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Land Capability Assessment
Biodiversity Survey
Drone Mapping & Survey
Bushfire Attack Level Assessment (BAL)
GIS Mapping & Analysis

Client:

Project: Mosquito Management Plan report for proposed subdivision at 109 Old Peterborough Road, Peterborough, Victoria.

Date: April 9, 2024

Contact:

Landtech:

Figure 1 – Distribution of within-site modified soakage areas.

Document control

Assessment	Mosquito Management Plan for subdivision development
Address	109 Old Peterborough Road, Peterborough, 3270, Victoria.
Project number	1093270
Project manager	
Client	
Bioregion	Warrnambool Plain Bioregion
CMA	Glenelg-Hopkins CMA
Council	Moyne Shire Council

Acknowledgements

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Figure 2 – View from south-east corner of near-level subject lot with Old Peterborough road adjoining the east of the lot.

SUMMARY

Landtech Consulting has been engaged to prepare a *Mosquito Management Plan* for a site (proposed subdivision) located within a residential area in Peterborough, Victoria.

The purpose of this report is to provide strategies to assist in minimising biting insect nuisance on and surrounding the development site.

The current proposal is for a residential subdivision of Lot 3 PS615833 to create fifty-seven residential lots and a residual lot, comprising two reserve areas that are ephemerally inundated depression areas.

The subject land is zoned *General Residential Zone 1 (GRZ1)* and includes coverage by *Significant Landscape Overlay (SLO)* and *Environmental Significance* overlays.

A site assessment was undertaken on 18 February 2023 to obtain information on mosquito mitigation potential issues relating to the stormwater treatment areas proposed for the site.

It is concluded that the biting insect nuisance and risk of disease transmission to future inhabitants of the subject site can be adequately minimised by implementing the recommendations of this management plan during development of the subdivision.

Figure 3 – Site subdivision configuration with twin wetland reserves shown (Source: SITEC 2024).

CONTENTS

Figure 4 – Site subdivision with reserve areas proposed shown.

1 INTRODUCTION

Purpose & Scope

The purpose of this report is to provide strategies to assist in minimising biting insect nuisance on and surrounding the proposed development site.

SITEC (Warrnambool) have designed depression drainage strategies (*Stormwater Management Plan dated: 30.8.2023*) to assist in the mitigation of mosquito nuisance typical in such coastal estuarine environments.

Council has confirmed their concern relates to stormwater areas, providing the potential to be stagnant, and creating potential mosquito nuisance issues.

This report covers the two stormwater treatment areas proposed within the subdivision (see *Figure 6*) and their potential to generate nuisance insect risks to the local Peterborough community.

Site Description

The subject site and area of subdivision comprises vacant grazing landscapes within the proposed Reserve Area A, toward the south-west parent lot area, and Reserve Area B to the north-east of the site. Both areas will include constructed wetland/stormwater basins requiring careful design to mitigate conditions for nuisance pests.

The existing site has recently been utilised as grazing paddocks with the overarching landform consisting of ancient sand dune and floodplain landscapes. The study site's geology was formed on both volcanic and sedimentary lithologies.[1]

The subdivision proposed will be accessed directly from Old Peterborough Road)to the east) with the lot interfacing with residential development to the west and south, farmland to the north, and large acre residential development beyond the roadway to the east.

The existing water soakages are typically devoid of moisture with occasional Winter retention not long-lasting.
The overall site is free of significant vegetation patches decreasing mosquito harbourage sites proximal to soakages.

The site is generally level, with a gentle north-eastern tilt occurring across the parent lot. Drainage of whole of subdivision follows natural north-eastern pathways minimising ponding of surface and stormwaters. The existing soakages are clear of all vegetation apart from pasture grasses and exotic sedges.

[1] Agriculture Victoria 2022, Victorian Geomorphology (sub-unit 6.2 Sedimentary plains; Accessed from: http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/landform_geomorphological_framework_6.2

Figure 5 – Site subdivision catchment plan (Source: SITEC 2024).

2 RISK ASSESSMENT

Risk Management Approach

The mosquito risk assessment methodology uses the following steps:

- Identify the hazards to humans: mosquito borne disease; biting nuisance;
- Identify risk of exposure: mosquito breeding site locations; development design;
- Prioritise risks; and
- Control the important risks.

Risk of Exposure – Public health risks

Nuisance biting impacts from mosquitoes can have serious impacts on the community. However, a more serious risk is to personal and public health through the transmission of disease-causing pathogens by mosquitoes.

The mechanisms involved in the transmission of vector-borne disease can be complex and vary with both the mosquito species and pathogen. Arbovirus activity is dependent on numerous factors such as the availability of water (especially rainfall and tidal amplitude), temperature, mosquito vectors, reservoir hosts, past activity, geography, and population demographics.

Because of the role of mosquitoes as vectors for diseases, health legislation incorporates regulations for the control of mosquito breeding.

Under *Section 29A of the Victorian Health Act 1958*,[2] "the function of every council under this Act is to seek to prevent diseases, prolong life and promote health through organised programs".

Mosquito Management in Victoria utilises an integrated approach that includes a statutory framework, policies, guidelines, practices, and consultative mechanisms that attempts to balance competing concerns, interests, and key stakeholders.

Arboviruses (arthropod-borne viruses)

Transmitted by mosquitos, arboviruses can cause Murray Valley Encephalitis (MVE), Ross River Virus (RRV) and Barmah Forest Virus (BFV) diseases. Other arbovirus diseases reported in Victoria (such as dengue fever) have been acquired interstate or overseas.

