Appendix T Guidelines for Preventing Biting Insect Problems for Urban Residential Developments or Subdivisions in the Top End of the NT

DEPARTMENT OF HEALTH AND FAMILIES

Guidelines for Preventing Biting Insect Problems for Urban Residential Developments or Subdivisions in the Top End of the NT

Medical Entomology

Centre for Disease Control

Department of Health and Families

Northern Territory Government

Darwin NT

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Guidelines for Preventing Mosquito Problems for Urban Residential Developments and Subdivisions in the Top End of the NT

Peter Whelan

Minimal Requirements

A contour map showing the Q100 line and/or seepage areas and maximum tidal limit is the minimal requirement for informed comment to planning applications. Contour intervals of 1m between maximum tide limit and 5m above maximum tide limit are required near tidal areas and at least 2m contours are required for other areas, and particularly around wetlands and seepage areas.

All of each block must be above the Q100, seepage line, or maximum tide limit.

Buffer Zones

There should be a buffer zone between urban residential development and significant sources of biting insects.

There should be no urban residential development within 1.6km of large uncontrolled areas of mosquito and biting midge breeding sites, unless specific medical entomology investigations are carried out. The major potential mosquito breeding areas are tidally influenced and seasonally inundated brackish reed swamps or flood plains, and relatively large areas of mangroves that are only flooded by the highest tides of the year. The major biting midge breeding sites are relatively large areas of dendritic mangroves.

Wherever practicable, a semi-rural or rural subdivision should be incorporated into a residential subdivision design to increase the effectiveness of a mosquito or biting midge buffer zone, Incorporating a rural residential or industrial buffer, between major sources of biting insects and the urban component of a subdivision, will generally allow the 1.6km buffer to be relaxed to 1km.

Lot sizes for those rural blocks located entirely within 500m of significant biting insect breeding sites must be 2ha or greater. Rural lots that will only have some portion of land located within 500m of significant biting insect breeding sites must be 1ha or greater, while rural lots located further than 500m from significant biting insect breeding sites must be 0.4ha or greater.

There should be no residential development within 1.6km of actual or planned soil, sand or gravel mining operations or mining leases unless such areas have been rehabilitated to the stage where they are not potential mosquito breeding sites.

There should be no urban development within 1.6km of sewage treatment plants and sites of effluent disposal, unless the facilities have been designed or with documented management plans such that they are not likely to be potential sources of mosquitoes.

Drains

A standard for drains is required for all urban residential development, which includes particular attention to the design and construction of the drains and the location of end points of such drains to prevent mosquito breeding.

Concrete sub soil drains, or open drains with concrete low flow capabilities are required for all urban residential drains and drains from urban facilities that are likely to have dry season low flows. These drains must be conveyed to a suitable end point that will not become a mosquito breeding site. Suitable end points are usually large rivers or daily flushed tidal areas. Guidelines on storm drains are attached as Appendix 1. Sub-soil drainage systems must be entirely free draining. i.e. the invert of all stormwater pits (eg side entry pits, grate pits, letterbox pits etc) must be level with the invert of the outlet pipe. Structures such as Gross Pollutant Traps must not pond water or lead to impeded flow in the sub-soil pipe system.

Stormwater drains may be required to cross adjacent properties to reach a satisfactory end point such as a daily flushed tidal area. Urban stormwater drains must not terminate at the development boundary. When stormwater drains are required to pass through neighbouring properties, the relevant landholder should be consulted and a drainage easement declared on the neighbouring property, to allow the owner of the stormwater drain to conduct annual maintenance.

Water features (dams, ponds, retention basins, detention basins etc)

Dams, ponds, retention basins or other constructed water features within or adjacent to a urban development should be constructed with steep sides (45° or greater) and be relatively deep (1.8m) to prevent the establishment of marginal semi-aquatic vegetation that promotes mosquito breeding. Management procedures for wetlands or water features should be in place to monitor and control mosquito breeding. This can include stocking ponds with native fish such as the delicate blue eye or black lined rainbow fish, and mechanical or weedicide methods to reduce marginal vegetation.

If water sensitive urban design principles are applied to urban development, they must be in accordance to the Medical Entomology guideline ‘Constructed Wetlands for Water Sensitive Urban Design- Guidelines to Prevent Mosquito Breeding’.

Detention basins should be constructed as ‘dry’ basins, with the basin designed to completely drain within at least 5 days of initial water ponding. Detention basins are not recommended in or adjacent to tidal areas, as they will have the high potential to breed mosquitoes.

Access provisions should be provided for all water features within or adjacent to a residential development, to allow machinery access to conduct routine maintenance such as desilting. Overflow provisions will be required for all water features, with an appropriate end point chosen for overflow water and erosion prevention structures constructed at the overflow/discharge point. Water features will need to be placed on an annual maintenance program, to be conducted by the relevant authority.

Easements

Any open unlined stormwater drains in a residential area should have drainage easements to allow periodic maintenance of such drains and be included in a register for maintenance and possible future upgrading when required by the relevant authority.

Drainage reserves or easements should be declared over permanent and semi-permanent swamps, lagoons, creek lines, or other wet season inundated areas within or adjacent to the development.

Drainage easements should be declared between water features that will be connected during the wet season, to prevent the impedance of water along natural flow lines within or adjacent to the development.

Any subdivision bordering freshwater swamp lagoons and other wetlands, waterways and tidal or tidally affected areas should maintain a 40m easement between residential boundaries and the Q100 or highest tide levels so that access is possible for the management of such areas and to minimise disturbance that would create new mosquito sites.

