Appendix K

Trans Territory Pipeline Project
Biting Insect Assessment
prepared by Northern Territory
Medical Entomology Branch



Northern Territory Government
Department of Health and Community Services

Trans Territory Pipeline (TTP) Project

Biting Insect Assessment

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1.0 Introduction

1.1 Background

The Trans Territory Pipeline (TTP) Project will consist of an underground pipeline from the vicinity of Wadeye, located on the south-west side of the Northern Territory, to Gove, located on the north-east corner of the Northern Territory.

EcOz Environmental Services was commissioned by Alcan Engineering Pty Ltd to assist in the preparation of a Draft Environmental Impact Statement (EIS) for the Trans Territory Pipeline Project. EcOz Environmental Services then commissioned the Medical Entomology Branch of the Department of Health and Community Services to provide a report on biting insects along the pipeline route.

The Medical Entomology Branch (MEB) of the Department of Health and Community Services (DHCS) was commissioned to;

- Conduct a desktop study of the proposed pipeline route and identify any areas that may have significant mosquito or biting midge populations.

- Identify any risk areas where the construction of the gas pipeline may lead to the creation of mosquito breeding sites.

- Provide mitigation measures to ensure the construction of the gas pipeline and associated facilities does not lead to the creation of mosquito breeding sites and the importation of exotic mosquito species.

- Provide mitigation measures to reduce the negative health impacts associated with biting insects.

An assessment of the pipeline route was made using aerial photography, using the biology of biting insects to determine any high risk areas. Weekly adult biting insect monitoring information from two different trap locations in Gove was assessed to provide actual information on the biting insects in this area.

1.2 Acknowledgments

We wish to acknowledge the assistance of Kylie Harvey of EcOz Environmental Services who provided background information and aerial photography of the TTP route.

Biting insect trapping in Gove was conducted by Bob Small of Environmental Health, with samples sent to MEB office in Darwin for identification.

MEB officers Jane Carter, Jennifer Grigg and Leah Stratford identified the Gove mosquitoes. MEB officer Nina Kurucz identified the Gove biting midges.

Tables and figures were prepared by Allan Warchot. Text by Allan Warchot and Peter Whelan.

2. Project Aims

2.1 Aims

The aims were to;

- Evaluate the plans of the proposed gas pipeline route to identify any areas that may have significant populations of biting insects.
- Identify any areas where the construction of the gas pipeline may lead to the creation of new mosquito breeding sites.
- Assess the information from the Gove weekly biting insect trapping.
- Provide mitigation strategies to prevent the construction of the gas pipeline and associated facilities from creating new mosquito breeding sites.
- Provide mitigation strategies to prevent the introduction of exotic mosquito species and malaria from development processes.
- Outline potential health risks and risk periods to the workforce.

2.2 Significance and scope of the project

An evaluation of the pipeline route for potential biting insect problems is required for the Draft EIS. It is also a requirement to consider the impact of the development on biting insect populations and outline management procedures to reduce the impact of biting insects.

Biting midges can be considerable pests within a few kilometres of the coast or large tidal rivers in the NT (Whelan 1991). These pests can disrupt the work force by causing direct effects due to their painful bites, and indirect effects due to secondary infection and loss of a sense of well being. Minor biting midge pest problems can occur in inland areas, particularly near freshwater lakes and streams.

Mosquitoes are a serious potential public health issue in the NT, both as pest insects and as vectors of a number of human diseases including the potentially fatal Murray Valley encephalitis virus (MVEV), and a number of other non-fatal diseases caused by Kunjin virus (KUNV), Ross River virus (RRV) and Barmah Forest virus (BFV).

The TTP Project area traverses across a variety of environments, including seasonally flooded waterways and swamps, which will be potential sources of mosquitoes and biting midges. Much of the pipeline crosses uninhabited areas. A general analysis will be provided for these areas. More specific analysis will be provided for those areas of the pipeline that will be constructed near human population centres.

2.3 Study site

The TTP Project site traverses across a variety of environments, beginning from near Port Keats (Wadeye) on the south-west side of the Northern Territory, and ending in Nhulunbuy, which is situated on the north-east corner of the Northern Territory. The study area is outlined in Figure 1.

3. Methods

Assessments of potential biting insect breeding sites affecting the pipeline route were carried out by reviewing 1:100,000 topographical maps prepared by Mipela (GIS) Pty Ltd for the TTP Project. Particular attention was paid to those areas of the pipeline route that came within close proximity to human populations. Potential problem areas were distinguished by the presence and extent of seasonally flooded areas.

Actual biting insect information was available for the township of Nhulunbuy, on the Gove Peninsula. Weekly adult biting insect traps are set at five locations in the Gove area by the local Environmental Health Officer, with the catch contents air mailed to the MEB Laboratory in Darwin for identification and analysis. Actual biting insect information was available for the coastal area associated with the Blacktip Project onshore gas processing facility, located at the western limit of the TTP gas pipeline. Trap collections from this area were killed by placing the catch containers in an esky with dry ice, with the contents then transported back to the MEB laboratory in Darwin for processing.

Traps used were carbon dioxide baited EVS traps (Rohe and Fall 1979). The traps consist of an insulated bucket, a suction fan powered by two 'D' cell batteries with 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 traps were set around chest height and baited with approximately 1kg of dry ice. Biting insect information from two of these trap sites located close to the TTP gas pipeline route was used for analysis.

Potential problem mosquito species and seasonal abundance were predicted using the biology and mosquito population information of various known human pest mosquito species. Most mosquito species have preferred breeding sites that have been deduced over many years through actual larval sampling. The likely seasonal abundance of potential human pest mosquito species was predicted based on the extent of the potential breeding site and likely duration of water inundation, and Medical Entomology Branch adult trapping information from relevant areas. The likely species abundance of various mosquitoes was predicted based on potential available habitat, and Medical Entomology Branch adult trapping data from relevant areas.

Potential human pest biting midge species also have preferred breeding sites that have been deduced by larval and adult sampling, although the information on the exact location of many biting midge breeding sites is restricted or unknown, due to limited studies conducted. Only one species of biting midge is likely to cause a significant pest problem, which is the mangrove biting midge species *Culicoides ornatus.* Other known significant human pest biting midge species, *Culicoides flumineus* and *Culicoides* undescribed Sp. (near *C. immaculatus*) can be encountered in mangrove areas. Most other biting midge species generally do not bite humans, or cause minor nuisance or pest problems only, therefore were not discussed in great detail.

4. Results

4.1 Biting midges

4.1.1 Blacktip Project onshore gas processing facility (South-west coast of the NT, near Port Keats (Wadeye).

Species Present

A total of 3531 adult female biting midges were collected from nine adult biting insect traps set on the night on June 2, 2004, representing at least 8 different species (Table 3, see Figure 15 for trap locations).

The majority of biting midges collected were *Culicoides ornatus*, representing 87.4% of total biting midges trapped. The next most frequently recovered species were *C. austropalpalis* (3.6%), *C. immaculatus* (3.34%), *C.* undescribed sp. *No. 6* (2.1%), *C. bundyensis* (1.5%), *C. narrabeenensis* (0.4%), *C. papuensis* (0.31%) and *C. actoni* (0.06%) (Table 3).

Culicoides ornatus was the only major pest human biting midge species trapped. The highest individual collection of female *C. ornatus* was 2,530.

Spatial abundance
The relative spatial abundance of all species collected from the nine adult biting insect traps is shown in Table 3. Trap locations are shown in Figure 15.

The highest spatial abundance of biting midges was at site 6, accounting for 74.79% of all biting midges collected. The site with the second highest spatial abundance was site 5, with 14.16% of all biting midges trapped.

Culicoides immaculatus was most abundant at site 6 (55), followed by site 4 (26), site 9 (20) and site 8 (15), with minimal to nil numbers at other trap sites.

Culicoides narrabeenensis was most abundant at site 5 (10), with minimal to nil numbers at other trap sites.

Culicoides austropalpalis was most abundant at site 5 (100), followed by site 7 (19), with minimal to nil numbers at other trap sites.

Culicoides bundyensis was most abundant at site 2 (44), with minimal to nil numbers at other trap sites.

Culicoides undescribed sp. *No. 6* was most abundant as site 6 (55), with minimal to nil numbers at other trap sites.

Culicoides papuensis was most abundant at site 5 (10), with minimal to nil numbers at other trap sites.

Culicoides actoni was only found in low numbers (2) at site 2.

For individual collections of *C. ornatus*, the highest numbers occurred at site 6 (2530), followed by site 5 (380), site 4 (68), site 2 (52), site 9 (34), site 7 (9), site 8 (8), site 3 (4) and site 1 (1) (Table 3).

Other species not trapped, but may be found inside and close to mangrove forests in this areas are *Culicoides flumineus* and *Culicoides* undescribed Sp. (near *C. immaculatus*). *Lasiohelia species* were not trapped, but may also be present in the area. A species of *Styloconops* may be found on open sandy beaches in this area.

4.1.2 Gove area

The year to date results (January to July 2004) for full moon periods from the Wallaby Beach and Nhulunbuy South trap sites (see Figure 11 for trap locations) are displayed in Tables 1 & 2 respectively. The location of the TTP gas pipeline corridor in relation to Gove is shown in Figure 10.

Culicoides ornatus was the most abundant species trapped at both sites, representing 74.5% of total midges trapped at Wallaby Beach (Table 1), and 74.07% of total midges trapped at Nhulunbuy South (Table 2). The highest individual total of *C. ornatus* at Wallaby Beach was 330 on June 4, 2004 (Table 1). The highest individual total of *C. ornatus* at Nhulunbuy South was 240 on July 2, 2004 (Table 2).

At Wallaby Beach, *Culicoides* undescribed *species No. 6* was the next most abundant species trapped, representing 13.75% of total midges trapped (Table 1). The highest individual total for this species was 128 on March 5, 2004 (Table 1). This was followed by *Culicoides papuensis* (9.76%, highest total of 44 on June 4, 2004), *Culicoides marksi* (0.78%, highest total of 9 on February 6, 2004), *Culicoides clavipalpis* (0.07%, highest total of 1 on February 6, 2004) and *Culicoides pallidothorax* (0.07%, highest total of 1 on April 30, 2004) (Table 1).

At Nhulunbuy South, *Culicoides marksi* was the next most abundant species trapped, representing 6.59% of total midges trapped, with a highest individual total of 70 on January 9, 2004 (Table 2). This was followed by *C. pallidothorax* (4.39%, highest total of 44 on March 5, 2004), *C.* undescribed *species Vic 42* (3.9%, highest total of 48 on March 5, 2004), *C. papuensis* (3.66%, highest total of 21 on January 9, 2004), *C.* undescribed *species No. 6* (2.93%, highest total of 24 on March 5, 2004), *Lasiohelia species* (0.81%, highest total of 10 on April 2, 2004), *C. immaculatus* (0.49%, highest total of 4 on April 30, 2004) and *C. austropalpalis* (0.16%, highest total of 2 on April 30, 2004) (Table 2).

Other species not trapped, but likely to be present in this area, are *Culicoides flumineus* and *Culicoides* undescribed Sp. (near *C. immaculatus*). Both of these species breed in mangrove areas, and are usually only found inside and close to mangrove forests. A species of *Styloconops* may be found on open sandy beaches in this area.

4.1.3 The remainder of the TTP gas pipeline route

Culicoides ornatus may be present in the remaining areas of the TTP gas pipeline corridor within 3.5km of extensive tidal mangrove areas, which are those areas nearby to the Gove Peninsula (Figure 10a). *Culicoides flumineus* and *Culicoides* undescribed Sp. (near *C. immaculatus*) may be present inside and close to mangrove forests nearby to the Gove Peninsula area.

Culicoides marksi may be present in moderate numbers nearby to freshwater lakes and streams in the late dry season, early wet season and early to mid dry season. Other species recorded in Sections 4.1.1 and 4.1.2 above may also be present in minor numbers along the TTP gas pipeline route, most notably near freshwater areas.

4.1.4 Culicoides ornatus

Culicoides ornatus numbers generally reach a peak in the months of August to November. The yearly results of the Fairway Waters biting midge investigation, in the town of Palmerston, are displayed in Figure 14. Trapping was conducted on the night of the full moon for a period of one year, and hence is indicative of the seasonal abundance of *C. ornatus.* The results from the Fairway Waters biting midge investigation indicate peak monthly numbers of *C. ornatus* in the peak season months of August to November are up to five times greater than peak monthly numbers during the next most abundant months of the year.

This indicates the peak season *C. ornatus* populations at the Wallaby Beach and Nhulunbuy South trap sites in the Gove vicinity could possibly be up to five times higher than that recorded in July 2004. The same trend would also be observed for the peak season *C. ornatus* numbers at the Blacktip Project onshore gas processing plant trap sites, with numbers possibly up to 10 times higher than that recorded in June 2004.

4.2 Mosquitoes

4.2.1 Mosquito trapping results for the Blacktip Project onshore gas processing plant area

Species present

There were a total of 6,429 female adult mosquitoes trapped from the nine adult biting insect traps, representing 19 species (Table 4). Trap locations are shown in Figure 15.

Anopheles farauti s.l. was the most abundant species trapped, representing 33.92% of all mosquitoes trapped. The next most abundant species were *Culex annulirostris* (20.28%), *Coquillettidia xanthogaster* (19.66%), *Culex sitiens* (9.52%), *Ochlerotatus vigilax* (5.15%) and *Culex vishnui* grp. (4.09%).

The highest number of females of various species from a single trap was *An. farauti s.l.* (1271), followed by *Cx. annulirostris* (604), *Cq. xanthogaster* (470), *Cx. sitiens* (326), *Cx. vishnui* grp. (167), *Oc. vigilax* (102) and *An. bancrofti* (96).

Culex vishnui grp. includes two undescribed species, *Cx. sp 32* of marks and *Cx. sp* near *vishnui.* Both species are very difficult to separate morphologically as adults, and are not regarded as human pest species.

Anopheles farauti s.l. is a species complex that includes the species *An. farauti* (brackish water breeder), *An. hinesorum* and *An. torresiensis* (freshwater breeders). These species are impossible to separate morphologically so are combined to form the *An. farauti s.l.* species complex. However, as the major mosquito breeding site Swamp 1 has extensive brackish water areas, the majority of *An. farauti s.l.* collected were likely to be *An. farauti.*

The biology and disease significance of the common mosquito species is described in Appendix 3.

Spatial abundance

The relative spatial abundance of all mosquito species collected from the nine adult biting insect traps is shown in Table 4.

The highest number of mosquitoes were trapped at site 7, representing 30.32% of all mosquitoes trapped, followed by site 1 (24.48%), site 5 (10.61%), site 6 (8.45%), site 3 (8.37%), site 4 (6.07%), site 8 (5.91%), site 2 (3.39%) and site 9 (2.41%).

The highest total number of *An. farauti s.l.* was at site 7 (1271), followed by site 1 (364), site 8 (269), site 2 (121), and site 5 (120), with relatively few or none at the remaining trap sites.

The highest total number of *Cx. annulirostris* was at site 1 (604), followed by site 7 (226), site 6 (124), site 3 (122), site 5 (87) and site 8 (54), with relatively few others at the remaining trap sites.

The highest total number of *Cq. xanthogaster* was at site 1 (470), followed by site 3 (378), site 6 (141), site 7 (113) and site 4 (50), with relatively few others at the remaining trap sites.

The highest total number of *Cx. sitiens* was at site 5 (326), followed by site 4 (98), site 6 (77) and site 7 (71), with relatively few to nil at the remaining trap sites.

The highest total number of *Cx. vishnui* grp. was at site 4 (167), followed by site 5 (68), with relatively few to none at the remaining trap sites.

The highest total number of *An. bancrofti* was at site 1 (96), followed by site 7 (50), with relatively few to none at the remaining trap sites.

The highest total number of *Oc. vigilax* was at site 6 (102), followed by site 7 (100) and site 9 (38), with relatively few at the remaining trap sites.

4.2.2 Gove vicinity

The weekly adult mosquito monitoring trap results from July 2003 to June 2004, for the Wallaby Beach and Nhulunbuy South trap sites, are presented in Tables 5 & 6 respectively. Trap locations are shown in Figure 11. Long term figures for six selected important mosquito species from the Wallaby Beach and Nhulunbuy South trap sites, from July 2000 to June 2003, are presented in Figures 12 and 13 respectively.

Species present

Twenty-seven (27) species of adult mosquitoes were collected at the Wallaby Beach trap site from July 2003 to June 2004 (Table 5). Twenty-six (26) species of adult female mosquitoes were collected at the Nhulunbuy South trap site from July 2003 to June 2004

Ochlerotatus vigilax was the most abundant mosquito species trapped, representing 69.1% of all mosquitoes trapped at Wallaby Beach, and 47.79% of all female mosquitoes trapped at Nhulunbuy South (Tables 5 & 6). Highest individual totals of this species were 3128 females at Wallaby Beach on January 17, 2004 (Table 5), and 755 females at Nhulunbuy South on January 10, 2004 (Table 6).

Culex annulirostris was the next most abundant mosquito species trapped at Wallaby Beach, representing 21.67% of all mosquitoes trapped at this site, with a highest individual total of 426 females on February 21, 2004 (Table 5). All other mosquito species were trapped in low numbers only (Table 5).

Coquillettidia xanthogaster was the next most abundant mosquito species trapped at Nhulunbuy South, representing 21.24% of mosquitoes trapped at this site, with a highest individual total of 172 adult females on August 23, 2003 (Table 6). This was followed by *Cx. annulirostris* (17.8%, highest individual total of 72 on January 17, 2004) (Table 6). All other mosquito species were trapped in low numbers only (Table 6).

Seasonal variations

Seasonal variations of six selected important mosquito species collected at the Wallaby Beach and Nhulunbuy South trap sites are presented in Figures 12 & 13. These figures show that the two most abundant species at these trap sites are *Oc. vigilax* and *Cx. annulirostris.* Peak numbers of these species can vary from season to season, dependant on factors such as monthly rainfall, and the success of Nhulunbuy Corporation mosquito control program.

4.2.3 Potential mosquito breeding sites

Mosquitoes will affect many areas of the pipeline route, with potential pest problems likely to occur near those areas that contain either seasonally flooded streams, seasonally flooded grasslands and floodways, paperbark and pandanus swamps, billabongs, and tidal areas.

For freshwater breeding mosquitoes in the Top End of the NT, highest abundance generally occurs in the post wet season months of April, May and June. Large paperbark or pandanus swamps that contain aquatic and semi-aquatic vegetation are likely to be sources of large numbers of pest and disease carrying mosquitoes. Swamps with freshwater stream inflows can be continual sources of mosquitoes until August, particularly if the swamp is heavily vegetated with reeds. Seasonally flooded creek lines can be sources of pest numbers of mosquitoes when stream flows cease and the water begins to dry, leaving behind isolated vegetated pools. Mosquito problems can occur until August nearby to larger creeks that hold water permanently, or for extended periods after the wet season. Rivers can be sources of pest numbers of mosquitoes from April to June, when receding water levels leave behind isolated, vegetated pools on levee river banks. Seasonally flooded grasslands and poorly draining floodways can be large sources of mosquitoes in the wet season months of January, February, March and April, after initial flooding with rainfall. Large floodplains associated with rivers can be sources of pest numbers of mosquitoes from January to June. Billabongs and lakes can be perennial sources of mosquitoes, particularly if there is perennial or long lasting surface water, and an abundance of semi-aquatic and aquatic vegetation.

Tidal areas can be sources of pest numbers of mosquitoes, with the main breeding areas being upper tidal creeks and brackish water swamps. Elevated mosquito breeding in upper tidal creeks generally occurs in the months of September to December. Elevated mosquito breeding in brackish water swamps generally occurs from September to June, with brackish water swamps that receive freshwater stream flows capable of breeding pest numbers of mosquitoes until August in extended wet season years.

4.3 Human habitation areas nearby to the TTP gas pipeline corridor

4.3.1 Port Keats (Wadeye)

The community of Wadeye at Port Keats is located 3km from the TTP gas pipeline corridor, at its nearest. (Figure 2).

Potential mosquito breeding sites are likely to be associated with the upper tidal areas with the large creeks system north of Port Keats, with high *Ochlerotatus vigilax* breeding likely to occur in these upper tidal creek areas, in the months of September to January. This species may disperse to the TTP gas pipeline corridor in minor to moderate pest numbers during these months. Pest problems from this species may be noticed within 5km of coastal areas along this section of the TTP gas pipeline route, although this species is capable of dispersing in pest numbers for up to 50km (Whelan 1997).

Moderate to large numbers of *Culex annulirostris* are likely to breed in the seasonally flooded areas nearby to Port Keats, in the months of January to June. Moderate to large numbers of *Cq. xanthogaster* are likely to be breeding in the seasonally flooded areas adjacent to Port Keats. Moderate to high numbers of *An. bancroftii* may also be breeding in the seasonally flooded areas adjacent to Port Keats in the months of January to June. These species may be dispersing in minor to moderate numbers to the TTP gas pipeline corridor in the months of January to June, from the seasonally flooded coastal and sub-coastal areas adjacent to Port Keats, and other seasonally flooded areas within 5km of the TTP gas pipeline corridor.

The ephemeral creeklines within the section of TTP gas pipeline corridor located approximately 5km south of Port Keats are unlikely to be appreciable sources of mosquitoes, as there appears to be no poorly draining areas associated with these creeklines.

4.3.2 Palumpa

Palumpa is a community situated at the southern end of an extensive area of flood plain with extensive areas of paperbark swamp. The pipeline corridor, at its nearest, is located approximately 1.5km south of Palumpa, where it crosses seasonal freshwater streams and inundated areas (Figure 3).

Potential mosquito breeding sites are likely to be associated with the seasonal streams and seasonally inundated areas within and nearby to the pipeline corridor. Species likely to be present in high numbers in this area include the common banded mosquito *Culex annulirostris*. This species is likely to be breeding in any poorly draining low lying grassy areas during the months of January to June, and in still water vegetated pools in the larger creek lines in the post wet season months of April, May and June. *Culex annulirostris* may be breeding in very high numbers in the extensive paperbark swamps to the north, within 6km of the pipeline corridor, especially if there are semi-aquatic reed areas associated with the paperbark swamps. This species may also be breeding in high numbers in the extensive seasonally flooded areas associated with the ephemeral creek lines within and adjacent to the TTP gas pipeline corridor. *Culex annulirostris* can disperse up to 10km from their breeding sites (Whelan 1997), so it is possible this species can disperse to the pipeline corridor from any extensive breeding sites within 10km.

Pest numbers of *An. bancroftii* may disperse to the TTP gas pipeline corridor from breeding sites in the seasonal streams and swamps within 5km of the pipeline corridor, particularly if these streams and low lying areas are vegetated and shaded. This species may also be breeding in the seasonal streams and swamps within the pipeline corridor, particularly if these streams and low lying areas are vegetated and shaded. Elevated numbers of this species are likely to be encountered in January to June.

Pest numbers of *Cq. xanthogaster* may disperse to the TTP gas pipeline corridor from breeding sites in the seasonal streams and swamps within 5km of the pipeline corridor, particularly if these streams and low lying areas are vegetated and shaded. This species may also be breeding in the seasonal streams and swamps within the pipeline corridor, particularly if these streams and low lying areas are vegetated. Elevated numbers of this species are likely to be encountered in January to June.

Pest numbers of *Ma. uniformis* may disperse to the TTP gas pipeline corridor from breeding sites in the seasonal streams and swamps within 3km of the pipeline corridor, particularly if these streams and low lying areas are vegetated and shaded. This species may also be breeding in the seasonal streams and swamps within the pipeline corridor, particularly if these streams and low lying areas are vegetated. Elevated numbers of this species are likely to be encountered in January to June.

