

# **Plant Biomass Management in the Ord Irrigation System**



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# ***Executive summary***

## **Growth and sources of plant biomass**

Weed growth in Ord River Irrigation Cooperative (ORIC) main channel consists of filamentous algae (mainly *Spirogyra*) and waterplants (mainly Ribbon Weed and Floating Pondweed).

Lake Kununurra will become increasingly enriched with nutrients and is a source of weed propagules including many new obstructive species.

Studies in the Daly River (Townsend and Padovan, 2005) are informative because climatic conditions and water quality are similar in the Daly River and Ord River Irrigation Area (ORIA). In the Daly River *Spirogyra* grows prolifically and is able to scavenge nutrients from the water even when concentrations are very low (close to or lower than undetectable concentrations). *Spirogyra* is expected to thrive in ORIA even though the water is oligotrophic (nutrient-poor).

The enrichment of M1 with effluent from the Waste Water Treatment Plant (WWTP) probably increases the growth of algae and waterplants but this was not demonstrated in the artificial substrate study.

## **Treatment with herbicides**

Acrolein is currently the only safe and effective herbicide for the OIC.

The efficiency of acrolein use in OIC channels can be improved substantially. Mixing at some injection sites is poor, dose rates when the main target is algae are too high, and positioning of injection points appears to be sub-optimal.

Timing of acrolein treatment in relation to the growth patterns of Ribbon Weed and Pondweed should be investigated.

Filamentous algae will continue to be a major problem in ORIA channels.

Vascular macrophytes can be more readily treated and controlled than algae.

Ribbon Weed and Floating Pondweed can be safely controlled by herbicides (glyphosate, imazapyr, carfentrazone) by application to static water during pauses in water supply. Research is needed to develop the methods.

## **Nutrient management**

A significant load of nutrients enters the Ivanhoe irrigation system from the WWTP; there is as much phosphorus load entering M1 from the WWTP as from Lake Kununurra.

Because the WWTP operates year round it is continuous source of nutrients for plants and their propagules. The algae and waterplants can rapidly reinfest the system as soon as irrigation commences.

## **Other control methods**

Mechanical harvesting has not been shown to be economical and energy efficient elsewhere in the world. The food value of the cut plants is generally low and requires supplementation. The time taken to cut 50 km of channel is many times greater than an acrolein treatment which will move through the whole system in a few days. Cutting inevitably results in pieces detaching and floating downstream, obstructing siphons. Filamentous algae is generally poorly managed by harvesting methods.

Piping irrigation water or shading is an effective control and may be economic where flows are small.

Draw-down is unlikely to be a regular suitable control method because of continual demand for water, the expansion of crops with high water demand, and the rapid reinfestation of the system with weed propagules from Lake Kununurra.

# ***Recommendations***

## **1 Control of algae and waterplants in the main supply channel**

### **1.1 Acrolein**

Vary the dose rate of acrolein to more accurately target the problem species.

Use the Magnacide test kit to determine the lowest rate of acrolein needed to control filamentous algae.

Evaluate the 'acrolein mixer' (Appendix 6) from Goulburn-Murray Water to overcome poor mixing and excessive loss of acrolein.

Develop a method to mix acrolein in static channel water to enable spot treatments to take place in short sections of channel.

Revisit the method of gathering information and reporting problem patches of instream weeds to the Water Superintendent to improve the precision of treatments.

Investigate the optimum timing for treatment of Ribbon Weed and Pondweeds.

### **1.2 Glyphosate**

Control Floating Pondweed by applying glyphosate to the floating leaves of the mature plant at 20L/ha during periods of temporary shutdown. This will require a permit as this species and the dose rate is not on the label.

### **1.3 Alternative herbicides**

Obtain approval from regulatory authority to test imazapyr and carfentrazone-ethyl on Ribbon Weed and Floating Pondweed when the channel is drawn down.

## **2 Control of algae in smaller and on-farm channels**

Given the inevitability of algal growth in the system and the problems it causes with blockages, establish methods of managing algae on farm by a range of methods including piping, localised treatment with acrolein, on-farm storage, shading and herbicides.

## **3 Nutrient management**

WWTP effluent probably stimulates the growth of plants in M1 during non-irrigation periods so the effluent should be diverted away from M1 canal.

Minimise nutrient enrichment of Lake Kununurra from town stormwater.

## **4 Education**

Organise and implement an annual workshop on aquatic weeds and algal issues for all involved in weed management in the area.

Arrange shed meetings as required to assist irrigators in understanding their role in preventative treatments (importance of draw-downs, reporting, acrolein, spot treatment with herbicides, on farm management of algae).

Consider the use of a web page to inform OIC personnel, other agency staff and the general public about plant management methods and to increase vigilance about the potential introduction of new species.

