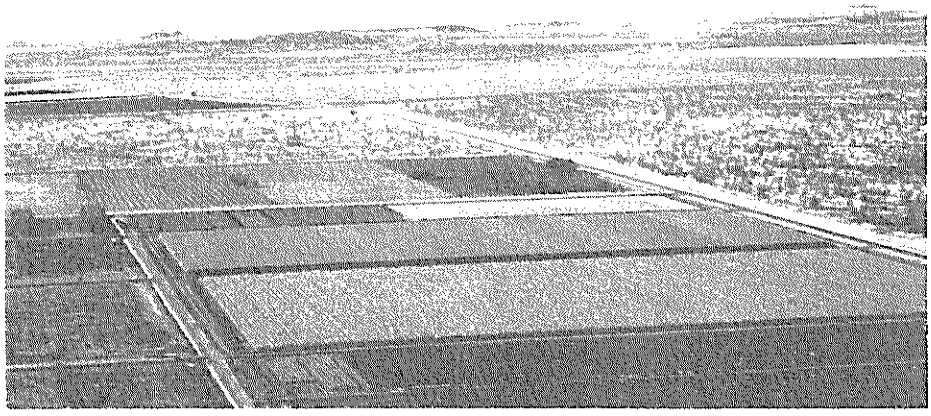
KIMBERLEY
DEVELOPMENT COMMISSION

ORD RIVER IRRIGATION AREA

BEST PRACTICE IN IRRIGATED AGRICULTURE



Some Innovative and Practical Techniques in Land and Water Management

THE GOVERNMENT OF WESTERN AUSTRALIA

ORD RIVER IRRIGATION AREA

BEST PRACTICE IN IRRIGATED AGRICULTURE

Some Innovative and Practical Techniques in Land and Water Management

A RESOURCE DOCUMENT

MARCH 1998

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FOREWORD

The Ord River Irrigation Scheme is a unique and successful agricultural development in the East Kimberley district of Western Australia, which offers significant potential to attract substantial new investment and provide new employment opportunities.

The area has proven resources that are well suited to a range of high-value and diversified irrigated agricultural production and industry value-adding opportunities. The region's comparative advantage includes its substantial and highly reliable water supply, land suitable for further scheme expansion, a twelve month growing season, 'off-season' supply into major southern markets, modern scheme design and the dynamic and professional approach of district growers to agriculture and industry issues.

The long term development and maintenance of successful agriculture on the Ord will be sustained by the effective and efficient management of its land and water resources. An important component of this sustainable approach to resource management will be the continued focus on innovative practices and techniques in irrigation and groundwater management to prevent any deterioration in surface and groundwater quality.

For this purpose I initiated, with the Kimberley Development Commission, some practical research to identify and describe a number of innovative and useful best practice techniques in water management suited to conditions on the Ord. This report BEST PRACTICE IN IRRIGATION FARMING: Some *Innovative and Practical Techniques in Land and Water Management*, summarises the outcomes of this research.

The Report describes the key features, broad performance issues and provides a technical overview for each of the land and water management techniques identified. The resulting comprehensive database referred to in the report includes a full set of papers, detailed references, technical notes, academic papers and industry contacts that can support further research into the performance and application of each of the identified management techniques.

Growers and industry people wishing to further assess these techniques and applicability to specific circumstances are encouraged to examine the complete database and use the industry contacts provided within it. The database is assembled to afford easy public access and is available at the office of the Kimberley Development Commission in Papuana Street, Kununurra.

I extend my appreciation to the Kimberley Development Commission, the project staff and management group involved in completing this important and valuable work. I commend this as a valuable resource to support and further develop the management of land and water resources on the Ord.

Monty House MLA
MINISTER FOR PRIMARY INDUSTRY; FISHERIES

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INTRODUCTION

This report is the result of a research project initiated by the Minister for Primary Industry and Fisheries, Hon Monty House.

The purpose of the study was to draw upon national and international water management research to identify innovative and practical technologies applicable to water management in the Ord River Irrigation Area (ORIA) located around Kununurra in the East Kimberley district of Western Australia.

The project focuses on techniques to improve irrigation resource management and efficiency including the control of rising groundwater and on-farm retention of sediment, nutrients and farm chemicals.

Information and published material was gathered from industry, government, academic and scientific sources. This was achieved through personal communication and internet research and used the introductory letter and project description included in Appendices 1 and 2.

The outcome of the project is in the form of an accessible information base that may be periodically updated and comprises an overview of best practice techniques, industry contacts and relevant source information. References to relevant and useful publications, articles and investigative reports gathered in the course of the project are provided in Appendix 3.

Copies of this summary report are available on request from the Kimberley Development Commission in Kununurra and the detailed and supporting documentation of the information base is available for industry and public use at the Commission's Kununurra library.

The techniques identified within this report may not be applicable to all primary production systems or environmental conditions throughout the ORIA. The output of the project will make an important and useful contribution to local research initiatives and provide a starting point for suitability and feasibility assessment of these best practice techniques. The report is considered to be an introductory resource document that will provide a practical reference relevant to the Land and Water Management Plan currently being developed for the ORIA.

The project was researched and compiled by Mr Alister Mackinnon, Project Officer at the Kimberley Development Commission, and overseen by a reference group comprising Mr Jeff Gooding and Mr Don Sutherland (Kimberley Development Commission), Dr George Gardiner (H.G. Gardiner and Associates) and Dr Joe Sherrard (Agriculture WA).

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1. MANAGING SOIL RETENTION & SURFACE WATER QUALITY

INTRODUCTION

The issue of soil erosion and sediment loss, and the associated impact on surface water quality from contaminants in irrigation runoff such as pesticides and nutrients, constitutes a potentially significant environmental concern for the Ord River Irrigation Area (ORIA). The following highlights existing or potential problems and management techniques to control on-farm soil erosion and reduce sediment and contaminant loads entering drains, the Ord River and associated tributaries.

Sources of Sediment Loss and Potential Associated Water Contaminants

- Transport and loss of sediment, nutrients (fertilisers), pesticides (eg. endosulfan) and other chemicals in irrigation drainage water from horticultural and cereal farming operations;
- Uncontrolled erosion in wet season runoff from land and drain banks [Manage by ensuring sufficient ground cover, using on farm retention measures, clay line / vegetate eroding banks];
- Irrigation tail water in irrigation season [Manage by on farm retention];
- Erosion of tail water drains due to highly erodible black soil. [Incorporate on farm retention and ensure minimal land gradient to reduce tail water velocities and subsequent erosion];
- Sediment removed with sugar cane to sugar mill & discharged via M1 channel as operational waste water. [A large proportion of sediment from the mill is, however, returned to the farm];
- Possible remobilisation of sediment (and nutrient and pesticide) when drains are desilted. [Reduce frequency of desilting by on farm management].

Potential Environmental Effects of Sediment Loss and Water Contaminants

1. **Loss of soil from properties** – and associated soil nutrients, biota and organic matter.

2. **Direct Toxicity** – pesticides attached to sediment particles (especially the smaller colloidal fraction) becoming mobilised again and increasing risk of potential fish kills

3. **Indirect Toxicity** – eg. from nutrients causing toxic algal blooms

4. **Deoxygenation** in channels and rivers caused by:
   a) organic carbon in the sediment being mobilised
   b) sugar content in the discharged water from sugar cane processing

5. **Mechanical** –abrasion of gills in aquatic organisms and stress to animals and plants

6. **Biostimulation** – algal blooms resulting from nutrient enrichment of channels. Excess growth of Vallisneria in channels

7. **Suppression of photosynthesis** of aquatic plants – eg. Vallisneria

8. **Smothering, deltas, channel fill** – eg. filling of pools, channels, smothering of fixed habitat, plants, rocks, logs etc resulting in changes to mobile and sessile flora and fauna.

Primary Objectives for Managing Soil Retention and Surface Water Quality

- Maximise retention of sediment, nutrients and chemicals on-farm;
- Minimise losses into channels and rivers;
- Minimise frequency of desilting operations;
- Accurately monitor input of nutrients, pesticides and other farm chemicals (eg. keeping log book record of chemical/nutrient levels applied to farms);
- Accurately monitor output of sediment, nutrients, pesticides and other chemicals and contaminants (eg. monitoring at tail drains, channels and river); and
- Potential adoption of a discharge licensing system to set standards.

Large amounts of runoff are produced during storms and heavy rainfall events and, as a result, significant volumes of sediment, nutrients and chemicals can be washed from agricultural fields into runoff producing large 'pulses' of sediment and nutrients that may enter drains and ultimately the river system.

To prevent large influxes of sediments and contaminants being transported through irrigation drainage systems and rivers, it is necessary to either prevent farm runoff waters from reaching the river system or, alternatively, decrease sediment loads present in the water prior to accession into the river system (Rummenie & Noble, 1996).

This can be achieved by:

- Increasing on-farm ground cover;
- Keeping slopes and furrow lengths to a minimum;
- Allowing runoff water to move slowly through lengthy irrigation drains;
- Keeping drains clear of previously deposited sediments; and
- Storage and recycling of tail water.

Techniques That Have Been Used to Manage Soil Retention & Surface Water Quality

i) **Minimum Tillage** – Maintaining soil structure and stability by direct drilling and reducing traffic and frequency of cultivation.

ii) **Cover Cropping** – Integrating a cover crop such as a cereal or legume within the main crop being grown to improve soil stability.

iii) **Mulching** – Incorporating straw, trash, stubble and other mulches in the furrows or soil profile to improve soil retention and reduce surface-flow velocities.

iv) **Sediment Traps & Channel-bank Erosion Control**– Constructed or vegetative barriers to trap sediment and/or reduce water velocity to minimise sediment transport.

v) **Chemical Mechanisms** – Application of soil-binding polymers with irrigation supply water to effectively bind and drop out small clay particles and sediment-bound nutrients & pesticides in solution in the furrows, reduce soil erosion, improve water infiltration and thus improve water use efficiency.

vi) **Tail water Return & Conjunctive Water Use** – Collection and recycling of irrigation drainage water provides an opportunity to trap and periodically remove sediment that has entered tail water return systems, thus preventing sediment from advancing further into the drainage systems and downstream riverine environments.

vii) **Environmental Buffers: (Constructed Wetlands & Riparian Buffer Strips)** – Sediment, nutrients, pesticides and other contaminants present in irrigation drainage water can be passed through an area of low flow velocity such as a sediment retention pond or constructed wetland system to drop out suspended sediment and sediment-bound contaminants before entering the river system. Similarly, grassed or tree buffer zones can act as filters for surface runoff to trap sediment and take up nutrients. [NB. Environmental buffers are only a remedial management option and do not address the initial prevention of sediment and contaminant loss from farms.]

Performance Indicators for On-Farm Sediment Control

- Reduction in turbidity and/or suspended sediment concentrations in tail waters re-entering the system;
- Proportion of farms with effective silt traps installed and properly operating;
- Reduced frequency of sediment-related algal blooms; and
- Reduced frequency of desilting operations and/or reduction in total amount of silt removed at local and regional development scales.

Performance Indicators for Surface Water Quality

- Zero / reduced frequency of algal blooms and fish kills (NB. These can also be caused by factors other than agricultural impact);
- Proportion of flocculate (course) and colloidal (fine) sediment particles trapped; and
- Comparative performance in trapping efficiency of colloidal sediment by physical sediment barriers, sediment retention ponds/constructed wetlands and soil-binding polymers. This is an essential performance indicator as a significant proportion of nutrients and chemical favor binding to the surface of fine clay particles in solution.

Control of High Intensity Storm Runoff

Storm runoff control measures can be designed to divert or retain pulse flows attributed to peak wet season rainfall. The possible adoption of such measures may be applicable in the ORIA due to the high wet season rainfall events that occur between December and March. Storm runoff from agricultural land can contribute to a mass mobilisation and transport of sediment, nutrients and chemicals that have collected during the dry season in farm furrows, tail water drains and main drains.

It is recommended that initial peak flows from wet season runoff are retained to collect contaminants that have settled in the dry season, while allowing the succeeding runoff to then be diverted back into the drainage system. Measures to control high intensity runoff may help to further manage soil retention and surface water quality and groundwater accessions.

Detention measures & design principles

- Delay high intensity flow & reduce flooding by increasing the time of concentration of flow;
- Lower peak discharges from a catchment;
- Reduce both channel capacity required downstream & stabilising works required to prevent channel/drain erosion;
- Promote settlement or filtration of pollutants (sediment/nutrients/chemicals) carried in stormwater runoff;
- Construct a detention basin, storage pond or natural/excavated depression [However, consideration of storage location and soil type is necessary to avoid further groundwater accession and contributing to localised waterlogging];
- Include a primary outlet to discharge runoff at a controlled rate is a high priority, as is a spillway to discharge overflows safely when storage capacity has been exceeded;
- Divert wet season runoff away from areas of soil instability or erosion risk;
- Prevent or minimise runoff from agitating or re-mobilising sediment and contaminants from drainage lines and prevent flushing material further downstream into the river system;
- Include emergency spillways, overflow structures, diversion channels, grassed waterways or ditches.

Detention measures may not be suitable on areas where land instability, soil permeability or high groundwater levels are a problem. It is, therefore, more desirable to divert large volumes of runoff from the affected area as quickly as possible in lined channels to minimise groundwater recharge. Design limitations should be taken into consideration.

Best Practice Agricultural Management of Farm Chemicals
Example: ENDOSULFAN

Source: (N.R.A. Review of Endosulfan, Public release draft 1997)

As stated in the N.R.A. Review of Endosulfan (Draft 1997), best practice management guidelines for cotton farmers are currently being developed by the Australian Cotton Growers Research Association and the Australian Cotton Foundation. Findings from the Minimising the Riverine Environmental Impact of Pesticides R&D Program will be particularly important in developing best practice management guidelines.

Surveys to date indicate that practices are relatively well advanced in the Macquarie valley, although problems remain with timing of irrigation relative to spraying, and that the Macquarie could be used as a benchmark for other areas, such as the Namoi where poor practices appear to be widespread. Some of the elements of the draft guidelines include the following:

Management of Spray Drift
Control of endosulfan by managing spray drift can be achieved by:

- Using ground rigs enabling spray to be directed at the crop, thereby reducing application rates and the potential for off-target contamination;
- Using ground rigs to reduce the potential for drift compared with aerial application;
- Avoiding wide swath ULV applications due to a high risk to drift from the site of application;
- Aerial spraying should adopt placement applications using large droplets, particularly near sensitive areas;
- Planting trees along boundaries to help intercept spray drift that may arise;

- Establishing no-spray buffer zones adjacent to environmentally sensitive areas such as waterways and downwind of the crop.

Management of Runoff

To control the loss of pesticides in irrigation runoff the following practices should be adopted:

- Do not irrigate while spraying, or for at least two days after application;
- Delay pesticide application after irrigation has occurred;
- Do not apply endosulfan where soils are waterlogged or while water remains in the furrow;
- Drainage recirculation systems should be installed to capture irrigation tail water and at least the first flush of storm runoff.

Inquiries regarding the NRA Review Of Endosulfan Report should be directed to Dr. Joe Smith (National Registration Authority - ACT) who is coordinating the chemical review program, phone (02) 6271 6370,

Development of Best Practice of Pesticide Use by the Cotton Industry

The R&D program 'Minimising the Impact of Pesticides on the Riverine Environment, using the Cotton Industry as a Model' was jointly developed by the Department of Land and Water Resources R&D Corporation, the Cotton R&D Corporation and Murray-Darling Basin Commission which commenced in July 1993. The program has three overlapping phases:

Phase 1: Determine and quantify major pathways of pesticide movement to rivers and assess the impact of these pesticides on river biota,

Phase 2: Identify and test potential methods for ameliorating problems,

Phase 2: Develop best management practices and regulatory guidelines.

The Best Management Practice Project involves an interdisciplinary team of pest and pesticide specialists, researchers, advisers from the industry and cotton growers. The outcome is a **Best Practices Manual** developed for use by growers and consultants as the main delivery mechanism for achieving the Program's goals. The manual advocates practices that minimise the amount of pesticide applied, minimise the transport of pesticide off farms, and minimise the impact of pesticide that remains at the application site.

A pilot study is underway to assess the implementation of the Best Practices Manual to draw on experience and information from growers in the major cotton growing areas and an assessment will be made of the particular conditions involved in implementing the Best Practices on each farm.

For more information and copies of the Cotton Best Practices Manual contact Allan Williams of the Cotton Research & Development Corporation, Narrabri, NSW. Phone (02) 6792 4088.

Research in the Ord River Irrigation Area further supports the contention that integrated management systems allow cotton to be grown with only minimal use of chemicals.

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References:

[1]Urban Erosion and Sediment Control, Revised Edn 1992, Edited by J.S. Hunt. / Department of Conservation and Land Management.

[2]Definition Statement of Key Environmental Issues and Responsibilities – Forum on Environmental Management of the Ord Stage 1 Irrigation Scheme – Transfer of Ownership / Water Corporation and Ord Irrigation Co-operative, 16th October, 1997.

[2]Ord Land and Water newsletter, Volume 1, Issue 3, 8th October 1997

[3]National Registration Authority (August 1997) Existing Chemicals Review Program – The Review by the NRA of ENDOSULFAN – DRAFT [Public Release Summary]

[3]Pesticides and the Riverine Environment - Program Newsletter Issue 11, Sep 1997 – BY: Land & Water Resource R&D Corptn., Cotton R&D Corporation, Murray-Darling Basin Comm.

[4]-Stace Rummenie and Bob Noble (1996) Drainage and Tail water Recycling Reduces Nutrient, Sediment Movement - QLD Dep of Natural Resources, Biloela. / In: The Australian Cottongrower, Vol 17, No 6, Nov-Dec 1996

Reference Locations:

[1]"SEDIMENT TRAPS & EROSION CONTROL" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

[2]"PLANNING & EXTENSION – Ord River Irrigation Area" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

[3]"ENDOSULFAN AND THE ENVIRONMENT" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

[4]"CULTURAL PRACTICES – Tail water Return" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

1.1 SEDIMENT TRAPS & EROSION CONTROL

1.1.1 TECHNICAL OUTLINE

a) SEDIMENT TRAPS

A number of sediment control mechanisms can be used to promote deposition (ie. sedimentation) or filtration of soil particles that have been displaced and transported in run-off waters. A range of sediment trap structures are used extensively in the construction industry to control run-off from construction sites, urban areas and stormwater.

The efficiency of using sediment or silt traps in an agricultural irrigation drainage scenario is yet to be fully determined. Such mechanisms may be used to trap large sediment particle movement from farm furrows into tail water drains and main drains and help prevent further transport into the river system.

Many factors need to be considered when designing and installing sediment traps for irrigation farming. The ability of traps to cope with high intensity storm run-off and sediment movement during the wet season will play a major role in their suitability in the ORIA.

Traps will require periodical maintenance whereby collected silt material is removed periodically throughout the year. This is especially important prior to the wet season to avoid traps becoming inundated from storm run-off resulting in the re-mobilisation of trapped sediment downstream into the river system. To be effective they will require management at all times to allow for sediment loading during irrigation.

As an aspect of best practice management, some farmers in the Ord River Irrigation Area have already begun installing traps to reduce the movement of large particulate clay into the drainage and river system.

The effectiveness of using sediment traps in irrigation farming to trap fine suspended soil particles needs careful evaluation. Sediment present in run-off from farms in the ORIA is made up of large clay particles and fine suspended clay colloids in solution. Colloids have a smaller surface area and higher ionic charge which creates a favorable site for nutrients and farm chemicals such as endosulfan to bind to.

It is important to realise that traps installed for the purpose of trapping and controlling sediment loss from farm run-off will provide no barrier to the movement of the finer colloids and colloidal-bound nutrients and chemicals.

Primary consideration of other best management practices to control sediment export (ie. improved irrigation efficiency, soil-binding polymers etc.) is therefore needed if nutrients and chemicals from irrigation runoff are to be effectively managed.

Sediment Trapping & Control Mechanisms

- **Drop Structures** – comprise a vertical drop constructed by a suitable material and a stilling basin for energy dissipation. Placed usually at the source of drainage water (eg. at the mouth of a tail drain) over which drainage water flows usually into a depression and exiting through an opening. Resistance created by the drop structure traps large sediment particles which settle at the base for periodical removal.

- **Concrete Barriers** – structures placed across a channel or tail drain creating resistance to flow and trapping mobile sediment. [Concrete sediment traps supplied from Kununurra have already been installed by some farmers in the ORIA]

- **Silt Fences** – various types of wire or steel mesh fencing covered with geotextile filter or fabric that can be staked across a channel, drain or slope to trap sediment and reduce water flow.

- **Straw Bale Barriers** – temporary straw bales placed and staked across a channel can reduce water velocity and provide a significant barrier to mobile aggregates. They will only remain effective if properly secured, prevention of gaps is ensured and sufficient spillway capacity over the top of the barrier is allowed.

- **Rock / Geotextile Barriers** – rocks or coarse aggregates wrapped in a geotextile mesh and positioned across a channel. Also known as 'Rock Bales'

- **Sediment Retention Basins** – natural depressions or excavated ponds used to collect run-off, reduce flow velocities and trap sediment and sediment-bound nutrients for periodic desilting. Careful consideration is needed regarding all-weather access for maintenance, ARI (Average Recurrence Interval) for high-intensity storms; the design of the primary outlet(s), emergency outlet/spillway; and a de-watering device or drop-structure to allow control of water level especially in the event of peak stormwater run-off entering the system.

- **Vegetative strips** – establishment of non-weed risk sedges and aquatic vegetation grown in strips across erosion gullies and along embankments, riparian zones or farm land/contours to reduce run-off flow velocities, control soil erosion, trap sediment and filter nutrients. For example Monto vetiver grass, a non-invasive tall rigid grass species, is extensively used throughout the world for soil & water conservation, sediment trapping, land rehabilitation and embankment stabilisation. [See p.11 and *Section 3.2 Riparian Buffer Strips*]

Silt Traps in the ORIA

Silt traps are already being used on some farms in Ord Stage 1. The following is an example of the design specifications and costs associated with a trap structure installed in the ORIA.
Source: Robert Boshammer, Oasis Farms, Kununurra, WA 6743

1. To do the job well on a uniform 40 ha block, you would lose approx. 600 x 15m (0.9ha).
2. Culvert cost: 8m x $133/m = $1064
3. Concrete Trap Structure = $750
4. Backhoe operation to install 2. & 3. = 6 hrs @ $50 = $300
5. Grader hire – new Tail Drain/Roadway = 5 hrs @ $50 = $250
6. Land out of production 0.9 ha x $7000/ha = $6300-
7. Re-laser paddock – probably as part of normal program therefore no charge.

8. Annual Maintenance non-farmed Drains/Roadways = $2000 x 0.9 ha = $1800
Initial Cost: $8664 / 40 ha block
Annual Cost: $1800

Factors Determining Sediment Trapping Efficiency in the ORIA

While erosion control techniques (vegetation, mulches, and erosion control blankets etc.) can be effective, Best Management Practices (BMPs) applied for the purposes of sediment control are often inefficient. Sediment trapping efficiency will depend on a number of the following important factors:

- volumes and flow velocities of run-off, including sediment, nutrients and chemicals;
- input vs. output of sediment and sediment-bound nutrients and chemicals;
- ability of traps to cope with inundation from high wet season flows;
- accessibility for cleaning and maintenance;
- maximum trapping capacity and resistance to flow of water & sediment;
- irrigation run length and slope.

Design Considerations for Sediment Trapping Mechanisms

- Determine flow velocities for dry and wet season run-off;

- Determine maximum design capacities to allow for peak intensity, frequency and duration of wet season run-off;

- Design Average Recurrence Interval of a storm of critical duration that should be applied for the design of all parts of the structure subject to major storm through-flow;

- Ensure easy access for periodic maintenance and desilting;

- Design irrigation drains or overflow channels in a "race-track" or meandering type fashion to reduce water flow and, thereby lowering water velocity and encouraging sediment to settle. Additionally, drainage water can be meandered through vegetative sedge stands established in strips or zones at interval through the channel. The increased distance for water to flow combined with the resistance of sedge or riparian strips will decrease water velocity and help drop out large sediment particles.

b) EMBANKMENT STABILISATION & EROSION CONTROL

There are a number of measures that can be used to stabilise the bed and banks of drains and waterways to control soil erosion and achieve stability by either reducing flow velocity or by providing a lining that will withstand high flow velocities.

Bank and Drain Linings

- Revegetation with grass, shrubs, sub-aquatic or aquatic plants. Appropriate plant species should be selected in that they pose no invasive weed risk, do not impede flow or create turbulence or capacity problems;
- Mulch;
- Geotextiles (usually combined with rock);
- Jute mesh;
- Natural/synthetic Erosion Mattings;
- Sandbags;
- Gravel and rock;
- Plastic sheeting across the mouth of tail water drains and other drainage outlets.

Vetiver Grass – "the hedge against erosion"

Vetiver grass has been used extensively throughout the world for soil and water conservation, land rehabilitation, and embankment stabilisation. Properties of the vetiver include:

- Tall, stiff reed-like grass with deep root system that can be grown in strips along farm contours, channel/drain embankments and erosion gullies to control soil erosion, retard run-off velocities, trap sediment and filter nutrients.
- **Monto Vetiver** (*Vetiveria zizanioides* L.) does not produce seeds and therefore poses no invasive weed risk.
- Vegetative propagation is achieved by planting slips in rows. As a result hedges are permanent and only grow where planted and cannot be washed out giving constant protection from erosion. Established by manual planting but mechanical transplanters have been used in Australia.
- Monto vetiver acts as a barrier to the rhizomes of cultivation weeds, which cannot penetrate its root system.
- Monto vetiver hedges are cheaper, more permanent and far more effective than structural methods of erosion control.
- Suitable for a range of environmental conditions including tropical, sub-tropical, semi-arid, temperate and wetland environments.
- Monto vetiver is salt tolerant and with its deep rooting characteristics can be used to lower saline water levels.
- Tolerant to heavy metal toxicity (eg. arsenic, cadmium, copper, chromium, nickel).

In Australia, Vetiver grass *Vetiveria zizanioides* L. was first found in the Brisbane Botanical Gardens, Queensland in the 1930's but thought to have been introduced in the 1910's from Fiji. At least four other cultivars have been introduced from overseas as test species for essential oil production. Four other native Vetiver species; *V. filipes, V. elongata, V. rigida* and *V. pauciflora* also exist in Australia.

It is essential that any introduced (or native) species used for soil and water conservation will not become a weed in the local environment, especially in a new country where its weed potential is greatest due to the lack of natural enemies.

Research, Development and Application Program of Vetiver Grass System in Queensland:

- This program is led and coordinated by Dr Paul Truong, Principal Soil Conservationist at the Resource Management Institute, Queensland Department of Primary Industries [now Department of Natural Resources], with major input from
- Land Conservation Officers throughout Queensland,
- Department of Agricultural Engineering, University of South East Queensland at Toowoomba.
- This program is being partly funded by the National Landcare Program

To investigate their sterility, trials of all cultivars were conducted for 8 years, from 1988 to 1995 in glasshouse conditions. Those with low germination or identified as sterile were then grown in a range of climatic field conditions including temperate, humid/sub-tropical, semi arid and wet land environments. Throughout that period the cultivar ***V. zizanioides*** produced no seeds under all environments conditions, and was also very vigorous and effective in soil and water conservation. This cultivar was registered as **Monto Vetiver** to commemorate the Monto district where the first field site was conducted.

Monto Vetiver is the most suitable species for land and water conservation measures because it does not pose any risk of being an invasive weed. Vetiver has been successfully used to control soil erosion and at the same time lower the saline water level in a trial in temperate southern Australia. Due to its salt tolerant ability and deep rooting characteristics, vetiver is now being trialled on a large scale for the same purpose in Western Australia.

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Hydroseeding & Hydromulching –innovative erosion control techniques

Hydroseeding involves the mixing, in a large tanker, of a slurry containing selected seed varieties, fertiliser, and a paper or wood pulp (cellulose fibre), adding water as an adhesive. A high pressure spray is used to pump the slurry over the area to be treated for erosion control. The seed generally adheres to the pulp, which improves the micro-climate for germination and establishment. Large areas can be treated at relatively low cost, compared to other specialised methods.

Hydromulching is a similar operation to hydroseeding except that a heavy covering of mulch, usually hay/straw, is spread with the seed. This mulch reduces evaporation rates from the soil, thus providing a far better micro-environment for the germinating seeds. Plant growth is also assisted due to improved humid conditions at the soil surface.

[Refer to literature material available in "Sediment Traps & Channel Bank Erosion Control" file, located at:
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[1]-Definition Statement of Key Environmental Issues and Responsibilities – Forum on Environmental Management of the Ord Stage 1 Irrigation Scheme. / Water Corporation and Ord Irrigation Cooperative, 16th October, 1997.

[2]-Urban Erosion and Sediment Control, Revised Edn (1992), Edited by J.S. Hunt. / Department of Conservation and Land Management.

[2]-Vetiver Grass System – Research, Development and Applications in Queensland, Australia – A Pictorial Record (1988 – 1986) / Dr Paul Truong, Principal Soil Conservationist, Resource Sciences Centre, QLD Dep. of Natural Resources, Brisbane, Australia.

[2]-Vetiver Grass for Soil and Water Conservation, Land Rehabilitation, and Embankment Stabilisation – A Collection of Papers and Newsletters Compiled by the Vetiver Network – World Bank Technical Paper No. 273 / Edited by Richard Grimshaw and Larisa Helfer. Dec. '95

Reference Location:

[1]"PLANNING & EXTENSION – Ord River Irrigation Area" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

[2]"SEDIMENT TRAPS & EROSION CONTROL" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

1.1.2 INDUSTRY CONTACTS

Sediment Traps & Erosion Control

NAME -**DR. JOHN BAVOR**
POSITION -HEAD OF WATER RESEARCH LABORATORY
ORGANISATION -UNIVERSITY OF WEST SYDNEY
LOCATION -SYDNEY, NSW 2006
PHONE NO. (02) 4570 1264
FAX NO. (02) 4570 1264
E-MAIL -
DETAILS -Wetlands specialist with expertise in constructed wetlands & retention basins, sediment control and removal, soil infiltration, improving irrigation efficiency, and soil conditioning. Provides consultancy and advisory service.

NAME -**ROBERT BOSHAMMER**
POSITION -FARMER – ORD RIVER IRRIGATION AREA
ORGANISATION OASIS FARMS
LOCATION -PO BOX 20, KUNUNURRA, WA 6743
PHONE NO. (08) 9168 1282
FAX NO. (08) 9168 1064
DETAILS -Has installed a number of sediment/silt traps on his farming enterprise to reduce sediment export into main drains and the Ord river system.

NAME -**LEITH BOWYER**
POSITION -REGIONAL WATER RESOURCE OFFICER
ORGANISATION -WATER & RIVERS COMMISSION
LOCATION -KUNUNURRA, WA 6743
PHONE NO. (08) 9168 1082
FAX NO. (08) 9168 3174
E-MAIL -
DETAILS -Specialist in water hydrology in respect to environmental management and protection of surface and ground water resources. Expertise includes hydrogeological investigation, monitoring protocols, studies in nutrient assimilation, groundwater management; and provision of information and advice for constructed wetlands, sediment retention basins, riparian zones, farm drainage systems and hydrological modeling.

NAME -**MALCOLM BROWN**
POSITION -PRINCIPAL CONSULTING
ORGANISATION -STORM CONSULTING
LOCATION -PO BOX 1113, PARRAMATTA, NSW 2124
PHONE NO. 0413 870 628
FAX NO. -
E-MAIL malcolm@nettl.usyd.edu.au
DETAILS -Originally with Department of Land & Water Conservation (02) 9351 4305. Has recently formed a consulting firm specialising in the application of retention basin and constructed wetland technology, aquatic plant technology, stream rehabilitation and stabilisation, riparian zone management and control of stormwater. Team of consultants includes project director, aquatic plant specialist and design engineer.

NAME -**MARK DOUGLAS**
POSITION -PRIVATE CONSULTANT LAND MANAGEMENT
ORGANISATION -DOUGLAS & ASSOCIATES
LOCATION -PMB 1812, GERALDTON, WA 6531
PHONE NO. (08) 9964 1674
FAX NO. (08) 9920 5343
DETAILS -Originally with Agriculture WA as Technical officer in land conservation. Now private consultant. Has conducted trials using Monto Vetiver stabilisation grass in Geraldton, stabilising irrigation drainage lines, and spoil dumps for lead mining and sediment trapping.

NAME -**MARK GOLDSTEIN**
POSITION -ENVIRONMENTAL MANAGER
ORGANISATION -MAIN ROADS, WESTERN AUSTRLALIA
LOCATION -EAST PERTH, W.A. 6892
PHONE NO. (08) 9323 4130
FAX NO. -
E-MAIL -
DETAILS -Specialises in erosion management of roads, ditches, drains and slopes. Experience with application of wetlands for sediment trapping, road bank vegetative stabilisation, straw / matting style sediment traps in channels, and diversion levies in drains to reduce water flow and bank erosion.

NAME -**FERGUS HANCOCK**
POSITION -ENVIRONMENTAL OFFICER – HUNTER REGION
ORGANISATION -DEPARTMENT OF LAND & WATER CONSERVATION – WATER SERVICES DISTRICT OFFICE
LOCATION -MUSWELLBROOK, NSW 2333
PHONE NO. (02) 6542 1222
FAX NO. (02) 6543 4164
E-MAIL fhancock@dlwc.nsw.gov.au
DETAILS -Conducts assessment of proposals for constructed wetlands and nutrient balance reviews. Has been involved in project with Ken Reynolds [DLWC 02 6545 1666] regarding the design and effectiveness of buffer strips on nutrient removal from water effluent; ;vegetative silt traps; and research using *Monto vetiver* grass for buffer application. Specialises in water quality issues and limnology, geomorphic stability assessment, and management and protection of ecosystems with focus on mining and storage catchments.

NAME -**Mr KIT JOLLEY**
POSITION -Supplier of Monto Vetiver grass
ORGANISATION -Currently Restaurant Manager [Oct. 1997]
LOCATION -KATHERINE, N.T. 0850
PHONE NO. (08) 8972 3170-Work & (08) 8972 2182-Work / (08) 8972 1837-Home
FAX NO. -
E-MAIL -
DETAILS -Conducted research into the application of **Vetiver** Grass System as a soil and water conservation plant in the Northern Territory. Submitted a Graduate Diploma Report (1994) to the University of Ballarat (Victoria) on the success of Monto Vetiver planted as a single row hedge and its use as an alternative to engineered structures. Kit has a supply of Monto Vetiver grass [approx. 8 km of vetiver hedge rows] available for channel soil-stabilization, buffer strips, on-farm hedges etc. Can provide assistance with supply and propagation techniques. Has good contacts. Familiar with mechanical transplanter also used for tomato and tobacco planting.

NAME -**JEFF KITE**
POSITION -PRINCIPAL ENVIRONMENTAL OFFICER
ORGANISATION -WATER & RIVERS COMMISSION – CATCHMENT & WATERWAYS MANAGEMENT BRANCH
LOCATION -HYATT CENTRE, EAST PERTH, WA 6004
PHONE NO. (08) 9278 0300
FAX NO. (08) 9278 0585
E-MAIL jeffrey.kite@wrc.wa.gov.au
DETAILS -Specialises in environmental water requirements for river and wetland management; river restoration; integrated catchment management; water-sensitive urban design; and the application of retention basins, constructed wetlands and riparian zones for removal of nutrients and sediment trapping.

NAME -CLIVE KNOWLES-JACKSON
POSITION -SENIOR DISTRICT ADVISOR
ORGANISATION -DEPARTMENT OF NATURAL RESOURCES
LOCATION -OAKEY COURT HOUSE, CAMPBELL ST., OAKEY, QLD 4011
PHONE NO. (07) 4691 1499
FAX NO. (07)
E-MAIL
DETAILS -Has conducted extensive research and field trials into the use of Monto Vetiver Grass as a measure to control soil erosion. Field trials are being conducted in south-east Queensland. Monto Vetiver, a sterile cultivar has been used for gully stabilisation; waterway & drain stabilisation; reduction of flood damage in strip-cropping layouts; and spreading of run off water.

NAME -GEORGE LUKACS
POSITION -RESEARCH SCIENTIST
ORGANISATION -JAMES COOK UNIVERSITY
LOCATION -TOWNSVILLE, QLD 4810
PHONE NO. (077) 81 5461
FAX NO. (077) 81 5589
E-MAIL georgelukacs@jcu.edu.au
DETAILS -Specialises in industry consulting and research in the areas of irrigation design and planning, water quality monitoring, water management, sustainable resource development, wetland application for treatment of waste water. Involved in research projects with the Land & Water Resources Research & Development Commission including -development of best practice guidelines for irrigation development; use of constructed wetlands and detention basins for nutrient control & sediment catchment; nutrient control in irrigation drainage; wetland health and water quality; and development of water quality monitoring programs.

NAME -LUKE PEN
POSITION -PRINCIPAL ENVIRONMENTAL OFFICER
ORGANISATION -WATER & RIVERS COMMISSION
LOCATION -HYATT CENTRE, EAST PERTH, WA 6004
PHONE NO. (08) 9278 0386
FAX NO. (08) 9278 0585
E-MAIL luke.pen@wrc.wa.gov.au
DETAILS -Specialises in Catchment Waterway Management, policy development and strategic planning in waterways development including design and modeling of constructed wetlands, sediment retention basins and drains.

NAME -JOHN POWELL
POSITION -NEW PRODUCT RESEARCH & MARKETING
ORGANISATION -JIMBOOMBA TURF COMPANY PTY LTD – [EROSION SOLUTIONS INTERNATIONAL PTY LTD]
LOCATION -PO BOX 6005, ACACIA RIDGE, QLD 4110
PHONE NO. (07) 3273 1166 or (07) 3273 1516
FAX NO. (07) 3273 3763
E-MAIL -
DETAILS -Supply and distribution of a range of products and services to aid in stormwater, sediment control and soil stabilisation. Specialise in Landform Design, Stormwater Treatment, Erosion and Sediment Control, Revegetation, Soil Treatment, Remediation and Streambank Stabilisation. Products include STAYturf; Greenfix Bio-Mulch Blankets; STAYspray; Siltstack and Gutter Buddy; Higgins Landcare Products; Continuous Berm Machine; Silt Stop™; STAYlogs; and Installation, remediation and revegetation service. [Catalogues and Capability Statement provided]

NAME	**-VIV REED**
POSITION	-REGIONAL MANAGER – MID WEST AVON
ORGANISATION	-WATER & RIVERS COMMISSION
LOCATION	-NORTHAM, WA 6401
PHONE NO.	(08) 9622 7055
FAX NO.	(08) 9622 7155
E-MAIL	viv.read@wrc.wa.gov.au
DETAILS	-Co-ordination of water resource management with community action. Includes integrated catchment management, use of constructed wetlands for treatment of waste water, sediment retention structures and stream flow sediment relations.

NAME	**-DR PAUL TRUONG**
POSITION	-PRINCIPAL SOIL CONSERVATIONIST – LAND STABILISATION & REHABILITATION
ORGANISATION	-QLD DEPARTMENT OF NATURAL RESOURCES – Resource Sciences Centre
LOCATION	-Block B, 80 Meiers Rd, Indooroopilly, Brisbane, QLD 4068
PHONE NO.	(07) 3896 9304
MOBILE	0412 193 381
FAX NO.	(07) 3896 9591
E-MAIL	truongp@dnr.qld.gov.au
DETAILS	-Paul has conducted extensive research and experience throughout Australia and overseas with **Vetiver grass** species; a world recognised plant used for soil and water conservation & erosion control, land rehabilitation, sediment retention & buffering, reducing surface run-off velocities, channel and embankment stabilisation and nutrient stripping. Paul has led and coordinated a program involving the research, development and application of Vetiver Grass System in Queensland with major input from Land Conservation Officers throughout Queensland and the Department of Agricultural Engineering, University of South East Queensland at Toowoomba. Can provide assistance with supply and propagation techniques. Has good contacts. [Technical research papers and newsletters detailing the history and widespread application of Vetiver grass are available in the "SEDIMENT TRAPS & EROSION CONTROL" resource file, Kimberley Development Commission, Kununurra, Western Australia 6743]

NAME	**-LANCE WATT**
POSITION	-RESOURCE OFFICER / ECONOMICS
ORGANISATION	-DEPARTMENT OF LAND & WATER CONSERVATION – HUNTER REGION
LOCATION	-464 KING ST., PO BOX 5166, NEWCASTLE WEST, NSW 2302
PHONE NO.	(02) 4929 4346 [Extension: 847]
FAX NO.	(02) 4929 6364
E-MAIL	-
DETAILS	-Development and implementation of sediment control strategies and programs for urban and catchment systems. Includes specialist knowledge of silt traps, constructed wetlands, retention basins, land revegetation, channel design and adoption of Erosion and Sediment Control Plans.

NAME	-
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ORGANISATION	-
LOCATION	-
PHONE NO.	(
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FAX NO.	(
DETAILS	-

1.2 MULCHING TECHNIQUES

1.2.1 TECHNICAL OUTLINE

The adoption of mulching techniques in irrigation farming can dramatically improve soil retention, aggregate stability and minimise erosion from irrigation run-off. Mulching by incorporating straw or residual material such as crop stubble or trash into the soil surface helps improve plant growth and yields by retaining moisture and nutrients, and encouraging lateral water flow along farm furrows.

Benefits of Mulching in Irrigation Farming

- Soil retention and improved aggregate stability;
- Reduced evaporation from sol and improved moisture retention especially during dry conditions;
- Improved lateral flow of irrigation water through furrows;
- Reduced water and wind erosion;
- Mulching is especially beneficial in wet conditions when bare soil is highly susceptible to erosion, such as during the wet season applicable for the ORIA.

Mulching Techniques for Managing Soil Retention on Farms

- Slashers / Mulchers - cut, rip and mulch crops and crop stubble to manage crop residues.
- Stubble retention
- Stubble or straw incorporation into topsoil
- Trash blanketing / Green cane harvesting
- Potential in harvesting aquatic plants from channels for mulch? (eg. Typha)

Innovative mulching techniques that have been developed and are currently used overseas include the Hobson Mulching System and Simba's Mulchmaster Series II.

Hobson Mulching System^{tm}

Researched and developed in Oregon and manufactured in Idaho, USA, the Hobson Mulching System^{TM} is a machine that feeds and spreads straw in the irrigation furrows.

