CLIENT: SHIRE OF BUSSELTON

SHIRE OF BUSSELTON
MOSQUITO MANAGEMENT PLAN
(RFQ05/10)

VERSION 2
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REVISION CONTROL

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1. INTRODUCTION

1.1 Background

Mosquitoes present serious health risks to humans by acting as transmitters or vectors of pathogenic arbovirus (Environmental Protection Authority 2000). In Western Australia, mosquito species can be divided according to their breeding habitat. These include coastal wetlands that are influenced by tides, permanent reed swamps or wetlands with emergent vegetation, containers; and temporary ground pools. While *Aedes camptorhynchus* (Southern saltmarsh mosquito and *Aedes vigilax* (Summer saltmarsh mosquito), both considered vectors of Ross River virus (RRv), commonly breed in coastal wetlands, *Aedes camptorhynchus* may also breed in temporary fresh groundwater sites. Both species also have the ability to disperse over long distances. Other species that are known to be disease vectors are *Aedes notoscriptus* (Container mosquito) (RRV) *Culex annulirostris* (Common banded mosquito) (RRV, Barmah Forest virus (BFv) and Murray Valley encephalitis, Kunjin virus and *Coquillettidia* sp. *near linealis* (RRv and BFv).

The need for mosquito management is reduced significantly where urban development is located outside of the flight range of known pest/vector mosquito species, or where there is an adequate buffer zone between residential areas and mosquito breeding sites, assuming that there are no additional breeding sites created as a result of urban development. However, due to the nature of the geography and historical development of the Shire of Busselton (the Shire), the Shire is often requested to support development applications for individual residences and residential developments to be constructed adjacent to or within relatively close proximity of significant mosquito breeding habitats within the Shire.

In 1993 in recognition of the serious threat to public health by vector mosquitoes, the Shire, in association with the Health Department of Western Australia (DoH) and the University of Western Australia (UWA), began collecting data relating to the incidence of RRv, the identification of mosquito species present, breeding site locations and environmental factors that are known or thought to influence mosquito breeding.

The initial mosquito identification process has involved extensive background research and mosquito monitoring along the extent of the Vasse / Wonnerup wetland areas, utilising the services of a consultant medical entomologist, DoH and UWA specialist personnel and also computer mapping which forms a component of Shire's Geographical Information System (GIS).

This investigatory study process has determined the main mosquito species responsible for the high nuisance levels and spread of RRv. Four major breeding sites were identified as priority treatment zones for a mosquito control program as it was believed that a significant level of mosquito control for the community could be achieved by focusing on these four zones. Baseline monitoring undertaken by the Shire and UWA/DoH indicates the presence of a range of freshwater vector species associated with the wetlands that commonly occur within the southern extent of the Swan Coastal Plain. In addition, the monitoring has confirmed that the main areas of urban development within the Shire are often situated in close proximity to known breeding sites of the main saltmarsh vector species (*Aedes vigilax* and *Ae. camptorynchus*) associated with the Vasse-Wonnerup Estuary (**Figure 1**).

1.2 Statutory Management

1.2.1 Department of Health

Under the Western Australian *Health Act 1911*, the Department of Health (DoH) has a state-wide charter to protect public health. This includes any threat to public health through mosquito-borne diseases such as Ross River virus (RRv) and Barmah Forest virus (BFv) diseases. The DoH has established a dedicated Mosquito-Borne Disease Control Branch whose function is to "protect public health by minimising public exposure to diseases transmitted by mosquitoes".

In 1990 the State Government introduced the Contiguous Local Authorities Group (CLAG) scheme In recognition of the need for local governments to receive assistance with the management of disease vector mosquitoes. There are currently ten CLAGs comprising 20 Local Government Authorities (LGA) that receive assistance through the CLAG funding scheme (Department of Health, 2009).

State Government funding via the DoH is available to a LGA for mosquito control where there is an actual or potential risk to public health. Assistance is however, only available to manage mosquitoes which are known vectors of mosquito-borne diseases; funding is not provided for the control of 'nuisance' mosquitoes (Department of Health, 2009).

The Mosquito Control Advisory Committee (MCAC) currently oversees the provision of DoH funding to LGAs with recognised mosquito-borne disease problems. The MCAC includes representatives from the DoH, the Department of Environment and Conservation (DEC), the Ministry for Planning, the Department of Water (DoW), the Environmental Protection Authority (EPA), the Peel Development Commission, the Local Government Association and the Country Shire Council's Association.

State Government funding for the management of mosquitoes requires as a pre-requisite the formation or membership of a CLAG. In November 1998 the Shire of Busselton's application for approval to form a CLAG for the control of mosquitoes in the Busselton region was supported by the DoH.

Funding for approved CLAGs, with respect to mosquito management, is provided for the following items of work:

- Helicopter hire for approved aerial treatments – 100% State Government;
- Cost of insecticides for aerial and ground larviciding – 50% State Government and 50% CLAG;
- Earthworks to reduce mosquito breeding – funding negotiated between State Government and CLAG;
- Ongoing monitoring of local mosquito breeding – 100% CLAG funded; and
- Local environmental monitoring – 100% CLAG funded.

The current scheme is therefore heavily weighted towards programs that manage mosquito through the application of chemical larvicides advantaging local governments with small, easily-accessible breeding sites and where there are existing officer resources to monitor larvae and apply larvicides, or where there is ready access to helicopter capacity for aerial spraying (Department of Health, 2009).

1.2.2 Environmental Protection Authority

The Environmental Protection Authority (EPA) expects that LGAs and proponents of residential developments will develop measures to manage mosquitoes through undertaking adequate surveys, in consultation with the Health Department of Western Australia, in order to establish the presence, extent and likely impact of mosquitoes on or adjacent to development sites and incorporating appropriate management measures to control mosquitoes if they have the potential to be a problem as a result of a proposed development.

The EPA's Guidance Statement No. 40: *Management of Mosquitoes by Land Developers* (http:www.epa.wa.gov.au/docs/1025_GS40.pdf) is a key guidance document that has been issued to assist developers and LGAs as to the EPA's expectations with respect to the management of mosquitoes and nuisance insects (Environmental Protection Authority, 2000). The guidance provides a framework that assists in the development of suitable mosquito management plans within a development area.

The principal objectives of the Guidance Statement are to ensure that:

- Mosquito numbers on-site and off-site should not adversely affect the health, welfare and amenity of future residents; and
- The breeding of mosquitoes is controlled to the satisfaction of the DoH without adversely affecting other flora or fauna.

1.2.3 Western Australian Planning Commission

With respect to mosquito management through the Western Australian planning approvals process overseen by the Western Australian Planning Commission (WAPC), following rezoning of the landholding any proposal to subdivide will require that a subdivision application be lodged with the WAPC in accordance with the provisions of the Western Australian *Planning and Development Act 2005*. The subdivision approvals process requires that the Department for Planning refer the subdivision application to a range of Stage Government agencies (e.g. the relevant LGA, DEC and DoH) seeking their comments and recommendations with respect to the imposition of conditions on the proposed development.

Through the subdivision process, the WAPC is therefore able to impose conditions on a proposed subdivision development such as the requirement for a landowner/developer to prepare and implement a mosquito management plan in respect to all or part of the proposed subdivision.

The WAPC is also able to require Notifications (or Memorials) be placed on land titles that warn of the risks of mosquitoes and mosquito-borne disease to prospective land purchasers (Department of Health, 2009). This approach is increasingly being applied to land within 3 km of saltmarsh wetlands (the zone where the majority of Ross River Virus cases occur in the south-west of Western Australia).

1.2.4 Local Government Authority

Under the Western Australian *Health Act 1911* LGA's play a key role in the management of mosquitoes. Part IX of the Act includes provisions that relate to the control of nuisance and disease-vector mosquitoes. Under the Act, the Shire of Busselton has a responsibility to undertake mosquito control (e.g. monitoring within their municipality, provision of education on mosquito management) or to require private landowners to implement control or management measures as deemed necessary.

Local Government Authorities through their assessment of development applications may recommend mosquito management conditions to the WAPC for inclusion in development approvals.

1.2.5 Commonwealth Government

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* came into effect on July 16, 2000. As both the Ford Road and Port Geographe major mosquito breeding zones are situated adjacent to the Vasse Wonnerup Wetlands, wetlands of international importance listed under the Ramsar Treaty to which the Commonwealth is a signatory, it is necessary to seek the approval of the Commonwealth Department of Environment, Water, Heritage and the Arts (DEWHA) prior to undertaking any action that may impact on the wetlands.

The Act therefore has implications for mosquito control programs associated with the Vasse-Wonnerup Wetlands, whether they involve physical site modifications or the application of chemical mosquito control agents to the environment.

1.3 Shire of Busselton Mosquito Strategy

Since 2004, the Shire has implemented a mosquito management strategy aimed principally at minimising the incidence of RRv amongst residents and visitors to the Shire (Shire of Busselton, 2004).

The objectives of the strategy are to:

- Reduce residents exposure to disease carrying mosquitoes;
- Minimize the use of chemicals for the control of mosquitoes;
- Control mosquitoes using the most cost effective and environmentally safe methods available;
- Educate the community about mosquitoes, mosquito born diseases and mosquito prevention;
- Enlist the support of the community in control efforts;
- Investigate the feasibility of regional co-operation in relation to mosquito control methods and resource sharing; and
- Investigate contribution requirements from land developers for mosquito control in high risk areas.

The overall aim of mosquito management operations implemented by the Shire is to reduce the numbers of the pest or disease vector species to a level where the impact on the adjacent human population is kept to an acceptably low level. The long-term goal is to maintain the mosquito populations below this threshold (Shire of Busselton, 2004).

Elements of the strategy that have/are being implemented include:

- Identification of major mosquito breeding sites;
- Larval sampling in 14 locations within breeding sites;
- Monitoring of adult mosquito trapping undertaken by UWA at four locations within the Shire;
- Application of the Larvicide S - Methoprene to mosquito breeding sites as determined by larval sampling;
- Post treatment sampling to review the effectiveness of larvicide application; and
- Barrier fogging with adulticide (Reslin) as determined by trapping numbers, complaints and virus prevalence.

To compliment the control operations, the Shire implement's a public education campaign to increase public awareness of the mosquito problem and identify some simple measures that can be carried out by the individual householder to prevent being bitten by mosquitoes and eliminate backyard breeding sites.

Another aspect of the management program is the control of development to ensure that the modification of the environment does not result in the creation of new, or exacerbation of existing significant mosquito breeding areas.

1.4 Scope of Work

PART A

The Shire of Busselton commissioned *Rankine Mosquito Management* to undertake a review of the current Shire mosquito management program. The review was to include an analysis and review of the following elements of the program:

- Assessment of larval sampling records and adult trapping numbers, in conjunction with treatment records;
- Comment of the effectiveness of the existing treatment measures;
- Assessment and mapping of mosquito breeding sites throughout the Shire;
- Comment regarding the selection of sampling sites and targeted breeding sites;
- Suggestions for the effective expansion of the adult trapping program;
- A desk-top audit and review of the current mosquito control strategy;
- Desktop study of water fluctuations in the Vasse Wonnerup Estuary and the feasibility of reducing mosquito breeding via water level manipulation utilising the existing floodgates; and
- Recommendations for alternate / additional treatment methods (physical, chemical, or biological).

PART B

Following an initial discussion with officers representing the Shire's Environmental Health Department, it was agreed that the information pertaining to the above elements would comprise background information to support the development of a comprehensive Mosquito Management Plan for the Shire.

The principal objectives of the Mosquito Management Plan are to ensure that:

- The plan complies with the requirements and principal objectives of the Environmental Protection Authority's Guidance Statement Number 40: *Management of Mosquitoes by Land Developers*;
- Measures implemented to manage disease vector and nuisance insects and protect the health, welfare and amenity of the residents do not adversely affect environmental values;
- As far as practicable that no new breeding sites are created through the Shire's role as a stakeholder in future urban residential developments;
- An integrated, environmentally responsible mosquito management program using industry best management practices (BMP) is implemented;
- There is ongoing review and assessment of the management program; and
- A public awareness program is implemented by the Shire.

The following documents have been used as guidance in the development of this management plan:

- Guidance Statement No. 40: *Management of Mosquitoes by Land Developers* (Environmental Protection Authority, 2000);
- Western Australian Department of Health *Mosquito Control Manual - Mosquito Surveillance and Monitoring Techniques* (Whelan, 2004);
- *Planning a Mosquito Management Program* (Environmental Health Directorate, Department of Health, 2006);
- *Mosquito Management Manual* (Department of Health WA, 2006); and
- *Chironomid Midge and Mosquito Risk Assessment Guide for Constructed Water Bodies* (Midge Control Group of Western Australia, 2007).

PART A

A1. SAMPLING AND TARGETED BREEDING SITES

Under the current monitoring program data is gathered from 16 larval monitoring sites and four adult monitoring sites. The breeding sites targeted are the four main breeding sites detailed in the Busselton Mosquito Management Strategy (Shire of Busselton, 2004).

A1.1 Larval Monitoring

The following sites are currently being monitored by the Shire:

1. Webster Road, Vasse-Wonnerup;
2. Layman Road Bridge, Vasse-Wonnerup;
3. Lookout at Captain Baudin Reserve, Vasse-Wonnerup;
4. Layman Road, Keel Retreat, Vasse-Wonnerup;
5. Nautilus Boulevard, Vasse-Wonnerup;
6. Ford Road, Vasse-Wonnerup;
7. Molloy Street, Vasse-Wonnerup;
8. Rushleigh Road, Vasse-Wonnerup;
9. Radio Tower West, Siesta Park;
10. Radio Tower East, Siesta Park;
11. Lakeview Boulevard, Vasse New Town;
12. Old Bridge, Toby's Inlet;
13. Cookworthy Road, Broadwater;
14. Old Broadwater Farm, Broadwater;
15. Wonnerup House, Layman Road, Vasse-Wonnerup; and
16. Blum Boulevard, Vasse Highway.

The number of sites monitored has been extended in recent years as a result of the Commonwealth approval being given to conduct larval treatments at the four main saltmarsh breeding sites. Nine of the 16 sites are located within or adjacent to sites at Ford Road and immediately to the east of this breeding area, and the Vasse-Wonnerup breeding areas. Four sites are located within the Siesta Park/Broadwater site. There is one site to the south of Siesta Park/Broadwater in the development at Vasse New Town. One monitoring site is located at Toby's Inlet and the final site where monitoring is carried out is at Blum Boulevard.

The nine larval monitoring sites in the Ford Road/Vasse-Wonnerup areas cover a good cross section of the breeding sites. The aim is to assess areas which are representative of the overall breeding site and to determine whether those sites are inundated on a regular basis or only occasionally. It is also important however, given the Vasse-Wonnerup Estuary's conservation status, that where practical, minimal impact results from regular monitoring.

The breeding site at Siesta Park/Broadwater covers an area of approximately 106 ha. Given the size of this site, it is recommended that the number of monitoring sites be increased at those times when the breeding sites are receiving inflow from rainfall events. Additional monitoring sites will allow a more detailed evaluation of the mosquito breeding areas within the site. This should in turn lead to a more cost effective and efficient treatment program.

At present there is only one larval monitoring site at Vasse New Town. Given this area will be a significant focus for future development, monitoring in this area needs to be extended

to include other potential mosquito breeding sites within and adjacent to the development to gather data on the likely impact that mosquitoes breeding onsite may have on residents. As this is a large development that is anticipated to be developed over an extensive timeframe, it is important that an ongoing assessment be made of the effectiveness of the stormwater management system to ensure that no mosquito breeding sites are created as the project proceeds.

The breeding site at Toby's Inlet covers an area of approximately 10 ha. It is recommended that at least one extra larval monitoring site is established at this location. There are other areas of samphire to the west of the existing monitoring site, plus an area of samphire along the north side of Caves Road opposite the Dunsborough Lakes Estate. Ideally these breeding areas should also be included in the larval monitoring program as they have the potential to result in significant localised breeding of the main vector species *Aedes camptorhynchus* and *Aedes vigilax.*

The final larval monitoring site is located at Blum Boulevard, off of Vasse Highway. This is the site of a freshwater wetland with a drainage channel running east-west. As part of the Provence Estate mosquito monitoring program, adult and larval monitoring is undertaken on the eastern side of the wetland as part this program. Ideally any monitoring carried out by the Shire should compliment that work.

Overall there is a need to increase the number of larval breeding sites being monitored as part of the program. To what extent this is achievable will be dependent upon the level of expansion and any resulting increase in budget and resources provided for the program. There is no doubt, however, that there is a need for a more comprehensive larval monitoring program which takes into account a greater range of mosquito species which breed in a variety of habitats. It is recommended that the monitoring program be extended to include natural freshwater wetlands, constructed wetlands, drainage channels and roadside gullies. This would also result in a requirement that the adult mosquito monitoring program be expanded to compliment the additional data gathered.

CLAG funding requires that pre- and post-treatment monitoring is carried out as part of any mosquito management program. While this is being carried out as part of the existing program, it would be beneficial if a detailed study was carried out on each saltmarsh site in order to develop a comprehensive management regime for each site.

A1.2 Adult Monitoring

Adult monitoring (trapping) is currently being conducted at the following sites:

1. Department of Environment and Conservation (ex-CALM) Village, Ludlow;
2. Ford Road, East Busselton;
3. Busselton Radio Tower, Siesta Park; and
4. Old Bridge, Wilson Road, Quindalup, Toby's Inlet.

The four sites monitored by the Arbovirus Surveillance and Research Laboratory (UWA) have been part of a larger study covering the Peel and Southwest districts for a number of years. The UWA program does not have the capacity to cover additional monitoring sites. The sites provide data on the level of localised mosquito activity. They are, out of necessity, widely spaced. Importantly, samples of mosquitoes trapped are processed for virus isolation. The

Busselton area has developed greatly over the last few years with further expansion expected in the future. As a result, further monitoring will be required to determine the impact that mosquitoes may have on the areas of rapidly growing population.