Site Planning

The natural flow of surface water must not be impeded by site development (eg. construction of access roads). Access roads may need to be fitted with culverts of sufficient size to prevent upstream flooding for periods that will enable mosquito breeding.

Any existing artificial depressions within the proposed development, or within 1km of the development boundary, that are capable of holding water for a period greater than 5 days must be rectified by filling or rendered free draining.

Any areas of intensive irrigation (eg. horticulture, landscaped areas, playing field or open spaces) within subdivisions or adjacent to the subdivisions must not create areas where water can pool for a period greater than 5 days.

Erosion and Sediment control

Urban subdivisions will require sediment control during the construction phase, due to the clearing of vegetation increasing the suceptivity of the development area to erosion. Sediment control is required to prevent the siltation of natural drainage lines, flow paths, open drains (including end points) and underground stormwater systems, which can lead to impeded drainage and mosquito breeding.

Although most temporary sediment control structures are removed once development has been completed, they can be short term mosquito breeding sites. Where possible, all sediment control devices should be designed to drain completely within 5 days. Adjacent to tidal areas, water retention should not exceed 3 consecutive days. This is required to prevent mosquito larvae from completing their larval stages.

There may be instances when temporary sediment control structures (eg. silt traps) cannot be designed to drain freely within the specified time to prevent mosquito breeding. For development sites away from tidal areas, mosquito breeding can be prevented by constructing sediment control structures with steep sides (2:1 slope), with a sloping floor towards the downstream side of the sediment control structure, and appropriate erosion control structures constructed at the overflow/discharge point. Regular inspections should be conducted to ensure the sediment control structure remains free of vegetation that can encourage mosquito breeding. Water retention adjacent to tidal areas should be avoided, otherwise weekly surveys by the developer will be required to monitor and control mosquito breeding.

Erosion prevention structures should be constructed where appropriate (eg. on the down stream side of culverts, dam spill ways, along storm water drains and at drain end points) to prevent erosion and siltation of water features that will promote the creation of mosquito breeding sites. Erosion prevention structures should also be constructed at the headwalls of culverts, and bends and significant water entry points in storm water drains.

Septic Tanks, Sewage Treatment and Dispersal

Department of Health and Families (DHF) has certain requirements for the positioning, installation and maintenance of septic tanks, rainwater tanks and the reuse of sewage effluent.

Any septic tank and absorption trench should be sited on the area above the Q100 and not within 40m of the maximum tide limit. Septic tanks must be of an approved design and be completely screened to prevent mosquito entry. All septic tanks approved within urban areas should be entered on a registry for periodic inspection.

All rainwater tanks must be of an approved design and be completely screened to prevent mosquito entry. All approvals for rainwater tanks should be entered on a registry so that periodic inspection can be made.

Guidelines on the requirements for the treatment, storage and disposal of sewage effluent are attached as Appendix 2, with additional requirements available from the DHF Environmental Health Directorate, Health House Darwin (*Policy for the Design of Off Site Sewerage Ponds and the Disposal or Reuse of Sewerage Pond Effluent*).

General Information

Advice on the potential biting insect problems for residential development should be sought from the DHF at the initial subdivision application stage.

Detailed comments on areas for urban development should be sought at the detailed design stage and at least 12 months before the construction stage.

The DHF's Medical Entomology is available for advice on what may constitute a potentially significant biting insect breeding site. In some instances a desktop examination of the plans and topographic information by Medical Entomology may be sufficient to ascertain the necessary information for recommendations on a specific site, but in other instances brief site inspections or longer term studies may be necessary. In some instances where detailed entomological investigations are necessary, up to 12 months entomological monitoring may be required to gather sufficient information before the detailed planning stage, particularly in areas near potential biting insect sources or if reduction in the recommended buffer distance is sought. This service would be provided on a user pays basis.

For significant urban developments, it may be necessary for the developer to engage a consultant to document and advise on rectification of the biting insect problems, with the consultant liaising with Medical Entomology DHF.

Relevant documents on the various aspects regarding mosquito or biting midges are available from:-

Medical Entomology,

Department of Health and Families

PO Box 40596

Casuarina NT 0811

Phone: (08) 8922 8901

Appendix 1

Northern Territory Government

DEPARTMENT OF **HEALTH AND FAMILIES**

Guidelines on urban mosquito control drains

Medical Entomology

Centre for Disease Control

Department of Health and Families

Northern Territory Government

GUIDELINES ON URBAN MOSQUITO CONTROL DRAINS

1. Drains for mosquito control only need to be of dimensions that will drain an actual or potential flooded mosquito breeding site over a period of days, ie. the drain should be as small as possible to achieve the desired aim.

2. Drainage times for flooded areas that come under tidal influence at any time of the year should be three (3) days, while all freshwater areas should drain within five (5) days. If a drain overflows its banks during periods of high tides or heavy rainfall, the overflow water should drain back into the drain within the above times. When drains are constructed in low lying or level areas, any berm of spoil should have regular breaks to allow lateral drainage into the drain such that no pooling occurs outside the drain. In other situations the berm should be placed on the downhill side of the drain to prevent ponding uphill of the berm.

3. End points for drains that have a potential to breed mosquitoes should be such that the drains discharge directly into daily flushed tidal areas, to a formalised channel or creek that drains directly into a daily flushed tidal area, or a large body of water, without flowing through or into any low lying areas of restricted flow.

