PRELIMINARY MATERIALS BUDGET (NUTRIENTS AND SEDIMENTS) IN THE ORD RIVER: IMPLICATIONS FOR CURRENT AND PROPOSED IRRIGATION AREAS.

M. A. Lund[1] and A. McCrea[2]

[1]School of Natural Sciences [2]Policy and Planning Division, Water and Rivers Commission

ABSTRACT

An ecological risk assessment (ERA) was undertaken of the impacts of irrigation return on the Lower Ord River catchment. A materials budget (mass balance) for nutrients and sediment was prepared for the ERA process to establish the relative contribution of irrigation return to the catchment. The Ord River Dam (forming Lake Argyle) effectively splits the River catchment into two sections. The lower section ranges from downstream of the Ord River Dam to near Carlton Crossing (the upper extent of the salt wedge). This section receives irrigation return from the Ivanhoe Plains and Packsaddle Plains areas and will be the focus of this study. In addition, runoff from rangelands enters through several creeks and the Dunham River.

All relevant water quality and flow data from the irrigation area or River were used to prepare the budgets. A high degree of interpolation and assumption was necessary due to the limited data availability, which limits the accuracy of the final budgets. Despite this, it appears that irrigation return water is a substantial contributor of Phosphorus (P) and nitrate/nitrite to the Lower Ord River. In comparison with rangelands, the irrigation area produced significantly higher loads of P, nitrate/nitrite and suspended sediment per unit area and in total. The return water produced a detectable increase in river P and nitrate/nitrite concentrations

This paper will discuss the impact of these results on current planning for the development of Ord Stage II and in moves towards best management practices within the current irrigation area.

INTRODUCTION

Irrigation has a have profound effect on river environments, either through regulation of flows or contaminated return to the river (see Napier and Fairweather, 1998). Despite more than thirty years of agricultural production, the ecological effects of land and water management practises in the Ord River Irrigation Area (ORIA), in north western Australia, has received little attention (Doupé et al, 1998). This is compounded by limited research, inconsistent sampling methodologies and specific foci of existing studies in the area (e.g. Jones 1997; Doupé et al. 1998).

The ORIA is located in the Kimberley region of Western Australia close to the Northern Territory border (Figure 1). Walker (1992) provides an interesting overview of the political machinations that led to the construction of the ORIA. The Lower Ord catchment (Figure 1) is bounded by the Ord River Dam (ORD), which forms Lake Argyle, and Carlton Crossing (the highest point reached by the saltwater wedge). Ord Stage 1 consists of 15,000 ha of irrigated land on the Ivanhoe Plain (13,000 ha) and the Packsaddle Plain (2,000 ha) (Jones 1997). The impoundment (Lake Kununurra) created by the Kununurra Diversion Dam (KDD) supplies irrigation water to both areas. Designed as flow-through systems these areas return significant quantities of drainage waters to the river. The water enters the Ivanhoe Plain area via a gravity fed main channel (M1), from which a series of smaller channels carry water to the farms (S channels). The water is then collected in a series of drains (D channels) and returned to the Ord River. Water is pumped onto the Packsaddle Plain, gravity fed to farms, and collected by drains leading to the Packsaddle Creek, which drains into the Dunham River. The Dunham River, and Spring and Valentine Creeks join the Ord River a short distance downstream of the KDD.

