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Abbreviations

BFV: Barmah Forest virus

CLAG: Contiguous Local Authorities Groups

DOH: Department of Health

EHO: Environmental Health Officer

FIMMWA: Funding Initiative for Mosquito Management in Western Australia

WNV_{KUN}: Kunjin virus

LEMA: Local Emergency Management Arrangements

LG: Local Government

MMBOP: Mosquito Management Business Operation Procedure

MoU: Memorandum of Understanding

MVE: Murray Valley Encephalitis

SoBMMS: Shire of Broome Mosquito Management Strategy

RAMSAR: Convention on Wetlands of International Importance especially as Waterfowl Habitat 1971

RRV: Ross River Virus

ULV: Ultra Low Volume (fogger)

1. INTRODUCTION

The Shire of Broome Mosquito Management Strategy (SoBMMS) provides a framework for the Shire's role and scope for the minimisation of potentially harmful mosquitoes, and so minimisation of mosquito borne diseases that affect human health. It is applicable within the Broome townsite and surrounds. The strategy is based on a continuous improvement model (figure 1) and is a component of the Local Government Integrated Planning and Reporting Framework as a form of measurement and reporting.

This document was first prepared following significant seasonal rainfall and large tides that subsequently lead to an increase in the number of mosquito borne disease cases that occurred in Broome as reported during the 2010-2011 wet season (Table 1 refers to cases from 2006-20). The 2010-2011 climatic conditions highlighted the need for an integrated mosquito management strategy to be used in the future to reduce the incidence of disease in the local population through improved control and management of mosquitoes.

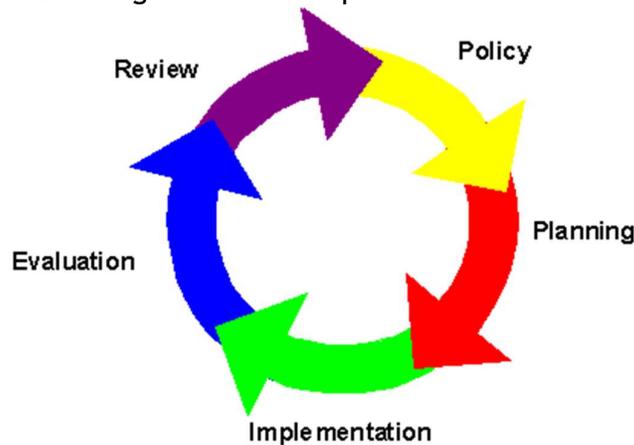


Figure 1 Continuous Improvement Model

During 2010/11 the Shire of Broome experienced elevated incidence of Mosquito Borne disease in comparison to previous (recorded) years. The number of reported cases of Ross River Virus, Barmah Forest Virus, Murray Valley Encephalitis and Kunjin Virus tends to correlate loosely with the rainfall received but other factors also influence human case numbers. The table overleaf shows rainfall and disease notifications each year since 2010-11 until 2020-21. It is important to note that total rainfall alone is not the only predictor of mosquito or mosquito borne virus activity in humans.

Table 1 Reported Cases of Mosquito Borne disease for Broome 2006 - 2021 (Values from DOH reviewed in 2021)

Year (July - June)	Total Rainfall (July - June)	Ross River Virus	Barmah Forest Virus	Murray Valley Encephalitis	Total notified human cases
2020/2021	617.2	9	6	-	15
2019/2020	580.1	24	1	-	25
2018/2019	299.4	7	1	-	8
2017/2018	1735.8	15	3	-	18
2016/2017	1109.8	80	6	-	86
2015/2016	339.6	10	6	-	16
2014/2015	470	21	4	-	25
2013/2014	878.2	57	4	-	61
2012/2013	688.1	40	0	-	40
2011/2012	611.4	28	4	-	32
2010/2011	1098.8	107	10	-	117
2009/2010	503.2	14	3	-	17
2008/2009	636.4	41	9	1	51
2007/2008	486.2	23	5	-	28
2006/2007	821.4	55	8	1	64

The Shire of Broome land area receives significant rainfall during the tropical wet season (November to March) and combined with heat and humidity, usually experiences an increase in mosquito numbers until naturally occurring pooling water has evaporated from the environment. There is recurring seasonal pooling in the wetland area behind the Broome Waste Management Facility/Lullfitz Drive including the intertidal dune area from Cable Beach up to Coconut Well as well as the Roebuck Plains wetland area on Roebuck Plains Station (see figures 1, 2 below). The Kimberley region including the Broome coast line experiences large tides especially with the equinox tides of autumn and spring. Inundation of tidal salt mangroves significantly contributes to an increase in mosquito breeding. The area is also affected by tropical lows and cyclones and localised flooding events that will provide for an increase in mosquito breeding as was evident throughout the Kimberley in early 2011.

Some species of mosquitoes common to the Broome area are nuisance mosquitoes, whereas others are known vectors (carriers) of disease including Ross River Virus, Barmah Forest Virus, Murray Valley Encephalitis and Kunjin Virus. These viruses are endemic and mosquito borne virus activity and human cases are detected every year. Elevated incidence of these diseases has the potential to impact community health, amenity, tourism and local business.

The SoBMMS will focus on the Broome townsite and the surrounding environment as this is the main population centre for the Shire. Environmental health services to remote Aboriginal communities are currently carried out by Nirrumbuk Aboriginal Corporation and Kimberley Regional Service Providers (KRSP). The Shire of Broome's environmental health team works collaboratively where practicable during times of increased mosquito breeding and elevated notifications of mosquito

borne illness to ensure common and consistent information is provided to the wider community and to complete mosquito control activities for remote communities.

Success has been evident in minimising incidence of disease in surrounding local government authorities who have implemented integrated mosquito control programs. Given a combination of environmental conditions in Broome, it is inappropriate to compare statistical data for local government authorities in the region. It is important to note the SoBMMS may assist in reducing the number of disease cases however there may be times when local environmental conditions will overwhelm the program and an excess number of disease notifications may still be reported.

