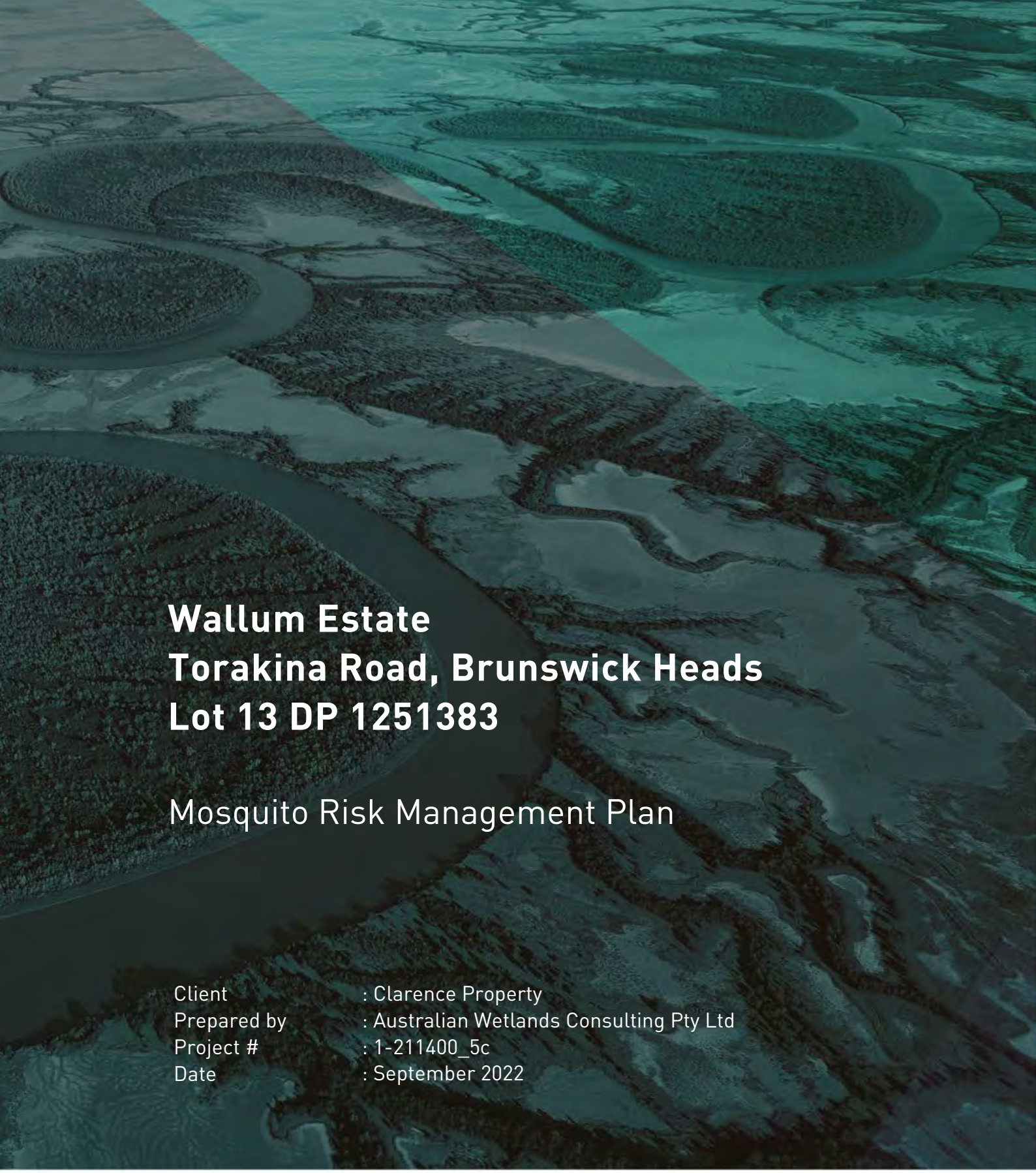

Wallum Estate
Torakina Road, Brunswick Heads
Lot 13 DP 1251383

Mosquito Risk Management Plan

Client	: Clarence Property
Prepared by	: Australian Wetlands Consulting Pty Ltd
Project #	: 1-211400_5c
Date	: September 2022

Leading environmental solutions...

AWC

Wallum Estate
Torakina Road, Brunswick Heads
Lot 13 DP 1251383

Mosquito Risk Management Plan

Project control

Project name: **Wallum Estate**
Torakina Road, Brunswick Heads
Lot 13 DP 1251383

Mosquito Risk Management Plan

Job number: 1-211400_05c
Client: Clarence Property
Contact: James Fletcher
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21/07/2021	A	Adrian Leader	Damian McCann	James Fletcher
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13/09/2022	C	Jesse Munro	Minor amendment only	James Fletcher

Table of Contents

List of Tables

List of Figures

1 Introduction

1.1 Background

Australian Wetlands Consulting (AWC) has been engaged by Clarence Property Pty Ltd to complete a Mosquito Risk and Management Plan (MRMP) in support of a proposed subdivision at Brunswick Heads within the Byron Shire Local Government Area (LGA). A description of the proposal is as follows:

Development consent is sought to undertake a staged subdivision to create 131 lots upon land described as 15 Torakina Road, Brunswick Heads, being Lot 13 in Deposited Plan 1251383.

The application proposes the subdivision of the land in 3 stages comprising, 124 residential lots, three (3) medium density lots, one (1) residue lot and three (3) public reserves together with associated public roads and infrastructure services (water, sewer, drainage and stormwater management works), bulk earthworks, tree removal and vegetation management works.

Mosquitos are known to present serious health risks and both mosquitos and midges cause considerable nuisance to residents of coastal areas. There are strategies applicable to the landscaping and vegetation management of residential and recreational areas, as well as the built environment, which can provide assistance in the mitigation of local pest impacts during periods of peak activity. Appropriate education as to the risks associated with mosquitos for the local community and personal measures to avoid exposure to mosquitos should also be undertaken as part of the overall mosquito management strategy.

1.2 Management plan objectives

This MRMP has been prepared for and will be implemented in accordance with guidelines from Byron Shire Council. The objectives of this plan are to ensure that:

- The development doesn't increase the mosquito or midge problem or create additional mosquito breeding sites
- Mosquitos and midges on-site will not adversely affect the health and welfare of future residents and populations will be controlled to the satisfaction of BSC
- Mosquitos and midge management will be undertaken without adversely affecting other native flora or fauna

1.3 DCP 2014

Chapter B7: Mosquitoes and Biting Midges of the Byron Shire DCP (2014) is used to address the public health and nuisance issues associated with mosquitoes and biting midges by recommending strategies to be incorporated into the approval and construction process of new residential and tourism developments.