## **1 Background**

This report describes options for the management of filamentous algae (dominated by *Spirogyra*) and water plants (vascular aquatic macrophytes, mainly Ribbon Weed and Pondweed) in the irrigation supply channels of the Ord River Irrigation Areas (ORIA).

Weed problems in ORIA channels are similar to those in some other parts of Australia and the world. However, issues unique to ORIA include the demand for water for all but a few weeks or months of the year; oligotrophic (very low nutrient) water, and high level of plant propagules in Lake Kununurra that continually seed the irrigation channels.

Weeds are a problem because they block outlets, foot valves, flumes and siphons within the farm. System maintenance is currently dependent on the use of acrolein to control weeds while maintaining water flow, so minimising the cost and inconvenience of interrupting water delivery to the farm.

### **1.1 Terms of reference**

The objectives of this consultancy are to understand the drivers of weed growth, investigate the causes of the problem, and recommend economical and environmentally-acceptable options for management.

We adopted the following procedures:

- Examination of supply channels and lake Kununurra to investigate the factors contributing to weed growth;
- Consultation with OIC staff and farmers in the Ivanhoe Irrigation Area about limitations on methods given commercial requirements for water supply;
- Review of previous reports on nutrient concentrations and loads in MI originating from upstream (Lake Kununurra) and from point sources (WWTP and the sugar mill).
- Review of reports and research reports relevant to aquatic plant management in irrigation supply channels and drains from Australia and USA
- Synthesis of all the finding to develop recommendations for immediate action and further studies.

## **1.2 Grower concerns**

Issues were distilled from several discussions and workshops as follows:

### **Ongoing blockages of structures and siphons**

OIC and farmers are concerned about increasing effects of filamentous algae and waterplants in reducing water flow and blocking siphons.

### **Cost of acrolein**

Farmers are concerned that the cost of managing plants in the system will be transferred to water charges. Approximately 14,000 litres of acrolein is injected annually at a cost for herbicide alone of around \$400,000. Additionally, there are substantial operating costs for contractors to inject the herbicide and shut the system down.

### **Interruption of water supply**

The acrolein label requires a withholding period of 48 hours or enough time for the treated block of water to pass the farm off- take. This can be inconvenient so approaches that do not interrupt supply would be favoured.

### **Foreshadowed removal of subsidy**

The WA Water Corporation currently provide funds to manage M1 channel operation and purchase of acrolein but after the foreshadowed removal of subsidy there is concern that the substantial cost will be transferred to irrigators.

### **Over-reliance on acrolein**

Reliance on acrolein is a risk because the source of supply is limited and there is a danger that its registration could be revoked. Farmers enquired about alternative management methods.

### **Inconvenience of draw-down as an alternative**

Current demand for water during the irrigation season does not allow for a draw-down. The need to continue irrigation in the ORIA channels varies from year to year, but the main season extends from autumn to late spring (usually April to October) when the opportunity to draw the system down is restricted or negligible. An increase in row-cropping in the Ord, together with hot dry and windy weather, increases the need to have water available without a break. The unrestricted availability of acrolein allows the system to operate continuously.

## **2 Plant biomass**

### **2.1 Background and previous studies**

The prime aim of this study is to investigate whether increased production of algae and waterplants could be caused by the inflow of effluent from the Kununurra Waste Water Treatment Plant (WWTP).

Previous studies (Durand and Penfold 1997; Jones, 1997 and Price, 2005) concluded that the WWTP effluent increases nutrient concentrations and loads, and contend that the growth of algae and waterplants will increase. The WWTP delivers approximately the same load of phosphorus to the M1 canal as enters the system from Lake Kununurra (Price 2005).

In the nearby Daly River studies, a study showed that *Spirogyra* sp. (the main alga in the Ord River Irrigation Area) will thrive in nutrient- poor water (Townsend and Padovan, 2005). The extremely low nutrient levels in the Daly River are lower than in ORIA water, but in the Daly River, where there were masses of *Spirogyra*, much of the nutrient was tied up in the plant biomass.

