertaken on a minimum of an annual basis and may also be undertaken after a flood or other significant event such as riverbank erosion or slumping, where damage to the levee system may occur. While it would be ideal for the inspector to have civil or geotechnical engineering qualifications, it is not essential. The auditor should have knowledge and experience in the techniques used in the construction of the levee and operations of associated works. This may include earthworks, concrete works, pipe laying, floodgates, pump systems and sheet piling. The inspector may also have undertaken specific training in Dam Safety Management with a qualified Dam Safety Consultant / Trainer. Dams Safety NSW can be consulted for further information regarding such training.

If previous operational inspections have been undertaken in the past, these can be used to inform the new Visual Audit which can concentrate on monitoring changes in existing defects, the identification of any new defects that have appeared since the previous audit and associated reporting.

The site inspection undertaken as part of visual audits would be assisted by any previous visual audits, documentation on the levee and the Guide Notes provided as part of this document. However, there are cases, particularly where the defects identified are likely to seriously jeopardise the performance of the levee relative to its design, where additional professional expertise may need to be sought.

## 5.2 Supporting Documentation

Documentation on the levee should exist with the levee owner but may need to be gathered from a range of sources to ensure that the levee and its O&M regime is understood to assist the visual audits. The necessary documentation is as follows:

- Relevant reports – flood studies, floodplain risk management studies and plans, particularly those that relate to the design of the levee or examine its performance. This will provide information on design floods.
- The Levee Owner’s Manual that includes the operation and maintenance tasks and plan, design criteria for the levee including design drawings, specifications and documentation (where available) and WAE drawings and the levee’s key supporting features. These documents may be separate if the Levee Owner’s Manual has not been prepared.
- Information on the infrastructure and community at risk behind the levee system and protected by particular portions of the levee system which may act independently and therefore fail in isolation. This will provide information on size and extent of the community protected.
- Previously completed operational inspection and visual audit reports including any recommendations for rectification works.
- Rectification works or changes to the levee since the last operational inspection / visual audit including WAE documentation where warranted.

This report concentrates on the methodology for visual inspections. However, the condition and reporting templates developed would also be suitable for reporting on detailed visual audits.



## 6. LEVEE ZONES

It is proposed that there be a hierarchy of zones on or adjacent to a levee so that more attention during an inspection / audit can be given to those areas of more importance. The levee zones are shown in Figure 6-1.

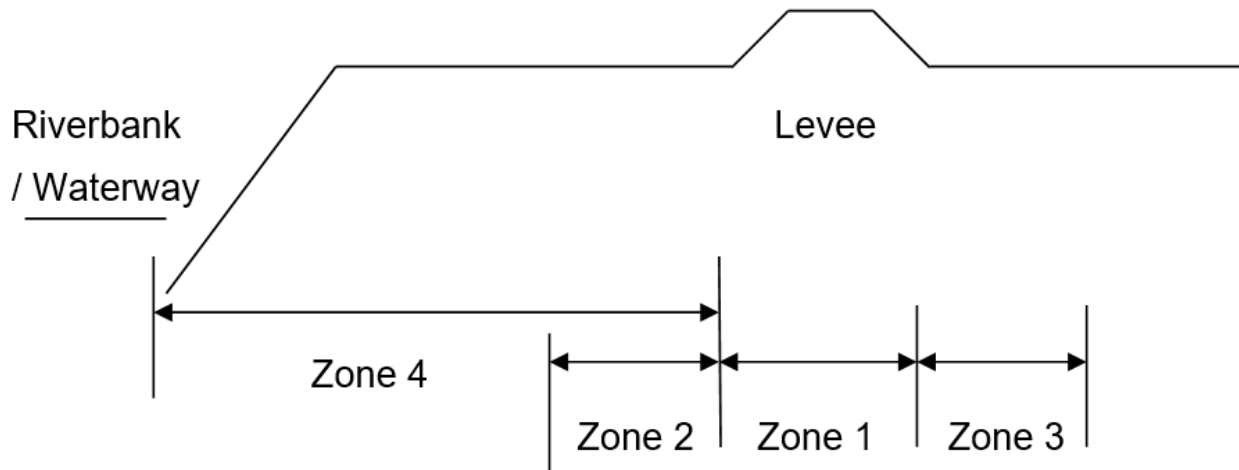


Figure 6-1 Levee Zones

Note:

- Zone 1** Levee footprint (including any footings for concrete levees);
- Zone 2** 4 – 5 m from the levee toe / levee footing toe on the river / flood side of levee;
- Zone 3** 4 – 5 m from the levee toe / levee footing toe on the town side of levee;
- Zone 4** Riverbank / waterway frontage (within 50 m of the toe of the levee).

Typical risks within the zones include:

<b>Zone 1</b>	Risks are critical as they could affect the structural integrity of the levee.
<b>Zone 2</b>	Water can weaken structures adjacent to the levee which can adversely affect its structural integrity.
<b>Zone 3</b>	Works on inside of levee e.g. house developments, can also adversely affect the structural integrity of the levee. Water can weaken structures adjacent to the levee which can adversely affect its structural integrity.
<b>Zone 4</b>	Water and waves from boats can undercut the riverbank leading to slumping. Where the levee is close to the riverbank, this can result in significant risk of failure. These issues are often more long term (e.g. riverbank erosion) and rectification can be difficult.

## 7. RATING SYSTEM

The template provided in this report relies upon visual audits and proposes a simple four (4) tier rating system to describe the type of risks identified with each issue that may arise on a levee system.

The recommended ratings are:

✓	<b>Acceptable</b>	<b>If an item is rated as acceptable, no specific action outside regular maintenance regime is required.</b>
±	<b>Marginal</b>	<p>If an item is rated as marginal, an action is required to remediate the issue. These issues do not affect the structural integrity or functionality of the levee.</p> <p>This defect should be monitored and, where recommended, rectification works undertaken.</p>
✘	<b>Unacceptable</b>	<p>If an item is rated as unacceptable, an action is required to remediate the issue. These issues do affect the structural integrity and/or the functionality of the levee but do not pose an imminent threat in the event of a flood.</p> <p>This defect should be monitored and where recommended rectification should be planned, contingency plans developed and EES and the NSW SES informed where warranted.</p>
☠	<b>Imminent Threat</b>	<p>If an item is rated as an imminent threat, an action is required to remediate the issue. These issues mean that they do not meet the levee design criteria and pose an imminent threat to the structural integrity and/or functional intent of the levee in the event of a flood.</p> <p>This defect should be rectified as per recommendations as a priority. Contingency plans should be developed to deal with the additional flood risk until rectification works are completed. Other parties, such as the EES and NSW SES, need to be informed so this can be considered in emergency response planning.</p>

## 8. AUDIT METHODOLOGY

Undertaking an audit involves both field work and reporting. This section provides advice on the equipment needed and methodology recommended in preparing audits.

### 8.1 Background Data

The availability of levee background data would not only greatly enhance the efficiency of carrying out a Visual Inspection, but also contributes to the preparation of the Levee Owner's Manual. Below are some useful information that will assist with the Visual Audit process:

- Crest Level Survey – centreline alignment and levee elevation.
- Locations (chainage) and invert levels of culverts, floodgates, pump stations, etc.
- Locations (chainage) and invert levels of road crossings, along with the availability of associated flood barriers, removable panels, sandbags, etc.
- Existence / location of other underground / overhead services in close proximity to the levee centreline alignment.
- Preparation of convenient plans / maps, encompassing the information mentioned above, to a reasonable quality to assist with the logging of issue locations during the Visual Audit.

Further information on levee on the levee survey capture is provided in the Levee Owner Guideline. Additional technical information for seeking services to carry out a Crest Level Survey can be obtained from the Crest Level Survey Brief document.

### 8.2 Field Equipment

An asset data collection tool, such as tablet or smartphone, is the standard technique used for collecting audit information. NSW government's preferred tool is the customized levee audit app used through Fulcrum software. The data collection tool should overlay background information such as crest level survey and aerial imagery with the visual audit template. Photos of interest should be collated by the device and recorded spatially as well as in accordance with crest survey chainages.

Additional tools such as a tape measure, probe and inclinometer may be useful to assist field officers in measure key levee features. Auditors should have read this document as well as the Levee Owner Guideline to have a reasonable understanding of the methodology and its purpose.

### 8.3 Field Inspection Methodology

The most effective means of conducting the field visual inspection is to treat each levee segment as an individual element, inspect it thoroughly, and record all observed issues prior to moving on to the next segment. These observations should be checked against information provided in this document or the asset collection tool such as Fulcrum or equivalent to identify the type of issue and to understand its seriousness. The sequence for inspection of each levee segment is as follows:

5. **The crest:** Walk along the top of the levee from one end to the other and look for general longitudinal alignment, erosion, depressions (puddles), settlements, rutting or cracks in the paved or unpaved surface or animal burrows, vegetation cover etc.

6. **The flood side of the embankment:** Walk along the flood side of the levee embankment in a zigzag, top to bottom fashion observe batter slope, vegetation cover, erosion, depressions, ruts, puddles or wet areas, slumps, woody vegetation or animal burrows. Note the proximity and condition of the river/creek bank including slope, erosion and vegetation cover.
7. **The town side embankment:** Walk along the town side face of the levee bank in a zigzag, top to bottom fashion to observe batter slope, vegetation cover, erosion, depressions, ruts, puddles or wet areas, slumps, woody vegetation or animal burrows. Note the nature of the area adjacent to the town side of the levee including features such as excavations, buildings, fences etc which may impact on levee performance.
8. **Stormwater pipes / culverts outlets, floodgates and pump stations:** Observe the condition of the upstream and downstream supporting structures (e.g. concrete headwalls) of culverts. Check for erosion, cracking or slumping around / through the structures. Check the condition of the culverts (pipes, box culverts) and floodgates / flaps (non-return valves). Note any blockage or cracks and the condition of locks and hinges including ease of opening. During the visual audit, demonstration of the operability of mechanical / electrical devices such as floodgates and pumps may not be possible due to time constraints or the required presence of specialists and equipment. However where possible with the assistance of the levee owner's operator, check the superficial condition of the outside and inside of floodgates, their ease of turning, identify rust, cracks, spalling, deterioration, etc. Check the condition of any pump stations for signs of rust and wear, exposed wiring, etc. Where possible, test run the pump and any backup and where this is a fuel pump, note when the fuel was last replaced as this may go stale.  
  
As a minimum, where demonstrations are not possible, a verbal check with the operator is required with the need for specialist attention indicated in the VB reporting.
9. **Test automatic release of automated floodgates where possible:** Check the condition of bolts, collar, hinges gate seal, floating barriers, if any, and function of all floodgates / flaps. Check for vandalism, debris and security (locking mechanism) that may affect operation.
10. **Services:** There may be other household, Council or utility services located within or through the levee and these may lead to failure of the levee. Background information (plans, records, photographs etc.) should be sought prior to a visual inspection to assist in locating these hidden or less obvious services (or at least for recording their presence).
11. **Road crossings:** Where appurtenant equipment is used to close of road crossings, check the integrity of the permanent levee terminals on both sides of road crossings, ensuring that both are robust in supporting temporary dam structures. If flood barriers are used, check if the site is readily available to allow appropriate and efficient assembly. Enquire the levee owner's operator on availability, storage and quality of required assistive equipment.
12. **Temporary Measures:** The need for temporary components to be deployed (e.g. emergency treatment of levee defects) should be noted along with any onsite issues that may affect deployment and installations. As part of the visual audit, knowledge on the fitness for purpose, adequacy of storage, security and accessibility to where these levee components need to be deployed should be enquired and reported.



Experience has shown that an efficient way to undertake the above inspection is to walk along the top as well as one batter in a “zigzag” pattern. At the end of the segment, return to the starting point by walking along the top and the other batter in a similar zigzag pattern.

It is also necessary to include in the field inspection adjacent zones beyond the levee Zone 1 to identify and record other away-from-levee issues (e.g. riverbank stability) that may affect the levee.

## 8.4 Visual Audit Report Presentation Guide

Guidance on how to complete the general audit report is as follows.

### 8.4.1 Levee Reporting Segments

- Divide levee into segments of similar levee types (i.e. don't mix earth levees with concrete levees) and note levee chainages where possible from plans.
- Divide the above segments into similar levee conditions with likely similar risk issues (e.g. one earth levee section with minimal adjacent trees and not near river bank compared to another earth levee section with adjacent trees and immediately adjacent to the river bank). These can be grouped into like sections in the report.
- Levee sections through residential properties should be separate from levee sections through other land use areas.
- Ideally maximum section length to be approximately 500 m, unless the levee is exactly the same for longer lengths e.g. through open paddocks.

### 8.4.2 Reporting

Report on the observed specific levee issue in detail within that segment and comment on its overall condition and appearance. Subsequently report on each risk or issue separately within that segment. The report should outline any preliminarily determined actions required to rectify or monitor any defects.

