

Constructed Wetlands in the Northern Territory

Guidelines to Prevent Mosquito Breeding

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Constructed Wetlands for Water Sensitive Urban Design in the NT Guidelines to Prevent Mosquito Breeding

1.0 Introduction

Constructed Wetlands are designed to manage and treat urban stormwater or are provided for aesthetic values, and can have various forms such as a simple open lake system, or periodically flooded shallow vegetated basins. Constructed wetlands have the potential to be much more productive breeding sites for mosquitoes compared to natural wetlands due to elevated nutrients from urban runoff, therefore constructed wetlands in the Northern Territory need to be appropriately designed and managed to prevent mosquito breeding.

Mosquito species that are likely to breed in freshwater constructed wetlands in the Top End of the NT include the major arbovirus vector *Culex annulirostris* (the common banded mosquito), various *Anopheles* species (potential malaria vectors) and the pest mosquitoes *Coquillettidia xanthogaster* (the golden mosquito) and *Mansonia uniformis* (the water lily mosquito). Constructed wetlands in tidal areas could become breeding sites for the northern salt marsh mosquito *Aedes vigilax*, the saltwater *Culex* species *Culex sitiens*, and the saltwater and brackish water *Anopheles* species *Anopheles farauti s.s. (An. farauti no.1)* and *Anopheles hilli*.

There may be conflicts between the design for water treatment alone and the design features to prevent mosquito breeding. However it is important to consider the potential for mosquito breeding while designing and constructing wetlands, as both aims can often be accommodated in a compromise design. Constructed water bodies that become mosquito breeding sites will not only affect nearby residents by increasing pest and potential mosquito borne disease transmission, but would incur a significant cost by the managing authority (usually a local council) for associated mosquito survey/control and site rectification.

The purpose of this guideline is to assist developers and land managers in deciding on an appropriate wetland design and management regime, which meets the public health requirements as well as water treatment and other requirements of a constructed wetland. Overall, the main reference documents for design criteria should be the [NT Subdivision Development Guidelines](#) and local council guidelines.

2.0 Mosquito species and constructed wetlands

The common banded mosquito *Culex annulirostris*

This species breeds in the vegetated margins and pools in permanent and semi-permanent freshwater swamps, creeks and floodways, temporary flooded vegetated ground pools, and in high nutrient water such as effluent discharge and urban stormwater drains. Potential breeding sites in constructed wetlands would include any shallow area containing semi-aquatic or aquatic vegetation, as well as vegetated stormwater drains and channels, areas of high nutrient water pools (i.e. stormwater pipe outfalls), and flooded vegetated depressions in landscaped areas.

Culex annulirostris is most common within 2km of productive breeding sites, but can disperse up to 10km from extensive breeding sites. *Culex annulirostris* is the most important vector of arboviruses in the NT. It is recognised as a good vector of Murray Valley encephalitis virus (MVEV), Kunjin virus (KUNV), Ross River virus (RRV) and Barmah Forest virus (BFV). Many other arboviruses have been isolated from this species.

Anopheles mosquitoes

Anopheles mosquitoes generally breed in fresh and brackish water swamps or creeks. Potential breeding sites in constructed wetlands include shallow flooded areas containing semi-aquatic vegetation and vegetated stormwater drains and channels. *Anopheles* mosquitoes are usually most common within 1.6km of breeding sites, although some species such as *Anopheles hilli* will fly several kilometres from their breeding sites. Some *Anopheles* mosquitoes such as *An. farauti s.l.* and *An. annulipes s.l.* are regarded as potential vectors of malaria.

The frosty mosquito *Culex gelidus*

This species breeds in freshwater ground pools, swamps and containers. In the NT, this species has often been associated with high organic wastewater ponds in piggeries, abattoirs, dairies and sewage treatment facilities. Potential breeding sites in constructed wetlands would be areas of high nutrient ponding, such as at stormwater pipe discharge sites. This species is a potential vector of Japanese encephalitis virus, MVEV, KUNV, RRV, BFV and other arboviruses.