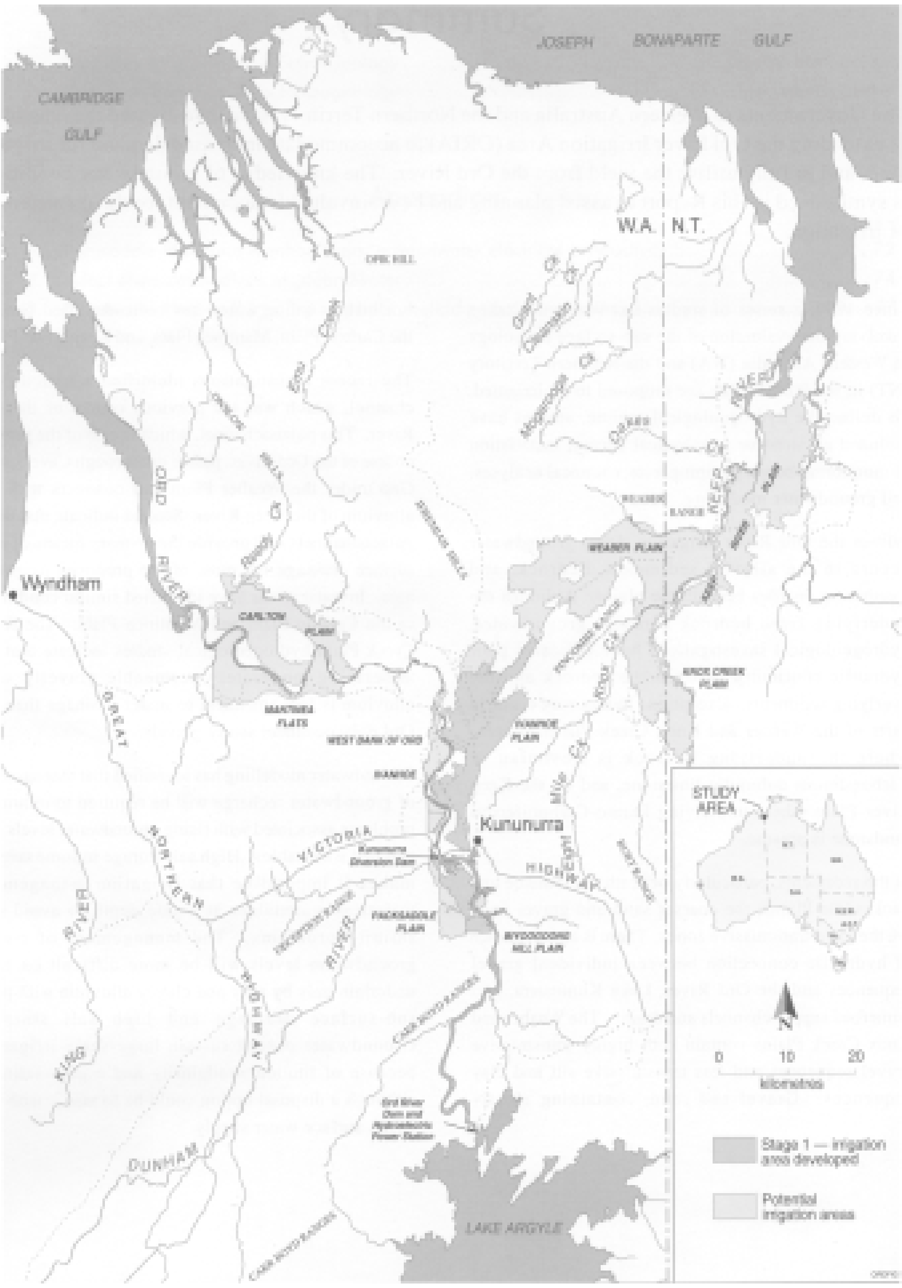

Figure 1: Locality map (used with permission from Water and Rivers Commission)

The most significant consequence of irrigation in the Ord catchment was the construction of the KDD (1962) and ORD (1973), which changed the Lower Ord river from being seasonally dry to permanently inundated, with highly regulated flows. Consequently there have been substantial changes in river dynamics, sediment transport, channel morphology, biodiversity, and riparian vegetation (Deegan, 2000). The Lower Ord is now currently evolving to suit its new flow conditions, a process, which is likely to continue for many years. The potential ecological consequences of irrigation water return were highlighted in 1997 with significant fish kills in the Dunham River and D4 drain due to Endosulphan poisoning (Doupé et al, 1998).

