Recommendations of the Environmental Protection Authority in relation to the environmental problems of the Albany harbours

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Preface

This document contains the Environmental Protection Authority's recommendations to Government for solving the pollution problems of the Albany harbours.

Concern for the water quality of Princess Royal Harbour dates back to the early 1970s when WAIT-Aid Ltd undertook a survey of the waters of Princess Royal Harbour on behalf of the Albany Port Authority. In response to the findings of this survey the Department of Conservation and Environment then commissioned a further survey of the waters of Princess Royal Harbour which indicated that some visual pollution of the harbour waters was occurring, although the long-term effects of waste discharge on the ecology of Princess Royal Harbour were unclear.

In 1976 the Albany Waterways Management Advisory Committee (AWMAC) was formed as a community-based group to liaise with Government agencies and to promote environmental management of the Albany harbours. In response to a request from AWMAC, the Department of Conservation and Environment, in collaboration with the University of Western Australia, undertook a water quality survey of Princess Royal Harbour between December 1978 and December 1979. Although some areas of the harbour were found to be polluted by faecal bacteria, the overall nutrient status of the water was low and the harbour was considered to be sufficiently well-flushed to cope with the nutrient loads at the time.

In 1983, a routine sample of fish, taken from the Perth metropolitan fish markets, was analysed by the Health Department and found to be contaminated by mercury. Subsequent investigations found that these fish had been caught in Princess Royal Harbour. An intensive survey of the sediments and biota in Princess Royal Harbour found that the western end of the harbour was extensively contaminated with lead and mercury. These findings led to the stoppage of further discharges of lead and mercury and the closure of the western end of Princess Royal Harbour to fishing.

In 1981 and 1984 the Department of Conservation and Environment funded surveys of the major marine plant communities in the Albany harbours. The latter survey reported extensive loss of seagrasses in both harbours and a considerable build-up of algae, usually a symptom of waterbodies that are severely polluted. In response to these findings, the Environmental Protection Authority prepared an overview report in June 1987 on the current state of the environmental problems in the Albany harbours. This report considered the situation in both harbours to be serious and requiring urgent attention.

As a result, in October 1987, the Western Australian Government approved funding for an intensive two-year study into the ecology and pollution of the Albany harbours on the understanding that the study would provide long-term solutions to the environmental problems of the harbours. The Albany Harbours Environmental Study (1988-1989) report on the pollution problems of the Albany harbours (Environmental Protection Authority Bulletin 412) was prepared under the direction of a Technical Advisory Group, and was released on 7 March 1990 for an eight-week public submission period.

The report and recommendations of the Technical Advisory Group and the major issues raised in public submissions on it, form the basis of the recommendations of the Environmental Protection Authority to Government. These recommendations, outlined below, provide a strategy to redress existing environmental problems and restore long-term ecological health to the Albany harbours.

Summary of recommendations

The Albany Harbours Environmental Study (1988-1989) report on the pollution problems of the Albany harbours (Environmental Protection Authority Bulletin 412) was prepared under the direction of a Technical Advisory Group, and released for public comment in March, 1990.

The Environmental Protection Authority has reviewed the report and the public submissions received on the recommendations contained in the report. The Authority concludes that the environmental problems of the harbours, and their causes, are reasonably and objectively described, and that the suggested management solutions provide a blue-print for the Authority's own recommendations to Government.

These recommendations, if implemented immediately, will not only retard the rate of seagrass decline and provide a marked improvement in the general environmental quality of the Albany harbours but will also provide guidelines for long-term environmental management strategies in the Albany region. All 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 wastes, particularly nutrients.

The annual nutrient assimilative capacity derived for Princess Royal Harbour is 7 tonnes of total phosphorus and 54 tonnes of total nitrogen. The annual nutrient assimilative capacity derived for Oyster Harbour is in the range of 7 to 14 tonnes of total phosphorus and 54 to108 tonnes of total nitrogen, depending on annual runoff from its catchment. The Authority considers it essential that long-term management strategies are formulated to ensure that the annual total nutrient loadings into Princess Royal Harbour and Oyster Harbour from all sources do not exceed the nutrient assimilative capacities of these waterbodies. To this end, pollutant inputs and upper limits on pollutant loads should be reviewed every five years.

The recommendations of the Environmental Protection Authority are listed below.

Recommendation 1

A management organisation be established to provide for future on-site management of the Albany harbours.

An Albany waterways management authority could be established under the Waterways Conservation Act with direct local government and community involvement.

Recommendation 2

Algal harvesters be deployed to enable 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 by March 1992.

Recommendation 3

The five industries currently discharging pollutants directly or indirectly into Princess Royal Harbour be directed to commence immediately, the formulation of a strategy, and to reduce, by March 1992, nutrient loads entering Princess Royal Harbour to levels outlined below in Table 1.

Effluent concentrations from the industries discharging directly to the harbour should not exceed the levels outlined below in Table 2.

If the waters in the vicinity of the industrial outfalls into Princess Royal Harbour are to be used for direct contact recreation, faecal coliform concentrations in these waters should not exceed 150 organisms per 100 millilitres. Waters where this limit is exceeded should be declared exclusion zones and direct contact recreation prohibited.

Industry	Total phosphorus	Total nitrogen
	(kilograms per year)	
Southern Processors	660	2190
Metro Meats	430	1420
Kailis and France	100	340
Albany Woollen Mills	150	780
CSBP and Farmers*	800	1250
TOTAL	**2140**	**5980**

*(including surface runoff, groundwater and spillages of diammonium phosphate fertilizers)

Table 1. Upper limits for industrial nutrient loads to Princess Royal Harbour.

Effluent constituent	Concentration (milligrams per litre)
Biological Oxygen Demand (BOD_5)	less than 20
Total suspended solids	less than 80
Oil & grease	less than 30
Total nitrogen	less than 10
Total phosphorus	less than 3

Table 2. Upper limits for Princess Royal Harbour effluent discharge concentrations.

Recommendation 4

The Water Authority of Western Australia commence immediately the formulation of a strategy to cease discharging domestic wastewater from the King Point outfall by March 1994.

Recommendation 5

The Town and Shire of Albany complete, by March 1991, 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 implement a management plan that will eliminate, within one further year, pollutant loads to the Albany harbours from existing point sources (eg Hanrahan Road tip). To facilitate this, local government authorities should seek advice from appropriate State Government departments in relation to co-operative use of existing State Government resources.

