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Draft
Integrated Mosquito Control Strategy for the Leschenault Estuary Region, Western Australia

Waterways Commission
184 St. George's Tce.,
Perth, W.A. 6000

November 1990

Report Number 21

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Integrated Mosquito Control Strategy for the Leschenault Estuary Region, Western Australia

Prepared by

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for

The Mosquito Control Review Committee

Waterways Commission
184 St. George's Tce.,
Perth, W.A. 6000

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PUBLIC SUBMISSIONS

The Mosquito Control Review Committee (MCRC) invites persons and organisations to make submissions on this draft strategy.

Comments received will assist the Mosquito Control Review Committee (MCRC) in preparing the final strategy.

DEVELOPING A SUBMISSION

You may agree or disagree, or comment on elements of the strategy.

When making comments:

- clearly state your point of view

- give reasons for your conclusions, supported by relevant data. Indicate the source of your data.

- suggest recommendations or alternatives.

Structure the submission in point form, referring each point to the relevant section of the strategy. A summary may be helpful.

Please indicate whether your submission can be quoted in part or in full.

THE CLOSING DATE FOR SUBMISSIONS IS :

March 31, 1991

Submissions should be addressed to:

The Director
Waterways Commission
184 St. George's Tce,
Perth, W.A., 6000

Attention: V. Klemm

SUMMARY OF OBJECTIVES AND ACTIONS

OBJECTIVES AND ACTIONS

AIM

'To establish a programme for the control of health threatening mosquitoes that is cost-efficient, effective by health standards and sustainable, whilst maintaining the integrity of wetland ecosystems".

PRIMARY OBJECTIVES

A. To effectively utilise the principles of integrated mosquito control.

B. To enable the strategy to be efficiently implemented on a regional (local) basis, following the guidelines set for funding.

C. To ensure that mosquito control is carried out in an environmentally responsible manner.

ACTIONS

1. The Shires of Harvey and Dardanup and the City of Bunbury should form a Contiguous Local Authorities Group (CLAG) for the purpose of mosquito control.

2. The Contiguous Local Authorities Group (CLAG) will appoint a Regional Mosquito Control Officer (RMCO) to co-ordinate mosquito control operations within the Contiguous Local Authorities Group (CLAG) boundaries.

3. The operational components of mosquito control will be funded and implemented according to the guidelines formulated by the Mosquito Control Task Force (MCTF) (Section 2.0) and the assessments of each breeding site made by the Mosquito Control Review Committee (MCRC) (Section 3.2).

4. The inclusion of new areas in the treatment programme will require a comprehensive study of mosquito breeding and environmental characteristics, an assessment of the appropriateness of treatments based on this data, and approval by the Mosquito Control Advisory Committee (MCAC), as outlined in Section 3.3.

5. Changes to the Regional Strategy will require the approval of the Mosquito Control Advisory Commiittee (MCAC).

SPECIFIC OBJECTIVES

Research

D. To provide knowledge and data essential to the fulfilment of the other objectives outlined in this strategy.

ACTIONS

6. The Health Department and Mosquito Control Advisory Committee (MCAC) will co-ordinate Ross River virus/mosquito research and surveillance and physical modifications research funded by the Government.

7. The Mosquito Control Advisory Committee (MCAC) will regularly inform the Contiguous Local Authorities Group (CLAG) about progress in research and will advise on updating the control programme accordingly.

Land Use Planning

E. To minimise mosquito problems through the land use planning process.

ACTIONS

8. The Health Department and the Department of Planning and Urban Development will liaise with local authorities to examine the scope that exists to reduce or prevent mosquito problems through land-use planning.

9. The Health Department and the Mosquito Control Advisory Commiittee (MCAC) will provide ongoing consultation over planning matters.

Education/Information

F. To educate the community in areas with potential mosquito problems so that personal preventative measures are taken.

G. To inform the community of the measures being taken to control mosquitoes and of the implications and limitations of these measures so that the expectations of residents with regard to mosquito control match achievable results.

Related Objective

H. To train and educate local government/Contiguous Local Authorities Group (CLAG) officers in the skills and information necessary to efficiently carry out mosquito control operations according to the strategy outlined in this document, and to ensure the efficient dissemination and exchange of information.

ACTIONS

10. The Health Department will provide educational materials to encourage the community to take measures to prevent mosquito bites and domestic mosquito breeding.

11. Local authorities will undertake community education regarding preventative measures and the implications and limitations of control measures.

12. The MCAC will undertake to train and educate Contiguous Local Authorities Group (CLAG)/local authority officers through training courses and literature.

13. A review of literature and other sources of information will be regularly performed under the supervision of the Mosquito Control Advisory Committee (MCAC).

14. Information will be exchanged and disseminated through a regular bulletin, produced by the Mosquito Control Advisory Committee (MCAC) and relying on contributions from Contiguous Local Authorities Group (CLAG).

Physical Modification (Source Reduction)

Ultimate Objective

I. To install low cost, low maintenance, physical modifications that provide effective control of salt marsh mosquitoes while having a minimal environmental impact.

Immediate Objectives

J. To determine the environmental impact of physical modifications upon salt marshes (through research) and to formulate design criteria.

K. To maintain modifications already made to salt marshes within the Leschenault region to ensure that they continue to function effectively.

ACTIONS

15. The Contiguous Local Authorities Group (CLAG) will maintain existing physical modifications to mosquito breeding areas and will monitor their effectiveness in reducing mosquito breeding.

16. The Mosquito Control Advisory Committee (MCAC) will supervise a study of the environmental effects and effectiveness of physical modifications to salt marshes with a view to formulating guidelines for their use.

17. The Contiguous Local Authorities Group (CLAG) may be required to monitor the environmental effects of physical modifications under the direction of the Mosquito Control Advisory Committee (MCAC).

18. Physical modifications further to those outlined in this strategy will require the approval of the Mosquito Control Advisory Committee (MCAC). The installation of such modifications would be supervised by the Mosquito Control Advisory Committee (MCAC).

Larviciding

Objectives

L. To provide a control option that can be applied rapidly and effectively in response to high levels of mosquito breeding, resulting in the number of pest adults being kept below an acceptable threshold.

M. To control the development of resistance to agents used.

ACTIONS

19. The Health Department and the Mosquito Control Advisory Committee (MCAC) will investigate new control agents and techniques. This will include phasing in granular *Bti* as soon as is practicable.

20. The Health Department will formulate decision making criteria for larviciding, to be used by the RMCO when assessing mosquito breeding.

21. Mosquito breeding will be monitored by the Contiguous Local Authorities Group (CLAG) under the supervision of the RMCO, according to the regime outlined in Section 8.2.

22. Larviciding should be initiated and carried out according to the procedures outlined in Section 8.2.1, with funding and responsibilities as per Section 8.1.3.

23. An intensive monitoring effort should be carried out by Contiguous Local Authorities Group (CLAG) officers over the first twelve months following the implementation of this strategy to gain a more detailed knowledge of mosquito breeding in each wetland. This will allow a refinement of treatments for maximum cost-effectiveness.

24. The Health Department will incorporate monitoring results into a data base management system and regularly analyse this. The aim will be to eventually construct predictive models.

25. Resistance control measures are to be practised by the Health Department and Contiguous Local Authorities Group (CLAG)s.

26. The Health Department will regularly monitor resistance to insecticides in mosquito populations.

PART A - THE STRATEGY IN CONTEXT

1.0 INTRODUCTION AND BACKGROUND

1.1 Background

The Mosquito Control Review Committee (MCRC) was established by the Waterways Commission in 1984 in response to the nuisance and potential health problems caused by mosquitoes in the Peel Inlet and Leschenault Estuary regions. Its role has been to review mosquito control methods used by local government and to assess the environmental impact of those methods. The Health Department of W.A. initiated field studies under the guidelines of the Committee to investigate the mosquito problem in the two regions. These studies were conducted in 1985 and a report on the Leschenault Estuary study released in 1986 (Wright, 1986).

State Government financial involvement in mosquito control was necessitated in the summer of 1988/89 by an epidemic of polyarthritis, caused by Ross River virus (RRV) transmitted by mosquitoes. In January 1989, a special grant of $500,000 was approved for the control of RRV carrying mosquitoes. As a result the "Interim Strategy for Mosquito Control in the Peel Inlet and Leschenault Estuary Regions" was formulated. Its implementation has relied upon a commitment from both local and State Governments. The strategy has been operating effectively since January 1989 with significant reductions in mosquito numbers. It expired in June 1990 and is superseded by this long-term strategy.

A Mosquito Control Task Force (MCTF), with representation from appropriate State and local authorities, was formed in November 1989 to review the control programme initiated under the Interim Strategy and to assess the need for continuing State Government involvement in mosquito control. On the basis of the Task Force's recommendations the Government has decided that ongoing financial involvement in this area is essential and has formulated the guidelines by which this will be implemented.

This long-term regional strategy has been compiled by the Mosquito Control Review Committee (MCRC) according to those guidelines and is based on experience gained through the Interim Strategy. It takes into account information from research initiated by the Committee, as well as input from local government and the public sector.

It is intended that Regional strategies be developed for each area of the State facing mosquito problems to promote effective control methods and the cost-efficient integration of State and local Government efforts.

1.2 Aim

"To establish a programme for the control of health threatening mosquitoes that is cost-efficient, effective by health standards and sustainable, whilst maintaining the integrity of wetland ecosystems".

A programme that adequately achieves the above must incorporate consideration of many complex and inter-related issues.

Cost considerations are limiting and the most efficient and cost-effective use of resources must be made. The biological processes involved in mosquito breeding must be understood in order to attain this efficiency. The use of chemicals must be managed so that mosquitoes do not develop resistance and render them ineffective.

Foremost among considerations is the quality of life of people who are affected by the mosquito problem.

The population of the Bunbury area was 38,000 in June 1987 and is anticipated to grow to 50,000 by 2001. The town and port of Bunbury surround the Leschenault Inlet and the communities of Eaton, Clifton Park and Australind have developed on the eastern foreshore of the estuary and the Collie River. The

Leschenault Inlet and Estuary and its tributaries are the major recreational focus for these communities and for visitors.

Leschenault Estuary and Inlet have a total area of about 2753 hectares with about 328 hectares (12%) being wetland marsh. Of this there are about 190 hectares of disturbed wetland (58% of the total marsh area), occurring mainly south of Point Douro.

The diverse range of wetland habitats in the northern part of the estuary are relatively undisturbed and in need of protection from development and pressures from urban areas. The relatively small areas of disturbed wetland in this zone are not beyond recovery and could be rehabilitated.

The rapid population growth in the Leschenault Estuary region places this waterway under pressure from urban development. This pressure is increased by the need to control mosquito breeding around the foreshore in close proximity to population centres.

Human land uses must be balanced with environmental concerns. These matters coincide to a large extent when the quality of life of the community in the area, and the importance of areas where mosquitoes breed to the health of the adjacent estuary are considered.

1.3 Integrated Mosquito Control

It is not possible to eradicate mosquitoes. They will breed wherever standing water exists under the right conditions and it is impossible to eliminate all breeding sites. Neither is any control method one hundred percent effective. However with proper management mosquitoes can be controlled to a degree acceptable to public health standards.

A truly effective local strategy must be based upon the concept of "integrated control". Such a mosquito control programme combines various treatments of low environmental impact with natural population controls. It is based on ecologically sound principles and a thorough knowledge of the ecosystem of which the mosquito is a part.

The long-term management of mosquito populations is emphasised over short-term control. An integrated control programme incorporates a continual revision and refinement of technique, with all information from research and monitoring being effectively utilised.

1.4 The Environmental Significance of Mosquito Breeding Areas

Wetlands where mosquitoes breed must be maintained in a healthy state. Salt marshes, the major sources of mosquitoes in the Leschenault Estuary region, are among the most biologically productive areas in the world and are thus extremely important to estuarine food webs. They act as sources and regulators of nutrients and serve as nurseries for juvenile fish and crustacea.

The aesthetic character of a region is enhanced considerably by the existence of healthy wetlands, affecting tourism, recreation and the quality of life for the community.

Small disturbances can have a great effect on the complex nutrient cycles of salt marshes, impacting in turn upon the food web in the adjacent estuary and hence upon commercial and recreational fisheries.

These wetlands provide important habitats and breeding areas for birds of international importance (some of which are protected by treaties to which Australia is a signatory). They are also important in shoreline protection, providing buffers against wave and tide action.

Leschenault Estuary and Inlet have a total area of about 2753 hectares with about 328 hectares (12%) being wetland marsh. Of this there are about 190 hectares of disturbed wetland (58% of the total marsh area), occurring mainly south of Point Douro.

The diverse wetland habitats in the northern part of the estuary are relatively undisturbed and in need of protection from development and pressures from urban areas. The relatively small areas of disturbed wetland in this zone are not beyond recovery and could be rehabilitated.

The Mosquito Control Review Committee (MCRC) commissioned several studies of the environmental significance of mosquito breeding areas.

A waterbird survey by Ninox Wildlife Consulting (1989) found that tidal salt marshes and other mosquito breeding areas in the Leschenault Estuary:

- are used by 94% of all species of waterbird recorded at the Inlet;

- support 38% of all individual waterbirds counted at Leschenault Inlet in an area representing 12% of the estuarine system;

- show a disproportionate usage per unit area by certain waterbird groups (77% of all herons, egrets and ibis; 49% of all ducks and grebes; 41% of all wading birds);

- act as refuges for large numbers of birds during high tides and stormy weather;

- provide rich intertidal and freshwater feeding areas for a large proportion of the waterbird species using the Inlet (37% of all individuals recorded in mosquito breeding areas were observed feeding);

- are virtually the only areas where breeding takes place and which can provide refuge for young birds;

- are used by a large number of migratory wading birds many of which are included in international conservation agreements to which Australia is a signatory member.

A further study was undertaken by the Department of Conservation and Land Management to investigate:

- the diversity of aquatic invertebrate fauna within a variety of mosquito breeding wetlands;

- the diets of waterbirds in these areas.

The results of this study (Halse *et al.*, 1989) reinforced those of Ninox in that salt marsh mosquito breeding areas provide an important waterbird habitat. The diverse invertebrate fauna of these areas indicated a high environmental quality.

The studies conducted on both the waterbird usage and the invertebrate fauna of the Estuary have demonstrated that the Estuary has significant value in a regional context. The System is listed amongst the ten most important wetlands in the South West and is quite likely to be elevated with further surveys.

The importance and sensitivity of wetland areas where mosquitoes breed has been a primary consideration in the preparation of this strategy. The Mosquito Control Review Committee (MCRC) believes that mosquito control is not incompatible with the maintenance of regional environmental quality and has incorporated strict guidelines and procedures to ensure that both aims are achieved.

1.5 Key Aspects of the Biology of the Major Nuisance and/or Disease Vector Mosquito Species

Twenty two (22) species of mosquito have been identified in the Mandurah and Bunbury regions. Of these species identified, two, *Aedes camptorhynchus* and *Aedes vigilax*, cause most of the nuisance. These two species breed in salt marshes throughout the year. The extent and rate of breeding is dependent on tidal and climatic conditions. *Aedes vigilax* breeding appears to be limited by low temperatures and is confined to the period November to April in south-west Western Australia.

Aedes camptorhynchus breeds all year round in saline, brackish or fresh water.

The life cycle of mosquitoes is dependent on the existence of pools of water. *Aedes* mosquito eggs lie dormant in dry salt marsh wetlands. Rising water levels (from high tide or rainfall) initiate the hatching of the eggs about 1-2 days after inundation. The larvae (also known as wrigglers) feed and grow in salt marsh pools and undergo four moults (called instars) before becoming non-feeding aquatic pupae. Adult mosquitoes form inside the pupal case and emerge at the water surface. The adults mate and feed, and then the female lays eggs.

Aedes mosquitoes hatch and develop synchronously, i.e. only one stage of the life cycle is generally present at once. Several other *Aedes* species breed in temporary freshwater pools and/or artificial containers, as does *Culex quinquefasciatus*.

Other mosquito species constituting a nuisance from freshwater (and in some cases slightly brackish water) breeding sites in the south-west include *Culex annulirostris*, *Anopheles annulipes* and *Coquillettidia linealis*. *Culex*, *Anopheles* and *Coquillettidia* species, unlike *Aedes* species, are not synchronous and breed continuously. Eggs are usually laid on the surface of the water or vegetation and hatch soon after. Particular problems are experienced in the monitoring and treatment of *Coquillettidia* species,as larvae attach to and obtain oxygen from emergent vegetation. Therefore they are extremely difficult to locate.

