Redbank Mine Mosquito Assessment

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Centre for Disease Control
Northern Territory Department of Health and Families
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Study undertaken on behalf of VDM Consulting EcOz for Redbank Mines Ltd

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Executive summary

The Redbank Copper operations are located in the Northern Territory, 30km west of the Queensland border on the Borroloola to Burketown road and 80km south of the coast of the Gulf of Carpentaria (Redbank Mines Notice of Intent April 2008) (Figure 1). The Redbank area has been a site of copper mining and ore concentration since its discovery in 1916, with current operations consisting of a heap and vat leach extraction process. The proposed operations are planned to be expanded to mine 5 separate deposits (NOI April 2008).

Mine sites have the potential to create or exacerbate mosquito breeding, potentially from the creation of water dams, wetland filters, borrow pits, sediment traps, dry season water discharge, and waste water disposal, as well as the construction of roads and mine waste dumps. Mine sites also have the potential to introduce new mosquito species into the Northern Territory, such as the dengue mosquito *Aedes aegypti* from North Queensland, if equipment is sourced from this area. As part of the environmental process, all major developments in the NT are required to consider mosquitoes during the preparation of Environmental Impact Statements or Public Environmental reports, to ensure new development does not create new mosquito breeding sites, and also to protect the health of workers. Medical Entomology, of the Centre for Disease Control (CDC), Northern Territory Department of Health and Families (DHF) was subsequently commissioned by VDM Consulting EcOz to conduct a desktop Biting Insect Assessment of the mine site.

Findings

The major findings of the desktop biting insect assessment were;

*Mosquito populations*

It is likely that *Aedes normanensis*, *Culex annulirostris* and *Anopheles* species mosquitoes will be the most common mosquito species at Redbank Mine. Breeding sites for these species will generally be seasonally flooded areas associated with Hanrahans Creek and Redbank Creek during the wet season. Isolated pools within Hanrahans Creek and Redbank Creek in the late wet to early/mid dry season, and in the early wet, could be breeding sites for *Cx. annulirostris* and *Anopheles* species.

Based on the extent of potential natural mosquito breeding habitat at Redbank Mine, and an examination of the 12 month baseline mosquito trapping results from McArthur River Mine, it is probable that seasonally low to moderate numbers of *Aedes normanensis*, *Culex annulirostris* and *Anopheles* mosquitoes would occur at the mine site. Mosquito numbers may be higher if the previous mine operations have created new and appreciable mosquito breeding sites.

The mosquitoes will be most common within 2km of appreciable natural mosquito breeding sites, indicating all areas of the mine site will be affected by mosquitoes at some point during the wet and post wet season due to the close proximity of potential breeding sites.
The planned mine also has the potential to create new mosquito breeding sites with the construction of water storage ponds, waste rock stockpiles, borrow pits, site clearance, construction of roads, pit water discharge and waste water disposal.

The mine site also has the potential to increase populations of the endemic receptacle breeding mosquito *Aedes notoscriptus* by providing artificial breeding sites, and potentially introduce the dengue mosquito *Aedes aegypti* from nearby North Queensland through road transport.

**Mosquito borne disease and pest problems**

*Culex annulirostris* will be the most important mosquito present at Redbank Mine, as it is the principal vector of arboviruses in the Northern Territory. This species has the potential to transmit Ross River virus, Barmah Forest virus, Kunjin virus, the potentially fatal Murray Valley encephalitis virus and other viruses. Due to the likely low to moderate abundance of this species at the mine, the potential for this species to transmit viruses will be relatively low at Redbank Mine. This mosquito only bites after sundown during the night, so pest problems, if they occur, will only affect exposed workers after sundown. Normal personal protection measures against mosquito attack would reduce the potential for mosquito borne disease to very low levels.

*Aedes normanensis* will probably be the most noticeable mosquito at Redbank Mine due to its aggressive biting habits, and potential to bite in shaded areas during the daytime as well as during the evening and night. This species is not considered a principal vector of human disease, but is a potential vector of Ross River virus, Barmah Forest virus and Murray Valley encephalitis virus, and therefore will pose a low risk of disease when it is present at the mine site in appreciable numbers.

*Anopheles annulipes s.l.* and *Anopheles amictus* are likely to be the two most common *Anopheles* mosquitoes present at Redbank Mine, although only seasonally low numbers are expected. Both species have the potential to transmit malaria, if an overseas traveller with the infective stages of malaria is present at the mine, and is bitten by *Anopheles* mosquitoes. *Anopheles* mosquitoes are generally less of a pest problem compared to *Ae. normanensis* and *Cx. annulirostris*. Protection of potential malaria cases from mosquito attack during the night until the person is appropriately treated with anti malaria drugs would reduce the potential for malaria transmission to negligible.

If populations of *Ae. notoscriptus* are increased at the mine site by providing artificial receptacle breeding sites, then this species would pose a potential risk of Ross River virus and Barmah Forest virus transmission, and could pose localised pest problems around the breeding sites. If the dengue mosquito *Ae. aegypti* becomes established, then there would be the potential for dengue transmission at the mine site. The potential for both species could be reduced by appropriate inspections and treatments of artificial receptacles.
Any septic tank lacking appropriate maintenance may become breeding sites for large numbers of the pest mosquito *Culex quinquefasciatus*, while any surface ponding of effluent could become prolific breeding sites for *Cx. quinquefasciatus* as well as the disease vector *Cx. annulirostris*.

**Development and mosquito breeding**

Mining activities have the potential to create new mosquito breeding sites, or exacerbate existing mosquito breeding sites, through the construction of roads, water storage dams, sediment traps, pit dewatering, waste water disposal, mine waste dumps, site clearing, borrow pits, and storage of artificial receptacles. However those mine storage ponds at Redbank Mine that contain high copper concentrations such as the Sandy Flat Pit are unlikely to support mosquito breeding.

Mosquito species that could take advantage of artificially created mosquito breeding sites include *Ae. normanensis*, *Cx. annulirostris*, and *Anopheles* species. All such development should therefore be carried out in such a manner that new mosquito breeding sites are not created.

Equipment such as machinery, used tyres, drums, rainwater tanks, building material wrapped in plastic sheeting, and any other item capable of ponding even small amounts of water, which are sourced from North Queensland and have previously held rainwater, have the potential to introduce the dengue mosquito *Aedes aegypti* into the NT. If equipment is to be sourced from North Queensland, inspection measures should be put in place to ensure the dengue mosquito is not imported into the mine site and other areas of the NT.

**Mosquito control**

The control of larval mosquitoes in natural breeding sites within 2km of the mine vicinity is likely to be time consuming, difficult and costly to conduct. In addition larval mosquito control of natural mosquito breeding sites within 2km of the mine would be only infrequently required, particularly as mosquito abundance is unlikely to reach high levels at Redbank Mine.

Mosquito breeding can be prevented in artificial impoundments by appropriate design and maintaining margins free from vegetation, and preventing silt deposition from creating isolated pools when water levels recede. Appropriate maintenance of septic systems and management of artificial receptacles would also prevent mosquito breeding. For impoundments containing suitable water quality, fish could be utilised for mosquito prevention.

Adult mosquito control operations such as bifenthrin barrier sprays could be conducted to reduce adult mosquito populations when numbers reach pest levels or when the risk of mosquito borne disease transmission risk is high.
**Mine closure and rehabilitation**

If the mine sites are not appropriately rehabilitated upon cessation of mining operations, there is the potential that mosquito breeding sites will remain after mining operations, which would impact on the future use of the land.

**Recommendations**

The major recommendations of the biting insect assessment were;

1. All workers should be advised that pest and disease carrying mosquito species may be periodically present at the mine sites and mine camp. Workers should be advised of potential problem periods and appropriate personal protection measures. Appropriate personal protection measures can be found in Appendix 2. In particular, sleeping quarters, recreation and mess facilities should be appropriately screened to prevent the entry of mosquitoes. There should also be annual inspections of insect screens prior to the wet season to ensure they are not damaged.

2. All artificial water impoundments at the mine site, particularly water impoundments without copper contaminated water, should be annually inspected for indicators of potential mosquito breeding. Indicators are areas of semi-aquatic vegetation, grass lined margins, and isolated shallow pools as water levels recede. Any semi-aquatic vegetation and grass at margins and accumulations of silt at shallow edges should be removed. Where water quality permits, all water impoundments should be stocked with suitable native fish species from Hanrahans Creek or Redbank Creek. Water impoundments with the likelihood of wet season overflow should have appropriate erosion prevent structures installed at the overflow point.

3. All water impoundments, access roads, mine waste dumps, sediment traps, borrow pits, site clearing and other development aspects that could result in the creation of water ponding, should be constructed and managed in accordance with information in this report (Section 5.2, Section 5.3.2) and information in the Medical Entomology Branch guideline ‘Guidelines for preventing mosquito breeding sites associated with mining sites’, provided as Appendix 1.

4. Extended dry season pit water discharge into adjacent creeklines could create extensive mosquito breeding by changing the ecology of the receiving creekline. If pit water discharge into a creekline is likely to only occur for 1 year as proposed, then it is unlikely to change the ecology enough in 1 year to promote extensive or on-going mosquito breeding, so would be acceptable from a mosquito ecology aspect. However any proposals for extended pit dewatering over a number of years would need to consider preventing dry season discharge into creeklines, by considering containing water for infiltration and evaporation in a suitable designed retention pond or disposal by sprinklers, or wet season release only. Water released into creeklines would need to be of a quality that allows fish survival.

5. The septic system at the camp should be maintained in a manner that prevents mosquito breeding. This would be ensuring the tank remains fully sealed from mosquito entry, and the absorption trench is functioning appropriately.
6. Any equipment sourced from North Queensland that has previously held rainwater should be treated with a 10% chlorine solution or appropriate residual insecticide such as lambda-cyhalothrin or alpha-cypermethrin, to prevent the importation of the dengue mosquito *Aedes aegypti*.

7. Periodic inspections of artificial receptacles should be conducted around the mine sites in the wet season, with any receptacle appropriately disposed of, stored under cover away from rain, have drainage holes drilled, or treated with an appropriate larvicide, to prevent endemic mosquito breeding and the potential for *Ae. aegypti* breeding. Artificial receptacles can include disused machinery, used tyres, drums, rainwater tanks, building material wrapped in plastic sheeting, buckets, bins and general rubbish items.

