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ASSESSMENT OF THE SUCCESS OF THE PEEL-HARVEY ESTUARY SYSTEM MANAGEMENT STRATEGY – A WESTERN AUSTRALIAN ATTEMPT AT INTEGRATED CATCHMENT MANAGEMENT

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ABSTRACT

The Peel-Harvey estuary and its catchment have been the subject of intensive investigation and management since the late 1970s, because of concern about worsening algal blooms and their associated impacts. After diagnosis of the problem, possible management options were assessed in the light of the available technical information, and a management strategy developed and implemented.

Various Integrated Catchment Management (ICM) approaches have been used, including voluntary reduction of fertilizer use, and the construction of a new channel to the ocean to achieve an appropriate socio-environmental solution. Innovative approaches were also taken in developing statutory and non-statutory management targets and land-use controls and guidelines. To date these measures appear to have been successful, although some of them are vulnerable in the long term.

This is currently the best Australian example of an ICM approach to the management of a complex environmental problem which has actually been implemented. It is also a good example on a world scale of addressing an environmental problem using a systems approach with an appropriate socio-environmental solution.

KEYWORDS

Algae; estuary; eutrophication; flushing; Integrated Catchment Management (ICM); land-use controls; *Nodularia*; phosphorus.

BACKGROUND

The Peel-Harvey estuary system lies about 70 km south of Perth in Western Australia (see Fig. 1). The area of the two basins is about 133 km^2 and average depth is about one metre. Most of the annual river input to the estuaries occurs over a 12-week period in winter. The area is prone to winter waterlogging and has been extensively affected by artificial drainage channels. Until recently, a single channel to the ocean (the Mandurah Channel) formed the only natural link for water exchange. The coastal part of the catchment has been extensively cleared of deep-rooted vegetation to support agricultural activities including grazing, dairying, intensive animal industries such as sheep yards for live sheep export and piggeries, and intensive horticulture. The coastal catchment soils have a naturally low phosphorus level and application of fertilizers is necessary. The soils are sandy and have a low phosphorus adsorption capacity. As a result a high proportion of the nutrients applied or produced in the catchment is rapidly lost from the catchment and reaches the rivers and estuaries. The system provides an ideal environment for algal growth because of the physiography, high phosphorus levels, poor water exchange with the ocean and high water temperatures (Hodgkin, *et al.*, 1980).

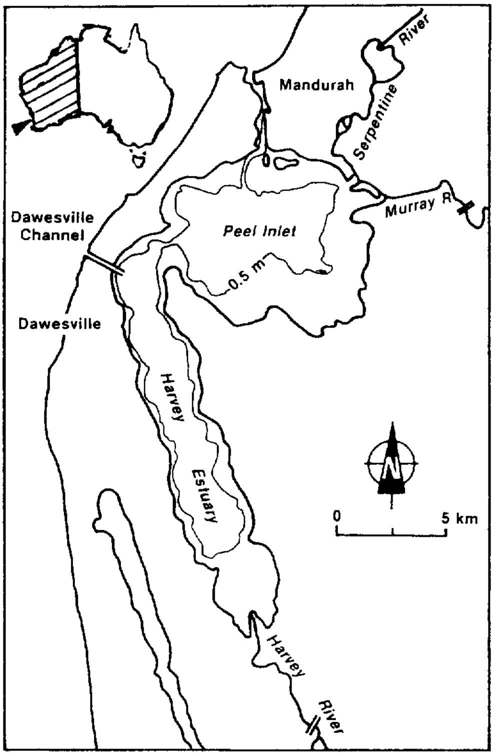


Figure 1. Location map of Peel Inlet and Harvey Estuary, showing the alignment of the Dawesville Channel and the main elements of the coastal plain drainage to the estuary.

Problems in the Peel Inlet were identified in the mid-1960s when large amounts of green algae were beached close to houses where they decomposed and caused a foul smell. The algae also caught in fishing nets and tangled boat propellers. It was thought to have reduced tourism and recreational enjoyment of the region and depressed property values.

