PEEL INLET AND HARVEY ESTUARY MANAGEMENT STRATEGY

Report and Recommendations

by the

Environmental Protection Authority

Assessment Report of Stage 1 ERMP

Department of Conservation and Environment
Perth, Western Australia

Bulletin 243 December 1985

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MANAGEMENT STRATEGY

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SUMMARY AND RECOMMENDATIONS

The Environmental Protection Authority has concluded its review of the Stage 1 ERMP on the Peel Inlet-Harvey Estuary Management Strategy. The Authority's assessment will assist in the development of the investigations leading to the preparation of the Stage 2 ERMP by the proponents.

The Authority has set its objective for management of the system, namely:

> "to produce and maintain an estuary system that is visibly clean and healthy and is ecologically healthy and resilient."

Within the context of the objective, the assessment report addresses:

- the staged assessment process;
- the description of the problem and its causes;
- possible management measures for reducing the nutrient level; and
- estuary and catchment use and management.

The Authority has reached a number of conclusions. The principal ones are as follows:

- the major source of nutrient input to the Peel-Harvey System is the Catchment Area, but there is also a large nutrient store in the sediments of the estuaries;

- there needs to be a reduction in the level of nutrients entering the estuaries from the Catchment Area, and a reduction in the amount of nutrient already held in the sediments of the estuaries;

- it will be necessary to develop a long-term land management plan for the Catchment Area and an appropriate enabling framework, to attain and secure for all time reductions in nutrient loading to the System;

- improvements to the water exchange between the Peel-Harvey System and the ocean will have to be made to reduce the impact of nutrients and to produce a System that is ecologically resilient;

- the nutrient oversupply cannot be cured either by management in the Catchment Area or by improving water exchange alone. A combination of both measures will be needed to restore the health and resilience of the System within the time that is envisaged; and

- commercial development and use of suitable low phosphorus fertilisers (eg a sulphur only fertiliser) would be beneficial to the pollution management of the Catchment Area.

In conclusion, the Authority, after giving due consideration to the information presently to hand and subject to the implementation of the following recommendations, is of the opinion that neither management of the Catchment Area nor construction of the Dawesville Channel alone can reduce the level of nutrient enrichment in the System sufficiently to achieve a clean, healthy estuary system, at least in the short term.

RECOMMENDATION 1

The EPA recommends that initiatives already in place, specifically, commitment to long term continuation of the fertiliser management programme, commercial development of a sulphur only (non-phosphorus) fertiliser, farmer extension programme, weed harvesting and monitoring of aspects of the catchment and estuary should be continued.The latter should be designed to meet the following management objectives:

- verify that the management programme will fulfil the EPA's objective;
- verify/improve predictions about the phosphorus rundown in soils and sediments;
- indicate what occurs if widespread use of sulphur-only (non-phosphorus) fertiliser commences in 1986;
- to allow for prediction of blooms (from measuring the chlorophyll$_a$ level and nutrients in the sediments in the estuaries);
- to provide data on whether and how an oxygen collapse develops; and
- to provide up-to-date information which will allow for an accurate description of the existing environment in the catchments and estuary at any time.

RECOMMENDATION 2

The EPA recommends that in order to protect the Peel-Harvey System from excessive loads of phosphorus (and other nutrients) a Catchment Management Plan and an appropriate mechanism to facilitate its implementation be developed. To secure continuation of gains already achieved in the Catchment Area, an interim mechanism should be instituted as a high priority.

RECOMMENDATION 3

The EPA recommends that the Peel Inlet Management Programme be reviewed and revised to be in accord with the EPA's management objective for the Peel-Harvey System and to be consistent with the Catchment Management Plan and enabling mechanism (see Recommendation 2).

RECOMMENDATION 4

The EPA recommends that if the dredging of both ends of the Mandurah Channel, to improve the flushing in Peel Inlet, is carried out early enough, then the work should be monitored in order to facilitate the following:

- the data obtained from the monitoring of the effects of the above dredging should be used to check the validity of the predictions from the mathematical modelling which has been used to predict the improved flushing of Peel Inlet; and

- the above findings should then be used to further enhance the predictive modelling of solute transport (phosphorus) resulting from the Dawesville Channel and the interactions between the improved flushing characteristics of the dredged Mandurah Channel and the Dawesville Channel.

RECOMMENDATION 5

The EPA recommends that investigations continue into the size, design, location and implications of construction of a channel (or channels) connecting the sea to the Harvey Estuary, specifically in the context of the EPA's objectives and other recommendations in this report.

In addition, there may be an improvement in the pollution problem in the Harvey Estuary if circulation is improved between the Harvey Estuary and the Peel Inlet. Therefore there should be further investigations into the dredging of the channel between Ward Point and Point Grey (see Section 5.3.1 and Figure 2 of this report).

RECOMMENDATION 6

The EPA recommends that environmental review of the management strategy should continue in the State's environmental impact assessment process in the following manner: (see Figure 7)

. the studies aimed at providing specific information to assist in management decisions contained in Recommendations 1-3 and 5 be implemented**;

. the Stage 2 ERMP be prepared when the results and/or data from the above are available to incorporate into that document;

. the Stage 2 ERMP should inter alia:

  - report the results of the implementation of recommendations made in this assessment report;

  - identify the probability of success associated with the management alternatives for meeting the EPA's objectives;

  - give the timetable for the preferred management strategy and the implications thereof;

  - consider the anticipated effects on the Estuaries resulting from the Catchment Management Plan and enabling mechanism;

  - outline a monitoring programme to verify that the management strategy is fulfilling the EPA's objectives;

  - outline a mechanism for review and reporting of the monitoring results; and

  - examine the impacts of the construction of a channel (or channels) and its/their consequences.

. to ensure a meaningful public review phase the following condition would be necessary:

  - ongoing EPA involvement in determining the level, nature and timing of assessment required for possible associated developments.

**this would also apply to Recommendation 4 if the work is completed early enough.

1. INTRODUCTION

Studies into the biophysical nature of the Peel-Harvey System have been in progress since 1976 and have fallen into three distinct phases. These are:

- Phase 1 - "to determine the causes of the excessive growth and accumulation of green algae in Peel Inlet and if possible to propose methods for its control", Estuarine and Marine Advisory Committee (EMAC*, 1981, p 6).

- Phase 2 - to determine how best to implement the recommendations made in EMAC, (1981) and in Hodgkin et al. (1980).

- Phase 3 - examination of the feasibility of possible management measures, leading to identification of a preferred strategy and a Stage 1 ERMP*.

These three phases are discussed below.

Phase 4 will consist of additional studies and monitoring, followed by preparation of a Stage 2 ERMP, assessment by the Environmental Protection Authority (EPA*), and, subsequently, implementation of a suitable management strategy by the Government.

1.1 PHASE 1 STUDIES

Peel Inlet and Harvey Estuary (the Peel-Harvey System*) are a major aquatic resource for a number of recreational activities and for residential development. In addition, the shallow waters of the estuaries support the largest inland fisheries in Western Australia and large numbers of resident and migrant water birds use the estuaries and their saltmarshes. Parts of the estuaries have been made into Nature Reserves.

In 1976, the Environmental Protection Authority (EPA) asked its Estuarine and Marine Advisory Committee (EMAC) to investigate Peel Inlet. The reasons for this were:

". in recent years large quantities of green algae* had accumulated and decayed on the shores causing a nuisance to residents. The continuing 'cosmetic' action required to ameliorate the effects of this was thought to be costly and offered no permanent solution. It was desirable to identify the cause or causes of this 'algal problem' and, if possible, propose long term solutions;

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*indicates that this appears in the glossary at the back of this report.

- the Metropolitan Water Board was investigating the possibility of damming the Murray River in order to supply water to the metropolitan area. Reduced freshwater input to Peel Inlet could greatly alter the aquatic environment and it was desirable to identify the nature of likely changes; and

- residential and recreational use of the area was increasing rapidly and the effect on the estuary had to be understood in order to formulate management policies that would minimise adverse environmental change." (EMAC, 1981, p 6).