Ochlerotatus normanensis may be breeding in high numbers in the poorly draining floodways surrounding the community of Palumpa and inside the pipeline corridor, in the wet season months of January to March. This species may disperse to the TTP gas pipeline corridor from breeding sites up to 5km away.

4.3.3 Dorisvale

The pipeline corridor encompasses the settlement of Dorisvale. The Dorisvale settlement is located near the banks of the large Bradshaw Creek. Crocodile Creek, a branch of Bradshaw Creek, is located within 3km west of the Dorisvale settlement. Ephemeral streams are also located within 5km of the Dorisvale Settlement (Figure 4).

Pest numbers of mosquitoes are likely to be breeding in Bradshaw and Crocodile Creek in the post wet season months of April to June. Mosquito breeding is likely to occur in still water pools along the creek banks, or in any heavily vegetated pools within the creek itself. The main species likely to be encountered would be *Cx. annulirostris, An. bancroftii* and *Cq. xanthogaster* and *Ma. uniformis.* Pest numbers of *Oc. normanensis* and *Cx. annulirostris* may be breeding in the seasonally flooded low lying areas associated with Bradshaw and Crocodile Creek, in the months of January to March.

4.3.4 Florina

The pipeline corridor, at its nearest, passes approximately 1km south of the Florina Station settlement (Figure 5).

This section of the pipeline passes through poorly draining floodways associated with the Daly River, and crosses the Daly River. These seasonally flooded areas may be breeding large numbers of *Cx. annulirostris, Cq. xanthogaster* and *An. bancroftii* during the post wet season months of April to June, and large sources of *Cx. annulirostris* during the wet season months of January, February and March. The poorly draining floodways may be sources of large numbers of *Oc. normanensis* during the wet season months of January to March. Pest problems of *Cx. annulirostris, An. bancroftii* and *Cq. xanthogaster* may be breeding along the banks of the Daly River in the months of April to June, when receding river levels leave behind isolated, vegetated pools along the river levee banks and minor.

Mosquito monitoring results from Katherine (MEB data), which is similar in habitat to this area (Figure 6 & 7), show *Cx. annulirostris* numbers to be high in the months of January to early April, and low for other months of the year. Other species have been recorded in low numbers only. This trend may be similar for this region.

4.3.5 Manbulloo

The pipeline corridor, at its nearest, passes approximately 1km south of the community to Manbulloo (Figure 6).

Pest numbers of *Cx. annulirostris, An. bancroftii* and *Cq. xanthogaster* may be sourced from the banks of the Katherine River in the months of April to June, when receding river levels leave behind isolated, vegetated pools. Pest problems of *Cx. annulirostris* and *Oc. normanensis* may be sourced from seasonally flooded low lying areas associated with the Katherine River in the months of January to March.

Mosquito monitoring results from Katherine (MEB data), which is similar in habitat to this area (Figure 6 & 7), show *Cx. annulirostris* numbers to be high in the months of January to early April, and low for other months of the year. Other species have been recorded in low numbers only. This trend may be similar for this region.

4.3.6 Tindal

The pipeline corridor, at its closest, passes within 4km of Tindal (Figure 6). Minor to high mosquito breeding is likely to occur in the ephemeral creek lines and poorly draining areas associated with the ephemeral creek lines.

4.3.7 Bamyili

The pipeline corridor, at its nearest, passes within 3.5km of the settlement of Bamyili (Figure 7). Mosquito breeding is likely to occur in the poorly draining floodways associated with the ephemeral streams and Beswick Creek. There does not appear to be any large seasonally flooded areas, so there are unlikely to be any large mosquito problem in the Bamyili vicinity. Mosquito breeding is likely to be limited to the wet season months of January to April only, with the main species encountered being *Cx. annulirostris* and *Oc. normanensis.*

4.3.8 Beswick

The pipeline corridor encompasses the community of Beswick (Figure 8). Minor to high mosquito breeding in this area may occur in isolated vegetated pools associated with the nearby river (Water House River) during the late wet season and early to mid dry season (April to August). The most abundant species are likely to be *Cx. annulirostris, An. bancrofti* and *Cq. xanthogaster. Culex annulirostris* numbers may be elevated during the mid wet season months of January to March, sourced from any poorly draining grassy areas associated with the Water House River.

Minor to high numbers of *Oc. normanensis* may be encountered in the months of January to March, sourced from poorly draining floodways associated with Water House River.

4.3.9 Bulman

The pipeline corridor passes within 1km of the community of Bulman, at its nearest (Figure 9).

Minor to high mosquito breeding may occur in isolated vegetated pools associated with the nearby river (Wilton River) during the late wet season and early to mid dry season (April to August). Minor to high mosquito breeding may occur in the seasonally inundated low lying areas adjacent to the Wilton River during the post wet season months of April to June. The most abundant species are likely to be *Cx. annulirostris, An. bancroftii* and *Cq. xanthogaster.*

High numbers of *Oc. normanensis* may be encountered in the months of January to March, sourced from poorly draining floodways associated with Wilton River. Minor to high numbers of *Cx.*

annulirostris may be sourced in the mid wet season months of January to March, sourced from poorly draining floodways associated with Wilton River.

4.3.10 Gove

The pipeline corridor encompasses the township of Nhulunbuy, located on the Gove Peninsula (Figure 10). Nhulunbuy Department of Health and Community Services (DHCS) Officers set mosquito traps weekly at five different locations around the township of Gove. Two traps are set nearby to the mine conveyer belt, at Wallaby Beach and Nhulunbuy South (Figure 11).

Very high numbers of *Oc. vigilax* can occur in the Wallaby Beach area in the wet season months of December, January and February (Figure 12). The main *Oc. vigilax* breeding site at the Wallaby Beach area is the old red mud ponds rehabilitated area (Figure 11), which is poorly draining and becomes seasonally inundated with rainwater. *Culex annulirostris* can occur in moderate to high pest numbers at Wallaby Beach (Figure 12), also sourced from the old red mud ponds rehabilitated area, and potentially any vegetated ground pools in the Wallaby Beach area. *Ochlerotatus vigilax* in the Wallaby Beach area also breeds in the upper tidal areas associated with Crocodile Creek (Whelan and Hayes 1992, Montgomery and Love 1995, Wilson 2000). Other mosquito species do not occur in appreciable numbers in the Wallaby Beach area (Figure 12, Table 5).

Further east from the Alcan Gove mine, at the Nhulunbuy South trap site, moderate to high numbers of *Oc. vigilax* can occur in the months of December, January and February (Figure 13). The source of these mosquitoes could be a multitude of areas, including dispersal from the Wallaby Beach area, and the upper tidal areas of East Woody Creek and Buffalo Creek (Whelan and Hayes 1992, Montgomery and Love 1995, Wilson 2000) (Figure 11). *Ochlerotatus vigilax* could potentially be breeding in significant numbers in Nhulunbuy Lagoon (Lamche 2004), which if occurring, would contribute to *Oc. vigilax* numbers to the TTP gas pipeline route south of Nhulunbuy Lagoon. *Culex annulirostris* can occur in minor pest numbers at Nhulunbuy South, sourced from Nhulunbuy Lagoon and from the freshwater creek located south of the Golf Course, and potentially any vegetated ground pools in the Nhulunbuy South area. *Coquillettidia xanthogaster* can occur in minor numbers in the Nhulunbuy South area, and are probably breeding in the vegetated areas of Nhulunbuy Lagoon (Table 6). Other mosquito species do not occur in appreciable numbers in the Nhulunbuy South area (Figure 13, Table 6).

5. Discussion

5.1 Biting midges

5.1.1 Species Present

C. ornatus is by far the major potential pest biting midge species likely to be encountered along the TTP gas pipeline route, both in terms of numbers and because this species is considered the most significant pest human biting midge species in the Top End of the NT. This species was trapped in Gove, and is likely to be present along those areas of the TTP gas pipeline route within 3.5km of tidal areas. Other common biting midge species in the Top End of the NT are mentioned below. (Also see Appendix 1).

Culicoides marksi were trapped at Nhulunbuy (see Section 4.1.2), and is likely to be present along those inland areas of the TTP gas pipeline route that passes nearby to freshwater lakes and streams. *Culicoides marksi* can be a minor human pest species.

Culicoides actoni were trapped during the Blacktip Project trapping, and is likely to be present in other areas of the TTP gas pipeline route. This species has been recorded biting humans (Wirth & Hubert

1989), although it is unlikely to be of any major pest significance. The larval habitat of this species is unknown (Wirth & Hubert 1989).

Culicoides austropalpalis were trapped during the Nhulunbuy and Blacktip Project trapping, and is likely to be present in some areas of the TTP gas pipeline route. This species is not regarded as human pest species.

Culicoides papuensis were trapped during the Nhulunbuy and Blacktip Project trapping, and breeds in similar areas as *C. ornatus* (Shivas 1999). This species may also be present near the tidal areas approaching the Gove Peninsula. There appears to be no published records of this species biting humans in Australia, and Shivas (1999) also did not record this species biting human bait. It is therefore unlikely that this species is of human pest significance in Australia.

Culicoides pallidothorax were trapped during the Nhulunbuy trapping, and is likely to be present near freshwater areas along the TTP gas pipeline route. This species rarely bites people, so it is unlikely to be of any pest significance in the TTP Project area. This species breeds near freshwater.

Culicoides undescribed sp. *No. 6* rarely bites humans so are not considered to be of any human pest significance. This species breeds in upper high tide mangrove areas, and were trapped were trapped during the Nhulunbuy and Blacktip Project trapping. This species may also be present near the tidal areas approaching the Gove Peninsula.

Culicoides flumineus were not recorded in any of the TTP gas pipeline corridor trap results, but is an important human biting midge pest species. This species breeds in similar areas to *C. ornatus,* but at a lower level on creekbanks of small tidal tributaries (Shivas 1999). This species is generally encountered in mangrove areas only.

Culicoides undescribed Sp. (near *C. immaculatus*) were not recorded in any of the TTP gas pipeline corridor trap results, but is an important human biting midge pest species. This species is relatively common in the lower reaches of tidal creeks, and is generally encountered in mangrove areas only. The larval habitat of this species is unknown (Shivas 1999).

Lasiohelia species do bite humans in Australia, although the larval habitat of most Australian species is unknown (Debenham 1983). Some species are thought to breed in damp, surface-terrestrial environments (Debenham 1983). This includes patches of tropical rainforest, and general vegetation ranging from wet-sclerophyll forest to open grassland (Debenham 1983), so it is possible this species may be encountered in these environments along the TTP gas pipeline corridor.

A species of *Styloconops* may found in small numbers biting and swarming around the head on open sandy beaches during the day (Whelan 2003).

5.1.2 *Culicoides ornatus*

Culicoides ornatus is a widespread species causing major pest problems throughout coastal areas of northern Australia and along the east coast of Queensland (Shivas and Whelan 2001). This midge species breeds in mangrove areas and the females migrate landward after emergence, with the bulk of dispersing females moving up to 1 to 2km inland of the mangrove margin (Shivas and Whelan 2001). Lower numbers can be encountered for at least 3.5km from the mangrove margin (Shivas and Whelan 2001). Higher numbers of this species are generally found on escarpment areas facing mangroves (Shivas and Whelan 2001). The dispersal characteristics of this species ensure that it is an important human pest biting midge species in coastal areas around the Top End of the NT. This midge species and other midge species in Australia are not vectors of human disease.

Peak dispersal of *C. ornatus* generally occurs around the time of the full or new moon, with peak dispersal occurring one day before the full moon in the warmer months (Shivas and Whelan 2001).

This generally correlates with dispersal from the more productive upper tidal creek breeding sites (Shivas and Whelan 2001). Peak dispersal from foreshore *Sonneratia* breeding sites occurs about four days before the upper tidal creek dispersal peak (Shivas and Whelan 2001).

5.1.3 *Culicoides ornatus* breeding sites

Investigations of breeding sites in Darwin Harbour have located the breeding sites of *C. ornatus* by adult emergence trapping (Shivas et. al. 1997, Shivas 1999). The midge breeds in the dry season in the mangrove mud in the creek banks of upper tidal tributaries between Mean Low Water Neap (MLWN) and Mean High Water Neap (MHWN). Larval sampling has revealed significant breeding at tidal elevations of 4.7m ACD to 5.5m ACD at creekbank habitats (Shivas 1999). The prime breeding sites are in a narrow zone in the upper section of narrow creek banks associated with the occurrence of pneumatophores of the mangrove species *Avicennia marina*. The prime dry season breeding site has an upper limit where the *Avicennia* reduces in height and predominance, and a lower limit where the creek opens out from the overhanging *Avicennia* canopy (Shivas 1999, Whelan 2003). Breeding also occurs in a broad band centred around the edge of the vegetation line on the upper part of the creekbank i.e. just above MHWN (Shivas 1999, Shivas 2001).

Other breeding sites of low to medium productivity occur at the front edge of the mangrove forest in the *Sonneratia* mangrove zone facing open water. These breeding sites are usually associated with mud substrates and not with sandy substrates. Narrow beach fringing mangrove areas are usually not appreciable sources of *C. ornatus*, particularly in areas with sandy substrates (Shivas 1999). Wet season emergence in foreshore breeding habitat shifts from the *Sonneratia* mangrove zone into the adjacent *Rhizophora* zone (Shivas & Whelan 2001).

During the wet season, emergence on the creek bank decreases to insignificant levels in direct response to rainfall (Shivas et. al. 1997). Significant emergence in the wet season shifts to the *Ceriops* transition zone at the back edge of the creek bank forest. This is just below MHWS (Mean High Water Spring or average high tide mark) or 6.9m ACD in Darwin Harbour. This is where the mixed *Ceriops* starts in a transition from the taller creek bank mangroves to the smaller mangroves in drier, less frequently flooded areas only reached by tides from 6.5 to 6.8m.

5.1.4 *Culicoides ornatus* breeding sites affecting the TTP gas pipeline corridor

Major breeding sites potentially exist within the upper tidal creek mangrove areas approximately 3km south of the western most limit of the TTP gas pipeline (Figure 2). Major *C. ornatus* breeding sites exist in the tidal creek mangrove areas north of Port Keats (Wadeye), although the pipeline corridor is at least 4km away from these areas (Figure 2). Major breeding sites potentially exist in the upper tidal creek areas approaching Gove and at Gove (Figures 10 & 10a).

5.1.5 Pest and public health significance

Moderate biting midge pest problems in the Gove Peninsula area of the TTP gas pipeline, from *C. ornatus,* are likely to occur in the August to November period, particularly for three or four days around full moon nights. A pest problem may also occur around new moon nights in this period, but will be lower than for full moon nights. There are unlikely to be significant pest problems for the remaining months of the year. Other sections of the TTP gas pipeline corridor approaching the Gove Peninsula pass within 3.5km of tidal creek mangrove areas, with these areas likely to have moderate pest numbers of *C. ornatus*, mainly in the months of August to November.

Some areas of the western most section of the TTP gas pipeline corridor, from the beach to approximately 6km east of the beach, occurs within 3.5km of tidal creek mangrove areas and may experience minor *C. ornatus* pest problems. The pipeline corridor does not encompass any areas within 2km of tidal mangrove areas, where most *C. ornatus* dispersal occurs, therefore is not exposed to the higher pest problems likely to be caused by this species. The remaining inland areas of the TTP gas pipeline corridor will not be exposed to *C. ornatus* problems.

The number of bites by *Culicoides* that will constitute a pest problem will largely depend on the individual being bitten. It has been suggested that over 60 bites per hour for most experienced biting midge workers are unacceptable (Whelan et. al. 1997a). For people unaccustomed to biting midge bites, one to five bites per hour may be unbearable.

Investigations near Darwin have suggested an approximate relationship between the numbers of biting midges collected in a carbon dioxide trap and the number of bites that can be expected at the peak biting period (Whelan et. al. 1997a). The number of bites in an hour on an exposed leg at the peak biting time around sunset is approximately a quarter of the number collected in a CO_2 trap over one night at the same position (Whelan et. al. 1997a). For example if there were 400 *C. ornatus* in a CO_2 trap this would equate to 100 bites per hour.

The trapping results at the Gove Peninsula indicate that the number of *C. ornatus* in a trap equating to 60 bites per hour (240 *C. ornatus* per trap night) was exceeded at Wallaby Beach and equalled at Nhulunbuy South (Figure 11, Table 1). Numbers at both these sites are expected to be up to four to five times higher in the peak season August to November period. Numbers of *C. ornatus* may reach 60 bites per hour in other areas of the TTP gas pipeline corridor that are located within 3.5km of tidal mangrove areas. This may include some areas of the western most section of the TTP gas pipeline corridor, from the beach to approximately 6km east of the beach, and those tidal areas encompassed in the TTP gas pipeline corridor approaching the Gove Peninsula.

Outdoor activities within the TTP gas pipeline corridor on the Gove Peninsula and approaching the Gove Peninsula, within 3.5km of tidal mangrove areas, may be moderately affected by *C. ornatus* pest problems in the months of August to November. During the remaining months of the year, minor *C. ornatus* pest problems may affect the pipeline corridor on Gove Peninsula area and approaching the Gove Peninsula area. Outdoor activities within the western limit of the TTP gas pipeline corridor within 3.5km of tidal mangrove areas (from the beach to 6km east of the beach) may be affected by minor *C. ornatus* pest problems in the months of August to November. Peak biting times for this species are in the hours either side of sunset and sunrise. It should be noted however that construction workers within 2km of tidal mangrove areas will be exposed to much higher levels of biting midges.

Culicoides ornatus bites can be a significant pest problem and can cause associated health problems. The bites are painful and large numbers of bites can cause a generalized reaction in non-immune people. Many people, particularly newly arrived or newly exposed people, suffer from bite reactions that can lead to intense itching, scratching, skin lesions, secondary infection and scarring.

Of other *Culicoides* species collected, *C. marksi* occasionally bites humans and may cause a minor pest problem for construction workers near inland freshwater lakes and streams in the early wet season, and early to mid dry season.

Culicoides flumineus and *C.* undescribed sp. (near *C. immaculatus*) may be encountered in high pest numbers by construction workers who venture into the mangrove areas in the section of TTP gas pipeline corridor approaching the Gove Peninsula, and on the Gove Peninsula. These species would not be encountered outside of mangrove areas.

Lasiohelia species may be causing minor pest problems near areas such as patches of tropical rainforest, and general vegetation ranging from wet-sclerophyll forest to open grassland.

A species of *Styloconops* may be causing minor pest problems on open sandy beaches within the TTP gas pipeline corridor.

Workers who are located within 2km of Port Keats, and within 2km of the tidal mangrove areas near the western limit of the TTP gas pipeline corridor, may be exposed to high *C. ornatus* pest problems in the months of August to November, and low to moderate pest problems for the remaining months of the year. Workers who are located in mangrove areas at Port Keats, and within 2km of the tidal mangrove areas near the western limit of the TTP gas pipeline corridor, may be exposed to high pest problems of *C. flumineus* and *C.* undescribed sp. (near *C. immaculatus*).

5.2 Mosquitoes

5.2.1 Species Present

There are over 100 species of mosquitoes recorded in the NT. Of these species, 16 are regarded as either potential pest species, or both potential pest and vector species (Appendix 2, Whelan 1997).

There are likely to be at least eight mosquito species capable of causing a potential minor to major pest and/or potential mosquito borne disease problem along the TTP gas pipeline route. These species are listed below, with a brief description of preferred breeding sites.

5.2.1.1 Ochlerotatus vigilax (The salt marsh mosquito)

This species breeds in extreme numbers in tidal and brackish water swamps, and also in the upper extremities of tidal creeks. High numbers of this species also breeds in interdunal areas and poorly draining areas along the coastline of the NT, as well as other tidal areas along the coast in Western Australia, Queensland, New South Wales and South Australia (Russell & Doggett 2002**)**. Peak numbers of this species in the NT occur from 9-10 days after monthly high tides and significant rainfall in the months of September to January, with pest problems occurring for up to two weeks.

This species is regarded as a serious pest species, due to its persistent and day biting habits. This species can disperse up to 50km in pest numbers from extensive breeding sites along the coast, with the major pest problem occurring within 5km of extensive breeding areas. As well as being a serious pest species, *Oc. vigilax* is also a vector of Ross River virus (RRV) disease (Tai et al 1993, Whelan and Weir 1993) and Barmah Forest virus (BFV) disease (Merianos et al 1992, Whelan et al 1993).

5.2.1.2 Ochlerotatus normanensis (The floodwater mosquito)

This species breeds in very high numbers in poorly draining floodways associated with minor and major creeks and rivers. Peak numbers of this species occurs from 9-10 days after extensive rainfall in the months of January to March, with pest problems occurring for up to two weeks.

This species mainly bites during the evening and night, and is regarded as a serious pest species. Pest numbers of *Oc. normanensis* can occur up to 5km from their breeding sites. *Ochlerotatus normanensis* is a known vector of RRV and BFV, and a potential vector of Murray Valley encephalitis virus (MVEV).

5.2.1.3 Culex annulirostris (The common banded mosquito)

This species breeds in the vegetated margins and pools in permanent and semi-permanent swamps, creeks and floodways, as well as temporary vegetated ground pools in the wet season. Peak numbers generally occur in the mid wet season months of January to March, with a major peak in the post wet season months of April to August. The pest problem can be continuous for these months.

Culex annulirostris bite mainly after sundown, and is regarded as a serious pest species, with pest numbers of this species occurring up to 10km from extensive breeding sites. *Culex annulirostris* is the most important vector of arboviruses in the NT (Whelan and Weir 1993). It is recognised as a good vector of MVEV, Kunjin virus (KUNV), RRV and BFV (Merianos et al 1992, Whelan et al 1993). Many other arboviruses have been isolated from this species (Whelan and Weir 1993).

5.2.1.4 Anopheles bancroftii (The black malaria mosquito)

This species breeds in very high numbers in seasonally inundated *Melaleuca* Paperbark swamps, as well as swamps and creeks with *Eleocharis* and *Typha* reeds. Peak numbers generally occur in the months of February to July, with highest numbers in the post wet season months of April to July. The pest problem can be continuous for the months of February to July.

Anopheles bancroftii bite after sundown or in the shade during the day, and bites any time near their breeding site. This species can travel up to 5km in pest numbers from large breeding sites, and can be a major pest species. *Anopheles bancroftii* is regarded as a possible vector of malaria, although this species is relatively short lived compared to other *Anopheles* species mosquitoes, therefore is not likely to be a major threat of local malaria transmission.

5.2.1.5 Coquillettidia xanthogaster (The golden mosquito)

This species breeds in high numbers in freshwater swamps and streams with aquatic and semi-aquatic vegetation. This species also breeds in association with soft rooted plants such as *Pandanus* (Lee et al 1988). Peak numbers generally occur in the post wet season months of March to August. Adults generally emerge around the time of the full moon (Whelan pers. comm.).

Coquillettidia xanthogaster bite mainly at dusk, although do bite in the shade during the day. *Coquillettidia xanthogaster* adults can travel up to 5km in pest numbers from large breeding sites, and is considered a major pest species. This species is not regarded as a vector species in Australia, hence only has significance as a pest species.

5.2.1.6 Anopheles farauti s.l. (The north Australian malaria mosquito)

Anopheles farauti s.l. is a species complex that includes three sibling species, *An. farauti, An. hinesorum* and *An. torresiensis.* These species are impossible to separate morphologically, and are therefore grouped together in the *An. farauti s.l.* species complex. These species breed in different habitats, with *An. farauti* larval habitats being brackish water reed swamps and creeks, while *An. hinesorum* and *An. torresiensis* breed in vegetated freshwater swamps and streams. Peak numbers generally occur in the post wet season months of March to June.