8. Any worker sourced from or returning from an overseas country where malaria is endemic, who experiences high fever should be kept indoors away from mosquito bites until cleared of malaria or treated for malaria by a health professional.

9. If pest mosquito problems arise, the mine camp could be treated with a suitable barrier insecticide such bifenthrin to minimise the potential for pest problems and mosquito borne disease transmission.

10. The potential natural breeding sites within 2km of the mine site would be difficult and time consuming to survey and control, particularly when extensive flooding occurs. Therefore personal protection and the use of barrier sprays would be the most practical options for preventing mosquito attack during pest periods and preventing mosquito borne disease transmission at the mine site.

11. The mine site should be rehabilitated such that no artificial depressions remain, and septic tanks and other infrastructure that can hold water should be removed from site or buried. Water dams and open pit voids can remain, as long as they have steep sides (ie 1:2 slope or greater) and are deep (2m or greater), and are stocked with native fish from Hanrahans Creek or Redbank Creek during the rehabilitation process. They should also have appropriate erosion prevention overflow measures that allow fish dispersal upstream during the wet season.
1.0 Introduction

The Redbank Copper operations are located in the Northern Territory, 30km west of the Queensland border on the Borroloola to Burketown road and 80km south of the coast of the Gulf of Carpentaria (Redbank Mines Notice of Intent April 2008) (Figure 1). The Redbank area has been a site of copper mining and ore concentration since its discovery in 1916, with current operations consisting of a heap and vat leach extraction process. The proposed operations are planned to be expanded to mine 5 separate deposits (NOI April 2008).

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The Redbank Mine is located in an area with an average annual rainfall of 800-1000mm (NOI April 2008). Other areas of the Northern Territory with similar rainfall patterns can be prone to seasonal problems from pest and disease carrying mosquito species. Seasonally flooded drainage lines nearby to the mine site could be sources of pest and disease carrying mosquitoes such as *Aedes normanensis* and *Culex annulirostris*.

In this assessment, which is primarily a desktop assessment, previous mosquito trapping from areas of similar rainfall in conjunction with an examination of aerial photography were conducted to determine the seasonal abundance and diversity of mosquitoes likely to be present at the mine site. The development processes were also examined, and recommendations provided on preventing the creation of mosquito breeding sites, and minimising the impact of mosquitoes on the workforce.

2.0 Aims

The aims of the biting insect assessment were to assess the information from the baseline biting insect investigations at the nearby McArthur River Mine, and investigate the applicability of this information to the Redbank Mine. Both areas receive similar annual rainfall and are a similar distance from the coast. Aerial photography was also to be examined to locate areas of potential mosquito breeding, and development processes would be examined for the potential to create or exacerbate mosquito breeding.
Conclusions and recommendations were to be provided based on the findings of the desktop assessment, which would include avoidance and control of pest and disease carrying mosquito species, preventing the creation or exacerbation of mosquito breeding, preventing the reintroduction of malaria into the NT, preventing the introduction of the dengue mosquito *Aedes aegypti* from North Queensland (if equipment was to be sourced from this area), and recommendations on the rehabilitation of mined areas to ensure actual and potential mosquito breeding sites do not remain upon cessation of mining operations.

3.0 Methods

Baseline trapping was conducted from April 1994 to May 1995 at McArthur River Mine, approximately 190km to the north-west of Redbank Mine. Further trapping was also conducted in February 1996 at the mine site. Information from the two trap sites utilised at McArthur River Mine, and the trap at Borroloola Police Station, which was set from April 1994 to May 1995, were analysed for this report.

The topography is flatter at McArthur River Mine compared to Redbank Mine, but in terms of mosquito species, there was expected to be similar mosquito species present at Redbank Mine. Species abundance was likely to be different to some extent, due to the different topography. An examination of aerial photography was conducted to determine the likely abundance of mosquitoes at Redbank Mine.

Development processes were also evaluated to determine the potential for mining activities to create new mosquito breeding sites or exacerbate existing mosquito breeding sites.

4.0 Results

The baseline trapping results for the two sites at McArthur River Mine and the Borroloola Police Station are displayed in Tables 1-3. The location of McArthur River Mine in relation to Redbank Mine is shown in Figure 1, with McArthur River Mine trap locations shown in Figure 2, and the Redbank Mine area shown in Figure 3.

4.1 Mosquito Species present McArthur River Mine

4.1.1 Trap Site 1 Barney Creek M1

This site was located on the southern side of Little Barney Creek and north of the mine operations camp. The creekline was shallow and the catchment area was intercepted by the Tailings Impoundment (Montgomery 1995). A total of 18 mosquito species were recorded at this trap site (Table 1). *Aedes normanensis* was the most common mosquito species collected at this site, accounting for 48.53% of all mosquitoes collected (Table 1). *Anopheles amictus* was the second most common mosquito, accounting for 36.94% of all mosquitoes. *Anopheles annulipes s.l.* (5.7%) and *Culex annulirostris grp* (4.11%) were the next most common mosquitoes collected, while other mosquitoes were recorded in very low numbers only.

The most productive month for mosquitoes at Trap Site 1 was February 1996, which recorded 47.65% of all mosquitoes collected at this site. During this month, *Aedes normanensis* accounted for 940 out of the total of 1135 adult female mosquitoes, with
Culex annulirostris the next most common species accounting for 53 out of the 1135 adult female mosquitoes. Anopheles annulipes s.l. accounted for 45 of the 1135 adult mosquitoes collected during this month.

March 1995 was the next most abundant month, accounting for 34.47% of all mosquitoes collected at this site during trapping in late March. Anopheles amictus was the most abundant mosquito, accounting for 588 of the 821 adult female mosquitoes collected in late March. Aedes normanensis was the second most common species at this site during late March 1995, with 166 adult females recorded, followed by An. annulipes s.l. with 38 females recorded. Other months recorded relatively low mosquito abundance compared to February 1996 and late March 1995.

When considering the seasonal abundance of important mosquito species, Aedes normanensis was most abundant during February and March, with very minor abundance in April, and was absent during other months. Anopheles amictus was most abundant during March, followed by May and April, with low abundance also during February and November. Minor abundance was recorded in most other months. Culex annulirostris was recorded in highest numbers in February, although in low abundance only. April and May were the next most productive months for Cx. annulirostris. Anopheles annulipes s.l. was most abundant during February and March, with low abundance during September and November.

4.1.2 Trap Site 2 Barney Creek M2

There were 18 adult mosquito species collected at Trap Site 2 (Table 2). Anopheles annulipes s.l. and An. amictus were the two most common mosquitoes collected, accounting for 35.42% and 34.99% of all mosquitoes respectively. The next most abundant mosquito was Ae. normanensis, accounting for 16.65% of all mosquitoes, followed by Cx. annulirostris (8.96%). Other mosquitoes were recorded in very low numbers only.

The most productive month for mosquitoes at Trap Site 2 was March, with 43.95% of all mosquitoes collected on the 31st of March 1995. The majority of mosquitoes were An. amictus, accounting for 1127 out of 1634 adult female mosquitoes. Aedes normanensis and An. annulipes s.l. were the next most abundant mosquitoes, accounting for 244 and 222 adult females respectively.

April 1995 and April 1994 recorded similar mosquito abundance, with 12% and 11.65% respectively, with An. annulipes s.l. the most abundant species on both occasions. February 1996 was the next most productive month, accounting for 9.41% of mosquitoes at this site, with Ae. normanensis the most abundant species during this month.

When considering the seasonal abundance of important mosquito species, Ae. normanensis was most common from January to March and absent during most other months. Anopheles annulipes s.l. was most abundant from March to May and August, with elevated abundance also during July and September. Anopheles amictus was most abundant in March and April, and Cx. annulirostris was most abundant in November and February to May.
4.2 Mosquito species present at Borroloola

4.2.1 Trap Site 3 Borroloola Police Station

There were 11 mosquito species collected at Borroloola Police Station (Table 3). *Anopheles amictus* (22.83%), *Culex quinquefasciatus* (22.94%), *Ae. normanensis* (22.48%) and *Cx. annulirostris* (19.95%) were the most common mosquito species collected. Other mosquitoes were recorded in very low numbers.

The most productive month for mosquitoes at Trap Site 3 was March, with 32.57% of all mosquitoes collected on the 31st of March 1995. The majority of mosquitoes were *Ae. normanensis* and *An. amictus*, accounting for 64 and 55 out of the total of 142 adult female mosquitoes. April 1995 was the next most productive month, accounting for 14.68% of all mosquitoes collected at this site, with *Cx. annulirostris* and *An. amictus* the most common mosquitoes during this month. Early March (1st) recorded similar numbers to April, with *Ae. normanensis* the most common mosquito collected. Mosquito abundance during April 1994 and May 1995 were relatively similar, with 11.7% and 9.63% of all mosquitoes respectively.

When considering the seasonal abundance of important mosquito species, *Ae. normanensis* was most abundant in March and absent during most other months, *An. amictus* was most abundant from March to May, *Cx. annulirostris* was most abundant from March to May, and *Cx. quinquefasciatus* was present in similar numbers on most months. It should be noted that no trapping was conducted at this site from November to February.
5.0 Discussion

5.1 Likely mosquito species present

The same mosquito species collected at McArthur River mine would probably also be present at Redbank Mine. Ground pool species such as *Anopheles annulipes* s.l., *An. amictus*, *Cx. annulirostris* and *Ae. normanensis* are common in sub-coastal Northern Territory (Medical Entomology annual report 2007/08) so would be present at Redbank Mine on a seasonal basis. Mosquito species that breed in tree holes and artificial receptacles, in particular *Aedes notoscriptus* would also be present at Redbank Mine. *Culex quinquefasciatus* is also likely to take advantage of artificial receptacles, and also any areas of high nutrient ponding.