4. The ultimate standards for urban drains are impervious underground pipes or open lined channels with central low flow inserts. Central impervious low flow capabilities are essential where there is a likelihood of dry season low flows in a particular drain.

5. Earth sided drains that do not have dry season low flows should be formalised, straight, smooth, have broad U shaped inverts where practical and flow direct to suitable end points. Maintenance easements should be included alongside all open earth lined drains.

6. The end point for 100 year flood drains without dry season low flows that flow into tidal areas should be constructed to just below the maximum high tide level or to the fringe of the mangroves, whichever is lower.

7. There should be no vegetation, cut off pools or silt deposits in drains. Drain maintenance such as silt removal, weediciding or vegetation and debris removal for earth lined drains should be programmed on an annual basis. Drains that discharge into dams or lakes will require periodic silt removal at the discharge point into the water body to prevent the establishment of aquatic and semi aquatic vegetation.

8. The invert of the end point of drains that require concrete inverts or have dry season low flows should be below the average high tide level or to a natural well defined tidal creek. A channel could be dug back from a tidal creek to satisfy this requirement. As a guide for Darwin Harbour, the end points of the invert of low flows into tidal areas should be one metre below maximum high tide (at the 7.0 m ACD (3.0 m AHD) level).

9. Open earth lined drains should have erosion prevention drop structures of stone and mesh gabions installed wherever there is a likelihood of erosion within the drain.

10. Silt traps should be constructed in major drains from urban or industrial development areas before the drains enter freshwater or tidal creek lines. This is considered necessary before a new area is developed, particularly if the constructed drainage discharges into relatively wide level areas or to a creek or other water body. Any silt trap should have access for regular maintenance and silt removal.

11. Any land clearing operation should include the rectification of small depressions, particularly in low lying areas or near creek lines, such that no pooling will remain for more than five (5) days after flooding or rain.

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September 1990

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Appendix 2

Northern Territory Government

DEPARTMENT OF **HEALTH AND FAMILIES**

Mosquito breeding and sewage pond treatment in the Northern Territory

Medical Entomology

Centre for Disease Control

Department of Health and Families

Northern Territory Government

2009

MOSQUITO BREEDING
AND SEWAGE POND TREATMENT
IN THE NORTHERN TERRITORY

SUMMARY

The majority of effluent treatment in the NT occurs in sewage pond facilities. These sewage treatment facilities can be major sources of pest and vector mosquitoes near urban centres in the Northern Territory. Mosquito breeding is usually associated with inadequate design, operation, maintenance and final effluent disposal practices. This paper outlines the potential problems, gives some examples from previous or present treatment installations and suggests design and operational practices that can reduce mosquito breeding.

INTRODUCTION

Sewage and treated sewage effluent have been major artificial sources of mosquitoes near urban areas in the Northern Territory (Whelan, 1981, 1984, 1988). Nutrient rich sewage has the capacity to produce enormous numbers of mosquitoes, and as treatment facilities are relatively close to communities, they usually give rise to large and continuous problems from pest and vector mosquitoes.

Mosquito breeding is usually associated with inadequate design, operation and maintenance or faulty methods of effluent disposal or dispersal. Some of these practices can be relatively easily rectified, but there is a need for increased awareness of the nature of potential breeding places among planners, designers and operators of sewage treatment facilities.

The object of this paper is to emphasise the need for awareness of potential mosquito breeding in sewage facilities, and to outline some design considerations and operational practices that can reduce mosquito breeding.

MOSQUITO SPECIES

***Culex gelidus*:** ‘The frosty mosquito’. This previously exotic mosquito species was first recorded in the NT sometime around 1996 (Whelan et al 2001), and has been in Australian since at least 1994 (Johnson et al 2006). It has been found breeding in high concentrations in primary, secondary and evaporation waste water ponds in the Top End of the NT, and in other high nutrient water bodies. This species also utilises many other habitats such as stormwater drains, artificial receptacles, septic tanks, and freshwater swamps with emergent vegetation (Johnson et al 2006).

Culex gelidus is a primary vector of Japanese encephalitis virus (JEV) in many parts of Asia (Williams et al 2005), and its introduction into Australia has been a concern. Recent testing of the vector competence of this species indicates it is highly susceptible to Murray Valley encephalitis virus, Kunjin virus and Ross River virus infection, indicating this species poses a potentially significant public health concern (Johnson et al 2006).

Culex quinquefasciatus: 'The brown house mosquito’. This species usually breeds in organically polluted water near human communities. It is frequently found breeding in high numbers in unsealed septic tanks and primary sewage ponds, although it will sometimes be found in organically overloaded secondary sewage ponds.

This is a very important pest species wherever favourable breeding sites exist. The females rarely travel more than two kilometres from their breeding sites. Due to the nature of the breeding sites, this species can be present throughout the year. *Culex quinquefasciatus* is a potential vector of arboviruses including West Nile virus, and is a possible vector of heartworm in dogs.

Culex annulirostris: 'The common banded mosquito', is the most common mosquito in the Northern Territory. It breeds in a variety of natural sites and is commonly found in open, shallow, vegetated freshwater swamps, streams and lagoons.

The most prolific artificial breeding places are in secondary sewage treatment and evaporation ponds and sewage pond effluent (Whelan, 1984, 1988). The larvae are most frequently found in still, sheltered areas where vegetation offers protection from disruptive wave action and aquatic predators.