A1.3 Breeding Sites

The following breeding sites were identified within the Shire of Busselton mosquito management strategy:

1. Zone 1: The vegetation perimeter of the water body behind the Busselton Radio Tower, Siesta Park. This site covers an area of approximately 106 ha.
2. Zone 2: Area of samphire near Ford Road, East Busselton. This site covers an area of approximately 40 ha.
3. Zone 3: Samphire area in the vicinity of Port Geographe. This site covers an area of approximately 100 ha.
4. Zone 4: The eastern end of Toby's Inlet. This site covers an area of approximately 10 ha.

The four main saltmarsh breeding sites listed represent the sites that are most likely to impact adversely on residents of the Busselton area from a mosquito-borne disease perspective. They contain significant areas of samphire fringing vegetation which provide ideal habitat for the main Ross River virus vector species *Aedes camptorhynchus* and *Aedes vigilax*. Some of these sites are adjacent to residential areas. Statistical data gathered by the DoH has demonstrated that there is an increased risk of residents contracting a mosquito-borne disease the closer they live to a saltmarsh mosquito breeding site. It is imperative therefore that these breeding sites continue to be monitored.

A2. ASSESSMENT OF SAMPLING AND TREATMENT RECORDS

A2.1 Larval Sampling

It is recommended that larval sampling be extended to include identification to species level where practicable. This should be carried out at all sites on a representative number of samples each breeding season to enable confirmation that the freshwater species known to be vector species are in fact breeding at these sites. There are a number of potential freshwater breeding sites especially over the spring period, where they could be originating from. If this is in fact the case and they are migrating into residential areas, further monitoring of both larval and adult mosquitoes will be required to be undertaken.

A2.2 Adult Trapping

Overall 12 species of mosquito have been trapped during the monitoring undertaken to date. There has been a number of freshwater species present in adult trap catches over most of the monitoring sessions conducted. Given that some freshwater species will also breed in saltmarsh areas especially when the water quality is high such as early in the season or after heavy rainfall, it does require further investigation to determine the level of activity of these species at these sites.

A2.2.1 Adult Monitoring Site 18 (DEC Village Ludlow Forest)

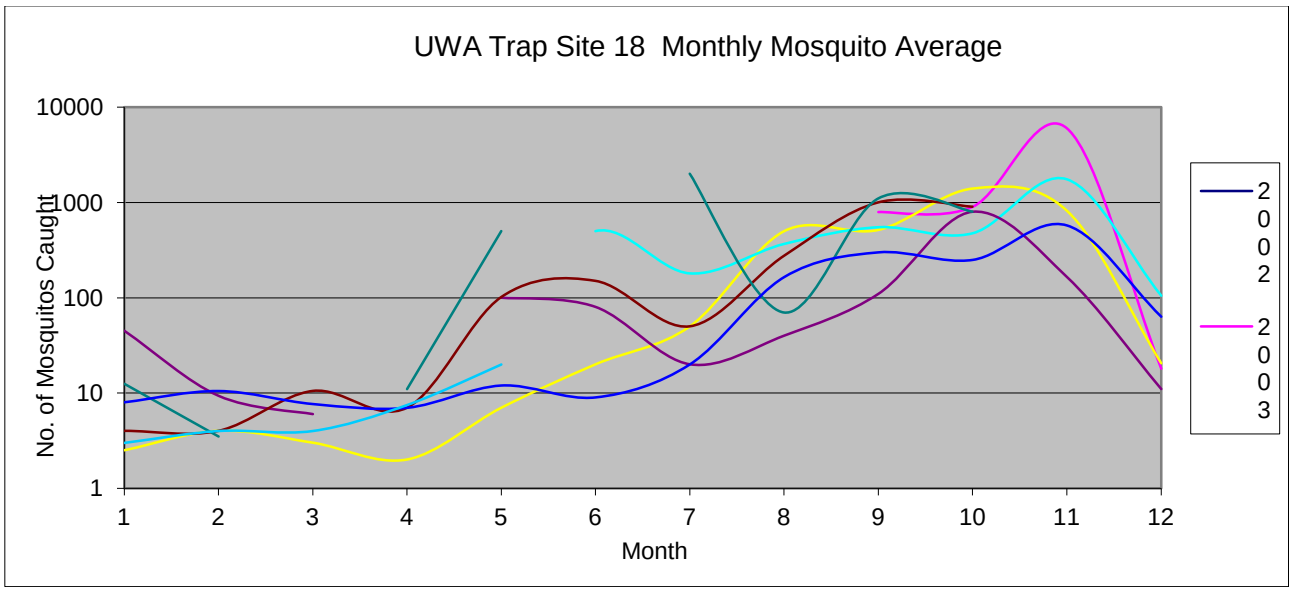

Chart 1: UWA Trap Site 18 Monthly Mosquito Average

Numbers trapped at this site are generally low over the early months of the year. Autumn and early winter rainfall will generally trigger a rise in numbers, with the numbers being historically at their highest during the period September-November.

The monitoring site is located at the DEC village in Ludlow Forest. It is an ideal harbourage area for mosquitoes breeding not only in the nearby samphire sites but also other seasonal sites in the area.

A2.2.2 Adult Monitoring Site 19 (Ford Road East Busselton)

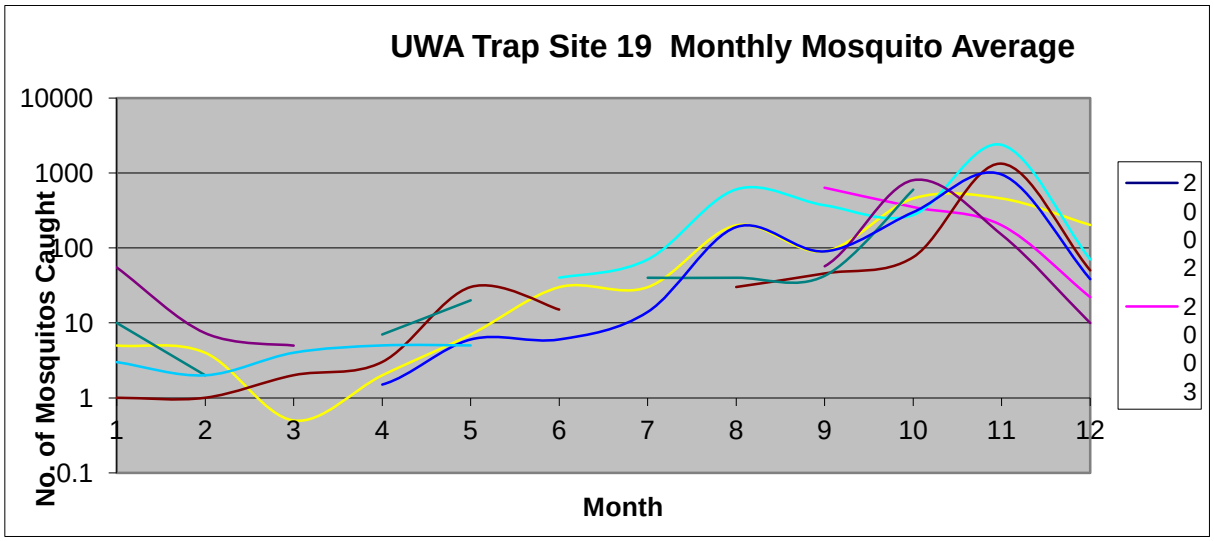

Chart 2: UWA Trap Site 19 Monthly Mosquito Average

This site follows similar patterns to Site 18. Numbers are generally low until early winter, with numbers rising significantly as the breeding areas are inundated from rainfall or inflow from the estuary. Numbers are at their peak over the period August-November.

A2.2.3 Adult Monitoring Site 20 (Busselton Radio Tower Siesta Park)

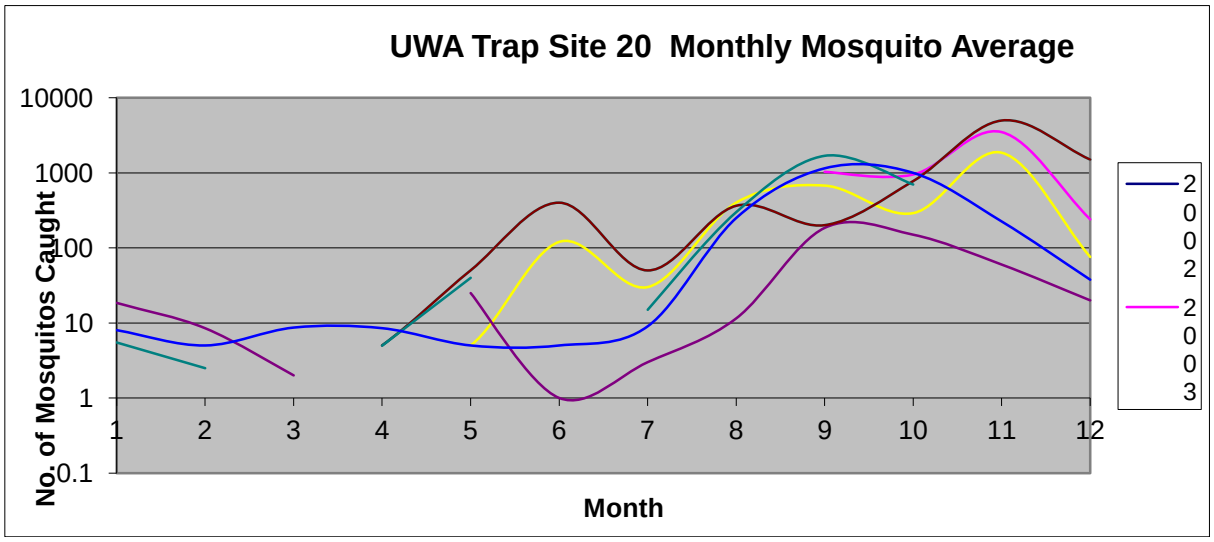

Chart 3: UWA Trap Site 20 Monthly Mosquito Average

The Siesta Park site receives its inflow mainly from rainfall. Unseasonal rainfall during the summer months may result in a significant activity of the saltmarsh vector species *Aedes camptorhynchus* and *Aedes vigilax.* Average or above average rainfall in the winter-spring period results in very high numbers of mosquitoes trapped at this site with the peak period of activity generally being between June-December.

As large sections of this site are difficult to access, it is recommended that further survey work be carried out to map this important site in greater detail.

A2.2.4 Adult Monitoring Site 21 (Wilson Road Quindalup Toby's Inlet)

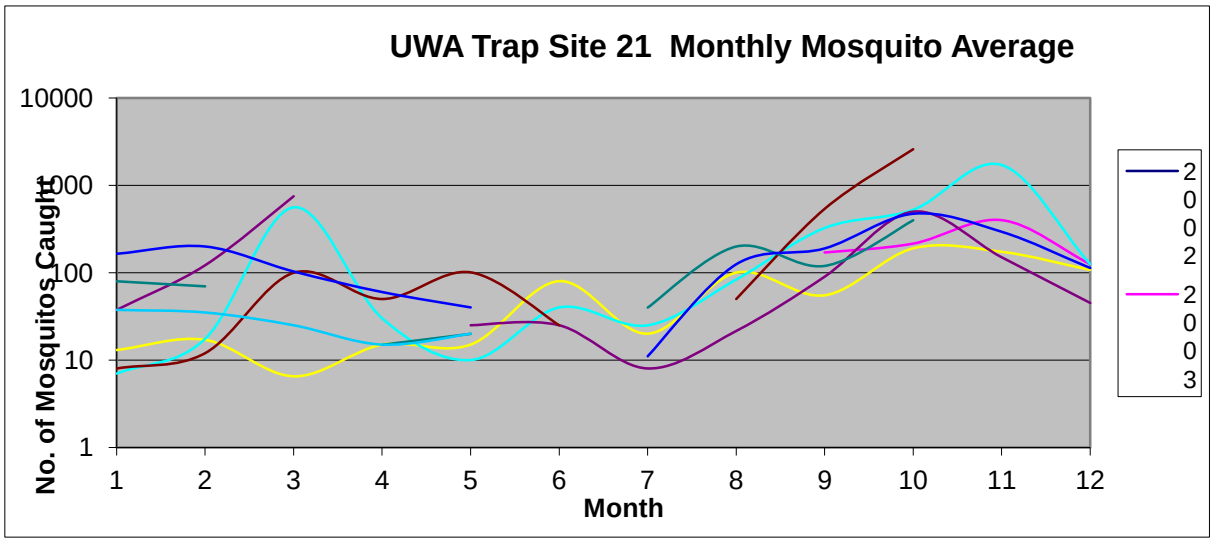

Chart 4: UWA Trap Site 21 Monthly Mosquito Average

Most of the inundation that occurs at this site results from tidal activity. This has the capacity to produce high numbers of vector species over a longer period than the other sites especially in those years where recorded tide levels are consistently higher than predicted levels. Peak activity can extend from August-January.

A2.3 Larval Treatment

The Shire of Busselton Mosquito Control Strategy (2004) identified four main breeding sites:

- Zone 1 - The vegetation perimeter of the water body behind the Radio Tower Caves Road (approximately 106 ha).
- Zone 2 - An area of samphire wetland near Ford Road (approximately 40 ha).
- Zone 3 - The samphire wetland in the vicinity of Port Geographe (approximately 100 ha).
- Zone 4 - The eastern end of Toby's Inlet (approximately 10 ha).

Larval treatment to the four main breeding sites commenced in 2007.

Zones 2 and 3 are located within the Vasse-Wonnerup Wetlands. The wetlands are recognised as being of international importance and are protected under the Ramsar Treaty. As such it has been necessary for the Shire to refer the action to implement mosquito control measures in these areas to the Department for the Environment, Heritage, Water and the Arts (DEWHA) in keeping with the requirements of the *Environment Protection and Biodiversity Conservation Act 1999*.

The referred action proposed the application of the larvicide s-Methoprene that was to be applied to wetland areas when the larvae are in the 2nd, 3rd and / or 4th instar stages.

Where larval breeding sites are extensive, the larvicide was to be administered via helicopter application to Zones 1 - 4 as described above.

Under the conditions of the approval provided by the DEWHA, treatments are restricted to a maximum of four treatments per calendar year for each of the three years that the approval period relates to.

Data received from the Shire of Busselton has shown that 11 treatments were previously carried out under an initial approval. According to the records provided, treatment dates were:

- 13 September 2007;
- 28 September 2007;
- 14 October 2007;
- 2 November 2007;
- 21 August 2008;
- 5 October 2008;
- 30 October 2008;
- 14 November 2008;
- 19 September 2009;
- 30 October 2009; and
- 21 November 2009.

Larval treatments were carried out where larval densities were greater than 100 larvae per square metre (/m^2). A review of the data indicates that treatments were generally very successful apart from the rare exception; most notably the treatment carried out on the 5 October 2008, where the estimated success rate for treated areas in the vicinity of Wonnerup House, Ford Road, Nautilus and Cookworthy Roads was low.

The timing of each treatment is critical. There is a small window of opportunity to apply the larvicide effectively. This is further complicated by the size of the areas to be treated and the fact that ambient conditions may quickly change. Rising water levels after the treatment is carried out (e.g. due to an increased tidal height or due to flushing from stormwater received from up-catchment) will result in a dilution of the application rate with a subsequent lowering of the effectiveness of that particular treatment.

Comparison of larval treatment dates with adult trapping data has at times given conflicting results. In some cases this has probably been due to the timeframe between treatment date and adult trapping sessions. It may well be further complicated by significant rainfall events triggering further breeding cycles in the interim.

The treatment sites have been chosen as they provide ideal habitat for the saltmarsh vector species *Aedes camptorhynchus* and *Aedes vigilax.* The latest that any individual treatment was carried out was the 21 November (2009). It is likely that given the seasonal breeding cycle of the species, that numbers of *Aedes vigilax* would be just starting to increase in November. Consideration should be given to the time taken for development through the larval stages which is known to be dependent upon a variety of environmental factors, the most important of which is temperatures, with availability of food and the extent of larval crowding within the habitat also being important factors (Russell, 2009). Given favourable environmental conditions *Aedes* species may complete development in as little as 4-5 days.

In April 2010, the Shire referred a further proposed action to the DEWHA to carry out larviciding of mosquito breeding wetlands (including Ramsar wetlands) in keeping with the requirements of the *Environment Protection and Biodiversity Conservation Act 1999* (Shire of Busselton, 2010).

The proposed action 'Aerial Application of larviciding and Barrier Fogging in the Vasse Wonnerup Wetland, WA' (EPBC Reference No. 2010/5490) can be downloaded at the DEWHA's website at:

http://www.environment.gov.au/cgi-bin/epbc/epbc_ap.pl?name=current_referral_detail&proposal_id=5593

In June 2010 the Shire was advised by the DEWHA that the referral had been assessed and the decision made under sections 75 and 77A of the *Environment Protection and Biodiversity Conservation Act 1999* that a *Notification of Referral Decision – not controlled action if undertaken in a particular manner* issued.

A copy of the DEWHA's referral decision is included as **Appendix 1**.

A3. EFFECTIVENESS OF EXISTING TREATMENT MEASURES

A3.1 Threshold Levels

It is generally regarded that mosquitoes are considered to be a 'nuisance' when the number of mosquitoes caught at a single location in a single carbon dioxide baited trap exceeds 50 over a normal sampling period (i.e. 12 – 18 hours) (Environmental Protection Authority 2000). Where the species caught are ones that are known, or suspected of being vectors of mosquito-borne disease, and the mosquito population is in close proximity to a heavily populated area, then the mosquitoes may present a health risk and there is a public health imperative that management be undertaken (Harrington and Lindsay, pers. comm. in Environmental Protection Authority 2000). The threshold of 50 has been adopted for this report but it should be noted that there are a number of other salient factors that need to be taken into consideration. These factors include:

(a) The species present: the main vector species *Aedes camptorhynchus* and *Aedes vigilax* are particularly aggressive and where residential areas are close to breeding sites the threshold should be reduced accordingly.
(b) The proximity of known breeding sites to residential areas.
(c) The presence and extent of any buffer zones that are to be created around known breeding sites.