The development of an effective SoBMMS requires an integrated approach, which identifies funding opportunities, contemporary and science-based interventions, and staff resources. It is important to note two very important components to the plan:

- No minimisation (or elimination) program will kill all mosquitoes. As such this document is considered a ‘management program’ and not a control program. This plan is not a definitive answer and significant work will need to be completed to achieve desired results.
- The program will only be as effective as the resources it receives.

Type, extent and duration of any intervention will be proportionate to the significance of the mosquito and disease problem, the resources available at the time and the additional resources which can be liberated to complement the actions. It is also important to consider the relative costs, including environmental costs of implementing this strategy versus the cost to the community and local business of increased disease case notifications (see table 1).

2. PURPOSE

The purpose of this document is to ensure timely and effective interventions that identify and mitigate mosquito and mosquito borne virus risks, with minimal secondary impacts on the environment to assist in protecting human health and Broome’s lifestyle, economy and amenity for residents and visitors. It also provides a reference for the community for information on mosquitoes, mosquito borne viruses and the Shire’s role in mosquito management

3. RISK ASSESSMENT

In accordance with the Shire of Broome’s risk identification planning and control matrix, the impact of mosquitoes on the health of the community is identified as a high risk (likelihood of occurrence and major consequences). This identified high risk requires urgent management attention and necessitates an action plan.

		A	B	C	D	E
		Negligible	Minor	Moderate	Significant	Severe
E	Very Likely	Low Med	Medium	Med Hi	High	High
D	Likely	Low	Low Med	Medium	Med Hi	High
C	Possible	Low	Low Med	Medium	Med Hi	Med Hi
B	Unlikely	Low	Low Med	Low Med	Medium	Med Hi
A	Very Unlikely	Low	Low	Low Med	Medium	Medium

Figure 2 Risk Matrix

4. STRATEGIC IMPLICATIONS

In accordance with the Shire of Broome Strategic Community Plan, this Mosquito Management Strategy addresses the Shire’s aspirations of:

People

We will continue to enjoy Broome-time, our special way of life. It’s laid-back but bursting with energy, inclusive, safe and healthy, for everyone.

Place

We will grow and develop responsibly, caring for our natural, cultural and built heritage, for everyone.

Prosperity

Together, we will build a strong, diversified and growing economy with work opportunities for everyone.

Performance

We will deliver excellent governance, service and value, for everyone.

5. STATUTORY FRAMEWORK

The following legislation is applicable to the management of mosquitoes:

- 1.1.Public Health (Miscellaneous Provisions) Act 1911
- 1.2.Water Act 2007 (Cwlth)
- 1.3.Environmental Protection Act 1986
- 1.4.Shire of Broome Health Local Laws 2006
- 1.5.Occupational Health and Safety Act 1984
- 1.6.Health (Pesticides) Regulation 2011
- 1.7.Environment Protection and Biodiversity Conservation Act 1999 (EPBC)

The Shire of Broome is responsible for action to be taken to protect public health as directed from time to time by the Western Australian Department of Health's Executive Director, Environmental Health.

6. MOSQUITO ECOLOGY

The mosquito life cycle is composed of four distinct stages of growth: egg, larva, pupa and adult.



Figure 3 Mosquito lifecycle

Following emergence from pupa stage to adult, the female mosquito will go in search of a 'blood meal' as blood protein is necessary for egg development. The blood source will depend on species' preference and will usually include a variety of mammals, including humans, and bird species.

Mosquito breeding varies in characteristics and location depending on the species. The female mosquito will select the larval habitat depending on physical and chemical parameters of the site including the water type. For example, fresh, salt, brackish and polluted waters are all utilised by different mosquito species.

Eggs are laid in a variety of size, number and location. Depending on the species of mosquito and the local climatic conditions, it can take from 4 days to 3 weeks for mosquitoes to complete their lifecycle. Broome's hot humid climate can enable mosquitoes to complete the aquatic part of their lifecycle in a number of days, and the adult lifespan is around 2 - 3 weeks.

Understanding of the lifecycle patterns of particular mosquito species allows for targeted control and management of problem mosquitoes.

7. HEALTH IMPACTS OF MOSQUITOES IN THE KIMBERLEY

In addition to the annoying and sometimes painful 'bite' of a mosquito, these insects are capable of spreading disease to humans. Mosquitoes act as transmitters or 'vectors' of pathogens or parasites. There are four mosquito borne diseases in the Kimberley include:

Ross River virus (RRV) and Barmah Forest virus (BFV)¹

These are the most common mosquito-borne viruses causing human disease in Western Australia (WA).

¹ The following information on the four mosquito borne diseases is sourced from the WA Department of Health

The diseases caused by infection with these viruses are known as RRV disease and BFV disease. The two viruses have similar life cycles and cause similar symptoms in people. In nature, RRV and BFV are passed back and forth between animals and mosquitoes. The only way humans can catch the disease is by being bitten by a virus-carrying mosquito.

RRV and BFV can occur anywhere in WA when conditions are warm enough for the viruses to be active and wet enough for the breeding of mosquitoes. In the northern half of WA, it is warm enough at any time of the year, whenever heavy rainfall or unusually high tides occur. Generally the risk is greater during and just after the wet season.

People living, camping or recreating within 3-5 km of saltmarshes, estuaries, tidal rivers and freshwater wetlands are at a greater risk of RRV and BFV infection than people living further away.

Symptoms of RRV and BFV diseases

The incubation period (the time between being bitten by an infected mosquito and becoming sick) for RRV and BFV diseases varies from 3 to 21 days, but is normally 7 to 14 days. During the incubation period, it may be possible for humans to pass the virus back to mosquitoes that bite them.

RRV and BFV cause symptoms in fewer than 1 in 3 people bitten by an infective mosquito.

Symptoms vary from person to person, but include:

- painful and/or swollen joints
- sore muscles
- aching tendons
- skin rashes
- fever
- tiredness
- headaches
- swollen lymph nodes.