This species can disperse up to 10 kilometres from the breeding area (Russell, 1986). It is abundant in the 'Top End' of the Northern Territory from January to August and in the southern region from October to April.

Culex annulirostris is the most numerous and common pest species in the Northern Territory, and is an important vector of a number of arboviruses (Russell, 2009). The most important disease carried by this species is the potentially fatal Murray Valley encephalitis. There have been confirmed cases of Murray Valley encephalitis in the Northern Territory, at an average of around one (1) case per year, and Murray Valley encephalitis virus (MVEV) is considered endemic to the Top End of the NT as far south as Tennant Creek (Kurucz et al 2005). *Culex annulirostris* also a vector of Kunjin virus (KUNV) disease, Ross River virus (RRV) disease and Barmah Forest virus (BFV) disease. Ross River virus disease is the most common and widespread mosquito borne disease in the Northern Territory. The most effective long term protection from these viruses lies in eliminating the breeding sites within flight range of urban areas.

Anopheles annulipes s.l.: 'The freshwater malaria mosquito' breeds in open, sunlit, temporary and permanent freshwater ground pools, streams or swamps. It is very rarely found in sewage ponds but it is frequently found in the lower organically loaded sewage effluent, particularly where the effluent flows into shallow, densely grassed areas.

The females can disperse up to two kilometres from their breeding places. The species is a potential vector of malaria where sufficient numbers occurs, and is a significant pest species in inland areas where suitable breeding sites exist.

DESIGN CONSIDERATIONS FOR EFFLUENT POND TREATMENT FACILITIES

Site Selection and Design

Disposal of Effluent

Appropriate planning for the final disposal is an important part of site selection. Disposal near the coast is relatively easy, but in inland areas can lead to major problems if appropriate disposal techniques are not used. These are discussed later.

Wind

Ideally ponds should be located in open windy areas since wind and the associated waves play an important part in preventing breeding by disrupting the larvae and pupae at the water surface. Also, wind action can restrict the growth of algae, aquatic floating ferns (*Azolla* sp.) and duck weed (*Lemna* sp.). These floating plants can shelter the larvae from both wave action and aquatic predators, unless they form a complete cover of a pond.

An example of bad siting was at Snake Bay, Melville Island, where small ponds with steep banks were protected from the wind by both a hill and a close, tall eucalypt forest. Colonisation of corner sections by duck weed (*Lemna* sp.) enabled *Cx. annulirostris* to breed in relatively large numbers.

Drainage

The choice of a site should consider the necessity to drain the ponds for maintenance without thereby creating swamps or pools of stagnant water. Effluent release from the final pond has usually been incorporated into design, but provision for emptying the intermediate ponds into suitable areas has often been overlooked.

Site design should ensure that there is no prevention of near site drainage pathways caused by any of the works. New diversionary drains should be constructed with erosion prevention principles to ensure there is no overland flow of surface water to the ponds or the disposal areas. Diversion drains should discharge to suitable endpoints that are free draining. Groundwater seepage from areas surrounding ponds or the ponds themselves should be intercepted by diversion drains to a free draining area. Long term ground water seepage will require drains with concrete inverts to promote flow and prevent vegetation growth.

With ponds constructed near tidal areas, particular consideration must be given to preserving existing tidal drainage patterns, or to ensure no dead tidal pockets are created. If upper mangrove drainage areas are blocked new breeding sites for salt water species of mosquitoes can be created. An example occurred at the Leanyer sewage ponds in Darwin, where considerable engineering work was required to drain non-draining tidal areas created by the location of the ponds and access embankments over tidal mud flats.

Access

Site design should allow for all weather access completely around the installation. Weed growth, tree growth, seepage, erosion and siltation must all be controlled, and fire prevention must be considered. There have been instances in Alice Springs of seepage from large pond systems causing swampy conditions and preventing vehicle access and hence control around the base of the ponds.

Pond Dimensions

Pond Size

Sewage pond size is primarily determined by engineering parameters related to design flowrates, pollution loadings, and the required effluent quality. Frequently there has been little consideration given the effect of pond size on mosquito breeding. Adoption of oversized ponds, either from inaccurate predictions of sewage volume or a desire to provide for future capacity, can lead to the ponds becoming shallow thickly vegetated swamps that are capable of breeding large numbers of mosquitoes.

This situation occurred at Batchelor and Tennant Creek, where the final evaporation ponds became swamplands breeding mosquitoes.

Consideration should be given to the staging of particularly evaporation pond construction, or the use of multiple smaller ponds rather than one large evaporation pond. In most cases, it is the margins of the ponds that provide the mosquito breeding conditions. Multiple small ponds can provide additional maintenance requirements so it is important to optimise the numbers and size of these ponds.

Attempts to reduce short-circuiting through a large pond by installing earthen peninsular barriers can markedly increase the mosquito breeding areas by providing additional margin length, and these are often inaccessible for mosquito control purposes.

Pond Depth

Selection of pond depth is usually dictated by the function of the pond, ie. primary, secondary, or evaporation. Adequate allowance must be made for solids deposition, particularly in primary ponds, otherwise excessive or longer term deposits will lead to siltation at the edges and corners, resulting in colonisation by vegetation and thus creating mosquito breeding locations.

Profiling the pond base, with the deepest side at the effluent entry point, can help alleviate the silt problem, particularly if there is a seasonal variation in input. For evaporation ponds, particularly those with earth sides or those which are operated on a continual basis, a minimum depth of two metres or more is recommended. This is to allow for the periodic drowning of any seasonal growth of grasses or semi aquatic vegetation such as *Eleocharis* sp. and *Typha* sp.