Features of the machine include:

- a series of bale chambers attached to a head frame spaced to match furrow widths and fit row spacing;
- powered through one connection by the tractor hydraulic system;
- each individual bale chamber will hold 3 two-string straw bales and are operated by individual hydraulic motors;
- bottom drag chain enables easy loading of straw followed by lowering of the overhead drag chain and removal of bale ties;
- bales are moved forward by bottom and top drag chains into a series of notched fingers that removes the straw from the bales without chopping it;
- straw is then discharged down an adjustable chute to the ground;
- each individual chamber has a press wheel that presses the straw into the soil surface (flat cleated wheels for sprinkler irrigation, tapered wheels for furrow irrigation);

- amount of straw applied is controlled by the tractor operator as the machine moves through the field;
- machine is approx. 13ft long, and each chamber is approx. 3 ½ ft wide;
- machines are built on order and can be designed as a 3-chamber up to 7-chamber setup depending on the needs of the farmer or area for which it will be used;
- as at August 1997, costs of machine ranged from $US 16,583 (3-chamber) to $US 35, 411 (7-chamber), excluding transport expenses.

Results from research in America funded by the U.S. Department of Agriculture, SBIR and CSRS which trialled the Hobson Mulching System™ under furrow irrigation have resulted in:

1. An increase in crop yields of trialled potatoes varied from 7.5 to 40%
2. The reduction of average sediment yield in the run-off water varied from 79 to 95%
3. The reduction of Total Phosphorus P loss varied from 65% to a net accumulation of P

The major benefits that have been achieved from mechanical straw mulching include:

- increased crop production;
- improved crop quality;
- reduced sediment loss;
- reduced nutrient loss;
- reduced insecticide use;
- reduced fertiliser use;
- reduced irrigation water required.

[For more information on the Hobson Mulching System™ refer to the "CULTURAL PRACTICES – Mulching Techniques" resource file at the Kimberley Development Commission, PO Box 620, Kununurra, WA 6743 Ph. (08) 9168 1044 / Fax. (08) 9168 1473]

Simba's Mulchmaster Series II

In Kenya, Africa, a cultivation machine has been developed by Simba International that is designed to mix and incorporate post harvest residue – normally straw stubble – into the top 100 to 200mm of the soil. The new 'Mulchmaster' Series II incorporates straw whilst leaving an open soil structure.

Features of the machine include:

- designed to break up residual hard pans allowing full root penetration & increased yields
- fitted with front mounted disc coulters that are used to chop residue into more manageable length which speeds breakdown of straw, and improves soil to straw contact;
- design is a large, box section construction providing significant weight to obtain penetration in hard or compacted soil conditions; and
- has been designed for the harsh Kenyan environment with characteristically hard, compacted soils.

Green Cane Harvesting

Green sugarcane harvesting has a number of environmental benefits in irrigated agriculture, however, its success in the ORIA will depend on a number of cultural and environmental variables. The principal of green cane harvesting eliminates the process of traditional burning of the cane prior to harvest and instead the vegetative leaf material and trash on the ground is left remaining.

Benefits of green cane harvesting

- blanket of trash (vegetative leaf matter) present in furrows acts as a mulch helps reduce erosion from surface run-off;
- retention of sediment and associated nutrients / chemicals in furrows thus preventing contamination of channels and river system;
- reduced evaporation, higher retention of soil moisture and reduced irrigation water required;
- improved lateral flow of water throughout furrows;
- provides habitat for worms and beneficial organisms.

Disadvantages of green cane harvesting

- thick or matted trash blanket present in the furrows tends to hold together bringing with it a considerable amount of soil when harvested. Increased volumes of extraneous matter in cane delivered to the sugar mill can result in increased harvest costs due to mechanical stress and harvesting difficulties;
- potential build up of disease pests in mulch environment – especially if green cane harvesting is adopted for continual seasons;
- reduces growth of young sugar cane due to decreased light penetration and soil temperature;
- increased duration of water on farm can result in potential accession to groundwater;
- potential difficulties with flood irrigation in regards to vegetative matter slowing the rate of water spread across the field;
- variable quality of sugar processed from green cane as burning is often needed to achieve a quality product;
- increases the risk of wild-fire spread.

Benefits of cane burning

- burning of sugar cane prior to harvest minimises volumes of trash and bound soil entering harvesting equipment and processing at the sugar mill;
- some quality sugar products require burning of cane before harvesting;
- kills pests and breaks pest/disease cycles present in trash;
- tourist attraction.

Disadvantages of cane burning

- risk of nutrients contained in ash being lost in water run-off or from wind erosion, especially P-phosphorus and K-potassium;
- difficult to re-incorporate ash and associated nutrients into soil which remains on the ground surface;
- smoke from burning - local inconvenience and human health considerations;
- ground surface being more susceptible to erosion after burning. [However, with high yielding crops the top fraction of cane which is usually unburnt falls to the ground and provides a thin trash layer providing a degree of ground cover];
- increased potential for contamination of waterways from mobilised sediment and associated nutrients / chemicals in run-off from exposed furrows. [Such problems, however, are not a major issue if minimum-tillage techniques are adopted.

Assessment of Best Practice Cane Harvesting in the ORIA

Green cane harvesting has successfully been adopted in the southern regions and far northern regions of Queensland. A major factor that may limit the success of green cane harvesting in the ORIA is the large volumes of trash produced that may pose mechanical problems during harvest and management problems in regrowing cane. This is mainly attributed to both the abundance of

water from irrigation and high light levels and longer light periods associated with a wet/dry tropical climate.

However, there may be potential in rotating between periods of burning and green cane harvesting. In some areas a significant increase in yield has resulted from adopting green cane harvesting following several years of burning. However, if green harvesting is then maintained during consecutive seasons, yields begin to decline. This is most likely as a result of the initial trash blanket acting as a mulch cover providing beneficial moisture and nutrient retention in the furrows for improved growth of the crop. However, the decline in yield when green harvesting is maintained for too long may be attributed to the increased populations of pest and diseases present in the undisturbed trash. Further trialling and investigations of the effect of various harvest method rotations on cane yields are essential to determine whether green cane harvesting in the ORIA is viable.

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References:

1-Notes on Hobson Mulching System™ - <Letter to: Ben Rose, District Officer, Agriculture WA, Manjinup, WA 6258 / From: Joe Hobson Sr., President, Hobson MFG Inc., Oregon, USA / August 23rd, 1997>

[1]-Mike Hodge (1994?) Simba's Mulchmaster II incorporates straw but leaves an open soil structure. Simba International Ltd, Sleaford, UK / In: Agric. & E Intl, Vol 46, Nos 1& 2

[2]-Urban Erosion and Sediment Control, Revised Edn (1992), Edited by J.S. Hunt. / Department of Conservation and Land Management.

Reference Location:

[1]"CULTURAL PRACTICES – Mulching Techniques" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

[2]"SEDIMENT TRAPS & EROSION CONTROL" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

1.2.2 INDUSTRY CONTACTS
Mulching Techniques

NAME -**MARK HEAP**
POSITION -MANJIMUP DISTRICT OFFICER
ORGANISATION -AGRICULTURE WESTERN AUSTRALIA
LOCATION -ROSE ST., MANJIMUP, W.A. 6258
PHONE NO. (08) 9771 1299
FAX NO. (08) 9771 2544
E-MAIL mheap@agric.wa.gov.au or markh@agric.wa.gov.au
DETAILS -Researching on-farm mulching techniques. Mark has investigated a mechanical straw mulching machine: the Hobson Mulching System™ in America. He has visited Oregon. USA and examined the latest model and researched the benefits of on-farm straw mulching.

NAME -**MIKE HODGE & ROBIN ULYATE**
POSITION -RESEARCH ENGINEERS?
ORGANISATION -SIMBA INTERNATIONAL LTD
LOCATION -WOODBRIDGE RD., SLEAFORD, LINCOLNSHIRE, NG34 7EW, UK
PHONE NO. 0529 304654
FAX NO. 0529 413468
E-MAIL
DETAILS -Construction, R&D and supply of mechanical straw/stubble & soil - cultivation machine: SIMBA'S 'MULCHMASTER' SERIES II. [details included in this report]

NAME -**JOE HOBSON SR.**
POSITION -PRESIDENT
ORGANISATION -HOBSON MFG., INC.
LOCATION -PO BOX 21510, KEIZER, OREGON, USA
PHONE NO. 0011-1-503-463-6966
FAX NO. 0011-1-503-463-6966
E-MAIL
DETAILS -Construction, R&D and supply of mechanical straw mulching machine: HOBSON MULCHING SYSTEM™. from Oregon, USA [details included in this report]

NAME -**MIKE MERRIN**
POSITION -ASSISTANT DIRECTOR
ORGANISATION -QLD DEPARTMENT OF NATURAL RESOURCES
LOCATION -ROCKHAMPTON, QLD 4700
PHONE NO. (0749) 384 815
FAX NO. (0749) 384 277
E-MAIL
DETAILS -Extensive experience in the sugar cane industry especially with R&D of green cane harvesting practices. Involved in trials that reduced soil loss of 400 t/ha to 20 t/ha by maintaining trash from a sugar cane crop.

NAME -**BEN ROSE**
POSITION -LANDCARE DEVELOPMENT OFFICER
ORGANISATION -AGRICULTURE WESTERN AUSTRALIA
LOCATION -ROSE STREET, MANJIMUP, WA 6258
PHONE NO. (08) 9771 1299
FAX NO. (08) 9771 2544
E-MAIL benr@manjdo.agric.wa.gov.au
DETAILS -Specialises in best practice farming including soil conservation, nutrient export, and salinity control. Includes research and adoption of on-farm mulching techniques; use of cover crops such as vetches [eg. pea flower with high nitrogen levels], tropical cereals and oats; tail water drainage systems; development of minimum tillage techniques for potatoes; surface water control; and application of ponds and retention basins to strip nutrients and trap sediment from agricultural drainage water. Has also investigated the mechanical straw mulching machine: HOBSON MULCHING SYSTEM manufactured in America [details included in this report]

NAME -**PROFESSOR CLINTON SHOCK**
POSITION -SUPERINTENDENT & PROF. OF CROP & SOIL SCIENCE
ORGANISATION -OREGON STATE UNIVERSITY
LOCATION -595 ONION AVENUE, ONTARIO, OREGON 97914
PHONE NO. 503 889 2174
FAX NO. 503 889 7831
E-MAIL mesosu@primenet.com
DETAILS -Has conducted research on the effect of the mechanical mulch machine on water infiltration of soil. Determined application rates [pounds straw / acre] and relative costs.

NAME -
POSITION -
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1.3 COVER CROPS

1.3.1 TECHNICAL OUTLINE

Cover crops are grown amongst existing crops or between crop rotations to provide groundcover and a range of associated benefits. Cover crops are commonly grown in regions with highly erodible soils. In the cotton industry cover crops are mostly used to provide groundcover additional to that provided by the previous year's cotton residue. The Conservation Compliance provisions require that at least 30 per cent of the ground surface be covered with residue following planting of the cotton crop (Castor, 1996).

Benefits of Cover Cropping

- Reduced soil loss and surface erosion;
- Increased levels of soil organic matter and associated nutrients;
- Long term improvements in soil features such as water and nutrient holding capacity;
- Provide organic nitrogen from legume cover crops;
- Improved surface friability;
- Assist in suppressing weed growth by shading of midrows and competing with weeds for water, light & nutrients;
- Provide shelter thereby helping improve plant establishment and final crop yields.

Management Considerations

The following points should be taken into consideration for best results regarding the adoption of cover cropping (Rose 1997).

- Cover crops should be established immediately after harvest;
- Install grade furrows to protect cover crops sown after late harvest;
- Minimise cultivation and avoid ploughing or using a rotary hoe to level the paddock;
- Broadcast or direct drill seed, follow with light harrow or crumbler, do not roll;
- Leave the roots of the crop intact for as long as possible; and
- Protect the crop from livestock during wet conditions to avoid pugging.

Preferred cover crops include tropical cereals and small grains such as wheat, rye and sorghum. These cover crops have:

- Relatively low seeding costs;

- Good residue (mulch) levels and persistence;
- Ability to absorb residual nitrates; and
- Are easier to terminate.

These types of cover crops can, however, increase the following crop's demand for fertiliser nitrogen, such is the case with cotton.

Considerable research has been carried out into the suitability of legumes for cover cropping such as hairy vetch: a pea flower with high nitrogen levels. They have the potential to reduce the fertiliser nitrogen requirement of the following cotton crops by at least 30 kg per hectare (Castor, 1996). However, such legumes can lack many of the desirable attributes of small grain crops as well as having some adverse effects upon cotton seedling establishment. This is attributed to a number of factors including:

- increased pest status (eg. cutworm activity);

- increased seedling disease; and

- the release of volatile simple organic compounds from the legume residue which can reduce the growth of other plants (allelopathic effect).

As stated by Castor (1996), the above mentioned organic compounds may reduce cotton seed germination by up to 40 per cent as well as reducing seedling root and shoot growth. This influence has also been show to be eliminated over time. It is therefore recommended that legume cover crops need to be desiccated (green manured) at least two to three weeks prior to planting to avoid this allelopathic effect.

Cover Cropping in the ORIA

Primary consideration should be given to maximising the retention of crop residues in the ORIA by adopting stubble retention, mulching and cover cropping techniques within existing crop rotations. Cover crops such as wheat or sorghum could be incorporated into crop rotations following the dry season immediately after the harvest of the previous crop such as cotton. This would provide ground cover during the wet season on areas normally left fallow thus reducing on farm surface erosion and sediment transport.

The feasibility of adopting cover cropping in the ORIA would require a number of factors to be taken into consideration, including:

- Selection of cover crop species (eg. wheat / sorghum) and associated opportunity and establishment costs;
- Establishment of a cover crop prior to the wet season in assist with the breakdown organic matter into the soil;
- Soil moisture requirements to establish and maintain the cover crop potentially contributing to groundwater accession;
- Suitability of soil conditions for cover cropping in terms of access for spraying affected by a wet soil profile during the wet season (ie. red clay loams as opposed to heavy black clays);
- Spray requirements to prevent and control seed development of the cover crop to avoid volunteer growth in the subsequent crop rotation;
- Mulching of cover crop at completion of rotation to increase organic matter, improve soil stability and reduce surface erosion.

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References:

[1]-Paul Castor (1996) Putting Good US Ideas to Work Down Under [P. 68, 'Winter Cover Crops'] IN: The Australian Cottongrower, Vol 17, No 6, Nov-Dec 1996

[1]-Ben Rose (1997) Preventing Erosion and Soil Structure Decline – A soil management practices guide for horticultural farmers in the South West high rainfall hills. Collated extracts for the Manjimup Land Conservation District Committee and the Manjimup Horticultural Soils Group.

Reference Location:

[1]"CULTURAL PRACTICES – Cover Cropping" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

1.4 MINIMUM TILLAGE

1.4.1 TECHNICAL OUTLINE

The adoption of minimum tillage practices in the cultivation of farm land has a number of advantages in soil physical properties and erosion control. Successful adoption of minimum tillage systems depends on adequate weed control which can be achieved by efficient utilisation of modern herbicides and selective grazing by stock.

Principals of Minimum Tillage Systems

1. **Reduced frequency of tillage operations and traffic of farm machinery**
2. **Maintaining crop residue and mulch ground cover**
3. **Adoption of direct seed drilling with minimal cultivation**
4. **Weed control achieved by grazing stock and/or by using herbicides**

Disadvantages of Excess Tillage

- Frequent and regular tillage breaks down the soil's structure;
- Rain falling on poorly structured soil can cause a surface crust to form which can reduce water absorption;
- Frequent cultivation and tillage operations can cause soil compaction thus limiting plant root growth and movement of water and associated nutrients through the soil.

Advantages of Minimum Tillage

- Reduces the effect of raindrop impact and surface sealing where stubble is retained;
- Prevents the mechanical breakdown of soil aggregates to smaller particles which are more susceptible to erosion and loss in run-off;
- Prevents hard pan formation and soil compaction, therefore, maintaining high moisture infiltration rate;
- Slows the decline of organic matter and soil moisture levels;
- Reduces the formation of hard pans in the soil;
- Reduces surface run-off and consequent water erosion;
- Decreases wind erosion;
- Fewer cultural operations required, leading to saving of time and fuel;

1.4 MINIMUM TILLAGE

1.4.1 TECHNICAL OUTLINE

The adoption of minimum tillage practices in the cultivation of farm land has a number of advantages in soil physical properties and erosion control. Successful adoption of minimum tillage systems depends on adequate weed control which can be achieved by efficient utilisation of modern herbicides and selective grazing by stock.

Principals of Minimum Tillage Systems

1. **Reduced frequency of tillage operations and traffic of farm machinery**
2. **Maintaining crop residue and mulch ground cover**
3. **Adoption of direct seed drilling with minimal cultivation**
4. **Weed control achieved by grazing stock and/or by using herbicides**

Disadvantages of Excess Tillage

- Frequent and regular tillage breaks down the soil's structure;
- Rain falling on poorly structured soil can cause a surface crust to form which can reduce water absorption;
- Frequent cultivation and tillage operations can cause soil compaction thus limiting plant root growth and movement of water and associated nutrients through the soil.

Advantages of Minimum Tillage

- Reduces the effect of raindrop impact and surface sealing where stubble is retained;
- Prevents the mechanical breakdown of soil aggregates to smaller particles which are more susceptible to erosion and loss in run-off;
- Prevents hard pan formation and soil compaction, therefore, maintaining high moisture infiltration rate;
- Slows the decline of organic matter and soil moisture levels;
- Reduces the formation of hard pans in the soil;
- Reduces surface run-off and consequent water erosion;
- Decreases wind erosion;
- Fewer cultural operations required, leading to saving of time and fuel;

- When direct drilling, fertiliser should be placed below the soil surface, reducing the possibility of it being washed from the site and polluting local drainage and stream systems

Types of Conservation Tillage Systems

1. **Reduced Tillage** – grazing of crop stubble & weed growth after harvest followed by seed bed preparation. Single cultivation may only be needed, followed by application of a contact herbicide before sowing.

2. **Minimum Tillage** – retention of stubble and most weed control achieved with herbicides during the fallow and after one primary cultivation.

3. **Direct Drilling** – no tillage prior to sowing directly into undisturbed soil. Grazing during fallow removes stubble from the previous crop and subsequent weed growth. Remaining stubble is usually burnt following seasonal break of rain. Fallow sprayed with contact herbicide prior to sowing.

4. **No Tillage** – retention of all stubble, with no tillage during the fallow period between crops. All weed control is with herbicides. Following crop sown directly into undisturbed soil through the remaining stubble and weed residue. This practice is applicable to areas where stubble is needed for protection against high intensity summer rainfall and where stock do not form such an important part of the farming system.

5. **Strip Tillage** – involves tillage of a strip centered on the plant line, leaving residues undisturbed within the midrows. In-row subsoiling can be performed to break compaction layers.

6. **Pre-till** – a narrow strip is tilled amongst stubble. Process encourages loosening and decomposition of residue over winter, and speeds drying in the spring so soils are ready to plant earlier. Pre-tilled strips speed germination and emergence, and help keep cereals in rotation. May require extra pass over the field.

7. **Slot Planting** – a slot is opened in untilled soil, and seed is placed at an appropriate depth. Several combinations of seed-firming devices and press wheels are used to close the slot, helping achieve adequate seed-to-soil contact. Slot planting is suited to soybeans and other cereals, however, does not work well in heavy crop residue, and moist, fine-textured soil.

8. **Ridge Till** – this is a derivation of strip tillage. Crops are planted on raised beds or ridges following some row cleaning. Herbicide may be incorporated with a rolling cultivator prior to planting. Plant residue is left undisturbed between the ridges until cultivation. Ridges are rebuilt during the last cultivation.

9. **Permanent Bed Systems** - facilitates use of minimum cultivation to achieve suitable seed beds with furrow irrigation.

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References:

[1]-No-Till: Making It Work / <Internet site>: http://res.agr.ca/lond/gp/bmp/notillbmp.html Date: 20/10/97

[1]-Conservation Farming for Erosion Control (1989) / Soil Conservation Service of New South Wales – Soil Note No. 2/82

[1]-Paul Castor (1996) - Putting Good US Ideas to Work Down Under / The Australian Cottongrower, Vol 17, No 6, Nov-Dec 1996.

Reference Location:

[1]"CULTURAL PRACTICES – Minimum Tillage" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

1.4.2 INDUSTRY CONTACTS
Minimum Tillage

NAME -**MARK HEAP**
POSITION -MANJIMUP DISTRICT OFFICER
ORGANISATION -AGRICULTURE WESTERN AUSTRALIA
LOCATION -ROSE ST., MANJIMUP, W.A. 6258
PHONE NO. (08) 9771 1299
FAX NO. (08) 9771 2544
E-MAIL mheap@agric.wa.gov.au or markh@agric.wa.gov.au
DETAILS -Researching on-farm mulching techniques. Mark has investigated a mechanical straw mulching machine: the Hobson Mulching System™ in America. He has visited Oregon, USA and examined the latest model and researched the benefits of on-farm straw mulching.

NAME -**BEN ROSE**
POSITION -LANDCARE DEVELOPMENT OFFICER
ORGANISATION -AGRICULTURE WESTERN AUSTRALIA
LOCATION -ROSE STREET, MANJINUP, WA 6258
PHONE NO. (08) 9771 1299
FAX NO. (08) 9771 2544
E-MAIL benr@manjdo.agric.wa.gov.au
DETAILS -Specialises in best practice farming including soil conservation, nutrient export, and salinity control. Includes research and adoption of on-farm mulching techniques; use of cover crops such as vetches [eg. pea flower with high nitrogen levels], tropical cereals and oats; tail water drainage systems; development of minimum tillage techniques for potatoes; surface water control; and application of ponds and retention basins to strip nutrients and trap sediment from agricultural drainage water.

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1.5 CHEMICAL MECHANISMS

1.5.1 TECHNICAL OUTLINE

A range of chemical mechanisms, or soil conditioners, are increasingly being used in mining, industry and farming throughout Australia and overseas to modify and improve a number of soil, water and nutrient properties. The benefits of soil conditioners in irrigated agriculture include:

- Improved sediment retention in irrigation furrows;
- Improved soil stability and minimise erosion;
- Improved water infiltration;
- Improved moisture retention and water use efficiency;
- Improved nutrient availability; and
- Modified pH (acidity/alkalinity) levels of the soil.

Soil-binding coagulants that have been used in the past, such as alum, ammonium alum, sodium aluminate, copperas (ferrous sulfate), ferric sulfate and pulverized limestone; have raised a number of environmental concerns and can be expensive and uneconomical for irrigation purposes. However, three commonly used soil conditioners that are low-cost, locally available and considered environmentally safe are **polyacrylamide (PAM)**, **lime** and **gypsum**.

POLYACRYLAMIDE (PAM)

Polyacrylamide, a soil-binding polymer, is used in irrigation farming to retain sediment on the farm and improve water infiltration. PAM can reduce soil erosion by up to 99% and virtually stop sediment loss. PAM can be added to the irrigation supply or directly into farm furrows to induce aggregation - the binding of fine suspended particles (**colloids**) to form larger particles or aggregates. The process of aggregation and settling of the colloidal fraction of sediment is referred to as coagulation or **flocculation**.

PAM is widely used as a settling agent for: food processing and packaging, paper and cardboard manufacture, clarification of mine water and industrial/municipal waste water, as a clarifier for sugar extraction, and removal of sediment from drinking water in counil water treatment plants.

PAM can be used to bind and settle suspended colloids and colloidal-bound nutrients and chemicals present in the water of irrigation furrows, drainage systems, sediment retention basins and tail water recycling reservoirs.

What are polyacrylamides?

Polyacrylamide is a high molecular weight, water soluble, anionic compound to which clay particles bind to form larger stable aggregates. PAM is a combination of acrylamide and acrylic acid. The acrylamide provides the 'backbone' for the polymer chain, the acrylic acid provides the anionic charge. These primarily interact with and attract the clay fraction or small particulate colloids of soil.

PAM has been shown to be effective in:

- Preventing sediment loading of taildrains, main irrigation drains and river systems;
- Reducing irrigation furrow top soil erosion by up to 99%;
- Preventing sediment-bound pesticides (eg. endosulfan, trifluralin, etc.) and nutrients from leaving the farm and contaminating waterways;
- Increasing aggregate stability; and
- Improving infiltration rates of water.

The development of PAM was initially conducted in the United States around the 1950's. The initial research and development was in the cotton industry which uses large quantities of water per hectare in furrow based irrigation systems. The early forms of PAM that were used (monoacrylamides) had lower molecular weights and as a result, rates as high as 500kg/ha were needed to achieve effective soil flocculation. This resulted in higher application costs being incurred by farmers in addition to environmental and health concerns regarding monoacrylamides.

Why use polyacrylamides?

PAM's with extremely high molecular weights have since been developed resulting in much lower amounts being needed to achieve effective levels of sediement flocculation. Results from long term trials have proven PAM to be highly effective in reducing sediment loss from furrow irrigation systems and improving water infiltration to crop roots.

PAM's have been proven in research work to reduce sediment erosion by up to 99%. PAM is effective in binding suspended sediment colloids, improving irrigation efficiency, reducing top soil erosion, and improving water infiltration; all of which have an indirect positive effect on crop growth and yield. The use of PAM is worth considering where water infiltration is poor or the lateral spread of moisture is unsatisfactory such as in heavy clays.

As stated by Sojka & Lentz (1997), PAM halts furrow irrigation erosion by about half tonne of soil per ounce (16kg/g) of PAM used. It removes most sediment, phosphorus and pesticides from return flows, and greatly reduces return flow biochemical oxygen demand (BOD). It increases infiltration, enabling water conservation. Issues such as turbidity and sedimentation of drains and river systems, and the frequency and intensity of algal blooms can be controlled using PAM by reducing sediment and nutrient loading of riparian areas such as river systems.

How Much is Needed?

Dose rates of as little as 1 – 3 ppm are all that is required. This is 1 – 3 kg per megalitre of applied water. Initial trial work conducted in Sunraysia on drip systems fertigated at 2.6 ppm indicated that lower rates of PAM should be applied. For example in a drip irrigated system applying 10 mm / ha, 100 grams of PAM would be required per hectare during the irrigation. A 10 hectare shift would require 1 kg of product (Shane Phillips, 1997).

Frequency of application depends heavily on soil type, environmental conditions and flow rate of irrigation water. Trials in furrow irrigation systems have found that on average, an initial application of 1 – 3 kg/ha of PAM per 10 to 12 day period (or each irrigation cycle) is sufficient with lower application rates needed as concentration of PAM in the soil increase over time.

Costs range between $6 - $12/kg or $6 – $36/ha per application depending on: water volume, irrigated area, irrigation time & rate, required dose, actual dose & rate, and application / product costs. Costs are partially or entirely retrieved by savings in erosion-related field operations,

preventing loss of fertile soil, improved infiltration, water conservation and improved crop yield responses.

What is Required for a Successful 'PAM' Application?
Successful application of PAM will depend on the following:
- Use correct rate – do not overdose;
- Use correct application point – eg. apply at point of high turbulence to ensure complete dispersion into the irrigation water (ie. the head ditch feed pipe at the irrigation channel);
- Use recommended applicators / feeders.

PAM and Siphon Irrigation
Irrigation water flow across a siphon set is significantly higher past the first siphons than across siphons further away from the irrigation water entry point. This indicates that it is impossible to evenly apply chemicals across an irrigated area when they are dosed to the irrigation water unless the head ditch is already charged with the chemical prior to the irrigation.

Important User Considerations
PAM is available in Australia under several trademarks, such as:

- **Soilfix™** **[ALLIED COLLOIDS]**
- **Flobond™** **[SNF - FLOERGER®]**
- **Irrigaid*** **[CYTEC]**

Water soluble PAM's are metered into irrigation supply ditches in the following forms:
- Dry bead granules or "powder";
- Predissolved aqueous concentrate;
- Compressed blocks or cubes for suspension in flowing ditches or furrow systems; or
- Oil-emulsified concentrates.

Each form has various advantages and drawbacks.
Powders – are easy to store, transport and meter into head ditches, but require vigorous agitation to make them dissolve.

Aqueous Concentrates - are limited as to the strength of concentrate that can be prepared before viscosity impairs practical use. The main advantage is better dissolving in stock solutions or in the head ditch than powders. The disadvantage is unknown storage effects and low % active ingredient for weight and volume of material handled.

Blocks and Cubes - are easy to handle and place, but do not dissolve uniformly. Cubes placed in furrows can wash dowstream. Erosion and infiltration performance has been more variable than with other application methods.

Emulsified Concentrates - provide the same advantages as aqueous concentrates, but have much lower viscosity and achieve ten times the % active ingredient, greatly reducing volume and weight transport considerations. Emulsified concentrates may be suitable for individual furrow application via a drip line at the upper field end; further trialling is needed. Shelf life and storage conditions may be factors for advers climates. Metering is somewhat simplified, but temperature related viscosity may affect calibration in some areas and at some times in the season.

As stated by Sojka and Lentz (1997), if dry granules or powder is metered into the flow, turbulence needs to be created in the head ditch just below the point of PAM addition to promote uniform PAM dissolution and distribution. Supply-ditch PAM concentration can be primed and brought to optimum concentration and then delivered to dry furrows at inflow rates that rapidly advance water across the field.

It is essential that no untreated water wet the furrow ahead of the PAM-treated flow. Untreated water destroys soil structure of erodible soils before PAM-treatment, greatly reducing PAM's effect (Sojka and Lentz, 1997).

If using PAM in a fertigation system

PAM is very sticky and under no circumstances should be added to a tank in 'one lump'. This will cause large problems in the tank and result in blockages along the line. PAM's can be dissolved at the rate of 1.2kg / 500 litres provided adequate agitation is applied to the tank.

For example: A grower with a 2000 L fertigation tank and was irrigating 10 hectares with 10 mm appliction over eight hours. This would require 1 kg of 'PAM' to be dissolved in the tank and injected into the line over the period of the irrigation. 1 kg PAM in 2000 L of water. This is a concentration of 500 ppm PAM in the fertigation tank.

(a) Use the correct rate – do not overdose. Add the product slowly to the fertigation tank.

(b) Ensure that the product is fully dissolved prior to fertigation (slowly add product to the tank and agitate for a minimum of one hour prior to fertigation).

(c) Inject at the beginning of the shift and allow at least 30 minutes to 1 hour to flush the line clean of the product.

(d) Double check to ensure the following "Right Rates, Right Dissolving Period and Right Irrigation Scheduling"

(e) Do not add PAM before filtration – always add product after the final filtration!

Where water is cheap the cost of treating furrow water may appear prohibitive but in drip systems treated costs per hectare are in the vicinity of $2.00 - $3.00. It is a volumetric dose rate and various irrigation systems are run at differing application rates per hectare.

If unsure of correct application rates ring your local agents:

-JIM LOWRIE & LINDSAY PETERSON, **Kimberley Rural Merchandising Pty Ltd**, PO Box 563, Kununurra, WA 6743 / Ph. (08) 9168 1926 / Mobile 015 610 089

-GARRY RAMSAY, **Barnyard Trading (Kimberley) Pty Ltd**, Lot 2408, Rivergum Av, Kununurra, Wa 6743 / Ph. (08) 9168 3033 / Fax. (08) 9168 3293

Application Equipment

-The Mobile Soilfix Applicator is a mobile chemical mixing system specifically developed by Allied Colloids for pre mixing solid grade Soilfix prior to dosing irrigation water. The applicator is designed for rapid relocation and setup. It is suitable for a wide range of irrigation flow rates,

from 1 to 30 ML/hr depending on dose rate (1 to 3 ppm). This is equivalent to a maximum of 300 hectares.

-The Horstine Microband or Gandy Applicator is paddlewheel, solar or DC motor driven which holds 10-15 kg of metered PAM for application to irrigation supply ditches.

-The Portible Applicator comprising a hopper is a pallet mounted applicator.

Environmental fate of polyacrylamide
Source: Seybold (1994) and Sojka and Lentz (1997)

Once soil micro-organisms have removed the easily metabolized amide functional groups as a nitrogen source, PAM is primarily degraded by mechanical abrasion and physical breakdown by cultivation and shrinking / swelling, photo-chemical / UV breakdown. It has been suggested that wetting and drying cycles may cause degradation of PAM and reduced efficacy.

PAM has been shown to be non-toxic to humans, animals, fish, and plants; the only concern has been the toxicity of its residual monomer (acrylamide) content, which is a known nuerotoxin to humans. The residual acrylamide content of PAM products is the major concern in regulation of this polymer. Acrylamide is very water soluble (2kg/L) and has a low or no adsorption capacity on sludges and sediment or on resins. Because of acrylamide's very high water solubility and low adsorption potential, it is a potential contaminant to groundwater (Seybold, 1994).

However, the acrylamide monomer is bio-degradable and does not accumulate in soils. At ambient temperatures half-lives of acrylamide range from 18 to 45 hours for 25 ppm acrylamide on a soil basis (Seybold, 1994 ref: Lande *et al.*, 1979). Decreasing the temperature, increasing the acrylamide concentration or presence in anaerobic conditions will increase the half-life of the acrylamide component of PAM.

The LD50 (lethal dose of acrylamide that will kill half of a test animal population) for a single dose in mice, rates, guinea pigs, and rabbits has been reported between 110 and 280 mg/kg body weight (Seybold, 1994). Studies have also shown that dry anionic PAM of the type that are effective in soil systems show no toxicity to fish (lethal concentration: LC50 >100mg/L) and indicate that a relatively high threshold of tolerance exists (Sojka and Lentz, 1997). The average PAM concentration of water leaving a field from a 24 hr irrigation is only 0.1% of the >100mg/L value or 0.1 ppm, which is actually below the current detectability of PAM in natural waters (Sojka and Lentz, 1997). Seybold (1994) concludes that PAM itself, does not pose any environmental threat and, providing it is applied correctly, can be used to treat soils to effectively reduce irrigation-induced erosion and as a soil conditioner.

Application of Polyacrylamide in the ORIA
PAM has proven to be highly successful in actually preventing furrow erosion and export of sediment and contaminants into irrigation drains and river systems. As a best practice technique in irrigation farming, PAM has significant potential throughout the ORIA to control sediment and contaminant export from farms. PAM is already being used in the ORIA and is locally available from suppliers in Kununurra. Monitoring of effectiveness should be undertaken including trialing of PAM's effect on soil properties including organic matter, pH and CEC. The adoption and effectiveness of PAM in the ORIA will be successful providing correct dosage, application methods and ongoing liaising between growers and suppliers is maintained. Details of contacts and suppliers are noted in section 1.5.2 'Industry Contacts'.

GYPSUM & LIME

Source: Hunt (1992)

GYPSUM

Gypsum (calcium sulphate) is a naturally occurring substance or industrial by-product which has numerous applications in farming, earthworks and revegetation. Its use in stabilising highly dispersible soils is well recognised in addition to a range of other benefits. Its other functions include:

- Preventing soil swelling and dispersion.
- Increasing soil porosity and structural stability.
- Increasing soil infiltration and hydraulic conductivity.
- Reducing dry soil strength and improving soil structure.
- Reducing soil crust strength.
- Improving root penetration and seedling emergence.
- Reducing erosion.
- Improving subsoil acidity in conjunction with lime.
- Use as a soil-binding flocculant in settling ponds.

Identifying gypsum-responsive soils

Source: Frost & Orr (1990)

All clays swell on wetting and the process of swelling causes particles to mechanically break off from the aggregate. This process is called slaking. This is a different observation to dispersion where the clay disperses to form a milky cloud around the aggregate. It is the dispersiveness of a soil that determines its likely response to gypsum.

Several tests to help identify gypsum-responsive soils have been developed through research, including trials conducted by Agriculture WA. Two simple assessments include using field observations and using a simple dispersion test.

Field observations

Soils that are likely to be structurally degraded (lose their crumb structure when wet) and likely to be gypsum-responsive may:

- be hard when dry or have a surface crust;
- become sticky or non-trafficable after light rainfall; puddles of water will have a milky appearance from the suspended clay;
- collapse after heavy rainfall;
- have low water infiltration and high run-off; and
- produce patchy crop emergence and early growth, particularly in poor seasons.

Visual dispersion test

This can be carried out on the farm by collecting topsoil and subsoil (15cm deep) samples from the area to be tested. Individual aggregates from a sample are added separately to small containers of distilled water and left standing for 24 hours without disturbance. The degree of dispersion can then be ranked on a scale from 0 to 5. The higher the percentage of dispersion the lower the aggregate stability and higher response to gypsum.

The recommended rate of applying gypsum is 2.5 t/ha (Frost & Orr, 1990). Surface application at a rate of 1 to 2.5 t/ha is generally required to reduce surface crusting. Gypsum can be incorporated into the soil profile, spread on the soil surface or dissolved in irrigation water.

When pH is less than 5.0 (in water) lime should also be used as gypsum has minimal effect on soil pH.

LIME

Applying agricultural lime is the most common method of treating acid soils. Using lime for agricultural purposes will:

- Raise soil pH thereby reducing acidity.
- Increase soil calcium.
- Reduce toxic manganese and aluminium.
- Increase molybdenum availability.
- Enhance legume nodulation

Lime should be applied to soils to reduce toxicity problems and improve soil pH levels to between 6.0 and 6.5 (in water). The quantity of lime to be added varies between soils; coarser textured soils generally require less lime than finer textured soils.

The quantity of lime to be applied should be determined by a lime treatment test to assess the response in pH of soil samples to different quantities of lime. Rates vary greatly, from less than 0.5 t/ha to over 10 t/ha. Lime is normally incorporated into the soil just before – or during – sowing. Lime can also be spread on the surface but the response time is much slower.

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References:

[1]- FROST F. & ORR G. (1990) Identifying gypsum-responsive soils, Farmnote No. 57/90, Western Australian Department of Agriculture.

[1]- SHANE PHILLIPS (1997) Notes on PAM, Riverland Horticultural Traders @ Barmera, South Australia / Ph. (08) 8588 2228

[1]- SOJKA R. & LENTZ R. (1997) A PAM Primer: A brief history of PAM and PAM-related issues.

[1]- SOJKA R. & LENTZ R. (1994) Polyacrylamide (PAM): A new weapon in the fight against Irrigation-induced erosion. USDA_ARS Soil and Water Management Research Unit, Station Note #01-94

[1]- SEYBOLD C.A. (1994) Polyacrylamide Review: Soil Conditioning & Environmental Fate, Virginia State University, PO Box 9081, Petersburg, Virginia / Commun. Soil Sci. Plant Anal., 25(11&12), 2171-2185

[2]- HUNT J.S. –Editor (1992) Urban Erosion & Sediment Control, Revised Edition, Department of Conservation & Land Management

Reference Location:

[1]"CHEMICAL MECHANISMS" resource file, at the Kimberley Development Commission, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

[2]"SEDIMENT TRAPS & EROSION CONTROL" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

1.5.2 INDUSTRY CONTACTS
Chemical Mechanisms

NAME -MICHAEL EPPLER
POSITION -FARMER – ORD RIVER IRRIGATION AREA
LOCATION -PO BOX 1088, KUNUNURRA. WA 6743
PHONE NO. (08) 9168 1613
FAX NO. (08) 9168 3198
DETAILS -Has experience in using polyacrylamide (soil-binding polymer) in his farming enterprise for improving on-farm soil retention and minimising the movement of colloidal soil particles and colloidal-bound nutrients and chemicals in run-off into the drainage system.

NAME -LYNDAL HUGO
POSITION -PhD STUDENT
ORGANISATION -UNIVERSITY OF SYDNEY
LOCATION -SYDNEY, NSW 2006
PHONE NO. (02) 9351 2379
FAX NO. (02) 9351 5108
E-MAIL l.hugo@agec.usyd.edu.au
DETAILS -Conducting an extensive research project studying the interactions between polyacrylamide (soil-fixing polymer), colloidal sediment and endosulfan. Continuing involvement with farmers in the Emerald Irrigation Area, coordination of field days and presentations, and providing extension and advice on the correct application techniques of polyacrylamide in varying irrigation systems. Working with Harvey Gainer and supervisor Dr. Ivan Kennedy → Ph: (02) 9351 3546 / Mobile: 0419 258596.

NAME -JIM LOWRIE & LINDSAY PETERSON
POSITION -SALES & DISTRIBUTION
ORGANISATION -KIMBERLEY RURAL MERCHANDISING
LOCATION -PO BOX 563, KUNUNURRA, W.A. 6743
PHONE NO. (08) 9168 1926
FAX NO. (08) 9168 1936
MOBILE 015 610 089
E-MAIL
DETAILS -Supply and distribution of SOILFIX (polyacrylamide) and specially adapted feeder systems for efficient application to irrigation systems in the Ord River Irrigation. Part of 'ALLIED COLLOIDS AUSTRALIA PTY LTD', Perth – (08) 9470 4111

NAME -ANDREW MCHUGH
POSITION -CONSULTANT
ORGANISATION -ALLIED COLLOID
LOCATION -TINGALPA, QLD. 4173
PHONE NO. (07) 3890 2377
FAX NO. -
MOBILE (018) 787 424
E-MAIL -
DETAILS -Specialises in the supply, distribution and management of SOILFIX™, a polyacrylamide flocculent added to head irrigation water to bind fine sediment particles, reduce soil erosion and improve water infiltration.

NAME	**-SHANE PHILLIPS**
POSITION	-SOIL, WATER & PLANT NUTRITION
ORGANISATION	-RIVERLAND HORTICULTURAL TRADERS – [ELDERS LTD.]
LOCATION	-PO BOX 321, STURT HIGHWAY, BARMERA, S.A. 5345
PHONE NO.	(08) 8588 2228-Wrk / (08) 8583 6478-Home
FAX NO.	(08) 8588 2211
MOBILE	0417 802 791
E-MAIL	-

DETAILS -Has developed a scheduling and modeling system for Polyacrylamide use in dripper and sprinkler irrigation. Experience using the Right Amount Right Time computer aided irrigation scheduling program which uses crop factors, ET, rainfall and soil information to predict crop water requirements and forecast irrigation schedules. Also has conducted trial work using Sub Surface Furrow Irrigation which uses a sub-surface pipe system for irrigation that is also designed for drainage.

