Waterbody Management Guideline

Module 4

Maintenance and Operations

VERSION 1 SEPTEMBER 2013

waterbydesign

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- Colin Bridges and Mike Jacques (Gold Coast City Council)
- Kate MacKenzie and Julian Wakefield (Sunshine Coast Council)
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Thank you to all involved for providing much more than content – the leadership, collaborative spirit and vision of the team, lead by Redland City Council, has resulted in a guideline that is a regionally significant contribution to sustainable waterbody management practice.

Redland CITY COUNCIL

Contents

List Of Figures

List Of Tables

4.1 INTRODUCTION

4.1.1 Purpose of module 4

The purpose of this module, *'Maintenance and Operations',* is to assist local government maintenance officers and asset managers to undertake on-ground works to maintain, rectify and where necessary remove waterbodies. It is designed primarily for local government managed waterbodies but the technical information can be applied to waterbodies managed by other entities. This module provides information on common waterbody issues, including how to investigate, identify and resolve issues. The information can be used by all mangers of waterbodies.

4.1.2 How to use module 4

This module contains four key sections (Figure 4.1).

Figure 4.1 How to use module 4

Section 4.2	
Scheduling Inspections and Maintenance	This section discusses how to schedule maintenance actions and inspections for waterbodies.
Section 4.3	
Identifying Issues and Selecting Actions	This section discusses the key problems that may occur within waterbodies and outlines methods to investigate, monitor, manage and rectify problems.
Section 4.4	
Management Actions	This section describes how to undertake key waterbody specific management actions.
Section 4.5	
Worked Example	This section uses a hypothetical example to demonstrate the waterbody management and maintenance processes outlined in this module.

4.2 SCHEDULING INSPECTIONS AND MAINTENANCE

Proactive maintenance usually involves activities that are simple to perform. These activities could include weeding and removing litter and debris. Activities that require specialised equipment or skills such as removing sediment may require a return trip to the waterbody with the appropriate equipment or personnel.

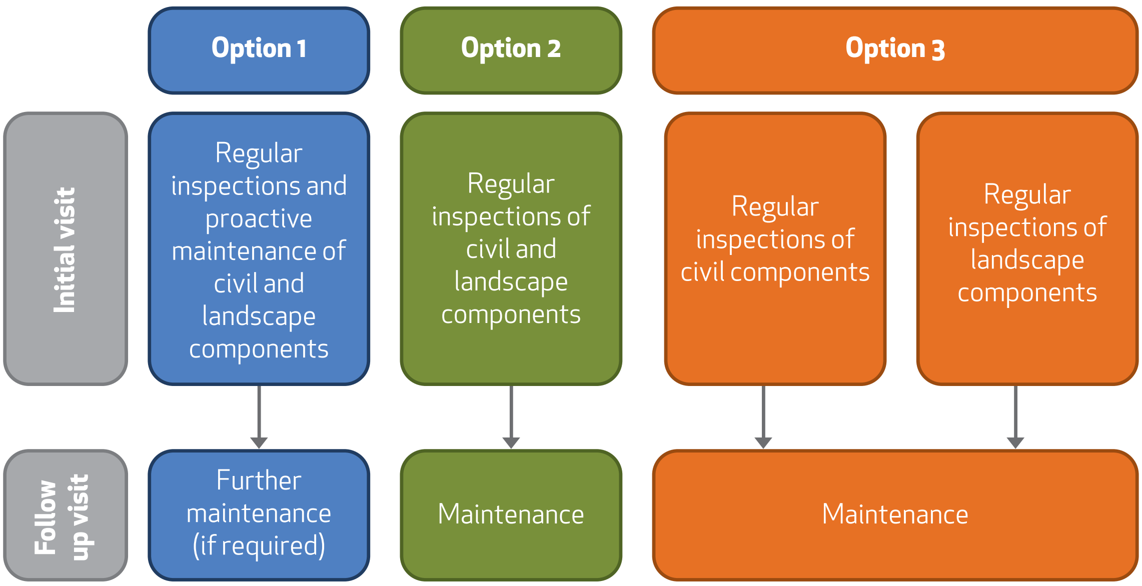
Ongoing, regular inspections and proactive maintenance can be scheduled in a number of different ways (Figure 4.2).

- Option 1 – Undertake regular inspections and proactive maintenance of both civil and landscaping components of the waterbody. If issues are identified during these inspections that cannot be completed with the equipment at hand then return to the waterbody with the appropriate equipment to resolve issue.
- Option 2 – Undertake regular inspection of both civil and landscaping components of waterbody. Return to the waterbody later to then complete all maintenance.
- Option 3 – Undertake regular but separate inspections of civil and landscaping components of the waterbody. Return to the waterbody later to then complete all maintenance.

The method chosen will depend upon the resources and internal structure of the local government.

The frequency with which inspections and maintenance are carried out on waterbodies depends on the season, recent rainfall, the landuse within the catchment, and any short term activities occurring within the catchment (e.g. earthworks). Inspections and maintenance of waterbodies should be regular. Proactive maintenance prevents problems from developing within waterbodies and ultimately saves money. Inspection frequencies should be increased during the wet season and in response to catchment pressures such as landuse change.

Figure 4.2 Options for undertaking inspections and maintenance



4.3 IDENTIFYING ISSUES AND SELECTING ACTIONS

When maintaining and operating waterbodies, asset managers are often required to identify, then respond to specific issues. Being able to easily identify issues, the cause of those issues and take appropriate management action is vital to how easily, quickly and cost effectively those issues are resolved. This section provides a comprehensive list of issues which have been grouped into one of five categories, namely:

- health and safety (Section 4.3.1)
- water quality (Section 4.3.2)
- profile and amenity (Section 4.3.3)
- engineering and hydraulic function (Section 4.3.4)
- flora and fauna (Section 4.3.5).

For each category a table is provided (amended from DesignFlow, 2012 and Limnologic, 2012) which describes common waterbody issues, helps the user identify each issue and provides appropriate management and rectification responses. Photographs are provided to help to identify the issues. Be aware that some waterbody issues may affect topics covered by more than one table. Be sure to check each table before undertaking management or rectification.

4.3.1 Health and safety

In certain circumstances waterbodies can be a risk to human health and safety. They are often located in close proximity to places where people live, work and recreate. Asset managers are often required to deal with waterbody issues which present a health and safety risk to the community.

Health and safety issues in waterbodies include:

- injury or drowning
- mosquitoes
- polluted water
- structural integrity

Table 4.1 expands on each of the above issues, detailing:

- methods to investigate and monitor each issue
- management actions – actions that can be implemented rapidly and cost effectively
- rectification actions – actions that require planning, design and budget to implement
- relevant supporting information.

Figures 4.3 to 4.7 provide photographs to help with identifying different health and safety issues.

Table 4.1 Waterbody health and safety issues and associated management and rectification actions

Issue – Risk of injury or drowning			
Description	**Investigations/ monitoring**	**Management actions**	**Rectification actions**
Potential safety issues (e.g. drowning) may be due to: • steep waterbody batters • lack of edge barriers • lack of perimeter vegetation • lack of a safety bench	Discuss with asset owner to identify and document any issues. Undertake desktop review and initial site inspection. Undertake risk assessment.	If risk is deemed unacceptable the following actions should be considered: • Install temporary protection (temporary fencing) to exclude public entry. • Erect signage to highlight risk to public and that a response is being identified.	Rectification actions will depend on the scale, type and degree of risk. Actions may include: • planting waterbody batters with dense vegetation (emergent and terrestrial) to restrict access • installing edge barriers such as balustrades and kick rails along pathways and erect permanent fencing where risk of access is high • modifying the waterbody edge to provide safe batters above and below the water level (a maximum batter slope of 1:4 is recommended and/or a 1:8 safety bench below the water level) • reducing the depth of the waterbody, particularly around the edges • where the waterbody is located near areas highly used by children (i.e. children's playground), consider moving the area to another part of the parkland. Refer to *Rectifying Vegetated Stormwater Assets* – Appendix B (Water by Design, 2012b) for additional guidance on the design of the approaches to and the area immediately below permanent water.
Relevant supporting information Water by Design (2012b)			

Issue – Human health risk due to large mosquito populations			
Description	**Investigations/monitoring**	**Management actions**	**Rectification actions**
The presence of large mosquito populations represents both a potential human health risk (as mosquitoes transmit many pathogens including protozoa, nematodes and viruses) and a nuisance to local residents.	Discuss safety with asset owner and environmental health department to identify and document any issues. Undertake site inspection to check for evidence of mosquito breeding sites around the margins of the waterbody and also in any isolated shallow pools in the near vicinity. Check for evidence of litter which may support mosquito breeding. Undertake risk assessment. Record whether or not: • the mosquito problem is associated with the waterbody (or the surrounding ecosystems) • simple management actions can be implemented to reduce populations • a mosquito control plan should be prepared and rectification actions implemented. Where a mosquito control plan is required then an audit of the mosquito species and population density both within waterbody and adjacent habitats is required.	Simple management actions may include: • implementing a regular litter removal program • spraying with ecologically friendly larvicides (Seek advice from environmental health experts within local government if the use of chemical control agents is deemed necessary. Not recommended as a long term strategy due to insecticide resistance, cost and possible inability to apply to all areas).	Where rectification is required, a mosquito control plan should be prepared in accordance with the *Mosquito Management Code of Practice for Queensland* (Local Government Association of Queensland, 2002) Rectification options may include: • draining isolated pockets of pooled water • filling in uneven areas where stagnant water accumulates • increasing depth in open water areas to >60 cm to limit mosquito breeding • increasing the slope of submerged batters (see 'Risk of injury or drowning' in this table for further discussion of waterbody batter slope) • increasing the diversity of plants (both emergent and submerged) in the waterbody • improving waterbody circulation and flushing • introducing mosquito predators (native fish).
Relevant supporting information Local Government Association of Queensland (2002),Queensland Health (2002), Water by Design (2012a), Water by Design (2012b)			

Issue – Health risks due to human contact with polluted water			
Description	**Investigations/ monitoring**	**Management actions**	**Rectification actions**
Potential health risks may exist where public have direct access to water contaminated with chemicals, faecal matter or cyanobacteria. Certain types of cyanobacteria can release toxins when they die that affect the liver or nervous system of animals and humans. This can be a major public health issue. In addition, all cyanobacteria contain toxins within their cell walls that can cause skin irritations and allergic responses in human skin tissue from direct contact with the cells.	Discuss waterbody contamination history with the asset owner, engineering and environmental health departments to identify and document any issues. Undertake desktop review, site inspection and risk assessment. Detailed investigations will depend on the nature of the contamination. Refer to 'Algal or cyanobacterial blooms', 'Chemical contamination' or 'Faecal and/or nutrient contamination' in Table 4.2.	Where contamination is reported, the relevant agency should be notified and monitoring/ management completed in accordance with DERM (2009) and NHMRC (2008). Management actions will be guided by monitoring outcomes but may include: • installing of temporary protection (e.g. temporary fencing to exclude public entry) • erecting signage to highlight risk to public and that a response is being identified • community consultation • clean-up/treatment or adaptive management as required. For ongoing management actions, refer to 'Algal or cyanobacterial blooms', 'Chemical contamination' or 'Faecal and/or nutrient contamination' in Table 4.2.	Refer to 'Algal or cyanobacterial blooms', 'Chemical contamination' or 'Faecal and/ or nutrient contamination' in Table 4.2.
Relevant supporting information			
DERM (2009), NHMRC (2008), WHO (1999)			

Issue – Structural integrity			
Description	**Investigations/ monitoring**	**Management actions**	**Rectification actions**
Structural integrity of waterbodies pertains to the failure (e.g. collapse) of a wall or embankment. Failure of a wall or embankment can put downstream communities and infrastructure at risk.	Discuss with asset owner and engineering department to identify and document any issues. Undertake desktop review, initial site inspection and risk assessment. Seek specialist engineering advice.	The management actions undertaken will depend on the cause and risk posed by the structural issues.	If the risk is deemed unacceptable, actions to rectify the structural issues must be undertaken. The actions undertaken will depend on the cause and risk posed by the structural issue. Actions may include: • removing the waterbody • replacing part or all of the waterbody wall or embankment • converting or redesigning the waterbody.
Relevant supporting information			
Nil			

Figure 4.3 A waterbody with vertical batters

Photo: Julian Wakefield, Sunshine Coast Council

Figure 4.4 A waterbody with easy access to water's edge, and a lack of perimeter vegetation

Photo: Colin Bridges, Gold Coast City Council

Figure 4.5 A waterbody with low lying adjacent areas likely to pond water after high rainfall

Photo Karen Waite, Moreton Bay Regional Council

Figure 4.6 A waterbody with a cyanobacterial bloom

Photo: Karen Waite, Moreton Bay Regional Council

Figure 4.7 Chemical contamination entering a waterbody

Photo: Colin Bridges, Gold Coast City Council

4.3.2 Water quality

The water quality in a waterbody is a function of the characteristics of the waterbody itself and the water flows into and out of the waterbody as well as the inputs to the waterbody from the catchment. Waterbodies with good water quality function well and have few management requirements. Conversely waterbodies with poor water quality can present a risk to human health, cause fish kills and aesthetic issues and have adverse downstream impacts. Waterbodies with poor water quality are an ongoing management burden to local governments. When assessing a waterbody for water quality issues it is important to understand the natural water quality characteristics of the waterbody. For example, some waterbodies have naturally high turbidity levels or may naturally exhibit variable salinity. Understanding the natural water quality of the waterbody will help guide appropriate management of that waterbody.