Construction Details

Concrete Margins

Vertical or sloping concrete margins have proven to be the most satisfactory engineering means of controlling mosquito breeding by promoting wave action, and maintaining margins free of vegetation and debris.

Vertical concrete walls have proven the most maintenance free and effective in reducing mosquito breeding. Sloping concrete margins have been tried in a number of locations. While better than unlined ponds, they have the drawback that wave action is damped by the slope. Debris and algae and organic matter can build up and enable emergent vegetation to establish. It is important that they have a concrete rim around the top to prevent landward inflow of water and silt, and sealed verges to prevent vegetation growth.

Concrete lining can be precast for remote locations or constructed in situ, and are cost effective. They should be deep enough to allow for wide variation in water level and should have a concrete lined horizontal bench just above the bottom level of the pond, to prevent establishment of vegetation along the margin in the initial stages of operation, and to prevent silt accumulation in the longer term. Sealed verges around the top of the banks are desirable to facilitate maintenance and to prevent entry of soil into the pond. Walled ponds may still have problems with floatables and wind blown debris in the corners and cut off pools near entry and exit points. Truncated corners and multiple or underwater entry and exit points can help to eliminate these latter problems.

Unlined earth banks

Sewage ponds with unlined earth banks have the greatest capacity for mosquito breeding, particularly those with gentle slopes where marginal vegetation can grow. They are accordingly not recommended, except as temporary or emergency measures. The banks should be constructed using low porosity materials such as compacted clay. If neglected, unlined earth banks can become either eroded, or overgrown with grass, shrubs and even trees such as *Acacia*, *Mimosa* and *Melaleuca* sp. Maintenance and corrective measures can be a major problem.

Other Linings

Various systems have been used to line earth banks as a temporary measure to reduce growth of vegetation, but they have not been entirely satisfactory.

Stone pitching of the margins is not satisfactory as it does not offer sufficient deterrent to vegetation growth, and mechanical maintenance of vegetation is subsequently difficult. Overlapping cement sheets have been used, but have problems with breakage and subsequent weed growth. Various types of bituminous or plastic sheeting have also been tried, and most have shown promise as short to medium term solutions. Problems encountered include inadequate anchoring, weed growth, ultraviolet deterioration, and human interference. The more modern ultra-violet resistant heavy duty plastics, anchored with earth mounds back from the rim of the ponds, have been more successful.

Maintenance

<u>New pond systems</u>

Before commissioning sewage pond systems, a general survey of the whole site should be conducted to ensure that mosquito breeding places have not been inadvertently created. Potential mosquito breeding sites include borrow pits formed during pond construction, pooling of water resulting from site drainage works, and pooling caused by road access blocking drainage paths. Any problems should be rectified before the ponds are commissioned.

<u>Pond maintenance</u>

Pond maintenance is a vital part of pond management. The highest levels of maintenance will be required for earth lined ponds with low and seasonally variable effluent flow rates. Some form of maintenance will be required, even for ponds with vertical concrete margins and sealed verges. Even those ponds in favourable locations, with ideal effluent characteristics, must have adequate provision for people and resources to carry out a regular and defined maintenance program.

Aspects of maintenance frequently overlooked include the regular control and removal of vegetation on the margins or the pond verges, the regular removal of floatables and other flotsam from accumulation points, and the repair of cracks and other failures that can allow pooling or increased soil moisture levels on the banks and subsequent vegetation growth.

For some ponds, a program of water level management may be adopted, which alternately floods and strands marginal vegetation or floatables. The form of maintenance will depend heavily on the pond design, effluent parameters, staff experience and staff availability.

Regrettably, it has been the NT experience that regular and adequate maintenance have been sometimes inadequate to prevent mosquito breeding. If there is any anticipation that regular and adequate maintenance can not be carried out, a maintenance-free design should be chosen.

EFFLUENT DISPOSAL OR DISPERSAL

Problems

Insufficient consideration was given to disposal of the effluent in many of the early sewage treatment facilities in the Territory. It was often assumed that 'adequate treatment' in the ponds was sufficient from an operational point, and therefore discharged treated effluent was frequently allowed to run down the nearest flow line. In practice this effluent often formed flooded, overgrown, stagnant pools that created prolific breeding grounds for *Culex* mosquitoes. Examples were the sewage treatment facilities at Coonawarra Naval Base and Nhulunbuy South in the 1970’s, where there was a lack of provisions for proper disposal.

In some instances, effluent from sewage treatment ponds was channelled or piped just beyond the perimeter fence or to the nearest available low lying area. In some situations, as at Nhulunbuy, the effluent was directed into sand dunes in the belief that infiltration would provide a satisfactory disposal method. This proved totally inadequate because the high organic loads of the effluent and algae invariably sealed against infiltration and resulted in pooling of effluent throughout the dunes.

Even after the final aerobic treatment in evaporation ponds, the resulting 'treated' effluent still retains a great capacity to breed mosquitoes. An example of this was the uncontrolled release of treated effluent into the Il Parpa Swamp area near Alice Springs during the period 1974-2002. The regular release of effluent created a large permanent vegetated swamp and very high numbers of *Cx. annulirostris* and *An. annulipes s.l*. This area has since been partially rectified by drainage measures in the swamp and a reorganisation of discharge practices (Kurucz et al 2002).