NAME	**-GARRY RAMSAY**
POSITION	-AGRICULTURAL SUPPLIER
ORGANISATION	-BARNYARD TRADING (KIMBERLEY) PTY LTD
LOCATION	-LOT 2408, RIVERGUM AVE, KUNUNURRA, WA 6743
PHONE NO.	(08) 9168 3033
FAX NO.	(08) 9168 3293

DETAILS -Supply and distribution of polyacrylamide soil-fixing polymer for irrigation farming for SNF Australia Pty Ltd. Has polyacrylamide in powder and liquid emulsion and slow-release tablet blocks.

NAME	**- COL SCHILLER & JOHN ROCHECOUSTE**
POSITION	-CONTRACTORS
ORGANISATION	-CYTEC
LOCATION	-PO BOX 92, TOOWOOMBA, QLD 4350
PHONE NO.	-John: (076) 350 824 / 0419 790 747
	-Col: (076) 361 077 / 0419 686 254

DETAILS -Field trialling and distribution of IRRIGAID* Soil Erosion Polymer. Reduces soil erosion by up to 95%, increases soil water infiltration by 15-30%, and reduces nutrient and pesticide run-off. When introduced to irrigation water, IRRIGAID retains soil and nutrients on the farm and minimises furrow irrigation soil loss. Col has had experience with trialling and application of polyacrylamide throughout QLD including the Burdekin Irrigation Area.

NAME	**-STEWART SHIPARD**
POSITION	-PROJECTS MANAGER
ORGANISATION	-S N F AUSTRALIA PTY LTD
LOCATION	-UNIT 4 / 168 BALCATTA RD, BALCATTA, PERTH, WA 6021
PHONE NO.	(08) 9345 3477
MOBILE	0411 866 114
FAX NO.	(08) 9345 3488
E-MAIL	snf@zeta.com.au

DETAILS -Supply and distribution of polyacrylamide soil-fixing polymer for irrigation farming. Supplies powder in emulsion form, emulsion liquid and new tablet form. Has set up distribution outlet through Garry Ramsay at: Barnyard Trading (Kimberley) Pty Ltd., Lot 2408 Rivergum Av. Kununurra, WA 6743.

NAME	**-DAVID WATERS**
POSITION	-SOIL CONSERVATION RESEARCH OFFICER
ORGANISATION	-DEPARTMENT OF NATURAL RESOURCES - QLD
LOCATION	-EMERALD, QLD
PHONE NO.	(079) 82 8806
FAX NO.	(079) 82 3459
E-MAIL	watersd@dnr.qld.gov.au
DETAILS	-Researching sustainable land and water use, managing soil retention, surface water quality, groundwater quality, and catchment management. Research includes methods of minimising soil/pesticide movement using polyacrylamide, rotation of cotton growing with stubble crops such as wheat, and using non-invasive *Monto vetiver* grass for channel bank and on-farm soil stabilisation.

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1.6 TAIL WATER RETURN

1.6.1 TECHNICAL OUTLINE

Tail drains are designed to collect and remove farm run-off from irrigation or rainfall by directing furrow tail water into drains and ultimately the river system. They are also the site of movement of farm sediment, nutrients and pesticides which may enter the drains and either settle or continue downstream depending on flow velocities.

Tail water return systems are being used in irrigated agriculture throughout Australia whereby irrigation tail water is captured and recycled using pumps. A significant benefit of a tail water return system is that nutrients and chemical entering into tail drains from farm run-off can be captured and prevented from moving further downstream. This minimises the risk of environmental impacts from contaminants occurring such as algal blooms and fish kills in the river system and tributaries.

The potential of implementing a tail water return system for the existing Ord Stage 1 will be difficult as the area was developed as a "flow through" system and large scale amendment of the existing infrastructure would not be viable. Current accessions to groundwater from infrastructure and fields is already in need of management and further accessions from any recycling storages needs to be avoided.

Tail water return is best suited to areas specifically designed for that purpose, therefore, the whole of Ord Stage 2 is to be designed specifically around a tail water return system.

A factor that needs to be taken into consideration is the size of recycling storages used to capture runoff and supply irrigation needs and the associated costs of lining with clay. Due to the cost of lining, large storages would need to be economically feasible. The cost of constructing storages as large as those used in other parts of Australia would prohibit their development if all water including wet season runoff had to be retained on-farm.

The use of retention basins for storing tail water for future irrigation is useful in preventing sediment and contaminant movement into rivers, however, careful consideration is needed regarding size and site location to avoid groundwater recharge from tail water storages. Such considerations will help minimise unnecessary groundwater accession and waterlogging.

Tail water storages should be located on areas of low permeability to avoid groundwater recharge. Site location is important as the cost of lining recycling storages to prevent accession to the groundwater are high.

On-site tail water recycling storage basins or reservoirs can be used to retain sediment and allow it to settle, although some fine particulate matter may stay suspended for extended periods. However, soil-binding polymers (ie. polyacrylamide) can be used to bind and settle suspended colloids and colloidal-bound nutrients and chemicals present in the water of irrigation furrows, drainage systems, sediment retention basins and tail water recycling reservoirs. [Refer to: Section 1.5 Chemical Mechanisms].

During storms and heavy rainfall events large amounts of run-off are produced. Sediments and associated nutrients that have dropped out into the drainage system are more likely to be re-mobilised due to the high velocities of these run-off waters.

High volumes of sediment and nutrients from agricultural fields are also washed into run-off which produce large 'pulses' of sediment and nutrients that may enter nearby streams and rivers (Rummenie & Noble, 1996).

To prevent large influxes of sediments and contaminants being transported through irrigation drainage systems and rivers, it is necessary to either prevent farm run-off waters from reaching the river system or, alternatively, decrease sediment loads present in the water prior to accession into the river system.

As stated by Rummenie & Noble (1996), this can be achieved by:

- Increasing on-farm ground cover – which stabilises soil structure and minimises sediment loss, decreases water impact from irrigation/run-off/rain and improves water infiltration.

- Keeping slopes and furrow lengths to a minimum – which reduces water velocities and length of water passage thereby decreasing surface erosion and improving water infiltration;

- Allowing run-off water to move slowly through lengthy irrigation drains – resulting in a decrease in the levels of sediment and sediment-bound nutrients/chemicals through various processes of settling, decomposition, assimilation, sedimentation, adsorption and dilution;

- Keeping drains clear of previously deposited sediments – which decreases the likelihood of previously deposited soil and nutrients being re-mobilised during high flow periods, ie. the Kimberley wet season; and

- Recycling and storage of tail water – which prevents (or minimises) the level of farm run-off and associated sediments/contaminants from entering drains and reaching the river system. This provides time for sediment and nutrient levels to decrease (through the processes detailed above) and the water can be utilised for irrigation purposes.

If possible, to overcome the problem of trying to match tail water pumps to varying tail water flows, buffer storage should be used to collect water passing through the tail drains. The water can then be pumped to a main storage or directly to the supply system for irrigation once sufficient volume has collected in the buffer storage (Purcell, 1993).

As stated by Purcell (1993), when the rate of water flowing into the system is in excess of pumping capacity, especially in the event of input from peak flow run-off, there is a need to safely dispose of water.

An emergency overflow facility such as a grassed bywash around the buffer storage may be used, or a gap can be provided in the bank of the tail water return drain to relieve excess water levels. A gated weir structure in the tail water system is sometimes required. This is important for water level control, especially as pumps may not be fully operational during a storm or there may be access problems.

Design and Management

A number of design principles will need to be investigated prior to construction of a tail water return system. These include:

- Size and associated costs including:
  a) Capacity, depth and surface area of storage basins for tail water return;
  b) Excavation and cost of lining with clay to prevent leakage;
  c) Maintenance cost.
- Site location of tail water return storages and soil permeability assessment necessary to prevent groundwater accession;
- Engineering specifications – safe design, storage time, inflow/outflow rates, pumping requirements etc.;
- Opportunity costs in terms of:
  d) Lost land;
  e) Construction;
  f) Pumping - match up against water loss/cost;
- Use of vegetation for erosion control and as a biofilter for increased nutrient uptake;
- Appropriate management involving:
  a) Management of initial 'pulse' storm run-off, flow velocities and water levels;
  b) Stabilisation of exposed tail drain outlets and banks, and protection from wave action and 'pulse' storm flows using grasses, rocks or sheeting etc. (Refer Section 1.1.1 Part B);
  c) Maintenance – Sediment removal and cleaning of overflow outlets;
  d) Monitoring water quality – ie. periodical analysis of levels of Suspended Solids (SS), Total Nitrogen (TN) and Total Phosphorus (TP) present in water in irrigation channels, farm furrows, tail drains, storage reservoirs, main drains and river outlets.

Tail water reuse schemes have many advantages, however, careful consideration needs be given to site location of storages to avoid exacerbating groundwater rise; and continual monitoring of water quality, especially to identify weed seeds, plant pests or diseases present in the tail water. Levels of contaminants such as chlorotic streak disease of sugar cane, for example, or other plant pests and diseases may be exacerbated if excessive use of tail water recycling occurs within a confined or localised area. Conjunctive use of fresh channel water and recycled tail water should be considered to prevent concentrations of contaminants increasing.

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References:

[1]-Stace Rummenie and Bob Noble (1996) Drainage and Tail water Recycling Reduces Nutrient, Sediment Movement - QLD Dep of Natural Resources, Biloela. / In: The Australian Cottongrower, Vol 17, No 6, Nov-Dec 1996

[1]-J.D. Purcell [Barrett Purcell & Associates Pty Ltd, Narrabri, NSW] (1993) A Selection of Irrigation Notes - Development of a Surface Irrigation System (Page 8); Irrigation Association of Australia, NSW NW Branch, Seminar Series, July 1993

Reference Location:

[1]"CULTURAL PRACTICES – Tail water Return" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

1.6.2 INDUSTRY CONTACTS
Tail water Return

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NAME	**-JOHN RUPRECHT**
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DETAILS	-Specialises in surface water modeling and hydrology throughout Western Australia. ie. Soil/crop water balance modeling, tail water return principles & associated management requirements.

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2. MANAGING GROUNDWATER RESOURCES & GROUNDWATER QUALITY

INTRODUCTION

Irrigated development for intensive agriculture has the potential for significant environmental changes including groundwater rise, water-logging, salinity and deterioration in both groundwater and surface water quality.

While rates of environmental change vary, their progressive effect has proven in numerous cases to have significant detrimental effects on land productivity. Rising groundwater levels can cause a range of soil and water problems and associated reduction in crop yields.

The issue of rising groundwater in the Ord River Irrigation Area (ORIA) is of concern. Current trends in the ORIA indicate that groundwater levels are rising under the irrigation area and in some areas are approaching the ground surface. The rising groundwater in the ORIA has implications for the areas already under irrigation and for the planned expansion and development of Stage 2.

The amelioration of waterlogged areas and prevention of groundwater rise in irrigation farming may be achieved by integrating a number of best practice techniques, including:

- Groundwater pumping & conjunctive use of groundwater for irrigation;
- Soil permeability mapping – to determine areas contributing to groundwater recharge;
- Improved irrigation efficiency – to minimise accession from farms to groundwater;
- Agroforestry and tree cropping – to help reduce excess water and minimise further groundwater accessions; and
- Sub-surface drainage – to collect and divert sub-surface water movement into drains or storages for irrigation use.

It is important to realise that groundwater is a resource which can be utilised as an alternative water source for crop irrigation providing groundwater quality (eg. salt level) is continually monitored. Dewatering bores are already being successfully trialled in the ORIA to lower groundwater levels by pumping groundwater into irrigation supply channels.

Primary consideration is needed to accurately define and monitor available groundwater resources and groundwater movement in the ORIA. Ongoing geophysical investigations in the ORIA need to be maintained on both a local and regional scale .

A clearer understanding of groundwater hydrology, areas of high soil permeability and preferred pathways of water movement through the soil will enable identification of target areas and ensure effective implementation of groundwater management strategies.

A range of computer software has been developed in the US for modeling and interpretation of groundwater hydrology by using available bore-hole information, soil type and water quality data.

Examples of current groundwater modeling software include:

- **MODFLOW for Windows 95/NT**
- **Visual MODFLOW**
- **Visual GROUNDWATER for Windows 95/NT**
- **USGS MODFLOW**
- **GMS (Groundwater Modeling System 2.1)**
- **MS-VMS (MODFLOW SURFACT – Visual Modeling System)**
- **BIOMOD 3D**
- **Groundwater Vistas**
- **Argus ONE - version 4.0**

[Information regarding the above modeling programs is contained in the information resource file: 'Modeling Software & Investigative Instruments', available at the Kimberley Development Commission, PO Box 620, Kununurra, WA 6743 / Ph. (08) 9168 1044 / Fax. (08) 9168 1044]

Visual MODFLOW and USGS MODFLOW have been used to provide 3-dimensional analyses of past, current and future trends in groundwater hydrology in the ORIA, however, the reliability and efficacy of some programs has yet to be fully determined.

The following identifies the existing groundwater problems in the ORIA and best practice techniques that need to be considered if productivity and economic benefits from irrigated agriculture are to be maximised and maintained in a sustainable context.

MANAGING GROUNDWATER

Major Causes of Groundwater Recharge & Rising Groundwater Levels

- **Water Supply Channels & Drains** – leakage of water through the channel wall to groundwater.
- **Inefficient Furrow Irrigation** – application of excess water to crops can result in movement of water past the root zone leading to excessive recharge of groundwater ("over irrigation").
- **Poor Surface Drainage**
- **Precipitation**
- **Diversion Dam**
- **Areas of particularly permeable soil situated in the field, channels and/or drains.**

Environmental Effects of Rising Groundwater

- **Soil Salinisation** – Elevating groundwater level raises salts to the upper soil horizons. Capillary action mobilises salt up into the root zone of plants, dramatically affecting plant

growth. Soils vary in their levels of salt and surface evaporation concentrates salt in the root zone and upper soil profile.

- **Waterlogging** – removes air spaces from root zone of crops and results in deoxygenation of the soil and consequent reduction in crop yields

Primary Objectives for Managing Groundwater and Groundwater Quality

- To prevent the loss of productivity
- Control and/or prevent rising groundwater
- Minimise groundwater accession
- Monitoring of water inputs from surface water sources
- Monitoring of groundwater quality
- Establish surface and groundwater balance model
- Implementation of a discharge licensing system for water quantity and quality on water leaving properties.

Management Options for Control of Rising Groundwater

➢ **Remove Excess Groundwater:**

- Groundwater pumping from water bores (assess localised /regional status);
- Conjunctive surface & groundwater use for irrigation supply;
- Agroforestry and tree cropping to take up existing groundwater.

➢ **Reduce Accessions to Groundwater:**

- Improved irrigation management and crop water use efficiency;
- Land forming including laser planing to improve drainage;
- Optimisation of irrigation water application with surface drainage;
- Lining of irrigation supply channels and drains;
- Reusing wastewater;
- Mapping of soil permeability and leaks to define areas of high/low infiltration;
- Agroforestry and tree cropping to take up groundwater and prevent groundwater recharge (ie. timber blocks, wind breaks, tree corridors along channel/drainage infrastructure)
- Sub-surface field drains (ie. tile drainage) and dewatering by groundwater pumping.

Performance Indicators for Control of Rising Groundwater

Short Term

- Reduction in the rate of groundwater rise in treated areas;
- Installation of recovery bores to lower groundwater;
- Incorporation of improved irrigation practices as a requirement in the LWMP;
- Measured reduction in difference between amount of water irrigated onto paddocks and water leaving paddocks (after irrigation) into drains (requires property level monitoring).

Long Term

- Increase in depth to groundwater level;
- Reduction in height of salt in soil profile below surface;
- Reduced salt concentrations and volumes in soil profiles;

GROUNDWATER QUALITY

Productive irrigated agricultural practices are based on the use of fertilisers and pesticides to obtain high crop yields. However, some of the chemicals applied to farm land move down from the root zone and can contaminate underlying groundwater. Other sources may include catchment systems including channels and irrigation drains that have accumulated contaminated surface run-off which can then leach through the soil profile.

The quality of groundwater is of great importance in determining its suitability for a certain use such as irrigation. As stated by Bouwer (1996), quality standards for irrigation water are based on:

1. Total salt concentration of the water as it affects crop yield through osmotic effects;
2. Concentration of specific ions that may be toxic to plants or that have an unfavorable effect on crop quality; and
3. Concentration of cations that can cause a reduction in potassium, deflocculation (or dispersion) of the clay in the soil and resulting damage to soil structure and declines in infiltration rate.

Land treatment systems such as applying sewage effluent to land by irrigation are being adopted more frequently due to rising costs of treatment plants, available nutrient supply in the effluent and greater awareness of the need for preserving the quality of surface water. There are many benefits to this technique as soil is highly capable of removing suspended and dissolved material from effluent. However, to prevent leaching of treated wastewater into the groundwater, preventative measures may be needed, such as intercepting its movement with sub-surface drains or bores. The intercepted water can then be re-used for irrigation

If groundwater has high concentrations of salt or other ions its use for irrigation may cause damage and limit plant production. Conjunctive use by combining both degraded groundwater and channel irrigation water can help dilute any accumulated contaminants.

The movement of groundwater is generally very slow, and many years may elapse after the start of pollution before affected water is detected. Similarly, many years may be required to rehabilitate contaminated aquifers after the source of pollution has been eliminated. It is

important to continually monitor the quality of groundwater (ie. salt concentrations and other chemicals) used for irrigation supply. If contaminant levels are high, appropriate measures can be taken, to minimise damage to crops.

Prevention of groundwater contamination is essential and can be achieved through best management practices such as efficient irrigation techniques (to minimise groundwater recharge, rise and associated salt rise) and efficient fertiliser and pesticide application. The use of groundwater for irrigation will facilitate this process and enable better monitoring of groundwater quality.

Groundwater monitoring has occurred in the ORIA since its inception in the early 1960's. Groundwater levels and salinity have been monitored over that time and have provided information leading to the implementation of a number of management strategies including improvement in on-farm water application efficiency and in dewatering using groundwater pumps.

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References:

[1]-Definition Statement of Key Environmental Issues and Responsibilities – Forum on Environmental Management of the Ord Stage 1 Irrigation Scheme – Transfer of Ownership / Water Corporation and Ord Irrigation Co-operative, 16th October, 1997.

[2]-Groundwater Hydrology / Herman Bouwer, Murdoch University Environmental Science, November 1996

Reference Location:

[1]"PLANNING & EXTENSION – Ord River Irrigation Area" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

[2]"GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

2.1 SOIL PERMEABILITY MAPPING

2.1.1 TECHNICAL OUTLINE

Soil permeability is a major factor which determines the rate of lateral and vertical water movement throughout a soil profile. Understanding the level of soil permeability in irrigated agriculture is an important factor to consider when developing a strategy to manage rising groundwater and groundwater recharge.

A number of advantages and benefits can be gained by mapping soil permeability at depths as low as the groundwater level. To determine the suitability of land for intensive agriculture and irrigation farming, extensive analysis and hydrogeological assessment of existing soil and water resources is required. The potential scope of conducting such investigations may include the following:

1. Establishing basic hydrogeology by:
    a) defining areas of recharge and discharge
    b) locating and mapping aquifers and aquitards
    c) estimating hydraulic gradients and flow directions
    d) measuring salt distribution in soils and groundwater

2. Estimating suitability for irrigation based on hydrogeological information, particularly salinity, depth of groundwater and effects of increased recharge.

3. Evaluating high-yielding aquifers as supplementary supplies.

The planning of hydrogeological investigations may be structured in the following stages:

1. Evaluation of existing data on water resources, geology and geomorphology.
2. Investigative geophysics, drilling, geology and test-pumping of bores.
3. Interpretation of results of the investigative stage, and correlation with known data.

The mapping of areas of high or low soil permeability to significant depths will enable more accurate location of preferred pathways of water movement in both horizontal and vertical directions. This will improve the use and effective positioning of de-watering measures such as groundwater pumping, sub-surface drainage and tree cropping. Such measures can be positioned at strategic sites to achieve more effective interception of lateral and downward water movement through the soil profile and help manage groundwater intrusions from irrigation farming, rainfall and channel/drainage seepage..

A number of techniques can be used for hydrogeological investigations. Techniques such as ground-based or airborne electromagnetic (EM) surveys can be used to assess electrical conductivity and movement of salts in the soil and identify areas at risk of developing salinity due to rising saline groundwater.

Hydrological investigations of groundwater hydrology and recharge modeling using data from monitoring bores can be used to map geology and water-quality. Electrical conductivity can relate to either salt storage, shallow groundwater or to basement rock-type changes. Soil surveying of subsurface formations such as palaeo-channels or gravel intrusions can therefore be mapped by integrating data with EM investigations and global positioning systems.

As stated by de Broekert (1996), areas of groundwater discharge can be detected by electromagnetic instruments, but higher accuracy is generally achieved by shallow sensing and should preferably also be able to give depth information. The use of airborne EM needs to be application-driven rather than technology-driven for it to remain viable in the long term.

Ground-based Electro-Magnetic Soil Surveying

Ground based EM mapping is currently being undertaken throughout Australia including the Murray Irrigation Area (MIA) and Riverina of NSW. A new method of soil surveying that has been researched and endorsed by NSW Agriculture at the Yanco Agricultural Institute is the EM31 Ground Conductivity Meter Global Positioning System (GPS) which is mounted on a four wheel motorbike enabling increased mobility, efficiency and accuracy. This method gives an indication of any changes in soil texture using an electro-magnetic wave emitted to a depth of six metres.

EM measures charged particles in the soil and readings are expressed as the level of salinity in the profile. Readings are effected by salt, clay, sand and water content, bulk density and temperature. EM can be used to distinguish between clay and sand and identify sand at shallow depths and areas of high water intake. The EM-38 surveys to a depth of around 2 metres (vertically & horizontally) while the EM-31 reaches 6 metres vertically.

In the MIA it is particularly suitable for surveying future rice paddocks where clay is required to a certain depth of three metres and indicates any sandy areas which can then be eliminated when laying out rice country. This method can be used for a range of applications to ensure sufficient clay is present for high water-use areas especially as drainage and recirculation systems are becoming more important in irrigated agriculture. The EM31 is also used to indicate the porosity of soil for drilling for water with spearpoints. The exact position of such areas can be located using the GPS.

Costing of capital items for EM-31 surveys

Source: Geoff Beecher, Research Agronomist, Yanco Agricultural Institute, AgNSW (1997)

EM-31	Analog output		$A26,000
	Digital output conversion		$2000+ ?
Realtime GPS	(including Racal satellite)		$20,000
	+ Racal access (1 year)		$2,500
4WD Motorbike			$8500
Software: Arcview & Spacial Analyst			$6000
		Approx.	$65,000

+ Trailer + Person with knowledge, skills etc.

The four wheel motorbike travels 15 km/hr on average taking readings every 10 – 15 metres. Ideally, a maximum of 1000 hectares can be surveyed in a day (Beecher, *pers comm.*, 1998).

Costing of EM-31 surveying & consultancy fees
Source: BW & TS DUNN, EM-31 Surveying & Consultancy, Leeton, NSW (1998)
[prices quoted for smooth ground conditions]

Prices for survey of irrigation land

Services includes: EM-31 Survey at 25m transects
Report including contour maps and recommendations
Travel within a 74km radius of Leeton.

Up to 25ha (65 acres) = $500
50ha (125 acres) = $800
100ha (250 acres) = $1400
150ha (375 acres) = $1800
200ha (500 acres) = $2100

Prices for survey of non-irrigation land

Up to 20ha (50 acres) = $500
50ha (125 acres) = $700
100ha (250 acres) = $1000
150ha (375 acres) = $1250
200ha (500 acres) = $1500

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The following is an excerpt from information supplied by Justin Anning, Environmental Geophysicist with TESLA-10, a geophysical organisation specialising in ground and air-borne geoscience, geophysical data processing and ground surveys and instrumental rentals around Western Australia.

Tesla-10 plan surveys and utilise equipment, including differential GPS, which is mounted on and within vehicles to map variations in the grounds conductivity and soil type. The relevant data sets for the Ord River district would probably be as follows:

- Conductivity is mapped using the EM-38 and the EM-31. These instruments use electromagnetic fields at specific frequencies, which non-invasively determine the conductivity, each sampling at a different depth. (Approx. 0-50cm and 0-6m respectively).
- Soil types are mapped using the GRS-320, a gamma-ray spectrometer which measures the natural concentrations of Potassium, Uranium and Thorium in the ground.

Surveys are performed at a line spacing which suits the intensity of farming being performed. For example intensive horticulture could be surveyed at a 20 to 50 m line spacing enabling groundwater and salinity factors affecting productivity to be mapped within the paddock itself.

Work performed by Agriculture WA in the south-west correlates the shallow conductivities (0-50cm) mapped at present by the EM-38, to both productivity and survival rates of pastures and trees. This research should be continued in the ORIA as the correlations with yield allow a rapid and detailed assessment to be made of the effect of salinity on crops before crop selection, fertilisation, and sowing is performed.

Remediation techniques (drains, dewatering bores, channel repairs etc.) can be performed in specific locations where they will address an immediate productivity loss due to salinity and rising groundwater. This allows effective allocation of money and capital works to where it will have an immediate beneficial effect.

Areas at risk of future salinity and rising groundwater levels can be identified by mapping the difference between shallow and deeper conductivities.

Soil mapping using the spectrometer provides another dataset which may explain variations in productivity. It is also used to identify areas which may have an increased recharge potential, ie sand or gravel. This is useful in the southwest where measures are taken to reduce recharge through tree plantings.

There are obvious and logical advantages of this type of survey over similar techniques. The main advantage is the detailed salinity and groundwater patterns which can be mapped within the paddocks themselves. The high resolution data allows specific planning solutions to be identified and applied with the maximum efficiency, and is of immediate interest to the farmer. Airborne techniques are not capable of this detail of identifying groundwater patterns at a sufficient scale. Costs (including final product) range from approximately $5 to $15 per ha depending on line spacing intensity.

A range of hydrogeological investigations throughout the Ord River Irrigation Area including the proposed areas for expansion of Stage 2, have been conducted and are continuing to obtain important data on groundwater hydrology and soil physical and chemical properties.

The use of EM soil surveying in the ORIA may have significant potential for land and water management in Stage 1 as well as Stage 2 by optimsing the adoption of best practice groundwater management techniques; future positioning of irrigation infrastructure and tail water return systems; and overall suitability of land for irrigated agriculture. Research initiatives and further liaising with industry contacts listed below should be considered to assess and evaluate the application of ground-based EM surveying methods in the ORIA.

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References:

[1]-Peter de Broekert (1996) An Assessment of Airborne Electromagnetics for Hydrogeological Interpretation in the Wheatbelt, Western Australia – Resource Management Technical Report 151 / Natural Resource Management Services, Agriculture Western Australia.

[1]-G. Humphreys, S Tickell, D Yin Foo & P Jolly (1995) Subsurface Hydrology of the Keep River Plains – Technical Report 25/95D / Water Resources Division & Power and Water Authority, Northern Territory

[1]-Geoff Beecher (1998) Personal communication & facsimile providing information on capital and consultancy costings of EM-31 GPS soil surveying technology.

Reference Location:

[1]"SOIL PERMEABILITY MAPPING" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

2.1.2 INDUSTRY CONTACTS
Soil Permeability Mapping

NAME	**-LLOYD ANGOVE & PETER MAHER**
POSITION	-EM31 SOIL SURVEYING CONTRACTORS
ORGANISATION	-ANGOVE & MAHER
LOCATION	-55 HAMPDEN ST., FINLEY, NSW 2713
PHONE NO.	(03) 5883 1013
FAX NO.	(03) 5883 3135
MOBILE	Lloyd: 018 575029 / Peter: 015 869713
DETAILS	-Contracting service using ground-based EM31 soil surveying methods and Global Positioning System to identify soil porositiy and clay content for optimum location of recycle systems, irrigation drains/channels, storage drains and high water use areas.

NAME	**-JUSTIN ANNING**
POSITION	-ENVIRONMENTAL GEOPHYSICIST
ORGANISATION	-TESLA - 10
LOCATION	-41 KISHORN RD., APPLECROSS, W.A. 6153
PHONE NO.	(08) 9364 8444
FAX NO.	(08) 9364 6575
E-MAIL	tesla10@wt.com.au
DETAILS	-Specialise in natural resource geophysics including Airborne Geoscience, Geophyscial Data Processing, Ground Surveys and Instrument Rentals, Electromagnetics for groundwater / salinity and environmental studies.

NAME	**-KEN BATES**
POSITION	-SOIL SURVEYING CONTRACTOR
ORGANISATION	-KEN BATES SOIL SURVEYING
LOCATION	-11 BURTON ST., DENILIQUIN, NSW 2710
PHONE NO.	(03) 5881 3459
FAX NO.	(03) 5881 5311
MOBILE	018 698735
DETAILS	-Contracting service covering the rice growing areas of the Riverina (NSW) using ground-based EM31 soil surveying methods and Global Positioning System to identify soil porositiy and clay content for optimum location of recycle systems, irrigation drains/channels, water storage sites and high water use areas; and identification of channel seepage, location of spear point sites, determination of salinity areas, and Land Water Management Planning.

NAME	**-GEOFF BEECHER**
POSITION	-RESEARCH AGRONOMIST – IRRIGATED FARMING SYSTEMS
ORGANISATION	-AGRICULTURE NEW SOUTH WALES
LOCATION	-YANCO AGRICULTURAL INSTITUTE, YANCO, NSW 2703
PHONE NO.	(02) 6951 2725 –Wk / (02) 6951 2611 –Switchboard / (02) 6953 3478 –A.H.
FAX NO.	(02) 6955 7580
MOBILE	(015) 262 997
E-MAIL	GEOFF.BEECHER@agric.nsw.gov.au / beechdg@agric.nsw.gov.au
DETAILS	-Developer of electromagnetic (EM) technology for geophysical soil surveying and soil salinity and electrical conductivity investigation in irrigation farming. Ground based systems based on Geoff's work are now being used throughout the Murray Irrigation Limited area based in Deniliquin / Ph. (03) 5881 9300. Geoff is also involved in land & water management planning in NSW and development of best management practices. Long term involvement in irrigated farming systems and development of Land & Water Management Plans in NSW including Murray and Murrumbidgee irrigation areas.

NAME	**-PETER de BROEKERT**
POSITION	-NATURAL RESOURCE MANAGEMENT SERVICES
ORGANISATION	-AGRICULTURE WESTERN AUSTRALIA
LOCATION	-SOUTH PERTH, WA 6151
PHONE NO.	(08) 9368 3333
FAX NO.	(08) 9368 1205
E-MAIL	-
DETAILS	-Conducted assessment of airborne electromagnetics for hydrogeological interpretation in the wheatbelt, Western Australia.

NAME	**-SIMON COOK**
POSITION	-RESEARCH SCIENTIST
ORGANISATION	-C.S.I.R.O. LAND & WATER
LOCATION	-FLOREAT, W.A. 6014
PHONE NO.	(08) 9333 6200
FAX NO.	(08) 9387 8991
E-MAIL	simonc@per.dms.csiro.au
DETAILS	-Specialises in a) Precision agriculture using GPS satellite technology [ie. fertiliser, chemical and yield mapping], b) Land resource assessment including mapping of soil, land suitability, land degradation. Use of E.M. technology, GIS base method and airborne gamma radiometrics.

NAME	**-BW & TS DUNN**
POSITION	-EM-31 SURVEYING AND CONSULTANCY
ORGANISATION	-BW & TS DUNN
LOCATION	-LOT 2, FARM 1287, DAALBATA RD., LEETON, NSW 2705
PHONE NO.	(069) 535377 AH
FAX NO.	
DETAILS	-Contracting service using ground-based EM31 soil surveying methods to survey irrigated and non-irrigated land to identify soil porositiy and clay content for optimum location of recycle systems, irrigation drains/channels, water storage sites and high water use areas; and identification of channel seepage, location of spear point sites, determination of salinity areas. Service includes travel within 75km radius of Leeton. Report provided including contour maps and recommendations. Prices range from $7 to $25 / hectare depending of scale of survey.

ORGANISATION	**-MURRAY IRRIGATION LIMITED**
LOCATION	-DENILIQUIN, NSW 2710
PHONE NO.	(03) 5881 9300
FAX NO.	
DETAILS	- Ground based mapping systems based on Geoff Beecher's work are now being used through the Murray Irrigation Limited area. M.I.L. has worked in close conjunction with the Yanco Agricultural Institute of NSW Agriculture in researching the ground based EM31 soil surveying method using Global Positioning System to identify soil porositiy and clay content for optimum location of recycle systems, irrigation drains/channels, storage drains and high water use areas. M.I.L. has available list of contacts of contractors specialising in soil EM mapping etc.

NAME	**-HENRY SMOLINSKI**
POSITION	-RESEARCH SCIENTIST
ORGANISATION	-Agriculture W.A., [LAND MANAGEMENT SERVICES]
LOCATION	-PERTH, W.A. 6000
PHONE NO.	(08) 9368 3829
FAX NO.	(08) 9474 2405
E-MAIL	hsmolinski@agric.wa.gov.au
DETAILS	-Experience in hydrogeological mapping, conductivity measuring, land management.

NAME -**GREG STREET**
POSITION -CHIEF SCIENTIST
ORGANISATION -WORLD GEOSCIENCE CORPORATION – AGARIA LTD
LOCATION -65 BROCKWAY RD., FLOREAT, W.A. 6014
PHONE NO. (08) 9273 6400
FAX NO. (08) 9273 6466 or (08) 9273 6411
E-MAIL -
DETAILS -Expertise is in the interpretation of airborne geophysical data in conjunction with other remote sensed and geographic data for land management decisions to be made through a hydrogeological assessment. Technology that is utilised includes airborne electro-magnetics, radiometrics, satellite imagery and digital terrain data. Projects include location and assessment of groundwater source and quality, salinity mapping and prediction (using SALTMAP), soil mapping with airborne radiometrics, pollution studies, crop yield interpretation from satellite data and land capability mapping. [Capability Statement provided]

NAME -**CARL WOLZAK & BILL HITCH**
POSITION -PRINCIPAL
ORGANISATION -RESOURCE MAPPING PTY LTD [GEOSCIENTIFIC INFORMATION SYSTEMS]
LOCATION -36 KINGS PARK RD., PO BOX 1297, WEST PERTH, W.A. 6005
PHONE NO. (08) 9322 2025
FAX NO. (08) 9321 0140
E-MAIL ausgis@wantree.com.au
DETAILS -Provide mapping services for GIS and analytical electromagnetic surveying data. Includes cartographic mapping and geographic information systems compilation and management.

NAME -
POSITION -
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2.2 GROUNDWATER PUMPING & CONJUNCTIVE WATER USE

2.2.1 TECHNICAL OUTLINE

Since 1962 when irrigated agriculture in the Ord River Irrigation Area (ORIA) was established and the completion of the Diversion Dam, over 13000 ha on the Ivanhoe Plain and Packsaddle Plain have been released. As stated by Yesertener (1996), the original groundwater level in the Ivanhoe Plain was around 16-17 m deep, but infiltration from the Diversion Dam, current infrastructure and irrigation practices has caused the groundwater to rise to within 1.5 m of the surface in some places with significant potential to reduce crop yields.
From the early 1960's an extensive number of monitoring bores have been set up to monitor water levels throughout the ORIA. Some areas have exhibited groundwater rises of between 0.2 – 0.6 meters per year. This is a cause for increasing concern and highlights the need for improved water management and more efficient irrigation practices.

Groundwater Pumping & Conjunctive Water Use
A method of ameliorating rising groundwater that is being trialled in the ORIA is the use of dewatering pumps that draw water from the groundwater and returning it to supply channels for irrigation practices. This provides a significant opportunity for wide scale adoption of conjunctive water use strategies involving the utilisation of both groundwater and channel water for irrigation. Conjunctive use of both surface and groundwater resources for irrigation will be a cost effective and sustainable development option in the long term.

The development of models for optimal conjunctive use of surface and groundwater needs to be taken into consideration with specific focus on existing groundwater quality and piezometric pressure gradients. These should be managed through appropriate patterns of crop rotation, localised bore pumping schedules and utilisation of possible future off-peak power availability.

The rate of draw down and efficiency of groundwater pumps will be largely influenced by the geology of the area and the variability of potential soil water transmissivity. This includes:

- **Permeability and geophysical layout of soils from which water is being pumped** – ie. saturated clays (hold large volumes of water but are generally poorly transmissive) vs. sands & gravels (release water readily due to being highly transmissive)
- **Permeability of surrounding areas** – which will effect rate of intrusion of water into pumping zones from localised and regional aquifers.
- **Pressure gradients from localised and regional aquifers** – will determine rate of draw down from pumping and overall effect on waterlogged soils and groundwater level.

A number of different types of pumps can be used to pump and lower groundwater, including:

- Variable discharge pumps [eg. Impeller pumps, Jet Pumps];
- Positive Displacement Pumps; and
- Suction Lifts.

Pumps should be carefully selected so that water is pumped efficiently at minimum cost.
[Detailed information on types of pumps and performance characteristics can be found in 'Groundwater Hydrology' H. Bouwer (1996) p. 181. Resource file: "Groundwater Pumping & Conjunctive Water Use" available at the Kimberley Development Commission, PO Box 620, Kununurra, W.A. 6743 / Ph. (08) 9168 1044]

The performance of existing pump bores located in Packsaddle Plain and Ivanhoe Plain have proven successful in lowering localised groundwater. Surrounding monitoring bores have exhibited similar trends in lowered groundwater levels. Initial effects of pumping resulted in a rapid drop in water level, a levelling off period, followed by further draw down.

In the first four weeks of pumping in November 1997, water levels at and around the Packsaddle pumping bore dropped 70cm from 2.5m below the surface to 3.2m below the surface. Water quality from this bore had minimal salt levels of only 1 mS/cm (Ord Land & Water, 1st December 1997)

Results from the Ivanhoe pumping bore exhibited draw down of between 20cm and 60cm recorded at monitoring bores close to the pumping site, compared with a 10cm drop at monitoring bores located about 500m away. (Ord Land & Water, 1st December 1997). Groundwater drawn from the pumping bores is pumped back into the supply channel for irrigation.

Intrusion from localised groundwater needs to be carefully monitored during dewatering, especially in respect to the effects of groundwater pumping on both a localised and regional scale.

While groundwater pumping may prove to be an effective remedy to rising groundwater, it should not be seen as the primary solution to groundwater management in the ORIA. The emphasis on preventative solutions such as improved irrigation efficiency needs to be maintained to avoid unnecessary dependency on dewatering bores. However, the adoption of large scale conjunctive groundwater use with channel supply has significant potential in controlling rising groundwater and hence potential water logging and salinity problems in the ORIA.

Effective management of groundwater will only be achieved by integrating groundwater pumping with the range of other best management practices on both a localised and regional scale.

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References:

[1]-C. O'Boy (1997) Ord River Irrigation Area Test Pumping – Hydrogeology Report No. 48/1997
[1]-C. Yesertener (1996) Review of Groundwater Monitoring Data in the Ord River Irrigation Area – Hydrogeology Report HR 60
[1]-H. Bouwer (1996) Groundwater Hydrology, Murdoch University, Environmental Science.
[2]-Ord Land and Water newsletter. Vol. 1, Issue 4, 1st December, 1997

Reference Location:

[1]"GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

[2]"PLANNING & EXTENSION – Ord River Irrigation Area" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

2.2.2 INDUSTRY CONTACTS
Groundwater Pumping & Conjunctive Water Use

NAME -**MATTHEW BETHUNE**
POSITION -GROUNDWATER HYDROLOGIST - NORTHERN IRRIGATION REGION
ORGANISATION -DEPARTMENT OF NATURAL RESOURCES & ENVIRONMENT – INSTITUTE OF SUSTAINABLE IRRIGATED AGRICULTURE
LOCATION -PRIVATE BAG 1, FERGUSON RD, TATURA, VICTORIA 3616
PHONE NO. (03) 5833 5227
FAX NO. (03) 5833 5299
E-MAIL bethunem@salty.agvic.gov.au
DETAILS -Specialises in groundwater hydrology and management, involved in salt action group Victoria. Experience in planning and adoption of groundwater pumping operations.

NAME -**LEITH BOWYER**
POSITION -REGIONAL WATER RESOURCE OFFICER
ORGANISATION -WATER & RIVERS COMMISSION
LOCATION -KUNUNURRA, WA 6743
PHONE NO. (08) 9168 1082
FAX NO. (08) 9168 3174
E-MAIL -
DETAILS -Specialist in water hydrology in respect to environmental management and protection of surface and ground water resources. Expertise includes hydrogeological investigation, monitoring protocols, studies in nutrient assimilation, groundwater management; and provision of information and advice for constructed wetlands, retention basins, riparian zones, farm drainage systems and hydrological modeling.

NAME -**PHIL COMMANDER**
POSITION -SUPERVISING HYDROGEOLOGIST
ORGANISATION -WATER & RIVERS COMMISSION
LOCATION -HYATT CENTRE, EAST PERTH, WA 6004
PHONE NO. (08) 9278 0473
FAX NO. (08) 9278 0586
E-MAIL pcommander@wrc.wa.gov.au
DETAILS - Involved in wide range of groundwater assessment and management issues throughout Western Australia. Involved in research and trialling of groundwater pumping tests in the Ord Irrigation Area.

NAME -**DR DEREK EAMUS**
POSITION(S) -ASSOCIATE PROFESSOR IN PLANT PHYSIOLOGY / ECOPHYSIOLOGY, N.T.U.; and ASSOCIATE DEAN OF BIOLOGICAL SCIENCES; and PROJECT LEADER IN THE CO-OPERATIVE RESEARCH CENTRE FOR SUSTAINABLE DEVELOPMENT OF TROPICAL SAVANNAS.
ORGANISATION -NORTHERN TERRITORY UNIVERSITY - SCHOOL OF BIOLOGICAL SCIENCES AND FACULTY OF SCIENCE
LOCATION -DARWIN, N.T. 0909
PHONE NO. (08) 8946 6716
FAX NO. (08) 8941 0460
E-MAIL D_Eamus@bligh.ntu.edu.au
DETAILS -Research interests include: Measurement, modeling and management of water use by savanna vegetation; The impact of elevated atmospheric CO2 upon plant growth and physiology; The impact of seasonal variation in water availability, photon flux density and VPD upon tree ecophysiology.

NAME	**-MR HEMANTHA DESILVA**
POSITION	-HYDROGEOLOGIST
ORGANISATION	-DEPARTMENT OF LAND & WATER CONSERVATION – HUNTER REGION
LOCATION	-NEWCASTLE WEST, NSW 2302
PHONE NO.	(02) 4929 4346
FAX NO.	(02) 4929 6364
E-MAIL	hdesilva@dlwc.nsw.gov.au
DETAILS	-Specialist in hydrogeology involving groundwater management and modelling, and groundwater allocation. Recent involvement in the mining industry in respect to salinity issues and ameliorating rising groundwater.