Excluding the WWTP effluent from the M1 canal will halve the nutrient enrichment of the system, but translating that into measurable differences in algal growth is difficult. We are wary of conclusions drawn from measuring concentrations upstream and downstream of the WWTP (which is used in licensing to demonstrate that impact is small) because nutrients may be readily scavenged (or taken up from the water) by algae and waterplants. Other complexities that make interpretation difficult include:

- Competition for nutrients between algae, waterplants, biofilms (aufwuchs) and sediments.
- Different forms of nutrient being more or less available to plants (eg phosphate – phosphorus, nitrate nitrogen and ammonium-nitrogen being more available; and total phosphorus and total nitrogen being less available). Also phosphorus that is adsorbed onto sediments suspended or particulate matter is less available than dissolved phosphorus.
- Transformation of nutrients from one form to another (less to more available or vice versa) through bacterial action.
- Losses of nitrogen as gas in the processes of nitrification (ammonium to nitrate nitrogen conversion that occurs in oxygenated conditions) and denitrification (nitrate nitrogen conversion to gaseous nitrogen and nitrous oxides that occurs in anaerobic (oxygen free) conditions).
- Phosphorus complexed with iron compounds in aerobic conditions is relatively insoluble and unavailable but may be dissolved and become more readily available to plants in more acid or anaerobic conditions.
- Some algae can fix their own nitrogen from the atmosphere and this may apply to *Spirogyra*.
- Nutrient availability to plant leaves is likely to be determined by the extent of close contact of leaf surfaces with the enriched water, which will be affected by the degree of turbulence, extent of plant clumping and protective coating on the leaves (biofilms and precipitated clays).

Consequently a range of factors are likely to be involved in determining the extent to which an increase of nutrients from the WWTP can be expected to result in an increase in algae and waterplants. In general terms the **concentration** of available forms of nutrients in water downstream might be regarded as a crude surrogate for increased probability of growth while the relative **load** of WWTP relative to upstream loads might be regarded as an indication of long term enrichment (i.e. increased growth may not result for some months or years, or until conditions are favourable to release of bioavailable forms of nutrients from sediments).

There are at least two main problems in the interpretation of concentration as a driver for algae and waterplant growth apart from the dot point listed above. One is that, as previously mentioned, any available nutrients may already have been scavenged from the water column by the existing plants. Secondly, very low concentrations, at or below limits of detection may be sufficient to drive the growth of algae and waterplants.

Because of these difficulties we used artificial substrates (glass surfaces anchored into the water upstream and downstream of the WWTP) to investigate the effects of nutrients on the potential of plant growth as it is reflected in the rate of growth of biofilms (Appendix 6).

The role of sediment in holding and releasing nutrients into the channel water was considered. The results from such a study are likely to be highly variable. Organically-rich sediment collects at structures and where water slows on bends in the channel. The organic matter content and aerobic status (presence or absence of oxygen) of the sediments is expected to influence their capacity to absorb or release nutrients, and this in turn may be affected by the rate of decomposition of organic material including decaying plant tissue. We consider that the logistics of sampling intensity and range of variables that would need to be measured to show trends would be intensive and beyond the time and scope of this current study.

## **2.2 Algae**

Species of *Spirogyra* and *Oedogonium*, both common filamentous algae, thrive in ORIA channels and Lake Kununurra.

Filamentous algae often forms mats on the water surface or caught on the channel bed or on macrophytes. Phytoplankton, including blue-green algae and diatoms, are either free floating throughout the water column or attached to surfaces (Boulton and Brock, 1999; Casanova, 2003; Entwisle, Sonneman and Lewis, 1997).

A boom and bust sequence of algal species usually occurs in all systems as a result of changes in velocity, light, nutrients, turbidity, temperature and the presence of grazing organisms. Conditions in Lake Kununurra and the ORIA channel system are conducive to the growth of algae and, apart from acrolein, there is no method known that could safely and economically stop this growth other than piping the flow.

Note that controlling the waterplants invariably results in an increase in the growth of algae. All aquatic plants are competing for nutrients in the system and if one plant group is reduced in abundance, the other group will scavenge the available nutrients.

The study has of *Spirogyra* in the Daly River (Appendix 3) has direct relevance to ORIA channels and provides an alert about the potential of algae to thrive in oligotrophic (low nutrient) waters.

Notes on filamentous (macroalgae) provided by Stephen Skinner, Senior Botanist, NSW Royal Botanic Gardens are provided in Table 1.

**Table 1 Notes on reproduction of algae (Stephen Skinner, pers.comm., 2006)**

*“The widespread Spirogyra is probably seasonal in natural (river) behaviour, going through a cycle of germination from spore when new season’s rain arrives, followed by rapid growth of filaments and filament fragmentation into short cell packets that again rapidly divide to make long filaments. This vegetative multiplication may continue while light, temperature, nutrient and depth conditions are favourable. With crowding, increased water temperature and less light penetration, and often a drop in potassium levels, and especially with stranding, the filaments will switch to conjugation, whereby the contents of cells from one filament join with the contents of a complimentary cell in another filament, and the zygote thus formed results in spore formation. These spores are thick walled and resist drying out. Mid to late dry season is the time for spore formation.”*