Heavy emergent or marginal vegetation generally encourages high levels of mosquito breeding in freshwater wetlands as it provides protection for larvae from predators such as fish and birds.

Only the female mosquito requires, and is capable of obtaining, a blood meal from birds, mammals (including humans) and sometimes reptiles and amphibians. The blood supplies the rich source of food required for the development of large numbers of eggs.

The male mosquito feeds on plant nectars and remains close to the site of emergence.

Female mosquitoes, when searching for a blood meal, may disperse widely. *Aedes vigilax* is known to migrate up to 50 km from its breeding ground in search of a blood meal. It is during this feeding period that mosquito nuisance is most prevalent. Both *Aedes camptorhynchus* and *Aedes vigilax* are vicious biters throughout the day and are particularly aggressive at dusk and dawn. Other, freshwater breeding mosquitoes are generally active only at night, with peak activity at dusk.

Like all insects, the rates of development of mosquito eggs, larvae and pupae are dependent on temperature. Above 30^{0}C (during summer) mosquito development from egg to adult takes between 7 and 10 days. When temperatures are below 20^{0}C (during winter) the mosquito life cycle is at least three weeks.

The other mosquito species found in the Mandurah and Bunbury regions are of little concern and may only constitute an occasional nuisance.

1.6 Ross River Virus

Ross River virus is active throughout Australia whenever appropriate rainfall or tidal conditions exist. The disease in humans caused by this virus is known as epidemic polyarthritis, or (erroneously) as Ross River fever.

Symptoms of epidemic polyarthritis in humans include joint pain, especially in the wrists, knees and ankles, and muscle pain of varying intensity. Fever is also a common symptom with a rash developing in some patients. The severity of symptoms is highly variable, ranging from mild cases with relatively slight aches and pains lasting only a day or two, to severe cases where the patient is incapacitated for weeks or even months, with severe pain. It is therefore a debilitating, but non-fatal disease. Long-term after effects are not known to occur.

Data obtained in South Australia suggest that between 20-30% of those people infected subsequently develop epidemic polyarthritis (Wright, pers comm.). The reported incidence of epidemic polyarthritis is widely accepted to represent only a small fraction of the actual incidence both in W.A. and elsewhere in Australia.

Aedes vigilax and *Aedes camptorhynchus* are the major vectors (carriers) of Ross River virus in the south-west of Western Australia. However, there is evidence to suggest that several freshwater mosquito species are also vectors (Wright, pers. comm.). Ross River virus is **NOT** carried by all biting mosquitoes.

1.7 Achievements Under the Interim Strategy

The formulation and implementation of this regional strategy is the final step in a process that began with the "baseline study" of mosquito breeding in the Leschenault region, by Wright (1986). This study and further work carried out by the Mosquito Control Review Committee gave information necessary to set up a programme to control mosquito breeding at sites around the Leschenault Estuary; the "Interim Strategy for Mosquito Control in the Peel Inlet and Leschenault Estuary Regions" resulted from this programme.

The Mosquito Control Task Force, in reviewing State Government involvement in mosquito control, concluded that the Interim Strategy and other expenditures under the $500,000 Government grant had been cost-effective, environmentally responsible and entirely justified as a preventative health measure. Furthermore, the Task Force found that infrastructures established for mosquito control activities and research since January 1989 would form a sound basis for a cost-effective ongoing control programme for Western Australia. The Task Force's recommendations were made in this context.

The following achievements have been made under the Interim Strategy:

(i)Physical modification of some degraded salt marsh mosquito breeding sites in the Mandurah/Bunbury region giving long-term control without the recurrent use (and expense) of insecticides;

(ii)Aerial treatment of large areas of mosquito breeding in the Mandurah/Bunbury region using granular larvicides to kill mosquito larvae before they emerge to cause health and nuisance problems;

(iii)Emergency treatment of adult mosquitoes in the Mandurah/Bunbury region during the 1988/89 RRV epidemic;

(iv)Fortnightly monitoring of RRV and mosquito activity levels in the Mandurah/Bunbury region and (since November 1989) in the Metropolitan Area.

(v)Investigations into improved chemical larvicdes for use in sensitive and conservation areas.

This mosquito control effort has largely achieved its aim of an immediate alleviation of the mosquito problem in the Peel and Leschenault areas.

The success rate in treated areas has been extremely high, with an 80-90% reduction in the number of larvae on most occasions (based on monitoring by local authority officers) and a corresponding reduction in the numbers of pest adults reaching populated areas (based on research funded by the Health Department). Any detraction from success has been due to mosquitoes emerging from small, usually freshwater breeding sites not located by monitors, and to operational factors beyond control. These problems will be alleviated with the formation of the Contiguous Local Authorities Groups (CLAG) and their ability to more closely monitor mosquito breeding and breeding sites.

Additionally, the implementation of the Interim Strategy has resulted in:

- -increased liaison between relevant State Government departments and local authorities regarding mosquito control;
- -a refinement of control techniques;
- -valuable experience being gained by all officers concerned, resulting in an ability to better respond to mosquito activity.

A research group was established under the Interim Strategy to study elements of RRV/mosquito ecology crucial to successful control. This research has increased our understanding of the environmental reasons, especially climatic conditions, for the 1988/89 RRV epidemic and the roles played by different mosquitoes. This has resulted in an improved ability to predict future epidemics of RRV and hence to reduce risks to human health via public information and more efficient use of mosquito control measures.

The Mosquito Control Review Committee (Mosquito Control Review Committee (MCRC)) perceived a need for more information before formulating long-term regional strategies for mosquito control. To this end it has:

- -established liaison and exchange of information with mosquito control groups in other states, especially Queensland, and;
- -supervised a review of mosquito control techniques and strategies used in Australia and overseas (Chester, 1990).

Through these actions, new possibilities for control and new initiatives on the means by which mosquito control would be funded and implemented have been identified

2.0 GUIDELINES FOR MOSQUITO CONTROL IN W.A.

The Mosquito Control Task Force (MCTF) was formed by Cabinet in November 1989 to review the mosquito control programme initiated under the $500,000 State Government grant from January 1989 to June 1990 and to assess the need for continuing Government involvement in this area. It included representatives from local authorities and State government agencies.

The MCTF concluded that effective mosquito control is usually beyond the resources of local government and that therefore ongoing State Government involvement in mosquito control is essential. The primary argument for State responsibility in the area of mosquito control has been that the majority of breeding occurs on Crown Land and that threats to public health can occur over wide areas.

State Government involvement will be in the control of mosquitoes which pose an actual or potential health threat to humans. The mosquitoes which carry Ross River virus are also those which present the greatest nuisance. Therefore, health-driven control will result in an alleviation of nuisance problems.

A regional approach is proposed, with funding being shared between the State Government (through the Health Department) and Contiguous Local Authorities Groups (Contiguous Local Authorities Group (CLAG)s). Contiguous Local Authorities Group (CLAG)s will consist of adjacent local authorities with pooled resources to deal with a shared mosquito problem.

2.1 Contiguous Local Authorities Group

The formation of Contiguous Local Authorities Groups and the acceptance of related conditions will be a prerequisite for receiving Government funds for mosquito control.

The Contiguous Local Authorities Group (CLAG) will form a committee of representatives from each local authority in the region. Local representatives of other organisations with related interests may also participate. Regular meetings of these representatives should be held at which decisions are made on a democratic basis.

The Contiguous Local Authorities Group (CLAG) will appoint a Regional Mosquito Control Officer (RMCO) to co-ordinate its regional mosquito control programme. The RMCO will be responsible for co-ordinating the actions of local government health surveyors and other officers in regional monitoring and ground larviciding to control mosquito breeding, and communications with the Health Department and the MCAC. This officer will be required to attend regular MCAC meetings and training courses.

This approach is necessary because some species of salt marsh mosquitoes can fly great distances (up to 50 km) in search of a bloodmeal and hence do not confine their activities within one local authority area. A single breeding site within the boundaries of one authority may affect an entire region. It is envisaged that a regional approach will enable a more efficient use of resources, through co-ordination and concentration of effort. Administration and liaison will also be greatly facilitated.

2.2 Mosquito Control Advisory Committee

A Mosquito Control Advisory Committee (MCAC) will be established to act as an administrative/advisory body.

This Mosquito Control Advisory Committee will supersede the Mosquito Control Review Committee of the Waterways Commission and will consist of representatives from relevant Government and non-government organisations (i.e. those represented on the MCTF), as well as Contiguous Local Authorities Group (CLAG) representatives. The Mosquito Control Advisory Committee Will be convened and Chaired by the Health Department of W.A.

The functions of the MCAC will be to:

(i)oversee State Government funding of mosquito control;

(ii)assist in the formulation of regional mosquito control strategies;

(iii)review the State's mosquito control programme and make budgetary recommendations;

(iv)interact with and provide expert advice to Contiguous Local Authorities Group (CLAG)s;

(v)educate Contiguous Local Authorities Group (CLAG)/local government officers through training programmes;

(vi)oversee research.

2.3 Integrated Strategy

The components of an Integrated Regional Mosquito Control Strategy were defined by the Task Force. The procedures for implementing them are outlined in Section B of this document. The components are:

1.Research into the ecology of Ross River virus and the mosquito breeding fluctuations;

2.Landuse planning to take into account potential mosquito problems before development occurs;

3.Education to ensure that preventative measures are taken by the public;

4.Monitoring of mosquito populations and the factors influencing them;

5.Larvicidal agents that kill larval mosquitoes before they emerge as adults and become a problem;

6.Source reduction, i.e. physical modification to reduce or eliminate breeding in some carefully selected areas.

These components, together with the associated infrastructure, form an integrated mosquito control programme for the Leschenault region and other parts of the State.

Funding arrangements are to be as follows:

(a) helicopter hire for approved aerial larvicide treatments - 100% Government;

(b)cost of insecticides for aerial and ground larviciding - 50% Government and 50% Contiguous Local Authorities Group (CLAG);

(c)earthworks will be initiated and carried out under the supervision of the Mosquito Control Advisory Committee, with funding to be negotiated with Contiguous Local Authorities Group (CLAG)s;

(d)ongoing monitoring of local mosquito breeding -100% Contiguous Local Authorities Group (CLAG) funded;

(e)local monitoring of the environmental effects of mosquito control treatments, especially physical modifications, may be undertaken by Contiguous Local Authorities Group (CLAG)s or other appropriate bodies such as Consercation and Land Management and the Waterways Commission.

Additionally,

(f)Contiguous Local Authorities Group (CLAG)s will be obliged to set up trust funds into which ten percent of their annual budget for mosquito control will be deposited and carried over. Funds accumulated in this manner will then be used during RRV epidemics when greatly increased levels of control activity will be required (currently predicted to occur once every 3-10 years).

A further condition for funding is that,

(g)Contiguous Local Authorities Group (CLAG)s must agree to abide by environmental standards, in the form of guidelines formulated by the MCAC, prior to receiving funding for mosquito control activities. This may include a requirement for Contiguous Local Authorities Group (CLAG)s to monitor environmental effects in designated areas. Additionally, Contiguous Local Authorities Group (CLAG)s will be required to gain written approval from the MCAC and Environmental Protection Authorities (EPA) for earthworks for mosquito control;

(h)Government will provide the research and education components of (integrated) mosquito control but some contribution may be required from the Contiguous Local Authorities Group (CLAG), e.g. mosquito collection for research purposes.

Mosquito (and hence Ross River virus) control will be on a pre-emptive basis, with mosquito populations being managed so that their numbers are kept below levels at which they pose a health risk and serious nuisance problem. In this way, unusual increases in mosquito activity, such as that which resulted in the RRV epidemic of 1988/89, can be effectively controlled.

3.0 THE REGIONAL STRATEGY

Primary Objectives

A. **To effectively utilise the principles of integrated mosquito control.**

B. **To enable the strategy to be efficiently implemented on a regional (local) basis, following the guidelines set for funding.**

C. **To ensure that mosquito control is carried out in an environmentally responsible manner.**

The Regional Strategy and the steps that have been taken to reach this stage for the Leschenault region are shown diagrammatically in Figure 1. The protocol is that adopted by the MCTF and applies (in a slightly modified sequence) to any region that chooses to participate in State assisted mosquito control. For other regions, the formation of Contiguous Local Authorities Group (CLAG)s will be followed by a "baseline study", supervised by the MCAC, and the formulation of a regional strategy.

While it is expected that the procedures outlined in this strategy will be closely followed, it is of course recognised that some modifications or additions may be required in the future. These may require approval from the MCAC. It is anticipated that a high degree of feedback and interaction will occur between Contiguous Local Authorities Group (CLAG)s, the MCAC, the Health Department and other organisations. Hence flexibility will be "built in".

3.1 The Contiguous Local Authorities Group

It is proposed that, for the Leschenault region, a Contiguous Local Authorities Group (CLAG) be formed comprising the City of Bunbury and the Shires of Harvey and Dardanup.

Equipment will be pooled and costs shared on an equitable basis.

3.2 Control Options for Mosquito Breeding Sites on the Leschenault Estuary/Inlet

Major mosquito breeding sites on or adjacent to the Leschenault Estuary/Inlet have been identified (see Wright, 1986) and control options have been formulated for each of them. The estuary/inlet and associated mosquito breeding sites are shown in Figure 2. Control options for each site are shown in Table 1, grouped in descending order of conservation value. These options have been formulated for each site as outlined in 3.3, and have largely been implemented under the Interim Strategy.

Generally there is a high correlation between the level of disturbance (low conservation value) and the intensity of mosquito breeding. The ranking system for wetlands and the corresponding conservation value is given below.

RANK	CONSERVATION VALUE
1 & 2	High
3 & 4	Medium
5 & 6	Low
7	Low control priority at present

This evaluation system has been developed for use in wetland assessments for mosquito control and should not be confused with the assessment process developed by the EPA (1990).