The DCP acknowledges that while elimination of mosquitoes is not possible, urban design practices can be used to minimise risks associated with mosquito populations.

This report has addressed the considerations raised in Table B7.1 - Entomological and Environmental factors to be considered in mosquito risk assessment reports.

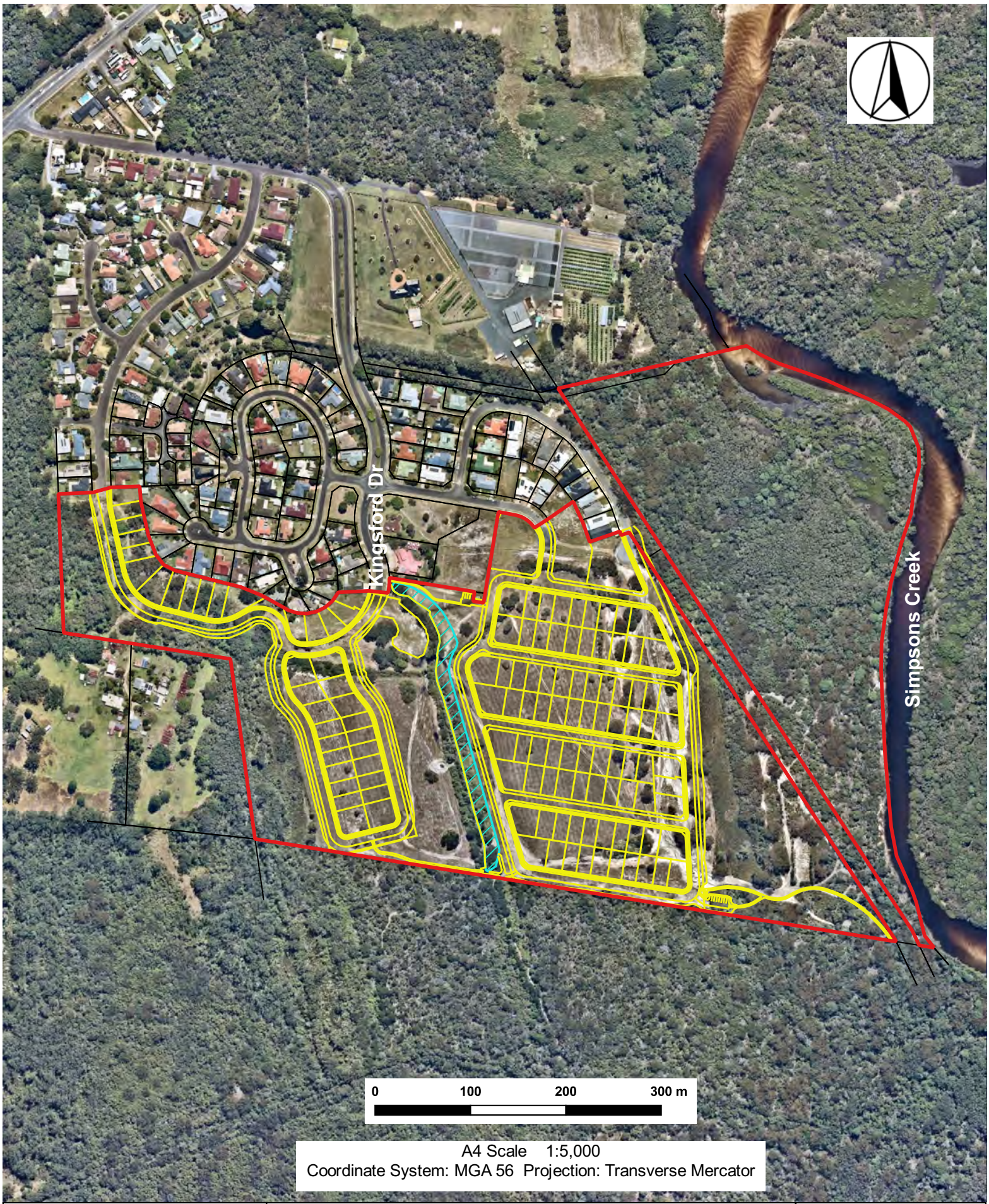
2 The Site

The subject site (Lot 13 DP1251383) is located immediately south of Brunswick Heads and has an area of approximately 30 hectares (refer figure 2.1). Soils at the site are predominantly estuarine alluviums overlain with Quaternary sands of aeolian origin (Morand, 1994).

The majority of the site is dominated by low heath which is maintained by slashing with an area of consolidated undisturbed forest in the east of the site. The property is dissected north-south by a constructed drainage line ('the central drain') which feeds into Everetts Creek to the south. It is understood the central drain is maintained by Byron Council and material removed as required.

Artificial and naturally occurring surface water channels or water bodies occur within the project area including constructed drains and extensive wheel ruts as a result of illegal access to the site.

Large sections of the sites vegetation and Wallum Froglet Habitat (WFH) will be retained and protected. WFH habitat will be created alongside the centre drain and on the far eastern side of the site. Wallum Froglet habitat consists of periodically inundated, high vegetated sedgelands and environments with low pH levels. These conditions can also act as breeding habitat for several mosquito species in the area.



A4 Scale 1:5,000
Coordinate System: MGA 56 Projection: Transverse Mercator

AWC

Legend

- Site
- Layout
- Side Swale

Figure 2.1 Proposed Development

Data source:
Aerial - Nearmaps
Layout - Cilviltech

Date:7-09-22
Job No:211400
Drawn:ED
Checked:DM

2.1 Mapping

Under the Byron Sire DCP (2014) the site is mapped as (refer figure 2.2):

- Saltmarsh Mosquito Secondary Habitat 500m Risk Zone &
- Coastal Swamp Mosquito Habitat 200m Risk Zone.

These zones detail dispersal patterns of estuarine and coastal swamp mosquitoes from known habitats. Within these zones, nuisance-biting should be expected during the warmer months with the severity of pest impacts dependent on local rainfall. These maps highlight areas were exposure to nuisance-biting mosquito populations, and consequently, potential Ross River virus (RRV) or Barmah Forest virus (BFV) transmission may occur.

It is noted that special attention should be given to developments that occur within any mapped mosquito habitat. Consideration should be given to the overall site plan of the proposed development including buffer zones (if appropriate), building design (i.e. screened openings), provision of screened outdoor recreation areas, vegetation plantings, stormwater structures (i.e. bioretention swales, wetlands, GPTs) and constructed wetlands.

2.2 Proposed development

Development consent is sought to undertake a staged subdivision to create 131 lots upon land described as 15 Torakina Road, Brunswick Heads (Lot 13 in DP 1251383). The application proposes the subdivision of the land in 3 stages comprising, 123 residential lots, three (3) medium density lots, one (1) residue lot and three (3) public reserves together with associated public roads and infrastructure services (water, sewer, drainage and stormwater management works), bulk earthworks, tree removal and vegetation management works (refer Figure 2.1).