Disease risk is high where vector mosquito numbers are abundant. Local conditions of irrigation and drainage management, rainfall, tidal fluctuation and temperature are important determinants of mosquito numbers.

The two most significant vectors for RRV and BFV in Victoria are *Culex annulirostris* in Northern Victoria and *Ochlerotatus camptorhynchus* (Southern Saltmarsh Mosquito) found along the southern coastline[3] such as Peterborough.

Mosquitoes are part of the natural environment and an integral part of the food chain for a number of terrestrial, amphibian, and aquatic animals. Some mosquito breeding sites are in wetlands of high conservation value including wetlands of national and international significance. The impacts of global warming could also see an increase in the number and range of mosquito-borne diseases in the future.

In Victoria councils conduct virtually all non-domestic mosquito management practice for health and amenity purposes as part of their responsibilities to residents and visitors.

[2] Department of Environment and Conservation WA (2007); Chironomid midge and mosquito risk assessment guide for constructed water bodies; Accessed from: https://www.health.wa.gov.au/~/media/Files/Corporate/general-documents/Mosquitoes/PDF/Chironomid-midge.pdf
[3] DELWP 2004; Framework for Mosquito Management in Victoria; Accessed from: https://catalogue.nla.gov.au/catalog/3422144

For most of Australia, peak incidence of the diseases is through the summer and autumn months, particularly from January through to March, when the mosquito vectors are most abundant. Outbreaks occur when local conditions of rainfall, tides, and temperature promote vector abundance.[4]

As a general rule, the areas where mosquito problems will regularly be a nuisance to the human populace will be within 1km of extensive biting insect breeding areas.

Nuisance biting

Biting mosquitoes can have a negative impact on community well-being and lifestyles. Economically, mosquitoes reduce real estate values, adversely affect tourism and related business interests, or negatively impact livestock or poultry production.

Furthermore, sever morbidity as a result of infection with a mosquito-borne virus can negatively impact on the economy through lost productivity and high costs of medical treatment.

The impacting mosquito

Ochlerotatus camptorhynchus (Southern Saltmarsh Mosquito) is the most common species impacting the Peterborough coastline preferring coastal and inland brackish riverine areas. Vertebrate hosts include humans, mammals, and birds, for a vector that bites aggressively through the day and night. The mosquito is a vector of Ross River Virus and Barmah Forest Virus in southern Victoria and a potential carrier of Murray Valley Encephalitis (MVE).[5]

Freshwater wetlands

Mosquito production from natural and constructed freshwater wetlands is dependent on a combination of physical and vegetative characteristics.

Aquatic vegetation management is the most useful strategy for mosquito management in these habitats.

When wetlands contain large areas of open water and vegetation at the margin is sparse, wind/wave action is relatively high, and predatory fish have unobstructed access to larvae; all these contribute to a reduction in larval populations but may not completely eliminate mosquito production.

Structures associated with stormwater retention (e.g. inlet pits, sullage pits or gross pollutant traps or drains) may contain free-standing water that persists and provides suitable habitats for some mosquitoes.

A routine maintenance program is typically essential to remove the inevitable buildup of organic material (leaves and other plant material, sediment, and general rubbish) that can create blockages and, subsequently, opportunities for mosquito breeding.

Constructed wetlands

These wetlands are typically small, but given their proximity to the community, may increase the relative risk of mosquito impacts. Saline wetlands are usually constructed to maintain local saltmarsh habitat, primarily for conservation value that can provide a significant habitat for saltmarsh mosquitoes.

The management strategies required to address the mosquito risks associated with constructed wetlands are often site-specific. However, there are general design, construction and maintenance principles that can be incorporated into wetland management to minimise mosquito production.

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[4] Byun & Webb 2012; NSW Health: Guidelines For Mosquito Risk Assessment And Management In Constructed Wetlands; Accessed from: https://cameronwebb.wordpress.com/wp-content/uploads/2014/03/byun-webb-guidelines-for-mosquito-risk-assessment-and-management-in-constructed-wetlands-wslhd-nov-2012.pdf
[5] DELWP 2004; Framework for Mosquito Management in Victoria; Accessed from: https://catalogue.nla.gov.au/catalog/3422144

Figure 6 – Local wetlands to site and proximity to Curdies Estuary (Source: WCC 2019).

