# The Environmental Condition of the Vasse Wonnerup Wetland System and a Discussion of Management Options

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# THE ENVIRONMENTAL CONDITION OF THE VASSE WONNERUP WETLAND SYSTEM AND A DISCUSSION OF MANAGEMENT OPTIONS

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**THE ENVIRONMENTAL STATUS AND A DISCUSSION OF MANAGEMENT OPTIONS FOR THE VASSE-WONNERUP WETLAND SYSTEM**


## SUMMARY

The Vasse - Wonnerup wetland system is a series of highly modified estuary basins with a common connection to Geographe Bay. The two main basins have one-way floodgates positioned in the exit channels to prevent tidal inflows and hence saltwater inundation of fringing grazing lands. The operation of the floodgates has resulted in the conversion of a tidal estuary into fresh to brackish lagoons. The lagoons become increasingly saline as they dry over the hot dry summer, often becoming hypersaline by autumn.

Nutrient loads to the system from the surrounding agricultural catchment are the highest measured into any waterbody in the southwest of Western Australia. If the lagoons did not dry out over summer, they would undoubtedly suffer from very severe algal blooms. Fish kills have regularly been reported behind the floodgates in late summer when water levels are low and water quality is very poor.

The wetlands are now known to be the most important waterfowl breeding habitat in the southwest of Western Australia. This is thought to be the result of retaining fresh water in the lagoons and increased productivity from the high nutrient loads.

It appears from this preliminary evaluation, that maintenance of the current hydrological regime is necessary to prevent severe, broadscale deterioration of the wetlands. It also appears that local management is required to prevent further fish deaths over summer and that a barrage constructed to form a lock system would be an appropriate method.

Without competent management, the high nutrient loads, low tidal flushing and continued development of adjacent land constitute a recipe for environmental degradation. Currently, the wetlands are only managed as compensation basins. Considering the very high conservation value of the wetlands this is not satisfactory, and with this in mind a number of potential management options have been outlined in this report for discussion and further evaluation. This is seen as a step towards producing a management plan for the wetlands and that catchment. A multi-disciplinary approach to management is considered more appropriate considering the number of different issues involved.

Recommendations for further investigations are made.

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## 1 INTRODUCTION

Following major fish kills in the channel of the Vasse arm of the Vasse-Wonnerup estuary, a study to understand the causes of the problem, and to identify potential solutions, was conducted by the Environmental Protection Authority. Fish kills have previously occurred in the channel, notably in 1984 and 1976, but none have been of the scale of the 1988 event. This paper assesses the potential for management of water quality in the Vasse-Wonnerup system and seeks to reduce the risk of further fish kills while retaining the estuaries' conservation value. The maintenance of agricultural productivity in the surrounding catchment is also addressed.

The wetlands of the Swan Coastal Plain have been subject to a dramatic reduction in both area and quality, resulting from factors such as drainage of both wetlands and catchments, nutrient enrichment and other forms of pollution, water level changes, grazing and landfill (Dept. Conservation and Environment, 1980; Dept. Fisheries and Wildlife, 1978). The Vasse-Wonnerup system, like other shallow estuarine basins in the south-west of Western Australia, is now exhibiting the symptoms of cumulative impacts from rural and urban development around the lagoon margins and in the adjacent catchments. These symptoms include a reduction in water quality caused by the excessive input of nutrients combined with a drastic reduction in tidal flushing from the operation of floodgates.

The Swan Coastal Plain is characterised by almost complete clearing of native vegetation for agriculture, followed by fertilizer application. These measures have largely been responsible for the nutrient enrichment, or eutrophication, of waterbodies downstream. The investigation of similar problems in Peel-Harvey estuary has identified five main reasons for the excessive leaching of nutrients, particularly phosphorus, into coastal waterbodies.

- limited nutrient-holding capacity of sandy coastal plain soils;
- high and strongly seasonal rainfall;
- shallow watertable;
- an efficient drainage network to drain waterlogged soils;
- over-use of fertilizers on land cleared for both broad acre and intensive agriculture;
- inadequate treatment of effluent from intensive animal industries;

(Birch, 1984; Yeates et al, 1985; Schofield et al, 1985; Humphries' et al, 1987 and Sanders et al, 1987).

Excessive quantities of nutrients in waterbodies stimulate the growth of algal blooms (Fig. 1) which often smother other aquatic vegetation such as seagrasses. Decomposition of this excessive load of organic matter raises the biochemical oxygen demand of the sediments and water column, often causing periodic odour problems. Deoxygenation of the water column may often occur under calm, stratified conditions and the resident fauna may be killed. Figure 2 shows the result of such an event behind the Vasse floodgates. Deoxygenation of the water directly over the sediments causes the further release of sediment-bound nutrients, and stimulates secondary

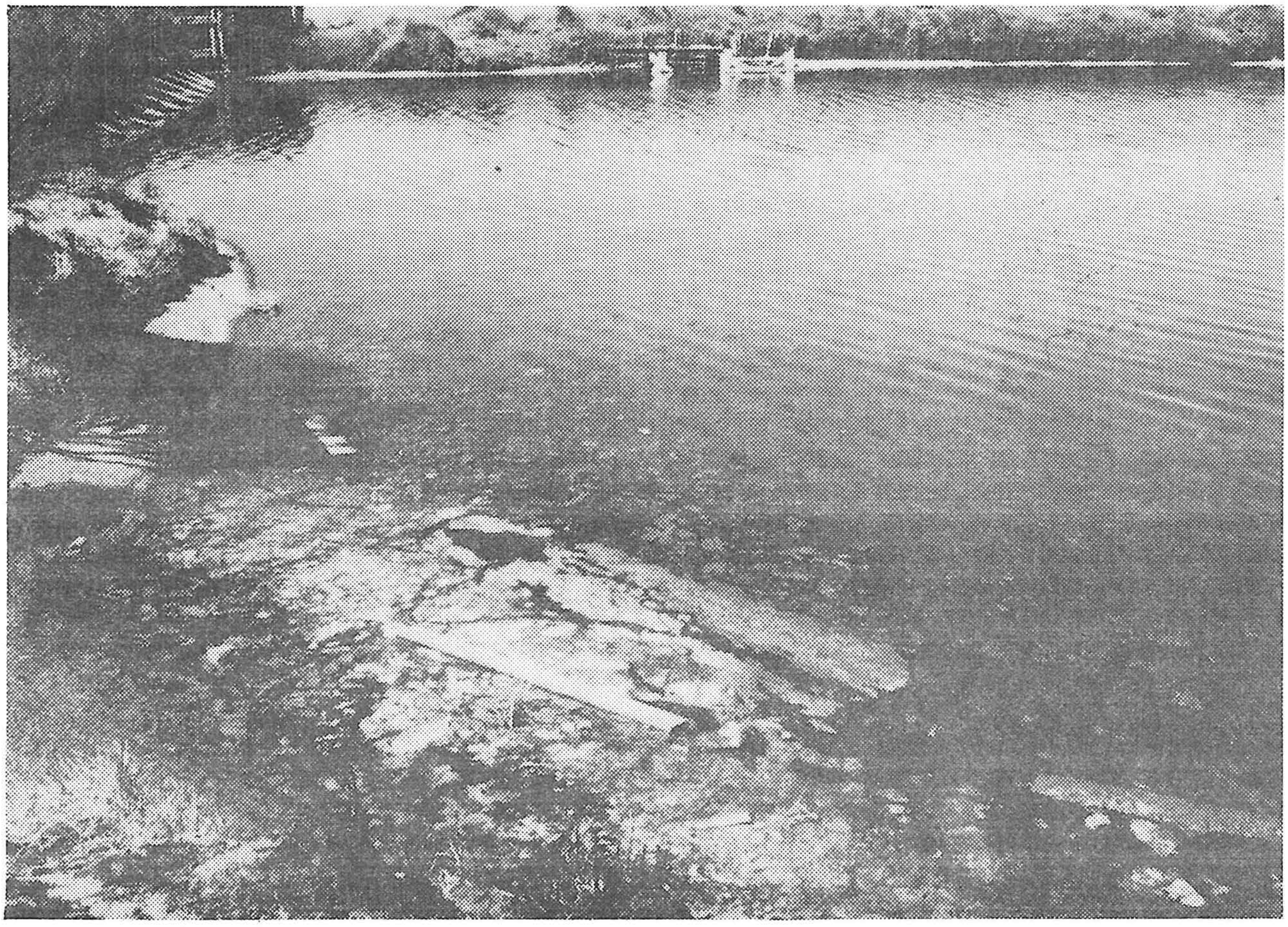

Figure 1. Algal scums on the surface of the Vasse Lagoon during summer.

Figure 2. Dead fish on the banks of the Vasse Lagoon and Wonnerup Inlet after the 1988 fish kill. (Photograph courtesy of Colin Bywaters, Busselton Photographic Centre).

algal blooms. These symptoms of eutrophication appear to be exacerbated in the Vasse-Wonnerup system by the decreasing water volume of the lagoons over summer and a corresponding rise in water temperature. As temperature increases, dissolved oxygen concentration in the water column decreases and biochemical oxygen demand increases.

Floodgates were constructed across the Wonnerup Inlet in both the Vasse and Wonnerup arms of the system in the 1930's to prevent saltwater intrusion onto farmland, while allowing winter outflow of freshwater. The construction of these floodgates greatly altered the hydrodynamics of both arms of the estuary, reducing marine flushing and turning the basins into fresh-to-brackish lagoons which can no longer be termed 'estuaries'. The gates have also diminished tidal currents in the channel, enhancing bar formation at the mouth of the system, which in turn has reduced water quality in Wonnerup Inlet downstream of the floodgates. Both the floodgates and the closed bar act as barriers against fish movement, inhibiting use of the system as a fish feeding and breeding ground.

The Vasse-Wonnerup wetland system was identified in the Conservation Through Reserves Committee report to the Environmental Protection Authority (Conservation Reserves in WA, 1974) as an area of high conservation value requiring protection and improvement. In 1976 the Environmental Protection Authority report on Conservation Reserves for Western Australia recommended that the Vasse-Wonnerup wetland system be managed for the preservation of existing scenic, recreational and tourism values and for the improvement of the wetland habitats (Conservation Reserves for WA, 1976).

The Vasse-Wonnerup wetland system is recognised as the most important breeding habitat for waterbirds in the State and the second most important in terms of bird numbers (J. Lane pers. comm.). However, its shorelines are under increasing pressure from residential, holiday and special rural development as the population of Busselton increases. There is now an urgent need to formulate a management plan for the system that addresses management of nutrient loss from the catchment, water quality within the lagoons, development adjacent to the lagoons and recreational use of the system. This report is intended to provide a number of management scenarios that may solve or at least ameliorate the current environmental problems of the Vasse-Wonnerup wetland system. The scenarios proposed are intended to stimulate discussion and provide a basis from which a long term management strategy for the Vasse-Wonnerup System can be developed.