3.3 Formulating Control Options for Breeding Sites Not Currently Addressed by the Strategy

An assessment of the need to control mosquitoes and recommendations for appropriate treatment measures can only be made on the basis of information regarding the locations of breeding sites, the extent and duration of breeding and major mosquito species at each site, as well as other information pertaining to

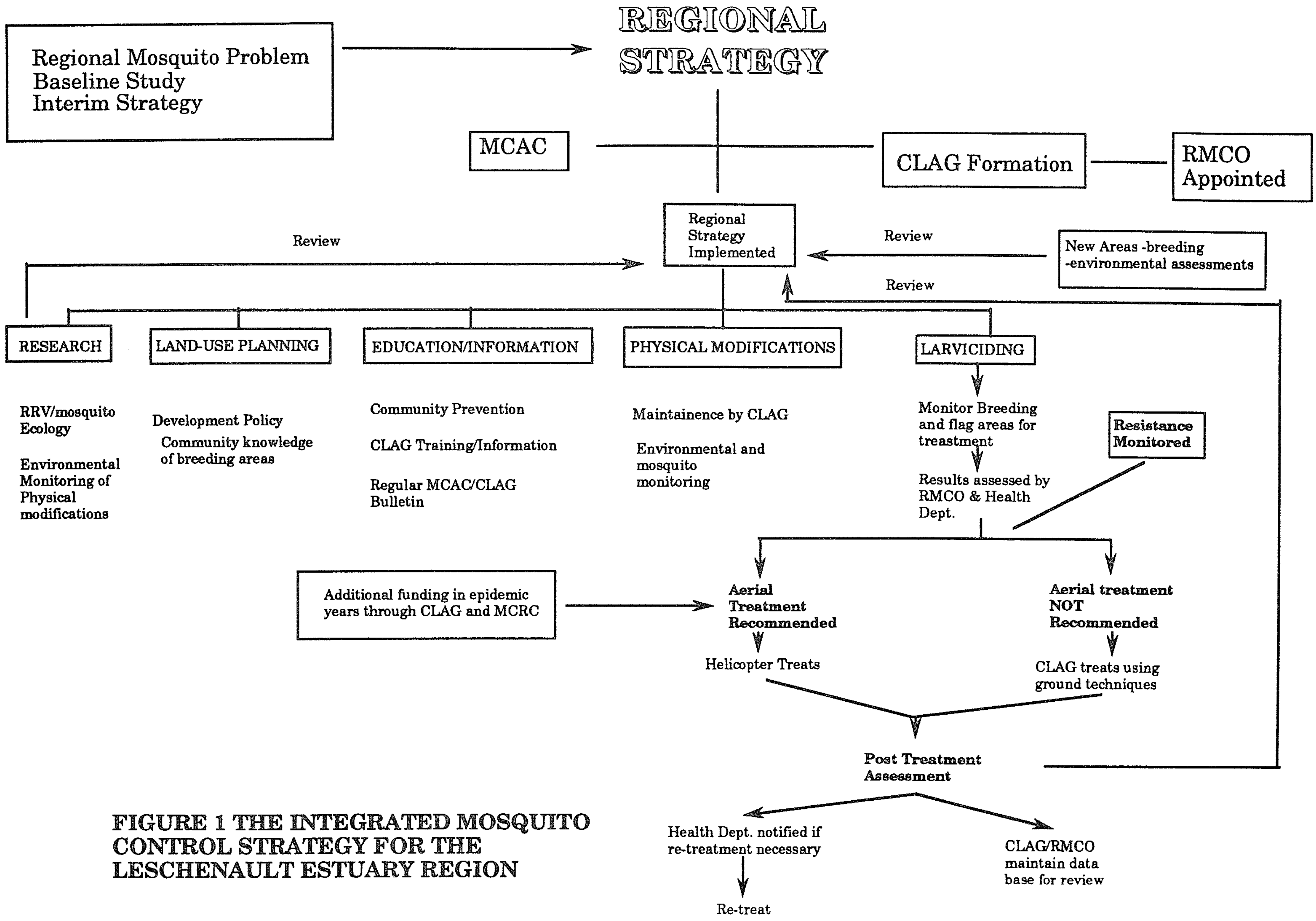


FIGURE 1 THE INTEGRATED MOSQUITO CONTROL STRATEGY FOR THE LESCHENAULT ESTUARY REGION

TABLE 1 CONTROL OPTIONS FOR MOSQUITO BREEDING SITES IN THE LESCHENAULT REGION

- GROUPED IN DESCENDING ORDER OF CONSERVATION VALUE

WETLAND NAME	MEC SITE NUMBER	BREEDING INTENSITY RANK	ENVIRONMENTAL CATEGORY	CURRENT AND/OR PROPOSED MOSQUITO CONTROL OPTION
PRESTON RIVER DELTA	108,112,113	Low to High	1	Larvicide as required
LESCHENAULT PENINSULA S.W. FORESHORE	28-30	Low	1	Aerial treatment with *Bti* preferred
LESCHENAULT PENINSULA N.W. FORESHORE	8-27	Low to Medium	1	Aerial treatment with *Bti* preferred
FORESHORE CATHEDRAL AVENUE	31-40	Low to Medium	1	Aerial treatment with *Bti* preferred
WATERBIRD SITE 22	None	Not Known	1	Too large for non-extensive physical control (at present). Establish extent of breeding. Aerial larviciding favoured
BLUNDERS AND ANGLESEA ISLAND	121-125	High	2	Channels installed. Maintain these and spot larviciding with Bti if necessary
CLIFTON PARK COLLIE RIVER	46-49	Low	3	Chemicals as required
CLIFTON PARK 500M UPSTREAM ALEXANDER ISLAND	46	No obvious signs of breeding - Low	3	Survey breedind and formulate treatment options
OPPOSITE CAW CLOSE	None	Unknown	3	Limited to backpack. Survey breeding
600M SOUTH OF BUFFALO ROAD	None	Unknown	3	Physical control ruled out. Survey breeding
OXBOW NEAR HARBOUR	117 a, b, c	High	4	Tidal channels installed
PELICAN POINT	101-105, 107	High	4	Modification of tidal flushing to be viewed as part of development. Currently aerial larviciding.
SCM FORESHORE	43-45	Medium	4	Channels installed. Maintenance only
POINT DUORO	50-65	Medium-High	4	"Spinner" channels installed. Maintain and extend if necessary.
WEST OF HARDING STREET	47	Some breeding evident - Low	4	Investigate top dressing while preserving *Melaleuca rhaphiophylla* (paperbark) stand
WEST OF COLLIE BRIDGE	101	High	4	Formalise outlet to Collie River
SCM - BACKWATER - COLLIE RIVER	None	Low-Medium (rough estimate only)	5	Limited to backpack larviciding. Survey breeding
SALTMARSH NEAR FLY-ASH PONDS SEC	110, 111, 114 118, 123	Moderate-High	6	Consumed by fly-ash pond extensions
PADDOCKS EATON	106, 103 153	Moderate-High	6	106 filled in 1989. Channel and/or fill as part of development. One-way culvert
SITE 41	41	Didn't rank in original survey	6	"Spinner" channels installed under Iterim Strategy

TABLE 1 CONTROL OPTIONS FOR MOSQUITO BREEDING SITES IN THE LESCHENAULT REGION

- GROUPED IN DESCENDING ORDER OF CONSERVATION VALUE

WETLAND NAME	MEC SITE NUMBER	BREEDING INTENSITY RANK	ENVIRONMENTAL CATEGORY	CURRENT AND/OR PROPOSED MOSQUITO CONTROL OPTION
WEST OF BRUNSWICK - COLLIE RIVERS CONFLUENCE	None	Limited	7	Low priority at present. Monitor breeding. No treatment at present
EAST OF WAWA PIPE AT	None	Limited	7	Low priority at present. Difficult
HOFF'S PROPERTY (NORTH WETLAND)	None	Unknown		Low priority at present Monitor breeding

environmental quality and site characteristics. This is referred to as a "baseline study".

Such information has been elucidated for major breeding areas around the Leschenault Estuary (Wright, 1986, and other work co-ordinated by the Mosquito Control Review Committee). This was the basis for the Interim Strategy and indeed for the present document.

Other mosquito breeding areas that have not so far been identified or addressed, such as sites on the Collie River, may be incorporated into the Regional Strategy in the future. Such sites must first be properly identified and studied as with other breeding areas in the Leschenault region. This work must be done under the technical direction of the MCAC and Health Department, who should be consulted before proceeding.

There are two components in a "baseline study" to assess mosquito breeding areas. These are: a mosquito breeding survey; and a wetland assessment.

3.3.1 Mosquito Breeding Surveys

Contiguous Local Authorities Group (CLAG) officers will be responsible for identifying new mosquito breeding sites.

Sites of significant mosquito breeding may first be brought to the attention of local authorities by complaints from residents who live nearby (although such a mosquito problem may not necessarily indicate that a breeding site is close by). Indeed a survey of the level of mosquito nuisance perceived by the community in particular localities may be used by local authorities to determine additional areas affected by mosquito breeding.

Field reconnaissance will enable the identification of areas with the potential to serve as mosquito breeding sites.

Salt marshes occur adjacent to rivers and estuaries and may serve as breeding areas for saltwater breeding *Aedes* mosquitoes when inundated periodically by tides and/or rainfall. These areas are very flat, hence slight depressions or ridges may retard drainage off the marsh and create breeding sites. Marshes with systems of temporary pools are likely to breed significant numbers of mosquitoes in the spring, summer and autumn.

Not all depressions on salt marshes will breed mosquitoes. Only those that retain water for longer than one to two weeks will produce significant numbers of mosquitoes.

Areas disturbed by the activities of humans or livestock are likely to contain breeding areas like pot holes and wheel ruts. Disturbance of this kind usually results in vastly increased mosquito breeding.

In freshwater wetlands, mosquitoes are produced in shallow, heavily vegetated fringes and flooded areas. Again, far more mosquitoes are produced when an area is degraded by human or livestock activity.

Remote sensing, such as colour infra-red aerial photography, has been used successfully to identify wetland mosquito breeding areas in some mosquito control programmes. Mosquitoes also breed in small depressions or objects that hold rain water (such as discarded tyres).

Different types of mosquitoes are produced in different types of breeding areas and the species emerging from each breeding area may vary seasonally. Only some of these species transmit disease. Some knowledge of the ecology of the target species is necessary in order to effectively treat for it. It is therefore important that the mosquito species breeding at each site at various times of the year be identified.

Surveys of mosquito breeding in new areas should be done under the technical direction of the Health Department. These will involve:

(i)The accurate location and mapping of breeding sites. New breeding sites may appear seasonally and these should be included in the survey;

(ii)Sampling of mosquito larvae by dipping with a net at breeding sites, once or twice a week;

(iii)Counting and identification of larvae from each sample in order to determine which species of mosquitoes are present and to what extent;

(iv)Recording some environmental conditions, such as wind and rainfall;

(v)Adult trapping (if necessary).

The skills necessary to carry out such surveys will be imparted through literature distributed by and at training courses run by the Health Department and the MCAC.

Further details of mosquito breeding surveys can be found in Wright (1986).

Advice regarding these can be obtained by contacting the Environmental Health branch of the Health Department of Western Australia.

3.3.2 Wetland Assessments

Wetland characteristics and attributes need to be investigated prior to mosquito control techniques being used. This is necessary to ensure that the environmental impact of these techniques is kept to a minimum. The assessment is based on the local (and regional), occasional, seasonal and year-round importance of the marsh habitat for aquatic and terrestrial species.

A proforma checklist was developed by the late Dr Jenny Arnold, as a mechanism of assigning an importance value (ranked 1 to 3 from low to high) for many aspects of mosquito breeding wetlands. This provides a basis for management and mosquito control as it documents specific characteristics of each component wetland and provides a "snapshot" of the wetland's current condition. The assessment procedure is broadly based on that detailed in EPA's Bulletin 374 (1990) although specifically modified for mosquito breeding wetlands. An environmental category is derived from the assessment and this is used to assign types of treatment (outlined in Appendix 1).

Wetland assessments should be incorporated into monitoring to identify areas of mosquito breeding within an estuarine system. The MCAC has accumulated a thorough ecological knowledge of mosquito breeding wetlands. Therefore, it will take the lead role in these environmental assessments and will encourage members of Contiguous Local Authorities Group (CLAG)s to participate and learn about the procedure. Subsequent to the survey, if additional mosquito breeding sites are identified (and records of breeding maintained), this assessment process enables options for control to be assigned to them.

Fifteen wetland characteristics are used in this assessment. These are divided into three categories - General Information, Summary of Wetland Condition from Inspection, and Management Issues and Development Pressures. General Information collates existing knowledge of each particular wetland (including System 6 and mosquito breeding). The Summary of Wetland Condition from Inspection indicates the condition of the wetland at the time of inspection. It also provides for a comparative review of wetland condition during subsequent years. The category on Management Issues and Development Pressures aims to identify short and medium term (5 years) issues and pressures from adjacent lands that may influence the management and ecology of the wetland.

In August 1987, the Mosquito Control Review Committee used the above procedure to assess the condition of wetlands adjacent to the Leschenault Estuary and Inlet. At this time a number of wetlands had been previously modified. Recommendations for mosquito control techniques for each wetland were made. Wetlands identified as suitable for physical modification (or requiring some maintenance or modification to existing works) were subject to special funding through the Interim Strategy.

In addition, in April 1989 the Mosquito Control Review Committee also applied the proforma to wetlands adjacent to the Collie River and a number of estuarine wetlands previously excluded.

The details of all these areas is contained in Appendix 1. Table 1 identifies each wetland area that has been assessed. The recommendations made are considered to be the most appropriate for each wetland. However, this does not preclude some physical modifications being made in the future, subject to the results of the environmental monitoring of physical modifications works already established under the Interim Strategy.

3.4 Actions

1. The Shires of Harvey and Dardanup and the City of Bunbury should form a Contiguous Local Authorities Group (CLAG), for the purpose of mosquito control.

2. The Contiguous Local Authorities Group (CLAG) will appoint a Regional Mosquito Control Officer (RMCO) to co-ordinate mosquito control operations within the Contiguous Local Authorities Group (CLAG) boundaries.

3. The operational component of mosquito control will be funded and implemented according to the guidelines formulated by the Mosquito Control Task Force (MCTF) (Section 2.0) and the assessments of each breeding site made by the Mosquito Control Review Committee (MCRC), (Section 3.2).

4. The inclusion of new areas in the treatment programme will require: a comprehensive study of mosquito breeding and environmental characteristics, an assessment of the suitability of treatments based on this data, and approval by the MCAC, as outlined in 3.3.

5. Changes to the Regional Strategy will require the approval of the MCAC.

PART B THE COMPONENTS OF THE STRATEGY IN OPERATION

4.0 RESEARCH

Objective

D. **To provide knowledge and data essential to the fulfilment of the objectives outlined in this strategy.**

Ongoing research is a necessary part of any mosquito control programme, providing knowledge that is absolutely essential if mosquito populations are to be managed to minimise nuisance and health risks.

Successful control of RRV carrying mosquitoes depends on a thorough understanding of the complex ecologies of both mosquito and virus. Improved knowledge improves the ability to more accurately predict mosquito/virus activity and hence allows a more efficient use of mosquito control measures.

To this end a research group, mainly funded by the State Government, has been established at the University of Western Australia, Department of Microbiology. The work done there involves the regular collection of mosquitoes from the south-west which are analysed for the presence of Ross River virus. Research to date has been found to be extremely valuable in understanding the virus and its occurrence in various mosquito species as well as the relationship between climatic conditions and mosquito activity.

Additional research, initiated early in 1990, aims to discern the effects of physical modifications on salt marshes and their effectiveness in controlling mosquitoes (see Section 7.0 Physical Modification).

This research and any related research carried out by other groups will be co-ordinated by the Health Department and the MCAC. Most research will be funded by State Government grants but assistance from Contiguous Local Authorities Group (CLAG)s and local groups may be required in the gathering of data.

Contiguous Local Authorities Group (CLAG)s will be regularly informed regarding progress in research through the MCAC so that control programmes can be updated accordingly.

4.1 Actions

6. The Health Department and MCAC will co-ordinate RRV/mosquito research and surveillance and physical modifications research funded by the Government.

7. The MCAC will regularly inform the Contiguous Local Authorities Group (CLAG) about progress in research and will advise on updating the control programme accordingly.

5.0 LAND USE PLANNING

Objective

E. **To minimise mosquito problems through the land use planning process.**

Mosquito problems are to a large extent due to the human tendency to develop and reside close to estuarine and freshwater mosquito breeding areas. Greater consideration needs to be given in the land use planning process to the potential for nuisance and health problems caused by mosquitoes, both by local and State planning authorities.

It is of course recognised that little can be done in this area to alleviate existing mosquito problems but it must be ensured that future development does not result in the exposure of people to health risks or nuisance from mosquitoes.

To this end, the Health Department and the Department of Planning and Urban Development will, before the end of 1990, liaise with local authorities to examine the scope that exists to identify mechanisms to achieve the above objective.

Ongoing consultation over planning matters will be available through the MCAC and the Health Department.

5.1 Actions

8. The Health Department and the Department of Planning and Urban Development will liaise with local authorities to examine the scope that exists to reduce or prevent mosquito problems through landuse planning.

9. The Health Department and the MCAC will provide ongoing consultation over planning matters.

6.0 EDUCATION - INFORMATION

Objectives

F. **To educate the community in areas with potential mosquito problems so that personal preventative measures are taken.**

G. **To inform the community of the measures being taken to control mosquitoes and of the implications and limitations of these measures so that the expectations of residents with regard to mosquito control match achievable results.**

Related Objective

H. **To train and educate local government/Contiguous Local Authorities Group (CLAG) officers in the skills and information necessary to efficiently carry out mosquito control operations according to the strategy outlined in this document, and to ensure the efficient dissemination and exchange of information.**

6.1 Personal Preventative Measures

Control measures can never be one hundred percent effective and there will always be a level of mosquito nuisance at some times in some areas. Personal measures to prevent mosquito bites and domestic breeding are therefore an important component of mosquito control.

The Health Department of Western Australia has produced a pamphlet for distribution to residents threatened by RRV carrying mosquitoes ("Mosquitoes and Ross River Virus" included as Appendix 2). This pamphlet outlines simple measures that can be taken to greatly reduce the nuisance and health threat posed by mosquitoes to the community. These include restricting outdoor activity and wearing mosquito repellant at times when mosquitoes are active, as well as the use of flyscreens and mosquito coils. Important measures can be taken to eliminate domestic breeding places such as in blocked gutters, inappropriately maintained septic tanks and rainwater tanks and discarded containers. Although mosquitoes breeding in these places may not carry RRV, nuisance levels can be significantly reduced.