Proposals to develop new irrigation areas in Weaber, Knox and Keep Plains (collectively referred to as Ord Stage II) and on Carlton Plains and Mantinea Flats has lead to increased Agency and research interest in the area. In particular the Water and Rivers Commission of Western Australia (WRC) has had to evaluate the potential effects of Stage II development including determining the amount of water required by the environment and what is available for Stages I and II irrigation diversion. This has resulted in the production of the Draft Interim Ord River Water Allocation Plan (WRC, 1999). Current ecological water requirement (EWR) planning focuses on maintaining and enhancing the post dam modified environmental conditions rather than attempting to return the river to a pre-dam condition.

The National Program for Irrigation Research and Development (NPIRD) has embarked on the development of a generic Ecological Risk Assessment (ERA) framework to assess the risks posed by irrigation to riverine environments. Ecological Risk Assessment is a recent variant on the well established process of Environmental Impact Assessment. It focuses on the quantitative assessment of risk of environmental damage occurring (see Hart et al, 1999). The approach can be used in a situations where there is little available information and can provide a useful means of targeting priorities (see Lund and McCrea, 2001). This paper aims to describe the materials budget for sediments and nutrients of the Lower Ord River as a subset of the larger NPIRD ERA project. In addition, the relative contribution of irrigation to the catchment and the impacts of Ord Stage II developments on this will be examined.

METHODS

Available data were collected from the WRC, Ord Irrigation Cooperative (OIC), Agriculture WA, Water Corporation, and Pacific Power (operators of the ORD hydroelectric plant). Full details of the sampling programme and materials budget calculations are described in Lund and McCrea (2001).

In summary, Ivanhoe Plains (no data available for Packsaddle Plains) water quality data were collected by OIC/ WRC at approximately monthly intervals from a number of river and irrigation drain sites between April 1998 and August 2000. As water quality data were not flow weighted, this is likely to led to underestimated nutrient and especially sediment (TSS) loads. Additionally access to sample sites was limited in the wet season and as result there were missing data points. Gauged flow data was collected from the main drains over the same period. Flow was also measured in the upper Dunham River and for releases from ORD and KDD. Data for the Ivanhoe Plains was estimated daily for 1998 to 2000 and then reduced to monthly averages. The gauging station data (1970-1999) on the upper Dunham was used to estimate average monthly runoff coefficients as a function of rainfall at the Kimberley Research Station and then used to calculate flows in ungauged tributaries. Water quality values for grazed (rangelands) catchments (e.g. Dunham) were estimated using average values from the Spring and Valentine Creeks.

The increase in river concentrations due to D4 drainage was determined by dividing the D4 load into the Tarrara Bar flow on a monthly basis. The only other input besides D4 between Ivanhoe and Tarrara Bar is Spring Creek, which is believed make only a minor contribution in the wet season.

Finally, the error in the budgets could not be calculated, the data for the river is less accurate than that of the irrigation area and so caution is recommended in interpretation of results.

RESULTS

The relative significance of irrigation return to nutrient and sediment loads in the Lower Ord compared to other catchment activities (rangelands) has always been a 'hotly' debated local topic. Compared to irrigated areas (Table 1) rangelands appear to contribute very low nutrient and sediment loads per unit area to the river. Despite the large area of rangelands the total contribution to loads in the river was similar or lower than from irrigated areas, especially for P (total and FRP) and nitrate/nitrite. Phosphorus and nitrate/nitrite are most likely derived from nutrient applications on the irrigated area. Interestingly, the results suggest that rangelands are not a major source of total suspended solids (TSS) as may have been expected given the effects of grazing. The lack of event sampling is likely to have substantially underestimated the sources of TSS, as it is during high flow events that this material tends to become suspended. Visually the river becomes highly turbid, indicating high TSS loads, during the wet season compared to relatively clear water in the dry season, these differences are not accurately reflected in the estimated loads. The loads produced by irrigated areas related to fertilisers (P and nitrate/nitrite) are similar to those that are released by KDD. The loads of TSS released by KDD are over double those of the irrigation area and reflect the large wet season transport of sediments from ORD to Lake Kununurra in the wet season. The high quantities of total N and ammonia produced by the KDD releases are believed to be derived from organic matter breakdown in Lake Kununurra.