Large Evaporation Ponds

In the Northern Territory evaporation ponds, either designed or of 'ad hoc' design have commonly been used for effluent disposal in inland sites. Large evaporation ponds are rarely full to capacity for the entire year, and in many instances are just bunded areas containing effluent to prevent escape to other areas. Because of their large area, the often variable inflow and the variation in climate, large evaporation ponds often become shallow, flooded swamps with dense weed and reed vegetation for at least part of the year. These ponds can become considerable sources of *Culex annulirostris, Culex gelidus, Culex quinquefasciatus* or *Anopheles annulipes s.l.* Also, evaporation ponds that dry up and are then seasonally inundated during rainy periods can become breeding grounds for floodwater mosquitoes such as *Aedes normanensis*. The numerous aspects to be considered in designing large ponds to reduce the amount of mosquito breeding, include:

- initial and regular removal of all emergent vegetation within the evaporation area:
- levelling of the floor of the evaporation area:
- division of the evaporation area into a number of smaller areas;
- constructing a sloping floor to concentrate the water in a sink' area at the effluent entry point;
- concrete lining of the 'sink' area on the floor of the evaporation area and the lining of embankments.

Incorporating some of these aspects into the initial design can be expensive, but the alternatives are to have a regular maintenance program, which could be more expensive in the longer term. The alternative to well designed evaporation ponds is to consider a different effluent disposal method such as dispersal to land, sophisticated tertiary effluent plants, or effluent re-use schemes.

Small Evaporation Ponds

The use of small concrete lined evaporation ponds can be a very effective method of effluent disposal. The best designs incorporate a series of relatively small ponds that can progressively fill by gravity overflow. Such a system may be expensive to construct, particularly if the whole evaporation area required is relatively large. However, the method has the advantage of being relatively maintenance free and it can better prevent mosquito breeding when there are large seasonal variations in effluent volume.

Disposal to the Sea

Disposal direct to the sea or to a daily flushed tidal area is one of the most suitable methods for effluent disposal to prevent mosquito breeding. The critical aspect for tidal creeks is to ensure there is good drainage at low tides. However dispersal at the end of a relatively long, narrow or tortuous tidal creek can result in effluent build up in the creek which can also be pushed higher up the creek line by incoming tides into areas where mosquito breeding sites can develop.

Disposal onto large flat inadequately flushed tidal areas can create breeding sites for freshwater species of mosquitoes, as well as brackish water species such as *An. farauti s.l.* and *Verrallina funerea*, and salt water species such as *Cx. sitiens, An. hilli,* and *Ae. vigilax,* by creating a complex of fresh and brackish water habitats.

Disposal to Rivers

The suitability of discharge to rivers depends upon the volume of flow in the river, the seasonal variability of flow, and the downstream effects of the disposal. This method is unsuitable when the flow in the rivers or creeks is small or subject to wide seasonable variation, as eutrophication or ecological and vegetation changes will lead to mosquito breeding.

Disposal to Land

<u>Large Sprinkler dispersal</u>

This method has been relatively successful in areas where there have been particular problems with other disposal methods. It is most successful onto areas with well-developed stands of trees on well drained areas with soils of good permeability, but the success will depend on adequate resting of the disposal areas and the rate of volumes of effluent disposed to these areas.

Jabiru provided an example of an initially successful sprinkler dispersal scheme. The final effluent was automatically and periodically dispersed via a system of overhead sprinkler heads, onto a fenced area of open native eucalypt forest. Initial problems from fire damage of above ground plastic pipes and algal blocking of spray heads were rectified by the construction of an underground pipe system with tall metal risers and metal sprinkler heads. Over the longer term, this area became a major source of mosquitoes with dead trees, wet season ponding on-site and in downstream off-site flow lines, and tall, dense and uncontrollable grass-weeds in the dispersal site. It has become obvious that the initial site levelling and draining was not adequate, and off site wet season runoff into the disposal area has compounded the effluent ponding problems. The lack of regular slashing of grass led to intense fires that destroyed the trees, and hence reduced evapotranspiration.

Ideally, sites should be relatively level but with good drainage during rainy periods. Off site run-off should be directed away from the disposal site. There should be adequate sprinklers to have areas off-line for up to a week for drying and weed maintenance. Feeder lines to sprayheads should be laid out along contours, rather than at right angles to contours, so that water retained in the lines after the finish of spraying will remain in the lines rather than drain to the lowest sprinkler head. The sprinkler heads should be positioned on mounds of crushed rock to enable better infiltration and to reduce the probability of creating permanent pools of effluent near the sprinkler heads.

The area required will depend upon the volume of effluent to be disposed, and the long-term absorption capacity of the soil and the vegetation. In monsoonal areas, additional site selection and preparation is required to ensure that effluent contaminated runoff cannot pool in nearby flow lines or creeks.

Sprinkler dispersal of effluent can be used for tree and pasture growing or landscape watering, but the National Health and Medical Research Council Guidelines for the Reuse of Waste Water must be adhered to (NH & MRC, 1979). Tertiary chlorination has been used to provide a high quality effluent for drip irrigation and recreational area watering at Yulara. Sprinkler disposal using large spray heads has been successfully used on Blatherskite Park in Alice Springs, but potential problems exist in this area because of the high salinity of the water and rising water tables, which requires regular monitoring of the water table and suspension of irrigation when water tables are high.