The study requested by the Authority in 1976 had two objectives:

"(a) Specific: to determine the causes of the excessive growth and accumulation of green algae in Peel Inlet and if possible to propose methods for its control.

(b) General: to gain an understanding of the working of this estuarine ecosystem so that environmental problems can be foreseen and decisions made about its management on the basis of sound knowledge." (EMAC, 1981, p 6).

In 1981, the Estuarine and Marine Advisory Committee reported the findings of research carried out between 1976 and 1980, to the Authority (EMAC, 1981) and made recommendations on management of the (Peel) estuary.

The principal conclusions presented were:

- that the Peel-Harvey System is eutrophic* (nutrient enriched) in that there is an excess of the nutrient elements phosphorus and nitrogen available for plant growth; and

- that proper management of it can only be achieved by reducing the present input of nutrients from agricultural drainage, by preventing any increase of nutrients from other sources and by not further restricting flushing of nutrients to the sea.

The studies also identified that the eutrophication in Peel Inlet is manifested as an abundance of bottom-living, large, green algae* (macroalgae), commonly Cladophora*, Chaetomorpha* and Ulva*. In Harvey Estuary the eutrophication is manifested as an abundance of microscopic plants (phytoplankton*) in the waterbody, in particular as spring-summer blooms of the blue-green alga (strictly a cyanobacterium*), known as Nodularia spumigena*.

The nature of the nutrient enrichment and its associated symptoms (ie excessive algal growth) are discussed in detail in Chapters 4, 5 and 6, later in this report.

The Peel-Harvey Estuarine System Study carried out for EMAC provided evidence that the aquatic environment had deteriorated, as manifested by accumulations of decomposing algae, massive blooms of phytoplankton, and by the localised death of fish and crabs, with associated nuisance and aesthetic consequences to the public and to responsible authorities. The study established that the main cause of the deterioration was man-induced eutrophication, resulting from the progressive increase of plant nutrients entering the estuary and remaining in it.

The studies also showed that remedial and preventive measures would need to be directed mainly towards control and substantial reduction of all sources of nutrients available to plants within the estuarine system.

The EMAC report (1981) made a number of recommendations on possible management, further research and ongoing monitoring.

1.2 PHASE 2 - IMPLEMENTATION OF RECOMMENDATIONS FROM PHASE 1 REPORTS

The second phase of the studies began in late 1981 and confirmed the importance of drainage from the soils of the coastal plain catchments as a source of phosphorus to the system. The occurrence of blooms of blue-green algae in the Harvey Estuary resulted in increasing concern about the eutrophic condition of the Harvey Estuary and a shift in emphasis to examine how the eutrophic condition of both the Peel Inlet and Harvey Estuary could be reduced.

1.3 PHASE 3 - EXAMINATION OF FEASIBILITY OF MANAGEMENT OPTIONS

In 1983 a study into the feasibility of all the possible management options for the Peel-Harvey System was carried out at the Centre for Water Research, at the University of Western Australia. A summary report of the findings is given in Humphries and Croft (1983) and in DCE (1984).

The management study established management objectives and constraints and recommended management strategies which would keep eutrophication of the estuary within "acceptable limits" (see Chapter 5 of this assessment report). These strategies have

been further examined by the Peel-Harvey Study Group and were presented in the Stage 1 ERMP. The ERMP was released to the public on 17 August, 1985 and was available for comment for 2 months until 17 October, 1985. A total of 19 written submissions was received and the Authority has considered all these in the preparation of its assessment report, wherever relevant. The Authority also made itself available to receive oral submissions from the public on 2 October, 1985 in Mandurah. A list of individuals making submissions and a list of points raised, is given in Appendix 1.

2. THE STAGED ASSESSMENT PROCESS

Under headpowers given in the Environmental Protection Act (1971-1980) the Environmental Protection Authority determines the appropriate level of environmental assessment required for any proposal which is referred to it. The Authority may refer the matter to the Department of Conservation and Environment or may request the preparation of a Notice of Intent (NOI*). Following submission of this document to the Authority, a Public Environmental Report (PER*) or Environmental Review and Management Programme (ERMP) may be sought.

2.1 STAGED ERMPs

For major projects, such as the management strategy for the Peel-Harvey System, the Authority considers that a staged assessment, with each ERMP involving public input, may be more appropriate than a single assessment. Typically, the Authority would require an ERMP to be staged for a number of reasons, two of which are:

- the environmental implications of a proposed development or course of action are too complex for adequate public review based on a single document; and/or

- the environmental impact assessment process for a particular development requires an analysis of a number of alternatives (eg alternative sites, technologies or strategies) followed by the detailed consideration of a smaller number of options.

The Peel-Harvey assessment clearly falls into the latter category and the Authority has determined that a two-stage ERMP is appropriate. The Authority's objectives for each of the stages and the associated assessment reports are outlined below.

2.1.1 THE STAGE 1 ERMP AND ASSESSMENT

The objective of the Stage 1 ERMP, presently being assessed, was to present the eutrophication problem and analyse possible management strategies to move the system closer to a mesotrophic* state.

The objective of the Authority's assessment of the Stage 1 ERMP is to provide "approval in principle" to a strategy (or strategies) that would meet the Authority's management objectives (see Chapter 3), to identify those matters that require consideration in the Stage 2 ERMP (see Chapters 4, 5, 6 and 7 of this assessment report), and to identify a framework for the Stage 2 ERMP that would ensure that the context for that assessment is appropriate (see Chapter 7 of this assessment report).

2.1.2 THE STAGE 2 ERMP AND ASSESSMENT

The Stage 2 ERMP and its associated EPA assessment report will be the documents on which final decisions on the ultimate management strategy to be implemented will be based. The ERMP should examine in detail the possible consequences of the land management strategy (or strategies) on the estuarine system and the implications of changes in condition in the estuarine system for land management. Any other associated developments arising from or impinging upon the above would also need to be considered within the context of the Stage 2 ERMP assessment.

The Stage 2 ERMP phase will be a complex assessment, particularly as it is likely that the components requiring review will not necessarily fall within a single ERMP document, rather, there may be separate documents from different proponents released concurrently. Because of the potential complexity of the Stage 2 assessment, the following condition would be necessary to ensure a meaningful public review phase and assessment:

- ongoing EPA involvement in determining the level, nature and timing of assessment required for possible associated developments.

3. THE AUTHORITY'S MANAGEMENT OBJECTIVES

Notwithstanding that the Peel-Harvey Study Group has adopted certain objectives and constraints for its assessment (see Section 5.1) the Authority's management objective can be simply stated as:

"to produce and maintain an estuary system that is visibly clean and healthy and is ecologically healthy and resilient."

4. DESCRIPTION OF THE PROBLEM AND ITS CAUSES

The Peel-Harvey System is nutrient-enriched (eutrophic) of which the major symptom is excessive growth of micro and macro-algae. The consequences are:

- rotting algae fouling beaches and creating nauseating odours which cause discomfort to tourists and residents;
- occasional mass mortality of fish;
- fouling of boat propellers and fishing nets; and
- degradation of the aesthetic environment.

Other effects include adverse effects on tourism and reduction in property values adjacent to the Peel Inlet and Harvey Estuary. The fishing industry, on the other hand, is gaining from increased catches of sea mullet and yellow- eyed mullet.