The species in the *An. farauti s.l.* species complex bite after dark. They generally do not fly more than 1.6km from their breeding sites, and are considered minor to moderate pest species, although high numbers of the brackish water breeder *An. farauti* can be found near extensive brackish water reed swamps. *Anopheles farauti* is considered a major potential vector of malaria, and was possibly the vector in the Cairns epidemic in 1942 (Russell 1987). The vector competence of *An. hinesorum* and *An. torresiensis* has not been determined, although they should not be discounted as potential vectors of malaria.

5.2.1.7 Anopheles annulipes s.l. (The Australian *Anopheles* mosquito)

This species is a species complex that includes at least 10 sibling species (Russell and Kay 2004). These species are difficult or impossible to separate morphologically. Preferred breeding sites for *An. annulipes s.l.* are freshwater streams and freshwater vegetated swamps. Peak numbers generally occur in the wet season.

This species is regarded as a potential vector of malaria (Russell 1987), and are considered minor to moderate pest species. *Anopheles annulipes s.l.* bites at night and can travel up to 2km from their breeding sites.

5.2.1.8 Mansonia uniformis (The waterlily mosquito)

This species breeds in high numbers in extensive freshwater reed swamps with water lilies. Peak numbers generally occur in the post wet season months of March to June, although at Holmes Jungle near Darwin elevated numbers have been shown to occur in the mid wet season months of January and February (Medical Entomology Branch data).

This species can be a major pest species near their breeding site, and can disperse in pest numbers for up to 2km. This species mainly bites at night, although can be serious pests in cool shade near their breeding site during the daytime. *Mansonia uniformis* are not considered vectors of disease in Australia, therefore have implications as pest species only.

5.2.2 Potential introduced species along the pipeline route

5.2.2.1 Aedes aegypti (The dengue mosquito)

Aedes aegypti is a vector of dengue fever and is endemic to North Queensland. The rest of Australia had been free of dengue vectors for over 50 years until February 2004, when a population of *Ae. aegypti* was located in Tennant Creek in the Northern Territory (Whelan et al 2004). The most likely source of this mosquito was road transport from North Queensland (Whelan et al 2004). This species is occasionally found breeding in machinery, cargo and other artificial receptacles on overseas vessels by Australian Quarantine Inspection Service (AQIS) officers in ports around Northern Australia. The vigilance of AQIS officers and the Medical Entomology Branch of the Department of Health and Community Services has prevented the establishment of this mosquito species in the NT from overseas incursions.

Aedes aegypti populations are only found in close association with human activity (Lee et al 1987a). Eggs from this species are desiccation resistant and have been shown to survive in dry storage in Sydney for 80 days (Lee et at 1987a). Preferred breeding sites are any artificial receptacles such as used tyres, buckets, machinery and any type of receptacle capable of holding water, as well as natural tree holes close to human activity. This close association with humans can have serious public health implications, with recent dengue fever outbreaks in North Queensland (Russell & Kay 2004). Dengue fever can be fatal. Control of this mosquito can be very difficult to achieve, as they breed in backyards and sometimes inside houses in places such as water vases, making searching for breeding sites time consuming and often difficult.

5.2.2.2 Aedes albopictus (Asian Tiger Mosquito)

This species is a vector of dengue fever, although it is currently not present in Australia. This species breeds in artificial containers as well as natural breeding sites such as tree holes, bamboo stumps, leaf axils and fallen palm fronds (Lee et al 1987a). This species is not as domesticated as *Ae. aegypti* and does not show any marked preference for either artificial or natural breeding sites (Lee et al 1987a). This species is occasionally found breeding in machinery, cargo and other artificial receptacles on overseas vessels by Australian Quarantine Inspection Service (AQIS) officers in ports around Northern Australia. The vigilance of AQIS officers and the Medical Entomology Branch of the Department of Health and Community Services has prevented the establishment of this mosquito species in the NT from overseas incursions.

5.2.3 Spatial abundance

The largest mosquito problems along the TTP gas pipeline route will occur within a few kilometres of extensive seasonally flooded swamps and floodways. Pest problems of mosquitoes can occur up to 5km from extensive mosquito breeding sites.

A large coastal freshwater and brackish water swamp was located 1km north of the western most limit of the TTP gas pipeline corridor in June 2004 (Warchot et al 2004, Figure 2). Large pest numbers of the salt marsh mosquito *Oc. vigilax* are likely to affect the western most section of the TTP gas pipeline within 5km of this swamp. This swamp may also contribute moderate to high pest numbers of *Cx. annulirostris, Cq. xanthogaster* and *An. bancroftii* to the section of TTP gas pipeline within five kilometres of this swamp. Pest numbers of *An. farauti s.l.* may be noticed along the TTP gas pipeline route within 3km of this swamp.

At the eastern most section of the TTP gas pipeline at and near Gove, moderate to severe pest numbers of *Oc. vigilax* may be experienced, with moderate to high pest numbers of *Cx. annulirostris* likely to be present. *Ochlerotatus vigilax* will be sourced from the old red mud ponds area of the Alcan mine, as well as poorly draining upper tidal areas associated with the various tidal creeks, and potentially from Nhulunbuy Lagoon. *Culex annulirostris* will be sourced from the old red mud ponds area, Nhulunbuy lagoon and any seasonally flooded grassy areas.

For the remainder of the TTP gas pipeline, the major mosquito problems will be experienced within a few kilometres of extensive seasonally flooded vegetated swamps, poorly draining grasslands and floodways, creeks and rivers, and tidal areas. The mosquito species likely to be abundant in greatest numbers would be *Oc. normanensis, Cx. annulirostris, An. bancroftii* and *Cq. xanthogaster.* Other species such as *An. farauti s.l., An. annulipes* and *Ma. uniformis* are likely to be present, but in lower numbers than the other species mentioned above.

5.2.4 Seasonal abundance

High to severe pest numbers of *Oc. vigilax* will be experienced along the western most section of the TTP gas pipeline within 5km of tidal areas, from the months of September to January, with minor to moderate numbers in February. Moderate to severe *Oc. vigilax* problems are likely to be experienced within 5km of tidal areas in the Gove vicinity, from the months of December to February.

Minor to severe pest numbers of *Oc. normanensis* may be experienced within 5km of poorly draining floodways associated with creeks and rivers in the inland areas of the TTP gas pipeline, in the months of January to March.

Culex annulirostris are likely to be present in minor to severe pest numbers along all sections of the TTP gas pipeline within 5km of seasonally flooded areas in the months of January to June, with this species likely to be present in minor to moderate numbers until August within 5km of extensive swamps that receive prolonged stream flows, and large vegetated creeks.

Minor to high pest problems of *Cq. xanthogaster* may be noticed within 5km of vegetated seasonally flooded areas in the months of March to June. This species is likely to be present in minor to moderate numbers until August near extensive swamps that receive prolonged stream flows, and large vegetated creeks.

Minor to high pest problems of *An. bancroftii* may be noticed within 5km of vegetated seasonally flooded areas in the months of March to June. This species is likely to be present in minor to moderate numbers until July near extensive swamps that receive prolonged stream flows, or large vegetated creeks.

Anopheles farauti s.l. are likely to be present in minor to moderate pest numbers within 3km of brackish or freshwater swamps and creeks along the TTP gas pipeline route, from March to June.

Minor to large pest numbers of *Ma. uniformis* may be present within 2km of extensive freshwater vegetated swamps and creeks along the TTP gas pipeline route, in the post wet season months of March to June. Minor to large pest problems can also occur in the mid wet season months of January and February.

Other mosquito species may be present in nuisance to minor pest numbers along the TTP gas pipeline route during the mid to late wet seasons.

5.2.5 Pest problems and public health

Several mosquito species will be of public health importance along the TTP gas pipeline route. Arbovirus disease risk periods in the Northern Territory are shown in Appendix 4. *Ochlerotatus* *vigilax* will present a major RRV and BFV transmission risk period for workers within 5km of tidal areas in the months of September to January, with the peak virus transmission risk period from this species being the months of December and January. *Ochlerotatus vigilax* can be a severe pest species, capable of biting in the day and night. This species can travel up to 50km in pest numbers (Whelan 1997), and will pose a RRV and BFV risk wherever they are encountered.

Culex annulirostris will present a RRV and BFV transmission risk period for workers within 5km of permanent and semi-permanent swamps, creeks and floodways, as well as temporary vegetated ground pools in the wet season, in the months of January to August. The main risk period will be the months of January to March. *Culex annulirostris* will also pose a risk for MVEV transmission in the months of January to August, with the main risk period being March to May. *Culex annulirostris* can be a severe pest species, and mainly bites after dark.

Ochlerotatus normanensis will present a RRV and BFV risk period for workers in the months of January to March, and a potential MVEV risk period in months of January to March, within 5km of poorly draining floodways associated with minor and major creeks and rivers. *Ochlerotatus normanensis* can be a severe pest species, capable of biting in the evening and night.

Anopheles farauti s.l. will present a potential local malaria transmission risk period for workers in the months of March to June. *Anopheles farauti s.l* is generally a minor pest species which bites after dark. High risk areas are those areas within 3km of brackish water reed swamps and creeks, and within 3km of freshwater swamps and creeks. Known high risk areas include the first 6km section of the western section TTP gas pipeline from the beach, and those areas within 3km of Buffalo Creek in Nhulunbuy (MEB data).

Anopheles annulipes s.l. will present a potential local malaria transmission risk period for workers during January to April, within 3km of freshwater streams and swamps. This species is generally a minor pest species which bites after dark.

Cq. xanthogaster, Ma .uniformis and *An. bancroftii* do not carry any human disease in Australia so are considered pest species only. All three species mainly bite at night, but also bite during the day in cool shaded areas. These species can be significant pest mosquitoes. Highest pest problems of *Cq. xanthogaster* will occur within 5km of freshwater swamps and streams with aquatic and semi-aquatic vegetation, in the months of March to August. Highest pest problems of *Ma. uniformis* will occur within 3km of freshwater swamps and streams with aquatic and semi-aquatic vegetation, in the months of January to June. Highest pest problems of *An. bancroftii* will occur within 5km of seasonally inundated *Melaleuca* Paperbark swamps, as well as swamps and creeks with *Eleocharis* and *Typha* reeds, in the months of February to July.

5.2.6 Potential mosquito borne disease

5.2.6.1 Arboviruses

The most important potential endemic mosquito borne diseases in this area are those caused by Murray Valley encephalitis virus (MVEV), Ross River virus (RRV) and Barmah Forest virus (BFV) (Mackenzie et al 1994, Russell 1995, Whelan et al 1992). As there is no vaccine against these diseases, the best method of prevention is self-protection from mosquito bites (Appendix 3).

The period of risk for Murray Valley encephalitis virus disease along the TTP gas pipeline route is when *Culex annulirostris* numbers are elevated in the mid wet season to early dry season months of January to August. The peak risk period for MVEV transmission are the months of March to May. *Culex annulirostris* is also a vector of RRV and BFV, with the greatest risk period of RRV and BFV transmission from this species being the January to March period, with the overall risk period being the months of January to August.

Ochlerotatus vigilax is a vector of RRV and BFV. The vector status of this species is enhanced due to its persistent and day biting habits. High to severe numbers of this species will occur within 5km of the coast on the western side of the TTP gas pipeline area in the months of September to January, with minor to moderate numbers likely in February. Moderate to very high numbers of this species are likely to present along the eastern section of the TTP gas pipeline at Gove from December to February. This species may be present in pest number from the months of September to January along other areas of the TTP gas pipeline within 5km of tidal areas. The greatest risk period of RRV and BFV transmission from this species will be from December to February, with the overall risk period being the months of September to February.

The dengue mosquito species *Aedes aegypti* and *Aedes albopictus* were not trapped, and are not likely to be present along the TTP Project route. *Aedes aegypti* is currently endemic to North Queensland, and a population has recently been detected in Tennant Creek. *Aedes albopictus* is not present in Australia. These two mosquito species breed in artificial receptacles, with *Ae. aegypti* usually only found in association with human residences (Lee et al 1987a).

There is a risk of importation of *Ae. aegypti* into developed human habitation areas along the TTP gas pipeline route from artificial receptacles from North Queensland and Tennant Creek. Any artificial receptacle from Queensland and Tennant Creek being transported into human habitation areas should be sprayed with a chlorine solution to kill any eggs that may be present. The risk of *Ae. aegypti* and *Ae. albopictus* introduction from overseas should be small, if all vessels are inspected by AQIS Officers before being unloaded.

5.2.6.2 Malaria

Malaria is no longer present in the Northern Territory, but there is always a risk of re-introduction, if a proportion of the workforce is mobile and sourced from countries where malaria is present. Cases of imported malaria may not be rapidly detected in isolated areas with reduced medical services and may subsequently infect the local species of *Anopheles* mosquitoes.

The primary potential vector species for malaria in Australia is generally considered to be *Anopheles farauti s.l.* because of its known association with the disease in Papua New Guinea, and because it was shown to be a vector in an epidemic in Cairns in 1942 (Russell 1987). It is the principal potential vector in the Top End of the NT (Whelan 1981). However, Russell (1987) showed that *An. annulipes* in south-east Australia was relatively long lived and therefore *An. annulipes* in the NT must also be considered a probable potential vector of malaria. *Anopheles annulipes* was the probable vector of malaria epidemics on some areas of the NT prior to 1962. *Anopheles hilli, An. bancroftii* and *An. amictus* must also be regarded as potential vectors, although *An. bancroftii* may not pose a significant risk as it is not as long lived as the other species (Russell 1987).

If more than 10 individuals of *An. farauti s.l.* or one of the other species bite a malarious person (with the sexual forms of the parasite in their blood) there is a good chance that at least one will survive the minimum of 10 days necessary before it is capable of transmitting malaria to another person. Malaria transmission is more likely to occur if relatively high numbers of female *An. farauti s.l.* have bitten the malarious person.

If imported malaria cases occur along the TTP gas pipeline route, the individual should be kept indoors at night away from mosquito bites until a risk assessment is made by MEB. It is important for the individual to receive appropriate treatment to eliminate the parasite in their blood, before the patient is exposed to mosquitoes. Patients should avoid spending evenings and nights exposed to mosquito bites. Any temporary accommodation facilities should be well screened to prevent mosquito entry.

Any personnel that have returned from overseas malarious areas and experience a sudden onset of fever should be considered as possibly having malaria. Only patients exposed after sundown would be at risk of spreading malaria, as potential malaria *Anopheles* species bite only after dusk. Suspected malaria patients should be advised to seek medical advice.

Along the TTP gas pipeline route, *An. annulipes* and *An. amictus* may be present in low to moderate numbers during the wet season, within 2km of seasonally flooded swamps and creeks. *Anopheles hilli* (brackish to saltwater breeder) may be present in low to moderate numbers in the post wet season months of April, May and June within 4km of tidal areas. Numbers of *An. bancroftii* may be present in moderate to high pest numbers in the period of April to June within 5km of seasonally flooded creeks and swamps.

Moderate to high numbers of *An. farauti s.l.* will be present in the months of April, May and June along the TTP gas pipeline route within 3km of the large brackish water and fresh water swamp located 1km north of the western limit of the TTP gas pipeline corridor. Numbers of *An. farauti s.l.* are not likely to be significant after June. For the remainder of the gas pipeline route, *An. farauti s.l.* may be present in low to moderate numbers within 3km of seasonally flooded swamps and creeks.

5.3 Evaluation of development plans and suggested mosquito control measures

5.3.1 Development elements

5.3.1.1 Gas pipeline

The greatest risk of this development creating new mosquito breeding sites arises from the laying of the gas pipeline. As the pipeline will cross many natural flowpaths, including creeks and rivers, there is a risk that the natural flow of surface water will be interrupted to the extent that new or increased mosquito breeding occurs.

The finished surface level of the buried pipeline should be the same level as the surrounding land, to prevent the upstream ponding of water for periods (five consecutive days or greater) that will lead to mosquito breeding. Of particular importance are those sections of the pipeline that cross natural flow lines such as creeks, streams and rivers, and flat areas of land with poor drainage. This is particularly important for those natural flow paths near human habitation areas (Port Keats (Wadeye), Palumpa, Dorisvale, Florina, Manbulloo, Katherine, Tindal, Bamyili, Beswick, Bulman and Nhulunbuy) that the pipeline will cross. Any upstream embankment of water near human habitation will lead to increased mosquito breeding and increased pest and potential mosquito borne disease problems for those people.

In those areas where the pipeline will be constructed above ground, appropriate measures should be taken to ensure the natural flow of surface water is not restricted in these areas. This would require the judicious placing of culverts to prevent upstream ponding of water for periods greater than five days.

Any excess spoil from site excavations should be appropriately stored to prevent the impoundment of water for periods that will enable mosquito breeding. Any borrow pit should be rendered free draining to prevent water pooling and mosquito breeding. No borrow pits should be constructed within 5km of any human settlement.

5.3.1.2 Access roads

Any access road, including the access corridor along the length of the pipeline, should not result in the upstream impoundment of water for periods that will enable mosquito breeding. Where necessary, access roads will need to be fitted with culverts of sufficient size to prevent the upstream ponding of water for periods greater than five consecutive days.

5.3.1.3 Construction activities

Construction activities may lead to machinery disturbance to the surrounding land, which in turn could lead to the creation of mosquito breeding sites, especially in and near seasonally inundated areas such as floodways, creeks and rivers. Activities should be conducted in a manner to minimise machinery disturbance to the surrounding land, with any machinery disturbed areas rectified to prevent the ponding of water.

5.3.1.4 Construction camps

Where practical, construction camps should be located as far as possible from extensive seasonally flooded areas such as floodways, swamps, billabongs, creeks and rivers, as well as tidal areas. This is required to minimise exposing the workforce to the larger mosquito problem areas along the TTP gas pipeline route.

Any rainwater tanks, sewage systems and waste water should be managed to prevent mosquito breeding. Any rainwater tanks should be screened to prevent mosquito entry. Sewage systems should not result in any effluent water pooling in nearby areas and should be sited away from seasonally flooded areas, and waste water should not be allowed to pool in nearby areas.

5.4 Mosquito breeding site control

Mosquito breeding site control of already existing natural breeding sites would not be feasible for this development, as it is likely the workforce will not be located in any one area for extended periods of time, and the extent of most breeding sites affecting the TTP gas pipeline route are unknown. Any mosquito breeding sites created at construction camps would need to be treated with the insecticide *Bacillus thuringiensis* var. *israelensis* (B.t.i) until a rectification solution is implemented.

5.5 Personal protection

Periodic personal protection measures will be required along those areas of the TTP gas pipeline route that are located within 5km of seasonal freshwater inundated areas, in the months of January to August. Periodic personal protection measures will be required along those areas of the TTP gas pipeline route that are located within 5km of tidal areas in the months of September to January.

Recommended measures to minimise mosquito problems can be found in Appendix 3. In general, personal protection measures include avoiding peak mosquito biting times, which are generally around sunset and sunrise, and after dark. Personal repellent containing the active ingredient DEET or Picaridin, and loose, light coloured long sleeved clothing and full length trousers are also recommended measures to minimise mosquito bites. If tents are to be used, they can be impregnated with permethrin or sprayed with bifenthrin, to kill mosquitoes that rest on the tent surface. Tents must be insect proof. Clothing can also be impregnated with permethrin, which kill the mosquitoes after they land, and can also interfere with the normal biting behaviour (Whelan 2003).

Construction camps should be located as far away from potentially extensive mosquito breeding areas as possible. Vegetated areas surrounding construction camps can be sprayed with bifenthrin, to provide an insecticide barrier to reduce mosquito numbers entering the construction camp areas. Other areas where mosquitoes are likely to rest, such as toilets, showers and other structures that contain dark, shaded areas, can be sprayed with bifenthrin to control mosquitoes that rest in these areas during the daytime.

All workers should be notified of the potential pest and disease problem associated with mosquitoes, and be made aware of periods and areas of expected high numbers. All prospective workers should be provided with personal protection guidelines, which are provided in Appendix 3.

Workers who experience mosquito problems should be advised to notify their supervisor or TTP environmental officer, who can then alert other workers of problem areas and periods, and the need for personal protection measures. The same personal protection measures for mosquitoes should also be used for biting midges when necessary.

5.6 Monitoring and Reporting

Workers should be advised to notify the TTP Environmental Officer, or a nominated officer, of any mosquito problem areas and periods, to allow other workers to be notified of problem areas and problem periods. The TTP Environmental Officer, or a nominated officer, should then notify the Medical Entomology Branch, who will provide recommendations to reduce the mosquito problem.

The TTP Environmental Officer, or a nominated officer, should monitor construction activities to ensure machinery disturbance is prevented or rectified, to prevent the exacerbation of mosquito breeding or creation of new mosquito breeding sites.

The TTP Environmental Officer, or a nominated officer, should monitor construction activities to ensure natural drainage paths are not disrupted by the laying of the pipeline, especially near Port Keats (Wadeye), Palumpa, Dorisvale, Florina, Manbulloo, Tindal, Bamyili, Beswick, Bulman and Gove. This officer should also ensure any borrow pit is rendered free draining, especially near Port Keats (Wadeye), Palumpa, Dorisvale, Florina, Manbulloo, Tindal, Bamyili, Beswick, Bulman and Gove. No borrow pit should be constructed within 5km of human populated areas. The Medical Entomology Branch should be requested to inspect the finished pipeline route near at least some of these areas within 1 year of completion, to ensure new mosquito problems have not been created.

The TTP Environmental Officer, or a nominated officer, should ensure culverts of sufficient size to prevent the upstream impoundment of water for more than five consecutive days are installed along any access track and above ground section of the gas pipeline where necessary.

The TTP Environmental Officer, or a nominated officer, should ensure any artificial receptacles sourced from North Queensland or Tennant Creek is treated with a chlorine solution, to prevent the introduction of *Ae. aegypti* into populated areas nearby to the TTP gas pipeline corridor.

All prospective workers should be screened for Malaria. Any worker suspected of having malaria should be kept indoors, and the TTP Environmental Officer, or a nominated officer, should immediately contact the nearest health centre or the Centre for Disease Control for appropriate treatment and advice.

6. Conclusions

6.1 Biting Midges

a) Species

- The main species likely to be present within the TTP gas pipeline corridor is the mangrove biting species *Culicoides ornatus*. Other main species that may be present along the TTP gas pipeline corridor include *Culicoides marksi, Culicoides flumineus, Culicoides* undescribed Sp. (near *C. immaculatus*), *Lasiohelia* species and a species of *Styloconops.*

b) Source

- *Culicoides ornatus* will be breeding in the upper tidal creek mangrove areas within 3.5km of the TTP gas pipeline route.
- *Culicoides marksi* will be breeding along the margins of freshwater lakes and streams.
- *Lasiohelia* species will be breeding in damp, surface terrestrial environments, such as patches of tropical rainforest, and general vegetation ranging from wet-sclerophyll forest to open grassland
- *Culicoides flumineus* will be breeding in the lower levels of creekbanks in small tidal tributaries. *Culicoides* undescribed Sp. (near *C. immaculatus*) will presumably be breeding in the lower reaches of mangrove creeks.
- *Styloconops* species may be breeding in open sandy beaches.

c) Pest and potential disease problem

- *Culicoides ornatus* may cause moderate pest problems in the Gove section of the TTP gas pipeline route in the months of August to November. The pest problem in other months is likely to be minimal. *Culicoides ornatus* may cause minor pest problems in western section of the TTP gas pipeline located within 3.5km of tidal creek mangrove areas.
- *Culicoides marksi* may cause minor pest problems in the inland section of the TTP gas pipeline route in the early wet season, and early to mid dry season.
- *Lasiohelia* species may be causing minor pest problems in damp, surface terrestrial environments such as patches of tropical rainforest, and general vegetation ranging from wet-sclerophyll forest to open grassland.
- A species of *Styloconops* may be causing minor pest problems at open sandy beaches within the TTP gas pipeline corridor
- *Culicoides flumineus* and *C.* undescribed Sp. (near *C. immaculatus*) may be causing high pest problems to workers inside mangrove areas located within the TTP gas pipeline corridor. Workers that are located inside mangrove areas outside of the TTP gas pipeline corridor may also experience high pest numbers of these species.
- Workers that are located within 2km of Port Keats (Wadeye) may be exposed to high *C. ornatus* problems.
- Biting midges do not transmit human disease in Australia.

d) Mitigation measures

- Personal protection measures such as the use of protective clothing, repellents, and avoidance of areas of high biting midge activity may be necessary. Tents should be impregnated with permethrin or sprayed with bifenthrin, to control biting midges that may rest on the tents. Tents should be well screened to prevent the entry of biting midges. Personal clothing can also be impregnated with permethrin. Outside areas can be sprayed with bifenthrin to control adult biting midges.