In addition to this general threshold level, Lindsay (2009) notes that there are some additional reference numbers when using CO_2 baited light traps that can also be used for three species: 20 adults *Aedes vigilax* usually represent a significant pest problem, counts of > 30 *Aedes notoscriptus*/trap indicate that there is a pest problem, and 100+ *Culex annulirostris* indicate a current pest problem.

A3.2 Data Analysis

The data gathered from the larval monitoring/treatment program have shown that it has overall been very effective. Despite this, in many instances, the numbers of vector species mosquitoes remained above threshold levels on a consistent basis throughout the periods covered by the larvicide treatment program.

Difficulties that are often encountered with a mosquito management program of the type being conducted by the Shire include:

- The areas to be treated are large;
- Time and resources (funding and manpower) are limited; and
- Where there are almost certainly other breeding sites in the area which remain untreated.

It does emphasise the need for a truly integrated approach to mosquito management where chemical treatment is only one aspect of the overall program. Larvicide treatments in isolation will only ever be partly effective. This is especially so where breeding sites are large and/or where sites are inaccessible and despite the efforts of trained, committed personnel using industry best management practices.

The larval treatment program may well be able to be further refined. Further emphasis can be placed on land-based treatment rather than aerial treatment where this is practical or where areas to be treated are small. As stated elsewhere in this review, there is a need to undertake further detailed survey work, not only of the four main breeding zones, but other sites which may be contributing to the overall high level of pest/vector mosquito activity. Emphasis should be placed initially on those sites which are closest to residential areas but it is important to take into account the flight range of the species concerned when preparing any risk assessment.

There is also a need to determine which species are actually migrating into residential areas. This will require a significant expansion of the adult mosquito monitoring program.

A4. EXPANSION OF ADULT TRAPPING PROGRAM

A4.1 Site Numbers and Location

The four sites monitored by UWA, whilst providing important long-term data for those sites, are totally inadequate in the context of forming any assessment of the impact that mosquitoes are having on the health and amenity of residents. The number of sites being monitored should therefore be significantly increased. It is important that the monitoring program is able to identify the levels of adult mosquito activity, from both vector and nuisance species, present in residential areas. This data will assist greatly the overall mosquito monitoring and management programs.

The location of any new sites should be chosen with regard to their proximity to residential areas, proximity to breeding sites (other than the four UWA sites already in operation) and harbourage areas (especially those sites which are between breeding sites and residential areas and which may allow mosquitoes to migrate from their breeding sites and into residential areas). Consideration should also be given to establishing monitoring sites in areas approved for future residential development. It is also important that there is not a duplication of effort. The data gathered from monitoring programs currently being implemented at individual developments should form part of the overall program.

Staff should ensure that they consider the potential for mosquitoes breeding in areas other than the four main saltmarsh breeding sites when assessing whether baseline mosquito monitoring is required as a condition of approval for any new development. Permanent and seasonal freshwater sites can provide suitable habitat for a number of pest/vector species. It is important therefore that their potential impact on residents and those involved onsite during the construction phase is considered.

It is likely therefore that a number of additional adult monitoring sites will be required.

A4.2 Complaints Response

It is recommended that monitoring be carried out on an ‘as needs basis’ in response to any complaints received from residents regarding mosquito activity. Monitoring traps can be set out in complainant’s yards after an onsite inspection of the property and surrounds has been carried out by staff from the Environmental Health Department and where no source of the breeding has been found. Monitoring in these situations will help determine the number of mosquitoes, which species are present and therefore possibly the likely breeding sites for those species.

It is also recommended that the Shire maintains a register of complaints to allow for complaint mapping fur use in managing breeding sites and making land use planning decisions.

A4.3 Dispersal Studies

Consideration should also be given to undertaking dispersal studies (e.g. trap/release/re-trap exercise) from the main saltmarsh breeding sites (after advice and consultation with staff

from the Department of Health Mosquito-Borne Disease Control Unit) to help identify mosquito dispersal routes from these sites.

A4.4 Resources

The expansion of the adult mosquito monitoring program will require not only additional trained staff if it is to be operated efficiently and effectively, but an ongoing commitment from Council that the program receives adequate funding.

The operation of the adult monitoring program should be reviewed on a regular basis as part of any overall review of the mosquito management program. There is the potential for a high level of variability between one season and the next. It is important therefore that contingency measures are set in place where any unused portion of the mosquito management budget can be held in trust and used in those years where there is a greater demand on the program.

The requirement for additional staff and resources will create further operational difficulties. The work is specialised and at times physically demanding. There is a need for sufficient trained staff to ensure that the program operates efficiently. This will require that staff enrol in either the mosquito management course run by the Mosquito-borne Disease Control Unit at the Department of Health Western Australia or one run by the Mosquito Control Association of Australia (usually in Queensland) as a basic introduction to mosquito management duties.

In addition there will be a need for ongoing training for all personnel involved in the program. All Environmental Health personnel should have a basic understanding of the program, including the location of the monitoring sites, basic monitoring procedures and any occupational health and safety issues arising from their participation in the program. Given the likelihood of staff turnover within the department, it is important that an adequate induction program be made available to new staff.

Staff actively involved in the application of larvicides or adulticides as part of any control program must be suitably qualified to carry out this work. Consideration should therefore be given to employing an experienced mosquito control officer similar to the posts created at the City of Mandurah and the City of Canning. The staff member could be assigned other duties outside the main mosquito season.

It is also recommended that other staff involved in the planning/development process and whose decisions can have an impact on the program, be briefed on its operation and objectives. It is anticipated that this would include staff from the Planning Department, senior management and all Councillors at the beginning of their term.

A5. AUDIT AND REVIEW OF CURRENT MOSQUITO CONTROL STRATEGY

A5.1 Strategy Objectives

The current Mosquito Control and Minimisation Strategy that was adopted by Council in 2004 has seven main objectives:

- Reduce residents exposure to disease carrying mosquitoes;
- Minimize the use of chemicals for the control of mosquitoes;
- Control mosquitoes using the most cost effective and environmentally safe methods available;
- Educate the community about mosquitoes, mosquito borne diseases and mosquito prevention;
- Enlist the support of the community in control efforts;
- Investigate the feasibility of regional cooperation in relation to mosquito control methods and resource sharing; and
- Investigate contribution requirements from land developers for mosquito control in high risk areas.

Since its adoption by Council in 2004 there has been significant progress made in a number of the main objectives and key outcomes listed above. This is however a highly complex issue requiring the Strategy to be assessed and further developed on a regular basis. It will require an ongoing commitment from Council, the wider community and other stakeholders for this progress to be maintained.

A5.1.1 Reduce Residents Exposure to Disease Carrying Mosquitoes

The approval from the DEWHA to undertake aerial larviciding at the four main breeding sites for a maximum of four treatments per calendar year would certainly have had an impact on the numbers of saltmarsh mosquitoes completing their development cycle. Numbers of adult mosquitoes should therefore have been at lower levels than in pre-treatment years with similar conditions.

The DEWHA approval granted to the Shire under the *Environment Protection and Biodiversity Conservation Act 1999* permits the Shire to undertake a total of four aerial and two hand applications of larvicide within the Vasse Wonnerup Wetlands between June 2010 and June 2011 (**Appendix 1**). From a mosquito management viewpoint, there are limitations to this program being restricted to four aerial treatments per calendar year. It does not allow for those years where the mosquito breeding season is extended, especially where this corresponds to a year of high Ross River virus activity. What is does highlight are the difficulties encountered where residential developments are built close to natural wetland systems. These important wetlands require and deserve environmental protection. There is a need therefore to look at the planning processes involved in approving developments close to protected wetlands to reduce residents' exposure to disease carrying mosquitoes when residential areas are located near the main breeding sites of vector species.

The larvicide program is only one aspect of an overall approach to reducing residents' exposure to disease carrying mosquitoes. There is a need to further refine the adulticide (fogging) program to ensure that this control approach is only implemented when there is a public health imperative that treatment be carried out (i.e. in the case of a RRv outbreak where monitoring indicates large numbers of adult vector species mosquitoes).

Since 2008, no fogging has been carried out in residential areas with the program concentrating on barrier protection between breeding sites and residential areas.

A5.1.2 Minimise Use of Chemicals for Control

This aim can only ever be partly successful. What has been achieved is that due to the introduction of the larvicide program, there has been less emphasis and reliance on the adulticide program.

The larvicides that are approved by the DEWHA for use in the mosquito breeding areas within the Shire are s-methoprene and Bti (both granular and liquid formulations). Both of these larvicides are specific to mosquito larvae (**Appendix 1**). Both are exempt from poisons scheduling and are only applied where mosquito larvae are present.

The synthetic pyrethroid used in the adulticide program, while of low toxicity, is non-selective in its mode of action. It will impact on non-target species as well as mosquitoes, although every effort is made to apply it at a time of day when numbers of non-target species should be at their lowest. There is however a degree of unpredictability with any adulticide which is applied through a thermal fogger. The nature of this method depends on the adulticide drifting through areas which are likely to harbour mosquitoes. There needs to be a continual assessment of ambient conditions to ensure that the treatment is being applied in an effective and safe manner.

A5.1.3 Cost Effective and Environmentally Safe Control Methods

This has to a large extent been successful with regard to the four main breeding areas. The larvicide used is specific to mosquito larvae. It is of very low toxicity and given the large areas of breeding sites, aerial application is the most cost effective method of application. Environmental Health staff has also carried out hand application treatments to small areas of the breeding sites when required.

A5.1.4 Community Education

The public education program has been running for some time. Council use a variety of methods to keep residents informed about mosquito issues. This is an ongoing program which needs to be reviewed on a regular basis given the influx of new residents into the area as further development takes place. This is partly covered by the necessity that developers address this issue as part of any Mosquito Management Plan which may be required for a new residential development.

A5.1.5 Enlisting Community Support in Control Efforts

This is a natural progression of the Public Education and Awareness Program. Council has been very proactive in advising residents about the program, timing of treatments, level of Ross River virus status, adulticide treatments and keeping a register of those residents who do not wish adulticiding to be carried out near their properties. The continual development of the Public Education and Awareness Program in response to community needs should ensure that there continues to be a high level of public support for the mosquito management program.

A5.1.6 Regional Cooperation and Resource Sharing

There has been significant advancement made with regard to this aim. The Shire of Busselton now works closely with the Shire of Capel in the practical operation of the mosquito management program and the recent signing of the Geographe Mosquito Management Group Partnership Agreement should result in more effective mosquito control.

In addition to this there has been contact between the Shires of Busselton / Capel and the member Councils in the Leschenault and Peel CLAG groups.

A5.1.7 Land Developer Contributions

This aim has been very successful with the implementation of the Shire of Busselton Mosquito Control Developer Contribution Policy. Developers are charged on a per lot basis with an annual increase based on the Perth CPI.

The policy is in line with similar schemes run by local authorities in other parts of Australia. It ensures that the increased cost of providing mosquito management services to an expanding residential base is at least partly funded by this policy. At the same time, the imposition of a developer contribution should not replace a developer's requirement to undertake mosquito survey and implement management measures for new residential estate developments in keeping with the requirements of the EPA's Guidance Statement No. 40 (Environmental Protection Authority, 2000).

A5.2 Key Outcomes of the Strategy

In association with the seven main objectives, within the Strategy each section contained its own key outcomes. These are dealt with individually below whereby key outcomes for each objective are shown initially, followed by an evaluation.

A5.2.1 Mosquito Monitoring

- Construct vector control maps for each major mosquito breeding zone
- Develop a monitoring system that provides earl notification of potential mosquito populations to enable effective control measures to be implemented
- The collation of climatic, environmental and social impact data for the ongoing evaluation of mosquito control measures and efficiency

Construct vector control maps for each major mosquito breeding zone

This has been carried out for the four main breeding areas. As part of the future development of the program and to further improve its efficiency and effectiveness, it is recommended that each site be mapped in detail to identify if there are areas within the site which require different levels of inundation, be it tidal or rainfall, to trigger larval emergence.

The preparation of vector maps should be extended to other seasonal or temporary breeding sites which have been identified as providing suitable habitat for pest/vector species. This would require the monitoring program to be extended to include these sites.

It is recommended that a full survey of potential breeding sites be carried out when water levels of seasonal wetlands or temporarily inundated sites are at their highest (early-mid spring).

Develop a monitoring system that provides early notification of potential mosquito populations to enable effective control measures to be implemented

This has been carried out mainly with regard to the four main breeding zones. Of the 16 sites monitored, 14 are located in the four main zones. Ideally the number of monitoring sites should be increased to provide a more detailed understanding of the four main zones. In addition it is recommended that monitoring be undertaken at seasonal sites which have the potential to provide suitable habitat for mosquito breeding and to determine the extent of any adverse impact on residents. A monitoring program should also be undertaken of the stormwater gullies and drainage channels in and around residential areas. Drainage channels can provide ideal habitat for vector species such as *Culex annulirostris* and *Coquillettidia species near linealis.* In the case of road gullies they can provide ideal habitat, depending on water quality and water level fluctuations, of the peri-domestic vector species *Aedes notoscriptus.* The challenge is to expand the program to ensure that we gain a greater understanding not only of the management options available within the four main zones but also other breeding sites close enough to residential areas to be of concern.

In conjunction with an expanded larval monitoring program there is a need to ensure that this also is the case with the adult mosquito monitoring program. At present only the four sites monitored by the Arbovirus Surveillance and Research Laboratory from the University of Western Australia are surveyed on a regular basis. There is a need for this aspect of the program to be significantly increased. Additional data is available from the monitoring carried out by developers. While this information is valuable there needs to be a greater understanding of the impact that mosquitoes have in other residential areas of the Shire.

The collation of climatic, environmental and social impact data for the ongoing evaluation of mosquito control measures and efficiency

This is being carried out. Data regarding rainfall, actual tide levels, water quality, pre and post treatment data, public complaints and Ross River virus and Barmah Forest virus notifications all for m part of the overall database which can be used to further develop and improve the mosquito management program.

A5.2.2 Mosquito Control Operations

- Identify immediate and long term action plans for the control of mosquitoes
- To implement an integrated, environmentally responsible mosquito control program utilising physical, biological and chemical control measures
- To minimise the numbers of larvae present at identified breeding areas
- To control the number of public health and nuisance risk mosquitoes in residential areas

Identify immediate and long term action plans for the control of mosquitoes

This has been achieved to a large degree but it is an area that requires regular review. The main problem with formulating any long term action plan will be the uncertainty as to

whether approvals will be given to continue with the larviciding program at the four main breeding zones.

To implement an integrated, environmentally responsible mosquito control program utilising physical, biological and chemical control measures

There is a need for this aspect to be developed further. At present emphasis is placed on chemical control measures through larval treatments and thermal fogging to reduce adult mosquito numbers. There are a number of options available which will enable the program to progress using a wider array of management strategies. It is important that as part of an overall plan, that each site has a comprehensive integrated management program to achieve the best outcome for that individual site, both from a mosquito control viewpoint and environmental one.

To minimise the numbers of larvae present at identified breeding areas

There is a fairly comprehensive larval monitoring program in operation at present. This has been developed in part out of necessity as it would have been a condition of approval to undertake larval treatment at the four main sites and would also have been required to obtain funding and support from the CLAG scheme. There has therefore been significant progress made since the Mosquito Management Strategy was adopted by Council. The aim now should be to further refine, expand and develop the monitoring program

To control the number of public health and nuisance risk mosquitoes in residential areas

There is no doubt that the larval treatment program at the four main breeding sites will have significantly reduced the overall adult mosquito population of the vector species targeted. The use of the thermal fogger to control adult mosquitoes has been refined since the adoption of the Mosquito Management Strategy.

There is a need to develop an adult mosquito monitoring program in the various residential developments to determine the level of mosquito activity within these areas and to identify the species diversity present. There is also a need to conduct dispersal studies at the four main sites to determine the migration routes that mosquitoes breeding at these sites take.

A5.2.3 Control Evaluation

- Evaluate the long term effectiveness of the mosquito control program
- Assist with compilation of data for the continual improvement of the mosquito control program
- Evaluate the effectiveness of each larval/adult treatment

The above three key outcomes are very closely related and is another area where there has been notable progress made over the last six years. A variety of data is collected which will assist in improving and developing the mosquito control program. Each treatment is evaluated.

A5.2.4 Development Control

- Future developments should not increase the potential for mosquito breeding within the Shire of Busselton

- Develop an increased awareness about mosquito management in the development community

Future developments should not increase the potential for mosquito breeding within the Shire of Busselton

The main aim under the Strategy is 'to ensure that future developments do not increase the potential for mosquito nuisance and the risk to residents of Ross River Virus'. This aim is repeated in the introduction section in the Developer Contribution Policy. The aim within the Strategy in the Development Control section however has been that no new mosquito breeding sites should be created as a result of the development. This is only part of the overall issue. There is no defined objective regarding inappropriate location where developments are approved even though they are adjacent or very close to major mosquito breeding sites. Residents living in developments close to vector species breeding sites will, at times, almost certainly experience nuisance levels of mosquito activity and therefore increased risk of exposure to mosquito-borne diseases such as Ross River virus and Barmah Forest virus.

Within the context of managing mosquito breeding within new developments, there has been significant progress made. There have been considerable challenges, especially with the requirement that stormwater within the development be handled onsite. The program of Water Sensitive Urban Design and 'Living Streams' policies can create the potential for increased mosquito activity if they are poorly designed or maintained.

The requirement that proponents of any new development prepare and adopt an approved Mosquito Management Plan for the development should greatly reduce the potential for new mosquito breeding sites to be created onsite. It is also imperative that any Action Plan detailed in the Mosquito Management Plan be enforced as ultimately Council will assume responsibility for the maintenance of the program. There should be regular checks to ensure that the practical maintenance aspects of any plan are being carried out. Council requires, as part of each Mosquito Management Plan, that the developer commit to rectifying any areas that have been identified as creating a breeding nuisance via a permanent physical control method wherever practical prior to handover, to the satisfaction of the Shire, however it is preferable if regular assessments are made in order that what may initially have been a relatively minor problem does not develop further.

