Western Desert Resources Ltd
Roper Bar Iron Ore Mine

February 2012 to January 2013

Study undertaken on behalf of VDM Consulting EcOz
for Western Desert Resources Ltd

Medical Entomology
Centre for Disease Control
NT Department of Health
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Executive summary

Western Desert Resources Limited (WDRL) proposes to construct and operate an iron ore mine within the Roper Bar Iron Ore Province, located in the Gulf Region of the Northern Territory, 50 km inland from the Gulf of Carpentaria at its closest point. The project area is approximately 60km south of the Aboriginal community of Ngukurr (Draft EIS Guidelines. Western Desert Resources Ltd – Roper Bar Iron Ore Project March 2012).

WDRL’s exploration tenements in the region total almost 1850km2, and approximately 5000Ha is under Mineral Lease Application (MLA). The tenements contain an estimated resource of 311 million tonnes (Mt). Initial mining is proposed of the high grade deposit located at Areas E South (MLA28264), with 25Mt minable resource and an expected mine life of approximately eight years. (Draft EIS Guidelines. Western Desert Resources Ltd – Roper Bar Iron Ore Project March 2012).

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, general site disturbance, 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. Mine sites can also be located in areas of seasonally high mosquito abundance, with associated pest and potential disease problems impacting on the workforce.

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 (DOH) was subsequently commissioned by EcOz Environmental Services to conduct a Biting Insect Assessment of the mine site. The biting insect assessment was to include monthly trapping over a 12 month period, and a field investigation to identify actual or potential mosquito breeding sites.

Due to logistical issues regarding trapping in a remote area, monthly mosquito trapping was not carried out over the 12 month period, however the important February to April period was covered by monthly trapping, with the mid dry season (July) and late dry season (October) also covered to provide an indication of dry season abundance arising from permanent water bodies. The larval field investigation was not carried out, as an examination of aerial photography was deemed sufficient to indicate the extensive potential mosquito breeding habitat nearby to the mine site. This report outlines the results of the results of the adult mosquito trapping and desktop examination of aerial photography, and the implications of the results in terms of pest and mosquito borne disease potential. The report also outlines mitigation measures to prevent exposure to mosquito problems, identifies artificially created mosquito breeding sites requiring rectification, and
evaluates proposed development with a focus on preventing the creation or exacerbation of mosquito breeding.

Findings

- The most common mosquito present at the WDRL Mine was the floodwater mosquito *Aedes normanensis*. This mosquito is an aggressive pest mosquito, and would be periodically present throughout the entire mine site ranging from low to very high numbers during the wet season, with maximum numbers likely to occur in the late wet season. Pest problems would begin 9 days after flooding rainfall and last for one to two weeks. *Aedes normanensis* is a potential vector of Ross River virus, Barmah Forest virus and Murray Valley encephalitis virus.

- The most productive *Ae. normanensis* breeding sites are likely to be associated with the Towns River and Magaranyi River, in floodplains, drainage floors and shallow depressions. Seasonally flooded wetlands/waterholes north of the mine site may also be potential breeding sites, particularly after initial wet season flooding.

- The common banded mosquito *Culex annulirostris* was the second most common mosquito species at the WDRL Mine. This mosquito bites at night, and would be present in low to relatively high numbers throughout all areas of the WDRL Mine during the wet season to mid dry season, with peak numbers likely to occur in the late wet and early dry season. *Culex annulirostris* is a major potential vector of RRV, BFV, MVEV, Kunjin virus and many other viruses.

- *Culex annulirostris* breeding sites are likely to be associated with the Towns River and Magaranyi River, in floodplains during the early wet season, and late wet to early dry season. Late wet season to mid dry season pools within the Towns River and Magaranyi River would also be potential breeding sites, particularly any shallow pool with emergent vegetation. Seasonally flooded wetlands/waterholes north of the mine site would also be potential breeding sites, mainly in the late wet to mid dry season on residual vegetated pools and shallow vegetated margins.

- The Australian malaria mosquito *Anopheles annulipes s.l.* was recorded in appreciable numbers at the WDRL Mine. This mosquito bites at night, and would be present in low to relatively high numbers throughout much of the mine, particularly areas of the mine within 1-2km of seasonally flooded areas and dry season ponding. The peak season would be the late wet season to mid dry season. This species is a potential vector of Malaria. *Anopheles annulipes s.l.* breeding sites would be similar to *Cx. annulirostris*.

- Other mosquito species of importance in terms of pest and disease potential at the WDRL Mine included another potential malaria vector *An. amictus*, and the northern salt marsh mosquito *Aedes vigilax*. *Anopheles amictus* is likely to be present in low to moderate numbers in the late wet to mid dry season in most areas of the mine, with main breeding sites likely to be residual pools in the rivers and associated floodplains, along with residual dry season pools associated with the wetlands/waterholes. *Aedes vigilax* is likely to be present in moderate to high numbers during the late dry and early wet season, with this mosquito dispersing from the distant tidal floodplains associated with the Roper River and Limmen Bight tidal floodplains, from around 10-12 days after major tide or rain flooding.
events. *Aedes vigilax* is an aggressive day biting mosquito, and is a vector of RRV and BFV.

- Bing Bong Port is subject to very high mosquito problems caused by *Ae. vigilax* and *Cx. annulirostris*, therefore these mosquitoes will affect workers at the WDRL ore stockpile operations at the port.

- The proposed expansion of the mine could create new mosquito breeding sites, with borrow pits, shallow ground depressions caused by machinery disturbance and road construction, pit dewatering, sediment traps/ponds, stockpiles and associated disturbance, effluent dispersal and the construction of artificial ponds all having the potential to create new mosquito breeding sites.

- The larval control of mosquito breeding sites at the WDRL Mine would be time consuming and expensive to execute in natural breeding areas, due to the extent of seasonally flooded areas adjacent to the mine site. However regular wet season inspections of development components that pond water, as well as the general development site, would assist in preventing an increase in mosquito numbers by identifying potential artificially created mosquito breeding sites that can be targeted for rectification.

- The use of residual barrier insecticides in select areas around the mine buildings could appreciably reduce adult mosquito numbers affecting staff.

- Staff would need to carry out personal protection from mosquitoes during certain periods of the wet season and post wet season, to prevent pest problems and reduce the risk of mosquito borne disease transmission.

**Recommendations**

- New development activities should avoid creating potential mosquito breeding sites. New or upgraded roads should have appropriate culvert provisions to prevent the creation or exacerbation of ponding upstream of the roads, borrow pits should be rendered free draining or filled when no longer required, sediment traps should be free draining or be deep and steep sided, and diversion drains should be constructed around stockpiles where they affect natural surface flows.

- There should be no dry season discharge of pit water into the adjacent ephemeral rivers, to prevent altering the ecology of the receiving river. Any dry season pit water should be discharged into a suitably designed water pond that has the capacity to receive the water without overflowing.

- Water ponds, Tailings Storage Facilities and other water holding ponds constructed for the mine should be deep (>1.8m) and steep sided (1V:2H), to minimise the potential for mosquito breeding. If shallow ponds are required, they should be plastic lined to minimise the potential for emergent and margin vegetation growth.

- Monthly inspections should be carried out at the WDRL Mine during the wet season, to identify areas of potential mosquito breeding associated with constructed or disturbed areas. Aspects to monitor would be the presence of emergent or margin vegetation in the water ponds, the presence of ponding, silt, erosion or vegetation in stormwater drains, the presence of ponding upstream of roads/tracks, the presence of ponding at the base of stockpiles, and the presence of any other shallow ground depressions ponding water.
• Effluent treatment and dispersal facilities should be suitably designed in accordance with relevant Department of Health regulations and guidelines. Effluent dispersal should be carried out in accordance with information outlined in the Medical Entomology guideline ‘Mosquito breeding and sewage pond treatment in the Northern Territory’.

• Monthly inspections of artificial receptacles should be conducted around the mine site during the wet season, with any receptacle ponding water appropriately disposed of, stored under cover away from rain, provided with drainage holes or treated with an appropriate larvicide on an appropriate schedule, to prevent endemic mosquito breeding and potential exotic dengue mosquito breeding. Rainwater tanks and septic tanks should be inspected to ensure they are adequately screened/sealed to prevent mosquito entry.

• Artificial receptacles sourced from North QLD that appear to have previously held rainwater should be treated with a 10% chlorine solution or an appropriate residual insecticide (alpha-cypermethrin or lambda-cyhalothrin), to prevent the possible introduction of *Ae. aegypti* into the WDRL Mine.

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

• The WDRL mine accommodation camps and mine personnel buildings should be treated with the barrier insecticide bifenthin or alpha-cypermethrin when adult mosquito populations reach, or are expected to reach pest levels, or when there is a mosquito borne disease risk, to minimise the potential for mosquito borne disease transmission to workers. Particular potential risk periods for mosquitoes at WDRL Mine would begin 9 days after heavy wet season rainfall events, begin around 10 days after very high tides or rain flooding in the Roper River and Limmen Bight tidal floodplains during the late dry and early wet season, during the late wet and early dry season, and if a worker at the mine is suspected of having malaria. Problem periods at Bing Bong Port would be the early and late dry season and most months of the wet season. A qualified pest controller is recommended to carry out the treatments.

• During pest mosquito periods or potential mosquito borne disease risk periods, staff at the WDRL Mine should be advised to implement personal protection measures from mosquitoes. Up to date information can be found in the Medical Entomology handout ‘Personal protection from mosquitoes and biting midges in the Northern Territory’, provided as Appendix 3.

• Mining pits should be rehabilitated such that the finished surface is free from shallow depressions, while all water ponds should be removed/filled, septic tanks, rainwater tanks and all other artificial receptacles removed, ground depressions filled and contoured, and the natural flow of surface water reinstated where it had been altered. Further information of mine site rehabilitation in regards to preventing a mosquito breeding legacy can be found in ‘Guidelines for preventing mosquito breeding sites associated with mining sites’, provided as Appendix 1.

• A biting insect management plan should be created, which summarises the potential mosquito risks, and outlines mitigation measures and commitments to managing and reducing mosquito populations at the WDRL Mine.
1.0 Introduction

Western Desert Resources Limited (WDRL) proposes to construct and operate an iron ore mine within the Roper Bar Iron Ore Province, located in the Gulf Region of the Northern Territory, 50 km inland from the Gulf of Carpentaria at its closest point. The project area is approximately 60km south of the Aboriginal community of Ngukurr (Draft EIS Guidelines. Western Desert Resources Ltd – Roper Bar Iron Ore Project March 2012).

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evaluates proposed development with a focus on preventing the creation or exacerbation of mosquito breeding.

2.0 Methods

2.1 Trapping

Adult biting insect traps were set at 4 locations at the WDRL mine during the afternoon, and collected the following morning after sunrise. Traps were set by EcOZ environmental staff. The trap type used was a carbon dioxide baited encephalitis virus surveillance (EVS) trap. The trap consisted of an insulated bucket, a suction fan powered by two ‘D’ cell batteries, a ‘grain of wheat’ light, and a rigid collection container (4 litre, 220 mm in diameter) fitted with a muslin sleeve and very fine wire mesh vents. The location of the 4 trap sites are shown in Figure 1.

The mosquitoes collected during trapping were killed by freezing and packaged by EcOz environmental officers, and then delivered to the Medical Entomology Laboratory in Darwin for identification. Adult mosquitoes were identified with the aid of stereo microscopes and various taxonomic keys.

2.2 Mosquito processing

Collected adult mosquitoes were stored in a labelled petri dish in a freezer (-10°C) for later identification. For collections of up to 300 adult mosquitoes, all mosquitoes were individually identified with the aid of light microscopes and various taxonomic keys (Lee et al 1944, 1982, 1984, 1987 and 1989, Marks and Reye 1982, Russell 1996). For collections of over 300 mosquitoes, a sub-sample of 300 mosquitoes was taken from the bulk sample and all mosquitoes in the sub-sample identified, with the sub-sample and bulk samples individually weighed to calculate a multiplication factor. The multiplication factor was then applied to the bulk-sample to calculate final mosquito numbers. The bulk sample was scanned for extra species not located in the sub-sample. All species and totals for each individual collection were then entered into a database for evaluation.

