Albany Harbours Environmental Study (1988-1989)

Summary and Recommendations

A Report to the Environmental Protection Authority
from the
Technical Advisory Group

Environmental Protection Authority
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Preface

This report presents a brief summary and recommendations of the Albany Harbours Environmental Study. A more detailed report of the Study is outlined in a companion document (EPA Bulletin 412). The Technical Advisory Group consisted of representatives from the Environmental Protection Authority, Waterways Commission, Department of Agriculture and Centre for Water Research (University of Western Australia/Murdoch University). This report and recommendations, and the issues raised by public submissions will form the basis of an Environmental Protection Authority submission to Government.

Precis

Seagrass meadows provide food, shelter and a breeding ground for fish and many other animals and, in the past, have been at the base of the food web of the Albany harbours. Since 1962, when these seagrass meadows were considered to be in a pristine condition, about 90% of the meadows in Princess Royal Harbour and 80% in Oyster Harbour have been lost. In recent years the rate of seagrass loss in the harbours has accelerated due to a proliferation of macroalgae which shade and smother the seagrass meadows. The growth of macroalgae has been stimulated by excessive nutrient inputs to Princess Royal Harbour from industrial, rural and urban sources, and to Oyster Harbour from rural and urban sources.

Current information on the 'recovery' of seagrass meadows suggests that the luxuriant *Posidonia* meadows that once covered most of the Albany harbours will never return to their former state. However, once the large accumulations of macroalgae that presently occur in the harbours are removed and pollutant inputs are drastically reduced, conditions in the harbours are likely to improve sufficiently to allow the remaining seagrasses to flourish and other seagrass species and animals to colonise suitable bare areas of seabed.

If the recommendations in this report are implemented, seagrass decline in both waterbodies will slow down and eventually stop as the biological systems stabilize. In addition, pollutants such as faecal bacteria, solids, oils & greases and visible effluent slicks in the waters and along the shorelines of Princess Royal Harbour and King George Sound will be significantly reduced within two years. Furthermore, if the amount of heavy metals in the sediments of the western end of Princess Royal Harbour is significantly reduced, the re-opening of this part of the harbour to fishing is likely to occur earlier than if the removal of heavy metals from the sediment is left to natural processes.

If, on the other hand, the current pollutant loadings to these harbours continue, the bacteriological and aesthetic quality of Princess Royal Harbour and parts of King George Sound will decline further. In addition, most of the remaining seagrasses will be lost within five years in Princess Royal Harbour and within 5-10 years in Oyster Harbour and the general ecology of the harbours will continue to deteriorate.

Recommendations

The principal recommendations which resulted from the Albany Harbours Environmental Study are listed below. The recommendations are divided into two groups: (i) specific recommendations which, if implemented immediately, will not only retard the rate of seagrass decline but will also provide an immediate improvement in the general environmental quality of the Albany Harbours and; (ii) general recommendations that provide guidelines for long-term environmental management strategies in the Albany region. Recommended Princess Royal Harbour effluent discharge criteria are outlined in Appendix I.

Specific Recommendations

Recommendation 1

Immediate removal of the large accumulations of macroalgae in Princess Royal Harbour and Oyster Harbour. The rate of algal removal should be sufficient to remove these accumulations within two years.

Recommendation 2

Evaluation of removal of nutrient-rich sediments from the Albany harbours as an effective environmental management strategy be undertaken, as a matter of high priority, by the proposed Albany waterways management authority.

Recommendation 3

The four industries currently discharging directly into Princess Royal Harbour be directed to commence immediately, the formulation of a strategy, and to reduce, within two years, industrial pollutant loads currently entering Princess Royal Harbour. In the event of continued discharge to Princess Royal Harbour, as a minimum requirement, effluent quality from these industries is not to exceed Princess Royal Harbour effluent discharge criteria and pollutant loads are to be acceptable to the Environmental Protection Authority.

Recommendation 4

CSBP be directed to commence, immediately, the formulation of a strategy and to reduce, within two years, surface runoff nutrient loads into Princess Royal Harbour from its industrial estate to levels acceptable to the Environmental Protection Authority.

Recommendation 5

CSBP be directed to complete, within one year, a program to determine the current and likely future groundwater nutrient loads into Princess Royal Harbour from its industrial estate. Upon completion, CSBP be directed, if necessary, to implement a management plan that will reduce, within one further year, current and future groundwater nutrient loads into Princess Royal Harbour to levels acceptable to the Environmental Protection Authority.

Recommendation 6

The Water Authority of Western Australia commence immediately, the formulation of a strategy to reduce, within two years, pollutant loads in domestic wastewater effluent from the King Point outfall to levels acceptable to the Environmental Protection Authority. Alternatively, the Water Authority of Western Australia commence immediately, the formulation of a strategy to divert, within four years, the domestic wastewater currently discharged from the King Point outfall.

Recommendation 7

The Town and Shire of Albany be encouraged to complete, within one year, a program to determine the groundwater and surface runoff pollutant loads into the Albany harbours from urban point sources. Upon completion of this program, the Town and Shire of Albany, if necessary, be encouraged to implement a management plan that will reduce, within one further year, current and future groundwater and surface runoff pollutant loads from point sources to the Albany harbours to levels acceptable to the Environmental Protection Authority. As an incentive to local government to reduce pollution from urban sources, co-operative use of existing State Government resources such as the Chemistry Centre, the Department of Health and the Department of Agriculture be provided.

Recommendation 8

The Town and Shire of Albany be encouraged to develop a management plan to minimize pollution of the Albany harbours from urban diffuse sources. To promote community involvement, the Town and Shire of Albany be encouraged to undertake an education programme related to minimising pollution from these sources.