It is important that local authorities support and promote such efforts. A short video film is being produced for distribution to public institutions and this will be a valuable promotional aid.

Local authorities need to ensure that their ratepayers are informed of efforts being made to control mosquitoes on their behalf and recognise the limitations of mosquito control methods i.e. that there will always be some level of mosquito nuisance in areas that are close to wetland breeding sites.

A significantly increased promotional effort will be required during RRV epidemic years. Additional Health Department funds may be made available for educational purposes in such years.

6.2 Information/Training and Contiguous Local Authorities Group (CLAG)s

The Mosquito Control Advisory Committee (MCAC) will undertake to train and educate local government/Contiguous Local Authorities Group (CLAG) officers in the skills and information necessary to implement the elements of mosquito control operations for which they bear responsibility.

This will take the form of training courses and regular information bulletins. The intention is that the RMCO be trained as a specialist officer, who can operate with a high degree of autonomy while being able to interact fully with the MCAC and other relevant organisations.

It is proposed that the MCAC produce a regular bulletin (e.g. quarterly) for distribution to Contiguous Local Authorities Group (CLAG)s, outlining developments and the status of statewide mosquito control. This will be based on minutes of MCAC meetings, research findings and other information pertaining to mosquito control operations. Contiguous Local Authorities Group (CLAG)s would be required to contribute to this bulletin in the form of status reports. This bulletin will greatly facilitate the dissemination of information and interaction between Contiguous Local Authorities Group (CLAG)s and with the MCAC and other bodies.

It is essential that literature and other sources of information relating to mosquito control be reviewed regularly so that new techniques can be assessed and incorporated into the State's mosquito control programmes as they become available. Such reviews would be co-ordinated by the MCAC yearly or when deemed appropriate. A precis of each review would be distributed to Contiguous Local Authorities Group (CLAG)s and other relevant organisations, with the literature itself being stored by the Health Department and available on request.

6.3 Actions

10. The Health Department will provide educational materials to encourage the community to take measures to prevent mosquito bites and domestic mosquito breeding.

11. Local authorities will undertake community education regarding preventative measures and the implications and limitations of control measures.

12. The MCAC will undertake to train and educate Contiguous Local Authorities Group (CLAG)/local authority officers through training courses and literature.

13. A review of literature and other sources of information will be regularly performed under the supervision of the MCAC.

14. Information will be exchanged and disseminated through a regular bulletin, produced by the MCAC and relying on written contributions from Contiguous Local Authorities Group (CLAG)s.

7.0 PHYSICAL MODIFICATION (SOURCE REDUCTION)

Ultimate Objective

I. **To install low cost, low maintenance physical modifications that provide effective control of salt marsh mosquitoes while having a minimal environmental impact.**

Immediate Objectives

J. **To determine the environmental impact of physical modifications upon salt marshes (through research) and to formulate design criteria.**

K. **To maintain those modifications already made to salt marshes within the Leschenault region to ensure that they continue to function effectively.**

7.1 Introduction

The physical modification of salt marshes can provide an alternative to the recurrent use of expensive chemicals in many areas. Filling and channelling are used to modify the drainage pattern of a marsh so that the mosquito life cycle is not completed.

Filling removes the depressions which, when temporarily filled with water, serve as breeding sites for mosquitoes.

No wetlands in the Leschenault Estuary have been recommended for wholesale filling. This reflects the high conservation value of the majority of wetlands in this area, and that the simple hand filling of depressions and wheel ruts may be all that is required to significantly reduce mosquito breeding.

In most salt marsh breeding areas where physical modifications are an acceptable means of treatment, a carefully planned system of channels and minor filling is required. Careful planning is essential in order to achieve satisfactory cost-effective control of mosquitoes with minimal modification of the salt marsh environment.

Inappropriate or poorly planned physical modifications will not alleviate mosquito breeding and may actually create new breeding areas.

Traditional deep drainage ditches and broad scale filling can cause great damage to the marsh environment. Modern systems of channels for mosquito control seek to cause minimal modifications to marsh characteristics.

In a well-planned implementation of physical control, channels will drain some areas of a marsh in a period of time just shorter than the larval part of the mosquito life cycle (7 - 10 days in summer).

Generally the function of channels is not to drain a marsh, but to increase tidal flushing, so that the environment becomes changed to one in which mosquito larvae cannot successfully breed and in which predators, such as fish, can gain access to consume any mosquitoes that do develop. Pools that are nearly always full of water may not be significant producers of mosquitoes and may be maintained to provide habitats for waterbirds and other animals, as well as reservoirs of mosquito predators. Some pools may need to be deepened so that they stay permanently filled with water.

Six wetland areas have been physically modified in the Leschenault Estuary region under the Interim Strategy. These modifications have been or are anticipated to be successful in significantly reducing the numbers of mosquitoes emerging from these breeding areas.

Wetlands in which physical modifications have been carried out under the Interim Strategy are generally those which are highly degraded, of moderate conservation value and/or exhibit high levels of mosquito breeding close to residential areas.

These modifications are outlined in the "Report on Mosquito Control in the Leschenault Estuary Region" (Klemm, 1989). Figure 2 gives the locations of modified areas (site numbers are taken from Wright, 1986). In summary these are:

1.Point Douro - an extensive system of shallow, "spinner" dug channels was installed by Harvey Shire in 1987. Modifications have been made to this under the Interim Strategy;

2.Paddocks, Eaton (City of Bunbury);

3.The Blunders and Anglesea Island - backhoe-dug channels were installed at the Blunders by the City of Bunbury in 1987 without surveying. Consequently, modifications to these channels and the filling of extensive wheel-rutting was carried out under the Interim Strategy;

4.Salt marsh opposite SCM Chemicals - spinner channels were installed by the Shire of Harvey in 1987. Filling has been carried out additional to this;

5.Site 41 (Shire of Harvey);

6.Oxbow near the Harbour (Site 117).

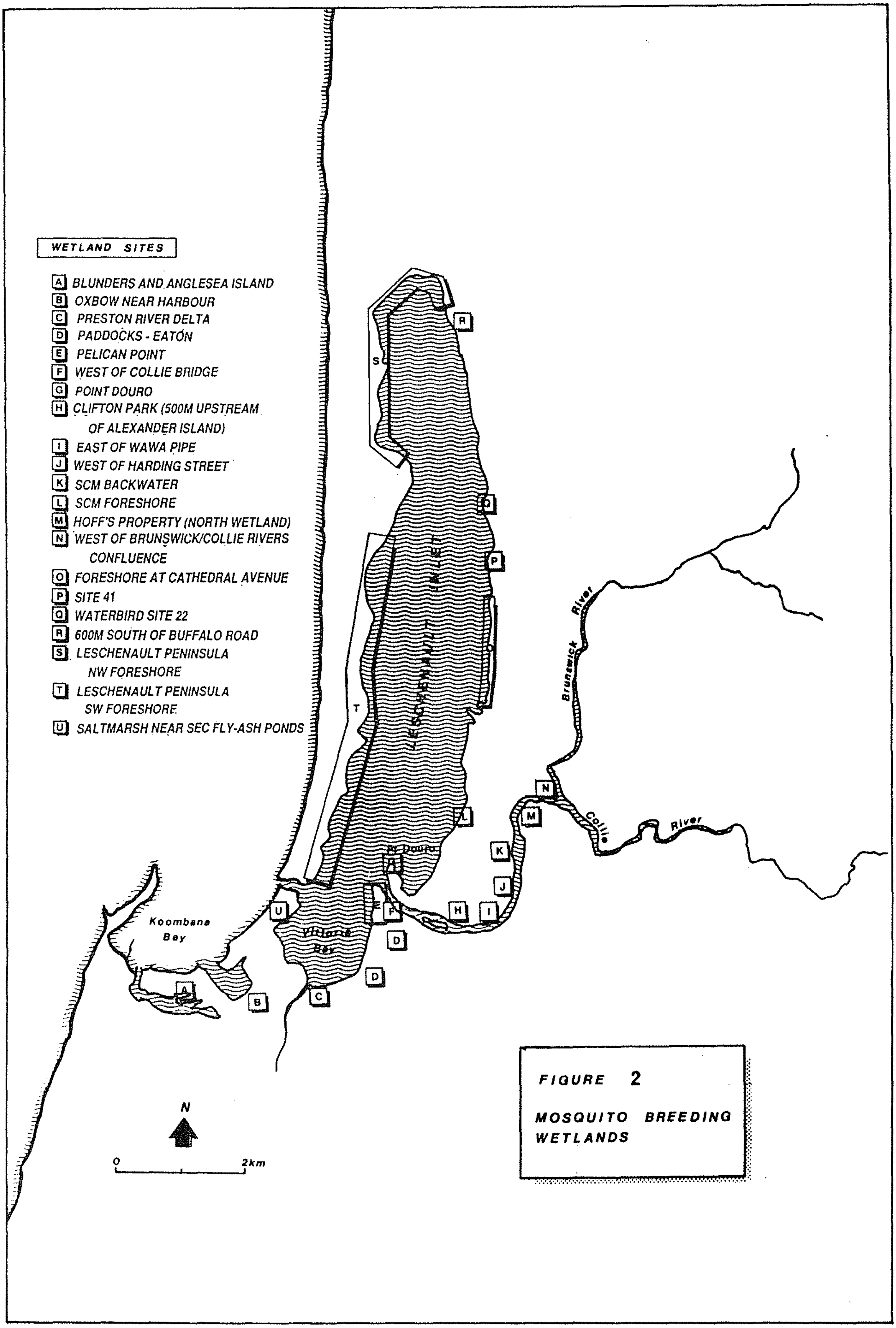


FIGURE 2

MOSQUITO BREEDING WETLANDS

Very little is currently known about the effects of physical modifications on salt marshes in the south-west of Western Australia. Salt marshes are an integral part of estuarine ecosystems and it is important, for economic as well as aesthetic reasons, that they are maintained in a healthy state. It is therefore imperative that the effects of physical modifications be investigated so that the possibility of significant environmental degradation can be ruled out. Physical modifications will not be initiated in more sensitive areas until it is shown that an acceptable impact on salt marsh ecology results.

For this reason, a study has been initiated whereby some marshes modified under the Interim Strategy will be monitored for ecological changes in the medium to long term. Initial study sites are in the Peel region, but it is anticipated that some sites in the Leschenault region will also be included.

It is hoped that this study will result in guidelines for physical modifications acceptable for broader application. Meaningful results are not expected to be gained for three to five years as some effects may require this time period to be detected.

In the meantime, experience gained during the installation of physical modifications under the Interim Strategy as well as information gathered by the Mosquito Control Review Committee (MCRC) has enabled the formulation of tentative guidelines for earthworks in salt marshes. These are of course subject to review and elaboration in the light of research results.

7.2 Interim Guidelines for Physical Modifications.

(i) Any implementation of physical modifications requires detailed topographical surveying (<10 cm contours) and reconnaissance to provide comprehensive details of mosquito breeding and of potential environmental impact (part of a "baseline study").

(ii) The flooding regime of the marsh should be altered as little as possible, therefore the total number and volume of channels and filled areas should be minimised. Salt water should not be allowed to intrude into areas receiving only freshwater inundation.

(iii) Only areas of a marsh where mosquitoes are produced should be modified. Not all areas that hold water following rain or a flooding tide will produce mosquitoes. Only those areas containing water one or more weeks following inundation will do so. Permanent or near permanent pools should not be drained (but may be connected to radial channels or a tidal channel to increase flushing).

(iv) The use of machinery should be minimal. Filling and channelling should be by hand wherever possible. Hand digging must be used for small lateral channels and when connecting pools to channels.

Machinery may only be used where:

- -The ground is dry enough so that ruts are not created.
- -The vehicle has a low "footprint" (ground pressure), i.e. has tracks or balloon tyres.
- -The area is accessible and no significant damage to vegetation results.

(v) Spoil from channelling must be properly spread or removed so that no high points are created as barriers to water movement. Spoil from within the site should be used to fill depressions or spread evenly.

(vi) Natural high points should not be breached. Channels should, as far as possible, follow natural drainage contours. This criterion must be balanced with the need to minimise sharp angles or curves in order to avoid erosion.

(vii) Several small channels should be used in preference to a single larger one in order to spread the water load, hence minimising erosion.

(viii) The gradient of channels should generally be in the order of 1:1000 or less in order to minimise erosion - it is only necessary for water to move slowly through the channels.

(ix) The depth of channels should be as shallow as possible so that:

- -water does not stagnate in them and breed mosquitoes
- -erosion is avoided
- -no local lowering of the marsh water table occurs

The depth should, as far as possible, be kept within the shallow clay layer over the marsh, avoiding the easily erodible sand beneath.

(x) The type of channel illustrated in Figure 3 is the preferred design. The channel should be three or more times wider than deep and not deeper than 30 cm. The cross section is an arc shape in order to minimise erosion. This type of channel is called a "runnel".

In practice a channel of this size would be used for long main channels only. Most channels would be 10 - 20 cm deep and 30 - 60 cm wide. Often just a few scoops with a shovel will suffice to adequately modify the flow of water. The size and number of channels will depend on factors such as catchment area and topography.

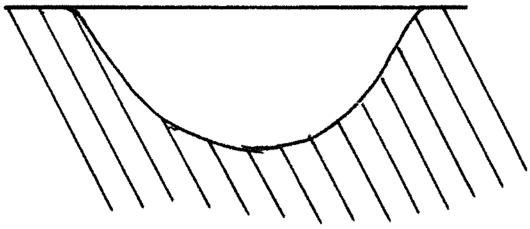


Figure 3 A Runnel Profile

In practice a channel of this size would be used for long main channels only. Most channels would be 10 - 20 cm deep and 30 - 60 cm wide. Often just a few scoops with a shovel will suffice to adequately modify the flow of water. The size and number of channels will depend on factors such as catchment area and topography.

A "spinner" rotary-ditching machine has been used to rapidly dig channels such as this in some areas. Care must be taken to avoid the creation of wheel ruts and to adequately dispose of the spoil. Spinner-dug channels usually must be supplemented with work done by hand.

One method used has been to utilise one of an existing set of wheel ruts as a channel, simply by formalising by hand digging and connecting it to a larger tidal channel.

In some areas, a deeper, "perimeter" ditch may be used, connecting at both ends to the waterway. Such a ditch diverts tidal floodwater and runoff away from the marsh and may also act to prevent human, stock or vehicle access to the wetland (and hence to prevent the formation of further breeding areas, i.e. ruts and potholes).

The length of deep perimeter ditches should be kept to a minimum.

(xi) Sand-bags or matting may be required to stabilise the entry point of a channel to the main tidal waterway, especially where a sand ridge must be breached. The mouth of the channel should be broad and flat.

Figure 4 and the accompanying Plates illustrate the principles outlined above.

Physical modification is not a final solution. Ongoing maintenance and monitoring will always be necessary while modification and "spot" treatments with larvicide will occasionally be required, especially after extreme tides.

Those modifications already made to salt marshes in the Leschenault region must be maintained in order to ensure continued effectiveness. The effectiveness of these modifications in controlling mosquito breeding will be determined from monitoring by Contiguous Local Authorities Group (CLAG)/local authority officers.

Proposals for physical modifications to wetlands for the purpose of mosquito control will in future require the approval of the MCAC. It is not anticipated that modifications to wetlands in the Peel/Harvey Estuary region further to those installed under the Interim Strategy will be initiated until firm conclusions are drawn from the research detailed above. In the event of any further wetlands being approved for physical modification, either in the Leschenault region or in other areas, the MCAC will supervise design and installation. Costs will be negotiated with local authorities by the Committee.

Plate 1 A very shallow hand-dug runnel (5-10cm) deep connecting a small area of low marsh to a waterway Such a channel is essentially a formalised natural drainage line. One of an existing set of wheel ruts may be formalised in the same way.