Develop an increased awareness about mosquito management in the development community

Land developers are now much more aware and better informed of the importance of effective mosquito management in regard to new developments. The requirement to consider mosquitoes as a relevant environmental issue in the planning process together with Council's Mosquito Control Developer Contribution Policy, and the need to prepare and operate an approved Mosquito Management Plan have ensured that mosquito management has a much higher profile than it enjoyed previously.

A5.2.5 Community Education

- Develop an increased awareness of mosquitoes and Council's control program within the general community

- Keep the community informed on relevant mosquito issues such as the timing of adult fogging and the risk of Ross River Virus

This is an area where a great deal has been achieved. The Environmental Health Department has taken a wide ranging approach using a number of different media to inform and educate the general community.

A6. RECOMMENDATIONS FOR ALTERNATE/ADDITIONAL TREATMENT METHODS

With any integrated mosquito management program there is a requirement to adopt a number of management initiatives to achieve an effective level of control with minimal environmental impact. These initiatives will include physical, cultural, biological and chemical measures. Each site's requirements should be assessed on an individual basis and the most appropriate mix of mosquito management measures adopted for that site. At present aerial larviciding using an s-methoprene sand based formulation is the treatment method used across all breeding sites.

A6.1 Physical Control Methods

Physical control methods involve managing mosquito breeding through a program of limiting, reducing or eliminating breeding sites. A physical control approach would therefore include filling, draining and/or water management. Physical control methods have an important part to play in any integrated mosquito management program; however there are very significant limitations depending on the individual site being assessed. There may well be particular areas within a site where physical measures would be appropriate. The difficulty with the main Busselton breeding areas are not only their size but also in the case of the Vasse-Wonnerup Estuary, their conservation status. It is extremely unlikely that approvals would be given for any ground based filling or draining projects. Draining would involve the construction of runnels. The concerns with regard to acid sulphate soils being disturbed in the runnelling process will probably mean that gaining approval for this type of management method will be extremely unlikely.

Filling of some sections of the other breeding sites may be possible where there are any sections which have been degraded through human or vehicle access to the site. It is recommended that public and vehicle access is limited to prevent any further damage to these sites. As with aspects of most proposed works on these sites, all environmental approvals from the appropriate State and Commonwealth departments would be required before any work would be able to commence.

The Siesta Park site receives most of its recharge through rainfall. It may be beneficial to have topographical and hydrological surveys carried out to determine whether any filling or drainage program, if approved, would be feasible. It would also be of benefit to determine the extent that inflow from groundwater has on this site and therefore whether a system of subsoil pumps could be used to control inflow at the lower lying areas of the breeding site.

The two main species of concern *Aedes camptorhynchus* and *Aedes vigilax* require fluctuations in water levels within their breeding sites. Their eggs can remain viable for extended periods. Where manipulation of water levels results in the site remaining dry or it remains flooded within controlled limits, breeding will be eliminated or significantly reduced. Water levels in breeding sites can be controlled through the construction of tidal gates or building bunds or levee banks between the main water body and the samphire fringed breeding areas. This type of control measure will not offer complete control as significant rainfall may flood dry sites or increase water levels in sites where water levels are controlled. Strong winds over large open sites may also increase the risk of localised breeding pockets within the waterbody. An assessment should also be made of the practicality of applying this type of control measure at the breeding side on the eastern side of Toby's Inlet.

A6.2 Cultural Control Methods

Cultural control methods involve utilising procedures which restrict the level of contact between humans and pest/vector mosquitoes. In many ways it is the one aspect that the Shire has the potential to have the greatest control over but the one that is generally paid least regard to. In simple terms the less people who come into contact with pest/vector species, the less impact mosquitoes will have on the health and wellbeing of the local population. Consequently, this will then result in a lower incidence of people contracting mosquito-borne diseases such as Ross River virus and Barmah Forest virus.

Mosquito monitoring data gathered, over a number of years, by the Arbovirus Surveillance and Research Laboratory from the UWA has shown that there are at times significant levels of mosquito activity at the four sites being monitored as part of the program. There is a need, therefore, that any mosquito management program which uses cultural methods as part of that program ensures that people are separated as far as practical from mosquitoes.

Cultural methods of addressing any mosquito problem involve a number of options. Some of these have been adopted by the Shire of Busselton while some, to date have not.

A6.2.1 Built Form Response

There are a number of ways that this can be achieved in and around the home (Department of Health, 2009). It is recommended that the following components of any built form initiatives be a compulsory requirement that builders are responsible for, at the time of construction of any dwelling. Generally these are left to the discretion of the home owner and at best it is likely that only some of them will be addressed and perhaps not for some time after the owner moves into the property.

- All doors and windows should have approved insect screens fitted; this should include any doors which allow entrance to the house directly from the garage. Where screens are fitted in conjunction with sliding doors they should be fitted with a spring mechanism to allow the screen to close automatically;
- Exterior doors other than sliding doors should have a draft or pest excluder fitted to the base of the door;
- All external vents and pipes should be screened;
- External finishing work should be of a high standard i.e. gaps around window frames, pipes, wall mounted air conditioning units etc should be sealed;
- Eaves should be enclosed or where this is not practical, mesh should be installed to prevent mosquitoes gaining access to the roof space;
- Yellow insect lighting should be used for exterior lights. These should not be installed directly next to doorways;
- If water tanks are installed, vents should be screened to prevent mosquito access and breeding;
- Residents should be encouraged to use block-out blinds and curtains; and
- Where practical street lighting next to dwellings should have yellow lights.

A6.2.2 Landscaping

From the householder point of view there are a number of things that they should be encouraged to do around their own yards. These are covered to a large extent in the leaflets

produced by the Shire and the Health Department of Western Australia. They already form part of the Shire's Public Education and Awareness Program.

Landscape architects must work with mosquito management consultants and the engineers responsible for stormwater management system of any new development to ensure that there is a coordinated effort to minimise the impact that mosquitoes may have on future residents.

Shrubs and trees should have open foliage to allow adequate light penetration and wind movement. This should also apply to larger-scale plantings, vegetated screened areas etc as dense vegetation corridors may allow mosquitoes to migrate into residential areas from breeding sites outside the immediate area.

A6.2.3 Land-use Planning

The location of residential developments relative to any mosquito breeding sites can have a direct influence on the level of impact that mosquitoes may have on residents. As a consequence of this it may also determine the level of exposure that residents may have to mosquito-borne diseases such as Ross River virus and Barmah Forest virus.

The Shire's planning department needs to work closely with the Environmental Health staff to ensure that proper regard is taken regarding the location of new developments, the potential impact from mosquito activity and the need for adequate buffer areas to separate the development from any mosquito breeding sites which may impact adversely on future residents of the development.

Studies carried out by the DoH and the UWA have shown that incidences of RRv cases were up to 11 times higher in residential areas that were located within 3 km of saltmarshes or seasonal wetlands than those residential areas located further than three kilometres from these breeding sites (see **Chart 5**). There is therefore a long term ongoing cost to the greater community of inappropriately located developments. This needs to be taken into account by all parties involved in the development approvals process.

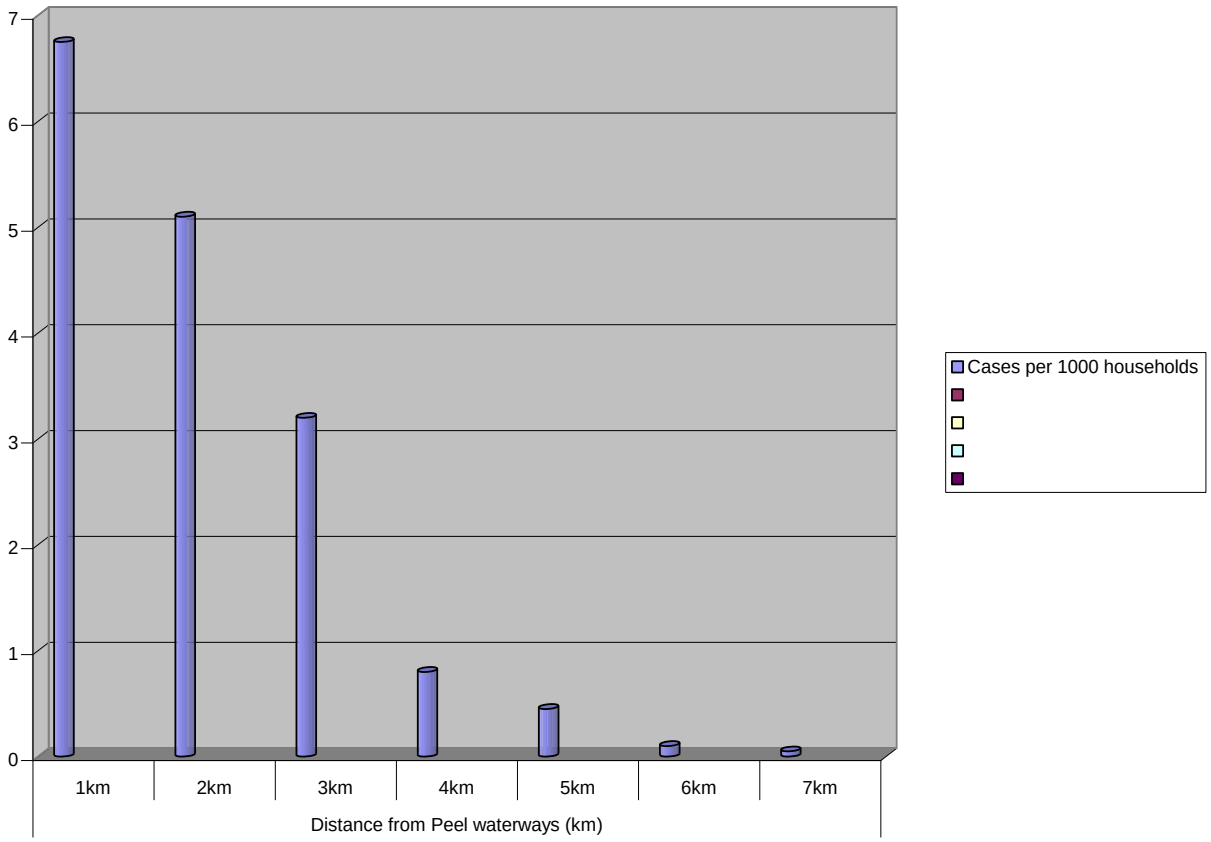

Chart 5: Cases of RRV disease per 1000 households in 1km buffers from Peel Region waterways, including the Murray and Serpentine Rivers (source Department of Health)

A6.3 Chemical Control Methods

There are a number of options that can be considered in addition to the use of s-methoprene in sand formulation for aerial work. The problem with this however would be that the helicopter would need to be fitted with different application equipment. This has been done on a trial basis with the City of Mandurah. The advantage of s-methoprene sand formulation is that it is much more effective in penetrating through any tree canopy covering the breeding sites. Liquid based formulations would be suitable for open samphire areas. Both granular and liquid formulations have been approved by use by the DEWHA (**Appendix 1**).

Smaller breeding sites can be treated with s-methoprene pellets or briquettes or *Bti* liquid or corn cob formulations. Ideally more than one type of larvicide, preferably with different modes of action, should be used on any program as a resistance management initiative (i.e. S-methoprene and *Bti* not two different formulations of the same larvicide).

If the control program is extended to include breeding areas with polluted water (road gullies etc), *Bacillus sphaericus* can be used. All of the larvicides mentioned are exempt from poisons scheduling and are target specific in regard to mosquito larvae.

Other control measures such as surfactant oils can be considered, however they are non-selective in their mode of operation and their use is unlikely to gain the necessary environmental approvals

A6.3 Biological Control Methods

Biological management methods may be possible at certain breeding sites but a thorough investigation would be required before they could be considered as part of an integrated approach to any individual breeding site. Fish, copepods, water beetles, waterbugs, dragon and damsel flies could all be considered but they should all be native species to the southwest. All necessary statutory approvals would be required beforehand and these may not be given in the case of the breeding sites located on the fringes of the Vasse-Wonnerup Estuary. The area where predators are collected needs to be considered as well to ensure that no non-native plants or fauna are introduced with the native predatory species.

A7. DESKTOP STUDY OF WATER FLUCTUATIONS IN THE VASSE-WONNERUP ESTUARY

A7.1 Water Levels

The breeding cycle of the mosquito species *Aedes camptorhynchus* responsible for the high nuisance levels and spread of RRv within the Shire is largely dependent upon water level rises in the Vasse-Wonnerup Estuary. The prime breeding season for this mosquito species occurs in spring.

Heavy rainfall can be experienced in the region in spring therefore causing a rise in the water level and hence causing the dormant eggs of this mosquito species to hatch, producing larvae and in turn adult mosquitoes. It was anticipated that putting the check boards in place earlier in spring would have the effect of reducing the range of fluctuations in water level for a longer period and may therefore reduce the amount of larvae that actually do hatch and mature into mosquitoes.

At the beginning of September therefore, the Water Corporation install check boards at the floodgates on the exit channels of the Vasse and Wonnerup Estuaries to stabilise water levels at +0.4m AHD. Gradually over mid to late summer evaporative losses cause the water levels to decrease, however sufficient water is maintained in the estuary to reduce the concentration of salt in the water such that when the winter rains commence surrounding farmlands are not affected by salinity.

An examination of four 'representative' graphs (**Charts 6-9**), two prior to the installation of the new floodgates, and two following installation have been undertaken. Annotations on Chart 9 identify phases in water level and relates to the discussion following. Rainfall data for that year is also included.