NAME	**-ALLEN GALE**
POSITION	-OPERATIONS MANAGER
ORGANISATION	-WOODWARD-CLYDE
LOCATION	-EASTPOINT PLAZA, 233 ADELAIDE TCE, PERTH WA 6001
PHONE NO.	(08) 9325 9077
FAX NO.	(08) 9325 9091
EMAIL	Ajgalex0@wcc.com
DETAILS	-Previously worked with Sinclair Knight Mertz Pty Ltd. And compiled the Ord River Irrigation Area Stage 1 Water and Nutrient Balance Report (Draft - July 1997) for the WA Water Corporation. Allen is now with Woodward-Clyde and environmental consultanting company specialising in groundwater and waste water management, geotechnical applications and environmental impact assessments.

NAME	**-GERHOME GOH**
POSITION	-HYDROLOGIST [CIVIL ENGINEERING]
ORGANISATION	-MAIN ROADS W.A.
LOCATION	-PERTH, W.A. 6000
PHONE NO.	(08) 9323 4461
FAX NO.	(08) 9323 4136
E-MAIL	-
DETAILS	-Hydrologist engineer specialising in groundwater / river dynamics, water balance modelling. Can provide services and consultant expertise for Ord Land & Water Management Plan.

NAME	**IAN GRIEVE & -CHRISTOPHER LANE**
POSITION	DIRECTOR/PRINCIPAL ENGINEERING GEOLOGIST & -MANAGING DIRECTOR/PRINCIPAL ENGINEERING & ENVIRONMENTAL GEOLOGIST
ORGANISATION	SOIL & ROCK ENGINEERING PTY LTD
LOCATION	PO BOX 1346, OSBORNE PARK, W.A. 6916
PHONE NO.	(08) 9242 7477
FAX NO.	(08) 9242 7479
E-MAIL	soilrock@soilrock.com.au or igrieve@soilrock.com.au or clane@soilrock.com.au
DETAILS	-Geotechnical consultancy firm involved in water management including groundwater assessment, monitoring, management and control with offices in Perth, Australia and Kuala Lumpur, Malaysia. Specialist groundwater services include: investigation for locating & designing water retaining & tailings storage structures, Site suitability assessments, Construction materials testing & assessment, Water quality determinations, Research & development including site specific testing of natural soils with additives in an attempt to reduce seepage and control water, Water diversion & interceptor systems, Rainfall intensity and PMP determinations, run-off assessments, Hydrological studies & water diversion, Seepage determinations, Whole of system water balance determination to assess water usage, water loss criteria and make up water requirements, and Drainage channel design. Company projects have varied from arid, semi arid, sub tropical to tropical climates. [Capability Statement provided]

NAME	**-JOHN HARMAN**
POSITION	-MANAGING DIRECTOR
ORGANISATION	-WATER MANAGEMENT CONSULTANTS PTY LTD
LOCATION	-SUBIACO, W.A. 6008
PHONE NO.	(08) 9380 8346
FAX NO.	-
E-MAIL	-
DETAILS	-Specialists in management of groundwater, surface water, modeling software capabilities. Experience overseas. Often act as intermediary between client and government. [Capability statement ordered]

NAME	**-TOM HATTON**
POSITION	-ECO-HYDROLOGIST
ORGANISATION	-C.S.I.R.O. LAND & WATER
LOCATION	-FLOREAT, W.A. 6014
PHONE NO.	(08) 9333 6200
FAX NO.	(08) 9387 8211
E-MAIL	tom.hatton@per.clw.csiro.au
DETAILS	-Specialises in catchment and groundwater hydrology and management, eco-physiology, plant / groundwater interactions, hydrological water balance modeling, and management of salinity issues regarding pumping techniques and tree / vegetation establishment.

NAME	**-GREG HOXLEY**
POSITION	-PRINCIPAL HYDROGEOLOGIST ASSOCIATE
ORGANISATION	-SINCLAIR KNIGHT MERZ PTY LTD
LOCATION	-590 ORRONG RD, ARMADALE, VIC 3143
PHONE NO.	(03) 9248 3345
FAX NO.	(03) 9248 3364
E-MAIL	-gregh@rwc.org.au
DETAILS	-Specialist consultant with extensive involvement and experience in hydrogeological and groundwater modeling investigations of the current and proposed areas of the Ord River Irrigation Area.

NAME	**-TONY LAWS**
POSITION	-MANAGER OF GROUNDWATER INVESTIGATION BRANCH
ORGANISATION	-WATER & RIVERS COMMISSION
LOCATION	-HYATT CENTRE, EAST PERTH, W.A. 6004
PHONE NO.	(08) 9278 0300
FAX NO.	(08) 9278 0586
E-MAIL	tony.laws@wrc.wa.gov.au
DETAILS	-Manages and co-ordinates four groundwater sections: i) Groundwater Exploration [Phil Commander], ii) Groundwater Resource Appraisal & Assessment [Angus Davidson], iii) Groundwater Information [Robin Smith], iv) Groundwater Contamination [Stephen Appleyard].

NAME	**-WALLY MENKE**
POSITION	-DIRECTOR
ORGANISATION	-TRIANGLE FILTRATION
LOCATION	-UNIT 2, 20-30 MALCOLM RD, BRAESIDE, VIC 3195
PHONE NO.	(03) 9580 2122
FAX NO.	(03) 9580 3131 / (03) 9509 4346 A.H.
E-MAIL	triangle@filtomat.com.au
INTERNET	www.filtomat.com.au
DETAILS	-Supply and distribution of water and irrigation pumps, self cleaning filters (filtomat), fertiliser injectors and subsurface drip irrigation systems.

NAME	-**RICHARD NIXON**
POSITION	-HYDROGEOLOGICAL CONSULTANT
ORGANISATION	-AUSTRALIAN BORE CONSULTANTS PTY LTD
LOCATION	-PO BOX 269, INGLEWOOD, WA 6052
PHONE NO.	(08) 9386 4725
FAX NO.	(08) 9386 4725
MOBILE	017 867 316
EMAIL	rnixon@space.net.au
DETAILS	-Specialises in hydrogeological and groundwater bore operations.

NAME	**-CHRIS O'BOY**
POSITION	-SENIOR HYDROLOGIST
ORGANISATION	-WATER & RIVERS COMMISSION – RESOURCES INVESTIGATION BRANCH
LOCATION	-HYATT CENTRE, EAST PERTH ,WA 6004
PHONE NO.	(08) 9278 0498
FAX NO.	(08) 9278 0586
E-MAIL	coboy@wrc.wa.gov.au
DETAILS	-Involved in wide range of groundwater assessment and management issues throughout Western Australia. Involved in research and trialling of groundwater pumping tests in the Ord Irrigation Area.

NAME	**-CHRIS ROBINSON**
POSITION	-SENIOR TECHNICAL OFFICER
ORGANISATION	-AGRICULTURE WESTERN AUSTRALIA
LOCATION	-FRANK WISE INSTITUTE, PO BOX 19, KUNUNURRA, WA 6743
PHONE NO.	(08) 9166 4037
FAX NO.	(08) 9166 4066
EMAIL	crobinson@agric.wa.gov.au
DETAILS	-Has 20 years experience in sustainable agriculture and land conservation issues. Extensive involvement in the management and co-ordination of dewatering pump trials in Stage 1 of the ORIA to investigate the effectiveness of groundwater pumping as a useful tool to manage groundwater in the ORIA.

NAME	**-IAN ROGERS**
POSITION	-SALES CONSULTANT
ORGANISATION	-LOWARA PUMPS PTY LTD
LOCATION	-MALAGA, W.A. 6062
PHONE NO.	(08) 9249 9077
FAX NO.	(08) 9248 9678
MOBILE	(0419) 760 283
E-MAIL	-
DETAILS	-Supply and distribution of water pumps including submersible applications. [Catalogue supplied]

NAME	**-BILL SCOTT**
POSITION	-CHEMICAL ENGINEER & APPLIED MODELLER
ORGANISATION	-MURDOCH UNIVERSITY – ENVIRONMENTAL SCIENCE
LOCATION	-SOUTH ST., MURDOCH, PERTH, WA 6150
PHONE NO.	(08) 9360 2328
FAX NO.	(08) 9310 4997
E-MAIL	scott@essun1.murdoch.edu.au
DETAILS	-Has taught groundwater hydrology for 10 years at Murdoch Uni, and has research base in hydrogeological software modeling, atmospheric interactions and the physical chemistry of nutrients.

NAME -**DR JOE SHERRARD**
POSITION -DISTRICT LEADER
ORGANISATION -AGRICULTURE WESTERN AUSTRALIA
LOCATION -FRANK WISE INSTITUTE, PO BOX 19, KUNUNURRA, WA 6743
PHONE NO. (08) 9166 4000
FAX NO. (08) 9166 4066
E-MAIL -
DETAILS -Extensive involvement in planning, development and adoption of the Ord Land & Water Management Plan as well as this best practice research project for irrigation farming around the Ord. Involved in coordination of groundwater studies in the ORIA. Agriculture W.A. promotes the sustainable development of farm businesses, rural communities and agricultural industries. Enhances the competitiveness of agriculture by providing efficient and effective agricultural and natural resource protection. Provides leadership and support to agricultural industries and for market development.

NAME -**BRIAN SWEENEY**
POSITION -MANAGER
ORGANISATION -QUINTI & CO – Irrigation & Pump
LOCATION -WELSHPOOL, W.A. 6106
PHONE NO. (08) 9362 1288
FAX NO. (08) 9470 2786
E-MAIL -
DETAILS -Wholesale & retail distributors of irrigation supplies, submersible pumps, trenching machine.

NAME -**JOHN WATERHOUSE**
POSITION -MANAGER, HYDROGEOLOGICAL SERVICES
ORGANISATION -GOLDER ASSOCIATES PTY LTD
LOCATION -441 VINCENT ST WEST, LEEDERVILLE, WA 6007
PHONE NO. (08) 9381 3444
FAX NO. (08) 9381 4041
DETAILS -Responsible for coordination and management of hydrogeological services, including dewatering and groundwater management for excavations (foundations and mines), groundwater contamination studies, water supply development and related groundwater resources management, groundwater-related components of environmental impact assessment, irrigation drainage and salinity control.

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2.3 IRRIGATION MANAGEMENT

2.3.1 TECHNICAL OUTLINE

Improved techniques in irrigation management in the Ord River Irrigation Area are currently being researched and developed by Agriculture Western Australia at the Frank Wise Institute, Kununurra and some farmers in the Ord River Irrigation Area. Investigations are focussing on the application of water meet the needs of crop water demands. The issue of rising groundwater over recent years in the ORIA and loss of sediment, nutrients and farm chemicals in irrigation run-off indicates the importance of improving irrigation efficiency in irrigation farming.

Current Environmental Problems in the ORIA

- Rising groundwater and potential salt rise;
- Potential water-logging;
- Transport of on-farm sediment, sediment-bound nutrients, pesticides and other contaminants in farm run-off entering drains & the Ord River system.

Sources of Problems

- Grower level management practices and inefficient irrigation application;
- Charging for water use on a per hectare basis regardless of amount of water applied;
- Application of water in excess of crop water demand required.

Performance Indicators for Control of Agricultural Water Use Efficiency

- Lower water application to the land while maintaining maximum crop yield & crop water demand;
- Less water leaves each property;
- More efficient irrigation technology is installed.

Primary Objectives for Improving Irrigation Management

- Determine actual crop water requirements of annual and perennial crops grown in the ORIA;
- Prevent "over-irrigation" of crops;
- Improve water use efficiency;
- Evaluate appropriateness of irrigation technique to particular soil types;
- Reduce levels of run-off and associated transport of sediment and sediment-bound contaminants in irrigation tail water;
- Determine efficiency of pump units in terms of overall water delivery and total head pressure;
- Develop irrigation scheduling programs for specific crops;

- Utilise modeling software programs to integrate groundwater hydrology, soil types, individual crop water requirements, and environmental conditions to obtain an accurate water balance and improve the efficiency of irrigation accordingly;

- Evaluate potential adoption of automated irrigation systems.

Automation for Flood Irrigation

Various systems have been used in Australia for at least 25 years. Automatic irrigation is a method that can be used to change water flow at the appropriate time. Systems used today include: hydraulic systems, pneumatic systems, mechanical timers, electronic systems and alarm systems. These structures are used to change the flow of water in channel systems and individual bay outlets. Automation can be used in a number of ways:

- to start and stop irrigation through supply channel outlets,
- to start and stop pumps,
- to cut off the flow of water from irrigation area – either a bay or section of channel and directing the water to another area.

Benefits of Automation

- Irrigator is able to perform other tasks;
- More timely irrigation and improved efficiency in water application;
- Allows irrigation at times that are not considered to be convenient;
- More accurate cutoff;
- Less water used;
- Allows fast irrigation;
- Reduced costs for vehicles used for irrigation;
- Improved lifestyle.

Disadvantages of Automation

- Variable precision in application and reliability of systems;
- Costs in purchasing, installing and maintaining automatic equipment;
- Increased channel maintenance to ensure system works correctly.

[Detailed information on various automatic irrigation systems including methods of operation and relative costs are included in the "IRRIGATION MANAGEMENT" resource file, located at the Kimberley Development Commission, PO Box 620, Kununurra, WA 6743 Ph. (08) 9168 1044]

IRRIGATION MANAGEMENT

Source: 'On-Farm Options – Murrumbidgee Irrigation Areas and Districts L&WMP, NSW Agriculture, May 1995.]

Irrigation Scheduling

Scheduling irrigations to match the timing and quantity of irrigation water applications with plant water requirements will improve yields and avoid unnecessary drainage and groundwater accessions.

Recommendations

- Undertake farmer extension in plant/soil/water relationships, to provide the community with an understanding of the need for timely irrigation and the role and benefits of irrigation scheduling.
- To achieve high irrigation efficiency (80% or greater) and production, irrigation scheduling should be encouraged irrespective of layout. Layouts need to be of a standard which allow for efficient operation and uniform application.
- Ongoing research to evaluate ET crop coefficients under local conditions.
- Encourage the development of improved decision support systems to assist farmers with irrigation scheduling.

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References:

[1]-Definition Statement of Key Environmental Issues and Responsibilities – Forum on Environmental Management of the Ord Stage 1 Irrigation Scheme – Transfer of Ownership / Water Corporation and Ord Irrigation Co-operative, 16th October, 1997.

[2]-Automation for Flood Irrigation / David Lawler, Agriculture Victoria, Echuca, VIC, 1995

[2]-Crop Irrigation Requirement Program / Compiled by: P Aylmore, G Luke & E Hauck – Agriculture Western Australia, 1994

Reference Location:

[1]"PLANNING & EXTENSION – Ord River Irrigation Area" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

[2]"IRRIGATION MANAGEMENT" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

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DETAILS -Specialises in industry consulting and research in the areas of irrigation design and planning, water quality monitoring, water management, sustainable resource development, wetland application for treatment of waste water. Involved in research projects with the Land & Water Resources Research & Development Commission including -development of best practice guidelines for irrigation development; use of constructed wetlands and detention basins for nutrient control & sediment catchment; nutrient control in irrigation drainage; wetland health and water quality; and development of water quality monitoring programs.

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NAME -WAYNE MEYER
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NAME	**-JOHN RUPRECHT**
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NAME	**-DR JOE SHERRARD**
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NAME	**-JOHN THOMPSON**
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2.4 SUB-SURFACE DRAINAGE

2.4.1 TECHNICAL OUTLINE

A technique that may prove viable in controlling rising groundwater in the Ord River Irrigation Area is the installation of sub-surface drainage systems. The predominant soil types in the ORIA are heavy black self-mulching clays that are relatively thin and overlay more porous medium textured clays and silty riverine deposits. In many areas the clays are further underlain with sand and gravel beds that follow palaeo-channels of the Ord River.

Waterlogged conditions can arise from high groundwater levels and can dramatically effect crop production and reduce crop yields.

The most effective strategy for preventing waterlogging at its source is to improve irrigation efficiency. However, sub-surface drainage can play a major role in ameliorating existing waterlogged conditions as well as minimising groundwater accessions by intercepting water and diverting it to either drains or storages for re-irrigation or direct drainage to the river system.

Sub-surface drainage is possible using a number of techniques, most of which utilise the mole drainage approach. Mole drains are unlined channels formed at a depth usually between 500 and 700 mm with a mole plough. The mole plough consists of a leg, usually about 200 mm wide and 15 mm thick, attached to a beam about 3 m long. A circular foot, between 50 and 75 mm in diameter and with a chisel point, is attached to the leg. A tapered expander, between 60 and 100 mm in diameter is attached to the back of the foot. When the plough is pulled through a moist clay soil, a channel is formed (Muirhead *et al.*, 1995).

The stability of the channel is determined by the geometry of the plough, soil characteristics, soil moisture content at ploughing and the time the channel is able to mature before it carries water. Water flows to the channel along the leg slot and fissures which are formed when the leg moves through the soil. A laser can be used to control the grade on the channel. Gypsum may be required to maintain the stability of the mole drainage channels (Muirhead *et al.*, 1995).

The major benefits of mole drains are:

- Relatively quick drainage of the root zone;
- Relatively small quantities of water removed;
- The quality of the drainage water is high and suitable for on-farm reuse;
- The hydraulic head and accessions to the groundwater is reduced.

The primary types of sub-surface drainage include:

- Mole;
- Slots - with no mole channels;
- Mole slots - mole channels beneath slots;
- Mole with gypsum enriched slots (GES) - eg. 4 to 8 t gypsum/ha incorporated into the slot
- Mole MES - mole channels beneath slots + poultry manure (eg. 24t/ha) incorporated into the slot
- Mole Slots Surf – mole channels beneath slots + gypsum spread on the surface of the bed
- Mole Surf – mole channels with no slots + gypsum spread on the surface of the bed

- Shallow Pipe drains +/- GES
- Deep Pipe ("tile") drains +/- GES

Cost factors of installing drains that need to be considered include:
- Survey/interceptors
- Collector mains
- Corrugated pipe
- Sump/pump
- Mole installation
- Slot installation
- Gypsum

Waterlogging has been reduced by lowering water tables with tile drains (eg. horticultural farms in the Murray Irrigation Area) or tube wells (eg. Goulburn Valley in Victoria). Both areas produce saline drainage water which requires storage (Muirhead *et al.*, 1995). If sub-surface drainage is adopted in the ORIA, monitoring of groundwater and drainage water quality will need to be taken into consideration.

Recommendations and criteria for mole installation

As stated by Muirhead *et al.* (1995), research has shown that mole drains can provide satisfactory control of waterlogging provided they are installed correctly on suitable soil. The main requirements are:
- A uniform clay soil at the depth of moling with moderate to good aggregate stability and preferable a smectitic clay with a very fine clay ratio greater that 0.50.
- Dry compact soil surface (for traction) with the soil at the moling depth, plastic (eg. after a rice crop or after prolonged irrigation following a non-rice crop).
- Moling below the critical depth to avoid a subsoiler type failure and ensure adequate confining stress. To achieve these conditions, moling should be carried out as early as possible in the cultivation cycle.
- The plough geometry should be a 15 mm thick straight leg, 50 mm diameter foot and 75 mm diameter expander.
- Adequate free flow of water from the mole channel so that it does not become surcharged.

The relative suitability of mole drainage systems will depend heavily on their performance in the deep-cracking clays of the ORIA. Although investigative studies using sub-surface drainage on clay soils have been carried out in other parts of Australia, the application and effectiveness in the Ord can only be fully realised by carrying out site-specific trialling to determine the effect of the shrink-swell behavior of the clays on the stability and duration of installed sub-surface drains. This is a major factor that should be considered prior to large scale adoption of sub-surface drainage systems.

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Reference:

[1]- Muirhead W., Christen E. & Moll J. (1995) Groundwater Control Using Shallow Subsurface Drains, Final Report to Natural Resources Management Strategy Program of the Murray-Darling Basin Commission / CSIRO Division of Water Resources Consultancy Report No. 95/23

Reference Location:

[1]"SUB-SURFACE DRAINAGE" resource file, held at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

2.4.2 INDUSTRY CONTACTS
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NAME	**-RICHARD DOYLE**
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NAME	**-GEORGE MORRISEY & MIKE CAZALET**
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NAME	**-SHANE PHILLIPS**
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DETAILS	-Has developed a scheduling and modeling system for Polyacrylamide use in dripper and sprinkler irrigation. Experience using the Right Amount Right Time computer aided irrigation scheduling program which uses crop factors, ET, rainfall and soil information to predict crop water requirements and forecast irrigation schedules. Also has conducted trial work using Sub Surface Furrow Irrigation which uses a sub-surface pipe system for irrigation that is also designed for drainage.

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2.5 TREE CROPPING

2.5.1 TECHNICAL OUTLINE

A specific area being promoted that requires further research is the potential use of tree cropping as a method of managing groundwater levels in the Ord River Irrigation Area. The potential benefits of incorporating a tree cropping system in existing farm management practices include:

- Uptake of water from the soil in localised areas and minimising accession of water from Irrigation farming to the groundwater system
- Potential to ameliorate water-logged soils (if tolerant to waterlogged conditions)
- Control of rising groundwater and amelioration of potential salt rise;
- Improvement of degraded and saline land
- Improved soil stabilisation and control of soil erosion
- Agro-forestry and economic products (eg. timber production, seed, oil)
- Filter sediment, nutrients and farm chemicals from agricultural surface run-off.
- Increased biodiversity and wildlife habitat

For tree planting to be effective in controlling rise of groundwater, it needs to be used in conjunction with other management practices including improved water and crop management. The selection and performance of tree species as groundwater pumps will depend on a number of vital attributes:

- Suitability to wet-dry sub-tropical environment
- Ability to perform in heavy cracking clay soils
- Tolerance to inundation, water-logged or water-stressed soils
- Rooting depth and accessibility to groundwater
- Soil permeability
- Water requirements and rate of uptake in varying conditions
- Size, rate of growth and age of maturity of individual tree species
- Size of plantations
- Pest and disease resistance / susceptibility
- Salt tolerance
- Regularity of irrigation for leaching of potential salts accumulated in root zone
- Economic value of wood, seed or oil

It is imperative that the potential effectiveness and environmental suitability of the various species proposed to be used for controlling rising groundwater is carefully evaluated.

The various species currently growing under irrigation on the cracking clays of the ORIA should be investigated to initially determine the extent of root system development, depth to groundwater level and zone of root system influence. Areas of high priority in the ORIA that warrant investigation include:

- mango plantation on block 63;
- eucalyptus planted in the S/W corner of block 72; and
- eucalyptus which were planted on the Frank Wise Institute in 1973
- sandalwood plantations

It is essential that information or base data on the effectiveness of trees as solar water pumps in wet-dry tropical environments is obtained from future investigative trials in the ORIA and from other studies in areas of Australia with similar conditions such as the Northern Territory and Queensland.

Perennial vegetation such as trees can be used to address specific and potential problem areas such as utilising existing groundwater, and intercepting both groundwater accessions from irrigation farming and seepage from on-farm channels.

On-farm options regarding tree cropping could comprise establishment of irrigated woodlots, alley farming of trees and crops on non-commandable land, and establishment of trees alongside channels .

If drainage water is used to irrigate the woodlot, this option can also assist in the reduction of drainage entering the regional drainage system and hence be an integral part of a drainage water quality control strategy (Coleambally L&WMP Draft, 1995).

Careful planning and scientifically based research is required for ORIA conditions and to determine what areas tree planting will be most effective. There is concern that uptake by trees will draw salts that could be contained in the groundwater towards the roots. Salts are not taken up by the roots and are likely to concentrate in the rootzone. This may reduce the trees capacity to take up water.

If the groundwater begins to rise beneath the plantation then trees may potentially die from a combination of salinity and waterlogging. If this occurs, carefully controlled irrigation may be needed to leach accumulated salts to lower soil depths. This again highlights the necessity for continual soil and water quality monitoring and the need to integrate tree cropping with a range of other land and water management practices.

Valuable Tree Species with potential for growing on the ORIA

Source: Chirs Done, Regional Manager Kimberley, Department of Conservation & Land Management - CALM (1998)

A number of tree species have been shown to have the potential to grow well in the Ord environment. Some of these are generally considered as horticultural crops (for example mangoes and grapefruits) usually grown for their edible fruit alone. Others are know for values including essential oils, timber, fodder values and pharmaceutical values. Many more are useful for values such as shade, shelter, aesthetics, and climate amelioration on a local scale.

In general terms CALM has been and will continue to be interested in trial species thought to have potential high value products and low volumes rather that high volume, lower value crops such as wood chip/pulp species. Many trees potentially have multiple values and in addition could play an important role in water table management.

Non tree species such as bamboos and rattans are also of interest.

The following list (Table 1) is by no means exhaustive and will be supplemented in time as more information comes to hand. Nor does listing imply recommendation or otherwise of a species by CALM.

TABLE 1: Tree Species with potential for growing in the ORIA.

Common Name	Scientific Name	Soil Pref.*	Product(s)	Comments
African Mahogany	*Khaya senegalensis*	Light & heavy	Timber of moderately high value	
Indian Sandalwood	*Santalum album*	Heavy	Essential oils, timber and aromatic powder	Extremely complex silvicultural requirements
Ti Tree	*Mealaleuca alternifolia*	Heavy to medium	Essential oils	
Leucaena	*Leucaena leucocephalia*	Heavy to medium	Fodder	Proven potential to become an environmental weed
Teak	*Tectona grandis*	Light	Valuable timber	
African Blackwood	*Dalbergia melanoxylon*	Heavy	Extremely valuable timber	Very thorny. Needs further observation to ensure there is no weed risk.
West Indian and South/Central American Mahogany	*Sweitenia spp*	Heavy to light	Valuable timber	
Rosewood	*Pterocarpus indicus*	Light to medium	Valuable timber	
Rosewood	*Dalbergia spp*	Light	Valuable timber	
Neem	*Azadirachta indica*			Proven potential to become an environmental weed
River Red Gum	*Eucalptus camaldulensus*		Timber	Salt & wet tolerant. Potential use for controlling rising groundwater
Chinchilla Whitegum	*Eucalyptus argophloia*	Heavy clay	Timber	Global endangered sp. Favors sub-tropical env. and seasonal wet conditions.
Pindan wattle				Tropical species. Withstands seasonal water inundation.
Dragon tree				Tropical species. Withstands seasonal water inundation.

* In ORIA environment.

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References:

[1]- R Neeson, A Glasson, A Morgan, S Macalpine & M Darnley-Naylor / Role of Trees in the MIA / In: On-Farm Options – Murrumbidgee Irrigation Areas and Districts Land and Water Management Plan, NSW Agriculture 1995.

[2]- Coleambally Land & Water Management Plan – Draft Nov 1996. Coleamball L&WMP Committee: Department Land Water Conservation, NSW Agriculture, CSIRO, EPA

Reference Location:

[1]"TREE CROPPING" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168

[2]"PLANNING & POLICY" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168

2.5.2 INDUSTRY CONTACTS
Tree Cropping

NAME	**-DAVID DEELEY**
POSITION	-MANGER, ENVIRONMENTAL ENGINEERING
ORGANISATION	-EVANGILISTI & ASSOCIATES PTY LTD
LOCATION	-SUITE G2, 614 NEWCASTLE ST, LEEDERVILLE, WA 6007
PHONE NO.	(08) 9328 3797
FAX NO.	(08) 9328 3791
E-MAIL	eamail@enangelisti.com.au
DETAILS	-Environmental consultants specialising in land and water management planning including design and construction of artificial wetlands for treatment of waste water etc. Have recently completed an investigation into a tree plantation for the Kununurra Waste Water Treatment Plant for CALM and the Water Corporation identifying effluent, site and soil conditions, growth rates and management of the tree plantation and economics of the venture.

NAME	**-CHRIS DONE**
POSITION	-REGIONAL MANAGER
ORGANISATION	-DEPARTMENT OF CONSERVATION & LAND MANAGEMENT
LOCATION	-PO BOX 942, KUNUNURRA, WA 6743
PHONE NO.	(08) 9168 0200
FAX NO.	(08) 9168 2179
EMAIL	chrisd@calm.wa.gov.au
DETAILS	-Co-ordination of conservation and management of the Kimberley's wildlife and the lands, waters and resources entrusted to the Department for the benefit of present and future generations. To manage and protect national parks, nature reserves and conservation areas and the flora and fauna of the Kimberley. Development of agroforestry in the East Kimberley and promotion of commercial trees such as Sandalwood for both their economic value and to determine their potential to control rising groundwater in the Ord Irrigation Area.

NAME	**-*DEREK EAMUS***
POSITION	-ASSOCIATE PROFESSOR OF TREE PHYSIOLOGY
ORGANISATION	-UNIVERSITY OF NORTHERN TERRITORY – SCHOOL OF BIOLOGICAL ENVIRONMENTAL SCIENCES
LOCATION	-DARWIN, NORTHERN TERRITORY, 0909
PHONE NO.	(08) 8946 6666-Enquiries / (08) 8946 6716-Office / (08) 8932 4788-Home
FAX NO.	(08) 8946 6847
E-MAIL	d_eamus@banks.ntu.edu.au
DETAILS	-Involved in extensive research into water use by trees in wet-dry topics of Northern Territory and comparative effects on groundwater. Research projects include studies of Eucalyptus tetrodonta (Stringy bark), Eucalyptus miniata (Woolybutt), and Acacia auriculiformus (Black wattle). Trials involve accurate monitoring of changes in groundwater level (using psiezometers for soil water sampling to a depth of 60m), rates of evapo-transpiration of water from tree canopy, tree sap flow (rate of water transpiration in tree), wind speeds and air moisture levels. Measurement and data can be correlated to determine the evapo-transpiration rates of tree species and their effect on groundwater. Noted that evergreen trees in the wet-dry tropics have an extensive deep root system for improved accesses to groundwater thus maintaining a significant rate of water consumption in the dry season. [Provided a Capability Statement]

NAME	**-TOM HATTON**
POSITION	-ECO-HYDROLOGIST
ORGANISATION	-C.S.I.R.O. LAND & WATER
LOCATION	-FLOREAT, W.A. 6014
PHONE NO.	(08) 9333 6200
FAX NO.	(08) 9387 8211
E-MAIL	tom.hatton@per.clw.csiro.au
DETAILS	-Specialises in catchment and groundwater hydrology and management, eco-physiology, plant / groundwater interactions, hydrological water balance modeling, and management of salinity issues regarding pumping techniques and tree / vegetation establishment.

NAME -**DR. ALFRED HUEPERMAN**
POSITION -SECTION LEADER OF SOIL & WATER MANAGEMENT SECTION
ORGANISATION -DEPARTMENT OF NATURAL RESOURCES & ENVIRONMENT – INSTITUTE OF SUSTAINABLE IRRIGATED AGRICULTURE
LOCATION -PRIVATE BAG 1, FERGUSON RD., TATURA, VICTORIA 3616
PHONE NO. (03) 5833 5246
FAX NO. (03) 5833 5299
E-MAIL huepermana@salty.agvic.gov.au
DETAILS -Specialises in salinity control with sustainable farm salt balance through integrated management. Has conducted trials and written reports assessing the water pumping capabilities of tree crops in irrigated agriculture, especially in regards to managing salinity and rising groundwater.

NAME -**JEFF MAUGER**
POSITION -MANAGER OF CATCHMENT SALINITY INVESTIGATIONS GROUP
ORGANISATION -WATER & RIVERS COMMISSION
LOCATION -HYATT CENTRE, EAST PERTH, WA 6004
PHONE NO. (08) 9278 0472
FAX NO. (08) 9278 0586
E-MAIL -
DETAILS -Specialises in integrated catchment management, salinity studies, saltland management, water catchment quality, selection and use of trees/shrubs for groundwater management and salinity control.

NAME -**FRANK MCKINNELL**
POSITION -DIRECTOR SPECIAL PROJECTS
ORGANISATION -DEPARTMENT OF CONSERVATION & LAND MANAGEMENT
LOCATION -CRAWLEY, WA 6009
PHONE NO. (08) 9442 0319
FAX NO. (08) 9386 1578
EMAIL frankm@calm.wa.gov.au
DETAILS -Involvement in projects focusing on the hydrological role of trees in groundwater control. Is very familiar with the Ord River Irrigation Area.

NAME -**MARK PITTAVINO**
POSITION -DISTRICT MANAGER – EAST KIMBERLEY
ORGANISATION -DEPARTMENT OF CONSERVATION & LAND MANAGEMENT
LOCATION -PO BOX 942, KUNUNURRA, WA 6743
PHONE NO. (08) 9168 0200
FAX NO. (08) 9168 2179
DETAILS - Co-ordination of conservation & management of the Kimberley's wildlife and the lands, waters and resources entrusted to the Department for the benefit of present and future generations. Management & protection of national parks, nature reserves and conservation areas and the flora and fauna of the Kimberley. Development of agroforestry in the East Kimberley and promotion of commercial trees such as Sandalwood for both their economic value and to determine their potential to control rising groundwater in the Ord Irrigation Area.

NAME -**ANDREW RADO**
POSITION -SANDALWOOD RESEARCH SCIENTIST
ORGANISATION -DEPARTMENT OF CONSERVATION & LAND MANAGEMENT
LOCATION -PO BOX 942, KUNUNURRA, WA 6743
PHONE NO. (08) 9168 0200
FAX NO. (08) 9168 2179
E-MAIL andrewr@calm.wa.gov.au
DETAILS -Extensive research and development of Indian sandalwood (*Santalum* spp.) in the Ord River Irrigation Area is currently being undertaken by CALM in conjunction with the Australian Centre for International Agricultural Research (ACIAR) the Sandalwood Research Institute (SRI), and CALM's own Sandalwood Conservation and Regeneration Program (SCARP). Trial programs are assessing the feasibility of sandalwood as a sustainable, high value source of timber, seed and oil. Trials of East African Ebony, Teak and Rosewood are also being undertaken by CALM. In addition to the economic benefits, there may be further potential to utilise sandalwood and other lucrative tree species in existing farming systems by helping to minimise groundwater rise, improve soil retention and possible application as riparian buffer strips.

NAME -BEN ROSE
POSITION -LANDCARE DEVELOPMENT OFFICER
ORGANISATION -AGRICULTURE WESTERN AUSTRALIA
LOCATION -ROSE STREET, MANJINUP, WA 6258
PHONE NO. (08) 9771 1299
FAX NO. (08) 9771 2544
E-MAIL benr@manjdo.agric.wa.gov.au
DETAILS -Specialises in best practice farming including soil conservation, nutrient export, and salinity control. Includes research and adoption of on-farm mulching techniques; use of cover crops such as vetches [eg. pea flower with high nitrogen levels], tropical cereals and oats; tail water drainage systems; development of minimum tillage techniques for potatoes; surface water control; and application of ponds and retention basins to strip nutrients and trap sediment from agricultural drainage water.

NAME -PAUL RYAN
POSITION -PRINCIPAL RESEARCH SCIENTIST
ORGANISATION -DEP. OF PRIMARY INDUSTRIES – QLD FOREST RESEARCH INSTITUTE
LOCATION -MS 483, FRASER RD, GIMPIE, QLD 4570
PHONE NO. (07) 54 820868
FAX NO. (07) 54 828755
E-MAIL RYANP@qfh1.fh.dpi.qld.gov.au
DETAILS -Specialises silvicultural tree species selection, best propagation techniques and methodology, genetic evaluation and species' suitability to varying growing conditions.

NAME -NICK SCHOFIELD
POSITION -PROGRAM MANAGER - WATER RESOURCES
ORGANISATION -LAND & WATER RESOURCES RESEARCH & DEVELOPMENT CORP.
LOCATION -97 NORTHBOURNE AVE., TURNER, CANBERRA 2612
PHONE NO. (02) 6257 3379
FAX NO. (02) 6257 3420
E-MAIL nick@lwrrdc.gov.au
DETAILS -Program manager for all water issues throughout Australia.

NAME -MELANIE STRAWBRIDGE
POSITION -PLANT BIOLOGIST
ORGANISATION -WATER & RIVERS COMMISSION
LOCATION -HYATT CENTRE, EAST PERTH, WA 6004
PHONE NO. (08) 9278 0468
FAX NO. (08) 9278 0586
E-MAIL melanie.strawbridge@wrc.wa.gov.au
DETAILS -Specialises in the selection of trees and shrubs for salinity control and saltland management with emphasis on management and protection of water catchments in regards to water quality and groundwater management.

NAME -PETER THORBURN
POSITION -PROGRAM COORDINATOR
ORGANISATION -CSIRO – TROPICAL AGRICULTURE
LOCATION -306 CARMODY RD, ST. LUCIA. BRISBANE, QLD
PHONE NO. (07) 3377 0209
FAX NO. (07) 3377 0325
E-MAIL peter.thorburn@tag.csiro.au
DETAILS -Involved in coordination of research and development programs in land and water management in tropical agriculture.

NAME	**-ROB VERTISSY**
POSITION	-DEPUTY DIRECTOR
ORGANISATION	-CSIRO – CRC FOR CATCHMENT HYDROLOGY
LOCATION	-CANBERRA, NSW
PHONE NO.	(02) 6246 5790
FAX NO.	(02) 6246 5845
E-MAIL	rob@cbr.dwr.csiro.au
DETAILS	-Research of tree function in irrigated areas.

NAME	-
POSITION	-
ORGANISATION	-
LOCATION	-
PHONE NO.	(
FAX NO.	(
E-MAIL	
DETAILS	-

NAME	-
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NAME	-
POSITION	-
ORGANISATION	-
LOCATION	-
PHONE NO.	(
FAX NO.	(
E-MAIL	
DETAILS	-

3. ENVIRONMENTAL BUFFERS

3.1 CONSTRUCTED WETLANDS

3.1.1 TECHNICAL OUTLINE

High levels of nutrients, sediment and other contaminants in irrigation drainage water can have adverse effects on downstream aquatic ecosystems. Environmental issues such as algal blooms and fish kills from contaminants in irrigation run-off can be cause for concern.

A possible solution to reducing the flow of more soluble components in the river may lie in the use of artificial or constructed wetlands or ponds through which irrigation and / or surface run-off from agricultural land can pass.

The presence of aquatic plants and biota and reduced flow velocities helps sediment and suspended contaminants including nutrients and chemicals entering the wetland to be trapped, filtered and deposited.

The concept of retention basins and constructed/natural wetlands as environmental filters for treating waste water has, in recent years, attracted an increasing level of research and adoption throughout Australia and overseas. Constructed wetlands have a number of applications including treatment of agricultural run-off, urban waste water and storm water, and mining and industrial effluent.

Run-off from agricultural land can contribute to a mass mobilisation and transport of sediment, nutrients and chemicals that have collected during the dry season in farm furrows, tail water drains and drainage channels. Measures to control stormwater run-off may help to further manage soil retention, surface water, groundwater and water quality.

Constructed wetlands have proved effective in filtering out contaminants and improving the quality of waste waters such as sewage. However, significant research is required to determine the effectiveness of wetlands in treating agricultural drainage waters in the tropics and sub-tropics.

Currently an artificial wetland experiment for the treatment of agricultural run-off is being conducted in the Burdekin region near Ayr in north-east Queensland. Contributors to the project include LWRRDC (Land & Water Resources R&D Corporation), QLD Department of Primary Industries, and Australian Centre for Tropical Freshwater Research, James Cook University. Details of the project have been included in the following technical overview.

Technical & Construction Specifications

It is important to distinguish the features of wetlands in the tropics from those in temperate regions. If retention basins and constructed wetlands were to be utilised in the Ord River Irrigation Area, a number of major factors would have to be considered. These include:

- Efficiency in trapping or filtering sediment, nutrient, pesticides and other contaminants;
- Ability to cope with high intensity wet season run-off;
- Ensuring drop structures and overflow channels are included to divert wet season flow;
- Appropriate site location and geohydrological analysis and surveying to ensure minimal recharge to rising groundwater;
- Suitable selection and establishment of tropical aquatic vegetation for trapping and filtering purposes;
- Making allowance for systems drying out prior to commencement of the wet season;
- Potential to incorporate a wetland system in existing drainage channel infrastructure;
- Area of available land needed to be effective vs. opportunity cost;
- Accessibility for periodic maintenance and removal of trapped silt and organic matter to be safely stored or returned to farms;
- Ability to control mosquito populations.

Engineering Design Objectives for a Constructed Wetland

- Capture sediments, nutrients and other contaminants;
- Establish and sustain appropriate aquatic vegetation;
- Gravity system operating under all climatic and site conditions;
- Flow measurement and control;
- Head loss minimisation;
- Monitoring facilities;
- Develop technology for "on farm" and "off farm" applications.

Effect of wet season rainfall

As a result of minimal water flows in the dry season, fine sediment and sediment-bound nutrients and chemicals from farming practices may build up in crop furrows and tail drains. Initial wet season rains can mobilise or flush sediment containing sediment-bound nutrients and chemical off the farm. If these materials are allowed to drain into the river system they may have an effect on water quality and on water users including aquatic organisms and fish. At the start of a wet season, consideration needs to be given to storing or diverting initial farm run-off following peak storm events in retention basins, constructed wetlands or trenches.

Drop-structure mechanisms and water inlet control mechanisms should be incorporated into the design to remove and control water level in the wetland. This also enables periodic draining of a retention basin or wetland thus exposing the sediment and bound chemicals to be rapidly degraded by direct UV light.

Water balance facilities

- Site rain gauge & nearby climatic station (Frank Wise Institute, AgWA)
- Inflow / outflow measurement
- Soil investigations (bores & identification)
- Soil permeability testing

Factors that also need to be determined include i) the **retention capacity** and ii) **maximum velocity capacity** of water allowed to flow through the wetland that will not disrupt existing

sediment and colloidal-bound nutrients/chemicals that have already settled. To control and manage significant fast-flowing volumes of water entering the wetland system a **bypass system** should be installed. This can be achieved in the form of overflow or spillway drains that divert excess water from the wetland. This is vital especially if storm water flow is expected to exceed the maximum velocity or retention capacity of the wetland.

Plant species selection & establishment

Species selection will be based upon their respective functions in the wetland (physical filtration, uptake, aeration of sediments, substrate for attached algae, shading & habitat). The selection of aquatic plant species is influenced by:

- availability of plants
- produce insignificant amounts of viable seeds (pose no weed threat)
- tolerance to required water depths and regimes
- use in other wetlands whereby performance data is available
- tolerance to potential inundation from wet season flows

Transplanting of aquatic macrophytes for the wetland are often sourced from local swamps and oxygen-low lagoons; removed with sediment to keep root and rhizome systems intact; and replanted into substrate to provide stability.

