MANAGING DIFFUSE SOURCES OF NUTRIENTS FROM IRRIGATION AREAS – EXPERIENCES FROM THE GOULBURN BROKEN CATCHMENT, AUSTRALIA

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ABSTRACT

In the Goulburn Broken catchment in northern Victoria management of nutrients from irrigation drainage has been targeted as a key activity during implementation of water quality strategies. Monitoring of water quality in drains shows that water quality in irrigation drains is degraded and substantial nutrient and sediment loads are exported from drains to regional waterways. Biocides (weedicides and pesticides) are rarely detected, but pathogens are a cause for concern. Nutrients from irrigated areas are mostly sourced from run off from irrigated perennial pasture, where phosphorus is applied as fertilizer. Strategies to address excess nutrient runoff are being implemented and include consideration of all nutrient sources in the catchment. On farm activities aim to reduce the volume of water and nutrients leaving the farm. Once water and nutrients reach drains, activities encourage the diversion of water from the drain. Trend analyses indicate that despite increases in nutrient concentrations, nutrient loads leaving drains are decreasing due to reduced flows.

Key Words: Goulburn Broken catchment, irrigation drainage, nutrients, water quality.

INTRODUCTION

The Goulburn Broken Water Quality Working Group (WQWG) and Catchment Management Authority's River Environment and Water Quality Committee have coordinated development of a water quality management Strategy for the Goulburn Broken Catchment. The Strategy was finalised in April 1997 and implementation commenced immediately.

Irrigation Drains as Nutrient Sources

As part of implementing Victoria's Nutrient Management Strategy for Inland Waters catchment based nutrient management plans, or strategies, have been prepared. In each of the plans covering the northern Victorian area, irrigation drainage has been identified as a major contributor of nutrients (phosphorus and nitrogen) to waterways. In the Goulburn Broken catchment, irrigation drains were estimated to contribute an estimated 169 t of Total Phosphorus in a typical year (45% of the total estimated catchment export - Table 1).

These nutrients can contribute to blue green algal blooms. Other potential water quality impacts of irrigation drainage include sedimentation, turbidity, biocides (pesticides and weedicides) and various pathogens. As part of the Goulburn Broken Water Quality Strategy a program has been developed to minimise the water quality impacts of irrigation drainage. During the Strategy development process the relative importance of nutrient sources and the cost effectiveness of a range of nutrient management options were identified.

Table 1 Nutrient Sources in the Goulburn Broken Catchment (Estimated – "Typical" year)

Source	Total catchment contribution (tonnes)	
	Total Phosphorus	**Total Nitrogen**
Irrigation Drains	169	619
Dryland	110	1866
Intensive animal industries	30	141
Urban	12.3	70
Sewage treatment plants	50.5	184.5
Total	**371.8**	**2880.5**

Nutrients from irrigation drains are delivered to the Goulburn and Murray Rivers via an extensive drainage network. Some 200 000 ha of the irrigated catchment of the Goulburn Broken is already served by drains and some 250 000 ha has been assessed as requiring drains (SPAC 1995). The Shepparton Irrigation Region Surface Drainage Strategy will implement the extra area drained over the next 10 years. This is predicted to increase the load of phosphorus reaching streams from 169 t to 208 t unless nutrient management options are implemented. In response to this, and the occurrence of cyanobacterial blooms, the Goulburn Broken Water Quality Strategy has a target of reducing phosphorus loads from irrigation drains by 50% to around 85 t over 10 years. Targets will be achieved by implementing a range of best management practices on farms and in drains.

The Drainage Strategy is implemented by Goulburn-Murray Water, the regional water authority, on behalf of the Goulburn Broken and North Central Catchment Management Authorities. On-going operation and maintenance of the constructed drain system is the responsibility of Goulburn-Murray Water.

Monitoring

Within the Shepparton Irrigation Region 17 irrigated sub catchments are currently monitored for continuous flow, salinity and nutrients (at fortnightly intervals) to determine the quality and quantity of water leaving the catchments. Monitoring results are reported regularly (for example SKM 2003a). Table 2 shows median values of water quality parameters in drains in 2001/02.