Recommendation 9

The Western Australian Department of Agriculture continue, in consultation with farmers and other groups, to develop and promote the adoption of catchment management plans which will assist with the reduction of nutrient loads to target levels as determined by the Environmental Protection Authority. As an incentive to adopt more efficient fertilizer use, funding be provided for two years, for a free soil testing service targeted on sandy (low reactive iron) soils in the catchments of the Albany harbours.

Recommendation 10

The Western Australian Department of Agriculture evaluate current soil survey, land-use and other natural resource information to identify high phosphorus source areas (including point sources) within the catchments of Princess Royal Harbour and Oyster Harbour, and prepare a strategy for their management by June 1990.

Recommendation 11

Further investigations to refine initial estimates of the annual nutrient assimilative capacity of Oyster Harbour be undertaken as a matter of high priority by the proposed Albany waterways management authority.

Recommendation 12

CSBP be directed to undertake an extensive survey of the heavy metal concentrations in the sediments and biota of Princess Royal Harbour to assess the current contamination of the harbour and, if necessary, to formulate, within one year, a management plan to reduce heavy metal contamination of Princess Royal Harbour to levels, and within a timeframe, acceptable to the Environmental Protection Authority.

General Recommendations

Recommendation 1

Annual total nutrient loading into Princess Royal Harbour and Oyster Harbour from all sources should not exceed the nutrient assimilative capacities of these waterbodies.

Recommendation 2

Future development proposals and management of industrial, urban and rural land-use in the catchments of the Albany harbours should have regard for the capacity of these waterways to assimilate pollutants, particularly nutrients.

Recommendation 3

A regional liaison structure be developed to ensure co-ordination of Government, technical and community involvement in the integrated management of the catchments and waterways of the Albany harbours.

Recommendation 4

A management presence be established to provide for future on-site management of the Albany harbours. An Albany Waterways Management Authority could be established under the Waterways Commission Act with direct local government and community involvement.

1. Introduction

Princess Royal Harbour and Oyster Harbour are located to the south and north of the Albany township. Both harbours are used extensively for recreational activities and professional fishing, and Princess Royal Harbour is also used as a port, and for the discharge of industrial wastes. The sheltered waters of the harbours provide ideal conditions for water-based recreational activities such as boating, fishing, windsurfing and swimming and these pursuits are enjoyed by the local community and by an increasing number of tourists.

Tourism is now generally regarded as a major growth industry in the Albany region with much of the attraction for tourists centred on water-associated activities in the harbours and along the surrounding coastline. The proposed redevelopment of the Albany foreshore is likely to further increase this focus.

A severe decline in the seagrass meadows in both harbours in recent years, the closure of the western end of Princess Royal Harbour to fishing in 1984 as a result of heavy metal contamination, and the continuing pollution of Princess Royal Harbour by grease slicks, solid wastes and faecal bacteria have raised widespread community concern about the environmental condition of these waterbodies and the ensuing long-term effects on the local inhabitants' lifestyle and on tourism.

In response to this concern, the Western Australian Government, in late 1987, approved funding for an intensive two-year study into the environmental problems of the Albany harbours with the ultimate aim of identifying solutions to these problems. The Albany Harbours Environmental Study consisted of a number of interrelated studies that provide the technical rationale for the recommendations that are contained in this report.

The remaining seagrass meadows were mapped to compare with past records of seagrass distributions and this information was used to assess the rate of decline and the urgency of remedial action. In the past, reduction in light reaching seagrass meadows caused by algal shading has been implicated in the loss of seagrasses in other parts of Western Australia. To assess the significance of light reductions to seagrasses in the Albany harbours, the light requirements of the main seagrass species were determined and an extended experiment was conducted in Princess Royal Harbour to gauge the rate of decline and recovery of a seagrass meadow subjected to different levels of light stress. An inventory of industrial, agricultural and urban inputs was undertaken to identify the main sources and types of pollutants entering the harbours. Water circulation studies were conducted to determine the flushing characteristics of these waterbodies and a water quality survey in both harbours was undertaken over a 14 month period to compare with a similar study conducted in Princess Royal Harbour in 1979. A survey of nutrient stores accumulated in the water, sediment and plants was carried out to determine the ultimate fate of nutrients entering the harbours.

Several other studies were also undertaken to assess the feasibility of potential management options. These included studies that determined initial estimates of the annual nutrient assimilative capacity of the harbours, that is, the level of external nutrient loading that can enter these waterbodies without further deterioration occurring after the decline is arrested and the systems stabilize, and the feasibility of remedial measures such as algal harvesting and seagrass restoration. Further studies were conducted in the catchments of Princess Royal Harbour and Oyster Harbour to identify ways to minimise losses of fertilizer from agricultural lands thereby reducing nutrient loadings into these waterbodies. The results of these studies are briefly outlined below.

2. The Problems

2.1 Nutrients and seagrass loss

Past and current nutrient loads into Princess Royal Harbour and Oyster Harbour have stimulated excessive growth of large algae (macroalgae) and smaller algae that grow on the leaves of seagrasses (epiphytes). These algae shade and smother the seagrasses, significantly reducing the amount of light reaching these plants. Light reduction is now considered the primary cause of the widespread loss and thinning of the seagrass meadows in both harbours.

Forty-five percent and 66% of the areas originally covered by seagrass meadows in Oyster Harbour and Princess Royal Harbour, respectively, were lost between 1962 and 1984. By 1988, only 40% of the seagrass present in both harbours in 1984, remained. Thus, almost 90% of the seagrasses in Princess Royal Harbour and 80% in Oyster Harbour have been lost since 1962 when these seagrass meadows were considered to be in a pristine condition.