In 1973 the problems became more severe when large blooms of the nitrogen-fixing cyanobacterium *Nodularia spumigena* occurred in the Harvey Estuary. This indicated that the system was severely nutrient-enriched (eutrophic) and deteriorating and that management was urgent. Research quickly showed that it would be necessary to reduce the amount of available phosphorus in the system if *Nodularia* was to be controlled, as the organism could fix atmospheric nitrogen

EVOLUTION AND DEFINITION OF THE PROBLEMS

European agricultural development of the coastal plain catchment has caused massive changes to the patterns of runoff and phosphorus loading to the estuary, summarised in Table 1.

Table 1. Estimated changes in the estuary system under pre-development, and pre- and post management conditions*

	Flow pre-clearing	Flow post-clearing	TP pre-clearing	TP post-clearing	Target TP	TP Load pre-clearing	TP Load post-clearing	Target TP Load
Harvey River and Drains	126	221	0.02	0.37	0.185	2.52	82	40.9
Serpentine River and Drains	20	115	0.02	0.36	0.18	0.4	41	20.7
Murray River	160	260	0.02	0.08	0.04	3.2	20	10.4
Total to Estuary	306	596				about 6	143	72.0

*Units are millions of cubic metres per year for flow, concentrations in milligrams per litre for total phosphorus (TP), and tons per year for phosphorus load

Much of the coastal plain catchment has infertile, swampy, sandy soils, with poor phosphorus retention properties. Artificial drainage and application of phosphatic fertilizers with trace elements was essential to allow the establishment of agriculture in the area.

Clearing, drainage and application of fertilizer for agriculture on the swampy coastal plain has caused an estimated doubling of the annual river inflow, an 18-fold increase in flow-weighted phosphorus concentration and a more than 20-fold increase in median annual phosphorus load to the estuary over about 30 to 40 years. About 245 m^3 of water is diverted each year from the hills catchments for metropolitan supply, and discharged to sea as irrigation tailwaters via a drain. This has prevented an additional phosphorus load of about 40 tons per year from entering the estuary.

IDENTIFICATION AND ASSESSMENT OF MANAGEMENT OPTIONS

Humphries and Croft (1984a,b,c) carried out a review of a wide range of possible management options, including all proposals from the public and extreme proposals such as using explosives to sink positively buoyant algae. They carried out a preliminary assessment of the advantages and disadvantages and costs of the various methods. Several emerged as the most feasible in terms of their ability to significantly reduce, remove or attenuate phosphorus. The Stage 1 environmental assessment process narrowed down the options to a few worthy of more detailed examination during Stage 2. These are listed below and the advantages, disadvantages and uncertainties of each are summarised in Table 2.

DEVELOPMENT OF MANAGEMENT TARGETS FOR THE ESTUARY

Humphries and Croft (1984b) made a first attempt to define a permissible phosphorus load target and used a variety of approaches, including that of Vollenweider (Vollenweider, 1975, 1978). They concluded that a 70 percent reduction in the observed average annual phosphorus load to Harvey Estuary was required to achieve a maximum *Nodularia* bloom frequency of one year in five, and that this could be achieved by a combination of a 40 percent reduction in average annual phosphorus losses from the coastal catchment, and by the construction of a new channel to the ocean from the northern end of Harvey Estuary. This channel (the Dawesville Channel, or "Cut"), would increase the flushing rate of Harvey Estuary fourfold, and also significantly increase the flushing of Peel Inlet (see Figure 2). They did not attempt to predict the likely effects of this level of increased flushing or nutrient load reduction on the Peel Inlet macroalgal population.

Table 2. A summary of the major management options considered, their advantages, disadvantages and key uncertainties