Recommendation 6

The Town and Shire of Albany jointly develop a management plan to reduce nutrient loads to the Albany harbours from urban diffuse sources (eg urban runoff and groundwater contaminated by garden fertilizers, septic tank leachate) to 400 kilograms of total phosphorus per year and 650 kilograms of total nitrogen per year, by March 1992. To promote community involvement, the Town and Shire of Albany undertake an education programme related to minimising pollution from these sources.

Recommendation 7

The Western Australian Department of Agriculture evaluate current information to identify high phosphorus source areas within the catchments of the Albany harbours, and prepare a strategy for their management by March 1991.

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 reduce rural nutrient loads (from diffuse and point sources) to the target loads specified.

Target rural phosphorus loads are less than 4.6 tonnes of total phosphorus per year for Princess Royal Harbour and less than 13.9 tonnes of total phosphorus per year for Oyster Harbour.

In addition, catchment management should endeavour to achieve rural nitrogen loadings of less than 13.5 tonnes of total nitrogen per year to Princess Royal Harbour and less than 107.9 tonnes of total nitrogen per year to Oyster Harbour.

The Western Australian Department of Agriculture report annually to the Environmental Protection Authority on the effectiveness of management strategies to reduce rural nutrient inputs to the harbours, and on the previous year's nutrient loads into the harbours from rural sources.

Considering that most of the remaining seagrasses in Princess Royal Harbour will be lost within five years and in Oyster Harbour within five to ten years if current nutrient inputs are maintained, appropriate timeframes for reaching target rural phosphorus loads to Princess Royal Harbour and Oyster Harbour are two years and four years respectively.

Recommendation 8

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 organisation.

Recommendation 9

The proposed Albany waterways management organisation be responsible for ensuring that all pollutant inputs to the Albany harbours are monitored in order to assess the overall effectiveness of management practices in reducing these inputs.

Recommendation 10

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 resulting from its former effluent discharges and, if necessary, to formulate, by March 1991, a management plan to reduce lead and mercury in the biota of Princess Royal Harbour to below State health limits which are 0.5 parts per million for mercury and 1.5 parts per million for lead (except for molluscs such as mussels and cockles where the limit for lead is 2.5 parts per million). CSBP is to report to the Environmental Protection Authority by June 1991.

Recommendation 11

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 12

Evaluation of removal of nutrient-rich sediments from the Albany harbours as an effective environmental management strategy be undertaken by the proposed Albany waterways management organisation.

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1. Introduction

Princess Royal Harbour and Oyster Harbour are located to the south and north of the Albany township and both harbours are connected to King George Sound via narrow openings (Figure 1). These sheltered waterbodies provide relatively safe, natural harbours and were the focus of the first settlement by Europeans in Western Australia. Both harbours, and King George Sound are used extensively for professional fishing, and Princess Royal Harbour is also used as a port. Furthermore, industries located along the northern shoreline of Princess Royal Harbour discharge industrial wastes into these waters (Figure 2).

The sheltered waters of Princess Royal Harbour and Oyster Harbour provide an ideal setting 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 on the understanding that the study would identify solutions to these problems. The Albany Harbours Environmental Study (1988-1989) consisted of a number of interrelated studies that provide the technical rationale for the recommendations of the Environmental Protection Authority 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.