*“Life in an irrigation channel has much less of this seasonality, and offers an always abundant supply of nutrients, usually associated with well-oxygenated water. The Spirogyra population may thus be in a loop of continuous cell division, and channels will fill quickly with Silkweed, as these algae have only the weakest of anchor cells, and most often form semi-submerged rafts in water-bodies. As the cells are efficient at photosynthesis, the rafts quickly trap large gas bubbles on warm sunny days and the buoyant rafts floats easily on any current or wind-drift, to form larger and larger metaphyton masses. Similar behaviour is true of any macroalgal streamers or raft-formers (Cladophora, Rhizoclonium, Pithophora, Hydrodictyon, Vaucheria and all the filamentous Zygnematales). In a free-flowing system with plenty of snags, the rafts may not bank up for long periods. In a closed system such as a channel, the rafts will bank up at the downstream end day after day, especially if there is no emergent vegetation that can catch and break-up such rafts before they reach the end.”*

*Like the Silkweeds, Oedogonium can multiply very rapidly by vegetative means, here involving flagellated spores rather than fragmentation. Usually a small number of thick walled non-motile spores are set late in the dry season, these germinate in the wet, and the filaments grow rapidly. When conditions are appropriate, the upper cells in filaments turn themselves into mobile bodies and the cells fold back at the top and release the swimming stage, say five to ten per filament on any one occasion. The swimmers settle and germinate and grow a new filament each. This multiplication phase can continue for some time. Sometimes the swimming stage from a male filament will be attracted to the potentially reproductive cells in a female filament, and settling on the cell that gives rise to the egg chamber, form a miniature filament with male cells at the tip. The male spermatozoid will find the pore in the egg chamber, fuse with the egg and form the spiny spore. This spore is drought proof.”*

*“Any solution (e.g. acrolein) which involves a sudden disappearance of one metaphyton community will almost certainly be followed by another equally difficult floating or suspended nuisance, so long as the conditions in the water and the upstream catchment have not changed. Indeed, clearing out one lot of weed, macrophyte or macroalgal, will provide a boost in light levels that can only favour another ‘bloom’. If the problem is one of wind concentration, or local stream flow concentration, of floating and suspended algae (metaphyton) then some form of barrage may be the least disruptive method of management.”*

*“Blooms of aquatic macrophytes or macroalgae are often symptoms of less than optimum agricultural practices in the catchment. Algae, not being sentient beings, are not malicious or vindictive. A bloom in one part of an aquatic system is a biological means of mopping up excess nutrients and, provided the flow is adequate, spreading the nutrient load down-stream. It is a natural, albeit not always attractive, method of cleaning a waterway.”*

*“No pattern of growth has been identified but algae generally bloom in cycles. Growth is rapid and dense infestations appear within a week. It is probable that turbid water aids the growth of algae during periods when the submerged macrophytes (higher flowering plants) are limited by poor light penetration.”*

## 2.3 Waterplants

The main obstructive species in the system are Ribbon Weed (*Vallisneria nana*) and Floating Pondweed (*Potamogeton tepperi*), both native robust perennials. These and similar species are major weeds of irrigation systems throughout Australia. Acrolein is temporarily effective on these species.

Lake Kununurra now supports a rich mix of submerged and emergent waterplants, mostly native species. However, there are also a number of minor annual weeds were observed. *Salvinia molesta*, *Urochloa mutica* and possibly *Typha* sp. are potentially serious weeds. The main species are listed with comment on their abundance.

**Table 2 Waterplants observed in Lake Kununurra, and abundance (GR Sainty, 2006)**

<b>Waterplant Species</b>	<b>Abundance</b>
<b>Submerged</b>	
<i>Vallisneria nana</i>	xxx
<i>Potamogeton tepperi</i>	xxx
<i>Potamogeton crispus</i>	x
<i>Hydrilla verticillata</i>	xx
<i>Salvinia molesta</i>	none sighted
<i>Utricularia</i> sp.	xx
<b>Emergent</b>	
<i>Typha orientalis</i> , <i>Typha ?domingensis</i>	xxx
<i>Phragmites vallatoria</i>	xx
<i>Ludwigia adscendens</i>	xxx
<i>Nymphoides indica</i>	xxx
<i>Nymphaea violacea</i>	x
<i>Wolffia angusta</i>	xxx
<i>Ludwigia octovalvis</i>	xxx
<i>Ludwigia adscendens</i>	x
<i>Persicaria attenuata</i>	x

## 2.4 Biofilms and aufwuchs

Heavy loadings of clay colloidal material with *aufwuchs* (epiphytic and filamentous algae, diatoms, bacteria and detritus) are often found on submerged waterplants (Bowmer 1982). Data on the algal components of *aufwuchs* are given by Cook (1979) who reports that diatoms may contribute significantly to productivity in submerged weed beds.