## 8.5 Assessment Limitation

Any visual audit is limited in its potential to assess issues as outlined below:

- Background information available (often scarce and anecdotal) particularly for some of the older levees. However, the levee owner can assist by making the effort to find any relevant information available. Where available, they should be appended to the Levee Owner's Manual such that it can be readily available for future reference.
- What can be seen above ground – Typically, only specific testing, background data and or history can identify potential issues below the surface of the structure.
- The audit cannot economically look under every blade of grass and find every potential risk / issue. It should however, be able to determine potential problematic issues.

## 9. GUIDE NTOES

The advice provided in Appendix A, forms part of the General Visual Audit Methodology. It is based on experience as to the best way to conduct a levee audit and describes common potential risks to levees that have been identified from past audits. They provide guidance on issues being

regarded as acceptable, marginal, unacceptable or an imminent threat as well as some guidance on other aspects, such as what further monitoring may be required and the reliability of the levee during a flood event.

This advice is in the form of a table which is separated into various categories of issues or risks. Where possible, photos are provided to illustrate the different issues. Information can be added to the Guide Notes over time as more knowledge is gained from further audits.

Note: These Guide Notes do not cover all possible levee situations and advice from relevant specialists may need to be sought where other situations or conditions are observed.

Guide notes to support the table in Appendix A are provided below.

## 9.1 Visual Audit Guide Notes

<b>Table</b>	Column 1
<b>Topic</b>	Description of Potential Risk and Assessment of Severity of Risk Issues
<b>Notes</b>	<p>A brief description of the various types of defects and potential threats to the structural adequacy of levees that may be discovered by visual audit. Where possible these issues are illustrated with photographs, sketches and/or drawings as an example of the type of problem to look for.</p> <p>Guidance is provided on how to assess the severity of the problem in the field and with the resources that could be reasonably expected to be available to a small Council with limited resources.</p> <p>It is envisaged that reporting and guidance will be adapted for use with electronic asset data collection tool as described in Subsection 8.2.</p>
<b>Table</b>	Column 2
<b>Topic</b>	Potential Consequences
<b>Notes</b>	The potential consequences of not dealing with the different types of identified problems, both in the short term as well as ultimate likely consequences in the long term if not addressed. The likelihood of failure and the seriousness of the problem should also be considered.
<b>Table</b>	Column 3
<b>Topic</b>	Details of any further investigations required
<b>Notes</b>	Guidance on when specific, more detailed investigations may be required.
<b>Table</b>	Column 4
<b>Topic</b>	Possible Rectification Work and Prioritisation
<b>Notes</b>	Guidance on possible rectification work and the prioritisation of such work.
<b>Table</b>	Column 5
<b>Topic</b>	Monitoring Program (if marginal risk only)

**Notes** Guidance on monitoring programs for less serious problems that have the potential to develop into more serious issues over time.

**Table** Column 6

**Topic** Assessment of Reliability of Levee System with current Risk

**Notes** This involves providing guidance on assessing the relative reliability of the levee to perform its design function until rectification work, if necessary, is undertaken. This may relate to limitations in the flood protection capability (magnitude/height of flood) or issues that may need to be managed (perhaps through contingency plans) during a flood event prior to further investigations and/or rectification works being completed.

If affecting the crest level, the level of protection is lowered by the same magnitude as the effect on the crest. If the risk or issue is rated unacceptable, rectification is necessary as a matter of priority and, as a minimum, prior to any imminent flood threat. Following an audit, the levee owner should:

- Inform the relevant government agencies, including EES and SES of any defects which impacts upon levee reliability so that additional emergency response planning can be undertaken as necessary.
- Prepare a contingency plan to protect the community until rectification works are completed. This should be ready to instigate using the levee owner's resources. The plan should include any necessary advice to the community.
- Review the contingency plan as required.
- Monitor the deficiency and contingency plan during any flood event and alert the relevant government agencies (including EES and SES) to any associated concerns.
- Prepare a priority list of work. This can be determined based upon the predicted flood height and which deficiencies are found to be the most urgent to rectify or result in the riskiest outcomes at that time based on local site conditions. For example, deficiencies facing the full river flow may be more urgent than ones in backwater areas, larger scour areas more urgent than smaller scour areas. This priority list should consider the likelihood of inundation of the area at risk, the likely velocity of water flow and magnitude of problem.

#### Priorities When a Flood Threat is Imminent

If rectification works are not complete and a flood event is imminent, then priority order given to addressing flood defects should be based on the risk rating system such that:

- Contingency plans are instigated to deal with imminent threats and unacceptable conditions.
- Deficiencies with marginal conditions are re-inspected and reassessed in relation to predicted flood height and current circumstances and where necessary contingency plans are instigated.
- Advice on the potential threats is then provided to the relevant government agencies, including EES and SES, so the risks can be considered in emergency response operations.

- Additional resources, often termed levee wardens, may be deployed by the levee owner during a flood to conduct field reconnaissance / monitor levee defects as frequently as felt necessary at the time during a flood.

## 10. COMMON ISSUES ENCOUNTERED

There are a range of common issues encountered when undertaking visual audits of levees that protect NSW communities. The following general advice is provided in dealing with these common issues in different zones of the levees and in levees protecting urban areas as well as rural areas.

### 10.1 Levees in Urban Areas

This type of levee often pass through privately owned urban land. They are generally small sections of levee which are maintained by the land owner rather than the levee owner. Some key issues relating to urban levees are:

- Poisoning of vegetation on batters – While the maintenance (mowing etc.) could then be reduced, this makes the batter highly susceptible to erosion and is unacceptable as a result of limited control over regrowth, etc.
- Grass should be maintained especially on the riverside and top of the levee embankment to reduce the potential for surface erosion and kept short to facilitate site inspections. Gardens and other foreign structures (e.g. sheds, up-and-over ramps that are no engineered, etc.) should not be established on or adjacent to the toe of the levee embankment and no digging or excavation should be undertaken as these can lead to structure instabilities.
- It is recommended that vegetation on the town batter be also kept short to enable site inspections. Note, grass and small plants with minor root structures are acceptable. Mulch can assist at reducing water loss and has been proven to slow the effects of runoff causing erosion, although care needs to be taken during inspections to ensure that defects are not concealed.
- Evident areas with minor erosion not top-dressed.

### 10.2 Levees in Rural Settings

These are generally long runs of levees located in open paddocks and / or public spaces that are maintained by the levee owner.

It is often impossible to water large sections of levee, especially in drought conditions. Rainfall after an extended dry period can cause erosion of the batters. Mulching, even with mown grass, is a proven solution to reducing this erosion and is a recommended inclusion in the owner's cyclical maintenance program. Note, while mulching provides excellent erosion prevention, be aware that mulching near existing stormwater structures may cause blockages and may conceal structural issues.

When reinstating eroded topsoil, it is recommended that sufficient depth of soil be added to the batter for groundcover root systems to establish themselves.

As a rule, DON'T GRADE A BATTER. Any existing vegetation (especially in arid zones) is invaluable and should be preserved at all costs. If intermittent scouring has taken place it is better to top dress the batter. The existing vegetation will grow through the new topsoil. If it is determined grading is required, this should be as a result on reconstructive works, not rehabilitation.

Stock should be fenced off the levee. Where stock crossings are required, the location of stock crossing should be limited and the surface appropriately protected and maintained as necessary.



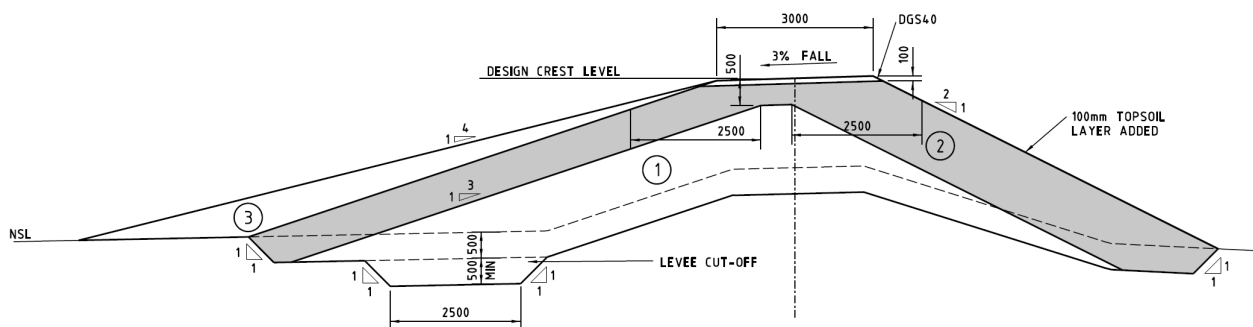
### 10.3 Erosion of Topsoil

It is common for topsoil on batters to be eroded by rainfall runoff and animal, pedestrian and vehicle movements where these are not prohibited or controlled. It is important that landowners who maintain their section of levee and the levee owner are informed of how to remediate or maintain their sections of levee to minimise this erosion.

### 10.4 The Keyway

The levee keyway (which also functions as a subsurface seepage cut-off) is a feature of earthfill levees. It is installed to:

- “Key” in the artificial levee embankment into the natural ground to minimise lateral movements.
- Block uncontrolled seepage through pervious foundation strata between the impervious part of the embankment and the impervious soil foundation. It usually consists of an excavated trench, backfilled with compacted clay as part of the embankment core. An example of a keyway is shown in Figure 10-1.



**Figure 10-1 Typical Keyway (cut-off) under a Levee Embankment**

The design of a levee needs to be checked for the presence of a keyway.

If one exists, it is typically located centrally under the earthen embankment. The keyway can also be located towards the toe of the levee (on either side of the levee). This typically occurs when existing embankments have been upgraded to heighten the design flood level.

Knowing the location of the keyway will have a bearing on decisions made in Zones 2 and 3 (shown in Figure 6-1). For example, if the keyway is located on the flood side of the levee, it becomes essential that existing small to medium trees be removed from within 5 m of the toe (in Zone 2) reducing the possibility of tree roots penetrating this keyway leading to a seepage path under the levee structure. Significant trees should also be removed wherever possible within this 5m zone, and the affected area remediated.

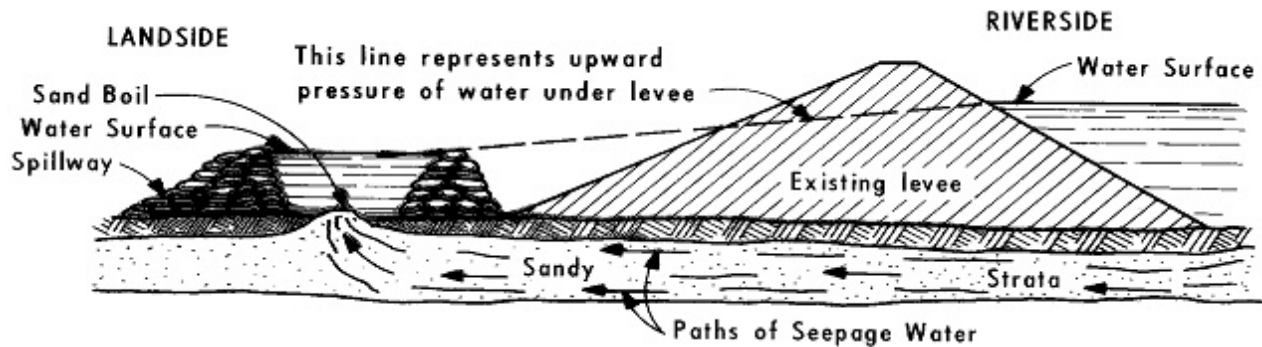
It is also important to note that not all levees have keyways. Many older style levees do not have keyways and may not have a clay core. This increases the importance that Zones 2 and 3 are clear of trees as there is no barrier under the levee to cut off seepage paths being formed.

As a general rule, the structural integrity of the keyway should be maintained. This should be protected by taking all precautions to avoid tree root intrusion, animal burrows, erosion and all other excavations including construction of services through or under the levee (e.g. stormwater / irrigation pipes, water mains, sewer mains, phone lines, power lines / cables etc).

Visual audits should look for and report signs of surface disturbances as works might have been undertaken without the levee owner's knowledge and rectification or protection works may be necessary to ensure the levee integrity is maintained.

If the keyway is to be disturbed specialist technical advice should be sought.

An example of what could happen if no keyway is in place, i.e. foundation piping, development of town side soil boils as a result of efficient foundation seepage paths, is shown in Figure 10-2.



**Figure 10-2 Uncontrolled Seepage under a Levee Embankment**

## 10.5 Trees

When undertaking visual audits, all trees and other thick tall vegetations in Zones 1, 2 and 3 (shown in Figure 6-1) should be identified and recommended for removal, unless they are of environment, cultural, etc. significance required to be retained. Note protected species may require permission for removal / special treatment. Trees should be prioritised for removal and removed as part of a maintenance program.