The rate of seagrass decline has been particularly rapid since 1984, suggesting that if immediate action is not taken to arrest the rate of decline, all the dense areas of seagrass will be lost in Princess Royal Harbour within five years and within 5-10 years in Oyster Harbour, leaving only patchy areas of sparse seagrass in both harbours. Current information on the recovery of seagrass meadows suggests that the luxuriant *Posidonia* meadows that once covered most of the Albany harbours will never return to their former state. However, once the large accumulations of macroalgae that presently occur in the harbours are removed and pollutant inputs are drastically reduced, conditions in the harbours are likely to improve sufficiently to allow the remaining seagrasses to flourish and other seagrass species and animals to colonise suitable bare areas of seabed.

Although phosphorus and nitrogen are both essential elements for plant growth, phosphorus probably controls the growth of algae in the Albany harbours. Thus control of phosphorus loadings into the Albany harbours is the key to long-term management of the excessive algal growth and seagrass decline in these waterbodies. Further additions of phosphorus are likely to result in increased algal growth with continued aggravation of environmental problems. Conversely, if phosphorus inputs are significantly reduced, both algal growth and the rate of decline of the seagrass meadows will decrease.

Nutrients are added to the waters of the Albany harbours in several different ways. Industrial effluents, urban runoff, domestic wastewater and agricultural inputs are the major external nutrient sources. In the past, CSBP & Farmers Ltd (CSBP) has been the major individual contributor of phosphorus to Princess Royal Harbour. Between 1954 and 1984, approximately 650 tonnes of phosphorus entered the harbour from CSBP's industrial estate via direct discharge and surface runoff, and this nutrient loading (about 80% of the total) was probably the single biggest factor in the nutrient enrichment of Princess Royal Harbour and the subsequent decline of the seagrass meadows.

In 1988, industrial, rural and community (including domestic wastewater) sources contributed 61%, 24% and 15% of the total phosphorus load into Princess Royal Harbour. Groundwater nutrient loadings from point sources such as piggeries, septic tanks etc, were estimated during this study but further surveys are required to assess, more accurately, the relative contribution of groundwater pollution. Preliminary data from surveys currently being undertaken, suggest that this source of nutrients to the harbours may be more significant than previously thought. In 1988, industrial wastewater discharges into Princess Royal Harbour, particularly from Metro Meats Pty Ltd and Southern Processors Pty Ltd, and surface runoff from CSBP contributed significant proportions of the total nutrient load into this waterbody.

Most of the nutrient load into Oyster Harbour enters via surface runoff and river discharge, particularly in average or above-average rainfall years. In low rainfall years, point sources of pollution such as dairies, piggeries, septic tanks and Water Authority of Western Australia package treatment plants contribute a more significant proportion of the total annual nutrient load into Oyster Harbour.

Large amounts of nutrients have accumulated in the sediments of both harbours and in the macroalgae in Princess Royal Harbour over the years and these stores provide a large internal store of nutrients, a proportion of which are recycled.

2.2 Heavy metals and pesticides

CSBP discharged significant quantities of heavy metals (lead and mercury) into Princess Royal Harbour in its effluent for about thirty years and this eventually led to the contamination of sediments and biota, particularly in the western end of the harbour. Following the discovery of contaminated fish in 1983, the western end of Princess Royal Harbour was closed to fishing in 1984. The direct discharge of effluent from CSBP stopped in 1984 and although the annual monitoring of mercury in fish from Princess Royal Harbour has indicated that, in general, mercury levels in certain fish species have declined since then, levels remain above the health limit and the western end of the harbour remains closed to fishing.

Other heavy metals such as zinc and chromium were discharged in the effluent from the Albany Woollen Mills Pty Ltd, but recent changes in industrial procedures by this company have substantially reduced the loadings of these metals into the harbour from this source. High concentrations of heavy metals were also found in urban runoff, particularly after the first rains.

Elevated concentrations of dieldrin and other organochlorine pesticides were present in initial urban drain flows and in the effluents of the Albany Woollen Mills Pty Ltd and Southern Processors Pty Ltd. The Albany Woollen Mills now ensures that these pesticides are not used for mothproofing wool that is imported from countries where these pesticides are still in common use. Organochlorines are now banned for agricultural use in Western Australia and thus residual levels in soils will gradually decline, resulting in decreasing amounts entering Princess Royal Harbour from vegetable processing. A limited survey of pesticide levels in mussels from Princess Royal Harbour in 1988 indicated that pesticide levels were well below the health limit in all samples.

2.3 Microbiological quality of shores and inshore waters

Elevated concentrations of faecal bacteria in seawater were first reported at Middleton Beach in a study conducted in 1979 (Atkins *et al.,* 1980). Following the recommendations of this study, a program was established to monitor the bacteriological condition of the waters of Princess Royal Harbour and Middleton Beach. Water samples were taken from within the mixing zones of the various effluent outfalls and also from Ellen Cove on 35 occasions from 1982 to 1988.

Faecal coliform counts of less than 50 per 100ml are considered satisfactory for direct contact recreation, while consistent counts above 200 per 100ml suggest that a distinct health risk exists and warrants a sanitary survey. Counts above 2000 per 100ml indicate objectionable water that is heavily polluted.

The nearshore effluent mixing zones of the Water Authority of Western Australia King Point domestic wastewater outfall and the Metro Meats Pty Ltd outfall in Princess Royal Harbour were found to be the most heavily polluted. Bacterial counts of greater than 100,000 organisms per 100 ml were recorded on 30% of the occasions the mixing zone of Metro Meats Pty Ltd was sampled and on 100% of the occasions the mixing zone of the King Point outfall was sampled. The waters within these mixing zones are grossly polluted. The faecal bacterial concentrations at Ellen Cove, a popular swimming beach, were above acceptable levels (200 per 100 ml) on at least 27% of the occasions samples were taken. This beach is north of the King Point wastewater treatment plant outfall and the contamination is assumed to be from this source. An extension to the outfall at King Point was completed in early 1989 and discharge now occurs near the seabed in a water depth of 10m, some 30m offshore. The extension is likely to have resulted in a significant decrease

in the surface concentrations of faecal bacteria due to increased initial dilution as the buoyant plume rises to the surface. As a result, the frequency of occurrence of unacceptable levels of faecal bacteria reaching Middleton Beach and Ellen Cove is now likely to be lower. Future monitoring will reveal the degree of improvement gained from the changes to the King Point outfall.