Component Options of the Strategy		Implications of Each Option		
Short-term (3-5 years)	Long-term (> 5 years)	Advantages	Disadvantages	Key Uncertainties
Weed Harvesting		Reduction in weed accumulation and decomposition on beaches	Minimal reduction of nutrients; no effect on *Nodularia*; loss of beaches and fringing vegetation	
Agricultural Fertilizer Management		Reduction in nutrient loads to estuary; small saving for farmers; reduced algal bloom intensities or frequencies.	Minimal short-term depletion of sediment nutrients.	Fragile, as relies on voluntary farmer co-operation over extended period; time needed for significant reductions of phosphorus in catchment soils and estuary sediments.
Dawesville Channel		Reduction in nutrient availability for algal growth; provides hostile habitat for *Nodularia*; improved flushing and estuary water quality; opportunities for development.	Large COST; possible short-term increase in macroalgae.	Time taken for available phosphorus reduction in sediments; alteration of estuary faunal composition and production; change to waterbird feeding & loafing areas; concern about nearshore flooding and increased mosquitoes.
Dredging of Mandurah & Sticks Channels		Improved navigation; improved flushing and oxygenation of northern Peel inlet	Minimal beneficial effect on Harvey Estuary.	Time taken for levels of available phosphorus reduction to be lowered in sediments.
Application of Algicides		Short-term control of *Nodularia* and macroalgal growth.	Repeated applications and ongoing costs; may increase estuary phosphorus retention and cause deoxygenation.	Effectiveness against algae; unknown effects on non-target species.
Nitrate Treatment of Sediments		Potential for inhibition of sediment phosphorus release.	Repeated applications and ongoing costs.	Duration and effectiveness of suppression of phosphorus release.
Control of Rural Point Sources of Nutrients		Reduced phosphorus load to estuary and streams.	Owner/operator resistance and costs to individuals.	Extent of phosphorus contribution.
	Changes in Land Use, e.g. forestry.	Reduction in phosphorus load to estuary and to amount of flow in streams.	Farmer resistance; lack of adequate silvicultural knowledge.	Effectiveness and time to reduce phosphorus inputs to the required levels and maintaining them.
	Controls Limiting Further Clearing and Draining.	Prevents further increases in phosphorus and water inflows to the estuary.	Farmer resistance and costs to individuals.	
	Soil amendment with Bauxite Residue.	Improves phosphorus and moisture retention in leaching soils.	Cost and lack of acceptance by farmers.	Cost-effectiveness, duration of effect; effects of trace contaminants in residue.

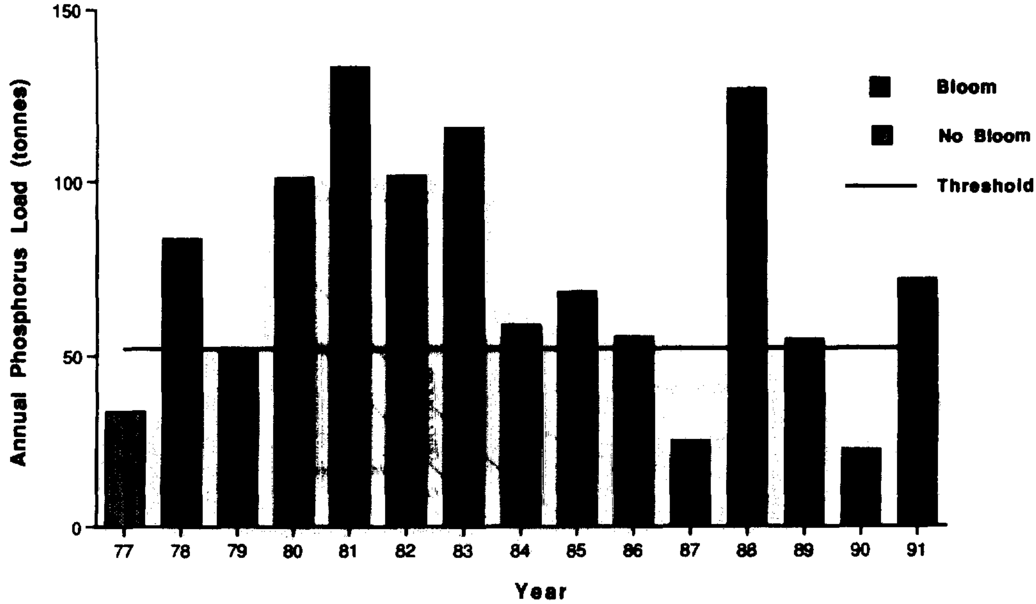


Figure 2. The relationship between annual external phosphorus loads to Harvey Estuary and the occurrence of blooms of *Nodularia spumigena*, showing that *Nodularia* blooms occur only in years in which total phosphorus loads to Harvey Estuary exceed 50 tons.