2.3 Desktop examination of potential mosquito breeding sites

High resolution aerial photography was used to identify potential mosquito breeding sites. Areas of interest were low lying drainage areas associated with creeklines, and semi-permanent and permanent water bodies, particularly shallow grassy water bodies. Creeklines were also of interest, particularly relatively open, sunlit creeklines, which have more potential for mosquito breeding than shaded creeklines.

3.0 Results

3.1 Mosquito species present

The results of the mosquito trapping are displayed in Tables 1 to 6. There were 20 adult female mosquito species collected during the trapping program. One male adult mosquito was recorded, *Aedes britteni* at Trap Site 2. In addition, *Ae. (mac) species* males were also recorded, of which they were either *Ae. (mac) nr species 121 or Ae.*
tremulus, with the males of these two species indistinguishable based on morphological features.

*Aedes normanensis* was the most common mosquito collected during trapping, accounting for 66.27% of all adult female mosquitoes (Table 1). *Culex annulirostris* was the second most common mosquito, accounting for 13.84% of all adult female mosquitoes, followed by *Aedes elchoensis* (5.91%) and *Anopheles annulipes* s.l. (4.27%). *Culex palpalis* and *Anopheles amictus* accounted for 2.72% and 2.67% of all adult female mosquitoes, with all other species individually accounting for less than 2% of all adult mosquitoes.

### 3.2 Spatial abundance

Trap Site 2 at the exploration camp was by far the most productive trap site, collecting 58.12% of all adult female mosquitoes, at an average per trapping episode of 1175 adult females (Table 1). Trap Site 3 at the mine camp was the next most productive trap, with 20.94% of all adult female mosquitoes at an average per trap of 423 adult females. This was closely followed by Trap Site 4 at the airstrip, with 15.91% of all adult female mosquitoes at an average per trap of 402 adult females. Trap Site 1 at the process plant recorded appreciably fewer mosquitoes, with 5.03% of all adult female mosquitoes at an average per trap of 170 adult females.

Trap Site 2 was the most productive trap site for *Aedes normanensis*, accounting for 4,629 adult females out of an overall total of 6,700 collected during trapping (Table 1). Trap Site 3 was the next most productive trap site for this mosquito, with a total of 1,100 *Ae. normanensis*, followed by Trap Site 4 (856 adult females) and lastly Trap Site 1 (115 adult females) (Table 1).

Trap Site 2 was also the most productive trap site for *Culex annulirostris*, accounting for a total of 531 adult females out of the 1,399 adult females collected during trapping (Table 1). This was followed by Trap Site 3 (412), Trap Site 4 (361) and lastly Trap Site 1 (95) (Table 1).

*Anopheles annulipes* s.l. was most abundant at Trap Site 2, with a total of 245 adult females, followed by Trap Site 3 (116), Trap Site 4 (41) and lastly Trap Site 1 (30). *Anopheles amictus* was most abundant at Trap Site 2, with 162 adult females collected, followed by Trap Site 3 (56), Trap Site 1 (32) and Trap Site 4 (20) (Table 1). *Culex palpalis* was most abundant at Trap Site 1, with 106 adult females, followed by Trap Site 3 (72), Trap Site 2 (53) and Trap Site 4 (44) (Table 1).

### 3.3 Seasonal abundance

April was by far the most productive month for mosquitoes, with 7,861 adult female mosquitoes collected at an average of 2,620 per trap, accounting for 77.75% of all adult female mosquitoes collected during trapping (Table 2). February was the next most productive month, with 865 adult female mosquitoes collected at an average per trap of 288, accounting for 8.56% of all mosquitoes. March was relatively similar to February, with 811 adult female mosquitoes at an average per trap of 270, accounting for 8.02% of all mosquitoes (Table 2). July recorded 5.12% of all
mosquitoes at an average per trap of 130, with October the least productive month for mosquitoes, with 0.54% of all mosquitoes at an average per trap of 14 (Table 2).

April was the peak abundance month for Ae. normanensis, Cx. annulirostris, An. annulipes s.l. and An. amictus. February was the most productive month for Aedes vigilax and Cx. palpalis (Table 2).

When considering the peak season results, Ae. normanensis reached a very high level at Trap Site 2 in April, with 4331 adult females recorded (Table 4). Trap Site 3 recorded 932 adult females in April (Table 5). Trap Site 4 recorded 561 adult females in April (Table 6), while Trap Site 1 recorded a trap failure (Table 3), but was likely to have recorded appreciable numbers in April.

_Culex annulirostris_ reached a peak season number of 453 adult females at Trap Site 2 in April, followed by 347 adult females at Trap Site 3 in April (Table 5), and 252 at Trap Site 4 in April (Table 6).

_Anopheles annulipes s.l._ recorded peak season numbers at Trap Site 2 in April, with 203 adult females collected (Table 4), followed by 96 at Trap Site 3 in April (Table 5). _Anopheles amictus_ reached a peak season number of 119 adult females at Trap Site 2 in April (Table 4), with the second highest individual trap result being 31 adult females at Trap Site 1 in July (Table 3).

### 3.4 Desktop examination of potential mosquito breeding sites

Potential mosquito breeding sites that were assessed by aerial photography are discussed below. The four main potential mosquito breeding habitats were creeklines, seasonally flooded areas associated with creeklines, shallow wetlands/lagoons, and tidal floodplains and swamps.

#### 3.4.1 Ephemeral rivers

The Towns River and Magaranyi River located within the mine lease are likely to be potential breeding sites for mosquito species such as _Culex annulirostris_ and the _Anopheles_ mosquitoes, when breeding occurs in residual pools. Ephemeral rivers are usually most productive as mosquito breeding sites during the late wet to mid dry season, in shallow pools left behind as the water dries out and fish leave the creeklines. Shallow dry season pools with marginal or emergent vegetation would be more productive for _Cx. annulirostris_ as opposed to open water ponding, while _An. annulipes s.l._ and _An. amictus_ would be breeding in bare open pools as well as in pools with vegetation.

Late dry and early wet season _Cx. annulirostris_ and _Anopheles_ sp. breeding could also occur in depressions in the rivers after isolated rainfall events, before the creeks begin to flow and fish and other aquatic predators colonise the creeklines.
The Towns River within the mine lease contains many associated cut off residual pools and small waterholes, which are likely to be some of the most productive late wet to early/mid dry season breeding sites for *Cx. annulirostris* and *Anopheles* sp. mosquitoes affecting the mine. The Magaranyi River appears to have a more defined central channel and fewer associated depressions and small waterholes, and thus is not likely to be as productive for mosquito breeding compared to the Towns River.

### 3.4.2 Seasonally flooded areas associated with creeklines

The broad, low lying floodplain and depressions associated with the Towns River within the mine lease are likely to be the main breeding sites for *Ae. normanensis*. *Aedes normanensis* breeding would occur after initial flooding rainfall in the early to mid wet season, and after subsequent flooding rainfall events for the remainder of the wet season. Populations are generally likely to build up from the early-mid wet season and culminate in a seasonal peak in March or April. Low lying areas associated with the Magaranyi River are also likely to be wet season *Ae. normanensis* breeding sites, particularly the extensive low lying areas south of the mine lease.

The low lying floodplain areas are also likely to be breeding sites for *Cx. annulirostris* after initial flooding in the early-mid wet season, and during the late wet and early dry season in residual pools. *Anopheles annulipes* s.l. and *Cx. palpalis* are also likely to breed in residual pools in the floodplains during the late wet season and early dry season.

### 3.4.3 Shallow wetlands/waterholes

The numerous wetlands/waterholes north of the mine lease are likely to contain productive breeding sites for *Cx. annulirostris* and *Anopheles* species, mainly in the late wet to mid dry season when water levels recede, leaving behind shallow vegetated pools which protect mosquito larvae from fish and other aquatic predators of mosquito larvae. *Culex annulirostris* breeding could also occur after initial early to mid wet season flooding of previously dry shallow wetlands, before aquatic predators colonise and provide natural mosquito control. The waterholes with semi-aquatic vegetation would be the more productive breeding sites. *Aedes normanensis* is usually associated with low lying drainage areas, but may also breed in newly flooded shallow wetlands/waterholes and associated low lying areas.

### 3.4.4 Tidal floodplains and swamps

The mine lease is located around 30km from the nearest upper tidal floodplains of the Roper River to the north, and Towns River to the northeast, and within around 60km of most of the Limmen Bight coastal floodplains. The appearance of minor numbers of the northern salt marsh mosquito *Aedes vigilax* in the traps indicates the mosquito is dispersing to the mine site from tidal areas. High seasonal numbers of *Ae. vigilax* have been recorded at McArthur River Mine, which is located over 70km from the nearest extensive tidal floodplains, indicating the WDRL mine site is also likely to affected by seasonally high numbers of *Ae. vigilax*. 
4.0 Discussion

4.1 Mosquitoes

4.1.1 Aedes normanensis

Potential Breeding sites

_Aedes normanensis_ 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 rainwater.

The very high numbers recorded at the Exploration Camp trap site (Trap Site 2) indicates that there are nearby very productive or extensive breeding habitat, most likely the floodplain and depressions associated with the Towns River within 2-3km east and south of the trap site. The Mine Camp was the next most productive trap site, indicating the floodplain and depressions associated with Towns River within 2-3km south of the trap site were the likely breeding sites, whilst the Airstrip would have also been affected by dispersal from breeding sites associated with the Towns River. The low lying areas associated with the wetlands/waterholes north of the mine are also potentially productive breeding sites after flooding rainfall events.

The shallow wetlands/waterholes to the north of the exploration camp/mine lease area may be seasonal _Ae. normanensis_ breeding sites, however they do not appear to be the typical drainage floor breeding areas that _Ae. normanensis_ are usually associated with.

Traps were not set or failed at the Process Plant trap site during the peak months of March and April, however the February _Ae. normanensis_ numbers were similar to the February numbers at the very productive Exploration Camp trap site, indicating the possibility of seasonally high numbers at the Process Plant. _Aedes normanensis_ would be dispersing to the Process Plant from low lying seasonally flooded areas of the Towns River 2-3km to the west and north, and possibly to a lesser extent from similar areas of the Magaranyi River 2-3km to the east and south. The Towns River appears to contain greater areas of low lying plains within and adjacent to the mine lease, and is likely be the more important breeding area affecting the Process Plant site.

Seasonal abundance

_Aedes normanensis_ breeds in the wet season, with January to April being the peak months (Whelan 1997a), although this species will also breed in October, November and May in those years when flooding rainfall occurs. Eggs hatch upon inundation with rainwater and pest problems generally begin 9 days after the flooding rain and last for up 1 to 2 weeks.

_Aedes normanensis_ reached a very high peak in April, after lower numbers in February and March. This mosquito was also likely to be present at the mine site in
January. Routine trapping at McArthur River Mine has generally revealed maximum numbers in March or April, indicating the late wet season months of March and April are likely to be the months of maximum abundance at the WRD mine, with elevated abundance in the other wet season months.

**Spatial abundance**

*Aedes normanensis* is generally most common within 2km of breeding sites, although can disperse up to 5km in pest numbers (Whelan 1997a).

The Exploration Camp was by far the most productive trap site, most likely due to potential breeding sites being located to the east and south of the site, as opposed to the second most productive site, the Mine Camp, which had potential breeding sites only to the south. The airstrip was located further away from potential breeding sites associated with the Towns River, hence the slightly lower numbers compared to the Mine Camp. The Process Plant can be expected to have seasonal numbers at least similar to the mine camp and Airstrip, but possibly similar to the Exploration Camp as it is situated in-between the Towns River and Magaranyi River, and could experience dispersal from breeding sites associated with both rivers. Overall, all areas of the mine lease can expect high seasonal *Ae. normanensis* abundance.

**Pest problems**

*Aedes normanensis* is considered a major pest species, and it bites mainly in the evening and at night although will bite in shaded areas during the daytime. Generally 30 or more adult females of this species in a CO2 baited EVS monitoring trap set inside residential areas indicates a likely pest problem (Whelan 1997a). This threshold was greatly exceeded in April at Trap Sites 1-3, and is likely to have been greatly exceeded at Trap Site 4 as well had the trap not failed. Pest thresholds were also exceeded by a low to moderate degree in February and March in all traps that were set, particularly at Trap Site 4 in March.