- Prospective workers should be notified of the potential minor to moderate biting midge pest problems within 3.5km of tidal areas along the TTP gas pipeline route, and the potential minor biting midge pest problems nearby to inland freshwater lakes and streams. Prospective workers should be advised that high biting midge pest problems exist inside mangrove areas. Workers travelling within 2km of Port Keats (Wadeye) should be advised that high biting midge pest problems occur in that area.

6.2 Mosquitoes

a) Species

- The main species likely to be present along the TTP gas pipeline route will be *Ochlerotatus vigilax* (The salt marsh mosquito), *Culex annulirostris* (The common banded mosquito), *Ochlerotatus normanensis* (The floodwater mosquito), *Anopheles farauti s.l.* (The north Australian malaria mosquito), *Anopheles bancroftii* (The black malaria mosquito), *Coquillettidia xanthogaster* (The golden mosquito), *Mansonia uniformis* (The waterlily mosquito) and *Anopheles annulipes s.l.* (The Australian *Anopheles* mosquito).

b) Source

- The large brackish water and freshwater reed swamp located 1km north of the western most limit of the TTP gas pipeline corridor, near the south-west coast of the NT, will be a source of large numbers of mosquitoes. Very high numbers of *Oc. vigilax,* and moderate to high numbers of *Cx. annulirostris, Cq. xanthogaster* and *An. bancroftii* are likely to affect the section of TTP gas pipeline within 5km of this swamp. Moderate to high numbers of *An. farauti s.l.* are likely to affect the section of TTP gas pipeline within 3km of this swamp.

- The old red mud ponds area near the Alcan Gove mine, upper tidal creek areas in the Gove Peninsula (Crocodile Creek, Buffalo Creek and East Woody Creek), and potentially Nhulunbuy Lagoon, will provide minor to very high numbers of *Oc. vigilax* to the section of TTP gas pipeline that runs parallel with the mine conveyer belt system. The old red mud ponds area will supply high numbers of *Cx. annulirostris,* and Nhulunbuy lagoon and any seasonally flooded grassy area may provide moderate numbers of *Cx. annulirostris* to the section of TTP gas pipeline that runs parallel with the mine conveyer belt system. Upper tidal areas approaching the Gove Peninsula may be sources of minor to high numbers of *Oc. vigilax.*

- For the remaining areas of the TTP gas pipeline route, poorly draining floodways associated with creeks and rivers may be sources of large numbers of *Oc. normanensis.* Vegetated seasonal swamps, floodways, billabongs, creeks and rivers may be sources of minor to large numbers of *Cx. annulirostris, An. bancroftii, Cq. xanthogaster* and *Ma. uniformis.* Temporary flooded vegetated ground pools and vegetated floodways will also be sources of minor to high numbers of *Cx. annulirostris.* Vegetated seasonal swamps and creeks may be sources of minor to moderate numbers of *An. annulipes* and *An. farauti s.l.*

c) Pest and potential disease problem

- *Ochlerotatus vigilax* will pose the most appreciable pest problem of all mosquito species encountered along the TTP gas pipeline route, due to the daytime and persistent biting habits of this mosquito species. High to very high numbers are likely to be encountered within 5km of the coast along the western section of the TTP gas pipeline, in the months of September to January, with minor to moderate numbers in February. Minor to very high numbers of this species may be encountered along the Gove section of the TTP gas pipeline, in the months of December to February. This species will pose a RRV and BFV risk for workers in the months of September to February, with the peak risk period from this mosquito being the months of December to February.

- *Ochlerotatus normanensis* may be encountered in minor to very high pest numbers in the months of January to March, nearby to inland poorly draining floodways associated with creeks and rivers. This species can be a serious pest during the evenings and at night. This species will pose a RRV and BFV risk in the months of January to March, and a potential MVEV risk in the months of January to March.

- *Culex annulirostris* will be the most common mosquito species encountered along the TTP gas pipeline route. This species may be encountered in minor to high pest numbers in the months of January to June nearby to seasonally flooded swamps, creeks, rivers and vegetated floodways. This species may cause a year round nuisance in areas nearby to perennial billabongs. This species may be present in elevated numbers until August, nearby to large vegetated creeks and rivers, and swamps that receive dry season stream flows. This species will pose a RRV and BFV risk for workers in the months of January to August, with the main risk period being January to March. This species will pose a MVEV and KUNV risk to workers in the months of January to August, with the main risk period being March to May.

- *Anopheles farauti s.l.* will pose a potential risk for local malaria transmission for all areas of the TTP gas pipeline within 1.6km of seasonally flooded swamps and creeks, in the months of March to June. This species is generally only a minor pest species.

- Other mosquito species such as *An. bancroftii* and *Cq. xanthogaster* may cause high pest problems in the late wet and early to mid dry season (March to August), along those sections of the TTP gas pipeline route within 5km of vegetated seasonally flooded swamps and creeks. *Ma. uniformis* may cause high pest problems in the late wet and early dry season (March to June), and in the mid wet season months of January and February, nearby to vegetated swamps and creeks. These species do not carry any human disease in Australia and are considered pest species only.

- Other mosquito species may be encountered in minor pest or nuisance numbers only, nearby to seasonally flooded areas.

d) Mitigation measures

- Prospective workers should be notified of the potential for mosquito pest and mosquito borne disease problems along the gas pipeline route within 5km of seasonally flooded swamps, floodways, creeks, rivers and billabongs. Personal protection measures such as the use of protective clothing, repellents, and avoidance of areas of high mosquito activity may be necessary. Tents should be impregnated with bifenthrin or permethrin, to control mosquitoes that may rest on the tents. Tents should be well screened to prevent the entry of mosquitoes. Personal clothing can also be impregnated with permethrin.

- Camp sites should be sited as far away as possible from seasonally flooded swamps, floodways, creeks and rivers during the wet season and early to mid dry season, to prevent exposing workers to the largest mosquito problems.

- The laying of the pipeline must not result in the impoundment of natural drainways such as seasonal streams, creeks and rivers. This is particularly important for those areas of the TTP gas pipeline that cross nearby to Port Keats (Wadeye), Palumpa, Dorisvale, Florina, Manbulloo, Katherine, Tindal, Bamyili, Beswick, Bulman and Nhulunbuy. Impoundment of natural drainways in these areas may increase mosquito numbers and lead to increased pest and potential mosquito borne disease problems. Excess spoil from trench digging should be stored appropriately to prevent the impoundment of water.

- Any borrow pit should be made free draining, particularly those located within 5km of human inhabitation areas.

- Culverts of sufficient size to prevent the upstream pooling of water for periods greater than five days may need to be fitted to access roads that cross natural drainage paths, and to those sections of the TTP gas pipeline that may be constructed above ground.

- Machinery disturbance to seasonally flooded areas should be avoided, to prevent the exacerbation of mosquito breeding or creation of new mosquito breeding in these areas. Machinery disturbed areas should be rectified to prevent water pooling.

- Artificial receptacles such as used tyres, buckets, machinery and any type of receptacle capable of holding water may introduce exotic dengue carrying mosquito species to human inhabitation areas nearby to the TTP gas pipeline route. Any artificial receptacle sourced from North Queensland, Tennant Creek, should be treated with a chlorine solution to kill any mosquito eggs that may be present. Artificial receptacles from overseas are currently treated by AQIS Officers, therefore further treatment of artificial receptacles from overseas would not be required.

e) Monitoring and reporting

- Workers should be advised to notify the TTP Environmental Officer, or a nominated officer, of any mosquito problem areas and periods, to allow other workers to be notified of problem areas and problem periods. The TTP Environmental Officer, or a nominated Officer, should notify the MEB, who will provide information on mitigation strategies to reduce the mosquito problem.

- The TTP Environmental Officer, or a nominated officer, should monitor construction activities to ensure machinery disturbance is prevented or rectified, to prevent the exacerbation of mosquito breeding or creation of new mosquito breeding sites.

- The TTP Environmental Officer, or a nominated officer, should monitor construction activities to ensure natural drainage paths and flat, poorly draining areas, are not disrupted by the laying of the pipeline, especially near Port Keats (Wadeye), Palumpa, Dorisvale, Florina, Manbulloo, Tindal, Bamyili, Beswick, Bulman and Gove. This officer should also ensure any borrow pit is rendered free draining, especially near Port Keats (Wadeye), Palumpa, Dorisvale, Florina, Manbulloo, Tindal, Bamyili, Beswick, Bulman and Gove. No borrow pits should be constructed within 5km of human populated areas. The Medical Entomology Branch should be requested to inspect the finished pipeline route near at least some of these areas within 1 year of completion, to ensure new mosquito problems have not been created.

- The Environmental Officer, or a nominated officer, should ensure any artificial receptacles sourced from North Queensland or Tennant Creek is treated with a chlorine solution.

- The TTP Environmental Officer, or a nominated officer, should ensure culverts of sufficient size to prevent the upstream impoundment of water for more than five consecutive days are installed along any access track and along above ground sections of the pipeline where necessary.

- All prospective workers should be screened for Malaria. Any worker suspected of having malaria should be kept indoors, and the TTP Environmental Officer, or a nominated officer, should immediately contact the nearest health centre or the Centre for Disease Control for appropriate treatment and advice.

- Mosquito monitoring currently occurs in Gove, carried out by Nhulunbuy Health and the Nhulunbuy Corporation. No further monitoring is required in this town.

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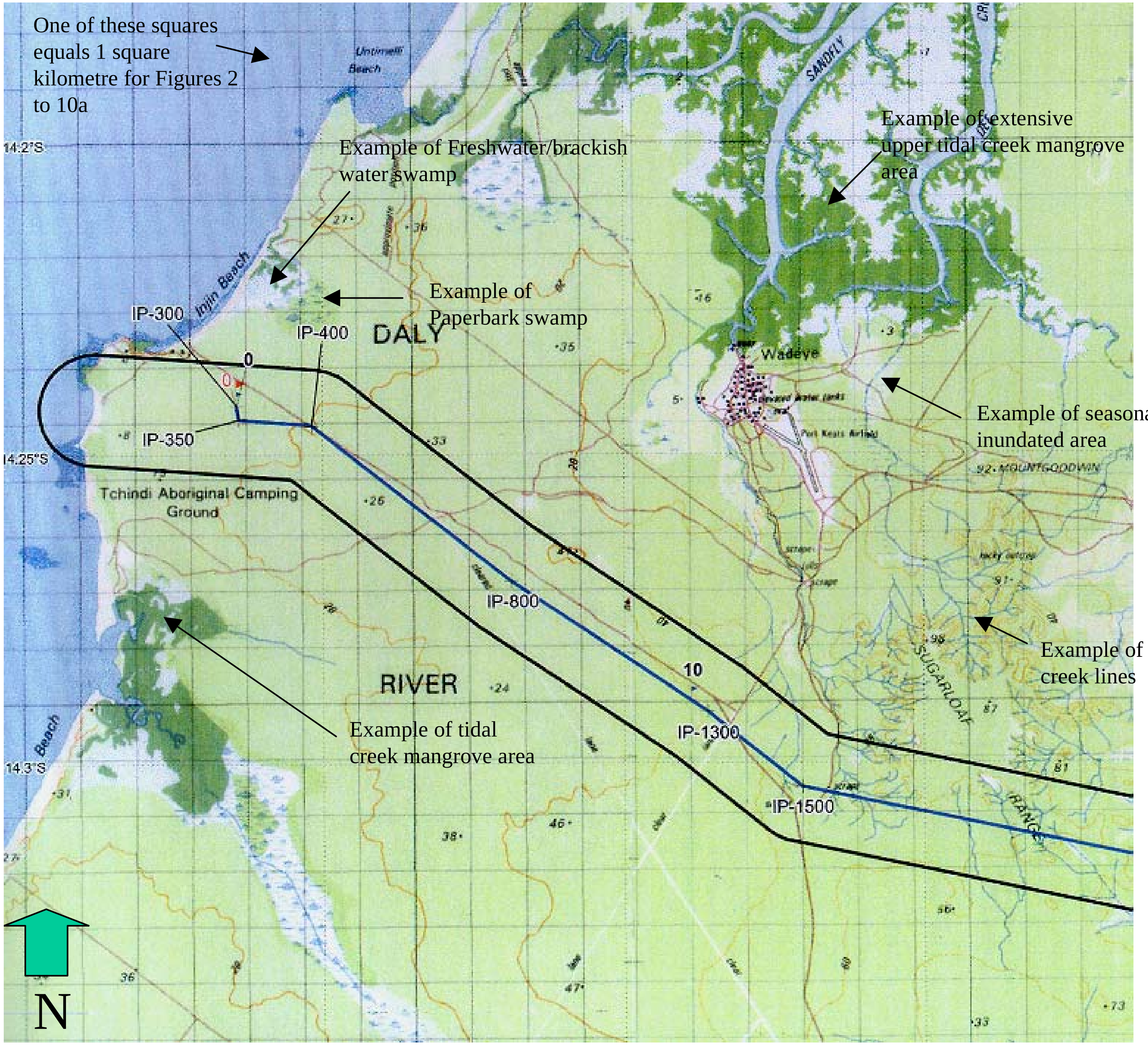
Figures

Figure 1 Study area

Figure 2 Port Keats (Wadeye)



Legend

Pipe Alignment Rev 5

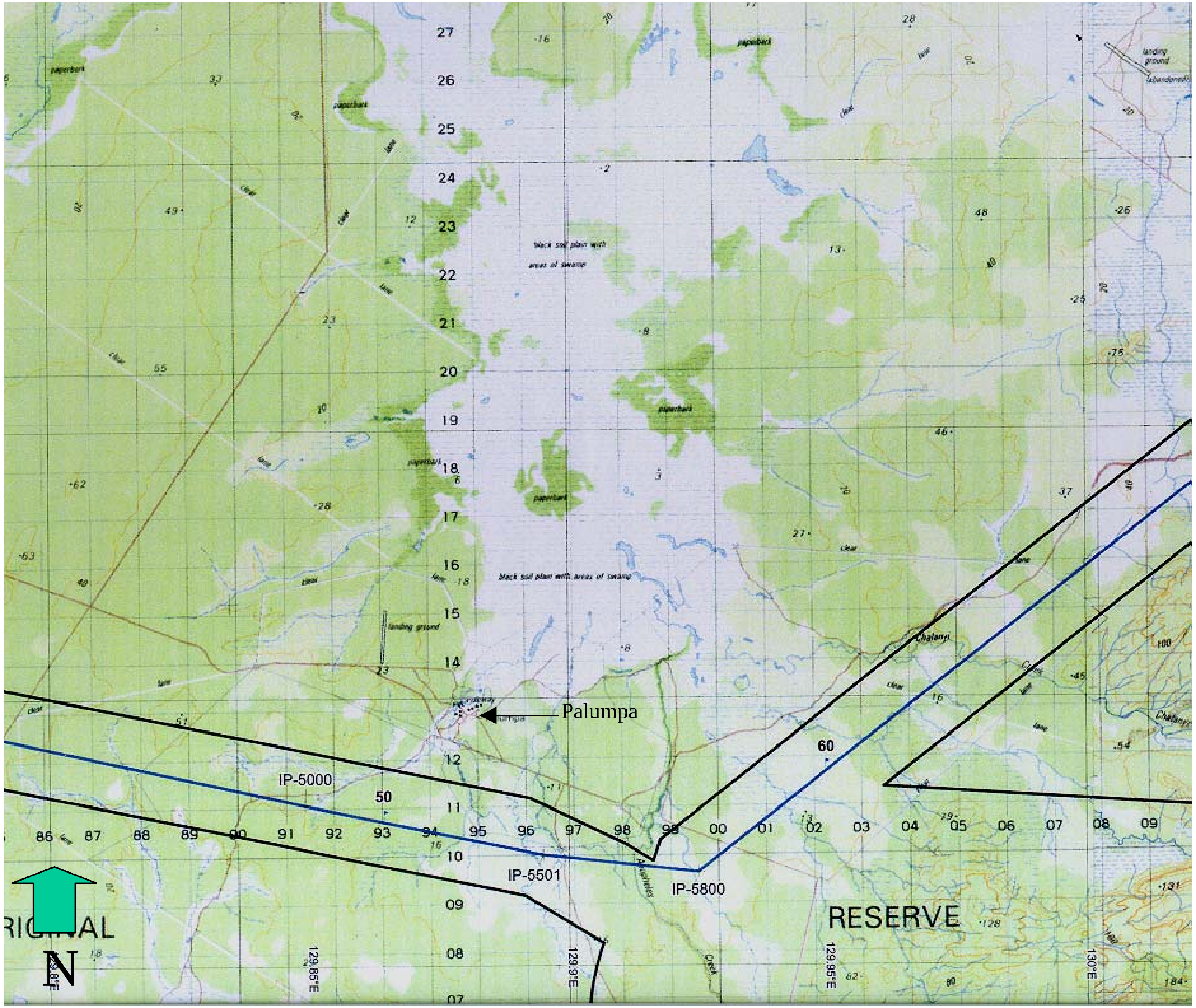
Pipe Alignment Rev 4

Pipeline Corridor

Scale: 1 square in map= 1Square Kilometre

Map source: Trans Territory Pipeline (TTP) Project. Proposed Pipeline Alignment - Revision 5 For Approvals. Topographical Maps 1:100,000 30 March 2004
Prepared by Mipela (GIS) Pty Ltd

Figure 3 Palumpa



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Pipe Alignment Rev 5

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Pipeline Corridor

Scale: 1 square in map= 1Square Kilometre

Map source: Trans Territory Pipeline (TTP) Project. Proposed Pipeline Alignment - Revision 5 For Approvals. Topographical Maps 1:100,000 30 March 2004
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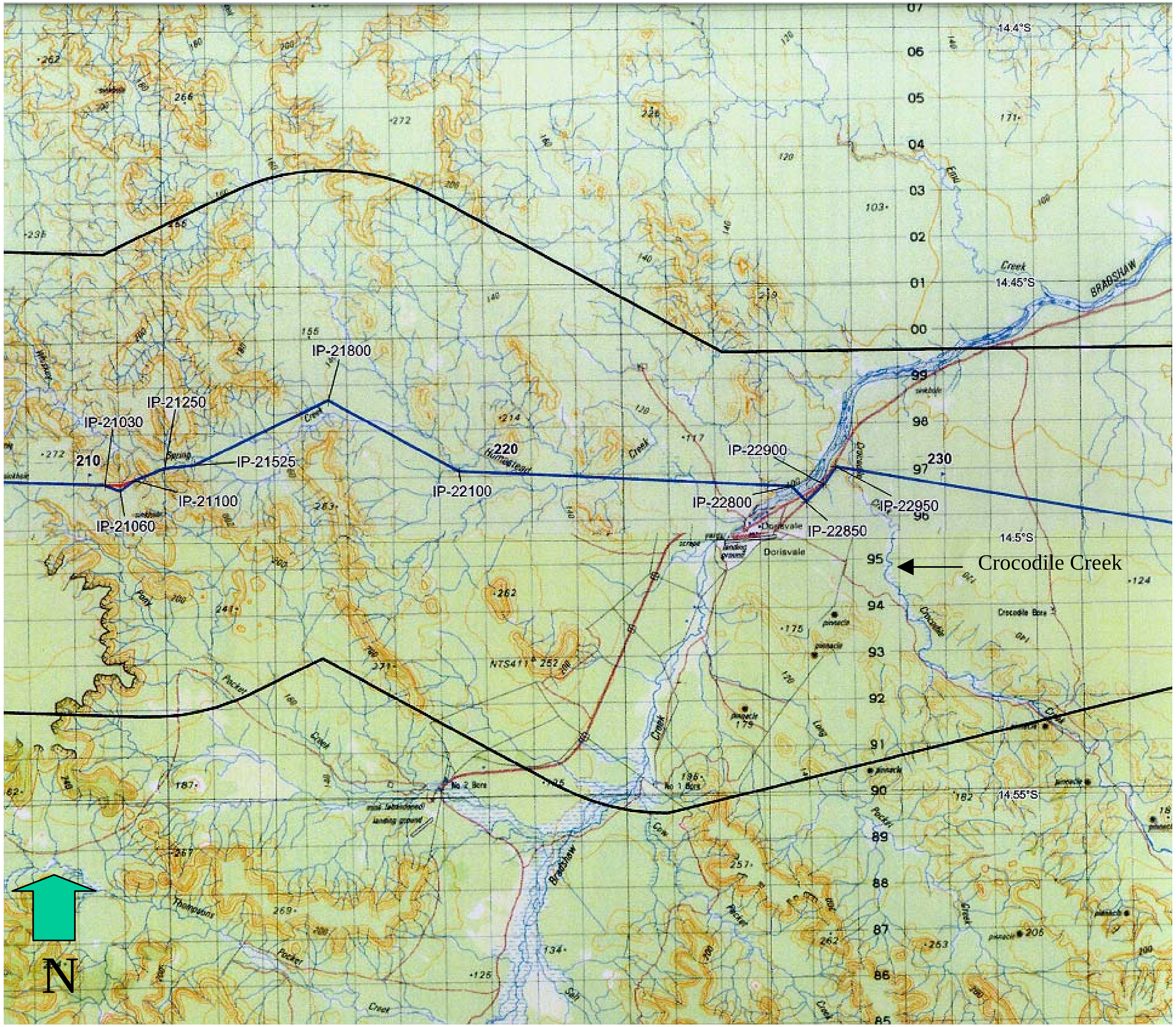
Figure 4 Dorisvale