4.1 THE PRINCIPAL SOURCES OF NUTRIENT ENRICHMENT

The Peel-Harvey System is a large body of shallow water receiving strongly seasonal river flow (mainly occurring in a period of about 12 weeks during winter) from the Serpentine, Murray and Harvey Rivers (Figures 1 and 2). The system has a high evaporation rate plus restricted exchange with the sea by way of the Mandurah Channel. This physical state (which predisposes the water body to eutrophication) has been reached via 'natural' processes with the end result most likely to be an infillng of the water body over geological time. Man's activities in the catchments (eg clearing and agricultural land uses) have rapidly increased the input of nutrients to the estuaries thereby greatly accelerating this process of nutrient enrichment. The input of nutrients now substantially exceeds the loss to the sea resulting in an abundance of nutrients left which can support algal growth. Figure 3 illustrates the nature of the nitrogen and phosphorus cycles. Data indicate an average input of phosphorus from rivers and drains of approximately 140 tonnes per year and a loss to the sea of about 60 tonnes per year (these figures vary annually with the volume of river flow). A survey in April 1984 showed a biomass of algae of 46 300 tonnes, more than at anytime since 1979 and, although by August 1984 it had dropped to 23 900 tonnes, the biomass remains at a high level.

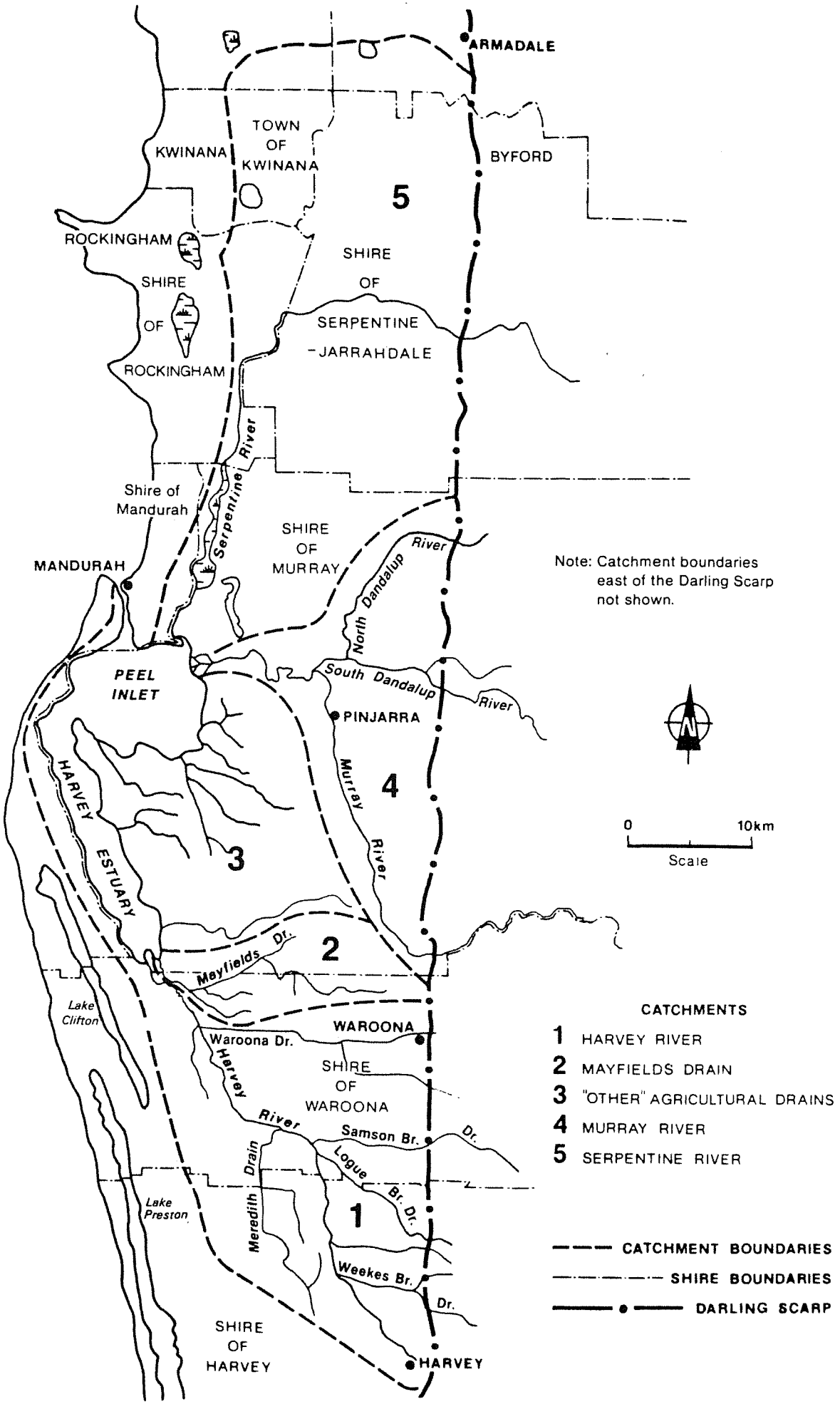


Figure 1 Peel Harvey System Catchment Area (as defined for the purposes of this assessment report).