There are a number of issues that need to be considered in deciding whether to retain a tree. These issues are discussed in terms of the relevant levee zone.

### 10.5.1 Zone 1 – The Main Embankment

This zone is the most critical area of an earthen levee. A tree being uprooted during a flood event could lead to structural failure of the levee system. It is therefore critical that where a tree can be removed from this zone, it is removed.

All small and medium sized trees are to be removed in the first maintenance program actioned by the levee owner. Not only is it more economical time to remove them the smaller they are, but the larger they grow, the more threat to the levee structure they pose.

All significant trees in the levee crest are to be removed. They not only restrict access for maintenance and emergency services, but if they collapse, they can significantly lower the flood protection level of the levee system. It is also difficult to repair the damage of a fallen tree during a flood event.

In levee batters significant trees located towards the shoulder of the levee or in proximity of the keyway must be removed and the batter remediated. Similar to the levee crest, these are the other two critical areas that require protection to maintain the structural integrity of the levee. When assessing other significant trees in the batter consideration needs to be given to whether wind, flow velocity, current, tide, wave action or flood debris has the potential to cause tree failure / collapse.

However, significant trees may need to be retained for reasons including the following:

- Cultural Heritage issues – Preservation of trees may be required, in light of Aboriginal and /or European heritage issues.
- Economic issues – Significant trees are costly to remove as well as the added cost to remediate the earthen levee. Levee owners may not have sufficient funding to remove all significant trees in Zone 1 in the first year of their cyclical maintenance program. If significant trees are in good condition with a solid root structure they may be left in place and put on an annual monitoring program. Where there are signs of root erosion, root surfacing and / or deterioration of the health of the tree, it must then be removed. Significant trees in the flood side batter should be programmed for removal before trees in the town side of the batter as they pose more risk of failure during flood events.

Where significant trees are retained, the levee owner must develop a general contingency plan of what to do if one of these significant trees fall during a flood event. They should also have the necessary resources to instigate this plan when required. Such procedures are to be recorded in the Levee Owner's Manual.

### 10.5.2 Zone 2 – Flood Side of the Levee, near the Main Embankment

This zone is the area within 4 – 5 metres of the toe of the levee on the flood side. Significant trees located in this area are still a threat on the structural integrity of the levee structure due to root systems having reasonable potential of penetrating the main embankment. The turbulence caused by flow around a tree can add to surface erosion. Should a tree fall in this zone it has the potential to remove a section of the levee embankment and possibly damage the keyway. This can lead to further erosion and / or result in seepage paths under the embankment. In time, this can lead to more serious levee failure including slumping of the flood side batter, piping failure and undermining of the embankment.

As per Zone 1, all small and medium sized trees are to be removed in the first maintenance program actioned by the levee owner.

The reasons to retain a tree are as per Zone 1 and contingency plans should also be developed as outlined above.

### 10.5.3 Zone 3 – Town Side of the Levee

This zone is the area within 4 – 5 metres of the toe of the levee on the town side. Significant trees in this zone are to be treated as per Zone 2 trees.

As per Zone 1, all small and medium sized trees are to be removed in the first maintenance program actioned by the levee owner.

The reasons to retain a tree are as per Zone 1.

### 10.5.4 Zone 4 – Riverbank Area and areas further from the Embankment

Trees in Zone 4 are generally not an issue unless the levee embankment is close to the riverbank, i.e. when Zone 2 doesn't exist and the toe of the levee is near or meets the waterway. In this case this, zone reverts to Zone 2 and any tree located within 5 m of the toe of the levee will need to be treated. The levee owner should be advised of the added issue of remediation on the water's edge and the potential for extra protection (e.g. riprap) that may be required to eliminate scouring leading to undermining of the levee.

### 10.5.5 Overall

Where significant trees are to remain and be removed over time as part of a tree removal program, the order of priority for removal should be Zone 1, followed by Zones 2 then 3. The exception to this is that if the keyway is located on the inside toe of the levee Zone 3 will need to precede Zone 2.

## 11. Work, Health and Safety

### 11.1 Introduction

Work, health and safety (WHS) issues should be a major consideration for levee owners, particularly for the levee's operation and maintenance procedures. The visual audit is not a mechanism to identify all the potential WHS issues relating to levees, rather, the visual audit process is intended to detect observed or unrectified WHS issues that may pose a hazard during O&M and / or the public during exposure to the levee. For routine day-to-day O&M activities, the levee owner must establish, implement and manage the use of safety measures in accordance with the relevant and current WHS Regulations and Guidelines (e.g. SafeWork NSW).

Some key WHS issues associated with levees and their appurtenant structures have been identified in this section and should be considered as a minimum during the visual audit. These WHS issues relate to:

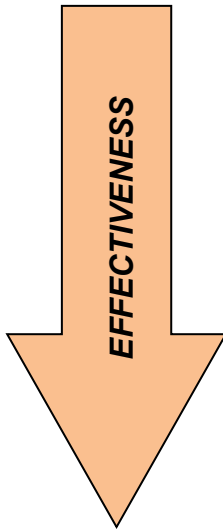
- **Access, operation and security of floodgates** – Floodgate locations should be conveniently accessible and must not cause injuries to the operation staff during access and operation. While floodgates could be accessible by the public, adequate security measures must be in place to minimise vandalism, not pose a significant risk to people and must only be operable by the Levee Owner.
- **Trip and Fall hazards** – The difference of surface elevations should either be eliminated or protected to prevent injuries as a result of falling from heights.
- **Confined spaces** – Appropriate and adequate training, equipment and monitoring must be available for the Levee Owner to access any confined spaces.
- **Protruding edges** – All protruding sharp edges shall be eliminated or covered to prevent injuries as a result of unintentional forceful contact.

It is important to note that the above list (and the contents within this subsection) does not present an exhaustive list of potential levee O&M hazards as levee features and associated risks differ for individual levees and WHS standards may evolve over time. It is therefore the responsibility of the levee owner to be familiar with, and be aware of updates, relevant WHS guidelines, Australian Standards, manufacturer specifications, etc. The levee owner should then eliminate / mitigate WHS risks in accordance with the relevant guidelines / regulations.

Any person/s carrying out works or procedures on a levee or its appurtenant structures must have appropriate local risk control measures, such as safe working procedures, that are implemented in accordance with contemporary engineering design philosophies and WHS management guidelines. These procedures should be compatible with the type of levee and its appurtenances and their operational requirements including appropriately trained personnel. Appendix A of the Methodology includes a suggested audit regime with typical features and recommendations relating to condition ratings based on each of the WHS issues.

### 11.2 Hierarchy of Control Levels

To eliminate / mitigate the risks of identified hazards, there are many different types of risk control measures that can be implemented. Management options are categorised under the Hierarchy of Control Levels (source: NSW Government – Code of Practice – How to Manage Work Health and Safety Risks), which is rated in accordance with “effectiveness”. The highest level of control as reasonably practical should be implemented to either eliminate or minimise risk(s) to a level that is “reasonably tolerable” for the levee owner.



1. **Elimination** – Remove the source of danger so that it no longer exists to cause harm / damage.
2. **Avoidance** – Relocate the work so that the source of danger no longer exists to cause harm / damage.
3. **Substitution** – Adoption of operation alternatives to carry out the work so that the probability and severity of harm / damage can be eliminated / minimised.
4. **Isolation** – Isolate the potential recipient from the source of danger by temporary relocation so that the probability and severity of harm / damage can be minimised.
5. **Engineering** – Protect the potential recipient from the source of danger with engineering solutions so that the probability and severity of harm / damage can be minimised.
6. **Administration** – Notify the potential recipient of the source of danger on-site so that the probability and severity of harm / damage can be minimised.
7. **Personal Protection Equipment (PPE)** – Potential recipient to administer on-body protection so that the probability and severity of harm / damage can be minimised.

If a control measure categorised as level 1 or 2 were to be successfully implemented, then the hazard / risk(s) are eliminated. If a control measure lower than level 2 were to be successfully implemented, then the hazard remains with the risk(s) mitigated, i.e. “residual risk(s)” would remain (e.g. some risks eliminated, severity of impact (damages, injuries, etc.) reduced).

When hazards and associated risks are identified through visual audits and operational inspections, the levee owner should proceed to identified and implement control measures to eliminate the hazards or to control the risks. It is important to determine the level of effectiveness of the implemented controls in accordance with the Hierarchy in order for the levee owner to subsequently devise the most appropriate safe work procedures for their operational staff, e.g. Safe Work Method Statements (SWMS) and availability and accessibility of relevant safety equipment.

Refer to Appendix A – Section 12 for further information and specific guidance on levee related WHS issues.



## 12. TRACKING AND REPORTING ON CHANGES

The Visual Audit reporting provides the basis for both reporting on current condition and tracking condition overtime. This can highlight where problems have deteriorated and where rectification may be necessary or most economical to reduce the need for greater rehabilitation.

Where works are required these should be added to the levee maintenance or asset management plan and resources and implemented in a timely manner in accordance to their relative priority.

Where monitoring of condition or contingency plans are required during extraordinary events, these aspects should be added to the operations plan and indicated in the Levee Owner's Manual. This plan should identify the resources necessary to undertaken these works and allocate responsibility for ensuring that they are undertaken in a timely manner in the lead up to or during flood events.

Where there are issues that may affect the reliability of the levee, it is important that this information is provided to those who need to know, beyond the levee owner, to the relevant government agencies, EES and SES, so this can be considered in emergency response planning and community awareness.

## Appendix A Visual Audit Guide Notes

The Guide Notes have been provided in the order of “Levee Type” first and “Levee Issue” second rather than “Levee Issue” first. It has just been found from experience that the focus is drawn to the type of levee first, then whereabouts on the levee the issue second, prior to what the issue is. However, there are Levee Issues that are common to all Levee Types, and hence they need to be shown separately.

While there is no “consistent” order throughout these Guide Notes, it has been found the most practical way to reference information when auditing.

As such, the following Contents are provided as an aid to locating the particular Levee Type / Levee Issue of interest.



### Contents

1. General
  1. Levee Owner’s Manual, O&M instructions and program
  2. Flood Preparedness and Training
  3. Visual audit and operational inspection Information Availability
2. Earth Levee – Crest
  1. Levee crest level below design crest level (i.e. surface erosion of crest due to local rain)
  2. Surface cracking – Longitudinal
  3. Surface cracking – Transverse
  4. Surface ruts / depressions / holes (i.e. low spots in crest due to settlement and vehicle / stock traffics)
3. Earth Levee – Batters
  1. Surface erosion of batters due to local rain
  2. Erosion of batters due to water flows
  3. Slumping of batters
  4. Over steep batters
  5. Structures on batters (Encroachments)
  6. River Bank Erosion (Zone 4 meets Zone 1)
  7. Seepage under or through the Levee
4. Concrete Levee
  1. Wall Movement / Settlement
  2. Surface Appearance
  3. Waterstops
  4. Undermined / Exposed Footings
5. Sheet Pile Levee
  1. Wall Movement / Settlement
  2. Surface Appearance

6. Vegetation
  1. Lack of Protective Vegetation
  2. Trees / shrubs growing on levee
  3. Trees / shrubs growing adjacent to levee (i.e. within Zones 2, 3 and 4)
7. Animal Burrows
  1. Rabbit / Fox / Echidna holes etc.
  2. Ant Nests
8. Stormwater Pipes
  1. Closure Mechanisms
  2. Impedance to Flow Capacity
  3. Vegetation
  4. Structural Integrity
  5. Erosion of the levee at inlets and outlets
9. Retaining Walls
  1. Retaining Wall (as levee and supporting structures to levees)
  2. Foundations
10. Ancillary Equipment
  1. Closure structures
  2. Flood Pumps / Pumping Stations
11. Spillways
  1. Condition
12. WHS
  1. Floodgate Access
  2. Floodgate Platform Walkway
  3. Trip Hazards
  4. Fall Hazards
  5. Confined Spaces
  6. Protruding Edges