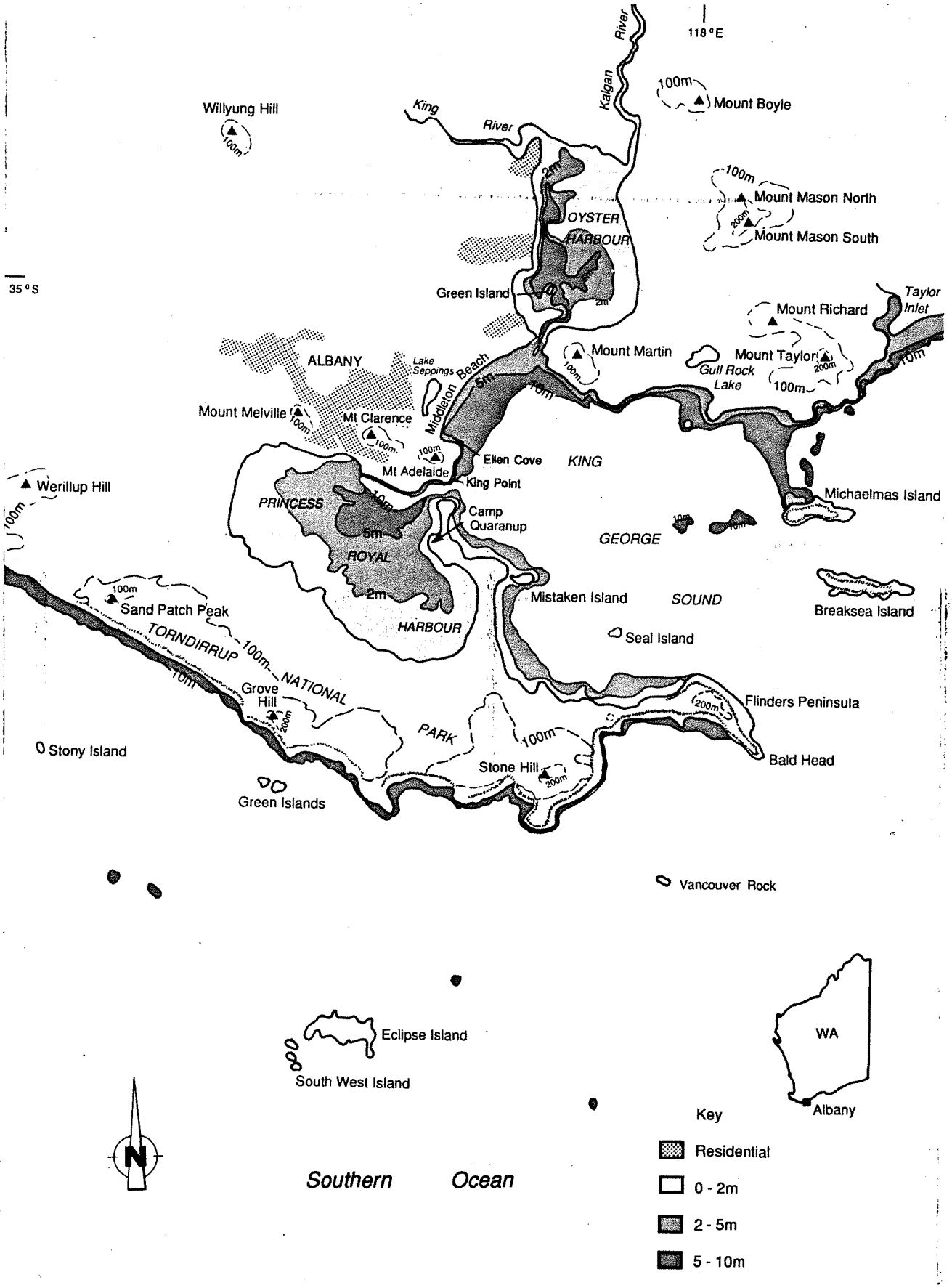

Figure 1: Albany harbours and adjacent areas

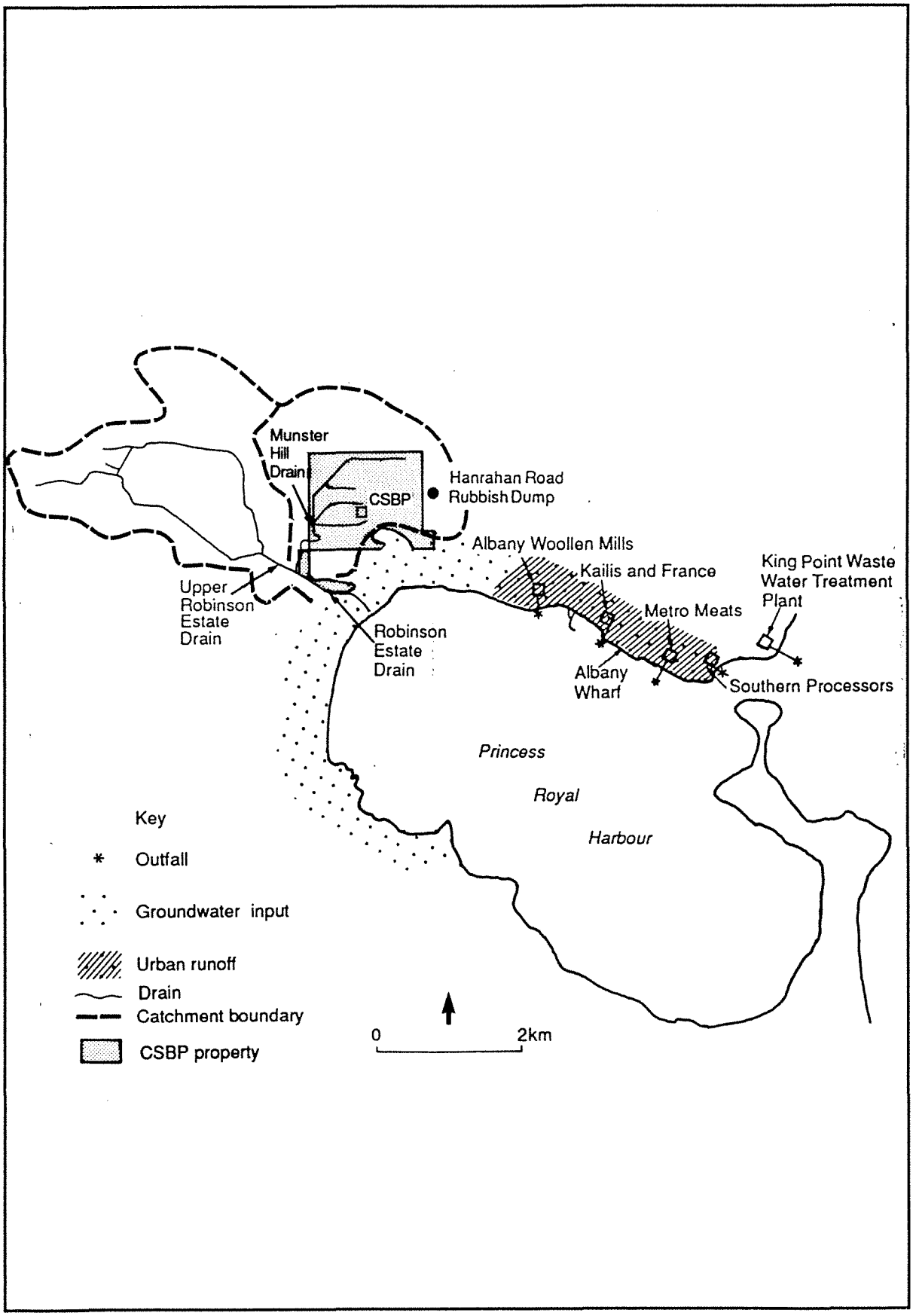

Figure 2: Location of the major sources of contaminants in Princess Royal Harbour

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 that was 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.

Seagrass meadows are at the base of the food chain, and provide important nursery grounds and shelter for numerous species of fish and other marine animals. Furthermore, the extensive root and rhizome systems of these seagrass meadows stabilise nearshore sediments and sandbanks, and the meadows trap fine particulate matter, thus enhancing water clarity. When seagrasses are lost, the dependant animal populations are also severely depleted and sediments may be more readily stirred up causing a decrease in water clarity.

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 five to ten 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, current evidence suggests that phosphorus 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, respectively. 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. Nutrients are transported either in solution or attached to soil particles washed off agricultural lands in the extensive catchment of Oyster Harbour. In general, the coastal soils of southern Western Australia have low nutrient retention capabilities, particularly for phosphorus. 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 accumulations provide a large internal store of nutrients, a proportion of which are continually re-used for algal growth.

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.

The current loadings of heavy metals into Princess Royal Harbour are very low and are not considered to be environmentally significant. However, mercury and lead remaining in the contaminated sediments of the western end of the harbour continue to accumulate in the biota and constitute an on-going risk to public health.

Elevated concentrations of dieldrin and other organochlorine pesticides were present in urban drain flows after the first rains, 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 nearshore waters

Elevated concentrations of faecal bacteria in seawater were first reported at Middleton Beach in a study conducted in 1979 by the Department of Conservation and Environment, in collaboration with the University of Western Australia. 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 in the vicinity of the various effluent outfalls and also from Ellen Cove, at the southern end of Middleton Beach, on 35 occasions from 1982 to 1988.