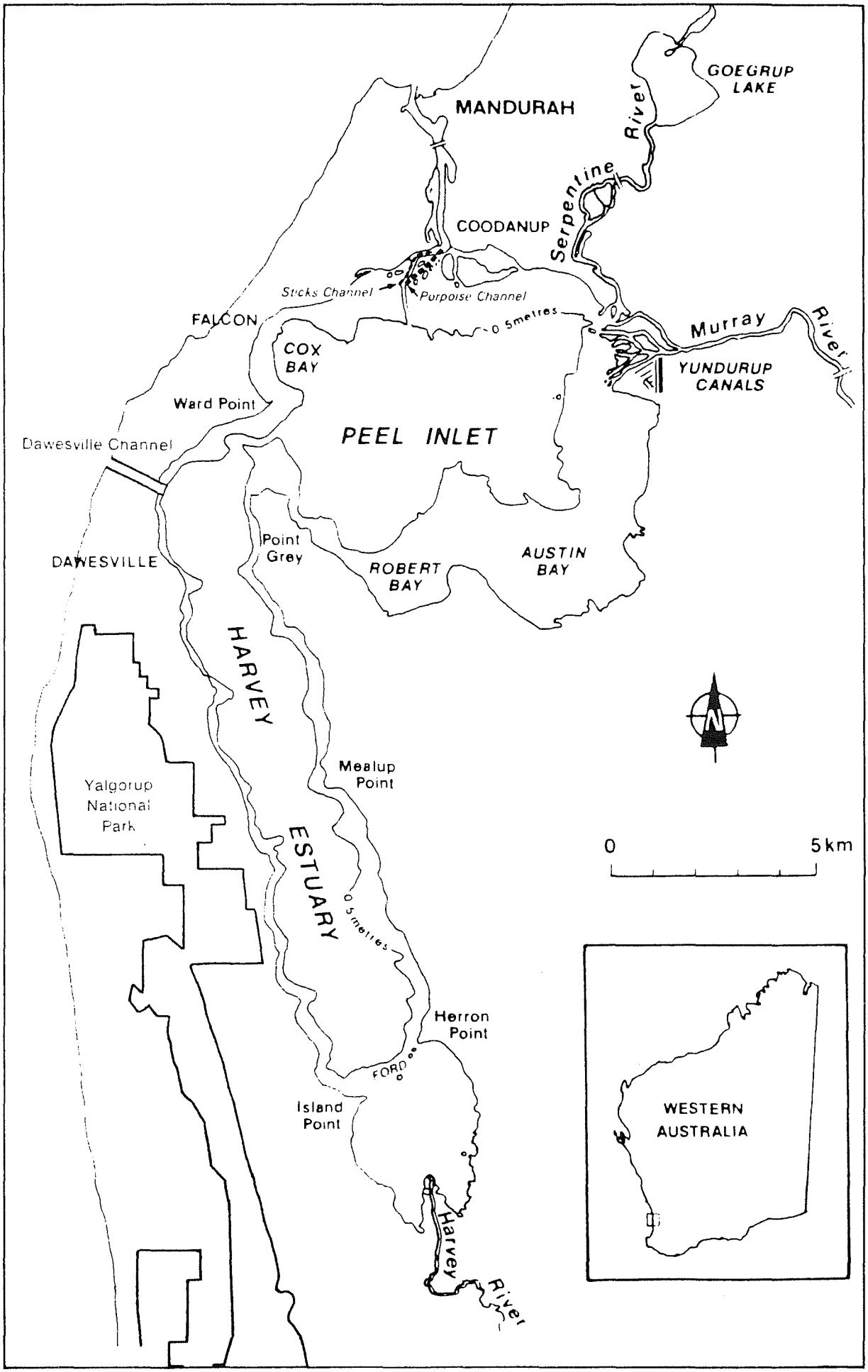


Figure 2 Peel-Harvey System Location Map

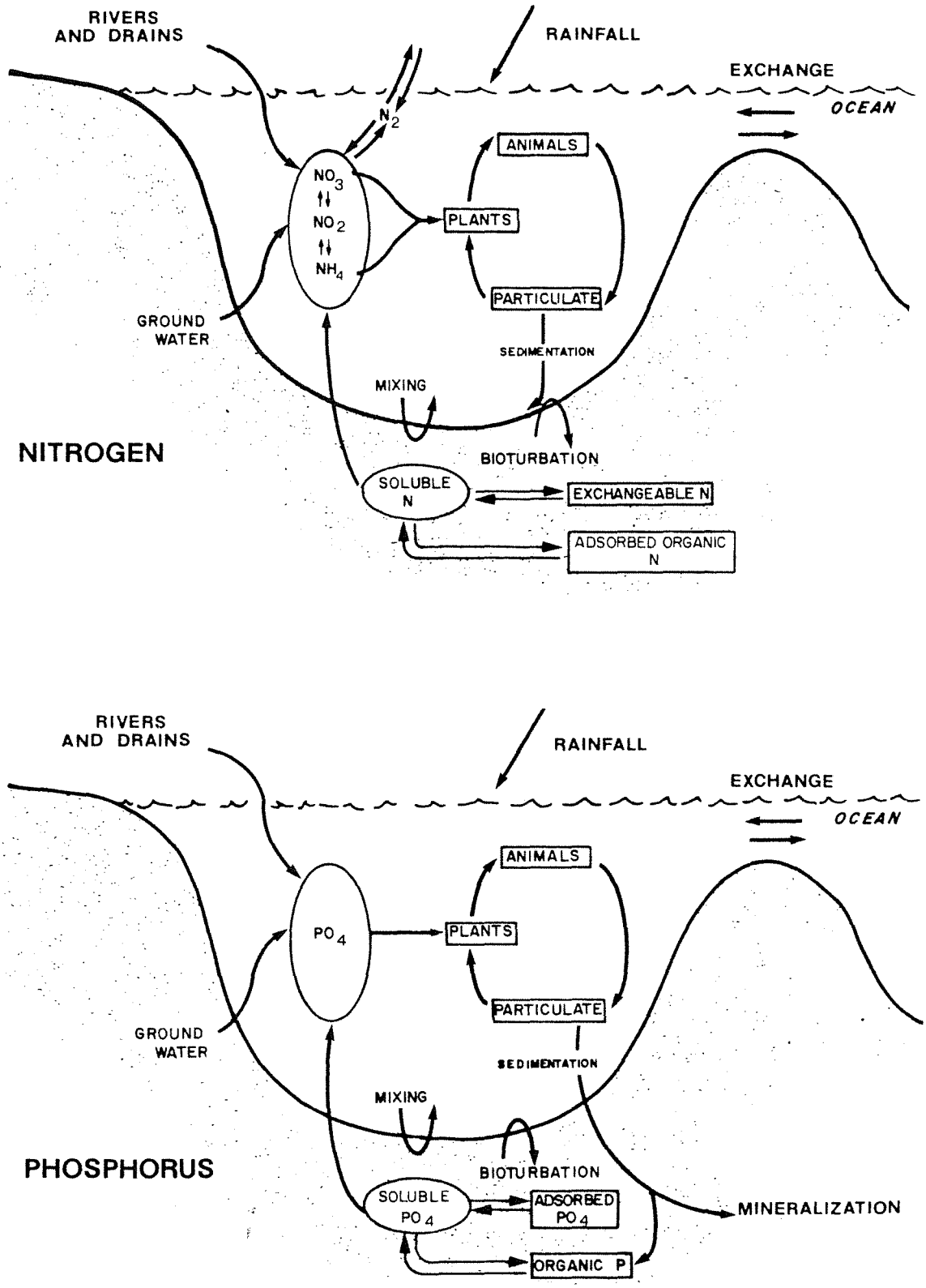


Figure 3 Schematic model of the nitrogen and phosphorus cycles. (Hodgkin *et al.*, 1980).

Nitrogen(N) and phosphorus(P) are essential nutrient elements for algal growth and if either is in short supply growth will be restricted.

Nitrogen supply is plentiful largely because of nitrogen fixing blue-green algae (principally Nodularia) and large loads of nitrogen entering the system particularly from the Murray River. It is estimated that in 1978 the Murray contributed 1 175 tonnes while the combined inputs from the Serpentine and Harvey were 455 tonnes (PHSG, 1985, p9). In 1979, which was a drier year, inputs were 100 tonnes and 410 tonnes respectively. There is no practical method of reducing the nitrogen input from these sources, because much of the nitrogen results from natural processes.

The principal source of phosphorus is from applications of phosphatic fertiliser to naturally phosphorus deficient soils in the agricultural areas of the Catchment Area (see Figures 1 and 4). The phosphorus is readily leached from these soils and enters the drains and rivers flowing into the Peel-Harvey System. Unlike nitrogen inputs, there are methods for reducing the amount of phosphorus entering the system by various means (see Chapter 5). Phosphorus has also accumulated in the estuaries' sediments. Although this source could not indefinitely support algal blooms in the absence of external inputs, it is considered significant and of increasing importance.

4.2 THE PHOSPHORUS BUDGET

During the last decade an average of about 1 500 tonnes of phosphorus per year has been applied to the coastal plain catchment (the Catchment Area of Figure 1). The fate of this phosphorus can be shown in broad terms in Figure 5.