*Aedes normanensis* seasonal pest problems would begin around 9 days after flooding rain events, and last for around 1-2 weeks. Pest problems throughout the mine site are likely to range from low to very high during periods of the wet season, with greatest pest problems expected during March and April.

**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 (MVEV) (Whelan 1997a). However, *Ae. normanensis* is not considered as important as *Culex annulirostris* and *Aedes vigilax* 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 of MVEV and BFV (Russell & Kay 2002).
Due to the seasonally high to very high numbers expected at the mine site, this species will pose a potential virus risk in the months of January to April. The risk of RRV and BFV transmission risk will range from low to very high in these months, while this species will also pose a potential risk of MVEV transmission.

4.1.2 Culex annulirostris

Potential 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).

*Culex annulirostris* was most common in the late wet season, with low abundance into the mid dry season, and low numbers in the mid wet season. The mid to late wet season breeding sites are likely to have been the floodplains and associated depressions the Towns River and Magaranyi River, with the depressions and cut off pools in the Towns River likely to have been breeding sites in the early dry season. The shallow wetlands/waterholes north of the mine site are also likely to be late wet season and early dry season breeding sites, and mid dry season breeding sites for those waterholes with persistent ponding and semi-aquatic vegetation. The late wet season/early dry season would be the more productive months for breeding, when water levels recede leaving behind shallow heavily vegetated pools suitable for productive mosquito breeding. An early wet season rise in numbers could also occur, after initial flooding of floodplains and shallow grassy depressions before fish and other aquatic predators colonise.

Late wet to mid dry season breeding could occur within the ephemeral Towns and Magaranyi Rivers, although is likely to be localised, and mainly restricted to shallow residual pools with margin or emergent vegetation. The middle to latter stages of the dry season is likely to be more productive due to pools becoming shallower and not suitable for fish habitation.

Seasonal abundance

*Culex annulirostris* is generally most common in the months of January to August inclusive in the Top End of the NT (Whelan 1997a). Early to mid wet season abundance is usually a result of breeding in temporary flooded low lying areas and initial flooding of floodplains and reed swamps, and is usually a short term peak until aquatic predators colonise the flooded areas. The late wet to mid dry season abundance is usually a result of breeding in vegetated pools in receding swamps and floodplains and in residual pools in vegetated creeklines.

There was a late wet season peak at the mine site, followed by a smaller mid dry season peak, and minor numbers in the mid wet season. No traps were set in the early dry season, although early dry season numbers are likely to have been higher than the mid dry season numbers, and possibly similar in magnitude to the late wet
season peak. The mid wet season month of February recorded minor Cx. *annulirostris* numbers, while no traps were set in January, which can be a month of short term high abundance. It is likely that the Cx. *annulirostris* peak season would be similar to that generally experienced in the Top End of the NT, with a short peak in January or February, followed by a longer peak from April to July, with maximum numbers likely to occur in the late wet and early dry season when breeding habitat is likely to be greatest.

**Spatial abundance**

*Culex annulirostris* can disperse up to 10km from extensive breeding sites, although are most abundant 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).

*Culex annulirostris* was most common at the Exploration Camp and Mine Camp, followed relatively closely by the Airstrip. Much lower numbers were recorded at the Process Plant, however the Process Plant trap in April failed, which was the peak month for Cx. *annulirostris*. Due to the Process Plant being located in between two creeklines and associated seasonally flooded areas, it is likely that elevated Cx. *annulirostris* numbers would have also occurred in the late wet season in the Process Plant area.

In summary it can be expected that all areas of the mine will be affected by this mosquito, with greatest abundance closer to its breeding sites.

**Pest numbers**

*Culex annulirostris* reaches pest levels when there are more than 50 per CO2 baited EVS trap per night, for traps set inside residential areas (Whelan 1997a). This level was exceeded to a relatively high degree at the Exploration Camp in April, and to a moderate degree at the Mine Camp and Airstrip in April. The threshold was likely to have been exceeded at the Process Plant in April also. The pest threshold was slightly exceeded at the Process Plant, Exploration Camp and Airstrip in July, and was likely to have been exceeded to a higher extent compared to July in May and June also.

*Culex annulirostris* only bites at night, and is less persistent in the presence of lights, personal protective clothing and repellents (Whelan & Hayes 1993), therefore the levels recorded at the WDRL during both baseline trapping programs represented a potentially low to relatively high pest problem during the peak season months.

**Disease potential**

*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), Ross River virus (RRV) and Barmah Forest virus
(BFV) (Merianos et al 1992, Whelan et al 1993, Russell & Kay 2004). Many other arboviruses have been isolated from this species (Whelan & Weir 1993).

The low to relatively high levels of Cx. annulirostris at the WRD mine indicates this species can be expected to cause a low to relatively high risk of arbovirus transmission during the wet season to mid dry season, with the greatest risk in the late wet and early dry season.

4.1.3 Anopheles annulipes s.l.

Potential breeding sites
This species mainly breeds in freshwater streams and vegetated swamps, and also breeds in some receptacles (Whelan 1997a). The main breeding sites for this species at the mine would be late wet to mid dry season residual pools in the creek lines, residual late wet to early dry season pools and depressions in the floodplains associated with the Towns River and Magaranyi River, and residual late wet season to mid dry season pools in the wetlands/waterholes to the north of the mine site.

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). Anopheles annulipes s.l. was most abundant during the late wet season and mid dry season at the WRD mine, similar to the general observations by Whelan (1997a). Greatest numbers were in the late wet season, due to the greater availability of breeding habitat, whilst numbers were much reduced in the mid dry season, indicating dry season breeding sites are more localised.

Spatial abundance
Anopheles annulipes s.l. spatial abundance was similar to Cx. annulirostris, most likely due to both species sharing similar breeding habitat. This mosquito however has a smaller flight range and are most common within 1-2km of their breeding sites, therefore areas of the mine closer to seasonally flooded areas can expect the greatest abundance. However as the mine site is surrounded by seasonally flooded areas, all areas of the mine site is likely to be affected by this mosquito to some extent during the late wet to mid dry season.

Pest numbers
The nominal pest level for An. annulipes s.l. is considered to be 30 per trap per trap night for a trap set within a residential area. This level was exceeded to a relatively high degree at the Exploration Camp in April, to a moderate degree at the Mine Camp in April, and slightly exceeded at the Airstrip in April. Numbers of this mosquito were likely to have also been exceeded to some extent at the Process Plant in April. The threshold was almost exceeded at the Process Plant in July. In terms of overall pest problems, this species would not be as important as Ae. normanensis and Cx. annulirostris based on expected seasonal abundance, and also due to this mosquito being less commonly implicated in pest problems in the NT.

Disease significance
Anopheles annulipes s.l. is considered a likely vector of malaria (Russell & Kay 2004). However the Anopheles annulipes s.l. species complex is known to include at least 10 sibling species, and nothing is known of the vector competence of each sibling species (Russell & Kay 2004). Nevertheless, An. annulipes s.l. will pose a potential low to moderate malaria risk at the WDRL mine.

As malaria is not endemic to Australia anymore, the risk of local malaria transmission would only occur if a person infected with malaria is bitten by Anopheles mosquitoes at the WDRL mine. Therefore any personnel that have returned from overseas malarious areas and experience a sudden onset of fever should be considered as possibly having malaria, and be advised to seek medical attention and avoid night time exposure to mosquitoes. Only people with malaria that are exposed after sundown would be at risk of spreading malaria, as Anopheles mosquitoes bite only after dusk. People suspected of having malaria should not be rostered on for night shifts until appropriately treated or cleared of having malaria by a health professional.

4.1.4 Other mosquitoes

Aedes vigilax (northern salt marsh mosquito)

This mosquito breeds in upper tidal areas after very high monthly tides during the late dry season and early wet season, and in the early wet season after rainfall flooding events. No potential breeding sites occur nearby to the WDRL mine, however this mosquito can disperse over 50km in pest numbers, and up to 200km from their breeding sites. Previous trapping at McArthur River Mine has revealed levels likely to cause high pest problems, and therefore in some years this mosquito is expected to cause up to high pest problems at the WDRL mine in the late dry-early wet season, particularly as the WDRL mine is located closer to tidal floodplains compared to McArthur River Mine. Trapping recorded minor numbers during most months at the WDRL mine, however there was no trapping conducted during the peak season months of November to January, while the early October trapping revealed minimal numbers due to a lack of very high tides occurring in September.

Aedes vigilax is a potential vector of RRV and BFV, and a major pest mosquito due to its aggressive and day biting habits, therefore this mosquito will cause appreciable pest problems when present in peak numbers at the mine, and will cause a potential virus risk. Peak numbers would begin to occur at the mine around 10-12 days after very high tides or flooding rain during the late dry to early wet season.

Anopheles amictus

This mosquito was less abundant than An. annulipes s.l., and breeds in open sunlit ground pools. This mosquito is regarded as a potential vector of malaria, and the trapping revealed this mosquito could pose a low to moderate risk at the WDRL mine, mainly during the late wet to dry season when the seasonal peak in numbers is expected to occur.

4.2 Mosquito breeding and development aspects

Information on minimising the mine site from creating new mosquito breeding sites can be found in the Medical Entomology handout ‘Guidelines for preventing mosquito breeding associated with mining sites in the NT’, provided as Appendix 1. Some
discussion on specific planning aspects is provided below, based on the proposed mine concept outlined in the Notice of Intent (VDM Consulting January 2012).

4.2.1 Stockpiles
Waste rock/overburden, run of mine and topsoil stockpiles, and any other stockpile has the potential to create mosquito breeding sites, if the stockpile disrupts natural surface flows or depressions are created at the base of the stockpiles via machinery disturbance. Diversion drains would be required for those stockpiles crossing major or minor flow paths, while any isolated depressions at the base of a stockpile should be filled. Appropriately designed sediment traps would be required in draining lines leaving the stockpile sites, to capture sediment and prevent the downstream sedimentation of creeklines or drainage lines.

4.2.2 Sediment traps, water ponds, tailings storage facilities
Any sediment trap, water pond and tailings storage facility should be deep (>1.8m) and have steep sides (1V:2H), to minimise the potential for emergent vegetation growth and mosquito breeding. If shallow ponds are required, they should have a suitable plastic lining to minimise the potential for emergent and margin vegetation growth.

Sediment traps should be designed to drain within 3-4 days after the rainfall event, or be designed as deep (>1.8m) steep sided (1V:2H) structures. Sediment traps should not be constructed within creeklines.

4.2.3 Haul roads, access tracks
The proposed road to Bing Bong Port, and roads and tracks around the mine site and Bing Bong Port stockpile should have appropriate culvert provisions where necessary, to ensure there is no shallow ponding caused by the road embankment. This would be particularly important for areas of the road that crosses low lying areas and creeklines, where an increase in shallow upstream ponding could greatly exacerbate mosquito breeding. Borrow pits used to create roads should be rendered free draining or filled when no longer required.

4.2.4 Effluent disposal
Any new effluent treatment and disposal system should be a suitable design approved by the Environmental Health Section of the NT Department of Health. The disposal of effluent must be carried out in a manner that prevents the creation of ponding and breeding in receiving areas. Further information on effluent dispersal in regards to preventing mosquito breeding can be found in the Medical Entomology guideline ‘Mosquito breeding and sewage pond treatment in the Northern Territory’.

4.2.5 Mining pits and dewatering
Active mining pits are unlikely to become mosquito breeding sites due to deep open water ponding. However pit dewatering has the potential to create mosquito breeding if the pit water is discharged into a creekline during the dry season, which could then alter the ecology of the creekline by promoting semi-aquatic reed growth and subsequently create potential mosquito breeding habitat. Therefore any dry season
pit water discharge should be discharged into a dam that has the capacity to receive the discharge without overflowing.

The final surface provided after the backfilling of pits must be free from surface depressions, to prevent mosquito breeding on the rehabilitated surface.