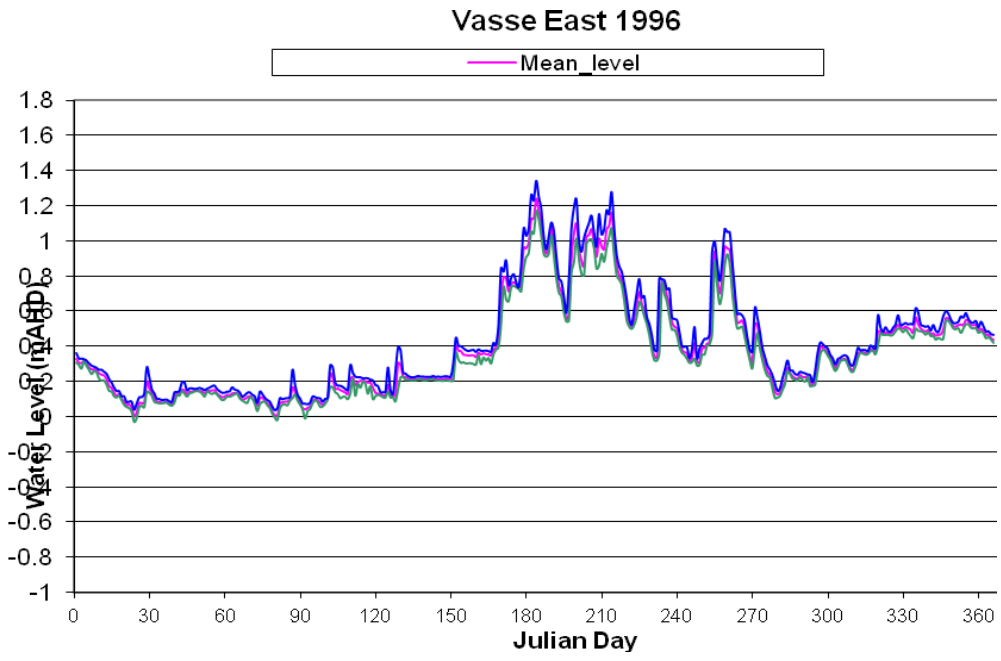

Chart 6: Vasse East 1996 Water Level Data

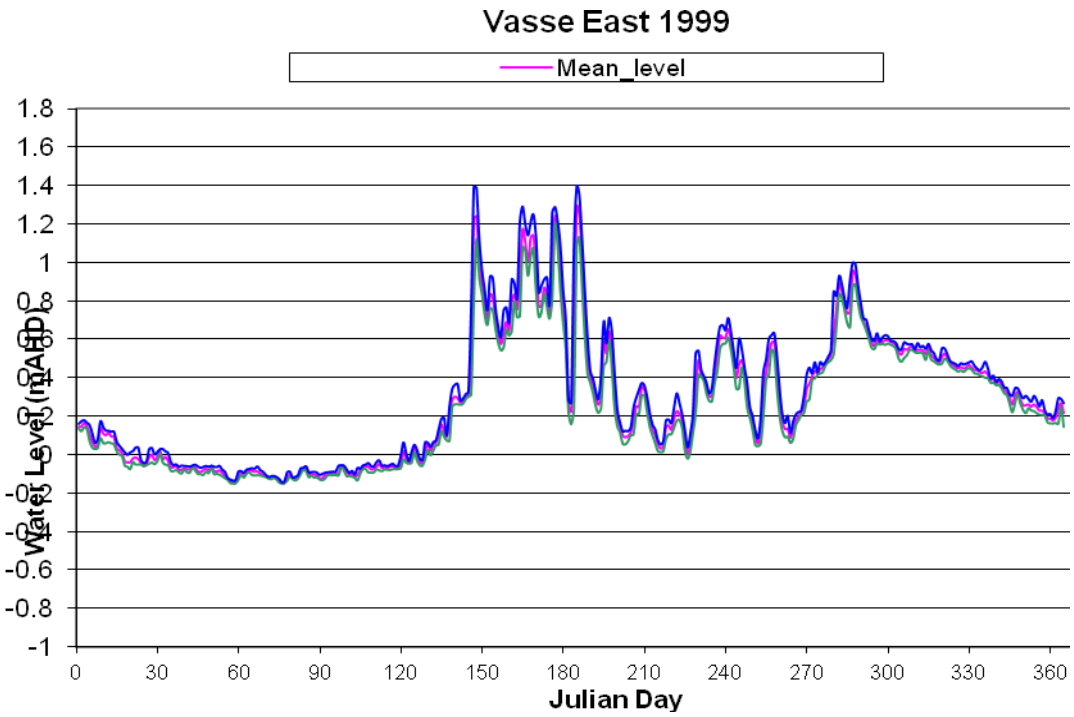

Chart 7: Vasse East 1999 Water Level Data

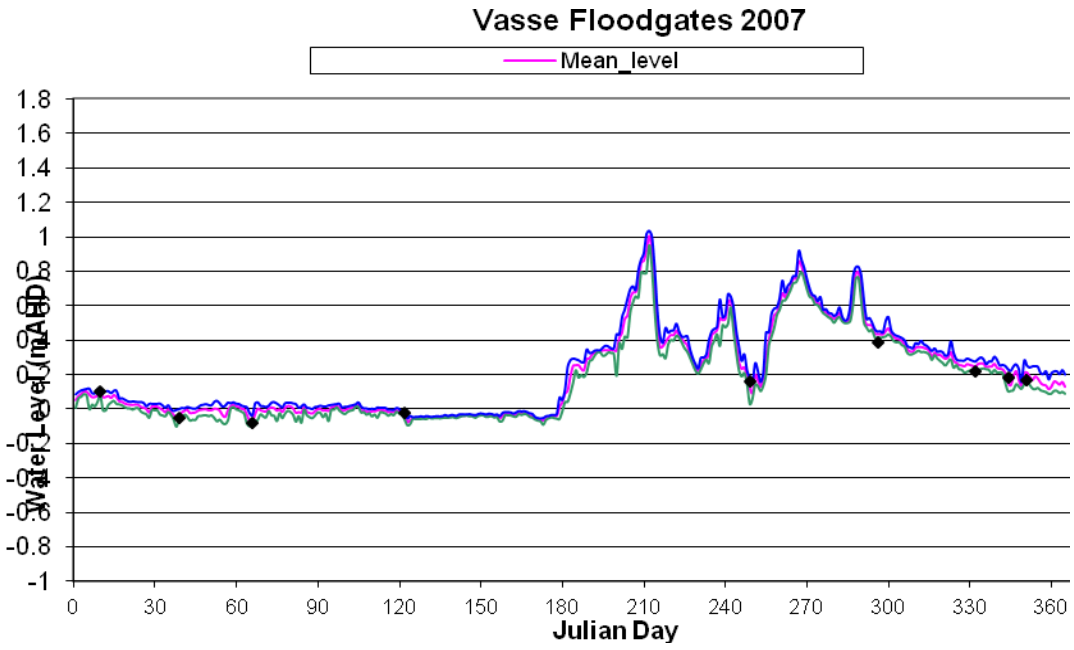

Chart 8: Vasse East 2007 Water Level Data

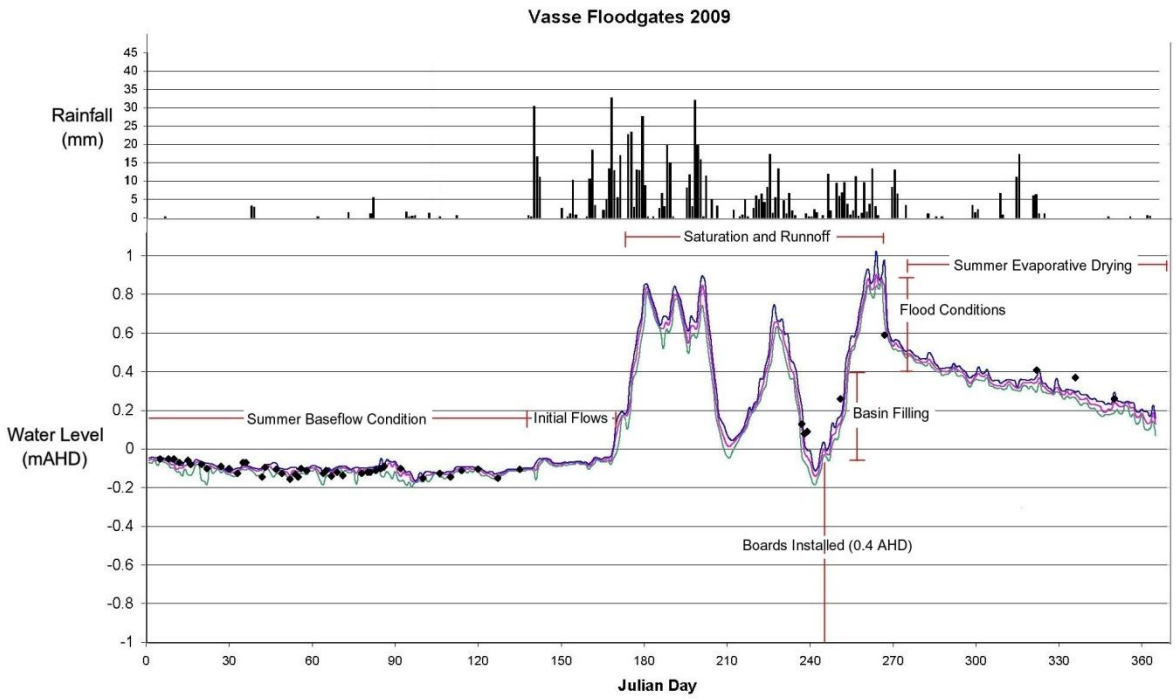

Chart 9: Vasse East 2009 Water Level Data

A7.2 Management and Historical Context

The Vasse Wonnerup Estuaries are fringed by salt marshes, sedges, paperbarks and eucalypts and their hydrological regime have been modified significantly since European settlement.

The first floodgates on the Vasse-Wonnerup system were installed in 1908 for the purpose of allowing for estuarine outflow but not saline inflow. Automated water level records (**Chart 9**) present data for 2009 indicate water levels vary significantly during winter flows, stabilize in spring with the installation of boards on the floodgates, and decline during summer largely due to evaporative effects. Rainfall over the period in question is also indicated.

Stop boards were installed on the 3rd September 2009 in an effort to maintain soil moisture levels. Water levels can be seen to reach approximately 0.9m AHD following insertion, (flood outflow conditions), discharge parity to the top of the boards can be seen to occur at the end of September with an approximate monthly decline (average of three automated level records indicated in **Chart 10** (over page).

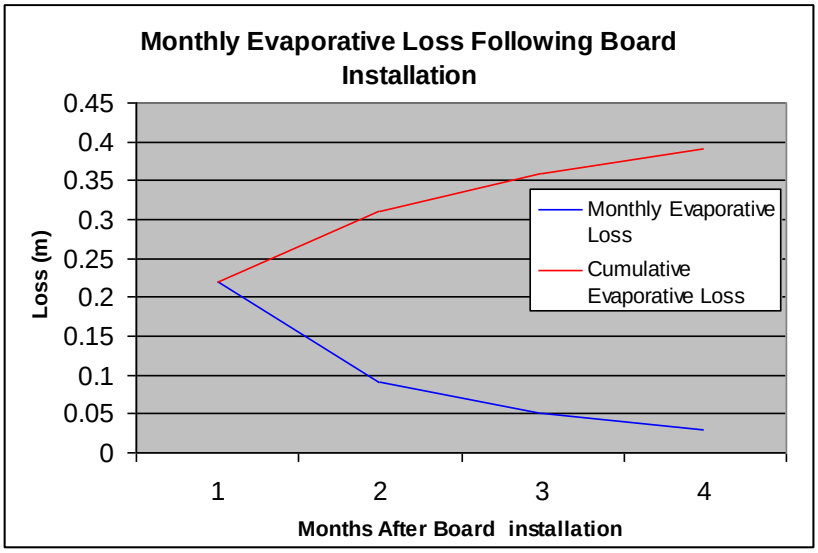

CHART 10: Record of Monthly Water Level Recorder Value Decline – Vasse-Wonnerup Estuary 2009

The following points are relevant:

- The floodgates and their exit channels enable water levels to be lowered during winter providing additional storage capacity during winter when high seas prevent ocean discharge;
- Storm surges associated with winds with a strong northerly component and low barometric conditions are largely prevented from entering the estuarine system;
- There is a clear relationship between significant rainfall events and elevated estuarine water levels, particularly when soils reach saturation;
- Installation of boards above sill height enable additional storage of water during spring / summer supporting pasture growth and ecosystem functions;
- Additional storage persists for the period approximately September to December when underlying base flow conditions persist (variable, depending on rainfall characteristics); and
- Summer opening of floodgates allowing saline water entry above approximately -0.1m AHD has been implicated in pasture damage.

Floodgates protected built areas from summer storm surges and pasture impacts from salinity. General guidelines for management of floodgates (and accordingly of water levels within the estuary) are presented in the then Water Authorities *Update to handbook of Basic Data* of 1990, as subsequently modified.

With the installation of the automated floodgates near the mouth of the Wonnerup Estuary subsequent operations are much easier and safer to carry out. As a consequence, the DEC and the Water Corporation were prepared to vary the operations for a trial period together with monitoring its effect on mosquito numbers being undertaken by the Shire. For the DEC a critical factor was to determine whether maintenance of the water levels at a constant height would facilitate the breeding of water fowl.

A7.3 Manipulation of Water Levels

Manipulation of water levels within the Vasse Wonnerup Estuarine system has historically focused on:

- Protection from summer storm surge;
- Maintenance of water quality and in turn native vegetation / pasture quality; and
- Maintenance of fish stocks (elevated water temperature and low dissolved oxygen).

Various guidelines were developed that relate to management of water level between +0.1m and -0.1m AHD relating to maintenance of fish populations, and are described in Lane *et al* (1997).

In particular, summer - autumn water levels are not allowed to exceed 0.1m AHD to stop salt water incursion, although Lane et al (1997) notes that estuarine levels of up to 0.3 m have resulted in longer periods of floodgate opening during the mid to late 1990's.

A7.3 Water Quality

By autumn, large areas of both Vasse and Wonnerup Estuaries are dry, and remain so until significant winter rains. During winter, spring and into early summer, waters are described as 'fresh brackish' (Lane *et al* 1997), with remaining water becoming increasingly saline during the late summer and early autumn. This is largely due to salt concentration resulting from evaporation, with minor incursion of salt water through the floodgates.

Clearly salinity increases in the lower Vasse / Wonnerup follow floodgate opening for maintenance of fishstocks, although these openings occur under strict guidelines.

Waters of both estuaries are highly nutrient enriched (McAlpine *et al* 1989), with frequent algal blooms occurring in the lower reaches of the estuary.

A7.4 Discussion

Water heights within the Vasse-Wonnerup have been historically manipulated for flood protection, pasture management and ecosystem protection purposes. This has been achieved through the installation of stop boards within at the floodgates during early spring (achieving an additional storage of approximately 0.6m AHD of water) and limited introduction of seawater during late summer / autumn for ecosystem maintenance purposes.

Earlier installation of boards (for example following soil saturation and significant inflow mid winter) would allow for the maintenance of water levels within the estuary within a reduced range at a minimum of the board height (0.4m AHD) until evaporative losses take effect in spring to lower standing levels. This would have the effect of reducing late winter fluctuations that could contribute to rises in the water level and hence causing the dormant eggs of *Aedes camptorhynchus* mosquito species to hatch, producing larvae and in turn adult mosquitoes.

Water levels of up to 0.3m AHD can be achieved by extended opening of the floodgates during summer (approximately 0.4 m above sustained minimum levels in late summer).

Under the current summer management guidelines, the clear implication for the manipulation of water levels for mosquito control is that once summer levels drop below -0.1m AHD, the options for opening the stop boards to the sea are limited as they would seem counter to pasture and natural vegetation protection measures identified in the management guidelines.

Practical benefits for mosquito management arising from the ability to sustain a level of 0.3 m AHD during summer would need to be considered in terms of additional oviposition and larval sites inundated (possibly through accurate basin modeling) and consideration of resulting environmental and pasture production losses.

A8. RECOMMENDATIONS

A8.1 Larval Monitoring

- The breeding site at Siesta Park/Broadwater covers an area of approximately 106 ha. Given the size of this site, it is recommended that the number of monitoring sites be increased at those times when the breeding sites are receiving inflow from rainfall events. Additional monitoring sites will allow a more detailed evaluation of the mosquito breeding areas within the site. This should in turn lead to a more cost effective and efficient treatment program.

- At present there is only one larval monitoring site at Vasse New Town. Given this area will be a significant focus for future development, monitoring in this area needs to be extended to include other potential mosquito breeding sites within and adjacent to the development to gather data on the likely impact that mosquitoes breeding onsite may have on residents.

- Overall there is a need to increase the number of larval breeding sites being monitored as part of the program. To what extent this is achievable will be dependent upon the level of expansion and any resulting increase in budget and resources provided for the program. There is no doubt, however, that there is a need for a more comprehensive larval monitoring program which takes into account a greater range of mosquito species which breed in a variety of habitats. It is recommended that the monitoring program be extended to include natural freshwater wetlands, constructed wetlands, drainage channels and roadside gullies. This would also result in a requirement that the adult mosquito monitoring program be expanded to compliment the additional data gathered.

- CLAG funding requires that pre and post treatment monitoring is carried out as part of any mosquito management program. This is being carried out as part of the existing program however it would be beneficial if a detailed study was carried out to each saltmarsh site to develop a comprehensive management regime for each site.

- It is recommended that larval sampling be extended to include identification to species level where practicable. This should be carried out at all sites on a representative number of samples each breeding season to enable confirmation that the freshwater species known to be vector species are in fact breeding at these sites. There are a number of potential freshwater breeding sites especially over the spring period, where they could be originating from.

- Of the 16 sites monitored, 14 are located in the four main zones. Ideally the number of monitoring sites should be increased to provide a more detailed understanding of the four main zones. In addition it is recommended that monitoring be undertaken at seasonal sites which have the potential to provide suitable habitat for mosquito breeding and to determine the extent of any adverse impact on residents. A monitoring program should also be undertaken of the stormwater gullies and drainage channels in and around residential areas. Drainage channels can provide ideal habitat for vector species such as *Culex annulirostris* and *Coquillettidia species near linealis.* In the case of road gullies they can provide ideal habitat, depending on water quality and water level fluctuations, of the peri-domestic vector species *Aedes notoscriptus.* The challenge is to expand the program to ensure that we gain a greater understanding

not only of the management options available within the four main zones but also other breeding sites close enough to residential areas to be of concern.

A8.2 Adult Mosquito Monitoring

- The four sites monitored by UWA, whilst providing important long-term data for those sites, are totally inadequate in the context of forming any assessment of the impact that mosquitoes are having on the health and amenity of residents. The number of sites being monitored should therefore be significantly increased. It is important that the monitoring program is able to identify the levels of adult mosquito activity, from both vector and nuisance species, present in residential areas. This data will assist greatly the overall mosquito monitoring and management programs.

- Staff should ensure that they consider the potential for mosquitoes breeding in areas other than the four main saltmarsh breeding sites when assessing whether baseline mosquito monitoring is required as a condition of approval for any new development. Permanent and seasonal freshwater sites can provide suitable habitat for a number of pest/vector species. It is important therefore that their potential impact on residents and those involved onsite during the construction phase is considered.

- Monitoring is carried out on an 'as needs basis' in response to any complaints received from residents regarding mosquito activity. Monitoring traps can be set out in complainant's yards after an onsite inspection of the property and surrounds has been carried out by staff from the Environmental Health Department and where no source of the breeding has been found. Monitoring in these situations will help determine the number of mosquitoes, which species are present and therefore possibly the likely breeding sites for those species.

- The Shire maintains a register of complaints to allow for complaint mapping fur use in managing breeding sites and making land use planning decisions.

- Consideration should also be given to undertaking dispersal studies (e.g. trap/release/re-trap exercise) from the main saltmarsh breeding sites (after advice and consultation with staff from the Department of Health Mosquito-Borne Disease Control Unit) to help identify mosquito dispersal routes from these sites.

- The operation of the adult monitoring program should be reviewed on a regular basis as part of any overall review of the mosquito management program. There is the potential for a high level of variability between one season and the next. It is important therefore that contingency measures are set in place where any unused portion of the mosquito management budget can be held in trust and used in those years where there is a greater demand on the program.

- In conjunction with an expanded larval monitoring program there is a need to ensure that this also is the case with the adult mosquito monitoring program. At present only the four sites monitored by the Arbovirus Surveillance and Research Laboratory from the University of Western Australia are surveyed on a regular basis. There is a need for this aspect of the program to be significantly increased. Additional data is available from the monitoring carried out by developers. While this information is valuable

there needs to be a greater understanding of the impact that mosquitoes have in other residential areas of the Shire.

- There is a need to develop an adult mosquito monitoring program in the various residential developments to determine the level of mosquito activity within these areas and to identify the species diversity present. There is also a need to conduct dispersal studies at the four main sites to determine the migration routes that mosquitoes breeding at these sites take.

A8.3 Staff Training

- There will be a need for ongoing training for all personnel involved in the program. All Environmental Health personnel should have a basic understanding of the program, including the location of the monitoring sites, basic monitoring procedures and any occupational health and safety issues arising from their participation in the program. Given the likelihood of staff turnover within the department, it is important that an adequate induction program be made available to new staff.

- Staff actively involved in the application of larvicides or adulticides as part of any control program must be suitably qualified to carry out this work. Consideration should therefore be given to employing an experienced mosquito control officer similar to the posts created at the City of Mandurah and the City of Canning. The staff member could be assigned other duties outside the main mosquito season.

- Other staff involved in the planning/development process and whose decisions can have an impact on the program, be briefed on its operation and objectives. It is anticipated that this would include staff from the Planning Department, senior management and all Councillors at the beginning of their term.

- There is a need to look at the planning processes involved in approving developments that are located close to protected wetlands to reduce residents' exposure to disease carrying mosquitoes when residential areas are located near the main breeding sites of vector species.

A8.4 Public Education

- The public education program has been running for some time. Council use a variety of methods to keep residents informed about mosquito issues. This is an ongoing program which needs to be reviewed on a regular basis given the influx of new residents into the area as further development takes place. This is partly covered by the necessity that developers address this issue as part of any mosquito management plan which may be required for a new residential development.