The following can cause water quality issues:

- algal or cyanobacterial blooms
- chemical contamination
- persistent high turbidity levels
- presence of exotic fish species
- faecal and/or nutrient contamination
- variable salinity
- stratification and low dissolved oxygen.

Table 4.2 expands on each of the above indicators, detailing:

- methods to investigate and monitor each issue
- management actions – actions that can be implemented rapidly and cost effectively
- rectification actions – actions that require planning, design and budget to implement
- relevant supporting information.

Figures 4.8 to 4.10 provide photographs to help with identifying different water quality issues.

Table 4.2 Waterbody water quality issues and associated management and rectification actions

Issue – Algal or cyanobacterial blooms			
Description	**Investigations/ monitoring**	**Management actions**	**Rectification actions**
Algal and cyanobacterial blooms are indicators of poor water quality and aquatic health within a waterbody system. While most species of algae (e.g. green algae and diatoms) are not dangerous to humans or animals, some may reduce aesthetic values through changes in water colour, odours and surface scum. The presence of persistent cyanobacterial/algal biomass may be due to a range of factors, including: • untreated stormwater inflows • nutrient released from the sediments • excessive waterbody residence times • high internal carbon (organic) loading (i.e. resulting from decay of aquatic weeds such as Salvinia) • low submerged or emergent macrophyte cover • excessive waterbird population • rapid variations in salinity • high turbidity levels.	Discuss algal and cyanobacterial issues with asset owner, engineering and environmental health departments to identify and document any historical issues. Undertake desktop review, site inspection and risk assessment. Further assessment is only required if persistent blooms are recorded and if the asset owner considers it necessary to obtain a more detailed understanding of waterbody processes to inform rectification. This may include monitoring for the following parameters: • chlorophyll-a, total phosphorus, soluble phosphorus, total nitrogen and nitrate-N • temperature, redox, salinity, pH and dissolved oxygen depth profiles at a number of locations • cyanobacterial identification and counts • cyanobacterial toxin concentrations (i.e. where counts exceed the red alert level).	If cyanobacterial/algal risks are deemed unacceptable, a specialist should be consulted to develop a monitoring program and implement an adaptive management framework in accordance with DERM (2009) and NHMRC (2008). Management actions will be guided by monitoring outcomes but may include: • contacting relevant agencies • restricting access to the waterbody (e.g. installing temporary fencing) • erecting signage to highlight risk to public and that a response is being identified • isolating waterbody to minimise downstream risks (e.g. blocking outlets) • community consultation • treatment (e.g. algaecides) • phosphorus management (e.g. Phoslock®) • netting or raking of filamentous algae. Immediate actions are not generally required for managing harmless algal blooms. However, long term rectification actions may be necessary to improve aesthetic values and aquatic habitat condition (refer to rectification actions).	The rectification actions will be resolved as part of the waterbody investigations. Potential rectification responses to persistent algal or cyanobacterial blooms include: • installation of stormwater treatment system in the upstream catchment to remove pollutants prior to entering the waterbody • removal of the waterbody sediments • resetting part or all of the waterbody system as a wetland • installing water recirculation system (e.g. wetland, sand filter) to deplete algal biomass and nutrient loading within the waterbody • configuring waterbody to receive flushing flows • installing floating wetlands to manage nutrients and turbidity • planting the waterbody with emergent and submerged vegetation. If cyanobacterial toxin concentrations exceed the primary contact recreation Water Quality Objectives, (WQO. DERM, 2009) powdered activated carbon dosing may be required (note that specialist advice should be sought before this action is undertaken).
Relevant supporting information			
DERM (2009), NHMRC (2008), WHO (1999)			

Issue – Chemical contamination			
Description	**Investigations/ monitoring**	**Management actions**	**Rectification actions**
The presence of chemical contamination may be indicated by: • obvious discolouration of the water within the waterbody (e.g. orange, red, grey) • chemical residues floating on the surface of the waterbody (e.g. oily scum) • fish kills.	Discuss with asset owner, engineering and environmental health departments to identify and document any historical issues. Undertake desktop review of potential contamination sources (e.g. proximity to environmental relevant activities) and site inspection. Undertake risk assessment.	Suspected contamination by toxic chemicals should be reported immediately to the relevant state government department. If toxic chemicals are found at levels which exceed the relevant WQOs (DERM, 2009) an adaptive management program should be implemented in accordance with the risk assessment framework set out in NHMRC (2008). Management actions may include: • contacting relevant agencies • restricting access to the waterbody (e.g. installing temporary fencing) • erecting signage to highlight risk to public and that a response is being identified • isolating waterbody to minimise downstream risks (e.g. blocking outlets) • installing floating booms • community consultation • treatment or adaptive management as required.	Cleanup of spills should be conducted with advice from the relevant state government department and an appropriate specialist as required, in accordance with the NHMRC (2008) risk assessment framework. The rectification actions will be resolved as part of the waterbody investigations. Potential rectification responses may include: • installing stormwater treatment systems in the upstream catchment to remove pollutants prior to entering the waterbody • installing valves at inlets to isolate inflows • installing permanent floating booms at inlets • redesigning the waterbody system as a treatment wetland.
Relevant supporting information NHMRC (2008)			

Issue – Persistent high turbidity levels			
Description	**Investigations/monitoring**	**Management actions**	**Rectification actions**
Excessive turbidity, total suspended solids or total dissolved solids can smother aquatic habitats and reduce sunlight penetration. This can provide conditions favourable to algal growth (gas-vacuolate cyanobacteria and flagellated algae) and invasion by exotic species (e.g. carp, tilapia) that have competitive advantages in turbid waters.	Discuss with asset owner and engineering department to identify and document any current or historical issues. Undertake desktop review and site inspection. Record turbidity level in situ using a water quality probe. Further monitoring during both wet and dry weather may be required if potential sediment sources are identified. Undertake risk assessment. If turbidity levels within the waterbody consistently exceed the relevant Water Quality Objectives (1-20NTU for the protection of moderately disturbed freshwaters) in DERM (2009), then further investigation may be required to determine the source/s of the high turbidity (e.g. development sites, stormwater inflows, sediment resuspension) and to consider other catchment management solutions.	Treatment of persistent high turbidity levels will not normally require any ongoing management actions (investigations will either show the risk to be acceptable, or require rectification be undertaken) – refer to rectification	Rectification actions will be dictated by the field investigations and whether or not the risk is identified by the asset owner as acceptable. Rectification actions may include: • establishing and maintaining healthy submerged and emergent macrophytes within the waterbody • establishing and maintaining healthy riparian vegetation on waterbody margins • repairing areas of bank erosion and revegetating using endemic species • stormwater treatment within the upstream catchment (e.g. providing additional sediment capture upstream of waterbody such as sediment basins and sand filters) • installing floating wetlands within the waterbody • managing runoff from construction sites in accordance with legislative requirements and IECA Australasia (2008) • removing exotic fish species (such as Carp) • replacing topsoil used within the waterbody (refer AS4419, 2003) • repairing areas of the waterbody where the clay liner has been exposed.
Relevant supporting information			
AS4419 (2003)			

Issue – Presence of exotic fish species			
Description	**Investigations/monitoring**	**Management actions**	**Rectification actions**
Exotic fish species (e.g. European carp, tilapia, mosquito fish, goldfish) are generally able to tolerate a wide range of water quality and environmental conditions, and so have a competitive advantage over many native fish species. Exotic fish contribute to the deterioration of water quality through sediment resuspension (bottom feeders), habitat destruction/ fragmentations and increased internal loading of nutrients.	Discuss with asset owner, engineering and environmental health departments to identify and document any current or historical issues. Undertake desktop review, initial site inspection and risk assessment Depending on the outcomes of the risk assessment, the asset owner may wish to undertake a fish survey to determine the native and exotic fish population, biomass and size distribution present. (Note: The capture, removal or destruction of fish is governed by strict ethical considerations and should only be undertaken by qualified staff, in accordance with NHMRC (2004) and with relevant permits obtained from the Queensland Department of Agriculture, Fisheries and Forestry (DAFF)).	The presence of exotic fish species will not normally require any ongoing management actions – refer to rectification	If the risk is deemed unacceptable, rectification actions to reduce/ eliminate the invasion of exotic fish species may include: • trapping and removal of pest species in accordance with NHMRC (2004) • reconfiguring waterbody for regular dewatering/fish management. This may include installation of fish barriers at inlet zones to waterbodies • improving aquatic habitat conditions to encourage recruitment and breeding of native species. This may include establishing and maintaining healthy submerged and emergent macrophytes, installing artificial habitat structures and introducing large woody debris (re-snagging) • implementing a native fish stocking program • improving hydraulic connectivity of on-river waterbodies (where possible) by modifying/replacing existing inlet/outlet structures to provide for suitable upstream passage of native fish and other aquatic organisms • improving water quality conditions.
Relevant supporting information NHMRC (2004), DAFF (2013b)			

Issue – Faecal and/or nutrient contamination			
Description	**Investigations/ monitoring**	**Management actions**	**Rectification actions**
Contamination of the waterbody by faecal microorganisms and nutrients may be due to: • large wildlife populations (e.g. birds, bats, possums) on or adjacent to the waterbody • untreated sewage entering the waterbody via stormwater inflows • leakage of septic systems into groundwater, surface water or stormwater • diffuse runoff from surrounding landuses, particularly areas with high concentrations of domestic animals (e.g. dogs, cats, cattle, sheep, pigs, poultry) • internal nutrient loading from the sediments. The presence of faecal contamination is often difficult to detect, however may be indicated by: • obvious discolouration of the waterbody water (e.g. grey, blue-grey) • unusual foaming on the surface of the waterbody, especially at inflow sites • unusual water odours (e.g. effluent).	Discuss with asset owner, engineering and environmental health department to identify and document any current or historical issues. Undertake desktop review, initial site inspection and risk assessment. Depending on the outcomes of the risk assessment, the asset owner may wish to undertake additional site surveys and/ or implement a water quality monitoring program in accordance with NHMRC (2008).	If faecal contamination is found at levels which exceed the relevant Water Quality Objectives (DERM, 2009) an adaptive management program should be implemented in accordance with the risk assessment framework set out in NHMRC (2008). Management actions may include: • contacting relevant agencies • restricting access to the waterbody (e.g. installing temporary fencing) • erecting signage to highlight risk to public and that a response is being identified • isolate waterbody to minimise downstream risks (e.g. block outlets) • community consultation • routine inspections and maintenance of existing dog waste bins • re-use or drawdown of water level to prevent accumulation of contaminants • treatment or adaptive management as required.	If the risk is deemed unacceptable, rectification actions may include: • removing, moving on or culling waterfowl from the waterbody system (permit may be required) • treating contamination sources from the catchment, including illegal sewer connections to drainage system, sewage treatment plan overflows, stormwater, on-site septic systems • treatment or containment of drainage from intensive agriculture and industry • signage, public education programs and behaviour change programs • installing and maintaining dog or domestic animal waste bins • installing floating wetlands to manage nutrients • repairing leaking sewer pipes.
Relevant supporting information NHMRC (2008), DERM (2009)			