2.4 Aesthetic quality of shores and waters

The high aesthetic quality of the marine and estuarine environments in the Albany region is an important attraction to the residents of Albany and tourists alike. The beaches of the Albany waterways have not yet been severely affected by large accumulations of decomposing algae, commonly associated with nutrient enriched waterbodies such as Peel Inlet near Mandurah. Another common symptom of eutrophication, again not yet apparent in the Albany harbours, is the excessive growth of microscopic algae (phytoplankton). These phytoplankton 'blooms' discolour and deoxygenate the water, as well as sometimes producing toxins which adversely affect aquatic life and constitute a public health risk. If no action is taken to reduce nutrient inputs to the harbours, the possibility of the Albany harbours changing from macroalgal-dominated systems to phytoplankton-dominated systems in the future should not be dismissed.

Various parts of the shoreline of Princess Royal Harbour are fouled periodically by lumps of fat originating from Metro Meats, and effluent slicks are commonly observed moving downwind from this outfall. During summer, when winds blow predominantly from the south-east, effluent slicks are noticeable near the Albany Town jetty. Strong odours from Metro Meats are also noticeable in the Albany township at times during summer. These conditions significantly reduce the aesthetic quality of this area and are incompatible with the proposed Albany foreshore redevelopment.

The existing state of the detention basins on the Albany foreshore also detract significantly from the visual appeal of this part of Princess Royal Harbour. Landfill and residential development at the water's edge is also destroying fringing vegetation and reducing the natural and aesthetic values of the harbour shores.

3. Conclusions

Seagrass meadows provide food, shelter and a breeding ground for fish and many other animals and, in the past, have been at the base of the food web of the Albany harbours. Since 1962, when these seagrass meadows were considered to be in a pristine condition, about 90% of the meadows in Princess Royal Harbour and 80% in Oyster Harbour have been lost. In recent years the rate of seagrass loss in the harbours has accelerated due to a proliferation of macroalgae which shade and smother the seagrass meadows. The growth of macroalgae has been stimulated by excessive nutrient inputs to Princess Royal Harbour from industrial, rural and urban sources, and to Oyster Harbour from rural and urban sources.

Current information on the 'recovery' of seagrass meadows suggests that the luxuriant *Posidonia* meadows that once covered most of the Albany harbours will never return to their former state. However, once the large accumulations of macroalgae that presently occur in the harbours are removed and pollutant inputs are drastically reduced, conditions in the harbours are likely to improve sufficiently to allow the remaining seagrasses to flourish and other seagrass species and animals to colonise suitable bare areas of seabed.

If the recommendations in this report are implemented, seagrass decline in both waterbodies will slow down and eventually stop as the biological systems stabilize. In addition, pollutants such as faecal bacteria, solids, oils & greases and visible effluent slicks in the waters and along the shorelines of Princess Royal Harbour and King George Sound will be significantly reduced within two years. Furthermore, if the amount of heavy metals in the sediments of the western end of Princess Royal Harbour is significantly reduced, the re-opening of this part of the harbour to fishing is likely to occur earlier than if the removal of heavy metals from the sediment is left to natural processes.

If, on the other hand, the current pollutant loadings to these harbours continue, the bacteriological and aesthetic quality of Princess Royal Harbour and parts of King George Sound will decline further. In addition, most of the remaining seagrasses will be lost within five years in Princess Royal Harbour and within 5-10 years in Oyster Harbour and the general ecology of the harbours will continue to deteriorate.

4. Management options

Some of the management options that have been considered in the Albany Harbours Environmental Study are presented in Appendix 2. The relative advantages and disadvantages from environmental, social and economic viewpoints are outlined. Costs are preliminary estimates only.

5. Recommendations

The principal recommendations which resulted from the Albany Harbours Environmental Study are listed below. The recommendations are divided into two groups: (i) specific recommendations which, if implemented immediately, will not only retard the rate of seagrass decline but also provide immediate improvements in the general environmental quality of the Albany harbours and; (ii) general recommendations that provide guidelines for long-term environmental management strategies in the Albany region. Recommended Princess Royal Harbour effluent discharge criteria are outlined in Appendix 1.

5.1 Specific recommendations

Large accumulations of algae are the direct cause of past and current widespread death of seagrasses in both harbours. The harvesting of the macroalgae in the Albany harbours will remove the direct cause of seagrass death, significantly reduce the store of nutrients bound up in the plants themselves, and facilitate oxygenation of the sediments, thereby minimising release of nutrients from the sediments. The main accumulations of macroalgae in Princess Royal Harbour occur in depths of less than 3m, particularly in the south-east and north-west sections of Princess Royal Harbour, and the south-east corner of Oyster Harbour. As these accumulations occur over essentially bare sediment, detrimental side-effects of harvesting operations on the remaining seagrasses are likely to be minimal. Similarly, the effects of harvesting on the animal populations in the harbours are also likely to be insignificant as the deoxygenated conditions that occur under thick layers of algae are unlikely to be favourable for most animals. Removal of the algae will provide the additional benefit of allowing these sediments to become re-oxygenated, thereby providing additional habitat for animals that live in the sediment.

Harvesting of algae should only be considered as an interim measure. The long-term solution involves reducing the supply of nutrients to these plants by substantially reducing the current external nutrient loadings into the harbours.