In broad terms the objectives of the study are defined as follows:

1. To identify the nature and the causes of the problems;

2. To identify the uses and users of the wetland system;

3. To identify a range of potential management options and order of magnitude costings;

## 2. DESCRIPTION OF THE SYSTEM

The Vasse-Wonnerup wetland system consists of three interconnected coastal lagoons which are connected to the sea by the narrow Wonnerup Inlet channel (Fig 3). These lagoons consist of two larger waterbodies, the Vasse and Wonnerup lagoons and the much smaller Deadwater lagoon, with a total surface area of approximately 900 ha of open water (Table 1). The two larger

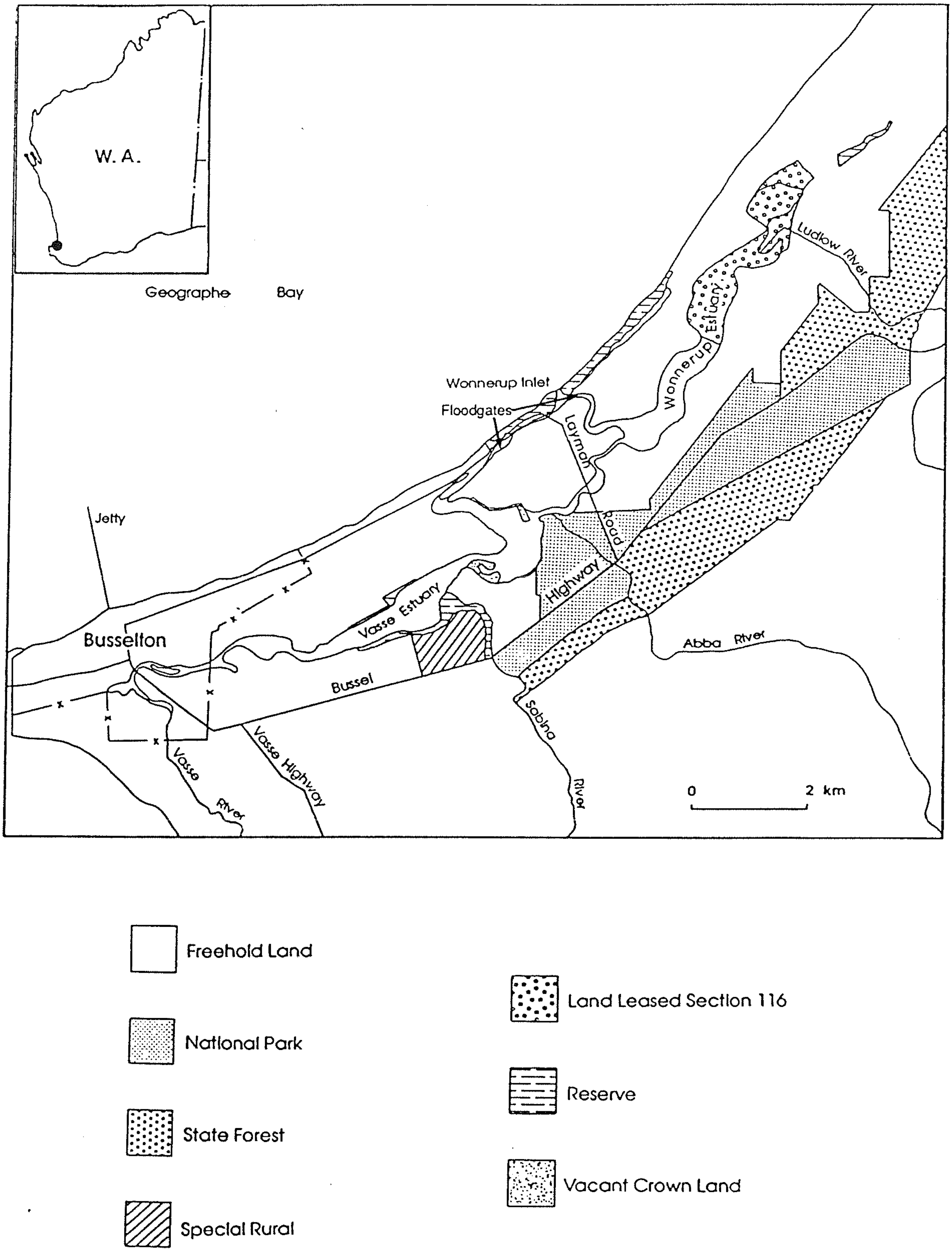


Figure 3. Map of the Vasse-Wonnerup wetland system showing location and surrounding land use.

waterbodies may also be interconnected by a shallow depression known as Malbup Creek, but only when water levels are high (greater than 0.8m AHD). The system is surrounded by a series of flat or undulating terraces which are marginally above sea level. As with most estuaries of the southwest of Western Australia, a seasonal sand bar forms at the mouth of the Inlet.

Table 1. Lagoon dimensions of the Vasse-Wonnerup Wetland System

| WATERBODY | AREA ($x10^6m^2$) | MEAN DEPTH (m) | VOLUME ($x10^6m^3$) |
|---|---|---|---|
| Vasse Lagoon | 5.9 | 0.5 | 3.0 |
| Wonnerup Lagoon | 3.1 | 0.5 | 1.6 |
| Deadwater | 0.3 | - | - |
| TOTAL | 9.3 | | 4.6 |

The Vasse-Wonnerup lagoons and their associated wetlands occupy a total area of approximately 1500 ha and have formed in the depressions between the Spearwood and more recent Quindalup dune systems. The dunes intersect the gently seaward sloping land, forming a natural barrier which intercepts inland drainage before it enters the ocean (McArthur and Bettenay, 1974). The main channel of the depression forms both the Vasse-Wonnerup lagoons and the Broadwater wetlands, and often contains permanent water over summer. The raised terraces surrounding the wetland system are inundated only in winter.

Historically, most of the rivers between Dunsborough and Bunbury flowed through the Vasse-Wonnerup system and out into Geographe Bay via the depression between the Spearwood and Quindalup Dune systems (Bretnall, 1987). With the development of agriculture along the coastal plain, most rivers were diverted directly to the ocean to reduce winter flooding of this relatively fertile strip of land.

The system now receives flow from only four rivers; the Vasse, Sabina and Abba Rivers feeding the Vasse Lagoon; and the Ludlow River flowing into Wonnerup Lagoon. The present combined catchment area of these rivers is 682 $km^2$, however, this catchment area is reduced to 405 $km^2$ during the major winter runoff period by artificial diversion of flows from most of the Vasse River catchment and about 60% of the Sabina River catchment directly to the ocean (Table 2). The diversion drain intersects both the Vasse and Sabina rivers and enters Geographe Bay west of Busselton, disconnecting the Broadwater wetlands from the Vasse-Wonnerup wetland system. The remaining downstream portion of the Vasse river is then managed by re-diverting water through at the beginning and end of winter. This contains the water level in the town section of the river to a maximum height of 0.45m AHD for aesthetic purposes, while also providing some flushing of this section with clean water. It was originally intended that flow down the Vasse River be maintained whenever possible, but this has not occurred in practice. The diversion system was built by the Water Authority of WA (formerly the Public Works Department) to cope with the increased flows resulting from clearing and drainage, and to prevent flooding in the relatively low lying town of Busselton during storms.

A levee bank was constructed in about 1965 across the northern end of the Wonnerup Lagoon. Its purpose was to prevent back flooding of the area by flood waters from the Ludlow River, which was diverted south of the levee.

## 2.1 THE CATCHMENT

The Wonnerup area was first settled between 1834 and 1837, with settlers taking advantage of the good grazing provided by the natural grasses occurring on the estuary flats. The patterns of land use surrounding the system have since changed (Fig 3), but remain predominantly agricultural. The area surrounding the Wonnerup Lagoon is still utilized mainly as summer grazing land with some irrigated potato crops also being grown. Similarly a smaller portion of the flats surrounding the Vasse Lagoon are still used for grazing. The remainder of the land is either special rural, residential (eg. Busselton Townsite) or under proposal for development (eg. a major marina and urban development complex is proposed for the northern shore of the Vasse lagoon). The principal landuse in the Vasse-Wonnerup catchment is cattle farming for both beef and dairy production. Sheep farming is of lesser importance and small areas are irrigated for crops of potatoes and lucerne.

The soil associations of the area have been described by McArthur and Bettenay (1974). Soil types have been mapped on a finer scale by the WA Department of Agriculture (Tille and Lantzke, in draft). They occur in a patchwork pattern over a flat topography of little variation. Generally the soils are sandy, low in natural fertility and are prone to leach nutrients. The low areas are subject to waterlogging and require drainage to establish and maintain agricultural productivity.

The coastal plain catchment to the Vasse-Wonnerup wetland system has been extensively cleared for agriculture as shown in the Landsat image in Figure 4. The convoluted line running midway through all four catchments delineates the inland limit of the coastal plain. Shaded areas indicate forested regions whereas white areas (the majority of the coastal plain) represent land that has been cleared for agriculture etc. The proportion of cleared land in each catchment has been computed from Landsat images and shown in Table 2. The low natural fertility of these sandy soils has encouraged the use of fertilizers to increase and maintain pasture growth and productivity. Because these soils typically have a low phosphorus adsorption ability, the soluble fertilizers used by farmers, and also waste discharges from intensive and semi-intensive animal industries such as dairies (Fig 5), are easily leached from the soil profile and enter the river systems through surface and ground water inflow. In addition, the development of an extensive drainage network has increased the quantity of runoff, and consequently the quantity of nutrients, lost from agricultural land. Accumulation of the leached nutrients in the lagoons is mainly responsible for the eutrophication of the system.

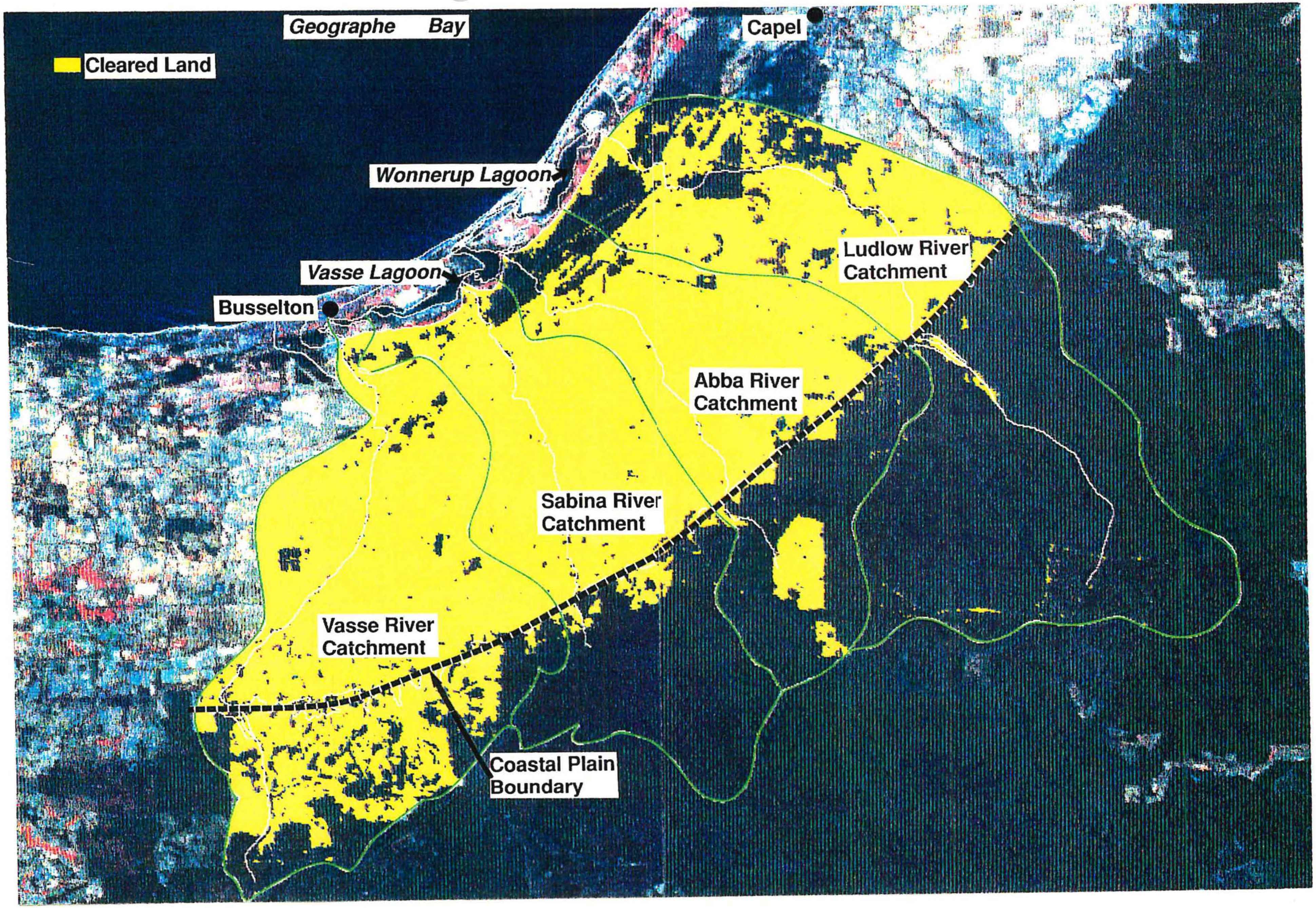


Figure 4. Landsat image showing clearing in the catchment of the Vasse-Wonnerup wetland system.