The development occupies approximately 13.33 ha (43.7 %) of the site. Residual land outside of the development footprint (~17.2 ha) will be managed for biodiversity and comprises public reserves (P1, P2, P3 and P4). Public reserves will be dedicated to Council once required works are completed. The portion of the site east of the road reserve flanking Simpsons Creek (10.24 ha) will also be dedicated to Council.

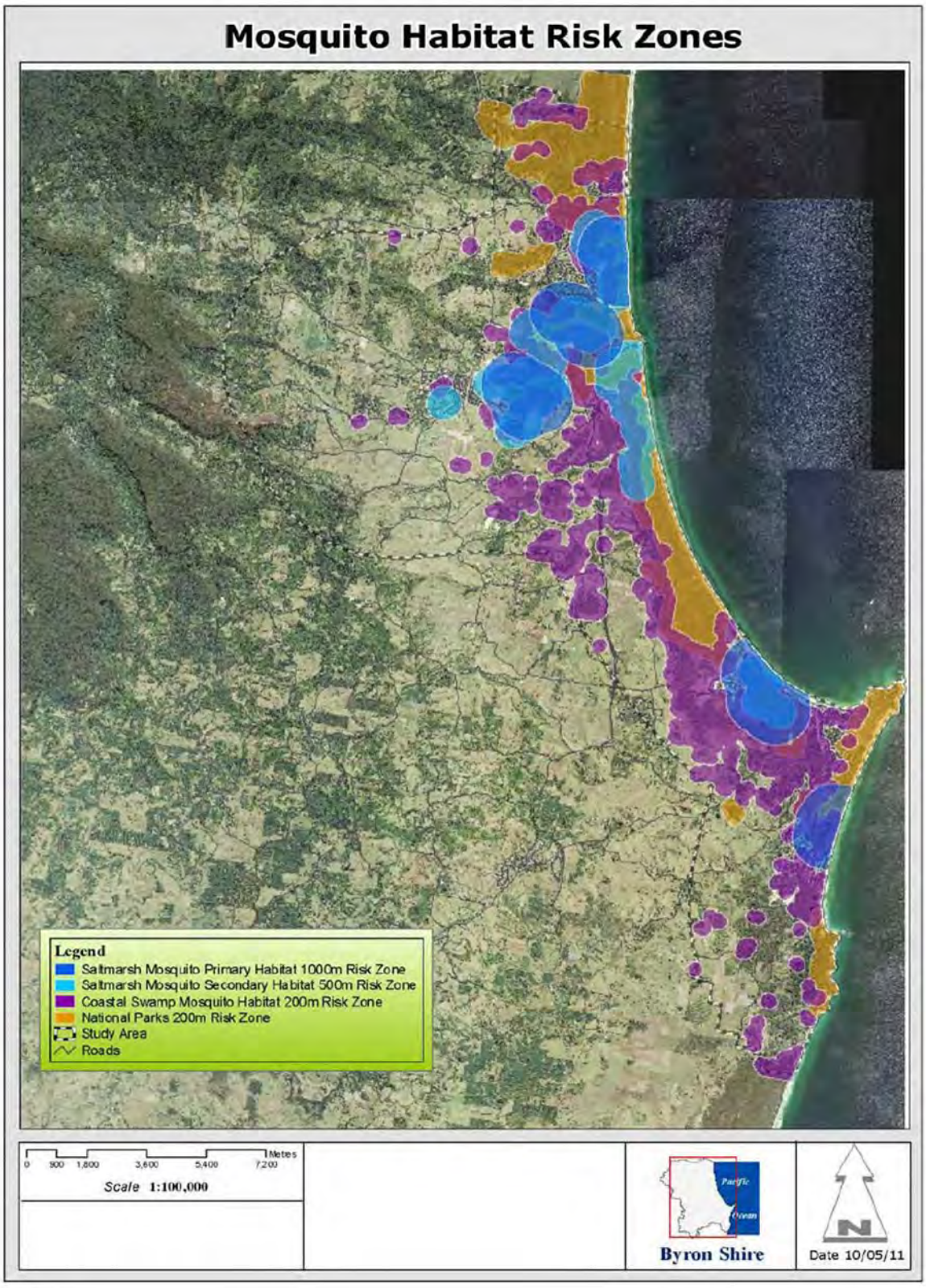


Figure 2.2 Mosquito risk zones associated with saltmarsh and coastal swamp habitats in Byron Shire (Sourced BSC DCP 2014)

3 Risks of Exposure

3.1 Midge and Mosquito Species and Habitat

3.1.1 NSW Arbovirus Surveillance and Vector Monitoring Program

The NSW arbovirus surveillance and vector monitoring program was established by the Medical Entomology Department, ICPMR Westmead Hospital and NSW Heath in order to monitor mosquito vector populations in coastal and inland areas of NSW at a risk of arbovirus activity.

There is no recent data collected within Byron Shire, however data is collected within Ballina and Tweed shires, which share similar environmental conditions. While there are some differences in the local habitats within the Tweed, Ballina and Byron Shire regions, mosquito populations within these regions are expected to be similar. Major differences are expected to relate to the abundance of individual species more so than the diversity of the mosquito fauna. This data provides an indication of species likely to occur at the site (*NSWASVMP, 2016a,b*).

The monitoring data collected in Lennox Head is considered to provide a good reference for the proposed development site as there are comparable habitats nearby, including a combination of *Melaleuca* and *Casuarina* forests, heathland, coastal saltmarsh and mangrove communities, flooded pasture/grassland and urban habitats (NSWASVMP, 2016b).

Data collected in Byron Shire Council from 2009 – 2011 has been considered in addition to data collected in surrounding councils to make an informed assessment of mosquito species that present a risk on the site (See Appendix A and B).

3.1.2 Byron Shire Council

Byron Shire provides suitable habitat for over 40 species of mosquito, however few of these species pose a serious threat to the community. Risks are highest within close proximity to coastal swamp and estuarine wetland environments, and in backyard habitats. or areas of standing water.

Although the abundance of mosquitoes in Byron Shire is generally lower than other regions in coastal NSW, populations are still sufficiently abundant to cause nuisance-biting and public health concerns. Much of the increased risk of mosquito-borne disease in coastal NSW can be attributed to the encroachment of urban development to productive mosquito habitats.

Byron Shire Mosquito Management Plan

The Byron Shire Mosquito Management Plan has been developed to provide comprehensive plan based on data gathered on local mosquito populations in a scientific manner with a view to developing maps of "mosquito risk zones". This plan is to be used for future site-specific mosquito-borne disease management strategies. This management plan specifically covers the Byron Shire Council LGA.