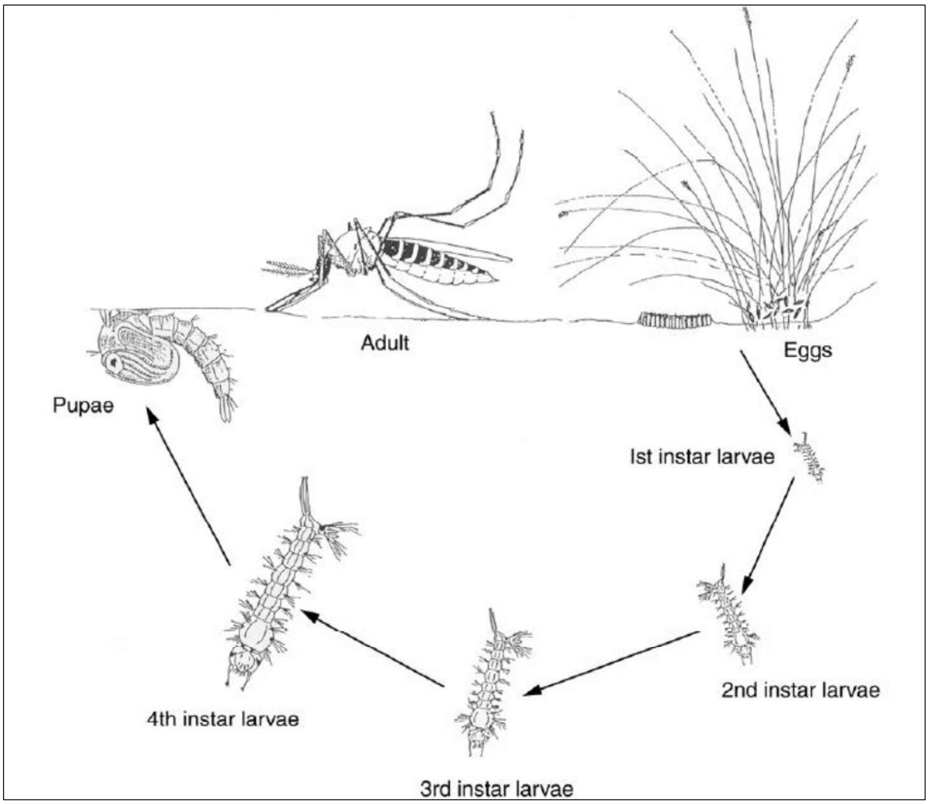

Figure 7 – Mosquito life-stages mostly controlled in the larval phases both environmentally and chemically (Source: Byun & Webb 2022).

WETLAND RISK ASSESSMENT

An assessment of risks to the surrounding community and to the environment should be a basic requirement of any mosquito management program.

A risk assessment should be conducted to determine the potential for mosquito breeding in proposed constructed wetlands. Consideration should be given to wetland design and features of the water body conducive to supporting mosquito populations.

As a general rule, areas where biting mosquito problems will regularly be a nuisance to the human populace will be within 1km of extensive biting insect breeding areas.

The subject area detailed below includes within a 1km buffer assorted saline and freshwater-based wetland systems, with the extensive Curdies Inlet estuarine area and adjoining saline wetlands proximal to the east of the site.

With prevailing winds from the south, south-west, and north, external site inputs are reduced, due to the south-west dominated by the Southern Ocean, and areas not conducive to mosquito breeding sites.

Local wetlands within 500m of the site include variable management so have the potential to provide some breeding habitat for biting mosquitos.

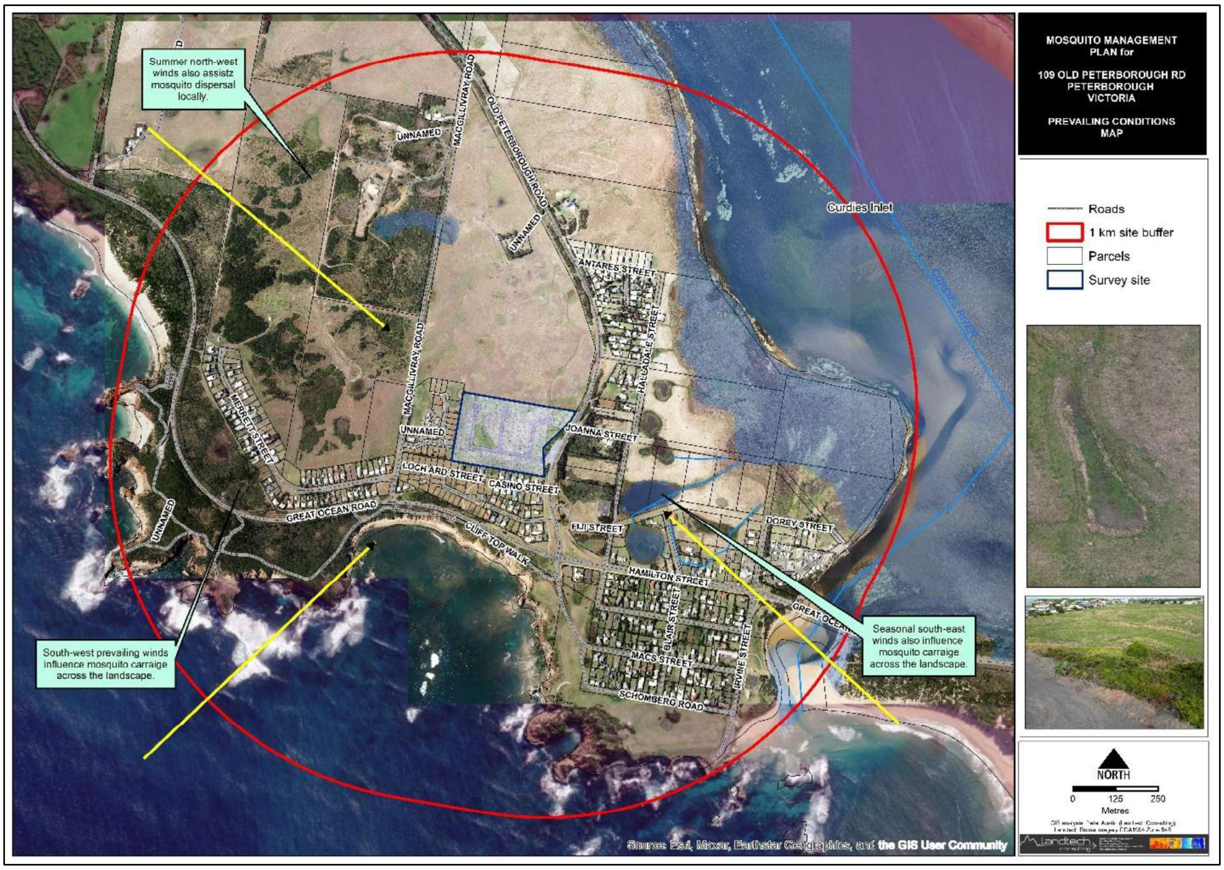

Figure 8 – Surrounding site factors relating to mosquito management.