Recommendation 1

Immediate removal of the large accumulations of macroalgae in Princess Royal Harbour and Oyster Harbour. The rate of algal removal should be sufficient to remove these accumulations within two years.

Analysis of the nutrient content of the sediments in the Albany harbours reveals that a significant proportion of the total sediment nutrient store occurs in the superficial sediments (top 20mm) of the deep basins in water depths over 6m. The relative importance, however, of sediment nutrient recycling in the Albany harbours, in comparison to external inputs of nutrients, is unknown and requires investigation. This aspect and a more detailed survey of sediment nutrient concentrations in the deep basins should be undertaken before dredging of the sediments in the harbours is considered. Dredging would substantially reduce the largest nutrient pool in Princess Royal Harbour without significant side-effects on the remaining seagrass meadows because the deep areas of the harbours are now devoid of any significant areas of seagrass.

Recommendation 2

Evaluation of removal of nutrient-rich sediments from the Albany harbours as an effective environmental management strategy be undertaken, as a matter of high priority, by the proposed Albany waterways management authority.

Pollutants enter the Albany harbours in groundwater, surface runoff and in industrial and domestic effluents. Diffuse sources of pollutants such as in rural and urban groundwater and surface runoff contribute a significant proportion of the total nutrient loads into the Albany harbours but are considerably more difficult to manage in the short-term than industrial and domestic effluent discharges, groundwater and surface runoff from point sources.

Until inputs from diffuse sources are significantly reduced, pollutants from rural runoff and groundwater will consume most of the assimilative capacity of Princess Royal Harbour. Thus, to achieve the goal of reducing total nutrient loads into Princess Royal Harbour to below the assimilative capacity of the harbour within two years and thereby arrest the current rapid decline in the remaining seagrass meadows, inputs from industrial, domestic and urban point sources must be substantially reduced within this time-frame.

Recommendation 3

The four industries currently discharging directly into Princess Royal Harbour be directed to commence immediately, the formulation of a strategy, and to reduce, within two years, industrial pollutant loads currently entering Princess Royal Harbour. In the event of continued discharge to Princess Royal Harbour, as a minimum requirement, effluent quality from these industries is not to exceed Princess Royal Harbour effluent discharge criteria and pollutant loads are to be acceptable to the Environmental Protection Authority.

Recommendation 4

CSBP be directed to commence, immediately, the formulation of a strategy and to reduce, within two years, surface runoff nutrient loads into Princess Royal Harbour from its industrial estate to levels acceptable to the Environmental Protection Authority.

Recommendation 5

CSBP be directed to complete, within one year, a program to determine the current and likely future groundwater nutrient loads into Princess Royal Harbour from its industrial estate. Upon completion, CSBP be directed, if necessary, to implement a management plan that will reduce, within one further year, current and future groundwater nutrient loads to Princess Royal Harbour to levels acceptable to the Environmental Protection Authority.

Recommendation 6

The Water Authority of Western Australia commence immediately, the formulation of a strategy to reduce,

within two years, pollutant loads in domestic wastewater effluent from the King Point outfall to levels acceptable to the Environmental Protection Authority. Alternatively, the Water Authority of Western Australia commence immediately, the formulation of a strategy to divert, within four years, the domestic wastewater currently discharged from the King Point outfall.

Recommendation 7

The Town and Shire of Albany be encouraged to complete, within one year, a program to determine the groundwater and surface runoff pollutant loads into the Albany harbours from urban point sources. Upon completion of this program, the Town and Shire of Albany, if necessary, be encouraged to implement a management plan that will reduce, within one further year, current and future groundwater and surface runoff pollutant loads from point sources to the Albany harbours to levels acceptable to the Environmental Protection Authority. As an incentive to local government to reduce pollution from urban sources, co-operative use of existing State Government resources such as the Chemistry Centre, the Department of Health and the Department of Agriculture be provided.

Pollutants from diffuse urban sources enter the Albany harbours via groundwater and surface runoff. Fertilizers and pesticides applied to household gardens, septic tanks as well as pollutants from car exhausts, tyres and accidental spillages all contribute to the pollution of the harbours. Minimization of the 'downstream' effects of these pollutants on the harbours requires a commitment by the community to control these pollutants at their source. The innovative approach by the Town and Shire of Albany in establishing the first successful urban-waste recycling program in Western Australia provides a good basis for continuing control of urban pollution. To achieve a reduction in the pollutant loads from urban diffuse sources, surface runoff into the harbours should be intercepted so that pollutants can be removed. Increased usage of more 'environmentally friendly' household products, appropriate planning strategies regarding the siting of septic tanks and the use of alternative technologies for the management of domestic wastes, should also be promoted.

Recommendation 8

The Town and Shire of Albany be encouraged to develop a management plan to minimize pollution of the Albany harbours from urban diffuse sources. To promote community involvement, the Town and Shire of Albany be encouraged to undertake an education programme related to minimising pollution from these sources.

The annual nutrient assimilative capacity of Princess Royal Harbour is estimated to be approximately 7 tonnes of total phosphorus and 54 tonnes of total nitrogen. Desirable loads during a 'recovery' phase of this waterbody, that is while the decline is arrested and the ecosystem stabilizes, are zero. The rate of 'recovery' will depend on the level of nutrient loading in excess of zero, provided the assimilative capacity is not exceeded. If the assimilative capacity is exceeded during this period, the ecosystem will continue to decline.

In 1988 approximately 29 tonnes of phosphorus entered Princess Royal Harbour. Of this total, about 7 tonnes were estimated to have entered from rural sources, about 4 tonnes from community sources and 18 tonnes from industrial sources. If the recommendations in this report are implemented, inputs from industrial and community sources will decrease, within two years, to less than about 5 tonnes, based on current input estimates. Although this represents a significant reduction in phosphorus loading of about 80%, when the remaining load from industrial and community sources is added to the existing rural phosphorus loading into Princess Royal Harbour, the assimilative capacity will be exceeded by about 50% and the harbour will continue to decline. This emphasizes the urgent need to substantially reduce nutrient losses, particularly phosphorus, from the rural catchment of Princess Royal Harbour.