4.2.6 Process plant

Any processing activity that has the potential to create dry season water discharge could create potential mosquito breeding sites. Any excess water created from operations should be appropriately conveyed to a suitable storage pond via a concrete lined open drain or pipe, and should not be discharged to a creekline or the natural surface.

4.2.7 General site disturbance

The mine site should be maintained free from surface depressions that could pond water and breed mosquitoes. Wheel ruts, site clearing and other activities that can alter the natural ground surface could create new mosquito breeding sites. Any depression created by development processes should be rectified by filling.

4.2.8 Bing Bong Port facility

Bing Bong Port is subject to seasonally very high mosquito numbers and subsequently has a high potential for mosquito borne disease transmission, with many potential breeding sites associated with the dredge disposal ponds and adjacent disturbed areas. *Aedes vigilax* and *Culex annulirostris* are the two most common mosquitoes at Bing Bong Port. The iron ore stockpile and associated road/track at Bing Bong Port should not create any impoundment of water, or creation of shallow surface depressions, otherwise mosquito breeding would be greatly increased. Conversely, the iron ore stockpile has the potential to rectify some of the current mosquito breeding issues at the port, if the stockpile pad is built over an existing low lying or disturbed area.

The stockpile pad at Bing Bong Port should have appropriate diversion drains and silt retention facilities where required, as discussed in Section 4.3.1 for stockpiles.

Bing Bong Port is adjacent to tidal areas with adjacent brackish and fresh water wetlands, are particularly sensitive to disturbance. Guidance on construction practice near tidal areas in regards to preventing mosquito breeding can be found in Appendix 2 'Guidelines for preventing mosquito breeding associated with construction practice near tidal areas in the NT'.

4.2.9 Artificial receptacles

Artificial receptacles such as used tyres, drums, unscreened rainwater tanks, disused machinery, disused septic tanks, stormwater sumps and any rubbish items that can collect rainwater can be potential mosquito breeding sites. Mosquito species that are commonly found breeding in artificial receptacles are *Aedes notoscriptus* and *Culex quinquefasciatus*, with the former a potential vector of RRV. Mosquito species that have been occasionally found breeding in artificial receptacles include the potential malaria vector *An. annulipes* s.l. and the major arbovirus vector *Cx. annulirostris*. Large tyres in particular can be more productive in terms of amount of breeding and diversity of mosquito species.
Any used tyres, water drums, unscreened rainwater tanks, machinery items that can pond water (ie backhoe buckets, excavator tracks), disused machinery, building material and equipment wrapped in plastic sheeting, and any other item capable of ponding even small amounts of water, which are sourced from North Queensland, has the potential to introduce the dengue mosquito *Aedes aegypti* as drought resistant eggs. Artificial receptacles that appear to have previously held rainwater should be treated with a 10% chlorine solution or an appropriate residual insecticide (alpha-cypermethrin or lambda-cyhalothrin), to prevent the possible introduction of *Ae. aegypti* into the WRDL mine.

Monthly inspections of artificial receptacles should be conducted during the wet season around the mine site, with any receptacle found ponding water either disposed of, stored under cover, have drainage holes drilled or treated with an appropriate insecticide on an appropriate schedule. Septic tanks systems should be regularly inspected to ensure the tank is completely sealed, and other potential mosquito entry points are suitably screened to prevent mosquito entry. Screens on rainwater tanks should be inspected for damage that could allow mosquito entry, and repaired as necessary. This would be required to prevent endemic mosquito breeding and minimise the potential for the re-introduction of *Ae. aegypti* from North Queensland.

### 4.3 Mosquito monitoring and control

Due to the extent of potential mosquito breeding sites affecting the mine, and likely environmental values of the potential mosquito breeding sites, it is unlikely from an economic or environmental perspective that the removal of mosquito breeding sites by engineering means can be achieved. The larval control of mosquito breeding is also unlikely to be economically viable, as larval mosquito control using insecticides can be time consuming to carry out as it would require regular surveys of individual sites to locate mosquito breeding, and a large scale aerial spray program.

Larval mosquito control or prevention in developed components of the mine site however should be carried out, as mine sites have the potential to greatly exacerbate mosquito breeding. All water ponds should be inspected monthly for the presence of emergent and margin vegetation, with vegetation removed to prevent the creation of mosquito breeding habitat in the ponds. The base of stockpiles should be inspected after heavy rainfall to identify areas of ponding requiring rectification by filling or draining. Stormwater drains and sediment traps should be inspected monthly for ponding, silt accumulation, erosion and vegetation during the wet season, with any problem drain rectified during the dry season, and sediment traps should be desilted as necessary. The general development site at the WDRL mine and Bing Bong stockpile site should also be inspected monthly during the wet season to locate ground depressions that pond water for greater than 4-5 days, which should then be rectified during the dry season.

As discussed in Section 4.3.11, wet season inspections should be carried out to identify artificial receptacles that pond water, with appropriate rectification measures implemented to prevent receptacle mosquito breeding.
Although the larval control of mosquitoes is unlikely to be feasible for the WDRL mine, the control of adult mosquitoes using an outdoor residual barrier insecticide would be achievable and would provide very good results if appropriately applied. Residual barrier insecticides such as bifenthrin or alpha-cypermethrin can kill adult mosquitoes that rest in shaded areas outside buildings, under demountables and in open work sheds, and appreciably reduce any mosquito problems. Barrier insecticides can be applied before expected *Ae. normanensis* peaks throughout the wet season (ie apply within 8 days of major flooding rainfall events), during October to January if *Ae. vigilax* problems occur, and during April to June/July when freshwater breeding mosquitoes such as *Cx. annulirostris* and *Anopheles* sp. reach their peak season levels.

### 4.4 Personal protection

Personal protection will be periodically required during the wet season, particularly when *Ae. normanensis* peaks occur after flooding rainfall events, and also in the late wet season when other freshwater breeding mosquitoes begin to increase in numbers. Early dry season abundance from *Anopheles* species and *Cx. annulirostris* may also warrant personal protection measures at night, particularly for *Cx. annulirostris* if there is a region wide risk of Murray Valley encephalitis virus transmission, and for *Anopheles* species if a worker is suspected of having malaria. Workers at Bing Bong Port will be subject to very high mosquito problems in the wet season, and therefore would also need to protect themselves from mosquito bites.

Personal protection can be undertaken by a number of means, with the best protection achieved from the use of personal repellents, light coloured protective clothing (which can be treated with permethrin), outdoor mosquito lanterns or gas powered outdoor insecticide vaporising devices, and outdoor residual barrier insecticides. Accommodation buildings should be appropriately screened/sealed to prevent mosquito entry. Further information can be found in Appendix 3 ‘Personal protection from mosquitoes and biting midges in the NT’.

### 4.5 Rehabilitation

The mine site and stockpile site at Bing Bong Port should be rehabilitated to remove potential mosquito breeding sites. This will include removing artificial wetlands, sediment traps, water ponds, infrastructure, artificial receptacles and septic tanks that could pond water, rectifying borrow pits, shallow surface depressions and impeded drainage areas, and reinstating natural flow paths where practical.

Open pit voids can be left as water holding structures if they have steep sides (at least 1V:2H) and have a relatively deep wet season water level (at least 2m), and are stocked with local native fish.

### 4.6 Limitations

Monthly mosquito trapping can be insensitive for plague mosquito species such as *Aedes normanensis*, which suddenly appear around 9 days after rainfall events and persist in peak numbers for 1-2 weeks. Therefore monthly trapping had the potential to miss maximum monthly numbers of this mosquito.
The common banded mosquito *Culex annulirostris* sometimes reaches a short peak in numbers over a few weeks in the mid wet season. Traps were not set in January, which can be a month of increased abundance. Traps were also not set in May, which can be a month of increased abundance in areas nearby to floodplains.

Traps were not set 12-14 days after the highest tide or heavy rainfall in November, December or January, therefore did not indicate the extent of salt marsh mosquito problems at the WDRL mine site.

Monthly mosquito trapping in general is relatively insensitive as mosquito populations can vary widely from week to week. Weekly or fortnightly adult mosquito trapping is generally the most informative adult mosquito trapping schedule.
5.0 Conclusions

- The most common mosquito present at the WDRL Mine was the floodwater mosquito *Aedes normanensis*. This mosquito is an aggressive pest mosquito, and would be periodically present throughout the entire mine site ranging from low to very high numbers during the wet season, with maximum numbers likely to occur in the late wet season. Pest problems would begin 9 days after flooding rainfall and last for one to two weeks. *Aedes normanensis* is a potential vector of Ross River virus, Barmah Forest virus and Murray Valley encephalitis virus.

- The most productive *Ae. normanensis* breeding sites are likely to be associated with the Towns River and Magaranyi River, in floodplains, drainage floors and shallow depressions. Seasonally flooded wetlands/waterholes north of the mine site may also be potential breeding sites, particularly after initial wet season flooding.

- The common banded mosquito *Culex annulirostris* was the second most common mosquito species at the WDRL Mine. This mosquito bites at night, and would be present in low to relatively high numbers throughout all areas of the WDRL Mine during the wet season to mid dry season, with peak numbers likely to occur in the late wet and early dry season. *Culex annulirostris* is a major potential vector of RRV, BFV, MVEV, Kunjin virus and many other viruses.

- *Culex annulirostris* breeding sites are likely to be associated with the Towns River and Magaranyi River, in floodplains during the early wet season, and late wet to early dry season. Late wet season to mid dry season pools within the Towns River and Magaranyi River would also be potential breeding sites, particularly any shallow pool with emergent vegetation. Seasonally flooded wetlands/waterholes north of the mine site would also be potential breeding sites, mainly in the late wet to mid dry season on residual vegetated pools and shallow vegetated margins.

- The Australian malaria mosquito *Anopheles annulipes s.l.* was recorded in appreciable numbers at the WDRL Mine. This mosquito bites at night, and would be present in low to relatively high numbers throughout much of the mine, particularly areas of the mine within 1-2km of seasonally flooded areas and dry season ponding. The peak season would be the late wet season to mid dry season. This species is a potential vector of Malaria. *Anopheles annulipes s.l.* breeding sites would be similar to *Cx. annulirostris*.

- Other mosquito species of importance in terms of pest and disease potential at the WDRL Mine included another potential malaria vector *An. amictus*, and the northern salt marsh mosquito *Aedes vigilax*. *Anopheles amictus* is likely to be present in low to moderate numbers in the late wet to mid dry season in most areas of the mine, with main breeding sites likely to be residual pools in the rivers and associated floodplains, along with residual dry season pools associated with the wetlands/waterholes. *Aedes vigilax* is likely to be present in moderate to high numbers during the late dry and early wet season, with this mosquito dispersing from the distant tidal floodplains associated with the Roper River and Limmen Bight tidal floodplains, from around 10-12 days after major tide or rain flooding events. *Aedes vigilax* is an aggressive day biting mosquito, and is a vector of RRV and BFV.
Bing Bong Port is subject to very high mosquito problems caused by Ae. vigilax and Cx. annulirostris, therefore these mosquitoes will affect workers at the WDRL ore stockpile operations at the port.

The proposed expansion of the mine could create new mosquito breeding sites, with borrow pits, shallow ground depressions caused by machinery disturbance and road construction, pit dewatering, sediment traps/ponds, stockpiles and associated disturbance, effluent dispersal and the construction of artificial ponds all having the potential to create new mosquito breeding sites.

The larval control of mosquito breeding sites at the WDRL Mine would be time consuming and expensive to execute in natural breeding areas, due to the extent of seasonally flooded areas adjacent to the mine site. However regular wet season inspections of development components that pond water, as well as the general development site, would assist in preventing an increase in mosquito numbers by identifying potential artificially created mosquito breeding sites that can be targeted for rectification.

The use of residual barrier insecticides in select areas around the mine buildings could appreciably reduce adult mosquito numbers affecting staff.

Staff would need to carry out personal protection from mosquitoes during certain periods of the wet season and post wet season, to prevent pest problems and reduce the risk of mosquito borne disease transmission.