Data presented in the plan, demonstrates relative abundance of all mosquito species collected in carbon dioxide baited light traps in the Byron Shire region, March – April 2011. Data collected within

close proximity of the study site was estimated at 57 individuals. This number is relatively lower than other coastal locations in the area, with numbers reaching up to 245 individuals just north of Ocean Shores and 371 on the southern end of Tyagarah Nature Reserve (Webb et al. 2011a).

3.1.3 Species within the Area

Based off past data collected in the local area and habitat present on site the species that are likely to occur in the highest abundance onsite include: *Ochlerotatus procax Ochlerotatus notoscriptus, Ochlerotatus vigilax, Ochlerotatus Multiplex, Culex Sitiens, Culex orbostiensis* and *Verrallina funerea (Webb et al. 2011b, Webb et al. 2010, JWA, 2003 & NSWASVMP, 2016a,b).* The habitat and risks associated with these species, along with other species likely to be found in the study area have been discussed in the table below (*Table 3-1*).

Table 3-1Mosquito species likely to occur in the study area

Mosquito species	Type	Habitat	Risks
Ochlerotatus alternans	Estuarine	Species usually breeds in saltmarsh that is tidally influenced. Can also be found in freshwater habitats. Larvae feed on other mosquito larvae.	Nuisance-biting pest. Not an important vector of disease
Ochlerotatus vigilax	Estuarine	This is a key saltwater species, capable of dispersing large (up to 50km) distances from breeding grounds when conditions are favourable. This species breeds in tidally inundated saltmarsh and is often associated with saltwater couch.	It is a known vector for RRV and BFV and bites both during night and day.
Culex sitiens	Estuarine	Species typically breeds in brackish pools formed by high tides and rainfall. Do not venture far from the breeding sites in NSW.	Not a nuisance-biting pest - prefers to bite birds. This species is not an important vector of disease.
Verrallina funerea	Estuarine	This species breeds in brackish to freshwater pools that are heavily shaded. It is commonly associated with tea-tree and paperbark swamp and is a serious pest in areas adjacent to these habitats. However, this species does not generally disperse far from its breeding grounds.	Severe nuisance-biting pest (day & night) and a vector of RRV and BFV.
Ochlerotatus multiplex	Coastal Swamp	Freshwater and mildly brackish flooded habitats in Melaleuca forests. Does not travel far from larval habitats.	Will bite humans but rarely a serious nuisance-biting pest. Role in RRV and BFV transmission is unknown.
Ochlerotatus procax	Coastal Swamp	Freshwater and mildly brackish flooded habitats in Melaleuca forests. Does not travel far from larval habitats.	Will bite humans but is generally not considered a serious nuisance-biting pest. May play an important role in RRV and BFV transmission.
Coquillettidia linealis	Coastal Swamp	Close association with well vegetated freshwater wetlands.	Nuisance-biting pest and may play a role in transmission of RRV and BFV
Coquillettidia xanthogaster	Coastal Swamp	Close association with well vegetated freshwater wetlands and sedgelands.	Nuisance-biting pest and may play a role in transmission of RRV and BFV
Verrallina Marks #52	Coastal Swamp	Freshwater and mildly brackish flooded habitats with Melaleuca forests. Does not travel far from larval habitats.	The pest status of this species has not been documented and the role this species plays in RRV and BFV transmission is unknown.
Ochlerotatus kochi	Coastal Swamp	An uncommon mosquito that breeds in leaf axils.	No information is known on its ability to transmit arboviruses.

Mosquito species	Type	Habitat	Risks
Culex orbostiensis	Coastal Swamp	Breeds in vegetated ground pools in coastal regions.	Not considered to be a serious pest. Uncommonly bites humans. Vector status unknown.
Culex annulirostris	Coastal Swamp	Breeds in freshwater swamps, pools and streams, as well as temporary sites including flooded grassed fields. The common range to which this species can be a pest is up to 5km from breeding sites.	Ability to breed in temporary environments makes them a considerable pest. They are a known vector of RRv and Australian and Japanese Encephalitis.
Ochlerotatus notoscriptus	Backyard	Small water holding containers around dwellings such as tins, pots, ornamental ponds, roof guttering, bird baths, as well as water holding plants (eg. bromeliads) and tree holes. Does not travel far from larval habitats.	Severe nuisance-biting pest and vector of RRV and BFV. **This is the most important pest mosquito in urban areas across Australia.**
Culex quinquefasciatus	Backyard	Species breeds in ground pools or artificial structures containing highly organic water such as drains and septic tanks.	Will bite humans but generally not considered a significant nuisance-biting pest. May play a role in the transmission of RRV and BFV.
Biting Midges	Estuarine	Midges require sandy, rocky or muddy substrates generally between the Mean High Water Spring Mark and Mean Low Water. They generally do not disperse as far as mosquitoes.	Species of biting midge can be a severe pest if adult numbers are high. Are not vectors for human disease.

*Information obtained from NSWASVMP, 2016 & Webb et al. 2011a.

3.1.4 Existing Habitat

Existing mosquito habitat (breeding, adult refuge and movement corridors) that is present on the site and adjacent property is discussed below. A range of freshwater and brackish mosquito species are likely to occur at the study site. The most significant potential breeding areas at the site include:

- Residential development
- Estuarine habitats
- Heathland with existing patches of Wallum Froglet Habitat
- Creeks; and
- Drainage lines.

Residential development:

- Located to the north of the site, the residential development consists of roads, dwellings, ornamental plantings, low density vegetation with minimal ponding.
- In residential areas two species of mosquito will typically be found as biting pests (*Culex quinquefasciatus & Ochlerotatus notoscriptus*). Cx *quinquefasciatus* usually bites at night within buildings and is not known to move far from its breeding site. *Ochlerotatus notoscriptus* will bite by day (shade) and night, usually outside and near vegetation.

Estuarine Habitats & Brackish Marsh:

- Located in the eastern most section of site, Tyagarah Nature Reserve & Brunswick Nature Reserve. These reserves contain swamp sclerophyll forest, saline wetland, paperbark forest and swamp oak forest with drainage lines and standing pools, which provides optimal breeding habitat for several mosquito species. These include *Ochlerotatus vigilax*, *Ochlerotatus alternans, Culex sitiens & Verrallina funerea. Ochlerotatus vigilax* breeds in temporary pools filled by highest monthly tides, populations fluctuate with tidal cycles, known to disperse far from larval habitats.