The frequency of monitoring was reviewed by SKM (2000) to examine the effect of altering the sampling frequency on nutrient median statistics and estimates of nutrient loads exported. Weekly, fortnightly and monthly data sets were generated and compared. Fortnightly sampling did not significantly reduce the accuracy of median nutrient concentrations. For load estimates, fortnightly sampling produced an acceptable outcome for the estimated annual load for all parameters. Sampling once per month produced highly variable annual and monthly load estimates.

Table 2 Water Quality in Selected Drains 2001/02 (median values, mg/L) (SKM 2003a)

Station	Monitoring Station	NOX	TN	FRP	TP	SS
405297	Warrigal Creek outfall	0.02	1.70	0.03	0.26	40
405757	Shepparton Drain 11	0.04	1.48	0.34	0.69	86
405758	Shepparton Drain 12	0.05	1.21	0.13	0.42	86
405720	Rodney Main Drain outfall at Wells Creek	0.03	0.52	0.01	0.08	66
405730	Toolamba Depression Drain outfall	0.20	1.46	0.07	0.17	50
406263	Mullers Creek, Murray Valley Highway	0.01	1.11	0.01	0.12	34
406265*	Campaspe River @ Echuca	0.03	1.03	0.01	0.10	20
406704	Deakin Main Drain Outfall	0.11	1.82	0.10	0.49	96
406750	Bamawm Main Drain @ Dargan's Bridge	0.02	1.82	0.20	0.43	35
406756	Mosquito Creek @ Curr's Road	0.01	1.51	0.10	0.38	35
406758	Bamawm Main Drain d/s Richardson's Lagoon	0.02	1.51	0.06	0.26	58
407712	Lockington Main Drain	0.02	1.02	0.10	0.23	29
409712	Murray Valley Drain 6	0.08	1.51	0.39	0.76	63
404210	Broken Creek @ Rices Weir	0.03	1.34	0.06	0.37	-
405232*	Goulburn River @ McCoy's Bridge	0.03	0.75	0.01	0.09	27
409207*	River Murray @ Torrumbarry Weir	0.01	0.40	0.00	0.05	-

NOX = oxidized nitrogen; TN = Total Nitrogen; FRP = Filtered (0.45 micron) Reactive Phosphorus;
TP = Total Phosphorus; SS = Suspended Solids.
** Not an irrigation drain - for comparison purposes only*

Water quality in drains does not meet ANZECC Guidelines (ANZECC 1992) and can be classified as degraded.

Trends in concentrations

SKM (2002) used a GAM (Generalised Additive Model) approach to detect trends in nutrient concentrations at the drain monitoring sites across the region. The analysis indicates that TN and TP concentrations are generally increasing in the irrigation drains and flows are predominantly decreasing. Trends in nutrient load were found to be decreasing at most sites, indicating the influence of flow on nutrient export loads. Flow trends were analysed independent of the effects of rainfall, irrigation deliveries and season, whilst trends in nutrient concentration were analysed independent of flow and season. This study also highlighted the distinct seasonality of nutrient concentrations. Summer concentrations of phosphorus are three to four times higher than winter. Nitrogen concentrations are higher in winter than in summer.

The seasonality of concentration is also apparent in nutrient load exports. Using the Deakin Drain as typical of all drains, 58% of the Total Phosphorus load is delivered to streams over summer (November to May (inc)). This is considered significant given the highest risk of cyanobacterial blooms occurring is in the late summer early autumn period. In contrast, the dryland catchment Total Phosphorus load (all sources) over the same period is 20.5%.

Annual Nutrient Loads

Nutrient and sediment loads from drains can be substantial and are highly influenced by annual rainfall patterns. Loads and exports rates over the past few years have been reduced due to dry conditions (Figure 1). Table 3 shows annual nutrient generation rates for irrigation drains. These vary substantially across the irrigation region and are generally substantially higher than rates fro m dryland catchments.