The preliminary analysis by Humphries and Croft was properly developed during the Environmental Protection Authority's (EPA) environmental impact assessment of the proposed management strategy for the estuary (EPA, 1985, 1988). The EPA supported a combined management strategy of catchment management measures and the proposed new channel to the ocean. The channel would increase flushing of the estuary, alter the salinity regime, which would deter germination and inhibit growth of *Nodularia*, and improve sediment oxidation (to inhibit phosphorus release from the sediments).

The Environmental Review and Management Programme Stage 2 (Kinhill Engineers, 1988) proposed as a management target that the total phosphorus load to the whole estuary should never exceed 85 tons per year. The EPA developed a probabilistic approach to allow for the natural variability of the system and applied a 60 percentile recurrence frequency to the 85 ton objective. This meant that the permissible phosphorus load to the whole estuary should be 85 tons or less in 60 percent of years. The equivalent 50 and 90 percentile median phosphorus loading criteria were 38 tons per year to Harvey Estuary and 37 tons per year to Peel Inlet, reductions from the observed 11-year mean loads of 136 and 58 tons respectively. These recommendations implied that the mean flow-weighted phosphorus concentrations in water flowing to the estuary should be reduced by about half, or that the amount of river and drain inflow to the estuary should be appropriately reduced.

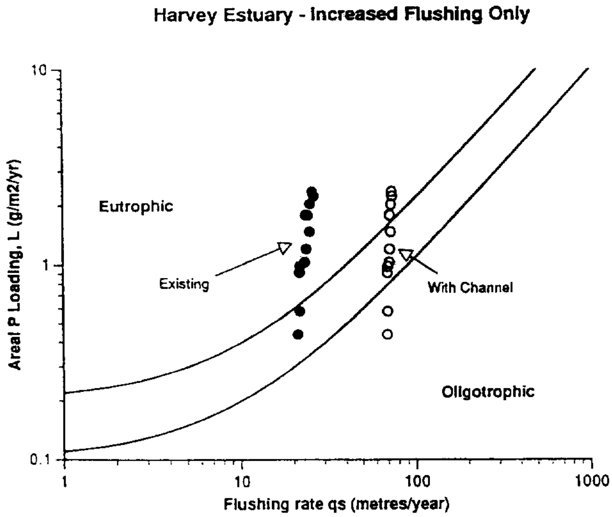
The EPA proposed the following qualitative and quantitative water quality management targets:

"to produce and maintain an estuary system that is visibly clean and healthy and ecologically healthy and resilient" (EPA, 1985). In the 1987 assessment the objective became "the Peel-Harvey system is clean, healthy and resilient" (EPA, 1987);

"annual phosphorus input to the system is not to exceed 165 tons in 9 years out of 10" (EPA, 1987); and

"average phosphorus concentration in estuary water is not to exceed 0.02 milligrams per litre in 9 years out of 10 (on average) (EPA, 1987).

The latter two became statutory targets when the Minister for the Environment set environmental conditions allowing the project to proceed. They were also stated in an Environmental Protection Policy (EPP) (EPA, 1992) which required all activities in the coastal catchment to focus on attainment of the targets. The statutory EPP also linked with a complementary Statement of Planning Policy, which specified the catchment planning measures needed (Department of Planning and Urban Development, 1992).



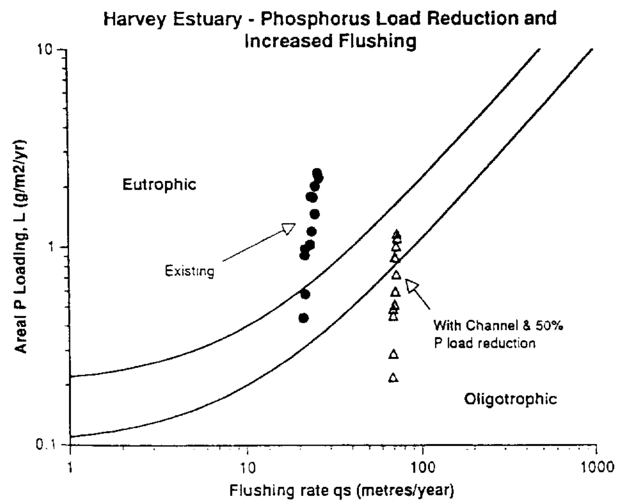


Figure 3. A Vollenweider plot showing the effects of increasing flushing only, and increasing flushing and reducing observed phosphorus loads by 50 percent on the trophic status of Harvey Estuary.