Heathland

- Periodically inundated sections of heathland which act as Wallum Froglet habitat. This habitat exists in drainage depressions within the heathland present onsite. This habitat is densely vegetated and is periodically inundated following heavy rainfall.
- Flooding of plains produces breeding habitat for a range of species including *Ochlerotatus & Verrallina* species. Females lay eggs in floodplain soil and large populations or larvae created immediately following flooding rains.
- Flooded channels and grass lined depressions are known to provide habitat for *Cx. annulirostris, Cx. quinquefasciatus* and *Cx. orbostiensis*.

Watercourse (Creek)

- Simpsons Creek, which is a tidal waterbody, flows parallel to the east of the site.
- It is unlikely that the creek provides good quality breeding habitat for mosquitoes due to depth and lack of vegetation. During times of high rainfall, flooding may occur along the banks, resulting in temporary breeding habitat.

Stormwater Drainage Lines

- Large open drainage lines on site and adjacent property which, flow after heavy rainfall. In times of low/no rainfall, these drainage lines often comprise of stagnant pools, providing mosquito breeding habitat.
- Water delivery channels are a main source of breeding which results from the pooling and stagnation of semi-permanent waters on flat land. Species which breed in this environment includes a range of *Ochlerotatus & Verrallina* species.
- Human influence on wetlands and water flow can increase mosquito breeding. Factors such as impedance of drainage, nutrient enrichment, creation of water retaining depressions, inappropriate locations of stormwater drain end points (scouring of depressions) being known problems.

3.1.5 Potential Habitat Created from Proposed Works

Wallum Froglet Ponds

The Wallum Froglet habitat to be constructed can be described as ephemeral wetlands, due to their periodic wetting and drying. Features such as shallow water, gradual banks, emergent vegetation, absence of predatory fish etc. provide an optimal breeding habitat for several mosquito species. However, these ponds will only be periodically inundated and so only provide breeding habitat during these times. Furthermore, mosquitoes act as food sources of Wallum Froglets and other more common frog species, therefore it is expected that a healthy frog population will control mosquito numbers within these ponds.

Bio Retention Basins and Swales

There are a series of bio-retention basins and swales that receive and treat stormwater from the proposed development prior to being discharged into the environment, are designed to only hold water for a matter of hours before draining. Additionally, the associated outlet pits are also designed to drain within hours, eliminating stagnant water. Rain gardens positioned throughout the proposed development will be constructed as small bio-retention systems, which too will only have a retention time of a matter of hours. Bio retention pools will only be inundated for brief periods of time after heavy rainfall and therefore it is highly unlikely that these ponds will contribute to mosquito breeding habitat in the area.

Open Drainage

The open drainage network will consist of the central drain, drainage swale. Features of the open drainage network are heavily vegetated with gentle banks, however the sandy nature of the soil will allow for quick filtration, reducing inundation times and therefore suitability for mosquito breeding.

Residential Area

The increased residential features such as fish ponds, water tanks, guttering and other house hold habitats may provide habitat for several mosquito species including *Culex quinquefasciatus & Ochlerotatus notoscriptus*. The potential habitat to be created in residential areas is expected to be low and can be minimised if mitigation measures and community awareness initiatives are implemented.

4 Risk Assessment

For the purposes of this Plan the hazards associated with mosquitoes and biting midges are identified as –

- Mosquito-borne disease transmission of Ross River virus (RRV) and Barmah Forest virus (BFV)
- Nuisance biting activity by mosquito and midge impacting on humans
- Negative impacts to human health due to allergic reactions and secondary infections

4.1 Disease

More than 300 mosquito species can be found in Australia, many of these species have been identified as vectors of some human diseases (Queensland Government 2007). Biting midges by contrast have not been identified as vectors for human diseases.

It is the ability of a mosquito to inject saliva during feeding that enables it to transmit diseases. This requires that a mosquito's salivary glands are infected by a virus and it is important to note that not all mosquitoes can or will be infected, nor will all infected mosquitoes transmit a disease (NSWASVMP, 2003).

Some of the most common diseases transmitted by mosquitoes in northern NSW include the RRV and BFV. RRV can be particularly debilitating with symptoms ranging from rashes and fevers to arthritis. There are no specific treatments available and symptoms can last from weeks to years (Webb et al. 2010, Wright 2002). As such actions which minimise mosquito bites are the best way to minimise the risk of being infected by this disease.

RRV and BFV are the most common disease-causing pathogens spread by mosquitoes in Australia. There are other arboviruses transmitted by mosquitoes, including Stratford virus (STRV), Sindbis virus (SINV) and Edge Hill virus (EHV), that are often isolated from mosquitoes in coastal regions of NSW and rarely cause disease in Australia (NSWASVMP, 2003).

In coastal regions of NSW, arboviruses have been isolated most commonly from *Oc. multiplex*, *Oc. notoscriptus*, *Oc. procax*, *Oc. vigilax*, *Coquillettidia* spp, *Cx. annulirostris*, *Culex sitiens* and *Ve. Funereal* (Webb, et al. 2010).

4.2 Biting Nuisance

4.2.1 Mosquitoes

The biting nuisance of mosquitoes arises from the female mosquito's requirement for a blood meal to develop their eggs. This blood meal is sourced from a variety of birds and mammals, however in urban environments humans are often more accessible than other targets. During feeding saliva is secreted by the mosquito to help prevent the coagulation of blood, this secretion can cause an allergic reaction in mammals and is an additional source of nuisance from mosquito bites.

Therefore, in areas where mosquito breeding and human habitation coincides, biting nuisance

problems arise. The location of the subject site is within close proximity of known and potential breeding locations for mosquitoes, specifically Tyagarah and Brunswick Nature Reserve. As such nuisance biting impacts from mosquitoes are likely to occur from time to time.

As a general rule, areas up to 5km from known breeding sites will have a noticeable nuisance biting impact from some species of mosquito (Queensland Government 2002).

4.2.2 Biting Midge

While biting midges have not been implicated in the transference of human diseases, they can cause severe levels of biting nuisance associated with their feeding activities. Like mosquitoes, midges secrete saliva which contains an anti-coagulant to help with feeding. This anti-coagulant combined with the lacerating feeding action of midges can lead to an intense allergic reaction and irritation. Uncontrolled itching can lead to secondary infection, which in extreme cases may require medical attention, particularly in children.

As a general rule, areas up to 1.5km from known biting midge breeding areas can be affected by intense levels of biting midge nuisance impacts (Queensland Government 2002).

4.3 Identification of Risk

The site of the proposed development lies within a large section mapped as Saltmarsh Mosquito Secondary Habitat 500m Risk Zone. Some of the species that are known to occur in this area are known to potentially transfer human diseases particularly RRV and BFV.

Biting midges are not expected to present a large nuisance risk to the human population at the proposed site, since it lies beyond the common dispersal distance from known midge breeding sites.