Median faecal coliform counts of less than 150 per 100ml, on the basis that at least five samples were taken over a period of no more than 30 days, 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.

Water in the vicinity 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 100ml were recorded on 30% of the occasions waters in the vicinity of Metro Meats Pty Ltd outfall was sampled and on 100% of the occasions waters in the vicinity of the King Point outfall was sampled. The waters in the vicinity of these

outfalls are grossly polluted and would pose a distinct health risk to anyone entering the water at these locations. The faecal bacterial concentrations at Ellen Cove, a popular swimming beach in King George Sound, were above acceptable health levels (200 per 100ml) 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 nutrient enrichment (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 less stable, 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.

2.5 Summary of problems

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 by March 1992. Furthermore, if the amount of heavy metals in 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 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 five to ten years in Oyster Harbour, and the general ecology of the harbours will continue to deteriorate.

3. Community attitudes

The Albany Harbours Environmental Study (1988-1989) report of the Technical Advisory Group was released in March 1990 for an eight-week public submission period prior to consideration by the Environmental Protection Authority. A survey of community attitudes in Albany was also conducted during this period.

3.1 A survey of community attitudes towards the Albany harbours

The study was conducted by CSIRO Division of Water Resources to provide a basis from which to gauge public opinion on the existing environmental state of the Albany harbours and to determine the extent of recreational usage of these water-bodies. This study consisted of 245 interviews conducted at two shopping centres in Albany and clearly demonstrated concern in all age groups of the community for the welfare of both harbours and their foreshores. The majority of people surveyed considered that poor water quality affected their recreational use of the harbours. Most people considered that fertilizer runoff was the major cause of the environmental problems in Oyster Harbour and industry the major cause of the problems in Princess Royal Harbour.

About half of the people surveyed considered that the State Government was primarily responsible for maintaining good harbour water quality and that it was falling well short of providing the desired level of service. Of the remainder who thought that the State Government was either partially or not responsible for the current state of the harbours, local government was nominated as having the highest responsibility, followed by the community and lastly by private industry.

The results of the survey indicate that the people of Albany are concerned for the health of the environment in its own right, and not only when it interferes with amenity or human activities. The community supports the maintenance of present foreshore industries but to a considerably lesser extent than for local employment in general. This tends to indicate that while the welfare of the community is important, it should not be achieved at the expense of the environment and therefore ways must be found to integrate employment opportunities while maintaining high environmental quality.

3.2 Summary of submissions on the report of the Albany Harbours Environmental Study (1988-1989) Technical Advisory Group

One hundred and fifty seven submissions were received by the Environmental Protection Authority on the Albany Harbours Environmental Study. The submissions included 37 from organisations, industries, local government authorities and State Government departments, and 120 submissions from individuals. The large number of submissions reflect considerable public interest in the Albany harbours' pollution problems. One hundred and forty seven, or 94% of the submissions supported the objectives and approach of the Albany Harbours Environmental Study. Strong support was also obtained for all of the proposed recommendations made by the Technical Advisory Group (Table 3), and this, coupled with the results of the attitudinal survey, highlights the desire of the community to redress the Albany harbours' environmental problems.

Numerous comments were made on the recommendations and other aspects of the Albany Harbours Environmental Study. The recommendations of the Technical Advisory Group and a summary of the major issues raised in public submissions are presented in Appendix I.

Specific TAG Recommendations	Individuals		Organisations		Total	
	For	Against	For	Against	For	Against
1	114	1	27	1	141	2
2	114	0	26	1	140	1
3	115	0	21	1	136	1
4	101	0	24	0	125	0
5	102	0	22	0	124	0
6	103	0	22	1	125	1
7	101	0	26	0	127	0
8	103	0	24	0	127	0
9	114	0	23	0	137	0
10	98	0	22	0	120	0
11	98	0	22	0	120	0
12	101	0	21	1	122	1
General TAG Recommendations						
1	53	0	24	0	77	0
2	51	0	21	0	72	0
3	51	0	21	0	72	0
4	53	0	20	0	73	0

Table 3 : Summary of public submissions: response to the recommendations of the Albany Harbours Environmental Study (1988-1989) Technical Advisory Group (TAG).

4. Recommendations

The recommendations of the Environmental Protection Authority were formulated in response to the report of the Albany Harbours Environmental Study Technical Advisory Group (Environmental Protection Authority Bulletin 412) released for public comment on March 7, 1990, and from consideration of the issues raised in the public submissions on this report. The Authority concludes that the environmental problems of the harbours, and their causes, are reasonably and objectively described in the study report and that the suggested management solutions provide a basis for the Authority's own recommendations to Government. The various considerations behind the recommendations of the Environmental Protection Authority are discussed in the following sections.

4.1 Nutrient assimilative capacity and the implications for management

Waterbodies generally have some capacity to disperse, dilute or absorb certain wastes 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. It is clear that for many years the Albany harbours have been receiving nutrient loads that are far in excess of their respective assimilative capacities and as a result their ecological health has deteriorated significantly.

Princess Royal Harbour is hydrodynamically well-mixed and receives a relatively constant input of nutrients from a number of sources. A significant proportion of the nutrients (such as nitrogen and phosphorus) that enter the harbour are used for aquatic plant growth, or become trapped in the sediments, particularly in the deep basin near the Albany town jetty. Nitrogen and phosphorus are essential elements for plant growth, however, when inputs are greater than those required to support the natural assemblage of plants in a waterbody, the extra nutrients cause excessive growth of the faster growing plants such as macroalgae and epiphytes, and these can accumulate in nuisance proportions and upset the ecological balance. Successful management relies on knowledge of the maximum amounts of nutrients that a system can assimilate without causing such undesirable changes. Studies have indicated that a maximum of seven tonnes of total phosphorus per year and 54 tonnes of total nitrogen per year could be absorbed by the system while still maintaining algal densities in the harbour at acceptable levels. These nutrient loads could be effectively assimilated by the ecosystem, and provide an ecologically-based nutrient assimilative capacity with respect to nitrogen and phosphorus for Princess Royal Harbour.