Because of the complexity of the physical processes in Oyster Harbour, the annual nutrient assimilative capacity is difficult to estimate with the information that is currently available. Limited data suggests that the mean annual nutrient loading into Oyster Harbour is approximately 30 tonnes of total phosphorus and about 350 tonnes of total nitrogen and that the source of most of these nutrients are fertilizers washed off agricultural land in the catchment of Oyster Harbour.

The estimated annual nutrient assimilative capacity of Oyster Harbour is about 7-14 tonnes of total phosphorus and 54-108 tonnes of total nitrogen. These estimates should be regarded as initial management targets and indicate that inputs of nutrients, particularly phosphorus, into Oyster Harbour from agricultural land must be drastically reduced if the current decline in the seagrass meadows in the harbour is to be arrested. Further investigations into the nutrient dynamics of Oyster Harbour are necessary to refine these initial estimates of the annual nutrient assimilative capacity.

Recommendation 9

The Western Australian Department of Agriculture continue, in consultation with farmers and other groups, to develop and promote the adoption of catchment management plans which will assist with the reduction of nutrient loads to target levels as determined by the Environmental Protection Authority. As an incentive to adopt more efficient fertilizer use, funding be provided for two years, for a free soil testing service targeted on sandy (low reactive iron) soils in the catchments of the Albany harbours.

Recommendation 10

The Western Australian Department of Agriculture evaluate current soil survey, land-use and other natural resource information to identify high phosphorus source areas (including point sources) within the catchments of Princess Royal Harbour and Oyster Harbour, and prepare a strategy for their management by June 1990.

Recommendation 11

Further investigations to refine initial estimates of the annual nutrient assimilative capacity of Oyster Harbour be undertaken as a matter of high priority by the proposed Albany waterways management authority.

The levels of mercury in 15 species of fish from Princess Royal Harbour have been monitored annually since 1984 when the effluent (containing lead and mercury) from CSBP's fertilizer works ceased discharging into the western end of Princess Royal Harbour. Mercury levels remain above the health limit in most of the species tested and it appears that the re-opening of the western end of Princess Royal Harbour to fishing is unlikely in the near future. A limited survey of heavy metal concentrations in the sediments in the vicinity of the former CSBP outfall was conducted by the Environmental Protection Authority in 1989. The results of this survey indicated that mercury concentrations in the sediments have not decreased significantly since 1984 suggesting that the natural flushing of heavy metals from the harbour is very slow.

Tourism in the Albany region depends largely on the public perception of the environmental quality of the Albany region, of which the Albany harbours are an integral part. The closure of the western end of Princess Royal Harbour to fishing mitigates against a perception of high environmental quality and thus all options in relation to the re-opening of the western end of the harbour should be examined.

Recommendation 12

CSBP be directed to undertake an extensive survey of the heavy metal concentrations in the sediments and biota of Princess Royal Harbour to assess the current contamination of the harbour and, if necessary, to formulate, within one year, a management plan to reduce heavy metal contamination of Princess Royal Harbour to levels, and within a timeframe, acceptable to the Environmental Protection Authority.

5.2 General recommendations

All waterbodies have a capacity to absorb some pollutants without long-term damage to their biological systems. This *"assimilative capacity"*, however, is limited and depends on the physical and biological characteristics of the receiving environment and the type of wastes that are discharged into it. For example, poorly-flushed waters have a much lower capacity to assimilate identical pollutant loads than well-flushed waterbodies.

Biological systems like the Albany harbours, where the assimilative capacity has been exceeded for many years, are usually severely degraded. During the 'repair' phase of degraded waterbodies, it is desirable that total pollutant loads are as close to zero as possible, that is well below the level the system could absorb once decline is halted and the system is stable. Any additional pollutant loads up to the level of the assimilative capacity will lengthen the 'recovery' time. If the assimilative capacity is exceeded during this period the ecosystem will continue to decline.

The assimilative capacity is a resource to be partitioned equitably between all the 'user' groups (industry, rural and community). The partitioning of the assimilative capacity may depend on factors such as the relative socio-economic importance of the 'user' to the community as a whole.

Current information indicates that the annual nutrient assimilative capacity for Princess Royal Harbour is approximately 7 tonnes of total phosphorus and 54 tonnes of total nitrogen. Initial estimates for Oyster Harbour indicate that the annual nutrient assimilative capacity is approximately 7-14 tonnes of total phosphorus and 54-108 tonnes of total nitrogen. These estimates should be considered as management targets for annual nutrient loading into the harbours and be subject to review as further information becomes available.

Recommendation 1

Annual total nutrient loading into Princess Royal Harbour and Oyster Harbour from all sources should not exceed the nutrient assimilative capacities of these waterbodies.

Princess Royal Harbour and Oyster Harbour are waterways of great ecological, aesthetic and recreational importance to Albany and the Great Southern Region. Currently, however, these waterways are severely degraded. If the recommendations in this report are implemented the environmental condition of Princess Royal Harbour and Oyster Harbour will improve significantly over the next five years. However, if significant reductions in nutrient loadings into the harbours are not achieved, the short-term prognosis for the Albany harbours is one of continued environmental deterioration.

To achieve real improvements to the current environmental state of these two waterbodies, it will be necessary, not only to significantly reduce nutrient loadings from existing sources, but also to severely limit, or prevent, future additional nutrient loadings from new sources. Future industrial, urban and rural developments in the catchments of the Albany harbours should be assessed from this perspective.