The consideration of stormwater drainage design and site flows should aim to avoid silt accumulation at stormwater discharge points and be free draining. Dry systems designed to drain completely following a storm event and remain dry are recommended as best practice to minimise potential of mosquito breeding on the subject site.

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 risk rising dramatically as organic loads increase. Simple freshwater lake systems that are constructed with deep water and relatively steep sides have not typically become significant mosquito breeding sites.[6]

Constructed wetlands are also likely to attract animals, which may act as reservoirs of various arboviruses such as 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.

Figure 9 – Proximal site wetlands and surface waters (Source: NatureKit 2024).

[6] Melbourne Water 2020; Wetland Design Manual Part A3: Design Considerations for Wetlands Manual; Accessed from: https://www.melbournewater.com.au/media/530/download

Table 1 – Risk factors proposed - assessment.

Parameter	Details	Proposed constructed wetland
Hydrology of water body[7]	Water bodies that are seasonal are advantageous over permanent water bodies as mosquito breeding is halted once the water body dries out. Additionally, wetlands are easier to access for maintenance when dry. However, when the water body is refilled, there may be an increase in mosquito development with the hatching of desiccation-resistant eggs and algal growth after nutrient rich sediments are submerged with water. A component of a constructed wetland should permanently retain water throughout the year to provide a refuge for fish during the dry season (if practicable).	Should prevent mosquito breeding when dry. Suggest deeper sections that may hold water to support predatory fish populations. Mosquito populations upon refilling should be monitored for nuisance impact.
Waterbody depth, and form	Shallow vegetated wetlands provide a favoured habitat for mosquito larvae. Shallow water depths result in higher water temperatures which promotes faster mosquito development and the proliferation of emergent vegetation. Shallow aquatic macrophyte zones can provide habitats for mosquitoes but their design will vary. Ideally, water depth should be between 0.6m and 2m to ensure that sufficient light penetrates the deeper levels for submerged plants and to minimise the chance of stratification. A balance is often required between water depth requirements for water treatment, vegetation growth, wildlife habitats and mosquito management. Often a variety of water depths can be incorporated into the design of the wetland and in complex system, infrastructure can be incorporated into the design of the wetland that allows for regulation of water levels during the season. If mosquito populations are increasing, reducing water levels in macrophyte zones can flush immature stages back into deeper water zones where fish may be present. Alternatively, increasing water levels may assist fish accessing immature stages within the macrophyte zone.	Proposed – Recommend deeper sections and reduced shallow areas that support mosquito breeding. Structure to enable draining of depression when needed for maintenance and/or reduction in mosquito levels.
Location of waterbody to residential areas	The proximity of residential allotments may predispose the community to higher pest mosquito impacts. Where possible, open areas of sparse vegetation between either the wetland or any dense stands of terrestrial vegetation should be incorporated into the site design. Residential areas that are located downwind of dominant prevailing winds from a mosquito breeding site will be affected by nuisance biting and be at risk from mosquito-borne diseases. Buffer zones between urban developments and mosquito habitats are often raised as a strategy to assist in minimising the impact of nuisance-biting.[8] Guidelines developed for buffer distances to preventing biting insect problems associated with estuarine mosquito species range from 50m to over 1km buffer zones may be considered appropriate to reduce harbourage sites for pest mosquitoes if they can be maintained as clear or sparsely vegetated zones, so as to not provide a corridor for adult mosquitoes moving between the larval habitat and the human population.	Proposed – Allow open areas proximal to the depression (constructed wetland proposed) and reduce over-planting site with low shrubbery that create wind-less habitat areas for adult mosquito harbourage. Avoid strips of dense vegetation close to constructed wetland to reduce harbourage points.
Wind related parameters	Increased wave action disrupts larval respiration and also inhibits the growth of algae and floating plants that provide protection. To maximise wave action, the water body should be orientated so that the long axis is parallel to known prevailing winds during spring and summer. The land adjacent to the water body should be relatively flat to allow for wind exposure.	Proposed – Suggest adjacent land to the constructed wetland should be relatively flat/open to allow for enhanced wind exposure.
Aquatic vegetation	Constructed wetlands incorporate semi-aquatic and aquatic vegetation to remove nutrients from stormwater and wastewater and to reduce the potential for algal blooms. However, semiaquatic/ aquatic vegetation have the potential to colonise extensive areas of the wetland, providing harbourage for mosquito larvae and restricting access for larval predators. The most important feature of the constructed freshwater wetlands is the macrophyte zone, an area of a wetland typically shallow and as vegetation	Proposed – Careful design and placement of semi-aquatic and aquatic vegetation, and macrophyte plantings is required to optimise beneficial predator habitats. Maintenance of aquatic macrophytes is a key factor ensuring that mosquito production from the wetland is minimized.