The development proposes to incorporate stormwater systems, such as bio retention ponds, frog habitat and drainage swales which may, if poorly designed or managed, increase the risk of infection at this site by increasing breeding sites and adult abundance.

The completed development will increase human activity at the site, but in the context of the broader region will not represent a significant increase given the proximity of Tyagarah Nature Reserve & Brunswick Nature Reserve.

A risk matrix was created to determine the level of risk from the three key hazards identified in Section 2. The matrix used can be seen in Table 4.1 below.

Table 4-1 Risk Matrix. Adapted from risk analysis framework (Commonwealth of Australia 2005)

Likelihood	Consequences			
	Negligible	Minor	Moderate	High
Likely	L	M	H	H
Possible	N	L	H	H
Unlikely	N	L	M	H
Rare	N	N	L	M

*NOTE - H – High risk; M – Moderate risk; L – Low risk; N – Negligible. Red line – Disease; Blue line – Nuisance; Green line - Infection

A characterisation of the three hazards identified in Section 2 show that for disease transmission there is high risk, for nuisance biting there is moderate risk and for allergic reactions and secondary infections the risk is moderate. Overall, the mosquito and midge risk for the proposed development is considered moderate. This is principally because of seasonal nuisance biting. It should be noted that as a result of the consequences associated with mosquito borne disease the risk for this hazard is high, despite a lower likelihood of occurrence. This matrix points to the fact that proper management and design decisions must be made to ensure the overall risk from mosquito and midge impacts is maintained as low as possible.

5 Management

5.1 Management measures

It must be noted that the mosquitoes are an important component of the wetland ecosystem, providing food for birds, bats, amphibians, fish and macro invertebrates. The environmental values of wetlands also mean that modification of such environments (eg draining or filling) to control mosquito breeding may be limited due to requirements to maintain and create Wallum Froglet Habitat. This report recognises the importance of protecting these environments in attempting to implement mosquito management initiatives. Due to the requirements under other statutory instruments large sections of the site's vegetation & Wallum Froglet Habitat will be protected and revegetated. This has the potential to enhance corridors for mosquitoes, potentially bringing them in closer contact with the users of the site (Webb et al. 2011).

It must be noted that the site is within a large section of mapped Saltmarsh Mosquito secondary habitat 500m risk zone, meaning that the site and surrounding land provide secondary habitat for mosquitoes, facilitating movement and breeding. As such it will be important for mitigation measures to be implemented to restrict the risk associated with mosquitoes, without altering ecological values for the Wallum Froglet.

To ensure that the objectives of this plan are achieved, there are a number of management measures that can be implemented. To achieve the maximum effectiveness for any mosquito control program, it is essential that an integrated approach is taken to control risk to humans whilst maintaining ecological values.

5.1.1 Building design

While some mosquito activity should be expected in outdoor areas, the entry of mosquitoes into buildings can often have significantly greater nuisance impacts. Control measures may include:

- Installation of insect screens: Insect screens of an appropriate mesh size (1.2mm x 1.2mm) should be installed on windows, doors etc.
- If possible, development should consider an effectively screened outdoor area of a size commensurate with the number of people who are likely to use it, to enable an outdoor lifestyle to continue to be enjoyed during periods of high mosquito and biting midge activity
- Blocking entrances: No entry points via ventilation, air-conditioning ducts or other connections between indoor and outdoor areas
- Generally daytime mosquito activity will be restricted to December to March. During these months' extra care should be taken to ensure that screens and entry points are closed
- Roof guttering should be fitted with a leaf guard to reduce the accumulation of leaves in gutters that can act as mosquito breeding
- Air Flow: – mosquito activity restricted when airflow is maintained, this can be achieved by wind or fans
- Lighting: lighting may attract male mosquitoes and other flying insects (chironomids), thus outdoor lighting should be directed towards the ground to minimise illumination

5.1.2 Water Sensitive Urban Design

To reduce the suitability for mosquito breeding water bodies such as drains should have surface movement, steep margins free of shelter. Ideally depths should be above 2m however is not practical in most instances.

Drainage Network

- Drainage Swale: due to the sandy conditions of the site this water is expected to infiltrate into the ground relatively quickly
- Central drain: is to be reshaped to efficiently convey water downstream. There will be no ponds within this drain. The catchment for the central drain consists of the existing Wallum Estate development up stream and the surrounding proposed development. In rain events the central drain will be fully flushed, interrupting any potential mosquito production
- Trunk drainage: Due to the limited fall across site the drainage system has been designed at minimum grade. This means water will move slowly through the system but will not allow for standing water. Associated pits will also be selected to allow drainage from base, ensuring no standing water occurs; and
- Any pollutant traps and sediment zones will be managed to prevent blockages to reduce stagnant water.

Bio retention Ponds (Dry Stormwater System)

- Designed to only hold water for brief periods (less than 2 hours), not allowing sufficient time for mosquito breeding to occur. As water will be retained for less than 2 hours within the ponds, it is considered that bio retention ponds will not act as breeding habitat for mosquitoes.
- Vegetation is restricted to sedges, grasses and small shrubs. No trees will be planted in bio retention ponds, reducing shade and suitability for mosquito foraging habitat.

Rainwater Tanks

Rainwater tanks may increase the available habitat for *Ae. notoscriptus*, which is a concern as this species is known to transfer both BFV and RRV.

- All water tanks must be properly installed with any openings (such as inflow, outflow and access points) completely screened to prevent entry by mosquitoes; and
- All screens should be regularly checked and maintained.

5.1.3 Constructed Wetlands

Wallum Froglet Habitat

- Designed to only be hydrated by ground water expression and rainwater falling directly into basins (no stormwater)
- Bathymetry designed such that there is regular wetting and drying periods
- There are no proposed gross pollutant traps, sediment zones or outlet devices associated with the constructed habitats which can often block and hold stagnant water
- Frogs are an important part of the ecosystem with a role for insect and pest control including mosquitoes. The introduction and regeneration of natural predators, with a focus on Wallum Froglets will naturally control mosquito numbers.

5.1.4 Earthworks and Roadworks

- Roadways and embankments should be, where possible, designed and constructed so as to eliminate potential ponding locations and such that flows from these surfaces do not enter 'un-controlled' potential breeding areas
- Fill opportunistic breeding sites such as depressions, wheel ruts and borrow pits during and post construction; and
- Monitor check retention ponds and sediment traps during construction to ensure no mosquito larvae are present.