Less common symptoms include:

- sore eyes
- sore throat
- nausea
- tingling in the palms of the hands or soles of the feet.

Fever, nausea and skin rashes usually disappear within the first 2 weeks of illness. Joint, muscle and tendon pain may last much longer and can be distressing. People also often experience severe tiredness. Severe symptoms or those that last a long time can cause emotional distress or depression and affect family, social and work relationships. Symptoms eventually lessen with few or no long-term effects. It is not possible to predict how long a person will take to fully recover from either disease. Some adults recover within 2 to 6 weeks of being infected, while others will still be unwell after 3 months. In rare cases, symptoms can persist for up to a year or more.

Because the symptoms may be similar to some rheumatic diseases or other viral diseases, a specific blood test organised by a doctor is the only reliable method of diagnosis.

Murray Valley encephalitis and Kunjin disease

Murray Valley encephalitis (MVE) virus and West Nile virus Kunjin strain (WNV_{KUN}) are two mosquito-borne viruses that occur in the north of Western Australia (WA). The disease caused by these viruses was previously known as Australian encephalitis but is now referred to as Murray Valley encephalitis (MVE) and Kunjin disease (WNV_{KUN}), respectively.

MVE is a rare but potentially fatal disease characterised by severe neurological symptoms, including encephalitis. WNV_{KUN} is a milder febrile illness but can occasionally be associated with encephalitis. In nature, MVE virus and WNV_{KUN} cycle between mosquitoes and water birds, while people are only incidental hosts. The common banded mosquito, *Culex annulirostris*, (right) is the main vector of both viruses in WA, with water birds, particularly herons, considered to be the major vertebrate hosts.

MVE and WNV_{KUN} viruses occur in the northern two thirds of WA only. The risk of infection is highest if you are travelling to the Kimberley and Pilbara regions during or shortly after the wet season. The viruses are occasionally active in other regions, including the Gascoyne, Goldfields, and Midwest.

MVE virus and WNV_{KUN} can be active during and in the months following heavy wet season rains. The highest risk months are February to April, but virus activity can commence as early as December and extend as late as July in very wet years.

MVE virus and WNV_{KUN} activity is more likely to occur near swamps, floodplains, river systems, irrigation areas and major dams where both mosquitoes and water birds are present.

Symptoms of Murray Valley encephalitis

MVE virus causes disease symptoms in approximately 1 in 1000 people bitten by an infective mosquito. Most people remain asymptomatic and do not develop any signs of disease. Once an individual has developed antibodies to MVE, it is unlikely that they will be reinfected in the future.

The incubation time for MVE varies from 5 to 15 days, but symptoms usually appear within 8 to 10 days after becoming infected. Whilst MVE is rare, it is important to note that severe cases can lead to coma and death. In young children, fever may be the only early sign of infection. Patients with the severe form of MVE get worse very quickly and present with confusion, worsening headaches, increasing drowsiness and in some cases, seizures. People with suspected MVE should be taken to the nearest hospital without delay.

Table 2 Summary of MVE symptoms in adults and children

MVE symptoms in adults and older children	MVE symptoms in younger children
Fever	fever
Drowsiness	Floppiness
Bad headache and stiff neck	Irritability
Nausea	Drowsiness
Muscle tremors	seizures
dizziness	

Symptoms of Kunjin disease

WNV_{KUN} causes similar but generally less severe disease symptoms compared to MVE. While the majority of infected individuals are asymptomatic, those people that do develop symptoms of WNV_{KUN} can present with encephalitis, requiring immediate medical attention.

Other mosquito borne diseases of concern for the Kimberley region include:

Dengue Fever

Currently, Western Australia is ‘dengue free’ due to the known vector mosquito, *Aedes aegypti*, having been eradicated from Western Australia for approximately 40 years. This species of mosquito has colonised in Northern Queensland and seasonal outbreaks of Dengue Fever in Cairns and Townsville are now common.

Given international shipping movements at Broome’s port and international flight arrivals at the airport there is a risk of *Aedes aegypti* being re-introduced in Western Australia. With international travel and in particular to and from Bali, the risk of importing Dengue Fever is also high and, as is the case in far north Queensland, local transmission of Dengue Fever could eventuate.

Dengue is regarded as a debilitating infection with short duration and a high attack rate but low fatality rate. There is no cross immunity to the 4 strains however there is an enhancement reaction, an increase in severity of symptoms, following a second infection with a different strain of the Dengue virus. There are 2 clinical forms being Dengue Fever which most patients fully recover from, and Dengue Haemorrhagic Fever which is a severe infection involving excessive bleeding internally and from the nose, mouth and gums. It may be followed by severe shock and can be fatal.

While the four endemic viruses have a non-human reservoir, the normal cycle of infection for Dengue Fever is human-mosquito-human. This mosquito species is a container breeding mosquito that flourishes in conditions of poor housing, overcrowding, inadequate sanitation, accumulated rubbish and tyres, especially in tropical and subtropical areas. The mosquito rests and feeds indoors, biting during the day and the female mosquito feeds almost exclusively on humans. Minimising container breeding ‘habitat’ is important to keep mosquitoes from establishing in our environment. The WA Department of Health undertakes monitoring for the known Dengue vectors to keep Western Australia ‘Dengue Free’.

8. MOSQUITO BREEDING SITES

There are a number of known areas of significant mosquito breeding that creates a high risk to the health of the community from mosquito borne disease (See also Figure 4 and Figure 5 below). The majority of Broome's known breeding areas are large, inaccessible areas of seasonal pooling water. Known sites include:

Wetland Areas

These areas include the inter-dune area from Cable Beach to Coconut Wells and wetland areas behind the current Waste Management Facility and Roebuck Plains. These areas comprise large, naturally occurring areas of pooling fresh/brackish water from seasonal wet season rainfall. Seasonal rainfall provides these large, vegetated expanses with an environment conducive to fresh or brackish water breeding mosquitoes, most noticeably *Culex annulirostris*. This species of mosquito is a known vector of RRV, BFV, MVEV and WNV_{KUN}. Combined with the large population of wallabies and other marsupials as well as water birds, these factors can lead to significant outbreaks of disease. This was the case during the 2011 wet season where by the end of March 2011, approximately 100 cases of RRV and 2 BFV notifications had been received for the Broome area.