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Pipe Alignment Rev 5

Pipe Alignment Rev 4

Pipeline Corridor

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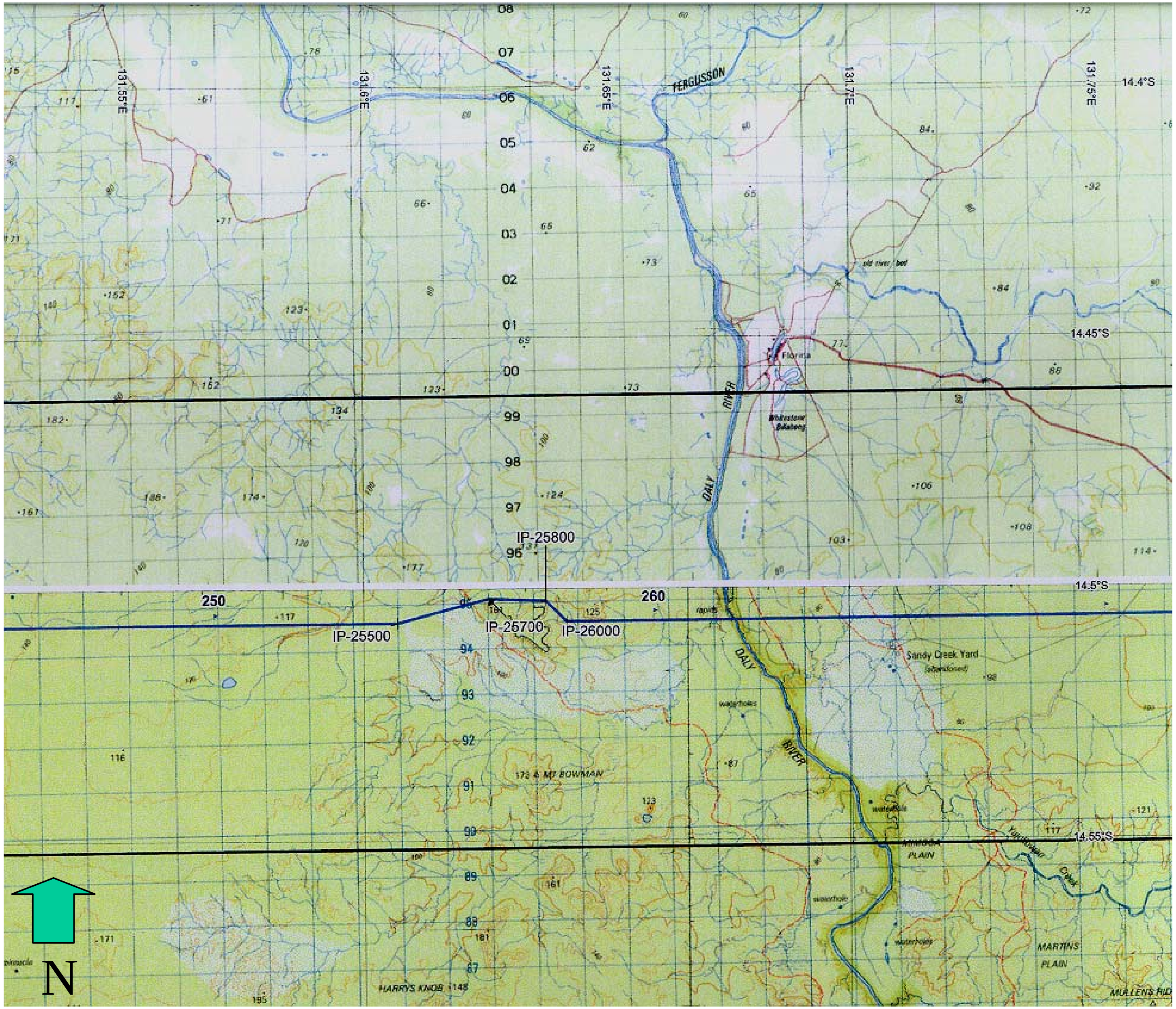
Map source: Trans Territory Pipeline (TTP) Project. Proposed Pipeline Alignment - Revision 5 For Approvals. Topographical Maps 1:100,000 30 March 2004
Prepared by Mipela (GIS) Pty Ltd

Figure 5 Florina



Legend

Pipe Alignment Rev 5

Pipe Alignment Rev 4

Pipeline Corridor

Scale: 1 square in map= 1Square Kilometre

Map source: Trans Territory Pipeline (TTP) Project. Proposed Pipeline Alignment - Revision 5 For Approvals. Topographical Maps 1:100,000 30 March 2004
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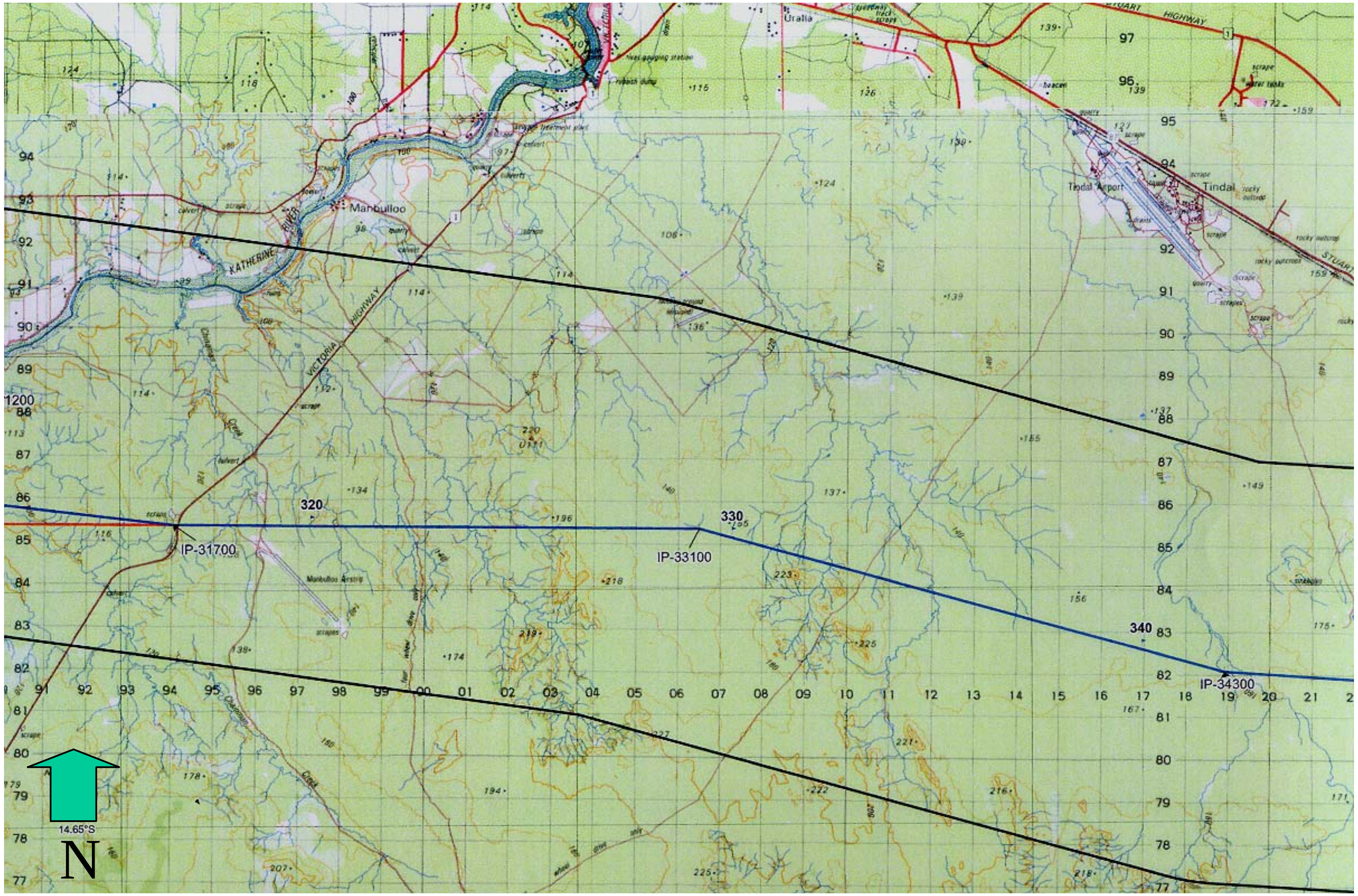
Figure 6 Tindal and Manbulloo



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Pipe Alignment Rev 5

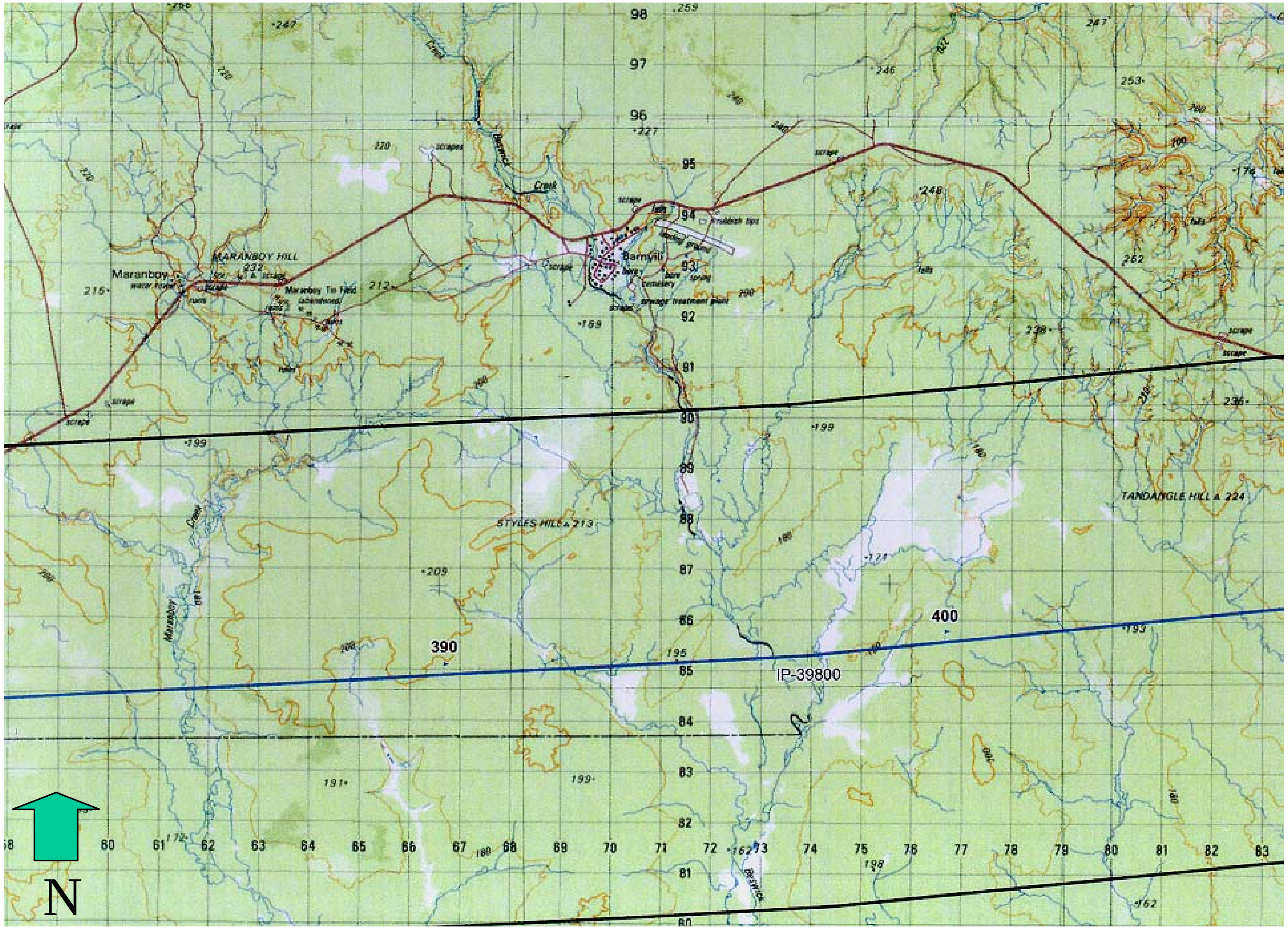
Pipe Alignment Rev 4

Pipeline Corridor

Scale: 1 square in map= 1Square Kilometre

Map source: Trans Territory Pipeline (TTP) Project. Proposed Pipeline Alignment - Revision 5 For Approvals. Topographical Maps 1:100,000 30 March 2004
Prepared by Mipela (GIS) Pty Ltd

Figure 7 Bamyili



Legend

Pipe Alignment Rev 5

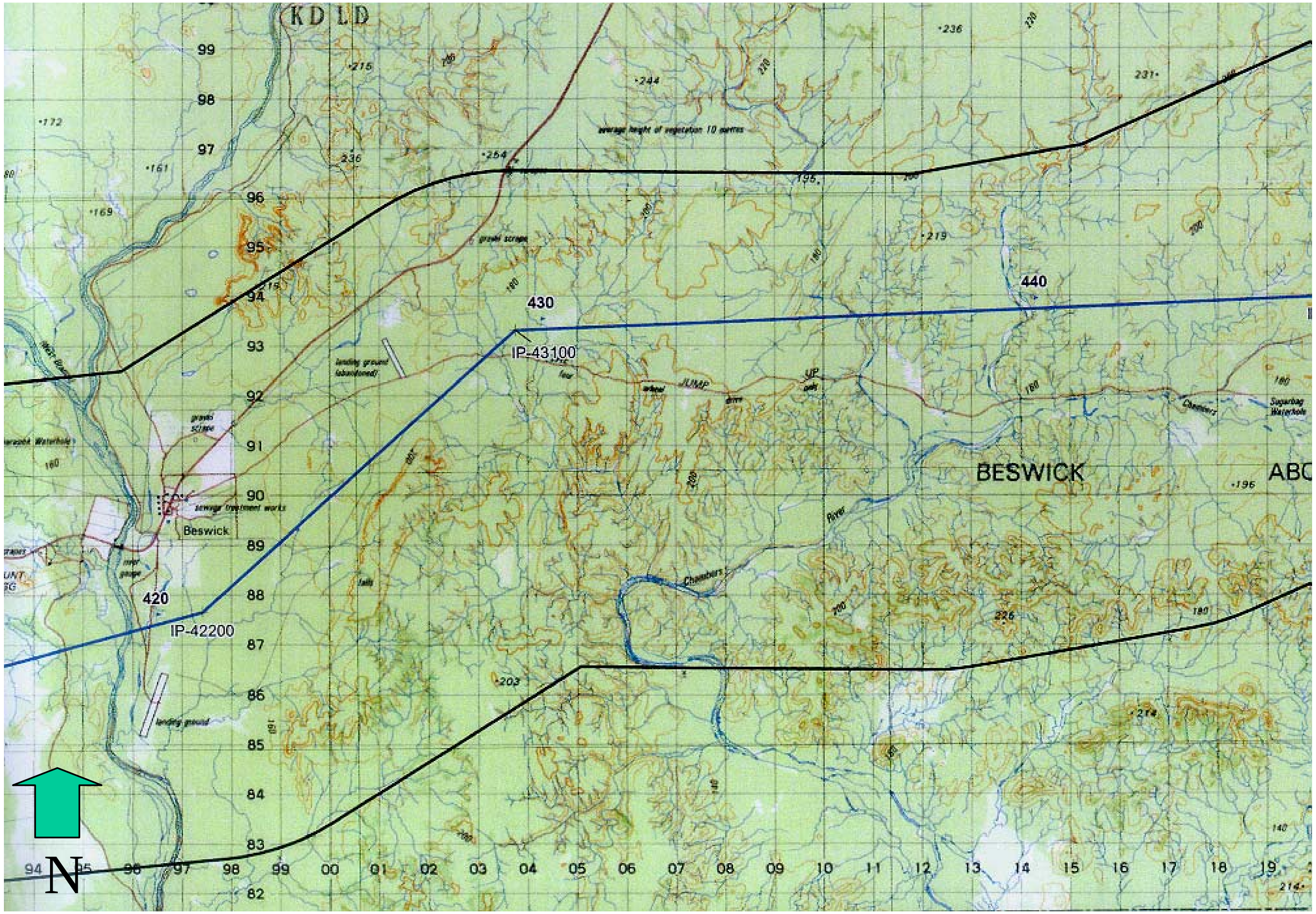
Pipe Alignment Rev 4

Pipeline Corridor

Scale: 1 square in map= 1Square Kilometre

Map source: Trans Territory Pipeline (TTP) Project. Proposed Pipeline Alignment - Revision 5 For Approvals. Topographical Maps 1:100,000 30 March 2004
Prepared by Mipela (GIS) Pty Ltd

Figure 8 Beswick



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Pipe Alignment Rev 5

Pipe Alignment Rev 4

Pipeline Corridor

Scale: 1 square in map= 1Square Kilometre

Map source: Trans Territory Pipeline (TTP) Project. Proposed Pipeline Alignment - Revision 5 For Approvals. Topographical Maps 1:100,000 30 March 2004
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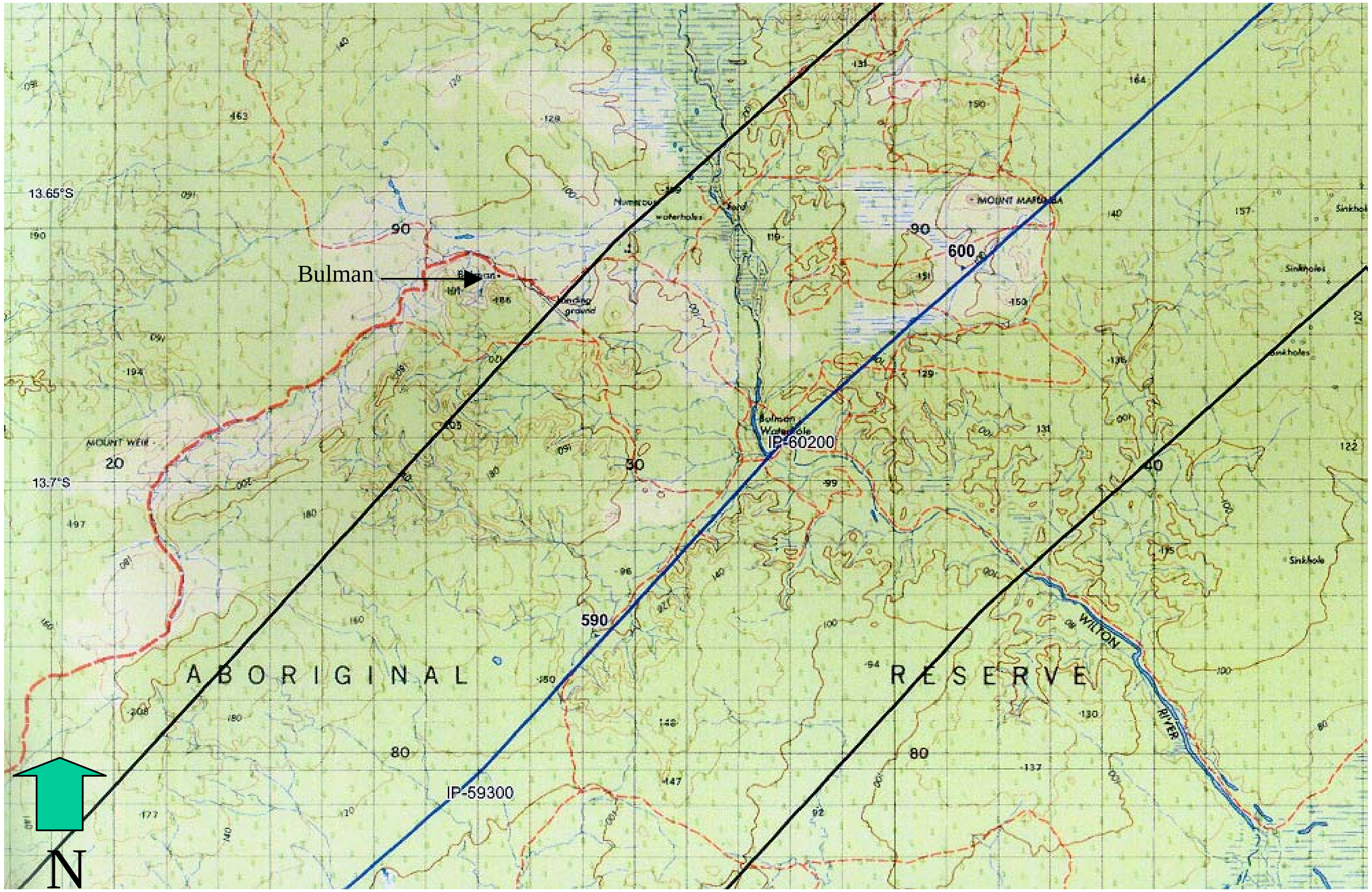
Figure 9 Bulman



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Pipe Alignment Rev 5

Pipe Alignment Rev 4

Pipeline Corridor

Scale: 1 square in map= 1Square Kilometre

Map source: Trans Territory Pipeline (TTP) Project. Proposed Pipeline Alignment - Revision 5 For Approvals. Topographical Maps 1:100,000 30 March 2004
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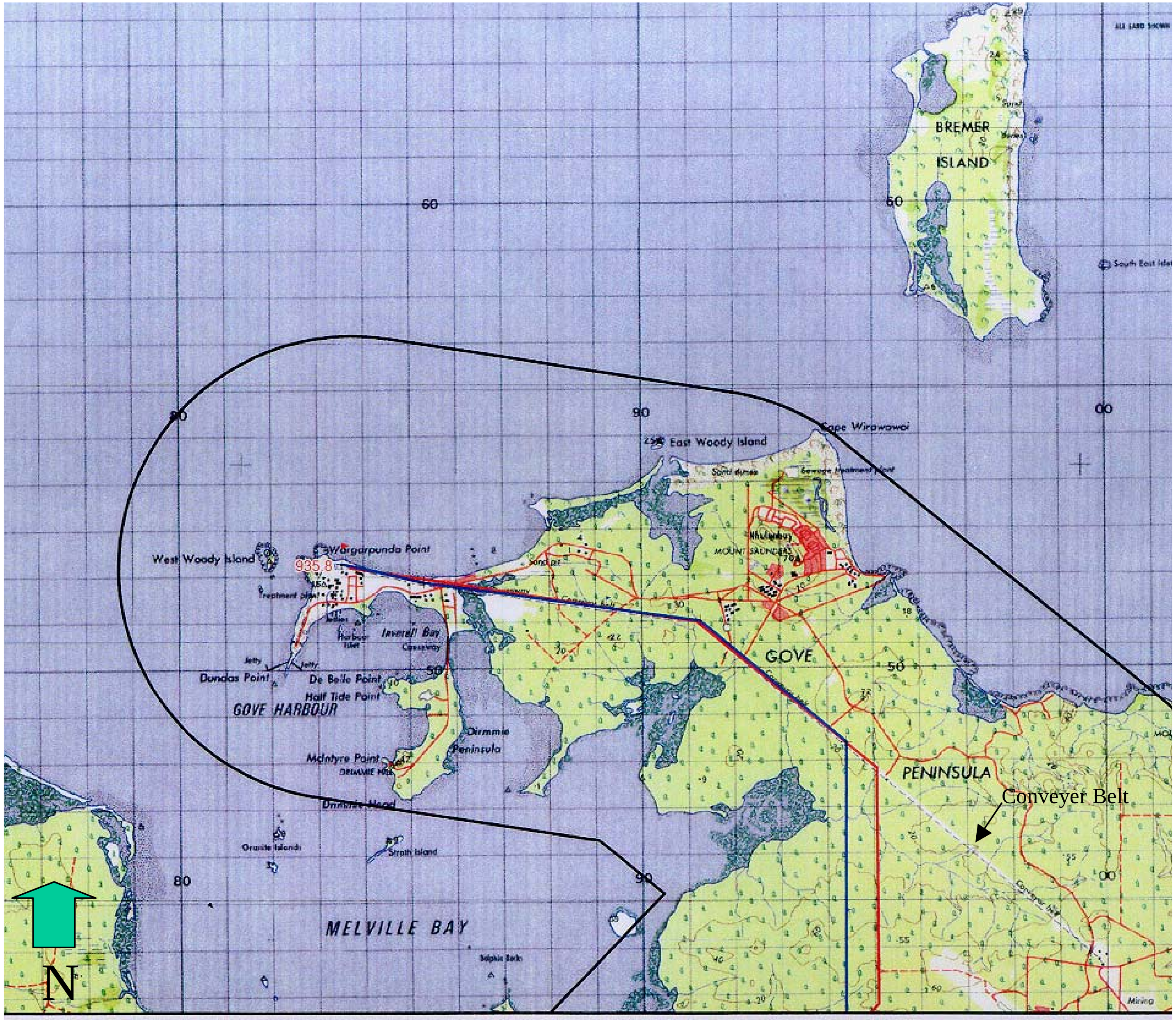
Figure 10 Gove