5.1.5 Vegetation Selection

- Vegetation planted within constructed habitat, will consist of grasses and small shrubs common to wallum heath and sedge land ecological communities. This low planting will reduce shade which is preferable for mosquito production
- Within the constructed WSF habitat *Leptospermum liversidgei* will be one of the predominant shrub species. This cultivar releases citronella into the atmosphere. Citronella is often used as a natural mosquito replant. In mass planting this could have a positive effect of mosquito control, although this has not been scientifically proven
- Where possible, landscaped trees should incorporate low foliage cover species; and
- Species such as *Typha spp. & Phragmites spp.* are prone to dense growth within wetlands, clogging wetland systems and creating a refuge for mosquito larvae (restricting access to of predators). For these reasons the species listed above should be avoided or controlled as part of site maintenance.

5.1.6 Existing Wetlands

The site and surrounds contain significant portions of natural wetlands that are both inherently valuable but also valuable for the fauna they support. As such it is not possible to physically modify these exiting wetlands to minimise breeding and shelter potential. These wetlands are generally located on the eastern portions of the site, some distance from the proposed dwellings. However other actions will need to be incorporated to minimise the impact of mosquitoes from this region. These may include regeneration of frog habitat, including Wallum Froglet habitat, which in turn will

result in an increase of natural predators in these wetland areas; and

A targeted larvicide control program has been considered and determined to be ineffective due to the large amount of habitat in the locality, including large sections of NPWS land.

5.1.7 Natural Control through Maintaining Ecosystem Heath

- One of the natural factors regulating mosquito distributions and population sizes is predation. Maintaining healthy ecosystem function is essential to naturally maintain mosquito numbers. Natural predators such as frogs, bats and fish are known to control mosquito numbers within the ecosystem, this may be through the predation of mosquito in their larval or adult form (Bowatte et al. 2013).

- Tadpoles are thought to have a substantial impact on mosquito populations, as mosquitos and frogs breed in many of the same places (pools, puddles, ditches, swamps, and water-filled containers) and often at the same time (the breeding of mosquitos and most frogs peaks during and after heavy rain). Tadpoles are thought to control mosquito in two ways; through predation on larvae and through competition (Bowatte et al. 2013, Rowley, 2016). Tadpoles compete with mosquito larvae so much that they reduce mosquito larval survival. Tadpoles of one of the most common backyard frog in Australia, the Striped Marsh Frog (*Limnodynastes peronii)* are known to control mosquito numbers through competition (Rowley, 2016).

- Smaller bat species such as *Vespadelus vulturnus* (Little Forest Bat) are known to have a diet that consist of about 55% mosquitoes, predominantly *Ochlerotatus vigilax,* which a vector of disease and culprit of nuisance biting (Gonsalves et al. 2013a,b). It is thought that this mosquito consumption helps to naturally control mosquito numbers in foraging habitats, similar to that present on site.
- Developing measures to protect amphibians in seasonal pools and maintaining values for microbat species may contribute to controlling mosquito production in wetlands, potentially minimizing disease risk to humans.

- Reducing the following threatening process will promote ecosystem health on the site: erosion, run-off, sedimentation; oil or chemical spills; weed introduction; disease; habitat fragmentation; habitat deterioration; introduced species; and trampling and use activities.

5.1.8 Broad Scale Mosquito Control

Byron Shire Council has advised against broad scale mosquito control activities. Evidence does suggest that mosquito control programs can reduce adult mosquito populations and, consequently, the risks of mosquito-borne disease, however mosquito control in coastal swamp environments can be operationally difficult due to the large area of extensive habitats, the heterogeneous distribution of immature mosquito habitats within these environments and the unpredictability of rainfall and flooding of these habitats.

Furthermore, studies have shown that a shift in foraging range by little forest bats (*V. vulturnus*), corresponds with a spatio-temporal variation in abundance of the mosquito species *Ae. vigilax.* This demonstrates that large scale mosquito control in the area may in turn impact on microbat populations (Gonsalves et al. 2013a).

Many of the areas identified as coastal swamp mosquito and estuarine mosquito habitat is located on land that is managed by NPWS. Therefore, it is beyond council's jurisdiction to undertake

mosquito control activities in these areas.

5.1.9 Buffer zones

Buffer zones between urban developments and mosquito habitats are often raised as a possible strategy to assist in minimising the impact of nuisance-biting. However, there is ongoing debate as to the design of such buffer zones and their relative effectiveness.

There is anecdotal evidence that vegetation free buffer zones of 100m can minimise the dispersal of mosquitoes associated with flooded Casuarina and Melaleuca forests including a suite of *Aedes spp and Verrallina spp*. However, several species such as *Ae. Vigilax* are known to disperse several kilometres from breeding sites making a 100m buffer ineffective. Due to the close extent of the proposed works to extensive breeding habitat (nature reserves containing extensive breeding habitat) and DA conditions to create further Wallum Froglet Habitat on the site, vegetation free buffers are not a viable management method in this case.

Buffer zones have not been deemed appropriate as they conflict with the objectives of the Wallum Froglet Management Plan, in which periodically inundated, highly vegetated ponds will be created.

5.1.10 Community Consultation

Enquiries from public

A protocol to deal with enquiries from the public regarding mosquitoes should be established. Individuals responsible for answering enquiries should be familiar with the current mosquito issues and a database of enquiries/complaints should be kept so that over time, any patterns in possible nuisance-biting impacts can be identified.

Education

Local residents should be informed of ways in which they can reduce mosquito numbers on their property, how to avoid getting bitten and what to do in suspected cases of RRV and BFV.

For example, residents can reduce mosquito breeding habitats in their backyard includes reducing stagnant water in:

- buckets, toys, and other items in yards
- untreated swimming pools
- pet food and water bowls
- bird baths
- rubbish bins and recycle containers
- outdoor potted plants with saucers
- water tanks
- fish ponds or other artificial water ponds
- gutters and downspouts that don't drain completely

The following publication should be used and referred to when providing advice to residents: *Beating the Bite of Mosquito-Borne Disease: A guide to personal protection strategies against Australian mosquitos* (Webb, 2011b).

5.2 Maintenance

Poorly managed stormwater devices can be a source for increased mosquito breeding. A properly designed system which is maintained in accordance with a site specific Operation and Maintenance Manual will largely reduce this risk. At a minimum maintenance activities should be conducted to ensure the following issues do not occur –

- Clogging of inlets, outlets and the system generally
- Growth of nuisance species, notably Typha (Bulrush)
- Scouring and sedimentation erosion generating clogging silt loads; and
- Rubbish accumulation.

6 Conclusion

Mosquito management on Wallum Estate, Brunswick Heads is complex due to its location within Saltmarsh Mosquito Secondary Habitat 500m Risk Zone & Coastal Swamp Mosquito Habitat 200m Risk Zone and due to the required creation of Wallum Froglet habitat throughout the site.

If the management methods discussed above are successfully implemented it is expected that risks associated with mosquitos will be minimised on the site.