Tidal mangroves and saltmarsh (Dampier Creek, Roebuck Bay)

Broome townsite is located adjacent to a large expanse of tidal mangroves and saltmarsh that fringes Roebuck Bay. This area provides an optimum breeding environment for common salt water breeding mosquitoes including *Aedes vigilax* (*saltmarsh mosquito*). This species of mosquito is very common in Broome especially following high tide events. It is an aggressive biter that will bite all hours of the day. This is a known vector of RRV and MVE. *Aedes vigilax* mosquitoes lay their eggs in mud or sand on the edge of the mangrove area. These eggs can lie dormant for up to 12 months until inundated with water from a high tide that then instigates the breeding cycle. There is evidence virus can remain in the eggs and once emerged as adults can be a vector of disease.

Control of the tidal mangrove areas is extremely problematic and economically prohibitive due to the significant size and inaccessibility of the area. A southern portion of the mangrove from the Broome Bird Observatory heading south is a protected Commonwealth listed RAMSAR wetland. This has ramifications for potential control methods as approval for physical and chemical control options need to be approved by the Commonwealth Government.

The area not identified as a RAMSAR site, however, is the area closest to the townsite and therefore more of a risk to the community. Investigation into control options for this area may be beneficial.

As this species of mosquito is an aggressive biter, the Shire experiences an increase in calls from concerned residents during times of increased *Aedes vigilax* numbers when climatic conditions are favourable. It is important to time community education and control to coincide with high tide events. This raises community awareness of the potential risk of increase mosquito numbers following seasonal high tide, in particular, the equinox tides.

Water Reuse Scheme

The Water Corporation and Shire of Broome managed waste water reuse system irrigates four sites within the Broome townsite including the golf course, Haynes Oval, St Mary's school oval and the Broome Recreation and Aquatic Centre ovals. This program that uses recycled water to maintain regularly used community recreation areas. However, proper management and operation of this system needs to be maintained to ensure breeding is not occurring in infrastructure and over watering in times of heavy rainfall does not result in areas of nutrient rich pooling water in community accessible location. Regular inspections of the on-site holding tanks at Haynes and BRAC ovals and St Mary's school are required to monitor and manage mosquito breeding.

Approvals from State Government agencies require this system to be switched off in times of heavy rainfall. Communication between the Shire of Broome and Water Corporation needs to be maintained to ensure this system is not creating a risk to community health by creating mosquito breeding sites on our popular community recreation areas.

The use of treated, reclaimed effluent is due to be replaced by supply of untreated bore water by no later than December 2022. This will result in a significant reduction of mosquito breeding potential of the tanks.

Broome Townsite

Through surveillance of the townsite, the Shire of Broome has highlighted a number of areas of known and potential mosquito breeding sites that require monitoring during the wet season until such time as water has evaporated from the environment. A range of mosquito species is common in this area including container breeders, salt water breeders namely *Aedes vigilax*, from nearby mangroves and freshwater breeding mosquitoes including *Culex annulirostris*. Weekly monitoring of the sites highlighted below is indicated however is required where standing water conducive to mosquito breeding persists for greater than four to five days (the length of the aquatic phase of the mosquito lifecycle). A mix of adult mosquito trapping and larva dipping is performed.

- Industrial areas with specific focus on Blue Haze: due to proximity to tidal mangroves and Roebuck Plains. Inspection of onsite wastewater systems, drainage and any water holding containers.
- Reuse water use sites including Broome Recreation and Aquatic Centre ovals, Golf Course, Haynes Oval and Saint Mary's College.
- Tidal mangroves (Broome Road).
- Monitoring of Shire drainage systems: inspection of low areas or areas holding water.
- Corner of Broome Highway and Gubinge Rd: this poses a small mosquito breeding threat however due to steep sides preventing vegetative growth for mosquito harbourage in shallow water has lead to no larvae having been detected in this area. Road runoff contaminated with surface oils and hydrocarbons may also compromise breeding. This site including the stormwater retarding basins needs to be monitored as it has the potential to act as a large mosquito breeding threat if it is not maintained.