6.0 Recommendations

New development activities should avoid creating potential mosquito breeding sites. New or upgraded roads should have appropriate culvert provisions to prevent the creation or exacerbation of ponding upstream of the roads, borrow pits should be rendered free draining or filled when no longer required, sediment traps should be free draining or be deep and steep sided, and diversion drains should be constructed around stockpiles where they affect natural surface flows.

There should be no dry season discharge of pit water into the adjacent ephemeral rivers, to prevent altering the ecology of the receiving river. Any dry season pit water should be discharged into a suitably designed water pond that has the capacity to receive the water without overflowing.

Water ponds, Tailings Storage Facilities and other water holding ponds constructed for the mine should be deep (>1.8m) and steep sided (1V:2H), to minimise the potential for mosquito breeding. If shallow ponds are required, they should be plastic lined to minimise the potential for emergent and margin vegetation growth.

Monthly inspections should be carried out at the WDRL Mine during the wet season, to identify areas of potential mosquito breeding associated with constructed or disturbed areas. Aspects to monitor would be the presence of emergent or margin vegetation in the water ponds, the presence of ponding, silt, erosion or vegetation in stormwater drains, the presence of ponding upstream of roads/tracks, the presence of ponding at the base of stockpiles, and the presence of any other shallow ground depressions ponding water.

Effluent treatment and dispersal facilities should be suitably designed in accordance with relevant Department of Health regulations and guidelines.
Effluent dispersal should be carried out in accordance with information outlined in the Medical Entomology guideline ‘Mosquito breeding and sewage pond treatment in the Northern Territory’.

- Monthly inspections of artificial receptacles should be conducted around the mine site during the wet season, with any receptacle ponding water appropriately disposed of, stored under cover away from rain, provided with drainage holes or treated with an appropriate larvicide on an appropriate schedule, to prevent endemic mosquito breeding and potential exotic dengue mosquito breeding. Rainwater tanks and septic tanks should be inspected to ensure they are adequately screened/sealed to prevent mosquito entry.

- Artificial receptacles sourced from North QLD that appear to have previously held rainwater should be treated with a 10% chlorine solution or an appropriate residual insecticide (alpha-cypermethrin or lambda-cyhalothrin), to prevent the possible introduction of *Ae. aegypti* into the WDRL Mine.

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

- The WDRL mine accommodation camps and mine personnel buildings should be treated with the barrier insecticide bifenthrin or alpha-cypermethrin when adult mosquito populations reach, or are expected to reach pest levels, or when there is a mosquito borne disease risk, to minimise the potential for mosquito borne disease transmission to workers. Particular potential risk periods for mosquitoes at WDRL Mine would begin 9 days after heavy wet season rainfall events, begin around 10 days after very high tides or rain flooding in the Roper River and Limmen Bight tidal floodplains during the late dry and early wet season, during the late wet and early dry season, and if a worker at the mine is suspected of having malaria. Problem periods at Bing Bong Port would be the early and late dry season and most months of the wet season. A qualified pest controller is recommended to carry out the treatments.

- During pest mosquito periods or potential mosquito borne disease risk periods, staff at the WDRL Mine should be advised to implement personal protection measures from mosquitoes. Up to date information can be found in the Medical Entomology handout ‘Personal protection from mosquitoes and biting midges in the Northern Territory’, provided as Appendix 3.

- Mining pits should be rehabilitated such that the finished surface is free from shallow depressions, while all water ponds should be removed/filled, septic tanks, rainwater tanks and all other artificial receptacles removed, ground depressions filled and contoured, and the natural flow of surface water reinstated where it had been altered. Further information of mine site rehabilitation in regards to preventing a mosquito breeding legacy can be found in ‘Guidelines for preventing mosquito breeding sites associated with mining sites’, provided as Appendix 1.

- A biting insect management plan should be created, which summarises the potential mosquito risks, and outlines mitigation measures and commitments to managing and reducing mosquito populations at the WDRL Mine.
7.0 Acknowledgements

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Mosquitoes were identified by Jane Carter and Nadine Copley from Medical Entomology.
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Figures
Figure 1. Western Desert Resources Ltd Roper Bar Iron Ore Project. Adult CO2 biting insect trap locations.

Legend

- Adult CO2 biting insect trap location

**Legend**

- Adult CO2 biting insect trap location

Absolute scale 1:50,000

Floodplain, cut off pools. Potential major mosquito breeding sites January to July/August.

Floodplain, cut off pools. Potential major mosquito breeding sites January to July/August.

Floodplain, cut off pools. Potential major mosquito breeding sites January to July/August.

Floodplain, cut off pools. Potential major mosquito breeding sites January to July/August.

Numerous wetlands/waterholes. Potential major mosquito breeding sites April to August. Shallow vegetated lagoons will be more productive breeding sites.

Low lying areas. Potential major mosquito breeding sites January to May.

Low lying areas. Potential major mosquito breeding sites January to May.

Low lying areas. Potential major mosquito breeding sites January to May.

Floodplain, cut off pools. Potential major mosquito breeding sites January to July/August.

Floodplain, cut off pools. Potential major mosquito breeding sites January to July/August.

Floodplain, cut off pools. Potential major mosquito breeding sites January to July/August.

Floodplain, cut off pools. Potential major mosquito breeding sites January to July/August.

Towns River central channel. Potential mosquito breeding site May to July/August.

Magaranyi River central channel. Potential mosquito breeding site May to July/August.

WDR Site 1 Process Plant

WDR Site 2 Exploration Camp

WDR Site 3 Mine Camp

WDR Site 4 Airstrip

Floodplain, cut off pools. Potential major mosquito breeding sites January to July/August.

Floodplain, cut off pools. Potential major mosquito breeding sites January to July/August.

Floodplain, cut off pools. Potential major mosquito breeding sites January to July/August.

Floodplain, cut off pools. Potential major mosquito breeding sites January to July/August.

Port Roper 40km

Ngukurr 48km

Bing Bong 142km
Tables
Table 1 - WDRL Roper Bar Iron Ore Project Biting Insect Assessment. Total number of all female mosquitoes caught at all trap sites during trapping.

<table>
<thead>
<tr>
<th>Trap location</th>
<th>No. of traps</th>
<th>Ave. per trap</th>
<th>%</th>
<th>Ave. per trap</th>
<th>%</th>
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<td>1</td>
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<td>1.35</td>
<td>0.23</td>
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<td>0.65</td>
<td>0.00</td>
</tr>
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<td>0.23</td>
<td>1.35</td>
<td>0.23</td>
</tr>
</tbody>
</table>

Table continued...

- **Ave. per trap** column shows the average number of mosquitoes per trap.
- **%** column shows the percentage of the total count that each species represents.

Medical Entomology, DoH.
<p>| Date collected | Ad. (Ady) catastica | Ae. (Cha) echoveirolita | Ae. (Fin) britteni | Ae. (Mac) nr species 12.1 | Ae. (Mac) species | Ae. (Mac) tremulus | Ae. (Mol) pecuniosus | Ae. (Muc) alternans | Ae. (Neo) lineatopennis | Ae. (Och) normanensis | Ae. (Och) vigilax | Ae. (Aro) bannorby | Ae. (Col) anticus | Ae. (Col) amnaloa s.l. | Ae. (Col) maruakensis | Ae. (Col) nunguansis | An. (Ano) bancroftii | An. (Cel) amictus | An. (Cel) annulipes s.l. | An. (Cel) meraukensis | An. species (hypomelanic) | Cq. (Coq) orthoavater | Cq. (Cux) annulirostris | Cq. (Cux) palpalis | Not collected mosquitoes | Ve. (Ver) reesi | Nos. of traps | Ave. per trap |
|-----------------|------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 1-Feb-12        | 3                | 5               | 232             | 0               | 15              | 0               | 36              | 19              | 0               | 0               | 297             | 20              | 0               | 0               | 24              | 0               | 1               | 1               | 37              | 174             | 0               | 1               | 0               | 865             | 8.56            | 3               | 288.33          |
| 7-Mar-12        | 3                | 1               | 142             | 0               | 0               | 0               | 8               | 7               | 0               | 0               | 576             | 2               | 1               | 2               | 17              | 1               | 0               | 0               | 0               | 43              | 2               | 1               | 0               | 2               | 811             | 8.02            | 3               | 270.33          |
| 18-Apr-12       | 17               | 5               | 169             | 0               | 0               | 0               | 10              | 88              | 1               | 119             | 5624            | 0               | 3               | 154             | 330             | 20              | 0               | 0               | 22              | 1052            | 47              | 0               | 1               | 0               | 7861            | 77.75           | 3               | 2620.33         |
| 19-Jul-12       | 0                | 0               | 18              | 0               | 0               | 0               | 4               | 1               | 0               | 0               | 3               | 1               | 1               | 108             | 60              | 6               | 0               | 0               | 1               | 265             | 50              | 0               | 0               | 0               | 518             | 5.12            | 4               | 129.50          |
| 2-Oct-12        | 0                | 0               | 37              | 0               | 0               | 0               | 0               | 0               | 0               | 0               | 3               | 0               | 6               | 1               | 0               | 0               | 0               | 0               | 4               | 2               | 2               | 0               | 0               | 0               | 55              | 0.54            | 4               | 13.75           |
| <strong>Totals</strong>      | <strong>23</strong>           | <strong>11</strong>          | <strong>598</strong>         | <strong>0</strong>           | <strong>15</strong>          | <strong>0</strong>           | <strong>58</strong>          | <strong>115</strong>         | <strong>1</strong>           | <strong>123</strong>         | <strong>6700</strong>        | <strong>28</strong>          | <strong>5</strong>           | <strong>270</strong>         | <strong>432</strong>         | <strong>27</strong>          | <strong>1</strong>           | <strong>1</strong>           | <strong>28</strong>          | <strong>1399</strong>        | <strong>275</strong>         | <strong>2</strong>           | <strong>10110</strong>       | <strong>100.00</strong>      | <strong>17</strong>          | <strong>594.71</strong>      |
| <strong>%</strong>           | 0.23             | 0.11            | 5.91            | 0.00            | 0.15            | 0.00            | 0.57            | 1.14            | 0.01            | 1.22            | 66.27           | 0.26            | 0.05            | 2.67            | 4.27            | 0.27            | 0.01            | 0.01            | 0.28            | 13.84           | 2.72            | 0.02            | 100.00          |
| <strong>Ave per trap</strong>| 1.35             | 0.65            | 35.18           | 0.00            | 0.88            | 0.00            | 3.41            | 6.76            | 0.06            | 7.24            | 394.12          | 1.53            | 0.29            | 15.88           | 25.41           | 1.59            | 0.06            | 0.06            | 1.65            | 82.29           | 16.18           | 0.12            | 594.71          |</p>
<table>
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<tr>
<th>Date collected</th>
<th>Ae. (Cha) elchoensis</th>
<th>Ae. (Mac) nr species 121</th>
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<th>Ae. (Mac) pecuniosus</th>
<th>Ae. (Mac) normanensis</th>
<th>Ae. (Och) vigilax</th>
<th>An. (Ano) bancrofti</th>
<th>An. (Cel) amictus</th>
<th>An. (Cell) annulipes s.l.</th>
<th>An. (Cell) meraukensis</th>
<th>Cq. (Coq) xanthogaster</th>
<th>Cx. (Cux) annulirostris</th>
<th>Cx. (Cux) palpalis</th>
<th>Not collected mosquitoes</th>
<th>Trap failure mosquitoes</th>
<th>Totals</th>
<th>%</th>
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<tr>
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<td>3</td>
<td>115</td>
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<tr>
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<td>0.20</td>
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<td>1.77</td>
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<td>1.77</td>
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<td>6.29</td>
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</table>