Leaves of *Potamogeton tepperi* and *Vallisneria nana* in the M1 canal in July, August and September were generally clear of *aufwuchs*, probably because most of the submerged leaves were stripped clean by the monthly acrolein treatment.

The significance of these leaf coatings is that they may adsorb herbicides and protect the leaves of waterplants. In introducing new herbicides it may be necessary to continuing some low level treatment with acrolein to increase efficiency.

### 3 Factors driving weed growth

#### 3.1 Propagules and sources

The M1 channel, associated laterals and lake Kununurra were inspected for algae and waterplants during a series of visits in July, August and September 2006 (Table 2). An outbreak of *Salvinia molesta* had occurred there, and an eradication program had been started. The section of Lake Kununurra known as Blue Lily Lagoon, adjacent to the town, contains thriving mats of emergent and floating waterplants as well as filamentous algae and phytoplankton. Pooled water in Lake Kununurra contains a wide range of aquatic plants and pieces and seeds are drawn into the Ivanhoe and Packsaddle channel systems, especially when the system is operating at full capacity. In due course, given the permanent pool of water in Lake Kununurra and the movement of people through the area, the number of species of waterplants and algae in the irrigation system is certain to rise. Consequently any weed control measures must be continuous to counter re-infection from Lake Kununurra.

#### 3.2 Nutrient enrichment

Waterplants can absorb nutrients from both sediments and the water column. Ribbon Weed has a well developed root system and sources some nutrients from the substratum. Pondweed, with a poorly-developed root system and large submerged leaves, is more dependent on nutrients in the water. Filamentous algae, including *Spirogyra*, are excellent scavengers of nutrients from water.

Jones (1997) described the Ord River as having amongst the lowest nutrient concentrations in Australia, reflecting low catchment development, low nutrient status rocks and soils, and high volumes of run-off. Water diverted into M1 has limited opportunity to be enriched in the diversion pool, although this is changing as the town grows.

Price (2005) examined water quality data gathered in the M1 from 1996/97 to 2003, finding a large variation over time. Guidelines (ANZECC /ARMCANZ) provide trigger concentrations for excessive growth of waterplants and algae. If phosphorus is the limiting nutrient, concentrations above 0.05 mg/L (equivalent to 50 micrograms per Litre) could lead to enhanced algal growth. Price found that trigger concentrations were exceeded on a number of occasions and for up to 6 km downstream of the WWTP discharge point.

The WWTP and Sugar Mill both supply nutrients to M1. Price (2005) compared nutrient loads from various ORIA studies (Appendix 5). The relative increase in load of phosphorus in M1 is much greater for WWTP than the sugar mill (Table3). Also the nitrogen to phosphorus ratio (N: P ratio) in M1 water was related to the Redfield ratio (the N: P ratio in plant tissue). There was a significant difference between the ratio in the irrigation channel before and after the WWTP effluent input. Price concluded that WWTP increases the load and concentration of nutrients in the channel and also brings them into a ratio that is ideal for plant growth.

**Table 3 Percent increase (+/- standard deviation) in nutrient loads in the M1 channel as a result of the WWTP and sugar mill discharge.**

Element	Sugar mill	WWTP
Nitrogen	21 +/- 33	89 +/- 206
Phosphorus	5 +/- 4	168 +/- 317

The difficulties of interpreting concentration and loads of nutrients in relation to growth of water plants and algae have been discussed earlier (Section 2.1).

## 4 Management options

### 4.1 Herbicides

#### 4.1.1 Treatment of flowing water with acrolein

Acrolein is the most efficient of the approved methods of managing waterplants and algae. Because of the volatile and toxic nature of the concentrate special diligence is required for handling, notification of use and supervision.

Comparative costs (Appendix 1) show acrolein to be the most cost effective method of controlling submerged vegetation in irrigation supply channels. It has a very short life, and the acrolein break-down product is an aldehyde that occurs naturally in the environment. Since 1960 there have been no cases in Australia where it has been shown that acrolein has caused crop loss. However the use of this herbicide is still constrained by the current label that restricts use to injections of 8 hours.

#### Efficient use of acrolein

Acrolein should be injected at the minimum concentration required to control a species at the most downstream point. This requires site-specific data on the half-life of acrolein and the sensitivity of the species to this herbicide (Table 4). Injection should take place immediately upstream of the weed growth and not necessarily at the regulator. A device developed by Goulburn-Murray Irrigation enables mixing to take place anywhere along the channel, and not necessarily at a structure.

A report to WA Water Corporation by Goulburn Murray Water (J Wilding pers. comm. to G R Sainty) concludes that there was inadequate mixing of acrolein at a number of injection points in ORIA channels and much of the herbicide was lost by volatilisation (see Appendix 6 for details). Also the dose rate for Floating Pondweed (*Potamogeton tepperi*) is many times that required for algae (Table 4). The concentrations required for an injection over 4 hours are 6.5 ppm for Pondweed and 0.25 ppm for algae. Algae multiply in days whereas Floating Pondweed and Ribbon Weed take weeks to regrow.