Oyster Harbour, on the other hand, has a different, more complex set of physical characteristics which vary seasonally and from year to year according to rainfall intensity, duration and frequency. Oyster Harbour is not well-mixed, and considerable volumes of fresh water can enter the harbour at its northern end via the King and Kalgan rivers. Under average-to-high runoff conditions the majority of the harbour's annual nutrient load enters via these rivers. The high nutrient content of the rivers is a result of broadscale agricultural use of phosphatic fertilizers and leguminous pastures within their catchments. On entering Oyster Harbour, the fresh river water forms a distinct layer overlying the denser, sub-surface waters before it flows out of the harbour entrance and into King George Sound. Given the complex hydrodynamic characteristics of the harbour and the strong relationship between nutrient input and rainfall in the catchments, the interaction between the nutrient loads in the river water and the benthic sediments and plant communities are difficult to determine. However in below-average rainfall years, when river flow is low, the annual assimilative capacity for nutrients is likely to be similar to that of Princess Royal Harbour, while in above-average rainfall years the assimilative capacity is likely to be significantly greater, and is estimated to be approximately double the assimilative capacity of below-average rainfall years. On this basis, the assimilative capacity of Oyster Harbour for nutrients is expressed here as a range of between 7 and 14 tonnes of total phosphorus and between 54 and 108 tonnes of total nitrogen per year.

The Environmental Protection Authority considers that the primary goal of any long-term management plan for the harbours is to ensure that all nutrient inputs are reduced to below the ecologically-based estimates of the harbours' nutrient assimilative capacities outlined above. The Albany harbours are

currently receiving nutrient loads that are far in excess of their respective assimilative capacities and, as a result, immediate and substantial reductions in nutrient inputs from all sources are necessary to stop the harbours deteriorating further, and to allow the biological systems to stabilise. If current pollutant loadings into the harbours continue, most of the remaining seagrasses will be lost within five years in Princess Royal Harbour, and within five to ten years in Oyster Harbour, and the general ecology of the harbours will continue to deteriorate.

To ensure the long-term environmental health of the Albany harbours all future development proposals and management of industrial, urban and rural land use in the catchments of the harbours should have regard for the capacity of these waterways to assimilate pollutants, particularly nutrients. It is essential that long-term management strategies are formulated to ensure that the annual total nutrient loading into Princess Royal Harbour and Oyster Harbour from all sources do not exceed the nutrient assimilative capacities of these waterbodies. The recommended upper limits on pollutant loads should be reviewed every five years to ensure the total pollutant loads remain below the nutrient assimilative capacities of these harbours.

The basis on which the maximum permissible nutrient loads to Princess Royal Harbour and Oyster Harbour were apportioned between the different sources are outlined below.

4.1.1 Princess Royal Harbour

The target nutrient loadings to Princess Royal Harbour from industrial, urban and rural sources are shown in Table 4.

Source	1988 Loads (tonnes)		Target Loads (tonnes)		Reduction (%)	
	Phosphorus	Nitrogen	Phosphorus	Nitrogen	Phosphorus	Nitrogen
Industrial	17.5	35.7	2.1	6.0	88	83
Rural	6.9	20.3	4.6	13.5	34	34
Urban	4.3	9.9	0.3	0.6	93	94
TOTAL	**28.7**	**65.9**	**7.0**	**20.1**	**76**	**70**

Table 4. Target nutrient loadings to Princess Royal Harbour

Substantial reductions in each of these sources are essential to achieve a cumulative load that can be assimilated by the ecosystem without further long-term damage occurring. The target reductions were distributed as equitably as possible after examining the feasibility of a wide range of alternative technologies and management options. The basis for setting maximum permissible loads from each source is as follows.

Industrial

The maximum annual permissible loads of nitrogen and phosphorus that can be discharged to the harbour from each industry discharging directly to the harbour were determined on the basis of applying upper limits for Princess Royal Harbour effluent discharge concentrations detailed in Table 2 to the estimated current annual effluent discharge volume for each industry*. As CSBP does not discharge directly to the harbour (and hence the Princess Royal Harbour effluent discharge concentrations do not apply), maximum annual permissible loads of nitrogen and phosphorus to the harbour were set using a 90% reduction in estimated total annual load from all of CSBP's activities. This reduction is consistent with the other industries discharging to the harbour.

* Recent information on waste discharge volumes suggests that the allocation of maximum annual permissible loads of nitrogen and phosphorus to Southern Processors (Table 1) may be too high.

Urban

Urban nutrient sources were identified and estimates made of the maximum achievable reductions. The reduction of nutrient inputs to target levels will require reductions in excess of 90% of 1988 inputs and will rely on the elimination of all urban point sources of nutrients (for example the Hanrahan Road tip and the WAWA Point King outfall) and the involvement and commitment of the entire community living in the urban catchment.

Rural

A reduction of at least 34% in the nutrients (particularly phosphorus) exported from rural catchments (based on 1988 estimates) is required to reduce total nutrient inputs from all sources to below the nutrient assimilative capacity of Princess Royal Harbour.

4.1.2 Oyster Harbour

Nutrient inputs to Oyster Harbour are largely rural, with urban sources contributing only a small percentage of the total load, except in below-average rainfall years. The required levels of reduction and target nutrient loads are shown in Table 5 for an average rainfall year.

Source	Estimated Mean Annual Loads (tonnes)		Target Loads (tonnes)		Reduction (%)	
	Phosphorus	Nitrogen	Phosphorus	Nitrogen	Phosphorus	Nitrogen
Industrial	0	0	0	0	n/a	n/a
Rural	28	348	<13.9	<107.9	>50	>69
Urban	2.0	2.0	0.1	0.1	95	95
Total	**30**	**350**	**<14**	**<108**	**>48**	**>69**

n/a= not applicable

Table 5. Target nutrient loadings to Oyster Harbour

The basis for setting maximum permissible loads for each nutrient source to Oyster Harbour is as follows.

Industrial

There are no industrial discharges to Oyster Harbour.

Urban

Urban nutrient sources were identified and estimates made of the maximum achievable reductions. As was the case for Princess Royal Harbour, this desired level of reduction (greater than 95%) will rely on the elimination of all urban point sources of nutrients (including WAWA package treatment plants, sullage pits) and the involvement of the entire community living in the urban catchment.

Rural

Reductions of over 50% in total phosphorus and 69% in total nitrogen exported from the rural catchments are required to reduce total nutrient inputs to below the assimilative capacity of Oyster Harbour.