Plate 2. A filled pool. This shallow pool has been filled to the same level as the surrounding marsh with the spoil from runnel and channel construction. Revegetation can be expected

Plate 3. A hand-dug channelconnecting a system of pools to a waterway. Note the sandbags in the foreground at the channel mouth. Depth is 20 - 30cm

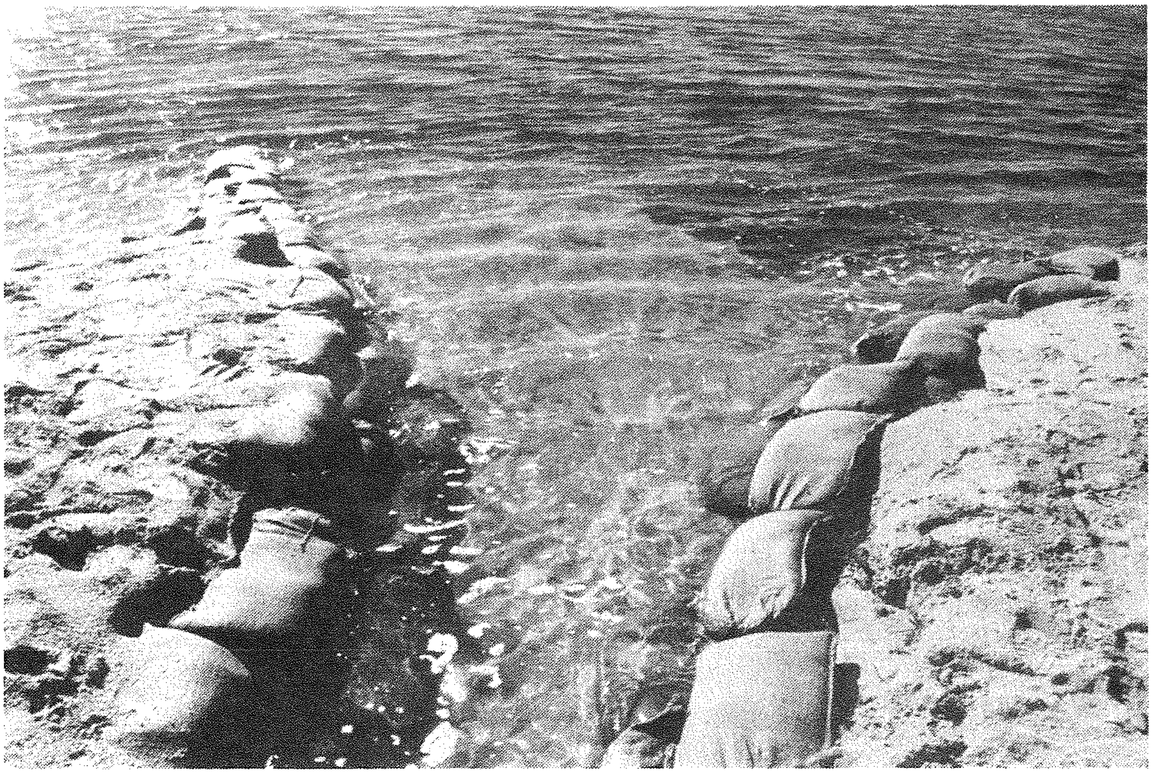
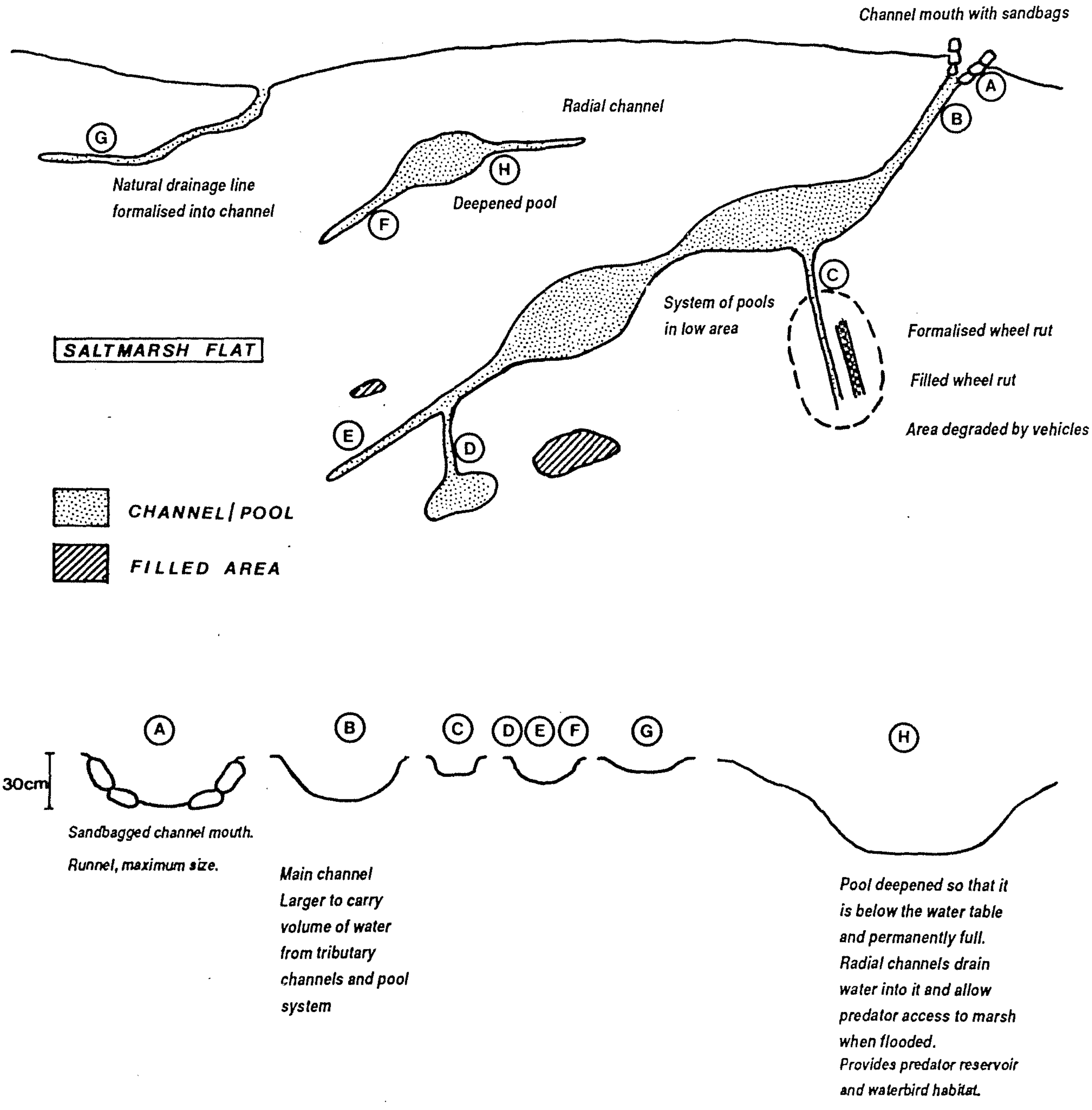


Plate 4. A channel connection to a waterway. this is stabilzed with cement-filled sandbags to prevent erosion.

Plate 5. A hand-dug runnel connecting a system of pools. Depth is 10 - 15cm and within the surface layer of clay. Width is 30 - 40cm. This runnel is level and relies on tidal flushing to operate.

Plate 6. A 'spinner' channel. Construction must be undertaken during summer when the marsh is dry enough to hold the machinery without creating wheel-ruts. Note the low spoil ridge to the right of centre, as broadcast from the spinner machine



RUNNEL DEFINITION

1. Curved profile
2. Three or more times wider than deep
3. Maximum size 30 x 90cm
4. Gradient generally less than 1:1000 - follows natural drainage contours
5. Depth is kept within the surface clay layer
6. Object is to tidally flush, rather than drain, therefore a drop to the channel mouth to drain an area is not needed. The minimum number of channels are used.

FIGURE 4

MARSH WATER MANAGEMENT – BY RUNNELING

7.3 Environmental Monitoring

The MCAC may find that it is necessary to monitor some physically modified areas for environmental effects, using procedures developed during the current study (as outlined in Section 7.1 and Section 4.0). This will be done to ensure that no detrimental impact occurs in modified areas, with corrective action being taken if any is detected. While the current study is being carried out to determine the broad effects of physical modifications, differences between salt marshes in different areas may mean that predictions regarding these effects cannot confidently be made in some areas without further monitoring. The MCAC would assist Contiguous Local Authorities Group (CLAG)s with this monitoring and would supervise analysis.

7.4 Actions

15. The Contiguous Local Authorities Group (CLAG) will maintain existing physical modifications to mosquito breeding areas and will monitor their effectiveness in reducing mosquito breeding.

16. The Mosquito Control Advisory Committee (MCAC) will supervise a study of the environmental effects and effectiveness of physical modifications to salt marshes with a view to formulating guidelines for their use (see also Action 6,Section 4.0).

17. The Contiguous Local Authorities Group (CLAG) may be required to monitor the environmental effects of physical modifications under the direction of the MCAC.

18. Physical modifications further to those outlined in this strategy will require the approval of the MCAC. The installation of such modifications would be supervised by the MCAC.

8.0 LARVICIDING

Objectives

L. To provide a control option that can be applied rapidly and effectively in response to high levels of mosquito breeding, resulting in the number of pest adults being kept below an acceptable threshold.

M. To control the development of resistance to agents used.

8.1 Introduction

While physical modifications may control mosquito breeding in many areas for much of the time, additional means of rapidly reducing mosquito populations in other areas and in times of unusual climatic conditions will always be necessary.

The application of larvicides is an effective and economical way (compared to adulticiding) of reducing the numbers of pest adults. The effect is felt at a stage in the life cycle when the mosquito population is concentrated in a relatively small area, actively feeding and suspended in water. These factors allow the efficient treatment of well-defined areas and a sustained exposure of the larvae to control agents. More importantly, treatment is effected before the nuisance stage emerges.

Larviciding will continue to be relied upon in areas where physical modifications are not acceptable or until research results indicate that modifications are acceptable in particular areas.

The chemical larvicide, temephos (trade name - Abate) has been applied from the air under the State Government funded Interim Strategy since January 1989. The effectiveness of these treatments have yet to be accurately determined from post-treatment monitoring results but the data appears to suggest a success rate of from 50% to greater than 90% in terms of the number of larvae killed at each site.

The variability in kill rates is dependent on many factors that are difficult to control. These include:

i)the efficiency of monitoring and identification of breeding sites;

ii)the accuracy of application;

iii)the timing of treatment following monitoring; and

iv)the weather - especially the wind which greatly affects the accuracy of application.

Accurate and properly timed monitoring by local authority officers and early treatment helps to ensure that high kill rates are achieved.

Temephos shows a high specificity in its toxicity towards mosquitoes, midges and blackflies. Toxicity is low for mammals, birds and fish at normal dosages but some non-target crustaceans and insects that live in the water are susceptible. These organisms are often important food sources for waterbirds. The effect on susceptible animals is however temporary as temephos rapidly breaks down. Because temephos is not residual, treatment is frequently required, as often as breeding occurs. A granular formulation is used in order to ensure that the toxin reaches the bottom feeding larvae. The toxin is not released until the granules are dissolved in water. Granules may however be harmful if picked up and eaten in quantity by birds.

8.1.1 Application Techniques

Three techniques for larvicide application are currently available. These are: by backpack or hand on foot, from a vehicle and by air (helicopter). The advantages and disadvantages of each technique are discussed in Wright (1986) (pages 22-23). These pages are included as Appendix 3.

Additional techniques, such as the use of tidally activated drip systems or slow-release briquettes may be investigated and eventually used in some areas. Such techniques may have implications for resistance control and should therefore only be implemented under the advice of the Health Department/MCAC.

Aerial application is the most expensive technique and should therefore be restricted to large areas that are difficult to access from the ground or too extensive to treat in the time available. Spot treatments on the ground should be carried out wherever possible. Accurate determination of breeding sites, such as small pools within a marsh, allows the effective use of ground larviciding. Some areas in the Leschenault region that are currently treated by aerial larviciding may be able to be treated from the ground following physical modifications and better identification of breeding sites. Care must be taken to prevent wheel ruts from being formed, creating additional breeding areas, when larviciding from the ground.

8.1.2 Timing of Application

The timing of larvicide application is crucial. Large broods of *Aedes* mosquitoes hatch at the same time, following the inundation of marshes by tides or rainfall. Development to adults then takes only 7-10 days in summer and approximately three weeks in winter. Larviciding with temephos in the summer requires an accuracy of several days or less in timing to be effective. Efficient monitoring is therefore necessary in order that larvicide applications are effective in preventing the emergence of adult mosquitoes.

8.1.3 Funding and Responsibilities for Larvicide Application

The following arrangements will apply with regard to the funding and responsibilities for larvicide application.

1.Government assistance with funding will be available upon the formation of a Contiguous Local Authorities Group (CLAG) and the written acceptance by local authorities of the conditions formulated by the Mosquito Control Task Force.

2.The cost of insecticides for aerial and ground larviciding in areas and seasons approved by the Health Department will be shared equally by the State Government and Contiguous

Local Authorities Group (CLAG)s.

3.Helicopter hire for approved aerial treatments will be funded wholly by the Government.

4.The Contiguous Local Authorities Group (CLAG) will carry out ground larviciding operations.

5.Monitoring of mosquito breeding will be carried out by Contiguous Local Authorities Group (CLAG)s.

In RRV epidemic years, funding taken from the accumulative Contiguous Local Authorities Group (CLAG) trust fund (and Government funding as required) will be used to pay for the additional effort required for larviciding and monitoring. The Health Department will notify the Contiguous Local Authorities Group (CLAG) if an epidemic year is expected.

8.2 Monitoring and Treatment Protocol

Mosquito populations must be monitored regularly in order to assess the necessity and effectiveness of aerial and ground larviciding to control intermittent mosquito breeding. This is done by determining the density and distribution of larvae in each breeding site (i.e. larvae /m2).

Mosquito breeding is precipitated by tidal and weather conditions. Current research aims to relate RRV/mosquito activity to predictable climatic events. Developments in this area will greatly improve the efficiency of monitoring by forecasting when mosquito breeding will be at levels requiring an intensive monitoring regime.

Local government personnel, co-ordinated by the Regional Mosquito Control Officer, will gather monitoring data.

The monitoring regime initiated under the Interim Strategy should be continued until reviewed in the light of research results, i.e. on the following basis:

-during summer, three or four days after each high tide that inundates a salt marsh breeding site or after the occurrence of significant (> 12 mm) rainfall;

-during spring and autumn once per week;

-during winter once per fortnight.

The decision as to whether to treat a wetland breeding area will be made by the RMCO according to decision making criteria to be formulated by the Health Department. Treatments should occur only when larval numbers exceed a particular level at each breeding site. This "threshold level" is the density of mosquito larvae at which the nuisance and health risk posed by mosquitoes emanating from a particular breeding site can no longer be tolerated. This level may vary between sites according to their size and proximity to residential areas, as well as other factors such as conservation value.

The criteria for deciding whether or not to treat will initially be formulated on the basis of information gathered in the "baseline study" of the Leschenault region (Wright, 1986) and during the implementation of the Interim Strategy, but may be reviewed if necessary.

Monitoring results must be recorded on standard data sheets containing these criteria and other information as required. These sheets must be kept as a record of mosquito breeding at each site and must be submitted to the Health Department in order to obtain funding for any larviciding that has been carried out at these sites.

Currently, whole wetlands in the Leschenault region are classified as mosquito breeding sites. During summer, mosquito breeding in these areas actually occurs in often not obviously defined depressions of various sizes within the greater site. Only local officers are in a position to discern the locations and extent of these sites through regular observation.

An intensive monitoring effort will be carried out by Contiguous Local Authorities Group (CLAG) officers over the first twelve months following the implementation of this strategy. This will involve mapping the sites within a wetland where mosquitoes breed and recording the number of larvae per surface area on standard data sheets.

These data will be used to further refine decision making criteria and treatment regimes (which will be reviewed by the MCAC), i.e. a more detailed knowledge of mosquito breeding will allow a more efficient monitoring and control programme.

Blanket aerial treatment may, in many breeding areas, be replaced by ground treatment of specific depressions as mapped and documented.

8.2.1 Procedures for Larviciding

Aerial Larviciding

1. Aerial larviciding will be initiated only when the Health Department receives and approves an assessment of the need to treat each breeding area from the RMCO, consisting of a standard form containing decision making criteria as outlined above.

   Aerial larviciding will only be available on a regional basis through the RMCO and not to individual local government authorities.

2. Contiguous Local Authorities Group (CLAG)/local government officers will be responsible for clearly identifying the areas requiring treatment by marking their boundaries with flags so that they can be seen from the air. Different coloured flags will be used in rotation, as per the Interim Strategy.

3. The Health Department will notify the RMCO and local authorities of its approval of aerial treatments and of the intended flightpath and other relevant details. If approval is not given, further information may be requested or suggestions made as to the appropriate course of action, e.g. ground larviciding.