Issue – Variable salinity			
Description	**Investigations/monitoring**	**Management actions**	**Rectification actions**
Brackish waterbodies which experience large variations in salinity should be avoided. For freshwater waterbody systems, large fluctuations in salinity levels may provide conditions that are unfavourable for submerged macrophytes and favour algae (particularly cyanobacteria). Increased salinity within freshwater waterbodies may be due to: • tidal intrusion of saline water into the waterbody • saline groundwater flowing into the waterbody • contamination from upstream landuses (e.g. industrial, agricultural) via stormwater inflows or diffuse runoff.	Discuss with asset owner and engineering department to identify and document any current or historical issues. Undertake desktop review, initial site inspection and risk assessment. Refer to Appendix G of the *Queensland Water Quality Guidelines* (DERM, 2009) to determine acceptable variations in salinity. Depending on the outcomes of the risk assessment, the asset owner may wish to undertake additional site surveys and/or implement a monitoring program including monitoring electrical conductivity both after rain and during long dry periods to observe changes in salinity. For freshwater waterbodies, electrical conductivity levels of >1500 mg/L pose an immediate risk to aquatic plants. For saline waterbodies, the risk of cyanobacterial blooms increases where electrical conductivity is <10 000 mg/L. Refer to the *Townsville Constructed Lakes Design Guidelines* (DesignFlow, 2010) for guidance on additional investigations to determine the source of the saline/ freshwater intrusion.	Variable salinity will not normally require any ongoing management actions – refer to rectification	If the risk of variable salinity is deemed unacceptable, rectification actions should be undertaken. If observations during large tide events and salinity monitoring confirm tidal backwatering into the waterbodies, consider: • raising the water level within the waterbody so that saline water cannot enter through the waterbody outlet. This will require modifying the configuration of the outlet structure. Upstream flooding impacts should be considered • installing a backflow preventing device on the outlet pipe to the downstream saline environment • raising bund levels to prevent tidal backwatering. If saline groundwater intrusion is evident within the waterbody and vegetation health is obviously impacted, it may be necessary to replace or repair the waterbody liner. Alternative options include: • trenching along the waterbody batter and placing a clay or bentonite barrier across the groundwater intrusion site • replanting the waterbody with saline or brackish tolerant plant species (note: there is an increased risk of mosquitoes in saline/brackish waters which will need to be monitored). Refer to 'Human health risk due to large mosquito populations' in Table 4.1 • raising operational water levels to create a hydraulic barrier and prevent groundwater flows entering the waterbody. If other catchment sources are suspected, contact the relevant state government department to investigate potential sources of contamination.
Relevant supporting information			
DERM (2009), DesignFlow (2010)			

Issue – Stratification and low dissolved oxygen			
Description	**Investigations/ monitoring**	**Management actions**	**Rectification actions**
Water column stratification may be present due to a range of factors including: • excessive water depth (>2.5 m) – although stratification can occur in highly eutrophic waterbodies less than 1 m deep • high surface water temperatures • elevated salinity in freshwater waterbody systems • freshwater inflows to saline waterbodies • elevated organic carbon, nutrient and sediment loading • long residence times or lack of wind mixing • low or absent cover of submerged or emergent aquatic macrophytes • unsuitable waterbody configuration/orientation. One of the major concerns associated with stratification is dissolved oxygen depletion. This may result in the release of dissolved (bioavailable) nutrients from the waterbody sediment which encourages algae and floating weed growth. Low dissolved oxygen concentrations are also a major cause of fish kills and sediment odour problems.	Discuss with asset owner, engineering and environmental health departments to identify and document any current or historical issues. Undertake desktop review, initial site inspection and risk assessment. Depending on the outcomes of the risk assessment, the asset owner may wish to undertake additional monitoring to determine the spatial extent and duration of stratification. This will involve regularly monitoring electrical conductivity, water temperature, dissolved oxygen, pH and redox potential through the entire water column at several locations throughout the waterbody system. (Note: as dissolved oxygen concentrations vary considerably throughout the day due to the process of respiration and photosynthesis it is recommended that monitoring is undertaken at multiple times during the day)	Intermittent stratification will not normally require ongoing management actions – refer to rectification for management of persistent stratification. Re-use or drawdown of water level may help prevent stratification.	If the risk of persistent stratification is deemed unacceptable, rectification actions may include: • installing mixing systems such as aerators and water pumps • modifying waterbody bathymetry to improve hydraulic efficiency and wind forced mixing (e.g. infilling backwater, moving inlet/ outlet structures, targeted planting, removal of clumped vegetation to promote longer flow paths, removal of islands, dredging) • establishment and management of healthy riparian vegetation on waterbody margins to improve shading and reduce sources of diffuse runoff • removing or treating (e.g. Phoslock ®) the waterbody sediments (refer to 'Fine sediment or organic matter accumulation' in Table 4.4) • installing stormwater treatment systems in the upstream catchment to remove pollutants before they enter the waterbody • installing floating wetlands to reduce surface water temperatures.
Relevant supporting information			
Nil			

Figure 4.8 A waterbody with an algal bloom

Photo: Karen Waite, Moreton Bay Regional Council

Figure 4.9 Chemical contamination of a waterbody

Photo: Leo Newlands, Redland City Council

Figure 4.10 A waterbody with high turbidity

Photo: Julian Wakefield, Sunshine Coast Council

4.3.3 Profile and amenity

Waterbodies are often located in close proximity to places where people live, work and recreate, and can greatly increase the amenity of surrounding areas (Figure 4.11). Waterbodies can however develop issues that reduce local amenity. When waterbodies are located in high profile areas, the public often expect these issues to be rapidly rectified. Waterbody amenity can be impacted by issues such as:

- algal/cyanobacterial blooms
- weeds and pests
- offensive odours
- litter.

Table 4.3 expands on each of the above issues, detailing:

- methods to investigate and monitor each issue
- management actions – actions that can be implemented rapidly and cost effectively
- rectification actions – actions that require planning, design and budget to implement
- relevant supporting information.

Figures 4.12 to 4.14 provide photographs to help with identifying different profile and amenity issues.

Figure 4.11 A waterbody contributing to the amenity of its surrounding landscape

Photo: Julian Wakefield, Sunshine Coast Council

Table 4.3 Waterbody profile/amenity issues and associated management and rectification actions

Issue – Algal or cyanobacterial blooms			
Description	**Investigations/ monitoring**	**Management actions**	**Rectification actions**
Cyanobacteria and algal blooms can lead to diminished amenity and aesthetics resulting from the presence of unsightly surface scum, mats of filamentous algae, water discolouration and odour problems. Although this has been identified as a separate issue, the investigations and management/rectification actions will be similar to those for the maintenance and improvement of water quality.	Discuss with asset owner, engineering and environmental health department to identify and document any current or historical issues. Undertake desktop review, initial site inspection and risk assessment	Refer to 'Algal or cyanobacterial blooms' in Table 4.2	Refer to 'Algal or cyanobacterial blooms' in Table 4.2
Relevant supporting information Nil			

Issue – Weeds and pests			
Description	**Investigations/ monitoring**	**Management actions**	**Rectification actions**
The presence of aquatic and/or riparian weeds and pest animals is one of the major contributors to reduced public amenity/aesthetics associated with waterbodies. Although the presence of weeds has been identified as a separate issue, the investigations and management/rectification actions will be similar to those for the maintenance and improvement of water quality.	Discuss with asset owner, engineering and environmental health department to identify and document any current or historical issues. Undertake desktop review, initial site inspection and risk assessment.	Refer to Table 4.5 'Waterbody flora and fauna issues and associated management and rectification actions'.	Refer to Table 4.5 'Waterbody flora and fauna issues and associated management and rectification actions'.
Relevant supporting information DERM (2011), DEEDI (2011a)			

Issue – Offensive odours			
Description	**Investigations/monitoring**	**Management actions**	**Rectification actions**
Odours can detract from public open space and present a nuisance for local residents. There are a number of reasons why odours may develop in waterbodies such as: • decomposing organic matter • exposed or anoxic sediments • chemical contamination • organic loading (sewage or faecal contamination).	Discuss with asset owner, engineering and environmental health department to identify and document any current or historical issues. Undertake desktop review, initial site inspection and risk assessment. Site inspections should be undertaken during early morning or low wind conditions to confirm presence of odour. Check the waterbody for possible sources of odour. This will include checking for: • decomposing organic matter • evidence of algal blooms (e.g. surface scum) • anoxic sediments (surface bubbling, sulphur-based odours when the sediment is disturbed) • chemical residues upon the water surface • large populations of water birds • chemical spillage (via the stormwater drainage system) • cross-connections from the sewage system, or cross-contamination from on-site septic systems in rural areas • dry weather inflows.	Where the odour issue is believed to be temporary or low nuisance then no action is required. Where odour is believed to be permanent and a high nuisance then rectification will be required. In the interim the odour issues could be managed by: • notifying residents of the issue • erecting signage notifying people of the issue.	Rectification actions may include: • installing mixers or aerators into the waterbody to increase dissolved oxygen levels (see 'Stratification and low dissolved oxygen' in Table 4.2 and 'Access for maintenance' in Table 4.4) • removing organic matter and sediment (see 'Fine sediment or organic matter accumulation' in Table 4.4) • managing bird populations (see 'Faecal and/or nutrient contamination' in Table 4.2) • removing or treating chemical contamination (see 'Chemical contamination' in Table 4.2) • identifying and sealing sewerage cross connections • rectifying the source of algal blooms (see 'Algal or cyanobacterial blooms' in Table 4.2).
Relevant supporting information			
Nil			

Issue – Litter			
Description	**Investigations/ monitoring**	**Management actions**	**Rectification actions**
The presence of excessive amounts of litter reduces the amenity of the waterbody. Some types of litter such can aluminium cans increase public health risk by harbouring mosquitoes.	Discuss with asset owner, engineering and environmental health department to identify and document any current or historical issues. Undertake desktop review, initial site inspection and risk assessment. Check for possible sources of litter. This will include checking for: • catchment runoff from residential, commercial or industrial zones • failure of gross pollutant traps • direct dumping of litter in adjacent parkland areas • overflowing or unmanaged bins.	Where risk is medium then litter removal should occur on a scheduled or reactive basis. If gross pollutant traps or trash racks exist then maintain them as required.	If the risk is deemed unacceptable rectification actions may include: • retrofitting the upstream drainage system with litter controls (e.g. a gross pollutant trap or a trash rack) • incorporating a gross pollutant trap to the inlet zone of the waterbody • providing litter disposal bins in the adjacent public open space • creating access to the zones in the waterbody where litter tends to accumulate for littler collection. This will typically be at the downwind end of the waterbody along the line of prevailing winds • undertaking a behaviour change campaign (for example, see Mackenzie-Mohr) within the catchment to modify behaviour to reduce litter entering waterbody.
Relevant supporting information			
Nil			

Figure 4.12 Waterbody with a cyanobacterial bloom

Photo: Karen McNeale, Redland City Council

Figure 4.13 Waterbody with a weed infestation

Photo: Kate MacKenzie, Sunshine Coast Council

Figure 4.14 Waterbody with litter

Photo: Colin Bridges, Gold Coast City Council

4.3.4 Engineering and hydraulic function

Waterbodies often play important hydraulic and hydrologic roles within the stormwater and broader waterway network and catchment. Waterbodies are dynamic systems which change over time. It is important to consider the long term maintenance requirements and any natural functioning of the waterbody and the broader system prior to implementing management actions. For example, always consider the waterbody formation and ask is the waterbody supporting or hindering natural catchment functioning.

A waterbody can develop engineering and hydraulic issues such as:

- water level remaining consistently too high
- water level remaining consistently too low
- flooding of adjacent land, parkland or property, or regular overtopping of the waterbody bund
- accumulation of coarse sediment within the waterbody
- accumulation of fine sediment or organic matter within the waterbody
- poor flushing or dead pockets
- poor access for maintenance
- scour of batters.

Table 4.4 expands on each of the above issues, detailing:

- methods to investigate and monitor each issue
- management actions – actions that can be implemented rapidly and cost effectively
- rectification actions – actions that require planning, design and budget to implement
- relevant supporting information.

Figures 4.15 to 4.21 provide photographs to help with identifying different engineering and hydraulic function issues.