Table 2. The areas and extent of clearing in the sub-catchments to the Vasse-Wonnerup wetland system.

| RIVER | TOTAL CATCHMENT AREA (km2) | | COASTAL PLAIN | |
|---|---|---|---|---|
| | Original | Current | Area (km2) | Percent cleared (%) |
| Vasse | 213 | 21* | 21 | 95 |
| Sabina | 130 | 45* | 45 | 90 |
| Abba | 129 | 129 | 82 | 87 |
| Ludlow | 210 | 210 | 95 | 75 |
| Capel | 654 | - | - | - |
| Buayanyup Drain | 162 | - | - | - |
| Broadwater | 29 | - | - | - |
| South Drain | 21 | - | - | - |
| Ruabon | 19 | - | - | - |
| TOTAL | 1,567 | 405 | 243 | 87 |

*The Vasse and Sabina Rivers are partially diverted from the Vasse-Wonnerup Wetland System during the main winter flow period.

The Estuarine Impacts Branch of the Environmental Protection Authority has monitored river flows and nutrient loads to the Vasse-Wonnerup lagoons since the winter of 1987 (Tables 3a and 3b). Both 1987 and 1988 were years of extreme annual rainfall and correspondingly, extreme river flows. 1987 was a very dry year with an annual rainfall reaching only the first decile of the recorded distribution of annual rainfall for Busselton. At the other extreme, 1988 was a very wet year with an annual rainfall in the ninth decile of recorded distributions.

Table 3a. 1987 River flows and nutrient loads to the Vasse-Wonnerup wetland system

| WATERBODY | RIVER | FLOW ($x10^6 m^3$) | PHOSPHORUS LOAD (TONNES) | NITROGEN LOAD (TONNES) |
|---|---|---|---|---|
| Vasse Lagoon | Vasse | 1.5 | 0.3 | 2.5 |
| | Sabina | 3.4 | 2.0 | 12.5 |
| | Abba | 6.6 | 1.4 | 14.1 |
| | TOTAL | 11.5 | 3.7 | 29.1 |
| Wonnerup Lagoon | Ludlow | 3.9 | 1.2 | 32.9 |

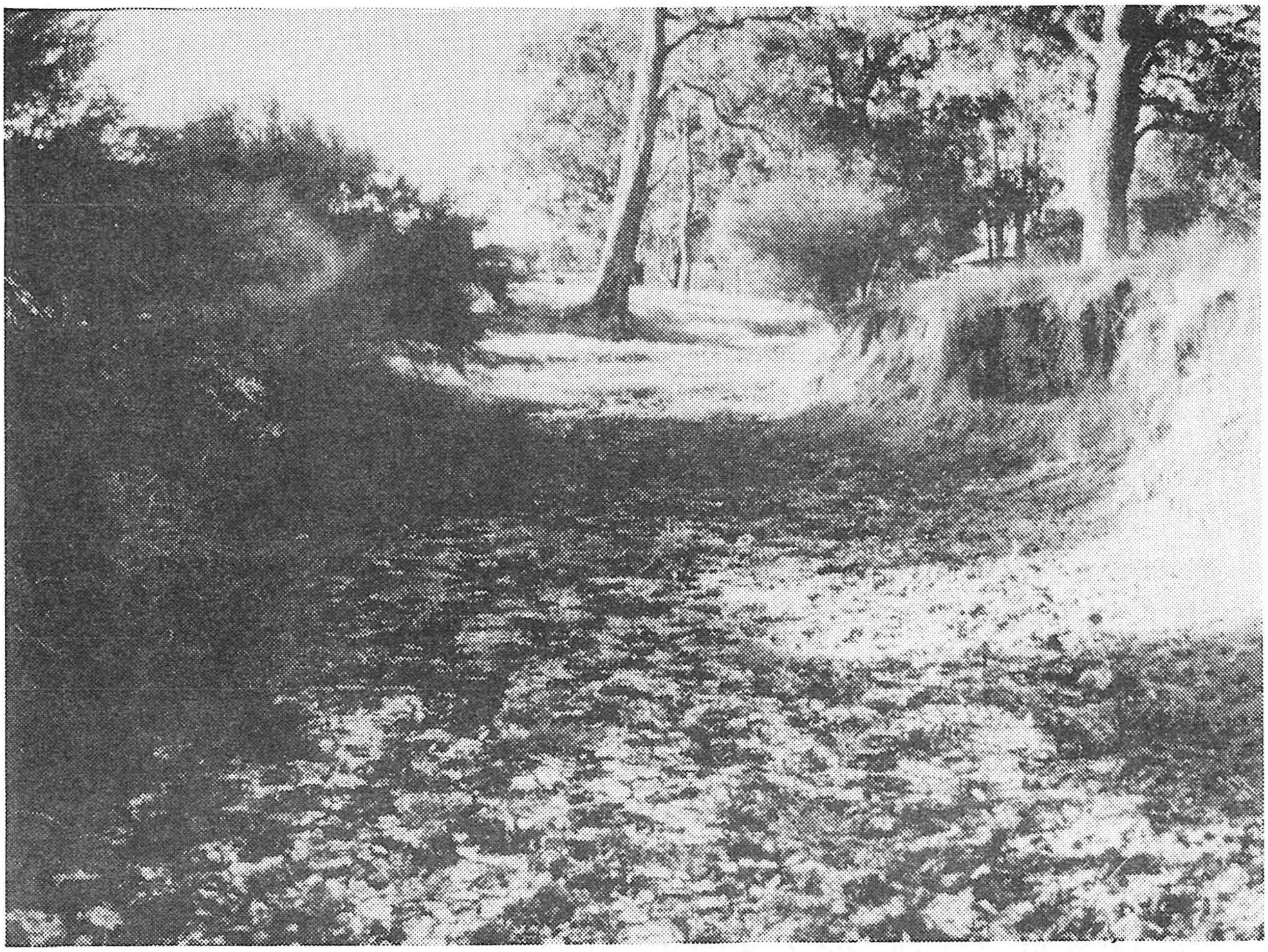

Figure 5. Dairy effluent smothering the Ludlow river bed adjacent to a milking dairy.

Table 3b. 1988 River flows and nutrient loads to the Vasse-Wonnerup wetland system

| WATERBODY | RIVER | FLOW ($x10^6 m^3$) | PHOSPHORUS LOAD (TONNES) | NITROGEN LOAD (TONNES) |
|---|---|---|---|---|
| Vasse Lagoon | Vasse | 1.4 | 0.4 | 3.1 |
| | Sabina | 17.0 | 8.6 | 62.9 |
| | Abba | 35.9 | 10.6 | 82.4 |
| | TOTAL | 54.3 | 19.6 | 148.4 |
| Wonnerup Lagoon | Ludlow | 37.9 | 16.2 | 117.1 |

As a consequence of the low rainfall, nutrient load to the wetland system in 1987 can be considered to be at the low end of the distribution of annual loads and probably well below the long-term average load. The 1987 annual nitrogen load to the Vasse and Wonnerup lagoons was estimated to be 29 and 33 tonnes respectively. Phosphorus loads to the same lagoons were 3.6 and 1.2 tonnes respectively. The nutrient load for 1988 is very high and is expected to be well above the long-term annual average, given the high rainfall for that year. Estimated nitrogen loads to the Vasse and Wonnerup lagoons respectively were 148 and 117 tonnes. Estimated phosphorus loads for 1988 are 20 and 16 tonnes respectively.

These nutrient loads when converted to a per volume basis for each lagoon (eg 0.8 - 10.1 g/m3 per annum for phosphorus in the Wonnerup lagoon) are very high compared with other estuarine systems in the southwest of Western Australia (Table 4). Indeed the Vasse-Wonnerup wetland system appears to be the most grossly enriched major wetland system known in Western Australia, particularly when considering the very limited flushing of the system. In Figure 6 the estuaries listed in Table 4 have been plotted on a graph developed by Vollenweider (Vollenweider, 1975, 1976; Vollenweider and Dillon, 1974) and based on eutrophication in northern hemisphere lakes. It includes a flushing component on the horizontal axis and an areal phosphorus loading rate on the vertical axis as g/m2/a. The method is applicable to phosphorus-deficient systems and takes into account both flushing of the waterbody and annual inflowing phosphorus load. The nutrient dymamics of the Vasse and Wonnerup lagoons have not been determined, however, most lakes and estuaries in the southwest are generally considered to be phosphorus-deficient. Although Vollenweider's equations may not be directly applicable to waterbodies in southwestern Australia, the processes involved are basically the same and therefore the water quality relationships will be similar, and in this way the Vollenweider plot is very useful for comparing the degree of nutrient enrichment of estuaries.

The comparatively high phosphorus load exported from the catchment of the Vasse-Wonnerup system is largely attributable to agricultural landuses on the coastal plain. Agriculture in this catchment doe not appear to be more intensive than in the Peel-Harvey catchment which has similar soils, and therefore it is not surprising to find that both catchments have similar phosphorus export rates. Observed phosphorus losses from the Peel-Harvey coastal plain catchment range from 0.3 to 1.2 kg/ha/a, whereas observed losses from the Vasse-Wonnerup coastal plain catchments range from 0.2 to 1.5 kg/ha/a. The comparatively high phosphorus loads to the Vasse-Wonnerup lagoons are in fact the result of a small waterbody size to catchment area ratio. Obviously this will affect the level of catchment management required if nutrient loads were to be reduced to an acceptable level in the future. Currently the lagoons do not exhibit widespread algal accumulations with associated odours because they dry up over summer and are not inundated again until the cooler winter months. Considering the high nutrient loads, continued summer drying of the lagoons should be supported in any future management plan for the system.

Table 4. Ranges of annual volumetric nutrient loadings for some south-west Western Australian estuaries and their associated symptoms of nutrient enrichment.

| ESTUARY | VOLUMETRIC NUTRIENT LOADING Phosphorus (g/m3/a) | Nitrogen (g/m3/a) | SYMPTOMS |
|---|---|---|---|
| PEEL INLET | 0.3 - 1.9 | 3.6 - 19.8 | Excessive macroalgal growth limited green and blue-green algal blooms. |
| HARVEY ESTUARY | 0.4 - 1.6 | 5.0 - 9.8 | Dense green and blue -green algal blooms. |
| PRINCESS ROYAL HARBOUR | 0.2 - 0.5 | 0.3 - 1.0 | Excessive macroalgal growth, losses of seagrass. |
| OYSTER HARBOUR | 0.06 - 0.9 | 2.1 - 6.6 | Excessive macroalgal growth, losses of seagrass. |
| WILSON INLET | 0.06 - 0.2 | 0.5 - 3.9 | Excessive seagrass, growth of epiphytic algae. |
| LESCHENAULT INLET | 1.1 | 14.7 | Excessive macroalgal growth. |
| SWAN ESTUARY | 0.4 - 0.5 | 3.9 - 4.6 | Limited microalgal & macroalgal growth. |
| VASSE LAGOON (1987)<br>(1988) | 1.2<br>6.5 | 9.7<br>49.5 | Green and blue-green algal blooms and fish deaths caused by deoxygenation of the water. |
| WONNERUP LAGOON (1987)<br>(1988) | 0.8<br>10.1 | 20.6<br>73.2 | Green and blue-green algal blooms. |

The WA Department of Agriculture has already begun to address the problem of nutrient losses from agricultural land and plans to extend its fertilizer management campaign from the Peel-Harvey catchment to the Vasse-Wonnerup and other estuarine catchments. The campaign is aimed at fertilizer users and promotes soil testing as a means to minimise use of fertilizers and fertilizer costs, while maintaining agricultural productivity. In addition farmers will be advised on environmentally acceptable methods for the disposal of dairy wastes.