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Pipe Alignment Rev 5

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Pipeline Corridor

Scale: 1 square in map= 1Square Kilometre

Map source: Trans Territory Pipeline (TTP) Project. Proposed Pipeline Alignment - Revision 5 For Approvals. Topographical Maps 1:100,000
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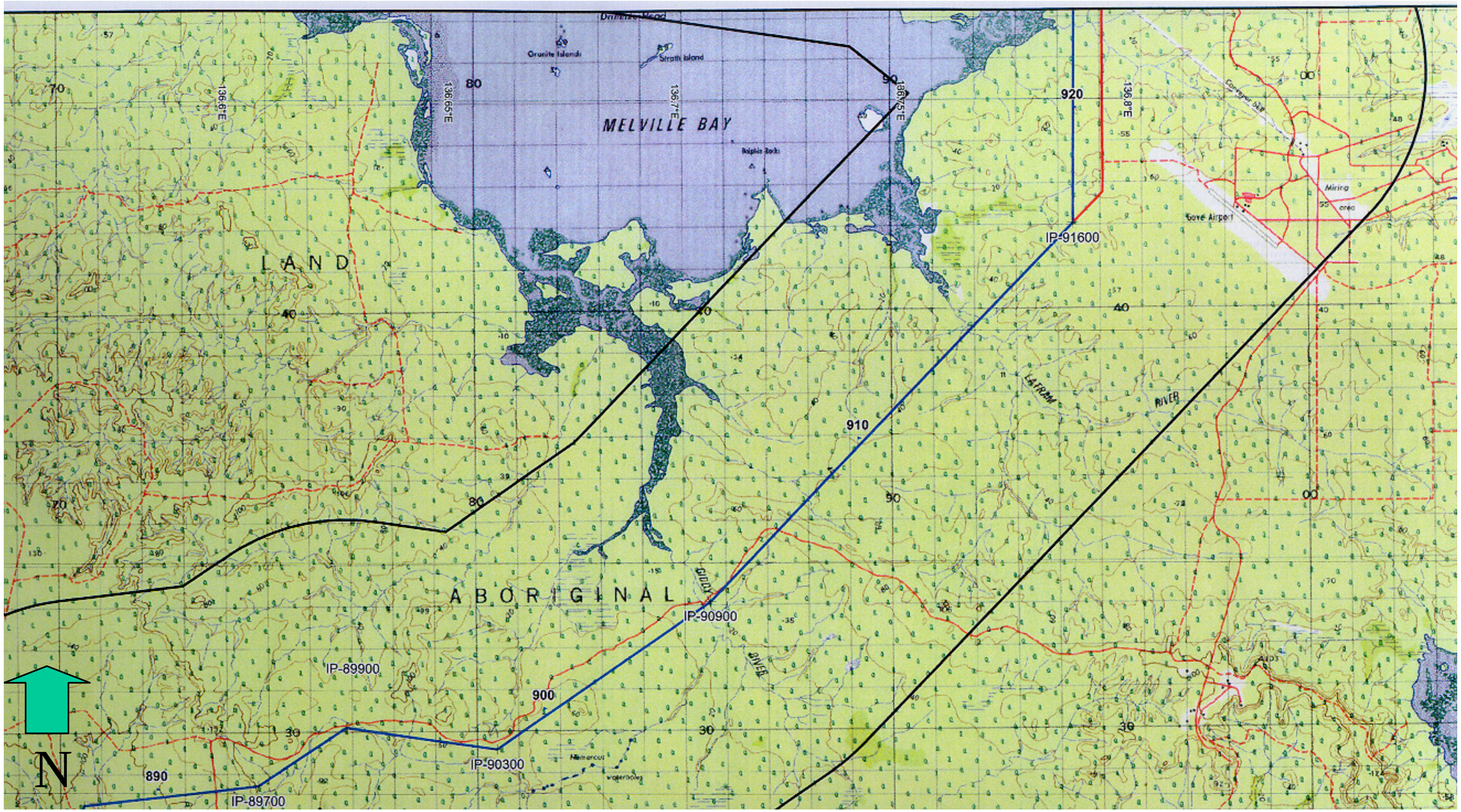
Figure 10a Approaching Gove Peninsular



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Pipe Alignment Rev 5

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Pipeline Corridor

Scale: 1 square in map= 1Square Kilometre

Map source: Trans Territory Pipeline (TTP) Project. Proposed Pipeline Alignment - Revision 5 For Approvals. Topographical Maps 1:100,000 30 March 2004
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FIGURE 11: **Nhulunbuy adult mosquito monitoring program location of weekly CO_2 trap sites.**

N

CO2 trap site

0 2 KM

Aerial photo from DLP&E 19/7/89

FIGURE 12- NHULUNBUY MOSQUITO MONITORING PROGRAM - CO_2 TRAPS

WALLABY BEACH 2000/03

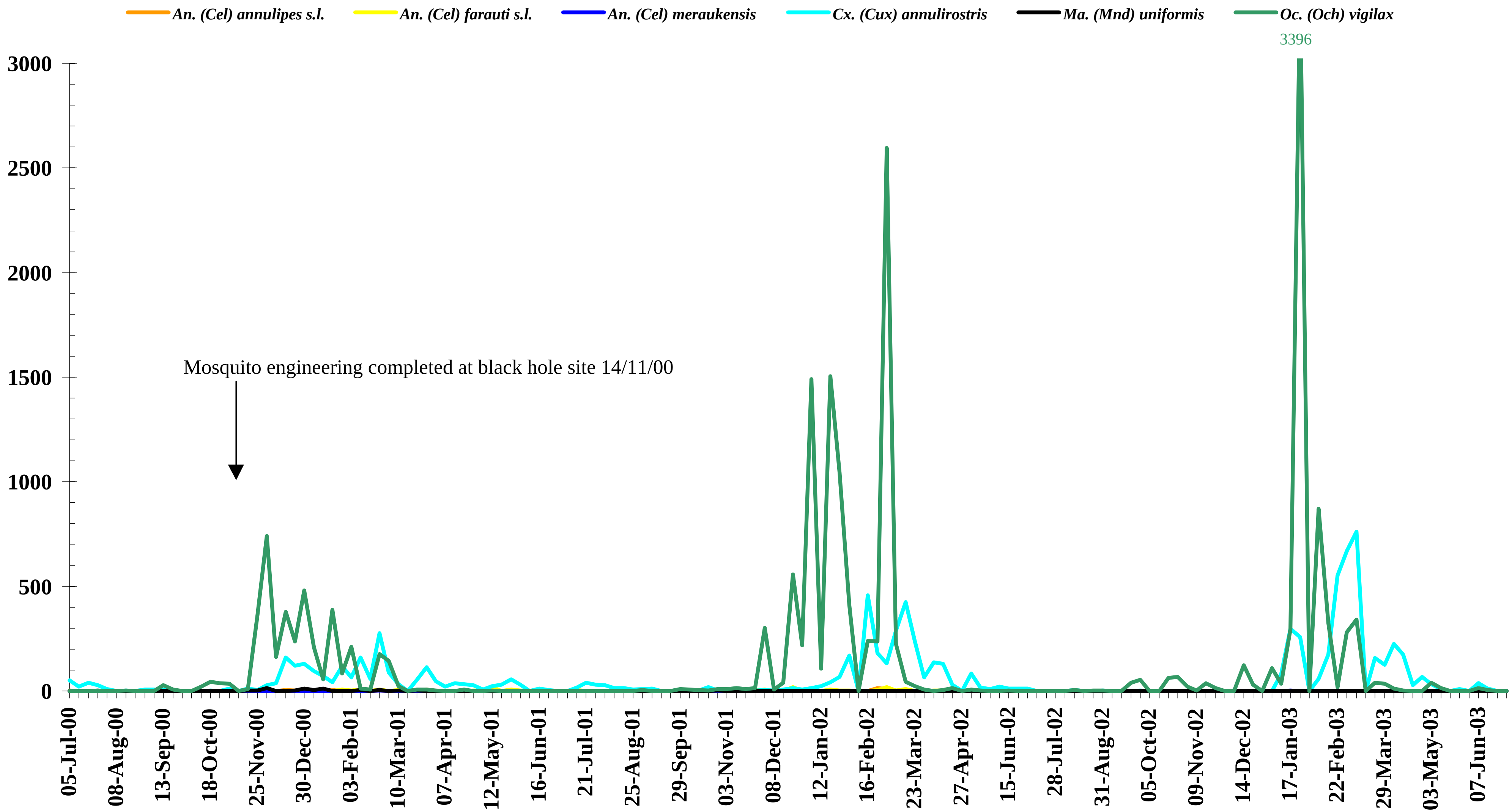
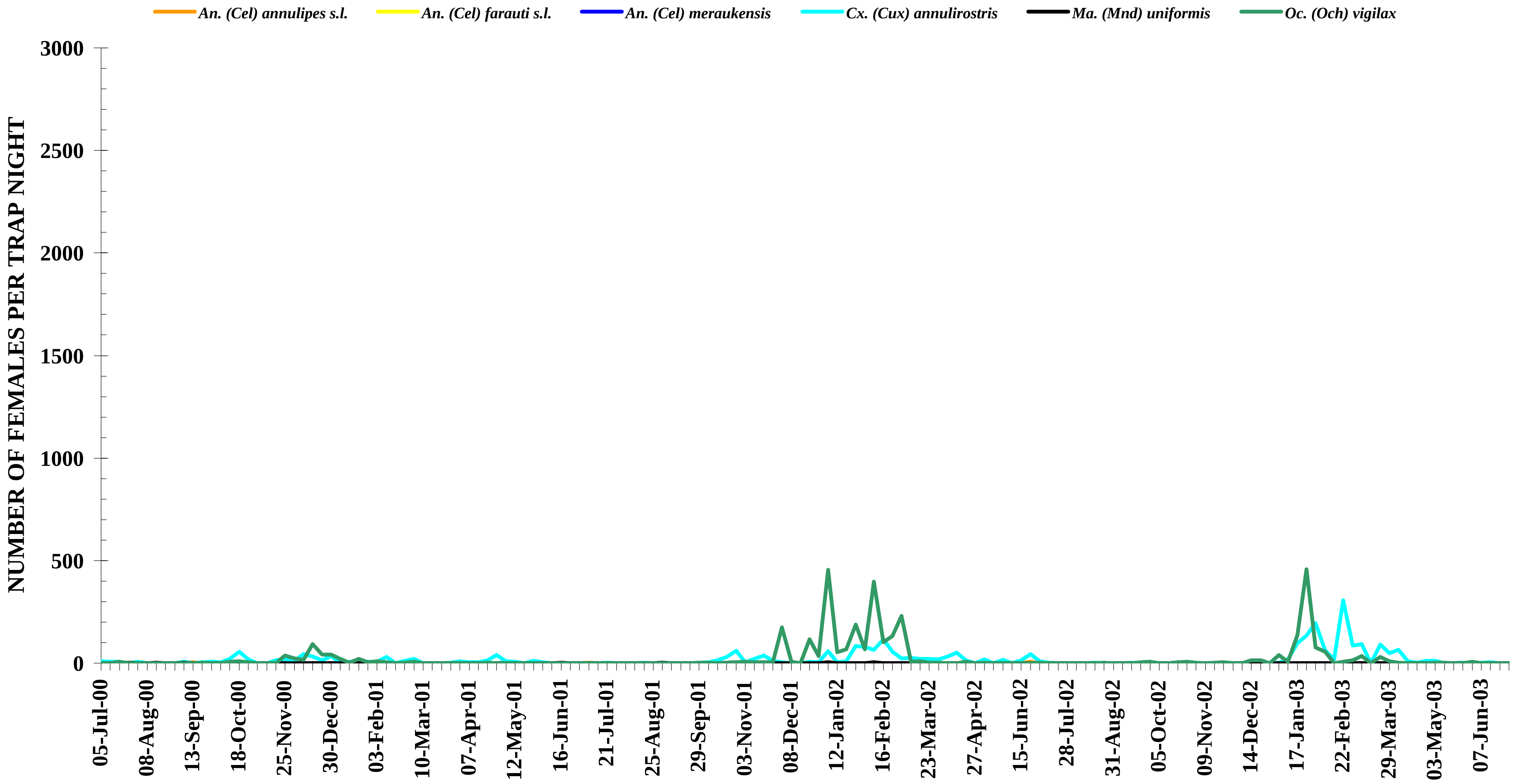


FIGURE 13-NHULUNBUY MOSQUITO MONITORING PROGRAM - CO_2 TRAPS

NHULUNBUY SOUTH 2000/03



F:\ENTO\ento_files\public_information\branch_reports\darwin_region\darwin_rural\TTP Blacktip to Gove project\Figures 12-13\Figure 13 Nhulunbuy South

Medical Entomology Branch DHCS 07/09/2004

Figure 14 - Biting midge investigations "Fairway Waters" Palmerston May 1996 to April 1997
Seasonal trend of *C. ornatus* collected from all sites on all monthly trap nights, and total monthly rainfall.

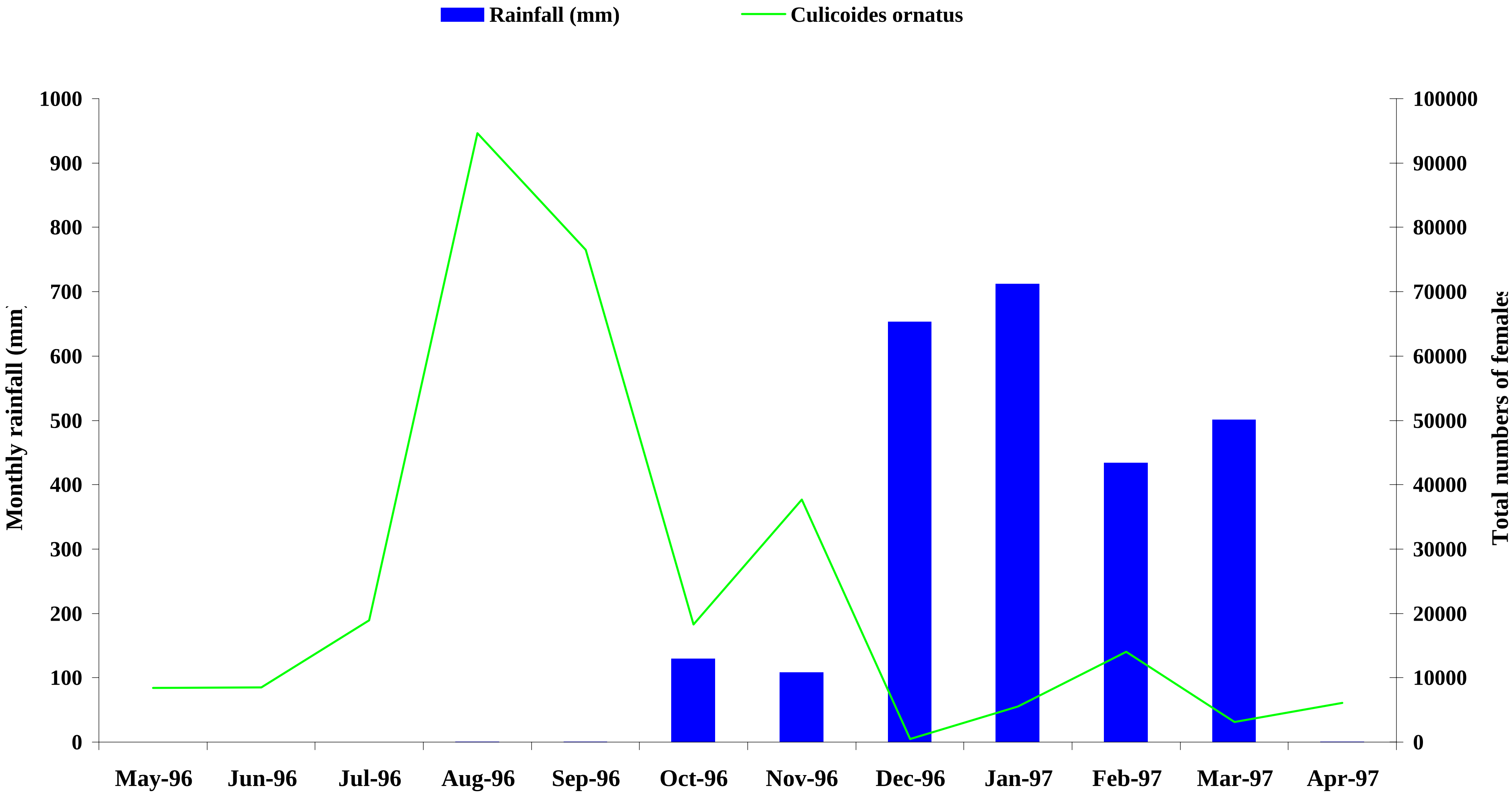
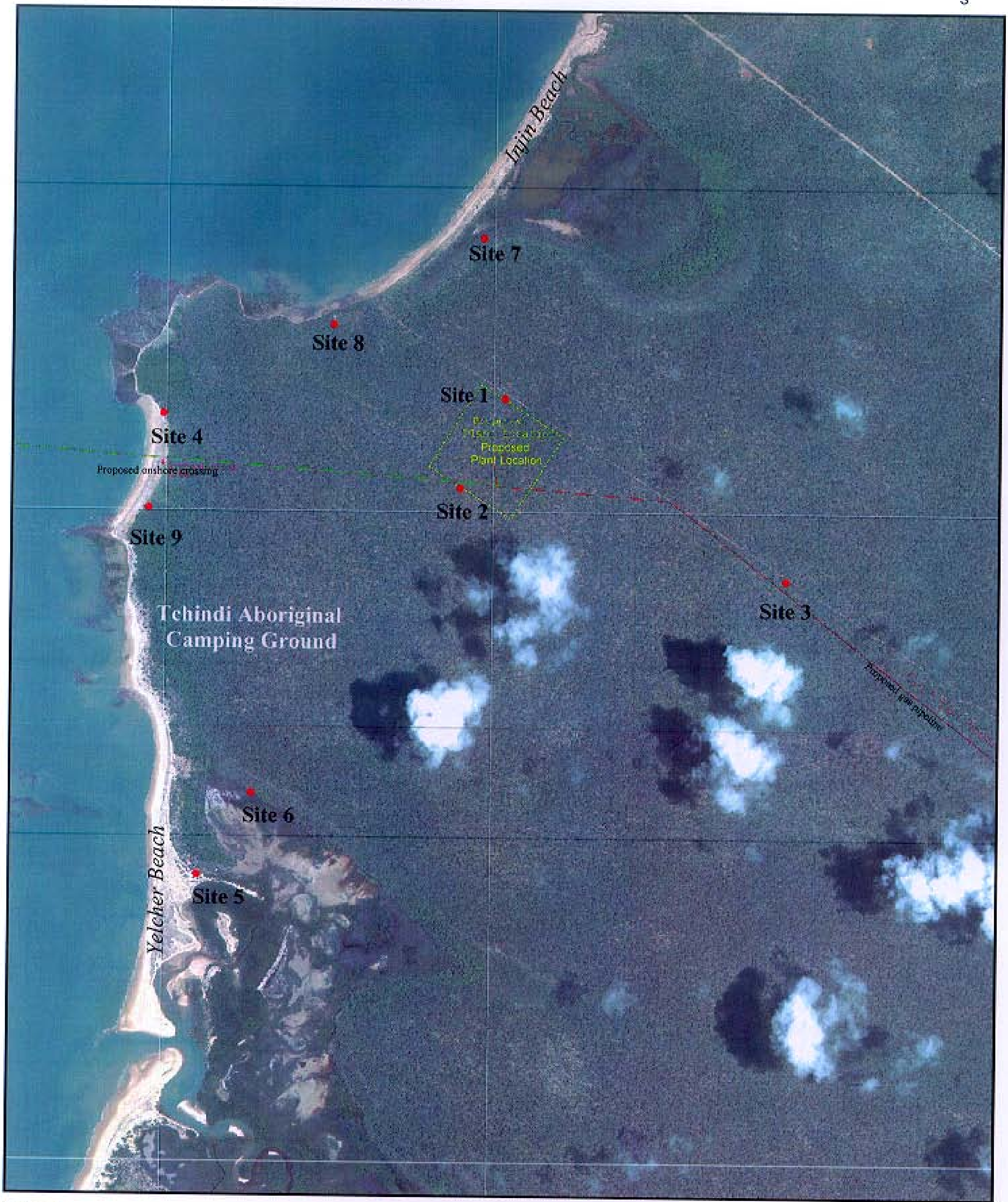


Figure 15: Blacktip Project Biting Insect Survey, 2 - 3 June 2004
Carbon Dioxide baited EVS trap site locations



Legend

• CO2 EVS trap site

0 500 1,000 1,500 Metres

Tables

Table 1: Nhulunbuy weekly biting insect monitoring program. Total number of adult female biting midges collected at Wallaby Beach trap site around full moon nights, January to July 2004. (Note FM=Full moon night)									
	Date set								
Insect Species	9/01/2004 FM 8/1/4	06/02/2004 FM 6/2/4	05/03/2004 FM 7/3/4	02/04/2004 FM 5/4/4	30/04/2004 FM 5/5/4	04/06/2004 FM 3/6/4	02/07/2004 FM 2/6/4	**Grand Total**	**% of total**
Culicoides clavipalpis	0	1	0	0	0	0	0	1	0.07
Culicoides marksi	0	9	0	0	0	1	1	11	0.78
Culicoides ornatus	6	35	74	230	63	330	308	1046	74.50
Culicoides papuensis	1	5	27	25	0	44	35	137	9.76
Culicoides undescribed sp No 6	0	4	128	0	15	44	2	193	13.75
Culicoides pallidothorax	0	0	0	0	1	0	0	1	0.07
Culicoides unidentifiable	2	1	5	0	0	0	7	15	1.07
Grand Total	9	55	234	255	79	419	353	1404	100
% of total	0.64	3.92	16.67	18.16	5.63	29.84	25.14	100	

Table 2: Nhulunbuy weekly biting insect monitoring program. Total number of adult female biting midges collected at Nhulunbuy South trap site around full moon nights, January to July 2004. (Note FM=Full moon night)									
	Date set								
Insect species	9/01/2004 (FM 8/1/4)	06/02/2004 (FM 6/2/4)	05/03/2004 (FM 5/3/4)	02/04/2004 (FM 5/4/4)	30/04/2004 (FM 5/5/4)	04/06/2004 (FM 3/6/4)	02/07/2004 (FM 2/7/4)	**Grand Total**	**% of total**
Culicoides marksi	70	5	1	4	0	1	0	81	6.59
Culicoides ornatus	224	12	132	70	21	212	240	911	74.07
Culicoides papuensis	21	3	0	12	1	8	0	45	3.66
Culicoides undescribed sp No 6	7	1	24	2	2	0	0	36	2.93
Culicoides pallidothorax	0	0	44	1	4	0	5	54	4.39
Culicoides undescribed sp Vic 42	0	0	48	0	0	0	0	48	3.90
Culicoides austropalpalis	0	0	0	0	2	0	0	2	0.16
Culicoides immaculatus	0	0	0	0	4	2	0	6	0.49
Culicoides species	0	0	0	0	1	0	0	1	0.08
Culicoides unidentifiable	21	0	4	2	0	4	5	36	2.93
Lasiohelia species	0	0	0	10	0	0	0	10	0.81
Grand Total	343	21	253	101	35	227	250	1230	100
% of total	27.89	1.71	20.57	8.21	2.85	18.46	20.33	100	