Table 4.4 Waterbody engineering and hydraulic function issues and associated management and rectification actions

Issue – Water level is consistently too high			
Description	**Investigations/monitoring**	**Management actions**	**Rectification actions**
Persistent high water levels (minor flood conditions) within the waterbody causing issues adjacent to the waterbody (e.g. death of vegetation, water logging of adjacent parkland area, tidal backwatering).	Determine what the original flow processes for the system were pre-European settlement and use this information to inform management actions. Discuss elevated water level with asset owner and engineering department to identify and document any current or historical issues. Complete site inspection following rainfall and during dry conditions to assess elevated water levels and identify potential causes. This will include checking for: • blockage of the outlet pipe or weir • incorrect design or construction of the outlet pipe or weir • blockage or siltation of downstream drainage system or waterway causing backwater in the outlet pipe • increased catchment inflows due to changes in catchment landuse or drainage • groundwater inflows to the waterbody • low bund levels relative to tidal variation. Undertake risk assessment. Where the risk of elevated water levels is high or very high and the solution is not straightforward then further technical assessment may be required. Seek advice from an engineer if the outlet is regularly blocked or undersized. Review catchment landuse to determine if there has been a significant increase in catchment imperviousness. Catchment modelling may be required to determine waterbody inflows. Assess the capacity of the waterbody outlet to cope with increased flows. Installations of a water level gauge may assist with technical assessment.	Management options for elevated water levels may include: • undertaking regular inspection and maintenance of waterbody outlet • cleanout of downstream waterways to ensure free drainage of waterbody • erecting signs to inform the community about the water level issue in the waterbody.	If the risk is deemed unacceptable rectification actions may include: • decreasing future risk of blockage (i.e. submerged outlets, inclined grates, large conveyance opening to allow for accumulation of litter) • providing increased capacity (i.e. new pit or pipes) • raise bunds above tidal influence • providing easy inspection and maintenance access (see 'Access for maintenance' in this table) • allowing adaptive management of the waterbody water levels (e.g. install value or staged outlet to allow water levels to be lowered or raised easily) • remove the structure and decommission the waterbody • sealing the base of the waterbody to prevent groundwater inflows.
Relevant supporting information			
Nil			

Issue – Water level is consistently too low			
Description	**Investigations/monitoring**	**Management actions**	**Rectification actions**
Persistent low water levels within the waterbody (even during only short periods without rain) causing the base of the waterbody to become exposed.	Determine what the original flow processes for the system were pre-European settlement and use this information to inform management actions. Discuss low water level with asset owner and engineering department to identify and document any current or historical issues. Complete site inspection following rainfall and during dry conditions to assess low water levels and identify potential causes. This will include checking for: • incorrect outlet structure • leaking outlet structure • leaking maintenance drain • the waterbody catchment is small (i.e. not enough inflow to sustain water level) • the base or bund of the waterbody is not properly sealed • depth of waterbody has reduced due to siltation • inflows are bypassing the waterbody. Undertake risk assessment. Where the risk of low water levels is high or very high and the solutions is not straightforward then further technical assessment may be required. Seek advice from a waterbody specialist to confirm the reason for the water level reduction: • obtain design information for the waterbody in particular catchment areas, inflow points, earthworks/ bathymetry and outlet structure • obtain certification and construction information for the waterbody • where required collect survey data to confirm the design levels are achieved	Management options for low water levels may include erecting signs to inform the community about the water level issue in the waterbody.	If the risk is deemed unacceptable rectification actions may include: • reconfiguring or installing a new outlet structure • fixing any leaks in the outlet structure • replacing leaking maintenance drain valves • for a waterbody with a small catchment, reducing the size of the waterbody or decommissioning • diverting more catchment runoff into the waterbody • using a proprietary product which flocculates fine sediment to the base of the waterbody to create a thick impermeable liner. Apply following a number of rainfall events where suspended solids are elevated to maximise sediment capture on base • draining and sealing the base or bund of the waterbody properly • decommissioning the waterbody • redesigning a waterbody which has a 'leaky' base to ephemeral wetland.

Issue – Water level is consistently too low			
Description	**Investigations/monitoring**	**Management actions**	**Rectification actions**
	• review the catchment area to ensure the catchment is suitably large enough to sustain water in the waterbody (waterbodies which are large in size compared to their catchment may experience significant water level variation) • review the depth of the system to confirm whether siltation has occurred (may require survey) • complete boreholes in the base of the waterbody to confirm the presence of a clay liner or otherwise.		Where the waterbody has been constructed recently and certified by a geotechnical engineering or civil engineer, consider taking action for compensation to cover costs of rectification works
Relevant supporting information			
Nil			

Issue – Flooding of adjacent land, parkland or property, or regular overtopping of the waterbody bund			
Description	**Investigations/monitoring**	**Management actions**	**Rectification actions**
Drainage into or out of the waterbody has the potential to flood adjacent land, park or property due to poor hydraulic controls (i.e. uncontrolled water flow out of waterbody)	Determine what the original flow processes for the system were pre-European settlement and use this information to inform management actions. Discuss flooding issues with asset owner and engineering department to identify and document any current or historical issues. Complete site inspection following rainfall to assess flow behaviour through the waterbody system with a focus on inflows and outflows from the waterbody and any recorded flood prone areas. Undertake risk assessment. Further assessment may be required if risk is identified as high. This may include undertaking detailed desktop catchment investigation (areas, landuse including changes, flood/stormwater management reports, flow calculations and/or modelling, complaints register)	Management actions may include: • undertaking regular inspection and maintenance of waterbody outlet • regular cleanout of downstream waterways to ensure free drainage of the waterbody.	If the risk is deemed unacceptable, rectification options may include: • modifying outlet structure to control flooding (i.e. lower water levels, increase capacity, staged outlet) • installing or increasing the size of the high flow weir outlet from the waterbody • increasing the capacity of downstream waterways • stabilising flood inflow and outflow locations • diverting upstream catchment into or around waterbody.
Relevant supporting information			
DEWS (2013)			

Issue – Coarse sediment accumulation			
Description	**Investigations/monitoring**	**Management actions**	**Rectification actions**
Coarse sediment is the largest (in terms of quantity) urban stormwater pollutant. Therefore coarse sediment deposition in the inlet zones to waterbodies will eventually be an issue for management. Excessive sediment accumulation within the waterbody may result in the blockage of the preferred flow path and the development of multiple flow paths. The growth of emergent macrophyte vegetation upon silted areas may also influence the hydraulic behaviour of a waterbody system.	Discuss coarse sediment accumulation with asset owner and engineering department to identify and document current or historical issues. Complete site inspection of each of the inflow points into the waterbody to assess coarse sediment accumulation: • visible sediment accumulation above or below the normal water level. Sediment accumulation is often most evident near the waterbody inlet zone/s • growth of emergent macrophytes within the waterbody • collection of sediment cores. Undertake risk assessment. Where coarse sediment has accumulated, the cause should be identified. For example: • untreated catchment runoff • catchment landuse or activities • failure of stormwater treatment systems within the catchment to adequately capture coarse sediments • erosion of upstream waterways.	Management actions for coarse sediment can be undertaken (provided access to the inlet zone is possible) and include: • desilting the inlet area with machinery or dredges • desilting sediment basins or gross pollutant traps located upstream of the waterbody.	If the risk is deemed unacceptable and cannot be treated by management actions alone, rectification actions may include: • de-watering the waterbody and mechanically removing the sediments • managing the coarse sediment at its source (e.g. stabilising the upstream waterway) • installing gross pollutant traps or sediment basins at the inflow points to the waterbody • creating maintenance access to the inflow zones or sediment capture systems • creating sediment drying and dewatering areas. Note: An analysis of the sediment quality should be undertaken prior to removing sediments in order to determine the contamination level.
Relevant supporting information Simpson *et al*, (2005)			

Issue – Fine sediment or organic matter accumulation			
Description	**Investigations/monitoring**	**Management actions**	**Rectification actions**

Fine sediment or organic matter accumulation on the bed of the waterbody system has a significant influence on waterbody function. Fine or organic sediment carries a large quantity of particulate nutrients.
 	
At the bed of the waterbody the sediment may become anaerobic and nutrients may be released in soluble form into the waterbody water column. Therefore, the fine organic sediment that accumulates on the base of the waterbody can become an almost limitless source of nutrients to support algal blooms and weed growth.
	It can generally be assumed that most waterbodies will have fine sediment accumulation. The question is how much accumulation. Discuss fine sediment accumulation with asset owner and engineering services to identify and document any current or historical issues.
	
	Complete site inspection of the waterbody to assess fine sediment accumulation. This will require collection of sediment cores using a simple grab sampler or corer and visual inspection. Sample testing may be considered but in most cases the accumulation of fine sediment and organic matter will be obvious. The sediment assessment should be combined with water quality profiling for dissolved oxygen, pH and redox to assess the state of the sediment (i.e. anoxic).
	
	Undertake risk assessment.
	
	Where fine sediment has accumulated the cause should be identified. For example:
	• untreated catchment runoff
	• failure of stormwater treatment systems within the catchment to adequately capture fine sediments
	• erosion of upstream waterways
	• waterbody is undersized for catchment and thus receiving high sediment and organic loads.
		Where fine sediment and organic matter accumulation is minor and the waterbody water quality is in relatively good condition, monitor waterbody water quality and health. There is no need to remove sediment or organic matter.
		
		Clean upstream gross pollutant traps at regular intervals.
			Where fine sediment and organic matter accumulation is significant, and has resulted in anoxic conditions and poor water quality in the waterbody then rectification is required. Rectification options include:
			• redesigning the waterbody to a wetland (if shallow enough)
			• filling in the waterbody
			• dewatering the waterbody, allowing to dry out and removing the sediment
			• dredging or desilting the waterbody in wet conditions
			• sealing the fine sediment under a layer of flocculated sediment (i.e. flocculent added to waterbody)
			• reconfiguring the inlet to allow capture of organic matter
			• where a waterbody is very undersized for its catchment, reconfigure inlet zone to either:
			  - include dedicated sediment capture area
			  - divert a portion of flows around waterbody.

Relevant supporting information Simpson *et al*, (2005)			

Issue – Poor flushing or dead pockets			
Description	**Investigations/monitoring**	**Management actions**	**Rectification actions**
Poor flushing or dead pockets are indicated by patches of still, stagnant water, sometimes accompanied by an odour and/or algal growth. This is caused locally by areas of open water that are rarely flushed (isolated 'dead pockets') or more broadly waterbodies that have relatively small or infrequent inflows.	Determine what the original flow processes for the system were pre-European settlement and use this information to inform management actions. Discuss poor flushing and dead pockets with asset owner and engineering services to identify and document any current or historical issues. Complete site inspection around the full perimeter of the waterbody to identify potential for dead pockets indicated by: • small backwaters which do not receive flowing water • poor water quality and presence of algal blooms. Use aerial images of the waterbody to review where problem areas are located. Poor waterbody bathymetry such as isolated deep zones may also result in localised stratified or deoxygenated zones. Undertake risk assessment.	Where poor flushing exists but is not leading to poor water quality, then no management action is required. Monitor the poorly flushed zones via regular visual inspection.	Where poor flushing is resulting in poor water quality outcomes (i.e. algal blooms) then rectification should occur. Options include: • installing recirculation system • removal of islands • reconnecting islands to bank • retrofitting of inlets/ outlets to maximise flushing • redirecting flows through the waterbody to ensure flows pass through dead pockets • reshaping base of the waterbody to remove or fill in dead pockets • decommission the waterbody • redesigning dead pockets to wetland zones.
Relevant supporting information			
Nil			

Issue – Access for maintenance			
Description	**Investigations/ monitoring**	**Management actions**	**Rectification actions**
Poor access for maintenance of hydraulic structures and pump infrastructure, removal of sediment from inlet areas, litter removal and weed harvesting can result in deterioration of the system. Ideally maintenance access should be provided to the following locations: • stormwater inflows to the waterbody for sediment desilting • edge of the waterbody for weed harvesting or to launch boat • hydraulic controls • broad perimeter of the waterbody for riparian weed management • the side of the waterbody that is downwind from the prevailing wind direction (for removing litter).	Discuss maintenance access allowance with asset owner, maintenance and engineering departments to identify any current or historical issues. Complete site inspection to identify existing maintenance allowance and obvious access problems.	Provided the maintenance access is constructed from suitable materials (i.e. gravel, concrete or reinforced vegetation), then maintenance will be minimal and based on inspections. Maintenance may involve weeding, removing litter and filling of wheel ruts.	Where maintenance access is deficient installation of formal access will be required. The nature of access for different maintenance activities should be discussed with the asset owner. Rectification actions may include: • provision of maintenance access for vehicles, boats and weed harvesters (e.g. ramps for sediment removal, tracks for access to structures) • provision of work areas for sediment drying, maintenance of hydraulic structures and erosion/scour • installation of access tracks.
Relevant supporting information			
Water by Design (2012a)			