**Table 4 Acrolein dose rates for waterplants and algae (Bowmer 1974, 1997; Wilding pers. comm.)**

Species	4 hours	24 hours
<i>Potamogeton tepperi</i>	6.5 ppm	1.1 ppm
<i>Vallisneria nana</i>	1	0.165
<i>Hydrilla verticillata</i>	2.1	0.35
<i>Elodea canadensis</i>		
Filamentous algae	0.25	0.1

Whilst the monthly treatment simplifies notification of farmers that the water cannot be used and enables flow to be reduced, the dose rate is often many times that required to control algae.

The climate at Kununurra results in a longer growing period for macrophytes than in temperate areas. Timing acrolein treatment in relation to the growth patterns has not been studied in ORIA channels and requires more investigation.

A review of acrolein application methods is recommended. A more targeted dose rate and better mixing at the injection point may lead to a significant reduction in acrolein use.

### **Risk of over-reliance on acrolein**

Growers have raised the risk of over-reliance on acrolein. Baker Petrolite is currently the sole supplier of acrolein (Magnacide H) to Australia and currently controls the world use of the product for use as a herbicide. Magnacide B is extensively used to control bacteria and fungi in oilfield water. Acrolein is produced in Europe and transported in bulk to a facility near Bakersfield in California USA then shipped to Australia in 200 litre cylinders.

Shell Chemicals (Australia) Pty Ltd developed and marketed acrolein under the name Aqualin. It was first used in the USA in 1959 and Australia in 1961 and since then it has been used widely and proven to be the safest and most effective herbicide for submerged weed control in irrigation systems.

Given the importance of acrolein to irrigated agriculture in many parts of the world and its short half life (Bowmer and Sainty, 1991), its withdrawal from sale is unlikely.

### **Risks from OH&S and OIC liability**

Undiluted acrolein is hazardous and if an operator inhales gas from the concentrate it may have serious consequences. A death from exposure to undiluted acrolein occurred in the USA in 2001 when an operator not using a mask came in contact with a ruptured hose whilst applying acrolein to a channel. He was not detained in hospital and collapsed away from medical help. Regulated transport, storage and restricted application (under permit) reduce the risk of accident. Vigilance and training is required.

#### **4.1.2 Treatment of static water with other herbicides**

Whenever irrigation ceases there should be a major programme to treat obstructive patches of waterplants. There are a few herbicides that can be used including applying acrolein to the shallow water retained in parts of the system and the water that flows from WWTP. (For a full list of potential herbicides see Appendix 1). A short list follows:

#### **Glyphosate**

Very effective on Floating Pondweed (R. Baker pers. comm.). Water containing the herbicide should be managed so that there is no possibility of claims succeeding alleging crop or ecosystem damage. Dissipating the first flush on fallow or non-crop land would further ensure that the residue does not move into the wider environment.

#### **Carfentrazone-ethyl and Triclopyr**

Not yet labelled for aquatic use in Australia. Carfentrazone is registered as Hammer in WA for crop weed control. Triclopyr is widely used for brush control. Both have obtained registration in aquatic ecosystems in many states in North America. Subject to a permit being obtained, these herbicides should be evaluated on Floating Pondweed and Ribbon Weed, the application to take place when the plants are first exposed at drawdown.

#### **Imazapyr**

Registered for aquatic use in Australia as Arsenal. Some potential for application to Floating Pondweed at drawdown. One of group of aquatic herbicides that require evaluation in ORIA.

**Fluridone**

Effective on Ribbon Weed in static water at extremely low concentrations (around 5 parts per billion), but is persistent and not recommended. Proved extremely effective on Ribbon Weed and Floating Pondweed in the 2000 Olympics rowing course. Persistence in water probably precludes its use in irrigation systems. Not registered in Australia.

**Dichlobenil**

Registered to control a wide range of waterplants but not sufficiently effective and too expensive for general use.

**Terbutryne**

Effective on submerged plants but not registered.

**Chelated copper**

Prohibitively expensive in large flows and the copper content presents an unacceptable residue risk.

**4.1.3 Guidelines for protection of water users and aquatic life**

Aquatic vegetation management methods that are appropriate for channels supplying water may be harmful to natural systems—creeks and rivers—that have different management objectives. Residues of herbicides may be inappropriate when water is used for stock and domestic purposes and irrigation.