Table 3 - WDRL Roper Bar Iron Ore Project Biting Insect Assessment. Total number of all female mosquitoes caught at Trap Site 1 Process Plant.
Table 4 - WDRL Roper Bar Iron Ore Project Biting Insect Assessment. Total number of all female mosquitoes caught at Trap Site 2 Exploration Camp

| Date collected | Ad. (Ady) catasticta | Ae. (Cha) elchoensis | Ae. (Mac) nr species 121 | Ae. (Mac) species | Ae. (Mac) tremulus | Ae. (Mol) pecuniosus | Ae. (Mac) lineatopennis | Ae. (Och) normanensis | Ae. (Och) vigilax | An. (Cel) amictus | An. (Cel) annulipes s.l. | An. (Cel) meraukensis | An. (Cel) novaguinensis | An. species (hypomelanic) | Cq. (Coq) xanthogaster | Cx. (Cux) annulirostris | Cx. (Cux) palpalis | Ve. (Ver) reesi | Totals | % |
|----------------|----------------------|----------------------|--------------------------|------------------|------------------|---------------------|----------------------|---------------------|-----------------|----------------|------------------------|----------------|----------------|------------------------|----------------|----------------|----------------|-------------|
| 1-Feb-12       | 3  3  35 0  3  0  1  6  0  116 9  0  17 0  1  1  1  3  43 0 | 242 4.12 |
| 7-Mar-12       | 3  0  1 0  0  0  0  0  0  3  182 0  1  8  1  0  0  0  6  1  2  208 3.54 |
| 18-Apr-12      | 12 0 12 0  0  0  0  0  12 119 4331 0  119 203 12 0  0  12 453 0  0  5285 89.94 |
| 19-Jul-12      | 0  0  1 0  0  0  0  0  0  38 16 1  0  0  1  69 7  0  133 2.26 |
| 2-Oct-12       | 0  0  0 0  0  0  0  0  0  4  1  0  0  0  0  0  2  0  8  0.14 |
| Totals         | 18 3 49 0  3  0  1  18 122 4629 10  162 245 14 1  1  14 531 53  2  5876 100.00 |
| %              | 0.31 0.05 0.83 0.00  0.05 0.00  0.02 0.31 2.08 78.78 0.17 2.76 4.17 0.24 0.02 0.24 9.04 0.90 0.03 100.00 |
| Date collected | Ad. (Ady) catastica | Ae. (Cha) elchoensis | Ae. (Mac) nr species 121 | Ae. (Mac) species | Ae. (Mol) pecuniosus | Ae. (Mac) tremulus | Ae. (Mac) alternans | Ae. (Muc) normanensis | Ae. (Mac) species | An. (Ano) bancroftii | An. (Cel) amictus | An. (Cel) annulipes s.l. | An. (Cel) meraukensis | Cq. (Coq) xanthogaster | Cx. (Cux) annulirostris | Cx. (Cux) palpalis | Totals | % |
|----------------|---------------------|----------------------|-------------------------|------------------|---------------------|-------------------|-------------------|-------------------|-------------------|-------------------|------------------|---------------------|---------------------|---------------------|---------------------|---------------------|-----------------|
| 1-Feb-12       | 0                   | 1                    | 127                     | 3                | 0                   | 4                 | 11                | 0                 | 0                 | 0                 | 6                | 0                  | 0                  | 8                  | 45                  | 278               | 13.14           |
| 7-Mar-12       | 0                   | 1                    | 22                      | 0                | 0                   | 3                 | 5                 | 0                 | 1                 | 99                | 1                | 1                  | 10                 | 0                  | 5                  | 0                  | 0                  | 11               | 149             | 7.04             |
| 18-Apr-12      | 5                   | 5                    | 96                      | 0                | 0                   | 5                 | 50                | 1                 | 0                 | 932               | 0                | 0                  | 27                 | 96                 | 5                  | 5                  | 347                | 14               | 1588            | 75.05            |
| 19-Jul-12      | 0                   | 0                    | 1                       | 0                | 0                   | 0                 | 0                 | 0                 | 0                 | 1                 | 0                | 29                 | 9                  | 1                  | 0                  | 46                 | 13               | 100             | 4.73             |
| 2-Oct-12       | 0                   | 0                    | 0                       | 0                | 0                   | 0                 | 0                 | 0                 | 0                 | 0                 | 0                | 0                  | 0                  | 0                  | 0                  | 1                  | 0                | 0               | 1               | 0.05            |
| Totals         | 5                   | 7                    | 246                     | 3                | 0                   | 12                | 66                | 1                 | 1                 | 1100              | 6                | 1                  | 56                 | 116                | 6                  | 6                  | 412                | 72               | 2116            | 100.00           |
| %              | 0.24                | 0.33                 | 11.63                   | 0.14             | 0.00                | 0.57              | 3.12              | 0.05              | 0.05              | 51.98             | 0.28             | 0.05               | 2.65               | 5.48               | 0.28               | 0.28              | 19.47              | 3.40            | 100.00          |
### Table 6 - WDRL Roper Bar Iron Ore Project Biting Insect Assessment. Total number of all female mosquitoes caught at Trap Site 4 Airstrip

<table>
<thead>
<tr>
<th>Date collected</th>
<th>Ae. (Cha) elchoensis</th>
<th>Ae. (Mac) tremulus</th>
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<th>Ae. (Och) nemanensis</th>
<th>An. (Ano) bancrofti</th>
<th>An. (Cel) amictus</th>
<th>An. (Cel) annulipes s.l.</th>
<th>An. (Cel) merakwenesi</th>
<th>Cq. (Coq) xanthogaster</th>
<th>Cx. (Cux) annulirostris</th>
<th>Cx. (Cux) palpalis</th>
<th>Trap failure mosquitoes</th>
<th>Totals</th>
<th>%</th>
</tr>
</thead>
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<td>0</td>
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<td>0</td>
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<td>0</td>
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</table>
Appendix 1 – Guidelines for preventing mosquito breeding sites associated with mining sites in the NT
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 (e.g. 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 can not 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 – Guidelines for preventing mosquito breeding sites associated with construction practice near tidal areas in the NT
Guidelines for Preventing Mosquito Breeding Associated with Construction Practice near Tidal Areas in the NT

Medical Entomology
Centre for Disease Control
Northern Territory Department of Health
Darwin NT
June 1988
Updated February 2011
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1.0 Introduction

There have been many instances of construction in or near tidal areas in the Top End of the Northern Territory that have resulted in ecological disturbance and subsequent mosquito breeding. Many of the deleterious disturbances have been the result of little or no recognition of the ecological consequences of construction practices, either during the construction period or on completion of the project. Much of the deleterious ecological disturbance can be avoided or minimized by consultation between engineers or construction authorities and people with ecological expertise.

One of the most significant impacts of construction in or adjacent to tidal areas is the creation of new sources of pest and potential disease causing mosquitoes. The creation of new mosquito breeding sites can have an enormous bearing of the quality of life, land values, costly rehabilitation measures, mosquito control programs and most importantly, the health and legal implications involved in an outbreak of mosquito-borne disease.

2.0 Aim of Guidelines

These guidelines are intended as a checklist for planners, engineers or any supervisory officers, responsible for the planning or implementation of any construction activity near tidal areas, in order to prevent the creation of mosquito breeding sites.

They are also intended to be used as a checklist in the preparation and evaluation of any Preliminary Environment Report or Environmental Impact Statement. In this way it is hoped that the potential for additional mosquito breeding areas will be recognized and avoided in the planning or implementation phases of any construction project, so that later costly or environmentally disruptive rectification works will not be necessary.

These guidelines should be used by the relevant construction or advisory authorities. Any doubts on the potential for creating mosquito breeding sites on any project can be referred to the Senior Medical Entomologist of the Northern Territory Department of Health.
3.0 Mosquitoes of Public Health Importance

Background information on mosquito biology, breeding sites, potential diseases and specific control measures can be found in "Mosquitoes of Public Health Importance in the Northern Territory and their Control" (1984), available from the Department of Health. Of the 100 species of mosquitoes in the Northern Territory, fifteen (15) species can breed in the intertidal zone, at least at certain sites and some times of the year. These include the principal vectors of malaria, Ross River virus, Murray Valley encephalitis, and a number of other arbovirus diseases, as well as some species regarded as the most important human pest species.

<table>
<thead>
<tr>
<th>Salt Water Mosquitoes</th>
<th>Common Name</th>
<th>Importance</th>
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<tr>
<td>Anopheles hilli</td>
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<tr>
<td>Culex sitiens</td>
<td>Saltwater Culex</td>
<td>Localized pest species</td>
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<tr>
<td>Aedes alternans</td>
<td>Scotch Grey</td>
<td>Negligible pest</td>
</tr>
<tr>
<td>Aedes vigilax</td>
<td>Northern Saltmarsh mosquito</td>
<td>Major pest and disease vector</td>
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<table>
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<td>Australian malaria mosquito</td>
<td>Major malaria vector</td>
</tr>
<tr>
<td>Verrallina funerea</td>
<td>Brackish forest mosquito</td>
<td>Important mosquito local pest</td>
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<table>
<thead>
<tr>
<th>Brackish to fresh water mosquitoes</th>
<th>Common Name</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
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<td>Culex annulirostris</td>
<td>Common banded mosquito</td>
<td>Major pest and disease vector</td>
</tr>
<tr>
<td>Anopheles bancroftii</td>
<td>Black malaria mosquito</td>
<td>Potential malaria vector and pest</td>
</tr>
<tr>
<td>Anopheles annulipes s.l.</td>
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<td>Anopheles meraukensis</td>
<td>Freshwater reed Anopheles</td>
<td>Pest species</td>
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<tr>
<td>Coquillettidia xanthogaster</td>
<td>The golden mosquito</td>
<td>Important pest species</td>
</tr>
<tr>
<td>Mansonia uniformis</td>
<td>Aquatic plant mosquito</td>
<td>important pest species</td>
</tr>
</tbody>
</table>
3.1 Malaria

Malaria was only eradicated in the Northern Territory in 1962 and many communities in the Northern Territory remain vulnerable to malaria reintroduction, particularly those communities which are near large sources of Anopheles mosquitoes. Each year up to thirty malaria cases are imported into the Top End from overseas, and the Department of Health investigates and follows up each case. With increasing numbers of people living in remote areas with large mosquito populations, or adjacent to mosquito sources in expanding urban areas, the potential for malaria reintroduction is increasing. In particular circumstances, adult mosquito control measures near urban areas may be necessary, but problems due to lack of access, thick vegetation, or the proximity to urban areas, may prevent or reduce the effectiveness of these measures. We need to reduce these potential problems by reducing the mosquito breeding areas adjacent to urban areas.

3.2 Arbovirus Diseases

Each year there can be from 100 to 400 cases of Ross River virus disease reported in the Top End. These are laboratory confirmed cases only, and it is thought the number of clinical cases is very much higher. Many of these cases have likely sites of transmission in towns adjacent to particularly productive mosquito breeding areas. With a tropical lifestyle and an expanding population, it is becoming increasingly necessary to provide mosquito free urban areas.

4.0 Mosquito Breeding Sites in Coastal Areas

The breeding sites of the various mosquito species are illustrated in Fig. 1. The area of greatest potential for mosquito breeding lies within the upper high tide zone (from 7.3m to 8.0m A. C. D. in the Darwin area). In addition, the region up to 1.0m above maximum high tide can be a significant mosquito breeding area, as this region is usually the recipient of seepage, rain water and silt inputs being transported to the tidal areas. These regions have the capacity for both natural and human disturbances that can lead to significant increase in mosquito breeding.

The intertidal areas of wide expanse, thick vegetation, very flat topography, and fresh water inflows are the largest sources of mosquitoes. These large tidally influenced marshes (e.g. Leanyer Swamp) have variable salinity water which is shallow and thickly vegetated and is the ideal breeding habitat for most of the important mosquito species. Natural tidal marshes such as these can be extended and made much more productive sources of mosquitoes with increased silt, nutrient and water inputs from urban and industrial developments.

Any construction practice that increases the flow of water, silt or nutrients, or interrupts or prolongs the drainage through these areas, has the capacity to increase the amount of mosquito breeding. This is particularly so in the upper high tide area, where the often naturally self draining margin of the mangroves can be easily disturbed and result in the pooling of tidal water. Such sites can be quite small, but extremely productive in the numbers of salt water mosquitoes such as Aedes vigilax.

At present the Northern Territory Government and the Darwin City Council have a continuing mosquito engineering control program around urban Darwin, to rectify
past poor construction practices. The annual expenditure is in the region of $300,000.