Description of Potential Risk and Assessment of Severity of Risk Issue	Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks
	Short Term	Long Term				
<b>1.0 General</b>						
<b>1.1 Levee Owner's Manual, Operating Instructions and Maintenance Program</b>						
<p><b>Acceptable</b></p> <p>Owner has an Levee Owner's Manual with detailed O&amp;M instructions and program. These have been sighted and there is documented evidence that maintenance has been regularly undertaken.</p> <p>Abovementioned emergency documentation are stored in central register. Document control procedures are in place.</p> <p>Key personnel are familiar with document location and content. Emergency Services and relevant State Govt. Agencies notified of location and availability of documentation. Electronic copies of documentation made available where possible.</p> <p>Document control procedures are in place.</p>	-	-	-	-	-	-
<p><b>Marginal</b></p> <p>Levee Owner's Manual with O&amp;M instructions and program exist but out of date.</p> <p>Key personnel are familiar with document location but not the content. Copies are unavailable to the SES and other relevant State Agencies.</p> <p>Document control procedures not in place.</p>	Maintenance program unreliable and therefore levee integrity could be compromised.	Levee operations could be flawed during major flood events, possibly compromising protection ability.	visual audit of levee required. Findings of visual audit to be addressed.	Update Levee Owner's Manual asap. Key personnel to familiarise themselves with documentation. Implement document control procedures.	visual audit of levee required.	Levee considered at moderate risk of failure during a significant flood event as maintenance has been lacking. Defects may be going undetected and may be deteriorating.
<p><b>Unacceptable</b></p> <p>Owner does not have an Levee Owner's Manual with no O&amp;M procedures being implemented.</p> <p>Document available but key staff unaware of existence or intent.</p> <p>Relevant State Govt. Agencies not notified of location and availability of documentation.</p>	Owner does not know how to operate or maintain the levee system.	Levee operations during major flood compromised	Seek any copies of Levee Owner's Manual from relevant State Government Agencies. Relevant agencies notified of levee issues so the need to revise emergency response planning can be considered. visual audit of levee required. Findings of visual audit to be addressed.	Prepare Levee Owner's Manual asap. Ensure key staff and relevant agencies are aware of any current relevant O&M procedures. Implement document control procedures.	-	Levee considered at high risk of failure during a significant flood event through unaddressed defects and / or lack of knowledge of O&M procedures.
<b>1.2 Flood Preparedness and Training</b>						
<p><b>Acceptable</b></p> <p>Owner has been undertaking periodic visual audits, operational inspections and prescribed O&amp;M procedures in accordance with the Levee Owner's Manual.</p> <p>Contingency / emergency plans are in place for known and unknown levee defects as per the Levee Owner's Manual.</p> <p>Relevant staff has knowledge of how to operate levee in time of flood.</p>	-	-	-	-	-	-
<p><b>Unacceptable</b></p> <p>Periodic visual audits, operational inspections not undertaken by levee owner.</p> <p>No contingency / emergency procedures are in place for known and unknown levee defects.</p> <p>Staff lacks knowledge of how to operate levee.</p>	Defects may go unnoticed. Integrity of Levee may be compromised.	Unrectified defects will increase in severity. Integrity of Levee may be compromised.	visual audit required as a matter of urgency. Imminent threats to be dealt with asap. Contingency / emergency plans put in place prior to rectification. Relevant State Agencies including Emergency Services informed Staff trained in levee O&M.	Depending on length of pre-warning to flood event will determine time frame for visual audit to be carried out.	-	High risk of failure during a flood event through unaddressed defects and / or lack of knowledge of operating Instructions.
<b>1.3 Visual audit / Operational inspection Information Availability</b>						

for NSW Flood Levee Systems

Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks
		Short Term	Long Term				
✓	<p><b>Acceptable</b></p> <p>All existing information has been sourced to assist future visual audits and operational inspections (i.e. Levee Owner's Manual, WAE drawings, previous visual audit / operational inspection reports, CLS, maps, guide notes etc.) and is kept in a QA'ed centralised register.</p>	-	-	-	-	-	-
✗	<p><b>Unacceptable</b></p> <p>No effort has been made to source existing information to assist future visual audits and operational inspection and / or a QA'ed centralised register has not been created.</p>	Minor	Historical data missing from report. Unknown defects could potentially leach to breach events.	<p>Search for any existing information to develop Levee Owner's Manual asap. Arrange for investigations to be carried out to fill information gaps.</p> <p>Provide copies of documentation to relevant State Agencies</p>	Obtain required information and file in QA'ed centralised register prior to next visual audit and operational inspection.	-	<p>visual audits and operational inspections may lack accuracy due to lack of historical information. Information may be lacking for emergency response planning decisions and therefore more conservative approaches may need to be considered in the interim in regards to emergency response planning.</p>
<b>2.0 Earth Levee – Crest</b>							
<b>2.1 Levee crest level below design crest level (i.e. surface erosion of crest due to local rain)</b>							
✓	<p><b>Acceptable</b></p> <p>Levee crest level at or above design crest level.</p>		-	-	-	-	-
±	<p><b>Marginal</b></p> <p>Levee crest level below design crest level by &lt; 150mm.</p> <p>Commonly occurs at vehicle and stock crossings.</p>		Minimal	The levee may not provide full protection in the design flood due to loss of freeboard.	Determine appropriate freeboard allowance if not known.	<p>Place and compact more gravel on top or more suitable clay material.</p> <p>Add this or equivalent in sandbagging to operational requirement if it can be addressed in the effective warning time available.</p> <p>Schedule for rectification within 6 months if warning time enables placement of material in lead time for flood.</p> <p>If little warning time schedule rectification within a shorter timeframe</p>	<p>Monitor annually if not used for vehicular crossing. If used for vehicular crossing monitor every 3 to 6 months.</p> <p>Level of protection lowered by amount levee crest below design crest level unless contingency plans can be readily enacted within the available warning time.</p>





for NSW Flood Levee Systems



Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks	
		Short Term	Long Term					
✘	<p><b>Unacceptable</b></p> <p>Levee crest level below design crest level by &gt; 150mm.</p> <p>Can occur at poorly maintained vehicle or stock crossings</p>		<p>May compromise maintenance access</p>	<p>In a major flood the design flood level will be compromised.</p> <p>Structural failure of the levee is possible</p>	<p>Determine appropriate freeboard if not known.</p> <p>Check stability/integrity of levee section.</p>	<p>Place and compact additional, suitable clay material plus 100-150mm gravel top.</p> <p>Add this or equivalent in sandbagging to operational requirement if it can be addressed in the effective warning time available.</p> <p>Schedule for rectification within 1 month.</p>	<p>Monitor every 3 to 6 months after rectification</p>	<p>Level of protection lowered by amount levee crest below design crest level unless contingency plans can be readily enacted within the available warning time.</p>
<b>2.2 Surface cracking – Longitudinal</b>								
✔	<p><b>Acceptable</b></p> <p>Cracks in the crest &lt;150mm deep (middle of levee).</p>		-	-	-	-	<p>Monitor crack depths and widths annually and during flood events</p>	<p>In event of a flood before rectified, check for any deterioration in condition</p>
±	<p><b>Marginal</b></p> <p>Cracks in the crest &lt;150mm deep adjacent to levee batters.</p>		<p>Nil</p>	<p>Allow minor amounts of rainwater to pond and seep into the levee but limited impact on levee stability.</p>		<p>To be repaired as moderate priority in Maintenance Program.</p>	<p>Monitor every 6 months and during flood event.</p>	<p>In event of a flood before rectified, monitor regularly to assess whether cracks are becoming unacceptable</p>
✘	<p><b>Unacceptable</b></p> <p>Cracks greater than 150mm deep that will pond water.</p>		<p>Allow significant amount of rainwater to pond and seep into the levee.</p>	<p>Allow significant amount of rainwater to pond and seep into the levee.</p> <p>Weaken the levee and lessen the level of protection and / or effectiveness of freeboard.</p>	<p>Levee audit required ASAP</p>	<p>Cracking to be remediated as a high priority in Maintenance Program</p>	<p>Monitor every 6 months and during flood event after rectification.</p>	<p>Moderate to high risk of failure depending on degree of penetration into levee structure.</p>



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Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks
		Short Term	Long Term				
<b>2.3 Surface cracking – Transverse</b>							
✓	<p><b>Acceptable</b></p> <p>Cracks in the crest &lt;150mm deep (from middle - town side only).</p>	Insert Photo	-	-	-	-	Monitor crack width and depth for deterioration annually-
±	<p><b>Marginal</b></p> <p>Cracks in the crest &lt;150mm deep (water side) that would not pond water.</p>		Nil	Allow minor amount of rainwater to pond and seep into the levee.	-	To be repaired as moderate priority in Maintenance Program.	Monitor crack width and depth for deterioration annually and during flood events. Risk of failure limited to moderate providing no other defects compound the issue.
✗	<p><b>Unacceptable</b></p> <p>Cracks greater than 150mm deep that extend across the full width of the levee.</p>	Insert Photo	Allow significant amount of rainwater to pond, seep into the levee.	Allow significant amount of rainwater to pond and seep into the levee. Weaken the levee and lessen the level of protection and / or effectiveness of freeboard.	Levee audit required ASAP Original design specification to be adhered to for remediation works.	Cracking to be remediated as a high priority in Maintenance Program	Monitor annually or during flood events once rectified. Moderate to high risk of failure depending on degree of penetration into levee structure. Risk can be compounded by other defects.
<b>2.4 Surface ruts / depressions / holes (i.e. low spots in crest due to settlement and vehicle/stock traffic)</b>							
✓	<p><b>Acceptable</b></p> <p>Scattered shallow ruts, holes or depressions unrelated to settlement. Levee crest well established and drains properly without any ponded water.</p> <p>Note vegetation cover in this photo would be unacceptable, see Section 6 of this appendix.</p>		-	-	-	Place and compact fill in depressions as part of long term maintenance plan-	Monitor annually. If public have access need to consider trip hazard and associated public liability.

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Description of Potential Risk and Assessment of Severity of Risk Issue			Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks
			Short Term	Long Term				
±	<p><b>Marginal</b></p> <p>Infrequent ruts, depressions or holes less than 100mm deep in crest that will pond water.</p>		Nil	Allow rainwater to pond, seep into the levee.	-	Place and compact more gravel on crest of levee as a medium priority in the maintenance plan	Monitor every 6 months	<p>Minimal risk of breach depending on design freeboard.</p> <p>If public have access need to consider trip hazard and associated public liability.</p>
✘	<p><b>Unacceptable</b></p> <p>Depressions greater than 100mm that will pond water.</p>		Allow significant amount of rainwater to pond and seep into the levee.	<p>Allow significant amount of rainwater to pond and seep into the levee.</p> <p>Weaken the levee and lessen the level of protection and / or effectiveness of freeboard.</p>	Determine depth of depression and investigate the structural integrity of the subgrade (material below topsoil/gravel) to determine deterioration.	Remediate depressions ASAP. This may involve replacing subgrade where it is unsuitable with more suitable clay material and placing and compacting more gravel on levee crest.	Monitor every 6 months after rectification	<p>Level of protection lowered by depth of depression if within 1m of waterside batter.</p> <p>If public have access need to consider trip hazard and associated public liability.</p>
<b>3.0 Earthen Levee – Batters</b>								
<b>3.1 Surface erosion of batters due to local rain</b>								
✓	<p><b>Acceptable</b></p> <p>Minor scouring less than 50% design depth of the topsoil leaving sufficient topsoil for groundcover to grow and stabilise batter.</p>		-	-	-	-	-	-



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Description of Potential Risk and Assessment of Severity of Risk Issue			Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks
			Short Term	Long Term				
±	<p><b>Marginal</b></p> <p>Scouring greater than 50% of the design topsoil.</p>		Nil	<p>Insufficient topsoil left for groundcover to grow and stabilise embankment leading to further erosion.</p>	-	<p>Reinstate topsoil to original design depth. Seed and / or mulch batters or place strips of turf where appropriate conditions exist.</p>	<p>Monitor annually and after a flood event</p>	<p>Low to moderate risk of structural failure of levee.</p>
✘	<p><b>Unacceptable</b></p> <p>Scouring that has removed all the topsoil and penetrated into the levee structure itself.</p>		<p>Insufficient topsoil left for groundcover to grow and stabilise embankment leading to further erosion.</p>	<p>Major erosion into levee structure has already occurred. Major maintenance required to avoid structural failure.</p>	<p>Refer to original construction specification for remediation guidelines.</p>	<p>Immediately repair structural defects in levee batters. Reinstate topsoil to original design depth. Seed and / or mulch batters or place strips of turf where appropriate conditions exist.</p> <p>Rectify concentration of rainfall runoff from levee crest.</p> <p>URGENT</p>	<p>Monitor annually and after a flood event once rectified</p>	<p>High risk of structural failure of levee</p>
3.2	<b>Erosion of batters due to water flows</b>							
✓	<p><b>Acceptable</b></p> <p>Minimal erosion not undercutting the river side batter of the Levee Bank.</p>		-	-	-	-	-	-

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Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks
		Short Term	Long Term				
✘	<p><b>Unacceptable</b> High water flows have eroded batter.</p> 	Structural failure of levee.	Structural failure of levee.	<p>Refer to original construction specification for remediation guidelines. Check stability/integrity of levee section.</p>	<p>Immediate reinstatement of batters including topsoiling, reseeding and / or mulching or placing of turf strips where appropriate conditions exist. Investigate options for further stabilisation. <b>URGENT</b></p>	Monitor annually and during flood events after rectification	High risk of structural failure of levee
3.3	<b>Slumping of batters</b>						
✔	<p><b>Acceptable</b> Batter not steeper than design grade with no slumping.</p> 	-	-	-	-	-	-
✘	<p><b>Unacceptable</b> Batter slumped due to water erosion (undercutting) at toe of levee.</p> 	Structural failure of levee.	Structural failure of levee.	<p>Refer to original construction specification for remediation guidelines or alternatively consult structural engineer for re-design of levee. Check stability/integrity of levee section.</p>	<p>Immediate repair/stabilisation/reinstatement of river bank (gabions, rip rap etc.) and reinstatement of batters including topsoiling, reseeding and / or mulching or placing of strips of turf where appropriate conditions exist. Engineered re-design may be required <b>URGENT</b></p>	-	High risk of structural failure.
✘	<p><b>Unacceptable</b> Batter slumped due to too steep levee batter</p> 	Structural failure of levee.	Structural failure of levee.	<p>Refer to original construction specification for remediation guidelines. Check stability/integrity of levee section.</p>	<p>Reconstruct batter at acceptable slope (new engineered design may be required). Ensure new works are keyed into existing structure.</p>	-	High risk of structural failure.