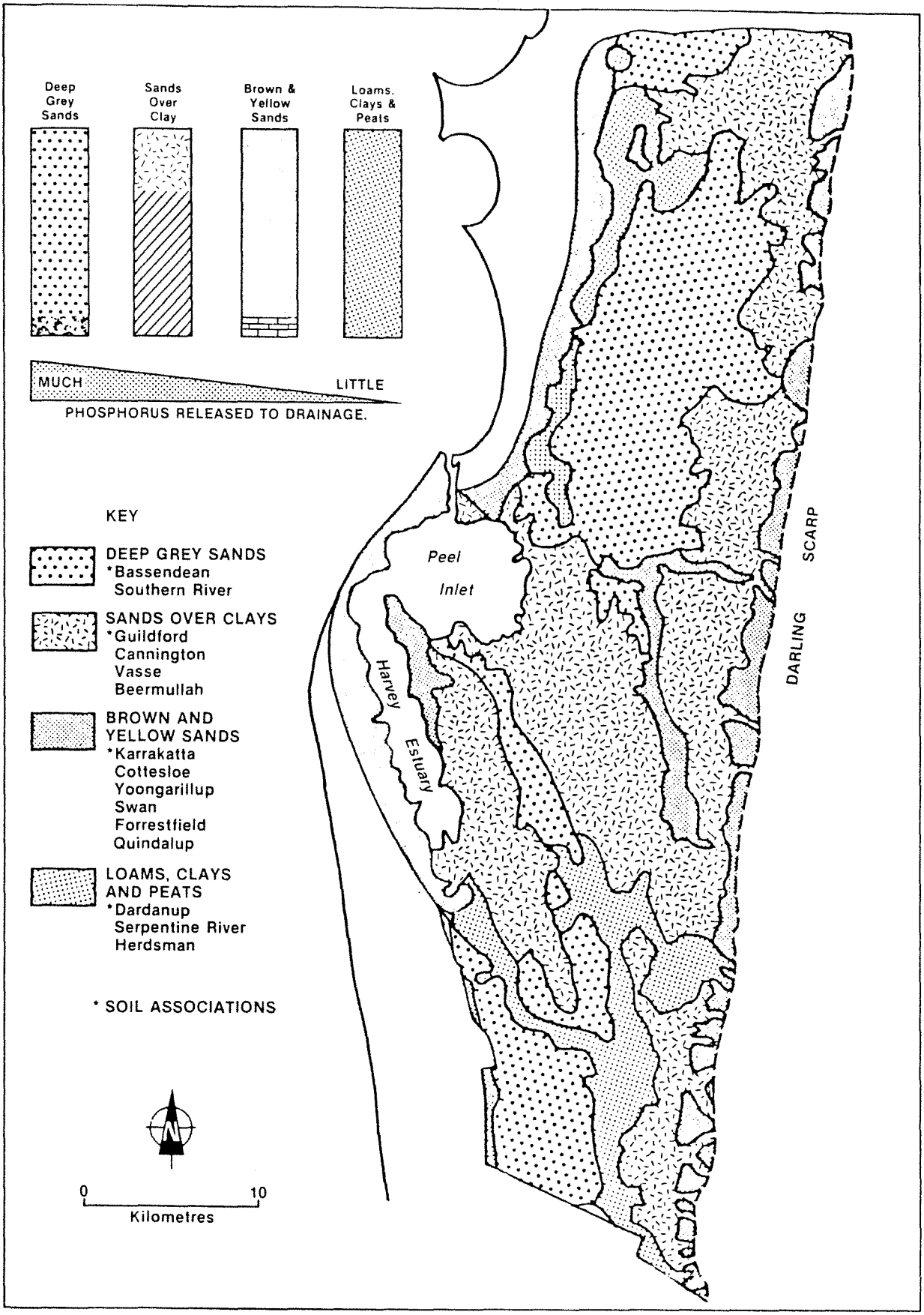
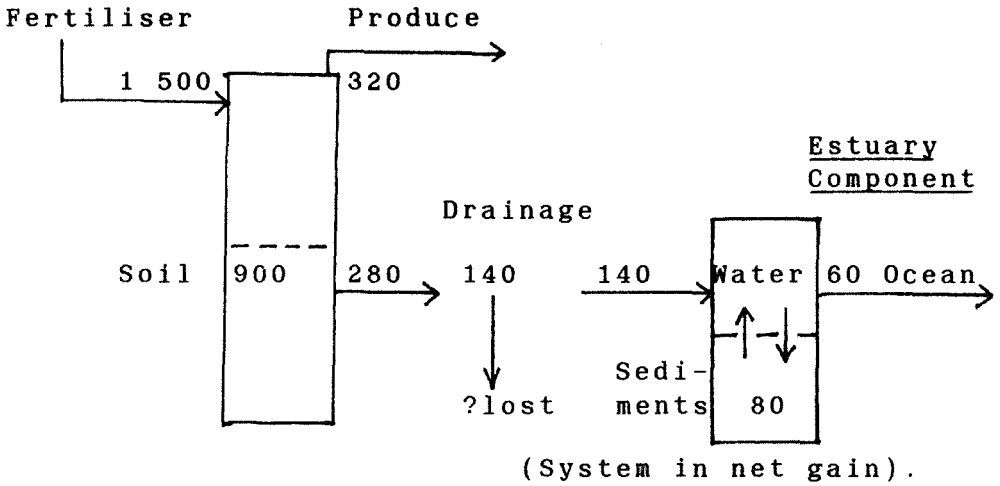


Figure 4 Soils of the Catchment Area.

Figure 5 Annual Phosphorus Budget-values are phosphorus in tonnes per year.

Agricultural Component.



(System in net gain).

From Figure 5 it is clear that the estuary component, while only receiving a small fraction of the fertiliser applied in agriculture, is nonetheless in a position of net phosphorus gain. As a result, there are four possible mechanisms for resolving the problem:-

1. reduce the phosphorus input to the estuary by controlling phosphorus input from the catchments;

2. increase phosphorus export to the ocean;

3. minimise the release of phosphorus from the sediments into the water column; and

4. a combination of the above.

In order to clarify the most appropriate management route, it is necessary to determine the phosphorus loading level to the estuaries that would approach a balance of input and output, and which would achieve a satisfactory non-eutrophic condition (ie a nutrient level resulting in acceptable levels of algal growth and fish productivity, defined as mesotrophic by Reckhow (1981)).

Table 1 summarises the situation with respect to phosphorus loading and clarifies differences between strategies. Firstly the maximum permissible phosphorus load (73 tonnes per year) based on consideration of a mesotrophic state, shows that the export to ocean (60 tonnes per year - Figure 5) is within 20% of this figure. Clearly if the system is near equilibrium with phosphorus input approximating phosphorus output, there would not be a long-term eutrophication problem. Secondly

TABLE 1 - **MAXIMUM PERMISSIBLE PHOSPHORUS LOADINGS FOR NON-EUTROPHIC (MESOTROPHIC) STATUS**

Estuary	Input Range loading Phosphorus (tonnes per year)	Average loading Phosphorus (tonnes per year)	Max. loading permissible without Dawesville Channel Phosphorus (tonnes per year)	Max. loading permissible with Dawesville Channel Phosphorus (tonnes per year)
Harvey	35 - 130	82	28	45
Peel	18 - 100	57	45	67
Total		139	73	112

See Appendix 2 for basis of Table 1

there is a large difference between the desirable phosphorus loading required for mesotrophic conditions and the actual phosphorus loading of 139 tonnes per year(Table 1). To increase the export component via an increased exchange with the ocean (eg through the Dawesville Channel) would reduce the amount of phosphorus but would still not resolve the problem (see Table 1).

4.3 THE REQUIRED APPROACH

From the above, it is clear that a combined approach is needed, one of reducing phosphorus input and increasing phosphorus export. Therefore the agricultural component of the phosphorus budget (Figure 5) and the catchment in general need to be examined to find options for reducing phosphorus input to the Peel-Harvey System. In addition, ways of increasing phosphorus export need to be addressed.

A corollary of the Peel-Harvey System being in a net phosphorus gain, is that each year substantial amounts of phosphorus are added to the estuarine sediments. It was estimated that in 1980, 260 tonnes of phosphorus were present in the top two centimetres of the bottom sediments (Hodgkin et al, 1980). If an average addition of 80 tonnes per year is assumed then the total loading would approximate 660 tonnes of phosphorus by late 1985. As a result of this large store of phosphorus in the sediments, implications for algal blooms are difficult to estimate as other factors, such as salinity changes, will also alter algal response (Hodgkin et al., 1985). However, it could mean that blooms of an algal organism could continue to occur in the Harvey Estuary even after the management measures have been implemented. There is an even greater possibility that in the case of the Peel Inlet and northern Harvey Estuary there will be an increase in the occurrence of macroalgae, at least in the short term, because of increased water clarity from improved flushing (Hodgkin et al., 1985).

4.4 THE CONSEQUENCES OF TAKING NO ACTION

If no action was taken, nutrient enrichment is highly likely to increase, with a resultant worsening of the problems referred to in Section 4. This contention is supported by the phosphorus budget (Section 4.2) which indicates the magnitude of the increase in phosphorus input which could be expected to result from a no action scenario. Furthermore, as stated in the ERMP (PHSG, 1985), the last 10 years have experienced below average rainfall and riverflow. The phosphorus input is directly proportional to the volume of riverflow

(and hence rainfall) and therefore a substantial increase in phosphorus input and problems in the estuaries would be likely when a return to normal rainfall occurs. (PHSG, 1985, p 11 and p 50).