4.2 Management body

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 organisation. An annual audit of total inputs to the harbours from industrial, urban and rural sources could also be undertaken by a management body to monitor the effectiveness of the management measures recommended in this report.

A management body in Albany would provide a clear focus for the co-ordinated management of the Albany harbours and associated areas.

Recommendation 1

A management organisation be established to provide for future on-site management of the Albany harbours.

An Albany waterways management authority could be established under the Waterways Conservation Act with direct local government and community involvement.

4.3 Algal harvesting

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. Furthermore, removal of these large accumulations will reduce the store of nutrients in the harbour, and facilitate oxygenation and retention of nutrients in 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, as the current levels of algal infestation of the harbours are not predicted to re-occur when the recommended management plans to reduce nutrient inputs to the harbours are implemented and the long-term target nutrient loadings achieved.

Recommendation 2

Algal harvesters be deployed to enable 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 by March 1992.

4.4 Point sources of pollution

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

Thus, to achieve the goal of reducing total nutrient loads into Princess Royal Harbour to below the assimilative capacity of the harbour and thereby arrest the current rapid decline in the remaining seagrass meadows, inputs from industrial, domestic and urban point sources must be substantially reduced as a matter of highest urgency on the basis that significant short-term reductions in nutrient loadings to the Albany harbours from rural catchments will be much more difficult to achieve.

4.4.1 Industrial

The maximum total permissible load of nutrients to Princess Royal Harbour from all industrial sources is 2.1 tonnes of phosphorus per year and 6 tonnes of nitrogen per year (Table 4). In the event of establishment of new industries in Albany, all possible attempts should be made to avoid discharge of pollutants to the harbours. If pollutant discharge to Princess Royal Harbour is unavoidable, the cumulative nutrient load of all industries must not exceed these maximum total permissible loads. The long-term objective of the Environmental Protection Authority is the cessation of all industrial discharges to the Albany harbours.

Recommendation 3

The five industries currently discharging pollutants directly or indirectly into Princess Royal Harbour be directed to commence immediately, the formulation of a strategy, and to reduce, by March 1992, nutrient loads entering Princess Royal Harbour to levels outlined below in Table 1.

Effluent concentrations from the industries discharging directly to the harbour should not exceed the levels outlined below in Table 2.

If the waters in the vicinity of the industrial outfalls into Princess Royal Harbour are to be used for direct contact recreation, faecal coliform concentrations in these waters should not exceed 150 organisms per 100 millilitres. Waters where this limit is exceeded should be declared exclusion zones and direct contact recreation prohibited.

Industry	Total phosphorus (kilograms per year)	Total nitrogen (kilograms per year)
Southern Processors	660	2190
Metro Meats	430	1420
Kailis and France	100	340
Albany Woollen Mills	150	780
CSBP and Farmers*	800	1250
TOTAL	**2140**	**5980**

*(including surface runoff, groundwater and spillages of diammonium phosphate fertilizers)

Table 1. Upper limits for industrial nutrient loads to Princess Royal Harbour.

Effluent Constituent	Concentration (milligrams per litre)
Biological Oxygen Demand (BOD_5)	less than 20
Total suspended solids	less than 80
Oil & grease	less than 30
Total nitrogen	less than 10
Total phosphorus	less than 3

Table 2. Upper limits for Princess Royal Harbour effluent discharge concentrations.

4.4.2 Domestic wastewater

Recommendation 4

The Water Authority of Western Australia commence immediately the formulation of a strategy to cease discharging domestic wastewater from the King Point outfall by March 1994.

4.4.3 Urban

Recommendation 5

The Town and Shire of Albany complete, by March 1991, 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 implement a management plan that will eliminate, within one further year, pollutant loads to the Albany harbours from existing point sources (eg Hanrahan Road tip). To facilitate this, local government authorities should seek advice from appropriate State Government departments in relation to co-operative use of existing State Government resources.

4.5 Diffuse sources of pollution

4.5.1 Urban

Pollutants from diffuse urban sources enter the Albany harbours via groundwater and surface runoff. Fertilizers and pesticides applied to streetside verges, household gardens, septic tanks as well as pollutants from car exhausts, tyres and accidental spillages all contribute to the pollution of the harbours. Minimisation 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 6

The Town and Shire of Albany jointly develop a management plan to reduce nutrient loads to the Albany harbours from urban diffuse sources (eg urban runoff and groundwater contaminated by garden fertilizers, septic tank leachate) to 400 kilograms of total phosphorus per year and 650 kilograms of total nitrogen per year, by March 1992. To promote community involvement, the Town and Shire of Albany undertake an education programme related to minimising pollution from these sources.

4.5.2 Rural

The annual nutrient assimilative capacity of Princess Royal Harbour is estimated to be approximately seven 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. Currently, phosphorus has been shown to be the primary nutrient controlling algal growth in the harbours, and therefore management focus should be on reducing the inputs of this nutrient.

In 1988 approximately 29 tonnes of phosphorus entered Princess Royal Harbour. Of this total, about seven tonnes were estimated to have entered from rural sources, about four tonnes from urban sources and 18 tonnes from industrial sources. If the recommendations in this report are implemented, inputs from industrial and urban sources will decrease to less than about 2.5 tonnes, based on current input estimates (Table 2). Although this represents a significant reduction in phosphorus loading from these sources of about 90% of 1988 estimates, when the remaining load from industrial and urban sources is added to the existing rural phosphorus loading into Princess Royal Harbour, the assimilative capacity will be exceeded by about 35% 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. If nutrient loads from rural sources are reduced by one third, that is 2.3 tonnes, the total load of phosphorus entering Princess Royal Harbour will be sufficiently low as to be assimilated by the ecosystem. The harbour will appear substantially cleaner and, more importantly, the current deterioration in the environmental health of the harbour will cease, and conditions will stabilise at a level enabling recolonization of denuded areas by some of the more opportunistic species of seagrass.

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. Most of these nutrients enter Oyster Harbour from farms in its catchment.

The estimated annual nutrient assimilative capacity of Oyster Harbour is in the range, depending on rainfall and runoff characteristics, of about 7 to 14 tonnes of total phosphorus and 54 to 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 7

The Western Australian Department of Agriculture evaluate current information to identify high phosphorus source areas within the catchments of the Albany harbours, and prepare a strategy for their management by March 1991.