[7] 2008 Constructed Wetlands in the NT, Guidelines to Prevent Mosquito Breeding; Accessed from: https://ntepa.nt.gov.au/__data/assets/pdf_file/0003/286815/appendix_v.pdf
[8] Melbourne Water 2020; Wetland Design Manual Part A3: Design Considerations for Wetlands Manual; Accessed from: https://www.melbournewater.com.au/media/530/download

	increases and/or accumulated debris or filamentous algal growth restrict water movement, suitable conditions for mosquito production may occur. As vegetation is often a crucial component of constructed wetlands, the incorporation of macrophyte zones can be designed to minimise mosquito populations by locating them in areas surrounded by deeper water or separating sections of dense vegetation by areas of deep water. The growth form of aquatic macrophytes can vary greatly but both floating and emergent vegetation can provide habitat for mosquitoes. More structurally diverse stands of vegetation assist the minimisation of mosquito populations by promoting a greater diversity of macroinvertebrates. The plant species of greatest concern are *Typha* spp. and *Phragmites* spp. that are prone to wetland invasion and exhibit rapid and dense growth. These species "clog" wetland systems with both actively growing and fallen decaying material that creates refuge and provides enhanced nutrition for mosquito larvae.	Monitor wetland water movement and identify and modify any areas of stagnancy. Problems arise if regular maintenance is not conducted and if the capacity and funding to undertake routine harvesting of vegetation is not included in a wetland management plan. An understanding of expected water levels will be required determine diversity and cover of aquatic plants needed.
Terrestrial vegetation	Vegetation corridors between mosquito breeding sites and residential areas provide harbourage sites for mosquitoes and acts as a dispersal route for mosquitoes to the populated areas. These harbourage sites can function as "stepping stones" or "bridges (a continuous corridor of vegetation) that facilitate the movement of mosquitoes into residential areas. In new developments where street trees/vegetation may be minimal or non-existent, stands of dense terrestrial vegetation around constructed wetlands can function as local harbourage sites, not only of mosquitoes produced from local wetlands, but also of mosquitoes produced in water-holding containers within residential allotments and nearby bushland habitats.	Proposed – Careful design of surrounding and proximal wetland vegetation to both optimise open areas and reduce establishment of harbourage sites.
Inflow water quality	Water quality is an important determinant in assessing mosquito breeding potential. Water quality should be of sufficient quality to minimise algal blooms, excessive vegetation growth and to support the survival of larvicidal predators. As water quality improves, as will the biological diversity of the wetland and increasing populations of fish and aquatic macroinvertebrates will assist in keeping mosquitoes to tolerable levels.	Proposed – Suggest maintenance of stormwater system to reduce impacts to water quality and wetland inflows.
Mechanical circulation	Mechanical circulation of water bodies is preferred as aeration of the water minimises algal growth and supports survival of mosquito larvae predators, such as fish. Water circulation mechanisms such as fountains also provides surface disturbance which may reduce larval mosquito survival. However, it is important to note that there are few scientific studies that show that a fountain in the middle of a wetland or pond will significantly impact mosquito production.	Proposed – With effective wetland design principles the use of mechanical circulation should not be required and would be a costly management option.
Engineering considerations	Stormwater structures (e.g. gross pollutant traps, infiltration systems, subterranean pipes) that retain water and are accessible to mosquitoes can provide habitat for mosquitoes. An accumulation of organic pollution along with debris that creates refuge for both adult and immature mosquitoes. The production of mosquitoes can be avoided by ensuring the structures are self-draining or designed so that the siltation depth shallow enough to encourage evaporative drying.	Proposed – When designing and locating stormwater structures the designer must avoid debris accumulation sites while using self-draining structures to minimise stagnant water pooling.
	Constructed wetlands should generally be steep-sided (at least 1V:3H) to maximise the effect of wave action on the water body and to disrupt mosquito larvae survival. The steep sides can limit the width of marginal macrophyte growth that may provide refuge for mosquito larvae. An alternative strategy if the recommended bank steepness cannot be maintained for safety or other considerations, a vertical 'lip' between 100 - 300mm may be used at the water margin, allowing more gradual slopes above and below the vertical edge. Simple water body shapes also allow for wind exposure to produce surface wave action.	Proposed – Suggest steep-sided wetland to maximise wave production and reduce marginal macrophyte plant dominance. Simple water body designs allow for good water circulation, improving water quality, and limits areas where mosquito larvae can evade predators.

Figure 10 – The proposed constructed wetland will be based on the linear-shaped wetland depicted within the Warrnambool LGA (Source: WCC 2019).

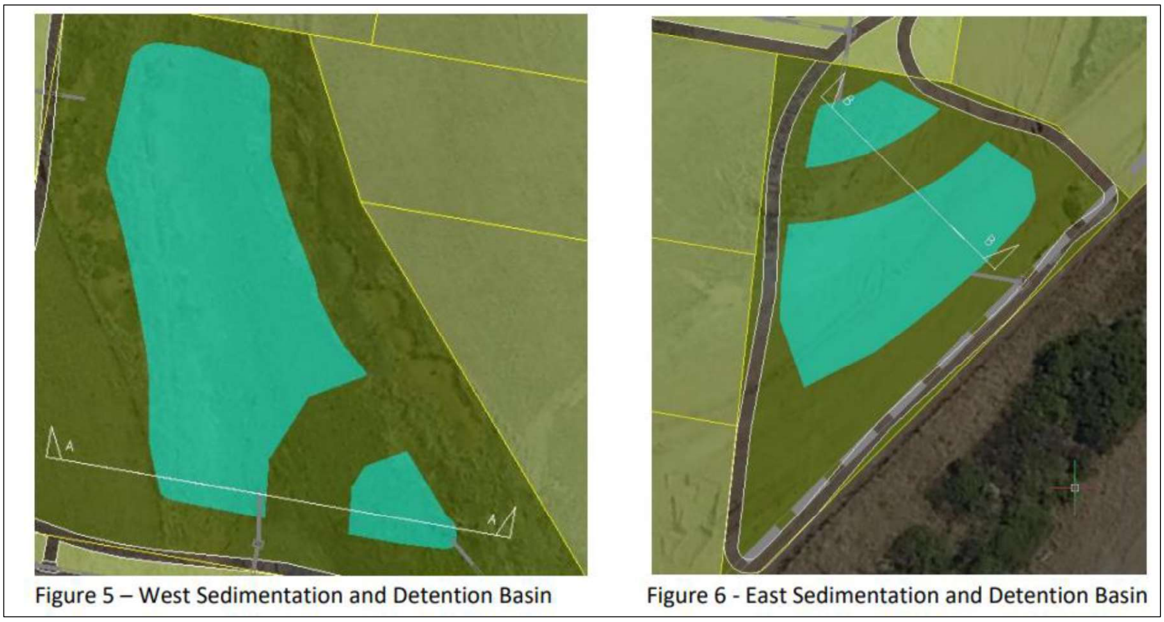

Figure 11 – Western and eastern wetland basins proposed (Source: SITEC 2024).