Also, oxygen deficiency is now being more frequently experienced and given appropriate weather conditions, in particular prolonged absence of wind along with a stratified water body, the potential for massive fish and crab mortality could signficantly increase. This would cause significant disruption to the ecology of the estuary and those activities which rely on it, such as fishing, recreation and tourism.

5. POSSIBLE MANAGEMENT MEASURES FOR REDUCING THE NUTRIENT LEVEL

Community pressure and the environmental implications of allowing the Peel-Harvey System to remain in its eutrophic condition has pointed to the need to determine and implement appropriate management and control measures. The Peel-Harvey Study Group was established in 1984 to recommend to Government those management measures necessary to reduce the algal problems of Peel Inlet and Harvey Estuary to acceptable levels within a reasonable time and within the framework of a number of constraints (PHSG 1985, p iii). These constraints are discussed in Section 5.1.

5.1 PEEL-HARVEY STUDY GROUP MANAGEMENT OBJECTIVES AND CRITERIA

The Peel-Harvey Study Group has been guided in the identification and review of management options by the following objective:

> "to reduce the algal nuisance to 'acceptable levels' without further damage to the estuarine environment"(PHSG, 1985 p 13)

The term 'acceptable' has been defined to include the following:

> ".Nodularia blooms should not occur more frequently than once in five years on average;
>
> .weed should not foul beaches near populated areas" (DCE, 1984).

This objective was constrained by the following criteria:

". public access to estuary by water or by land should not be reduced;

. productivity of the estuarine fishery should be maintained;

. productivity of coastal plain agriculture should be maintained;

. changes to surrounding natural ecosystems should be minimised;

. introduction of exotic plants and animals should be avoided."(PHSG, 1985, p 13; DCE, 1984).

An important additional criteria upon which options were reviewed was the belief that:

> "priority must be given to measures that can achieve the stated aims within three to five years rather than to measures which may take ten or more years to be effective or measures which will require further 'prolonged' study, even through they might be less costly and cause less interference with the present estuarine ecosystem." (Hodgkin et al., 1985)

5.2 PEEL-HARVEY STUDY GROUP MANAGEMENT PROGRAMME

Approximately 120 management options were investigated by Humphries and Croft (1983) and by the Peel-Harvey Study Group. Most were rejected as not warranting detailed evaluation. The options are listed in Tables 4.1 to 4.5 in the ERMP (PHSG, 1985).

The ERMP identifies a total of ten options that could form the basis of a management programme, four preferred options and six supplementary options. These options are listed in Tabie 2.

The preferred strategy (PHSG, 1985) consists of:

- continued harvesting of weed;
- modifying agricultural fertiliser practices on the coastal plain;
- improving exchange between the ocean and Peel Inlet by dredging the Mandurah Channel; and
- improving tidal flushing of the Peel-Harvey System by construction of a new channel to the ocean near Dawesville.

The combination of the weed harvesting, modifying fertiliser practices and the Dawesville Channel is seen as being the most likely strategy to succeed in the short term (Hodgkin et al., 1985). However, even this combination cannot be expected to reduce the algal nuisance to acceptable levels in less than three to five years. (DCE, 1984). The supplementary measures are considered to have the potential to contribute to control of the nutrient enriched System.

Table 2 outlines in summary form anticipated (expected) advantages and disadvantages of each option and those aspects of each option that are unkown or uncertain. It is clear that there are disadvantages to some options that must be considered and many aspects are not known. The advantages are generally more easily identified.

TABLE 2 - MANAGEMENT OPTIONS AND THEIR IMPLICATIONS

STRATEGY		MANAGEMENT OPTIONS AND THEIR IMPLICATIONS		
SHORT (3-5)	LONG (>5)	ADVANTAGES	DISADVANTAGES	UNCERTAINTIES
WEED HARVESTING		REDUCED ACCUMULATION AND DECOMPOSITION ON FORESHORES.	MINIMAL EFFECT ON NUTRIENT LEVELS AND NODULARIA LOSS OF FORESHORE AND VEGETATION.	
AGRICULTURAL FERTILISER PRACTICES		REDUCED NUTRIENT INPUT INTO P-H SYSTEM. POTENTIALLY REDUCED MACROALGAL BLOOM INTENSITY.	MINIMAL SHORT TERM EFFECT ON PHOSPHORUS LEVELS IN SEDIMENTS.	. FARMER CO-OPERATION . HOW LONG FOR CHANGE AND EXTENT OF CHANGE TO OCCUR IN STORED PHOSPHORUS IN SOILS AND SEDIMENTS
DAWESVILLE CHANNEL		IMPROVED FLUSHING OF P-H SYSTEM REDUCES PHYSICAL CONDITIONS FAVOURED BY NODULARIA. IMPROVED WATER QUALITY IN P-H SYSTEM. REDUCES AVAILABLE NUTRIENTS TO MACRO AND MICRO ALGAE.	INCREASE ALGAL PROBLEM IN SHORT TERM(except Nodularia) ALTER SPECIES COMPOSITION AND POSSIBLY ABUNDANCE OF FISH FAUNA. REDUCE HABITATS AND FEEDING SITES FOR WATERBIRDS. MAY ALTER FISHERY PRODUCTIVITY.	EFFECT ON RETENTION/LOSS OF PHOSPHORUS IN SEDIMENT. TIME FOR REDUCED PHOSPHORUS CONDITION TO BE ACHIEVED. QUANTIFICATION OF EFFECTS ON CIRCULATION, AQUATIC FLORA AND FAUNA.
MANDURAH CHANNEL (INCLUDING STICKS CHANNEL)		IMPROVED NAVIGATION OF CHANNEL. IMPROVED FLUSHING OF PEEL INLET ALLOWS MONITORING FOR ASPECTS OF DAWESVILLE CHANNEL.	MINIMAL EFFECT ON HARVEY ESTUARY. MAY INCREASE MACROALGAL PROBLEM IN SHORT TERM.	EFFECT ON LOSS/RETENTION OF PHOSPHORUS IN P-H SYSTEM.
APPLICATION OF ALGICIDES		CONTROLS NODULARIA GROWTH	POSSIBLY INCREASE NUTRIENT RETENTION IN P-H SYSTEM	. HOW EFFECTIVE . WHAT SIDE EFFECTS . EFFECT OF SUB-LETHAL CONCS . FREQUENCY OF APPLICATION . EFFECT ON NON-TARGET SPECIES . COST
USE OF NITRATES		POTENTIALLY INHIBITS PHOSPHORUS RELEASE FROM SEDIMENTS	(1)	RATE, MEANS AND COST OF APPLICATION. LENGTH OF SUPPRESSION OF PHOSPHORUS RELEASE.
RURAL POINT SOURCES		REDUCES PHOSPHORUS INPUT.		EXTENT OF PHOSPHORUS CONTRIBUTION.
	CHANGES IN LAND USE	REDUCES PHOSPHORUS INPUT AND WATER VOLUME.	(1)	EFFECTIVENESS OF REDUCING PHOSPHORUS INPUT TO P-H SYSTEM. ECONOMICS TO FARMER.
	CLEARING AND DRAINAGE CONTROLS	RESTRICTS INCREASE IN PHOSPHORUS AND WATER INPUT.	(1)	EFFECT ON PHOSPHORUS INPUT.
	SOIL AMENDMENT WITH BAUXITE RESIDUE	REDUCES PHOSPHORUS LEACHING FROM SOILS.	(1)	COST AND EFFECTIVENESS AND METHOD OF APPLICATION. FARMER ACCEPTANCE.

(1) The precise nature and extent of any disadvantages has not yet been determined.
SOURCE: Birch et al. (1985)

Aspects of two of the preferred management options are already in place. Changes to fertiliser practices are already occurring, through an active farmer extension programme, and the development of more appropriate fertilisers for use on the coastal plain soils. Weed harvesting has been undertaken over the past two years and beach clearance commenced in 1974.