A8.5 Vector Control Maps

- The preparation of vector control maps has been carried out for the four main breeding areas. As part of the future development of the program and to further improve its efficiency and effectiveness, it is recommended that each site be mapped

in detail to identify if there are areas within the site which require different levels of inundation, be it tidal or rainfall, to trigger larval emergence.

- The preparation of vector control maps should be extended to other seasonal or temporary breeding sites which have been identified as providing suitable habitat for pest/vector species. This would require the monitoring program to be extended to include these sites.

- A full survey of potential breeding sites be carried out when water levels of seasonal wetlands or temporarily inundated sites are at their highest (early-mid spring).

A8.6 Integrated Mosquito Control Program

- There is a need for the implementation of an integrated, environmentally responsible mosquito control program utilising physical, biological and chemical control measures to be developed further. At present emphasis is placed on chemical control measures through larval treatments and thermal fogging to reduce adult mosquito numbers. There are a number of options available which will enable the program to progress using a wider array of management strategies. It is important that as part of an overall plan, that each site has a comprehensive integrated management program to achieve the best outcome for that individual site, both from a mosquito control viewpoint and environmental one.

A8.7 Alternate/Additional Treatment Methods

- The Siesta Park site receives most of its recharge through rainfall. It may be beneficial to have topographical and hydrological surveys carried out to determine whether any filling or drainage program, if approved, would be feasible. It would also be of benefit to determine the extent that inflow from groundwater has on this site and therefore whether a system of subsoil pumps could be used to control inflow at the lower lying areas of the breeding site.

- The two main species of concern *Aedes camptorhynchus* and *Aedes vigilax* require fluctuations in water levels within their breeding sites. Their eggs can remain viable for extended periods. Where manipulation of water levels results in the site remaining dry or it remains flooded within controlled limits, breeding will be eliminated or significantly reduced. Water levels in breeding sites can be controlled through the construction of tidal gates or building bunds or levee banks between the main water body and the samphire fringed breeding areas. This type of control measure will not offer complete control as significant rainfall may flood dry sites or increase water levels in sites where water levels are controlled. Strong winds over large open sites may also increase the risk of localised breeding pockets within the waterbody. An assessment should also be made of the practicality of applying this type of control measure at the breeding side on the eastern side of Toby's Inlet.

A8.8 Cultural Control Methods

A8.8.1 Built Form Response

- All doors and windows should have approved insect screens fitted; this should include any doors which allow entrance to the house directly from the garage. Where screens are fitted in conjunction with sliding doors they should be fitted with a spring mechanism to allow the screen to close automatically.

- Exterior doors other than sliding doors should have a draft or pest excluder fitted to the base of the door.

- All external vents and pipes should be screened.

- External finishing work should be of a high standard (i.e. gaps around window frames, pipes, wall mounted air conditioning units etc should be sealed).

- Eaves should be enclosed or where this is not practical, mesh should be installed to prevent mosquitoes gaining access to the roof space.

- Yellow insect lighting should be used for exterior lights. These should not be installed directly next to doorways.

- If water tanks are installed, vents should be screened to prevent mosquito access and breeding.

- Residents should be encouraged to use block-out blinds and curtains.

- Where practical street lighting next to dwellings should have yellow lights.

A8.8.2 Landscaping

- Landscape architects must work with mosquito management consultants and the engineers responsible for the stormwater management system of any new development to ensure that there is a coordinated effort to minimise the impact that mosquitoes may have on future residents.

- Shrubs and trees should have open foliage to allow adequate light penetration and wind movement. This should also apply to larger-scale plantings, vegetated screened areas etc as dense vegetation corridors may allow mosquitoes to migrate into residential areas from breeding sites outside the immediate area.

A8.8.3 Land-use Planning

- The Shire's planning department needs to work closely with the Environmental Health staff to ensure that proper regard is taken regarding the location of new developments, the potential impact from mosquito activity and the need for adequate buffer areas to separate the development from any mosquito breeding sites which may impact adversely on future residents of the development.

PART B

B1. MOSQUITO BIOLOGY AND ECOLOGY

B1.1 Biology

In order to understand the complexities of the transmission of disease and nuisance mosquito problems and the specific methods of mosquito control that are appropriate in different situations, the life cycle of the mosquito needs to be understood (Russell, 2009).

The mosquito life cycle consists of four distinct stages; egg, larva, pupa and adult (**Figure 3**). The larval and pupal stages of the mosquito life cycle are aquatic, feeding on microscopic organisms, decaying vegetation or bottom detritus, however it is only the adult mosquito that is regarded as a pest. Adult female mosquitoes require a blood meal in order to obtain the necessary protein required to produce a large numbers of eggs (usually between 100–500 eggs).

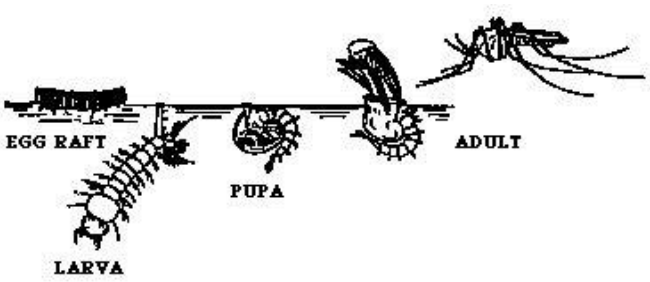

Figure 3: Mosquito Life Cycle

The following information has been adapted from Richard Russell's article *Mosquito Biology and Ecology* (2009).

B1.1.1 Egg

The eggs of the *Anopheles* species are laid singly on the surface of the water and are not resistant to desiccation and therefore will not be viable if the water body dries out. `*Anopheles* species are therefore generally associated with permanent or semi-permanent water bodies.

The eggs of the *Culex* and *Coquillettidia* species are laid in rafts of up to 200 eggs which float on the water surface and, as with the *Anopheles* species, are generally found in permanent or semi-permanent bodies of water, are not resistant to desiccation and may hatch after two days.

The eggs of the *Aedes* species are laid singly on the damp edges above the receding waterline and are resistant to desiccation and therefore can remain viable for a considerable period until the area is inundated again either through rainfall or tidal action. Because of this characteristic, *Aedes* mosquitoes are able to colonise a wide variety of breeding sites ranging from temporary to semi-permanent or permanent sites which experience fluctuations in water level. Another important aspect of the biology of *Aedes* species with respect to implementing effective measures to control the species is that not all the eggs will

hatch at the same time; some will hatch a few days after the initial batch and a proportion will not hatch until the site is inundated again at a later stage.

B1.1.2 Larva

The egg hatches out into a larva that is entirely aquatic and goes through four developmental stages (known as instars) with the average larval development time being between 5-7 days. Larva feed on microscopic organisms in the water or on decaying vegetation. Some species habitually feed at the water surface (e.g. *Anopheles*), some in the middle range below the surface (e.g. *Culex*) and others typically feed on the bottom (e.g. *Aedes*).

The rate of larval growth or development through the larval stages is dependent upon a number of environmental factors including temperature, larval density within the breeding site and the availability of food. Again, different species exhibit varied rates of development depending upon ambient conditions. During summer when environmental conditions are most favourable *Anopheles* and *Culex* species may complete larval development within 7-10 days, while *Aedes* species may take only 4-5 days. In temperate areas of Australia (such as the South West region) exposure to very low or extremely high (40^{o}C+) temperatures is often lethal to mosquito larvae.

B1.1.3 Pupa

After the larva has matured to the fourth instar stage and completed its growth within this stage it moults and develops into a pupa. The pupa is still mobile but has ceased feeding at this stage. The pupa will generally complete its development in water; however it does have the ability to survive in a moist environment if the breeding site dries out before the adult mosquito has emerged.

The duration of the pupal stage is dependent upon temperature but is generally in the order of 2-3 days for *Anopheles, Aedes* and *Culex* species, and 6-9 days for *Coquillettidia* species.

The adult mosquito develops within the casing of the pupa.

B1.1.4 Adult

The adult mosquito rests on the water surface after emerging from the pupal casing to allow its cuticle to harden. Males will generally emerge before the females with the first meal after emergence often being nectar or plant juices. Males generally have a short life-span and do not bit humans nor feed on blood from any source.

Upon emergence, the adult female will generally seek out a carbohydrate mean of plant juices. Mating (with a male) will then take place usually near the breeding site and often at dusk. Females only mate once with the sperm packet serving to fertilise all batches of eggs that she produces. In order for the development of the eggs to occur, the female require protein which may be provided either from nutritional reserves from the larval stage or from blood.

The life span of a female mosquito can vary significantly with adults reaching sexual maturity in one or two days. In a natural environment, it would be surprising for a mosquito to survive for more than 3-4 weeks. However with vector species the older the female the

greater the concern with regard to disease transmission because there will be a greater chance that she will have taken an infected blood meal and be able to pass it on to the next host animal.

B1.2 Ecology

B1.2.1 Habitats

Mosquito numbers vary between seasons and years and a major contributing factor to this is the amount of rainfall received, or the height and frequency of tidal inundation. In addition, the majority of mosquito species are active for only part of the year, and this is often determined by the seasonal availability of breeding sites. Other species breed opportunistically, following rainfall, or in artificial wetlands such as drains or stormwater systems. Mosquitoes are often most prolific in very temporary water bodies, such as tidal salt marshes. However, within a particular habitat, other factors such as sunlight or shade, the presence or absence of emergent vegetation and predators as well as prevailing winds may also be important factors determining breeding habitat formation.

Regional and local weather will generally have the greatest influence on the production of mosquitoes for a given area over short periods of time (Whelan 2009). Mosquito breeding requires optimal weather conditions with rainfall, temperature and humidity being major factors in their breeding lifecycles, often dictating how long standing water will support breeding, how quickly the breeding cycle will be completed and how active the emergent adults will become. Once the adults have emerged, temperature, humidity and wind speed and direction will all influence how far and wide adult mosquitoes will travel (City of Armadale 2009). Most mosquito species display patterns of seasonal abundance with fluctuations associated with meteorological conditions; many species are highly seasonal with peak adult abundance in mid-summer and complete absence in winter or the dry season (Russell 2009).

The amount of rainfall received in any given area is an important determinant in providing suitable habitat for mosquito breeding. Wind speed and direction may help to explain why a pest species is collected in an area remote from a breeding site. This is particularly important for the *Aedes* vector species who have known flight ranges in search of a blood meal in excess of 6 km.

The time taken for development from egg to adult varies greatly with environmental variables, particularly temperature (Whelan 2009). Temperature measurements are therefore most useful when determining generation times of individual species and is often a key factor in determining treatment times with respect to the application of larvicide (Australian Mosquito Control Association Inc. 1998).

Eleven species of mosquito have been consistently represented in the adult monitoring sessions conducted during the course of the current monitoring program being undertaken by the Shire.

Table 1 (over page) summarises the breeding habitat characteristics and the pest and vector status (i.e. whether the species is a known or potential carrier of either RRv or BFv) of each of the species of mosquito.

TABLE 1
MAJOR BREEDING HABITAT CHARACTERISTICS FOR THE MOSQUITO SPECIES TRAPPED

SPECIES	BREEDING HABITAT CHARACTERISTICS	PEST	VECTOR
Aedes alboannulatus	Ground pools and creekline rockpools	✓	
Aedes camptorhynchus	Brackish to fresh ground pools and tidal saltmarsh areas	✓	RRv , BFv
Aedes clelandi	Breeds in variety of freshwater sites often devoid of vegetation		RRv , BFv
Aedes notoscriptus	Tree holes, rock pools, artificial containers, stormwater drains	✓	RRv, BFv
Aedes ratcliffei	Fresh groundwater pools with or without vegetation, often in shaded swamps with high tannin content.	✓	
Aedes vigilax	Coastal saltmarshes and brackish swamps	✓	RRv, BFv
Anopholes annulipes	Ground and rock pools, generally freshwater but also in polluted and brackish water	rare	Potentially RRv but not considered important vector
Coquillettidia sp. near linealis	Freshwater in areas with dense emergent vegetation (*Typha*)	✓	Potential vector of RRv, BFv
Culex annulirostris	Shallow freshwater sites, also brackish and polluted waters	✓	RRv, BFv
Culex globocoxitus	Freshwater swamps and ground pools	✓	Yielded isolates of RRv and BFv does not generally bite people
Culex quinquefasciatus	Many types of artificial environments near human habitation, containers and ground pools	✓	Potentially RRv but shown to carry Murray Valley Encephalitis
Culiseta atra	Freshwater species		Not thought to bite humans

Source: Russell (1996) and Department of Medical Entomology, University of Sydney

Further background information relating to the biology and ecology of each of the species listed in **Table 1** is included in **Appendix 2**.

B1.2.2 Dispersal

Many mosquitoes have only one generation per year, while others can have two to five or more. Under favourable environmental conditions and by having a high reproductive potential and a short life cycle, the abundance of mosquitoes can increase reaching nuisance levels at particular locations in a very short space of time.

Dispersal is therefore an important factor in mosquito ecology. While many species typically move relatively short distances (50-100m) from their larval habitats (providing appropriate blood sources are available in the vicinity), some species have a range of 1-5 km. Some species are known to exhibit migratory behaviour such as *Aedes vigilax* known to be able to disperse 50 km (often downwind) associated with peak adult activity.

B2. MOSQUITO BREEDING SITES

An assessment and mapping of the mosquito breeding sites throughout the Shire was identified as a key objective of the scope of works.

The area identified to be covered by the fieldwork lies between Layman Road Wonnerup in the east to Naturaliste Drive Dunsborough in the west and south to the township of Vasse (see **Figures 1 and 2a-e**). This area was chosen as it is considered to be the area of the Shire that it currently is, or is most likely in the future to be subject to the most pressure for intensive urban residential development. It is acknowledged that outlying areas such as in the Wonnerup area as a result of current Shire zoning under Town Planning Scheme No. 20 are more likely to be developed as Special Rural. The Ambergate area on the other hand, while currently sparsely populated, is anticipated to become an urban residential growth area.

Detailed aerial photographs (scale of 1:10000 and 1:5000) and the DEC's *Geomorphic Wetlands of the Swan Coastal Plains dataset* mapping (*WA Atlas* refer https://www2.landgate.wa.gov.au/bmvf/app/waatlas/) for the Shire of Busselton were studied to identify potential mosquito breeding sites prior to the ground survey being undertaken.

Ground surveying of the project area was undertaken in late May 2010. During the survey, the locations of potential mosquito breeding sites and harbourage areas that were either identified for examination during the desktop survey or were found to be present during the course of the survey were recorded using a GPS unit for follow up mapping.

The location of each of these Observation Points is shown on **Figures 2a-e**.

During the ground survey, potential mosquito breeding sites that contained surface water were sampled using a standard larval dipper. However, due to the timing of the ground survey and the absence of rainfall within the weeks immediately preceding the survey, there were limited opportunities for larval dipping to be undertaken. Dipping that was undertaken predominantly in tidal influenced waterbodies was not prospective. This is most likely due to the seasonality of the breeding cycle of the main saltmarsh species. Where freshwater was standing, there was very little larval activity observed. Again, this is most likely due to the seasonality of breeding cycles for main freshwater species that have been trapped.

Approximately 50 potential breeding sites were surveyed in the area from Wonnerup to Dunsborough. The overall intent in choosing the sites was to include a variety of breeding site types (e.g. swamp, constructed wetland, samphire marsh, drain) that would be representative of those site types within the general area in which the observation was made.

Field report sheets for each of the field observation points and photographs taken are included as **Appendix 3**.

The results of the field investigation undertaken to determine the location of additional breeding sites would indicate that additional larval monitoring sites are required at Siesta Park/Broadwater, Toby's Inlet, plus a number of other sites within the Shire. However this can only be determined following a comprehensive survey of the potential breeding sites identified in the survey. Ideally this should be undertaken in spring 2010 when water levels

in the various seasonal wetlands should be at their highest ensuring that the survey results are more representative and conclusive.

It is important that this work be undertaken in the event that the Shire is asked to consider any further expansion of intensive urban residential development along the Abbey – Quindalup corridor. This would enable potential buffers between residential development and confirmed breeding areas to be clearly identified.

B3. MANAGEMENT MEASURES

There are a number of critical factors which determine the abundance of mosquito populations. Most significantly, both require an aquatic environment in which to breed and midges also require sufficient organic material during their larval stage. Factors important for adult mosquito survival include temperature, wind and humidity. These factors in turn influence the ability of adult mosquitoes to act as vectors and to disperse away from breeding sites.

Mosquito numbers vary between seasons and years with major contributing factors to this include rainfall (for freshwater mosquito species), or the height and frequency of tidal inundation (for saltmarsh mosquito species). The monitoring program undertaken to date, has shown that tidal inundation is critical to the development of breeding habitat for the saltmarsh mosquito species *Aedes vigilax* and *Aedes camptorhynchus* both of which are known RRv vector species.

B3.1 Monitoring Program

Mosquitoes are considered a nuisance when the number of mosquitoes caught at a single location in a single carbon dioxide baited insect trap exceeds 50 over a normal sampling period (12 to 18 hours) (EPA 2000). If the species caught are ones that are known, or suspected to be vectors of mosquito-borne disease, and the mosquito population is close to heavily populated areas, then the mosquitoes may present a health risk and will require control (EPA 2000).

Data gathered at the four sites monitored under the UWA program (results discussed in **Section A2.2** in tabular form for each site) indicate that the thresholds for nuisance and vector mosquitoes are being exceeded on a regular basis with the peak period of activity generally between August-December each year. There is an urgent need for the program to be expanded as discussed in **Sections A1 and A4** of this report.

The monitoring program must adequately cover the requirements of the aims and objectives of any ongoing management program. It needs to determine:

- Which species of mosquito larvae are present;
- Which species of adult mosquito are present and the impact that they have in residential areas;
- Fluctuations in the target mosquito numbers including an estimate of the adult population size based on trapping results, an estimate of larval abundance within the numerous permanent and seasonal breeding sites and an indication of whether mosquito breeding is carried out in the same locations throughout the entire year, which is important for effective larvicide treatment;
- Any environmental impacts associated with the implementation of any mosquito control techniques; and
- Potential impacts of control agents on fringing wetland vegetation.