The 2000 ANZECC Water Quality Guidelines have been developed to protect human health, crops and aquatic ecosystems. The Guidelines place emphasis on maintaining productivity of agricultural land in accordance with ecologically sustainable development and integrated catchment management. The Guidelines take account of the different characteristics of an area and provide the process by which appropriate 'trigger' levels can be set for a particular pesticide.

**4.2 Drawdown**

The opportunity to drain the channels is, at present, restricted to the period between October and April and then the shutdown is dependent on rain falling in the summer. This provides limited time to carry out structural work and maintenance including mechanical and chemical treatment to control waterweeds. Undoubtedly draw-down and drying is a most the most effective treatment if it can be achieved. Capacity to store water on-farm to bridge the drawdown period is currently limited.

Lining channels, and piping water may reduce or eliminate the problems caused by aquatic plant growth but capital and operating costs will be substantial. Assessments have been made recently in the Murrumbidgee Valley Water Feasibility project (Pratt Water, 2004)

**4.3 Other physical methods**

Submerged and emergent waterplants have thrived in Lake Kununurra and are frequently cut by propellers. Submerged species, notably Ribbon Weed periodically shed leaves (commonly observed in temperate Australia) and these float to the surface and are drawn to the M1 intake. These pieces block structures and siphons. The only practical control is regular cleaning and maintenance of the floating boom positioned at the intake to M1 and Packsaddle pumps.

Other physical methods that are occasionally used are described in Appendix 1. Mechanical cutting has not been shown to be economical or efficient elsewhere in the World. Cut pieces of unharvested pieces block siphons. The time taken to cut through a system is many times longer than that achieved by a single application of acrolein. Cutting handles filamentous algae poorly.

#### **4.4 Reduction in nutrient loading**

As noted earlier (Section 2.1) there are five previous reports on the role of nutrients in the system in driving growth of waterplants and algae (Jones, 1997; Durand and Penfold, 1997; Doupe, 1998; Rosich and Partridge, 1998; and Price 2005).

Penfold and Durand concluded that:

- The soils of the Ord River catchment and those adjacent to irrigation channels are naturally low in nitrogen and phosphorus and do not significantly contribute to nutrient levels in channel water.
- Effluent from the Kununurra WWTP piped into the M1 main supply channel is a major point source of nutrients, particularly phosphorus. Similar loads of phosphorus are entering the M1 from the WWTP and from Lake Kununurra. The phosphorus discharge from the Sugar Mill was considerable in 1996.
- Acrolein could be more efficiently injected if a low dose injection was introduced, as has been the practice in Victoria for many years. (Note: this is contrary to the acrolein label and cannot be adopted).

Price (2005) investigated nutrients produced by the WWTP and the Sugar Mill. She calculated that WWTP with a flow of 1 ML/day adds as much phosphorus to M1 as 1000 ML/day flow from Lake Kununurra. She concluded that:

- It is highly likely that the problem of weed and algal growth in the M1 channel is caused by nutrient input from the WWTP.
- The concentration of phosphorus in the M1 channel past the WWTP discharge has on occasions exceeded the ANZECC/ARMCANZ trigger levels for irrigation water.
- The concentration in the M1, past the Sugar Mill discharge, has exceeded trigger levels on occasion but this changed dramatically since the removal of sludge from the discharge in 1999. Since then trigger level for phosphorus has been exceeded slightly only once.
- Over the last half of 2003 and all of 2004 the increase in total phosphorus and total nitrogen loads into the M1 from the WWTP effluent has been 985% and 167%. The maximum was 1000% increase in nitrogen and a 1500% increase in phosphorus in February 2004.
- In comparison the Sugar Mills contribution is much less, with a negligible increase in phosphorus load and an averaging increase of about 21% in nitrogen load.
- In addition to an increase in total nutrients in the channel from the WWTP discharge, there is a significant shift in the nutrient ratio that makes conditions more favourable for algal growth.
- The shift in nutrient ratio is not significant from the Sugar Mill discharge

The full report by Price (2005) is at Appendix 5.

Reduction in nutrient loads can be achieved by re- routing WWTP flow from M1 channel, by retrofitting Water Sensitive Urban Design (WSUD) principles to Kununurra, and by reducing fertiliser drainage in flow to Lake Kununurra.

### **Water sensitive urban design**

As noted earlier, Ord River water is extremely poor in nutrients and low in turbidity (Jones 1996). Water pooled in Lake Kununurra inevitably increases in nutrients given human activities on its shores. The arm of Lake Kununurra (Lily Creek Lagoon) adjacent to the town of Kununurra (near where the M1 off take is situated) seems to be significantly enriched with nutrients since the growth of waterplants there is profuse.