*Anopheles* species and *Cx. annulirostris* would breed in similar habitats in adjacent seasonally flooded areas and pools within creeklines, with *Cx. annulirostris* more common in areas with emergent vegetation, whereas *An. amictus* and *An. annulipes* s.l. can also exploit bare ground pools. The major breeding sites affecting Redbank Mine would be seasonally flooded low lying grassy associated with Hanrahans Creek and Redbank Creek, usually in the mid to late wet season (Figure 3). Breeding would also occur in pools within the creeks during the late wet/early dry season when creek flows cease, leaving behind isolated pools. Generally shallow pools or pools with semi-aquatic vegetation would be the likely potential breeding sites. A short term spike in productivity could also occur in the early wet season when rainfall leads to ponding in the creeks before they begin to flow. The deeper pools in Hanrahans Creek receiving overflow from Sandy Flat Pit may not be conducive to mosquito breeding however, as the copper concentration of 5ppm (NOI April 2008) would be potentially toxic to mosquito larvae. The breeding sites are expected to produce at least low to moderate seasonal numbers of *Anopheles* mosquitoes and *Cx. annulirostris*.

*Aedes normanensis* would also breed in low lying flooded areas associated with the nearby creeklines from January to April, when initial flooding or re-flooding of low lying areas occurs. Potential breeding sites are shown in Figure 3. It is expected that the breeding sites affecting Redbank Mine would produce at least low to moderate seasonal numbers of this species.

Receptacle breeding mosquitoes such as *Ae. notoscriptus*, as well as *Cx. quinquefasciatus* and *Aedes tremulus* would utilise any artificial receptacles around the mine site. Breeding productivity would depend on the number of available receptacles. *Culex quinquefasciatus* and *Ae. tremulus* are not recognised as disease vectors in Australia and therefore will not discussed in detail in this report, although they can be appreciable pest mosquitoes.

The abundance of mosquito species at Redbank Mine is likely to be different compared to McArthur River Mine. Both localities have different topography to some extent, with the Redbank Mine area being hillier in the areas adjacent to the mine, although both mine sites are located adjacent to ephemeral streams. Mosquitoes at Redbank Mine are not expected to be higher compared to McArthur River Mine, and
could be lower for some species, but this could not be determined without conducting baseline adult mosquito trapping.

Adult mosquito trapping was not conducted at Redbank Mine, although the likely species present could be predicted based on trapping at McArthur River Mine and Borroloola (Montgomery 1995), and an examination of mosquito trapping results from other similar areas in the NT (Medical Entomology Annual Report 2007/08). The trapping at McArthur River Mine and Borroloola both indicated the same species present, and very similar seasonal occurrence and relative numbers. The analysis of previous trapping information from other areas in the NT indicated the most common species in sub-coastal and inland areas of the NT, which can also be applied to the Redbank Mine area. The more important mosquito species that would be present at Redbank Mine are discussed below. Potential breeding sites are indicated in Figure 3.

5.1.1 *Aedes normanensis* (floodwater *Aedes* mosquito)

**Breeding sites**

This mosquito species generally breeds in broad, flat sub-coastal drainage floors of minor and major creeks (Whelan 1997a). Drought resistant eggs from this species are laid in drying mud, and hatch after subsequent inundation with rain or floodwater. There are usually limited mosquito larvae predators after initial inundation with water, which can result in high productivity breeding sites.

The low lying areas associated with the ephemeral creek lines adjacent to Redbank Mine are likely to be breeding sites for this species. There are some low lying areas associated with Redbank Creek and Hanrahans Creek (Figure 3), indicating the possibility of seasonally low to moderate populations of *Ae. normanensis*. The major potential breeding sites appear to be the upper reaches of Hanrahans Creek, and the section of Redbank Creek near the Redbank Camp. The low lying area near the airstrip is also a potential breeding site for *Ae. normanensis*.

There is an absence of extensive areas of broad, flat drainage floors at Redbank Mine, which has a steeper topography and better drainage compared to McArthur River Mine and Borroloola. Therefore the mine site is likely to have appreciable numbers of *Ae. normanensis*, but is unlikely to experience the very high numbers of *Ae. normanensis* that can be encountered in other inland areas of the NT.

**Seasonal abundance**

*Aedes normanensis* breeds in the wet season, with peaks in January to April (Whelan 1997a), although this species will also breed in October, November and May in those years when significant rainfall occurs in these months. Eggs hatch soon after inundation and pest problems generally begin 9 days after the flooding rain and last for up to 2 weeks. *Aedes normanensis* was most abundant in the months of January to March at McArthur River Mine and is similarly likely to be most abundance in these months at Redbank Mine.
It can be expected that for most years at Redbank Mine, *Ae. normanensis* will follow the usual trend of highest numbers in January to April, and no abundance during the dry season. Abundance would probably be low to moderate and less that at McArthur River Mine, due to the presence of potential localised but less extensive breeding sites compared with McArthur River Mine.

**Dispersal**

*Aedes normanensis* is most common within 2km of breeding sites, although it can disperse up to 5km in pest numbers (Whelan 1997a). Potential breeding sites associated with Hanrahan and Redbank Creek are located within 2km of Redbank Camp and Redbank Plant, as well as the Redbank, Azurite and Bluff deposits. This indicates that all areas of the mine site are likely to experience *Ae. normanensis* during its peak occurrence.

**Pest problems**

*Aedes normanensis* is considered a major pest species, and readily bites humans, mainly in the evening and at night, although this species has been known to bite in shaded areas during the daytime. Pest problems are likely to occur in the months of January to April, and also in October to December in those years when appreciable flooding occurs in these months. The degree of pest problems experienced by workers would be dependant on abundance of the mosquito, exposure during peak biting times around sunset, and the level of personal protection. At McArthur River Mine, *Ae. normanensis* was recorded in numbers high enough to cause moderate to high pest problems for an exposed person around sundown, although McArthur River Mine is located closer to broader drainage areas compared to Redbank Mine. Therefore based on potential breeding sites at Redbank Mine, there could be seasonal numbers at levels likely to cause low to moderate pest problems for an exposed person, particularly around sundown.

**Disease significance**

*Aedes normanensis* is a potential vector of Ross River virus (RRV) and Barmah Forest virus (BFV) (Whelan & Weir 1993), and a potential vector of Murray Valley encephalitis virus (Whelan 1997a).

*Aedes normanensis* is not considered as important as *Culex annulirostris* as a potential RRV vector, but depending on region and conditions this species can be involved in RRV transmission (Russell 2002). This species is also not considered a principal vector or MVEV and BFV (Russel & Kay 2002).

The main risk for RRV transmission in the NT is the months of December to June, with the peak risk months of January to March (Whelan 1997b). The main risk period for BFV transmission in the NT is from October to July, with the peak risk months from January to March (Whelan 1997b). The main risk period for MVEV transmission is January to July, with March to May the peak risk period (Whelan 1997b).

The potential for virus transmission from this species will occur during the wet season months starting 9 days after appreciable rainfall floods their breeding sites, with the potential virus risk lasting from 2-3 weeks after single rainfall events, or for more
extended periods with follow up rains. The potential for virus transmission will affect unprotected workers in the evenings and at night, and in shaded areas during the daytime. Depending on the abundance of this mosquito, there may be periods of the wet season when *Ae. normanensis* may cause a low to moderate risk of virus transmission to an unprotected worker.

5.1.2 *Culex annulirostris* (common banded mosquito)

**Breeding sites**

*Culex annulirostris* generally breeds in freshwater and brackish water swamps with emergent vegetation such as grasses and semi-aquatic reeds, freshwater streams with vegetation, as well as temporary flooded grasslands, sewage ponds with vegetation, and semi-polluted stormwater drains (Whelan 1997a).

This species was relatively uncommon at McArthur River Mine, indicating surrounding areas did not contain extensive breeding sites (Montgomery 1995). The main breeding site at McArthur River Mine was a stretch of Barney Creek receiving sewage discharge, which was to be rectified (Montgomery 1995). Ephemeral creek lines and depressions were thought to be potential breeding sites in the area (Montgomery 1995). At Redbank Mine, the main breeding sites for this species would be the seasonally flooded low lying grassy areas during the wet season, with any grass fringed pools within ephemeral creeklines likely to be low level breeding sites in the late wet/early dry and beginning of the wet season. Any creekline with limited flow and clogged vegetation with no fish would be productive breeding sites. Shallow open temporary flooded areas or depressions with grass or thick vegetation could also be possible breeding sites.

The creeklines and pools within the escarpment area could also contain breeding sites for this species, dependant on the availability of semi-aquatic vegetation or debris to provide shelter for larvae against predators. However these habitats are generally likely to be minimal breeding sites for mosquitoes because of probable regular flow and predators such as fish and aquatic insects.

**Seasonal abundance**

*Culex annulirostris* is generally most common from January to August in the Top End of the NT (Whelan 1997a). The months of peak abundance at Redbank Mine would depend on the type of nearby habitat. At McArthur River Mine, although uncommon, this species showed a peak in the months of November, February, April and May. This indicated early wet season flooding promoted breeding, and late wet/early dry season residual ponding also provided breeding sites. The same seasonal pattern of abundance is likely to occur at Redbank Mine, with highest abundance during the wet season and early dry season.

Any presence of water dams with vegetated margins, wetland filters, and dry season discharge of water into creek lines has the potential to create productive and extended breeding for this species into the late dry season. Inappropriate sewage disposal also has the potential to create productive breeding for this species.
**Dispersal**

*Culex annulirostris* can disperse up to 10km from extensive breeding sites, although are most common within 4km of breeding sites (Whelan 1997a), and there is usually a significant drop in *Cx. annulirostris* numbers up to 2km away from significant breeding sites (Whelan 2004). The mine site is surrounded by potential breeding sites, therefore all areas of the mine site are likely to experience similar, although probably low to moderate levels of *Cx. annulirostris*.

**Pest numbers**

*Culex annulirostris* reaches pest levels when there are more than 100 per CO2 baited EVS trap per night, for those traps set away from residential areas (Whelan 1997a). This pest threshold was not exceeded at McArthur River Mine at either of the trap sites during baseline monitoring, although levels during November, April and May at Site 2 were representative of potential nuisance problems. Based on the proviso that no new breeding sites have been created, it is likely that *Cx. annulirostris* would only be present in low to moderate numbers at Redbank Mine, and hence only pose a nuisance to minor pest problem.

*Culex annulirostris* only bites at night, and is less persistent in the presence of lights, personal protective clothing and repellents (Whelan et al 1994), so therefore will only pose a potential nuisance to unprotected workers in the evening and at night.