4. An assessment of breeding 12 to 24 hours following the aerial treatment of an area is necessary in order to establish the treatment's success. This assessment will be made using the standard data sheets for breeding assessment, further action being decided upon by the standard criteria. Flags should be removed or shifted accordingly.

5. The Health Department will require notification of successful aerial treatment (or that only ground larviciding is required) from the Contiguous Local Authorities Group (CLAG) RMCO.

Ground Larviciding

The RMCO will be responsible for overseeing ground larviciding operations. Pre- and post-treatment assessments should be performed as with aerial larviciding. The Health Department need not be notified of the intention to treat an area if the assessment criteria are met. However, accurate records must be kept, consisting of the standard data forms for assessment of the need to treat, as well as details of larvicide use in the form of a log book. The records must be submitted to the Health Department in order to obtain Government funding for larvicide used. Any use of larvicide that cannot be justified according to the set criteria must be wholly paid for by the Contiguous Local Authorities Group (CLAG).

Advice and technical assistance with ground larviciding will be available from the Health Department.

Monitoring of treated areas for environmental effects (such as waterbird mortality) will be co-ordinated by the MCAC, but may involve Contiguous Local Authorities Group (CLAG) personnel. Any observations pertaining to effects on waterbirds or other animals (e.g. fish) should be reported immediately to the Health Department. Contiguous Local Authorities Group (CLAG)/local authority officers should look out for any such effects when inspecting breeding sites during larval monitoring.

If any sick or dead waterbirds are found they should be handled according to the procedure given in Appendix 5.

It is expected that Contiguous Local Authorities Group (CLAG) personnel will monitor breeding areas that have been physically modified, even if an area does not appear to be producing significant numbers of mosquitoes. This will provide data for an assessment of the effectiveness of such modifications and the need for their ongoing maintenance.

8.2.2 Analysis of Monitoring Data

It is anticipated that all monitoring data will be incorporated into a data base management system. This will greatly facilitate analysis and access to data. Analysis of these data will be performed periodically by the Health Department to yield information such as the success rates of treatments and trends in levels of breeding. It may eventually be possible to use this information in the construction of predictive models which will greatly assist in decision making.

8.3 Alternatives to Temephos

Alternatives to temephos are, or may in the future be available which may replace or supplement this chemical in aerial and ground treatments. These are compounds with various modes of action or biological agents which infect, parasitise or predate upon mosquito larvae.

8.3.1 *Bti*

It is intended, as soon as possible, to phase in *Bti*, a toxin produced by the bacterium, *Bacillus thuringiensis* subsp. *israeliensis* as the main larvicide in use. Currently, some local authorities use *Bti* sprayed from backpacks. A granular formulation suitable for aerial application against salt marsh mosquitoes has recently been developed and is currently being field-trialled. *Bti* is very specific in its toxicity to mosquitoes, blackflies and a few midges and has no toxicity toward other organisms except at very high dosages. It is also much less likely to induce resistance than temephos.

The timing of application of *Bti* is more crucial than with temephos. *Bti* acts as a stomach poison and must be ingested by actively feeding larvae, i.e. it is ineffective against larger 4th instar larvae and pupae. An efficient monitoring programme is therefore essential for its effective use.

8.3.2 Insect Growth Regulators (IGRs)

Insect growth regulators are another alternative to temephos. These chemicals do not kill mosquito larvae directly, but instead prevent them from becoming adults. Larval numbers remain high following treatment, but at the completion of the larval stage no adults emerge. Post-treatment monitoring must be modified accordingly, with adult numbers giving the only true indication of effectiveness. Kits are available to test the concentration of IGRs in the water following treatment, in order to assess their effectiveness.

One advantage may be the maintenance of mosquito larvae as food for waterbirds and other animals. IGRs may however affect some non-target aquatic insects and crustaceans.

IGRs may be useful as slow release formulations in freshwater wetlands and irrigation ditches, especially when treating for *Coquillettidia linealis* mosquitoes (which carry RRV) in heavily vegetated swamps such as those in the suburb of Eaton. This species is otherwise difficult to monitor and treat due to its plant-stem breathing biology. No insect growth regulator is currently approved for use against mosquito larvae and extensive trials would be performed before they could be used. Such trials would be supervised by the MCAC.

A new IGR, Sumilarv, appears to be extremely effective against both midges and mosquitoes and is currently undergoing the assessment process. It is anticipated that this product will be available in the near future.

8.3.3 Surface Films

Surface films have long been used for cheap and efficient mosquito control. Such films prevent the emergence of mosquito larvae and the laying of eggs on the water's surface (as occurs with some freshwater breeding mosquitoes) and are easily applied from the ground. Traditionally used agents such as kerosene are no longer acceptable because they are environmentally damaging. However, modern oil formulations (e.g. Arosurf) form a single molecule thick layer which does not appear to greatly affect non-target organisms.

Such oils are not practicable for use on salt marshes for Ross River virus control, but may be of use in some freshwater breeding areas such as irrigation ditches. Surface films are not effective where there is dense emergent vegetation or in windy conditions, as often occurs in the south west of W.A. Some success has been gained using combinations of a surface film and other agents, such as *Bti*, applied together.

Liquid paraffin or vegetable oil are useful in treating domestic breeding sites, such as rainwater tanks.

8.3.4 Biological Agents

Living organisms may act as larvicidal agents by predating upon, parasitising or infecting mosquito larvae. Fish and invertebrate predators (such as beetles) are effective in reducing the numbers of mosquito larvae. Non-native introduced species, such as the mosquito fish, *Gambusia affinis*, have, however, been shown to be destructive and in most cases ineffective when introduced into a natural environment. It is therefore desirable to maintain the marsh environment in a state that encourages the presence of native species of these organisms.

Any physical modifications to salt marshes where mosquitoes breed must encourage the access of fish and invertebrate predators to the mosquito larvae and not alter the habitat such that their presence is precluded. It may be desirable to maintain permanent pools on the marsh as reservoirs for predators.

Parasitic and infective biological agents are being developed for use against mosquitoes in various habitats. No biological agent has been identified which can be released in salt marshes and survive and breed there to give control of mosquitoes. Some fungi and nematode parasites do however show potential for use in freshwater wetlands, although none are currently available, or are likely to be, in the immediate future. Any use of these organisms would first require extensive trials to identify the impact and implications of their release.

The bacterium, *Bacillus sphaericus*, is currently under development as an agent capable of remaining active for several weeks, although it is not yet fully effective against salt marsh *Aedes* mosquitoes. This agent would be applied as a normal larvicide but, because of its sustained action, would require fewer treatments in order to be effective. It is proposed to trial *Bacillus sphaericus* locally as soon as it becomes available.

Research is currently intense in the area of bacterial and viral agents and useful products may be available within several years.

Any new agent must undergo stringent testing to ascertain the implications of its use before being approved for use in mosquito control. Even if it is approved for use in other countries, differing local conditions may give different results in W.A. Extensive field trials are also required to determine the operational cost-effectiveness of new agents and to enable them to be used efficiently. The MCAC and the Health Department will regularly inform Contiguous Local Authorities Group (CLAG)s as to the status of new mosquito control agents. Procedures for their use will be formulated by the MCAC, integrating them into the existing regional strategy.

8.4 Resistance Control

The frequent, regular use of most mosquito control agents, especially chemicals like temephos, will lead to the development of resistance to those agents in mosquito populations.

A failure in managing resistance results in a loss of control over the target pest population. It is often impossible to eliminate resistance in a mosquito population once it has developed. In such a case, a control agent will become increasingly ineffective, with ever increasing dose rates being required to gain an effective kill. This can continue to the point where dose rates are unacceptably high, both in terms of cost and environmental damage (i.e. the death of non-target organisms) while little control is gained over the target population. This situation has occurred in other countries with mosquito species developing resistance to many insecticides and in Western Australia with temephos resistant midges.

In addition, resistance to one chemical agent may also confer resistance to others and hence preclude their use as alternatives. It is therefore vitally important that resistance control measures be implemented as part of any programme of larviciding. Resistance management must be undertaken on a regional basis.

Measures that must be taken in order to reduce the likelihood of the development of resistance include:

i)Using agents that do not readily induce resistance or that induce resistance that is quickly lost from a population.

ii)Using agents that do not persist once applied. Sustained-release formulations or devices should be used with extreme judiciousness.

iii)Where more than one agent is used they should be chemically unrelated. Generally, the use of more than one agent at a time in a particular area should be avoided.

iv)Application of control agents as infrequently as possible.

v)Application of control agents only to specific breeding areas (rather than blanket treatments of large areas).

vi)A programme of monitoring for resistance in mosquito populations, with resistance management decisions being made on the basis of the results.

Bti appears to be very much less likely to induce resistance in mosquitoes than temephos. Additionally, exposure to one of these agents does not appear to affect susceptibility to the other in any way because the modes of action are different.

Bti is likely to eventually be the main mosquito control agent in use, greatly facilitating resistance control. It must be stressed that relatively little is known of the long-term effects of *Bti* on the development of resistance. Prudence must therefore be exercised in using this agent.

In order to further reduce the possibility of the development of resistance to *Bti*, treatments with this agent must be as infrequent and confined to as small a total area as possible. Alternative control methods like physical modifications will assist in achieving this.

Occasional rotations of *Bti* with other chemicals may be necessary to retard the development of *Bti* resistance. Temephos is suitable for rotation with *Bti* and should kill any mosquitoes with *Bti* resistance.

Insect growth regulators (IGRs) are other alternatives to *Bti* and their use does not appear to affect the susceptibility of mosquitoes to *Bti* or vice versa. Treatments should, as far as possible, be restricted to specific breeding sites in each area. Blanket aerial application of larvicides to wetlands must be kept to a minimum.

To minimize resistance, spot treatment on the ground is the preferred method of application

Larviciding should occur at each breeding site only when that breeding site is producing mosquitoes at levels which pose a significant nuisance and/or health risk. The accurate monitoring of mosquito breeding is essential to ensure that treatments occur only when necessary.

Where sustained formulations or devices are used, they should be of agents that are completely unrelated to *Bti* and temephos so that the efficacies of the latter agents are maintained. Insect growth regulators may be suitable for this application.

Oil-based surface films do not induce any kind of resistance and may be used where conditions are suitable.

The development of resistance can to some extent be inferred from the success rates of treatments, as determined from the monitoring of breeding by Contiguous Local Authorities Group (CLAG)s, and it is hence essential that a regular analysis of monitoring results be performed. The MCAC would supervise this exercise. Additional, regular yearly monitoring of resistance in mosquito populations is necessary and will be performed by the Health Department with assistance from Contiguous Local Authorities Group (CLAG)s as required. The MCAC will determine the course of action should an increase in resistance be detected.

8.5 Action

19. The Health Department and the MCAC will investigate new control agents and techniques. This will include phasing in granular *Bti* as soon as is practicable.

20. The Health Department will formulate decision making criteria for larviciding, to be used by the RMCO when assessing mosquito breeding.

21. Mosquito breeding will be monitored by the Contiguous Local Authorities Group (CLAG) under the supervision of the RMCO, according to the regime outlined in Section 8.2.

22. Larviciding should be initiated and carried out according to the procedures outlined in Section 8.2.1, with funding and responsibilities as per Section 8.1.3.

23. An intensive monitoring effort is to be carried out by Contiguous Local Authorities Group (CLAG) officers over the first twelve months following the implementation of this strategy to gain a more detailed knowledge of mosquito breeding in each wetland. This will allow a refinement of treatments for maximum cost-effectiveness.

24. The Health Department will incorporate monitoring results into a data base management system and undertake regular analysis. The aim will be to eventually construct predictive models.

25. Resistance control measures are to be practised by the Health Department and Contiguous Local Authorities Group (CLAG)s.

26. The Health Department will regularly monitor resistance to insecticides in mosquito populations.

9.0 ADULTICIDES

Wright (1986) reviews the advantages and disadvantages of adulticides to control mosquitoes (pages 18-22; reproduced in Appendix 4). Fogging is the responsibility of local authorities and should be considered as largely a public relations exercise rather than an effective means of mosquito control. Adulticide fogging does not prevent or control mosquito breeding (largely due to the dispersal ability of the target species) and only controls adult mosquitoes in the area at the time of treatment. In addition, adulticides kill useful insects such as dragonflies (which are mosquito predators) and bees. Food resources for insectivorous birds, mammals, amphibians and reptiles can also be reduced.

10.0 REFERENCES

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11.0 APPENDICES

APPENDIX 1

DETAILS OF WETLAND ASSESSMENT PROFORMA

APPENDIX 1

DETAILS OF WETLAND ASSESSMENT PROFORMA

The wetland assessment proforma has been designed to simplify the collection and interpretation of information on mosquito breeding wetlands. This Appendix aims to give details and interpretations of what each of the 15 wetland characteristics mean and their relative importance to decision making about mosquito control options. It must be remembered that no singlecharacteristic will determine mosquito control recommendations but that it is a combination of the entire proforma.

Wetland assessment will be made under the guidance of the MCAC, who will assist with the assigning of ranks for each characteristic and in determining an environmental category from these ranks.

1. PROFORMA

A. <u>General Information</u>

1. Wetland Name and Location - This is straightforward and it is suggested that a map be used as a location plan. In addition, it may be useful to draw a sketch plan of each wetland identifying the location of major features (eg pools, vegetation types of sand ridges, etc). This can also be used later.

2. Mosquito Survey Site Number. The number allocated to the wetland during the baseline mosquito breeding survey.

3. System 6. The System studies (12 in total) identified opportunities for reserving areas of land for the purposes of conservation of natural areas and recreation in natural surroundings. The System 6 report is relevant to the Leschenault Estuary Region. Development or change to wetlands identified as System 6 reserves requires referral to the Environmental Protection Agency for assessment (this process can be streamlined through the MCAC). In addition, specific recommendations for a wetland may have been detailed, thereby providing additional guidance for mosquito control options.

4. Proximity and direction to nearest residential areas. Attempt to estimate the distance and location of nearby residences. Also record whether the separation of wetland and residences is land or water. This gives an indication of the likely significance of the breeding in a wetland to the adjacent wetlands. That is, close proximity will increase the pressure to use some mechanism of mosquito control.

5. Breeding Intensity Rank. This is a system developed by Wright (1986 & 1988) to rank wetlands according to mosquito breeding intensity. The hierarchy obtained enables the easy identification of significant mosquito breeding wetlands by recording the frequency of breeding in each season. It is important to note that this ranking method cannot be conducted as a one-off assessment but requires that breeding is monitored for 12 months prior to ranking.

6. Dominant Mosquito Species. This information is from the baseline survey. The dominant mosquito species provides an indication of the potential nuisance problems that nearby residences may experience. For example, *Aedes vigilax* is most productive during the summer months and due to its vicious biting nature, could create a significant human nuisance as well as disease risk. Treatment to control this mosquito would, therefore, only be necessary during its peak activity.

B. Summary of Condition from Inspection

7. General Description. This description should include the dominant vegetation type (eg saltmarsh, *Melaleuca raphiophylla / Juncus*), as well as less dominant aspects (eg intermittent saltmarsh, pools). From this a broad understanding of habitat types represented can be made. Also, comparison will provide an indication of the diversity of wetlands in the Region.

8. Condition of Vegetation. The condition of the vegetation is ranked 1 to 3. Rank 1 represents vegetation that is of poor quality, unhealthy or in a degraded state (eg weed invasion). A rank 2 corresponds to reasonable health/condition that will recover with the appropriate management. For example, vegetation that has been trampled will recover if access is prevented. Ranking the vegetation condition as 3 indicates a reasonably pristine environment that should be maintained in that form (eg an island with limited access). The ranking is important to developing mosquito control recommendations as it sets the limitations of techniques that may be implemented. For example, in a wetland with a rank of 3 the implementation of substantial physical modifications may not be favoured. Conversely a rank of 1 may indicate that significant changes, including channels, are acceptable.

9. Waterbird Habitat Value. A rank of 1 to 3 is used to assess the waterbird habitat value. In the absence of a comprehensive waterbird survey, a subjective assessment of the probable waterbird use is made (eg roosting, feeding sites) based on knowledge gained through previous studies (eg Ninox Wildlife Consulting 1989). It is important that this assessment be made using existing knowledge as a decision to physically modify may impact on the regional waterbird population (eg destroying breeding areas). Aspects to be considered in ranking include wetland size, shelter (trees, shrubs, sedges), emergent vegetation (trees, etc), macrophyte abundance, productivity, food sources (eg open water) and nesting sites (cover and canopy). This information is then used to rank the waterbird value in the following way.