→"In order to achieve rapid density of plants it is necessary to have supplies of plant corms. The natural spread of aquatic plants may take several years to achieve a satisfactory density. It is therefore appropriate to use rapid propagation techniques by planting corms into a prepared surface such as composted grass material or peat deposits. Plant stocks can be secured from existing wetlands or by planting well in advance.

It is desirable to have dense plant growth to trap sediment. These conditions enhance mosquito numbers. It is therefore necessary to ensure that fish refuges (deeper slots) are included in the wetland design."

Source: Barry N. Noller, Department of Mines & Energy, Darwin, Northern Territory, 0800 Ph. (08) 8999 5438 / Fax. (08) 8999 6527 ←

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References:

[1]-*BURDEKIN ARTIFICIAL WETLAND EXPERIMENT* for Treatment of Agricultural Run-off – Project Outline / Project Team: J Simpson, H Gibson, G Rayment, H Hunter (DPI) & G Lukacs. Contributors: Land & Water Resources R&D Corporation / QLD Department of Primary Industries (DPI) / & -Australian Centre for Tropical Freshwater Research, James Cook University (JCU) 1994

[2]-Urban Erosion and Sediment Control, Revised Edn 1992, Edited by J.S. Hunt. / Department of Conservation and Land Management.

Reference Location:

[1]"CONSTRUCTED WETLANDS" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

[2]"SEDIMENT TRAPS & EROSION CONTROL" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

3.1.2 INDUSTRY CONTACTS
Constructed Wetlands

NAME -**BRENDAN ATKINS & -GREG WHITE**
POSITION -SENIOR CONSULTANT & -PRINCIPAL CONSULTANT/PROJECT DIRECTOR
ORGANISATION -AUSTRALIAN WATER TECHNOLOGIES [AWT] – ENVIRONMENT & SCIENCE ENSIGHT
LOCATION -PO BOX 73, 51 HERMITAGE RD., WEST RYDE, NSW 2114
PHONE NO. (02) 9334 0766
FAX NO. (02) 9334 0700
E-MAIL atkinsb@awtensight.nsw.gov.au & whiteg@awtensight.nsw.gov.au
DETAILS -Expert consultants in catchment management, natural wetland and stream management, constructed wetlands and riparian buffer strips.[Capability statements provided]

NAME -**DR. JOHN BAVOR**
POSITION -HEAD OF WATER RESEARCH LABORATORY
ORGANISATION -UNIVERSITY OF WEST SYDNEY
LOCATION -SYDNEY, NSW 2004
PHONE NO. (02) 4570 1264
FAX NO. (02) 4570 1264
E-MAIL
DETAILS -Wetlands specialist with expertise in constructed wetlands & retention basins, sediment control and removal, soil infiltration, improving irrigation efficiency, and soil conditioning. Provides consultancy and advisory service.

NAME -**JOHN BLACKWELL**
POSITION - PRINCIPAL RESEARCH ENGINEER/SCIENTIST
ORGANISATION -C.S.I.R.O [Land & Water]
LOCATION -GRIFFITH LAB., N.S.W. 2680
PHONE NO. (02) 6960 1521
FAX NO. (02) 6960 1600
E-MAIL john.blackwell@grf.clw.csiro.au
DETAILS - John has produced or contributed to three patent applications, about 30 referenced journal papers, 50 conference papers and 30 technical papers and reports covering agronomic research, scientific instrumentation, greenhouse environment/solar energy research, irrigation research and modeling of crop-water relations, groundwater management, soil science, machinery fabrication, engineering design, environmental engineering and waste management and application of constructed wetlands. Recently he has been playing a role in the development of FILTER technology which will utilise the augmented slotting machine for pipe laying.

NAME -**LEITH BOWYER**
POSITION -REGIONAL WATER RESOURCE OFFICER
ORGANISATION -WATER & RIVERS COMMISSION
LOCATION -KUNUNURRA, WA 6743
PHONE NO. (08) 9168 1082
FAX NO. (08) 9168 3174
E-MAIL -
DETAILS -Specialist in water hydrology in respect to environmental management and protection of surface and ground water resources. Expertise includes hydrogeological investigation, monitoring protocols, studies in nutrient assimilation, groundwater management; and provision of information and advice for constructed wetlands, retention basins, riparian zones, farm drainage systems and hydrological modeling.

NAME	**-DR PETER BREEN**
POSITION	-RESEARCH SCIENTIST
ORGANISATION	-MONASH UNIVERSITY
LOCATION	-MELBOURNE, VIC 3168
PHONE NO.	(03) 9903 2577
FAX NO.	(03) 9571 3646
E-MAIL	peter.breen@sci.monash.edu.au
DETAILS	-Researching the application of constructed wetlands to treat irrigation drainage water and other forms of waste water. Study of microbial biofilm production on the surface of aquatic wetland plants and the benefits it has in regards to dramatically improving the catchment of fine sediment and uptake of nutrients.

NAME	**-MALCOLM BROWN**
POSITION	-PRINCIPAL CONSULTING
ORGANISATION	-STORM CONSULTING
LOCATION	-PARRAMATTA, NSW, 2124
PHONE NO.	0413 870 628
FAX NO.	
E-MAIL	malcolm@nettl.usyd.edu.au
DETAILS	-Originally with Department of Land & Water Conservation (02) 9351 4305. Has recently formed a consulting firm specialising in the application of retention basin and constructed wetland technology, aquatic plant technology, stream rehabilitation and stabilisation, riparian zone management and control of stormwater. Team of consultants includes project director, aquatic plant specialist and design engineer.

NAME	**-CHRIS CARROL**
POSITION	-
ORGANISATION	-DEPARTMENT OF PRIMARY INDUSTRIES - QLD
LOCATION	-EMERALD, QLD 4720
PHONE NO.	(079) 82 8809
FAX NO.	(079) 82 8838
E-MAIL	
DETAILS	-Experience with constructed wetlands.

NAME	**-JANE CHAMBERS**
POSITION	-BOTANIST
ORGANISATION	-MURDOCH UNIVERSITY
LOCATION	-PERTH, W.A.
PHONE NO.	(08) 9360 2739
FAX NO.	(08) 9310 4997
E-MAIL	chambers@essun1.murdoch.edu.au
DETAILS	-Specialises in nutrient dynamics and selection of aquatic plant species for nutrient filtration and uptake in wetland environments.

NAME	**-PETER COTTINGHAM**
POSITION	-SENIOR CONSULTANT
ORGANISATION	-WATER ECO SIGNS [with AUSTRALIAN WATER TECHNOLOGIES (A.W.T.) - ENSIGHT]
LOCATION	-68 Bracketts Rd. MT WAVERLY, VIC 3149
PHONE NO.	(03) 9550 1044
FAX NO.	(03) 9543 7372
E-MAIL	wes@c031.aone.net.au
DETAILS	-Provide consulting services for design and management of constructed wetlands, analytical services for water quality monitoring, and develop water and catchment management plans, and environmental impact statements. [Capability Statement supplied]

NAME -**JIM DAVIES & -ROBERT NG**
POSITION -MANAGING DIRECTOR/PRINCIPAL HYROLOGIST & -PRINCIPAL WATER RESROURCE ENGINEER
ORGANISATION -JIM DAVIES & ASSOCIATES
LOCATION -
PHONE NO. (08) 9388 2436
FAX NO. (08) 9381 9279
E-MAIL jda@iinet.net.au
DETAILS -Provide hydrological and engineering services for design and construction of wetlands, sediment detention basins, sub-soil drainage design. [Capability statement provided]

NAME -**NOLE DAWSON**
POSITION -PROGRAM CO-ORDINATOR
ORGANISATION -LAND & WATER RESOURCES RESEARCH & DEVELOPMENT CORPORATION
LOCATION -QLD
PHONE NO. (07) 3822 3053
FAX NO. (07) 3822 5292
E-MAIL -
DETAILS -Involved in irrigation research and the design and construction of artificial wetlands to treat agricultural run-off in the Burdekin region of eastern Queensland.

NAME -**DAVID DEELEY**
POSITION -MANGER, ENVIRONMENTAL ENGINEERING
ORGANISATION -EVANGILISTI & ASSOCIATES PTY LTD
LOCATION -SUITE G2, 614 NEWCASTLE ST, LEEDERVILLE, WA 6007
PHONE NO. (08) 9328 3797
FAX NO. (08) 9328 3791
E-MAIL eamail@enangelisti.com.au
DETAILS -Environmental consultants specialising in land and water management planning including design and construction of artificial wetlands for treatment of waste water etc. Have recently completed an investigation into a tree plantation for the Kununurra Waste Water Treatment Plant for CALM and the Water Corporation identifying effluent, site and soil conditions, growth rates and management of the tree plantation and economics of the venture.

NAME -**MAX FINLAYSON**
POSITION -HEAD OF WETLAND PROTECTION AND MANAGEMENT
ORGANISATION -ENVIRONMENTAL RESEARCH INSTITUTE OF THE SUPERVISING SCIENTIST [ERISS]
LOCATION -Locked Bag 2, JABIRU, N.T. 0886
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E-MAIL enquiries@eriss.erin.gov.au OR maxf@eriss.erin.gov.au
DETAILS -Involved in tropical wetland protection, management and various application of constructed wetlands for nutrient stripping and filtration especially from mining effluent. Experience in choice of aquatic plant species for wetland application, specifically for control of nitrogen and phosphorus levels.

NAME -**ROSEMARY GLASS**
POSITION -CO-ORDINATOR
ORGANISATION -BAYSWATER INTEGRATED CATCHMENT MANAGEMENT
LOCATION -CITY OF BAYSWATER, W.A. 6053
PHONE NO. (08) 9272 0643
FAX NO. (08) 9272 0665
DETAILS -Involved in co-ordination of I.C.M. programs especially use of plants & biofilm for nutrient stripping of drainage water in wetlands and catchment systems.

NAME -**MARK GOLDSTEIN**
POSITION -ENVIRONMENTAL MANAGER
ORGANISATION -MAIN ROADS, WESTERN AUSTRLALIA
LOCATION -EAST PERTH, W.A. 6892
PHONE NO. (08) 9323 4130
FAX NO. -
E-MAIL -
DETAILS -Specialises in erosion management of roads, ditches, drains and slopes. Experience with application of wetlands for sediment trapping, road bank vegetative stabilisation, straw / matting style sediment traps in channels, and diversion levies in drains to reduce water flow and bank erosion.

NAME -**MARGARET GREENWAY**
POSITION -WETLAND ECOLOGIST
ORGANISATION -GRIFFITH UNIVERSITY QLD
LOCATION -GRIFFITH, QLD 4111
PHONE NO. (07) 3875 7111
FAX NO. (07) 3875 7459
E-MAIL -
DETAILS -Specialises in wetland design and ecology with emphasis on constructed wetlands for nutrient uptake and sediment trapping from waste water.

NAME **IAN GRIEVE & -CHRISTOPHER LANE**
POSITION DIRECTOR/PRINCIPAL ENGINEERING GEOLOGIST & -MANAGING DIRECTOR/PRINCIPAL ENGINEERING AND ENVIRONMENTAL GEOLOGIST
ORGANISATION SOIL & ROCK ENGINEERING PTY LTD
LOCATION PO BOX 1346, OSBORNE PARK, W.A. 6916
PHONE NO. (08) 9242 7477
FAX NO. (08) 9242 7479
E-MAIL soilrock@soilrock.com.au or igrieve@soilrock.com.au or clane@soilrock.com.au
DETAILS -Geotechnical consultancy firm involved in water management including groundwater assessment, monitoring, management and control with offices in Perth, Australia and Kuala Lumpur, Malaysia. Specialist groundwater services include: investigation for locating & designing water retaining & tailings storage structures, Site suitability assessments, Construction materials testing & assessment, Water quality determinations, Research & development including site specific testing of natural soils with additives in an attempt to reduce seepage and control water, Water diversion & interceptor systems, Rainfall intensity and PMP determinations, run-off assessments, Hydrological studies & water diversion, Seepage determinations, Whole of system water balance determination to assess water usage, water loss criteria and make up water requirements, and Drainage channel design. Company projects have varied from arid, semi arid, sub tropical to tropical climates. [Capability Statement provided]

NAME -**FERGUS HANCOCK**
POSITION -ENVIRONMENTAL OFFICER – HUNTER REGION
ORGANISATION -DEPARTMENT OF LAND & WATER CONSERVATION – WATER SERVICES DISTRICT OFFICE
LOCATION -PO BOX 297, MUSSLEBROOK, NSW 2333
PHONE NO. (02) 6542 1222
FAX NO. (02) 6543 4164
E-MAIL fhancock@dlwc.nsw.gov.au
DETAILS -Conducts assessment of proposals for constructed wetlands and nutrient balance reviews. Has been involved in project with Ken Reynolds [DLWC 02 6545 1666] regarding the design and effectiveness of buffer strips on nutrient removal from water effluent; ;vegetative silt traps; and research using *Monto vetiver* grass for buffer application. Specialises in water quality issues and limnology, geomorphic stability assessment, and management and protection of ecosystems with focus on mining and storage catchments.

NAME -TOM HATTON
POSITION -ECO-HYDROLOGIST
ORGANISATION -C.S.I.R.O. LAND & WATER
LOCATION -FLOREAT, W.A. 6014
PHONE NO. (08) 9333 6200
FAX NO. (08) 9387 8211
E-MAIL tom.hatton@per.clw.csiro.au
DETAILS -Specialises in catchment and groundwater hydrology and management, eco-physiology, plant / groundwater interactions, hydrological water balance modeling, and management of salinity issues regarding pumping techniques and tree / vegetation establishment.

NAME -HEATHER HUNTER
POSITION -SENIOR SOIL SCIENTIST
ORGANISATION -RESOURCE SCIENCES CENTRE – DEP. OF NATURAL RESOURCES, QLD
LOCATION -80 MEIERS ROAD, INDOOROOPILLY, QLD 4068
PHONE NO. (07) 3896 9637
FAX NO. (07) 3896 9591
E-MAIL hunterh@dip.qld.gov.au
DETAILS -Specialist in design, construction, engineering and maintenance of constructed wetlands. Including nutrient dynamics, sediment trapping and plant species establishment

NAME -JEFF KITE
POSITION -PRINCIPAL ENVIRONMENTAL OFFICER
ORGANISATION -WATER & RIVERS COMMISSION – CATCHMENT & WATERWAYS MANAGEMENT BRANCH
LOCATION -HYATT CENTRE, EAST PERTH, WA 6004
PHONE NO. (08) 9278 0300
FAX NO. (08) 9278 0585
E-MAIL jeffrey.kite@wrc.wa.gov.au
DETAILS -Specialises in environmental water requirements for river and wetland management; river restoration; integrated catchment management; water-sensitive urban design; and the application of retention basins, constructed wetlands and riparian zones for removal of nutrients and sediment trapping.

NAME -PAUL LAVERY
POSITION -LECTURER IN ENVIRONMENTAL MANAGEMENT & MEMBER OF CENTRE OF ECOSYSTEM MANAGEMENT
ORGANISATION -EDITH COWAN UNIVERSITY - SCHOOL OF NATURAL SCIENCES
LOCATION -JOONDALUP, W.A. 6027
PHONE NO. (08) 9273 8333
FAX NO. (08) 9400 5717
E-MAIL p.lavery@cowan.edu.au
DETAILS -Specialist in wetland design principles, operating efficiency, management and application for nutrient filtration and sediment catchment. This involves bio-remediation which uses organisms [ie. biofilm] on the surface of aquatic plants to trap fine sediment and take up nutrients from the water.

NAME -DR ROPERT LOCH & -KEN INGBRITSEN
POSITION -DIRECTOR/PRINCIPAL CONSULTANT & DIRECTOR/BUSINESS MANAGER
ORGANISATION -LANDLOCH PTY LTD
LOCATION -67 BRIDGE ST., TOOWOOMBA, QLD 4350
PHONE NO. (076) 32 0410
FAX NO. (076) 32 0489
MOBILE (0419) 713 193
E-MAIL lochr@t130.aone.net.au
DETAILS -Specialist environmental consultants in soil, water and plant interactions. Services include landform design, computer simulations of sediment movement, erosion control strategies, revegetation strategies, erosion/water quality monitoring, land/soil rehabilitation and management. [Capability Statement provided]

***NAME**	-**GEORGE LUKACS**
POSITION	-RESEARCH SCIENTIST & WETLANDS ECOLOGIST
ORGANISATION	-JAMES COOK UNIVERSITY
LOCATION	-TOWNSVILLE, QLD 4810
PHONE NO.	(077) 81 5461 / 077 814262
FAX NO.	(077) 81 5589
E-MAIL	georgelukacs@jcu.edu.au
DETAILS	-George specialises in industry consulting and research in the areas of irrigation design and planning, water quality monitoring, water management, sustainable resource development, wetland application for treatment of waste water. Involved in research projects with the Land & Water Resources Research & Development Commission including: development of best practice guidelines for irrigation development; use of constructed wetlands and detention basins for nutrient control & sediment catchment; management advice & propagation of aquatic plants; nutrient control in irrigation drainage; wetland health and water quality; and development of water quality monitoring programs. He is currently [1997] completing a PhD in tropical wetland management.

NAME	**-LUKE PEN**
POSITION	-PRINCIPAL ENVIRONMENTAL OFFICER
ORGANISATION	-WATER & RIVERS COMMISSION
LOCATION	-HYATT CENTRE, EAST PERTH, WA 6004
PHONE NO.	(08) 9278 0386
FAX NO.	(08) 9278 0585
E-MAIL	luke.pen@wrc.wa.gov.au
DETAILS	-Specialises in Catchment Waterway Management, policy development and strategic planning in waterways development including design and modeling of constructed wetlands, retention basins and drainage channels.

NAME	**-VIV REED**
POSITION	-REGIONAL MANAGER – MID WEST AVON
ORGANISATION	-WATER & RIVERS COMMISSION
LOCATION	-NORTHAM, WA 6401
PHONE NO.	(08) 9622 7055
FAX NO.	(08) 9622 7155
E-MAIL	viv.read@wrc.wa.gov.au
DETAILS	-Co-ordination of water resource management with community action. Includes integrated catchment management, use of constructed wetlands for treatment of waste water, sediment retention structures and stream flow sediment relations.

NAME	**-KEN REYNOLDS**
POSITION	-RESOURCE ASSESSMENT RESEARCH SCIENTIST
ORGANISATION	-DEP. OF LAND & WATER CONSERVATION, SCONE RESEARCH CENTRE
LOCATION	-SCONE, NSW 2337
PHONE NO.	(02) 6545 1666
FAX NO.	(02) 6545 2520
E-MAIL	-
DETAILS	- Researching constructed wetlands and retention basins for nutrient removal. Researching riparian buffer strips adjacent to channels for nutrient removal from surface run-off and drainage. Involved in the use of *Vetiver* grass for channel stabilisation and buffer hedges. Management and prevention of groundwater contamination.

NAME -**GEOFF SAINTY**
POSITION -PRINCIPAL
ORGANISATION -SAINTY & ASSOCIATES
LOCATION -PO BOX 1219, POTTS POINT, NSW 2011
PHONE NO. (02) 9332 2661
FAX NO. (02) 9331 5372
E-MAIL geoff@sainty.com.au
DETAILS -Consulting engineers in wetland design, construction & plant selection & establishment.

NAME -**LANCE WATT**
POSITION -RESOURCE OFFICER / ECONOMICS
ORGANISATION -DEPARTMENT OF LAND & WATER CONSERVATION – HUNTER REGION
LOCATION -464 KING ST., PO BOX 5166, NEWCASTLE WEST, NSW 2302
PHONE NO. (02) 4929 4346 [Extension: 847]
FAX NO. (02) 4929 6364
E-MAIL -
DETAILS -Development and implementation of sediment control strategies and programs for urban and catchment systems. Includes specialist knowledge of silt traps, constructed wetlands, retention basins, land revegetation, channel design and adoption of Erosion and Sediment Control Plans.

NAME -**TONY WONG**
POSITION -SENIOR LECTURER IN CIVIL ENGINEERING
ORGANISATION -MONASH UNIVERSITY
LOCATION -VIC 3168
PHONE NO. (03) 9903 2113
FAX NO. (03) 9887 2066-home fax
E-MAIL tony.wong@eng.monash.edu.au
DETAILS -Specialises in constructed wetlands for wastewater treatment, flood modeling. Is a member of the CRC for Catchment Hydrology and has worked with Evangilisti and Associates. [Is providing Curriculum Vitae]

NAME -**RACHAEL YOUNG**
POSITION -ACTING NUTRIENT MANAGEMENT OFFICER
ORGANISATION -DEPARTMENT OF LAND & WATER CONSERVATION
LOCATION -PO Box 136, FORBES, NSW 2871
PHONE NO. (02) 6852 1222
FAX NO. (02) 6852 3419
E-MAIL ryoung@dlwc.nsw.gov.au
DETAILS -Extensive involvement as project manager in the development of a constructed wetlands design manual [approx 500pgs / due: July 1998 / $185]. Other expertise with buffer strips and nutrient control, erosion control, urban stormwater management planning, administration of river care and landcare projects, and provision of technical advice to community groups and landowners.

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3. ENVIRONMENTAL BUFFERS

3.2 RIPARIAN BUFFER STRIPS

3.2.1 TECHNICAL OUTLINE

Riparian Land
Riparian land is defined as any land which adjoins or directly influences a body of water. This includes:

- the land immediately alongside small creeks and rivers, including the riverbank itself;
- gullies and dips which sometimes run with surface water;
- areas surrounding lakes;
- and wetlands on river floodplains which interact with the river in times of flood.

The width of riparian land will range from very narrow or non-existent, through to a wide, densely-vegetated corridor. Good management of riparian lands is an essential component of sustainable management of a property or landscape and can yield numerous benefits.

Streams and water systems can be contaminated by a range of material from adjacent land. These materials include soil particles (sediment), nutrients such as phosphorus and nitrogen, salt, litter, chemicals and microbes. In addition to irrigation drainage systems, sediment and nutrients are carried to streams in the overland flow of water. Nutrients, chemicals and other dissolved materials can also move through the soil in underground lateral flow and contaminate water.

What is a Buffer Zone?
A buffer zone is an area of vegetated land located between an area of activity (eg. farming, urban etc.) and a drainage line, creek or river. A buffer zone extends a certain distance from the edge of a stream where overland flow from general catchment run-off enters the stream channel. Types of buffer zones can vary from a grassed buffer strip through to a near-natural riparian forest. The buffer zone is specially managed for the purpose of protecting the quality of water catchments, reservoirs and their tributaries by reducing the velocity of overland water flow and causing sediment, nutrients and chemicals to be deposited on land before it reaches the stream channel.

Benefits of a Buffer Zone
Decreased erosion
Vegetation including deep-rooted species on riparian land can result in a dramatic reduction of sheet, bank, and stream bed erosion by stabilisation of the ground surface on the banks of channels, reservoirs and their tributaries and by a reduction in overland flow velocities. Buffer zones can protect such areas especially in time of flood or high seasonal rainfall events.

Improved water quality
A vegetated buffer strip can take up and retain sediment and attached and dissolved pollutants such as nutrients, pesticides and heavy metals from overland flow by providing opportunities for filtration, deposition, infiltration, absorption, adsorption, decomposition, and volatilization.

Riparian vegetation also controls the light and temperature levels for stream ecosystems which helps control the growth of nuisance plants and algae within rivers. Deep-rooted vegetation may, in some circumstances, act to lower groundwater, reducing the flow of salt and nutrients into streams from sub-surface flows.

Fish Habitat and Stream Ecology

Being part of a natural stream environment, vegetated buffer zones provide shade and shelter and sometimes food for fish and stream life. Biodiversity is enhanced providing habitat for a diverse range of terrestrial and aquatic animal and plant life. Buffer zones can also act as a corridor for the movement of native animals.

Design and Effective Use of Riparian Buffers

The design and effectiveness of riparian buffer strips requires extensive planning and is highly site specific. Extensive studies have shown the benefits and effectiveness of riparian buffer strips in removing water pollutants from surface run-off. However, their effectiveness on a broad scale catchment basis needs to be determined for each region.

The design and effectiveness of vegetated buffer strips for water quality control on a catchment basis depends on a number of important factors:

1) Physical and environmental information:

- Structure, density and species of the vegetation;
- Adjoining land use.
- Soil physical characteristics;
- Length, gradient and shape of the run-off area (ie. width / steepness of the buffer zone);
- The rate of flow of surface water and associated seasonal rainfall;
- Likelihood of surface water being concentrated into a narrow pathway;
- The depth of surface water in comparison with the height and density of vegetation;
- Hydraulic conductivity and holding capacity of the buffer zone soil.
- Presence of stock, vehicle tracks or gullies which generate sediment;

2) The types of pollutants which buffer zones are likely to encounter and parameters to be protected:

- Sediment trapping;
- Nutrient, chemical and pesticide trapping;
- Stream biota protection;
- Stream temperature.

3) The general proximity of buffer zones to sources of surface water pollution.

Natural riparian vegetation can be combined with a planted, rough grass buffer strip between it and intensively-used agricultural land. The grass strip provides an initial slowing of overland flow and trapping of sediment, and this process is continued in the natural vegetation along the streambank or channel. Vegetation can grow quickly over and through the trapped sediments, thereby protecting them from future storms.

Riparian buffer strips will not be effective if poor management practices leading to excessive soil erosion are permitted on the broader lands of a catchment.

The following design criteria need to be considered:

- Establish where flow concentrates and surface water enters landscape depressions and small river channels;
- A broad well-grassed buffer zone should be used to cover the entire area of flow concentrations to ensure there is no break-through of flow in times of heavy rain;
- Determine maximum water velocity and volume capacities that may pass through the buffer zone;
- To trap sediment, the width of a buffer zone will depend on the volumes of water and sediment being transported and the nature of the landscape adjacent to the stream or channel.

Buffer strips operate as horizontal run-off filters. For this reason flow velocities are critical to their success as high flows could overload and negate the value of the strips.

The success of buffer zones in controlling water quality will be improved if positioned close to sources of surface water pollution. In general, as the volume of flow or the amount of sediment increases, the wider the riparian strip need to be.

In addition to the major advantages of using buffer zones for erosion control and soil retention, the frequency and intensity of wet season rainfall in the Ord Irrigation Area will be a predominant factor in determining the capacity and ultimate success of vegetated buffer zones for nutrient and sediment trapping.

Criteria for Plant Selection

- Low weed risk
- Growth density
- Use local species unless for revegetation and relying on natural water supply
- Nutrient filtering efficiency
- Level of root development and soil protection
- Fast growing
- Easy to plant
- Adaptable to poor soils
- Adaptable to local environment
- Regrowth in subsequent years
- Available commercially
- Low maintenance and cost
- Drought tolerance
- Water inundation tolerance
- Low fire hazard / easy fire management

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References:

[1]. Riparian Management fact sheets: No. 1 Managing Riparian Land & No. 3 Water Quality By: Land & Water Resources Research & Development Corporation, November 1996

[1]. Buffer Zones Along Rivers an Creeks. By: Department of Water Resources, Grafton, NSW. August 1994.

[1]. The Use of Buffer Zones to Protect Water Quality: A Review By: Vol Norris. / Water Resources Management 7: 257-272, 1993

[1]. Riparian Forests as Nutrient Filters in Agricultural Watersheds By: R. Lowrance *et al.* / Bioscience Vol. 34, No. 6, June 1984

[1]. Flow resistance and sediment transport by concentrated overland flow in a grassland valley. By: I Prosser, W Dietrich & J Stevenson / Geomorphology 13 (195) 71-86

[1]. Buffer strips to protect water supply reservoirs: A model and recommendations. By: G Nieswoand *et al.* / Water Resources Bulletin, Vol 26, No. 6, December 1990

[2]. Urban Erosion & Sediment Control, Revised Edition, Edited by J.S. Hunt, Department of Conservation and Land Management

Reference Location:

[1]"RIPARIAN BUFFER STRIPS" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

[2]"SEDIMENT TRAPS & EROSION CONTROL" resource file, at the Kimberley Development Commission, PO Box 620, Kununurra, Western Australia, 6743 / Ph. (08) 9168 1044]

3.2.2 INDUSTRY CONTACTS
Riparian Buffer Strips

NAME	-**BRENDAN ATKINS & -GREG WHITE**
POSITION	-SENIOR CONSULTANT & -PRINCIPAL CONSULTANT/PROJECT DIRECTOR
ORGANISATION	-AUSTRALIAN WATER TECHNOLOGIES [AWT] – ENVIRONMENT & SCIENCE ENSIGHT
LOCATION	-PO BOX 73, WEST RYDE, NSW 2114
PHONE NO.	(02) 9334 0766
FAX NO.	(02) 9334 0700
E-MAIL	atkinsb@awtensight.nsw.gov.au & whiteg@awtensight.nsw.gov.au
DETAILS	-Expert consultants in catchment management, natural wetland and stream management, constructed wetlands and riparian buffer strips.[Capability statements provided]

NAME	**-STEWART BUNN**
POSITION	-RESEARCH SCIENTIST
ORGANISATION	-GRIFFITH UNIVERSITY
LOCATION	-QLD 4111
PHONE NO.	(07) 3875 7111
FAX NO.	(07) 3875 7615
E-MAIL	s.burn@ens.gu.edu.au
DETAILS	-Specialises in research and development of riparian zones as buffers for catchment of nutrients and sediment, as well a freshwater ecology and water quality.

NAME	**-PAUL COLLINS**
POSITION	-RIPARIAN & RIVER CARE PLANNER
ORGANISATION	-DEPARTMENT OF LAND & WATER CONSERVATION
LOCATION	-MUSSWELLBROOK, NSW 2333
PHONE NO.	(02) 6542 1222
FAX NO.	(02) 6543 4164
DETAILS	-Specialises in stream, river bank and riparian zone management and protection, channel bank erosion control.

NAME	**-DARYL EVANS**
POSITION	-SOIL CONSERVATION OFFICER
ORGANISATION	-DEPARTMENT OF NATURAL RESOURCES – CENTRE FOR WET TROPICS
LOCATION	-SOUTH JOHNSTON, QLD 4859
PHONE NO.	(07) 4064 3911
FAX NO.	(07) 4064 2249
E-MAIL	evansd@dnr.qld.gov.au
DETAILS	-Specialises in on-farm and channel bank erosion control. Research and development of *Monto vetiver* grass for on-farm soil retention and minimising erosion in gullies, channels and sloped cane growing areas.

NAME	**-PETER HAIRSINE**
POSITION	-CONSERVATION OFFICER
ORGANISATION	-CSIRO DIVISION OF SOILS
LOCATION	-PO BOX 639, CANBERRA, ACT 2601
PHONE NO.	(06) 246 5924
FAX NO.	(06) 246 5965
E-MAIL	-
DETAILS	-Conducting research into the use and effectiveness of riparian forests and grassed areas as filter strips to take up nutrients and reduce the movement of sediments from surface run-off.

NAME -**FERGUS HANCOCK**
POSITION -ENVIRONMENTAL OFFICER – HUNTER REGION
ORGANISATION -DEPARTMENT OF LAND & WATER CONSERVATION – WATER SERVICES DISTRICT OFFICE
LOCATION -MUSWELLBROOK, NSW 2333
PHONE NO. (02) 6542 1222
FAX NO. (02) 6543 4164
E-MAIL fhancock@dlwc.nsw.gov.au
DETAILS -Conducts assessment of proposals for constructed wetlands and nutrient balance reviews. Has been involved in project with Ken Reynolds [DLWC 02 6545 1666] regarding the design and effectiveness of buffer strips on nutrient removal from water effluent; ;vegetative silt traps; and research using *Monto vetiver* grass for buffer application. Specialises in water quality issues and limnology, geomorphic stability assessment, and management and protection of ecosystems with focus on mining and storage catchments.

NAME -**DALE HEINER**
POSITION -EXPERIMENTALIST
ORGANISATION -DEPARTMENT OF NATURAL RESOURCES – CENTRE FOR WET TROPICS
LOCATION -SOUTH JOHNSTON, QLD 4859
PHONE NO. (07) 4064 3911
FAX NO. (07) 4064 2249
E-MAIL heinerd@dnr.qld.gov.au
DETAILS -Researching the effectiveness of riparian buffer zones to treat agricultural run-off. Involved in trials using trees, grass, *Brachiaria decumbins* and *Monto vetiver* in riparian buffer strips designed to trap sediment and nutrients from agricultural run-off. Combined use of underground tanks to collect run-off water and trap and monitor sediment levels before and after passing through riparian zones. Has also conducted research on the fate of applied fertilisers and developed recommendations to minimise nutrient losses in the environment.

NAME -**Mr KIT JOLLEY**
POSITION -Supplier of Monto Vetiver grass
ORGANISATION -Currently Restaurant Manager [Oct. 1997]
LOCATION -KATHERINE, N.T. 0850
PHONE NO. (08) 8972 3170-Work & (08) 8972 2182-Work / (08) 8972 1837-Home
FAX NO. -
E-MAIL -
DETAILS -Conducted research into the application of **Vetiver** Grass System as a soil conservation plant in the Northern Territory. Submitted a Graduate Diploma Report (1994) to the University of Ballarat (Victoria) on the success of Monto Vetiver planted as a single row hedge and its use as an alternative to engineered structures. Kit has a supply of Monto Vetiver grass [approx. 8 km of vetiver hedge rows] available for channel soil-stabilization, buffer strips, on-farm hedges etc. Can provide assistance with supply and propagation techniques. Has good contacts. Familiar with mechanical transplanter also used for tomato and tobacco planting.

NAME -**JEFF KITE**
POSITION -PRINCIPAL ENVIRONMENTAL OFFICER
ORGANISATION -WATER & RIVERS COMMISSION – CATCHMENT & WATERWAYS MANAGEMENT BRANCH
LOCATION -HYATT CENTRE, EAST PERTH, WA 6004
PHONE NO. (08) 9278 0300
FAX NO. (08) 9278 0585
E-MAIL jeffrey.kite@wrc.wa.gov.au
DETAILS -Specialises in environmental water requirements for river and wetland management; river restoration; integrated catchment management; water-sensitive urban design; and the application of retention basins, constructed wetlands and riparian zones for removal of nutrients and sediment trapping.

NAME -GEORGE LUKACS
POSITION -RESEARCH SCIENTIST
ORGANISATION -JAMES COOK UNIVERSITY
LOCATION -TOWNSVILLE, QLD 4810
PHONE NO. (077) 81 5461
FAX NO. (077) 81 5589
E-MAIL georgelukacs@jcu.edu.au
DETAILS -Specialises in industry consulting and research in the areas of irrigation design and planning, water quality monitoring, water management, sustainable resource development, wetland application for treatment of waste water. Involved in research projects with the Land & Water Resources Research & Development Commission including -development of best practice guidelines for irrigation development; use of constructed wetlands and detention basins for nutrient control & sediment catchment; nutrient control in irrigation drainage; wetland health and water quality; and development of water quality monitoring programs.

NAME -JOHN POWELL
POSITION -NEW PRODUCT RESEARCH & MARKETING
ORGANISATION -JIMBOOMBA TURF COMPANY PTY LTD – [EROSION SOLUTIONS INTERNATIONAL PTY LTD]
LOCATION -PO BOX 6005, ACACIA RIDGE, QLD 4110
PHONE NO. (07) 3273 1166 or (07) 3273 1516
FAX NO. (07) 3273 3763
E-MAIL -
DETAILS -Supply and distribution of a range of products and services to aid in stormwater, sediment control and soil stabilisation. Specialise in Landform Design, Stormwater Treatment, Erosion and Sediment Control, Revegetation, Soil Treatment, Remediation and Streambank Stabilisation. Products include STAYturf; Greenfix Bio-Mulch Blankets; STAYspray; Siltstack and Gutter Buddy; Higgins Landcare Products; Continuous Berm Machine; Silt Stop™; STAYlogs; and Installation, remediation and revegetation service. [Catalogues and Capability Statement provided]

NAME -DR IAN PROSSER
POSITION -PROJECT LEADER – CRC FOR CATCHMENT HYDROLOGY
ORGANISATION -C.S.I.R.O - DIVISION OF LAND & WATER
LOCATION -GPO BOX 1666, CANBERRA, ACT 2601
PHONE NO. (02) 6246 5830
FAX NO. (02) 6246 5845
E-MAIL ianp@cbr.dwr.csiro.au
DETAILS -Extensive research and study of the application of vegetative buffer strips and surface water flow and run-off. Taking a large scale synoptic catchment approach in determining their effectiveness in creating flow resistance and controlling sediment in water courses

NAME -KEN REYNOLDS
POSITION -RESOURCE ASSESSMENT RESEARCH SCIENTIST
ORGANISATION -DEPARTMENT OF LAND & WATER CONSERVATION, SCONE RESEARCH CENTRE
LOCATION -SCONE, NSW 2337
PHONE NO. (02) 6545 1666
FAX NO. (02) 6545 2520
E-MAIL -
DETAILS -Researching riparian buffer strips for nutrient removal from surface run-off and drainage. Involved in the use of *Monto vetiver* grass for channel stabilisation and buffer hedges. Researching constructed wetlands and retention basins for nutrient removal.

NAME -**DR PAUL TRUONG**
POSITION -PRINCIPAL SOIL CONSERVATIONIST – LAND STABILISATION & REHABILITATION
ORGANISATION -QLD DEPARTMENT OF NATURAL RESOURCES – Resource Sciences Centre
LOCATION -Block B, 80 Meiers Rd, Indooroopilly, Brisbane, QLD 4068
PHONE NO. (07) 3896 9304
MOBILE 0412 193 381
FAX NO. (07) 3896 9591
E-MAIL truongp@dnr.qld.gov.au
DETAILS -Paul has conducted extensive research and experience throughout Australia and overseas with Vetiver grass species; a world recognised plant used for soil and water conservation & erosion control, land rehabilitation, sediment retention & buffering, reducing surface run-off velocities, channel and embankment stabilisation and nutrient stripping. Paul has led and coordinated a program involving the research, development and application of Vetiver Grass System in Queensland with major input from Land Conservation Officers throughout Queensland and the Department of Agricultural Engineering, University of South East Queensland at Toowoomba. Can provide assistance with supply and propagation techniques. Has good contacts. [Technical research papers and newsletters detailing the history and widespread application of Vetiver grass are available in the "SEDIMENT TRAPS & EROSION CONTROL" resource file, Kimberley Development Commission, Kununurra, Western Australia 6743]

NAME -**DAVID WATERS**
POSITION -SOIL CONSERVATION RESEARCH OFFICER
ORGANISATION -DEPARTMENT OF NATURAL RESOURCES - QLD
LOCATION -EMERALD, QLD 4720
PHONE NO. (079) 82 8806
FAX NO. (079) 82 3459
E-MAIL watersd@dnr.qld.gov.au
DETAILS -Researching sustainable land and water use, managing soil retention, surface water quality, groundwater quality, and catchment management. Research includes methods of minimising soil/pesticide movement using polyacrylamide, rotation of cotton growing with stubble crops such as wheat, and using *Monto vetiver* grass for channel bank and on farm soil stabilisation.

NAME -**LANCE WATT**
POSITION -RESOURCE OFFICER / ECONOMICS
ORGANISATION -DEPARTMENT OF LAND & WATER CONSERVATION – HUNTER REGION
LOCATION -464 KING ST., PO BOX 5166, NEWCASTLE WEST, NSW 2302
PHONE NO. (02) 4929 4346 [Extension: 847]
FAX NO. (02) 4929 6364
E-MAIL -
DETAILS -Development and implementation of sediment control strategies and programs for urban and catchment systems. Includes specialist knowledge of silt traps, constructed wetlands, retention basins, land revegetation, channel design and adoption of Erosion and Sediment Control Plans.

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4. PLANNING & POLICY

The following list comprises useful contacts in the industry who have experience in various fields of land and water management planning and development, development of best practice programs, investigative research in irrigation farming, environmental consulting, project coordination and development of environmental policy and codes of practice.

INDUSTRY CONTACTS

NAME -**LEITH BOWYER**
POSITION -REGIONAL WATER RESOURCE OFFICER
ORGANISATION -WATER & RIVERS COMMISSION
LOCATION -KUNUNURRA, WA 6743
PHONE NO. (08) 9168 1082
FAX NO. (08) 9168 3174
E-MAIL -
DETAILS -Specialist in water hydrology in respect to environmental management and protection of surface and ground water resources. Expertise includes hydrogeological investigation, monitoring protocols, studies in nutrient assimilation, groundwater management; and provision of information and advice for constructed wetlands, retention basins, riparian zones, farm drainage systems and hydrological modeling.

NAME -**GEOFF BEECHER**
POSITION -RESEARCH AGRONOMIST – IRRIGATED FARMING SYSTEMS
ORGANISATION -AGRICULTURE NEW SOUTH WALES
LOCATION -YANCO AGRICULTURAL INSTITUTE, YANCO, NSW 2703
PHONE NO. (02) 6951 2725 –Wk / (02) 6951 2611 –Switchboard / (02) 6953 3478 –A.H.
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MOBILE (015) 262 997
E-MAIL GEOFF.BEECHER@agric.nsw.gov.au / beechdg@agric.nsw.gov.au
DETAILS -Developer of electromagnetic (EM) technology for geophysical soil surveying and soil salinity and electrical conductivity investigation in irrigation farming. Ground based systems based on Geoff's work are now being used throughout the Murray Irrigation Limited area based in Deniliquin / Ph. (03) 5881 9300. Geoff is also involved in land & water management planning in NSW and development of best management practices. Long term involvement in irrigated farming systems and development of Land & Water Management Plans in NSW including Murray and Murrumbidgee irrigation areas.

NAME -**PAUL COLLINS**
POSITION -RIPARIAN & RIVER CARE PLANNER
ORGANISATION -DEPARTMENT OF LAND & WATER CONSERVATION
LOCATION -MUSSLEBROOK, NSW 2333
PHONE NO. (02) 6542 1222
FAX NO. (02) 6543 4164
DETAILS -Specialises in stream, river bank and riparian zone management and protection, channel bank erosion control and integrated catchment management.