The EPA's conclusions were based on the application of Vollenweider's (1975, 1978) phosphorus loading criteria (see below), combined with the observation that *Nodularia* blooms in Harvey Estuary were triggered by annual external phosphorus loads of more than about 50 tons, and did not occur if annual external phosphorus loads were lower than 50 tons (see Figure 3). Once *Nodularia* blooms are initiated, the peak biomass reached is not related to the size of the external phosphorus load, as the blooms make use of sediment-stored phosphorus released during periods of anoxia in the estuary water and fix atmospheric nitrogen.

The combined effects on Harvey Estuary of reducing phosphorus loads from the catchment and increasing estuary flushing by dredging the existing Mandurah Channel and by building the Dawesville Channel are shown in Figure 2. The revised flushing estimates are based on recent modelling work done by the Department of Marine and Harbours (Department of Marine and Harbours, 1993). The estimates indicated that Harvey Estuary would be more dramatically affected than Peel Inlet, with marine flushing increasing about fourfold, and the estuary being moderately nutrient-enriched (mesotrophic) for most of the time.

IMPLEMENTATION OF MANAGEMENT AND ACHIEVEMENTS TO DATE

Catchment management, including planning controls, has resulted in a statistically significant downward trend of phosphorus loads to the estuary – the phosphorus loads before management was initiated have been reduced by about 40 percent to date (see Table 3). Significant further improvement is unlikely, while reducing fertilizer input remains a voluntary activity and not a requirement.

Table 3. Reduction in annual phosphorus loads to harvey estuary (from Bott, 1993)

Before Fertilizer Management (1977-1982)		After Fertilizer Management (1983-1988)		% P Reduction	Soil Phosphorus Rundown (1989-1991)		% P Reduction
Total P (tons)	Flow ($10^6 m^3$)	Total P (tons)	Flow ($10^6 m^3$)		Total P (tons)	Flow ($10^6 m^3$)	
89	225	75	225	16%	50	209	40%
Running P Concentration = 0.40 mg/ℓ		Running P Concentration = 0.33 mg/ℓ			Running P Concentration = 0.24 mg/ℓ		

Note: all numerical values quoted are mean values

The $60 million Dawesville Channel was opened in April 1994, and although the full monitoring data for the subsequent period are not yet available, measurements of tidal levels, chlorophyll$_a$ and water clarity suggest that it is working, at least to the level predicted. In addition, the usual spring and summer bloom of *Nodularia* has not occurred.

Perhaps the greatest achievement has been the unified sense of purpose and determination to improve the state of the estuary by a majority of those in the community and government, and the achievement of a socio-environmental compromise. The construction of the channel was supported by the general community and enabled significant and valuable agriculture to continue in the Peel-Harvey catchment.

VULNERABILITIES OF THE STRATEGY

As with any attempt to restore a complex system, the Peel-Harvey Management Strategy is not an absolute solution and is vulnerable in a number of ways. The West Australian (WA) Government was advised to delay construction of the Dawesville Channel until the level of co-operation of the rural community in reducing phosphorus inputs could be gauged. This was essential because the channel alone would not result in the necessary reduction in phosphorus in the system, and if farmer co-operation was not forthcoming, would be a waste of money. The strategy depended on reduction of nutrient inputs from the catchment in combination with the channel to be successful.

Although rural co-operation has been impressive to date, and an appropriate administrative and legal framework has been developed, at least for the short-term, the strategy remains vulnerable in the long term in a number of areas, as follows.

The fertilizer management (reduction) programme is applied in a voluntary manner. Currently compliance is about 70 percent of farmers. This is regarded as a very high figure by the WA Department of Agriculture, but not good enough by others. The non-compliance level of 30 percent is of considerable concern to environmental managers, both because of the phosphorus contribution this represents as well as the negative example it sets to other farmers. Whether some of those currently complying decide that they too will not remains to be seen.