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 reduce rural nutrient loads (from diffuse and point sources) to the target loads specified.

Target rural phosphorus loads are less than 4.6 tonnes of total phosphorus per year for Princess Royal Harbour and less than 13.9 tonnes of total phosphorus per year for Oyster Harbour.

In addition, catchment management should endeavour to achieve rural nitrogen loadings of less than 13.5 tonnes of total nitrogen per year to Princess Royal Harbour and less than 107.9 tonnes of total nitrogen per year to Oyster Harbour.

The Western Australian Department of Agriculture report annually to the Environmental Protection Authority on the effectiveness of management strategies to reduce rural nutrient inputs to the harbours, and on the previous year's nutrient loads into the harbours from rural sources.

Considering that most of the remaining seagrasses in Princess Royal Harbour will be lost within five years and in Oyster Harbour within five to ten years if current nutrient inputs are maintained, appropriate timeframes for reaching target rural phosphorus loads to Princess Royal Harbour and Oyster Harbour are two years and four years respectively.

4.6 Nutrient assimilative capacity of Oyster Harbour

As outlined above in sections 4.1 and 4.5, the assimilative capacity of Oyster Harbour should be regarded as an initial management target only and further investigations into the nutrient dynamics of the harbour are required to refine these initial estimates.

Recommendation 8

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 organisation.

4.7 Nutrient input monitoring

Currently, nutrient inputs to the Albany harbours are well in excess of their respective abilities to assimilate these loadings and as a result their ecological health continues to decline. In order to halt any further deterioration in their ecological health, substantial reductions in nutrient inputs to the Albany harbours, from all sources, to below their nutrient assimilative capacities are required. To achieve this goal, a wide range of management measures aimed at industrial, rural and urban nutrient sources will need to implemented. It is important that nutrient inputs to the harbours are monitored in order to assess the effectiveness of management plans implemented, and if necessary, to implement additional or alternative measures to reduce nutrient loadings to levels that can be readily assimilated by these systems.

Recommendation 9

The proposed Albany waterways management organisation be responsible for ensuring that all pollutant inputs to the Albany harbours are monitored in order to assess the overall effectiveness of management practices in reducing these inputs.

4.8 Heavy metal contamination

The levels of mercury in 15 species of fish from Princess Royal Harbour have been monitored annually by the Department of Fisheries 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 undermines any 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 10

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 resulting from its former effluent discharges and, if necessary, to formulate, by March 1991, a management plan to reduce lead and mercury in the biota of Princess Royal Harbour to below State health limits which are 0.5 parts per million for mercury and 1.5 parts per million for lead (except for molluscs such as mussels and cockles where the limit for lead is 2.5 parts per million). CSBP is to report to the Environmental Protection Authority by June 1991.

4.9 Integrated environmental management

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 natural 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 11

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.

4.10 Nutrient pool reduction

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 12

Evaluation of removal of nutrient-rich sediments from the Albany harbours as an effective environmental management strategy be undertaken by the proposed Albany waterways management organisation.

5. Conclusions

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.

The Albany Harbours Study has highlighted the vulnerability of protected and enclosed waterbodies to activities in their catchments. The Government and community should be aware of the long-term consequences of these activities, not only in Albany but in other parts of Western Australia, and should ensure that potential problems are identified, and action is taken to ensure that significant or irreversible damage to these ecosystems does not occur.

Appendix

Summary of comments arising from public submissions on the Albany Harbours Environmental Study (1988-1989) report of the Technical Advisory Group.

The Albany Harbours Environmental Study (1988-1989) report of the Technical Advisory Group (Environmental Protection Authority Bulletin 412) was released in March 1990 for an eight week public submission period prior to consideration by the Environmental Protection Authority. The recommendations of the Technical Advisory Group (in italics) and a summary of the major issues raised in public submissions are presented on the following pages.

1. Comment on the specific recommendations of the Technical Advisory Group

Recommendation 1 of the Technical Advisory Group

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.

Public comments on recommendation 1

- Algal harvesting should be a high priority in terms of Government expenditure and it should commence immediately.
- Feasibility of utilising harvested material should be examined and encouraged.
- Possible indirect effects such as modification of the seabed, damage to remaining seagrass and alterations to faunal composition of the biota should be evaluated.

Recommendation 2 of the Technical Advisory Group

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.

Public comments on recommendation 2

- Evaluation of removal of nutrient-rich material should include: analysis of cost; technical feasibility; potential damage to remaining seagrass by factors such as erosion and elevated turbidity; interference with colonising species; possibility of elevated sediment nutrient release during the removal process and possible transference of associated heavy metals to water and biota.
- Recommendations 3-8 should be implemented prior to this recommendation to avoid further accumulation of nutrients in the newly exposed sediment.
- The feasibility of promoting algal growth on the nutrient enriched sediments and then harvesting the algae should be evaluated as an alternative method to reduce sediment nutrient pools.

Recommendation 3 of the Technical Advisory Group

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.

Public comments on recommendation 3

- Immediate reduction in pollutant loads from all sources is necessary. Short-term measures should also be implemented to control pollution in the interim.
- Government and industry should share costs in providing adequate treatment/disposal facilities.
- Princess Royal Harbour Effluent Discharge Criteria should have a faecal coliform limit depending on the method of disposal and position of the discharge point.
- Proposed Princess Royal Harbour Effluent Discharge Criteria are too stringent. WAWA should provide all necessary facilities to accept waste and industry should not have to reduce effluent loads or concentrations until the facilities are available.
- Princess Royal Harbour Foreshore redevelopment proposal should receive lower priority and the funds would be better spent on effluent disposal system.
- Industries should be fully liable for their effluent and past pollution.
- Industries should be congratulated for their performance of late.

Recommendation 4 of the Technical Advisory Group

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.

Public comments on recommendation 4

- Immediate reduction required in nutrient loads carried in surface runoff. The runoff could be used to irrigate pulpwood trees.
- Government and industry should share remedial costs.
- CSBP is directly responsible for the pollution of Princess Royal Harbour and indirectly responsible for the pollution of Oyster Harbour.
- Timeframe for implementation is unrealistically short/long.

Recommendation 5 of the Technical Advisory Group

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.