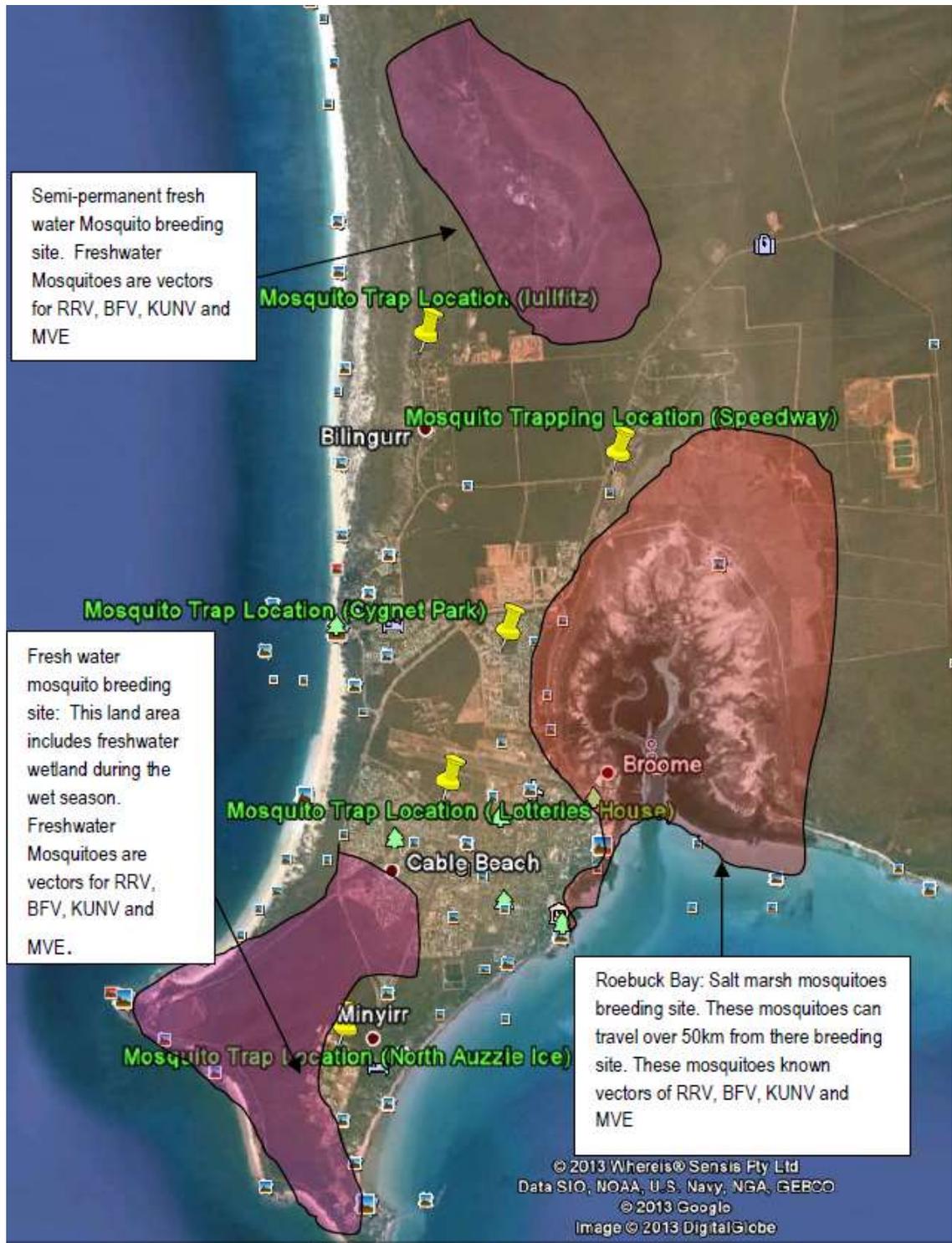


Figure 4 Mosquito breeding sites in proximity to Broome townsite



Figure 5 General area of Roebuck Plains where tidal and flood waters provide breeding locations for mosquitoes

9. MOSQUITO MONITORING

Adult Mosquito Trapping and Identification

A comprehensive adult mosquito trapping program is conducted by Shire environmental health officers as this action will give an indication of the numbers and species of mosquitoes in and around breeding sites and will give an overall view of mosquito breeding, indicating potential for disease outbreak.

The Shire's environmental health officers take a flexible approach to adult mosquito traps in accordance with climatic conditions, tidal movements, wind behaviours and anecdotal reports of excessive mosquitoes. Ideally Adult mosquito traps are set weekly from February - April and monthly from May - January depending on the other factors noted. Six traps are to be set with suggested locations being:

- Broome Speedway
- End of Lullfitz Dr
- Bureau of Meteorology office (Gus Winkel Drive)
- Roebuck Plains
- BRAC/Lotteries House
- Cygnet Park (Roebuck Estate)
- Complaint location or other town locations

All trapped mosquitoes will be identified and counted with results recorded on trapping sheets and filed for later comparison.

Larval Surveillance

A larval surveillance program is also conducted by the Shire to monitor larvae abundance and species (on occasion) in areas of pooling water including drains, tidal areas and flood plains. Residences and commercial properties can also be

assessed if there is suspicion that there is significant standing water which is conducive to mosquito breeding. These include for example, the tyre retailers in the town site who enable Shire sampling after rain events to support better control.

Larval Surveillance is conducted weekly from January - April or following rainfall and major tidal events. Reuse water tanks are monitored all year round. Sites for monitoring include:

- Recycled water irrigated ovals and golf course
- Old Broome drainage systems
- Broome North drainage systems
- 'Six Seasons' development drainage system
- Drainage sump on the corner of Gubinge Road and Old Broome Road
- Samphire/mangrove area on Old Broome Road adjacent to Broome Airport
- End of Lullfitz Drive
- Broome Waste Management Facility
- Ad hoc locations if suspected of providing harbourage

Following identification of areas breeding mosquitoes, an appropriate control method is undertaken where possible. Follow up inspections are required following treatment to assess results.

Pre and post treatment larval surveillance results are to be recorded on Larval Surveillance Sheet and filed for later comparison.

10. DISEASE MONITORING

MVEV and WNV_{KUN} activity in the North West of Western Australia is monitored by detecting seroconversions from blood samples collected from sentinel chicken flocks. This involves Shire of Broome environmental health staff taking a blood sample from the sentinel chickens. Seroconversions in sentinel chickens provide an early warning of virus activity in the environment at which times the WA Department of Health and Shire of Broome issue community alerts via media releases and social media posts.

The program has University of Western Australia animal ethics approval and the field program is coordinated by the WA Department of Health as well as undertaking analysis of samples and providing monthly reports. There are 2 chicken flocks (of 12 chickens each) located in the Shire of Broome, these being Broome town, Roebuck Plains Station. The staff at Roebuck Plains Station maintain a sentinel flock which the Shire of Broome collects samples from, and Nirrumbuk Aboriginal Corporation maintains and samples the Broome town flock.

Blood samples are collected fortnightly during the wet season (when viral activity is more likely and more intense) and monthly during the dry season.

Shire of Broome environmental health staff are also notified of human cases of mosquito borne viruses in Shire residents. This confidential notification triggers contact with the affected person for the administration of a follow up questionnaire. This questionnaire is designed to assist in identifying the most likely time/place of exposure to the mosquito-borne virus. The Environmental Health Directorate within the WA Department of Health uses this information to define

high risk regions and direct mosquito management priorities throughout WA. Information collected from this questionnaire will remain completely confidential. It will be used solely for the purpose of guiding the WA Department of Health to prevent the spread of mosquito-borne diseases. No information that identifies individuals will be made available outside of the Department of Health.