Table 1 Relative contributions to Ord River loads by rangelands (based on Valentine Creek), irrigated areas (based on Ivanhoe Irrigation Area) and KDD releases determined per unit area (100 km^2) and total loadings (irrigated areas - 148 km^2; rangelands - 4760 km^2) as applicable.

Parameter	Irrigated Area (tonnes)		Rangelands (tonnes)		KDD
	Per 100 km^2	Total	Per 100 km^2	Total	(tonnes)
Total Suspended Solids	16849	24937	136	6493	56715
Total P	14.8	22	0.2	11	21.3
Filterable Reactive P	7.1	10.5	0.1	2.4	8.52
Ammonia	7.7	11.3	0.3	13.8	54.5
Nitrate/nitrite	20.2	29.8	0.1	3.8	25.73
Total N	86.8	128.5	3.2	152.8	428.8

The Ivanhoe irrigation area takes in low loads of TSS and nutrients, and exports four times the P and three times the nitrate/nitrite in half the quantity of water (Figure 2). The loads of ammonia decrease slightly possibly due to nitrification to nitrate/nitrite. The increase in exported total N is probably explained by the increase in nitrate/nitrite. Interestingly, an unexplained observation was that the peak loads of these nutrients occurred in September to December (the start of the wet season) rather than directly following fertiliser application. This indicates a short-term storage in the irrigation area (Lund and McCrea, 2001).

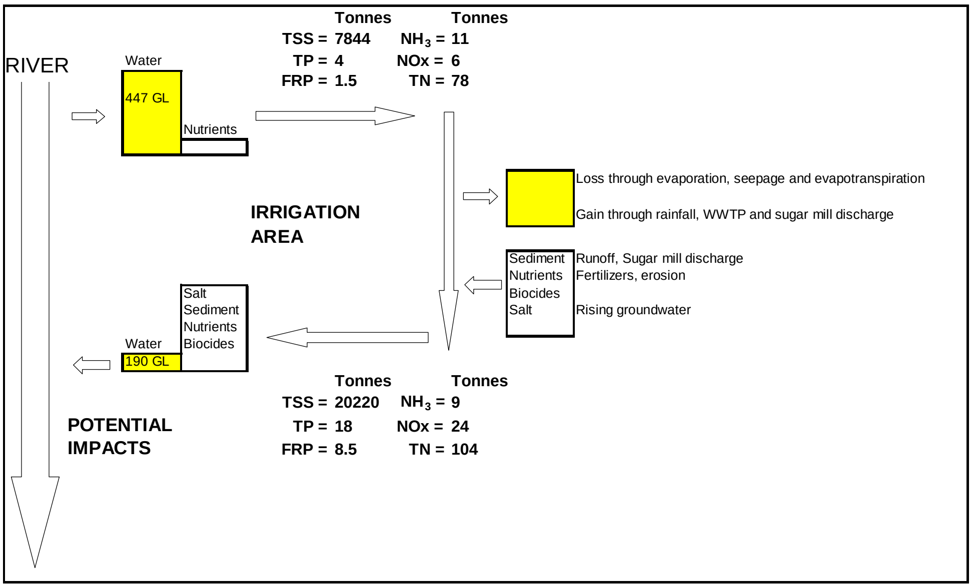

Figure 2 Model of loads in and out of the Ivanhoe irrigation area for water, nutrients and sediments

The flow from KDD varies little throughout the year. The Dunham River is unregulated and adds nearly 600 GL to the river, mainly during the wet season. The contributions from Spring and Valentine Creek and the drains are small by comparison. The irrigation area was designed as a flow through system with no on farm recycling, hence overall mean water us efficiency (WUE) is very low at <60% (excluding rainfall and channel losses). The WRC has a goal of substantially improving WUE and with the OIC are developing a range of measures that should see substantial reductions in irrigation return to the river in the future.

There is a significant discrepancy between the TSS found in the river at Tarrara Bar and the loads predicted by summing all the known inputs (Figure 3) which highlights the potential errors within the materials budget. The highest release of suspended solids from KDD occurs in the dry season, which runs counter to observations. A possible explanation is that M1 concentrations that were used to calculate KDD TSS loads, as M1 drains surface water from Lake Kununurra and the KDD drains bottom water from the lake.