Table 3 Annual Nutrient Generation Rates based on Catchment Area (kg/ha) for NO_x, TN, FRP, TP and SS for 2001/02 (SKM 2003)

Station	Station	Catchment Area [ha]	Annual Nutrient Generation Rate [kg/ha]				
			NOx	TN	FRP	TP	SS
405297	Warrigal Creek	40,015	0.01	0.08	0.01	0.02	2.63
405720	Rodney Main Drain, Wells Creek	20,127	0.03	0.32	0.01	0.06	27
405730	Toolamba Depression	3,008	0.07	0.41	0.07	0.14	29
405757	Shepparton Drain 11	50,665	0.003	0.08	0.02	0.04	5.37
405758	Shepparton Drain 12	15,062	0.03	0.57	0.10	0.21	41
406263	Mullers Creek, Murray Valley Highway	7,939	0	0.02	0	0.003	0.73
406265	Campaspe River at Echuca	N/A	N/A	N/A	N/A	N/A	N/A
406704	Deakin Main Drain Outfall	195,509	0.01	0.06	0.01	0.02	3.02
406750	Bamawm Main Drain at Dargan's Bridge	14,217	0.01	0.27	0.05	0.10	11
406756	Mosquito Creek at Curr's Road	40,677	0.003	0.03	0.001	0.01	1.09
406758	Lockington Main Drain adjacent to Richardson's Lagoon	N/A	N/A	N/A	N/A	N/A	N/A
407712	Lockington Main Drain	27,413	0.002	0.11	0.02	0.04	4.19
409711	Murray Valley Drain 3	11,568	N/A	0.25	N/A	0.003	N/A
409712	Murray Valley Drain 6	19,111	0.11	1.44	0.48	0.83	82

N/A – Area, flow or nutrient data unavailable

Sources of water and nutrients in drains

Water in irrigation drains can originate from a number of different sources, including:

- tailwater, from an irrigation area, district or farm resulting from excess applied irrigation water
- tailwater as above plus storm event induced runoff (occurs in the irrigation season)
- storm event runoff (non-irrigation season).

ANCID (1998) defines ***tailwater*** as the "flow of surface water from a given area resulting from the effects of applied irrigation water in excess of crop water requirement and leaching". ***Drainage runoff*** is defined as the "flow of surface water from a given area resulting from the effects of rainwater and/or applied irrigation water in excess of crop water requirement and leaching". Management options need to take into account these different sources of water. In most drains the bulk of nutrient loads reaching streams occur in high flow events associated with storms (Smith and Carey 2002). These can occur at any time of the year.

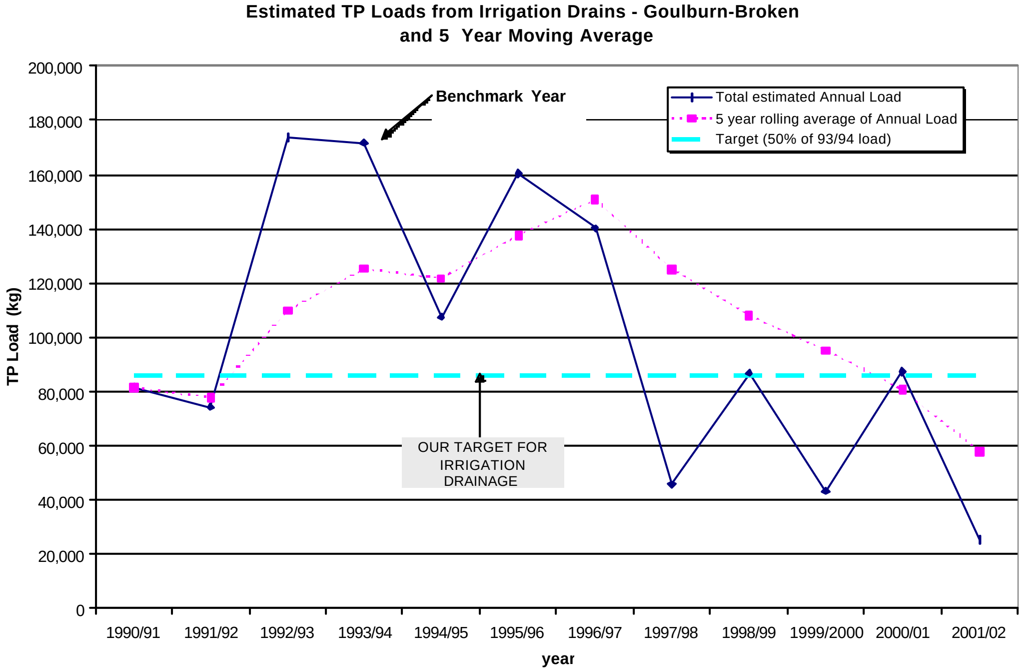

Figure 1 Total Phosphorus (tonnes/year) Exported from Irrigation Drains in the Broken and Goulburn Catchments

Irrigation Drain Nutrient Sources/Contributors.