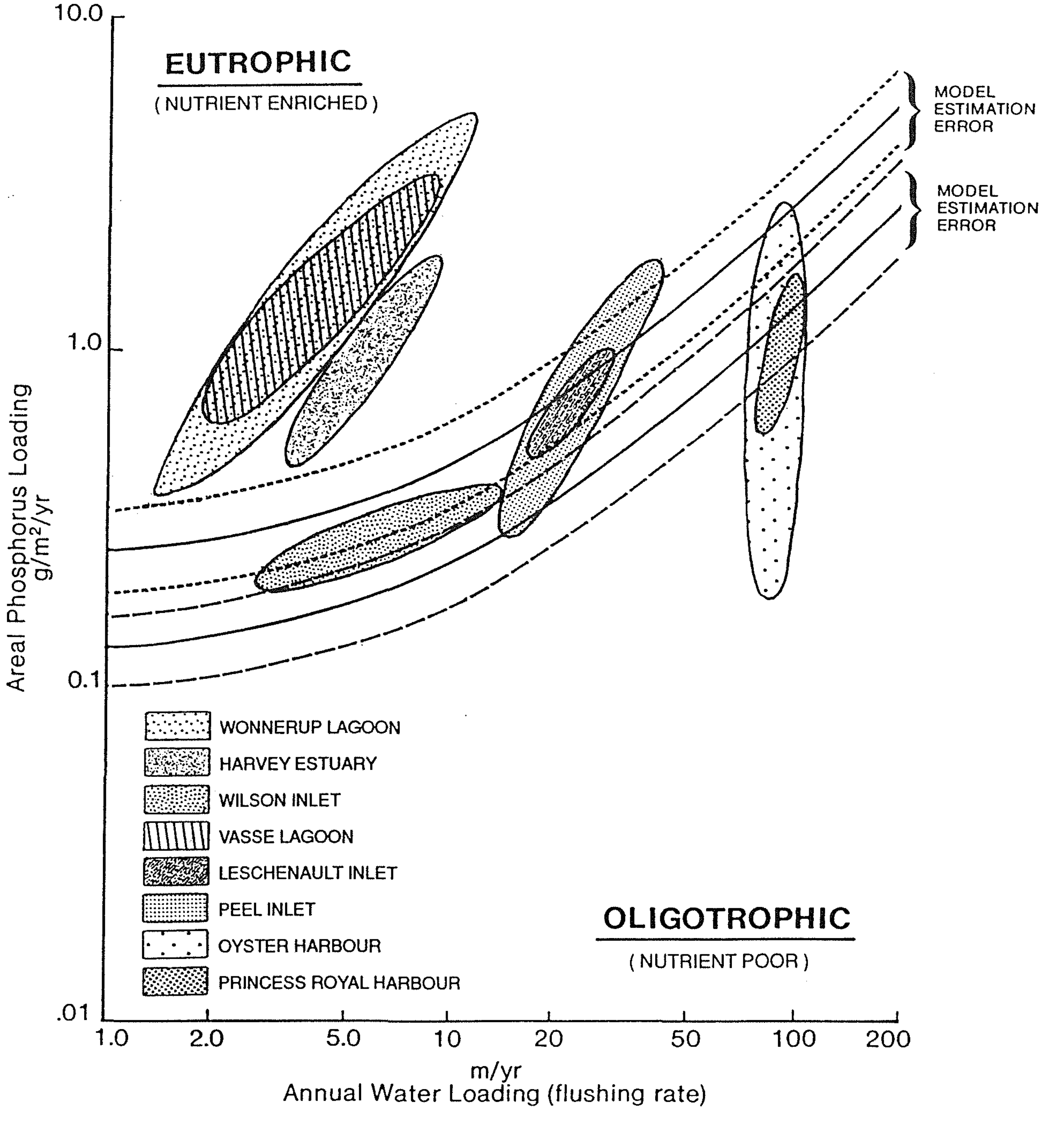


Figure 6. Trophic status of some south-west estuaries estimated from Vollenweider's phosphorus loading criteria (as adapted from K H Reckhow, Lake Data Analysis and Nutrient Budget Modelling).

## 2.2 THE WETLAND SYSTEM

The wetland vegetation of the system has been described by Tingay (unpub. 1980) and is mainly composed of salt-tolerant species. Pasture plant species have encroached on the margins of both the Vasse and Wonnerup Lagoons as a result of grazing and reduced soil salinity resulting from the control of seawater intrusion. This vegetation provides an important breeding and feeding habitat for a diverse range of waterbirds.

The Vasse-Wonnerup wetland system and associated Broadwater together form one of the most important wetland complexes of the South West of Western Australia (Dept. Fisheries and Wildlife, 1978). Unfortunately, historical drainage of the surrounding coastal plain has reduced the number of other freshwater wetlands in the area by up to 96% (Dept. Fisheries and Wildlife, 1978; Halse, 1989). The wetland provides shallow, semi-permanent bodies of fresh-to-brackish water and forms an important summer refuge for waterbirds which is of both regional and national significance. Only the Peel-Harvey estuary supports a greater number of water fowl. Waterbird surveys undertaken by the Royal Australasian Ornithologists Union (RAOU) have found that at least 75 species utilize the wetlands and 9 species are known to breed there (Table 5). The importance of the wetland in an international context is highlighted in that 21 of the recorded species have international protection under the Japan Australian Migratory Bird Agreement (JAMBA). In recognition of this importance, and because the Vasse-Wonnerup wetland system satisfies the criteria for nomination, the Department of Conservation and Land Management has recently supported its nomination to the RAMSAR Treaty (Convention on Wetlands of International Importance, particularly as waterfowl habitat). Unfortunately, the wetland habitat is still under threat from both development of the fringing land, and pollution by nutrients leached from the surrounding catchment.

Table 5. WATERBIRD SPECIES THAT HAVE BEEN RECORDED IN THE VASSE-WONNERUP WETLAND SYSTEM*

| SPECIES | BREEDING RECORDS |
|---|---|
| Hoary-headed Grebe | |
| Australasian (Little) Grebe | yes |
| Australian Pelican | |
| Darter | |
| Great (Black) Cormorant | |
| Pied Cormorant | |
| Little Black Cormorant | |
| Little Pied Cormorant | |
| Pacific (White-necked) Heron | |
| White-faced Heron | |
| Great (Large) Egret | |
| Little Egret | |
| Eastern Reef (Heron) Egret | |
| Rufous (Nankeen) Night Heron | |
| Australasian (Brown) Bittern | |
| Glossy Ibis | |
| Sacret (White) Ibis | |
| Straw-necked Ibis | |
| Royal Spoonbill | |
| Yellow-billed Spoonbill | |
| Black Swan | yes |
| Australian Shelduck | yes |

| SPECIES | BREEDING RECORDS |
| --- | --- |
| Pacific Black Duck | yes |
| Grey Teal | yes |
| Chestnut Teal | |
| Australasian Shoveler | |
| Pink Eared Duck | |
| Hardhead (White-Eyed Duck) | |
| Maned (Wood) Duck | |
| Musk Duck | yes |
| Osprey | |
| White-bellied Sea-Eagle | |
| Marsh (Swamp) Harrier | |
| Buff-Banded (Land) Rail | yes |
| Baillon's (Marsh) Crake | |
| Australian (Spotted) Crake | |
| Spotless Crake | |
| Black-Tailed Native-Hen | |
| Dusky Moorhen | yes |
| Purple (Western) Swamphen | |
| Eurasian Coot | |
| Painted Snipe | |
| Pied Oystercatcher | |
| Banded Lapwing (Plover) | |
| Grey Plover | |
| Lesser Golden Plover | |
| Red-Kneed Dotterel | |
| Red-Capped Plover (Dotterel) | yes |
| Black-Fronted Plover (Dotterel) | |
| Black-Winged (Pied) Stilt | |
| Banded stilt | |
| Red-Necked Avocet | |
| Wood Sandpiper | |
| Grey-Tailed Tatler | |
| Common Sandpiper | |
| Greenshank | |
| Marsh Sandpiper | |
| Black-Tailed Godwit | |
| Bar-Tailed Godwit | |
| Red Knot (Knot) | |
| Great Knot | |
| Sharp-Tailed Sandpiper | |
| Pectoral Sandpiper | |
| Red-Necked Stint | |
| Long-Toed Stint | |
| Curlew Sandpiper | |
| Ruff | |
| Silver Gull | |
| Whiskered Tern | |
| White-Winged (Black) Tern | |
| Caspian Tern | |
| Crested Tern | |
| Clamorous Reed Warbler | |
| Little Grassbird | |

* Information from RAOU waterbird surveys

2.2.1 Floodgates (Fig. 7)

Floodgates were constructed at the mouths of the two main lagoons in the early 1930's to prevent tidal intrusions of salt water from flooding pastures on the estuary margins. During storms sea levels can rise to between 1.1m and 2.0m AHD. The floodgates have also severed the connection between the Vasse and Wonnerup lagoons except in times of high water levels when Malbup Creek may flood. The existing floodgates are designed to operate as one way gates using a tide-generated differential head of pressure to allow outflow of winter runoff from the catchment, but prevent the inflow of sea water. Check boards are inserted into each floodgate over the winter to a height of 0.4m AHD. These act as barrages and are used to maintain a reasonably high water level in the lagoons at the end of winter to allow for summer evaporation. The boards are removed after the first winter rains produce runoff. Without an inflow of marine water, the lagoons fill with freshwater from the surrounding catchment, and this sits above saline sediments. Present opinion suggests that it is the fresh water that attracts large numbers of waterfowl to this system (J. Lane pers. comm.)

By ponding freshwater, the floodgates have indirectly facilitated the invasion of the lagoon basins and the natural fringing vegetation by pasture plant species. This has led to further deterioration of the native vegetation by stock which are free to roam over the lagoons, since adjoining property boundaries are not fenced. Since the construction of floodgates the old boundary definition of high water mark no longer applies and therefore these boundaries need re-definition.

The floodgates also enable the Water Authority of WA to use the Vasse Lagoon as a compensating basin to reduce the risk of flooding in Busselton from high river flows and/or tide levels. An artificially reduced water level is maintained in the lagoon to accommodate increased river flows during heavy rainfall.

The floodgates have compounded the problems of nutrient enrichment by limiting flushing in the lagoons. In the absence of tidal movement through the system the only significant flushing mechanism is freshwater outflow, and therefore the accumulation of nutrients and sediments in the lagoons is enhanced. Similarly, the absence of strong tidal currents in Wonnerup Inlet causes a bar of sand and seagrass to form at the mouth. Seagrass detritus is washed into the Inlet by storms and trapped. Subsequent decomposition causes a reduction in water quality and nauseous odours.

Drying of the lagoons over summer is of potential benefit to the system in the short term. If the basins remain largely dry over the summer months, aquatic weed growth and other symptoms of nutrient enrichment will be kept to a minimum. The sediments in both lagoons contain sufficient quantities of nutrients to support a large algal biomass (Walker et al, 1980). As the sediments dry out and become oxidised, nitrogen is lost to the atmosphere by denitrification.