NAME -**NOEL DAWSON**
POSITION -PROGRAM COORDINATOR
ORGANISATION -LAND & WATER RESOURCES RESEARCH & DEVELOPMENT CORPORATION
LOCATION -50 OCONNEL PARADE, WELLINGTON POINT, QLD 4160
PHONE NO. (07) 3822 3053
FAX NO. (07) 3822 5292
MOBILE 0419 742 641
E-MAIL noledurm@onaustralia.com.au
DETAILS -Responsible for coordination of projects throughout Australia under the National Program for Irrigation Research and Development. Project areas include: Water Use Efficiency, Application on Farm, Water Supply Systems, Drainage Systems, Integrated Farm/Supply Systems, Adoption and Education, Planning and Evaluation, and Communication.

NAME -**KIM DEAN**
POSITION -CHAIRMAN, WA REGION
ORGANISATION -IRRIGATION ASSOCIATION OF AUSTRALIA
LOCATION -42 FARIBROTHER ST, BELLMONT WA 6104
PHONE NO. (08) 9388 0088
FAX NO. (08) 9478 2896
DETAILS - Co-ordination and management of irrigation services, technology and information transfer, research and development, irrigation trials & field work throughout Western Australia. Production of 'Irrigation Australia' quarterly journal with mailing list of over 3000 including irrigators, consultants, agency staff, retailers and manufacturers nationally and internationally.

NAME -**NEILL FARMER**
POSITION -MANAGER
ORGANISATION -CSR ORD SUGAR
LOCATION -WEABER PLAINS RD., KUNUNURRA, WA 6743
PHONE NO. (08) 9166 4600
FAX NO. (08) 9166 4611
DETAILS -Manager of the CSR Ord Sugar mill in Kununurra, WA.

NAME -**GEORGE & ELAINE, and MARIE GARDINER**
POSITION -AGRICULTURAL CONSULTANTS
ORGANISATION -H. G. GARDINER & ASSOCIATES
LOCATION -PO BOX 898, KUNUNURRA, WA 6743
PHONE NO. (08) 9168 1850
FAX NO. (08) 9168 2715
MOBILE 015 444 328 / 0419 856 749
E-MAIL hggardiner@onaustralia.com.au
DETAILS -Extensive involvement in planning, development and adoption of the Ord River Irrigation Area Land & Water Management Plan, Tropical Agriculture Team, Ord Irrigation/River District Co-operative, Land Conservation District Committee, Ord Land & Water Newsletter and Ribbons of Blue environmental education and awareness program.

NAME -**ROSEMARY GLASS**
POSITION -CO-ORDINATOR
ORGANISATION -BAYSWATER INTEGRATED CATCHMENT MANAGEMENT
LOCATION -CITY OF BAYSWATER, W.A. 6053
PHONE NO. (08) 9272 0643
FAX NO. (08) 9272 0665
DETAILS -Involved in co-ordination of Integrated Catchment Management programs specialising in aquatic plants and wetlands for nutrient stripping operations.

NAME -**JEFF GOODING**
POSITION -DIRECTOR at the KIMBERLEY REGIONAL OFFICE
ORGANISATION -KIMBERLEY DEVELOPMENT COMMISSION
LOCATION -PO BOX 620, PAPUANA ST., KUNUNURRA, WA 6743
PHONE NO. (08) 9168 1044 / 041 990 7668
FAX NO. (08) 9168 1473
DETAILS -Extensive involvement in the planning and development of this current Best Environmental Practice Research Project as part of the Ord Land & Water Management Plan. The KDC facilitates economic and social development and infrastructure needs in the Kimberley. This is achieved through liaison and the establishment of working links with Government at all levels, with industry and commerce, employer and employee organisations, education & training institutions, as well as other sections of the community.

NAME -**TOM HATTON**
POSITION -ECO-HYDROLOGIST
ORGANISATION -C.S.I.R.O. LAND & WATER
LOCATION -FLOREAT, W.A. 6014
PHONE NO. (08) 9333 6200
FAX NO. (08) 9387 8211
E-MAIL tom.hatton@per.clw.csiro.au
DETAILS -Specialises in catchment and groundwater hydrology and management, eco-physiology, plant / groundwater interactions, hydrological water balance modelling, and management of salinity issues regarding pumping techniques and tree / vegetation establishment.

NAME -**TIM HODGEKINS**
POSITION -NATIONAL CHAIRMAN
ORGANISATION -IRRIGATION ASSOCIATION OF AUSTRALIA
LOCATION -TOWNSVILLE, NSW
PHONE NO. (02) 9242 3001 or (02) 9746 0531
FAX NO. (02) 9242 1334
DETAILS - Co-ordination and management of irrigation services, technology and information transfer, research and development, irrigation trials & field work throughout Australia. Production of 'Irrigation Australia' quarterly journal with mailing list of over 3000 including irrigators, consultants, agency staff, retailers and manufacturers nationally and internationally.

NAME -**JAMES HOLDEN**
POSITION -MANAGER OF INTEGRATED RESOURCE PLANNING
ORGANISATION -BURDEKIN SUGAR EXPERIMENT STATION
LOCATION -TOWNSVILLE, QLD 4810
PHONE NO. (077) 825 455
FAX NO. (077) 825 487
DETAILS -Involved in irrigation extension programs and land and water management planning in the Burdekin Irrigation Area drawing on past research and improving implementation of R&D programs .

NAME -**BOB HUMPHRIES**
POSITION -ENVIRONMENTAL MANAGER
ORGANISATION -WATER CORPORATION
LOCATION -LEEDERVILLE, W.A. 6007
PHONE NO. (08) 9420 2928
FAX NO. (08) 9420 3179
DETAILS -Co-ordinates and manages environmental water issues throughout Western Australia including river, catchment and irrigation systems.

NAME -**ANDREW KELLY**
POSITION -MANAGER
ORGANISATION -ORD IRRIGATION CO-OPERATIVE LTD
LOCATION -PO BOX 573, KUNUNURRA 6743
PHONE NO. (08) 9168 3300
FAX NO. (08) 9168 3100
DETAILS -Co-ordination and management of the irrigation infrastructure of the ORIA

NAME -**JEFF KITE**
POSITION -PRINCIPAL ENVIRONMENTAL OFFICER
ORGANISATION -WATER & RIVERS COMMISSION – CATCHMENT/WATERWAYS MGT BRANCH
LOCATION -HYATT CENTRE, EAST PERTH, WA 6004
PHONE NO. (08) 9278 0300
FAX NO. (08) 9278 0585
E-MAIL jeffrey.kite@wrc.wa.gov.au
DETAILS -Specialises in environmental water requirements for river and wetland management; river restoration; integrated catchment management; water-sensitive urban design; and the application of retention basins, constructed wetlands and riparian zones for removal of nutrients and sediment trapping.

NAME -**GEORGE LUKACS**
POSITION -ASSISTANT DIRECTOR
ORGANISATION -AUSTRALIAN CENTRE FOR TROPICAL FRESHWATER RESEARCH
LOCATION -JAMES COOK UNIVERSITY, TOWNSVILLE, QLD 4811
PHONE NO. (07) 4781 5461
FAX NO. (07) 4781 5589
E-MAIL George.Lukacs@jcu.edu.au
DETAILS -Specialises in industry consulting and research in the areas of irrigation design and planning, water quality monitoring, water management, sustainable resource development, wetland application for treatment of waste water. Involved in research projects with the Land & Water Resources Research & Development Commission including: development of best practice guidelines for irrigation development; use of constructed wetlands and detention basins for nutrient control & sediment catchment; nutrient control in irrigation drainage; wetland health and water quality; and development of water quality monitoring programs.

NAME -**ALISTER MACKINNON**
POSITION -PROJECT OFFICER
ORGANISATION -KIMBERLEY DEVELOPMENT COMMISSION
LOCATION -PO BOX 620, PAPUANA ST., KUNUNURRA, WA 6743
PHONE NO. (08) 9168 1044
FAX NO. (08) 9168 1473
E-MAIL amackin@ozemail.com.au
DETAILS -Conducted research and compiled the information for this project researching best environmental practice management techniques for irrigation farming throughout Australia and overseas. This project focuses on innovative solutions and appropriate technologies that could be utilised in the Ord River Irrigation Area for the management of groundwater and retention of sediment, chemicals and nutrients on-farm. Information has been collected comprising technical outlines, industry contacts and references to collected material and publications. As part of the Ord Land & Water Management Plan, the project addresses management strategies to combat environmental issues identified around the Ord. Literature and publications are held at the Kimberley Development Commission's library in Kununurra, Western Australia.

NAME -**PETER McCOSKER**
POSITION -ORD PROJECT CO-ORDINATOR
ORGANISATION -ORD DEVELOPMENT COUNCIL
LOCATION -PO BOX 620, PAPUANA ST., KUNUNURRA, WA 6743
PHONE NO. (08) 9168 1044
FAX NO. (08) 9168 1473
E-MAIL -
DETAILS -Planning, coordination and development of Stage 2 of the Ord River Irrigation Area.

NAME -**GEOFF McLEOD**
POSITION -ENVIRONMENTAL MANAGER
ORGANISATION -MURRAY IRRIGATION LTD.
LOCATION -DENILIQUIN, NEW SOUTH WALES 2710
PHONE NO. (03) 5881 9331
FAX NO. (03) 5881 9317
E-MAIL milenu@deni.net.au
DETAILS -Extensive involvement in the development of the Murray Irrigation Area including land and water management planning and best environmental practice management techniques for irrigation farming.

NAME -DR BOB MILES
POSITION -RURAL SERVICES COORDINATOR
ORGANISATION -CENTRAL REGION, QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES
LOCATION -cnr BRUCE HWY / OLD YEPPOON RD, ROCKHAMPTON QLD 4702
PHONE NO. (07) 4936 0399
FAX NO. (07) 4936 0317
E-MAIL -
DETAILS -Provides corporate leadership and coordinates service delivery for 350 Research, Development & Extension staff in the Central Queensland Region. In 1993 he was awarded his PhD for work in quantifying the extent and severity of degradation in the Mulga Lands south-west Queensland. This work leading to the initiation of the $50M south-west strategy. Dr Miles represented Australian agriculture in 1997 coordinating the development of the National Greenhouse Response Strategy for the agriculture sector. Dr Miles is currently involved with the Queensland Irrigation Technology Steering Committee which is reviewing irrigation technology needs in Queensland. The committee undertook a survey which revealed that there were eight major areas of R,D&E need - Water use efficiency, Sustainability/environmental issues, Risk management, Monitoring, Best management/whole farm efficiency, Information and technology transfer, Policy and Social impacts. The major directions identified from the survey and review of irrigation point to the need for a northern Australian R,D&E network, a refocus of R,D&E efforts to northern Australia, improved transfer and adoption of new technology, and improved coordination in the provision of information and services to irrigators.

NAME -DICK PASFIELD
POSITION -CHAIRMAN
ORGANISATION -LAND CONSERVATION DISTRICT COMMITTEE
LOCATION -CUMMINGS BROS., PO BOX 464, KUNUNURRA WA 6743
PHONE NO. (08) 9166 4024 / (08) 9168 1400
FAX NO. (08) 9168 1517
DETAILS - Chairman of the LCDC in Kununurra ensuring sustainable management of land and water resources throughout the Ord district.

NAME -PETER PEARSON
POSITION -CHAIRMAN
ORGANISATION -SWAN AVON INTEGRATED CATCHMENT MANAGEMENT
LOCATION -EAST PERTH, W.A. 6004
PHONE NO. (08) 9377 3710
FAX NO. (08) 9377 3710
MOBILE (0419) 984 818
DETAILS -Chairman of Bennett Brook Catchment Group and other integrated catchment management programs.

NAME -LUKE PEN
POSITION -PRINCIPAL ENVIRONMENTAL OFFICER
ORGANISATION -WATER & RIVERS COMMISSION
LOCATION -HYATT CENTRE, 3 PLAIN ST, EAST PERTH, WA 6004
PHONE NO. (08) 9278 0386
FAX NO. (08) 9278 0585
E-MAIL luke.pen@wrc.wa.gov.au
DETAILS -Specialises in Catchment Waterway Management, policy development and strategic planning in waterways development including design and modelling of constructed wetlands, retention basins and drainage channels.

NAME -**JOE SHERRARD**
POSITION -DISTRICT LEADER
ORGANISATION -AGRICULTURE WESTERN AUSTRALIA
LOCATION -FRANK WISE INSTITUTE, PO BOX 19, KUNUNURRA, WA 6743
PHONE NO. (08) 9166 4000
FAX NO. (08) 9166 4066
E-MAIL -
DETAILS -Extensive involvement in planning, development and adoption of the Ord Land & Water Management Plan as well as this current best practice research project for irrigation farming around the Ord. Agriculture W.A. promotes the sustainable development of farm businesses, rural communities and agricultural industries. Enhances the competitiveness of agriculture by providing efficient and effective agricultural and natural resource protection. Provides leadership and support to agricultural industries and for market development.

NAME -**DON SUTHERLAND**
POSITION -ASSISTANT DIRECTOR / SPECIAL PROJECTS OFFICER
ORGANISATION -KIMBERLEY DEVELOPMENT COMMISSION
LOCATION -PO BOX 620, PAPUANA ST., KUNUNURRA, WA 6743
PHONE NO. (08) 9168 1044
FAX NO. (08) 9168 1473
MOBILE 0417 996 743
E-MAIL drsuther@ozemail.com.au
DETAILS -Coordination, planning and development of corporate, industry, tourism, mining, transport and agricultural development projects throughout the Kimberley.

NAME -**TANYA VERNES**
POSITION -TECHNICAL OFFICER
ORGANISATION -DEPARTMENT OF CONSERVATION AND LAND MANAGMENT
LOCATION -PO BOX 942, MESSMATE WAY/KONKERBERRY DR, KUNUNURRA, WA 6743
PHONE NO. (08) 9168 0200
FAX NO. (08) 9168 2179
E-MAIL calmknx@calm.wa.gov.au
DETAILS -Extensive involvement with C.O.V.E (Care of the Ord Valley Environment) environmental committee in Kununurra which focuses on conservation and sustainable environmental management of land and water resources in the ORIA. Tanya has a Bachelor of Forest Science (Honors) and is involved with the Sandalwood research project in the ORIA with CALM as well as the development of a draft management plan for the Lower Ord Ramsar Site.

NAME -**DR. COLIN WALKER**
POSITION -SENIOR ENVIRONMENTAL SCIENTIST
ORGANISATION -GEO & HYDRO –ENVIRONMENTAL MANAGEMENT PTY LTD
LOCATION -SUITE 1, 66 MILL POINT RD., SOUTH PERTH, WA 6151
PHONE NO. (08) 9368 1919 –W / (08) 9496 1970
FAX NO. (08) 9368 1970
MOBILE (015) 775 711
E-MAIL/INTERNET wa@geohydro.com.au
DETAILS -Provides professional services to both industry and government in the areas of Environmental management projects, Rural planning & management, Investigation, risk analysis, & remediation of contaminated sites. Specialist consulting services include: Development of environmental plans, Hydrogeological catchment management & modeling, Crop nutrition – sustainable production, Evapo-transpiration & water balance, Ecological Value Assessment, Salinity & Land Constraint Surveys, Whole Farm Planning, Surface water & groundwater hydrology & modeling, and Waste management. [Capability Statement provided]

NAME -**RICHARD WHYTE**
POSITION -MANAGER
ORGANISATION -ENVIRONMENTAL PROTECTION AUTHORITY – WEST REGION
LOCATION -BATHURST, NSW 2795
PHONE NO. (02) 6332 1838
FAX NO. -
DETAILS -Involved in the licensing of the New South Wales water scheme.

NAME -DON YOUL
POSITION -REGIONAL SCIENCE COORDINATOR
ORGANISATION -QLD DEPARTMENT OF NATURAL RESOURCES
LOCATION -ROCKHAMPTON, QLD 4700
PHONE NO. (07) 4938 4600
FAX NO. (07) 4938 4011
EMAIL YoulD@dnr.qld.gov.au
DETAILS -Involved in water catchment and land and water management planning in the sub-tropics of Queensland. Has publications available regarding the Emerald Irrigation Area.

NAME -
POSITION -
ORGANISATION -
LOCATION -
PHONE NO. (
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E-MAIL
DETAILS -

APPENDIX 1 An introductory letter requesting information sent to industry personnel.

KIMBERLEY
DEVELOPMENT COMMISSION

ORD RIVER IRRIGATION AREA

IRRIGATION FARMING - BEST ENVIRONMENTAL PRACTICE RESEARCH PROJECT

Dear Sir / Madam,

The Ord River area in Tropical North Western Australia is the site of a current irrigation planning and management project initiated in May 1997 that is in the process of being expanded significantly. The Ord has a pronounced monsoonal wet season (Dec to March) during which period localised flooding and waterlogging can occur, and a prolonged dry season (April to November). Average rainfall is about 780mm per year and almost all of it falls in the wet season. The soils are classified as black self mulching clays commonly referred to as cotton type soils. The clay layers are relatively thin and overlay more porous medium textured clays and silty riverine deposits. In many areas the clays are further underlain with sand and gravel beds that follow palaeo-channels of the Ord River.

The main issues have been transport of sediment-bound nutrients and chemicals and rapidly rising ground water during recent years as the full 13000 hectares of farm land has been brought under production. Representatives of all interest groups are currently becoming involved in a planning process that will lead to the development of a suite of best management practices for the Ord.

The following request is for information regarding a range of land and water management strategies that will need to be developed and employed by farmers to ensure that their practices are sustainable. The information will be gathered from throughout Australia and overseas and will form an integral part of the final Plan by offering sufficient detail for Ord farmers to see the merits of established and innovative approaches to land and water management. The detail of the concepts involved is an important element.

We would appreciate your ideas and thoughts and any further information and leads that will help develop a comprehensive package of management options for Ord farmers.

Yours sincerely,

Alister Mackinnon
Project Officer

KIMBERLEY DEVELOPMENT COMMISSION
PO Box 620, Kununurra WA 6743
Telephone: (08) 9168 1044 - W. / (08) 9168 1953 - AH.
Facsimile: (08) 9168 1473 / E-mail: amackin@ozemail.com.au

APPENDIX 2 Project description sent to industry personnel.

KIMBERLEY
DEVELOPMENT COMMISSION

ORD RIVER IRRIGATION AREA

IRRIGATION FARMING - BEST ENVIRONMENTAL PRACTICE RESEARCH PROJECT

Task- To undertake research and compile an information base comprising of a literature search and information from industry sources.

Scope- The project will draw upon national and international land & water management research.

Approach- The project will access innovative solutions [new emerging approaches] and appropriate technologies.

Techniques- The techniques for which information will be gathered are:-

1. MANAGING SOIL RETENTION & SURFACE WATER QUALITY
   - 1.1 Sediment Traps & Erosion Control
   - 1.2 Mulching Techniques
   - 1.3 Cover Cropping
   - 1.4 Minimum Tillage
   - 1.5 Chemical Mechanisms
   - 1.6 Tailwater Return

2. MANAGING GROUNDWATER & ITS QUALITY
   - 2.1 Soil Permeability Mapping
   - 2.2 Groundwater Pumping & Conjunctive Water Use
   - 2.3 Irrigation Management
   - 2.4 Sub-surface Drainage
   - 2.5 Tree Cropping

3. ENVIRONMENTAL BUFFERS
   - 3.1 Constructed Wetlands
   - 3.2 Riparian Buffer Strips

4. PLANNING & POLICY

   Industry Contacts:
   - Land & Water Mgt Planning / Integrated Catchment Mgt;.
   - Best Practice Programs / Codes of Practice
   - Policy & Regulation

Aspects - The aspects of the above techniques which require research include the following:-

- Design
- Construction and technical specifications
- Physics of operation
- Performance - requirements and rating specifications
- Suitability and limitations
- Equipment costs and availability
- Management requirements
- Impacts - Economic (financial and taxation)
  Biological and Physical
- Research and Development
- Opportunity cost
- Testing and evaluation
- Efficiency / cost factors and effectiveness

Deliverables - The outcome of the project is expected to be in the form of an accessible information base to which new information will be continually added. The information base will comprise of a technical review, industry contacts, data source information and references to collected publications and reports which will be located at:

Contact:

Alister Mackinnon
Project Officer

KIMBERLEY DEVELOPMENT COMMISSION
PO Box 620, Kununurra WA 6743
Telephone: (08) 9168 1044 / Facsimile: (08) 9168 1473

APPENDIX 3 References to collected publications and reports available at the Kimberley Development Commission's library.

ORIA BEST ENVIRONMENTAL PRACTICE RESEARCH PROJECT

PUBLICATION LIST

[as at MARCH 1998]

RESOURCE FILE: *CHEMICAL MECHANISMS*

Researched Literature Available at:

Kimberley Development Commission
PO Box 620
Papuana Street
Kununurra, Western Australia, 6743
Ph. (08) 9168 1044
Fax. (08) 9168 1473

TITLE: <Video> "SOILFIX IR" – Interviews of US farmers using polyacrylamide [< 20mins]
AUTHOR: ALLIED COLLOID PTY LTD
YEAR: - **LOCATION**: "CHEMICAL MECHANISMS" file, KDC

TITLE: <Brochure>: SOILFIX^{tm} for Sustainable Production
AUTHOR: ALLIED COLLOID PTY LTD
YEAR: 1997 **LOCATION**: "CHEMICAL MECHANISMS" file, KDC

TITLE: POLYACRYLAMIDE AS A TOOL FOR CONTROLLING SEDIMENT RUNOFF & IMPROVING INFILTRATION UNDER FURROW IRRIGATION
AUTHOR: CW Ross, RE Sojka and RD Lentz
YEAR: 1996 **LOCATION**: "CHEMICAL MECHANISMS" file, KDC

TITLE: HORTICULTURAL FACT SHEET: Talking Polyacrylamides
AUTHOR: Riverland Horticultural Traders
YEAR: 1997 **LOCATION**: "CHEMICAL MECHANISMS" file, KDC

TITLE: POLYACRYLAMIDE REVIEW: SOIL CONDITIONING AND ENVIRONMENTAL FATE
AUTHOR: CA Seybold, Virginia State University, Petersburg
YEAR: 1994 **LOCATION**: "CHEMICAL MECHANISMS" file, KDC

TITLE: THE EFFECT OF POLYACRYLAMIDE ON RUNOFF, EROSION AND COTTON YIELD FROM FIELDS IRRIGATED WITH MOVING SPRINKLER SYSTEMS
AUTHOR: GJ Levy, M Ben-Hur and M Agassi
YEAR: 1990 **LOCATION**: "CHEMICAL MECHANISMS" file, KDC

TITLE: POLYACRYLAMIDES AS SOIL CONDITIONERS: OVERSEAS EXPERIENCE
AUTHOR: Peter Chamberlain, Allied Colloids, United Kingdom [The Aust. Cottongrower, Vol 17, No.1, Nov-Dec '96]
YEAR: 1996 **LOCATION**: "CHEMICAL MECHANISMS" file, KDC

TITLE: REDUCING PESTICIDE RUNOFF WITH POLYACRYLAMIDE
AUTHOR: Lyndal Hugo, R Caldwell and Ivan Kennedy, University of Sydney [The Aust. Cottongrower, Vol.17, No.1, Nov-Dec '96]
YEAR: 1996 **LOCATION**: "CHEMICAL MECHANISMS" file, KDC

TITLE: POLYACRYLAMIDES REDUCE EROSION AND PESTICIDE RUNOFF
AUTHOR: David Dowling [The Aust. Cottongrower, Vol 17, No. 6 Nov-Dec '96]
YEAR: 1996 **LOCATION**: "CHEMICAL MECHANISMS" file, KDC

TITLE: PAM (POLYACRYLAMIDE) KEEPS SOIL IN ITS PLACE
AUTHOR: Marcia Wood, Agricultural Research / September 1997
YEAR: 1997 **LOCATION**: "CHEMICAL MECHANISMS" file, KDC

TITLE: STOPPING EROSION WITH GYPSUM AND PAM (POLYACRYLAMIDE)
AUTHOR: Hank Becker, Agricultural Research / September 1997
YEAR: 1997 **LOCATION**: "CHEMICAL MECHANISMS" file, KDC

TITLE: POLYACRYLAMIDE (PAM) – A NEW WEAPON IN THE FIGHT AGAINST IRRIGATION-INDUCED EROSION
AUTHOR: RE Sojka and RD Lentz, US Department of Agriculture – Agric. Research Service, Idaho
YEAR: 1994 **LOCATION**: "CHEMICAL MECHANISMS" file, KDC

TITLE: A PAM (POLYACRYLAMIDE) PRIMER: A BRIEF HISTORY OF PAM AND PAM-RELATED ISSUES
AUTHOR: RE Sojka and RD Lentz
YEAR: 1997 **LOCATION**: "CHEMICAL MECHANISMS" file, KDC

TITLE: PAM (POLYACRYLAMIDE) PUBLICATIONS RELATED TO THE KIMBERLY, IDAHO IRRIGATION/PAM RESEARCH EFFORT.
AUTHOR: RE Sojka and RD Lentz
YEAR: 1997 **LOCATION**: "CHEMICAL MECHANISMS" file, KDC

TITLE: SOILFIX TRAINING COURSE NOTES
AUTHOR: Allied Colloids Australia Pty. Ltd., September 1996
YEAR: 1996 **LOCATION**: "CHEMICAL MECHANISMS" file, KDC

TITLE: EROSION TAKES A POWDER – EMERGING POLYMER CHEMISTRY HELPS REDUCE SOIL SEDIMENTATION ON IRRIGATED FIELDS / In: Farm Chemicals Vol 156(12), Dec 1993
AUTHOR: Dennis Senft
YEAR: 1993 **LOCATION**: "CHEMICAL MECHANISMS" file, KDC

TITLE: IDENTIFYING GYPSUM-RESPONSIVE SOILS
AUTHOR: Fionnuala Frost - / Farmnote No 57/90, Western Aust Dep of Agriculure
YEAR: 1990 **LOCATION**: "CHEMICAL MECHANISMS" file, KDC

TITLE:
AUTHOR:
YEAR: **LOCATION**: "CHEMICAL MECHANISMS" file, KDC

TITLE:
AUTHOR:
YEAR: **LOCATION**: "CHEMICAL MECHANISMS" file, KDC

ORIA BEST ENVIRONMENTAL PRACTICE RESEARCH PROJECT

PUBLICATION LIST

[as at MARCH 1998]

RESOURCE FILE: *CONSTRUCTED WETLANDS*

Researched Literature Available at:

Kimberley Development Commission
PO Box 620
Papuana Street
Kununurra, Western Australia, 6743
Ph. (08) 9168 1044
Fax. (08) 9168 1473

TITLE: THE USE OF WETLANDS FOR THE TREATMENT OF IRRIGATION RETURN WATER – [Sub-consultant report for Sinclair Knight Merz Pty Ltd]
AUTHOR: Dr. Peter Breen – CRC for Freshwater Ecology, & Neil Craigie Pty Ltd
YEAR: 1997 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: *BURDEKIN ARTIFICIAL WETLAND EXPERIMENT* FOR TREATMENT OF AGRICULTURAL RUNOFF – PROJECT OUTLINE.
AUTHOR: J.Simpson, H. Gibson, G, Rayment, H. Hunter (DPI) And G. Lukacs (JCU).
YEAR: 1994 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: NUTRIENT CONTROL IN IRRIGATION DRAINAGE SYSTEMS USING ARTIFICIAL WETLANDS – National Program for Irrigation R&D, Projects 1996
AUTHOR: QDNR and James Cook University / In: Water Wheel Supplement
YEAR: 1994-98 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: INTERIM GUIDELINES ON THE PLANNING, DESIGN AND MANAGEMENT OF ARTIFICIAL WETLANDS IN QUEENSLAND
AUTHOR: Water Resources, DPI QLD
YEAR: 1995 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: CREATED & NATURAL WETLANDS FOR CONTROLLING NONPOINT SOURCE POLLUTION. - Designing Constructed Wetlands Systems To Treat Agricultural Nonpoint Source Pollution.
AUTHOR: Donald A. Hammer, Regional Waste Management Department Tennessee Valley Authority.
YEAR: 1993 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: CREATED AND NATURAL WETLANDS FOR CONTROLLING NONPOINT SOURCE POLLUTION. - Introduction to Nonpoint Source Pollution and Wetland Mitigation.
AUTHOR: Lawrence A. Baker, Water Resources Research Center, University of Minnesota.
YEAR: 1993 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: POTENTIAL USE OF IRRIGATION DRAINS AS WETLANDS.
AUTHOR: K.H. Bowmer, M. Bales and J. Roberts.
YEAR: 1994 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: USE OF WETLANDS FOR SMALL COMMUNITIES: STRATEGIES FOR RESEARCH & DEVELOPMENT
AUTHOR: J Simpson and P Beavers; Water Resources Commission, DPI, Brisbane
YEAR: 1992 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: ESTABLISHING WETLAND PLANTS IN ARTIFICIAL SYSTEMS
AUTHOR: J Chambers & A McComb; Institute for Environmental Science, Murdoch University, Perth, WA
YEAR: 1992 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: FLOW CHARACTERISTICS OF PLANTED SOIL FILTERS
AUTHOR: R Netter; Institute of Water Quality Control & Waste Mgt., Technical Uni. of Munich, Germany
YEAR: 1992 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: DESIGN CRITERIA AND PRACTICE FOR CONSTRUCTED WETLANDS
AUTHOR: Ronal Crites; Nolte & Associates, Sacremento, California, USA
YEAR: 1992 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: DESIGNING CONSTRUCTED WETLANDS FOR NITROGEN REMOVAL
AUTHOR: Donald Hammer & Robert Knight
YEAR: 1992 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: COUPLING WETLAND TREATMENT TO LAND TREATMENT: AN INNOVATIVE METHOD FOR NITROGEN STRIPPING?
AUTHOR: A. Bryce Cooper
YEAR: 1994 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: ARTIFICIAL WETLANDS FOR WASTEWATER TREATMENT, WATER REUSE AND WILDLIFE IN QUEENSLAND, AUSTRALIA.
AUTHOR: Margaret Greenway and John Simpson
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: THE USE OF WETLANDS FOR WATER POLLUTION CONTROL IN AUSTRALIA: AN ECOLOGICAL PERSPECTIVE.
AUTHOR: D.S. Mitchell, A.J. Chick and G.W. Raisin
YEAR: 1995 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: SEDIMENT DEPOSITION IN A FORESTED INLAND WETLAND WITH A STEEP – FARMED WATERSHED.
AUTHOR: Sherwood C. McIntyre and James W. Naney.
YEAR: 1991 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: BENEFITS TO DOWNSTREAM FLOOD ATTENUATION AND WATER QUALITY AS A RESULT OF CONSTRUCTED WETLANDS IN AGRICULTURAL LANDSCAPES.
AUTHOR: Taylor A. De Laney.
YEAR: 1995 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: CONSTRUCTED WETLANDS FOR RIVER WATER QUALITY IMPROVEMENT.
AUTHOR: R.H. Kadlec and D.L. Hey.
YEAR: 1994 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: IMPACT OF LANDSCAPE FEATURE AND FEATURE PLACEMENT AGRICULTURAL NON-POINT-SOURCE-POLLUTION CONTROL..
AUTHOR: Udoyara S. Tim, Robert Jolly, and Hsiu – Hua Liao.
YEAR: 1995 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: NITRATE REMOVAL IN RIPARIAN WETLANDS SOILS: EFFECTS OF FLOW RATE, TEMPERATURE, NITRATE CONCENTRATION AND SOIL DEPTH.
AUTHOR: Hans P.L. Willems, Matthew D.Rotelli, Duane F. Berry, Eric P. Smith, Raymond B..Reneau And Saied Mostaghimi.
YEAR: 1997 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: NITROGEN REMOVAL AND CYCLING IN RESTORED WETLANDS USED AS FILTERS OF NUTRIENTS FOR AGRICULTURAL RUNOFF.
AUTHOR: Francisco A. Comin, Jose A. Romero, Valeria Astorga And Carmen Garcia.
YEAR: 1997 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: THE STATE OF PEEL HARVEY ESTUARY (WATERWAYS).
AUTHOR: Waterways Commission.
YEAR: 1993-94 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: A FEASIBILITY STUDY OF MALALEUCA TREES FOR USE IN CONSTRUCTED WETLANDS IN SUBTROPICAL AUSTRALIA.
AUTHOR: Keith G.E. Bolton And Margaret Greenway
YEAR: 1997 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: SUITABILITY OF AQUATIC MACROPHYTES FOR CONSTRUCTED WETLANDS RECEIVING SEWAGE EFFLUENT IN QUEENSLAND.
AUTHOR: Margaret Greenway.
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: NUTRIENT CONTENT OF WETLAND PLANTS IN CONSTRUCTED WETLANDS RECEIVING MUNICIPAL EFFLUENT IN TROPICAL AUSTRALIA.
AUTHOR: Margaret Greenway.
YEAR: 1997 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: WETLANDS FOR WASTEWATER AND WILDLIFE – AN ECOLOGISTS PERSPECTIVE.
AUTHOR: Margaret Greenway.
YEAR: 1993 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: CONSTRUCTED WETLANDS IN QUEENSLAND – PERFORMANCE EFFICIENCY AND NUTRIENT BIO-ACCUMULATION
AUTHOR: Margaret Greenway And Anne Woolley.
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: CONSTRUCTED WETLANDS – A NATURAL OPTION
AUTHOR: B Atkins, P Swanson (Australian Water Technologies Pty Ltd.
YEAR: 1997 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: CREATING ENVIRONMENTAL KIDNEYS: WETLAND ECOSYSTEMS AS POLLUTION FILTERS AND HABITAT RESTORATIVES.
AUTHOR: Patrick L. Osborne & Peter W. Adock
YEAR: 1995 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: AN EVALUATION OF THE EFFECTIVENESS OF EN ROUTE WETLANDS FOR THE REMOVAL OF NUTRIENTS FROM IRRIGATION DRAINAGE.
AUTHOR: Peter Cottingham, Tracy Clark & Kelly O'shanassy.
YEAR: 1997 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: ENHANCED NITROGEN ELIMINATION IN SUBSURFACE FLOW ARTIFICIAL WETLANDS - A MULTI STAGE CONCEPT.
AUTHOR: Christoph Platzer
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: TWO STRATEGIES FOR ADVANCED NITROGEN ELIMINATION IN VERTICAL FLOW CONSTRUCTED WETLANDS.
AUTHOR: Johannes Laber, Reinhard Perfler, Muthgasse 18, 1190 Vienna, Austria.
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: WATER QUALITY AND OCCURRENCES OF PROTOZOA AND METAZOA IN TWO CONSTRUCTED WETLANDS TREATING DIFFERENT WASTEWATERS IN THAILAND.
AUTHOR: Orathai Chavalparit And Thingchai Panswad.
YEAR: 1990 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: ROLE OF PLANT UPTAKE ON NITROGEN REMOVAL IN CONSTRUCTED WETLANDS LOCATED IN THE TROPICS.
AUTHOR: Thammarat Koottatep And Chongrak Polprasert.
YEAR: 1997 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: POTENTIAL OF REMOVAL OF PARTICULATE MATTER & THE NITROGEN THROUGH ROOTS ATTACHMENT IN WATER HYACINTH IN A TROPICAL NATURAL WETLAND.
AUTHOR: S.K Billmore, Ritu Bharadia And Anil Kumar.
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: NITROGEN REMOVAL AND CYCLING IN RESTORED WETLANDS USED AS FILTERS OF NUTRIENTS FOR AGRICULTURAL RUNOFF.
AUTHOR: Francisco A. Comin, Jose A. Romero, Valeria Astorga, Carmen Garcia.
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: DESIGN OF SUBSURFACE FLOW WETLANDS TREATING MUNICIPAL WASTEWATER.
AUTHOR: Dennis B. George And Michael C. Kemp.
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: NUTRIENT BIO-ACCUMULATION IN WETLAND PLANTS RECEIVING MUNICIPAL EFFLUENT IN CONSTRUCTED WETLANDS IN TROPICAL AUSTRALIA.
AUTHOR: Margaret Greenway.
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: USE OF IMPROVED MACROPHYTES FOR EFFICIENT REMOVAL OF NITROGEN IN WETLANDS.
AUTHOR: S.K. Billmore And J.K. Sharma
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: WASTEWATER TREATMENT IN CONSTRUCTED WETLANDS: SYSTEM DESIGN, REMOVAL PROCESSES, AND TREATMENT PERFORMANCE.
AUTHOR: H. Brix
YEAR: 1993 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: INVESTIGATION OF ALTERNATIVE METHOD FOR NITRIFICATION IN CONSTRUCTED WETLANDS.
AUTHOR: Michael Green, Eran Friedler And Iris Safari.
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: APPLICATION OF CONSTRUCTED WETLANDS FOR TREATMENT OF SEWAGE IN TROPICAL REGION
AUTHOR: Chongrak Polprasert, Lim Poh – Eng, Supatpong Mattaraj, Nawa Raj Khatiwada & Thammarat Koottatep.
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: RAINFALL, PONDING AND FLOOD IRRIGATION – THEIR IMPORTANCE TO RICE GROWING IN THE ADELAIDE RIVER AREA.
AUTHOR: Brian Cann And Yan Diczbalis
YEAR: 1988 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: LAND RECLAMATION USING PONDING BANKS IN CENTRAL AUSTRALIA.
AUTHOR: Bob Keetch And Gary Bastin
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: LOSS OF DISSOLVED AND PARTICULATE PHOSPHORUS FROM ARABLE CATCHMENTS BY SUBSURFACE DRAINAGE.
AUTHOR: R. Grant, A. Laubael, B. Kronvang, H.E. Andersen, L.M. Svendsen And A. Fuglsang.
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: ROLE OF WETLANDS IN REDUCING PHOSPHORUS LOADING TO SURFACE WATER IN EIGHT WATERSHEDS IN THE LAKE CHAMPLAIN BASIN.
AUTHOR: Christine M. Weller, Mary C. Watzin And Deane Wang.
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: FLOW AND NUTRIENT EXPORT PATTERNS FOR AN AGRICULTURAL HILL – LAND WATERSHED.
AUTHOR: H.B. Pionke, W.J. Gburek, A.N. Sharpley And R.R. Schnabel.
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: NITRATE REMOVAL IN STREAM RIPARIAN ZONES.
AUTHOR: Alan R. Hill
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: PHOSPHORUS AND NITRATE LOSS FROM HORTICULTURE ON THE SWAN COASTAL PLAIN.
AUTHOR: Neil Lantzke
YEAR: 1997 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: STREAMLINING – AN ENVIRONMENTALLY SUSTAINABLE DRAINAGE NETWORK FOR THE SWAN COASTAL PLAIN.
AUTHOR: Garry Heady And Neil Guise
YEAR: 1994 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: DESIGN OF CONSTRUCTED WETLANDS AND WET DETENTION BASINS FOR STORMWATER QUALITY MANAGEMENT.
AUTHOR: Tony H F Wong, Nicholas L G Somes And Marino R Evangelisti.
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: WETLAND RESEARCH IN THE WET – DRY TROPICS OF AUSTRALIA.
AUTHOR: CM Finlayson
YEAR: 1995 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: QUANTIFYING THE ROLE OF WETLANDS IN CATCHMENT NUTRIENT DYNAMICS.
AUTHOR: D Mitchell, A Chick & G Raisin.
YEAR: 1994 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: SOME CONSIDERATIONS & REQUIREMENTS FOR MONITORING & ASSESSMENT PROGRAMS FOR FRESHWATER ECOSYSTEMS OF NORTHERN AUSTRALIA.
AUTHOR: CL Humphrey & RWJ Pidgeon
YEAR: 1994 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: ECOLOGICAL IMPACT OF CONTAMINANTS ON WETLANDS: TOWARDS A RELEVANT METHOD OF RISK ASSESSMENT.
AUTHOR: DJ Baird, Cm Finlayson & C Camilleri.
YEAR: 1995 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: WETLAND FILTRATION RESEARCH AT ERA RANGER MINE.
AUTHOR: H Nisbet
YEAR: 1995 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: THE ROLE OF WETLANDS IN CONTROLLING CONTAMINANT DISPERSION FROM MINE WASTE WATERS.
AUTHOR: BN Noller.
YEAR: 1995 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: DELINEATION OF INUNDATED AREA AND VEGETATION IN WETLANDS WITH SYNTHETIC APERTURE RADAR.
AUTHOR: LL Hess & JM Melack
YEAR: 1995 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: ECOLOGICAL IMPACT CONTAMINANTS ON WETLANDS: TOWARDS A RELEVANT METHOD OF RISK ASSESSMENT.
AUTHOR: DJ Baird, CM Finlayson & C Camilleri.
YEAR: 1995 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: CONSTRUCTED WETLANDS IN NSW BEST MANAGEMENT PRACTICE.
AUTHOR: Greg White & Rod Wiese.
YEAR: 1995 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: SOIL AND WATER MANAGEMENT FOR URBAN DEVELOPMENT WETLANDS WORKSHOP.
AUTHOR: Greg White
YEAR: 1995 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: GUIDELINES FOR DESIGN OF EFFECTIVE BUFFERS FOR WETLANDS ON THE SWAN COASTAL PLAIN.
AUTHOR: Peter M. Davies & J.A.K. Lane.
YEAR: 1995 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: STREAM QUALITY IMPACTS OF BEST MANAGEMENT PRACTICES IN A NORTHWESTERN ARKANSAS BASIN.
AUTHOR: D.R Edwards, T.C. Daniel, H.D Scott, J.F. Murdoch, M.J. Habiger, And H.M. Burks.
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: TENDER TO DESIGN AND CONSTRUCTION – STAGE 1 ARTIFICIAL WETLANDS TOWN CREEK CLARENCE TOWN.
AUTHOR: Woodlots & Wetlands Pty Ltd.
YEAR: 1995 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: GROUNDWATER INFLUENCE ON THE WATER BALANCE AND NUTRIENT BUDGET OF A SMALL NATURAL WETLAND IN NORTH-EASTERN VICTORIA
AUTHOR: G Raisin, J Bartley and R Croome
YEAR: 1997 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: WETLAND RESEARCH – RESTORING THE BALANCE
AUTHOR: Land and Water Resources R&D Corporation
YEAR: 1997 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: ARE THERE SEEDS IN YOUR WETLAND
AUTHOR: Land and Water Resources R&D Corporation
YEAR: 1997 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: CONSTRUCTED WETLANDS & MOSQUITOES – SOME PROBLEMS & SOME SOLUTIONS
AUTHOR: Richard Russel [Uni of Sydney] and Laura Kuginis [Dep of Land & Water Conservation, NSW]
YEAR: 1995 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: THE USE OF WETLAND PLANTS IN ARTIFICIAL WETLANDS IN QUEENSLAND
AUTHOR: R Dowling & K Stephens [QLD Herbarium Dep of Environment & Heritage]
YEAR: 1995 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: CONSTRUCTED WETLANDS SAFETY ISSUES
AUTHOR: G Hunter [Stormwater Management Engineer; Blacktown City Council, NSW 2148]
YEAR: 1995 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: WETLANDS FOR WATER QUALITY CONTROL – CONFERENCE PAPERS {CONTENTS}- James Cook University, Townsville, QLD, 25-29 Sept 1995
AUTHOR: WITA, AUST CENTRE FOR TROPICAL FRESHWATER RESEARCH, QLD DPI
YEAR: 1995 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

Wetland Application in the Treatment of Mining Effluent

TITLE: Case Studies of Wetland Filtration of Mine Waste Water in Constructed and Naturally Occurring Systems in Northern Australia
AUTHOR: Barry Noller, P Woods and B Ross
YEAR: 1994 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: Wetlands for Water Pollution Control on Tropical Minesites in the Northern Territory, Aust.
AUTHOR: Guan-Hua Gao and Barry N. Noller
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: Design of Wetland Systems at Mining Projects in the Tropics to Control Contaminant Dispersion from Waste Water
AUTHOR: Barry Noller and Gretel Parker
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: Medium-term Performance of Wetlands Improving Water Quality of Near-neutral Mine Drainage in the Northern Territory.
AUTHOR: Peter Woods and Barry Noller
YEAR: 1995 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: The Control of Contaminant Dispersion from Mine Waste Water in the Tropics Using Designed Wetland Systems
AUTHOR: Barry Noller and Gretel Parker
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: The Role of Biogeochemical Processes in Minimising Uranium Dispersion from a Mine Site
AUTHOR: Barry Noller, Roger Watters and Peter Woods
YEAR: 1996 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: Land Application at Ranger Uranium Mine, Northern Australia: Six Years' Review
AUTHOR: B Noller and J Zhou
YEAR: 1991 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

TITLE: The Role of Wetlands in Controlling Contaminant Dispersion from Mine Waste Waters
AUTHOR: BN Noller
YEAR: 1995 **LOCATION**: "CONSTRUCTED WETLANDS" file, KDC

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AG Goyen – Director
CG Thiering - Director
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ORGANISATION:
CONTACT(S):
LOCATION: "CONSULTANTS, ENGINEERS & RESEARCH PERSONNEL" file, KDC

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ORIA BEST ENVIRONMENTAL PRACTICE RESEARCH PROJECT

PUBLICATION LIST

[as at MARCH 1998]

FILE NAME: *CULTURAL PRACTICES* -
MULCHING TECHNIQUES / MINIMUM TILLAGE / COVER CROPPING / & TAIL WATER RETURN

Researched Literature Available at:

Kimberley Development Commission
PO Box 620
Papuana Street
Kununurra, Western Australia, 6743
Ph. (08) 9168 1044
Fax. (08) 9168 1473

MULCHING TECHNIQUES

TITLE: SIMBA'S MULCHMASTER II INCORPORATES STRAW BUT LEAVES AN OPEN SOIL STRUCTURE
AUTHOR: Mike Hodge, Simba International Ltd, UK / IN: Agric & E Intl, Vol 46, Nos 1 & 2
YEAR: 1994? **LOCATION**: "CULTURAL PRACTICES – Mulching Techniques" file.