The most environmentally sound and effective mosquito control method identified for the Busselton wetlands is to control mosquitoes in the larval stage whilst in a localised area, before the mosquitoes emerge as adults. The larval and adult mosquito monitoring programs primary aim therefore is to provide sufficient data to enable effective

management of disease vector and nuisance insects and to ensure that the health, welfare and amenity of residents is protected without any adverse environmental impact.

The current strategy is aligned with the Shire of Busselton Environment Policy in that the implementation of the strategy and associated control methods will comply with all environmental legislation, conform to best practice management standards and adhere to the principles of the Environment Policy.

B3.1.1 Larval Monitoring

The larval monitoring program currently covers 16 sites. The monitoring program is discussed in **Section A1.1** of this report. As previously discussed there is a need to expand the program further. The results of the field investigation undertaken to determine the location of additional breeding sites would indicate that importantly additional monitoring sites are required at Siesta Park/Broadwater, Toby's Inlet, plus a number of other sites within the Shire which will be determined following a comprehensive survey of any potential breeding sites. Ideally this should be undertaken in spring 2010 when water levels in the various seasonal wetlands should be at their highest.

It is important that trained competent staff is involved with the larval monitoring program. To assist with this aspect, the Standard Operational Procedures detailed in **Appendix 4** should be followed for larval surveys, and for both pre and post treatment phases. These procedures are designed to offer guidance. They should however be subject to ongoing review to ensure that they remain relevant as the program develops.

B3.1.2 Adult Monitoring

At present adult monitoring is being undertaken at four sites as part of a wider program being conducted by UWA in the coastal South West region. Adult monitoring is undertaken to keep valid information as to the changes in adult populations over time and to determine whether significant (i.e. >50) vector mosquitoes per trap are being recorded.

- The current program includes monitoring of mosquito populations carried out on a fortnightly basis between September – April (monthly for the remainder of the year).
- Records are kept of the results of each monitoring session and added to the management program database.
- The monitoring program is reviewed annually.
- The mosquitoes trapped are processed for virus isolation.

The four sites monitored as part of the UWA program are located at;

1. DEC (ex CALM) Village, Ludlow
2. Ford Road, East Busselton
3. Busselton Radio Tower, Siesta Park
4. Old Bridge, Wilson Road, Quindalup, Toby's Inlet

These four sites have produced a significant amount of important data, however there is a need to determine the impact that nuisance and vector species have on residential areas. The program should be expanded as a matter of urgency. This has been discussed in greater detail in **Section A4** of this report.

It is important that trained competent staff is involved with the adult monitoring program. To assist with this aspect, the Standard Operational Procedure detailed in **Appendix 4** should be followed for adult surveys. These procedures are there for guidance. They should however be subject to ongoing review to ensure that they remain relevant as the program develops.

B3.2 Control Measures

The key to providing long-term effective control of mosquitoes within wetlands lies in the development of a range of integrated control measures which essentially aim to restore water quality and natural ecosystem balance within the problem wetlands and to prevent the further degradation of wetlands (City of Cockburn, 2007) employing a combination of physical, biological, chemical and cultural control methods and targeting both larval and adult mosquitoes.

Early identification of large mosquito populations will therefore allow control methods to be developed. As discussed in **Section A6** control strategies may include:

- Physical – Physical modification or removal of source to prevent breeding through techniques such as runnelling, filling, draining or water level management;
- Chemical – Application of larvicides and adulticides;
- Biological – Introduction of appropriate mosquito predators; and
- Cultural – Encouragement of public to implement personal preventative measures through the provision of signage in POS areas advising people about the risk posed by mosquitoes.

B3.2.1 Physical Control

This is by far the preferred option to be implemented in order to ensure that potential breeding habitats are not created and to minimise the need for other forms of mosquito control within the site as far as is practicable.

Physical control of mosquitoes will include, but not necessarily be limited to, the following:

- Filling of some sections of the other breeding sites may be possible where there are any sections which have been degraded through human or vehicle access to the site Where sites have been modified by filling they will be inspected on a regular basis to ensure that they remain unlikely to promote future mosquito activity.
- Manipulation of water levels resulting in the site remaining dry or it remains flooded within controlled limits to eliminate or reduce breeding. Water levels in breeding sites can be controlled through the construction of tidal gates or building bunds or levee banks between the main water body and the samphire fringed breeding areas.
- Maintenance will be carried out on detention storage basins/drains on an annual basis to remove weeds, dead plants and to thin out vegetation as required in accordance with the various approved management plans at development sites, or in Shire controlled basins.
- Any build up of waste will be removed from gross pollutant traps. This maintenance will be carried out at least twice per year (usually undertaken by the Shire engineering department).

- A gully eduction program will be established to service any soakwells and bubble up pits within road reserves/swales/detention basins. This will be carried out at least twice per year (end of autumn and beginning of spring).

B3.2.2 Chemical Control

There are two forms of chemical control currently approved for mosquitoes by the DoH and DEWHA: larvicides that are used to kill larvae; and adulticides that are used to kill adult mosquitoes.

Larviciding

The larvicides currently approved by the DEWHA for mosquito control and being used in the Shire program are s-methoprene and *Bacillus thuringiensis israelensis* (Bti). As discussed in **Section A6.3** both of these larvicides are of low toxicity to non-target fauna and are highly target-specific to mosquito larvae. It is proposed that both larvicides will be used, if treatment is required, as part of a resistance management initiative. *Bacillus sphaericus* will also be used in breeding sites where the water is polluted or has high nutrient levels. While other chemical options are available, the final choice will be determined through liaison with both the Shire and the DEWHA. It is important to vary the larvicides used as a means of reducing the risk of mosquitoes becoming resistant to any one larvicide.

To be effective, larviciding requires that monitoring the number of mosquito larvae present is required to determine if, and when, the mosquito control is required. This will be conducted as part of the monitoring program using Standard Operational Procedure 01: Larval Pre-Treatment Survey (**Appendix 4**). If required, a treatment program will need to be implemented from the end of August through to the end of April.

Where a treatment program is in place, larval monitoring may need to be undertaken on a weekly basis and will be conducted as part of the monitoring program using Standard Operational Procedure 04: Post-treatment Larval Monitoring (**Appendix 4**).

The monitoring is particularly necessary if the target species has a development cycle of 7-10 days from first instar to adult emergence and a larvicide such as Prolink is used, it is only effective when the larvae are at the fourth instar stage or earlier. This requirement can change depending upon the formulation. Monitoring is also carried out to confirm the effectiveness of the larvicide. Prolink is an insect growth regulator so it does not kill the larvae. The larvae develop normally until the pupae stage and do not emerge as adults.

Chemical control of the larval stage of mosquito development will include, but not necessarily be limited to, the following:

- Larval treatment will be undertaken where larval surveys identify the presence of high numbers of mosquito larvae and when the adult mosquitoes are pest/vector species and trapped in significant numbers and where physical management of the site is not appropriate.
- Warning signs will be placed around areas that are to be treated.
- Larvicides will only be applied in accordance with the manufacturer's instructions regarding recommended application rates using calibrated equipment by operators who are qualified and experienced in mosquito management.

Larviciding of smaller and more accessible breeding areas will be conducted in accordance with Standard Operational Procedure 02: Hand Application of Larvicide (**Appendix 4**). In larger and less accessible breeding areas (e.g. Zones 2 and 3, see **Section 2.4**), larviciding will be conducted in accordance with Standard Operational Procedure 03: Helicopter Larvicide Operation (**Appendix 4**).

Adulticiding

The use of adulticides to control mosquitoes is the option of last resort. Unlike the larvicides detailed above, adulticides are non-target specific that have the potential to impact on a wide range of insects and spiders which come into contact with them. Most of the adulticides used are synthetic pyrethroids that are toxic to fish and aquatic organisms if droplets of the adulticide reach waterways.

Adulticiding should only be undertaken when there is a public health imperative that treatment is carried out (i.e. during an outbreak of RRv where the DoH advises the Shire that there is the need to quickly control large numbers of vector mosquitoes that are already on the wing).

In keeping with the DEWHA approval, in areas within 1.5km of the Vasse Wonnerup Wetland System (**Appendix 1**), adulticide may only be applied where:

a. Ross River Virus or Barmah Forest isolates have been detected by the UWA Arbovirus Surveillance Program; and/or
b. The State Department of Health have issued a current Health Warning regarding the prevalence of Ross River Fever in the region;

and in the following conditions:

a. Wind conditions are below 8 knots, and
b. Wind direction will carry the adulticide away from the wetland system.

.
In all other areas of the Shire, adulticide treatment may include the following:

- The use of bifenthrin as an external treatment, around buildings and garden areas has proven effective in reducing adult mosquito numbers. This information will be provided to individual property owners but it is important that any treatment be carried out by a licensed pest control operator.
- Warning signs will be in place at least 24 hours before any treatment is scheduled to be undertaken.
- Public access to the area will be prohibited while the treatment is in progress.
- A register will be kept of residents who wish to be notified of any scheduled treatment. The register will be updated regularly.

Adult larviciding will be conducted in accordance with Standard Operational Procedure 06: Adulticide Fogging (**Appendix 4**).

B3.2.3 Biological Control

Biological control involves the introduction or the promotion of naturally occurring species that are harmful to the target species (i.e. mosquitoes) and are harmless to the non-target

species. The major biological controls currently in use are fish, aquatic beetles and bugs. Fish can control mosquito larval numbers directly by eating the larvae or indirectly by reducing algae that provide protection from other predators. Aquatic beetle larvae and bugs can also be very efficient mosquito larvae predators (refer to **Section A6.3**). Biological controls can however, become ineffective when vegetation is too dense within the wetland and therefore marginal vegetation should ideally be kept to a minimum.

Biological control of mosquitoes will include, but not necessarily be limited to, the following:

- Maintaining the abundance and diversity of predator species within the wetlands through the promotion of a healthy ecosystem.
- Maintaining the structural diversity of native plant species in wetland areas by excluding weed/undesirable species (e.g. *Typha orientalis*) infestations.
- Minimising the amount of aggressive weed growth within Shire detention storage areas as part of the weed control program.

B3.3 Built Form

Mosquito monitoring data gathered during the current monitoring program indicates that there is a significant level of adult mosquito activity in the Shire for at least part of the year. As discussed in **Section A.6.2.1** the built form response needs to ensure, as far as practicable, that residents are separated from mosquitoes within the home environment.

It is recommended that the components of any built form initiative as identified in **Section A.6.2.1** be a compulsory requirement that builders are responsible for, at the time of construction of any dwelling. Built form control could therefore be implemented through the building approval process.

B3.4 Landscaping

Inappropriate landscaping has the potential to make the area around a building (whether it is residential or commercial) highly attractive to mosquitoes (refer **Section A6.2.3**).

The landscaping response to mosquito management will include, but not necessarily be limited to, the following:

- Soils used in landscaped areas should be free draining and not subject to ponding.
- Shrubs should have open foliage to allow adequate light penetration and wind movement. This requirement should apply to vegetated areas in public open spaces.
- Pruning and under-cutting of vegetation should be undertaken in landscaped POS areas to remove habitat for mosquito harbourage.

B3.5 Public Education, Advice and Warnings

In many cases public education and awareness programs involve no more than a couple of notices each year in a local newsletter. Given the high number of vector species breeding within the Shire, it is important that an ongoing education and awareness program is

initiated for the residents. The program should be reviewed on an annual basis to ensure that it remains relevant to the changing needs of the community.

The public awareness and education program will include, but not be restricted to, the following:

- Information pamphlets detailing a range of mosquito management issues (e.g. reminders on controlling mosquitoes around the home, media statements from the DoH and the Shire regarding mosquito nuisance or mosquito-borne disease outbreaks) will be made readily available to residents at the Shire office or website.
- All complaints from residents regarding mosquitoes will be recorded and dealt with promptly by the Shire.

B3.6 Documentation

Data sheets are required to be completed as part of the following Standard Operational Procedures:

- SOP-01 – Larval Data Sheet (Pre-treatment)
- SOP-02 – Field Treatment Data Record Sheet (hand application)
- SOP-03 – Field Treatment Data Record Sheet (helicopter application)
- SOP-04 - Larval Data Sheet (Post-treatment)
- SOP-05 – Adult Trap Data Sheet

Following the completion of fieldwork and return to base, information that has been entered into the field data sheets will be entered electronically into the mosquito management program database and incorporated into the annual report (refer **Section B4.3**).

Copies of the various field data sheets are included as **Appendix 5**.

B4. PROGRAM IMPLEMENTATION, RESPONSIBILITIES AND FUNDING

B4.1 Program Implementation

Management recommendations contained within Part B of the management plan, responsibility and applicable management timeframe are identified on **Table 2** (over page).

The timeframe for the implementation of the management measures identified in this management plan are also identified in the table. If, during this management timeframe, the proposed control measures implemented are not effective in reducing mosquito numbers, the Shire will investigate alternative measures in consultation with the DoH prior to implementing them.

The implementation of the management measures identified in this report will be an ongoing process requiring regular review.

B4.2 Program Funding

The recommendations contained within this report clearly indicate the need for the program to be expanded. This will require additional funding from Council. There therefore needs to be an ongoing commitment from Council to ensure that the program operates efficiently and delivers the best service possible to the community.

The Developer Contribution Policy should be reviewed on a regular basis, not only in respect of any annual CPI increases but to ensure that it remains relevant to the needs of the Mosquito Management Program. There also needs to be an annual assessment of the likely income to the program from this source as this in turn may have a bearing on the level of commitment required from Council.

Council will need to consider the options available to finance the expanded program. One option which has been used successfully in the eastern states and in the United States of America, is that Council raise a set levy from each householder to help fund the program. This would be applied to all ratepayers irrespective of where their property was in relation to any known mosquito breeding sites.

The level of mosquito activity is dependent upon a number of environmental factors. As a consequence of this there can be significant variations from season to season. The program therefore needs to have procedures in place where any funds unused in any particular season can be set aside and held in trust. These funds can then be released in those years where there are greater demands on the program.

TABLE 2
RESPONSIBILITY AND TIMEFRAME FOR IMPLEMENTING MANAGEMENT MEASURES

ISSUE	AREA	RESPONSIBILITY	TIMEFRAME
Larval monitoring	Pre-treatment survey Post-treatment survey Additional survey work	Shires of Busselton and Capel Shires of Busselton and Capel Shire of Busselton	Ongoing to maintain database Dependent upon approval to continue the program Spring 2010 then ongoing
Larval treatment	Existing program	Shires of Busselton/Capel Dept of Health	Dependent upon approval to continue the program
Adult monitoring	Existing program Additional monitoring	UWA Shire of Busselton	Ongoing ASAP then ongoing
Adult treatment	Existing program	Shire of Busselton	Ongoing
Public education	Existing program	Shire of Busselton/developers	Ongoing
Staff training	New program	Manager Environmental Health	ASAP
Reporting	Monitoring results Program activities	Manager Environmental Health Manager Environmental Health	Annually Annually with review every three years

B4.3 Reporting

An annual report should be prepared detailing the activities of the mosquito management program over the previous 12 months. The report should be published on the Shire of Busselton website for Shire residents to view.

The report should include, but not be restricted to, the following:

- Results and comment/recommendations on the larval monitoring program;
- Results and comments/recommendations on the larval treatment program;
- Results and comments/recommendations on the adult monitoring program;
- Results and comments/recommendations on the adult treatment program;
- Details of any changes to the program since the last report was published;
- Details and activities undertaken as part of the Public Education and Awareness Program;
- A financial report on the funding/budget for the program with details of any surplus or shortfall;
- Details of staff involved in the program including training received under the staff development program;
- Details of changes made to any of the Standard Operating Procedures; and
- Recommendations for the following season.

A copy of the annual report should be forwarded to the Mosquito-borne Disease Control Unit at the Department of Health for comment and review.

It is important that the program is subject to regular review to ensure that it continues to maintain a high level of efficiency, whilst remaining relevant to the changing needs of the community. It is therefore recommended that a comprehensive assessment and review of the program be undertaken every three years.

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FIGURES

APPENDICES

APPENDIX 1

EPBC REFERRAL DECISION
(SOURCE: DEWHA, 2010)

APPENDIX 2

DETAILED INFORMATION FOR MOSQUITO SPECIES TRAPPED DURING THE MONITORING PROGRAM (SOURCE: RUSSELL, 1996)

Aedes alboannulatus

Plate 1 – *Aedes alboannulatus*

This is a common species which breeds in a wide variety freshwater habitats including rockpools, temporary ground pools and containers. It is a significant nuisance species as it bites humans both during the day and at night. As with most *Aedes* species their eggs are resistant to desiccation. The species is most commonly found between May and October.

Aedes comptorhynchus

Plate 2 – *Aedes camptorhynchus*

This is the most common species in the south-west of the state. It will breed in a wide variety of temporary swamps, ground pool and tidal saltmarsh areas over the autumn-early summer period. It is especially abundant during spring.

This species has a flight range of at least 5 km. It is one of the main vectors of both RRv and BFv in south-west Western Australia. It is a vicious biter which will attack day or night.

Aedes clelandi

This moderate sized species is found in coastal regions in the South West of Western Australia breeding in a variety of freshwater sites that are usually devoid of vegetation. The species is generally only present from late winter through to late spring (April to October) when they are most active. It is univoltine (single generation per year) and will breed in a variety of temporary habitats. This species will bite humans viciously and are a day-biting species (Russell, 1996). The species has a flight range of up to 3 km. It is a vector of RRV and a potential vector of BFV (Whelan, 2009).

Aedes notoscriptus

Plate 3 – *Aedes notoscriptus*

Aedes notoscriptus are found in a variety of natural and peri-domestic habitats. These include tree and rock holes, small containers, stormwater drains especially early in the season where the water quality is reasonable and the drains contain leaf litter, tyres, gutter, bird baths etc. This species has a limited flight range and will bite during the day in cool well shaded areas. Its presence in peri-domestic habitats and its limited flight range indicate that a comprehensive ongoing proactive public education and awareness program may be of significant benefit. During RRv outbreaks, this species has been shown to be infected and may have an important role in RRv transmission.