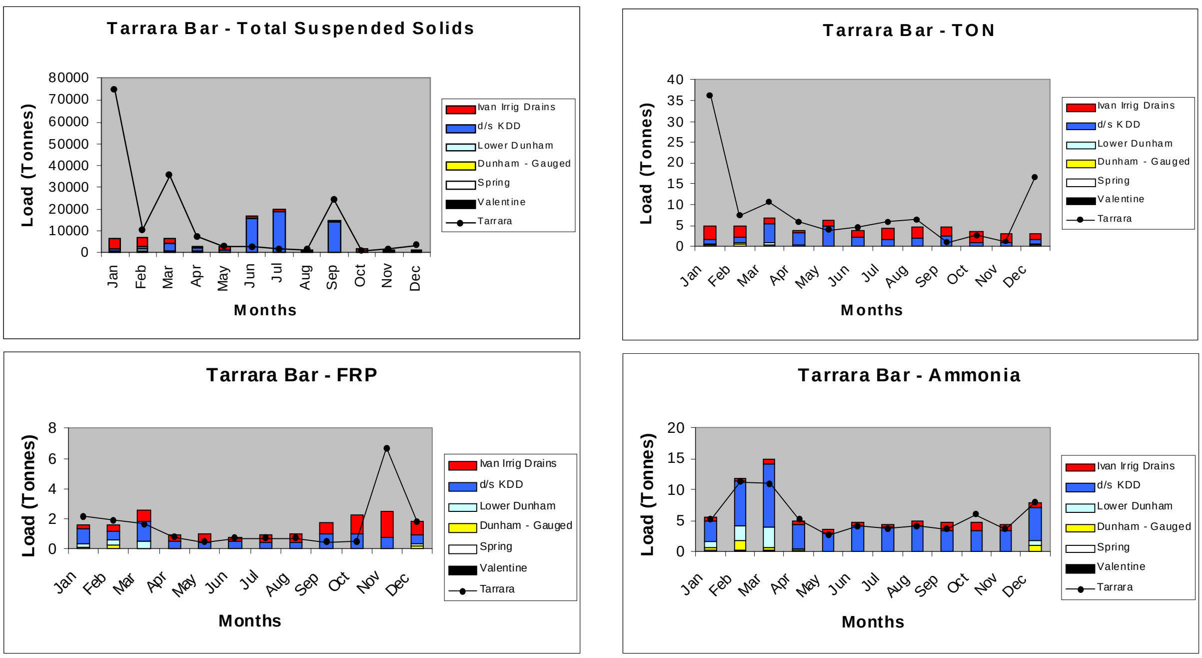

Figure 3 Total Monthly loads of total suspended solids, nitrate/nitrite (TON), FRP and Ammonia from all contributors to the river load. The line shows the load at Tarrara Bar, this was determined from measured concentrations and the summed flow.

Loads at Tarrara Bar reflect the cumulative sum of inputs closely for FRP and ammonia, with low variability between months. Nitrate/nitrite at Tarrara Bar matched the cumulative sum of inputs well except during December and January where the river had much higher loads than expected. Irrigation made a substantial contribution to river FRP levels in the build up to the wet season (September to December). Wet season flows from the rangelands make a substantial contribution to the river load of ammonia. The source of the ammonia in the rangelands requires further investigation.

Irrigation return makes a significant contribution to nutrient loads within the river, however the observed ecological impact is primarily the change in concentration that the river experiences. The D4 loads when combined with the flow at Tarrara Bar result in minor increases in concentrations of nutrients in the river (Table 2). The median monthly increase over the year for most nutrients and TSS closely matches the median difference between upstream of D4 (Ivanhoe Crossing) and downstream of D4 (Tarrara Bar).

Table 2 Median monthly concentrations (µg l^{-1}) of nutrients and sediment at Ivanhoe Crossing and Tarrara Bar, with the median increase in concentration due to D4 drainage.