Table 3: BlacktipProject. Total number of female biting midges collected in CO2 baited EVS traps set on the afternoon of June 2, 2004 (one night before full moon). Refer to Figure 14 for trap locations											
	Biting midge species										
Trap location	*Culicoides actoni*	*Culicoides ornatus*	*Culicoides papuensis*	*Culicoides undescribed sp No 6*	*Culicoides bundyensis*	*Culicoides austropalpalis*	*Culicoides narrabeenensis*	*Culicoides immaculatus*	*Culicoides unidentifiable*	TOTAL	% OF TOTAL
Site 1 - Port Keats Site 1, Centre of northern margin of proposed Gas plant	0	1	0	0	0	0	0	0	7	8	0.23
Site 2 - Port Keats Site 2, Centre of southern margin of proposed Gas Plant	2	52	0	0	44	0	0	2	0	100	2.83
Site 3 - Port Keats Site 3, 2 km from north east corner of proposed Gas Plant on access track	0	4	0	0	5	8	1	0	25	43	1.22
Site 4 - Port Keats Site 4, Vine thicket near sand dunes on western beachline	0	68	0	6	0	0	0	26	0	100	2.83
Site 5 - Port Keats Site 5, 100m north of northern mangrove margin of Tidal inlet south of Tchindi Aboriginal Camping Ground	0	380	10	0	0	100	10	0	0	500	14.16
Site 6 - Port Keats Site 6, Northern edge of paperbark/mangrove swamp	0	2530	1	55	0	0	0	55	0	2641	74.79
Site 7 - Port Keats Site 7, South west edge of Injin Beach Swamp, in paperbark margin	0	9	0	12	4	19	3	0	0	47	1.33
Site 8 - Port Keats Site 8, West end of Injin Beach, 100m back from cliff edge	0	8	0	0	0	0	0	15	0	23	0.65
Site 9 - Port Keats Site 9, Vine thicket near sand dunes on western beachline	0	34	0	1	0	0	0	20	14	69	1.95
TOTAL	2	3086	11	74	53	127	14	118	46	3531	100
% OF TOTAL	0.06	87.40	0.31	2.10	1.50	3.60	0.40	3.34	1.30	100	

Table 4: BlacktipProject. Total number of female mosquitoes collected in CO2 baited EVS traps set on the afternoon of June 2, 2004 (one night before full moon). Refer to Figure 14 for trap locations

	Mosquito species																				
Trap location	*Anopheles bancroftii*	*Anopheles powelli*	*Anopheles farauti s.l.*	*Anopheles hilli*	*Coquillettidia xanthogaster*	*Culex pullus*	*Culex annulirostris*	*Culex palpalis*	*Culex sitiens*	*Culex squamosus*	*Culex Vishnui group*	*Culex (Lop) species 167*	*Hodgesia species 157*	*Mansonia uniformis*	*Ochlerotatus elchoensis*	*Ochlerotatus notoscriptus*	*Ochlerotatus vigilax*	*Uranotaenia lateralis*	*Verrallina funerea*	**TOTAL**	**% OF TOTAL**
Site 1 - Port Keats Site 1, Centre of northern margin of proposed Gas plant	96	0	364	10	470	0	604	0	0	0	0	0	10	0	1	0	19	0	0	1574	24.48
Site 2 - Port Keats Site 2, Centre of southern margin of proposed Gas Plant	4	1	121	0	27	0	40	9	1	0	0	0	0	0	2	0	13	0	0	218	3.39
Site 3 - Port Keats Site 3, 2 km from north east corner of proposed Gas Plant on access track	7	0	4	2	378	4	122	11	0	0	4	4	0	0	0	0	2	0	0	538	8.37
Site 4 - Port Keats Site 4, Vine thicket near sand dunes on western beachline	0	0	7	1	50	7	30	2	98	0	167	0	0	5	0	0	23	0	0	390	6.07
Site 5 - Port Keats Site 5, 100m north of northern mangrove margin of Tidal inlet south of Tchindi Aboriginal Camping	7	0	120	0	26	14	87	0	326	0	68	2	0	2	0	2	26	0	2	682	10.61
Site 6 - Port Keats Site 6, Northern edge of paperbark/mangrove swamp	15	0	25	33	141	12	124	0	77	0	0	0	2	10	0	0	102	2	0	543	8.45
Site 7 - Port Keats Site 7, South west edge of Injin Beach Swamp, in paperbark margin	50	0	1271	13	113	38	226	0	71	0	13	0	17	29	0	0	100	4	4	1949	30.32
Site 8 - Port Keats Site 8, West end of Injin Beach, 100m back from cliff edge	7	0	269	1	34	0	54	0	0	0	1	0	1	5	0	0	8	0	0	380	5.91
Site 9 - Port Keats Site 9, Vine thicket near sand dunes on western beachline	2	0	0	0	25	10	17	0	39	2	10	3	0	9	0	0	38	0	0	155	2.41
TOTAL	188	1	2181	60	1264	85	1304	22	612	2	263	9	30	60	3	2	331	6	6	6429	100
% OF TOTAL	2.92	0.02	33.92	0.93	19.66	1.32	20.28	0.34	9.52	0.03	4.09	0.14	0.47	0.93	0.05	0.03	5.15	0.09	0.09	100	

TABLE 5: NHULUNBUY ADULT MOSQUITO MONITORING PROGRAM - RESULTS OF CARBON DIOXIDE BAITED EVS TRAPS 2003/04
TRAP LOCATION: WALLABY BEACH

Insect species	05/07/2003	12/07/2003	19/07/2003	26/07/2003	02/08/2003	09/08/2003	16/08/2003	23/08/2003	30/08/2003	06/09/2003	13/09/2003	20/09/2003	27/09/2003	04/10/2003	11/10/2003	18/10/2003	25/10/2003	01/11/2003	08/11/2003	15/11/2003	22/11/2003	29/11/2003	06/12/2003	13/12/2003	20/12/2003
Aedeomyia catasticta	21	14	0	14	39	10	0	26	17	0	15	0	35	41	30	0	0	39	27	7	14	0	0	3	3
Aedes alboscutellatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anopheles bancroftii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anopheles amictus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anopheles annulipes s.l.	0	0	0	0	4	1	0	1	0	0	0	0	0	5	1	0	0	3	2	0	2	0	0	2	1
Anopheles farauti s.l.	0	1	0	0	0	2	0	0	1	0	0	0	2	4	1	0	0	6	3	4	4	0	0	9	2
Anopheles hilli	21	26	0	16	11	4	0	10	8	0	8	0	4	6	4	0	0	9	12	11	9	0	0	1	3
Anopheles meraukensis	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anopheles novaguinensis	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Anopheles Species	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coquillettidia xanthogaster	1	1	0	0	0	0	0	2	2	0	7	0	48	4	2	0	0	1	4	0	1	0	0	0	0
Culex pullus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Culex annulirostris	11	2	0	7	9	4	0	8	6	0	1	0	9	6	1	0	0	2	8	23	72	0	0	4	184
Culex bitaeniorhynchus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Culex quinquefasciatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Culex sitiens	0	1	0	1	4	1	0	0	1	0	0	0	1	0	0	0	0	2	0	2	4	0	0	4	18
Culex Vishnui group	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Culex hilli	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
Mansonia uniformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
mosquitoes unidentifiable (damage	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0	1	0	0	0	0	1
Not collected mosquitoes	0	0	1	0	0	0	1	0	0	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0
Ochlerotatus daliensis	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	3	0	2	0	0	0	0	0
Ochlerotatus notoscriptus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ochlerotatus pecuniosus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ochlerotatus alternans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ochlerotatus normanensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ochlerotatus phaecasiatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ochlerotatus vigilax	11	1	0	2	0	0	0	0	1	0	3	0	1	6	166	0	0	6	70	203	37	0	0	74	315
Trap failure mosquitoes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Verrallina funerea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Verrallina reesi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	65	47		41	67	24		47	38		34		102	73	205			74	126	254	143			101	528
%	0.40	0.29		0.25	0.41	0.15		0.29	0.23		0.21		0.62	0.45	1.26			0.45	0.77	1.56	0.88			0.62	3.23

Insect species	27/12/2003	31/12/2003	10/01/2004	17/01/2004	24/01/2004	31/01/2004	07/02/2004	14/02/2004	21/02/2004	28/02/2004	06/03/2004	13/03/2004	20/03/2004	27/03/2004	03/04/2004	09/04/2004	17/04/2004	25/04/2004	01/05/2004	08/05/2004	15/05/2004	22/05/2004	29/05/2004	05/06/2004	12/06/2004	19/06/2004	26/06/2004	Totals	%
Aedeomyia catasticta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	1	1	0	1	361	2.21
Aedes alboscutellatus	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0.01
Anopheles bancroftii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	3	0.02
Anopheles amictus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0.01
Anopheles annulipes s.l.	0	0	7	11	0	9	20	0	5	10	6	1	13	0	3	6	6	0	2	0	0	5	24	34	16	0	4	204	1.25
Anopheles farauti s.l.	0	0	0	0	0	3	9	0	9	0	2	0	3	0	3	16	1	9	3	0	0	15	22	15	11	0	4	164	1.00
Anopheles hilli	0	0	1	0	5	1	7	0	2	2	5	0	1	0	0	0	0	1	1	0	0	0	2	1	1	0	0	193	1.18
Anopheles meraukensis	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	1	1	0	0	0	2	0	1	0	0	1	12	0.07
Anopheles novaguinensis	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	0.02
Anopheles Species	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0.01
Coquillettidia xanthogaster	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	74	0.45
Culex pullus	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0.01
Culex annulirostris	0	66	195	223	54	129	191	0	426	144	64	228	84	0	33	107	180	157	55	0	0	193	129	57	318	0	149	3539	21.67
Culex bitaeniorhynchus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.01
Culex quinquefasciatus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	5	0.03
Culex sitiens	0	0	0	0	27	0	2	0	0	47	0	0	4	0	0	0	3	0	0	0	0	0	0	0	0	0	6	128	0.78
Culex Vishnui group	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.01
Culex hilli	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0.06
Mansonia uniformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0.01
mosquitoes unidentifiable (damage	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	8	0.05
Not collected mosquitoes	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0		
Ochlerotatus daliensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0.05
Ochlerotatus notoscriptus	0	6	0	21	22	15	26	0	46	2	25	22	7	0	4	5	9	4	0	0	0	10	6	12	16	0	2	260	1.59
Ochlerotatus pecuniosus	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.01
Ochlerotatus alternans	0	0	1	11	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	18	0.11
Ochlerotatus normanensis	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0.07
Ochlerotatus phaecasiatus	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	12	0	0	27	0.17
Ochlerotatus vigilax	0	764	2473	3128	1818	122	67	0	1278	390	72	52	29	0	10	10	1	0	0	0	0	13	50	64	42	0	5	11284	69.10
Trap failure mosquitoes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0		
Verrallina funerea	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0.01
Verrallina reesi	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	5	0.03
Totals		836	2677	3394	1938	280	322		1775	597	182	306	143		53	148	201	174	62			238	241	202	419		174	16331	100.00
%		5.12	16.39	20.78	11.87	1.71	1.97		10.87	3.66	1.11	1.87	0.88		0.32	0.91	1.23	1.07	0.38			1.46	1.48	1.24	2.57		1.07	100.00	

TABLE 6: NHULUNBUY ADULT MOSQUITO MONITORING PROGRAM - RESULTS OF CARBON DIOXIDE BAITED EVS TRAPS 2003/04
TRAP LOCATION: NHULUNBUY SOUTH

Insect species	05/07/2003	12/07/2003	19/07/2003	26/07/2003	02/08/2003	09/08/2003	16/08/2003	23/08/2003	30/08/2003	06/09/2003	13/09/2003	20/09/2003	27/09/2003	04/10/2003	11/10/2003	18/10/2003	25/10/2003	01/11/2003	08/11/2003	15/11/2003	22/11/2003	29/11/2003	06/12/2003	13/12/2003
Aedeomyia catasticta	4	3	0	0	4	0	0	4	2	0	0	0	7	8	11	0	0	2	8	2	1	0	0	1
Anopheles bancroftii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anopheles annulipes s.l.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1
Anopheles farauti s.l.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anopheles hilli	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anopheles meraukensis	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anopheles novaguinensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anopheles Species	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coquillettidia xanthogaster	28	7	0	7	28	28	0	172	128	0	0	0	123	44	55	0	0	3	18	22	12	10	2	0
Culex pullus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Culex annulirostris	10	10	0	2	7	3	0	1	5	0	0	0	4	1	7	0	0	2	5	22	19	12	12	14
Culex bitaeniorhynchus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Culex palpalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Culex quinquefasciatus	0	1	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Culex sitiens	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	7	6	9
Culex Vishnui group	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Culex cubiculi	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mansonia uniformis	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
mosquitoes unidentifiable (damage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Not collected mosquitoes	0	0	1	0	0	0	1	0	0	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0
Ochlerotatus elchoensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ochlerotatus kochi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ochlerotatus notoscriptus	2	3	0	0	1	0	0	0	3	0	0	0	1	2	0	0	0	0	1	0	1	1	3	2
Ochlerotatus tremulus	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ochlerotatus pecuniosus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ochlerotatus alternans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ochlerotatus normanensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ochlerotatus vigilax	0	0	0	0	0	0	0	0	0	0	0	0	1	1	10	0	0	0	4	49	5	27	20	24
Trap failure mosquitoes	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Verrallina reesi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	45	25		9	40	31		178	148				136	56	85			9	36	95	41	57	44	51
%	1.42	0.79		0.28	1.26	0.98		5.62	4.67				4.29	1.77	2.68			0.28	1.14	3.00	1.29	1.80	1.39	1.61

Insect species	20/12/2003	27/12/2003	31/12/2003	10/01/2004	17/01/2004	24/01/2004	31/01/2004	07/02/2004	14/02/2004	21/02/2004	28/02/2004	06/03/2004	13/03/2004	20/03/2004	27/03/2004	03/04/2004	09/04/2004	17/04/2004	25/04/2004	01/05/2004	08/05/2004	15/05/2004	22/05/2004	29/05/2004	05/06/2004	12/06/2004	19/06/2004	26/06/2004	Totals	%
Aedeomyia catasticta	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	0	4	66	2.08
Anopheles bancroftii	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	3	0.09
Anopheles annulipes s.l.	0	0	0	0	5	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	1	1	0	0	2	15	0.47
Anopheles farauti s.l.	0	0	0	0	0	0	0	1	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	8	0.25
Anopheles hilli	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.03
Anopheles meraukensis	0	0	0	0	0	0	0	0	0	0	0	4	0	1	0	1	0	0	3	0	0	1	2	0	1	0	0	0	14	0.44
Anopheles novaguinensis	0	0	0	0	0	0	0	0	0	0	0	4	0	1	0	0	0	0	0	4	0	0	0	0	0	0	0	1	10	0.32
Anopheles Species	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0.03
Coquillettidia xanthogaster	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	689	21.74
Culex pullus	0	0	0	0	3	0	0	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0.22
Culex annulirostris	55	0	27	50	72	27	13	64	0	0	1	22	15	16	0	0	0	0	8	8	0	2	12	17	2	10	0	7	564	17.80
Culex bitaeniorhynchus	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0.06
Culex palpalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0.03
Culex quinquefasciatus	0	0	0	2	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	12	0.38
Culex sitiens	0	0	0	5	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	35	1.10
Culex Vishnui group	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0.16
Culex cubiculi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.03
Mansonia uniformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.03
mosquitoes unidentifiable (damage	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0.09
Not collected mosquitoes	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0		
Ochlerotatus elchoensis	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.03
Ochlerotatus kochi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0.03
Ochlerotatus notoscriptus	1	0	6	11	29	10	8	2	0	0	4	34	2	6	0	9	0	0	4	8	0	10	6	7	2	0	0	4	183	5.77
Ochlerotatus tremulus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.03
Ochlerotatus pecuniosus	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0.13
Ochlerotatus alternans	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.03
Ochlerotatus normanensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	2	0.06
Ochlerotatus vigilax	28	0	44	755	421	66	6	6	0	0	5	16	0	3	0	1	0	0	0	0	0	0	0	3	6	1	0	3	1505	47.49
Trap failure mosquitoes	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0		
Verrallina reesi	0	0	0	0	2	0	0	0	0	0	0	24	0	2	0	0	0	0	0	0	0	0	0	5	0	0	0	0	33	1.04
Totals	84		78	826	534	105	27	77			10	113	18	33		12			17	23		13	22	39	16	15		21	3169	100.00
%	2.65		2.46	26.07	16.85	3.31	0.85	2.43			0.32	3.57	0.57	1.04		0.38			0.54	0.73		0.41	0.69	1.23	0.50	0.47		0.66	100.00	

Appendix 1

TABLE 1

SUMMARY OF THE BIOLOGY OF SELECTED *CULICOIDES* SPECIES IN THE TOP END OF THE NORTHERN TERRITORY

Peter Whelan, Medical Entomology Branch, Territory Health Services

Species	Larval Ecology	Adult Ecology
C. ornatus	Dry season – breeds between Mean Low Water Neap (MLWN) and MHWN tide mark extensive areas of mangroves with mud substrates. Breeds in highest numbers at creekbank habitats around Mean High Water Neap (MHWN) in association with *Avicennia* pneumatophores. Breeds in *Sonneratia* foreshore habitats associated with mud substrates. Wet season – breeds in transitional *Ceriops* zone just below Mean High Water Spring (MHWS) at back edge of creekbank forest, and *Rhizophora* transitional zone adjacent to *Sonneratia* foreshore habitats.	Bites people readily and a serious human pest. Bites other mammals; crepuscular; disperses in pest numbers to 2 km and up to 4 km. Emergence around neap tide time with peak dispersal over 3 days around full moon. Disperses readily to higher ground up to 1.5 km from mangroves.
C. undescribed species (Ornatus grp) No. 6 (Dyce) (formerly C. sp. near hewitti)	Upper estuary, freshwater influenced extensive mangrove areas. Breeds in highest numbers just below MHWS.	Crepuscular. Rarely bites people.
C. marksi	Breeds in the margins of freshwater lakes and streams.	Crepuscular to diurnal; feeds on cattle and occasionally bites people; a minor pest at times.
C. narrabeenensis	Breeds at edge of fresh water.	Rarely bites people.
C. undescribed species (Victoriae grp) No. 42 (Dyce) (formerly C. ?pangkorensis)	Upper estuary.	Occasionally bites people.
C. pallidothorax	Breeds near fresh water.	NT species, rarely bites people.
C. flumineus	Similar to *C. ornatus* but at a lower level on creekbanks of small upper tidal tributaries. Also breeds in crab burrows on creekbank.	Readily bites people but rarely encountered out of mangroves.
C. undescribed sp. (near *C. immaculatus*)	Possibly breeds below neap tide zone in mangrove creeks. Spring tide species.	Relatively common in lower reaches of mangrove creeks and bites viciously.
C. immaculatus	Sandy wave washed beach sand	A relatively rare to minor pest .

	often with rocks, near neap high tide level. Neap tide species	Found near breeding sites only.
C. ?subimmaculatus (northern form)	Maritime sands in wave sheltered areas often with small crabs between neap and spring tide zone.	Crepuscular. A minor to moderate pest. Bites man readily near breeding sites. Pest range generally up to 0.5 km.

Adapted from information by Allan Dyce and pers com Martin Shivas 1998. Minor revision January 2004.

TABLE 2

SEASONAL PREVALENCE OF SELECTED *CULICOIDES* SPECIES IN THE TOP END OF THE NT

Peter Whelan
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Species	Seasonal Prevalence
C. ornatus	The major human pest species within 2km of mangroves at coast. High localised populations all year round, with maximum numbers occurring in August to November and minimum in the wet season.
C. undescribed species (Ornatus grp) No. 6 (Dyce) (formerly C. sp. near hewitti)	A major species near extensive areas of mangroves at coast. High numbers in the late dry season and early wet season, and has low populations in the post wet season.
C. marksi	A major species in sub-coastal and inland areas, with only low populations at coast. Low populations in the late dry season and moderate populations in the early wet and post wet to mid dry seasons.
C. narrabeenensis	A minor species with peak numbers in the early to mid dry season.
C. undescribed species (Victoriae grp) No. 42 (Dyce) (formerly C. ?pangkorensis)	A minor species. Peak numbers in mid wet season.
C. pallidothorax	A minor species. Peak populations during the early to mid wet season.
C. flumineus	An important pest species with high numbers inside mangroves only. Peaks in late dry season, early wet season.
C. undescribed sp. (near *C. immaculatus*)	A serious pest in lower reaches of mangrove creeks
C. immaculatus	A minor to rare species near rock-sand or sandy beaches only. Peak numbers in mid to late dry and early wet season.
C. ?subimmaculatus (northern form)	An important pest species. Moderate numbers near favoured wave sheltered breeding sites only. Peak numbers in mid dry season tapering to late dry season.

Adapted from information by Allan Dyce and pers. comm. Martin Shivas 1998. Minor revision January 2004.

Appendix 2

NORTHERN TERRITORY GOVERNMENT

DEPARTMENT OF HEALTH AND COMMUNITY SERVICES

PROBLEM MOSQUITO SPECIES IN THE TOP END OF THE NT PEST AND VECTOR STATUS HABITATS AND BREEDING SITES

P.I. Whelan
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PROBLEM MOSQUITO SPECIES IN THE TOP END OF THE NT
PEST AND VECTOR STATUS HABITATS
AND BREEDING SITES

Peter Whelan
Senior Medical Entomologist
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1997

These summary tables are intended as a guide and for assistance to environmental health officers and other public health officers involved in mosquito awareness, surveillance and control programs. They are of a general nature only. They are based on selected literature and my 25 years of field experience as an entomologist in the NT.

Flight range
Adult mosquitoes generally disperse in reasonable numbers, at least 1.6 km from their breeding site. However, some fly much longer distances in search of blood meals (eg. *Oc. vigilax, Oc. normanensis* and *Cq. xanthogaster*) and some generally do not fly far at all (eg. *Ve. funerea, Oc. kochi, Oc. tremulus, Cx. quinquefasciatus* and *Ma. uniformis)*

Species identities
Where there are species complexes which are difficult or impossible to separate morphologically, there is no data regarding the vector capacity of the individual members of the complex. For example, *An. farauti* (formerly *An. farauti* No. 1) is a probable vector of malaria in New Guinea and was probably responsible for the Cairns epidemic in 1942. However, there is no indication of the vector performance of *An.hinesorum* (formerly *An. farauti* No. 2) or *An. torresiensis* (formerly *An. farauti* No. 3) in Australia.

Pest levels
Pest level is very subjective and depends on the population of people subjected to attack and their habits/clothing/location at sunset in an overall setting of size and productivity of nearest breeding sites. CO2 trap levels below the threshold may still be a localised nuisance but are not regarded as at a significant pest level. CO2 trap threshholds generally hold for the Top End of the NT but may vary under different local conditions such as, proximity to breeding site and productivity of breeding site, the topography and vegetation between breeding sites and residential areas, and location and exact position of mosquito traps.

Total of all species present at a given location gives an indication of the total pest level. For protected people, (people inside screened houses at night after sundown) there is no real pest problem even at very high levels. Before sundown the pests in residential areas are primarily *Ochlerotatus vigilax* and *Ochlerotatus notoscriptus* within flight range of breeding sites and on a seasonal basis. Other species can be pests in shaded/heavily vegetated areas at times during the day but generally have peak biting levels in the first two hours after sundown.