Public comments on recommendation 5

- Further studies are needed to determine phosphorus and heavy metal levels in the groundwater. CSBP should bear the cost and Environmental Protection Authority should assess the results of the studies.
- Tree planting on site would draw-down the water table, lower groundwater pressure and therefore nutrients entering Princess Royal Harbour.
- Department of Agriculture and CSBP need to co-operate in evaluating a management plan for groundwater on CSBP's industrial estate.
- Timeframe for implementation is unrealistically short/long.

Recommendation 6 of the Technical Advisory Group

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.

Public comments on recommendation 6

- The current location of the outfall at King Point is unsuitable and should be moved.
- Recommended timescale is too short and no effluent discharge criteria are provided.
- Tertiary treatment of waste is imperative and new facilities should be sufficient for double the existing population. Discharge should be to the land and used for agroforestry.
- WAWA should promote the use of dry septic systems in areas where sewerage is not available.

Recommendation 7 of the Technical Advisory Group

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.

Public comments on recommendation 7

- Tree planting should be carried out near sullage pits and other point sources to reduce nutrient losses.
- Sewerage or dry septic systems should be mandatory in new sub-divisions in Albany and will alleviate groundwater pollution.
- Use of the current Hanrahan Road tip site should be reviewed and it should be relocated if necessary. Town and Shire of Albany should be encouraged to establish a joint agreement for solid waste disposal.

Recommendation 8 of the Technical Advisory Group

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.

Public comments on recommendation 8

- The education program is strongly supported. The program should target schools as well as the community in general. A community based Education Action Plan should be formulated.

Recommendation 9 of the Technical Advisory Group

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.

Public comments on recommendation 9

- This recommendation requires urgent action. The recommendation should precede recommendations 1 and 2.
- Agroforestry and strategic tree planting should be encouraged where agricultural production is low and along water courses to reduce bank erosion and surface runoff.
- Department of Agriculture has misplaced priorities focussing on economic rather than ecological considerations.
- The Department of Agriculture should place more emphasis on mixed and organic farming rather than practices centred on phosphate rich fertilizers.
- Slow release fertilizers should be made more available. Farmers should be educated on the effects of nutrient runoff.

Recommendation 10 of the Technical Advisory Group

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.

Public comments on recommendation 10

- This recommendation requires urgent action.
- Some method of enforcement is required to control nutrient losses from point sources within the harbour catchments.
- Farmers with high leaching soil types will resist the implementation of this recommendation as it may adversely affect property values.

Recommendation 11 of the Technical Advisory Group

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.

Public comments on recommendation 11

- This recommendation should give equal priority to a revision of the assimilative capacity of Princess Royal Harbour as the existing data is insufficient.
- Refining the estimate of assimilative capacity should be the top priority for the proposed Albany waterways management authority.
- The nutrient assimilative capacity of the harbours should be zero.
- Nutrient assimilative capacity estimates for the harbours are extremely important as management tools.

Recommendation 12 of the Technical Advisory Group

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.

Public comments on recommendation 12

- This recommendation should be implemented immediately.
- This is a vague and unsoundly based recommendation that is expensive and possibly deleterious.
- Heavy metal depletion should not be left to natural processes and CSBP should be responsible for costs of testing and cleanup.
- Remedial costs should be shared by industry and government.

2. Comments on the general recommendations of the Technical Advisory Group.

General recommendation 1 of the Technical Advisory Group

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

Public comments on general recommendation 1

- The assimilative capacity of the harbours for nutrients should be zero.
- Immediate reduction in nutrient input to the harbours is required.
- Data used for the calculation of assimilative capacity is not sufficiently accurate. It is suggested that the calculated figures be used to emphasise the need to decrease nutrient inputs.

General recommendation 2 of the Technical Advisory Group

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.

Public comments on general recommendation 2

- Strong support for this approach.
- Environmental Protection Authority should set guide-lines for future development.
- A 'land-use' capacity should be determined.

General recommendation 3 of the Technical Advisory Group

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.

Public comments on general recommendation 3

- Strong support for the development of a regional liaison structure to facilitate integrated catchment and waterways management.

General recommendation 4 of the Technical Advisory Group

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.

Public comments on general recommendation 4

- Emphasis for the need for early government commitment to fund and implement this recommendation as a matter of high priority.
- Strong support for this recommendation. The proposed Albany Waterways Management Authority is seen as an essential factor for controlling pollution of the waterways of the region.
- The Albany Waterways Management Authority should initiate a monitoring program to detect and document the introduction of foreign organisms through activities such as ballast water discharges from ships.

3. Summary of general issues raised in public submissions

A number of issues raised in public submissions were not considered to be directly related to the specific or general recommendations of the TAG. A summary of these issues is presented below.

- Government commitment is required to conduct comprehensive future studies into the ecology of the Albany harbours in the future to monitor the response of the ecosystem to the management strategies adopted.
- The amenity afforded by the harbours has declined significantly over the years and action must be taken to redress this decline.
- The report is inconsistent in relation to the importance of macroalgae and epiphytes as the major cause of seagrass decline.
- The submission period for the study is too short for farmers to respond.
- Discontent with the inconsistent wording of the directives in the recommendations.
- Lack of economic analysis in the study.
- Land-clearing in the catchments of the Albany Harbours should be stopped using the Soil and Land Conservation Act. The definition of land degradation should include ecological, biological and hydrological aspects.
- The report exhibits poor experimental technique and blatant bias.
- Community involvement and awareness of the environmental problems experienced in the Albany Harbours could be facilitated through a 'Ribbons of Blue' programme to monitor phosphates in the catchments of Princess Royal and Oyster Harbours.
- Technical source documents should be subject to peer review to establish credibility and assist in the formulation of the recommendations.
- Federal funding should be sought for a rural and urban community education program through the 'Soil Conservation Programme'.
- Disagreement that pond-based (low-technology) treatment is inappropriate claiming that odour effects should be addressed by State and local government as a separate issue related to the benefits of a particular industry to the community.
- The results of the Albany Harbours Environmental Study will be valuable for the management of other estuaries on the south coast of Western Australia.
- Cost estimates for some of the management options in Appendix 2 of Bulletin 426 are inaccurate. Suggestion that ongoing costs for high-technology treatment and for the industrial/domestic sewer were underestimated.
- License conditions for industry should be tightened.
- Seagrass restoration may be economically viable given the potentially high cost of treatment/relocation.