Consideration of potential land use nutrient export rates and land use suggests that the major land use contributing nutrients is irrigated perennial pasture. Potential land use nutrient export rates are calculated as follows, and are shown in Table 4:

*Potential land use export rate (kg/ha) = Water applied (ML/ha) * (% runoff) * (estimated nutrient concentration (mg/L).*

*Potential land use nutrient contribution (kg) = land use export rate (kg/ha) * area of that land use (ha).*

Consideration of Table 4 indicates the need to concentrate nutrient management activities on perennial pasture. However, catchment audits identified urban stormwater and industrial outfalls as significant contributors of nutrients that require management. The potential nutrient loads are considerably higher than those actually measured at drain outfalls. This may be due to reuse of water and nutrients on farm and along drains, the non conservative nature of nutrients and uncertainties associated with calculations.

Table 4: Potential Nutrient export rates for the irrigation season and over the non-irrigation period and Potential Land Use Nutrient Export rates (GBWQWG 1995).

IRRIGATED LANDUSE	EXPORT RATES (kg/ha)						
	Irrigation season		Non-irrigation period		Area of Land Use (ha)	Potential Nutrient Load kg	
	TP	TN	TP	TN		TP	TN
Perennial pasture(a)	8.36	13.1	0.30	0.8	145,630	1217458	1907739
Annual pasture	1.22	3.0	0.15	0.4	112,297	137002	336891
Crops	1.77	6.7	0.12	0.5	12,997	23004	87079
Vegetables	1.62	8.1	0.15	0.8	11,846	19190	95952
Fruit - surface drainage	0.23	4.5	0.04	0.8	1,671	384	7519
Fruit - subsurface drainage	0.18	90.9	0.02	7.6	-	-	-

(a) TP irrigation season rate includes allowance for increased TP concentrations in the period following fertiliser application.

Biocides (weedicides and pesticides), Heavy Metals and Pathogens.

Sampling and analysis in 1998 and 1999 for the presence of a range of biocides and heavy metals did not detect the presence of biocides in drain sediments at eight different locations across the region. Some metals were detected but only at concentrations below ANZECC guidelines for environmental impact, where those guidelines existed. Sediments were analysed in preference to water since concentrations of biocides in surface waters are likely to occur in short duration spikes which are difficult to detect in a spot sampling program. Since many biocides bind to suspended sediments, sampling of bed sediments generally gives a better picture of biocide contamination on a region wide scale. Further sampling in at 13 sites in 2001 detected a low level of a DDT breakdown product at one site. The overall impression is that biocides and heavy metals are not a major issue in irrigation drains of the Shepparton Irrigation Region. This is not altogether surprising given the virtual zero use of biocides on the major land use type, irrigated perennial pasture.

Monitoring of pathogens using E.coli and faecal coliforms as indicators showed high levels of pathogen contamination in half the drains sampled. Some sites displayed large temporal variation in pathogen levels while other sites showed little variation from week to week.

Management of Nutrients

A number of principles have been adopted for the management of sediment and nutrients in irrigation drain water. These include:

Adoption of key policy directions by irrigation peak organisations - Peak groups in the irrigation industry have adopted key policy directions for minimising the environmental impacts of sediment and nutrients from irrigation return water. The principles provide leadership and guidance for the various sectors of the industry. At the same time peak organisations must promote the message that sustainable irrigation is not possible without sustainable drainage.

Systems, or catchment, approaches – Management of sediment and nutrients from irrigation return water is examined in an overall catchment context, which initially establishes how important irrigation drainage is, then establishes the impacts and finally agrees on the targets or objectives. This approach considers the various components of tail water - excess irrigation water, irrigation and non irrigation season stormwater – and the targeting of those components where the greatest gains can be achieved at the least cost.