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Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks
		Short Term	Long Term				
3.4	<b>Over steep batters</b>						
✓	<p><b>Acceptable</b> Batter installed as per design grade.</p> 	-	-	-	-	-	-
✗	<p><b>Unacceptable</b> Over steep batter due to incorrect design or erosion.</p> 	Oversteep batters compounded by continued erosion of the bank due to runoff.	Slumping or major erosion of the batter.	Refer to original construction specification for remediation guidelines. Check stability/integrity of levee section.	High priority to reconstruct batter at acceptable grade and uniform profile (engineered redesign of levee batter grades). Ensure new works are keyed into existing structure.	Monitor annually and during flood events after rectification -	Moderate to High risk of structural failure.
3.5	<b>Structures on batters (Encroachments)</b>						
✓	<p><b>Acceptable</b> No structures within Zone 1, 2 or 3.</p> 	-	-	-	-	-	-

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Description of Potential Risk and Assessment of Severity of Risk Issue			Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks
			Short Term	Long Term				
±	<b>Marginal</b> Temporary structures on batters in Zone 1		Minimal	Interference with maintenance access and emergency services activities during flood event	The levee owner needs to have a policy in place to deal with temporary structures. No new structures shall be permitted in zone 1. Any structure removed from zone 1 shall not be replaced. Levee to be reinstated to appropriate condition when temporary structures removed	Existing temporary structures that do not impede the levee structure may be permitted.  Landholders to be informed that emergency services may destroy structures in a flood event. If maintenance is required landholder may need to move structure.	All temporary structures in zone 1 shall be recorded on a register following an initial audit. Levee owner policy to be enforced from this point on.	Easily removed structures pose a low threat to long term levee reliability if don't impinge on maintenance access to other areas.
±	<b>Marginal</b> Structures in Zone 2 or 3		Minimal if appropriate protection of topsoil maintained, otherwise erosion may be an issue	Interference with maintenance access and emergency services activities during flood event	The levee owner needs to have a policy in place for structures within easements in zone 2 and 3. No new structures shall be permitted. Any structure removed from within easements in zones 2 and 3 shall not be replaced. Levee to be reinstated to appropriate condition when temporary structures removed	Structures within levee easements in Zone 2 or 3 are susceptible to demolition by emergency services in a flood event to save the levee structure or where they impinge on maintenance access along the levee.	All structures within easements in zone 2 and 3 shall be recorded on a register following an initial audit. Levee owner policy to be enforced from this point on.	Only a threat if they restrict access to the levee structure for maintenance / emergency services activities during flood event or reduce protection to vegetation cover or result in concentrations of erosions around structures.
✘	<b>Unacceptable</b> Structures on Levee Crest		Restricted access to levee for maintenance.	Restricted access to levee for maintenance and emergency services activities during flood event.	Structures on the crest of an earthen levee are not negotiable and shall be removed. Levee to be reinstated to appropriate condition when temporary structures removed	The only structure that is allowed on the crest on an earthen levee is a gate on a dividing boundary. Any locks should be on a master key system and the levee owner and emergency services is required to have a master key. Alternative is to have multiple locks for owner, council and/or emergency services.	-	May affect operational issues in relation to maintenance and / or emergency services activities during a flood event.
<b>3.6</b>	<b>River Bank Erosion (Zone 4 meets Zone 1)</b>							
✓	<b>Acceptable</b> No erosion generated from current, tide or wave action.	Insert Photo	-	-	-	-	Monitor Annually or after a flood event	-
±	<b>Marginal</b> Minor erosion of levee and undercutting of tree roots generated from current, tide or wave action	Insert Photo	Minimal	Tree collapse and major damage to toe and batter of levee	Engineer to inspect and provide recommendation on remediation and bank protection.  Necessary approvals obtained. This may include contacting the relevant water way authority prior to any works being undertaken.	Remove trees within 5m of the water side toe of the levee and remediate batter.	Monitor annually and after a flood event	Moderate risk of levee breach during flood event.



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Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks	
		Short Term	Long Term					
✘	<p><b>Unacceptable</b></p> <p>Major erosion / undercutting of levee bank and trees within 5m of the toe due to current, tide or wave action.</p>		Tree collapse and major damage to toe and batter of levee	Tree collapse and major damage to toe and batter of levee	<p>Engineer to inspect and provide recommendation on remediation and bank protection.</p> <p>Water way authority may be required to be contacted prior to any works being undertaken.</p>	Immediately remove trees within 5m of the water side toe of the levee and remediate batter.	Monitor 6-monthly and after a flood event	Moderate to high risk of levee breach during flood event
<b>3.7 Seepage under or through the Levee</b>								
✔	<p><b>Acceptable</b></p> <p>No identified seepage paths or sand boils.</p>	Insert Photo	-	-	-	-	-	-
±	<p><b>Marginal</b></p> <p>Potential sites identified as seepage paths (major trees, sand boils etc)</p>	Insert Photo	Minimal	Development into seepage paths	-	-	Monitor annually and during floods (sand boils are difficult to detect during routine inspections as they typically only appear during high water)	Moderate risk of seepage resulting in flooding in protected areas behind the levee during a flood event.
✘	<p><b>Unacceptable</b></p> <p>Seepage paths / sand boils positively identified.</p>		Expense of repair	Breach of levee	Engineer to inspect and provide recommendation for remediation works.	Immediately implement engineers recommendations	Monitor 6-monthly and during floods (sand boils are difficult to detect during routine inspections as they typically only appear during high water)	High risk of seepage leading to flooding in protected areas behind the levee during a flood event.



Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks	
		Short Term	Long Term					
<b>4.0 Concrete Levee</b>								
<b>4.1 Wall Movement / Settlement</b>								
✓	<p><b>Acceptable</b></p> <p>There is no settlement of the levee. No significant tilting or sliding of concrete wall.</p>		-	-	-	-	-	
±	<p><b>Marginal</b></p> <p>There is settlement of the levee less than 25mm.</p> <p>Concrete wall has tilted by no more than 1H : 100V.</p> <p>Concrete wall has slid by no more than 10mm.</p> <p>Differential movement between sections less than 25mm</p>		<p>Wall leaks during flood event.</p>	<p>Continued settlement leading to failure of wall and uncontrolled leakage through levee during flood event.</p>	<p>Structural Engineer to assess wall and foundation.</p>	<p>Action recommendations of Structural Engineer according to timelines provided by Structural Engineer. (If no timeline provided implement immediately.)</p> <p>Possibly can be placed in annual works program.</p>	<p>Monitor annually or after a flood unless otherwise advised by Structural Engineer</p>	<p>Could be high. Should be based on Risk assessment by Structural Engineer.</p>

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Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks	
		Short Term	Long Term					
✘	<p><b>Unacceptable</b></p> <p>There is settlement of the levee greater than 25mm.</p> <p>Concrete wall has tilted by more than 1H : 100V.</p> <p>Concrete wall has slid by more than 10mm.</p> <p>Differential movement between sections &gt; 25mm</p>		Movement of wall requiring support during flood.	Structural failure and collapse of wall.	Structural Engineer to assess wall and foundation.	Immediately implement recommendations of Structural Engineer. URGENT	-	Expected to be a high risk. Should be based on Risk assessment by Structural Engineer.
<b>4.2 Surface Appearance</b>								
✔	<p><b>Acceptable</b></p> <p>Minimal spalling or cracking. Cracks less than 1mm wide and not penetrating through the concrete thickness.</p>		-	-	-	-	-	-
±	<p><b>Marginal</b></p> <p>Some spalling and cracks greater than 1mm wide but not penetrating through the concrete thickness.</p>		Wall leaks during flood event.	Continued movement leading to failure of wall and uncontrolled leakage through levee during flood event.	Structural Engineer to assess wall and foundation. This assessment should consider possible concrete cancer.	Follow Structural Engineers Recommendations for remediation. Undertake surface repairs as required in cyclical maintenance program.	Leave on annual monitoring list unless cleared by Structural Engineer following any rectification that is required	Moderate risk of failure




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Description of Potential Risk and Assessment of Severity of Risk Issue			Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks
			Short Term	Long Term				
✘	<b>Unacceptable</b> Spalling and cracks greater than 1mm wide and penetrating through the concrete thickness.	Insert Photo	Wall leaks during flood event.	Reinforcing fails leading to structural failure of wall and uncontrolled leakage through Levee	Structural Engineer to assess wall and foundation.	Follow Structural Engineers Recommendations for remediation. Undertake surface repairs as required in cyclical maintenance program.	Leave on annual monitoring list unless cleared by Structural Engineer following any rectification that is required	High risk of failure
4.3	<b>Waterstops</b>							
✓	<b>Acceptable</b> Water stops intact		-	-	-	-	-	-
±	<b>Marginal</b> Water stop still intact however wall movement is such that water stop is stressed		-	Wall continues to move, water stop fails, uncontrolled leakage of levee.	Engineer to inspect and recommend repair method if required	Repair as per engineer's recommendation.	Monitor gap movement frequently	Low risk of major breach
✘	<b>Unacceptable</b> Shrinkage visible – light visible through joint from other side. No water stop installed in joint.	Insert Photo	Uncontrolled leakage through Levee	Uncontrolled leakage through Levee. Possible foundation failure due to concentrated erosion.	Engineer to recommend repair method	Repair as per engineer's recommendation.	Leave on annual monitoring list unless cleared by Engineer following any rectification that is required	Moderate risk of major breach if wall hasn't failed. If wall has failed as well risk will be high
4.4	<b>Undermined / Exposed Footings</b>							
✓	<b>Acceptable</b> No undermining / exposure of footings	Insert Photo	-	-	-	-	-	-

for NSW Flood Levee Systems





Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks	
		Short Term	Long Term					
✘	<p><b>Unacceptable</b> Undermined / Exposed footings</p>	Insert Photo	<p>Collapse of concrete levee. Major breach</p>	<p>Collapse of concrete levee. Major breach</p>	<p>Engineer to inspect and recommend repair method</p>	<p>Immediately implement recommendations of Engineer. <b>URGENT</b></p>	-	High risk due to difficulty of repair during flood event.
<b>5.0 Sheet Pile Levee</b>								
<b>5.1 Wall Movement / Settlement</b>								
✓	<p><b>Acceptable</b> There is no settlement of the levee. No significant tilting or sliding of sheet pile wall.</p>		-	-	-	-	-	-
±	<p><b>Marginal</b> There is settlement of the levee less than 50mm over an extended length of piling indicating a general movement / settling of the foundations. Sheet Pile wall has tilted by no more than 1H : 50V. Sheet Pile wall has slid by no more than 10mm.</p>	Insert Photo	Minimal	Possible destabilisation of levee and surrounding area.	Have Structural Engineer check the surrounding foundations for movement.	Implement as a high priority based on recommendation from Structural Engineer.	Monitor annually and after a flood for further movement.	Treat as low risk of failure but as there has been movement engineers report is required.
✘	<p><b>Unacceptable</b> There is settlement of the levee greater than 50mm over an extended length of piling indicating a general movement / settling of the foundations. Sheet Pile wall has tilted by more than 1H : 50V. Sheet Pile wall has slid by more than 10mm.</p>	Insert Photo	Possible destabilisation of levee and surrounding area.	Total failure of levee	Have Structural Engineer check the surrounding foundations for movement.	<p>Immediately implement recommendations of the Structural Engineer. This should be treated seriously. The depth to which sheet piling is installed should not lead to movement or settlement. <b>URGENT</b></p>	Leave on annual monitoring list unless cleared by Structural Engineer following any rectification that is required	Rate as high risk of failure until Structural Engineers Report is available and any remediation works complete.