Recommendation 2

Future development proposals and management of industrial, urban and rural land-use in the catchments of the Albany harbours should have regard for the capacity of these waterways to assimilate pollutants, particularly nutrients.

Until about 15 years ago, the environmental implications of certain activities in the catchments of enclosed waterbodies, like the Albany harbours, were little appreciated and poorly understood. As a result, the clearing of land for agriculture and the widespread application of fertilizers to supplement nutrient-poor soils, as well as the use of waterways for the discharge of industrial and domestic wastes, were undertaken without considering possible 'downstream' environmental problems.

As these problems became apparent in the 1970s, an appreciation developed of the interconnectedness of activities within the catchments of these waterbodies. By this time however, many of these activities were firmly entrenched and no easy solution to the environmental problems could be found. The end result, in many cases, has been severe deterioration of the biological communities and, as a result, a loss of valuable community resources. This scenario essentially describes the decline of the Albany harbours.

To arrest the decline and facilitate recovery of the Albany harbours, the community as a whole must take account of the influence and potential impacts of activities in their catchments upon the health of the harbours. This requires an integrated approach to environmental management involving extensive community consultation, co-operation and co-ordination of all activities that potentially threaten the long-term ecological viability of the harbours.

Recommendation 3

A regional liaison structure be developed to ensure co-ordination of Government, technical and community responses to the integrated management of the catchments and waterways of the Albany harbours.

The effective management of the Albany harbours requires an on-site management presence. Furthermore, the implementation of several of the recommendations contained in this report requires some form of management structure in Albany. Management-related activities such as algal harvesting, pollution control and refining initial estimates of the annual nutrient assimilative capacities of the harbours as well as providing waterways management expertise to Government, local government and community groups concerned with the 'restoration' of the Albany harbours could be part of the role of an on-site management authority. An annual pollution audit from industrial, urban and rural sources could also be undertaken by a management authority to monitor the effectiveness of the management measures recommended in this report.

Recommendation 4

A management presence be established to provide for future on-site management of the Albany harbours. An Albany Waterways Management Authority could be established under the Waterways Commission Act with direct local government and community involvement.

Appendix 1

Recommended Princess Royal Harbour effluent discharge criteria.

APPENDIX I: Recommended Princess Royal Harbour effluent discharge criteria.

Effluent Category	WAWA sewer entrance criteria (mg/L)	Princess Royal Harbour effluent discharge criteria (mg/L)
Discharge volume	to be determined	to be determined
BOD_5	<3000	<20
Suspended Solids	<1500	<80
Oil&Grease	<100	<30
Surfactants	not applicable	<10
Total nitrogen	not applicable	<10
Total phosphorus	not applicable	<3

Appendix 2
Management options

Appendix 2: Management options

KEY:
1= highly desirable
2= desirable
3= undesirable
NA = not available, not applicable

Option	Method	Harbour effected	Implementation	Time for effect after implementation	Input reductions to harbour (% of 1988 annual nutrient load)		Reduction in nutrient store (% of 1988 sediment + biomass nutrient store)		Capital cost	Ongoing cost	Benefits	Negative social impact	Negative environmental impact	Priority
					%N	%P	%N	%P						
Algal harvesting (75% removal)	Suction harvesting of algal accumulations which smother the seagrass.	PRH	6-12 months	Immediate	0%	0%	12%	6%	$500 000 - $1 000 000	$500 000	Arresting seagrass decline. Limiting sediment release of nutrients. Nutrient export from the system.	None	None	1
Dredging	Removal of contaminated sediment from PRH.	PRH	12-24 months	Immediate	0%	0%	21%	36%	NA	NA	Removal of nutrients and some heavy metals from the system.	None	Increased turbidity. Damage to seagrass beds. Disposal of spoil.	2
Industrial licensing	Under the licensing provisions of the Environmental Protection Act (1986).	PRH	In progress	Immediate	0%	12% (already achieved in 1989)	0%	0%	NA	NA	Reduced nutrient loads. Visual improvement in water quality.	Possible closure of some industries.	None	1
Tidal ejection	Contain all industrial effluent then synchronous release into the outgoing tidal jet.	PRH	12 months	Immediate	25%	17%	0%	0%	$500 000	NA	Rapid reduction in nutrient inputs.	Continuation of slicks. On-site storage of effluent. Possible contamination of King George Sound.	Does not remove sediment sources of nutrients. Possible contamination of KGS.	3
Relocation of all PRH industries	Move all PRH industry to a new location in Albany	PRH	Within 5 years	Immediate	54%	61%	0%	0%	$200 000 000	nil	Contaminant inputs almost nil. Beneficial for proposed foreshore redevelopment. Reduced impact from obnoxious odours.	Costs. Negative social impact at site of relocation.	None providing proper environmental planning of the new site is undertaken.	3
Relocation of 2 industries	Relocate Metro Meats and Southern Processors.	PRH	Within 3 years	Immediate	25%	19%	0%	0%	$50 000 000	none	Contaminant inputs greatly reduced. Foreshore asthetically more attractive.	Negative social impact at site of relocation.	None provided proper planning.	3
CSBP nutrient sources	Treatment of CSBP groundwater and runoff to extract phosphorus.	PRH	6-12 months	Immediate	0%	20%	0%	0%	$100 000	$8 000	Significant reduction in the phosphorus input to PRH.	None	None	1
Low-technology effluent treatment	On-site pond treatment (PRH industries).	PRH	12-24 months	Immediate	10%	2%	0%	0%	NA	NA	Reduction in biological oxygen demand and bacteria in effluent.	Associated odours. Land availability. Cost of premium land. Conflict with proposed foreshore redevelopment.	Some contaminant levels will remain high.	3
High-technology treatment	Anaerobic digestion and nutrient stripping (PRH industries).	PRH	12-24 months	Immediate	30%	20%	0%	0%	$1 800 000	$80 000	Possible methane gas power by-product. Compact treatment area. No odours. Potential reticulation of effluent to parks and gardens.	None	Minimal. Discharges will then meet the required criteria.	1