Treating problems at source - As a guiding principle it is best to prevent pollution at the source and therefore it is better to concentrate sediment and nutrient control efforts on the farm. However, even with the best management, water, nutrients and sediment will leave the farm in some events, so there has to be focus on management aspects on, and off, farm.

Risk based approaches- Ensure that the critical issues are addressed.

Scale issues are a concern. It is difficult to transfer results from plot to paddock to farm to sub catchment scale and may lead to erroneous conclusions. Different processes may be important at different scales.

As part of the Goulburn Broken Water Quality Strategy programs to address the issue of nutrients from irrigation drainage have been developed and are being implemented. These programs are closely integrated with implementation of the Shepparton Irrigation region Land Water Salinity Management Plan. Management activities revolve around two key elements, farm and drain, and typically focuses on minimising the flows of water from farms to drains and from drains to regional waterways. Management of sediment has yet to be seriously addressed, although activities to manage the volume of water in drains has an impact on sediment loads.

Farm Nutrient Management

As shown above irrigated pastures are significant contributors of nutrients to drains. On farm nutrient management involves farmers adopting a range of best management practices, including fertiliser management, dairy effluent management and on farm reuse of irrigation water. Bush and Austin (2001) showed that efficiency of applied phosphorus use could be substantially improved by delaying irrigation by three days after fertilizer application. Such practices aim to reduce the load of nutrients leaving the farm and entering drains.

Drain Nutrient Management

Once water and nutrients have reached the drain the emphasis is on minimising the load of nutrients leaving the drain. Strategies are being implemented to encourage the diversion of excess flows in drains for productive uses. Some landholders are building large storages (~200 ML) to divert excess flows in drains for later use for productive purposes. Other sources of nutrients in drains, for example from industry, are also targeted for action. Industrial sources in the Deakin Drain in 1993/94 were estimated to be 8.3 t of TP. In 1998/99 these were estimated to be less than 3 t of TP.

Projects to investigate the impacts of altered drain construction and management programs are underway. The use of in drain wetlands for drainage water treatment is being investigated. (SKM 2003b). Another option may the construction, by regional water authorities, of large storages (or wetlands) along drains be built to minimise flow.

Finally, when drainage water and nutrients leave the drain monitoring programs need to be in place to determine whether or not management activities are achieving Strategy objectives.

CONCLUSION

Irrigation drainage is a significant source of nutrients. However nutrinets from this source can be managed, subject to consideration of dominant sources and cost benefit of management activities. Management activities implemented over the past 10 years appear to be reducing loads of nutrients delivered to regional waterways.

REFERENCES

ANCID (1998). Rural Water Industry Terminology and Units. Australian National Committee on Irrigation and Drainage.

Bush, B.,and Austin, N. (2001). Timing of Phosphorus Fertilizer Application within an Irrigation Cycle for Perennial Pasture. J. Environ. Qual. 30:939-946.

Goulburn Broken Catchment and Land Protection Board. (1997). Goulburn Broken Catchment Water Quality Strategy 1997.

Goulburn Broken Water Quality Working Group (GBWQWG). (1995). Issues Paper No 5. Nutrients in Irrigation Drainage Water from the Goulburn and Broken Catchments.

SKM (2000). Shepparton Drain Nutrients – Review of Monitoring Frequency. September 2000. Sinclair Knight Merz.

SKM (2002). C806 A&B Shepparton Drain Nutrient. Trend Analysis of Nutrients in Irrigation Drains in the Shepparton Irrigation Region. Sinclair Knight Merz.

SKM (2003).a). Nutrients in Irrigation Drains in the Shepparton Irrigation Region - July 2001 to June 2002. Sinclair Knight Merz.

SKM (2003) b) Final Report on Nutrient Removal from Rural Drainage Systems using Wetlands. Sinclair Knight Merz.

Smith, G. and Carey, R. (2002). Cumulative Nutrient Load Analysis for Surface Drains in the Shepparton Irrigation Region. Goulburn-Murray Water.

SPAC (1995). Shepparton Irrigation Region Surface Drainage Strategy.

Note: A number of these references are available in electronic format from the author.