The brown house mosquito *Culex quinquefasciatus*

This species breeds in septic tanks, polluted stormwater drains, effluent treatment facilities, flooded depressions with high organic content and water filled domestic receptacles. Potential breeding sites in constructed wetlands include high nutrient ponding areas at stormwater pipe outfalls. *Culex quinquefasciatus* is usually most common within 500m of productive breeding sites. *Culex quinquefasciatus* is only a pest mosquito in Australia.

The golden mosquito *Coquillettidia xanthogaster*

This species breeds in swamps, billabongs and creeks with semi-aquatic and aquatic vegetation, particularly semi-aquatic reeds. Potential breeding sites in constructed wetlands would include any shallow flooded areas with semi-aquatic vegetation. *Coquillettidia xanthogaster* is usually most common within 3km of productive breeding sites, and is not regarded as a human disease vector in Australia.

The water lily mosquito *Mansonia uniformis*

This species breeds in similar habitats as *Cq. xanthogaster*, but are more associated with floating vegetation. Potential breeding sites in constructed wetlands would include any shallow flooded areas with semi-aquatic and aquatic vegetation. This species is most common within 2km of breeding sites, and is not regarded as a human disease vector in Australia.

The northern salt marsh mosquito *Aedes vigilax*

Natural breeding sites for *Ae. vigilax* are temporary flooded areas in tidal to brackish swamps, creeks, salt marshes, upper mangrove areas and coastal dune depressions. Constructed wetlands could create breeding sites for this species if they are built in or adjacent to tidal areas. *Aedes vigilax* will breed in depressions within salt influenced wetland systems that periodically dry and then become inundated with tide water, stormwater or rain. This species will also breed in inappropriately landscaped areas surrounding tidal wetlands, and in stormwater drains with tidal influence. *Aedes vigilax* is a major pest mosquito.

Aedes vigilax is most common within 5km of breeding sites, but can fly up to 50km in pest numbers from large breeding sites. *Aedes vigilax* is a vector of RRV and BFV.

The saltwater *Culex* mosquito *Culex sitiens*

Breeding sites for *Cx. sitiens* are the same as for *Ae. vigilax*, although *Cx. sitiens* only breeds when extended saline ponding occurs. *Culex sitiens* is most common within 2km of breeding sites. *Culex sitiens* is regarded as a potential vector of RRV disease, and can be an appreciable pest near productive breeding sites.

3.0 Constructed wetlands and the potential for mosquito breeding

Constructed wetlands can be either relatively simple lake systems, or more complex systems that include shallow areas of flooded semi-aquatic vegetation. It is the shallow vegetated areas of these wetlands that have the greatest potential for mosquito breeding, with their potential rising dramatically as organic loads increase.

Simple freshwater lake systems that are constructed with deep water and relatively steep sides have been built in areas of Darwin and Palmerston, and the lakes themselves have not become significant mosquito breeding sites. The lakes generally have minimal or a thin margin of semi-aquatic reed growth, as well as relatively steep sides and deep water to minimise the extensive colonisation of semi-aquatic vegetation and facilitate fish survival. The potential for mosquito breeding in such lake systems usually only arises if regular maintenance is not conducted to remove silt deposition in inlet areas and excess semi-aquatic reed growth, or when fish populations are eliminated.

Shallow vegetated wetlands provide a favoured habitat for mosquito larvae. The potential for productive mosquito breeding in shallow vegetated wetlands is dependant on the extent and density of semi-aquatic reed growth. Dense shallow mats of fallen reeds in a constructed wetland will give rise to productive mosquito breeding. These dense shallow mats of reeds would provide mosquito habitat both during initial flooding in the early wet season, and during the late wet and early to mid dry season when reeds fall over as water levels recede. Constructed wetlands with extensive shallow areas of semi-aquatic vegetation will require a high degree of maintenance and will be costly to minimise mosquito breeding. Shallow wetlands receiving stormwater flow are also likely to be more productive mosquito breeding sites than comparable natural wetlands, due to the higher nutrient input from stormwater discharge.