	Ivanhoe	D4	Tarrara
TSS	11125	4777	13643
Total P	15.5	5.1	24.3
FRP	4.3	2.6	3.8
NH3	29.6	2.6	21.2
NOx	17.8	8.8	24.2
Total N	224	37.3	245

When Total P concentrations at Ivanhoe Crossing and Tarrara Bar are compared between years (1998-2000) for samples taken on the same day, a real increase in concentrations can be observed (Figure 4). The extent of the increase is highly variable especially during the wet season, but is in line with the predicted increase shown in Table 2.

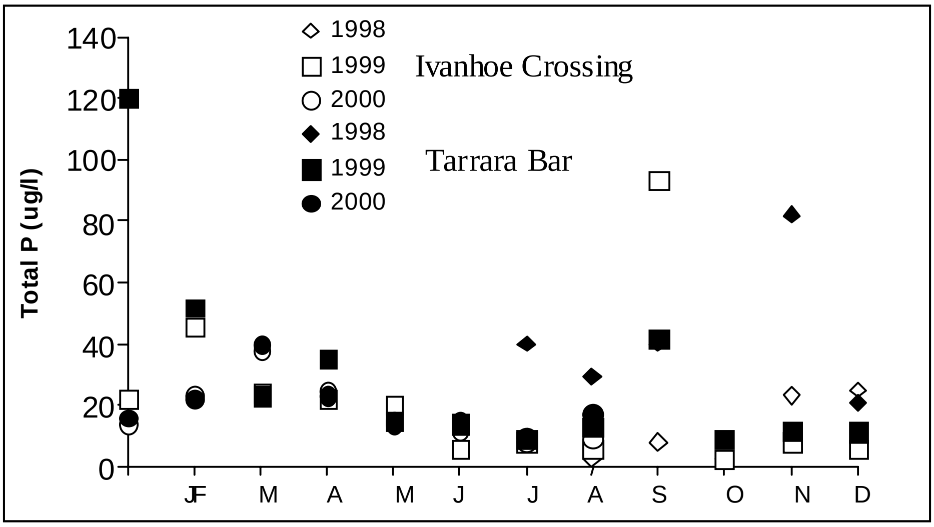

Figure 4 Measured concentrations taken the same day of Total P at Ivanhoe Crossing and Tarrara Bar illustrating the impact of the D4 drain on river concentrations (similar symbols represent data from 1998 to 1999)

DISCUSSION

The WRC has decided, on the basis of expert panel advice (Deegan, 2000), to recommend a minimum flow within the Lower Ord to meet EWRs, by preventing pooling in the river and maintaining a desirable wetted perimeter (Loh et al., 2001). Irrigation can then access water above this requirement. In addition, licensing and public consultation will be used to reduce irrigation return from Stage 1 by moving towards Best Management Practices on farms. The minimum flow currently being suggested is 45 $m^3.s^{-1}$, which provides 690GL.$year^{-1}$ for Ord Stage II (89.5% security) (Loh et al. 2001). This approach is predicted to minimise changes to concentrations of nutrients during the dry season while causing a minor increase during December to February (wet season). At these flow rates the residence time of water in the river is 1-3 days, which limits opportunities for algal blooms to develop. The increase in nutrient concentrations found in this study was small, but detectable. Although algal blooms are unlikely, increases in primary productivity of submerged macrophytes and biofilms may occur. Nutrient concentrations in the Ord River are typical of those from similarly sized rivers in Northern Queensland with agriculture in the catchments (Wilhelm, 2001). The river drains into Cambridge Gulf and high tidal flushing is likely to reduce the impact of river nutrient loads in the estuary (Doupe et al. 1998). It is suggested in Deegan (2000) that the regulated flows of the river are resulting in channel infilling, resulting in a substantial loss of sediments from the estuary. Although high TSS loads are carried by irrigation return its impact on the river and estuary needs further investigation.