**Disease significance**

*Culex annulirostris* is the most important vector of arboviruses in the NT (Whelan & Weir 1993). It is recognised as a good vector of Murray Valley encephalitis virus (MVEV), Kunjin virus (KUNV), RRV and BFV (Merianos et al 1992, Whelan et al 1993, Russell 2002). Many other arboviruses have been isolated from this species (Whelan & Weir 1993). *Culex annulirostris* will pose a potential disease risk when it is present in moderate numbers at Redbank Mine, especially when present during the main risk months for the various arboviruses (Appendix 2), and when present in the warmer, humid months of January to March, when the longevity of this species will be increased. Increased longevity increases the chance of this species obtaining a virus from a vertebrate host and passing it on to a human.

Despite the likelihood of low to moderate numbers at the mine site during average rainfall years, it only takes the bite of one mosquito to transmit a virus, therefore there is at least a low risk that *Cx. annulirostris* could transmit mosquito borne diseases at Redbank Mine.

**5.1.3 Anopheles annulipes s.l. (Common Australian Anopheles mosquito)**

**Potential breeding sites**

This species mainly breeds in freshwater streams and vegetated swamps, and also occasionally in larger receptacles (Whelan 1997a). Larvae are generally associated with algae and emergent vegetation, which provide shelter for larvae, although bare ground pools with limited biological control could also be breeding sites. At McArthur
River Mine, breeding sites were associated with filamentous algae in relatively unvegetated isolated pools in Barney Creek/McArthur River, and in effluent ponding in Barney Creek (Montgomery 1995).

Breeding sites for *An. annulipes s.l.* at Redbank Mine are similarly likely to be isolated pools in Hanrahans Creek and Redbank Creek, as well as ephemeral ground pools.

**Seasonal abundance**

This species is generally most abundant during the wet season and post wet season, depending on the availability of surface water in the post wet season (Whelan 1997a). At McArthur River Mine, this species was most common during the late wet season and early dry season (March to May), when water levels recede, leaving isolated pools conducive to mosquito breeding. Elevated numbers were also recorded in the late dry season (August-September), from pools within the McArthur River (Montgomery 1995).

A similar pattern of abundance is likely to occur at Redbank Mine, with the late wet season and early dry season likely to be peak months. There may be minor breeding into the mid dry season, depending on the availability of isolated pools within the creeklines.

**Dispersal**

*Anopheles annulipes s.l.* are most common within 2km of breeding sites, therefore all areas of Redbank Mine are likely to be affected by any appreciable source of this species within 2km of the mine. However highest numbers would generally be encountered within 500m of their breeding sites.

**Pest numbers**

*Anopheles annulipes s.l.* is generally not as aggressive compared to *Ae. normanensis* and *Cx. annulirostris*. This species bites at night, particularly around dawn and dusk, so therefore only people exposed after sundown within 2km of breeding sites are likely to experience problems from this species.

Seasonally low to moderate numbers were recorded at McArthur River Mine. Numbers are Redbank Mine are not expected to be higher than McArthur River Mine, and based on potential breeding sites, would probably only be present in numbers sufficient to cause minor to low pest problems during peak season months.

**Disease significance**

*Anopheles annulipes s.l.* is considered a potential vector of malaria (Russell & Kay 2004). The *Anopheles annulipes s.l.* species complex is known to include at least 10 sibling species, although nothing is known of the vector competence of each sibling species (Russell & Kay 2004). The risk for malaria transmission at Redbank Mine will only occur if a person with the infectious stages of malaria acquired overseas is bitten by an *An. annulipes s.l.* female at the mine. The risk threshold for *Anopheles* species in a CO2 baited EVS trap and malaria transmission after a case of infective malaria is regarded as 10 females per trap per trap night. This number was exceeded
at both sites at McArthur River Mine during peak season months, and would probably be exceeded during peak season months at Redbank Mine.

Malaria is not endemic to Australia, so a risk will only arise if a person returning from overseas with the infectious stages of malaria is exposed to An. annulipes s.l. at the mine site. Therefore all personnel sourced or returning from overseas who suddenly becomes ill with high fever should be considered as possibly having malaria, and be kept indoors away from mosquito bites until cleared of having malaria, or cleared of the infectious stages of malaria by a health care practitioner.

5.1.4 Anopheles amictus

This species was trapped in high numbers at McArthur River Mine, and was thought to be breeding in muddy pools associated with the McArthur River and associated creeklines (Montgomery 1995). General breeding sites are freshwater ground pools and swamp or creek margins, often associated with muddy water (Montgomery 1995). This species was most common from March to May at McArthur River Mine (Montgomery 1995). As with Anopheles annulipes s.l., An. amictus is a potential vector of malaria and bites at night.

Anopheles amictus is expected to be present at Redbank Mine, most likely in lower numbers than McArthur River Mine, but at least in numbers high enough to cause seasonally minor to low pest problems.

5.1.5 Aedes notoscriptus

This species is common throughout the Northern Territory, and breeds in natural receptacles such as tree holes, as well as artificial receptacles such as pot plant drip trays, buckets, used tyres and any other receptacle that can hold water. Mine development has the potential to increase breeding sites for this species by providing new breeding sites. Although not usually a serious pest, high breeding in artificial receptacles can create localised pest problems within a few hundred metres of the breeding sites. This species is also a potential vector of Ross River virus and Barmah Forest virus.

5.2 Development and potential mosquito breeding

General guidelines to prevent mosquito breeding associated with mine sites can be found in Appendix 1 ‘Guidelines for preventing mosquito breeding sites associated with mining sites’. Specific comments on some aspects of the mine site are provided in the following section. The conceptual layout for the mine is shown in Appendix 3 (VDM Consulting EcOz 25 September 2009). The most likely new mosquito breeding sites are discussed below.

5.2.1 Effluent treatment and disposal

The inappropriate storage and disposal of effluent could create prolific breeding sites for mosquitoes. Inappropriately sealed septic tanks can be productive breeding sites for Cx. quinquefasciatus, while inappropriate disposal of effluent could create breeding sites for Cx. annulirostris and Cx. quinquefasciatus. It was mentioned that sewage from the camp and plant sites will be treated through appropriate septic systems at the both sites (NOI April 2008), therefore mosquito breeding should not
be an issue if the tanks are appropriately maintained and infiltration trenches are appropriately operating.

5.2.2 Water storage
The Sandy Flat Pit is unlikely to be a mosquito breeding site due to the high concentrations of copper (0.6g/L) (NOI April 2008). The existing tailings dam probably also contains water unsuitable for mosquito breeding. Other existing water storage ponds at the mine site that collect copper ion contaminated water would probably also have minimal potential for mosquito breeding.

The potential for mosquito breeding would arise if water without high copper concentrations is stored in ponds of an unsuitable design. Generally a deep pond (2m) with steep sides (1:2 slope) and no semi-aquatic vegetation would have minimal potential for mosquito breeding. This design should be considered when constructing new water storage features such as the process area retention dam or when modifying existing water features. Ponds lined with concrete or HDPE liner would also have minimal potential for mosquito breeding.

Water storage features such as the process area retention dam should be inspected annually for indicators of potential mosquito breeding, which would be semi-aquatic vegetation or grass at the margins, and shallow isolated pools as water levels recede. Any potential problem could be mitigated by removing semi-aquatic vegetation and grass at the margins, and removing silt accumulation at the corners or shallow areas. The overflow for any dam should have appropriate erosion prevention structures installed.

For the proposed tailings dam, a tailing dam with copper contaminated water would unlikely be a mosquito breeding site at Redbank Mine. However to further reduce the potential for mosquito breeding the proposed tailings dam should be deep and steep sided, and be inspected annually for mosquito breeding potential as outlined above for water storage facilities.

5.2.3 Pit dewatering
Pit dewatering has the potential to create extensive mosquito breeding sites by changing the ecology of receiving waterways, if significant dry season discharge occurs. Prolonged dry season discharge over a number of years can promote extensive growth of semi-aquatic reeds in the receiving creekline, which would then be large breeding sites for pest and disease mosquitoes. It is mentioned in the NOI that during mining operations, dewatering will be necessary at Azurite and Redbank pits, with mining expected to be under 1 year, and water discharged through settlement ponds. In general, dry season pit water should be contained within a water pond/dam to prevent dry season discharge into creeklines. However in this instance for these two pits, dry season discharge into the adjacent creek for only 1 year would probably not increase mosquito breeding to any great extent, as long as the discharge water is of a quality that would allow fish and other aquatic predator survival. The settlement ponds provided to contain pit water initially should be deep and steep sided to discourage mosquito breeding.
It is mentioned that the ultimate goal is to completely dewater Sandy Flat Pit, although it was mentioned that this was not part of the NOI for the current operations. Nevertheless the same principles apply, if pit dewatering was to occur in future and over a number of years, then dry season pit water should not be discharged into the adjacent Hanrahans Creek, but rather contained within a water pond/dam for dry season evaporation and infiltration, or dispersed by sprinkler irrigation. During the wet season pit water can be continually released into defined creeklines without the potential to create mosquito breeding.

5.2.4 Artificial receptacles

Artificial receptacles such as used tyres, drums, disused machinery and any rubbish items that can collect rain water are potential mosquito breeding sites. Mosquito species that are commonly found breeding in artificial receptacles are *Aedes notoscriptus, Aedes tremulus* and *Culex quinquefasciatus*, with the former a potential vector of RRV. Mosquito species that occasionally breed in larger exposed artificial receptacles include the potential malaria vector *An. annulipes s.l.* and the major arbovirus vector *Cx. annulirostris*.

Any receptacles sourced from north QLD such as used tyres, water drums, rainwater tanks, machinery items that can pond water (ie backhoe buckets, excavator tracks), building material and equipment wrapped in plastic sheeting or with the potential to hold water, and any other item capable of ponding even small amounts of water, has the potential to introduce the dengue mosquito *Aedes aegypti* as drought resistant eggs. Artificial receptacles from north QLD that have previously held rain water should be treated with a 10% chlorine solution or an appropriate residual insecticide (lambda-cyhalothrin or alpha-cypermethrin), to prevent the possibility of the importation of *Ae. aegypti* into the Redbank Mine site.

Periodic inspections of artificial receptacles should be conducted during the wet season at the mine sites and mine camp. Any receptacle found ponding water should either be disposed of, stored under cover, have drainage holes drilled or treated with an appropriate insecticide on an appropriate schedule, to prevent potential endemic mosquito breeding and minimise the potential for the re-introduction of *Ae. aegypti* from North Queensland.