3 ENVIRONMENTAL MANAGEMENT PLAN

Environmental Management Plan

An environmental management plan for the water body could be developed and implemented which clearly defines the monitoring and maintenance program, detailing the actions required, and the estimated annual cost.

The management plan should cover the following and include local Council collaboration on matters such as:

1. A clear description of the designated role of the water body i.e. whether it is for drainage, aesthetic, or environmental purposes. This may have implications for any additional work in the future;
2. Routine maintenance program detailing type and frequency of required actions;
3. Nuisance complaints to Council;
4. Monitoring of limited environmental parameters, such as water temperature, nutrient levels etc to allow prediction of peak insect activity periods;
5. Vegetation control including harvesting, herbiciding, and processes involved, frequency of required actions and estimated costs;
6. Developers to provide prospective purchasers with information relating to ways to minimising nutrient runoff where stormwater drains into the water body such as water efficient gardens and not using phosphorus based fertilisers.
7. Issuing public warnings and other notices (in collaboration with Council).
8. Safety aspects, such as the need for railings, signage etc should also be considered.
9. A contingency plan should problems arise that provides options which can be easily implemented. Provision should be made to ensure there is adequate space, access, and funding for implementing actions, or decommissioning the water body if required.

Maintenance

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;
- 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.

Maintenance of Stormwater Management Devices

There are several conditions that may increase the probability of breeding mosquitoes over time in various stormwater management devices following construction. Appropriate maintenance should be conducted on the stormwater management devices to minimise the occurrence of these conditions:

- Clogging
- Establishment of invasive or exotic vegetation
- Groundwater fluctuations
- Non-stormwater runoff (i.e., increases in runoff frequency, residence time, and/or volume)
- Scouring and sediment erosion generating silt accumulation
- Structural damage (e.g., shifting or settling, roots)
- Trash and sediment accumulation (e.g., formation of pools, clogging, redirected water flows)
- Vandalism
- Vegetation overgrowth

4 RECOMMENDATIONS

1. 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.

2. The design, implementation, and maintenance of the proposed constructed wetland must include effective design principles with regular maintenance in collaboration with Moyne Shire Council who manage mosquito nuisance across the LGA.

3. In Victoria, the *Public Health and Wellbeing Regulations 2019 (the Regulations)* outline responsibilities for mosquito management and are administered by the Moyne Shire Council Environmental Health Unit. Mosquito management is the responsibility of all landowners or land occupiers including land owned/managed by the public sector or government, or private residents, businesses, and organisations.

4. Responses to mosquito nuisance lies with the local Council who in many cases provide educative and/or reactive larval mosquito control where required.

5. It is not expected the proposed constructed wetland will develop nuisance mosquito breeding and biting with careful design proposed by the subdivision proponents.

6. Moyne Shire Council would be able to provide guidance to the proponents and future residents regarding mitigating mosquito nuisance by way of educative information, habitat modification information, enforcement, and potential limited larval control. Their website has basic information for residents and information regarding the reporting of mosquito nuisance.

7. Longer-term management and/or the development of an Environmental Management Plan (EMP) to guide the sustainability of the constructed wetland requires proponent and Council input regarding the need for such a guidance procedure.

8. SITEC (Warrnambool) have designed depression drainage strategies (*Stormwater Management Plan dated: 30.8.2023*) to assist in the mitigation of mosquito nuisance. It is proposed that the constructed wetland will be based on the 10-year-old wetland on Boston Drive in Warrnambool which was installed as part of the Marrakai and Toohey's estates (see *Figures 10-12*).

9. Management requirements include annual inspections of wetland margins and removal of silt and marginal vegetation, and annual inspections of the vegetation zone, with maintenance conducted to remove silt, isolated depressions, dead-zones, and over-dominant vegetation.

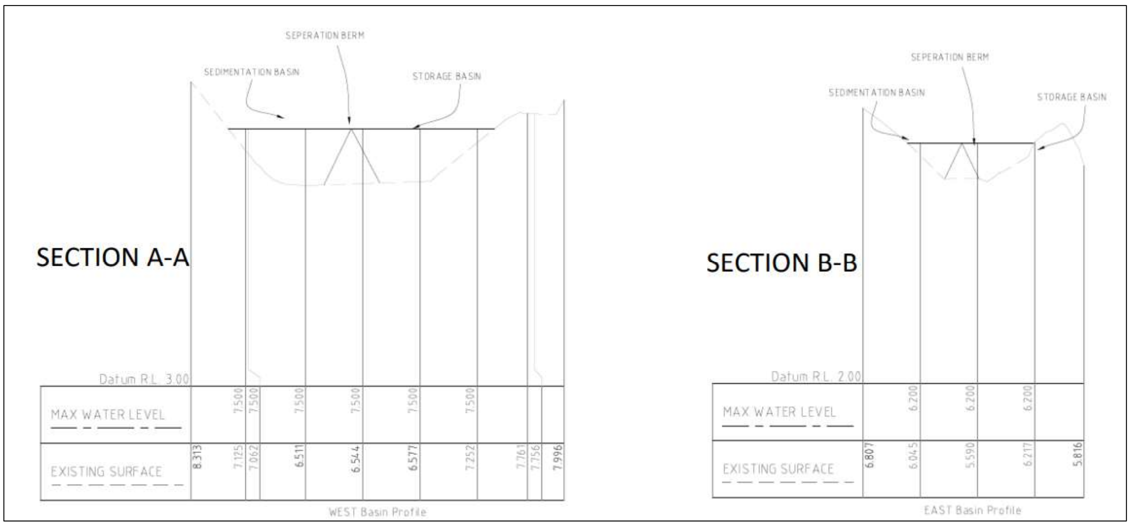

Figure 12– Basin cross-section design plans (Source: SITEC 2024).