Constructed wetlands are also likely to attract animals, which may act as reservoirs of various arboviruses, for example water birds which are hosts for the potentially fatal Murray Valley encephalitis virus, and macropods (wallabies), which are hosts for Ross River virus. It is therefore important not to have the combination of animal reservoirs and the mosquito vectors of disease, particularly within mosquito flight range of residential areas.

4.0 Risk assessment

There should be a risk assessment conducted to determine the potential for mosquito breeding in constructed wetlands. For example, a shallow constructed wetland within 2km of urban residential areas will pose a high risk of creating pest and arbovirus transmission problems. Mitigation measures to reduce mosquito breeding in such a wetland would be ongoing and costly, and are discussed further in this document. Conversely, a deep, steep sided lake would pose minimal mosquito breeding issues for adjacent residents.

When there are likely to be significant mosquito breeding issues with a particular wetland design, consideration should be given to an alternative design with a lower mosquito breeding potential. An alternative design may reduce the water treatment efficiency of the wetland to some extent, but in most instances there should be a balance between water treatment and public

health. Both designs should be compared for positives and negatives from all perspectives (eg Water treatment efficacy, mosquito breeding, public safety, maintenance costs etc), before the final design is chosen. It should be noted that it would be a requirement under the Public and Environmental Health Act and associated regulations to prevent mosquito breeding

For each constructed wetland, the time for significant levels of contaminants to settle out of the water would need to be determined, with design and management measures tailored to suit these calculations. For example in Brisbane, it is suggested 72 hours is a preferable period of detention in the macrophyte (vegetation) zone of a constructed wetland to allow removal of contaminants. Therefore there in some situations there may be no need to retain water for periods greater than 3 days in a heavily vegetated shallow area. This would generally avoid mosquito breeding, as mosquito larvae take from 6 to 10 days to complete their aquatic development stages.

5.0 Design considerations

5.1 Siting

Preferably, constructed wetlands should be sited in an open area exposed to wind, to maximise the impact of wave action to disrupt mosquito breeding. To maximise the effect of wind, the water body should be orientated so its long axis is in line with known prevailing wind direction (south-east dry season winds and north-west wet season monsoon winds for Darwin region).

If practical, constructed shallow vegetated wetlands likely to breed mosquitoes should be sited at least 1.6km from any urban residential areas. This would provide a buffer distance to minimise the potential for mosquito breeding to impact on residents. Constructed wetlands in tidal areas should generally be avoided due to the inherent difficulties in constructing and maintaining a wetland in a tidal area. In tidal areas, the inundated areas would generally need to be free draining on a daily basis, or have steep sides around a salt to brackish water lake.

Wetlands should be sited in an area where a relatively simple design can be achieved, as wetlands with simple shapes and a low edge to area ratio have a lower potential to become productive mosquito breeding sites.

5.2 Hydrology

There should be a component of a constructed wetland that permanently retains water throughout the year. For example, a lake should retain water at one end to provide a refuge for fish during the dry season. A constructed wetland that completely dries and then re-floods will lack mosquito predators for a short period after re-flooding, and could become a short term mosquito breeding site. A constructed wetland should however be allowed to recede during the dry season to some extent, to allow maintenance of edges (eg silt and vegetation removal). Lakes or water features in the Northern Territory, with virtually no rain for 5-6 months, need to be designed to retain water during these long periods of no rain, or be periodically topped up with water.

5.3 Aquatic vegetation

The provision of semi-aquatic and aquatic vegetation is generally necessary to remove nutrients from water, and is required to reduce the potential for algal blooms. Relatively sparse or narrow marginal areas of emergent vegetation are unlikely to lead to mosquito breeding, as fish access would not be restricted. Potential problems will arise if regular maintenance is not conducted

and semi-aquatic/aquatic vegetation becomes dense and extensive and creates harbourage for mosquito larvae.