<u>Small sprinkler dispersal</u>

When disposing of small volumes of effluent, the use of mini sprinklers fed by irrigation lines is a suitable alternative to drip irrigation. Small sprinklers tend to promote more evaporation compared to drippers by wetting larger areas and allowing greater soil infiltration. In addition it is easier to spot blockages with mini sprinklers compared to drippers. There is however a need to have regular maintenance of dispersal area to prevent grass and weeds from smothering the sprinklers.

<u>Drip Irrigation</u>

Disposal by dripper systems requires a high standard of effluent, usually with a tertiary chlorine treatment, to prevent dripper blockage by algae. Dripper systems can be used for both small or large scale disposal, but is usually only suitable for plantation situations where the vegetation growth at each dripper site can be practically and economically maintained. Drippers held off the ground can reduce root blockages of the drippers. Generally dripper systems are only suitable for the dispersal of small volumes of effluent per unit area or periodic release, and are generally expensive because of their high maintenance requirement.

There has been past issues with drip irrigation at Hermansburg, and Kings Canyon (Whelan 1994). The continuous volume of effluent released in both situations was too high for drip disposal, which created effluent ponding and mosquito breeding. Both systems did not receive adequate maintenance to prevent blockages of drippers, and treatment areas were not appropriately spelled. In both instances, a switch to sprinkler irrigation was required to adequately dispose of the required volumes of effluent over a wider area in the irrigation area.

This method is useful for relatively small volumes of effluent on sandy soil in low rainfall areas. A feeder channel is used to deliver effluent to a ploughed area of small furrows sloping gently away from the feeder channel. Disposal is by infiltration into the sandy soil. When infiltration becomes less efficient, the flow is directed to an adjacent ploughed area, and the original area is allowed to dry out and is reploughed.

This system requires a considerable amount of attention and maintenance, but was used successfully at Perth Airport, largely due to the sandy soils and relatively low effluent volumes per unit area.

Channel Infiltration

In this system, permanent infiltration channels are constructed and effluent flow is directed down a number of groups of channels which are alternatively spelled and maintained. The method can be used on less porous soils than is possible for furrow irrigation. If this method is to be used for the irrigation of tree or bush crops, intensive monitoring is required to ensure viability of the crop in the long term. Small scale use of this method has been tried at Batchelor and at the Katherine Abattoirs, but proved to be relatively labour intensive. A variation of the method has been used on a larger scale at Il Parpa in Alice Springs, for the growth of eucalypt trees. Problems on the larger scale have included high labour input, weed control in the channels, siltation in the feeder channels, rising salinity levels and rising water tables.

Flood Bay Irrigation

The degree of land preparation for flood bay irrigation is usually considerable, as a system of correctly graded flood bays is necessary to allow for efficient flooding and to prevent pooling at the end of the flood bays. The bays are periodically flooded and the effluent is allowed to evaporate or infiltrate in the bays over a period of four to five days. This method has been used successfully to grow eucalypts in Ilparpa in Alice Springs. Problems with flood bay irrigation arise during extended rainy periods, when extended flooding of the bays can occur and can result in mosquito breeding. A more sophisticated delivery system for a flood disposal method has been designed for Gapuwiyak. It incorporates an automatic siphon and a distribution drain designed to release effluent evenly over a very large flood bay.

Vegetated Treatment Ponds

Vegetated treatment or polishing ponds, using large aquatic plants such as Salvinia (water lettuce) or Eichornia (water hyacinth) have been used overseas, but many of these have faced major problems with the maintenance or removal of vegetation, and have become major mosquito breeding sites. This has resulted in expensive re-design or maintenance issues, or in some instances they have had to be decommissioned. There has been some success with prostrate water plants such as duckweed (*Lemna* sp) which can form total cover over ponds, thus denying suitable oviposition sites and preventing air access for larvae. However the pond sizes need to be relatively small so that the duckweed is not blown into corners by wind and wave action.

BIOLOGICAL CONTROL

Biological control, though not usually applicable to primary ponds, can be a very efficient means of controlling mosquito larvae in secondary and evaporation ponds.

The major biological control agents are fish, aquatic beetles and aquatic bugs. Fish can control mosquito larval numbers directly by eating the larvae, or indirectly by eating or disturbing algae or aquatic weeds which provide protection from other predators or wave action. Fish are usually only suitable for the higher oxygenated waters. Several species have shown promise in the Northern Territory, including the herbivorous bony herring (*Nematalosa erebi*), which was successful in reducing surface algae in the former Ludmilla sewage ponds in Darwin, and rainbow fish (*Melanotaenia* sp.), which was a very efficient larval predator in the final evaporation ponds for the Ranger sewage treatment. Other suitable fish species includes the blue eyes (*Pseudomugil* sp.) and gudgeons (*Mogurnda* sp, *Hypseleotris* sp.).

It is essential that marginal vegetation such as couch grass and reeds be eliminated or kept to a minimum, so that fish can have physical access to the mosquito larvae. Actively growing *Eleocharis* sp. and *Typha* sp., with upright stems, may not restrict access. However, when these weed species die or lodge over, they prevent physical access for the fish and enable mosquito breeding.

Aquatic beetle larvae (Family:*Carabidae*) and aquatic bugs (Family:*Belostomatidae*) are the most efficient mosquito larvae predators in secondary and evaporation ponds. The aquatic bugs are able to live in higher organic water than the aquatic beetle larvae, and can be present in very high numbers. Again, physical impedance by thick vegetation at the margins will reduce the effectiveness of these predators. These insect predators can achieve almost total control of mosquito larvae in sewage ponds of suitable water quality, and narrow or sparse vegetation margins.