The principal focus of the proposed management strategy is to reduce the amount of nutrients, especially phosphorus, available to algae. Potential reduction from various options are estimated and are shown in Table 3.

5.3 MANDURAH AND DAWESVILLE CHANNELS

Two engineering options have been reviewed; the dredging of the existing Mandurah Channel and the construction of a new channel between Harvey Estuary and the ocean (the Dawesville Channel).

5.3.1 THE MANDURAH CHANNEL

This proposal is for the dredging of the channel between the Mandurah Bridge and the ocean, and also the Sticks Channel/Porpoise Channel in Peel Inlet (Figure 2). Provided both portions of the proposal are carried out, an improvement in tidal flushing of the Peel Inlet would occur. The effect of dredging on tidal exchange and water circulation has been estimated by using mathematical models, including those developed for the Dawesville Channel proposal. Two reports and recommendations to Government have already been provided by the Authority on the dredging of the ocean entrance sand bar and Fairbridge Bank and ocean entrance channel (DCE, 1985).

Although not strictly part of the management strategy proposed for reducng the Nodularia problem in the Peel-Harvey System, the Mandurah Channel dredging would improve flushing in Peel Inlet when the restrictions at both ends of the channel are removed. If this work was to be carried out, it would provide useful data from monitoring, which would allow the mathematical model predictions for the Mandurah Channel dredging to be validated. Data from this exercise could also be used to fine-tune the mathematical modelling of the Dawesville Channel.

A consequence of the improved flushing resulting from the dredging of both ends of the Mandurah Channel would be improved water clarity, which could lead to an increase in macro-algal growth in Peel Inlet in the short term.

TABLE 3

ESTIMATES OF THE POTENTIAL OF THE MANAGEMENT OPTIONS FOR A REDUCTION IN PHOSPHORUS AVAILABILITY TO ALGAE

OPTION	EFFECTIVE REDUCTION	
	HARVEY	PEEL
Modify Fertiliser Practices	30-40% in 3-5 yrs up to 60% in 10 yrs	
Soil Amendment (Bauxite Residue)	15-50% (1)	35-65% (1)
Control Point Sources	(?)	>10%?
Mandurah Channel Dredging	5%?	up to 30% (summer) up to 40% (winter)
Dawesville Channel	50%	25%?
Weed Harvesting	less than 5%	(?)
Changes in Land Use	35-85% (1)	45-90% (1)
Algicides	(?)	(?)
Nitrates	up to 100%	
Clearing & Drainage Control	up to 10%	

(1) Range dependent on area of catchment treated.
(?) not determined.

Source: Peel-Harvey Study Group, pers. comm.

Any effect on flushing of Harvey Estuary resulting from the Mandurah Channel dredging would be minimal. Part of the reason for this is the restriction of flows that exists in the narrow channel linking Peel Inlet and Harvey Estuary between Ward Point and Point Grey (see Figure 2). This restriction would also reduce the potential improvements in the flushing of Peel Inlet that would result from the construction of the Dawesville Channel.

5.3.2 DAWESVILLE CHANNEL

Investigations into the creation and implications of a new channel linking Harvey Estuary and the ocean near Dawesville were not initiated until after EMAC reported to the EPA in March 1981 (EMAC, 1981). Since then, studies into the consequences of constructing a Dawesville Channel have indicated that:

- flushing of nutrients from the Harvey Estuary and also portions of the Peel Inlet to the Ocean would be improved; and

- the creation and maintenance of marine conditions in the Harvey Estuary over much of the year would minimise the growth of Nodularia.

By maintaining a more marine-like environment in Harvey Estuary, the Dawesville Channel would improve the resilience of the System and provide stability to the ecosystem. This is because marine environments have demonstrated consistent ability to remain relatively stable through time, despite a variety of pressures. This would not occur without some alteration to components of the existing Peel-Harvey System. A number of changes would not be seen as beneficial by all interested people. Some of them are outlined in Table 2.

However, although the Dawesville Channel would require a two and a half year construction period, without taking lead time into account, it would provide an effective reduction of nutrients in the system, within a shorter period than other major options.

6. ESTUARY AND CATCHMENT USE AND MANAGEMENT

6.1 INTRODUCTION

In Chapters 4 and 5 of this report, the eutrophic condition of the Peel-Harvey System, and options for reducing nutrient inputs to the system, are reviewed. This Chapter examines land uses within the portion of the estuaries' coastal plain catchments most critical in terms of nutrient inputs to the system (see Figure 1). This area (referred to as the Catchment Area in this report) is only part of the total catchment of the Peel-Harvey System but is, nevertheless, extensive (approximately 2 000 square kilometres area and extending across seven local government authorities).

In examining land uses in the Catchment Area, the aim is to gain an appreciation of how they could be managed so as to lessen nutrient outflow from the Catchment Area and hence reduce nutrient input to the Peel-Harvey System.

6.2 CATCHMENT LAND USE

Clearly, the pattern of land use throughout the Catchment Area is not static. It is important that both changes in the type of land use occurring (eg conversion of rural areas to non-rural uses), and alterations to land use practices (eg changes in agricultural techniques) are considered.

The extent of the Catchment Area compounds problems associated with the dynamics of the land use pattern. For instance, each of the seven local government authorities has land use and development aspirations which are achieved through their individual Town Planning Schemes. These Schemes are continuously being amended and are subject to periodic major reviews.

The regional land use strategies that encompass parts of the Catchment Area are also reviewed periodically. For instance, the northern portion of the Catchment Area that is within the Perth Metropolitan Region will be affected by the review of the Corridor Plan for Perth.

The dynamic nature of the land use pattern within the Catchment Area is, therefore, evident. However, changes within this basic pattern can also occur, particularly in the agricultural sector, for instance in response to economic influences.

Detailed information on existing and proposed land uses in the Catchment Area would be desirable as an