Semi-aquatic reeds such as *Typha sp.* and, *Eleocharis sp.* can provide major habitat for mosquito larvae, but are important for removing nutrients from the water. Semi-aquatic reeds can be restricted to small areas of upright vegetation by the use of sub-surface concrete boxes or barriers to prevent rhizome spread. This design will allow predator access and prevent mosquito breeding, while at the same time provide refugia for fish. Semi-aquatic reeds in shallow lakes or basins can quickly spread and create extensive areas of vegetation which will enhance mosquito breeding. If the design of a wetland incorporates flooded semi-aquatic vegetation, there would be a requirement for at least an annual maintenance program to harvest vegetation.



Photo A

Natural billabong, dense *Eleocharis sp.* reeds, shallow margins and very high *Cx. annulirostris* breeding. Ground control with larvicides would be very difficult.

Semi-aquatic reeds should not be allowed to become dense as pictured above (Photo A-natural billabong), as this will give rise to high levels of mosquito breeding and ground control with mosquito larvicides in the dense vegetation would be very difficult.

Alternatively, semi-aquatic reeds can be planted along a thin margin at the upper water limit of a steep margin of the wetland. The water level can be seasonally manipulated during the dry season and stranded vegetation can be easily maintained or removed (see Photo B). The spread of rhizomes of semi-aquatic reeds such as *Eleocharis* or *Typha* could be limited by constructing a narrow concrete retaining wall along the wetland margin. Generally if steep sides and deep water (at least 1.5m deep) are provided, the spread of reeds would be restricted to the shallow upper margin.



Photo B

Gardens Golf Course Lake, small stand of *Typha spp.* reeds, stranded during dry season. Allows easy maintenance.

The same principles also apply to other semi-aquatic plants such as sedges, with sparse vegetation unlikely to lead to mosquito breeding. Aquatic plants such as water lilies are recommended for smaller shallow wetlands, as they provide shade for fish.

Annual maintenance is generally required to remove dead semi-aquatic vegetation, either by physical removal or by burning. Semi-aquatic vegetation that has begun to spread beyond their desired location should also be physically removed, or controlled by herbicide.

5.4 Water quality

Water quality in constructed lakes should be maximised by utilising some form of mechanical aeration, which can be achieved by using fountains or waterfall features. Well circulated, oxygenated water bodies are less likely to produce algal blooms and are less likely to produce fish death. The use of fountains in smaller water bodies is also useful to disturb the water surface and disrupt mosquito breeding. Smaller fountains located near the margins of a lake could be utilised to create disturbance to the shallow edges where mosquito breeding usually occurs. Mechanical aeration would be particularly important during the late dry season, when temperatures are high and oxygen levels are likely to be low.



Photo C

Gardens Golf Course Lake, mechanical aeration, steep vegetation free margin.

5.5 Lake systems

Lake systems should be simple in design, and generally should have steep sides (at least 1V:2H) and relatively deep (1.5 to 2m) wet season stabilised water level. There can be areas of semi-aquatic vegetation and aquatic vegetation provided to treat water, although vegetation should be limited to relatively small stands that are regularly maintained by harvesting/physical removal, or extensive vegetated areas that are only flooded for 2-4 days. Stormwater should flow into the deepest section of any lake.

There may be issues with public safety when providing steep edges. In those instances when shallow edges are required, a concrete vertical lip (200-300mm) should be provided at the lake margin to maximise the effect of wave action. The shallow area of the lake adjacent to the vertical lip would need to be maintained free of semi-aquatic vegetation. The concrete lip can be aesthetically acceptable if constructed appropriately (see Photo D).



Photo D

George Brown Darwin Botanical Gardens water feature. Shallow water, concrete vertical edges.

5.6 Constructed wetlands with shallow vegetation treatment zones

These types of wetlands include a shallow vegetated component (macrophyte zone) to treat stormwater, and a deep lake or deep pools to provide refuge for fish. These wetlands require careful design considerations, as the shallow vegetation treatment zones could become productive mosquito breeding sites.