Issue – Scour of batters			
Description	**Investigations/ monitoring**	**Management actions**	**Rectification actions**
Scoured batters may be hazardous due to the instability of the waterbody edges and presence of under-cut edges. Scour of the batters may result from: • high, uncontrolled discharges due to storm inflows • lateral surface flows entering the waterbody via drainage lines • localised high velocities (e.g. shape of waterbody, around inlet) • lapping of water against exposed turf edges • use of inappropriate soils around the edge of the waterbody (dispersive soils and the associated tunnel erosion) • loss of vegetation.	Discuss scour of waterbody batters with asset owner and engineering and environmental health department to identify and document any potential current and historical issues. Complete a site inspection to check for evidence of scour around the margins of the waterbody and assess the scale of the problem and cause of scour. Following the investigation tasks listed above a decision needs to be made regarding whether the scour issues require rectification or not. This decision will be dictated by the amount of scour, risk of further scour and the public safety risk. Where rectification is undertaken, in most cases this will not require detailed assessment but rather will involve in situ stabilisation.	Where scour exists and has stabilised or is not considered a risk to local government, then no management action is required. Monitor the scour zones via regular visual inspection.	Rectification of significant scour will be dictated by the investigations and may require specialist input from a soil scientist and/or stormwater engineer. Rectification responses may include: • reinforcing the eroded areas (e.g. rock protection) • directing inflows to rock-lined channels that feed down the batters to the waterbody • replacing topsoil in scoured zones and re-establishing the vegetation • modifying hydraulic control structure (i.e. inlet and outlet pipes and weirs). If the soil is problematic, seek advice from the soil laboratory for rectification options to meet the specification. In some cases, in situ rectification may be possible (e.g. treating with gypsum followed by placing of non-dispersive topsoil and grass seeding). If not, remove and replace the soil.
Relevant supporting information			
Nil			

Figure 4.15 Blocked waterbody outlet

Photo: Ralph Williams, DesignFlow

Figure 4.16 Leaking waterbody outlet structure

Photo: Ralph Williams, DesignFlow

Figure 4.17 Waterbody where siltation has reduced the water depth, resulting in the growth of aquatic macrophytes

Photo: Maree Manby, Redland City Council

Figure 4.18 Inundation of low-lying land adjacent to a waterbody

Photo: Julian Wakefield, Sunshine Coast Council

Figure 4.19 Waterbody with coarse sediment accumulation around the inlet

Photo: Colin Bridges, Gold Coast City Council

Figure 4.20 A poorly flushed waterbody with irregular inflows

Photo: Jack Mullaly, Logan City Council

Figure 4.21 Waterbody with scoured batters adjacent to inlet structure

Photo: Colin Bridges, Gold Coast City Council

4.3.5 Flora and fauna

Managing flora and fauna is an important component of managing waterbodies and needs to be undertaken with consideration of the surrounding riparian and wetland fringes and broader catchment. Healthy flora and fauna are an essential element of a healthy waterbody. Healthy flora and fauna increase the amenity provided by the waterbody. Unhealthy and problematic flora and fauna often generate public complaints. It is an issue in its own right but can also be symptomatic of broader waterbody issues such as water quality. The issues associated with flora and fauna include:

- aquatic weeds
- terrestrial weeds
- deterioration in health of native aquatic and terrestrial vegetation
- introduced or nuisance fauna
- deterioration in health of native fauna.

Table 4.5 details the management of flora and fauna including:

- methods to investigate and monitor each issue
- management actions – actions that can be implemented rapidly and cost effectively
- rectification actions – actions that require planning, design and budget to implement
- relevant supporting information.

Figures 4.22 and 4.23 provide photographs to help with identifying different flora and fauna issues.

Table 4.5 Waterbody flora and fauna issues and associated management and rectification actions

Issue – Aquatic weeds			
Description	**Investigations/ monitoring**	**Management actions**	**Rectification actions**
The persistence of aquatic weeds within the waterbody may be due to: • uncontrolled weed infestations in the upstream catchment • excess sediment accumulation within the waterbody • high nutrient concentrations present within the waterbody • die back of native vegetation allowing weeds to colonise • accidental or illegal introduction (e.g. ornamental ponds or aquarium species such as Salvinia) • seed dispersal (e.g. animals, wind) • lack of regular maintenance • colonisation amongst desirable vegetation making removal difficult.	Discuss aquatic weed issues with asset owner, engineering and environmental health departments to identify and document any issues. Complete a site inspection to determine presence, proportion, species etc. of weeds Undertake risk assessment. Seek advice from a weed specialist for long term weed removal or control strategies. This will require: • confirming the weed species present • identifying the cause/s of the weed infestation • considering the biological characteristics of the weed species • determining long term weed management options.	The control of declared weeds is mandated under the legislation. Therefore, these weeds must be dealt with as part of the regular maintenance schedule. Refer to *Maintaining Vegetated Stormwater Assets* (Water by Design, 2012a) for general advice about managing weeds. Management actions may include: • regular harvesting using aquatic weed harvester • chemical control (Note: Seek advice from weed specialist if chemical control is being considered. The potential impacts of chemical herbicides on the aquatic ecosystem should be considered) • biological control agents such as the salvinia weevil *(Cyrtobagous salviniae)* and water hyacinth weevil *(Neochetina eichorniae)* (Note: Specialist advice should be sought from the CSIRO division of entomology).	If the risk is deemed unacceptable and the aquatic weed infestation cannot be controlled by management alone, rectification actions include: • completely removing the weed species using control methods listed in *Maintaining Vegetated Stormwater Assets* (Water by Design, 2012a) • draining and drying out the waterbody in order to desiccate the weed species. Obtain specialist advice about the required drying out period • establishing and maintaining healthy submerged and emergent macrophytes within the waterbody • establishing and maintaining healthy riparian vegetation on waterbody margins to improve shading and reduce sources of nutrients. Generally a combination of the above actions is required to manage and/or eradicate infestations.
Relevant supporting information Water by Design (2012a), Refer to Biosecurity Queensland (DAFF, 2013a) website (http://www.daff.qld.gov.au/4790.htm), Australian Weeds Committee (2012), Sainty and Associates Pty Ltd (n.d.), DEEDI (2011b)			

Issue – Terrestrial weeds			
Description	**Investigations/ monitoring**	**Management actions**	**Rectification actions**
The persistence of terrestrial weeds along waterbody edges or adjacent to the waterbody may be due to: • uncontrolled weed infestations in the upstream catchment • discontinuous or fragmented perimeter vegetation • die back of native vegetation allowing weeds to colonise • accidental or illegal introduction • seed dispersal (e.g. animals, wind) • lack of maintenance • contaminated fill and/ or mulch (on batters) • sediment deposition following flood events • poorly draining edges which result in sodden conditions conducive to weed (e.g. Typha) growth.	Discuss terrestrial weed issues with asset owner, engineering and environmental health departments to identify and document any current and historical issues. Complete a site inspection to determine presence, proportion, species etc. of weeds. Undertake risk assessment. Seek advice from a weed specialist for long term weed removal or control strategies. This will require: • confirming the weed species present • identifying the cause/s of the weed infestation • considering the biological characteristics of the weed species • determining long term weed management options.	The control of declared weeds is mandated under the legislation. Therefore, these weeds must be dealt with as part of the regular maintenance schedule. Refer to *Maintaining Vegetated Stormwater Assets* (Water by Design, 2012a) for general advice about managing weeds. Management actions include: • chemical control (Note: Seek advice from weed specialist if chemical control is being considered. The potential impacts of chemical herbicides on the aquatic ecosystem should be considered) • regular inspection and application of clean mulch around waterbody perimeters.	If the risk is deemed unacceptable and the terrestrial weed infestation cannot be controlled by management alone, rectification actions include: • completely removing the weed species using control methods listed in *Maintaining Vegetated Stormwater Assets* (Water by Design, 2012a) • establishing and maintaining healthy riparian vegetation on waterbody margins. Generally a combination of the above actions is required to manage and/or eradicate infestations.
Relevant supporting information Water by Design (2012a), Australian Weeds Committee (2012), Sainty and Associates Pty Ltd (n.d.). DEEDI (2011b)			

Issue – Deterioration in health of native aquatic and terrestrial vegetation			
Description	**Investigations/ monitoring**	**Management actions**	**Rectification actions**
Deterioration in the health of native aquatic and terrestrial vegetation in and around waterbodies can lead to a decrease in amenity values and a loss of habitat and ecological function, as well as being symptomatic of other waterbody issues. Deterioration in the health of native aquatic and terrestrial vegetation can be due to: • inappropriate water levels • variable water levels • disease • competition from weeds • damage by fauna, particularly birds • erosion of batters • poor water quality • overspray of herbicides for weed control • extreme weather events (e.g. flood, drought) • use of non-endemic vegetation not suitable for the location.	Discuss the deterioration in health of native aquatic and terrestrial vegetation with asset owner, engineering and environmental health departments to identify and document any current and historical issues. Complete a site inspection to determine the extent and severity of the deterioration in health of native aquatic and terrestrial vegetation. Undertake a risk assessment. Seek advice from a vegetation specialist to determine the cause of the deterioration in health of the vegetation.	The management actions undertaken will depend upon the cause of the deterioration in health of the native aquatic and terrestrial vegetation. For information on: • inappropriate or variable water levels, refer to Table 4.4 • competition from weeds, refer to 'Aquatic weeds' or 'Terrestrials weeds' in this table • damage by fauna, particularly birds, refer to 'Introduced or nuisance fauna' in this table • erosion of batters, refer to 'Scour of batters' in Table 4.4 • poor water quality, refer to Table 4.2.	If the risk is deemed unacceptable, actions to rectify the deterioration in health of native aquatic and terrestrial vegetation must be undertaken. The actions undertaken will depend on the cause of the problem. For information on: • inappropriate or variable water levels, refer to Table 4.4 • competition from weeds, refer to 'Aquatic weeds' or 'Terrestrials weeds' in this table • damage by fauna, particularly birds, refer to 'Introduced or nuisance fauna' in this table • erosion of batters, refer to 'Scour of batters' in Table 4.4 • poor water quality, refer to Table 4.2.
Relevant supporting information DERM (2011)			

Issue – Introduced or nuisance fauna			
Description	**Investigations/ monitoring**	**Management actions**	**Rectification actions**
Introduced and/or nuisance fauna (e.g. Ibis, ducks, exotic fish) can lead to a decrease in amenity values and a decrease in water quality. The presence of introduced or nuisance fauna may be due to: • their presence in nearby environments • a readily available food source • suitable habitat • dumping of domestic fauna.	Discuss the introduced or nuisance fauna with asset owner, engineering and environmental health departments to identify and document any current and historical issues. Complete a site inspection to determine the extent and severity of the introduced or nuisance aquatic fauna. Undertake a risk assessment. (Note: The capture, removal or destruction of animals is governed by strict ethical considerations and should only be undertaken by qualified staff, in accordance with NHMRC (2004))	The management actions undertaken will depend on the type of introduced or nuisance fauna and the cause. Actions may include: • reduction in food sources • signage to discourage feeding of wildlife. See Table 4.2 for further details on management actions for the presence of exotic fish species.	If the risk is deemed unacceptable, actions to rectify the introduced or nuisance fauna must be undertaken. The actions undertaken will depend on the type of fauna and the cause of the problem. Actions may include: • removing, moving on or culling introduced or nuisance fauna by an appropriate contractor in accordance with NHMRC (2004) (permit may be required) • where repeated dumping of domestic fauna occurs, community education should occur to build education and understanding of the issue • removing habitat (may require permit). See Table 4.2 for further details on rectifying the presence of exotic fish species
Relevant supporting information NHMRC (2004), DEEDI (2011b)			

Issue – Deterioration in health of native fauna			
Description	**Investigations/monitoring**	**Management actions**	**Rectification actions**
The deterioration in health of native fauna can lead to decrease in amenity and lead to public complaints. It can also be symptomatic of other issues within the waterbody. The deterioration in health of native fauna may be due to: • predation and competition • disease • poor water quality • lack of food and habitat.	Discuss the deterioration in health of native fauna with asset owner, engineering and environmental health departments to identify and document any current and historical issues. Complete a site inspection to determine the extent and severity of the deterioration in health of native fauna. Undertake a risk assessment. Where the cause of the deterioration in health of native fauna is not immediately apparent, seek specialist advice. Where disease or poor water quality is suspected, consider testing of dead animals and water quality to determine cause. (Note: The capture, removal or destruction of animals is governed by strict ethical considerations and should only be undertaken by qualified staff, in accordance with NHMRC (2004))	Management actions include: • removing carcasses of dead animals • capture and treatment of unwell animals • where predation by non-native fauna is suspected, refer to 'Introduced or nuisance fauna' in this table • where poor water quality is suspected, refer to Table 4.2.	If the risk is deemed unacceptable, actions to rectify the deterioration in health of native fauna must be undertaken. The actions undertaken will depend on the cause of the problem. For information on: • predation and competition by non-native fauna, refer to 'Introduced or nuisance fauna' in this table • poor water quality, refer to Table 4.2 Undertake testing of dead animals to determine if disease is the cause. The response will be dependant on the disease and a specialist should be consulted. When lack of habitat resources is the suspected cause, it may be possible to reintroduce aquatic or terrestrial habitat by restoring vegetation cover and structural components.
Relevant supporting information			
NHMRC (2004)			

Figure 4.22 Waterbody with aquatic weeds (Salvinia)

Photo: Colin Bridges, Gold Coast City Council

Figure 4.23 Waterbody with terrestrial weeds

Photo: Julian Wakefield, Sunshine Coast Council

4.4 MANAGEMENT ACTIONS

Section 4.3 detailed how to identify common waterbody issues, investigate them and select appropriate management and rectification actions. Many of these actions are simple, and the skills are likely to already exist within many local governments. Other actions however, are more complex and require specialist knowledge and skills. This section explores these more complex actions and provides useful advice about how and where to obtain more information. The actions addressed in this section are:

- providing appropriate access for maintenance
- dewatering a waterbody
- modifying waterbody configuration
- repairing erosion
- managing silt and organic matter
- repairing leaking waterbodies
- promoting mixing of waterbody waters
- managing weeds
- redesigning waterbodies to high ecological value wetlands
- recirculating water through treatment systems
- in situ water treatment with floating wetlands
- removing a waterbody.