7 References

Bowatte, G., Perera, P., Senevirathne, G., Meegaskumbura, S., Meegaskumbura, M. (2013). Tadpoles as dengue mosquito (Aedes aegypti) egg predators, Biological Control. 67(3) 469-474,

Byron Shire Council (2014) Development Control Plan 2014: Chapter B7 Mosquito and Biting Midges

Gonsalves, L., Law, B., Webb, C., & Monamy, V. (2013a). Foraging ranges of insectivorous bats shift relative to changes in mosquito abundance. PLoS One. 8(5)

Gonsalves, L., Bicknell, B., Law, B., Webb, C., & Monamy, V. (2013b). Mosquito consumption by insectivorous bats: Does size matter? PLoS One. 8(10).

NSW Arbovirus Surveillance & Vector Monitoring Program (2003). Mosquito Production & Management. http://medent.usyd.edu.au/arbovirus/ Accessed September 2016.

NSW Arbovirus Surveillance & Vector Monitoring Program (2016a). The Mosquitoes. http://medent.usyd.edu.au/arbovirus/mosquit/mosquitoes.htm. Accessed September 2016.

NSW Arbovirus Surveillance & Vector Monitoring Program (2016b). Monitoring Locations. http://medent.usyd.edu.au/arbovirus/location/locations.htm. Accessed September 2016.

Queensland Health (2002). Guidelines to Minimise Mosquito and Biting Midge Problems in New Developments. Queensland Government, Brisbane.

Rowley, J. (2016). Can Frogs Help Combat the Zika Virus? Healthy frog populations may help keep disease-carrying mosquitos at bay, but not in the way you might expect. Australian Museum.

Webb, C. E., Russell, R. C. (2010). Mosquito Risk Assessment: West Byron, Byron Bay, NSW. Sydney West Area heath Service.

Webb, C. E., Russell, R. C. (2011a). Mosquito Management Plan, Byron Shire Council.

Webb, C. E. (2011b). Beating the Bite of Mosquito-Borne Disease: A guide to personal protection strategies against Australian mosquitos. Medical Entomology. University of Sydney.

Webb, C. E (2016). Mosquito Research and Management. A summary of research projects and publications dealing with mosquitoes, wetlands and urban ecology (as well as other Medical Entomology activities) by Dr Cameron Webb. University of Sydney & Pathology West. https://cameronwebb.wordpress.com/ Accessed September 2016.

Wright, A.E. (2002). Mosquito Management in Ballina Shire. A Report to Ballina Shire Council.

Appendix A

The Mosquito species recorded from the Byron Shire as part of the NSW Arbovirus Surveillance and Mosquito Monitoring Program 2008-2011.

Mosquito Species	Byron Bay			Ocean Shores		
	2010-11	2009-10	2008-09	2010-11	2009-10	2008-09
Aedes aculeatus	0	51	0	0	0	4
Aedes burpengaryensis	0	37	0	2	4	1
Aedes candidoscutellum	0	0	0	1	0	1
Aedes gahnicola	0	6	5	0	1	0
Aedes kochi	7	15	5	100	65	43
Aedes multiplex	171	247	104	83	167	14
Aedes notoscriptus	232	542	370	605	1541	669
Aedes palmarum	1	16	0	10	46	9
Aedes procax	14	150	102	136	305	221
Aedes quasirubithorax	0	0	0	1	0	0
Aedes sp. Marks 51	0	0	0	0	11	155
Aedes vigilax	2	87	15	6	83	20
An. annulipes	0	1	0	0	1	0
Cq. linealis	80	40	81	10	0	14
Cq. variegata	1	1	3	0	1	0
Cq. xanthogaster	51	4	27	8	0	0
Cx. annulirostris	1	7	2	13	26	9
Cx. australicus	1	0	4	8	1	7
Cx. bitaeniorhynchus	3	0	0	0	0	0
Cx. edwardsi	0	0	0	3	0	0
Cx. halifaxii	1	0	0	0	1	0
Cx. orbostiensis	36	156	30	52	78	9
Cx. pullus	1	0	0	10	0	0
Cx. quinquefasciatus	2	2	4	6	7	1
Cx. sitiens	0	32	9	7	261	25
Cx. sp. Marks No. 32	1	0	0	0	0	1
Cx. squamosus	5	0	0	0	0	0
Ma. uniformis	3	4	3	16	0	0
Tp. marksae	0	1	0	1	5	0
Tp. tasmaniensis	0	0	0	0	2	0
Ur. pygmaea	0	0	0	0	1	0
Ve. funerea	0	20	0	10	31	17
Ve. sp. Marks No. 52	1	24	3	0	5	7
Total	614	1443	767	1088	2643	1229

Appendix B

Site 1, Tweed heads, NSW Arbovirus Surveillance and Mosquito Monitoring Program

Species	Feb 2016>				Mar >				Apr >				May >			
	7	14	21	28	6	13	20	27	3	10	17	24	1	8	15	22
Aedes aculeatus	1															
Aedes alternans	1															
Ae. burpengaryensis	1					1										
Ae. gahnicola																
Ae. kochi																
Ae. multiplex																
Ae. notoscriptus	19	5	6	19	5	9	14									
Ae. notoscriptus (M)																
Ae. palmarum																
Ae. procax		1		1		3	1									
Ae. vigilax	77	33	14	26	6	21	11									
Ae. vigilax (M)																
Ae. vittiger																
Anopheles annulipes																
Coquillettidia linealis							1									
Coquillettidia xanthogaster	2	1		8	1											
Cq. xanthogaster (M)		1		2												
Culex annulirostris	31	47	2	27	24	8	28									
Cx annulirostris (M)																
Cx. australicus																
Cx. edwardsi																
Cx. orbostiensis		1		3	2											
Cx. orbostiensis (M)																
Cx. pullus																
Cx. quinquefasciatus																
Cx. sitiens	41	59	6	95	103	12	12									
Cx. sitiens (M)																
Cx. squamosus																
Mansonia uniformis	1		1	1	1	1										

Mimoyia elegans		3														
Uranotaenia lateralis																
Uranotaenia pygmaea																
Verrallina funerea	5	5		1		3	4									
Verrallina funerea (M)																
Verrallina sp. Marks no. 52						1										
Weekly Totals	179	156	29	183	142	59	71									
LTA *Ae. vigilax*	27	18	17	40	44	11	16	27	8	5	5	20				
Long Term Ave. Total	125	139	139	200	187	124	143	126	69	35	51	83				
Virus Result	0	0	0	0	0	0										
Species	Feb 2016>				Mar >				Apr >				May >			
	7	14	21	28	6	13	20	27	3	10	17	24	1	8	15	22

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