MAJOR PEST AND VECTOR MOSQUITO SPECIES

IN THE TOP END OF THE NT*

Peter Whelan, Medical Entomology Branch, Department of Health and Community Services 1997

SPECIES	PEST STATUS [1]	VECTOR STATUS
An. annulipes s.l. [2]	Widespread pest, bites at night and will enter houses.	Potential malaria vector.
An. bancroftii	Major pest, widespread, bites anytime near breeding site, nightly or shaded areas elsewhere.	Potential malaria vector.
An. farauti s.l. [2]	Local pest, bites at night. Uncommon, except near mostly sub-coastal and extensive freshwater or brackish swamps.	Major potential vector of malaria.
An. hilli	Coastal pest, bites at night, enters houses. Common near brackish water swamps.	Potential malaria vector.
An. meraukensis	Local pest, bites after dark. Very common near extensive freshwater swamp.	Not potential malaria vector.
Cx. annulirostris	Major pest, very common and widespread in both urban an rural areas. Bites mainly in evening and at night.	Major arbovirus vector of Murray Valley encephalitis virus (MVEV), Kunjin virus, Ross River virus (RRV) and Barmah Forest virus (BFV) and dog heart worm. Vector of numerous other arboviruses.
Cx. quinquefasciatus	Major urban pest, bites at night, indoors, rests indoors, populations common with polluted water in dry season.	Potential arbovirus vector (MVEV). Vector of heartworm of dogs.
Cx. sitiens	Localized coastal pest, breeds in brackish or tidal waters, disperses widely, bites at night.	Probably no diseases. Possible RRV disease.
Cq. xanthogaster	Major localized pest near extensive reed swamps, disperses widely, bites at night, or in dense shade in day, attracted to lights.	No diseases. Filariasis in frill neck lizard
Ma. uniformis	Localized pest, bites at night near the breeding site, attracted to lights, does not disperse far from breeding sites.	No diseases.
Oc. kochi	Local pest at breeding site, does not disperse. Restricted to *Pandanus* thickets.	No diseases.
Oc. normanensis	Major pest, bites in evening and night within 3 km of breeding sites. Plagues in inland areas a week after widespread flooding rains in wet season.	Major vector of Ross River and Barmah Forest viruses. Potential vector of MVEV. Potential vector of many other arboviruses.
Oc. notoscriptus	Local urban pest, container or tree hole breeder, bites persistently, anytime in cool shade. Found naturally in forest areas.	Potential Ross River virus vector. Major vector of heartworm of dogs.
Oc. tremulus	Local urban pest, container or tree hole breeder, bites at sundown and dawn. Often caught in forest areas.	No diseases.
Oc. vigilax	Major pest, bites day or night within 5 km of breeding sites. Plagues associated with high tides in late dry season, early wet season. Fly up to 60 km in pest numbers.	Major vector of Ross River and Barmah Forest virus diseases and dog heartworm. Potential vector of many other arboviruses.
Ve. funerea	Local pest near breeding grounds, does not disperse. Common by day only locally inclosed forrest near tidal brackish swamps & Creeks.	Potential RRV and BFV arbovirus vector.

*** Adapted and revised from P. Liehne et al. "Mosquitoes and biting midge investigation, Palmerston 1982 -85".**

BIOLOGICAL ATTRIBUTES OF THE MAJOR PEST AND VECTOR MOSQUITO SPECIES IN THE TOP END^ OF THE NT* **Peter Whelan, Medical Entomology Branch, Department of Health and Community Services 1997**		
SPECIES	**IMMATURE STAGES**	**ADULT STAGES**
An. annulipes s.l.	Eggs laid singly on water surface; any freshwater body but numerous near *Eleocharis* reed swamps; temporary or permanent; some containers; larvae float on water surface and feed on particles on top of water.	Feeds on a variety of mammals include cattle and humans. Bites at night, especially dawn and dusk. Flies up to 2 km from breeding site; rests in cool shady locations such as stream margins, drains etc.
An. bancroftii	Eggs laid singly. Dark larvae, feeds at water surface; found in heavily shaded fresh to slightly brackish ground pools or swamps, especially in paperbark or *Eleocharis* reed swamps.	Feeds on all mammals readily; will fly up to 4 km from breeding site; bites any time near breeding site, nightly or in shade elsewhere.
***An. farauti s.l.* (Includes *An. farauti, An. hinesorum* and *An. torresiensis*)**	Eggs laid singly on surface; larvae feed on water surface. *An. farauti* breeds in brackish water; *An. hinesorum* and *An. torresiensis* breed in freshwater swamps and pools. Larval habitat often sunlit.	Bites readily at night; feeds on humans, other mammals and birds. Will fly approximately 2 km from the breeding site.
An. hilli	Eggs laid singly on surface; larvae feed at surface; sunlit or shaded brackish to saline ground pools or swamps. Numerous in *Schoenoplectus* reed swamps near coast.	Bites humans, cattle and horses; mainly after sunset. Disperses up to 4 km from breeding site.
An. meraukensis	Eggs laid singly on surface of water; larvae feed at the surface; usually in freshwater *Eleocharis* reed swamps, sunlit or shaded.	Bites readily at dusk, feeds on humans and other mammals.
Cx. annulirostris	Eggs deposited as rafts of up to 200 on the water surface; larvae hang from surface and feed on suspended particles; breed in freshwater pools and swamps with emergent vegetation temporary or permanent; will colonize domestic containers and breed readily in semi polluted water in storm drains or sewage effluent with vegetation.	Adults are the most common species encountered in the NT and are present throughout the year; feed at night and will bite humans, other mammals and birds; will fly distances of up to 10 km from the breeding site, although common up to 4 km from breeding site.
Cx. quinquefasciatus	Eggs laid as rafts on the surface; breeding grounds are polluted to fresh domestic waters; major sources are septic tanks, leach drains, primary sewage ponds and other polluted ground waters.	Severe domestic pest of humans but will feed on poultry and dogs as well; will feed and rest indoors; bites at night; flies up to 1 km from breeding site.
Cx. sitiens	Eggs laid as rafts on surface; brackish coastal ground pools under tidal influence with or without vegetation; larvae hang from the surface and rest on bottom. Feed on suspended matter or on substrate.	Bites mammals and birds at night; pest near coast, will fly up to 5 km but common within 2 km of breeding site.
Cq. xanthogaster	Eggs laid as small raft on the surface; larvae attach themselves to the stems of aquatic plants by a modified siphon and obtain oxygen from the plants; breed in semi-permanent to permanent swamps with emergent vegetation; associated with *Eleocharis* and *Typha* reeds, water lilies and paperbark; larvae feed on suspended material in the water.	Adults are strong fliers and will disperse widely up to 3 - 5 km. Readily feed on birds and mammals including humans; rest in cool vegetation and bite mainly at dusk, also shade during day. Strongly attracted to light and easily disturbed.
Ma. uniformis	Eggs laid as small cluster attached to the under surface of floating leaves water lilies and plant stems; larval habitats and breeding area similar to *Cq. xanthogaster.*	Adults bite humans, other mammals and birds readily at night. Severe pest in cool shade near breeding site during the day and evening; generally does not fly more than 1 - 2 km from breeding sites; strongly attracted to light; adults rest in dense vegetation; pest in the wet season near breeding areas only.

SPECIES	IMMATURE STAGES	ADULT STAGES
Oc. vigilax	Eggs deposited singly in the mud or near plant stems in suitable habitats; breeds in tidal pools and marshes, usually those filled by tides in upper tidal zone associated with *Schoenoplectus littoralis* or landward ill draining mangrove areas; larvae browse on substrate.	Major and severe pest species; adults feed very readily on humans, other mammals and birds, day or night; will fly up to 60 km; shelter in thick vegetation.
Oc. kochi	Eggs laid singly on the axils of *Pandanus* leaves. Larvae feed on detritus and debris in the water collected in the axil space.	Severe pests near the breeding sites. Do not disperse far from the breeding habitat.
Oc. normanensis	Eggs deposited singly in drying mud substrate in poorly draining floodways. Pale larvae can be inconspicuous in colloidal clay suspension water. Tend to dive to bottom when disturbed. Feed by browsing on substrate. Mainly inland rural habitats.	Major pest species. Extreme numbers after flooding rains for 1- 2 weeks. Feeds readily on humans and other mammals, mainly in evening and night. Will fly 3 - 5 km in pest numbers.
Oc. notoscriptus	Eggs laid singly on the sides of tree holes. Dark larvae hang from the surface by siphon and feed by browsing on the substrate. Common in domestic container habitats.	Feeds on humans and all mammals; bites day or evening in the cool shade. Does not disperse widely.
Ve. funerea	Eggs laid singly on moist substrate at edge of breeding area, usually shaded with some salt influence. Dark larvae hang from water surface, generally feeding by browsing on the bottom of the water body.	Vicious biter in cool shaded vegetation near breeding site in day and in evening. Does not continue biting in sun. Do not disperse far from the breeding habitat.
*** Adapted, revised and expanded from P. Liehne et al. "Mosquitoes and biting midge investigation, Palmerston 1982-85". ^ Applicable for general area of Top End north of and including Mataranka, Larrimah, from Victoria River to Roper River mouths.**		

SEASONAL PREVALENCE OF THE MAJOR PEST AND VECTOR MOSQUITO SPECIES IN THE TOP END OF THE NT*

Peter Whelan Medical Entomology Branch, Department of Health and Community Services 1997

SPECIES	SUMMARY OF BIOLOGY & SEASONAL PREVALENCE
An. annulipes s.l.	Freshwater streams and vegetated swamps. Low to moderate numbers in the wet season, the persistence of populations after the wet season dependent on surface water.
An. bancroftii	Freshwater, paperbark and *Eleocharis* reed swamps and creeks. High to very high numbers at post wet and early dry season, when emergent vegetation at peak and standing water starting to recede.
An. farauti s.l.	Brackish and freshwater species, in vegetated swamps or creeks. Low to moderate numbers in late wet and early post wet season.
An. hilli	Brackish/saltwater breeder, often associated with *Schoenoplectus* reed swamps or creeks or remnant pools in landward mangroves. Low numbers except near extensive brackish water swamps in late wet and early dry season.
An. meraukensis	Open shallow freshwater *Eleocharis* reed swamps and creeks. Moderate to high numbers in the late and immediate post wet season,
Ma. uniformis	Same as *Cq. xanthogaster* but more associated with floating vegetation, (water lilies). Moderate to very high numbers near habitats in late wet, early dry season.
Cx. annulirostris	Breeds in the vegetated margins and pools in permanent and semi-permanent swamps, creeks and floodways Exploits temporary vegetated ground pools in wet season. High numbers in polluted or wastewater with vegetation in dry season. High to very high numbers in the early to mid dry season.
Cx. quinquefasciatus	Domestic water sites, often with organic pollution. Moderate numbers in mid to late dry season, but can be present all year.
Cx. sitiens	Breeds in salt to brackish coastal pools or swamps. Low numbers except locally in tidal pools in upper tide zone in late dry, early wet season, and late wet season.
Cq. xanthogaster	Breeds in freshwater *Eleocharis* reed swamps and creeks. Very high numbers in mid to late dry season when maximum plant growth present in permanent and semi permanent swamps and creeks.
Oc. kochi	Breeds in *Pandanus* axils. Moderate numbers in wet season in *Pandanus* thickets.
Oc. normanensis	Floodwater, ground pool breeder in poorly draining floodways associated with creeks and rivers. Very high numbers during wet season, absent at other times.
Oc. notoscriptus	Tree hole or artificial container breeder. Low numbers in wet season but persists in dry season with artificial breeding sites.
Oc. tremulus	Tree hole or container breeder. Low numbers in wet season and early dry season.
Oc. vigilax	Breeds in tidal to brackish swamp or tidal pools in creeks. Extreme numbers in the very late dry and early wet season.
Ve. funerea	Brackish to tidal ground pools in tidal creeks and swamps, often in shade. Localised pest numbers in the pre wet and wet.

*** Adapted, revised and expanded from P. Liehne et al. "Mosquitoes and biting midge investigation, Palmerston 1982-85".**

PROBLEM MOSQUITO SPECIES IN THE TOP END OF THE NT
PEST AND DISEASE VECTOR STATUS
Peter Whelan 1997
Medical Entomology Branch, Department of Health and Community Services

Species/	**Nuisance status**	**Disease Vector Status**		**Potential vectors in the NT**	**Peak Abundance**
(Common Name)		**Current**	**Potential**		
Ochlerotatus vigilax (Salt marsh mosquito)	+++++	+++	++++	RRV BFV	September - January
Ochlerotatus normanensis (Floodwater mosquito)	+++++	+++	++++	RRV BFV	January - April
Culex annulirostris (Common banded mosquito)	+++++	+++++	+++++	MVEV, KUN RRV, BFV, JEV, others	January - August
Culex gelidus (The frosty mosquito)	+	+	+++	MVEV, KUNV, RRV BFV, JEV, others	January-April
Culex palpalis (Freshwater banded mosquito)	+++	++	+++	MVEV, KUNV RRV, BFV, JEV, others	January-August
Anopheles bancroftii (Black malaria mosquito)	+++	Nil	+	Malaria (possible)	February - July
Coquillettidia xanthogaster (The golden mosquito)	+++	Nil	Nil	None known	March - August
Mansonia uniformis (Waterlily mosquito)	+++	Nil	Nil	None known	March - June
Anopheles farauti s.l. (Australian malaria mosquito)	+	Nil	+++++	Malaria (probable)	March - June
Culex quinquefasciatus (Brown house mosquito)	+++	+	+	MVEV (possible)	January - Jun
Ochlerotatus notoscriptus (Container mosquito)	+	+	++	RRV (probable)	Jan - June
Verallina funerea (Brackish water moquito)	+++	+	++	RRV, BFV (probable)	Oct - Jan

LEGEND

RRV - Ross River virus BFV - Barmah Forest virus	MVEV - Murray Valley encephalitis virus JEV - Japanese encephalitis virus KUNV - Kunjin virus	+ Minor pest on Disease Potential	+++++ Major pest on Disease Potential

PROBLEM MOSQUITO SPECIES IN THE TOP END OF THE NT
INDICATIVE PEST LEVELS
Peter Whelan 2002
Medical Entomology Branch, Department of Health and Community Services

Species	**Main distribution**	**Peak Period**	**CO_2 Trap at Residence ***	**CO_2 Trap at Monitoring Site #**
Ochlerotatus vigilax	Top End, north of Wave Hill, Larrimah and Borroloola	September - January	20	50
Ochlerotatus normanensis	Subcoastal Top End south to Ti Tree	January - April	30	50
Culex annulirostris	NT wide	January to August	50	100
Anopheles bancroftii	Top End north of Victoria and Roper River, south to Larrimah	February - July	30	60
Coquillettidia xanthogaster	Top End north of Victoria and Roper River, south to Larrimah	March - August	30	60
Mansonia uniformis	Top End south to Larrimah	March - June	30	60
Anopheles farauti s.l.	Top End north of Port Keats, Pine Creek, and Numbulwar	March - June	30	50
Culex quinquefasciatus	NT wide, primarily near residential areas	January - June	20	30
Ochlerotatus notoscriptus	NT wide, generally near residential areas	January - June	30	30
Verrallina funerea	Top End primarily coastal and sub-coastal but occasionally south to Larrimah	Nov - March	20	100

Pest Levels

* Indicative significant pest threshold levels (mosquitoes per CO_2 trap per night) at residence for relatively unprotected people at peak biting times.

Indicative significant pest threshold levels (mosquitoes per CO2 trap per night) in residential areas from monitoring sites close to but outside of residential areas, and for monitoring sites between the residential areas and major mosquito breeding areas that are within 2km of residential areas.

Problem Mosquito Species In The Top End Of The NT Habitat and Flight Range Peter Whelan 1997 Medical Entomology Branch, Department of Health and Community Services			
Species/Common name	**Habitat Description**	**Habitat Indicators**	**Flight Range & Pest Solutions**
Ochlerotatus vigilax (Salt marsh mosquito)	Brackish reed swamps Upper mangrove margin and tidal creek extremities	Extensive mangrove areas with freshwater creek entry. Tidally or sea spray affected rock pools, depressions in coastal sand dunes and vegetated areas above tidal limit. Disturbed upper tidal areas. Tidal brackish swamps with *Schoenoplectus* reeds.	0 - 5 km major pest 5 - 50 km pest numbers 50 - over 200 km dispersal
Ochlerotatus normanensis (Floodwater mosquito)	Flooded freshwater sub-coastal or inland floodways and creeks	Broad, flat sub-coastal and inland drainage floors of minor and major creeks.	0 - 2 km major pest 2 - 5 km pest numbers
Culex annulirostris (Common banded mosquito)	Freshwater and coastal reed swamps. Streams, storm drains, and sewage effluents	Extensive reed swamps with *Eleocharis* or *Typha* reeds. Temporary flooded grasslands in sub-coastal and inland areas with organic matter. Sewage effluent and organic waste water with grass, *Lemna* (Duckweed), *Azolla* (water fern).	0 - 3 km major pest 2 - 10 km pest numbers 10 - 15 km dispersal
Verrallina funerea *(brackish mosquito)*	Upper reaches of mangroves with fresh water inflow. Rain filled coastal swamps	Brackish mangroves & mangrove fern. Schoenoplectus reed swamps. Shaded rainfilled coastal depressions & creeklines. Under beach hibiscus & Casuarina trees	0-500m minor pest Day pest in closed forrest near breeding sites.
Anopheles bancroftii (Black malaria mosquito)	Freshwater and coastal reed swamps. Shaded streams and swamps	Extensive seasonally inundated *Melaleuca* paperbark swamps. *Eleocharis* and *Typha* reed swamps.	0 - 3 km major pest 3 - 5 km pest numbers
Coquillettidia xanthogaster (The golden mosquito)	Freshwater swamps with reeds Vegetated streams	Extensive *Eleocharis* and *Typha* reed swamps. Paperbark creek lines.	0 - 3 km major pest 3 - 5 km pest numbers
Mansonia uniformis (Waterlily mosquito)	Extensive freshwater reed swamp	Extensive *Eleocharis* and *Typha* reed swamps with water lilies.	0 - 2 km major pest 2 - 3 km dispersal
Anopheles farauti s.l. (Australian malaria mosquito)	Coastal and brackish reed swamps Freshwater swamps and vegetated streams	Brackish *Schoenoplectus* and *Eleocharis* reed swamps. Upper reaches of mangrove creeks with freshwater influence.	0 - 1.5 km minor pest 1.5 - 3 km dispersal
Culex quinquefasciatus (Brown house mosquito)	Storm drains, artificial containers Septic tanks Waste water ponds	Polluted ground or artificial containers. Filamentous green algae, *Lemna* (Duckweed), Azolla (water fern), or high organic water. Tyres, drums and other containers	0 - 500 m major pest 500 m - 1 km pest numbers
Ochlerotatus notoscriptus (Container mosquito)	Tree holes or artificial containers	Trees with natural collections of water including *Eucalyptus, Ficus, Poinciana* and *Adansonia*. Tyres, drums, pot plant drip trays, roof gutters, rainwater tanks.	0 - 500 m minor pest 500 m - 1 km dispersal

Appendix 3

Northern Territory Government
Department of Health and Community Services

PERSONAL PROTECTION FROM MOSQUITOES & BITING MIDGES IN THE NT

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* Minor revisions 2004

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PERSONAL PROTECTION
FROM MOSQUITOES & BITING MIDGES

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April 2004

Adapted from paper by P. Whelan in "Australian Mosquito Control Manual" by a panel of authors, Editors C. Morris and P. Dale. Australian Mosquito Control Association, 1998, ISBN 0-646-35310-1.

1.0 MOSQUITO & BITING MIDGE BITES

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

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

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

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

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

When a mosquito or biting midge bites, fine stylets sheathed in the proboscis are inserted into 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 substances that the human body recognises as foreign and often stimulates a bite reaction. Sometimes the saliva can contain viruses or other pathogens that can cause disease.

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

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

2.0 MOSQUITO & BITING MIDGE AVOIDANCE

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

The upper high tide areas near creeks or low-lying areas, particularly near salt marsh habitats, can be significant sources of salt marsh mosquitoes (particularly *Aedes vigilax* and various other pest mosquitoes (Russell 1995). The period of high salt marsh mosquito activity is usually during the late dry season and early wet season in tropical latitudes. Generally they are prevalent for one to two weeks after the highest tides of the month or significant rain. Dense vegetation near the breeding sites should be avoided during the day over this period. Pest problems during the evening and night can occur within 3 km of productive breeding sites (Whelan, Merianos et al., 1997).

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

Extensive areas of mangroves or estuarine areas with sandy beaches are potential sources of biting midges. These midges have seasonal and monthly population peaks with the monthly peaks usually associated with the tidal regime. When camping or choosing a permanent living site, a separation distance of at least 2 km from these areas is recommended unless specific biting insect investigations indicate there are no seasonal pest problems (Whelan 1990, Whelan, Hayes et al., 1997).

If camping or selecting house sites near creeks, rivers or lagoons, choose localities of the water body which have steep margins or little marginal emergent vegetation, have swiftly running water with little marginal pooling or vegetation, or do not arise from or empty into a nearby swamp area. Exposed beaches or cliffs away from mangrove or estuary areas are preferred sites to avoid both mosquitoes and biting midges. In more inland areas, locations on hills or rises at least 3 km from ill defined drainage lines, poorly flowing creeks and seasonally flooded areas should avoid the worst mosquito problems.

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

3.0 SCREENING

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

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

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

4.0 MOSQUITO NETS

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

5.0 INSECT PROOF CLOTHING

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

6.0 REPELLENTS

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

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

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

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

Electronic insect repellers that emit ultrasonic or audible sounds do not offer any protection against mosquitoes or biting midges. They are based on a false premise and have been found to have no repellent effect under scientific testing (Curtis 1986). Electronic ultrasonic repellers do not repel mosquitoes or biting midges and should not be relied upon for personal protection (Mitchell 1992).

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

7.0 ANIMAL DIVERSION

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

8.0 LIGHTING DIVERSION

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

9.0 ADULT INSECT CONTROL

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

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

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

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

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

10.0 INSECTOCUTORS AND INSECT TRAPS

Electric insect insectocutors and other trap or killing devices utilising an attracting light or carbon dioxide have been claimed to clear areas of biting insects and thus protect people. These claims have not been substantiated in outdoor situations with people nearby. While trap devices can attract biting insects, as well as a range of other insects, these devices can not be relied on for protection from biting insect attack (Mitchell 1992). When used in outdoor situations it is possible that they can increase local problems by attracting insects to the vicinity of people. Attractive odours and carbon dioxide emitted by humans then divert the insects from the trap device to the people.

11.0 TREATMENT OF BITES

Relief from bites and prevention of secondary infection can be obtained by the application of various products, either to the skin or internally. The effectiveness of various products is variable, depending on individual reaction. Skin application products include proprietary products such as Eurax, Stingose, Medicreme, Katers lotion, Dermocaine and Paraderm creme, and non-proprietary products such as tea tree oil, eucalyptus oil, aloe vera gel, ice, or methylated spirits.

Ice packs to the general bite site will give usually give immediate relief for painful and itchy bites and swelling or blisters from of mosquitoes and biting midges in particular. The sooner the ice pack is applied after bites or reactions, the better the relief, and can often avoid more intense reactions.

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

12.0 EMERGENCY BITING INSECT PROTECTION

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

Some protection can be obtained by rubbing exposed skin areas with the leaves of certain plants such as eucalypts, turkey bush, warnulpa, 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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Appendix 4

TABLE 16: **ARBOVIRUS RISK PERIODS IN THE NORTHERN TERRITORY**

VIRUS	FROM VECTORS/ ABUNDANCE & LONGEVITY	FROM VIRUS ISOLATION	FROM SENTINEL ANIMALS	FROM CASE DATA	PEAK RISK PERIOD	PROBABLE MAIN RISK PERIOD
MVE	JAN-SEPT	MAR	DEC-OCT	FEB-JULY	FEB-MAY	JAN-JULY
KUNJIN	JAN-SEPT	APRIL-JUN	DEC-SEPT	MARCH-JUN	FEB-MAY	JAN-JULY
RR	NOV-SEPT	JAN-APR	-	JAN-DEC	JAN-MAR	DEC-JUN
BF	NOV-SEPT	DEC-APR	-	DEC-OCT	JAN-MAR	DEC-JUN