5.2.5 Waste rock stockpiles

Waste rock stockpiles have the potential to create mosquito breeding sites by runoff from the waste dumps depositing silt in natural drainage lines, or the inappropriate siting of stockpiles, causing disruption or pooling in drainage lines. The proposed stockpile at Bluff will be located in a drainage line, therefore a diversion drain would be required to divert surface flows around the stockpile to prevent the upstream impoundment of water, which would create mosquito breeding.

The sediment dams provided to capture silt runoff from waste rock stockpiles should either drain within 5 days, or be deep and steep sided and be maintained free from vegetation, and regularly cleared of silt to maintain appropriate function.
5.2.6 Access roads

All future access roads should either have culverts or floodways installed at a level that prevents the upstream impoundment of water. Culverts should be of sufficient size to prevent the upstream impoundment of water for periods greater than 5 consecutive days. Any existing track that has created upstream ponding should be upgraded with appropriate culverts/floodways. Any impoundment of water may create additional breeding sites for the pest and disease carrying mosquitoes *Ae. normanensis* and *Cx. annulirostris*.

5.2.7 Construction camp

All sleeping quarters and recreation/mess areas should be appropriately screened to prevent the entry of mosquitoes. There should also be annual inspections of insect screens to ensure they are not damaged, with inspections best carried out just before the wet season.

The use of yellow lights outside of recreation and night use areas in the construction camp will help in reducing insects in these areas, while the use of light proof curtains will also minimise insects being attracted to sleeping quarters. Further information can be found in Appendix 2 ‘Personal protection from mosquitoes and biting midges in the NT’.

5.3 Mosquito avoidance and control

5.3.1 Personal protection

Personal protection from mosquitoes may be required during certain periods of the year at the mine sites and mine camp. Most mosquito species bite at night, so can be easily avoided by avoiding night time exposure, although some species such as the floodwater mosquito *Ae. normanensis* will often bite in shaded areas during the daytime as well as at night. If work activities are to be conducted at night, appropriate personal protection measures may be periodically required. The wet season and early dry season are likely to be the periods of the year when mosquitoes will be most abundant. Information on personal protection from mosquitoes can be found in Appendix 2.

5.3.2 Mosquito control

There should be annual inspections of water impoundments for mosquito habitat indicators such as semi-aquatic vegetation growth and isolated pools caused by silt deposition or disturbance. Also a general site inspection should be conducted in the wet season to locate any ground depressions caused by development, with depressions subsequently earmarked for rectification as soon as practical. The septic tank should also be inspected to ensure the tank is sealed and the absorption trench is functioning correctly. There is unlikely to be a need for larval mosquito control in artificial sites if appropriate maintenance is conducted, or if ponds are designed to minimise the potential for mosquito breeding.

Fish are major predators of mosquito larvae. Where water quality permits, all areas of artificial water ponding should be stocked with predatory native fish species from Hanrahans Creek or Redbank Creek. Species such as rainbow fish, various grunter species, various gudgeon species, the pacific blue eye or glass perchlets would be suitable.
Larval mosquito control of natural breeding sites outside the immediate mine area is unlikely to be warranted, as the natural breeding sites would be widespread and time consuming to control, and are generally only expected to be minor to low sources of mosquitoes. *Aedes normanensis* may reach moderate levels from adjacent breeding sites, but the time and resources required to survey and control breeding would make control of these breeding sites impractical. Other methods such as personal protection and or adult mosquito control would be a more feasible option.

There may be periods when adult mosquito populations from natural breeding sites reach pest levels and workers may request adult mosquito control. The current best practice for adult mosquito control in Australia is to use a suitable barrier insecticide such as ‘bifenthrin’. Bifenthrin is a residual insecticide with low irritancy to mosquitoes, thus increases the adult mosquito-insecticide contact time to provide better control (WHO 2002). Bifenthrin can be applied to external walls, under demountables, on insect screens, floorboards, areas of dense vegetation and other likely mosquito harbourage areas around mine buildings and accommodation areas to control adult mosquitoes. The months of December to May, when the transmission risk for many arboviruses is at its greatest and mosquito abundance is likely to be highest, are the months when bifenthrin treatments may be beneficial.

**5.4 Decommissioning and rehabilitation**

A decommissioning and rehabilitation plan should be in place to ensure no actual and potential mosquito breeding sites remain after cessation of mining operations, to prevent ongoing mosquito problems for the future use of the land and surrounding areas. All disturbed areas should be rehabilitated to be free draining where practical, and septic tanks and other artificial receptacles should be either removed or buried.

Facilities such as open pit voids and water dams can be left as water holding pits if they are constructed with steep sides (at least 1:2 slope) and are deep (2m or greater), and are stocked with fish during the rehabilitation process, and have erosion prevention overflow measures that allow fish dispersal upstream during the wet season.

**5.5 Limitations**

The information provided on mosquito abundance in this report was an estimation of what may be encountered at the Redbank Mine, based on an examination of aerial photography and previous baseline mosquito assessments at McArthur River Mine, and based on the knowledge of the authors. To provide a more accurate indication on mosquito abundance at Redbank Mine, monthly trapping for 12 months, and peak abundance trapping for *Ae. normanensis* would have been required, as well as a ground assessment of potential mosquito breeding sites.

*Aedes normanensis* abundance would be the most variable out of the important mosquito species discussed. This species can breed in high numbers in localised areas, therefore a small breeding site could produce relatively high numbers. However based on aerial photography, it does not appear likely that this species will occur in higher numbers than at McArthur River Mine.
6.0 Conclusions

6.1 Mosquito populations

It is likely that *Aedes normanensis*, *Culex annulirostris* and *Anopheles* species mosquitoes will be the most common mosquito species at Redbank Mine. Breeding sites for these species will generally be seasonally flooded areas associated with Hanrahans Creek and Redbank Creek during the wet season. Isolated pools within Hanrahans Creek and Redbank Creek in the late wet to early/mid dry season, and in the early wet, could be breeding sites for *Cx. annulirostris* and *Anopheles* species.

Based on the extent of potential natural mosquito breeding habitat at Redbank Mine, and an examination of the 12 month baseline mosquito trapping results from McArthur River Mine, it is probable that seasonally low to moderate numbers of *Aedes normanensis*, *Culex annulirostris* and *Anopheles* mosquitoes would occur at the mine site. Mosquito numbers may be higher if the previous mine operations have created new and appreciable mosquito breeding sites.

The mosquitoes will be most common within 2km of appreciable natural mosquito breeding sites, indicating all areas of the mine site will be affected by mosquitoes at some point during the wet and post wet season due to the close proximity of potential breeding sites.

The planned mine also has the potential to create new mosquito breeding sites with the construction of water storage ponds, waste rock stockpiles, borrow pits, site clearance, construction of roads, pit water discharge and waste water disposal.

The mine site also has the potential to increase populations of the endemic receptacle breeding mosquito *Aedes notoscriptus* by providing artificial breeding sites, and potentially introduce the dengue mosquito *Aedes aegypti* from nearby North Queensland through road transport.

6.2 Mosquito borne disease and pest problems

*Culex annulirostris* will be the most important mosquito present at Redbank Mine, as it is the principal vector of arboviruses in the Northern Territory. This species has the potential to transmit Ross River virus, Barmah Forest virus, Kunjin virus, the potentially fatal Murray Valley encephalitis virus and other viruses. Due to the likely low to moderate abundance of this species at the mine, the potential for this species to transmit viruses will be relatively low at Redbank Mine. This mosquito only bites after sundown during the night, so pest problems, if they occur, will only affect exposed workers after sundown. Normal personal protection measures against mosquito attack would reduce the potential for mosquito borne disease to very low levels.

*Aedes normanensis* will probably be the most noticeable mosquito at Redbank Mine due to its aggressive biting habits, and potential to bite in shaded areas during the
daytime as well as during the evening and night. This species is not considered a principal vector of human disease, but is a potential vector of Ross River virus, Barmah Forest virus and Murray Valley encephalitis virus, and therefore will pose a low risk of disease when it is present at the mine site in appreciable numbers.

*Anopheles annulipes s.l.* and *Anopheles amictus* are likely to be the two most common *Anopheles* mosquitoes present at Redbank Mine, although only seasonally low numbers are expected. Both species have the potential to transmit malaria, if an overseas traveller with the infective stages of malaria is present at the mine, and is bitten by *Anopheles* mosquitoes. *Anopheles* mosquitoes are generally less of a pest problem compared to *Ae. normanensis* and *Cx. annulirostris*. Protection of potential malaria cases from mosquito attack during the night until the person is appropriately treated with anti malaria drugs would reduce the potential for malaria transmission to negligible.

If populations of *Ae. notoscriptus* are increased at the mine site by providing artificial receptacle breeding sites, then this species would pose a potential risk of Ross River virus and Barmah Forest virus transmission, and could pose localised pest problems around the breeding sites. If the dengue mosquito *Ae. aegypti* becomes established, then there would be the potential for dengue transmission at the mine site. The potential for both species could be reduced by appropriate inspections and treatments of artificial receptacles.

Any septic tank lacking appropriate maintenance may become breeding sites for large numbers of the pest mosquito *Culex quinquefasciatus*, while any surface ponding of effluent could become prolific breeding sites for *Cx. quinquefasciatus* as well as the disease vector *Cx. annulirostris*.

### 6.3 Development and mosquito breeding

Mining activities have the potential to create new mosquito breeding sites, or exacerbate existing mosquito breeding sites, through the construction of roads, water storage dams, sediment traps, pit dewatering, waste water disposal, mine waste dumps, site clearing, borrow pits, and storage of artificial receptacles. However those mine storage ponds at Redbank Mine that contain high copper concentrations such as the Sandy Flat Pit are unlikely to support mosquito breeding.

Mosquito species that could take advantage of artificially created mosquito breeding sites include *Ae. normanensis*, *Cx. annulirostris*, and *Anopheles* species. All such development should therefore be carried out in such a manner that new mosquito breeding sites are not created.

Equipment such as machinery, used tyres, drums, rainwater tanks, building material wrapped in plastic sheeting, and any other item capable of ponding even small amounts of water, which are sourced from North Queensland and have previously held rainwater, have the potential to introduce the dengue mosquito *Aedes aegypti* into the NT. If equipment is to be sourced from North Queensland, inspection
measures should be put in place to ensure the dengue mosquito is not imported into the mine site and other areas of the NT.