This annual expenditure included funds for the construction of drains and a proportion to permanently upgrade those drains that repeatedly breed mosquitoes. The program will need to be relatively long term to rectify all the past poor construction practices and achieve a relatively mosquito-free city, particularly when poor construction practices are still proceeding. In contrast, planners of the new satellite city of Palmerston considered the potential for mosquito breeding at an early stage. The siting of the urban areas, the rectification of existing mosquito breeding areas, the design and endpoints of the storm drains, and reclamation works in Palmerston have resulted in a relatively mosquito-free urban environment. This consideration in the planning stage has been a very cost-effective solution.

5.0 Construction practices that can result in mosquito breeding

Mosquito problems created by previous construction practices are detailed in Appendix I.

5.1 Sand Extraction

Deposits are usually found in low-lying areas along swamps and creeks or close to the tidal areas. Any sand extraction activity has the capacity to produce wet season flooded depressions or waterfilled borrow pits that quickly become colonized with aquatic or semi-aquatic vegetation and result in new mosquito breeding areas. These areas can be extremely productive, particularly if the borrow pits have some tidal influence, as this can eliminate many of the freshwater aquatic predators of mosquito larvae. Those sand extraction areas that are deep enough to penetrate the water table can become perennial mosquito sources.

5.2 Storm Water Drainage

Storm water drain construction can produce mosquito breeding sites by poor placement of berm material and the disruption of normal drainage patterns. If the disruption of drainage is in tidal areas it can create extreme mosquito problems.

Open unlined storm drains with relatively permanent dry season flows can be mosquito sources, particularly if the drain receives organic nutrients from urban runoff or industrial processes.

If storm drains with considerable dry season flows are directed into low-lying areas, particularly in the upper high tide zone, considerable ecological disturbance can result in dramatic increases in mosquito breeding.
5.3 Road embankments and Access Roads

Road embankments and access roads can result in impoundments or impedance of normal drainage patterns and frequently cause at least wet season pooling. Detailed topographic and vegetation surveys are usually necessary to avoid such disturbances.

5.4 Water Retention in Tidal Areas

The construction of water retention features can result in altered vegetation patterns that can give rise to mosquito breeding. Water retention in standing mangrove areas which results in the death of mangroves can create extremely productive sources of the salt marsh mosquito, the salt water Anopheles or the salt water Culex mosquito. Inundation of disturbed tidal areas by high tides, rain or waste water can result in emergence of large numbers of mosquitoes. Meticulous planning or water retention features is necessary to avoid creating mosquito breeding sites. Aspects that need particular attention include the final water level, the quality and salinity range of the impounded water, the maintenance drainage capability, the potential vegetation growth in or at the edges, and the inflow of silt.

5.5 Land Fill Operations

Land fill in tidal areas can disrupt previously self draining areas and result in pooling of water. This is particularly so if the land fill has silt laden run off and is sited in a complex drainage pattern. Pollution and vegetation growth at the edge of land fill operation in water can eliminate or restrict the normal activity of aquatic predators and give rise to mosquito problems.

5.6 Sewage Pond Construction

The siting of sewage ponds is one of the most important factors in reducing potential mosquito problems. Correct siting of ponds is vital near coastal areas, as disruption of mangrove drainage patterns can create new breeding sites, and access and service embankments can impound water to create additional mosquito breeding sites.

Maintenance needs, such as emptying certain ponds, can cause extreme mosquito problems unless the pond contents can be channelled or discharged directly to a daily flushed tidal area. These maintenance practices need to be considered in the planning stages and should be important factors in the choice of a site.

The type of ponds, particularly the depth, size and bank material can have a large bearing on whether the ponds are mosquito sources.
5.7 Urban Subdivisions

When urban subdivisions are poorly sited near pre-existing mosquito sources, or sites that have the potential to become sources, it is very likely that there will be public pressure at a later date to rectify the mosquito breeding. Sometimes the rectification works can be extremely expensive, or severely disrupt natural features such as swamplands. It is logical to avoid such costly rectification works or possible destruction of animal and fish habitats, by the correct siting of urban subdivisions.

The Department of Health has recommended avoiding large and uncontrolled tidally influenced mosquito breeding areas by having a 1.6km buffer between the breeding areas and the proposed urban development.

This buffer is very relevant for those large salt marsh swamps with fresh water input such as Leanyer Swamp and Howard Swamp, but it is of little relevance for very small areas that are not very productive, or that can be easily controlled or rectified.

If urban areas are built near these large and at present uncontrollable mosquito breeding areas, then attempts will be necessary to control the breeding. Examples of types of physical control methods recommended include:

1. Swamp drainage by a system of channels
2. Tidal bunds, tide gates and an internal drainage system
3. Steep sided relatively deep (greater than 2.0m) excavated fresh water lake
4. Salt water lake.

Insecticide control for extended periods should not be contemplated as a control measure around urban areas, as there can be no certainty that such methods will be effective in the longer term.

6.0 Guidelines for Construction Practice

Borrow Pits and Excavations

1. No borrow pits, extractive industry or excavation should be conducted within the tidal zone, unless provision is made to prevent ecological changes.

2. Borrow pits or extractive operations should not excavate to a base level below maximum high tide level.

3. Cover material and vegetation should not be pushed into the tidal zone. There should be no impedance of overland flow into the tidal zone.
4. All borrowing or extractive areas should be rehabilitated immediately upon completion of the operation such that all operational areas are completely self draining.

5. Vehicle disturbed areas such as wheel ruts and compacted soil areas should be rectified as soon as practical to prevent water ponding.

6.3 Embankments and Access Roads

1. No embankments should be constructed across tidal areas unless provision is made for sufficient tidal exchange to prevent any considerable ecological change. If upstream impoundments of tidal water are completely flushed at least once in 7 days, there is usually no significant mosquito breeding in the impounded tidal water.

6.2 Storm Water Drainage

1. Drains should be constructed to discharge direct into regularly flushed tidal areas, such as tidal creeks or a formalized channel dug back from a tidal creek. In Darwin 100 year flood drains should be constructed to the 3.7 AHD level and low flow drains to the 3.5 AHD (or below this level if silt accumulation is a potential problem).

2. Drains through tidal areas need to be of dimensions that will not result in silt accumulation in or near the drain. Low flow drains should be installed wherever there is the possibility of longer term dry season flows. Such drains can be either impervious above ground inverts or sub soil pipes.

3. Low flow drains should be installed wherever there is the possibility of longer term dry season flows. Such drains can be either impervious above ground inverts or sub soil pipes.

4. Access along all drains is necessary for regular maintenance.

5. Drains through tidal areas should follow the course of existing creeks or flow lines wherever possible.

6. Drains for mosquito control purposes should be only of dimensions that are necessary to drain over a period of 2 to 3 days for tidal areas, and 4 to 5 days for fresh water, unless there are other considerations requiring larger drains.

7. Silt traps should be installed in drains that are likely to carry considerable silt loads. This is particularly necessary in large urban drains during subdivision construction.
2. Embankments should have provision for complete drainage of upland areas at least over a period of less than five days after flooding. This particularly applies to areas near the tidal limit, which would only be reached by tides once in 10 to 14 days.

3. Embankments for land reclamation purposes should have an internal drainage system with tide valves at the embankment. If upland flows are diverted around the reclamation area, the diverted flow should be discharged direct to the major tidal drainage line immediately seaward of the embankment.

4. Vehicle access along the upper high tide zone should be restricted as much as possible, to prevent the creation of vehicle disturbed areas that could pond tide and rainwater.

6.4 Water Retention in Tidal Areas

1. An ecological and hydrological study should be undertaken before any water retention feature is constructed in a tidal area.

2. Those aspects that are considered critical to the success of an aquatic feature include:

   - the levels and seasonal fluctuations in salinity;
   - the possible aquatic and semi aquatic vegetation changes likely to occur;
   - the effect on aquatic animal life;
   - the number of days under tidal influence;
   - the depth of the retained water;
   - inputs of organic and other pollutants into the system;
   - the source, amounts, and quality of possible top up water;
   - the provisions for periodic maintenance;
   - possible ecological effects seaward of the retention.

3. If the tidal regime in the water feature is significantly reduced or eliminated, all existing mangroves in the retention area should be removed.

4. Silt traps should be constructed at all significant silt entry points.

5. Regular vegetation maintenance or control programs will be necessary. The provision of 1:1 side slope or impervious margins should be considered to reduce maintenance needs.

6. There should not be any small cut off areas at any height level of the water.
6.5 Land Fill in Tidal Areas

1. Land fill operations should not impede any established drainage patterns, either by the land fill operations, or possible erosion from the fill area.

2. There should be drainage provisions all around the base of sanitary land fill operations, and these drains should discharge direct to a daily flushed tidal system.

6.6 Sewage Pond Construction

1. Sewage ponds should be sited preferably on bare mud flat areas or land backed in preference to existing mangrove areas to minimize ecological disturbances.

2. The siting of ponds should not result in any impedance to pre-existing drainage lines, either landward or within the tidal area.

3. Pond drainage during maintenance should be direct to daily flushed tidal areas.

6.7 Urban Subdivision

1. A mosquito buffer zone for the exclusion of urban residential development is recommended within 1.6km of large and uncontrolled tidally influenced mosquito breeding areas, unless specific biting insect studies indicate this can be modified.

2. No urban residential developments are recommended within 1km of extensive areas of mangroves, unless biting midges are not likely to be a significant problem.

3. Any subdivisions bordering tidal areas should incorporate a buffer distance between the high tide level and property boundaries, so that access is possible for management purposes, and to prevent the creation of new mosquito breeding sites.

7.0 Consultation

Medical Entomology of the Northern Territory Department of Health is available for advice on what may constitute a potentially significant mosquito breeding site. In some instances where detailed entomological investigations are necessary, 12 months entomological monitoring may be required before the detailed planning stage. For significant entomological investigations, it may be necessary for the developer to engage an entomological consultant.
Consultation for any project within a tidally affected area may be required with the Northern Territory Department of Lands and Planning, or the Environmental Assessments section of the Northern Territory Department of Natural Resources, Environment, the Arts and Sports.

Peter Whelan Senior Medical Entomologist, NT Department of Health 2011
Previous mosquito problems in the Top End of the NT created by Construction Practice

Medical Entomology
Centre for Disease Control
Department of Health and Families
Darwin NT
1987
Previous mosquito problems in the Top End of the NT created by Construction Practice

1.0 Sand Extraction

Bynoe Harbour

Sand extraction on a beach area in Bynoe Harbour resulted in an area of mangroves being bulldozed and pushed further into a tidal area to form a retarding barrier. Fresh water inflow into the retarding basin resulted in an area of impounded water varying from brackish to salt, depending on tidal movement. The large quantities of dead and dying mangroves contributed to high levels of organic matter and flotsam. The area proceeded to breed very large numbers of salt marsh mosquitoes and a range of other pest and potential disease carrying mosquitoes.

Casuarina Beach

Sand mining at Casuarina Beach was carried out behind the frontal dunes, to a depth below high tide level. Although initially the pits only collected freshwater, the weakened frontal dunes soon collapsed, allowing tidal entry into the pits.

The result was a range of fresh, brackish and tidal water pools, with mangroves and dense salt water couch grass, providing ideal habitats for a large range and huge numbers of mosquitoes. These mosquitoes seriously disrupted the recreational use of the nearby park, and affected nearby residential areas and the hospital area.

2.0 Storm Water Channelization Ludmilla Creek

During the installation of storm water drainage in the Ludmilla area, a large channel was constructed through the upper reaches of the Ludmilla mangroves to convey the increased storm water further downstream. The spoil from the channelization was thrown up on the sides of the channel to form a continuous embankment. This embankment disrupted the free drainage of the nearby mangrove and mud flat areas, resulting in cut off tidal depressions throughout the upper reaches of mangroves. These depressions created the breeding sites for hordes of salt marsh mosquitoes that plagued the general area for many years until rectified by the re-establishment of a drainage system under the combined mosquito engineering control group.
3.0 Storm Water Discharge, Sandy Creek, Tiwi

The construction of storm water drainage in the Tiwi area resulted in the discharge of storm water into the upper reaches of Sandy Creek along Rocklands Drive. With residential development, this extensive drainage system had considerable dry season flows from overwatering and wash down activities, which transformed the seasonal drainage line into a permanently flowing creek. Ecological changes occurred in the creek and for a considerable distance downstream into the mangrove areas of Sandy Creek. Fresh water and brackish water reeds began growing beneath mangroves and on former bare mud flat areas.