4.4.1 Providing appropriate access for maintenance

Easy access to a waterbody is critical for undertaking maintenance activities such as sediment removal or weed harvesting and control. Access should be provided to the:

- main water
- inlets and outlets
- the perimeter of the waterbody.

Ideally maintenance access should be provided in accordance with Table 4.6

Some waterbodies will not contain the appropriate maintenance access. Maintenance access can be expensive to construct, particularly if retrofitting it to an existing waterbody. Before constructing maintenance access to a waterbody, consider how regularly the maintenance access will be used. A waterbody in good condition with limited pressures may require only very irregular access into the waterbody itself, and may not justify the expense of a concrete or rock access ramp.

Where accesses are to be constructed, landscape integration should be considered to soften the impact. Shared paths could be considered to provide public trails as well as maintenance access.

Table 4.6 Maintenance access requirements

Access Provided	Purpose	Design Specifications
Stable access ramp into the waterbody	For machine/boat access into or onto the waterbody	• appropriate to the machinery required to maintain the waterbody • concrete or rock • maximum grade of 1:4 • minimum width of 4 m • equipped with a barrier suitable to the location to restrict public access
A stable, well drained dewatering pad	For dewatering of removed sediments	• large enough to store wet material extracted from waterbody until it can dry and be removed • where the waterbody contains an inlet pond, dewatering pad should be located adjacent to the inlet pond
Access for trucks to waterbody	For removal of sediment and weeds	• hardstand vehicular access
Access to the entire perimeter of waterbody	For vegetation and mosquito management	• trafficable trails
Access to inlets, outlets and other hydraulic structures	For managing hydraulic structures	• stable surface that minimises vehicle rutting • minimum 2.5 m width

4.4.2 Dewatering a waterbody

In some instances it will be necessary to lower the water level, drain or dewater a waterbody in order to undertake other maintenance or rectification activities such as removing sediment or repairing a waterbody's impermeable liner.

Prior to dewatering a waterbody, be sure to consider:

- acid sulfate soils – acid sulfate soil maps should be reviewed, and if the waterbody is in a high risk area, on-ground investigation (e.g. test pitting) must be undertaken. If acid sulfate soils are present, engage the help of a specialist to develop and implement a management plan prior to dewatering
- approvals – investigate whether any approvals are required prior to discharging water particularly in relation to spread of aquatic weeds or pests
- any potential fish kills or species die off that may result from dewatering
- removing and relocating fauna
- whether the system is online or offline from a watercourse and its connection to the broader wetland and catchment
- where to discharge the water after dewatering, including consideration of options for re-use (e.g. rural fire fighting)
- the effect of dewatering on environments sensitive to environmental flows
- presence of invasive species or toxins.

Prior to dewatering, all inlets to the waterbody should be blocked to prevent inflows. Where the waterbody is offline, this can be done by simply blocking the inlet. Where the waterbody is online, a bypass must also be established. This could include constructing a diversion channel, or partitioning the inlet off from the majority of the waterbody, and pumping any inflows to the waterbody outlet. When blocking inlets be sure not to cause upstream flooding.

Dewatering can be undertaken either by pumping, or gravity. Some waterbodies will contain a dedicated maintenance valve which allows the water level to be controlled and the waterbody to be free-drained. It is possible to drain a waterbody by gravity by breaching the waterbody wall or bund, however, be aware that a structurally sound bund must be reinstated if the waterbody is not being removed. This may be an expensive task.

When dewatering a waterbody by pumping out the water it may be possible to discharge it onto adjacent vegetated areas. This will help to remove sediments and solids from the water before entering downstream waterways. Be sure that:

- the area where water is discharged is not susceptible to erosion
- any contaminants in the water do not present a risk to human health
- the water does not create a flooding or a drainage nuisance.

Regardless of the method used to dewater the waterbody, many waterbodies will have an uneven base, which will form isolated pools which must each be drained individually.

In some instances a waterbody may be fed by groundwater. In these cases, the rate of draining must be greater than the rate of groundwater inflow to the waterbody. The works must be undertaken promptly to avoid artificially lowering the local groundwater (even temporarily), and to reduce dewatering costs.

If a waterbody contains a large amount of organic matter (either accumulated organic matter or fresh plant material) and the waterbody remains dewatered for more than a short period of time, the organic matter may start to decompose releasing odours.

4.4.3 Modifying waterbody configuration

When managing waterbodies it may be necessary to modify the configuration (shape, size or bathymetry) of a waterbody. The configuration of a waterbody may be modified to:

- reduce the risk of injury or drowning because of inappropriate batters or edges to the waterbody
- reduce mosquito habitat
- improve the hydraulic efficiency of the waterbody (improve flushing, reduce stratification and eliminate dead pockets).

Modifying the configuration of a waterbody may include activities such as:

- re-profiling the edges
- modifying the profile of the base of the waterbody
- removing islands
- filling parts of the waterbody (including reconnecting islands to the waterbody bank).

The waterbody should generally be dewatered (see Section 4.4.2) prior to modifying its bathymetry, although in some cases it may be possible to modify by placing and configuring rock material from the edges.

Before modifying a waterbody's bathymetry, obtain and comply with any necessary approvals and standards.

Achieving a cut and fill balance is desirable when modifying the configuration of a waterbody as this will avoid costs associated with importing or disposing of fill offsite. If the activity being undertaken necessitates the disposal of material from the site, the potential for soil contamination will need to be considered.

It is not unusual for sediment in urban waterbodies to become contaminated with heavy metals and other toxic substances. The disposal of contaminated sediment is expensive and should be undertaken in accordance with legislative requirements.

If soil is imported to the site, it must:

- be uncontaminated (e.g. no toxic materials or weeds)
- preferably be clay type material
- not be dispersive.

When modifying the configuration of a waterbody it is important to make sure that the clay liner is not damaged (this will ensure that the waterbody continues to retain water). Where excavation occurs this is particularly important and the clay liner may need to be reinstated. Clay liners can be constructed from:

- compacted clay sourced on-site
- proprietary liners such as bentonite sheets
- imported clay.

Over time all waterbodies will accumulate some silt or organic material at the base. Accumulated material will typically appear as an unconsolidated layer lying upon the sediment or clay base.

The unconsolidated layer generally ranges in depth between 25-500 mm (but may range in depth up to 1 m in some waterbodies) and must be managed in areas where work is taking place as it is unlikely to compact/stabilise sufficiently if left in situ with no treatment. If large quantities of unconsolidated silt or organic matter are present, options include:

- removing the unconsolidated silt or organic matter
- stabilising the unconsolidated silt or organic matter in situ – specialised methods exist such as mixing in very low percentages of cement to improve the properties of silt and make it workable.

Where planting is proposed, topsoil should be laid at a minimum depth of 150 mm over all clay liners to provide a substrate for aquatic macrophytes to grow in. Topsoil should be in accordance with AS4419 (2003) *Soils for Landscaping and Garden Use.*

Design Tips

When modifying a waterbody's configuration to reduce the risk of unsafe edges, consider the guidance supplied in Appendix A of *Rectifying Vegetated Stormwater Assets* (Water by Design, 2012b)

Design Tips

When modifying a waterbody's configuration to reduce mosquito habitat, ensure that:

- the waterbody edge is free draining across all operating water levels (i.e. the profile of the base does not contain any isolated areas where water can pool during times of reduced water level)
- a minimum (shallowest) grade of 2% of waterbody batters below the maximum possible water level to allow free draining areas.

Design Tips

When modifying a waterbody's configuration to remove dead spots, consider the following techniques:

- round-off sharp corners surrounding dead spots
- infill dead pockets to create terrestrial or wetland plant dominated areas
- fill in deep isolated pools.

Design Tips

When modifying a waterbody's configuration to improve hydraulic efficiency:

- achieve a length to width ratio of 3:1 or greater
- consider reconnecting islands to bank flow paths and reduce total waterbody volume.

4.4.4 Repairing erosion

In some instances it will be necessary to repair erosion within waterbodies. Erosion can occur within waterbodies for a variety of reasons. Small amounts of erosion can, in the long term, extend and turn into a large problem, including channelling of flows, undermining of headwalls and pipes, compromising the integrity of bunds and clay liners and impacting on plant health. The response will depend on the type of erosion. Table 4.7 details possible responses to repair common types of erosion. Refer to *Rectifying Vegetated Stormwater Assets* (Water by Design, 2012b) if erosion is recurring or severe.

Table 4.7 Responses to repair common types of erosion

Erosion Type	Response
Erosive lateral flows down waterbody batters	If dispersive soils are present, treat (ameliorate) soils and formalise inflows with stable channels down batters.
High flows around outlet structures	Reinforce or redesign outlet as required. Refer to the *Queensland Urban Drainage Manual* (DEWS, 2013) for typical responses.
Wind induced wave actions acting on batters	Where the fetch length of the waterbody is short (<500 m): • treat (ameliorate) or replace dispersive soils • re-profile batters • place good quality, non-dispersive topsoil (AS4419, 2003 compliant) on batters • heavily revegetate on batters. Where the fetch length of the waterbody is long (>500 m): • implement structural response such as revetment walls.
Poorly structured or dispersive soils on waterbody batter/s (Figure 4.24)	Treatment options include mixing dispersive sub-grade with gypsum and capping with non-dispersive topsoil. Revegetation can then occur (e.g. hydroseeding) (Figure 4.25).

Figure 4.24 Erosion of a waterbody batter caused by dispersive soils

Photo: Ralph Williams, DesignFlow

Figure 4.25 Revegetation of a waterbody batter

Photo: Ralph Williams, DesignFlow

4.4.5 Managing silt and organic matter

Silt and organic matter may need to be removed from a waterbody for a number of reasons. In most cases it is to improve water quality. Managing silt and organic matter can entail either removing the matter or stabilising it in situ.

Removing silt and organic matter can occur either while the waterbody is full of water (and thus the silt or organic matter is saturated) or after the waterbody is dewatered. Sediment and organic matter can be removed from a waterbody while full of water by:

- suction dredging via barge
- suction dredging from waterbody edge (smaller waterbodies only)
- suction dredging using specialised equipment such as a 'sludge rat'
- mechanical extraction from waterbody (Figure 4.26).

Figure 4.26 Mechanical extraction of silt, organic material and weeds from a waterbody

Photo: Colin Bridges, Gold Coast City Council

Disposing of the sediment or organic matter while saturated is best avoided as it is difficult to transport and can leak on public roads, and it significantly adds to the cost of both transport and disposal. It is recommended that sediment or organic matter is dewatered prior to disposal. Methods for dewatering include:

- drying on-site in a dedicated dewatering area
- dewatering within suction trucks (some suppliers only)
- dewatering on-site using geotextile bags.

Dewatering the waterbody enables the sediment and organic matter to be removed in a drier form via mechanical means (i.e. excavation).

In some cases it may not be necessary to remove accumulated silt or organic matter to solve the waterbody issues. In these situations, stabilising the matter in situ may be a viable alternative. Silt and organic matter can be stabilised in situ in waterbodies by:

- capping – see the *Townsville Constructed Lakes Guideline* (DesignFlow, 2010) for further details on sediment capping
- amelioration – additive such as concrete may be added in small quantities (using specialised equipment) to turn otherwise unstable and unworkable silt into a stable, workable material (Figure 4.27). Seek specialist assistance.

Figure 4.27 Stabilising silt by ameliorating it with concrete

Photo: Ralph Williams, DesignFlow

4.4.6 Repairing leaking waterbodies

Leakage from waterbodies generally occurs via either the impermeable liner or a component of the outlet (e.g. pit, embankment). The method used to fix the leaking waterbody is dependent on where the waterbody is leaking from. An alternative option to repairing the leak is to redesign the leaky waterbody into an ephemeral wetland, further information on this is provided in Section 4.4.9.