The floodgates also act as a barrier to fish movement. Estuaries normally function as breeding grounds and nursery areas for many marine and freshwater species of vertebrates and invertebrates. In the Vasse-Wonnerup system some fish manage to enter the old estuary basins either as juveniles through cracks in the gates or by swimming upstream against the outflowing

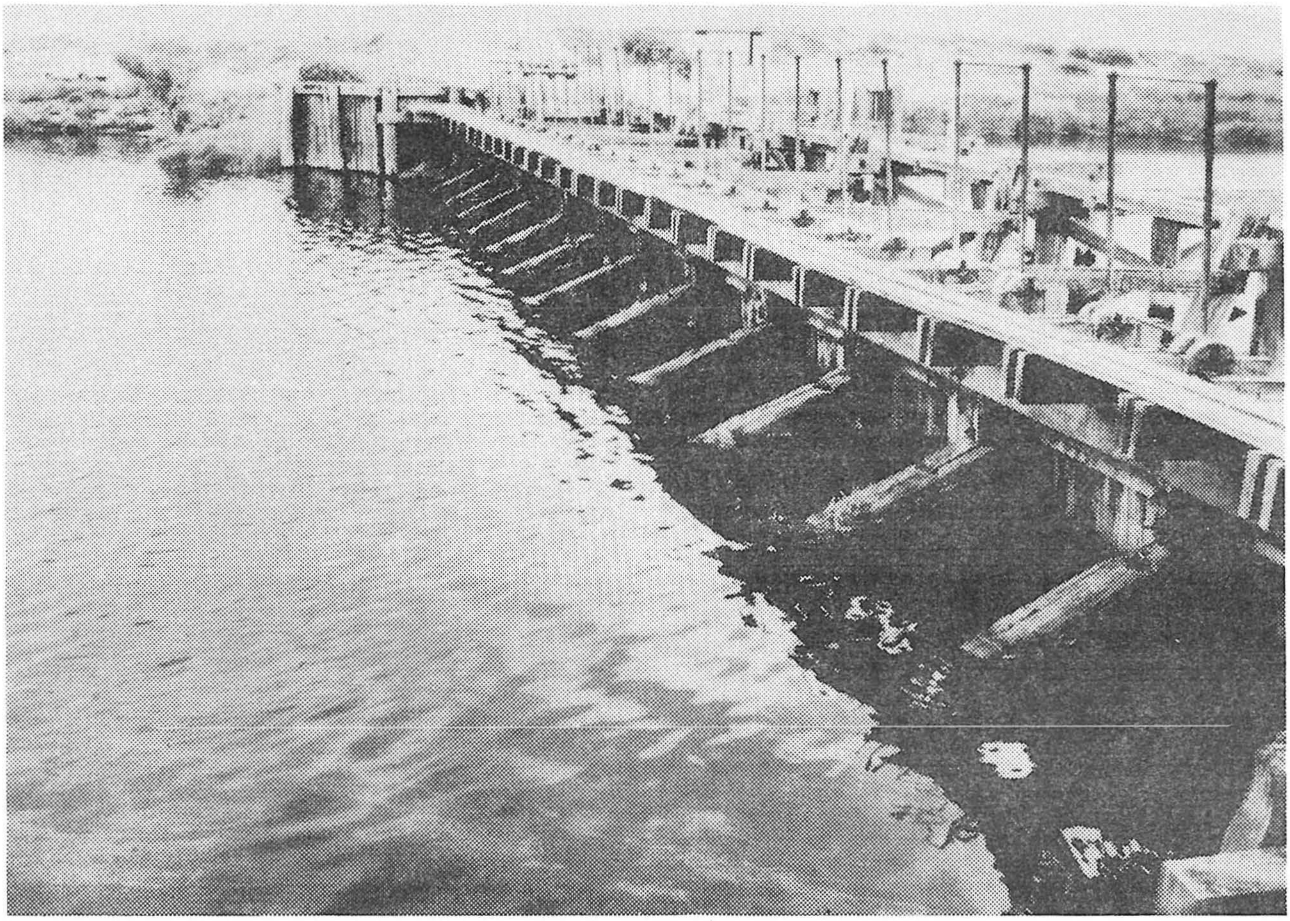

Figure 7. Floodgates to the Vasse Lagoon.

Figure 8. Seagrass detritus and sand accumulating on the bar at the entrance to Wonnerup Inlet.

water when the gates are open. Many of these fish then remain in the lagoons and are trapped behind closed gates over summer. Those fish which escape being netted by fishermen as the lagoons dry out, cannot escape the declining water quality and oxygen levels. They become stressed, and in extreme cases mass mortality results, which is what occurred in the Vasse Lagoon in March 1988.

On previous occasions the Water Authority temporarily opened the floodgates at the first sign of fish deaths, allowing some seawater inflow and providing an opportunity for the fish to escape from the lagoons. In 1988 Wonnerup Inlet was completely barred at the mouth, which caused similarly poor water quality in the channel between the floodgates and the ocean, therefore, when the gates were opened the fish deaths continued.

2.2.2 Bar (Fig. 8.)

Reduced river through-flow and restricted tidal exchange has resulted in the bar now being closed for longer periods throughout the year, particularly over summer. This has the effect of creating a static water body between the bar and the floodgates from which fish cannot escape, and which tends to accumulate seagrass detritus washed in from Geographe Bay. Over summer, evaporation, rising temperatures and increased oxygen demand lead to the progressive deterioration of the water quality.

The Water Authority of WA presently manages the opening of the bar to ensure that it does not remain closed over winter, leading to flooding of surrounding farmland and parts of Busselton. The bar is broken by the Water Authority if water levels in the Vasse Lagoon reach as high as 0.7m AHD (G. Holtreter pers. comm.). The Water Authority may also attempt to open the bar in summer if it is closed and fish are dying behind it. To successfully open the bar in summer is a difficult operation because of the lack of flow, and it therefore requires favourable tides and winds.

## 3. POTENTIAL FOR MANAGEMENT TO IMPROVE THE WETLAND ENVIRONMENT

Management issues were defined after consideration of the current catchment and wetland use patterns and after discussions with relevant groups involved with the system. The issues identified are:

- maintenance of agricultural pursuits;
- maintenance of wetland habitat for water fowl;
- provision of a summer refuge for waterbirds;
- re-establishment of a fish nursery;
- maintenance of a compensation basin for flood mitigation;

- development of recreation resource potential; and

- improvement of water quality.

The potential for management is limited by the number of variables available for manipulation, particularly the floodgates and the bar. In addition, less direct management options are available and include acquisition of land surrounding the lagoons, alteration of drainage patterns, diversion of rivers and reduction of nutrient loss from catchments.

## 3.1 OUTLINE OF MANAGEMENT OPTIONS

### 3.1.1 Bar Management

a *Leave the bar as it is allowing it to open and close without any manipulation.* The main advantage here is that there is no cost involved, but taking no action in the long-term will only exacerbate the problem of poor water quality and recurring fish deaths.

b *Open the bar when necessary.* Timing of the bar opening will be determined by winter water levels in the lagoons and by water quality in both the lagoons and Wonnerup Inlet. There is the potential for the bar to close again soon after and require reopening. Over summer this will ensure relatively clean water in Wonnerup Inlet and a direct route to Geographe Bay for fish. This option would require that water quality was monitored in the lagoons to determine when the bar should be opened.

c *Maintain the bar permanently open.* This may require the design and construction of a costly groyne structure at the mouth of the Inlet or perhaps a rock retaining wall on the sides of the opening. Some on-going maintenance would probably still be required to keep the mouth open. Tidal mixing would ensure relatively good water quality within Wonnerup Inlet.

### 3.1.2 Floodgates

a *Replace the existing structure with a similar oneway flow structure, but with the facility to allow marine water back into the lagoon from Wonnerup Inlet for short periods when necessary.* This is the option currently being considered by the Water Authority, it allows fish to escape and fresh oxygenated inlet water back into the lagoons when water quality is poor and fish are stressed (providing the bar was open). The gates can be closed before saltwater encroaches on pastured land. This system does not prevent the further deterioration of water quality once the gate is closed and would accumulate salt behind the floodgates, leading to hypersaline conditions over summer. The structure will still act as a barrier to fish and tidal movements for most of the year.

b *Construction of storm surge gates allowing two way flow.* This option would return the lagoons to a tidal regime and they would once again function as true estuaries with an improved nutrient flushing capacity and provide a valuable nursery for fish species. The quantity of water moving in and out of the system with each diurnal tide would be determined by the cross sectional area of the constructed gate and the status of the bar at the entrance channel. The gates would only be closed when sea levels rose to heights that would threaten flooding of pastures and urban property. However, if two-way gates were constructed then the present function of the lagoons as a compensation basin to reduce the likelihood of flooding in Busselton would be lost.

Pastures that have invaded the fringing margins of the lagoons would become inundated with salt water on a regular basis, returning the vegetation to less agriculturally productive salt-tolerant species. In addition, inundation of these shallow, nutrient-enriched lagoons in summer would promote blooms of macroalgae at least as large as those experienced in the Peel-Harvey system. Although water quality in the entrance channel of the Vasse Lagoon will be improved, the presence of large quantities of decomposing algae may reduce water quality locally throughout the system and result in bad odours and an aesthetically displeasing shoreline for present and future residents. Moreover, the effect on the waterbirds of increased salinity in the Vasse-Wonnerup system is not certain, but there is evidence that some species, including breeding populations, would be lost from the system.

c *Removal of the floodgates*. The effects of this option would be similar to 3.1.2.b above except that flooding during storms or during periods of high sea level would be more severe because of the elimination of the surge gates. Nutrient export from the system to Geographe Bay would be higher than option 3.1.2.b because tidal flushing would be increased.

d *Relocation of the floodgates upstream to increase the length of the tidal reach within Wonnerup Inlet*. This option will not increase nutrient loss from the system or prevent fish deaths over summer, but it will increase the area available for recreational fishing in the Inlet. Although the area of Wonnerup Inlet downstream of the floodgates would have adequate water quality provided the bar was open, the inundated section behind the floodgates would still suffer from poor flushing and high nutrients loads, causing algal growths and death of trapped fish. The Water Authority of WA favours this option because it will also reduce the probability of storm waves breaching the foredunes behind the floodgates and flooding the Vasse Lagoon with marine water.

e *Increase the height of the gauge boards immediately behind the floodgates*. In this case the depth of stored water in the lagoons at the end of winter would be increased with the aim of providing a greater summer water resource for waterbirds and fish, thereby reducing the chance for fish deaths. This option is not likely to improve water quality, in the long-term, because both nutrients and biological oxygen demand can still be expected to increase behind the floodgates, eventually resulting in fish deaths. Water levels in the Vasse Lagoon cannot be increased much more without risking flooding in Busselton.

f *Remove the floodgates on Wonnerup Lagoon*. Vasse Lagoon has been excluded because of its function as a compensation basin to reduce flooding in Busselton. Wonnerup Lagoon would then be open to tidal fluctuations and act as a normal estuary, providing a summer refuge for salt-tolerant waterbirds and a nursery for fish species. The marine influence on the lagoons will increase salinity to the detriment of grazing pastures that have encroached upon the estuarine margins, and may adversely affect its use by waterbirds.

### 3.1.3 Catchment Management

a *Manage fertilizer applications*. For many farmers it is common practice to apply more fertilizer than their pastures, or crops, require to ensure maximum production. The excess fertilizer nutrients then leach to the drainage system over the wet winter and accumulate in the lagoons, stimulating algal growth. The WA Department of Agriculture is beginning a fertilizer management programme directed at farmers within the Vasse-Wonnerup catchment. The programme is based on fertilizer education and uses soil tests to determine the optimum fertilizers, time of application and application rates for the best economic returns.

b *Manage nutrient discharge at point sources*. There are a range of industries that are classified as point sources of nutrient pollution eg. piggeries, horticultural gardens, abattoirs, dairies, etc. In the Vasse-Wonnerup catchment dairy discharges are presently considered to be the most significant. Many dairies are sluicing effluents either directly into drains and rivers, or onto paddocks directly adjacent to a water course. The nutrient load exported from the catchment attributable to dairy operations is not known. Calculations based on information obtained from the WA Department of Agriculture indicate that currently these industries within the catchment, have the potential to export 4 tonnes of phosphorus to the drainage system, or equivalent to 80% of the present phosphorus load to the lagoons. Dairy operators therefore should be encouraged to construct settling ponds, pasture effluent irrigation systems or other forms of effluent treatment to reduce downstream pollution.

c *Convert pastured land on the coastal plain to forestry*. Trees require less fertilizer and use more water than pastures. The result is reduced nutrient export from the site. In the long-term, extensive tree planting may reduce the groundwater table in an area. Studies by the Department of Conservation and Land Management indicate that growing and harvesting the Tasmanian Blue Gum (Eucalyptus globulus) for woodchips could be at least as profitable as grazeland farming on many soils (B. Mattinson pers. com.). There are several share-farming schemes available to assist landowners with the conversion of land to forestry.