1 = low waterbird value (ie limited roosting and feeding sites)

2 = medium waterbird value (eg good feeding but limited roosting sites)

3 = high waterbird value (eg habitat diversity).

Medium to high ranked wetlands may have specific limitations to modifications permitted.

10. Level of Disturbance. In this category aspects including extent of wheel rutting and ponding, channeling and soil type are considered in a rank of 1 to 3. A rank of 1 represents a minor level of disturbance and the wetland would be considered to be relatively pristine (see 8). Rank 2 represents medium disturbance such as some wheel rutting and ponding that may be easily filled or drained. A 3 rank indicates a significant level of disturbance and degradation (eg exposed clay pan).

11. Special Conservation Features. This section enables expansion of wetland features that may be considered unique or representing a remnant ecosystem or vegetation type. Some examples are remnant vegetation , pristine saltmarsh, evolving deltas, or a good quality stand of associated wetland trees and shrubs.

12. Landscape and Wildlife Values. This ranking of 1 to 3 aims to combine the conservation and wildlife values of the wetland into an overall regional wetland perspective. A ranking of 1 is a low significance generally representing highly degraded wetlands. Rank 2 is a wetland that displays many but not all high quality environmental characteristics. Attributing a rank of 3 indicates that the wetland is regionally significant and of the highest quality.

C. Management Issues and Development Pressures

13. Human Access. This is used to describe the accessibility of the wetland from nearby and remote population centres. It is important to record nearby roads/tracks access method (foot, vehicle) and the extent or use of that access. Information collected provides an indication of recreational use of a wetland which may need to be considered in control recommendations.

14. Stock access, trampling disturbance, breeding sites. This section assesses the level of disturbance caused primarily by stock but also humans. Historically estuarine wetlands have been used as grazing areas. It is different to the Level of Disturbance (10) as it excludes vehicle or machinery disturbance. A rank of 1 to 3 is used. Rank 1 represents no trampling disturbance. A rank of 2 indicates some disturbance that could be reversed with appropriate management. A wetland with a ranking of 3 is highly disturbed and would require a significant resource investment to return to a more natural condition.

15. Development Pressure. A record of developments that may impact on the wetland should be recorded. This will indicate whether special consideration for protection or modification of a wetland should be given.

2. PROCESSING THE ENVIRONMENTAL ASSESSMENT

The information collected using the Wetland Assessment Proforma is used to categorise wetlands into environmental categories. The categories used are listed below:

Category:	High Conservation Value.
Rank 1:	larvicide treatment
Rank 2:	physical treatment
Category:	Medium Conservation Value
Rank 3:	larvicide treatment
Rank 4:	physical treatment
Category:	Low Conservation Value
Rank 5:	Larvicide treatment
Rank 6:	physical treatment
Category:	Low Priority of Control at Present

A high conservation value site is identified as being regionally and locally significant. Wetlands falling into this category will generally be pristine (or close to it) in condition, have high quality vegetation, are important to waterbirds, are identified as System 6 wetlands and have a low level of disturbance. Options for mosquito control in these wetlands are limited to treatment with larvicides (preferably *bti*) and no minor physical works, such as filling of wheel ruts.

A medium conservation value wetlands are identified as representative of ecosystems of the region, that may be more remote from centres of population, that do not have high levels of mosquito breeding, that have some level of degradation (eg wheel ruts), are used by waterbirds and/or may be System 6 wetlands. Mosquito control options involve treatment with larvicides as necessary and some physical modification. The installation of runnels may be permitted in this category of wetland.

Low conservation value wetlands may be highly degraded or they may be deemed so for other reasons. Physical modification (channelling and filling) in highly degraded wetlands is likely to be the major mosquito control option used. Those wetlands which are remote from population centres are unlikely to require modification but may require treatment on occasion.

The final category, Low Priority of Control at Present, generally describes wetlands that are remote from population centres and have low mosquito breeding, or that for some other reason mosquito control has been determined to be unnecessary or undesirable. Control techniques will generally only involve larvicide (*bti*) treatment occasionally.

Proposed Mosquito Control Options are recorded on the environmental assessment proforma. the details may be limited but the general principles should be outlined. Prior to any physical modification options being implemented approval must be gained from the Environmental Protection Authority and the Mosquito Control Advisory Committee.

WETLAND NAME	BLUNDERS & ANGLESEA ISLAND	SALT MARSH NEAR FLY-ASH PONDS SEC	OXBOW NEAR HARBOUR
General Eradication			
Mosquito Eradication Campaign Survey Site Numbers (see attached map)	121-125	110,111,114,118,123	117a, b, c
System Six Recommendations Apply	C68		
Proximity, direction, across water to nearest residential areas	E 500 m over water otherwise remote	< 100 m to SEC residence (6)	500 m
Breeding Intensity Rank MEC Survey (see attached table)	High	Mod-high	High
Dominant Mosquito Species	Aedes viglax A. camptorhyncus	A. vigilax A. campt	A. vigilax A. campt
Summary from Inspection			
General Description Island	Isolated channel around margins Mangroves and saltmarsh, tidal channels & reclamation	Saltmarsh, weeds	Isolated river oxbow, narrow margin of saltmarsh, weed complex & mature flooded gums surrounding
Condition of Vegetation (Rank of 3)	+++	+	+
Waterbird habitat value (Rand of 3)	++	++	++
Level of Disturbance, soil type, or pools or connected channels, wheel ruts etc (Rank of 3)	Wheel ruts from installation of channels in 1985 ++	+++	+ - ++
Special Conservation features	White mangroves	-	remnant flooded gums
Landscape & Wildlife Value (Rank of 3)	+++	+	+
Management & Development Pressures			
Human Access	Minor	Minor/nil	minor fishing & camping
Stock Access, trampling disturbance breeding sites (Rank of 3)	nil	nil	nil
Development Pressures	reserved land minimal	to become fly-ash pond (is now 1990)	future harbour extension
Environmental Category (see attached table)	2	6	4
Proposed Mosquito Control Option	maintenance of channels then bti	consumed by fly-ash pond extensions	tidal channels installed

WETLAND NAME	PRESTON RIVER DELTA	PADDOCKS EATON	PELICAN POINT
General Information			
Mosquito Eradication Campaign Survey Site Numbers (see attached map)	112,113	108,106,103,153	101-105,107,
System Six Recommendations Apply	Nil	Nil	Nil
Proximity, direction, across water to nearest residential areas	1-2 km from large residential < 100 m from a few houses	< 100 m to east	100 m to east over land
Breeding Intensity Rank MEC Survey (see attached table)	Low to High	Mod-high	High
Dominant Mosquito Species	A. viglax A. campt	A. vigilax A. campt	A. vigilax A. campt
Summary from Inspection			
General Description	Salt marsh delta, mudflats & islands <u>Casuarina</u> stands	East of road, hydrology interrupted by road embarkment Saltmarsh weed complex	low dunes, woodland, tidal channels, saltmarsh, mixed deltaic deposits
Condition of Vegetation (Rank of 3)	+++	+	saltmarsh +++ woodland (fire affected) +
Waterbird habitat value (Rand of 3)	+++	+	+++
Level of Disturbance, soil type, or pools or connected channels, wheel ruts etc (Rank of 3)	+	++	++
Special Conservation features	Newly formed delta	-	wetland channel
Landscape & Wildlife Value (Rank of 3)	+++	+	++
Management & Development Pressures			
Human Access	Minor	Future private access	Future development currently limited
Stock Access, trampling disturbance breeding sites (Rank of 3)	Nil	++	+
Development Pressures	Industrial Park zone abutting, Future realignment of Preston R.	likely to be filled for development (is now 1990)	future development
Environmental Category (see attached table)	1	6	4
Proposed Mosquito Control Option	chemical as required	106 filled 1989 channel and/or fill as part of development. One-way culvert	Modification of tidal flushing to be viewed as part of development

WETLAND NAME	POINT DUORO	CLIFTON PARK COLLIE RIVER	SCM FORESHORE
General Information			
Mosquito Eradication Campaign Survey Site Numbers (see attached map)	50-65	46-49	44
System SixC68 Recommendations Apply		C67	C68
Proximity, direction, across water to nearest residential areas	300 m to east < 100 m from a	< 100 m north and west	@ 500 m north & south land
Breeding Intensity Rank MEC Survey (see attached table)	Med to High	Low	Medium
Dominant Mosquito Species	Ae viglax Ae campt	Ae vigilax Ae campt	Ae vigilax Ae campt
Summary from Inspection			
General Description	Low dunes, wetland tidal channels, saltmarsh, mixed daltaic deposits	River terrace, *Juncus Melaleuca*	Saltmarsh, Some *Casuarina* and Melaleuca
Condition of Vegetation (Rank of 3)	++	++	++ woodland (fire affected) +
Waterbird habitat value (Rand of 3)	+++	?	++
Level of Disturbance, soil type, or pools or connected channels, wheel ruts etc (Rank of 3)	Old racetrack four wheel drive access ++	+	+
Special Conservation features			Close to egret rookery
Landscape & Wildlife Value (Rank of 3)	++		+++ ++
Management & Development Pressures			
Human Access	Some 4WD access	Minor access by adjacent residents	Medium
Stock Access, trampling disturbance breeding sites (Rank of 3)	++	+	+
Development Pressures	Future development	Foreshore reserve (is now 1990)	Nil
Environmental Category (see attached table)	4	3	4
Proposed Mosquito Control Option	Maintenance and extension of channels	Chemicals as required	Channels installed maintenance only, southern portion filled

WETLAND NAME	FORESHORE CATHEDRAL AVE	LESCHENAULT PENINSULAR N.W. FORESHORE	LESCHENAULT PENINSULAR S.W. FORESHORE
General Information			
Mosquito Eradication Campaign Survey Site Numbers (see attached map)	31-40	8-27	28-30
System Six Recommendations Apply	C66	C66	C66
Proximity, direction, across water to nearest residential areas	Moderate to SE over land	Remote	Remote
Breeding Intensity Rank MEC Survey (see attached table)	Low to medium	Low-medium	Low
Dominant Mosquito Species	A. viglax A. campt	A. vigilax A. campt	A. vigilax A. campt
Summary from Inspection			
General Description	Juncus - saltmarsh	Juncus saltmarsh some pools and mangroves	Juncus saltmarsh
Condition of Vegetation (Rank of 3)	++	+++	+++
Waterbird habitat value (Rand of 3)	++	+++	+++
Level of Disturbance, soil type, or pools or connected channels, wheel ruts etc (Rank of 3)	+	+	+
Special Conservation features	Foreshore	White mangroves	Foreshore
Landscape & Wildlife Value (Rank of 3)	++	+++	+++
Management & Development Pressures			
Human Access	Major fishing & boating recreation	To Peninsular	Limited
Stock Access, trampling disturbance breeding sites (Rank of 3)	+	+	+
Development Pressures	Increased residential & population use	Conservation Park	Conservation Park
Environmental Category (see attached table)	1	1	1
Proposed Mosquito Control Option	Aerial treatment with Bti preferred	Aerial treatment with Bti preferred	Aerial treatment with Bti preferred

WETLAND NAME	CLIFTON PARK 500 M UPSTREAM ALEXANDER IS.	EAST OF WAWA PIPE AT	WEST OF HARDING STREET
General Information			
Mosquito Eradication Campaign Survey Site Numbers (see attached map)	46		47
System Six Recommendations Apply	C67	C67	C67
Proximity, direction, across water to nearest residential areas	< 100 m N	< 100 m N	< 50 m N
Breeding Intensity Rank MEC Survey (see attached table)	No obvious signs of breeding low	Limited signs of mosquito breeding	Some breeding evident low
Dominant Mosquito Species	A. campt		A. campt
Summary from Inspection			
General Description Island	Sedgeland swamp. Very stagnant,	Melaleuca raphiophylla wetland	Degraded lowland area with M. raphiophylla, some sedge & saltmarsh
Condition of Vegetation (Rank of 3)	+++	+++	+
Waterbird habitat value (Rand of 3)	+	+	+
Level of Disturbance, soil type, or pools or connected channels, wheel ruts etc (Rank of 3)	+	+	+++
Special Conservation features	Good quality Juncus & Melaleuca swamp	Good quality immature Melaleuca	
Landscape & Wildlife Value (Rank of 3)	++	+++	+
Management & Development Pressures			
Human Access	Some through foreshore reserve	Some through foreshore reserve	Pressure from recreation and nearby residents
Stock Access, trampling disturbance breeding sites (Rank of 3)	+	+	+++
Development Pressures	None	None	Foreshore management plan
Environmental Category (see attached table)	3	7	4
Proposed Mosquito Control Option	Survey	Difficult	Investigate top dressing while preserving Melaleuca raphiophylla

WETLAND NAME	OPPOSITE CAW CLOSE	SCM - BACKWATER - COLLIE RIVER	WEST OF BRUNSWICK - COLLIE RIVER'S CONFLUENCE
General Information			
Mosquito Eradication Campaign Survey Site Numbers (see attached map)	Not identified	Not identified	Not identified
System Six Recommendations Apply	Clifton Park Management Plan - Conservation Area C67	C67	C67
Proximity, direction, across water to nearest residential areas	< 100 m North	1 km to N.W. & S.W.	1 km W
Breeding Intensity Rank MEC Survey (see attached table)	Unknown	Some breeding - estimate low - medium	Limited
Dominant Mosquito Species	?	?	?
Summary from Inspection			
General Description Island	*Melaleuca raphiophylla* *Juncus* wetland. *E. rudis* periphery	Freshwater, old creek line,	*M. raphiophylla* & Juncus wetland
Condition of Vegetation (Rank of 3)	+++	++ - +++	+++
Waterbird habitat value (Rand of 3)	+	+	+++
Level of Disturbance, soil type, or pools or connected channels, wheel ruts etc (Rank of 3)	+	+ in actual wetland, disturbed around	+
Special Conservation features	Very good fringing wetland		Very good quality vegetation
Landscape & Wildlife Value (Rank of 3)	+++		+++
Management & Development Pressures			
Human Access	Recreation facilities to be established nearby & boating recreation	None, on SCM property	Limited
Stock Access, trampling disturbance breeding sites (Rank of 3)	Minor trampling	None	Access to East end
Development Pressures		None	None
Environmental Category (see attached table)	3	5	7
Proposed Mosquito Control Option	Limited to backpack	Limited to backpack	Until monitored & record maintained, no treatment

WETLAND NAME	HOFF'S PROPERTY (NORTH WETLAND)	600 M SOUTH OF BUFFALO ROAD	WATERBIRD 22
General Information			
Mosquito Eradication Campaign Survey Site Numbers (see attached map)	Not identified		Not identified
System Six Recommendations Apply		C66	C66
Proximity, direction, across water to nearest residential areas	1 km South	East < 1 km	East 2 km
Breeding Intensity Rank MEC Survey (see attached table)			
Dominant Mosquito Species			
Summary from Inspection			
General Description Island	_Juncus_ - _Melaleuca_ fringe around open water	Samphire wetland approximately 100 X 20 m surrounded by _Juncus_ (small areas of samphire in area appear to drain well)	_Juncus_/samphire complex surrounded by _Melaleuca_ and _Casuarina_ largely freshwater
Condition of Vegetation (Rank of 3)	+++	++ weed grass in samphire	++ some weeds on periphery
Waterbird habitat value (Rand of 3)	++	?	+++
Level of Disturbance, soil type, or pools or connected channels, wheel ruts etc (Rank of 3)	+ Some cattle	++	++ Some historic stock & vehicle access
Special Conservation features		Good quality foreshore vegetation	Significant waterbird area
Landscape & Wildlife Value (Rank of 3)	++	+++	+++
Management & Development Pressures			
Human Access	Private property	Limited	Limited
Stock Access, trampling disturbance breeding sites (Rank of 3)	++	++	Historic access +
Development Pressures	None	None	None
Environmental Category (see attached table)	7	3	1
Proposed Mosquito Control Option	Monitor	No physical control	Too large for physical control, aerial treatment favoured

WETLAND NAME	SITE 41	WEST OF COLLIE BRIDGE
General Information		
Mosquito Eradication Campaign Survey Site Numbers (see attached map)	41	101
System Six Recommendations Apply	C66	C66
Proximity, direction, across water to nearest residential areas	> 2 km South	< 100 m E
Breeding Intensity Rank MEC Survey (see attached table)	Didn't rank	High
Dominant Mosquito Species		
Summary from Inspection		
General Description	Remnant saltmarsh/ <u>Juncus</u>, connection to estuary silted	<u>Casuarina</u>, <u>Melaleuca</u> Juncus, some samphire swamp
Condition of Vegetation (Rank of 3)	++ appears to be old pasture	++
Waterbird habitat value (Rand of 3)	?	?
Level of Disturbance, soil type, or pools or connected channels, wheel ruts etc (Rank of 3)	++ some wheel rutting	++
Special Conservation features		
Landscape & Wildlife Value (Rank of 3)	+	++
Management & Development Pressures		
Human Access	None	Limited
Stock Access, trampling disturbance breeding sites (Rank of 3)	Historically, little currently +	+
Development Pressures	None	None
Environmental Category (see attached table)	6	4
Proposed Mosquito Control Option	Spinner channels be installed by Interim Stategy	Formalize outlet to Collie River

APPENDIX 2

MOSQUITOES AND ROSS RIVER VIRUS

Health Department of W.A. Pamphlet

Ross River virus infection is one of several human virus diseases spread by mosquitoes in Australia. The virus was first found in mosquitoes from the Ross River in Townsville, Queensland.
It is not fatal and in most cases it is not severe. The illness affects mainly adults, and usually lasts two to six weeks. Most people who are infected show no signs of illness at all. Young children who are infected are less likely than adults to show any signs of illness.
The illness is usually accompanied by lethargy, a body rash and joint and muscle pains. In more severe cases, which are uncommon, arthritic pains may occasionally last for several months, but eventually this is followed by complete recovery. Once you have had the virus, you are immune for life.
Ross River virus infection is one of the less severe mosquito borne human diseases in Australia. Some more serious virus infections, such as Australian encephalitis, are spread by mosquitoes in the tropical North.