Dry season flows need to be directed into the deepest section of the permanent lake or deep pool within the wetland system. This deeper section is where fish and other aquatic predators are likely to be present, and where the potential for semi-aquatic vegetation growth is minimal. Silt traps would be required where stormwater drains lead into the constructed wetland.

5.6.1 Wetlands with detention vegetation zones

Wetlands that have vegetated components which detains water for a period of 48-72 hours, with water then draining into a lake or deep pools are unlikely to become significant mosquito breeding sites. Detention in an extensively vegetated area for 48-72 hours would not breed mosquitoes, as this period of time would not allow full larval development. This detention period should still provide removal of fine sediment and soluble pollutants. This type of design is appropriate for any proposed shallow constructed wetlands within 2km of residential areas in the Northern Territory.

There should be periodic inspections during the wet season to ensure the detention zone does not pond water for greater than 3-4 days. Any shallow depressions that pond water for greater than 4 days should be earmarked and rectified during the following dry season. Annual maintenance would be required to remove dead vegetation, and harvest or remove vegetation that has become dense or spread to other areas of the wetland.

5.6.2 Wetlands with retention vegetation zones

This design includes a shallow vegetation area that ponds water for extended periods, with a lake/deep pools provided for fish refuge during the dry season. Wetlands with shallow heavily vegetated treatment zones, which retain water for the duration of the wet season and into the early to mid dry season will breed mosquitoes. This type of design should typically be avoided unless detailed studies indicate these systems can be designed to remove sediment, pollutants and nutrients and not breed mosquitoes.

Wetlands with vegetated retention zones will require a comprehensive monitoring and maintenance program to minimise mosquito breeding. This includes weekly adult mosquito monitoring around the wetlands, as well as monitoring in nearby areas, to establish if mosquito populations are originating from the constructed wetland. Weekly larval surveys during the wet season to mid dry season would also be required to locate any actual mosquito breeding within the shallow vegetated component of the wetlands. Annual maintenance such as vegetation removal and silt removal would also be required, as well as regular visual inspections to ensure there are suitable fish populations. This monitoring and maintenance program would need to be conducted by the landholder or responsible authority.

Wetlands designed with vegetated retention zones need to have an emergency drainage provision provided, which will allow the shallow component to be drained over a period of a few days. The emergency drainage would be utilised if significant mosquito breeding is located and mosquito larval control operations are unlikely to be effective (ie if ground control is impossible due to dense vegetation, lack of required personnel). This could be achieved by installing a pipe system or contour system in the lowest point of the shallow area, to direct water to the lower lake/deep pool component. A gate in the bund wall separating the shallow vegetated retention zone from the deep lake, with a provision to close and open when needed, could an option for emergency drainage (ie similar to a lock system for a marina). The shallow area would require annual maintenance to ensure there are no isolated depressions that could pond water for extended periods after it has been drained, and to ensure the emergency drainage system is in working order.

5.7 Constructed wetlands in or adjacent to tidal areas

Constructed wetlands in or adjacent tidal areas have the great capacity to breed mosquitoes. This is due to saline mosquito species such as *Aedes vigilax* and *Culex sitiens* being able to breed in high numbers in vegetation free shallow water areas.

It is very difficult to achieve a depression free surface in tidal areas, particularly in shallow extreme upper tidal areas that are infrequently inundated by tides. These areas tend to have minimal slope, and subtle changes in vegetation growth or silt deposition can create shallow depressions conducive to mosquito breeding. A relatively deep (1-2m), steep sided tidally influenced lake with a tidal water retaining barrier is one design that can be recommended for water retention in tidally affected areas. This design has worked very well at Vesteys Beach in Darwin (see Photo E).



Photo E

Vestey's Lake, steep margins, fish, no semi-aquatic vegetation. Tidally influenced. No mosquito breeding.