Option	Method	Harbour effected	Implementation	Time for effect after implementation	Input reductions to harbour (% of 1988 annual nutrient load)		Reduction in nutrient store (% of 1988 sediment + biomass nutrient store)		Capital cost	Ongoing cost	Benefits	Negative social impact	Negative environmental impact	Priority
					%N	%P	%N	%P						
Domestic wastewater diversion from KGS	Diversion of King Point to new treatment plant for land or ocean disposal.	PRH	Within 4 years	Immediate	10%	6%	0%	0%	$5 000 000	$200 000	Part of a rationalized sewerage plan for Albany. No domestic wastewater to PRH. Minimal bacterial levels at Middleton Beach. No slicks in KGS.	None	Environmental impact studies are required to assess the effects of land and/or ocean disposal.	1
Combined industrial and domestic wastewater sewer	Industries use high technology options and connect to WAWA sewer.	PRH	Within 5 years	Immediate	42%	30%	0%	0%	$15 000 000	<$200 000	Contaminant inputs to PRH would be minimised. Minimal bacterial levels at Middleton Beach. No slicks in PRH.	Some costs to be borne by industry.	Environmental impact studies are required to assess the effects of land and/or ocean disposal.	1/2
Industrial effluent disposal to King George Sound	Untreated effluent piped to KGS.	PRH	18 months	Immediate	30%	18%	0%	0%	NA	NA	Rapid reduction in contaminant inputs to PRH.	Slicks in KGS. Bacterial levels at Middleton Beach would increase.	Pollution of KGS (localised). Some of the effluent would return to PRH on flood tide.	3
Urban runoff detention basins	Purify urban water by filtration through managed, artificial or enhanced wetlands.	PRH	in progress-36 months	6-12 months	1% (45% red'n in urban N export to PRH)	1% (90% red'n in urban P export to PRH)	0%	0%	$2 500	$50 000	Reduction in contaminant inputs. Creation of wetland habitats. Visual improvement of PRH foreshore.	Potential mosquito breeding areas.	None	1
Yakamia Creek detention basin	Retain the wetland nutrient filter and minimize nearby flooding.	OH	6-12 months	currently effective	1% (45% red'n in urban N export to OH)	1% (90% red'n in urban P export to OH)	0%	0%	$130 000 - $200 000	~$5 000	Retention of a valuable natural nutrient removal system.	Potential mosquito breeding areas. May require land resumption.	None	1
Groundwater restoration (Hanrahan Rd tip)	Extract contaminated groundwater for treatment.	PRH	12 months	12-36 months	3%	7%	0%	0%	$50 000 - $100 000	$5 000 - $10 000	Interception and removal of contaminants from the groundwater.	None	None, assuming reinjection of purified groundwater.	1
Improved household practices	Promote the use of: phosphorus-free detergents; installation of half-flush cisterns and; proper use of fertilizers and pesticides.	PRH OH	3-6 months	6-12 months	0% (PRH) 0% (OH)	2% (PRH) 2% (OH)	0%	0%	$5 000	$2 000	Public awareness. Reduction in contaminant generation. More efficient use of wastewater treatment facilities.	Change in household habits (eg. use of phosphorus-free detergents).	None	1
Septic tank alternatives	Promote connection to deep sewerage or alternative biological package treatment systems.	PRH OH	12-36 months	~5 years	2% (PRH) 4% (OH)	4% (PRH) 2% (OH)	0%	0%	up to $5 000 /house	NA	Reduced risk of gross groundwater contamination. Reduction in the contaminant inputs to the harbours.	Cost to be borne by the householder.	Increased sewerage treatment plant loads, effluent requires disposal.	1

Option	Method	Harbour effected	Implementation	Time for effect after implementation	Input reductions to harbour (% of 1988 annual nutrient load)		Reduction in nutrient store (% of 1988 sediment + biomass nutrient store)		Capital cost	Ongoing cost	Benefits	Negative social impact	Negative environmental impact	Priority
					%N	%P	%N	%P						
Improved farm practices	Timing of fertilizer application. Slow-release phosphatic fertilizers. Rates of fertilizer application. Soil testing support.	OH PRH	6-12 months	Immediate	0%	25% (OH) 6% (PRH)	0%	0%	$100 000	$100 000	Cost savings to the farmer whilst maintaining productivity. Healthier and more resilient harbours.	Modification of traditional farm practices.	None	1
Nutrient point source (intensive agriculture) management.	Management plans to control nutrient losses from piggeries, dairies, sullage pits, stockyards and horticulture, etc.	PRH OH	in progress	Immediate	1% (PRH) 3% (OH)	1% (PRH) 10% (OH)	0%	0%	NA	NA	Preventing current and future landuses from contributing to the nutrient problems of the harbours	Costs to be borne by the owner.	None	1
Agroforestry (based on an adoption rate of 7%).	Broadscale tree planting or introduction of deep-rooted pasture varieties.	OH (PRH)	18-24 months	~5-10 years	?	17% (PRH) 5% (OH)	0%	0%	> $500 000	NA	Alternative cash crop. Reduced salinity problems. Reduced soil erosion. Prospects for new local industry. Nutrient uptake from surface and groundwater. Stock shelter.	Change in traditional farmer attitudes and farm practices. Long periods before cash return.	Planting densities must be carefully assessed to prevent excessive groundwater draw-down.	1
Total Priority 1				PRH	47%	81%	12%	6%						
				OH	8%	45%	0%	0%						
Total Priority 1 + Priority 2				PRH	49%	85%	33%	41%						
				OH	8%	45%	0%	0%						