Silt accumulation caused drainage pattern changes and pooling of both fresh and tidal waters over considerable areas. Some areas of mangroves died while others colonized new areas. These ecological changes led to the creation of a range of mosquito breeding habitats and serious mosquito pest problem.

4.0 Road Embankments and Access Tracks

Tiger Brennan Drive

During the construction of the Tiger Brennan Drive extension, a large area of mangroves was cut off from regular tidal influence by an earth embankment. Some areas of the mangroves were flattened and left in situ, while other areas were bulldozed clear, leaving deep machinery tracks. Inadequate temporary drainage pipes were installed which were too small to allow sufficient drainage of impounded water, sited too high to allow complete drainage, and yet sufficient to allow tidal ingress and water level fluctuations. This situation led to a stagnant brackish water impoundment, with periodic tidal flooding of sheltered shallow water and artificial depressions. The resultant emergence of salt marsh and other species of mosquitoes required regular surveys and mosquito control operations in areas of inaccessible swamp. Notwithstanding that the affected area will soon be landfilled for future commercial development, even short-term impoundment of brackish water provides an unacceptable environment that promotes mosquito breeding.

Access Tracks

Access tracks, particularly those constructed by Electricity or Sewerage authorities, are frequently just above tidal reach, due to the positioning of many of their facilities. These tracks sometimes have inadequate drainage provisions which can interrupt overland water flow into tidal areas or disrupt tidal drainage patterns. This can result in the retention of water in drainage lines and creeks, creating swampy areas, or cause pooling on the uphill sides of the track. In some instances, when drainage is constructed under the road, scouring on the downhill side of the drain can result in depressions that can fill after rain or high tides.
5.0 Water Retention Features in Tidal Areas

Examples of the range of problems created by water retention in tidal areas can be illustrated by the construction of the Frances Bay Mooring Basin, the old Fannie Bay Golf Club dam, the Gove alumina final retention pond and Palmerston Lake on the Darwin City Council Golf Course. All of these projects had water retained either permanently or temporarily during construction, and were periodically under water level fluctuations by tidal or storm water influence. Each impoundment exhibited a range of salinities and resulted in vegetation changes which included either death of mangroves, growth of fresh or brackish water reeds, death of fish or other aquatic mosquito predators or prolific algal growth.

Any of these factors can result in prolific breeding of mosquitoes. The ecological modifications caused by the construction has usually been considerable and the mosquito breeding can only be alleviated by expensive or critically timed water management procedures.

In the Frances Bay mooring basin, the mangrove death and coincident mosquito breeding was caused by the embankment of an area of mangroves upstream of the mooring basin, with inadequate provision for stormwater drainage from the impounded area.

The Old Fannie Bay Dam (now Lake Alexander) mosquito problems arose from the creation of a non draining tidal depression which was periodically flooded by high tides.

Extensive algal growth and colonization by dense reeds in the Palmerston Lake resulted from infrequent tidal entry, inadequate pumping capacity for top up sea water, inflow of organic rich storm water and the insufficient side slope and depth of the impoundment.

The Gove waste water retention pond was created by impounding a large area of mangroves behind an embankment. The low salinity and high PH of the impounded water caused the death of a large area of dense mangroves and destroyed all aquatic life except for periodic pulses of enormous numbers of mosquito larvae. The periodic plagues of salt marsh mosquitoes from this area precipitated industrial problems and ushered in a mosquito control program which was frequently inefficient. The large area of mosquito breeding and the inaccessibility of the breeding areas by a tangle of dead mangroves hindered larval control, and adult mosquito control by fogging was restricted by the lack of all around access to cope with varying wind directions.
6.0 Sanitary Land Fill, Leanyer Dump

Urban refuse fill into the edge of a salt marsh resulted in areas of polluted marsh becoming significant mosquito breeding sites as the normal aquatic predators such as fish beetles and bugs were eliminated. Other areas became breeding sites by poor placement of the fill creating cut off pools or silt runoff interrupting surface drainage patterns. Additional problems were created by depressions left by the operation of machinery on the salt marsh floor. In one instance, the stockpiling of a large number of tyres without a covering of soil led to appreciable numbers of artificial container breeding mosquitoes affecting nearby suburbs.

7.0 Sewer Line Construction

The installation of sewer lines, by the nature of gravity flow requirements, are invariably installed near the tidal zone. The creation of mosquito breeding has been caused by the construction of embankments to carry pipes across tidal areas, the subsidence of excavations, or the pushing of earth and debris into the mangroves. An embankment across a former tidal creek in Coconut Grove resulted in changing a free draining section of tidal creek into a dense swampy fresh water reed swamp. The ecological changes were not confined to upstream of the embankment. Continued seepage through the embankment caused mangrove species change in the tidal area below the embankment and the resultant root growth and silt accumulation created a series of brackish and saline cut off pools. A section of the control zone sewerage scheme bordering tidal areas of Fannie Bay created depressions by machinery disturbance and subsidence of earth cover. More recent installations for the Trade Development Zone created additional mosquito breeding sites by pushing earth and mangroves into the tidal zone.

8.0 Construction of Leanyer Sewage Ponds

The siting of the Leanyer Ponds and associated embankments led to severe disruption of mangrove drainage patterns. One embankment had provision for drainage but the culvert was not installed with any consideration for possible ecological consequences. This area retained fresh water in the wet season, but was still subject to very high tides. Mangroves within the embankment died and the previous mud flat was transformed into a dense brackish water reed swamp. In addition, the maintenance of certain ponds could only be achieved by effluent release into the impounded area. In the tidal area, the drainage pattern disruptions led to very large areas of mangrove channels and flow lines without the capacity to drain freely at low tides. Subsequent mangrove vegetation growth further aggravated the disruption and resulted in large areas of tidal pooling. The consequences of these practices led to enormous populations of a range of mosquito species, severely affecting nearby residential areas.
Plate 1  This tidally flooded ex-sand mining pit is now the site of prolific breeding by *Aedes vigilax*, *Culex annulirostris* and *Anopheles farauti* s.l..

Plate 2  An artificial drain constructed without an outlet to the tidal zone will simply pond and stagnate – and breed mosquitoes.
Plate 3  Inappropriate landfill here has blocked natural drainage on the salt marsh, leading to ponding and mosquito breeding.

Plate 4  Interruption of drainage by nearby roadworks has led to tidally influenced ponding and killed the mangroves: large numbers of the saltmarsh mosquitoes, absent before, were a problem here during the construction phase.
Plate 5  Pooling of stormwater through inadequate drainage creates mosquito breeding sites.

Plate 6  A sand dam placed through mangroves leads to upstream ponding; mangrove death and high numbers of mosquitoes.
Plate 7  Machinery distribution of the tidal area can give rise to significant numbers of mosquitoes after high tides.

Plate 8  Damming of a mangrove creek for water storage, killed the mangroves and the resultant brackish water gave rise to very high numbers of mosquitoes.
Appendix 3 – Personal protection from mosquitoes and biting midges in the NT
Personal protection from mosquitoes & biting midges in the NT

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Personal protection from mosquitoes & biting midges in the NT

1 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 enter 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 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 *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 appreciable rain. Salt marsh mosquito and midge pest calendars are available from the health website [http://www.health.nt.gov.au/Medical_Entomology/index.aspx](http://www.health.nt.gov.au/Medical_Entomology/index.aspx).

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 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 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, drums, fallen palm fronds, pot plant drip trays, plant striking buckets, animal water, garden equipment, plastic sheeting, 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. Fish ponds or ponds used for frogs can be rectified by the addition of a few fish.
3 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, deltamethrin, bifenthrin, or alpha-cypermethrin 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. Tents can be made more mosquito effective by spraying them inside and out with bifenthrin or alpha-cypermethrin.

4 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 dipping impregnation with permethrin (Lines et al. 1985) or by spraying them inside and out with bifenthrin, lambda-cyhalothrin or alpha-cypermethrin.

5 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, loose fitting long sleeved shirts and full-length trousers are recommended. Dark clothing such as dark blue denim or black clothing is much more attractive to salt marsh mosquitoes than white clothing. Many mosquitoes including salt marsh mosquitoes or *Anopheles bancroftii* will bite through tight fitting shirts or pants. 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). Some work wear clothing outlets and camping stores stock a range of clothing that has been impregnated with permethrin insecticide during manufacture. 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 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 good protection, with DEET based repellents the best. Many botanical based products do not offer sufficient protection. Some specific repellent products, such as standard Aerogard, which are formulated to repel flies, are generally not efficient against mosquitoes or biting midges. Brands with DEET such as Rid, Tropical Strength Aerogard, Bushman's, and Muskol, or products with picaridin such as 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 or close fitting 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 gels are best and creams usually last longer than the aerosol formulations. Repellents can prevent bites from 1 to 4 hours, depending on the repellents, the species of biting insect, or the physical activity of the wearer. In general aerosol alcohol based repellents will only give one hour protection in the tropics so reapplication is necessary. Products labelled low irritant generally mean less active ingredient.

Insecticide impregnated mosquito coils offer good protection in relatively wind protected areas, while candle powered mosquito lanterns (Mortein, Raid and Hovex) or gas powered repellent dispensers (ThermaCELL) offer excellent protection in patio or veranda or other outdoor situations in still or very light breeze conditions. Mosquito lanterns and gas powered repellent dispensers utilise allethrin impregnated pads and are cost effective for events such as barbeques or congregations of people, with two or more dispersed around the group to cater for breeze direction. Candle and gas powered devices need to be used with care in the vicinity of flammable liquids and fumes as they include a naked flame. Automatic outdoor aerosol dispensers that release regular short bursts of allethrin and tetramethrin from canisters can be used in similar outdoor situations as for mosquito lanterns, and can be more safely used in the vicinity of flammable liquid storage (such as small boats).

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 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 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 ADULT INSECT CONTROL

If mosquitoes or biting midges have entered a screened area or house or premises they can be knocked down with hand held 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.

Automatic aerosol dispensers for repelling and/or killing adult mosquitoes or flies are available in both outdoor and indoor models. These generally dispense pyrethroid insecticide aerosol in short bursts every 20 to 40 seconds and can last up to 40 hours before refilling. Outdoors devices need to be in wind protected areas such as verandas and patios.

Other devices that can be effective at repelling and/or killing biting insects include mosquito lanterns and gas powered repellent dispensers (Collier 2006), mosquito coils (Charlwood & Jolley 1984) and electric plug-in insecticide pads. The plug-in pad devices are very effective inside buildings but care is needed in reading the labels. These devices are only effective in relatively protected or closed areas such as patios, inside buildings or where there are only slight breezes. Use of coils and other mosquito repellent devices in outdoor or unscreened areas 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, bioresmethrin 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 may 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 the older residual insecticides such as maldison, or permethrin 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, lambda-cyhalothrin and alpha-cypermethrin that can be used as barrier sprays and provide excellent (up to 6 weeks) protection (Standfast et al 2003, Li et al 2010). These residual insecticides can be applied according to label recommendations with the aid of a garden sprayer for dark coloured walls, fences and solid surfaces on the outside of houses or back pack mechanical misters in a band 1-2 m high on low thick vegetation and shrubbery areas around houses. If there is no vegetation screen, black weed matting or shade cloth 1-2 m high all around fence lines in urban settings can substitute for vegetation as the application surface. Application should be at label rates and made to the point of just before runoff. For vegetation care is needed to apply under leaves as well as on leaves and surfaces. Use of these insecticides can give immediate relief from salt marsh mosquito plagues on a house block scale and the effect should last up to 4 weeks.

Application can be done by householders with appropriate equipment and familiarisation with the chemical and provisions and safeguards for use, although generally it is advisable for applications to be done by a licensed pesticide company.

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 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 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 crème and topical antihistamine products, and non-proprietary products such as paw paw ointment, tea tree oil, eucalyptus oil, aloevera 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 oral 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 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 Pterocaulan 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.
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