5.8 Silt traps

Silt traps are required to capture coarse sediments and minimise silt deposition in wetlands. Silt traps are best designed with a hard floor (eg concrete) and steep sides (preferably concrete), with a suitable access ramp for machinery. Silt traps need to be positioned at stormwater discharge points. Due to the likelihood of dry season flows, there should be provisions provided in all silt traps to dam or divert dry season flows to a deep section of the receiving lake or water body, so annual maintenance can be performed. Silt should be removed from the silt trap on at least an annual basis by the responsible authority. Silt traps with vegetation should be designed to completely drain within 3-4 days, alternatively silt traps should incorporate a design that does not include vegetation.



Photo F

Stormwater outfall at Palmerston. Silt trap. Dense *Typha spp.* growth, algal bloom, likely mosquito breeding. Lack of maintenance.

5.9 Stormwater drains

All urban stormwater drains leading into constructed wetlands must be the standard underground stormwater pipe or concrete invert open drain, to prevent the creation of mosquito breeding within stormwater drains. This includes ensuring all stormwater road side entry pits, grate inlet pits and letterbox pits are free draining, and ensuring grassed swale drains have

concrete low flow inverts when there is the likelihood of low flows during the dry season. Dry season low flows must be directed into the deepest section of any water body.

5.10 Landscaping

Appropriate landscaping of areas surrounding constructed wetlands is vital, as poorly draining surrounds has caused many mosquito problems around constructed wetlands in Darwin. Appropriate grades would need to be applied to all landscaped areas surrounding wetlands, to allow the sheetflow of water into the wetland. More extensive and wider surrounds may need swale drains with concrete inverts leading into wetlands.



Photo G
Low gradient applied to landscaping. Wet season mosquito breeding site.



Photo H
Concrete invert open drain. Surrounding areas graded to flow into drain. Dry season flows directed to lake.

5.11 End point of discharged water

There must be no dry season discharge of water from a constructed wetland, unless the discharge is directed to a lake or the sea via an appropriate drain that will not give rise to mosquito breeding. Constructed wetlands without an appropriate end point for dry season

discharge water should have sufficient capacity to retain water, or be appropriately managed to prevent the dry season discharge of water.

Wet season overflows from constructed wetlands should be directed to the 4.0m AHD level for those developments adjacent to tidal areas, or to a defined river or free draining creekline for those developments away from tidal areas. The overflow should be suitably designed and maintained such that it will not have the capacity to breed mosquitoes.

6.0 Maintenance

Before the construction of any lake system or water sensitive urban design strategy, the relevant authority that will assume control of the water feature would need to be determined. The relevant authority would then need to develop a mosquito management plan in consultation with the developer and Medical Entomology of DHCS, to ensure the water feature is managed appropriately by the relevant authority to avoid any appreciable mosquito breeding.

Management measures would involve annual maintenance such as; removing silt from sediment traps; removing silt from lakes/deep pools; harvesting semi-aquatic vegetation from shallow treatment zones and lakes/deep pools; burning/removal of dead vegetation from the shallow treatment zone; rectification of surface depressions in shallow treatment zones; desilting and removal of vegetation from open drains and filling and grading landscaped areas to remove surface depressions.

7.0 Mosquito monitoring

Any wetland with a retention vegetation zone should have a mosquito monitoring program established for the life of the wetland. Mosquito monitoring should involve adult trapping once a week at the wetland, and at a site at least 500m away from the wetland, to allow an evaluation of the origin of mosquito numbers at the wetland site. Recommended adult mosquito traps would be carbon dioxide baited Encephalitis Virus Surveillance (EVS) traps, as they are the same traps used in most other parts of the NT. Indicator mosquito species in the adult mosquito traps would be the species with a low effective flight range (eg *Anopheles* species, *Mansonia uniformis*, and *Culex quinquefasciatus*, and also *Culex annulirostris*).