11. MOSQUITO AND DISEASE MINIMISATION

Mosquitoes are a ubiquitous and essential part of the ecosystem. Their elimination is neither possible nor desirable as they fill essential roles in the system including as pollinators of plants and as food for other invertebrates. Furthermore, of the perhaps 30 species found in the region, only a small number of species bite humans and a smaller number can carry human disease-causing organisms.

There is no vaccine or immunisation for any of the four common mosquito-borne viruses and nor is there any effective treatment. Mosquitoes will be prolific in the wet season and around the time of the equinox tides (late September and late March), and at these times easterly winds will bring mosquitoes in from salt marsh breeding areas around the low-lying Roebuck plains making effective control practically impossible.

Management measures need to reflect these realities. They are categorised into the four following measures.

Cultural Control

The Fight the Bite program promotes cultural controls including the three key messages:

Cover Up - wear light coloured, loose-fitting long-sleeved shirts with long trousers when outdoors;

Clean Up - remove items from your yard which can hold water in which mosquitoes can breed. This can include filling plant pot saucers with sand and being mindful that some plants such as bromeliads can hold sufficient water for sufficient time for mosquito larvae to pupate and emerge as adult mosquitoes; and removing containers which might otherwise hold water, such as old car tyres and children's toys, and ensuring ornamental ponds and pet water bowls do not enable mosquito breeding; and

Use repellent - repellents containing DEET or picaridin are proven to be effective. Pyrethrum compounds can also be effective in repelling mosquitoes but are subject to dispersion by wind.

In addition, the State wide Fight the Bite program has a range of resources available; and media releases are distributed when virus activity is detected.

Additional measures can include reviewing development applications and subdivisions to ensure that Developers are required to submit Mosquito Management Plans for new developments. Any such developments are to be designed and constructed in accordance with the WA Department of Health's 'Chironomid Midge and Mosquito Risk Assessment Guide for Constructed Water Bodies'.

Consideration needs to be given to planning residential developments that encroach on known breeding areas that are inhabited by vectors including wallabies and waterbirds. Whilst it is evident these areas of land are necessary for

development of additional residential housing areas; mosquito control and prevention of breeding must be planned in the development of these sites.

Physical Control

Physical control or modification of habitats can take the form of filling low lying land and depressions, draining inundated areas, improving existing drainage systems. This action can take the form of filling depressions on ovals associated with the effluent reuse areas, rectifying low areas in drainage systems, residents removing unused or poorly maintained swimming pools and fish ponds etc.

Physical control methods are the preferred control method as they are generally more permanent options of mosquito control and reduce the need for chemical use in the environment.

Mosquito breeding generally occurs in still water and the movement generated by wind on open water, or by tidal action filling and emptying wetlands can inhibit breeding. It is sometimes possible to design and construct channels (runnelling) in low salt marsh or swamp areas such that the receding tide moves with a pace and drains the land such that mosquitoes can no longer breed.

Chemical Control

Chemical controls involve the application of chemical to control or destroy either larvae or adult mosquitoes. Chemical control includes:

Larviciding

Destroys mosquito larvae or prevents larvae from forming into functioning adult mosquitoes. Larvicides take the form of liquid, granule, pellets or briquettes and can be applied by hand or chemical spreading equipment. Larviciding is considered an effective form chemical treatment as it prevents the adult mosquito from emerging and hence reducing the impact of mosquitoes. A number of products available on the market do not impact the environment and enable the larvae to continue its role in an aquatic food chain.

Larviciding is considered an effective treatment option for breeding areas in the townsite area including drain networks. However, during the wet season, water pools in large, broad acre areas that are inaccessible prevent treatment with larvicides. It is for this reason the Shire may need to rely on adult mosquito control, adulticiding, to destroy mosquitoes flying from these areas into populated areas.

Adulticiding

Includes 'fogging' or 'misting' adult mosquitoes using thermal foggers or Ultra Low Volume (ULV) misters to pump out a fine fog or mist that destroys mosquitoes on the wing at the time of treatment. There is limited residual effect however timed application when target mosquitoes are most active will reduce mosquito numbers and prevent them from continuing their breeding cycle for short periods. When considering adulticiding programs, it must be highlighted that the product used will kill other insects on the wing at the time of application including bees and natural mosquito predators such as dragonflies. Adulticiding can only be completed in favourable weather conditions and is not as effective in windy, rainy conditions.

Whilst adulticiding may not be considered to be an as effective form of chemical control, it is a consideration as an emergency option, where mosquito numbers are high, climatic conditions are conducive to optimal impact, breeding sites are active and human and/or sentinel chicken notifications indicate that the virus is active in the environment. Adulticiding has some short-lived benefit in reducing adult mosquito numbers when disease transmission is imminent.

In order to undertake adulticiding, the Shire of Broome maintains a ULV fogger and chemical stocks for this purpose. The ULV fogger has occasionally been used as a management tool only when the risk to the health of community far outweighs the minimal environmental risk.

ULV adulticide fogging is an indiscriminate control measure and the compounds used will also kill other flying and non-flying invertebrates such as dragon flies, bees, spiders etc. The compounds are also toxic to fish for example in ornamental garden ponds.

Adulticiding also includes the application of residual surface sprays to the exterior of buildings. These sprays work by destroying adult mosquitoes and other insects that contact the spray on the surface of buildings. These products have a residual of up to 6-8 weeks and can be effective for the treatment of mosquitoes at remote sites or around Shire Buildings including recreation centres, public toilet blocks and public buildings.

Biological control

Specific biological controls are available to control mosquito breeding under certain circumstances. These controls contain either *Bacillus thuringiensis israelensis* or *Bacillus sphaericus*. These are dispersed in water in which mosquito larvae are present. The larvae ingest the bacteria which destroys the digestive system thus killing the larvae before they can mature to adults. Generally these are rotated with chemical control measures and used only intermittently to reduce the chance of reduced efficacy over time through resistance.