TITLE: RETAIN YOUR COTTON STUBBLE – BURNING CAN REDUCE YIELDS
AUTHOR: Ian Rochester & Greg Constable, CRC for Sustainable Cotton Production – [The Aust. Cottongrower, Vol 17, No 1, Jan-Feb '96]
YEAR: 1996 **LOCATION**: "CULTURAL PRACTICES – Mulching Techniques" file.

TITLE: EVAPORATION THROUGH A SOIL MULCH IN RELATION TO MULCH CHARACTERISTICS AND EVAPORATIVITY
AUTHOR: S.K. Jalota, Punjab Agric University, Ludhiana, India – [Aust. J. Soil Res, 1993, **31**, 131-6]
YEAR: 1993 **LOCATION**: "CULTURAL PRACTICES – Mulching Techniques" file.

TITLE: <Letter: to Ben Rose> Mechanical Straw Mulching Machine (HOBSON MULCHING SYSTEM™)
AUTHOR: From: Joe Hobson, Snr. President, Hobson MFG. Inc., PO Box21510, Keizer, Oregon USA
YEAR: Aug '97 **LOCATION**: "CULTURAL PRACTICES – Mulching Techniques" file.

TITLE: USEFUL INFORMATION RELATED TO FURROW MULCHING
AUTHOR: Tim D. Stieber, University of Idaho, USA
YEAR: - **LOCATION**: "CULTURAL PRACTICES – Mulching Techniques" file.

TITLE: STRAW MULCH SURVEY RESULTS
AUTHOR: Nancy Hutchison and Tim Steiber - The Farm Planner, Idaho, USA, August '94
YEAR: 1994 **LOCATION**: "CULTURAL PRACTICES – Mulching Techniques" file.

TITLE: WATER FLOW THROUGH A SURFACE IRRIGATION SYSTEM
AUTHOR: Tim Steiber - The Farm Planner, Idaho, USA, August '94
YEAR: 1994 **LOCATION**: "CULTURAL PRACTICES – Mulching Techniques" file.

TITLE: CROPPING PRACTICES SURVEY – IRRIGATION RESULTS
AUTHOR: Tim Steiber - The Farm Planner, Idaho, USA, August '94
YEAR: 1994 **LOCATION**: "CULTURAL PRACTICES – Mulching Techniques" file.

TITLE: MECHANICAL STRAW MULCHING EFFECTS ON SHEPODY POTATO YIELDS IN THE TREASURE VALLEY UNDER CENTRE PIVOT SPRINKLER IRRIGATION
AUTHOR: J Hobson, L Jensen, T Jensen, C Shock, J Simplot Co., T Steiber, M Thorton – Oregon, USA
YEAR: 1993 **LOCATION**: "CULTURAL PRACTICES – Mulching Techniques" file.

TITLE: STRAW MULCHING BENEFITS ARE WELL WORTH THE INVESTMENT, WASHINGTON GROWER SAYS
AUTHOR: 'Potato Country' June/July, 1994
YEAR: 1994 **LOCATION**: "CULTURAL PRACTICES – Mulching Techniques" file.

TITLE: EFFECT OF STRAW FURROW MULCHING ON IRRIGATION EFFICIENCY / EROSION PROTECTION / PRODUCTION / NUTRIENT LOSS
AUTHOR: Joe Hobson, Clint Shock, Jennifer Banner, Monty Saunders and Brad Townley, Oregon
YEAR: 1992 **LOCATION**: "CULTURAL PRACTICES – Mulching Techniques" file.

TITLE:
AUTHOR:
YEAR: **LOCATION**: "CULTURAL PRACTICES – Mulching Techniques" file.

TITLE:
AUTHOR:
YEAR: **LOCATION**: "CULTURAL PRACTICES – Mulching Techniques" file.

TITLE:
AUTHOR:
YEAR: **LOCATION**: "CULTURAL PRACTICES – Mulching Techniques" file.

COVER CROPPING

TITLE: PUTTING GOOD US IDEAS TO WORK DOWN UNDER (P. 68, Winter Cover Crops)
AUTHOR: Paul Castor – [The Aust. Cottongrower, Vol 17, No 6, Nov-Dec '96]
YEAR: 1996 **LOCATION**: "CULTURAL PRACTICES – **Minimum Tillage**" file.

TITLE:
AUTHOR:
YEAR: **LOCATION**: "CULTURAL PRACTICES – Cover Cropping" file.

TITLE:
AUTHOR:
YEAR: **LOCATION**: "CULTURAL PRACTICES – Cover Cropping" file.

TITLE:
AUTHOR:
YEAR: **LOCATION**: "CULTURAL PRACTICES – Cover Cropping" file.

MINIMUM TILLAGE

TITLE: CONSERVATION FARMING FOR EROSION CONTROL – REDUCED TILLAGE SYSTEMS
AUTHOR: Soil Conservation Service of New South Wales
YEAR: 1989 **LOCATION**: "CULTURAL PRACTICES – Minimum Tillage" file.

TITLE: PUTTING GOOD US IDEAS TO WORK DOWN UNDER
AUTHOR: Paul Castor – [The Aust. Cottongrower, Vol 17, No 6, Nov-Dec '96]
YEAR: 1996 **LOCATION**: "CULTURAL PRACTICES – Minimum Tillage" file.

TITLE: NO-TILL: MAKING IT WORK
AUTHOR: Internet address: http://res.agr.ca/lond/gp/bmp/notillbmp.html
YEAR: 1997 **LOCATION**: "CULTURAL PRACTICES – Minimum Tillage" file.

TITLE: DEEP DRAINAGE FORM CONSERVATION TILLAGE
AUTHOR: Garry O'Leary, Dep of Agriculture, Minerals & Energy; Vic Institute for Dryland Agriculture, Horsham, Vic/ / In: Murray Darling 1995 Workshop – Extended Abstracts. Wagga Wagga, 11-13 Sept. 1995 - AGSO
YEAR: 1995 **LOCATION**: "CULTURAL PRACTICES – Minimum Tillage" file.

TITLE:
AUTHOR:
YEAR: **LOCATION**: "CULTURAL PRACTICES – Minimum Tillage" file.

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AUTHOR:
YEAR: **LOCATION**: "CULTURAL PRACTICES – Minimum Tillage" file.

TAIL WATER RETURN

TITLE: DRAINAGE AND TAIL WATER RECYCLING REDUCES NUTRIENT, SEDIMENT REMOVAL
AUTHOR: Stace Rummenie & Bob Noble, QLD Dep. of Natural Resources – [The Aust. Cottongrower, Vol 17, No 6, Nov-Dec '96]
YEAR: 1996 **LOCATION**: "CULTURAL PRACTICES – Tail water Return" file.

TITLE: <extract> DEVELOPMENT OF A SURFACE IRRIGATION SYSTEM – {Tail Drains / Tail water Return Systems}
AUTHOR: J D Purcell - Barrett Purcell & Associates Pty Ltd, Narrabri, NSW / A Selection of Irrigation Notes - Irrigation Association of Australia, NSW NW Branch, Seminar Series, July 1993
YEAR: 1993 **LOCATION**: "CULTURAL PRACTICES – Tail water Return" file.

TITLE:
AUTHOR:
YEAR: **LOCATION**: "CULTURAL PRACTICES – Tail water Return" file.

TITLE:
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YEAR: **LOCATION**: "CULTURAL PRACTICES – Tail water Return" file.

TITLE:
AUTHOR:
YEAR: **LOCATION**: "CULTURAL PRACTICES – Tail water Return" file.

Literature Obtainable from Other Library Sources

-Agriculture WA, South Perth, WA – Pauline Sawyer Ph. (08) 9368 3243 / Fax. (08) 9368 3846
-Water Corporation, Leederville, WA – Janet Megarrity Ph. (08) 9420 2852 / Fax. (08) 9420 3198
-QLD Dep. of Natural Resources, Brisbane, QLD – Margaret Walters Ph. (07) 3224 7116 / Fax. (07) 3224 7571
-Agriculture Victoria, Tatura, VIC – Christine Uren Ph. (058) 335 287 / Fax. (058) 335 319

Advances in irrigation technology
Author: Barrett-JWH (Irrigation-Association-of-Australia)
SO: Journal of the Australian Institute of Agricultural Science, 1985, 51 (4), p263-267, 1 table.
PY: 1985 DT: Journal-article
Abstract: This article discusses advances in irrigation technology in terms of physical improvements (surface irrigation, land grading, **tail water recirculation**, on-farm storage, etc.) and water management (irrigation scheduling, soil based measurements, plant based measurements, evaporation devices, etc.). An increasing world population will put greater demands on irrigation production at the same time as other uses compete for the water which sustains it. Further advances in irrigation technology can therefore be expected to be directed specifically at increasing crop yield per unit of water diverted.
CLC: 970
DN: 006128

A novel hydraulic jump type energy dissipator for low tail water conditions
Author: Keller-RJ (Monash-University-Department-of-Civil-Engineering); Mitchell-DJ (Camp-Scott-Furphy-Pty-Ltd)
SO: Conference on Hydraulics in Civil Engineering, 3rd, 12-14 Oct 1987, Melbourne, Preprints. Institution of Engineers, Australia, Barton ACT, 1987, ISBN 0858253550, p179-180, 3 figs.
PY: 1987 SE: National conference publication (Institution of Engineers, Australia); 87/14.
DT: Conference-paper
Abstract: A novel energy dissipator of particular application to low tail water conditions is described. The structure incorporates a raised sill, convex in plan, which acts to spread the flow, thereby prompting the formation of a stable hydraulic jump. The theoretical basis of the design is presented and model studies of a particular prototype structure discussed (A). CLC: 1150
DN: 013070

Efficient and fast watering a vital key
Author: Dunstan-M (P-Wylie-and-Associates)
SO: Farm, 1986-08, 7 (8), p40-43, 4 photos.
PY: 1986 DT: Journal-article
Abstract: Describes a rapid watering irrigation plan adopted by a cotton farmer in the Darling Downs QLD. The property has been designed to get water on the crop and off again within 10 hours. The pumping system, siphons and furrows and described and the advantages of water return systems are examined.
CLC: 650 LO: Darling Downs QLD
DN: 007611

High cost sprayers or less efficient furrows
Author: Lake-B
SO: Farm, 1987-08, 8 (8), p41-42, 1 photo.
PY: 1987 DT: Journal-article
Abstract: Farmers on the Darling Downs QLD, are re-examining the efficiency of siphoning water into a furrow irrigation system after several years of low rainfall. The ideal system is mechanical - either lateral move or central pivot. These systems are highly efficient for broadacre farming, as precise application is made through computer-controlled sprays. Labor costs are low, and there is no tail water or waterlogging. However installation costs are high. Cheaper furrow irrigation results in wastage, as large quantities of water are soaked up at the furrow entry point. Some farmers are using surge systems which result in more even water distribution and less wastage without requiring high-tech equipment. Farmers are also increasing their holding capacity by installing ring tanks and trapping more overland flow and tail water. CLC: 970
LO: Darling Downs QLD; Condamine-Culgoa Rivers (IV22)
DN: 010514

Central Queensland: is it profitable to install ring tanks in the EIA for storm/tail water reticulation?
Author: McMeniman-S-L (Queensland-Department-of-Primary-Industries)
SO: Queensland, Department of Primary Industries, Brisbane QLD, 1992-01, 3p, tables.
PY: 1992 SE: Farm note (Queensland, Department of Primary Industries); F6/JAN92.
DT: Pamphlet
Abstract: This note illustrates that the profitability of installing a ring tank can be determined using a computer model, OZCOT, to estimate the lint yields at various soil water deficits. Two examples show the profitability of installing a tank to increase timeliness of water application, and to increase the area of cotton grown.
CLC: 970; 905 LO: Emerald QLD; Fitzroy River (I30); AER (5)
ID: OZCOT-;
DN: 026836

Less water lost in revised Bourke tail water system
SO: The land, 1987-12-10, 3979, p63, 1 photo.
PY: 1987 DT: Journal-article
Abstract: Recycling irrigation tail water from flood irrigated cotton has maximized water use efficiency on an extensive Bourke NSW irrigation property. The tail water reticulation system has been revamped with the installation of a 600mm diameter axial flow pump and revised paddock layouts and channel systems. River pumps are also being updated with new, efficient axial flow pumps.
CLC: 650
LO: Bourke NSW; Darling River (IV25)
DN: 013723

Managing tail water in the Macquarie River Valley
Author: Cooper-B (New-South-Wales-Department-of-Water-Resources)
SP: Land and Water Resources Research and Development Corporation
SO: New South Wales, Department of Water Resources, Parramatta, NSW, 1995-02, 10p, photos, refs.
PY: 1995 DT: Report
Abstract: In New South Wales, water licenses for irrigation developments are issued with the condition that tail water does not return to the river. This paper outlines the history of tail water operation audits within the Macquarie River Valley NSW and discusses the processes of cooperation and consultation between Department of Water Resources licensing and metering staff in the valley, the Macquarie Cotton Growers Association, aerial contractors and the cotton growers which have resulted in an increased perception of the environmental and legal consequences of tail water release.
CLC: 970 LO: Macquarie River NSW; Macquarie-Bogan Rivers NSW (IV21); AER (5); AER (7)
DEMJ: Irrigation-; Tail water-; Water-Quality (Natural-Waters); Farms-and-Farming; Streams (in-Natural-Channels);
DEMN: Cotton-; Licences-and-Licensing; Audits-; Environmental-Management;
DN: 033465

Reducing fertiliser nutrient losses through improved flood irrigation management
Author: Austrin-NR; Prendergast-JB; Collins-MD; (Institute-of-Sustainable-Irrigated-Agriculture)
SP: Pivot Fertilizers; Phosphate Cooperative Company of Australia; Land and Water Resources Research and Development Corporation; Victoria, Salinity Pilot Program Advisory Council
SO: Water Down Under 94, 21-25 Nov 1994, Adelaide SA, Preprints of papers. Institution of Engineers, Australia, Barton ACT, 1994-10, ISBN 08525607X, 1, p543-546, 5 figs, 8 refs. PY: 1994
SE: National conference publication (Institution of Engineers, Australia); 94/10. DT: Conference-paper
Abstract: Algal blooms in waterways have resulted in increased emphasis on the management of water and fertilizers on dairy pastures. It is hypothesized that the three main management determinants which dictate fertilizer application efficiency on flood irrigation bays are irrigation water velocity, soil water deficit and tail water runoff volume. The main design variable to be considered is irrigation bay length. The effect of various irrigation management scenarios on nutrient runoff, deep percolation losses and distribution uniformity was determined for six perennial pasture bays in the Shepparton Irrigation Area VIC. Results indicate that 15% of total applied phosphorus and 4% of total applied nitrogen is lost in runoff under typical irrigation practice. Additional losses occur through deep percolation. The fact that nutrient runoff loads were dictated by runoff volume implies that minimizing tail water runoff will minimize nutrient runoff loads without compromising irrigation uniformity. Management of irrigation to minimize tail water runoff is most critical during initial irrigation after broadcasting fertilizer (A).
CLC: 650; 970 LO: Shepparton Irrigation Area VIC; Goulburn River (IV5); AER (7)
DN: 031744

Surface irrigation
SO: Irrigation Australia, 1987-08/10, 3 (3), p6-10.
PY: 1987 DT: Journal-article
Abstract: Describes the steps necessary in the design of surface irrigation systems including (i) whole farm layout planning, (ii) pump and motor selection and pumping station layout, (iii) landforming to a predetermined grade, (iv) water application, (v) drainage, (vi) tail water return system (drainage reuse) and, (vii) culverts. An appendix details pump efficiency and running costs.
CLC: 970
DN: 013367

Tail water systems
Author: Edwards-J (Rural-Water-Commission-of-Victoria)
SO: Irrigation Short Course, 29 July-2 Aug 1985, Dookie, Proceedings. Victoria, Department of Agriculture and Rural Affairs, Rural Water Commission of Victoria and Irrigation Association of Australia, Melbourne, 1985, p370-380, 4 figs. PY: 1985
SE: Agriculture note series (Victoria, Department of Agriculture and Rural Affairs); no 155.
DT: Conference-paper
Abstract: A 'tail water system' is a system on a farm where drainage and other water is diverted to a common storage. The stored water is then reused for irrigation. The topics covered in relation to this subject are source of water, storage sizes, storage types, drains, water quality and pumps.
CLC: 650
DN: 005264

Whole farm irrigation efficiency and water management for the 1984-85 cotton crop at Moree
Author: Cull-PO (Neutron-Probe-Services); George-B; Finney-B
SO: Groundwater and Water Management in the Ord River Irrigation Area, 21 Aug 1986, Kununurra WA, Proceedings. Western Australia, Department of Agriculture, Kununurra WA, 1986, ISBN 0730913376, p73-83, 2 tables, 4 figs, 4 refs. PY: 1986
DT: Conference-paper
Abstract: A previous study by the author in the 1982-83 irrigation season on a cotton farm at Moree NSW determined the whole farm irrigation efficiency in that season to be 75%. The 1984-85 irrigation season was essentially free of rainfall and hence presented an ideal opportunity to determine the whole farm irrigation efficiency for a dry season to contrast to the findings of the wetter 1982-83 season. There were 3 crop irrigation applied in this season compared with 7 crop irrigation in the 1984-85 season. The dry season also showed aspects of cotton root activity not previously observed, but which were important to consider when scheduling irrigation. The inputs of water onto the farm were storage on hand, allocation and rainfall. The outputs of water from the farm were evaporation and soakage from water storage, catchment channels, tail water drains and crop evapo-transpiration. Soakage was determined previously from neutron probe measurements taken immediately before and after each irrigation from aluminium access tubes placed in channel bottoms and tail water drains. Evapo-transpiration was determined by measuring the field soil water content immediately before and after each irrigation using the neutron probe (A). CLC: 970 LO: Moree NSW; Gwydir River (IV18)
DN: 013420

ORIA BEST ENVIRONMENTAL PRACTICE RESEARCH PROJECT

PUBLICATION LIST

[as at MARCH 1998]

RESOURCE FILE: *ENDOSULFAN AND THE ENVIRONMENT*

Researched Literature Available at:

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Fax. (08) 9168 1473

TITLE: EXISTING CHEMICALS REVIEW PROGRAM – THE REVIEW BY THE NRA OF ENDOSULFAN – DRAFT, August 1997 [Public Release Summary]
AUTHOR: National Registration Authority for Agricultural & Veterinary Chemicals
YEAR: 1997 **LOCATION**: "ENDOSULFAN AND THE ENVIRONMENT" file, KDC

TITLE: PESTICIDES AND THE RIVERINE ENVIRONMENT – Program Newsletter Issue 11, Sep 1997
AUTHOR: Land & Water Resource R&D Corptn., Cotton R&D Corporation, Murray-Darling Basin Comm.
YEAR: 1997 **LOCATION**: "ENDOSULFAN AND THE ENVIRONMENT" file, KDC

TITLE: DEVELOPMENT OF BEST PRACTICE FOR PESTICIDE USE BY THE COTTON INDUSTRY
AUTHOR: Land & Water Resource R&D Corptn., Cotton R&D Corporation, Murray-Darling Basin Comm.
YEAR: 199 **LOCATION**: "ENDOSULFAN AND THE ENVIRONMENT" file, KDC

TITLE: ENDOSULFAN AND THE AQUATIC ECOSYSTEM
AUTHOR: John Chapman and R Sunderam, Centre for Environmental Toxicology – IN: The Australian Cottongrower, May-June 1992
YEAR: 1992 **LOCATION**: "ENDOSULFAN AND THE ENVIRONMENT" file, KDC

TITLE: DISTRIBUTION & DISSIPATION OF ENDOSULFAN & RELATED CYCLODIENES IN STERILE AQUEOUS SYSTEMS: IMPLICATIONS FOR STUDIES ON BIODEGRADATION
AUTHOR: T Guerin and I Kennedy, Dep Agric Chemistry, Uni of Sydney – IN: Journal Agrical Food Chemical, 1992, 40, 2315-2323
YEAR: 1992 **LOCATION**: "ENDOSULFAN AND THE ENVIRONMENT" file, KDC

TITLE: ENDOSULFAN: USE IT WELL OR LOSE IT
AUTHOR: Bruce Pyke – IN: The Australian Cottongrower, Vol 17, No 6, Nov-Dec 1996
YEAR: 1996 **LOCATION**: "ENDOSULFAN AND THE ENVIRONMENT" file, KDC

TITLE:
AUTHOR:
YEAR: **LOCATION**: "ENDOSULFAN AND THE ENVIRONMENT" file, KDC

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RESOURCE FILE: *GROUNDWATER PUMPING & CONJUNCTIVE WATER USE*

Researched Literature Available at:

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Ph. (08) 9168 1044
Fax. (08) 9168 1473

TITLE: GROUNDWATER HYDROLOGY
AUTHOR: Herman Bouwer / Murdoch University – Environmental Science
YEAR: 1996 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: REVIEW OF GROUNDWATER MONITORING DATA IN THE ORD RIVER IRRIGATION AREA
AUTHOR: Cahit Yesertener / Water & Rivers Commission
YEAR: 1996 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: SHARING THE COSTS OF GROUNDWATER PUMPING IN THE SHEPPARTON IRRIGATION REGION LAND & WATER SALINITY MANAGEMENT PLAN
AUTHOR: Lyndall Ash, Groundwater Extension Officer, Agriculture Victoria / In: Murray Darling 1995 Workshop – Extended Abstracts, Wagga Wagga 11-13 Sept. 1995 - AGSO
YEAR: 1995 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: GROUNDWATER PUMPING SYSTEMS FOR WATER TABLE CONTROL
AUTHOR: Adrian Stallman, Resource Mgt Institute, QLD DPI, Indooroopilly, QLD / In: Murray Darling 1995 Workshop – Extended Abstracts, Wagga Wagga 11-13 Sept. 1995 - AGSO
YEAR: 1995 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: AIR LIFT PUMPING SYSTEM
AUTHOR: A Mahendran, Dep of Land & Water Conservation, Deniliquin, NSW / In: Murray Darling 1995 Workshop – Extended Abstracts, Wagga Wagga 11-13 Sept. 1995 - AGSO
YEAR: 1995 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: GROUNDWATER INTERCEPTION FROM A MULTI WELL POINT SCHEME USING AIR LIFT PUMPING
AUTHOR: G Linke & M Kendall, Sinclair Knight Merz, Armadale, Vic / In: Murray Darling 1995 Workshop – Extended Abstracts, Wagga Wagga 11-13 Sept. 1995 - AGSO
YEAR: 1995 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: MURRAY-DARLING 1997 WORKSHOP – EXTENDED ABSTRACTS, GROUNDWATER IN THE BALANCE. TOOWOOMBA, QLD 26-28 August 1997
AUTHOR: Salt Action Task Force (NSW), Murray-Darling Basin Commission, & Department of Natural Resources (QLD)
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TITLE: MURRAY DARLING 1995 WORKSHOP – EXTENDED ABSTRACTS, WAGGA WAGGA 11-13 Sept. 1995 – Record 1995/61
AUTHOR: AGSO Australian Geological Survey Organisation – Compiled by: Environmental Geoscience & Groundwater Division
YEAR: 1995 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: USING PUMPS AND SIPHONS TO CONTROL SALINITY AT A SALINE SEEP IN THE WALLATIN CREEK CATCHMENT – TECHNICAL REPORT 91
AUTHOR: RJ George and PWC Frantom / Division of Resource Management – Agriculture Western Australia
YEAR: 1990 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: PUMPS – A METHOD OF FINANCIALLY ASSESSING GROUNDWATER PUMPING USED TO MITIGATE SALINITY IN SOUTH WESTERN AUSTRALIA – Technical Report 87
AUTHOR: Richard J George / Salinity and Hydrology Branch – Agriculture Western Australia, Bunbury
YEAR: 1989 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: PUMPIT - A DECISION-SUPPORT PROGRAM TO OPTIMISE SALINITY MANAGEMENT OF LAND AND STREAMS BY ENHANCED DISCHARGE – USER'S MANUAL, Version 1.0
AUTHOR: Claus Otto / Division of Water Resources – CSIRO Perth Laboratory
YEAR: 1993 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: GROUND WATER PUMPING FROM SHALLOW AXISYMMETRIC PONDS
AUTHOR: Mustafa M Aral, Terry W Sturm – Proceedings of the American Society of Civil Engineers, Vol 108, No HY12, December 1982
YEAR: 1982 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: GROUNDWATER PUMPING – AN EFFECTIVE MEANS OF SALINITY CONTROL
AUTHOR: J Nolan / *WATER*, December 1992
YEAR: 1992 **LOCATION**: ""GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: GROUNDWATER PUMPING BOOK FOR THE SHEPPARTON IRRIGATION REGION
AUTHOR: Rural Water Corporation, Goulburn Murray Region & Department Of Agriculture
YEAR: 1993 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: COMBATING THE UNDERGROUND FLOOD – A Draft Groundwater Management Plan for the Shepparton Irrigation Region
AUTHOR: Athol Mcdonald / Goulburn-Murray Water, Tatura, Victoria
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TITLE: EFFECT OF GROUNDWATER PUMP MANAGEMENT ON RECLAIMING SALINISED LAND IN THE GOULBURN VALLEY, VICTORIA
AUTHOR: CP Norman / Australian Journal of Experimental Agriculture, 1995, **35**, 215-22
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TITLE: A DELICATE BALANCE SALINITY IN THE NON-IRRIGATED PARTS OF THE GOULBURN/BROKEN CATCHMENT
AUTHOR: SALT FORCE - Rural Water Commission Victoria
YEAR: 199? **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: REVIEW OF GROUNDWATER MONITORING DATA IN THE ORD RIVER IRRIGATION AREA
AUTHOR: Cahit Yesertener
YEAR: 1996 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: WATER TABLE CONTROL HIKES YIELDS
AUTHOR: Boyd Kidwell / Australian Farm Journal, August 1994, Vol 4 (6)
YEAR: 1994 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: PYRAMID CREEK GROUNDWATER INTERCEPTION USING AIRLIFT PUMPING
AUTHOR: PJ Alexander, GK Linke & KR Cummins / 1994 Conference on Engineering in Agriculture, Lincoln University, Christchurch, New Zealand. 21-24 August 1994
YEAR: 1994 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: RECLAMATION OF A SALINE/SODIC SOILD BY AQUIFER PUMPING, APPLICATION OF TILLAGE AND GYPSUM AND REUSE OF SALINE GROUNDWATER.
AUTHOR: AH Mehanni / Australian Journal of Experimental Agriculture, 1987, 27, 381-7
YEAR: 1987 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: GROUNDWATER PUMPING
AUTHOR: Roger Wrigley / *Power Farming*, Vol 101 (5), October 1991
YEAR: 1991 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: IRRIGATION INCREASES GROUNDWATER RECHARGE IN THE MACQUARIE VALLEY
AUTHOR: TM Willis and AS Black
YEAR: 1996 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE:
AUTHOR:
YEAR: **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

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AUTHOR:
YEAR: **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

CONJUNCTIVE WATER USE

TITLE: THE TONGALA GROUND WATER PUMPING AND CONJUNCTIVE USE PROJECT
AUTHOR: C Chrys, JM Heath and CP Norman / Institute of Sustainable Irrigated Agriculture – Agriculture Victoria
YEAR: 1995 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: IRRIGATING WITH GROUNDWATER
AUTHOR: Jim Murphy / *Power Farming*, Vol. 100 (4), August 1990
YEAR: 1990 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: UTILISING UNDERGROUND WATERWAY FOR REVERSE FLOW IRRIGATION
AUTHOR: *Dairy Exporter*, Vol 69 (7), January 1994
YEAR: 1994 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: A MODEL FOR CONJUNCTIVE USE OF GROUNDWATER AND SURFACE WATERS FOR CONTROL OF IRRIGATION SALINITY
AUTHOR: J Prendergast, C Rose & W Hogarth / *Irrigation Science* 14: 167-175
YEAR: 1994 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: SUSTAINABILITY OF CONJUNCTIVE WATER USE FOR SALINITY CONTROL IN IRRIGATION AREAS: THEORY & APPLICATION TO THE SHEPPARTON REGION, AUST.
AUTHOR: J Prendergast, C Rose & W Hogarth / *Irrigation Science* 14: 167-175
YEAR: 1994 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: GROUND WATER PUMPING / RE-USE IN NORTHERN VICTORIA RECHARGE PROCESSES, AQUIFER SALINISATION AND FARM PRODUCTIVITY
AUTHOR: B Prendergast and AF Heuperman
YEAR: 198? **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: ECONOMIC AND ENVIRONMENTALLY SUSTAINABLE USE OF VARIOUS WATER SUPPLY SOURCES FOR IRRIGATION
AUTHOR: John Hillier, John Doherty, Jerome Arunakumaren, Kiran Bajracharya, Steven Bengtson, & Sellarthuray Kuhanesan – Land & Water Resources R&D Corporation, QLD
YEAR: 1997 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE: TECHNICAL & ECONOMIC EVALUATION OF THE CONJUNCTIVE USE OF SURFACE & GROUNDWATER IN THE CAMPASPE VALLEY, NORTH-CENTRAL VIC., AUSTRALIA
AUTHOR: F Chiew, T McMahon, M Dudding & A Brinkley – Dep of Civil & Env Engineering, Melb Uni, Vic. / Hydrotechnology, Armadale, Vic. / In: Water Resources Management 9:251-275
YEAR: 1995 **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE:
AUTHOR:
YEAR: **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE:
AUTHOR:
YEAR: **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

TITLE:
AUTHOR:
YEAR: **LOCATION**: "GROUNDWATER PUMPING & CONJUNCTIVE WATER USE" file, KDC

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PUBLICATION LIST

[as at MARCH 1998]

RESOURCE FILE: *IRRIGATION MANAGEMENT*

Researched Literature Available at:

Kimberley Development Commission
PO Box 620
Papuana Street
Kununurra, Western Australia, 6743
Ph. (08) 9168 1044
Fax. (08) 9168 1473

TITLE: AUTOMATION FOR FLOOD IRRIGATION
AUTHOR: David Lawler – Agriculture Victoria
YEAR: 1995 **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

TITLE: BENEFITS OF DRIP IRRIGATION
AUTHOR: John Thompson, NETAFIM Irrigation & Drip Systems, NT. Ph. (08) 8932 8883 or 014 415 481
YEAR: 1995 **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

TITLE: SITUATION STATEMENT ON AUTOMATION FOR FLOOD IRRIGATION
AUTHOR: Rabi Maskey – Dept Natural Resources and Environment, VIC- Cobram District Office
YEAR: 1995 **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

TITLE: INTERIM REPORT – ATTITUDES OF DAIRY FARMERS ABOUT THE AUTOMATION OF FLOOD IRRIGATION.
AUTHOR: Rabi Maskey – Dept Natural Resources and Environment, VIC - Cobram District Office
YEAR: 1996 **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

TITLE: IRRIGATION PERFORMANCE OF DAIRY FARMERS IN THE MURRAY VALLEY IRRIGATION AREA – [***DRAFT***]
AUTHOR: Dept Natural Resources And Environment - Cobram District Office
YEAR: 1996 **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

TITLE: SEMI-AUTOMATION OF IRRIGATED BASINS & BORDERS: ii. DUAL-FUNCTION TURNOUT GATES
AUTHOR: A S Humphreys / In: 1995 American Society of Agricultural Engineers, Vol 11 (1):75-82
YEAR: 1995 **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

TITLE: ESTABLISHING A PROCESS TO IMPROVE IRRIGATION AUTOMATION
AUTHOR: Agriculture Victoria, GMW, the Dairy R&D Corporation, & Murray Valley dairy farmers
YEAR: 1995-98 **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

TITLE: A SELECTION OF IRRIGATION NOTES
AUTHOR: Dr Hugh Barrett [Barret Purcell & Associates Pty Ltd, Narrabri, NSW] & Mr Arthur Wardle [NSW Water Resources Commission]
YEAR: 1997 **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

TITLE: REDUCING FERTILISER NUTRIENT LOSSES THROUGH IMPROVED FLOOD IRRIGATION MANAGEMENT
AUTHOR: N Austin, J Prendergast & M Collins - Institute of Sustainable Agric., Tatura, Vic / In: Water Down Under '94 Conference, Adelaide, Australia, 21-25 November 1994
YEAR: 1994 **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

TITLE: SURVEY OF IRRIGATION EFFICEIENCIES ON HORTICULTURAL PROPERTIES IN THE PEEL – HARVEY CATCHMENT
AUTHOR: Sam Milani - Agriculture WA
YEAR: 19 **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

TITLE: CROP IRRIGATION REQUIREMENTS PROGRAM
AUTHOR: PM Aylmore, GJ Luke And EJ Hauck – Agriculture WA
YEAR: 1994 **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

TITLE: ECONOMIC AND ENVIRONMENTALLY SUSTAINABLE USE OF VARIOUS WATER SUPPLY SOURCES FOR IRRIGATION
AUTHOR: John Hillier, John Doherty, Jerome Arunakumaren, Kiran Bajracharya, Steven Bengtson, & Sellarthuray Kuhanesan – Land & Water Resources R&D Corporation, QLD
YEAR: 1997 **LOCATION**: **"GROUNDWATER PUMPING & CONJUNCTIVE WATER USE"** file, KDC

TITLE: AGRIFLOW – MAKES WATER GO FURTHER
AUTHOR: Colin Austin, Cohort International, Vic. / Internet: http://www.cohort.com.au/aerogatn/booklet
YEAR: 1997 **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

TITLE: INTELLIGENT IRRIGATION
AUTHOR: DRW Water Management, SA 5355 / Internet: http://www.cohort.com.au/aerogatn/booklet
YEAR: 1996 **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

TITLE: THE DRW REAL TIME IRRIGATION SYSTEM
AUTHOR: DRW Water Management, SA 5355 / Internet: http://www.cohort.com.au/drw/general.html
YEAR: 1996 **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

TITLE: AGRILINK WATER MANAGEMENT SERVICES IRRIGATED HORTICULTURE
AUTHOR: Peter Moller / Internet: http://www.iinet.net.au/~agrilink/hort.html
YEAR: 1996 **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

TITLE: MANAGING SOIL, WATER AND IRRIGATED CROPS
AUTHOR: C.S.I.R.O. Division of Water Resources
YEAR: 1997 **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

TITLE:
AUTHOR:
YEAR: **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

TITLE:
AUTHOR:
YEAR: **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

TITLE:
AUTHOR:
YEAR: **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

IRRIGATION PRODUCT/SUPPLIES CATALOGUES

TITLE: <Blue Folder> LOWARA PUMPS W.A. PTY LTD
CONTACT: Ian Rogers (Sales Consultant) - Lowara Pumps W.A. Pty Ltd, Malaga, WA 6062
YEAR: 1997 **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

TITLE: ONGA – PUMP CATALOGUE 1997
AUTHOR: Onga Pumps, PO Box 268, Cloverdale, WA 6105 / Ph. (08) 9277 7500 / Fax. (08) 9478 3026
YEAR: 1997 **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

TITLE: <Blue folder> TRIANGLE FILTRATION – 'Get it right first time'
CONTACT: Wally Menke (Director) – Triangle Filtration, Braeside, Vic 3195
YEAR: 1997 **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

TITLE: NETAFIM AUSTRALIA - IRRIGATION & DRIP SYSTEMS
CONTACT: John Thompson. 1 Cocos Rd. Durack Fairwaters Palmerston, NT 0830 Ph. 014 415 481
YEAR: 1998 **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

TITLE:
AUTHOR:
YEAR: **LOCATION**: "IRRIGATION MANAGEMENT" file, KDC

Literature Obtainable from Other Library Sources

-Agriculture WA, South Perth, WA – Pauline Sawyer Ph. (08) 9368 3243 / Fax. (08) 9368 3846
-Water Corporation, Leederville, WA – Janet Megarrity Ph. (08) 9420 2852 / Fax. (08) 9420 3198
-QLD Department of Natural Resources, Brisbane, QLD – Margaret Walters Ph. (07) 3224 7116 / Fax. (07) 3224 7571
-Agriculture Victoria, Tatura, VIC – Christine Uren Ph. (058) 335 287 / Fax. (058) 335 319

A novel hydraulic jump type energy dissipater for low tail water conditions
AU: Keller-RJ (Monash-University-Department-of-Civil-Engineering); Mitchell-DJ (Camp-Scott-Furphy-Pty-Ltd)
SO: Conference on Hydraulics in Civil Engineering, 3rd, 12-14 Oct 1987, Melbourne, Preprints. Institution of Engineers, Australia, Barton ACT, 1987, ISBN 0858253550, p179-180, 3 figs.
PY: 1987 SE: National conference publication (Institution of Engineers, Australia); 87/14.
DT: Conference-paper
AB: A novel energy dissipator of particular application to low tail water conditions is described. The structure incorporates a raised sill, convex in plan, which acts to spread the flow, thereby prompting the formation of a stable hydraulic jump. The theoretical basis of the design is presented and model studies of a particular prototype structure discussed (A). CLC: 1150
DN: 013070

Advances in irrigation technology
AU: Barrett-JWH (Irrigation-Association-of-Australia)
SO: Journal of the Australian Institute of Agricultural Science, 1985, 51 (4), p263-267, 1 table.
PY: 1985 DT: Journal-article
AB: This article discusses advances in irrigation technology in terms of physical improvements (surface irrigation, land grading, tail water recirculation, on-farm storage, etc.) and water management (irrigation scheduling, soil based measurements, plant based measurements, evaporation devices, etc.). An increasing world population will put greater demands on irrigation production at the same time as other uses compete for the water which sustains it. Further advances in irrigation technology can therefore be expected to be directed specifically at increasing crop yield per unit of water diverted.
CLC: 970
DN: 006128

High cost sprayers or less efficient furrows
AU: Lake-B
SO: Farm, 1987-08, 8 (8), p41-42, 1 photo.
PY: 1987 DT: Journal-article
AB: Farmers on the Darling Downs QLD, are re-examining the efficiency of siphoning water into a furrow irrigation system after several years of low rainfall. The ideal system is mechanical - either lateral move or central pivot. These systems are highly efficient for broad-acre farming, as precise application is made through computer-controlled sprays. Labor costs are low, and there is no tail water or waterlogging. However installation costs are high. Cheaper furrow irrigation results in wastage, as large quantities of water are soaked up at the furrow entry point. Some farmers are using surge systems which result in more even water distribution and less wastage without requiring high-tech equipment. Farmers are also increasing their holding capacity by installing ring tanks and trapping more overland flow and tail water. CLC: 970
LO: Darling Downs QLD; Condamine-Culgoa Rivers (IV22)
DN: 010514

Central Queensland: is it profitable to install ring tanks in the EIA for storm/tail water reticulation?
AU: McMeniman-S-L (Queensland-Department-of-Primary-Industries)
SO: Queensland, Department of Primary Industries, Brisbane QLD, 1992-01, 3p, tables.
PY: 1992 SE: Farm note (Queensland, Department of Primary Industries); F6/JAN92.
DT: Pamphlet
AB: This note illustrates that the profitability of installing a ring tank can be determined using a computer model, OZCOT, to estimate the lint yields at various soil water deficits. Two examples show the profitability of installing a tank to increase timeliness of water application, and to increase the area of cotton grown.
CLC: 970; 905 LO: Emerald QLD; Fitzroy River (I30); AER (5)
ID: OZCOT-;
DN: 026836