Aedes ratcliffei

Plate 8: *Aedes ratcliffei*

This freshwater species generally has only one generation per year (univoltine) therefore numbers can increase dramatically over a short period during spring. Its preferred breeding habitat is in fresh groundwater pools that are with or without vegetation, however in the south-west of Western Australia is more commonly found in shaded areas in *Melaleuca* (Paperbark) swamps where the water has a naturally high tannin content (Wright 2009).

Aedes ratcliffei is a vicious biter both during the day and at night but it has no known or suspected relationship to disease. The species appears to have a relatively limited flight range (~ 1km) and it is therefore more of a nuisance in residential areas that are close to the breeding site.

Aedes vigilax

Plate 4 – *Aedes vigilax*

This species is present only during the hotter summer months. It is present therefore over the peak period for RRv infection. It breeds in coastal saltmarsh areas and brackish swamps. *Aedes vigilax* has the ability to disperse over a significant distance from its breeding site. They can therefore be present in substantial numbers in location far removed from the breeding site and are a vicious biter which will bite readily during the day with peak activity around dusk. They are a vector of both RRv and BFv.

Anopheles annulipes

Plate 10 – *Anopheles annulipes*

This species will breed in a wide variety of habitats, from permanent, semi-permanent or temporary pools and containers. It will bite humans both during the day and after sunset.

Coquillettidia* sp. *near linealis

This is a freshwater species occurring along the Swan Coastal Plain and generally breeding in waterbodies with dense emergent vegetation. It is most prevalent in wet years when high water levels maximise the area of *Typha* (Bulrush) and is active from October onwards until water levels recede away from emergent vegetation (Wright 2006). It is a vicious biter during the night. Larval monitoring of this species is virtually impossible because the larvae remain submerged, attached to emergent aquatic vegetation and breathing through a modified siphon or breathing tube. It is a potential vector of both RRv and BFv.

Culex annulirostris

This freshwater species is generally only present from late winter through to late spring and is univoltine (single generation per year). It will breed in a variety of temporary habitats but mainly in heavily vegetated permanent or semi-permanent lakes and wetlands and only reaches significant nuisance levels during the summer months (Wright 2006). This species will bite viciously both during the day and at night and has a flight range of up to 3 km. It is a vector of RRv and a potential vector of BFv.

Plate 5 – *Culex annulirostris*

Culex globocoxitus

Plate 7 – *Culex globocoxitus*

This species is similar in appearance to *Culex australicus* and also in the fact that it generally does not bite humans. This species breeds in open swamps but will also breed in slightly brackish water.

Culex quinquefasciatus

This is the major domestic pest in many urban areas being generally active only during the warmer months; they usually attack humans towards the middle of the night indoors and outdoors, and will enter buildings in search of bloodmeals (Wright 2006). *Culex quinquefasciatus* breeds in a wide variety of domestic situations and street gullies (particularly silt traps). It also breeds in organically polluted drains and ditches (Wright 2006). With respect to human disease it has been shown to be able to carry Murray Valley Encephalitis (MVE).

Plate 8 – *Culex quinquefasciatus*

Culiseta atra

Plate 9 – *Culiseta atra*

Culiseta atra tend to be a dark mosquito that is not often collected in traps (NSW Arbovirus Surveillance). This particular species occurs in the southwest of Western Australia and is a freshwater species that is not thought to bite humans.

APPENDIX 3

FIELD SURVEY SHEETS

APPENDIX 4

STANDARD OPERATIONAL PROCEDURES

STANDARD OPERATIONAL PROCEDURES

It should be noted with regard to the following standard operational procedures that mosquito management work is specialised. Operators involved in this work should be qualified and preferably experienced. Inexperienced operators should be under the direct supervision of an experienced colleague. ALL staff should have completed the pesticide safety course run by the Department of Health and preferably have completed the Mosquito Management Course run by the Mosquito-borne Disease Control Unit from the Department of Health.

It is important that all staff involved in the program receive regular, ongoing staff development to ensure that their skills remain relevant, up to date and in line with industry best management practices.

STANDARD OPERATIONAL PROCEDURE - 01: LARVAL PRE-TREATMENT SURVEY

PRIOR TO LEAVING BASE

- If data is held regarding sites to be surveyed a check should be made regarding vegetation type present at the site, size of the site, likely species breeding at the site and that there are copies of the vector control map of the site.
- Use the vector control maps to plan the order in which the sites will be visited.

NOTE:

1. The sites to be visited will also determine the timing of any survey. Saltmarsh areas should be visited two or three days after inundation from high tides or heavy rainfall.
2. Part of the data gathered should include (in the case of tidal breeding sites) the expected tide height that individual sites will be flooded.

Prior to leaving base ensure that all OH&S procedures are followed for working in remote/isolated areas. It is preferable that staff do not work alone in these areas.

The field operator should:

- Advise base of the exact order that sites will be visited.
- Ensure that protocols are set up regarding contact timeframes for the operator to check in with the base. These must be adhered to so that if a field operator does not contact base at any scheduled time, this can be followed up by the base.

EQUIPMENT CHECKLIST

EQUIPMENT CHECKLIST	
Item	**Tick**
Larval dippers	
Small vials with stopper tops	
Map of sites to be visited	
Notebook, labels, pens, pencils	
GPS and digital camera	
Larval data sheets (to be completed for each site)	
Mobile phone (ensure that battery is charged)	
Water pH and salinity tester	
Thermometer	
PVC boots	
Overalls	

CHECK ALL EQUIPMENT PRIOR TO LEAVING BASE

ONSITE

Advise base of arrival onsite.

Prior to commencing sampling:

- Look at the water before disturbing it with the dipper. Note the presence of any fish, other predator species or mosquito larvae. Take care not to cast a shadow over the area to be sampled as larvae are likely to dive to the bottom if a shadow is cast over the water surface.

PROCEDURE:

- Set sampling sites should be used at each location.
- Record date/time, weather conditions, GPS co-ordinates on the larval data sheet.
- Check pH, salinity and water temperature and record on the data sheet.
- Ten dips per individual sampling point.
- Dip only at points likely to contain larvae.
- Record number of dips and results on the larval data sheet (i.e. number of larvae per dip and percentage of larvae from each development stage e.g. 1^{st}, 2^{nd}, 3^{rd}, 4^{th} instars and pupae).
- Use pipette to transfer 4^{th} instar larvae and pupae to the small vials.
- Complete label using pencil.
- Label should have date, site code, location code, enough to identify exactly where and when the sample was taken once back at base.

WHEN SURVEY WORK IS COMPLETED FOR THE DAY ADVISE BASE THAT THE SURVEY TEAM IS LEAVING THE REMOTE/ISOLATED AREA AND HEADING BACK TO BASE

BACK AT BASE

Advise base that survey team has returned from the field.

- Pupae collected can be transferred to rearing trays.
- Transfer 4^{th} instar larvae to vials containing 70% alcohol to await identification.
- It is important that the label containing the details of the sample is transferred to the new vial with the sample.
- Calculate the larval density per square metre for each site surveyed.
- Add the data collected to the database.
- Advise supervisor and if above any threshold levels (currently 100 larvae per square metre) larval treatment may be required.

STANDARD OPERATIONAL PROCEDURE - 02: HAND APPLICATION OF LARVICIDE

PRIOR TO LEAVING BASE

- Check on vector control map the location of the area to be treated.
- Check that all equipment to be used is in good working order.
- Calibrate the equipment per manufacturer's instructions to the output rate required.
- Read and be conversant with the rate of application, any restrictions noted on the label. **If in doubt ask a supervisor.**

Prior to leaving base ensure that all OH&S procedures are followed for working in remote/isolated areas. It is preferable that staff do not work alone in these areas.

The field operator should:

- Advise base of the exact order that sites will be visited.
- Ensure that protocols are set up regarding contact timeframes for the operator to check in with the base. These must be adhered to so that if a field operator does not contact base at any scheduled time, this can be followed up by the base.

EQUIPMENT CHECKLIST

EQUIPMENT CHECKLIST	
Item	**Tick**
Larvicide chemicals	
Catch bags	
Sieve	
Ground tarpaulin	
Anemometer	
Electronic scales	
Calculator	
Pre-marked maps of sites to be treated	
Tape measure	
Funnels and catch containers	
PPE	
Field treatment data record sheets	
Site maps	
Larval dippers	
PPE - hat, overalls, visor or eye protection, respirator or dust mask (read label instruction on larvicide container to determine what is required), gloves, PVC boots	
Larvicide to be used (this should be stored in a lockable storage box on the vehicle).	
MSDS for any larvicide to be used	
Sufficient water (if the larvicide requires dilution with water)	
Container of petrol (if four stroke motorised equipment being used or petrol plus two stroke mix if two stroke motorised equipment being used).	

CHECK ALL EQUIPMENT PRIOR TO LEAVING BASE

ONSITE

Advise base of arrival onsite.

PROCEDURE:

NOTE: Ensure that spill/cleanup kit is to hand before commencing

- Check weather conditions and ensure that they are suitable for treatment.
- Undertake larval check with dipper to confirm larvae are present.
- Measure treatment area.
- Calculate amount of larvicide required.
- Record above information on the larval treatment data sheet.
- Record date/time, weather conditions, GPS co-ordinates on the larval data sheet.
- Set out warning signs.
- Mix required larvicide (do this away from sensitive areas and on plastic sheet if granules used).
- Apply larvicide at recommended rates.
- Carry out continual check on flow/application rates especially at each fill up to ensure that correct rate is being applied.
- Record amount of larvicide used on data sheet.
- Collect and store all equipment on vehicle.
- Undertake final check of site to ensure that nothing has been left behind.

WHEN SURVEY WORK IS COMPLETED ADVISE BASE THAT THE SURVEY TEAM IS LEAVING THE REMOTE/ISOLATED AREA AND HEADING BACK TO BASE

BACK AT BASE

Advise base that survey team has returned from the field.

- Store any unused larvicide in original containers in chemical storage area.
- Clean and store equipment.
- Transfer data on data sheets to main program database.

STANDARD OPERATIONAL PROCEDURE - 03: HELICOPTER LARVICIDE OPERATION

Per original procedure detailed in Strategy

Prior to leaving base ensure that all OH&S procedures are followed for working in remote/isolated areas. It is preferable that staff do not work alone in these areas.

The field operator should:

- Advise base of the exact order that sites will be treated.
- Ensure that protocols are set up regarding contact timeframes for the operator to check in with the base. These must be adhered to so that if a field operator does not contact base at any scheduled time, this can be followed up by the base.

PROCEDURE:

Load Mosquito Ute and trailer with larviciding chemical, catch bags, larvicide sieve and safety equipment.

Arrive at staging area?

Set up catch bags.
Ensure the collectors are firmly attached to underneath of cone.
Set up sieve drum, position on ground tarp and then sieve four drums of chemical.
Place sieved chemical back into empty drum.
Load chemical into helicopter hoppers. **Do not do this while the helicopter is re-fuelling.**

Helicopter will fly over catch bags at a speed of 50knots at 30 feet (9m).

Record wind speed and direction as helicopter flies over catch bags.

Collect catch containers, weigh and average amount of larvicide/m^2.
If calibration is not within the recommended rate of application, adjust the hoppers and repeat procedure.

Record weather conditions and time of departure and arrival of the helicopter.
Note the wetland areas covered.

Repeat catch bag procedure each time hoppers are loaded.

Complete Aerial treatment form and forward to both the Manager Environmental Health Services Section and Medical Entomology Section, Health Department of WA.

Discuss findings with the Manager, Environmental Health Services Section.

Enter details onto Mosquito control database.

Conduct post treatment survey.

EQUIPMENT CHECKLIST

EQUIPMENT CHECKLIST	
Item	**Tick**
Larvicide chemicals	
Catch bags	
Sieve	
Ground tarpaulin	
Anemometer	
Electronic scales	
Calculator	
Pre-marked map of sites to be treated	
Tape measure	
Funnels and catch containers	
PPE	
Field treatment data record sheets	

CHECK ALL EQUIPMENT PRIOR TO LEAVING BASE

STANDARD OPERATIONAL PROCEDURE - 04: POST TREATMENT LARVAL MONITORING

PRIOR TO LEAVING BASE

Prior to leaving base ensure that all OH&S procedures are followed for working in remote/isolated areas. It is preferable that staff do not work alone in these areas.

The field operator should:

- Advise base of the exact order that sites will be visited.
- Ensure that protocols are set up regarding contact timeframes for the operator to check in with the base. These must be adhered to so that if a field operator does not contact base at any scheduled time, this can be followed up by the base.

EQUIPMENT CHECKLIST

EQUIPMENT CHECKLIST	
Item	**Tick**
Larval dippers	
Small vials with stopper tops	
Map of sites to be visited	
Notebook, labels, pens, pencils	
GPS and digital camera	
Larval data sheets (to be completed for each site)	
Mobile phone (ensure that battery is charged)	
Water pH and salinity tester	
Thermometer	
PVC boots	
Overalls	

CHECK ALL EQUIPMENT PRIOR TO LEAVING BASE

ONSITE

Advise base of arrival onsite.

PROCEDURE:
The same procedures should be followed as SOP-01 PRE TREATMENT LARVAL MONITORING with the following additions:

- Estimate level of larval activity (per metre square)
- Count and collect larval and pupa samples for post treatment emergence studies where s-methoprene has been the larvicide used.
- Record data on to the post treatment data sheet and calculate success of treatment following emergence studies.

WHEN SURVEY WORK IS COMPLETED FOR THE DAY ADVISE BASE THAT THE SURVEY TEAM IS LEAVING THE REMOTE/ISOLATED AREA AND HEADING BACK TO BASE

BACK AT BASE

Advise base that survey team has returned from the field.

- Pupae collected can be transferred to rearing trays.
- Transfer 4th instar larvae to vials containing 70% alcohol to await identification.
- It is important that the label containing the details of the sample is transferred to the new vial with the sample.
- Calculate the larval density per square metre for each site surveyed.
- Add the data collected to the database.
- Advise supervisor and if above any threshold levels (currently 100 larvae per square metre) larval treatment may be required.

STANDARD OPERATIONAL PROCEDURE - 05: ADULT MOSQUITO SURVEY

PRIOR TO LEAVING BASE

Order dry ice. Depending on the supplier this may need to be done the day before the monitoring traps are to be set. Generally 2kg of dry ice per three traps should be sufficient, however in hot weather at least 1kg per trap should be used. The efficiency of the esky used to store the dry ice must also be considered plus the temperature and the length of time taken to complete the monitoring schedule for that day. Dry ice does evaporate therefore if the operator is likely to be out in the field for a number of hours in hot weather up to 1.5kg of dry ice per trap may be required. It is preferable to slightly over estimate the amount required. Ideally the dry ice should be picked up from the supplier just before it is to be used.

Prior to leaving base ensure that all OH&S procedures are followed for working in remote/isolated areas. It is preferable that staff do not work alone in these areas.

The field operator should:

- Advise base of the exact order that sites will be visited.
- Ensure that protocols are set up regarding contact timeframes for the operator to check in with the base. These must be adhered to so that if a field operator does not contact base at any scheduled time, this can be followed up by the base.

EQUIPMENT CHECKLIST

EQUIPMENT CHECKLIST	
Item	**Tick**
Dry ice	
Eskies	
Small trowel or similar to aid filling the trap with dry ice	
Spare trap rotors	
Spare trap catch baskets, dry ice containers, motor units	
D cell batteries	
Map of sites to be visited	
Notebook, pens, pencils	
GPS and digital camera	
Trap data sheets (to be completed for each site)	
Mobile phone (ensure that battery is charged)	
Hat	
PVC boots	
Overalls	

CHECK ALL EQUIPMENT PRIOR TO LEAVING BASE

NOTE: Change batteries and ensure that they are fitted correctly. The fan should be turning in such a way that it forces air into the catch basket. As the rotor runs continuously this prevents trapped mosquitoes escaping from the catch basket.

ONSITE

Advise base of arrival onsite.

PROCEDURE:

1. Collect Dry Ice.
2. Test that the motor, light and fan are in good working order.
3. Go to site(s) to be monitored.
4. Fill container with dry ice and hang from tree or other adjacent structure.
5. Attach the motor unit underneath the dry ice container.
6. Attach the catch basket to the motor unit. Make sure this is securely tied.
7. Ensure that the base lid on the catch basket is fitted properly.
8. Turn on the switch on the motor unit and ensure it is directing air into the catch basket.
9. Hang out of public view if possible.
10. Note weather conditions and time was set on adult trapping form.
11. Recheck that motor unit is turned on and that it and small light is working.
12. Leave trap over night.
13. Collect trap the next morning, noting time collected, weather conditions and if the motor was still running. Disconnect catch container from the motor unit ensuring that no mosquitoes escape.
14. Empty remaining dry ice into the esky.
15. Place catch containers into the esky to kill the mosquitoes.

WHEN SURVEY WORK IS COMPLETED ADVISE BASE THAT THE SURVEY TEAM IS LEAVING THE REMOTE/ISOLATED AREA AND HEADING BACK TO BASE.

BACK AT BASE

Advise base that survey team has returned from the field.

- Count number of mosquitoes per catch container and identify the mosquitoes present. It is important that the mosquitoes are kept frozen. The content of each catch basket can be transferred to smaller specimen jars and stored after the jar has been labelled with the date, trap number and location of the trap site.
- If there is an excessive number of mosquitoes, weigh 200 and correlate weight to number of mosquitoes.
- Note results onto data form.
- Enter results onto database.
- Send copy of the results to Manager, Environmental Health Services. Determine if adulticide fogging will be necessary depending on mosquito numbers.

STANDARD OPERATIONAL PROCEDURE - 06: ADULTICIDE FOGGING

It is understood that a new operational procedure was implemented in 2009-10 after Occupational Health and Safety requirements were identified. This included a requirement that staff employed in fogging operations undergo training in the safe handling of pesticides. It is recommended that the new procedure be studied before any amendments or review of the relevant operational procedures is made.