APPENDIX 1 - DESIGNING TO AVOID MOSQUITOS

Mosquitos are a natural component of wetland fauna. The construction of any waterbody will create a habitat suitable for mosquito breeding and growth. Healthy, well vegetated wetlands function as balanced ecosystems and have predators that control mosquito populations. Coordinated programs and on-going monitoring are necessary for effective mosquito management in the long term.[9] The risk of mosquito breeding can be addressed through:

- Ensuring all parts of the wetland are well connected to provide access for mosquito predators to all inundated areas of the wetland;[10]
- Providing areas of permanent open water that provide refuges for mosquito predators (even during long dry periods);
- Ensuring wetland water quality is adequate to support of mosquito predators such as macroinvertebrates and fish (this is normally the case for wetlands where stormwater is the dominant inflow);
- Providing a bathymetry that ensures that regular wetting and drying is achieved and water draws down evenly so isolated pools are avoided;
- Ensuring wetland configuration does not provide dead spots or open areas away from normal direction of flow;
- Maintaining water level fluctuations that disturb the breeding cycle of some mosquito species;
- Providing gross pollutant control upstream of the wetland so that gross pollutants do not accumulate and provide mosquito breeding habitat within the wetland; and
- Ensuring that maintenance procedures do not result in wheel ruts or other localised depressions that create isolated pools when wetland water levels fall.

Principles of mosquito management

Mosquito management attempts to solve existing problems and to prevent or mitigate future problems. Integrated Mosquito Management (IMM) used by local Councils in Victoria is based on community involvement and recognises the importance of collaborative stakeholder coordination. It uses physical, chemical and biological methods within a broader context of educational and planning-based strategies such as:

- *Mosquito management involves health, environmental, and socio-economic values.*
- *Disease control and reduction in nuisance value of mosquitoes is a legitimate aspect of improved community well-being.*
- *Mosquitoes are an integral part of the ecosystem and their treatment may have positive and negative environmental impacts.*
- *Integrated mosquito management includes mosquito reduction, personal protection, community education, and land use planning.*
- *Coordinated programs and on-going monitoring are necessary for effective mosquito management in the long term.*
- *Treatment of mosquito larvae or adults is an on-going activity.*
- *Treating larvae is always more effective and targeted than treating adult mosquitoes.*

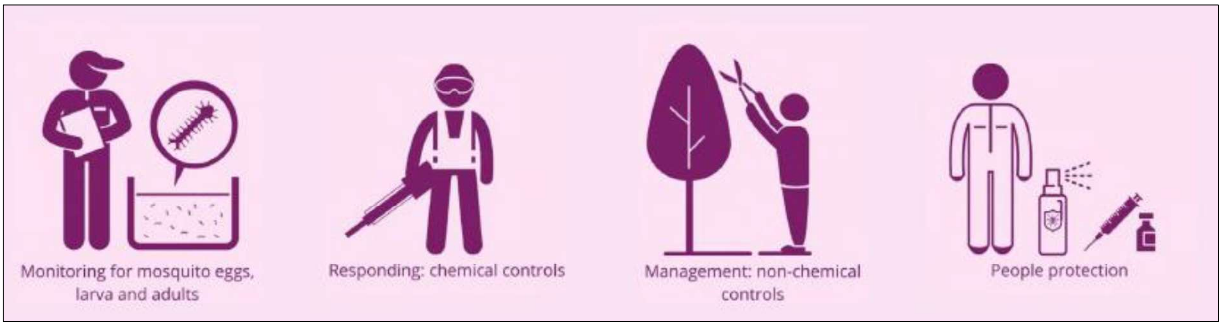

Figure 13 – Key mosquito management methodologies.[11]

[9] DELWP 2004; Framework for Mosquito Management in Victoria; Accessed from: https://catalogue.nla.gov.au/catalog/3422144
[10] Byun & Webb 2012; NSW Health: Guidelines For Mosquito Risk Assessment And Management In Constructed Wetlands; Accessed from: https://cameronwebb.wordpress.com/wp-content/uploads/2014/03/byun-webb-guidelines-for-mosquito-risk-assessment-and-management-in-constructed-wetlands-wslhd-nov-2012.pdf
[11] Byun & Webb 2012; NSW Health: Guidelines For Mosquito Risk Assessment And Management In Constructed Wetlands; Accessed from: https://cameronwebb.wordpress.com/wp-content/uploads/2014/03/byun-webb-guidelines-for-mosquito-risk-assessment-and-management-in-constructed-wetlands-wslhd-nov-2012.pdf

Mosquito management in constructed wetlands

The purpose of mosquito management is to reduce the likelihood of residents being exposed to disease carrying mosquitoes, either by reducing the potential of mosquito habitats to maintain high mosquito populations or by the use of mosquito control agents in reducing adult or immature mosquito populations.