Less water lost in revised Bourke tail water system
SO: The land, 1987-12-10, 3979, p63, 1 photo.
PY: 1987 DT: Journal-article
AB: Recycling irrigation tail water from flood irrigated cotton has maximized water use efficiency on an extensive Bourke NSW irrigation property. The tail water reticulation system has been revamped with the installation of a 600mm diameter axial flow pump and revised paddock layouts and channel systems. River pumps are also being updated with new, efficient axial flow pumps.
CLC: 650 LO: Bourke NSW; Darling River (IV25)
DN: 013723

Managing tail water in the Macquarie River Valley
AU: Cooper-B (New-South-Wales-Department-of-Water-Resources)
SP: Land and Water Resources Research and Development Corporation
SO: New South Wales, Department of Water Resources, Parramatta, NSW, 1995-02, 10p, photos, refs.
PY: 1995 DT: Report
AB: In New South Wales, water licenses for irrigation developments are issued with the condition that tail water does not return to the river. This paper outlines the history of tail water operation audits within the Macquarie River Valley NSW and discusses the processes of cooperation and consultation between Department of Water Resources licensing and metering staff in the valley, the Macquarie Cotton Growers Association, aerial contractors and the cotton growers which have resulted in an increased perception of the environmental and legal consequences of tail water release.
CLC: 970 LO: Macquarie River NSW; Macquarie-Bogan Rivers NSW (IV21); AER (5); AER (7)
DN: 033465

Reducing fertiliser nutrient losses through improved flood irrigation management
AU: Austrin-NR; Prendergast-JB; Collins-MD; (Institute-of-Sustainable-Irrigated-Agriculture)
SP: Pivot Fertilizers; Phosphate Cooperative Company of Australia; Land and Water Resources Research and Development Corporation; Victoria, Salinity Pilot Program Advisory Council
SO: Water Down Under 94, 21-25 Nov 1994, Adelaide SA, Preprints of papers. Institution of Engineers, Australia, Barton ACT, 1994-10, ISBN 08525607X, 1, p543-546, 5 figs, 8 refs. PY: 1994
SE: National conference publication (Institution of Engineers, Australia); 94/10. DT: Conference-paper
AB: Algal blooms in waterways have resulted in increased emphasis on the management of water and fertilizers on dairy pastures. It is hypothesized that the three main management determinants which dictate fertilizer application efficiency on flood irrigation bays are irrigation water velocity, soil water deficit and tail water runoff volume. The

main design variable to be considered is irrigation bay length. The effect of various irrigation management scenarios on nutrient runoff, deep percolation losses and distribution uniformity was determined for six perennial pasture bays in the Shepparton Irrigation Area VIC. Results indicate that 15% of total applied phosphorus and 4% of total applied nitrogen is lost in runoff under typical irrigation practice. Additional losses occur through deep percolation. The fact that nutrient runoff loads were dictated by runoff volume implies that minimizing tail water runoff will minimize nutrient runoff loads without compromising irrigation uniformity. Management of irrigation to minimize tail water runoff is most critical during initial irrigation after broadcasting fertilizer (A).
CLC: 650; 970
LO: Shepparton Irrigation Area VIC; Goulburn River (IV5); AER (7)
DN: 031744

Surface irrigation
SO: Irrigation Australia, 1987-08/10, 3 (3), p6-10.
PY: 1987 DT: Journal-article
AB: Describes the steps necessary in the design of surface irrigation systems including (i) whole farm layout planning, (ii) pump and motor selection and pumping station layout, (iii) landforming to a predetermined grade, (iv) water application, (v) drainage, (vi) tail water return system (drainage reuse) and, (vii) culverts. An appendix details pump efficiency and running costs.
CLC: 970
DN: 013367

Surface irrigation: tail water and stormwater drainage design
AU: Purcell-JD (Barrett-Purcell-and-Associates)
SO: Large scale surface irrigation development and redevelopment: a guide for farm managers, Swann, B (comp). Irrigation Association of Australia, North West NSW Branch, Dubbo NSW, 1994?, 5p. PY: 1993
SE: Seminar series (Irrigation Association of Australia, North West NSW Branch). DT: Report
AB: Drainage of water from fields under surface irrigation must be as quick and as efficient as possible to avoid waterlogging. Tail water and stormwater drains should be hydraulically designed to act as an integrated system at the required capacity to prevent backing up of water. To achieve this, estimates of both stormwater runoff and tail water must be made. Two methods of stormwater runoff are described, instantaneous peak discharge and average surface runoff over a critical period. Estimates of tail water volume depend on irrigation method and can usually be made by experience. Having calculated the required capacity, tail water drains and canals can then be designed using Manning's equation and a field culvert of the same capacity can be selected. The required capacity of a tail water drain is calculated from the summation of inflowing tail water drains upstream of that section. Precautions for prevention of overflowing are briefly discussed.
CLC: 970
DN: 033380

The benefits of on-farm soil water monitoring and irrigation scheduling for improved water management - case studies
AU: Cull-P (Neutron-Probe-Services); Stone-M (Integrated-Crop-Management-Services); Struss-S (Integrated-Crop-Management-Services)
SO: Management of the Murray-Darling Headwaters, 17-19 Sept 1984, Toowoomba, Proceedings. Darling Downs Institute of Advanced Education, Toowoomba, 1984, v 2, ISBN 0909306753, p275-283, 2 tables, 2 figs, 2 refs.
PY: 1984
DT: Conference-paper
AB: The case studies discussed illustrate the use of soil water monitoring to schedule irrigation for high yields and to develop data bases to solve water related field production problems by farmers in Eastern Australia. The case studies include: (i) the evaluation of drip irrigation compared with flood irrigation in terms of water savings and yield improvements for cotton at Wee Waa NSW, (ii) the determination of a whole farm irrigation efficiency by studying channel and tail water soakage losses for use to aid water ordering in periods of limited allocation at Moree NSW, (iii) the quantification of a through drainage problem with furrow irrigation on an alluvial soil at Biloela QLD, and (iv) the scheduling of irrigation on compacted soils for high cotton yields at Emerald QLD (A).
CLC: 650
LO: Wee Waa NSW; Namoi River (IV19); Moree NSW; Gwydir River (IV18); Biloela QLD; Emerald QLD; Fitzroy River (I30)
DN: 004640

Whole farm irrigation efficiency and water management for the 1984-85 cotton crop at Moree

AU: Cull-PO (Neutron-Probe-Services); George-B; Finney-B

SO: Groundwater and Water Management in the Ord River Irrigation Area, 21 Aug 1986, Kununurra WA, Proceedings. Western Australia, Department of Agriculture, Kununurra WA, 1986, ISBN 0730913376, p73-83, 2 tables, 4 figs, 4 refs. PY: 1986

DT: Conference-paper

AB: A previous study by the author in the 1982-83 irrigation season on a cotton farm at Moree NSW determined the whole farm irrigation efficiency in that season to be 75%. The 1984-85 irrigation season was essentially free of rainfall and hence presented an ideal opportunity to determine the whole farm irrigation efficiency for a dry season to contrast to the findings of the wetter 1982-83 season. There were 3 crop irrigation applied in this season compared with 7 crop irrigation in the 1984-85 season. The dry season also showed aspects of cotton root activity not previously observed, but which were important to consider when scheduling irrigation. The inputs of water onto the farm were storage on hand, allocation and rainfall. The outputs of water from the farm were evaporation and soakage from storage, catchment channels, tail water drains and crop evapo-transpiration. Soakage was determined previously from neutron probe measurements taken immediately before and after each irrigation from aluminium access tubes placed in channel bottoms and tail water drains. Evapo-transpiration was determined by measuring the field soil water content immediately before and after each irrigation using the neutron probe (A).

CLC: 970 LO: Moree NSW; Gwydir River (IV18)

DN: 013420

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[as at MARCH 1998]

RESOURCE FILE: *LAND & WATER MANAGEMENT PLANNING & POLICY*

Researched Literature Available at:

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PO Box 620
Papuana Street
Kununurra, Western Australia, 6743
Ph. (08) 9168 1044
Fax. (08) 9168 1473

TITLE: CONTROLLING SEDIMENT AND NUTRIENT MOVEMENT WITHIN CATCHMENTS – INDUSTRY REPORT 97/9
AUTHOR: L Bren, F Dyer, P Hairsine, J Riddford, V Siriwardhena & C Zierholz – CRC for Catchment Hydrology, Monash Uni, VIC 3168 / Website: http://www-civil.eng.monash.edu.au/centres/crcch/
YEAR: 1997 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: TATURA SALINITY PROGRAM REPORT
AUTHOR: Department Of Agriculture And Rural Affairs
YEAR: 1989 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: WATER, LAND AND PEOPLE
AUTHOR: Irrigation Committee Of The Shepparton Irrigation Region
YEAR: 1996 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: DRAFT MIA & DISTRICT LAND AND WATER MANAGEMENT PLAN
AUTHOR: MIA And District L&WMP Working Group
YEAR: 1997 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: THE FUTURE OF IRRIGATION IN THE MURRAY DARLING BASIN
AUTHOR: C.S.I.R.O.
YEAR: 1993 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: HEADS OF AGREEMENT – MURRAY REGIONAL LAND AND WATER MGMT PLANS
AUTHOR: Paul Percival
YEAR: 1996 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: CADELL COMMUNITY'S LAND AND WATER MANAGEMENT PLAN
AUTHOR: Cadell LWPM Working Group
YEAR: 1995 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: DENIMEIN COMMUNITY LAND AND WATER MANAGEMENT PLAN
AUTHOR: Denimein LWMP Working Group
YEAR: 1995 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: WAKOOL COMMUNITY LAND AND WATER MANAGEMENT PLAN
AUTHOR: Wakool LWMP Working Group
YEAR: 1995 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: MURRUMBIDGEE IRRIGATION AREAS & DISTRICT LAND & WATER MNGT PLAN
AUTHOR: Robyn Neeson, Andrew Glasson, Alison Morgan, Sue Macalpine & Mike Darnley-Naylor.
YEAR: 1995 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: THE MURRAY DARLING BASIN – A TECHNOLOGICAL SOLUTION
AUTHOR: Colin Austin
YEAR: 1997 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: WATER WHEEL – NATIONAL PROGRAM FOR IRRIGATION RESEARCH AND DEV
AUTHOR: Department of Land And Water Resources
YEAR: 1996 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: JANDAKOT GROUNDWATER SCHEME AREA – A STUDY OF LAND RESOURCE AND PLANNING CONSIDERATIONS
AUTHOR: Mr Wells, NLB Richards & AJ Clarke
YEAR: 1986 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: TECHNICAL REPORT 75 – DIVISION OF RESOURCE MANAGMENT
SOIL CONSERVATION AND MANAGEMENT STRATEGIES FOR THE TOOLIBIN CATCHMENT
AUTHOR: SJ. Hearn
YEAR: 19 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: STREAM MANAGEMENT PLAN HERBERT RIVER AND DISTRICT
AUTHOR: Ian Drummond & Associates
YEAR: 1993 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: TECHNICAL REPORT 61 – DIVISION OF RESOURCE MANAGEMENT
SURVEY OF RESEARCH PRIORITIES IN WATER EROSION
WATERLOGGING AND FLOODING IN SOUTH WESTERN AUSTRALIA
AUTHOR: D.J Mcfarlane & EG Barrett-Lennard
YEAR: 1987 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: WETLAND SYSTEMS IN WATER POLLUTION CONTROL
AUTHOR: Australian Water & Wastewater Association & International Association On Water Quality
YEAR: 1992 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: STREAMLINING – AN ENVIRONMENTALLY SUSTAINABLE DRAINAGE NETWORK FOR THE SWAN COASTAL PLAIN
AUTHOR: Garry Heady & Neil Guise
YEAR: 1994 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: PROCEEDINGS OF THE TROPICAL FLOODPLAIN DEVELOPMENT WORKSHOP
AUTHOR: GP Lukacs And Mowg Thomas
YEAR: 1997 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: WORKING PAPER ON GROUNDWATER MANAGEMENT IN THE JANDAKOT AREA
AUTHOR: Western Australian Water Resources Council
YEAR: 1986 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: SHEPPARTON IRRIGATION REGION – LAND AND WATER SALINITY MANAGEMENT STRATEGIC PLAN – THE SECOND FIVE YEARS.
AUTHOR: Michael Young
YEAR: 1995 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: DRYLAND SALINITY
AUTHOR: Scott Taylor
YEAR: 1996 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: THE ALGAL MANAGEMENT STRATEGY- FOR THE MURRAY DARLING BASIN
AUTHOR: Murray Darling Basin Ministerial Council
YEAR: 1994 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: BERRIQUIN COMMUNITY LAND AND WATER MANAGEMENT PLAN
AUTHOR: Berriquin LWMP Working Group
YEAR: 1995 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: MURRAY DARLING BASIN COMMISSION NATURAL RESOURCES MANAGEMENT STRATEGY – FINAL REPORT
AUTHOR: Mr HG Beecher, Mr GD McLeod, Mr KE Pritchard, Mr K Russell
YEAR: 19 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: COLEAMBALLY LAND AND WATER MANAGEMENT PLAN – DRAFT – NOV. 1995
AUTHOR: Coleambally LWMP Working Group
YEAR: 1995 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: DOWNSTREAM EFFECTS OF LAND USE
AUTHOR: HM Hunter, AG Eyles And GE Rayment
YEAR: 1995 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: PROCEEDINGS OF THE TROPICAL FLOODPLAIN DEVELOPMENT WORKSHOP
AUTHOR: GP Lukas & Mowg Thomas
YEAR: 1995 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: AQUATERRAIN
AUTHOR: James Cook University
YEAR: 1996 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: AUSTRALIAN CENTRE FOR TROPICAL FRESHWATER RESEARCH
AUTHOR: James Cook University
YEAR: 1997 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: WATER ALLOCATION AND MANAGEMENT PLANNING
AUTHOR: Department Of Natural Resources
YEAR: 1997 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: NUTRIENT MANAGEMENT IN IRRIGATED AGRICULTURE
AUTHOR: Agriculture Victoria
YEAR: 1995 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: THE EFFECT OF FURROW LENGTH ON RAIN AND IRRIGATION INDUCED EROSION ON A VERTISOL IN AUSTRALIA
AUTHOR: C Carroll, M Halpin, K Bell And J Mollison
YEAR: 1995 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: AUSTRALIA'S INLAND WATERS
AUTHOR: Bruce Cooper, Gary Jones, Michael Burch, Richard Davis
YEAR: 19 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: NUTRIENT AND FERTILISER MANAGEMENT IN PERENNIAL HORTICULTURE
AUTHOR: Stuart McNab Peter Jerie, Rachel Dick
YEAR: 1994 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: BEST MANAGEMENT PRACTICES FOR STORM WATER AND INFILTRATION CONTROL
AUTHOR: William Whipple Jr
YEAR: 1992 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: HYDRAULIC ASPECTS OF FLOODS & FLOOD CONTROL
AUTHOR: HS Stephens, Mrs CA Stapleton
YEAR: 1983 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: OPTIONS FOR MANAGING DIFFUSE DRAINAGE DISHCHARGES
AUTHOR: Sandy Booth
YEAR: 1993 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: PLANNING FOR SUSTAINABLE WATER RESOURCE DEV – THE NEED FOR A NEW APPROACH
AUTHOR: Dr NJ Schofield, Mr N Dawson, Mr G Lukacs
YEAR: 19 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE: SOILpak$_{\beta}$ - A SOIL MNGT PACKAGE FOR COTTON PRODUCTION ON CRACKING CLAYS
AUTHOR: NSW Agriculture
YEAR: 1991 **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE:
AUTHOR:
YEAR: **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

TITLE:
AUTHOR:
YEAR: **LOCATION**: "LAND & WATER MANAGEMENT PLANNING & POLICY" file, KDC

ORIA BEST ENVIRONMENTAL PRACTICE RESEARCH PROJECT

PUBLICATION LIST

[as at MARCH 1998]

RESOURCE FILE: *MODELLING, SOFTWARE & INVESTIGATIVE INSTRUMENTS*

Researched Literature Available at:

Kimberley Development Commission
PO Box 620
Papuana Street
Kununurra, Western Australia, 6743
Ph. (08) 9168 1044
Fax. (08) 9168 1473

TITLE: < 3 disks & booklet> PAM (Paddock Action Manager) Interfarm – Getting started & installation guide
DETAILS: FAIRPORT TECHNOLOGIES, Applecross, WA Ph. 1800 500 195
LOCATION: "MODELLING, SOFTWARE & INVESTIGATIVE INSTRUMENTS" file, at KDC

TITLE: AQUATERR – SOIL MOISTURE & TEMPERATURE PROBES
DETAILS: ICT Irricrop Technologies Pty Ltd, Narrabri, NSW 2390
LOCATION: "MODELLING, SOFTWARE & INVESTIGATIVE INSTRUMENTS" file, at KDC

TITLE: SWAGMAN PRODUCTS – SALT WATER AND GROUNDWATER MANAGEMENT
DETAILS: CSIRO Division of Water Resources, Griffith, NSW Ph. (069) 601 569
LOCATION: "MODELLING, SOFTWARE & INVESTIGATIVE INSTRUMENTS" file, at KDC

TITLE: SWAGMAN DESTINY: WHERE TO WATERTABLES AND SALINITY LEVELS IN IRRIGATED AREAS
DETAILS: W Meyer, D Godwin & J White, CSIRO Division of Water Resources / In: Murray Darling 1995 Workshop – Extended Abstracts, Wagga Wagga, 11-13 Sept 1995 - AGSO
LOCATION: "MODELLING, SOFTWARE & INVESTIGATIVE INSTRUMENTS" file, at KDC

TITLE: EnviroSCAN – THE SOIL WATER CONTINUOUS MONITORING SYSTEM
DETAILS: CROP TECH RESEARCH, Southern QLD [John Hall} Ph. (071) 556 344
LOCATION: "MODELLING, SOFTWARE & INVESTIGATIVE INSTRUMENTS" file, at KDC

TITLE: BOOTH Technology – PHOENIX / PADDOCK ACTION MANAGER [PAM] / INTERFARM / FARMSTAR
DETAILS: Booth Technology [Colin Booth], Cottosloe, WA 6011
LOCATION: "MODELLING SOFTWARE & INVESTIGATIVE INSTRUMENTS" file, at KDC

TITLE: SCIENTIFIC SOFTWARE BULLETIN – GROUNDWATER SOFTWARE FOR WINDOWS – Visual MODFLOW / Visual GROUNDWATER / AquiferTest
DETAILS: Scientific Software Group, Washington D.C., USA / Internet: http://www.scisoftware.com
LOCATION: "MODELLING, SOFTWARE & INVESTIGATIVE INSTRUMENTS" file, at KDC

TITLE: ENVIRONMENTAL SOFTWARE & PUBLICATIONS – Catalog 1997-98
DETAILS: Scientific Software Group, Washington D.C., USA / Internet: http://www.scisoftware.com
LOCATION: "MODELLING SOFTWARE & INVESTIGATIVE INSTRUMENTS" file, at KDC

TITLE: RORB Runoff Routing Program – Rainfall runoff event modelling
DETAILS: RORB c/o Dep of Civil Engineering, Monash Uni, Clayton, Vic Ph. (03) 9905 4989
LOCATION: "MODELLING, SOFTWARE & INVESTIGATIVE INSTRUMENTS" file, at KDC

TITLE: Modelling Sediment and Contaminants in Wetlands
DETAILS: Author: Dr P.L. Shrestha webcivil@www.ust.hk
LOCATION: "MODELLING, SOFTWARE & INVESTIGATIVE INSTRUMENTS" file, at KDC

TITLE: Software for Sediment Control in Irrigation Canals
DETAILS: Author: Philip Lawrence, Overseas Development Unit, Oxon, UK
LOCATION: "MODELLING, SOFTWARE & INVESTIGATIVE INSTRUMENTS" file, at KDC

TITLE: MANAGING SOIL, WATER AND IRRIGATED CROPS - SIRAG
DETAILS: CSIRO DIVISION OF WATER RESOURCES
LOCATION: "MODELLING, SOFTWARE & INVESTIGATIVE INSTRUMENTS" file, at KDC

TITLE: ECONOMIC & ENVIRONMENTALLY SUSTAINABLE USE OF VARIOUS WATER SUPPLY SOURCES FOR IRRIGATION
DETAILS: Land & Water Resources R&D Corporation, Milestone Report III, June 1997
LOCATION: "MODELLING, SOFTWARE & INVESTIGATIVE INSTRUMENTS" file, at KDC

TITLE:
DETAILS:
LOCATION: "MODELLING, SOFTWARE & INVESTIGATIVE INSTRUMENTS" file, at KDC

TITLE: REX [REVEGETATION EXPERT SYSTEM]
DETAILS: A database on CD-rom containing all tree species grown in Western Australia. Put together by CALM, AgWA and Greening Australia. By Robin Road Software: [by Tom Brown]
LOCATION: [David Bicknell at AgWA– who helped create the program Ph. (08) 9881 0222]

TITLE:
DETAILS:
LOCATION: "MODELLING, SOFTWARE & INVESTIGATIVE INSTRUMENTS" file, at KDC

TITLE:
DETAILS:
LOCATION: "MODELLING, SOFTWARE & INVESTIGATIVE INSTRUMENTS" file, at KDC

TITLE:
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ORIA BEST ENVIRONMENTAL PRACTICE RESEARCH PROJECT

PUBLICATION LIST

[as at MARCH 1998]

RESOURCE FILE: *OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA*

Researched Literature Available at:

Kimberley Development Commission
PO Box 620
Papuana Street
Kununurra, Western Australia, 6743
Ph. (08) 9168 1044
Fax. (08) 9168 1473

TITLE: LISTING OF LWRRDC FUNDED R&D - CURRENT PROJECTS AND FINAL REPORTS
DETAILS: Land & Water Resources Research & Development Corporation [November 1997]
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: NATIONAL PROGRAM FOR IRRIGATION R&D – Projects funded July 1996
DETAILS: Land & Water Resources Research & Development Corporation
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: NATIONAL PROGRAM FOR IRRIGATION R&D – New projects, assessments and milestones achieved, November 1996
DETAILS: Land & Water Resources Research & Development Corporation
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: ASSESSMENT OF CRITICAL ECONOMIC AND FARM MANAGEMENT ASSUMPTIONS IN LAND AND WATER MANAGEMENT PLANS IN THE MURRAY VALLEY
DETAILS: Mr D Collins Ph. (06) 2722044 - Australian Bureau Of Agriculture And Resource Economics
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: IMPROVING COMMUNICATION PRACTICES IN LAND AND WATER MANAGEMENT
DETAILS: Dr AD Shulman – Communication Research Institute Of Australia (07) 33656748
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: MEASURE AND MODEL WATER BALANCE COMPONENTS, WATER TABLE MOVEMENTS AND SALINISATION PROCESSES IN IRRIGATED RIVERINE SOILS
DETAILS: Prof WS Meyer (069) 601562 – CSIRO Division Of Water Resources
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: NUTRIENT MANAGEMENT IN IRRIGATION DRAINS
DETAILS: KH Bowmer Ph (069) 332221 – CSIRO Division Of Water Resources
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: COMMUNITY INVOLVEMENT IN INTEGRATED CATCHMENT MANAGEMENT
DETAILS: Mr H Halla (08) 83917121 – Primary Industries SA
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: USING ARTIFICIAL WETLANDS TO REDUCE NUTRIENTS IN EFFLUENT
DETAILS: Mr RS Geary (049) 216726 – University Of Newcastle - Department of Geography & Environmental Science.
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: IMPROVING IRRIGATION AUTOMATION
DETAILS: RS Roberts (058) 721889 R Maskey (058) 721899 Victorian Dept Of Natural Resources And Environment.
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: HYDROLOGICAL PROCESSES ASSOCIATED WITH PESTICIDE TRANSPORT
DETAILS: EB Wronski – Land And Water Resources And Development Corporation
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: ESTIMATION OF ECOLOGICALLY SUSTAINABLE GROUND WATER PUMPING RATES – LWRRDC Project Reference No. NTU1
DETAILS: Dr Derek Eamus, Northern Territory University
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: INSTRUMENT RESEARCH AND DEVELOPMENT GROUP
DETAILS: Mr Peter Fitch – CSIRO Division Of Water Resources (06) 246 5862
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: WATER AND SALT BALANCE OF IRRIGATED CROPS IN THE PRESENCE OF SHALLOW WATER TABLES
DETAILS: Professor Wayne Meyer – CSIRO Division Of Water Resources (069) 601562
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: GROUNDWATER MANAGEMENT AND SITE REMEDIATION
DETAILS: Dr Chris Barber (08) 9387 0278 http://www.dwr.csiro.au/CGS
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: SUGAR R&D CORPORATION – Increasing sugarcane productivity through development of integrated surface drainage systems for low lying canelands
DETAILS: Mr J Reghenzani – Bureau Of Sugar Experiment Stations (077) 762500
Dr Christian Roth – CSIRO Division Of Soils (077) 538569
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

National Program for Irrigation R&D – (Current or recently completed Projects) Nov 1997

Water Use Efficiency

TITLE: IMPROVING WATER USE AND EFFICIENCY OF HORTICULTURE CROPS
DETAILS: Brian Loveys – CSIRO Division Of Horticulture – SA - Ph. (08) 8303 8615
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: GUIDELINES FOR EFFICIENT AND SUSTAINABLE TRICKLE IRRIGATION SYSTEMS
DETAILS: Peter Thorburn – CSIRO Tropical Agriculture - Ph. (07) 3377 0209
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: DETERMINATION OF OPTIMAL IRRIGATION EFFICIENCY FOR IRRIGATION AREAS
DETAILS: Wayne Meyer – CSIRO Division Of Water Resources – NSW - Ph. (06) 960 1562
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: IMPROVING WATER USE EFFICIENCY BY REDUCING GROUNDWATER RECHARGE UNDER IRRIGATED PASTURES
DETAILS: Hayden Kingston – NSW Agriculture - Ph. (03) 5883 1644
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: CONTROL OF IRRIGATION SALINITY THROUGH CONJUNCTIVE USE OF GROUNDWATER AND SURFACE WATERS
DETAILS: Mathew Bethune – AG Victoria - Ph. (03) 5833 5227
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: ENVIRONMENTALLY SUSTAINABLE FERTILISER USE THROUGH IMPROVED FLOOD IRRIGATION MANAGEMENT TECHNIQUES
DETAILS: Nick Austin – AG Victoria - Ph. (03) 5833 5338
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: ALTERNATIVE IRRIGATION TECHNOLOGIES IN FIELD CROPPING TO INCREASE WATER USE EFFICIENCY
DETAILS: Sam Lolicato – Institute Of Sustainable Irrigated Agricultural – VIC - Ph. (03) 8333 5277
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: CONSERVATION OF WATER FROM OPEN STORAGE BY MINIMISING EVAPORATION
DETAILS: Aliakbar Akbarzadeh – 12 LaTeobe St. Melbourne, VIC - Ph. (03) 9660 2164
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: BEST PRACTICE IDENTIFICATION IN IRRIGATION PROVIDERS THROUGH BENCHMARKING
DETAILS: Chris Stolz – PO Box 817, Irymple, VIC - Ph. (03) 5021 9770
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

Application on Farm

TITLE: PERFORMANCE TESTING OF AUTOMATIC IRRIGATION EQUIPMENT FOR FLOOD IRRIGATION
DETAILS: Jeremy Cape – AITC – South Australia - Ph. (08) 8252 5311
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: DEVELOPMENT OF A VALUE SELECTION METHOD FOR CHOOSING BETWEEN ALTERNATIVE SOIL MOISTURE SENSORS
DETAILS: -
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: EFFECTIVE IRRIGATION OF SUITABLE SOILS ON UNEVEN SURFACES
DETAILS: Lionel Tilley – QLD - Ph. (07) 954 5100
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: USE OF SALINE WATER IN RICE BASED FARMING SYSTEMS
DETAILS: John Thompson – NSW Agriculture- Ph. (03) 5881 1499
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: DEVELOPMENT OF IMPROVED FERTILISATION TECHNIQUES FOR IRRIGATED HORTICULTURE
DETAILS: Peter Jerie – ISIA, Tatura, VIC- Ph. (03) 5833 5208
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: PREDICTION OF SIXTY YEAR TRENDS IN ROOTZONE SALINITY
DETAILS: Mathew Bethune – AG Victoria - Ph. (03) 5833 5227
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: SALINITY CONTROL WITH SUSTAINABLE FARM SALT BALANCE THROUGH INTEGRATED MANAGEMENT
DETAILS: Alfred Hueperman – Ag Victoria - Ph. (03) 5833 5222
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: REAL TIME MONITORING AND CONTROL OF ON FARM SURFACE IRRIGATION SYSTEMS
DETAILS: Hector Malano – Dept Of Civil Ag Engineering - VIC - Ph. (03) 9344 6645
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

Water Supply Systems
TITLE: CONSTRUCTION AND REFURBISHMENT OF EARTHEN IRRIGATION CHANNEL BANKS
DETAILS: Ian Moorhouse – Goulburn Murray Water – VIC - Ph. (03) 5824 0111
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: REPLACEMENT OPTIONS FOR CONCRETE LINED CHANNELS
DETAILS: Brett Stevenson – QLD - Ph. (070) 922 555
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: REVIEW OF IRRIGATION FLOW CONTROL AND MEASUREMENT TO FARMS
DETAILS: Brian Foley – VIC - Ph. (03) 9248 3354
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: AN EVALUATION OF THE APPLICABILITY OF GENETIC ALGORITHM TECHNOLOGY TO FLOW MANAGEMENT OF OPEN CHANNEL GRAVITY SYSTEM
DETAILS: -
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

Drainage Systems
TITLE: NUTRIENT CONTROL IN IRRIGATION DRAINAGE SYSTEMS USING ARTIFICIAL WETLANDS
DETAILS: Resource Sciences Centre, Indooroopilly, QLD- Ph. (07) 3896 9637
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: EVALUATION OF ENROUTE WETLAND SYSTEMS FOR NUTRIENT REMOVAL FROM IRRIGATION DRAINAGE
DETAILS: Peter Cottingham – - Ph. (03) 9550 1000
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

Integrated Farm / Supply Systems
TITLE: TO DEVELOP AN AGREED FOCUS AND SCOPE FOR BENCHMARKING
DETAILS: John Hillier – DNR – QLD - Ph. (07) 3896 9845
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: RESEARCH AND DEVELOPMENT OF BEST PRACTICE FOR HORTICULTURAL IRRIGATION REHABILITATION
DETAILS: Chris Stanton - NSW - Ph. (02) 9980 6651
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: VIABILITY OF IRRIGATION INFRASTRUCTURE REFURBISHMENT AND IMPLICATIONS FOR PRIVATE OWNERSHIP.
DETAILS: Michael Bryant – Centre for Water Policy Research – Uni of New England, NSW- Ph.(06) 773 2420
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

Adoption and Education

TITLE: INCREASING IRRIGATION EFFICIENCY IN THE AUSTRALIAN SUGAR INDUSTRY
DETAILS: James Holden - BSES, QLD - Ph. (07) 782 5455
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: AN EVALUATION OF SUB SURFACE IRRIGATION CONFIGURATIONS
DETAILS: Philip Charlesworth – Griffith, NSW - Ph. (06) 960 1584
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: CONSULTANCY BRIEF ON IRRIGATION EDUCATION AND SKILLS DEVELOPMENT
DETAILS: Wayne Meyer – CSIRO Div Of Water Resources, Griffith NSW - Ph. (06) 960 1562
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: IRRIGATION EDUCATION MODULES
DETAILS: Wayne Meyer – CSIRO Div Of Water Resources, Griffith NSW - Ph. (06) 960 1562
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: ADOPTING IMPROVED USE OF CURRENT WATER MONITORING TECHNOLOGY TO MANAGE RECHARGE
DETAILS: Elizabeth Humphreys – CSIRO Water Resources - NSW - Ph. (06) 9601528
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: TOWARDS EXCELLENCE IN DRIED VINE FRUIT PRODUCTION
DETAILS: Robert Hayes – Ag Victoria - Ph. (03) 50514568
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: ESTABLISHING A PROCESS TO IMPROVE IRRIGATION AUTOMATION
DETAILS: Greg Roberts – Dep Agriculture And Natural Resources – VIC - Ph. (03) 5872 1899
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: LOCAL BEST PRACTICE AMONG COTTON PRODUCERS IN CENTRAL QLD
DETAILS: Geoffrey Lawrence – Central QLD University - Ph. (079) 309 053
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: REVIEW OF EXISTING PARTICIPATIVE ACTION MANAGEMENT MODEL
DETAILS: Shankariah Chamala – Ag Dept University Of Qld - Ph. (07) 3365 2159
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

Planning and Evaluation

TITLE: POSITION PAPER ON STANDARDS AND CODES FOR THE IRRIGATION INDUSTRY
DETAILS: Jeremy Cape – AITC – SA - Ph. (08) 8262 6311
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

Communication

TITLE: PREPARATION OF A COMMUNICATION STRATEGY FOR THE NATIONAL IRRIGATION PROGRAM
DETAILS: -
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

TITLE: COOPERATIVE RESEARCH CENTRE FOR CATCHMENT HYDROLOGY – Information Pack
DETAILS: Centre Office – Dep Civil Engineering, Monash Uni, Clayton, Victoria, 3168 ph. (03) 565 2704
LOCATION: "OTHER RESEARCH & DEVELOPMENT PROJECTS IN AUSTRALIA" file, KDC

ORIA BEST ENVIRONMENTAL PRACTICE RESEARCH PROJECT

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RESOURCE FILE: *PLANNING & COMMUNICATION*
– Ord River Irrigation Area

Researched Literature Available at:

Kimberley Development Commission
PO Box 620
Papuana Street
Kununurra, Western Australia, 6743
Ph. (08) 9168 1044
Fax. (08) 9168 1473

DETAILS: A short-term assessment of point source pollution in the M1 irrigation supply channel with notes on agricultural discharge into the lower Ord River. / by: Robert Doupe, Mark Lund [Centre for Ecosystem Management, Edith Cowan University, WA] and Scott Ranford [School of Biological and Environmental Sciences, Murdoch University, WA] - A report funded by and prepared for the WA Water Corporation. [March 1998]
LOCATION: "PLANNING & COMMUNICATION – Ord River Irrigation Area" file, KDC

DETAILS: Ord Land and Water presents The Environmental Symposium "The Issues Facing the Ord Today" Proceedings, March 1998. Kununurra, Western Australia
LOCATION: "PLANNING & COMMUNICATION – Ord River Irrigation Area" file, KDC

DETAILS: Definition Statement of Key Environmental Issues and Responsibilities – Forum on Environmental Management of the Ord Stage 1 Irrigation Scheme – Transfer of Ownership / Water Corporation and Ord Irrigation Co-operative, 16th October, 1997.
LOCATION: "PLANNING & COMMUNICATION – Ord River Irrigation Area" file, KDC

DETAILS: Ord Land and Water newsletter, Volume 1, Issue 1, 1st June 1997
LOCATION: "PLANNING & COMMUNICATION – Ord River Irrigation Area" file, KDC

DETAILS: Ord Land and Water newsletter, Volume 1, Issue 2, 8th August 1997
LOCATION: "PLANNING & COMMUNICATION – Ord River Irrigation Area" file, KDC

DETAILS: Ord Land and Water newsletter, Volume 1, Issue 3, 8th October 1997
LOCATION: "PLANNING & COMMUNICATION – Ord River Irrigation Area" file, KDC

DETAILS: Ord Land and Water newsletter, Volume 1, Issue 4, 1st December 1997
LOCATION: "PLANNING & COMMUNICATION – Ord River Irrigation Area" file, KDC

DETAILS: Ord Land and Water newsletter, Volume 2, Issue 1, 14th January 1997
LOCATION: "PLANNING & COMMUNICATION – Ord River Irrigation Area" file, KDC

DETAILS:
LOCATION: "PLANNING & COMMUNICATION – Ord River Irrigation Area" file, KDC

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LOCATION: "PLANNING & COMMUNICATION – Ord River Irrigation Area" file, KDC

ORIA BEST ENVIRONMENTAL PRACTICE RESEARCH PROJECT

PUBLICATION LIST

[as at MARCH 1998]

RESOURCE FILE: *RIPARIAN BUFFER STRIPS*

Researched Literature Available at:

Kimberley Development Commission
PO Box 620
Papuana Street
Kununurra, Western Australia, 6743
Ph. (08) 9168 1044
Fax. (08) 9168 1473

TITLE: BUFFER ZONES: THEIR PROCESSES & POTENTIAL IN WATER PROTECTION – Proceedings of the International Conference on Buffer Zones, September 1996
AUTHOR: Quest Environmental / Edited by: N Haycock, T Burt, K Goulding & G Pinay
YEAR: 1996 **LOCATION**: "RIPARIAN BUFFER STRIPS" file, KDC

TITLE: AGROFORESTRY NOTES 3 – Riparian Buffers for Agricultural Land
AUTHOR: National Agroforestry Centre, USDA Forest Service, Nebraska, USA / January 1997
YEAR: 1997 **LOCATION**: "RIPARIAN BUFFER STRIPS" file, KDC

TITLE: AGROFORESTRY NOTES 4 – How to Design a Riparian Buffer for Agricultural Land
AUTHOR: National Agroforestry Centre, USDA Forest Service, Nebraska, USA / January 1997
YEAR: 1997 **LOCATION**: "RIPARIAN BUFFER STRIPS" file, KDC

TITLE: AGROFORESTRY NOTES 5 – A Riparian Buffer Design for Cropland
AUTHOR: National Agroforestry Centre, USDA Forest Service, Nebraska, USA / January 1997
YEAR: 1997 **LOCATION**: "RIPARIAN BUFFER STRIPS" file, KDC

TITLE: VEGETATIVE FILTER STRIP EFFECTS ON SEDIMENT CONCENTRATION IN CROPLAND RUNOFF
AUTHOR: C Robinson, M Ghaffarzadeh & R Cruse / Journal Soil & Water Cons. 50 (3) 227-230, May-June
YEAR: 1996 **LOCATION**: "RIPARIAN BUFFER STRIPS" file, KDC

TITLE: REVEGETATION SITES SUCCESSFUL IN BANK STABILISATION
AUTHOR: Simon O'Donnell, DPI Gympie / News & Views, No. 10, Feb 1996
YEAR: 1996 **LOCATION**: "RIPARIAN BUFFER STRIPS" file, KDC

TITLE: CONSERVATION TILLAGE AND FILTER STRIPS TRAP POTENTIAL WATER CONTAMINANTS
AUTHOR: W Thom and R Blevins / Better Crops, Vol. 80 (1996, No. 2)
YEAR: 1996 **LOCATION**: "RIPARIAN BUFFER STRIPS" file, KDC

TITLE: GUIDELINES FOR ESTABLISHING WARM SEASON GRASS HEDGES FOR EROSION CONTROL
AUTHOR: C Dewald, J Henry, S Bruckerhoff, J Ritchie, S Davney, D Shepherd, J Douglas & D Wolf / Journal of Soil and Water Conservation, Vol 51 (1) Jan-Feb 1996.
YEAR: 1996 **LOCATION**: "**SEDIMENT TRAPS & EROSION CONTROL**" file, KDC

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AUTHOR: Land & Water Resources Research & Development Corporation
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AUTHOR: Vol Norris – Centre For Water Policy Research, University Of New England, Armidale, NSW 2351
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Vetiver Grass

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AUTHOR: Dr Paul Truong, Principal Soil Conservationist / Resource Sciences Centre, Qld Department of Natural Resources, Brisbane, Australia
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Kununurra, Western Australia, 6743
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AUTHOR: Murray Mchugh
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AUTHOR: Ontario Soil And Crop Improvement Association (OSCIA)
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AUTHOR: Ian Rogers, Malaga, Western Australia 6062
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RESOURCE FILE: *SOIL PERMEABILITY MAPPING*

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Kimberley Development Commission
PO Box 620
Papuana Street
Kununurra, Western Australia, 6743
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Fax. (08) 9168 1473

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AUTHOR: Peter de Broekert
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AUTHOR: HG Beecher, IH Hume, ST Dawe (NSW AG)
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YEAR: 1998 **LOCATION**: "SOIL PERMEABILITY MAPPING" file, KDC

TITLE:
AUTHOR:
YEAR: 19 **LOCATION**: "SOIL PERMEABILITY MAPPING" file, KDC

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YEAR: 19 **LOCATION**: "SOIL PERMEABILITY MAPPING" file, KDC

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YEAR: 19 **LOCATION**: "SOIL PERMEABILITY MAPPING" file, KDC

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CONTACT(S): Justin Anning – Environmental Geophysicist
YEAR: 1997 **LOCATION**: "SOIL PERMEABILITY MAPPING" file, KDC

ORGANISATION: GEOSCIENTIFIC INFORMATION SYSTEMS – Cartographic Mapping and Geographic Information Systems Compillation & Management [Capability Statement Provided]
CONTACT(S): Karl Wolzak - Principal
YEAR: 1997 **LOCATION**: "SOIL PERMEABILITY MAPPING" file, KDC

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AUTHOR:
YEAR: 19 **LOCATION**: "SOIL PERMEABILITY MAPPING" file, KDC

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RESOURCE FILE: *SUB-SURFACE DRAINAGE*

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PO Box 620
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Ph. (08) 9168 1044
Fax. (08) 9168 1473

TITLE: GROUNDWATER CONTROL USING SHALLOW SUBSURFACE DRAINS
AUTHOR: WA Muirhead, EW Christen and JL Moll
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AUTHOR: PR George
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AUTHOR: National Building Technology Centre
YEAR: 19 **LOCATION**: "SUB-SURFACE DRAINAGE" file, KDC

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AUTHOR: Harvey Rubenstein
YEAR: 1980 **LOCATION**: "SUB-SURFACE DRAINAGE" file, KDC

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AUTHOR: OC Young
YEAR: 1971 **LOCATION**: "SUB-SURFACE DRAINAGE" file, KDC

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AUTHOR: Frank Mickan
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AUTHOR: Building Research Establishment Digest
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AUTHOR: Dr. Derek Eamus
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AUTHOR: Cooperative Research Centre for the Sustainable Development of Tropical Savannas
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AUTHOR: Mohammed Bari, Nick Schofield and David Boyd
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AUTHOR: Dr Derek Eamus, Northern Territory University
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