### 3.1.4 Dredging

a *Dredging of Wonnerup Inlet only*. Dredging would be a costly option, but removal of the enriched sediments and increased depth of water may reduce summer temperatures and may prevent deoxygenation of the entire water column. Benthic fauna would be disrupted during dredging operations and could suffer deoxygenation events, especially over winter when increased depth is likely to result in stratification of the water column. This option would not improve water quality or flushing within the lagoons, but may improve water quality in the channel behind the bar in the short-term, particularly if the bar silts up.

b *Dredging of a channel from the floodgates into the lagoon basins*.This would remove the accumulation of sedimented organic matter in the channel and improve water quality in the short-term. Again maximum summer temperatures in the channel may be reduced and deoxygenation of the entire water column may be prevented. In the long-term,the dredged channel would be likely to silt up, and therefore improvements in water quality are likely to be minimal. Benthic fauna are likely to suffer the same disruptions as 3.1.4.a above from dredging and stratification. Enriched dredge spoil would need to be transported out of the immediate vicinity of lagoons and pastures to minimise the impacts of leached salts and nutrients re-entering the system. Other dredge spoil could be used to create artificial islands as waterbird refuges for nesting and shelter.

3.1.5 Levee Banks

a *Construct levee banks around one or both lagoons using on-site materials.* This strategy has been considered by concerned local groups for some time. It would enable the wetland system to function as a tidal estuary but large areas of fringing wetlands would be lost under levee banks and during construction. Surrounding pastures outside the levee banks are likely to flood with fresh water for periods over winter, until surface water drained to the estuary through a number of small floodgates incorporated in the levee banks. Regular maintenance of these floodgates should prevent saline water from leaking back onto pastures. The Vasse Lagoon could no longer be used as a compensation basin for flood mitigation in Busselton. As for 3.1.2.b and c above, the effect on the waterbirds of changing from an essentially fresh to brackish wetland system to a brackish to hypersaline system would need further investigation.

3.1.6 River Re-diversion

a *Redivert flow from the Vasse diversion drain back into the Vasse Lagoon.* Under this strategy the increased river inflow would improve the flushing of the system, however, this would be negated by the consequent increase in nutrient load compounding the eutrophic condition of the system. The risk of flooding urban and industrial land in Busselton would be high because of the presence of several artificial constrictions in the river course and of low lying land. Water levels in the Vasse Lagoon would increase over high runoff periods with resultant short term flooding of fringing pastures.

b *Redivert flow from the upper Sabina River back down the lower Sabina River and into the Vasse Lagoon.* The impacts of this option are as for 3.1.6.a above, except that flooding in Busselton would not be affected. There would be minor loss of grazing land over winter, downstream of the Sabina River diversion point, as flows return to their natural course.

c *Redivert flow from the Capel River into the Wonnerup Lagoon.* This option would not only improve the flushing of Wonnerup Lagoon but also increase the nutrient load due to runoff from agricultural land which comprises much of the Capel River Catchment area so that the overall effect would need further investigation. This diversion may also result in flooding of substantial areas of lowlying pasture between the Capel River and Wonnerup Lagoon. Extension of the fertilizer management programme would be required to include the Capel River catchment.

d *Redivert all the original river flows back through the Vasse-Wonnerup system.* The impacts of the strategy would include all those in 3.1.6. a, b and c above including flooding of further large areas of low lying land southwest of Busselton. Most of Busselton would need relocation because of winter flooding.

3.1.7 Control of landuse fringing the lagoons (Consideration of these options may be required in conjunction with some of the other options)

a *Do nothing.* Farmers will bear the cost of any reduction in productivity on pastures inundated with fresh or salt water.

b *Compensate for loss of productivity.* Farmers surrounding the estuarine margins could be compensated for loss of productivity caused from flooding by fresh or salt water. Property boundaries abutting the lagoons are unclear and need redefinition.

c *Acquire the land fringing the lagoons.* The land up to high water mark could be purchased or resumed by Government and reserved for conservation purposes. Grazing pressures on wetland vegetation would be eliminated and disturbance of waterbird feeding areas minimized.

d *Enter into a voluntary agreement with landowners to manage specific habitat areas requiring protection and those pastures that may become flooded.* Grazing can be managed to minimize impacts on both fringing vegetation and stock. There is evidence to suggest that limited grazing may enhance the suitability of an area for use by waterbirds. This strategy is consistent with Regional Park policy developed by the State Planning Comission, and could be incorporated into long-term plans for management of the Vasse-Wonnerup wetland system. Subsidies for fencing may be required.

3.1.8 Artificial aeration

a *Construct a fountain to aerate remaining water over summer.* This system aerates the water in a localized area but can draw water from some distance away. This method sets up internal currents which will distribute the oxygenated water, but will also stir up the fine organic sediments from the bottom of the shallow system. The effect of this re-suspension will be to initially increase biological oxygen demand in the water column and probably also enhance sediment/water nutrient cycling and encourage further algal growth. To be effective the water pump would probably need to work continuously for 10 hours each night, 3 -4 months per year. A prolonged mechanical breakdown would result in rapid water quality deterioration and a high probability of a fish kill.

b *Aerate the water column by bubbling compressed air.* This method increases oxygen concentration in the water by two methods; diffusion of gases through the bubble surface and by setting up currents which bring bottom water to the surface for oxygen uptake. Both mechanisms would be ineffective in the Vasse-Wonnerup system because of its shallow nature. Oxygenation may be possible using pure oxygen but this is very expensive. The problems relating to artificial currents, as discussed in 3.1.8.a above, also apply in this case and any other method that involves stirring of the water column. Aeration of the water column does not improve general water quality other than to increase oxygen content and increase the sediment phosphorus binding capacity. As soon as oxygenation stops water quality will begin to deteriorate again.

3.1.9 Increase volume of water in the lagoon

a *Pump groundwater into the lagoons over summer.* To supply enough water to account for evaporation losses from the summer lagoon a bore into the deep Yarragadee formation would be required. Iron content of this water is quite high (2 ppm) and the water would require treatment before utilization. The intention is to maintain an adequate water resource for fish to escape the effects of deoxygenation in the worst affected areas. Water quality may be improved with this option, but will probably deteriorate with time as sediments become further enriched with organic matter. This would be an expensive option both to operate and to maintain.

### 3.1.10 Barrage across the lagoon

a *Construct a barrage across a section of the lagoon upstream of the floodgates.* The barrage would need to be of sufficient height to hold all but the most extreme fluctuations in sea level, but without risk of flooding Busselton by restricting winter flows from the system. A gate in the barrage would improve winter through flow and allow fish into the deeper water downstream as the lagoons dry up. When lagoon levels have dropped sufficiently low for fish to have entered the deeper water downstream of the barrage the gate is closed. The floodgates can then be opened up to allow exchange with Wonnerup Inlet and closed only when extreme sea levels are threatening. In addition, by manipulating water levels the following autumn, limited flushing of the summer waterbody can be achieved. Catchment runoff would backup behind the barrage to maximum height and then at low tide the barrage gate opened to obtain a rapid through flow of water to the ocean. The system could be manual or automatic. The option of least cost would be manual operation and will require a minimal number of man hours to operate, depending on design of the new floodgates.

# 4. PRELIMINARY ASSESSMENT OF MANAGEMENT OPTIONS

## 4.1 MANAGEMENT OBJECTIVES

This report considers the Vasse-Wonnerup wetland system as a resource, with a certain level of resource potential. Implicit in the decision to manage a system is the need for a clear definition of the goals of management. It is necessary therefore to form an image of the desired wetland system and to interpret this in view of the requirements to which the system is, or is likely to be, subject. The proposed goals for management are:

- to protect the system against further degradation;

- to maintain it as an important waterfowl habitat;

- to improve its conservation and recreation potential.

Achievement of these goals may not necessarily mean returning the system to its original condition.

Short Term Goals

- maintain the system's function as an important waterbird habitat;

- improve the water quality of the system over the summer period;

- prevent further fish deaths in the system;

- reduce the annual nutrient load retained in the lagoons;

- maintain productivity in the catchment;

Longer Term Goals

- manage the nutrient budget for the Vasse-Wonnerup wetland system at an acceptable level for all activities;

- improve the Vasse-Wonnerup system as a habitat for birds and fish and as an aesthetic and recreation resource for people;

Since the available knowledge on the biology and environment of the Vasse-Wonnerup system is limited, this paper has focused only on the short term goals. The longer term goals may be achieved after further studies and monitoring programmes have been conducted in both the catchment and lagoons, and also after public awareness and support for those goals. For example, catchment fertilizer reductions currently rely on voluntary agreement by farmers to accept Department of Agriculture fertilizer advice.

## 4.2 ASSESSMENTS OF MANAGEMENT OPTIONS

The proposed options can be broadly classified into two major groups:

1) Those management options which will require repeating periodically to ensure an ongoing improvement in environmental quality,

2) Those options which when instigated offer an ongoing improvement in environmental quality.

Specific options and combinations of options have been identified, and are assessed below in terms of the advantages and disadvantages of their perceived environmental impacts and implications. In some cases there is insufficient information available to fully assess the potential impacts of an option and in such cases, further studies are recommended. Some potential management scenarios have been summarised in Figure 9.

### Group 1

### 4.2.1 Bar Management

The mouth of the Wonnerup Inlet is the only opening to the sea for the Vasse-Wonnerup system and as such it is the only point through which tidal flushing of the system can occur. Consequently, it is one of the principal factors determining water quality in the Wonnerup Inlet channel, and would be the prime factor determining flushing in the lagoons if the floodgates were removed.

There are three approaches to management of the bar, and these can be classified by the level of management input required. From an economic viewpoint the most attractive option is to leave the bar to open and close naturally since it requires no management and no expenditure of money. However, this would result in substantial costs to the environment and flooding of surrounding properties. The bar would remain closed for long periods of time, particularly over summer, and water quality will continue to deteriorate each year resulting in almost annual fish deaths. This option is not recommended as it encompasses the present system of bar management, which has undesirable impacts on the physical and biological environment of the system. The Water Authority of WA has been responsible for opening the bar on past occasions to prevent early winter flooding upstream, or as an attempt to prevent fish from dying.

Opening the bar on an *as required basis* necessitates a relatively small financial outlay, depending on how often the bar requires opening. Estimated costs from the Water Authority of WA indicate that a winter opening, when rivers are flowing, would cost approximately $100. Over summer, if the tides are low providing a relatively large difference in water levels inside and outside the bar, the cost is likely to be $250, otherwise approximately $1000. Water quality and levels in the Inlet should be monitored to determine when the bar should be opened, based on set criteria.

To construct a permanently open system involves a much greater capital expenditure of approximately $70 000 and an annual maintenance cost which may be as high as $150 000. The advantage of this option is that water quality in Wonnerup Inlet will always be reasonably high.

Since river outflow generally keeps the bar open over winter it is the summer/autumn period for which management is of primary concern. For this six month period there is a need for the bar to be open to allow tidal exchange and fish movement through the opening. The opening need not be permanently maintained throughout summer although the greater the marine influence generally the better the water quality. A permanently open channel is not recommended for further evaluation considering the cost involved, and adequate water quality and fish movement may be achieved by opening the bar as conditions require. The cost of this option will depend on the number of times the bar requires opening, tide conditions and the quantity of sand and weed accumulation. If the bar was required to be opened 5 times through summer then the maximum recurrent cost is expected to be $5000.

#### 4.2.2 Dredging

There are two approaches to reducing the quantity of enriched sediment that has accumulated in the system. The first is to dredge Wonnerup Inlet to reduce the nutrient and organic store in the sediments at a cost of $8/m3 to dredge and relocate the spoil. This translates to a total cost of approximately $200 000 for a strip 50m wide and 0.5m deep. The effect on water quality within Wonnerup Inlet, if the bar was regularly opened, is expected to be be minimal but with a substantial deleterious impact on the bottom fauna (benthos). The channel would require periodic re-dredging to remove accumulated sediments.

The second approach is to dredge a channel from the floodgates to the lagoon basin, again with a deleterious impact on the benthos and only limited improvement in long-term water quality. The cost for this option is likely to be over $500 000 and would require maintenance dredging as the sediments reaccumulate. Dredging will not enhance water quality greatly by itself, but deepening the channel may have merit in conjunction with other management options. Originally the channels from the lagoons to the ocean entrance would have been substantially deeper from tidal current scour and greater volumes of river runoff.