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Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks	
		Short Term	Long Term					
<b>5.2 Surface appearance</b>								
✓	<b>Acceptable</b> Minimal rust		-	-	-	-	-	
±	<b>Marginal</b> Moderate rust in surface	Insert Photo	Minimal	Leaks at clutches or through holes.	If sheet piling is showing signs of moderate rust a Structural Engineer is required to estimate the remaining life span of the structure and provide maintenance recommendations as applicable.	Implement recommendations of the Structural Engineer. May include: Painting, cathodic protection, minor repairs. Place in cyclical maintenance program.	Monitor annually	Low to moderate risk of leaking during a flood event.
✗	<b>Unacceptable</b> Major rust (holes / flaking)	Insert Photo	Leaks at clutches or through holes.	Structural failure of levee.	A structural engineer is required to determine if the structure can be repaired or replacement is required.	Immediately implement recommendations of the Structural Engineer.	Leave on annual monitoring list unless cleared by Structural Engineer following any rectification that is required	High risk of leaking during flood event.
<b>6.0 Vegetation</b>								
<b>6.1 Lack of protective vegetation</b>								
✓	<b>Acceptable</b> Greater than 90% of surface area of the earth levee batter which is subject to receipt of rainfall runoff from the crest of the levee, covered by grass.		-	-	-	-	-	






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Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks	
		Short Term	Long Term					
±	<p><b>Marginal</b></p> <p>Greater than 50% but less than 90% of surface area of the earth levee batter which is subject to receipt of rainfall runoff from the crest of the levee, covered by grass.</p> <p>Individual patches of bare ground showing minor effects of erosion.</p>		Minimal	Further erosion of topsoil leading to structural damage of the levee bank.	-	Topsoiling and seeding / mulching to be included in Maintenance Program.	Erosion to be monitored annually and after a flood. Maintenance program to be updated as required.	Structural integrity of levee not threatened in the short term.
✘	<p><b>Unacceptable</b></p> <p>Less than 50% of surface area of the earth levee batter which is subject to receipt of rainfall runoff from the crest of the levee, covered by grass.</p>		Depending on level of erosion structural integrity could be compromised.	Structural integrity of the levee compromised, possible failure during flood.	Original construction specification to be consulted for remediation of levee structure for major erosion. Clay material with the same properties as the original levee to be used for repairs.	Repair structural faults first. Topsoil as per original specification, seed and / or mulch levee batters and/or place strips of turf where appropriate conditions exist. Gravel and compact levee crest.	-	Low to high risk of levee failure depending on degree of erosion and side exposure to flood impacts.
6.2	<b>Trees / shrubs growing on levees (i.e. within Zone 1)</b>							
✓	<p><b>Acceptable</b></p> <p>No trees or shrubs growing on levee. (In Zones 1, 2 &amp; 3)</p> <p><i>Note: That this photo shows unacceptable access to levee (see Section on Access to levee).</i></p>		-	-	-	-	-	-
±	<p><b>Marginal</b></p> <p>Small shrubs / trees</p>		Minimal	As the trees grow, they pose a greater threat to the structural integrity of the levee.	-	Remove all small shrubs / trees ASAP	Monitor annually for new growth.	No structural issues with levee.


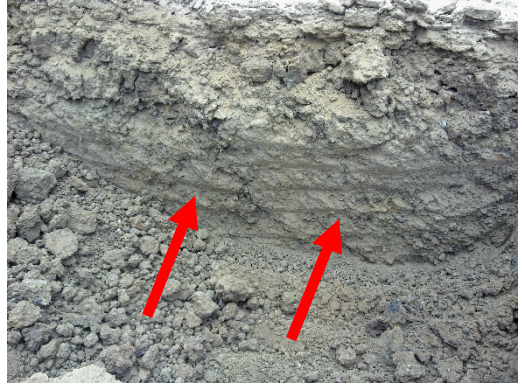
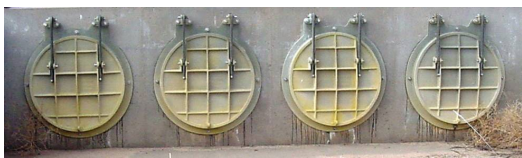

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Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks	
		Short Term	Long Term					
✘	<p><b>Unacceptable</b></p> <p>Trees / woody shrubs growing on levee bank (as it is uncertain to ascertain the effect on the structural integrity of the levee bank).</p>		Moderate risk of collapse	Collapse during a flood event could lead to breach of the levee structure	<p>Horticulturalist to check all significant trees in zone 1 that are nominated to remain due to exceptional circumstances.</p> <p>Refer Tree Philosophy. (see Section 10.5.1)</p> <p>Seek all necessary approvals in relation to vegetation removal.</p>	<p>Where relevant authorities permit immediately remove all large trees and remediate levee.</p> <p>Where not permitted seek further engineering/horticultural advice to develop appropriate management plan and develop any necessary contingency plans and include in levee operational plan.</p> <p>Refer to Tree Philosophy for exceptional circumstances.</p>	<p>Monitor significant trees annually and during/after a major flood.</p>	<p>Moderate to high risk of tree collapse during flood event leading to possible breach of levee structure.</p>
✔	<p><b>Acceptable</b></p> <p>Trees / shrubs greater than 5m away from toe of levee.</p>		-	-	-	-	-	-
±	<p><b>Marginal</b></p> <p>Trees / shrubs between 2m-5m away from toe of levee and the drip zone is not within zone 1.</p>		Minimal.	Tree collapse during flood event could threaten structural integrity of levee system.	<p>Confirm impact of tree root zone on levee.</p> <p>Horticulturalist <u>may</u> be required to provide health check on all trees in zones 2 and 3.</p> <p>Seek all necessary approvals in relation to vegetation removal</p>	Where permissible remove trees in cyclical removal program considering horticulturalists advice.	If restrictions apply add to monitoring and removal program.	While trees are healthy low to moderate risk of effecting reliability.
✘	<p><b>Unacceptable</b></p> <p>Trees / shrubs less than 2m away from Levee Zone 1. (Refer tree philosophy).</p>		Possible cause of seepage path under levee structure.	Tree collapse may cause structural damage to levee structure.	<p>Confirm impact of tree root zone on levee.</p> <p>Horticulturalist <u>may</u> be required to provide health check on all trees in zones 2 and 3.</p> <p>Seek all necessary approvals in relation to vegetation removal</p>	Where permissible remove trees ASAP considering horticulturalists advice, and remediate levee	If restrictions apply add to monitoring and removal program.	<p>While trees are healthy moderate risk of effecting reliability.</p> <p>If trees are not healthy risks may be higher</p>






Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks	
		Short Term	Long Term					
<b>7.0 Animal Burrows</b>								
<b>7.1 Rabbit / Fox / Echidna holes etc.</b>								
✓	<p><b>Acceptable</b></p> <p>No animal burrows in Levee. No animal burrow within 5m of Zone 1.</p>		-	-	-	-	-	
±	<p><b>Marginal</b></p> <p>Animal burrows of any kind limited to within levee Zone 2 or 3 (i.e. that will not result in seepage under the levee or slope stability problems).</p> <p>Also, animal scratchings in topsoil only in zone 1</p>	Insert Photo	Nil	Animals may burrow into Zone 1 and cause seepage issues through levee.	Determine depth/extent of burrows.	Fill in scratchings in Zone 1. Cave in and fill animal burrows in Zones 2 and 3. Eradicate vermin or trap and relocate animals as required.	Monitor annually.	Very low risk of affecting levee bank if monitored.
✗	<p><b>Unacceptable</b></p> <p>Animal burrows of any kind within levee Zone 1. Major animal burrows in Zone 2 or 3</p>		Possible seepage issues through levee.	Large burrows could cause levee to fail during flood event.	Refer to original construction specification for remediation guidelines.	Burrows will require total excavation to determine extent of burrow prior to remediation.	-	Moderate to high risk of causing seepage path through levee. If this occurred damage would be quite significant.
<b>7.2 Ant Nests</b>								
✓	<p><b>Acceptable</b></p> <p>No ant nests.</p>		-	-	-	-	-	

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Description of Potential Risk and Assessment of Severity of Risk Issue			Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks
			Short Term	Long Term				
±	<p><b>Marginal</b></p> <p>Ant nest on town side batter slope. Smaller ant nests on crest or river side batter.</p>		-	Minimal	Determine depth/extent of nests.	Exterminate Ants.	Monitor annually	Smaller nests pose a minimal threat to the levee structure.
×	<p><b>Unacceptable</b></p> <p>Ants nest on levee with mound.</p>		Minimal	Seepage path created through levee embankment leading to eventual failure.	-	Excavation of nest, importation and compaction of clay fill.	-	If a major ant nest is discovered, it should be monitored for seepage in a flood event.
<b>8.0 Stormwater Structures</b>								
<b>8.1 Closure Mechanisms</b>								
✓	<p><b>Acceptable</b></p> <p>Pipe is fitted with Gate Valve or Flap Valve that is fully operational. Gate / Flap Valve is mechanically sound and provides a functional watertight seal. Closure mechanism not impeded by any obstruction. No sign of deterioration in fittings, anchorages etc.</p>		-	-	-	-	-	-
±	<p><b>Marginal</b></p> <p>Closure structures that cannot being operated or accessed during flood events e.g. metal plates Structures subject to repeated vandalism.</p>		Minimal	Potential for dislodgement during floods	-	Long term plan to upgrade to suitable flood gates.	Monitor occurrences of vandalism and develop strategy to eliminate problem.	Minor risk Potential for dislodgement during floods causing internal flooding.



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Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks	
		Short Term	Long Term					
✘	<p><b>Unacceptable</b></p> <p>Any closure mechanism not fully functioning (worn, damaged or bent).</p> <p>Any impedance of obstruction to closure mechanism.</p> <p>Gate seals leaking or damaged.</p> <p>Location is likely to be exposed to perpendicular flows which may force gate open or tear the gate from its hinges. (Lack of protection due to insufficient wing walls and / or headwalls.)</p>		Internal area inundated due to backflow from waterway resulting in levee not providing its design protection.	Internal area inundated due to backflow from waterway resulting in levee not providing its design protection.	-	Remove obstructions, repair or replace closure mechanism. Develop contingency plans: small pipes may be able to be sandbagged if necessary; larger pipes can use thick sheet of plywood as a temporary measure. This information to be added to O&M manual.	Check all closure mechanisms annually (as a minimum)	Moderate to high risk of failure during flood event. The larger the pipes the greater the risk.
	<p><b>Imminent Threat</b></p> <p>Stormwater pipes with no closure mechanism.</p>		Internal area inundated due to backflow from waterway resulting in levee not providing its design protection.	Internal area inundated due to backflow from waterway resulting in levee not providing its design protection.	Consult engineer for closure mechanism design on existing structure.	Closure mechanism to be fitted at earliest opportunity. If advanced warning on flood events is minimal this issue to be addressed IMMEDIATELY. Develop contingency plans: small pipes may be able to be sandbagged if necessary; larger pipes can use thick sheet of plywood as a temporary measure. This information to be added to O&M manual.	Check all closure mechanisms annually (as a minimum)	High risk as Levee System not able to provide design protection. Risk increases with the size of the pipe and the length of time of inundation
<b>8.2 Impedance to flow capacity</b>								
✓	<p><b>Acceptable</b></p> <p>Pipe is not silted up and full pipe available to convey stormwater.</p>	Insert photo.	-	-	-	-	-	-
±	<p><b>Marginal</b></p> <p>Pipe partially silted up only marginally impeding stormwater.</p> <p>Note: photo also shows impact on closure mechanism as discussed separately above.</p>		Minimal	Flow obstruction likely to limit internal drainage discharge resulting in a minor increase in internal flood levels and extents	Investigate cause of silting. Assess pipe condition (including internal inspection e.g. camera).	Clean out pipes on cyclical Maintenance program. Ensure pumps are operational and available.	Site conditions will determine frequency of inspections. Minimum annual inspection.	Levee structure not threatened. Low to moderate risk of internal flooding from localised stormwater.




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		Short Term	Long Term					
✘	<p><b>Unacceptable</b></p> <p>Pipe silted up impeding stormwater.</p> <p>Note: Photo also shows a lack of floodgates as discussed separately above</p>		Flow obstruction likely to limit internal drainage discharge resulting in an increase in internal flood levels and extents	Major flow obstruction due to full blockage. Likely to limit internal drainage discharge resulting in a significant increase in internal flood levels and extents	-	Clean out pipes ASAP Ensure pumps are operational and available.	-	Levee structure not threatened.  Internal flooding from localised stormwater may be an issue.
<b>8.3 Vegetation</b>								
✔	<p><b>Acceptable</b></p> <p>Minimal vegetation at inlet / outlet. Flow not impeded. Operation of closure mechanism not impeded.</p> <p>Note: Photo shows a manually bolted-on horizontal crossbeam, seemingly to ensure that the flap valve is closed. This practice is <u>not recommended</u> as subsequent levee "internal" flooding could occur if operators forget to remove the crossbeam after the subsidence of river flooding.</p>		-	-	-	-	-	-
±	<p><b>Marginal</b></p> <p>Moderate volume of vegetation impeding flow into stormwater structures but closure mechanism operable.</p>		Partial blockage of stormwater system causing localised flooding and erosion.	Complete blockage of stormwater system causing internal flows to result in more internal flooding with potential ramifications to protected properties.	-	Arrange for high priority clearance of debris away from headwalls and closure mechanisms.	Monitor annually and in the lead up to flood events	Moderate risk of internal localised flooding.