Ross River virus is carried by the saltmarsh mosquito

The main carrier of Ross River virus is the summer saltmarsh mosquito, ***Aedes vigilax***. Certain freshwater mosquitoes are also believed to harbour the virus.
The summer saltmarsh mosquito is found all along the Australian coastline, in estuaries, tidal rivers, mangroves, salt marshes and tidal flats.
Saltmarsh mosquito plagues are largely predictable, as enormous batches can emerge from pools and puddles left behind after high tides.
Female mosquitoes need animal or human blood before they can breed, and will travel up to 10 km looking for it.
There are some 90 varieties of mosquito in Western Australia. Saltmarsh mosquitoes can be distinguished by the black and white bands across their body and hind legs, though there are mosquitoes with similar markings which are not known carriers of Ross River virus.

Protect yourself from mosquitoes

Because Ross River virus infection can occur wherever mosquitoes are plentiful, people should take precautions to protect themselves from mosquito bites and to prevent mosquitoes from breeding.
Northern tropical climates and southern summers provide ideal conditions for the right mosquitoes to breed and people can put themselves at risk by spending warm evenings outdoors.
Because of this, the Health Department of Western Australia has suggested that, during South-West summers and in areas where mosquitoes occur, people should take special care if they are outdoors between sunset and 9pm, unless protected by adequate clothing and/or a suitable insect repellent.
Dawn is another time when female mosquitoes will actively seek blood, though saltmarsh mosquitoes will bite at any time of the day or night if conditions are suitably still and humid.
Not all insect repellents effectively repel mosquitoes. Choose one with the active ingredient Diethyl-M-toluamide (DEET). Though DEET is the most effective mosquito repellent known, there may be a toxic reaction if it is applied too heavily or too frequently. Be particularly careful with spray repellents not to over-apply. For children, repellents should contain less than 20 per cent DEET.
Some product names of suitable repellents are: Rid Cream and Rid Roll-On (16%), Rid Spray (10%), Aerogard Tropical Strength Lotion (19%), Apex Super Stick and Apex Super Lotion (20%), and Apex Super Spray (15.6%).

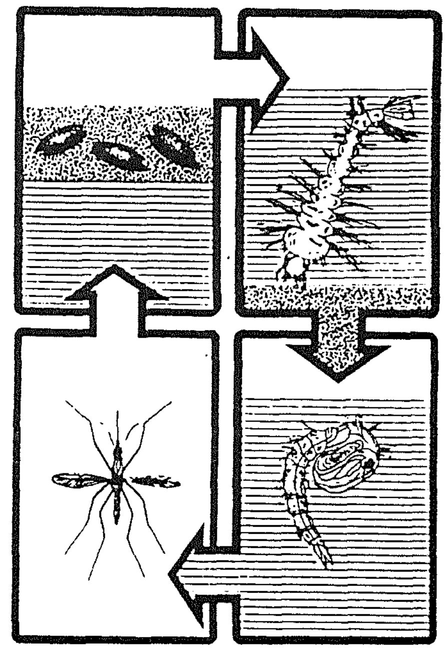
Mosquito control

All mosquitoes are a nuisance and some species are a risk to personal and community health. It is important to control them, especially in areas where people live, work and play.
Mosquito control is a community responsibility. Public authorities can assist by treating mosquito breeding areas and ensuring there are no stagnant pools in saltflat areas.
But it is up to us to deal with mosquitoes around our homes. The main task is eliminating breeding places, but personal protection from adult mosquitoes is also needed.
Here is a checklist for your protection:

- Remove debris from roof gutters and drain pipes.
- Pick up garden rubbish that may hold water – jars, bottles, plastic cartons, old tyres.
- Empty bird baths and pet water bowls regularly.
- Stock water gardens or ponds with mosquito-eating fish.
- Use flywire screens on doors and windows.
- Seal septic tank lids and cover vents with flywire. Use larvicide if necessary.
- Put flywire round rainwater tank inlets and overflows, or a cup and half of liquid paraffin or household cooking oil on top of the water in the tanks.
- Wear cover-up clothes when out of doors in the evening.
- Use insect repellent on exposed skin areas when mosquitoes are about.
- Protect sleeping babies and children with well-anchored mosquito nets.
- Holiday makers should remember to zip up mosquito net hatches on tents.
- Mosquito coils and lamps are useful for outdoor evenings.

Summer life cycle of the saltmarsh mosquito (Aeges vigilax)

1. Single eggs on moist tidal ground.
2. Larva in shallow pools 4-8 days.



4. Emerging females need blood before breeding.
3. Pupa – at rest 1-2 days.

APPENDIX 3

THE USE OF LARVICIDES FOR THE CONTROL OF MOSQUITO BREEDING

Extracted from Wright (1986))

5.3 THE USE OF LARVICIDES FOR THE CONTROL OF MOSQUITO BREEDING

5.3.1 Types of Equipment Used for Larvicide Application

5.3.1.1 Hand or Backpack Application.

Advantages over other application techniques include -

(i) Low initial costs of application equipment.

(ii) Little or no physical damage to the sites being treated.

(iii) Increased access to areas which are difficult to treat using vehicle mounted applicators.

(iv) Labour costs can be reduced using these techniques as operators can double as monitors to assess and record breeding in conjunction with larviciding operations.

The single major disadvantage of these techniques when compared to other application methods is that the size of areas which can be treated in a given amount of time is very limited.

In situations where mosquito breeding is synchronous (as for tidal *Aedes* species) and extends over a substantial area this limitation can mean that this technique is not viable.

5.3.1.2 Vehicle Mounted Larvicide Application

The major advantage of this technique when compared to hand or backpack application techniques is that much larger breeding areas can be treated in a given amount of time.

There are four disadvantages to this method of application:

(i) The initial cost of application equipment is relatively high.

(ii) Access to wet and boggy areas often associated with mosquito breeding sites is limited.

(iii) Vehicles used for larviciding operations can leave tyre marks in treated areas. These can hold water, thus facilitating future mosquito breeding by creating new breeding areas.

(iv) Vehicles used for larviciding operations can cause physical environmental damage to breeding areas. Obviously if such breeding areas are recreational areas, flora and fauna reserves or similar this is not desirable.

5.3.1.3 Aerial Application of Larvicides

Advantages over other application techniques include -

(i) Vast areas of mosquito breeding can be treated in a relatively short space of time. This factor is extremely important in the treatment of large, widely separated or otherwise inaccessible areas which breed Aedes species mosquitoes synchronously following inundation by high tides.

(ii) No physical damage to breeding areas should result from aerial application of larvicides. Obviously this is advantageous if the areas to be treated have value as recreation areas, flora and fauna reserves and the like.

Disadvantages compared to other application techniques.

(i) The high cost of aircraft and application equipment can be prohibitive.

(ii) It is not always easy, or for that matter possible, to treat breeding areas with the required precision using this technique.
Some breeding areas can be missed whilst other non-breeding areas can be needlessly treated. The needless use of larvicides has two disadvantages. Firstly and obviously unnecessary use of insecticide is costly. Secondly the excessive use of insecticide usually hastens the development of resistance to that insecticide in the target mosquito species.

APPENDIX 4

THE USE OF ADULICIDES FOR MOSQUITO CONTROL

Extracted from Wright (1986)

5.2 THE USE OF ADULTICIDES FOR MOSQUITO CONTROL

5.2.1 Types of fogging equipment

Adulticide fogging is usually carried out using either ULV (ultra low volume) cold fogging equipment or thermal fogging equipment. Both types of equipment produce insecticide fogs of extremely small droplet size (less than fifty microns diameter). The smaller the droplet size the greater the number of droplets produced per unit volume of insecticide and the greater the chance of contact with target mosquitoes. Therefore the smaller the droplet size the greater the effectiveness of insecticide application, until droplet size falls below ten microns when effectiveness is reduced due to inadequate impaction on target mosquitoes (N.T.Health Department) (Whelan, 1984) ULV cold fogging and thermal fogging have inherent advantages and disadvantages relative to each other.

5.2.1.1 Advantages and disadvantages of ULV cold fogging.

(i) ULV cold fogging by definition involves a low volume of insecticide which is often further reduced by dilution.

(ii) The fog produced is cold and therefore tends to stay close to the ground. Obviously if the target mosquitoes are flying or resting close to the ground this is an advantage. Conversely if the mosquitoes are flying higher or resting in trees this is a disadvantage.

(iii) ULV foggers are usually relatively large and vehicle mounted. This means that the speed of movement can be regulated enabling even application of insecticide at recommended dosages.

(iv) The output of ULV foggers means that relatively large areas can be treated.
Obviously if the terrain to be fogged is unsuitable for vehicles (eg thick forest or steep rocky ground) the size of ULV foggers is a disadvantage.

5.2.1.2 Advantages of Thermal Fogging

i) Small thermal foggers are more portable giving access in difficult terrain where vehicular access is prevented.

(ii) The fact that thermal fogs tend to rise is advantageous in situations where the target mosquitoes are either flying high or resting in tall trees.

5.2.1.3 Disadvantages of Thermal Fogging

Disadvantages of this technique include lack of control over speed of movement and adulticide dosage, the reduced size of the area which can be treated and the reduced effectiveness in treating mosquitoes flying or resting close to the ground.

5.2.2 <u>Insecticides used for adulticide fogging</u>

5.2.2.1 Availability and cost of Adulticides

In Western Australia two types of insecticide are widely used for adulticide fogging of mosquitoes. These are Maldison (Malathion) and ULV Pyrethroids, which are a mixture of Bioallentrin, Bioresmethrin and Piperonyl butoxide.

The use of Maldison is long established, with ULV Pyrethroids being only available since 1984.

The cost of application of these two adulticides is approximately the same per unit area to be treated, despite the much greater cost of ULV Pyrethroids. This is because Maldison is fogged in an undiluted form whereas ULV Pyrethroids are diluted at a ratio of 9:1 with diesolene.

5.2.2.2 Effectiveness of Adulticides

Reports vary as to the relative effectiveness of the two adulticides for mosquito control, however it is generally accepted that ULV Pyrethroids are at least as effective as Maldison if not more so. Lack of proper scientific assessment of the relative effectiveness of Maldison and ULV Pyrethroids in W.A. thus far prevents definitive comment in this regard.

5.2.2.3 Safety and Public Acceptance of Adulticides.

Maldison is considered fairly safe with a relatively low mammalian toxicity (acute oral LD50 for Rats 2800) (Worthing, 1983). The toxicity of ULV Pyrethroids generally even lower.

There have been reports throughout W.A. of complaints by residents concerning the use of Maldison for ULV fogging of mosquitoes. Claims of asthma, tainted food and a generally unpleasant smell are often made. In contrast the use of ULV Pyrethroids generally provokes less negative reactions from residents.

5.2.3 Advantages of Adulticide Fogging for Mosquito Control

(i) The biggest advantage of adulticide fogging is that the effect is almost instantaneous. If carried out properly all mosquitoes which come in contact with the fog are killed. This is especially important in situations where the mosquitoes concerned are carry ing disease. The only mosquito borne human disease of concern in the southwest of W.A. is epidemic polyarthritis caused by Ross River Virus. However quick results are also important in situations where ephemeral plagues of nuisance mosquitoes occur.

(ii) ULV fogging especially is very visible to residents so it can have an important public relations impact.

(iii) Where it is logistically impossible or not economically feasible to control or prevent mosquito breeding, adulticide fogging can be useful in creating a temporary buffer zone around susceptible residential areas. This is particularly so if the residential area concerned is small and surrounding mosquito breeding areas are both temporary and large, for example small isolated towns temporarily surrounded by floodwaters.

(iv) Insecticides for adulticide fogging are usually readily available and the cost of treatment per hectare is not excessive.

5.2.4 <u>Disadvantages of Adulticide Fogging for Mosquito Control</u>

(i) The capital cost of fogging equipment, especially the larger ULV machines, is considerable.

(ii) The cost of insecticides for adulticiding mosquitoes is recurrent; adulticide fogging only kills adult mosquitoes active at that time. It does not have a lasting effect, nor does it prevent or control mosquito breeding.

(iii) The effectiveness of adulticide fogging should be monitored using appropriate adult mosquito trapping techniques before and after fogging.
Therefore there is a considerable cost involved in manpower terms, especially for the identification of adult mosquitoes trapped.

(iv) Adulticide fogging cannot be undertaken when wind speeds are greater than approximately 10kph because at such speeds the fog disperses too quickly to be effective.

(v) Adulticide fogging must be carried out with the fogger moving across the direction of the breeze and the fog drifting downwind into the area being treated if treatment is to be effective. Therefore unless areas requiring fogging have access (via roads or tracks in the case of ULV foggers) on all four sides, fogging is limited to days when the wind is in the appropriate direction only. Obviously this means that sometimes fogging is not possible despite it being necessary.

(vi) Adulticide fogging should be carried out when adult mosquitoes of the target vector or nuisance species are actively flying, otherwise it is largely ineffective. The combination of (iv) (v) and (vi) often means that fogging has to be carried out at inconvenient times (eg dawn) and at short notice. The rates paid to operators are therefore often high.

(vii) The effectiveness of adulticide fogging is often reduced by thick vegetation such as that found along river margins and in some residential gardens.

(viii) Mosquitoes can develop resistence to insecticides in a relatively short space of time, especially if only one chemical is relied upon for control purposes.

(ix) Adulticides have some effect on non-target organisms as well as humans. Examples include useful insects such as bees, and predators of mosquitoes and flies such as dragonflies.

APPENDIX 5

PROCEDURE FOR HANDLING WATERBIRD MORTALITIES

APPENDIX 5

PROCEDURE FOR HANDLING WATERBIRD MORTALITIES

1. Prior to application of larvicide confirm that there are no sick/dead birds at each site.

2. Following the application of larvicide granules inspect each site for sick/dead waterbirds twice at 24 hour intervals after the actual application.

3. Sick Birds
If the bird is not moribund and rehabilitation is practicable it may be taken to a receival point at Mandurah or Bunbury where treatment can be obtained.

4. Moribund Birds.
Birds beyond help should be delivered live to the Department of Agriculture or killed and frozen for delivery as soon as possible to the laboratory.

5. Dead Birds.
Should be frozen as soon as possible with aldetailed label.
Information required: date, time sequnce, site information, condition and species.

6. Despatch.
Specimens should be delivered on a working day live or frozen to Dr J. Griffiths, Poultry Pathology Branch, "C" Block Department of Agriculture, Jarrah Road, South Perth. The specimens must be handed to a technician.