6.4 Mosquito control

The control of larval mosquitoes in natural breeding sites within 2km of the mine vicinity is likely to be time consuming, difficult and costly to conduct. In addition larval mosquito control of natural mosquito breeding sites within 2km of the mine would be only infrequently required, particularly as mosquito abundance is unlikely to reach high levels at Redbank Mine.

Mosquito breeding can be prevented in artificial impoundments by appropriate design and maintaining margins free from vegetation, and preventing silt deposition from creating isolated pools when water levels recede. Appropriate maintenance of septic systems and management of artificial receptacles would also prevent mosquito breeding. For impoundments containing suitable water quality, fish could be utilised for mosquito prevention.

Adult mosquito control operations such as bifenthrin barrier sprays could be conducted to reduce adult mosquito populations when numbers reach pest levels or when the risk of mosquito borne disease transmission risk is high.

6.5 Mine closure and rehabilitation

If the mine sites are not appropriately rehabilitated upon cessation of mining operations, there is the potential that mosquito breeding sites will remain after mining operations, which would impact on the future use of the land.
7.0 Recommendations

1. All workers should be advised that pest and disease carrying mosquito species may be periodically present at the mine sites and mine camp. Workers should be advised of potential problem periods and appropriate personal protection measures. Appropriate personal protection measures can be found in Appendix 2. In particular, sleeping quarters, recreation and mess facilities should be appropriately screened to prevent the entry of mosquitoes. There should also be annual inspections of insect screens prior to the wet season to ensure they are not damaged.

2. All artificial water impoundments at the mine site, particularly water impoundments without copper contaminated water, should be annually inspected for indicators of potential mosquito breeding. Indicators are areas of semi-aquatic vegetation, grass lined margins, and isolated shallow pools as water levels recede. Any semi-aquatic vegetation and grass at margins and accumulations of silt at shallow edges should be removed. Where water quality permits, all water impoundments should be stocked with suitable native fish species from Hanrahans Creek or Redbank Creek. Water impoundments with the likelihood of wet season overflow should have appropriate erosion prevent structures installed at the overflow point.

3. All water impoundments, access roads, mine waste dumps, sediment traps, borrow pits, site clearing and other development aspects that could result in the creation of water ponding, should be constructed and managed in accordance with information in this report (Section 5.2, Section 5.3.2) and information in the Medical Entomology Branch guideline ‘Guidelines for preventing mosquito breeding sites associated with mining sites’, provided as Appendix 1.

4. Extended dry season pit water discharge into adjacent creeklines could create extensive mosquito breeding by changing the ecology of the receiving creekline. If pit water discharge into a creekline is likely to only occur for 1 year as proposed, then it is unlikely to change the ecology enough in 1 year to promote extensive or on-going mosquito breeding, so would be acceptable from a mosquito ecology aspect. However any proposals for extended pit dewatering over a number of years would need to consider preventing dry season discharge into creeklines, by considering containing water for infiltration and evaporation in a suitable designed retention pond or disposal by sprinklers, or wet season release only. Water released into creeklines would need to be of a quality that allows fish survival.

5. The septic system at the camp should be maintained in a manner that prevents mosquito breeding. This would be ensuring the tank remains fully sealed from mosquito entry, and the absorption trench is functioning appropriately.

6. Any equipment sourced from North Queensland that has previously held rainwater should be treated with a 10% chlorine solution or appropriate residual insecticide such as lambda-cyhalothrin or alpha-cypermethrin, to prevent the importation of the dengue mosquito *Aedes aegypti*. 
7. Periodic inspections of artificial receptacles should be conducted around the mine sites in the wet season, with any receptacle appropriately disposed of, stored under cover away from rain, have drainage holes drilled, or treated with an appropriate larvicide, to prevent endemic mosquito breeding and the potential for *Ae. aegypti* breeding. Artificial receptacles can include disused machinery, used tyres, drums, rainwater tanks, building material wrapped in plastic sheeting, buckets, bins and general rubbish items.

8. Any worker sourced from or returning from an overseas country where malaria is endemic, who experiences high fever should be kept indoors away from mosquito bites until cleared of malaria or treated for malaria by a health professional.

9. If pest mosquito problems arise, the mine camp could be treated with a suitable barrier insecticide such as bifenthrin to minimise the potential for pest problems and mosquito borne disease transmission.

10. The potential natural breeding sites within 2km of the mine site would be difficult and time consuming to survey and control, particularly when extensive flooding occurs. Therefore personal protection and the use of barrier sprays would be the most practical options for preventing mosquito attack during pest periods and preventing mosquito borne disease transmission at the mine site.

11. The mine site should be rehabilitated such that no artificial depressions remain, and septic tanks and other infrastructure that can hold water should be removed from site or buried. Water dams and open pit voids can remain, as long as they have steep sides (ie 1:2 slope or greater) and are deep (2m or greater), and are stocked with native fish from Hanrahans Creek or Redbank Creek during the rehabilitation process. They should also have appropriate erosion prevention overflow measures that allow fish dispersal upstream during the wet season.
8.0 Bibliography


Figures
Figure 1 - General location of Redbank Mine and McArthur River Mine
Figure 2 - McArthur River Mine baseline mosquito monitoring sites 1994-1995.

Legend

- Adult mosquito monitoring trap location

Site 1 Barney Creek M1

Site 2 Barney Creek M2
Figure 3 - Redbank Mine. Potential mosquito breeding sites

- Low lying area of creek. Potential Ae. normanensis, Anopheles sp and Cx. annulirostris mosquito breeding site.
- Pools within creek. Potential Anopheles sp and Cx. annulirostris breeding sites.
- Low lying area of creek. Potential Ae. normanensis, Anopheles sp and Cx. annulirostris mosquito breeding site.

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Table 3 - McArthur River Mine baseline mosquito monitoring April 1994 to May 1995. Borroloola Police Station.

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Appendix 1 – Guidelines for preventing mosquito breeding sites associated with mine sites in the Northern Territory.
Guidelines for Preventing Mosquito Breeding Sites Associated with Mining Sites

Medical Entomology
Centre for Disease Control
Department of Health and Families
Northern Territory Government
Darwin NT
November 2005
Guidelines for Preventing Mosquito Breeding Sites Associated with Mining Sites

Peter Whelan and Allan Warchot

General Comments

All mining operations need to include a section in an Environmental Management Plan for the monitoring and control of mosquitoes. This is necessary because of the potential of mine sites to provide extensive breeding sites for mosquitoes of pest and disease significance. Mine sites also provide the potential for the introduction of mosquito species and mosquito borne diseases into the NT that are either exotic to the NT or have previously been eliminated.

The monitoring of adult mosquitoes in any new mine should include trapping of adult mosquitoes once a month at a number of sites for the initial 12 months baseline mosquito monitoring program. The baseline mosquito-monitoring program provides an indication of the seasonal distribution of the mosquito species present and the relative potential impact of mosquito borne disease to mine personnel.

The monitoring and control of mosquito larvae should be an ongoing operation for the life of the mine. Mosquito larvae must be controlled with an approved mosquito larvicide (Bacillus thuringiensis var. israelensis or methoprene) as part of an organised monitoring and control program. Any mosquito control program should be discussed with the Medical Entomology Branch of the Department of Health and Community Services with regard to methods and insecticides.

Accommodation for personnel should be sited as far as possible from the most important biting insect breeding sites and be adequately insect screened or otherwise protected to reduce the impact of mosquitoes.

The potential for artificially created mosquito breeding sites can be minimised with the appropriate design of water holding facilities and water management procedures.
1. Water Dams

- All water storage dams should be constructed with relatively steep sides (45° slope minimum) to discourage the establishment of semi-aquatic vegetation (eg. *Typha* and *Eleocharis* reeds) that will provide suitable habitats for mosquito breeding.

- Dam margins should be as straight as possible to minimise the linear area available for the establishment of semi-aquatic vegetation.

- Where possible, any closely grouped dams should be joined together to minimise the linear margin of vegetation.

- The bottom of any dam should be graded as level as possible, with a slight slope to one end to form a deeper section for periods of low water. This will remove the potential for the formation of isolated pools as the water level recedes in the dry season.

- Areas surrounding any dam that will be flooded during the wet season should be graded to enable water to drain freely into the dam as the water level recedes, without the formation of isolated pools that are capable of retaining water for a period greater than 5 days.

- There must be no islands formed within any dam. All areas of impounded water should have a relatively deep (2 m) wet season stabilised water level to prevent the emergence of semi-aquatic vegetation.

- Any drainage line directed into a dam must be fitted with a sediment trap or erosion prevention structures just upstream from the dam. This is necessary to prevent the formation of “alluvial fans” that will promote the establishment of semi-aquatic vegetation in the area of the fan where silt will be progressively deposited.

- Any overflow areas from dams should have erosion protection measures to prevent the creation of plunge pools.

- Local native fish should be introduced or have access into any dams where the water quality is suitable for their survival, to provide natural predators for the control of mosquito larvae.

- The margins of any water dam should be inspected annually for vegetation growth such as semi-aquatic vegetation and grass. Any dense marginal vegetation should be herbicided or physically removed, to prevent the vegetation from creation suitable mosquito breeding sites.
2. Wet land filters

- Wetland filters have the potential to provide prolific breeding sites for mosquito species of pest and disease significance. If no other alternative is available for the treatment and disposal of waste water, a wetland filter should incorporate the ability to annually reduce the build up of any dead vegetation. Plans for wetland filter design and siting should be forwarded to the Department of Health and Community Services (Medical Entomology Branch) at the planning stage to ensure that their potential impact on the health of mine site personnel is minimised.

- Annual maintenance could be achieved by dividing a wetland filter into separate sections. A dual system will enable water to be directed into one section of the filter while vegetation is burnt or otherwise reduced in the other section. An ability to manipulate the water level in the filter to strand or drown vegetation would be beneficial for the management of vegetation and mosquito numbers.

- Stocking the wetland filter with local native fish will provide a significant measure for controlling mosquito larvae. The provision of fish however will not remove the need for annual maintenance of the wetland filter.

- Where appropriate, consideration should be given to the provision of a fish ladder on any overflow facility to enable the dispersal of fish into and upstream of the filter.