It is critically important that no mosquito control program be undertaken before first assessing the actual mosquito risk and identifying the target pest species. Mosquito control can be expensive and may also pose a risk to non-target organisms in the local environment. Unless the target species is identified and appropriate control strategies implemented, the objectives of mosquito control may not be met.

A mosquito control program should aim to use the most cost effective and environmentally safe methods available and be combined with a plan to educate the community about mosquitoes, mosquito borne diseases and personal protection strategies.

Assessment of potential public health risks

It is important to record the pre-construction level of mosquito activity as any assessment of future mosquito production associated with a constructed wetland should be done with reference to existing habitats.

Adult mosquito monitoring

A survey of the adult mosquito population should be performed to provide an indication of the potential for nuisance biting and mosquito-borne disease to the community.

An analysis of adult mosquito data can provide information on both the local pest and public health risks as well as an indication of local wetland mosquito production. As each mosquito species has species habitat associations, an assessment of the proportion of mosquito populations likely to have originated from the local wetlands (as opposed to nearby estuarine wetlands, bushland or backyard habitats) can be made.[12]

It is crucial to determine if mosquitoes responsible for local nuisance-biting impacts are likely to have been produced from the local wetland.

It is important to know which species are collected to determine whether they are potential vectors of disease, common nuisance biting pests or of no pest concern.

Larval mosquito monitoring

While it is possible to assess the likely diversity of mosquitoes produced from a constructed wetland by sampling adult mosquito populations, larval sampling will be the only way to confirm the presence of mosquitoes in the wetland.

Most importantly, it will enable the identification of key “hot spots” of mosquito production that may assist vegetation management or mosquito control strategies.

Complaints from the public

Complaints from the public about nuisance biting can be a useful indicator of mosquito activity or for identify a new breeding site, but each complaint will need to be assessed as to their location relative to a known constructed wetland and the pest species identified.

An overnight EVS trap could be used to identify the offending species and determine the likely source. The number of complaints received will vary between locations and hence Councils should determine the specific number of complaints that equate to the level of concern and the different risk threshold levels.

It is important to note that the number of complaints to local authorities on mosquito numbers is not a reliable measure of local mosquito populations and is an inappropriate substitute to mosquito surveys.

Reducing suitable mosquito habitats in constructed wetlands

More economically beneficial if this strategy is incorporated into the original design of the wetland. Retro-fitting or redesigning a wetland once constructed may be extremely expensive.

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[12] 2008 Constructed Wetlands in the NT, Guidelines to Prevent Mosquito Breeding; Accessed from: https://ntepa.nt.gov.au/__data/assets/pdf_file/0003/286815/appendix_v.pdf

Habitat modification

There are elements of constructed water bodies can be altered to reduce their capacity for mosquito production.

Water body redesign

Constructed water bodies can be re-shaped, in particular the edge of the water body, to facilitate wave action on the surface and dredging to increase water depth. Modification may also include rectification of surface depressions in shallow treatment zones and filling and grading landscaped areas to remove surface depressions. Improvement in water movement through the constructed wetland can also help minimise mosquito populations.

Vegetation management

Vegetation management is key to reducing the suitability of constructed wetland habitats for mosquito production.

Harvesting of semi-aquatic and aquatic vegetation from shallow treatment zones in the wetland removes mosquito harbourage sites, allows for access by larval predators and improves water movement. The growth of emergent, floating and submerged aquatic macrophytes present a range of risk factors that will be site-specific depending on the locally abundant pest species.

These risks may be seasonally variable so no vegetation management should be undertaken without assessing the mosquito-specific risk first.[13]

Water flows

Increasing water flow through the wetland will assist in reducing suitable mosquito habitats. As well as the potential to create physical disturbance to immature mosquitoes, increased water flow will assist in improving overall water quality and ecological diversity in the wetland. Increased populations on mosquito predators will contribute to minimizing the production of mosquitoes.

Biological control

A number of organisms have been investigated to determine their suitability as effective predators of either adult or immature mosquitoes. These include aquatic invertebrate (e.g. Diptera and Coleopteran larvae, Crustaceans, Notonectids, Odonates) and vertebrate (fish) predators of immature mosquitoes.

Fish are most commonly employed to act as a biological control agents of mosquitoes in constructed wetlands.

A number of native fish have been identified that may be appropriate for mosquito control in Australia. While native fish introductions alone will not significantly reduce mosquito populations, they do provide an important component of integrated mosquito management and have been shown to provide a valuable link to the wider community promoting environmentally sensitive mosquito management.

Insecticides

Such products may include products targeting adult or immature mosquito populations. Before any product is used, target species should be identified to determine the most appropriate product for effective control.

Larvicides are a more appropriate options for constructed wetlands. They target the immature stages and bring with them far fewer potential non-target impacts. The naturally occurring soil bacterium *Bacillus thuringiensis israelensis* (B.t.i) produces a protein crystal which contains a number of microscopic pro-toxins that when ingested are capable of destroying the gut wall and killing mosquito larvae. This is the most common larvicide used in Australia but there are some limitations to using this product in highly organic habitats.

The insect growth regulator s-methoprene is a synthetic mimic of the juvenile hormone produced by insect endocrine systems and, when absorbed by the larvae, development is interrupted and immature stages fail to successfully develop to adults, usually dying in the pupal stage. This product is commonly used in Australia, particularly in highly organic rich environments (e.g. waste-water treatment ponds, drains, septic tanks) where B.t.i. may not be as effective.

[13] 2008 Constructed Wetlands in the NT, Guidelines to Prevent Mosquito Breeding; Accessed from: https://ntepa.nt.gov.au/__data/assets/pdf_file/0003/286815/appendix_v.pdf