CHEMICAL CONTROL

The aim of chemical control of mosquito larvae should be to apply the minimum amount of insecticide to prevent the production of adult mosquitoes. Chemical control should not be used as a long term strategy in sewage treatment areas, in order to avoid insecticide resistance and unwanted effects on non-target organisms. However, it may be necessary to apply insecticides during the initial operational period or when proper maintenance has not been carried out. The insecticides of choice to control mosquito larvae in sewage ponds and effluents are either temephos, methoprene, *Bacillus thuringiensis* var *israelensis* (*Bti*) or *Bacillus spaericus* (*Bs*), with *Bs* having advantages over Bti due to its persistence after application. Correct rates for temephos must be strictly adhered to, as over treatment can kill fish and other aquatic insects.

MOSQUITO SAMPLING

Regular inspections for mosquito larvae should be carried out in sewage ponds and their effluents to determine whether breeding is occurring and to determine the necessity for weed control or chemical control. Chemical control with temephos or *Bti* may be necessary at weekly or longer intervals. Methoprene may give longer control if applied as pellets or briquettes. In general briquettes will give the longer residual effect but need to be tethered in netting on sticks near the surface of the water, so that they do not sink into the silt or mud. Methoprene applications do not necessarily kill larvae or pupae, so an experienced operator is required to assess treated areas or take pupal samples and check emergence efficiency. The presence of late instar or pupae with the first two insecticides above indicates that control should have been carried out at shorter intervals. If only first and second instar larvae are present, then either biological control is quite efficient, or the mosquitoes have just started to breed in that area, and continued monitoring is necessary.

Mosquito larval or pupal samples can be collected by dipping into sheltered vegetated zones with a soup ladle. Generally care should be taken not to disturb the larvae by shadows or surface water agitation before dipping, and multiple dips should be performed to adequately assess population numbers. Any larvae collected should be stored in small vials with 70% alcohol or methylated spirits, together with information on collection locality, site, date and collector. Larval or pupal identifications should be checked by an entomologist.

Adult specimens collected by biting or harbourage collections can be sent for identification, packed loosely in tissue paper in a small box, together with all the details of collection.

Chironomid midge pupae or adults are often mistaken for mosquitoes and their presence has often resulted in control programs being instituted where none has been necessary.

SUMMARY

In the past, the design of sewage treatment ponds and their effluent disposal facilities in the NT has been largely dictated by engineering and microbiological principles. Little attention was paid to the possibility of breeding mosquito populations close to residential areas, with the resultant risk to public health. Appreciation of this potential risk followed by the application of design principles and adequate maintenance can reduce this problem. Biological control can then operate effectively. Chemical control can be used for start-up or emergency situations, although should not be relied on for ongoing mosquito control in ponds or effluent disposal areas.

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REFERENCES

Johnson PH, van den Hurk AF, Jansen CC, Ritchie SA, Smith GA , Moore PR, Mackenzie D, Whelan PI (2006). 'Northern Exotics - vector competence of *Culex gelidus* and *Aedes albopictus* for arboviruses in Australia ' (Abstract presented at the 7 th Conference of the Mosquito Control Association of Australia. 15-18 August 2006).

Kurucz N, Whelan PI, Jacups SP, Broom A, Melville LF (2005). 'Rainfall, Mosquito Vector Numbers and Seroconversions in Sentinel Chickens to Murray Valley Encephalitis Virus in the Northern Territory' *Arbovirus Research in Australia .* 9:188-192.

Kurucz N, Whelan PI and Porigneaux P. (2002). 'Mosquito control in Ilparpa Swamp – A Big Step Forward'. *The Northern Territory Disease Control Bulletin.* 9:1:22-23.

NH & MRC (1979). 'Guidelines for Re-use of Wastewater', Australian Water Resources Council, National Health and Medical Research Council, Department of National Development, Canberra.

Russell, RC (1986). Dispersal of the arbovirus vector Culex annulirostris Skuse (Diptera: Culicidae) in the Murray Valley of Victoria Australia. Gen. App. Enn Ifl: 5_9.

Russell, RC (2009). Mosquito borne disease and climate change in Australia: time for a reality check. *Australian Journal of Entomology* (2009) 48**,** 1-7.

Williams CR, Ritchie SA and Whelan PI (2005). 'Potential distribution of the Asian disease vector *Culex gelidus* Theobald (Diptera: Culicidae) in Australia and New Zealand : a prediction based on climate suitability' *Aust. J. Ent.* 44:4:425-430.

Whelan, PI (1981). The vulnerability and receptivity of the Northern Territory mosquito borne disease. Transactions of the Menzies Foundation 2: 165-171.

Whelan, PI (1984). 'Mosquitoes of Public Health Importance in the Northern Territory and their Control'. (Northern Territory Department of Health, Darwin).

Whelan, PI (1988). 'Mosquito breeding and sewage treatment in the Northern Territory'. "Water" Journal of the Australian Water and Wastewater Assosciation.

Whelan, PI (1994). Sewage effluent dispersal and mosquito breeding. Kings Canyon Resort 21-22 October 1994. Medical Entomology Branch, Territory Health Services.

Whelan P, Hayes G, Tucker G, Carter J, Wilson A & Haigh B. (2001). The detection of exotic mosquitoes in the Northern Territory of Australia. *Arbovirus Research in Australia* **8,** 395-404.