The construction of a materials budget from the limited data available has proven a useful tool in understanding the magnitude of the contribution of irrigation return to the catchment. It has helped provide evidence to dispel some commonly held beliefs in the region, particularly that irrigation was a small contributor to the river compared to rangelands. It is important to understand the limitations of the budget, this includes incomplete gauged data and monthly water samples (not flow weighted), and no gauged data for the river. This has probably underestimated sediment loads from rangelands and possibly underestimated loads of nutrients from the drains. The gauged drains had highly variable flows, which would have been inadequately captured in load calculations using monthly grab samples. A monitoring program to refine the estimates of flow, nutrients and TSS loads is currently being developed for implementation in 2002 as part of the next NPIRD project.

The ERA undertaken on the Lower Ord River considered the risks posed under the current Ord Stage I and under Stage II. Stakeholder consultations were used to determine the level of risk, priorities and key ecological consequences in the river (Lund and McCrea, 2001). The key priority risk was taken as loss of biodiversity (Table 3) this will form the focus of the next phase of the NPIRD study.

Table 3 Ecological effects ranking matrix table for Ord catchment and irrigation (L = Low, M = Medium and H = High)

Ecological Consequence	Importance in catchment		Impact of Irrigation	Risk	
	Local	Broad		Stage I	Stage II
Algal Blooms	M	L	H	L	M
Biota Kills (biocides)	H	L	H	M	M
Loss of biodiversity	M	M	M	M	M-H
Channel	M	L	L	M	M

Infilling					
Weeds	M	M	M	M	M

The irrigation infrastructure is being transferred to the Ord Irrigation Cooperative, this combined with planning for Ord Stage II (an expansion of the irrigation area) is leading to substantial changes to irrigation practices in the area. A stated aim of these reforms is to reduce nutrient loads leaving the irrigation area by 50%, mechanisms to achieve this include licensing and improved WUE on farms. It is therefore likely that ecological risks posed by irrigation water return will need to reassessed in the future.

ACKNOWLEDGEMENTS

This project received financial and in-kind support from the National Program for Irrigation Research and Development, Water and Rivers Commission, and Edith Cowan University. Thanks to Leith Bowyer, Simon Rodgers, John Ruprecht, Chris O'Boy, of the Water and Rivers Commission for sharing and gathering the data necessary for the mass balance. The assistance of the Water and Rivers Commission staff in Kununurra was greatly appreciated in provision of data, facilities and hospitality.

REFERENCES

Deegan, P.(ed.) (2000). "Ord River Scientific Panel Recommendations for estimation of interim ecological water requirements for the Ord River." Water and Rivers Commission, Perth.

Doupé, R.G., Lund, M.A., & Ranford, S.R. (1998). "A short-term assessment of point source pollution in the M1 irrigation supply channel with notes on agricultural discharge into the lower Ord River." Water Corporation WA, Perth.

Hart, B.T., Maher, B. & Lawrence, I. (1999) New generation water quality guidelines for ecosystem protection. *Freshwater Biology* 41:347

Jones, G. (1997). "Ord irrigation area water quality investigation." CSIRO Division of Water Resources.

Loh, I., Trayler, K. and Rodgers, S. (2001) "Consideration of drought period environmental water provisions for the Lower Ord River, Western Australia". Discussion Paper May 2001, Water and Rivers Commission, Perth.

Lund, M.A., & McCrea, A. (2001) "Assessment of the ecological risk associated with irrigation in the Ord River catchment." Centre for Ecosystem Management Report No. 2001-05, Edith Cowan University, Perth.

Napier, G.M. and Fairweather, P.G. (1998) An approach to biomonitoring wetlands to assess impacts of agricultural drainage. In. "Wetlands for the Future" Eds. McComb, A.J. and Davis, J.A., Gleneagles Publishing, Adelaide.

Walker, K.J. (1992). The neglect of ecology: The case of the Ord River scheme in K. Walker (Ed.) "Australian environmental policy - ten case studies." pp.183-202. Sydney: New South Wales University Press.

Wilhelm, G. (2001) "Water quality report for catchments containing sugar cane in Queensland" Queensland Department of Natural Resources and Mines, Indooroopilly.

WRC (1999) "Draft interim water allocation plan Ord River, Western Australia" Water Resource Allocation Planning Series, WRAP 2. Water and Rivers Commission, Perth.