12. RESOURCE CONSIDERATIONS

This plan has identified a number of actions to be undertaken for mosquito management and resourcing these commitments is an ongoing consideration. For the plan to function and achieve the best results, a collaborative approach between all parties needs to be established. This will include Council, other Shire departments, state government agencies and private and commercial property owners. Mosquito programs can necessitate large amounts of both financial and human resources in a somewhat cyclical manner associated with wetter wet seasons and herd immunity in reservoir animals.

Budget requirements can vary year on year in advance for such programs as it to some degree unpredictable.

1.1. Financial Resources

From a financial viewpoint it is necessary to budget for known and probable activities that are anticipated, for example, a reasonable amount of chemical to enable larviciding. A nominal budget will be completed prior to each financial year

to enable the purchase of some larvicide and adulticide as well as monitoring equipment.

However, there will be situations during disease outbreaks or following a disaster where quick access to funds will be required to respond to such events. Support from Council is imperative to ensure the Shire is resourced appropriately to respond to such situations, assisting to minimise harm to the health and safety of the community during disease outbreaks. The Chief Executive Officer and Shire President will be consulted during these events to approve release of funds where applicable.

CLAG funding (Contiguous Local Authority Group)

Since 2014, the Shire of Broome CLAG comprising the Shire of Broome and the WA Department of Health is supported by a memorandum of understanding (MOU) between the Shire and the Department. Through this group, funding can be sought yearly for 50% of the agreed cost of the annual mosquito management needs of the management program. To be considered for this funding, the Shire is invited in May/June each year to submit a proposed budget based on past and predictive expenses for approval.

FIMMWA funding (2013-2017)

The Funding Initiative for Mosquito Management in Western Australia (FIMMWA) provides additional funding to Local Governments (LGs) to enhance mosquito management and control in Western Australia (WA), for the benefit of public health. FIMMWA aimed to provide additional funds for the purchase of goods/services outside the scope of the existing CLAG scheme. This program has now ceased.

1.2. Human Resources

Having identified trained staff to assist in minimisation efforts as required is vitally important for the success of the program.

In most cases the need to undertake large larvicide or adulticide treatments will be dependent on the weather conditions experienced at that time. Unfortunately, it is the type of work that can't be accurately programmed into work schedules or be completed at a specific time. It is more of a case of 'all hands on deck' when the need arises which can be frustrating and difficult especially when other priorities have been set.

The tasks of monitoring, surveillance and control are the responsibility of the Shire's Environmental Health Services however, during times of significant mosquito breeding and disease outbreaks, assistance may need to be sought from other departments including Rangers, Engineering Services, Parks and Gardens team and commercial pest control operators may be considered. The Department of Health's Medical Entomology section in Perth can be called upon for guidance and advice. Ideally, an additional Environmental Health position would be largely beneficial to implement this plan, in the form of a Technical Officer. Previously the Shire of Broome was successful in complementing the Environmental Health Services team with a Mosquito Technical Officer for a period of 3 months (February

- April). The role of this person was to provide expert advice and training to the existing Environmental Health Services team and bolster resources during the wet season (January- May).

The Shire of Broome shall ensure that enough EHOs have undertaken the DoH mosquito management course which is conducted every two years teaching skills and competencies required under the *Health (Pesticides) Regulations 2011* and covers (DOH,2014):

- Basic mosquito ecology;
- Principles of integrated mosquito management;
- Surveillance/monitoring techniques;
- Collection and recording of mosquito samples;
- Standard operating procedures for equipment;
- Safe storage, handling and application of chemicals/larvicides in accordance with product labelling and MSDS;
- Use of appropriate PPE in accordance with product labelling, MSDS and environmental conditions;
- Calibration techniques;
- Information technologies/geographical information systems;
- Budget management;
- First aid.

The Shire of Broome shall ensure all that all employees:

- Have received appropriate training in the type of pest control work required by Shire of Broome in the safe and effective use of pesticides
- Are adequately supervised by a person who holds appropriate qualifications in this area
- Are provided with well maintained equipment and PPE that is appropriate to the pesticide being used
- Understand their obligation and rights under the Occupational safety and health legislation
- Adopt safe practices at the work site, including the use of appropriate Occupational Safety and health checklists and procedures
- Comply with all applicable legislation, policies, codes and the Local Government Authority pesticide use plans.
- If an external contractor is used to undertake the application the Mosquito controls and pesticide use, then a Memorandum of Understanding (MoU) is to be negotiated so as the contractor complies with Shire regulations

1.3. Equipment, resources

In the event of an emergency or when triggers are met, the Shire of Broome has the ability to mobilise the Cougar Fogger to control Mosquitoes on the wing. Sufficient supplies of chemicals are kept in stock as outlined in BOP.

The Shire also retains for applying residual surface spray to relevant buildings, and structures

13. REVIEW OF PLAN

This plan is based on a continuous improvement model (**Figure1**) and is subject to regular review to ensure that implementation techniques are documented and reflect current practises and procedures. This plan is to be reviewed annually prior to common mosquito breeding 'season'. The monitor and review process has been ongoing, includes completed tasks in **Table 2**. A Mosquito Management Business Operating Procedure (MMBOP) was developed in 2015 to complete the strategy. The results from 2006 through to results from 2014 continue to show a correlation between rainfall and disease incident rates. This supports the need to continue monitoring and educating residents and visitors to lower the risk to vector borne disease within the community.

14. EMERGENCY MANAGEMENT

In emergency situations where there is a Human Epidemic that is related to Mosquito borne disease this strategy can assist to make effective decisions based on SOB Local Emergency Management Arrangements (LEMA). LEMA would require an incident controller (IC) to be part of the Department of Health (DOH) and that the Shire works under the directive of such body and react under part 3 Response LEMA.:

As first responders the LGLO's key responsibilities are to:

- Make contact with DOH or Controlling Agency Incident Controller;
- Represent the local government at all Incident Support Group (ISG) meetings;
- Provide the IC with timely information on local issues and key factors affecting response activities;
- Provide the IC with a copy of the Local Emergency Management Arrangements;
- Identify vulnerable groups within the local government area;
- Provide information relating to community evacuation, welfare centres and community safe places.
- Provide Local government response activities;
- Provide Local government impact assessment (if known)
- Provide Local government resource status;
- Significant issues.
- Coordinate local government resources;

Coordinate the transition from response to recovery on behalf of the local government in partnership with the Local Recovery Coordinator.