#### 4.2.3 Artificial Aeration

Because the water in the channels over summer is only about 0.5m deep, oxygenation is achieved by surface exchange as wind mixing turns the water mass over. To facilitate greater oxygenation, mechanical aeration would be required for 8 - 10 hours per day, about 4 months every year. If the mechanical system were to break down for 3 - 4 days, subsequent deoxygenation may cause further fish kills. The estimated cost to hire and install aeration equipment, using a fountain design to service a 50m section of the Vasse channel, is $10 000 with ongoing running and maintenance costs of perhaps $5 000. A similar cost would be incurred to set up a diffuse bubble aeration system, however this system is not considered to be as efficient as the fountain design. Further study would be required to determine the effects on sediment resuspension and algal growth.

4.2.4 Increase water volume in the lagoon

This option will maintain a larger volume and greater depth of water in the lagoon over summer and may initially improve water quality behind the flood-gates but as nutrients and organic matter accumulate, and with the risk of saline stratification, deoxygenation would probably still occur.

The estimated cost to install both bore and pump is $65 000 plus running costs. Additional expenditure may be required to reduce the iron concentrations in the bore water. Considering the cost involved and likelihood of a poor result, this option is not recommended for follow up.

Group 2

4.2.5 Floodgates

There are three basic approaches to floodgate design and management:

- replace the existing structure but with the facility to allow marine water back into the lagoon over summer.

- open the Vasse-Wonnerup system to tidal influences.

- increase the height of the gauge boards.

The first approach is currently being considered by the Water Authority of WA for implementation when the existing structures are renewed. These floodgates are almost 60 years old and due for replacement within the next few years. This approach maintains the status quo of the system and the Water Authority of WA estimate that it will cost $250 000 per structure. It requires some form of bar management to ensure that water quality in the Wonnerup Inlet is adequate, and water quality would need to be monitored to determine when gates should be opened and how often. Although this option does not treat the cause of the observed fish kills it is likely to improve water quality behind the floodgates, at least initially. In the long-term, stratification may occur with associated deoxygenation of bottom water and there may be an accumulation of salt behind the floodgates causing hypersaline conditions towards the end of summer which may affect the fauna. The waterfowl habitat would be maintained assuming that saline water will be flushed from the lagoons over winter by river inflows. The height to which the lagoons could be flooded with salt water without affecting pasture, both in summer and in winter, needs to be determined by further assessment of this option. Considering the above, and the expected increase in algal biomass, this option is not considered to be the most favourable and would require further evaluation.

The second approach involves two options:

- remove the floodgates;

- construct two-way storm surge gates.

The gate's present function is to prevent salt water inundation of fringing pastures and to allow the Vasse Lagoon to function as a compensation basin. Removal of the floodgates will flood fringing pastures and substantially increase the risk of flooding in Busselton township. This option needs to be considered in conjunction with the construction of levee banks or the control of landuse fringing the lagoons.

Removal of the floodgates would return the system to an estuary with associated ocean exchange increasing the extent of marine influence. The benefits of this approach are an increase in the tidal flushing of the system, reducing the rate of nutrient and sediment accumulation, and the opening of the system to function as a fish feeding ground and nursery. The effect on the waterbird populations of returning the system to an estuarine habitat is an important point that requires further evaluation. The system's value as a freshwater habitat has increased as other wetlands throughout the State have been drained and developed for alternative land uses. The construction of storm surge gates reduces the potential for flooding in Busselton, however, salt water flooding of the lagoon fringes would still require consideration. The cost of constructing a storm surge gate structure is estimated to be $250 000 plus $40 000 for each 5 metre wide movable gate.

This approach to management of the Vasse-Wonnerup system cannot be adequately evaluated using the information available. Additional studies are required to fully assess the impacts of reverting the system to an estuary, and to design a new flood mitigation plan for Busselton.

There is little to be gained immediately by only removing the floodgates from the Wonnerup lagoon. Water quality problems in the Wonnerup lagoon over summer do not appear to be as severe as in the Vasse lagoon, and grazing land will be affected by salt water inundation. In the long-term water quality will be improved and fish may utilize the estuary freely, but, its value as a waterbird habitat may decline. The Vasse Lagoon would remain unaffected and fish kills would be expected to continue.

The third approach to floodgate management entails little or no extra cost, but is unlikely to improve water quality behind the floodgates. The initial volume of water trapped behind the gates would be larger, and by late summer/autumn, water quality would have deteriorated and evaporation would have reduced the depth of water to critical levels. This option is not recommended.

### 4.2.6 Catchment Management

The extensive investigations of the Peel-Harvey Estuary System have clearly established that agricultural practices within the catchment of an estuary can cause the eutrophication of such systems. Nutrient enrichment of the Vasse-Wonnerup system is a result of over-fertilization of the surrounding catchment and, to a lesser extent, poor management of dairy effluents. The WA Department of Agriculture has established management strategies to reduce nutrient export from catchments. It would be beneficial for the Department of Agriculture to extend its management strategies to the Vasse-Wonnerup catchment and initiate a fertilizer and effluent education and management programme. Tree farming could also be introduced as a viable landuse alternative on appropriate soils. A certain level of nutrient enrichment is of benefit to waterbirds, and therefore an integrated catchment management plan is required for the catchment to the Vasse-Wonnerup wetland system, so that a beneficial level of nutrient supply can be maintained to the system.

#### 4.2.7 Levee Banks

This option should be considered in conjunction with the removal of the floodgates. Damage to the surrounding wetlands and the aesthetics of the area is likely to be great and will need to be carefully assessed. The effect on the waterbirds is not certain but is likely to be detrimental since many feeding areas are likely to be lost. This option should only be evaluated further if alternative options are considered to be inappropriate. The cost for levee banks and associated floodgates is estimated by the Water Authority of WA at $330 000 and $250 000 for the Vasse and Wonnerup Lagoons respectively.

#### 4.2.8 River Re-diversion

Drainage and clearing of the catchment has increased the quantity of runoff from the land. The inability of the Vasse and Sabina watercourses to cope with the increased flow has led to flooding of the surrounding land, and has resulted in their diversion to the sea through the Vasse River diversion drain. Rediversion of the Vasse River through Busselton would cause large scale flooding. Nutrients from both re-diverted rivers would accumulate in the Vasse lagoon and exacerbate its eutrophic condition. This approach is not recommended for further consideration as a management option.

Similarly, rediversion of the original river catchments (eg Capel River) back through the Vasse-Wonnerup System will flood large areas of farmland and is expected to exacerbate the already eutrophic situation of the wetlands. Additional monitoring would be required to properly assess the impacts of this option.

#### 4.2.9 Control of Land Use Fringing the Lagoons

This proposal requires careful consideration in regard to the formulation of long-term goals for the Vasse-Wonnerup system. The system is a valuable wetland in a national and international context, and as such it qualifies as an area requiring management for conservation purposes. To date there have been no resources put into a conservation management plan for the wetland. Development in the Busselton region is expanding rapidly, and consequently land fringing the lagoons is becoming more popular for residential subdivision and redevelopment. Associated impacts on the wetland and its animals are also increasing, and for this reason it is imperative to develop and implement an overall management plan for the protection of the flora and fauna of the system. Some form of control of landuse fringing the lagoons would be implicit in this plan, and may involve monetary exchange or voluntary agreements with landowners to manage specific areas for conservation.

If the decision was made to flood the lagoons with salt water then a scheme to either buy back land from the farmers or compensate farmers for loss of productivity would need to be implemented. Approximately 400 ha and 600 ha of private land adjoining the Wonnerup and Vasse Lagoons respectively would be affected. Good land used for rural purposes would cost in the order of:

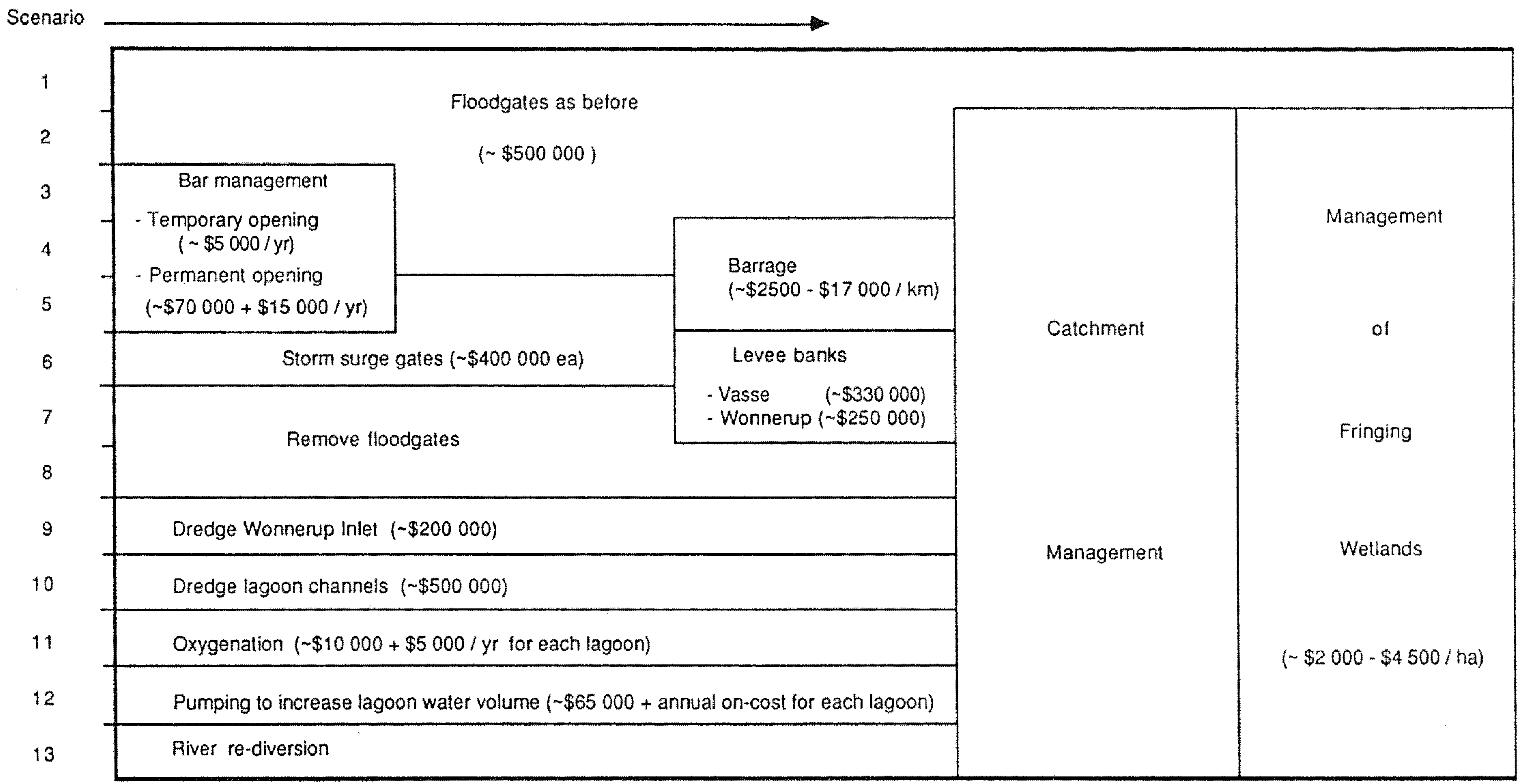


Figure 9. Management options for the Vasse-Wonnerup wetland system.

$2 200 - $4 400/hectare (greater than 50 hectares)

$2 600 - $3 300/hectare (20 - 50 hectares)

$3 300/hectare (5 - 20 hectares)

$4 400/hectare (less than 20 hectares)

Information from the Valuer General's office suggests that if land were purchased it would be at rural value, or less if the land is salt-affected.

### 4.2.10 Barrage across the lagoon

Building a barrage across the lagoon at a height of 0.75 metres AHD is an approach that could satisfy all of the short-term goals for the system without causing any additional impacts to the area. It would increase the estuarine portion of the system and also increase the area available for fish. In addition, portions of the barrage may be raised to create small islands as safe resting and nesting places for use by waterbirds. The barrage would need to be upstream of the deeper area of lagoon water, ideally in a region where the natural banks of the lagoon downstream were sufficiently high to ensure that all marine water was retained. Unfortunately, because the surrounding land is very flat, the only place on the Vasse Lagoon with the appropriate topography is the channel adjacent to the floodgates, but the water is too deep there. To increase the area of the lagoon contained within the barrage, it could be moved upstream and then extended to form banks on both sides of the lagoon. An on-site survey is required to determine the exact location for construction of the barrage, preferably just downstream from the Malbup creek entrance. A much longer barrage wall would be needed to contain marine water to a height of 0.75 metres AHD in the Wonnerup Lagoon.