A major challenge with fixing leaking waterbodies, particularly those leaking from the impermeable liner is that it can be very difficult to locate the leak. Implementing an effective solution can also be difficult. It is therefore possible to waste a large amount of time and resources attempting to fix a leaking waterbody with no success.

The first step in fixing a leaking waterbody is to identify the source of the leak. There are certain indicators that can be used to help locate the source of the leak. For example, an obvious wet or lush green area downstream of the wall is a likely sign of a leak in that vicinity. Similarly, checking outlet structures for cracks, leaking valves or seepage can help to identify if the outlet structure is the source of the leak.

Monitoring waterbody water level over a period of time can quantify the extent of the leakage. Seasonal variations may be indicative of groundwater interactions (i.e. when the groundwater level is high the waterbody is not likely to leak and when the groundwater level is low waterbody leakage is more likely). If groundwater monitoring wells are available in close proximity to the waterbody, monitor groundwater levels together with waterbody levels.

Repairing leaking liners

Prior to embarking on waterbody liner rectification, field investigations should be completed to determine if this is the primary cause. This is likely to require the installation of shallow monitoring wells around the edge of the waterbody, and subsequent water level monitoring of both waterbody and groundwater. These monitoring wells can be simple 50 mm diameter PVC pipe installations backfilled with sand around the pipe opening. Refer to the *Townsville Constructed Lakes Design Guideline* (DesignFlow, 2010) for a typical installation.

Where the waterbody liner is determined to be the source of the leak, possible fixes include:

- Distributing bentonite across the water surface in order for it to settle and seal the leaks. Note: This is considered a highly unreliable method for sealing waterbodies.
- Dewatering waterbody, removing unconsolidated silt and organic matter and then rotary hoeing the bentonite layer into the consolidated base material. When the waterbody is refilled, the bentonite will absorb water, swell and seal base. Note: This method is considered to be a more reliable strategy than distributing bentonite across the water surface.
- Dewater waterbody and lay geotextile clay liner on the base of waterbody to seal base. Whilst this method is commonly used to seal waterbodies, it is expensive and results can be variable due to difficulties sealing the interface between the geotextile clay liner and the outlet structures (e.g. outlet pit)
- Dewater waterbody, desilt and reconstruct compacted clay liner, similar to the method used when constructing stormwater treatment wetlands.

Care must be taken to fully seal areas such as pipes perforating impermeable liners as these can be common sources of leakage.

Repairing leaking embankments

Where the waterbody embankment is determined to be the source of the leak, the problem may be solved by:

- installing a cut-off wall
- sealing the face of the embankment.

Installing a cut-off wall is done by:

1. determining the general location of the leak within the waterbody embankment
2. digging a vertical trench along the embankment in the vicinity of the leak
3. filling the trench with compacted clay (or clay mixed with bentonite) to form an impenetrable barrier.

Sealing the face of the embankment is done by dewatering the waterbody, desilting and then reconstructing compacted clay liner as typically done when constructing stormwater treatment wetlands. Clay liner is constructed on the internal (wet) side of the embankment and generally has a minimum depth of 300 mm. A protective topsoil layer should be provided over the clay liner to minimise any potential cracking from drying out.

Further information is provided by various Australian State governments in the form of advice to landholders on sealing leaking farm dams. For example, see *Leaking Farm Dams* (DPI, 2004) and *Treatment of Leaky Dams* (DA, 2006).

Repairing leaking hydraulic structures

Hydraulic outlet structures can leak in any number of ways. Common leaks include:

- faulty maintenance valves (for draining waterbody)
- poorly sealed pipes
- faulty weir plates
- damaged pipes and pits.

Fixing leaking structures such as these will be site specific, and specialist advice is generally required to have the greatest chance of success.

Where tunnel erosion occurs adjacent to an installed pipe due to improperly compacted materials or pipe leakage, it may be necessary to reinstall the pipe with a cut-off wall and/or seepage collars. Seek specialist advice.

4.4.7 Promoting mixing of waterbody waters

Promoting mixing within waterbodies is used to minimise stratification. Mixing also keeps the waterbody oxygenated, sediments healthy and thus decreases the risk of nutrient release and related algal growth occurring within the waterbody. Oxygen enters the water via diffusion at the water's surface. Increasing turbulence at the water surface can increase the uptake of oxygen within waterbodies.

Well designed waterbodies promote oxygenation via wind forced mixing. This can be achieved by orientating the waterbody appropriately to the prevailing wind direction and establishing a smooth, flat base within the waterbody. Once a waterbody has been constructed it is much harder to promote additional wind mixing. Wind mixing can be encouraged by:

- altering the shape or size of a waterbody (see Section 4.4.3) (e.g. removing an island) to increase the fetch length of the waterbody in the prevailing wind direction
- modifying the bathymetry of the waterbody (see Section 4.4.3) to create a smooth flat base as this promotes more turbulent mixing at the waterbody surface.

One of the most effective ways to promote mixing is to retrofit the waterbody with a recirculation system that is able to circulate water from poorly mixed areas to well mixed areas. This has been shown to be effective in large waterbodies such as the Gold Coast Botanic Gardens. Do some simple calculations and try to move the volume of water in dead pockets out every 2-3 days. For example, a 2 m deep, 20 m^2 section of dead water equates to 40 m^3 or 40,000 L of water. For this water to be pumped out in 3 days (72 hours, or 4320 min), it would take a pumping rate of about 10 L/min.

Proprietary devices are also available that enhance mixing within waterbodies. Effective mixing systems promote both convection (movement of water within the waterbody) and oxygenation (via turbulence at the water surface).

For this reason, systems such as fountains which are not designed to establish convection are usually ineffective at promoting mixing and preventing stratification.

Effective mixing devices are typically one of two types:

- floating or submersible pump systems – these pump water from the base of the waterbody and distribute it on the surface to promote both convection and oxygenation
- aerators – these release air bubbles at the base of the waterbody to promote both convection and oxygenation.

Proprietary mixing devices can be expensive to purchase and operate. In most circumstances, the size and configuration of the mixing system will need to be custom designed for the waterbody to ensure that they are effective.

Solar powered proprietary mixing devices are also available. These are often an attractive option as they have substantially reduced running costs (Figure 4.28).

Figure 4.28 Solar water circulation system close up

Photo: Karen McNeale, Redland City Council

4.4.8 Managing weeds

Weed management is a critical component of looking after waterbodies effectively. Consult *Maintaining Vegetated Stormwater Assets* (Water by Design, 2012a) for detailed information on managing weeds in waterbodies. Note that while the information provided pertains to constructed stormwater treatment wetlands and sediment basins it is equally applicable to waterbodies.

4.4.9 Redesigning waterbodies to high ecological value wetlands

In many instances, redesigning a waterbody to a wetland is an option to reduce long term maintenance costs and create a more sustainable system, particularly where external pressures such as nutrient loadings are high and the waterbody experiences water quality problems. It can also be used to repurpose a leaking waterbody.

Redesigning a waterbody to a wetland may take several forms:

- redesigning the entire waterbody into a wetland
- redesigning a strip or band across the main flow path within the waterbody into a wetland
- redesigning a dead pocket within a waterbody into a wetland
- redesigning a leaking waterbody into an ephemeral wetland.

The first three options should be designed in accordance with the wetland chapter of the *Water Sensitive Urban Design Technical Design Guidelines for South East Queensland* (Water by Design, 2006) and the *Wetland treatment systems* section of the *Wetland Management Handbook: Farm Management Systems* (DEEDI, 2011b). Note that this guidance is tailored towards designing wetlands to treat stormwater. When redesigning a waterbody into a wetland, the primary purpose is to reduce maintenance and create a more sustainable asset. Stormwater treatment is likely to be a secondary consideration. Priority should be given to designing the most sustainable, easily maintained wetland possible.

Figure 4.29 Inside a detention basin configured as an ephemeral wetland

Photo: Jack Mullaly, Logan City Council

Redesigning a leaking waterbody into an ephemeral wetland should also be undertaken in accordance with the *Water Sensitive Urban Design Technical Design Guidelines for South East Queensland* (Water by Design, 2006), with the following considerations:

- in South East Queensland, an ephemeral wetland dominated by Melaleuca species to mimic the natural Melaleuca wetlands of South East Queensland is likely to be a low maintenance, sustainable solution
- creating a sustainable, biodiverse terrestrial ecosystem similar to that described in Blanche (2010)
- modification of the outlet structure to achieve appropriate inundation duration (the existing outlet arrangement of the waterbody is likely to result in inundation for longer than an ephemeral wetland can sustain)
- careful selection of outlet structure to prevent blockage.

Figure 4.29 depicts the understory of an ephemeral detention basin which presents many of the same features that could be incorporated into the conversion of a tree dominated waterbody to an ephemeral wetland.

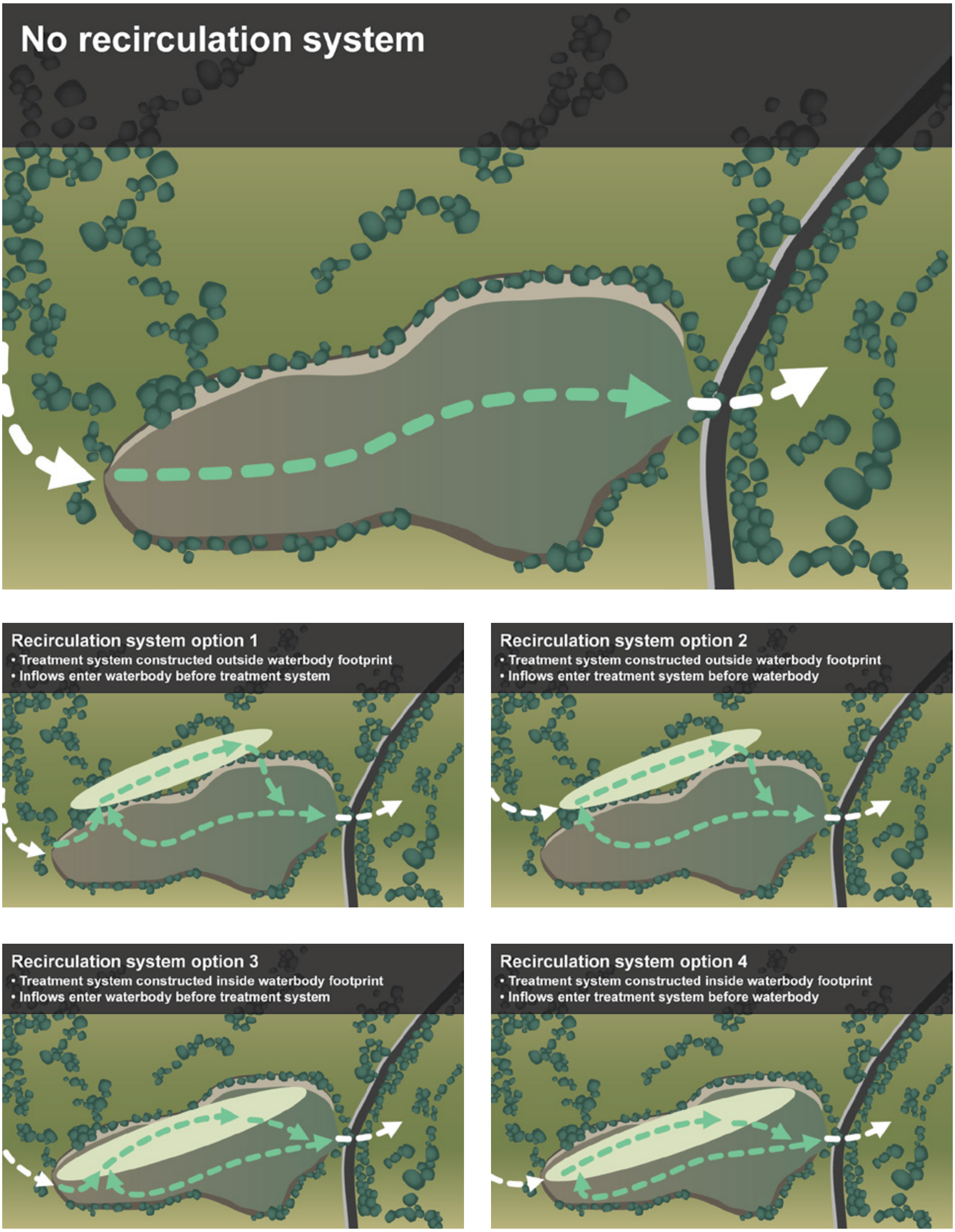
4.4.10 Recirculating water through treatment systems

Recirculating waterbody water through treatment systems can be used to manage water quality in waterbodies. Most often, constructed wetlands are proposed, however bioretention systems and mechanical systems such as sand filters and ultra-filtration could also be used.