- Wetland filters may need to be removed after mining operations are completed to enable the future development of adjacent land.

3. Weirs

- Any spillways must be fitted with erosion prevention structures to prevent scouring and siltation of creek lines during periods of overflow.

- Fish ladders should be constructed where appropriate to enable the upstream dispersal of fish following periods of dam overflow.

4. Mine Waste Dumps

- The final surface of mine waste dumps should be contoured so that the surface area is free draining and has no surface depressions.

- Any runoff from a waste dump should be directed to a silt trap to prevent any siltation of natural creek lines. Siltation in creek lines can promote the formation of isolated pools or disrupt fish ecology and may lead to the subsequent establishment of mosquito breeding sites.

- Mine waste dumps should be located away from natural drainage lines, to prevent the upstream impoundment of natural surface water flows. If impractical to locate
mine waste dumps away from natural drainage lines, diversion drains will be required to direct surface water flows around the waste dump.

### 5. Sediment Traps

- Sediment traps need to be designed where possible to be free draining within a period of 5 days after flooding.

- Sediment traps that cannot be free draining within 5 days must be steep sided and have a sloping bottom base to one end, with erosion protection (e.g. reno mattress) at the inflow and overflow facility.

- Sediment traps should be maintained by silt and vegetation removal on an annual basis. There should be a designated and designed access path for silt removal.

- Sediment traps with dry season low flows should be sampled for mosquito larvae monthly in the dry season and appropriate mosquito control programs arranged with the appropriate authority.

### 6. Borrow Pits

- Borrow pits, costeans or scrapes must be rehabilitated, where possible, such that they do not hold water for a period greater than 5 days. These sites within 5km of urban residential areas must be rehabilitated either by filling or rendering them to be free draining.

- Borrow pits that cannot be rehabilitated must be steep sided, have a sloping floor to one end and have surrounding stormwater catchments directed to the upper end, so that they will fill with silt over time.

- There should be no dry season low flows from storm water drainage directed into borrow pits.

### 7. Drainage Paths

- Natural drainage patterns should be maintained where possible. Access roads across drainage lines may need to be fitted with culverts of sufficient size to prevent upstream flooding for periods that will enable mosquito breeding. Culverts should be installed flush with the upstream surface level. Erosion prevention structures will need to be constructed on the downstream side of any culvert, and erosion prevention structures may also be required at the headwalls of any culvert.

- Any disruption to surface drainage should be removed at the end of the mining operations.
8. Pit Dewatering

- Pit water discharge should be free of silt. Dry season pit water discharge should be directed into a water dam, and not into natural drainage lines or creek lines unless there is provision to prevent the growth of semi-aquatic reeds in the discharge area.

9. Waste Water Disposal

- Septic tanks must be installed to DHCS guidelines and should be inspected on an annual basis by the Environmental Officer to ensure that tanks and their effluents do not breed mosquitoes.

- Discharge, overflow or excess effluent from sewage treatment systems must be disposed of in a manner approved by DHCS. A sprinkler disposal system is suitable under most situations. Infiltration systems are acceptable if soil conditions are favourable. The discharge of excess effluent into ephemeral creek lines is not acceptable.

- Sewage ponds should be constructed with steep sides with an impervious lining and be regularly maintained to prevent vegetative growth at the margins (see “The prevention of mosquito breeding in sewage treatment facilities”, available from the Medical Entomology Branch). Surface debris and algal scum should be removed on a regular basis. Monitoring of mosquito larvae should be conducted in sewage ponds on a regular basis and control treatments conducted when necessary.

- Disposal of water into “Application areas” must ensure that water does not pool for a period greater than 5 days.

10. Artificial Containers

- Rainwater tanks must be adequately screened to prevent the entry of mosquitoes.

- Any container capable of holding water, eg. Machinery tyres, drums, disused tyres, tanks, pots, etc. should be stored under cover, be provided with drainage holes, emptied on a weekly basis, treated with an appropriate insecticide on an appropriate schedule, or disposed of in an appropriate dump site to prevent the formation of mosquito breeding sites.

- No used tyres, machinery or other containers that have previously held rain water should be brought to the NT from Queensland unless the containers or machinery has been thoroughly treated with chlorine or an appropriate insecticide to remove the possibility of the introduction of drought resistant eggs of exotic *Aedes* mosquito species.
11. Rubbish and Garbage Dumps

- Rubbish and garbage dumps must be operated in such a matter that there is no ground surface or water filled receptacle pooling of water for a period greater than 5 days, to prevent the formation of mosquito breeding sites.

- Rubbish and garbage dumps must be rehabilitated by filling and surface contouring to ensure they are free draining and have no surface depressions.

12. Decommissioning and Rehabilitation

- A decommissioning and rehabilitation plan should be in place for all mining operations to ensure no actual or potential mosquito breeding sites remain after cessation of mining operations. All disturbed areas should be rehabilitated to be free draining where practical. The proponent should consult the Medical Entomology Branch for input when preparing this document.

- Aspects to consider when decommissioning and rehabilitating a mine site include removing and appropriately grading all sediment ponds, removing all bund walls created for the development, removing infrastructure and artificial receptacles that could pond water, removing water dams and reinstating existing flowpaths where practical, rehabilitating borrow pits, removing wetland filters, sediment traps, and other facilities that could pond water and breed mosquitoes.

- Facilities such as open pit voids and water dams can be left as water holding pits if they are constructed with steep sides (at least 1:2 slope), and stocked with fish during the rehabilitation process.

13. Notes

- These guidelines replace former guidelines ‘Guidelines for preventing mosquito breeding sites associated with mining sites’, by Brian Montgomery and Peter Whelan May 1997.
Appendix 2 – Personal protection from mosquitoes and biting midges in the Northern Territory.
Personal protection from mosquitoes & biting midges in the NT

Medical Entomology
Centre for Disease Control
Department of Health and Families
Northern Territory Government
August 2009
1.0 MOSQUITOES AND BITING MIDGE BITES

Mosquitoes and biting midges (genus *Culicoides* and sometimes erroneously called sand flies) can reach sufficient numbers in various localities to be considered serious pests. The bites themselves can be painful and extremely annoying, and people suffer varying degrees of reaction to bites (Lee 1975). However the possibility of the spread of various diseases by their blood sucking habits to either humans or animals is a more serious outcome. Mosquitoes can carry viruses such as Murray Valley encephalitis, Kunjin, Ross River, and Barmah Forest virus, which cause human disease (Russell 1995). Biting midges do not carry any pathogens in Australia that cause human disease.

Female mosquitoes or biting midges bite to take blood from their hosts, which is necessary for the development of eggs.

Mosquitoes and biting midges show considerable variation in their preference for hosts. Some species feed selectively on cattle, horses, marsupials, amphibians, birds or humans, while other species are relatively indiscriminate feeders.

The time of feeding varies for different species. Many mosquitoes feed just after sunset while others are more active at other times including late in the night, in the late afternoon, or in the early morning. Biting midges are most active in the evening and early morning.

The place of feeding by mosquitoes or biting midges is varied. Some species, such as the brown house mosquito, readily entering houses to feed on people, while others will only bite people outdoors.

When a mosquito or biting midge bites, fine stylets sheathed in the proboscis are inserted into small capillaries in the skin. Blood is sucked up through one of the channels in the stylets, while saliva is injected down an adjacent channel. This saliva contains histamine like substances that the human body recognises as foreign and
often stimulates a bite reaction. Sometimes the saliva can contain viruses or other pathogens that can cause disease.

Some people can become very sensitive after being bitten and suffer a general reaction from further bites. The bites may itch for days, producing restlessness, loss of sleep and nervous irritation. Scratched bites can lead to secondary infections and result in ugly scars. On the other hand, some people become tolerant to particular species and suffer little after-effects from repeated bites.

Biting insects create problems in the enjoyment of outdoor activities, causing a reluctance to enter certain areas after sundown or forcing people to be confined to insect-proof areas at certain times of the year. Personal protection and avoidance measures can offer considerable protection from bites, as well as offering protection against mosquito-borne disease.

2.0 MOSQUITO & BITING MIDGE AVOIDANCE

A sensible precaution to prevent biting insect attack is to avoid areas that are known to have high biting insect activity.

The upper high tide areas near creeks or low-lying areas, particularly near salt marsh habitats, can be significant sources of northern salt marsh mosquitoes (particularly *Aedes vigilax* and various other pest mosquitoes. The period of high salt marsh mosquito activity is usually during the late dry season and early wet season in tropical latitudes. Generally they are prevalent for one to two weeks after the highest tides of the month or significant rain. Dense vegetation near the breeding sites should be avoided during the day over this period. Pest problems during the evening and night can occur within 3 km of productive breeding sites (Whelan, Merianos et al., 1997).

Other areas of high mosquito activity are the large seasonally flooded areas associated with rivers or drainage lines, flooded coastal swamps, extensive reed swamps and lagoons, ill defined or poorly draining creeks, extensive irrigation areas, and wastewater disposal facilities. Densely shaded areas near these habitats should be avoided during the day, and accommodation areas should be at least 3 km from extensive areas of these habitats.

Extensive areas of mangroves with small dendritic creeks or estuarine areas with muddy banks are potential sources of mangrove biting midges. These midges have seasonal and monthly population peaks with the monthly peaks usually associated with the tidal regime. When camping or choosing a permanent living site, a separation distance of at least 2 km from these areas is recommended unless specific biting insect investigations indicate there are no seasonal pest problems (Whelan 1990, Whelan, Hayes et al., 1997).
If camping or selecting house sites near creeks, rivers or lagoons, choose localities of the water body which have steep margins or little marginal emergent vegetation, have swiftly running water with little marginal pooling or vegetation, or do not arise from or empty into a nearby swamp area. Exposed beaches or cliffs away from mangrove or estuary areas are preferred sites to avoid both mosquitoes and biting midges. In more inland areas, locations on hills or rises at least 3 km from ill defined drainage lines, poorly flowing creeks and seasonally flooded areas should avoid the worst mosquito problems.

In residential areas, a local source of mosquitoes may be the cause of the problem. Check nearby potential artificial sources of mosquitoes such as disused swimming pools, receptacles such as tyres and drums, blocked roof gutters, old fishponds, or localised ponding of drains. Sites with mosquitoes breeding can be rectified by physically removing the source or through the use of insecticides.