The coastal catchment has some complex problems, such as increasing salinity levels in soils in some areas, for which the management method of choice is to install drainage. Even though annual applications of phosphorus are not needed in the catchment, most areas do require regular applications of sulphur, potassium and trace elements. The cheapest way to apply these at present is by using superphosphate, even though the phosphorus will simply be lost to the estuaries. These matters should not be a problem for the management strategy but are due to a lack of appropriate advice to farmers given by the Department of Agriculture, which focuses narrowly on production considerations and neglects the government strategy and custodial aspects.

In the Western Australian setting, local governments are responsible for statutory planning in their areas and in most cases rural land is either uncontrolled or is subject to sophisticated levels of planning control. Even where the state government has particular concerns, these do not necessarily have to be taken into account by local authorities. In the case of Peel-Harvey, enforcement of the environmental targets was achieved by means of the Ministerial Conditions (statutory) and an Environmental Protection Policy (statutory). These provided broad environmental constraints on planning and land use in the area. It was useful to have the targets translated more specifically into types of land use which were and were not acceptable. This was achieved at the strategic level through a Statement of Planning Policy, and at a local level by incorporation of considerable detail about rural land use into local government town planning schemes and rural strategies. Although this approach was not perfect, any control of rural land use by means of the planning statues represented an innovative approach for Western Australia.

Notwithstanding the above, the apparent legislative underpinning is vulnerable in the longer term because:

- all Environmental Protection Policies must be reviewed no later than seven years after development; in this case it will be 1998.
- the Statement of Planning Policy is non-statutory and can therefore be cancelled by the state government at any time.
- aspects of the planning approach and controls are very "soft" and vulnerable to change; and
- it is almost impossible to monitor or enforce the environmental limits or planning controls on an individual property basis. One can only measure performance over a whole catchment or subcatchment. This also makes it difficult to give fair credit to people who are now doing the right thing.

The construction of the Dawesville Channel has provided a new and attractive development node. Indeed the cost of construction was financed through a joint venture between the developers, who owned the land along the alignment, and the State Government, and development approval was part of this agreement. Because of this, the channel design was changed and marinas have been built on each side behind the main channel. In addition, the area has always been subject to considerable pressure for additional residential canal developments. As water quality in the estuary improves, this pressure will become greater. Some areas are inherently unsuitable for this type of development (the system is an important area for water birds and migratory waders and is affected by several international conventions) but they may prove impossible to prevent.

There has already been inadequate pressure applied by governments to intensive rural and animal industries in the Serpentine catchment to reduce phosphorus inputs and losses to the system, with the result that phosphorus inputs from this area have increased while decreasing in other areas. The means of control exists through pollution control and licensing provisions under the Environmental Protection Act. As several of the industries have an asset value in the order of millions of dollars, successive governments have been reluctant to apply pressure for them to move, because of fears of compensation.

There is a lack of cost-effective technologies for management of urban stormwater.

There appears to be a lack of real commitment from some landholders to other aspects of catchment management designed to retain water in the landscape. Such aspects include large-scale tree planting and rehabilitation of swamps so they act as wetland filters. There is also lack of provision of appropriate incentives by governments to facilitate works on a suitably large scale.

There is ongoing tension between the various proponent government agencies, in particular between those agencies whose focus is development (whether it be agricultural, industrial or urban development) and those agencies with a management focus. This means that private developers are often provided with conflicting advice from within the state government system and are not sure whose advice to follow.

All of the above will need to be monitored closely and strategies developed to prevent the management strategy from failing in the long term.

CONCLUSIONS

Although it took about fifteen years overall to arrive at a management solution, it is a fine example of turning scientific investigation and information into on-the-ground management of a whole system.

The development of an innovative administrative structure to support implementation involved a combination of top-down (government) statutory instruments as well as community-up voluntary measures. It is the first example of an integrated catchment management approach taken in Western Australia and still stands as the best Australian example to date.

The management measures installed are already working. The Dawesville Channel appears to be performing better than predicted and reduction in phosphorus loads are almost on target, except for the Serpentine Catchment which may become worse if tighter controls on intensive activities are not implemented.

The Peel-Harvey Coastal Catchment area may lend itself well to trialling the approach of transferable pollution entitlements, whereby a high phosphorus polluter may achieve their necessary reduction by purchasing land from another part of the coastal catchment which can be left fallow or used to plant extensive areas of deep-rooted vegetation.

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