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		Short Term	Long Term					
✘	<p><b>Unacceptable</b></p> <p>Flow and Operation of closure mechanism impeded.</p>		<p>Complete blockage of stormwater system causing internal flooding with potential ramifications to protected properties.</p> <p>Ingress of flood waters due to inability to close gates</p>	<p>Complete blockage of stormwater system causing internal flooding with potential ramifications to protected properties.</p> <p>Ingress of flood waters due to inability to close gates</p>	<p>Check closure mechanism for required repairs.</p>	<p>Immediately arrange for clearance of vegetation from pipes, inlet / outlet and closure mechanism.</p> <p>Repair closure mechanism ASAP.</p>	<p>Monitor annually and in the lead up to flood events.</p>	<p>If internal drainage fully blocked there is a high risk of internal flooding which may result in adverse impacts upon properties protected by the levee.</p>
8.4	<b>Structural integrity</b>							
✓	<p><b>Acceptable</b></p> <p>Pipes, headwalls or pits are in good, sound condition with no cracks or openings between joints.</p>		-	-	-	-	-	-
±	<p><b>Marginal</b></p> <p>Pipes, headwalls or pits with minor structural issues.</p> <p>Closure mechanism and stormwater pipe must be sound as discussed separately above.</p>	<p>Insert Photo</p>	<p>Minimal</p>	<p>Further deterioration could lead to piping / structural failures which could lead to protection not being achieved for the design flood.</p>	<p>Engineer to inspect and provide recommendations for repair / replacement.</p>	<p>Repair or replace pipes, headwalls and/or pits as per engineer's recommendations. Depending on recommendation work could be added to cyclical maintenance program.</p>	<p>Monitor annually and after a flood event</p>	<p>Low to moderate risk of structural issues.</p>
✘	<p><b>Unacceptable</b></p> <p>Pipes, headwalls or pits structurally unsound. Issues can include pipe joint displacement (see photograph), corrosion, cracking etc.</p>		<p>Total Breach of Levee</p>	<p>Total Breach of Levee</p>	<p>Engineer to inspect and provide recommendations for repair / replacement.</p>	<p>Arrange for recommendations of the Engineer to be implemented as a high priority.</p>	<p>After rectification monitor annually or after a flood for any future deterioration</p>	<p>High risk of structural issues leading to reduction in protection provided by the levee</p>

Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks	
		Short Term	Long Term					
8.5	<b>Erosion of the Levee at Inlets and Outlets</b>							
✓	<p><b>Acceptable</b></p> <p>There is no active erosion or bank collapse at outlet or inlet.</p>		-	-	-	-	-	
±	<p><b>Marginal</b></p> <p>There is some erosion or bank collapse at outlet or inlet but the integrity of the levee not threatened.</p>		Minimal	Further erosion could lead to structural issues of levee.	Original construction specification to be consulted for remediation of levee structure for major erosion. Clay material with the same properties as the original levee to be used for repairs.  Rock protection should also be considered.	Repair and / or add rock protection around inlet and outlet ASAP	Repair and monitor annually or after a flood event	Low to moderate risk of levee failure
✗	<p><b>Unacceptable</b></p> <p>The levee surrounding the outlet or inlet has failed.</p>		Erosion in the vicinity of the inlet or outlet of a structure which may lead to erosion of the levee embankment between the inlet and outlet and a breach of the levee flooding protected areas	Erosion in the vicinity of the inlet or outlet of a structure which may lead to erosion of the levee embankment between the inlet and outlet and a breach of the levee flooding protected areas	Engineer to inspect and provide recommendation to remediate embankment including rock protection.	Arrange for recommendations of the Engineer to be implemented as a high priority.	After rectification monitor annually or after a flood for any future deterioration	Moderate to high risk of levee failure





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		Short Term	Long Term					
<b>9.0 Retaining Walls</b>								
<b>9.1 Retaining Wall (as Levee and Supporting Levee)</b>								
✓	<p><b>Acceptable</b></p> <p>No significant tilting or sliding of wall.</p>		-	-	-	-	-	
±	<p><b>Marginal</b></p> <p>There is settlement of the levee less than 25mm. Wall has tilted by no more than 1H : 100V. Wall has slid by no more than 10mm.</p>	Insert Photo	Wall may have minor leaks that require sand bagging.	Possible Failure of wall and associated levee breach.	Structural Engineer to inspect walls and provide recommendation for repair.	Arrange for recommendations of the Structural Engineer to be implemented as a high priority.	Monitor annually and after a flood	Moderate
✗	<p><b>Unacceptable</b></p> <p>There is settlement of the levee more than 25mm. Wall has tilted by more than 1H : 100V. Wall has slid by more than 10mm. The structural elements cracked. Existing drainage system inoperable.</p>	Insert Photo	Possible failure of wall and resultant levee breach.	Failure of wall, Levee breach.	Structural Engineer to inspect walls and provide recommendation for repair.	Arrange for recommendations of the Structural Engineer to be implemented as a high priority.	After rectification monitor annually and after a flood	High risk. The potential for a full breach during a flood event.
<b>9.2 Foundations</b>								
✓	<p><b>Acceptable</b></p> <p>Solid foundation with no erosion or subsidence.</p>	Insert Photo	-	-	-	-	-	
±	<p><b>Marginal</b></p> <p>Unretained foundations showing signs of erosion or slumping. Retaining wall still supported.</p>	Insert Photo	Minimal	Potential retaining wall collapse	Structural Engineer to inspect walls and provide recommendation for repair.	Arrange for recommendations of the Structural Engineer to be implemented as a high priority.	After rectification monitor annually and after a flood	Location of retaining wall in respect to levee structure will determine risk.
✗	<p><b>Unacceptable</b></p> <p>Foundations have failed and no longer support retaining wall.</p>	Insert Photo	Retaining wall at risk of collapse and/or floodwater ingress underneath wall.	Retaining wall collapse and / or floodwater ingress underneath wall.	Structural Engineer to inspect walls and provide recommendation for repair.	Arrange for recommendations of the Structural Engineer to be implemented as a high priority.	After rectification monitor annually and after a flood	Location of retaining wall in respect to levee structure will determine risk.




Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks	
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<b>10.0 Ancillary Equipment</b>								
<b>10.1 Closure structures (There are numerous types of these structures. They are usually used in levee openings that need to remain open during non-flood times e.g. roads. Commonly in the form of temporary levees, floodgates, earth stockpiles, flood barriers, etc.)</b>								
✓	<p><b>Acceptable</b></p> <p>Closure structure in good repair.</p> <p>Closure equipment (e.g. stop logs, flood gates or other materials) are available.</p> <p>Components are clearly marked and installation instructions / procedures available.</p>		-	-	-	-	Check annually and in the lead up to a flood to see that all components are still in sound order	-
±	<p><b>Marginal</b></p> <p>Closure structure in good repair.</p> <p>Closure equipment (e.g. stop logs, flood gates or other materials) are available.</p> <p>Operations manuals not available.</p>	Insert Photo	Minimal	Confusion preceding flood event.	Find / update operations manual.	Store operations manual in central register (readily available). Train key staff in operational requirements of levee.	Check annually and in the lead up to a flood to see that all components are still in sound order	Low to moderate risk of not being able to be placed effectively during flood event leading to a flood breaching the levee.
✗	<p><b>Unacceptable</b></p> <p>Closure structure in poor repair.</p> <p>Closure equipment (e.g. stop logs, flood gates or other materials) are not readily available.</p> <p>Components are not clearly marked or installation instructions / procedures not available.</p>		Levee owner not prepared for flood.	Breach of levee during flood event.	Find / update operations manual.	Repair / obtain closure structures (including documentation of borrow pit locations if required.) ASAP. Develop contingency plans if there is any potential delay Store operations manual in central register (readily available). Train key staff in operational requirements of levee.	-	High risk of not being able to be placed effectively during flood event leading to a flood breaching the levee.
<b>10.2 Flood Pumps / Pumping Stations</b>								
✓	<p><b>Acceptable</b></p> <p>The levee owner has adequate flood pumps (allocated for flood event purposes) regularly serviced and in good working order.</p> <p>Pump stations are regularly audited (as per O&amp;M manual) to ensure pumps, pipes, valves and switchboards are maintained and operational and fuel is fresh (if required). If dual fuel (electricity and petrol) then check the battery is fully charged to crank the engine.</p>		-	-	-	-	-	-






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✘	<p><b>Unacceptable</b></p> <p>Inadequate or inoperable flood pumps. (Any pumps that require constant maintenance to keep them operable should be considered for replacement.)</p> <p>Pump Stations not regularly maintained and / or O&amp;M manual not available.</p>	Insert Photo	Stormwater flooding inside the levee during flood.	Stormwater flooding inside the levee during flood.	<p>Floodplain risk management plan to be checked to ensure adequate flood pumps are available.</p> <p>Staff training in how and where to install and operate pumps during a flood.</p>	<p>Purchase new pumps and have them on standby for a flood event.</p> <p>Service existing pumps.</p> <p>Ensure pumps are allocated for specific purposes for a flood event.</p>	<p>Inspect pumps quarterly (or as per manufacturers recommendation) to ensure they are operable. Start monthly</p>	Moderate to High as the flood pumps are to pump localised stormwater over or through the levee in a flood event when the gravity stormwater lines are not operational
<b>11.0 Spillways</b>								
<b>11.1 Spillway condition</b>								
✔	<p><b>Acceptable</b></p> <p>No slumping / erosion of crest level. Erosion protection is still in place.</p> <p>Spillway operational with no defects (all materials).</p>		-	-	-	-	-	-
±	<p><b>Marginal</b></p> <p>Minor erosion on spillway. Majority of erosion protection still in place.</p> <p>Spillway still structurally sound.</p>	Insert Photo	Minor reduction in flood protection of town	Reduction in flood protection of town	Undertake crest level survey	Reinstate erosion protection in accordance with original design.	Monitor annually and after a flood	Moderate risk of levee breaching over spillway in design flood.
✘	<p><b>Unacceptable</b></p> <p>Erosion protection compromised. Any reduction in design crest level of spillway.</p> <p>Structural integrity of spillway compromised (All materials)</p>	Insert Photo	Reduction in flood protection of town	Potential for Major breach of levee at spillway during major flood near to the design event	<p>Undertake crest level survey.</p> <p>Engineer to inspect and provide recommendation to remediate spillway protection</p>	<p>Reinstate spillway to design crest level and ensure erosion protection in place and operational</p> <p>Arrange for recommendations of the Engineer to be implemented as a high priority.</p>	Monitor annually and after a flood	High risk of breaching in below design flood level
<b>12.0 Work, Health &amp; Safety (WHS)</b>								
<b>12.1 Culvert Floodgate – Access and Operability</b>								
✔	<p><b>Acceptable</b></p> <p>Clear access to floodgate. Presence of warning signage. Operable structures / devices locked and secured. Applied operation force of floodgate handwheel adequately less than 130 N.</p>		---	---	---	---	<ul style="list-style-type: none"> <li>Operational (annual) Inspections as a minimum;</li> <li>Pre-Flood Inspections;</li> <li>Visual Audits.</li> </ul>	No issues

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Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks	
		Short Term	Long Term					
±	<p><b>Marginal</b></p> <p>Access to floodgate slightly impeded by vegetation and / or other unwanted items. Structure / device operable and covered but not locked. Applied operation force of floodgate handwheel requiring over 130 N.</p>		<p>Floodgate accessible but with inconvenience during operation and maintenance.</p> <p>Risk of damage from vandalism.</p>	←	---	<p>Completely remove all obstructions to ensure safe access to floodgate. Provide locking mechanism.</p>	<p>Must be monitored and maintained frequently as obstructions can cause injuries and internal flooding:</p> <ul style="list-style-type: none"> <li>• General Inspections;</li> <li>• Operational (annual) Inspections;</li> <li>• Pre-Flood Inspections;</li> <li>• Visual Audits.</li> </ul>	<p>Reliable but with minor disturbance and delay (if not damaged by the public).</p>
✘	<p><b>Unacceptable</b></p> <p>Access to floodgate severely impeded by overgrown vegetation and / or other foreign items. Structure / device could be operable but not locked. Absence of warning signage. Required applied operation force of floodgate handwheel significantly greater than 130 N or inoperable.</p>	 	<p>Floodgate inaccessible and hence not able to be operated leading to floodwater intrusion from river into town.</p>	←	---	<p>Completely remove all obstructions to ensure safe access to floodgate immediately.</p>	<p>Must be monitored and maintained frequently as obstructions can cause injuries and internal flooding:</p> <ul style="list-style-type: none"> <li>• General Inspections;</li> <li>• Operational (annual) Inspections;</li> <li>• Pre-Flood Inspections;</li> <li>• Visual Audits.</li> </ul>	<p>Unreliable</p>






Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks
		Short Term	Long Term				
12.2	<b>Culvert Floodgate – Elevated Floodgate Platform Walkway</b>						
✓	<p><b>Acceptable</b></p> <p>Walkway width and accessories (e.g. handrails (incl. of in front of floodgate handwheel), floor grating) in full compliance with AS 1657 – Fixed platforms, walkways, stairways and ladders – Design, construction and installation. Platform soundly founded on the levee batter / river bank.</p> <p>Floodgate and lifting frame securely installed on outlet structure / platform.</p>		---	---	---	---	<ul style="list-style-type: none"> <li>Operational (annual) Inspections as a minimum;</li> <li>Pre-Flood Inspections;</li> <li>Visual Audits.</li> </ul> <p>No issues</p>
±	<p><b>Marginal</b></p> <p>Walkway width and accessories (e.g. handrails, floor grating) in minor non-compliance with AS 1657. Platform currently soundly founded on the levee batter / river bank but structural members showing signs of deterioration. Stability acceptable in the short term.</p> <p>Floodgate and lifting frame observed to be loosening with some bolts / anchors missing.</p>		Platform accessible but standards of accessories outdated. Walkway too narrow, handrails too short and floor grating deteriorating, etc. Risk of Operators suffering from minor to moderate injuries.	←	Review AS 1657 and other relevant standards. Specific engineering assessment of platform's structural members and floodgate accessories.	Replace all sub-standard items to ensure safe access to and operation of floodgate prior to flood season.	<p>Must be monitored and maintained frequently as instability can cause injuries and internal flooding:</p> <ul style="list-style-type: none"> <li>General Inspections;</li> <li>Operational (annual) Inspections;</li> <li>Pre-Flood Inspections;</li> <li>Visual Audits.</li> </ul> <p>Reliable but with risk of Operators suffering from minor to moderate injuries.</p>
✗	<p><b>Unacceptable</b></p> <p>Minimal safety features present. Floor gratings missing. Questionable stability (e.g. no intermediate piers). Undermining of platform piers on bank. Structural members observed to be unlevel, leaning, bending, buckling, loosening, etc. Platform and floodgate on the verge of collapse.</p>		Imminent complete destruction of platform which would destroy floodgate and result in loss of lives.	←	----	Redesign and reconstruct entire structure to ensure safe access to floodgate immediately.	<p>Must be monitored and maintained frequently as instability can cause injuries and internal flooding:</p> <ul style="list-style-type: none"> <li>General Inspections;</li> <li>Operational (annual) Inspections;</li> <li>Pre-Flood Inspections;</li> <li>Visual Audits.</li> </ul> <p>Unreliable (high risk of fatalities)</p>

Description of Potential Risk and Assessment of Severity of Risk Issue	Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks
	Short Term	Long Term				
<p>12.3 Trip Hazards</p> <p><b>Acceptable</b></p> <p>Absence of any solid items protruding &gt; 5 mm and &lt; 900 mm (AS 1657).</p> <p>Crest of floodgate structure flushed with ground access surface.</p> <p>Presence of hand / guardrails to advise and prevent tripping.</p> <p>Specific structures (e.g. sheet pile wall) installed at ≥ 900 mm height to eliminate trip hazard.</p>	---	---	---	---	<ul style="list-style-type: none"> <li>Operational (annual) Inspections as a minimum;</li> <li>Pre-Flood Inspections;</li> <li>Visual Audits.</li> </ul>	No issues








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Description of Potential Risk and Assessment of Severity of Risk Issue	Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks	
	Short Term	Long Term					
<p><b>Marginal</b></p> <p>Presence of minor trip items (&lt; 100 mm) that may not be obvious on levee and broken / displaced parts of appurtenant structures (e.g. floor gratings, unloaded retaining structures).</p> <p>Absence of hand / guardrails to advise and prevent tripping for features that cannot be levelled out flat.</p>	  	<p>Minor to moderate trip and fall injuries.</p>	<p>←</p>	<p>---</p>	<p>Level out the surfaces as soon as possible.</p>	<p>Must be monitored and maintained frequently as trips can injure Operators and public;</p> <ul style="list-style-type: none"> <li>• General Inspections;</li> <li>• Operational (annual) Inspections;</li> <li>• Pre-Flood Inspections;</li> <li>• Visual Audits.</li> </ul>	<p>Reliable (marginal for some cases) but with risk of Operators suffering from minor to moderate injuries.</p>

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Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks
		Short Term	Long Term				
<p><b>Unacceptable</b></p> <p>✘ Obvious major trip hazards of any temporary / permanent solid structural items up to 900 mm in height that cannot be levelled out.</p>		<p>Moderate to major trip and fall injuries.</p>	<p>←</p>	<p>Specific safety and / or structural review may be required.</p>	<p>Install hand / guardrail protection or steps if through access is required immediately.</p>	<p>Must be monitored and maintained frequently as trips can injure Operators and public;</p> <ul style="list-style-type: none"> <li>• General Inspections;</li> <li>• Operational (annual) Inspections;</li> <li>• Pre-Flood Inspections;</li> <li>• Visual Audits.</li> </ul>	<p>Unreliable (high risk of moderate injuries)</p>
							
<p>12.4</p>	<p><b>Fall Hazards</b></p> <p>WHS Regulations 291: 18 High Risk Work Activities – Item 1 considers the potential of a person falling more than 2 m to be a “high-risk activity”. However, the risk of non-fatal injuries (e.g. rolling / twisting of ankle / wrist, broken limbs and unconsciousness due to head knock) remains present from falling from heights less than 2 m. Levee owners should act in accordance to the regulation to eliminate / mitigate all risks according to the ALARP principle.</p>						
<p>✔</p>	<p><b>Acceptable</b></p> <p>Direct vertical elevation drop ≥ 300 mm (culvert floodgate structures, flood barrier road crossings, etc.) protected with hand / guardrails or man proof fencing to prevent falling or steps provided in accordance with AS 1657.</p>		<p>---</p>	<p>---</p>	<p>---</p>	<p>---</p>	<ul style="list-style-type: none"> <li>• Operational (annual) Inspections as a minimum;</li> <li>• Pre-Flood Inspections;</li> <li>• Visual Audits.</li> </ul> <p>No issues</p>



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Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks
		Short Term	Long Term				
							
±	<p><b>Marginal</b></p> <p>Direct vertical elevation drop &lt; 900 mm (culvert floodgate structures, flood barrier road crossings, etc.) not protected with hand / guardrails or man proof fencing to prevent falling or no steps provided in accordance with <u>AS 1657</u>.</p> <p>In some cases, could also be considered 'unacceptable' trip hazard.</p>	 	<p>Fall from crest of structure resulting in minor to moderate injuries.</p>	<p>←</p> <p>Specific safety and / or structural review may be required.</p>	<p>Install hand / guardrail protection or steps as soon as possible.</p>	<p>Must be monitored and maintained frequently as falls can injure Operators and public:</p> <ul style="list-style-type: none"> <li>• General Inspections;</li> <li>• Operational (annual) Inspections;</li> <li>• Pre-Flood Inspections;</li> <li>• Visual Audits.</li> </ul>	<p>Unreliable (high risk of minor injuries)</p>

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Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks	
		Short Term	Long Term					
✘	<p><b>Unacceptable</b></p> <p>Direct vertical elevation drop &gt; 900 mm (culvert floodgate structures, flood barrier road crossings, etc.) not protected with hand / guardrails or man proof fencing to prevent falling or no steps provided in accordance with <u>AS 1657</u>.</p>		<p>Fall from crest of structure resulting in moderate to major injuries.</p>	<p>←</p>	<p>Specific safety and / or structural review may be required.</p>	<p>Install hand / guardrail protection or steps immediately.</p>	<p>Must be monitored and maintained frequently as falls can injure Operators and public:</p> <ul style="list-style-type: none"> <li>• General Inspections;</li> <li>• Operational (annual) Inspections;</li> <li>• Pre-Flood Inspections;</li> <li>• Visual Audits.</li> </ul>	<p>Unreliable (high risk of major injuries)</p>
12.5	<p><b>Confined Spaces</b></p> <p>“Confined Spaces” is not specific for pits and shafts. Its full description is defined in AS 2865.</p>							
✔	<p><b>Acceptable</b></p> <p>Confined spaces with the presence of designated entry and exit points. Adequately covered / closed and locked to prevent accidental / unauthorised access.</p> <p>Operators are appropriately trained for entry (confined space entry permit) and possess adequate contemporary safe entry equipment such as:</p> <ul style="list-style-type: none"> <li>• Tripods with winches.</li> <li>• Body harnesses.</li> <li>• Breathing apparatus.</li> <li>• Portable firefighting equipment.</li> <li>• Gas detection devices.</li> </ul>		<p>---</p>	<p>---</p>	<p>---</p>	<p>---</p>	<ul style="list-style-type: none"> <li>• Operational (annual) Inspections as a minimum;</li> <li>• Pre-Flood Inspections;</li> <li>• Visual Audits.</li> </ul>	<p>No issues</p>



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Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks
		Short Term	Long Term				
							
±	<p><b>Marginal</b></p> <p>Entry / exit to the confined space unlocked.</p> <p>Operators' training and safe entry equipment outdated or not adequately available.</p>	Insert Photo	Cannot enter into the confined space for O&M. Potential fatalities if accessed by the public.	←	---	<p>Lock entry / exit points immediately. Update training course and obtain new entry equipment immediately.</p> <p>When locked and training / equipment updated:</p> <ul style="list-style-type: none"> <li>Operational (annual) Inspection as a minimum;</li> <li>Pre-Flood Inspections;</li> <li>Visual Audits.</li> </ul>	Unreliable (moderate risk of fatalities)

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		Short Term	Long Term					
✘	<p><b>Unacceptable</b></p> <p>Confined spaces with no designated entry / exit points. Entry / exit points uncovered and accessible by the public.</p> <p>Operators have no training and no safe entry equipment.</p>	Insert Photo	Cannot enter into the confined space for O&M. Potential fatalities for Operators and the public.	←	Stability analysis of confined space structure may need to be undertaken, especially if structure is in excess of 15 years old.	Install lockable cover and / or closing mechanism immediately. Obtain training and entry equipment immediately.	When lockable access installed and training / equipment obtained: <ul style="list-style-type: none"> <li>• General Inspections;</li> <li>• Operational (annual) Inspections;</li> <li>• Pre-Flood Inspections;</li> <li>• Visual Audits.</li> </ul>	Unreliable (high risk of fatalities)
✔	<p><b>Acceptable</b></p> <p>No dangerous protrusion of any items (permanent or damaged levee features).</p> <p>Protection provided for protruding items that cannot be eliminated.</p> <p>Top example photo: Floodgate's rising spindle protected with cover tube.</p> <p>Bottom example photo: Sheet pile crest protected with appropriate capping.</p>	 	---	---	---	---	<ul style="list-style-type: none"> <li>• Operational (annual) Inspection as a minimum;</li> <li>• Pre-Flood Inspections;</li> <li>• Visual Audits.</li> </ul>	No issues



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Description of Potential Risk and Assessment of Severity of Risk Issue		Potential Consequences		Details of any further investigations required	Possible rectification and prioritisation	Monitoring Program (if marginal risk only)	Assessment of Reliability of levee with Current Risks
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±	<p><b>Marginal</b></p> <p>Protruding object obvious but not eliminated / protected.</p> <p>Example photo: Floodgate's rising spindle not protected and would be in close proximity to operator's head when turning the handwheel.</p>	←		Specific safety and / or structural review may be required.	Eliminate the protrusion or install protection to prevent contact with the protrusion as soon as possible.	<p>When protrusion eliminated / protected:</p> <ul style="list-style-type: none"> <li>Operational (annual) Inspection as a minimum;</li> <li>Pre-Flood Inspections;</li> <li>Visual Audits.</li> </ul>	<p>Reliable (providing that e.g. the appurtenant structure is still operable) but with risks of injuries to Operators and public.</p>
✘	<p><b>Unacceptable</b></p> <p>Protruding object not obvious and not eliminated / protected.</p> <p>Example photo: Short sharp sheet pile crest edge exposed.</p>	←		Specific safety and / or structural review may be required.	Eliminate / protect protrusion immediately.	<p>When protrusion eliminated / protected:</p> <ul style="list-style-type: none"> <li>General Inspections;</li> <li>Operational (annual) Inspections;</li> <li>Pre-Flood Inspections;</li> <li>Visual Audits.</li> </ul>	<p>Unreliable (high risk of major injuries)</p>