3.0 SCREENING

The best method of avoiding attack at night is to stay inside insect-screened houses. Screens can be made of galvanised iron, copper, bronze, aluminium or plastic. Near the coast, iron or copper screens are not recommended because of the corrosive action of salt sprays. Homes near biting midge breeding sites require either fine mesh screens or lightproof curtains.

Screens should be of the correct mesh, fit tightly and be in good repair. Biting insects frequently follow people into buildings and for this reason, screen doors should open outward and have automatic closing devices. Insecticides such as permethrin or deltamethrin sprayed on or around screens may give added protection against mosquitoes or biting midges, but care is needed as some insecticides affect screens.

It is advisable to use an insect proof tent when camping near potential biting insect areas. Coastal areas subject to attack by biting midges require tents to be fitted with a finer mesh screening.

4.0 MOSQUITO NETS

Mosquito nets are useful in temporary camps or in unscreened houses near biting insect breeding areas. Generally standard mosquito nets are not sufficient to prevent biting midge attack. White netting is best as mosquitoes accidentally admitted into the net are easily seen and killed. The net is suspended over the bed and tucked under the mattress. An aerosol pyrethrin spray can be used to kill mosquitoes that enter the net. Care is needed not to leave exposed parts of the body in contact with the net, as mosquitoes will bite through the net. Nets can be made more effective by impregnation with permethrin (Lines et al. 1985).
5.0 INSECT PROOF CLOTHING

Head nets, gloves and boots can protect parts of the body, which are not covered by other clothing. Head nets with 1-1.5 meshes to the centimetre are recommended for good visibility and comfort, and additional treatment of the net with a repellent will discourage insect attack. Thick clothing or tightly woven material offers protection against bites. Light coloured, long sleeved shirts and full-length trousers are recommended. For particular risk areas or occupations, protective clothing can be impregnated with permethrin or other synthetic pyrethroid insecticides such as bifenthrin to give added protection (Burgess et al. 1988). Sleeves and collars should be kept buttoned and trousers tucked in socks during biting insect risk periods. Protection is very necessary near areas of salt marsh, mangroves, or large fresh water swamps where the various species of mosquitoes may be very abundant during the day in shaded situations, as well as at night.

6.0 REPELLENTS

Relief from biting insect attack may be obtained by applying repellents to the skin and clothing (Schreck et al. 1984). Many repellents affect plastics and care is needed when applying them near mucous membranes such as the eyes and lips.

Repellents with the chemical diethyl toluamide (DEET) or picaridin give the best protection. Some specific repellent products, such as Aerogard, which are formulated to repel flies, are generally not efficient against mosquitoes or biting midges. Brands such as Rid, Tropical Strength Aerogard, Bushman’s, Muskol, or Repel include specific products that are effective. Those products with higher amounts of DEET or picaridin are usually the most efficient.

Application of repellents over large areas of the body or on extensive areas of children is not recommended particularly those repellents with concentrations of DEET greater than 20%. Protection from mosquito penetration through open weave clothes can be obtained by applying a light application of aerosol repellent to the exterior of clothing. Repellents should be supplementary to protective clothing and should not be regarded as substitutes.

Personal repellents are available as sprays, creams or gels. The creams or gels usually last longer than the aerosol formulations. Repellents can prevent bites from 2 to 4 hours, depending on the repellents, the species of biting insect, or the physical activity of the wearer.

There are some new metofluthrin vapour active pyrethroid spatial repellents on the market where there is passive evaporation from impregnated strips or pads. These have been shown to be very effective in preventing landing or biting of many species of mosquitoes and midges, even in outdoor situations within a close surround of the devices, or within rooms in more enclosed areas.
Electronic insect repellers that emit ultrasonic or audible sounds do not offer any protection against mosquitoes or biting midges. They are based on a false premise and have been found to have no repellent effect under scientific testing (Curtis 1986). Electronic ultrasonic repellers do not repel mosquitoes or biting midges and should not be relied upon for personal protection (Mitchell 1992).

Plants with reported insecticidal properties such as neem trees and the citrosa plant have not been shown to act as mosquito repellents just by growing in the vicinity of people (Mitchell 1992, Matsuda et al. 1996). Growing or positioning these plants near evening activity areas will not prevent mosquito attack. However some plants have some repellency effects as smoke or liniments (see section 12, emergency biting insect protection).

7.0 ANIMAL DIVERSION

Camping upwind near congregations of stock or domestic animals will serve to divert mosquitoes or biting midges to alternative hosts. Similar considerations can be made when planning residential sites and animal holding areas in a rural situation. Dogs of darker colour tend to attract some species of mosquitoes more than lighter colours and can divert some pest problems from people in close vicinity in outdoor situations in the evening.

8.0 LIGHTING DIVERSION

Many mosquito and biting midge species are attracted to white light. This can cause pest problems in unscreened houses or when camping. The use of yellow or even better red incandescent bulbs or fluorescent tubes rather than white light will reduce the attractiveness of lights to insects. An incandescent or ultra violet light placed at a distance from a house or camp can serve to attract insects to an alternative area. This is more effective if the light is close to the breeding site, or between the breeding site and the accommodation area. The attractive lights should not be close to accommodation or directly down wind of accommodation areas. Light proof curtains or similar screening can be very effective in reducing the attraction of biting insects to areas that are illuminated at night.

9.0 ADULT INSECT CONTROL

If mosquitoes or biting midges have entered a screened area they can be knocked down with pyrethrin aerosols. Care should be taken by reading the label to ensure only knockdown aerosols suitable for spraying in the air are used in proximity to people or food.

Other devices that can be effective at killing and/or repelling biting insects include mosquito coils (Charlwood & Jolley 1984) and electric insecticide pads. These devices are only effective in relatively closed areas such as inside buildings or where...
there are only slight breezes. They should be backed up with other measures such as suitable protective clothing or repellents

Large scale adult biting insect control can be achieved for short terms (hours) by using portable or industrial fog generators, backpack misters, or heavy duty ultra-low-volume aerosol generators to knock down active adult insects. The insecticides of choice in these machines are maldison, bioremethrin or pyrethrum. Control relies on good access, open vegetation, and light breezes in the direction of the breeding or harbouring sites. Application should only be during the peak biting insect activity period of those insects actually causing the problem, which is usually the late evening and early night.

There are some synthetic pyrethroid aerosol products available as outdoor yard or patio repellents. Control will only be temporary (hours) and re-invasion will usually occur within hours or from one to a few days, depending on the species, nearby vegetation, proximity to breeding sites, environmental conditions and times of activity of the pest species.

Application of residual insecticides such as maldison, permethrin or other synthetic pyrethroids sprayed as a mist spray to point of run off on building surfaces or nearby vegetation can sometimes give short term (a few days to a few weeks) relief. This method is useful as a barrier protection when large numbers of mosquitoes or biting midges are present near accommodation or outdoor use areas (Helson & Surgeoner 1985). There are some longer term residual synthetic pyrethroids such as bifenthrin that can be used as barrier sprays and provide up to 6 weeks protection (Standfast et al 2003). These residual insecticides can be applied according to label recommendations with the aid of a garden sprayer for walls and solid surfaces and back pack mechanical misters for vegetation screens. Care must be taken with all synthetic pyrethroids around fishponds, fish tanks and other nearby fish habitats to avoid spray drift or run off, as these insecticides are efficient fish poisons.

10.0 INSECTOCUTORS AND INSECT TRAPS

Electric insect insectocutors and other trap or killing devices utilising an attracting light or carbon dioxide have been claimed to clear areas of biting insects and thus protect people. These claims have not been substantiated in outdoor situations with people nearby. While trap devices can attract biting insects, as well as a range of other insects, these devices can not be relied on for protection from biting insect attack (Mitchell 1992). When used in outdoor situations it is possible that they can increase local problems by attracting insects to the vicinity of people. Attractive odours and carbon dioxide emitted by humans then divert the insects from the trap device to the people.
11.0 TREATMENT OF BITES
Relief from bites and prevention of secondary infection can be obtained by the application of various products, either to the skin or internally. The effectiveness of various products is variable, depending on individual reaction. Skin application products include proprietary products such as Eurax, Stingose, Medicreme, Katers lotion, Dermocaine and Paraderm creme, and non-proprietary products such as paw paw ointment, tea tree oil, eucalyptus oil, aloe vera gel, ice, or methylated spirits.

Ice packs to the general bite site will give usually give immediate relief for painful and itchy bites and swelling or blisters from of mosquitoes and biting midges in particular. The sooner the ice pack is applied after bites or reactions, the better the relief, and can often avoid more intense reactions. Some people have had good results from the application of paw paw ointment following bite reactions in the reducing the itching and aiding the healing process.

Other products for internal application for more general symptoms include antihistamine products such as Phenergan, Telfast and Vallergan. Check with your doctor or pharmacist for any products for the latest product and safety information.

12.0 EMERGENCY BITING INSECT PROTECTION
There are a number of emergency measures that can be taken when exposed to biting insects with no protection. Sheltering downwind next to smoky fires can offer considerable protection. Burning dung or aromatic and oil producing foliage from plants such as Hyptis (horehound), Vitex (black plum), Calytrix (Turkey bush), Melaleuca species (Paper bark) and Eucalyptus species (gum trees) can make the smoke more effective. A small native plant Pterocaulon serrulatum (warnulpu) has sticky strongly aromatic leaves, and branches are burnt or the moist leaves are rubbed on the skin by Aborigines in the Katherine district to repel mosquitoes (Aborigines of the NT 1988). Climbing relatively high trees or choosing locations exposed to the wind can also offer protection from some species.

Some protection can be obtained by rubbing exposed skin areas with the leaves of certain plants such as eucalypts, turkey bush, warnulpu, paperbarks or tea-trees that contain volatile oils. However these are not as efficient as proprietary repellents containing deet or picaridin. Other emergency protection measures include coating the skin with mud, or burying yourself in shallow sand with some form of head protection. If all else fails, keep running. The best form of protection, and the most comfortable, require an awareness of the potential problems and adequate preparation.
References


Lee, D. J. (1975), 'Arthropod bites and stings and other injurious effects', School of Public Health & Tropical Medicine, University of Sydney.


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Appendix 3 – Redbank Mine Conceptual Layout Plan