The use of treatment wetlands incorporated as part of waterbody recirculation systems is often linked to attempts to manage cyanobacterial blooms in waterbodies. It should be noted that there is little evidence to suggest that constructed wetlands directly remove cyanobacterial cells from water. Treatment wetlands function to improve water quality and thereby reduce the likelihood of cyanobacterial and algal blooms occurring within the waterbody.

Constructed wetlands or bioretention systems can be configured in multiple ways as part of a waterbody recirculation system as shown in Figure 4.30.

Figure 4.30 Possible configurations of vegetated stormwater treatment systems for recirculating waterbody water



Where a recirculation system is considered for use in a waterbody that is oversized for its catchment, locating the treatment system within the existing footprint of the waterbody is desirable as this decreases the overall volume of the waterbody and hence increases hydraulic efficiency and overall resilience of the waterbody to algal and cyanobacterial blooms.

Where a wetland is proposed as part of a waterbody recirculation system it should be designed in accordance with the *Water Sensitive Urban Design Technical Design Guidelines for South East Queensland* (Water by Design, 2006) and the recirculation systems advice provided in the *Townsville Constructed Lakes Design Guideline* (DesignFlow, 2010) and the *Water by Design Urban Lakes Discussion Paper* (2012c).

Due care must be given to the design of wetlands that will receive both stormwater inflows and recirculated waterbody flows. For example, the residence time required in a recirculation wetland is typically longer than for stormwater treatment, and the outlet configuration of the wetland must be appropriately designed to achieve the desired wetland performance.

Recirculating wetlands are also likely to operate over extended periods of time. Due care should be taken when selecting plants for the expected operating conditions.

Bioretention systems can also be used in a waterbody recirculation system. Bioretention systems should be designed in accordance with the *Bioretention Technical Design Guideline* (Water by Design, 2012d). Note that bioretention systems will grow algae on the filter media surface and block if continually loaded with recirculated water. A waterbody recirculation system using a bioretention system for treatment will require multiple bioretention cells so that individual cells can be rested periodically to dry, preventing algal growth. This will require additional pumping and distribution systems compared to a recirculation system using a constructed wetland.

4.4.11 In situ water treatment with floating wetlands

Floating wetlands are growing in popularity as a potential tool for managing water quality in waterbodies. As an emerging technology there still needs to be more research undertaken to fully understand the performance they can be expected to deliver.

Many local governments in South East Queensland are currently trialling floating wetlands in urban waterbodies. Further data can be expected to be available in the future.

Floating wetlands can be either purchased as proprietary off the shelf products, or constructed from simple materials. Both options present their advantages and disadvantages.

Regardless of the option chosen, the key functional elements of floating wetlands are:

- buoyancy – even under fully grown vegetation
- lightweight – to allow for easy handling and movement, and contribute to buoyancy
- durable – the floating wetland must be long lasting to allow for plants to establish
- bird protection – birds will roost in floating wetlands damaging vegetation. Netting or other protection must be robust to prevent damage by birds, particularly during the establishment phase of vegetation
- support for vegetation – ideally the stems of vegetation should sit slightly above the water surface. Vegetation can be either supported by a growing media, or suspended in the water column similar to a hydroponic system
- anchor points and cable fixing – to allow position and secure floating wetlands within waterbodies.

4.4.12 Removing a waterbody

In some circumstances, removing a waterbody may be the best outcome for a local government and the community. There are several ways to remove a waterbody. Some methods include:

- removing an embankment and restoring as a waterway
- infilling waterbody and restoring as a waterway
- disconnecting drainage to waterbody (when located offline), infilling waterbody and restoring usable land
- converting to a stormwater treatment system (Figure 4.31)
- converting to a stormwater detention system (Figure 4.32).

Figure 4.31 A waterbody converted into a stormwater treatment system

Photo: Andrew O'Neill, Water by Design

Figure 4.32 A waterbody converted into a stormwater detention system by inserting a pipe through the embankment

Photo: Jack Mullaly, Water by Design

Prior to removing a waterbody, consider the following to ensure unexpected adverse outcomes are avoided:

- What is the community's expectation from the waterbody?
- Does the waterbody have a flood or conveyance function?
- Does the waterbody have flora or fauna that rely on the ecosystem?
- Does the waterbody have weeds that must be managed? How will this be done?
- Does the waterbody need to be dewatered before being removed? How will this be done?
- How will the waterbody area be stabilised prior to removing?
- How will the sediments be managed?

4.5 WORKED EXAMPLE

This worked example demonstrates how a hypothetical local government may go about using information provided in this module to select the correct maintenance or rectification action for a waterbody, and then implement that action.

4.5.1 Setting

Sunnyside Council is a small to medium sized local government in South East Queensland. It contains several creek systems and one river. The lower reaches of these catchments are typically urban. The upstream reaches are a combination of rural, forest and conservation. There are a large number of waterbodies in Sunnyside Council. Approximately 70% are on private land, with the remaining 30% on Council land.

Due to a series of prominent incidents in Council managed waterbodies, including a fish kill, Sunnyside Council recently undertook to improve how it manages its waterbodies. The two main aims of this were to achieve acceptable environmental outcomes and avoid unnecessary cost to the community.

Module 3, Section 3.8 explained how Sunnyside Council:

- investigated their waterbody roles, responsibilities and resources
- identified and characterised their waterbodies
- prioritised their waterbodies
- managed the financial aspect of looking after their waterbodies.

In this Section we see how Sunnyside Council used the 'waterbody issues and actions tables' (Table 4.1 to Table 4.5) to identify a problem with one of their waterbodies, investigate it, then identify and implement an appropriate response.

4.5.2 Identifying the problem

Sunnyside Council received several public complaints regarding mosquitoes from residents living near a waterbody at Cockatoo Crescent. The complaints described a recent increase in mosquito numbers, particularly noticeable in the late afternoon, believed to be associated with the waterbody.

From the work Sunnyside Council undertook prioritising their waterbodies, the Cockatoo Crescent waterbody was identified as a high priority waterbody with large pressure from the surrounding catchment. Located in a high profile park, it was also highly valued by the community.

Sunnyside Council used Table 4.1, *Waterbody health and safety issues and associated management and rectification actions*, to investigate and identify the problem.

The first step was to investigate the problem (Figure 4.33)

Figure 4.33 Step 1 – Investigating the problem

STEP 1

Issue – Human health risk due to large mosquito populations			
Description	**Investigations/monitoring**	**Management actions**	**Rectification actions**
The presence of large mosquito populations [illegible] h a [illegible] n health risk (as mosquitoes transmit many pathogens including protozoa, nematodes and viruses) and a nuisance to local residents.	Discuss safety with asset owner and environmental health department to identify and document any issues. Undertake site inspection to check for evidence of mosquito breeding sites around the margins of the waterbody and also in any isolated shallow pools in the near vicinity. Check for evidence of litter which may support mosquito breeding. Undertake risk assessment. Record whether or not: • the mosquito problem is associated with the waterbody (or the surrounding ecosystems) • simple management actions can be implemented to reduce populations • a mosquito control plan should be prepared and rectification actions implemented. Where a mosquito control plan is required then an audit of the mosquito species and population density both within waterbody and adjacent habitats is required.	Simple management actions may include: • implementing a regular litter removal program • spraying with ecologically friendly larvicides (Seek advice from environmental health experts within local government if the use of chemical control agents is deemed necessary. Not recommended as a long term strategy due to insecticide resistance, cost and possible inability to apply to all areas).	Where rectification is required, a mosquito control plan should be prepared in accordance with the *Mosquito Management Code of Practice for Queensland* (Local Government Association of Queensland, 2002) Rectification options may include: • draining isolated pockets of pooled water • filling in uneven areas where stagnant water accumulates • increasing depth in open water areas to >60 cm to limit mosquito breeding • increasing the slope of submerged batters (see 'Risk of injury or drowning' in this table for further discussion of waterbody batter slope) • increasing the diversity of plants (both emergent and submerged) in the waterbody • improving waterbody circulation and flushing • introducing mosquito predators (native fish).
Relevant supporting information Local Government Association of Queensland (2002),Queensland Health (2002), Water by Design (2012a), Water by Design (2012b)			

The Stormwater and Flood Plain Management department (recently appointment as responsible for managing waterbodies) consulted with the Parks Maintenance department and Pest Management department, and together undertook a site inspection to determine whether:

- the mosquito problem was associated with the waterbody
- there were any simple management actions that could be implemented.

Sunnyside Council inspected the waterbody in the late afternoon and quickly determined that there was indeed a mosquito problem.

They undertook an inspection of the perimeter of the waterbody and located an isolated pool of open water approximately 200 m² in size and 20 cm deep. It was determined to be mosquito breeding habitat. No other suitable habitat was found so it was determined to be the primary source of the mosquito problem.

As this was the first known mosquito outbreak at the Cockatoo Crescent waterbody, further investigations were undertaken. Sunnyside Council determined that the isolated pool of water was not a normal feature of the waterbody. Due to a prolonged period of dry weather, evaporation had lowered the water level to the point where the uneven base of the waterbody caused the shallow isolated pool of water to develop in a location normally more than 70 cm deep and connected to the rest of the waterbody.

4.5.3 Deciding on management and rectification actions

Having identified the source of the mosquito outbreak, the next step was to determine the appropriate management or rectification action(s) (Figure 4.34)

From Table 4.1, possible actions included:

- regular spraying with larvicides
- draining isolated pockets of pooled water
- filling in uneven areas where stagnant water accumulates
- increasing depth in open water areas to >60 cm to limit mosquito breeding
- improving waterbody circulation and flushing
- introducing mosquito predators (native fish).

Sunnyside Council chose to fill the uneven area where water ponded to remove the mosquito habitat, and replant with fringing ephemeral vegetation to create ephemeral wetland. Table 4.8 explains why this option was chosen.

Table 4.8 Rationale for choosing to fill mosquito habitat

Possible Action	Chosen (Yes/No)	Reason
Regular spraying with larvicides	No	Council wanted a long term solution which did not involve chemical use in a high profile park.
Draining isolated pockets of pooled water	No	Would have required dewatering waterbody.
Filling in uneven areas where stagnant water accumulates	Yes	Could be undertaken without dewatering waterbody. Enabled the creation of a small pocket of ephemeral wetland. Long term solution.
Increasing depth in open water areas to >60 cm to limit mosquito breeding	No	Would have required removal of materials offsite and dewatering of waterbody. Could have compromised waterbody liner.
Improving waterbody circulation and flushing	No	Would have required major works to bathymetry.
Introducing mosquito predators (native fish)	No	Considered to already exist within main body of waterbody and would inhabit the breeding area once water levels rose again.

Figure 4.34 Step 2 – Management and rectification actions

Issue – Human health risk due to excessive mosquito populations			
Description	**Investigations/monitoring**	**Management actions**	**Rectification actions**
The presence of large mosquito populations represents both a potential human health risk (as mosquitoes transmit many pathogens including protozoa, nematodes and viruses) and a nuisance to local residents.	Discuss safety with asset owner and environmental health department to identify and document any issues. Undertake site inspection to check for e[illegible] breeding si[illegible]gins of the waterbody and also in any isolated shallow pools in the near vicinity. Check for evidence of litter which may support mosquito breeding. Undertake risk assessment. Record whether or not: • the mosquito problem is associated with the waterbody (or the surrounding ecosystems) • simple management actions can be implemented to reduce populations • a mosquito control plan should be prepared and rectification actions implemented. Where a mosquito control plan is required then an audit of the mosquito species and population density both within waterbody and adjacent habitats is required.	Simple management actions may include: • implementing a regular litter removal program • spraying with ecologically friendly larvicides (Seek advice from environmental health experts within local government if the use of chemical control agents is deemed necessary. Not recommended as a long term strategy due to insecticide resistance, cost and possible inability to apply to all areas).	Where rectification is required, a mosquito control plan should be prepared in accordance with the *Mosquito Management Code of Practice for Queensland* (Local Government Association of Queensland, 2002) Rectification options may include: • draining isolated pockets of pooled water • filling in uneven areas where stagnant water accumulates • increasing depth in open water areas to >60 cm to limit mosquito breeding • increasing the slope of submerged batters (see 'Risk of injury or drowning' in this table for further discussion of waterbody batter slope) • increasing the diversity of plants (both emergent and submerged) in the waterbody • improving waterbody circulation and flushing • introducing mosquito predators (native fish).
Relevant supporting information Local Government Association of Queensland (2002),Queensland Health (2002), Water by Design (2012a), Water by Design (2012b)			

STEP 2 →

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