The estimated cost of building a 0.75 metre high barrage wall of 3 metres width ranges from $250 to $1 700 per 100 metres. The least cost assumes all materials are available on-site, and that a bulldozer alone can carry out the work.

## 5. CONCLUSIONS

The Vasse-Wonnerup wetland system contains the two most nutrient-enriched waterbodies in the southwest of Western Australia. The high nutrient loads are caused by animal waste discharges and soluble fertilizers leaching from a large and extensively cleared catchment with sandy soils. The nutrient enrichment of these wetlands has been exacerbated by the construction of floodgates near the mouth of the system preventing tidal water exchange, which reduces water quality and precipitates fish kills. The gates were originally installed to prevent inundation of fringing pastures by sea water, and are now also essential to prevent flooding of Busselton during storms.

The floodgates have changed the ecology of the Vasse-Wonnerup wetlands by excluding marine water and retaining freshwater and by limiting use of the lagoons by fish species. Since marine water is excluded, evaporation causes the lagoons to dry out in summer. If this seasonal drying process did not occur, the high nutrient loads would undoubtedly precipitate catastrophic algal blooms, probably far worse than those experienced in the Peel-Harvey system. The conversion of the system to an essentially fresh-to-brackish water wetland has been of major benefit to waterfowl at a time when other wetlands in the region have been lost. Its value to waterfowl is further enhanced by increased feeding opportunities as the lagoons begin to dry over the spring/summer breeding season. Despite, or perhaps because of its nutrient-enriched state, the Vasse-Wonnerup wetland system is currently recognised as the most important waterfowl breeding habitat in the southwest of Western Australia and the second most important in terms of bird numbers. The additional nutrients have increased productivity in the wetlands and hence the availability of food to the birds.

A study recently carried out in the Vasse Lagoon by Murdoch University staff has found extremely high numbers of midge and mosquito larvae around the edges of the lagoons. These larvae are a very important food source to waterbirds, often up to 100% of dietary intake, and therefore contribute significantly to the value of the system to waterbird populations. The high productivity of this enriched system will continue to support very high midge and mosquito larval densities, however, if residential developments are permitted adjacent to the lagoons there will inevitably be heavy pressure for pest control programmes to be initiated.

The State Planning Commission Report 'Leeuwin Naturaliste Region Plan: Stage One' (1987) recognizes the conservation, recreation and scenic amenity value of the Vasse-Wonnerup 'estuary'. The study identified the need to "maintain and promote the values of natural environments" (objective 8). The State Planning Commission report provides a planning context within which to consider the management of the Vasse-Wonnerup system, whereas this report provides the environmental background and the objectives to which management of the system might be targetted.

It is highly desirable, if not essential, to continue excluding marine water from the wetlands using a system of floodgates. Local management of summer water quality will be necessary to prevent the continuation of fish kills near the floodgates as the lagoons dry out. Water quality could be managed using a number of the options described in Section 3.1, including a barrage to create a lock situation, oxygenation and possibly dredging. Regulations to prevent the destruction of fish stocks by netting should apply over the main channels, both above and below the floodgates, as the lagoons dry up.

The impact of mosquito and midge control programmes on the wetlands and waterbirds is potentially severe. Apart from the possibility of direct poisoning of birds, the loss of the small invertebrate fauna will dramatically reduce the food resource necessary to sustain the waterbirds, particularly over the breeding season. To protect this wetland habitat, mosquito and midge control operations should be confined to residential areas, and drainage waters from residential developments should not enter the wetlands.

The maintenance of waterfowl habitat is considered to be the most important environmental objective for the Vasse-Wonnerup Wetland System, and therefore it is not appropriate to dramatically reduce nutrient loads. The wetland system should be managed as a 'beneficially' nutrient-enriched habitat to sustain the waterbird populations. While current nutrient loads into the system do cause environmental problems, they do not compromise the system's function as an important waterbird habitat. In the long-term, if catchment nutrient leaching losses continue at current rates, or increase, then worse environmental problems in the wetlands may occur, particularly if raw animal wastes such as sluicings from dairy sheds continue to be discharged directly to the drainage system. Raw animal waste discharges deliver high organic, bacterial and nutrient loads to the waterways and can cause the outbreak of disease in native fauna. Strategies to improve fertilizer and animal waste management in the catchment would be mutually beneficial to both the wetlands and to the catchment farmers.

The mining of mineral sands in the catchment is a landuse which has not been addressed in this document, but one that may also have a significant impact on the wetlands. In the past effluent discharges from mining and refining operations in the catchment to the Wonnerup lagoon have been responsible for manganese concentrations in the Ludlow River that exceed the maximum recommended levels for environmental and domestic uses. Currently mining discharges are subject to Environmental Protection Authority pollution licence conditions and manganese concentrations are being reduced under the terms of this licence. Mining companies are being required to manage and monitor their discharges to ensure that the conservation value of the Vasse-Wonnerup wetlands is maintained.

Currently the only management of the Vasse-Wonnerup wetland system is by the Water Authority of WA for flood control. Because of the environmental significance of the wetlands, it seems to be appropriate for other agencies to become involved in jointly managing the wetlands to ensure that their ecological values are not lost or compromised. The major agencies involved in management of the system should probably include the Water Authority of WA, Department of Conservation and Land Management, WA Department of Agriculture, Environmental Protection Authority, Local Government Authorities and the Fisheries Department. With such a management committee, the values and amenity of the Vasse-Wonnerup wetland system may be maintained.

The need for management of the Vasse-Wonnerup wetland system and its catchment should not be viewed in isolation, but in the context of the well-documented pressure currently being experienced by the wetlands of southern Western Australia. The Swan coastal plain has experienced a dramatic reduction in both area and quality of wetlands, as a result of factors such as drainage for agriculture, landfill, pollution (including eutrophication) erosion, grazing, salination and water level changes (Dept. Conservation and Environment, 1980). The elevated nutrient loadings to the lagoons are one of the causes of the environmental problems in the Vasse-Wonnerup system. This system is highly modified, and is very different from most other coastal waterbodies in Western Australia, and therefore many of the possible management scenarios are not applicable elsewhere. If agriculture is to continue on the coastal plain, then it must be integrated into an environmentally acceptable framework which will reduce its impacts on remaining wetlands, particularly those of great environmental, social or economic importance. Pollution from urban developments is easier to control, because it can often be treated as a point source, and the costs of treating polluted urban discharges are easier to meet. However, extensive urbanization of a coastal plain will lead to elevated pollutant loads to nearby wetlands. An additional impact associated with urban development, and one not considered in this report, is disturbance to wildlife by both people and their pets. This can have a significant effect on wildlife populations in areas utilized for feeding, resting and particularly breeding.

Management of wetland systems for multiple uses is possible, and priority should be given to developing management techniques before it is too late. The Vasse-Wonnerup system provides an ideal situation in which to initiate integrated management. One of the first steps should be to recognise the international importance of the wetlands as a waterbird habitat by nomination of the Vasse-Wonnerup wetlands to the RAMSAR Treary. A land development plan which limits disturbance of the waterbird habitat and also reduces impacts to the wetland environment, should be developed for the area immediately surrounding the wetlands. Concurrently, management of nutrient losses from the surrounding catchment should be initiated to reduce nutrient loads to the lagoons to acceptable levels.

## 6. RECOMMENDATIONS FOR FURTHER STUDY

A number of management options have been outlined in the previous sections, but there is very limited information on the biology and the hydrodynamics of the Vasse-Wonnerup wetland system available, and nothing on the interactions between them. Before a final management scenario can be fully evaluated, more information about the wetland system is required. Important areas requiring further study and/or monitoring are listed below.

1. The hydrodynamics of the system should be analysed and modelled to show the expected changes in salinity throughout the year, particularly if floodgates were to be removed.

2. The effects of salinity on the value of the wetland habitat for the waterbirds.

3. The current seasonal patterns of change in water quality (including salinity), particularly as the lagoons dry.

4. The value to the waterbirds of grazed land compared with ungrazed land fringing the lagoons.

5. The impacts of past dishcarges of mining wastewaters on the wetlands.

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## 8. REFERENCES


Birch, P.B. (1984). Catchment management to reduce phosphorus discharge into the estuary - setting the scene, pp 33 - 42. In 'Potential for Management of the Peel-Harvey Estuary', Department of Conservation and Environment. Bulletin 160.

Bretnall, R. (1987) Busselton Regional Flood Study. Water Authority of Western Australia, Report No.WS4 (Orig. WD3).

Conservation Reserves in Western Australia (1974) Report of the Conservation through Reserves Committee to the Environmental Protection Authority 1974.

Conservation Reserves for Western Australia: as recommended by the Environmental Protection Authority 1976. Systems 1, 2, 3, 5.

Department of Conservation and Environment (1980). Guidelines for the conservation and management of wetlands in Western Australia. Department of Conservation and Environment. Bulletin 79.

Department of Fisheries and Wildlife (1978). Wetlands of the South-West of Western Australia : with special emphasis on the Bussleton area.

Halse, S. (1989). Wetlands of the Swan coastal plain - past and present, pp 105 - 112. In 'Swan Coastal Plain Groundwater Management Conference'. Western Australian Water Resources Council, publication number WRC 1/89.

Humphries, R. and Bott G. (1988) Intensive animal industries on the Swan coastal plain and their associated pollution problems, pp 59 - 66. In 'The Swan Coastal Plain in Crisis: Agriculture and the Environment. The Australian Institute of Agricultural Science. Occasional Publication No.10.

Leeuwin-Naturalist Region Plan - Stage One (1987). State Planning Commission.

McArthur, W.M. and Bettenay, E. (1974) Development and Distribution of Soils of the Swan Coastal Plain, WA. C.S.I.R.O. Soil Publication No.16.

Sanders, C., Robinson, S., McAlpine, K. and Bott, G. (1988). Environmental objectives : what are the criteria and how can we achieve change? pp 95 - 105. In 'The Swan Coastal Plain in Crisis: Agriculture and the Environment. The Australian Institute of Agricultural Science. Occasional Publication No.10.

Schofield, N.J., Bettenay, E., McAlpine, K.W., Height, M.I., Ritchie, G.S.P., and Birch, P.B. (1985) Water and Phosphorus Transport Processes in Permeable Grey Sands at Talbot's Site Near Harvey, Western Australia, Department of Conservation and Environment. Bulletin 209.

Tille, P. and Lantzke, N. (Draft) The Busselton-Margaret River-Augusta Land Capability Study. Western Australia Department of Agriculture.

Tingay, A. and Tingay, S.R. (unpub. 1980). Vegetation and Flora of Wetlands near Busselton. (available in Environmental Protection Authority library).

Vollenweider, R.A. (1975). Input-Output Models, with special reference to the phosphorus loading concept in limnology. Schweiz. z. Hydrol. 37: 53-83.

Vollenweider, R.A. (1976). Advances in defining critical loading levels for phosphorus in lake eutrophication. Mem. Ist., Ital., Idrobiol., 33: 53-83.

Vollenweider, R.A. and Dillon, P.J. (1974). The application of the phosphorus loading concept to eutrophication research. National Research Council Canada, NRC Associate Committee on Scientific Criteria for Environmental Quality, NRCC, No 13690.

Walker, D. I, Lukatelich, R.J. and McComb, A.J. (1987). Impacts of Proposed Developments on the Benthic Marine Communities of Geographe Bay. Environmental Protection Authority, Tech. Series No. 20.

Yeates, J.S., Arkell, P.T., Russell, W.K., Deeley, D.M., Peek, C, and Allen, D. (1985). Management of agricultural losses from the soils of the Peel-Harvey catchment, pp 59 - 76. In 'Peel-Harvey Esturarine System Study Management of the Estuary', Department of Conservation and Environment. Bulletin 195.