Larval mosquito surveys are required on a weekly basis during the wet season and early to mid dry season for any shallow flooded vegetated retention areas. Larval surveys involve surveying in shallow areas with dense vegetation growth with a 300ml ladle. A larval density* of 1 larvae per 2 ladle dips or higher is likely to indicate a potential mosquito problem for adjacent residents. If the larvae are identified as important pest or disease mosquitoes and if the breeding area is large, some form of mosquito control would be required, such as draining the retention area or using a suitable mosquito larvicide. An evaluation of the cause of the breeding should then be conducted, with rectification measures implemented to prevent further breeding.

*Please note that these larval densities are only suggested threshold levels. If complaints from residents or adult trapping reveals significant pest mosquito problems despite larval counts being lower than the threshold, then the threshold will need to be re-evaluated.

8.0 Mosquito control

Mosquito control capabilities is vital for constructed wetlands. In general biological control agents such as fish are the most efficient method of controlling mosquito breeding, providing fish have sufficient access to all areas of the wetland. Fish species to be used in constructed wetlands must be sourced from local waterways, to prevent the introduction of exotic fish species. In general the rainbow fish (*Melanotaenia spp.*) are very hardy and should be stocked

in all wetlands. Other fish species that can be stocked in constructed wetlands include blue eyes (*Pseudomugil spp*), glass perchlets (*Ambassis spp.*), grunters (*Leiopotherapon spp.*) and gudgeons (*Mogurnda spp.*).

Along with fish, annual vegetation maintenance should keep mosquito breeding to minimal levels. However, there may be periods of high mosquito breeding that would require temporary insecticide control until the cause of the breeding is rectified. The use of insecticides can quickly control mosquito breeding, but is not recommended as a long term strategy due to potential issues with insecticide resistance, long term cost of maintaining a mosquito control program and the possibility of the insecticide applications not being able to target all areas of breeding. Mosquito breeding can be controlled with the specific and ecological friendly insecticides *Bacillus thuringiensis* var. *israelensis*, *Bacillus sphaericus* or methoprene until a solution to prevent/minimise mosquito breeding is implemented.

9.0 Summary

Constructed wetlands can potentially create habitat for mosquito larvae. There are however specific design and management options that can be used to minimise or prevent mosquito breeding. The general wetland design and management requirements by the responsible authority are listed in order of priority. This information is also displayed in Appendix 1.

1. Wetlands constructed as a deep (1-2m wet season stabilised water level), steep sided (at least 45⁰ angle or 1V:2H) lake, with stormwater discharged to the deepest point via a silt trap. Management requirements include annual removal of silt and semi-aquatic vegetation. Overall, ensure the [NT Subdivision Development Guidelines](#) or local council design guidelines are followed.

2. Wetlands with detention vegetation treatment zones. The wetland should include a deep, steep sided lake/deep pools with dry season flows directed to the deepest point, while the vegetation treatment zone should only pond water for a period of 3-4 days. Management requirements include annual inspections of the lake margins and removal of silt and marginal vegetation, and annual inspections of the vegetation treatment zone, with maintenance conducted to remove silt, isolated depressions and dead or lodged vegetation.

3. Wetlands with retention vegetation treatment zone. There should be a main lake/deep pools provided with deep and steep sides. Dry season water should discharge into the deepest point of the lake. There should be an emergency provision provided in the retention zone to allow rapid drainage into a lake/deep pool if mosquito breeding becomes a problem. A weekly adult mosquito monitoring and larval mosquito monitoring program is required to ensure mosquito populations do not reach pest or public health risk levels. Annual maintenance is required to remove vegetation from the retention zone, remove silt and rectify isolated depressions in the retention zone, and remove semi-aquatic vegetation and silt from the main lake.

In conclusion, constructed wetlands have the potential to create new mosquito breeding sites that could impact on the public health of nearby residents. Design aspects and management options should be carefully considered before construction commences. Each wetland will require a case by case analysis using these guidelines, which have been developed to assist developers and land managers in choosing a suitable design.

10.0 References and further reading

Brisbane City Council Water Sensitive Urban Design Practice Note Series. Practice Note 6 Constructed Wetlands.

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Appendix 1