The population of Kununurra fluctuates from 6000 to 12000 and this will probably double with the planned irrigation expansion. Water from gardens, industry, roads and playing surfaces drains from a large part of the town into Lake Kununurra, where much of the nutrient load is probably absorbed by waterplants and algae. By extrapolation from evidence elsewhere in Australia, at least 0.5 kg P/ha annum may be produced by urban areas, draining into Lake Kununurra in pulses, especially during flooding rain. Given that the town covers about 3 km<sup>2</sup> or 300 ha, 100 to 150 kg of P could drain to Lake Kununurra each year. During winter, sediments under pooled water near the town may periodically release phosphorus when oxygen levels are depleted, enriching M1 once flows return.

Methods have been developed to reduce urban production of nutrients by principles of Water Sensitive Urban Design, but in monsoonal areas where 100 mm rainfall events occur regularly, intercepting more than 50% of the phosphorus is unlikely and if WSUD was implemented, enrichment of the system is slowed down but not stopped.

The Kununurra Caravan Park appears to drain directly into the M1 channel. This should be avoided since it will result in ponding in the channel during shut down periods.

### **4.5 Do nothing option**

Integrated pest management (IPM) is a weed management approach that has been generally adopted overseas and in Australia. The basis of IPM is a measuring of economic injury level (EIL) and economic threshold (ET). The threshold concept rests on the premise that not all pests require management and that some level of presence or abundance is tolerable.

Channel emergent and bank weeds are being effectively controlled in most circumstances. Apart from the major weeds continued care needs to be taken to ensure that vegetation is retained on the banks to prevent erosion from taking place. However control of filamentous algae presents a special problem, as growth is rapid—measured in days—and re-infestation of the system is continually taking place from Lake Kununurra. A critical question is whether the growth of algae could be tolerated if siphon blockage could be avoided or limited. The use of larger siphons (with head ditches) and mechanical methods for skimming off clumps of floating algae might be worth investigation.

## **5 Education and governance**

### **5.1 Education and extension**

Effective weed control requires an ongoing understanding of the variables that affect plant growth. We suggest that workshops to inform OIC staff about the problems and vegetation management methods, and information seminars for the wider community would go a long way to improving waterplant management. A frequently updated web page might be another useful approach.

## **5.2 Role of Water Corporation of Western Australia**

Currently the M1 channel is maintained by OIC in a contract with WA Water Corporation. This allows OIC to carry out maintenance and recoup expenses, including acrolein needed to treat M1. In the event of transfer of ownership and responsibility for M1 management to OIC we recommend that the open ended discharge of sewage effluent to M1 should cease.

## **6 Conclusion**

Ord River waters, although naturally low in nutrients, are probably able to support substantial growth of filamentous algae because they are able to scavenge the water for phosphorus and may be able to fix their own nitrogen. The effects of nutrient loading on growth of algae and waterplants is likely to be complicated by competition for nutrients between algae, plants and sediment, losses of nitrogen to the atmosphere under certain conditions, and changes in availability of phosphorus through chemical and biological reactions.

Studies with artificial substrates (Appendix 8 of this report) did not demonstrate that WWTP effluent increased the growth of algae but this may reflect the complexities described above and the competition of waterplants in nutrient scavenging. Extrapolating from various studies elsewhere it seems that the enrichment of the system with phosphorus from the WWTP and from urban stormwater run-off will increase the growth of plants and algae, though the relationship between load and plant growth may not be a linear one

We recommend a precautionary approach with management to reduce current nutrient sources and planning to minimise nutrient enrichment from future urban developments. Meanwhile, and whether or not nutrient loadings are reduced, we expect that algae and waterplant management with acrolein will remain a central feature of OIC operations. Optimisation of application methods to improve efficiency with acrolein should be adopted as a sensible and economic strategy.

Mechanical harvesting has limited potential and is inefficient when compared with the speed of an acrolein treatment. Mechanical harvesting does not control algae that grows diffusely and blocks siphons.

Floating Pondweed, a major obstructive native plant in ORIA channels can be controlled by glyphosate, as has been demonstrated in channels in Victoria.

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## **8 Appendices**

***Appendix 1 Alternatives to acrolein—methods of controlling algae and waterplants***

***Appendix 2 Daly River Study (Townsend and Padovan, 2005)***

***Appendix 3 The Acrolein Review (Bowmer and Sainty, 1991)***

***Appendix 4 Nutrient Loading in the M1 Channel (Price, 2005)***

***Appendix 5 Carfentrazone-ethyl, imazapyr, triclopyr. Herbicide Fact Sheets***

***Appendix 6 Acrolein Efficiency Study***

***Appendix 7 Ecological Risk Assessment***

***Appendix 8 ANCID (2007) paper on biomass management***

***Appendix 9 Biomass chlorophyll data set***

***Appendix 10 Benthic Algae. Measurement of effects of WWTP on algal productivity using artificial substrates***