15. RECOMMENDED ACTIONS

Table 3 Action list

Action	Frequency	Responsible Officer	Comment	Status
Monitoring of known mosquito breeding sites plus locations of complaints received for that week.	Weekly (subject to rain patterns and tides) Jan - Apr	Environmental Health	Dipping of known and suspected breeding sites recording numbers and stage of cycle. Adult trapping.	Adult Trapping and Larval dipping Program established.
Larvicide application where possible to breeding sites identified through surveillance.	As needed Wet season	Environmental Health with assistance from Engineering	Application of granular or briquette larvicide products as appropriate. Use of aquatain in reuse tanks.	Fortnightly application of reuse tanks with Larvicide and application to breeding sites when needed
Annual survey of industrial areas for evidence of mosquito breeding.	Annually March	Environmental Health	Check for evidence of breeding and discuss removal of breeding sources with property owner/occupier	Monitoring and education Program established. Commercial tyre retailers surveyed after rain events
Annual drainage maintenance program - include evidence of mosquito breeding or areas of pooling water/low points.	Annually Wet season	Engineering	Determine if drain can be improved to prevent pooling water or need for ongoing larvicide treatment. Maintenance to include herbiciding or physical removal of invasive vegetation.	Ongoing program established. Liaison with Engineering and EHS as required
Health Promotion -engage local artist or communications company to generate locally	Initially generate resources.	Environmental Health	Combination of poster, flyers stickers etc.	Health Promotion program established

appropriate mosquito information communication for education programs.	Distribute each season as required.		Use of graphics instead of wording. Budget \$3000 to complete this action	between EHS and DOH to educate community 2015 "Fight the Bite" campaign is ongoing.
Mosquito management plans to be incorporated into planning process for large scale developments. Drainage system design to consider mosquito breeding in concept phase.	As required.	Environmental Health, Planning, Environment and Engineering. Developers	Mosquito management plans to be submitted for approval for future developments. Developments to incorporate the WA Department of Health's 'Chironomid Midge and Mosquito Risk Assessment Guide for Constructed Water Bodies' document.	Policy developed between EHS, Planning and Engineering departments requiring all new developments to have Mosquito Management plan.
Distribute Health Warnings to Shire staff, and community stakeholders.	As required or when DOH issues media warnings, etc.	Environmental Health.	Distribute Health Warnings to staff and community stakeholders as information is received and local monitoring indicates disease risk. Shire social media also used to promote mosquito awareness and disease warnings	Established BOP with Media program when set parameters are breached
Investigate and implement findings of physical control methods of natural breeding areas.	As opportune	Environmental Health and Engineering	Monitor opportunities for physical control methods including depression infilling and draining levelling.	Completed, strategy now in place in Conjunction with Engineering.
Maintenance of mosquito control plant including misters and ULV fogger	biannual	Environmental Health, Fleet management team	On average fogger is not used in each year	Equipment is operational
Budget for and purchase chemical and equipment for mosquito control.	2011-12 budget	Environmental Health DOH and Shire CLAG	Ensure there is suitable budget to purchase a nominal amount of chemical and monitoring	Ongoing budget established and monitored in line with CLAG requirements

			equipment to ensure the Shire is 'cyclone ready'.	
Equipment and Chemical Storage Shed	2015	Environmental Health and Engineering DOH and Shire CLAG	An equipment and chemical storage shed is secured at the Shire's Depot.	Enclosed safety ladders for reuse tanks have been installed.
Monitor tide chart and rainfall to time release of information to the community	Monthly or more often after rain/tide events	Environmental Health	Monitor tide chart and rainfall (with guide >117mm leading to RRV outbreak) to time release of information to the community regarding potential increase in mosquito numbers and risk of disease.	Strategy in place for media campaign to coincide with breach of set parameters to alert community members
Liaise with Nirrumbuk Aboriginal Corporation to ensure fortnightly chicken bleeding is completed in the Broome town and Roebuck flocks. Community flocks to be monitored by Nirrumbuk.	As required.	Environmental Health.	Ensure fortnightly chicken bleeding is completed to provide an early warning for presence of MVEV and WNV _{KUN} in the environment.	Co- operation established and information shared to ensure support is available between groups
Collaborate with Nirrumbuk Aboriginal Corporation for mosquito management activities in remote communities.	As required and agreed	Environmental Health	Subject to resource availability	Informal arrangement
Document and complete disease notifications as received from Kimberley Population Health Unit.	As received.	Environmental Health.	Document and complete follow up interviews of disease notifications as received from KPHU. Questionnaire completed subject to	Procedure established with recorded information in Synergy

			competing priorities and ease of contacting identified cases.	
Commitment from Council to access funds quickly for mosquito control following disaster events or disease outbreaks.	September 2011 Ordinary Council Meeting Strategy adopted	Environmental Health	Council support to enable quick access to funds by Environmental Health Services for mosquito control during a disease outbreak. CLAG requires that a trust fund is held by the Shire for this purpose	Emergency management plan established in line with Shire policy
Apply to the Mosquito Control Advisory Committee for CLAG funding	Annually in July	Environmental Health	Funding to subsidise 50% of cost agreed mosquito management resources.	CLAG group ongoing
Review Mosquito Management Strategy	Biennially October-November	Environmental Health	Review plan to reflect current practise and procedure.	Monitor and review conducted on biennial basis

2. REFERENCES

Department of Health (DoH), 2014. *A guide to developing a mosquito management plan for Local government part A&B*. Government of Western Australia. Perth

Department of Health (DoH), 2009 *A guide to the management of pesticides in Local government pest control programs in Western Australia*. Government of Western Australia. Perth