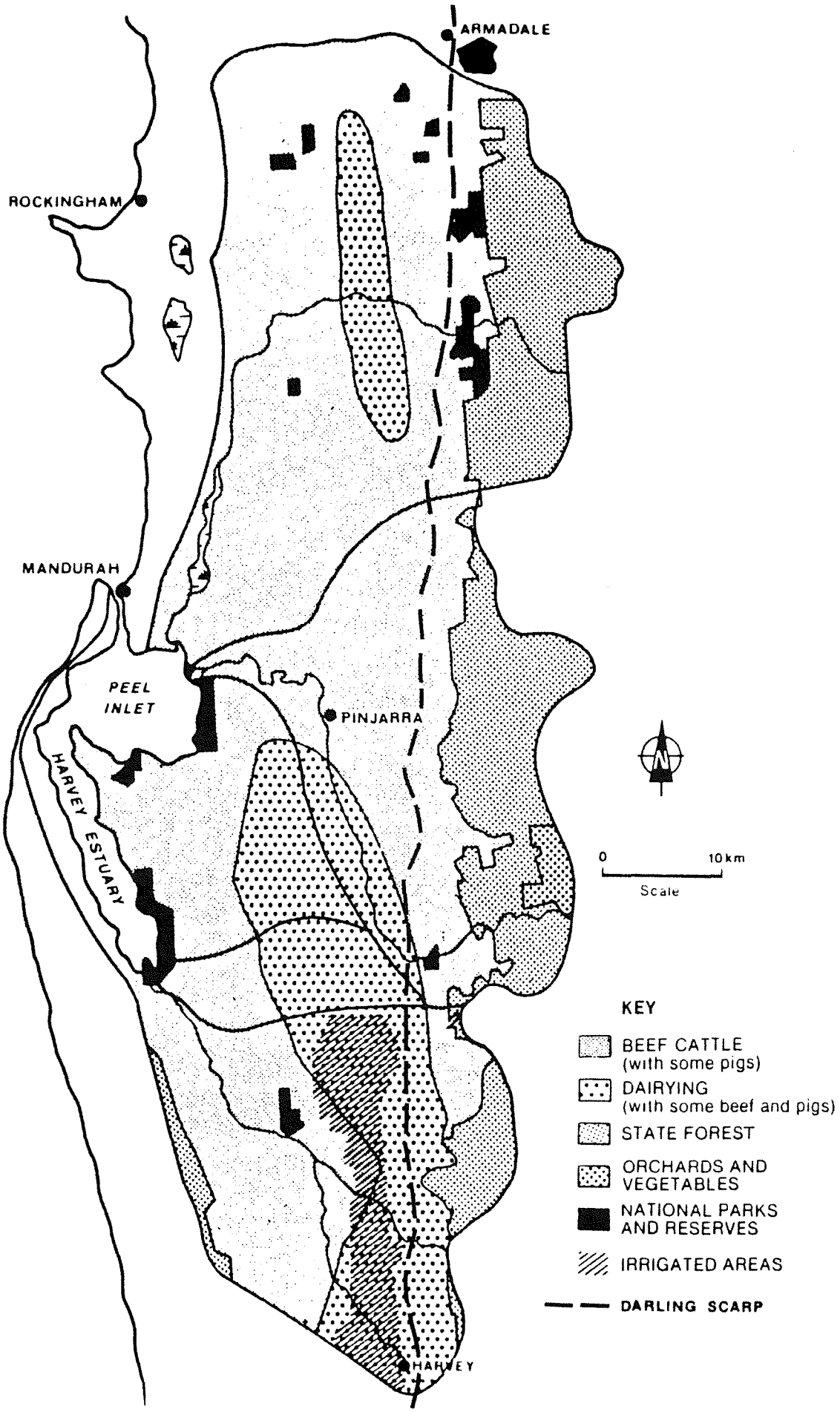


Figure 6 Land Uses in the Catchment Area.

aid to making decisions on strategies to reduce nutrient levels in the Peel-Harvey System. However, in this report, a broad review only of major land uses in the Catchment Area has been undertaken. Four categories of land use have been considered (ie rural, special rural, non-rural, and conservation).

6.2.1 RURAL

Agriculture occupies most of the Catchment Area, with some 155 000 hectares cleared for cultivation (125 000 hectares on sandy soils, 30 000 hectares on heavier soils). The annual value of agricultural production is about $40 million (1983 dollars), the major activities being beef production, dairying, orcharding and horticulture.

The extent of these activities is shown in Figure 6. Piggeries and stock feed-lots also occur, and the production of sheep for live export is presently increasing.

The intensive agricultural activities represent point sources of nutrients and are, therefore, potentially manageable. Effluent licensing provisions under the Rights In Water And Irrigation Act would provide one means for regulating outflows from the point sources. Additionally, some of these activities would be subject to requirements under the Health Act that could assist in controlling nutrient outflows.

It is more difficult to manage nutrient outflow from the extensive, pasture-based agricultural activities (beef, dairying, sheep and fodder production), because they represent non point-sources. Historically, the degree of control exercised over broad-scale rural activities through local authority planning and development regulations has been limited.

6.2.2 SPECIAL RURAL

Special Rural (ie small holding lot) development is widespread throughout the Catchment Area, particularly in the following areas:

- adjacent to the Serpentine River north of Lake Goegrup;
- the West Murray locality in general; and
- west of the Harvey Estuary.

Although a low-density form of development, Special Rural (SR) lots represent a significant intensific-

ation of human habitation compared with rural activities. Because lot sizes are being reduced, SR development can also lead to an intensification of land usage.

However, land use management provisions, to safeguard environmental quality, are an accepted component of SR development. The scope of provisions applied to SR development varies between local government authorities, as does the expertise available to these authorities in their implementation. The provisions do, nevertheless, provide the opportunity to realise pre-determined land use and management objectives.

6.2.3 NON RURAL

Although activities such as residential development, recreation/tourist facilities, and industrial pursuits are quite widespread throughout the Catchment Area, attention has only focussed on them as sources of nutrient input to the Peel-Harvey System when they occur in the near estuarine environs. In this regard, the Mandurah and West Murray localities, and the western shores of the estuaries have been considered the most sensitive.

However, industrial activities (such as abattoirs) that are some distance from the estuaries also need to be considered.

Sewage is the main concern with residential and recreation/tourist development. Nutrients leaching from on-site disposal systems can enter the estuaries via the groundwater. Nutrient-rich waste water from treatment plants can also reach the estuaries via the groundwater or surface flow. Reticulated sewerage, and diversion of wastewater from treatment plants away from the estuaries would reduce the risk of nutrient inputs from residential and recreation/tourist developments.

The principal concern with industrial activities is waste products that could contribute nutrients and possibly toxic wastes to the estuaries, although sewage also requires consideration. The nature of industries in the near estuarine areas is unlikely to involve significant quantities of nutrient-rich or toxic wastes and the provision of reticulated sewerage would reduce risks from sewage.

The distant industrial activities would represent point sources of nutrients and, therefore, are potentially manageable. Again, provisions under the Rights In Water And Irrigation Act, and the Health Act, would apply.

6.2.4 CONSERVATION

The Catchment Area contains over 20 sites that are covered by recommendations from the System 6 Study (EPA, 1983). Most are already reserved, or are within State Forest. The opportunity to manage them towards pre-determined objectives therefore already exists. However, some of these sites include freehold land to which this opportunity might not apply.

Other sites with conservation value but not encompassed by the System 6 recommendations are likely to be identified. Examples would include the Yunderup Delta, and the Punrack Drain. The recent establishment of a committee to examine conservation requirements around the Peel-Harvey System is also of relevance in this context.

While other activities in the Catchment Area need to be managed towards limiting nutrient inputs to the estuaries, the priority for these areas is maintenance of their conservation value. The effects of adjoining activities and human intrusion are the major issues requiring attention.

6.3 REQUIRED MANAGEMENT APPROACH

The eutrophic condition of the Peel-Harvey System has two components. These are the input of nutrients from the Catchment Area, and the nutrients already present in the estuarine sediments. Catchment management will limit further nutrient inputs, but a short-term reduction of nutrients in the sediments will only occur if flushing of the estuaries is enhanced.

The fertiliser trials undertaken indicate that the reduction in nutrient outflow from the Catchment Area apparently achievable, combined with the increased flushing afforded by the Dawesville Channel, would reduce algal blooms to acceptable levels in the short term. Although a 40% reduction in nutrient outflow from the Catchment Area should be sufficient in this regard, a greater decrease would enhance certainty regarding algal bloom reduction, and would improve the ecological resilience of the Peel-Harvey System.

Attainment of an ecologically resilient system is an important component of the management objective the Authority has adopted for the Peel-Harvey System. Accordingly, maximal reduction in nutrient outflow from the Catchment Area is desirable. Comprehensive management of land use activities in the Catchment Area could achieve this.

This would probably involve modifying the land use pattern within the Catchment Area through time, a process that would require determination of what uses are the most appropriate in the context of the adopted objective. In so doing, an ecological approach to land utilisation, based on the concepts of land capability and sustainable yield, should be employed. This approach is consistent with the World and National Conservation Strategies (International Union for Conservation of Nature and Natural Resources, 1980; and Department of Home Affairs and Environment, 1984). It would also facilitate preparation of both an appropriate land use strategy for the Catchment Area, and suitable management programmes for the activities occurring in the Area.

Necessary components of this process would include:

- definition of the geographical area to be planned and managed;

- continuation of the current fertiliser modification and farmer extension programmes;

- continued investigations into the commercial development of a sulphur fertiliser suitable for widespread use on phosphorus deficient sandy soils in the Catchment Area; and

- maintenance of necessary catchment monitoring programmes.

Discussion so far in this Chapter has focussed on the importance of implementing land use and management strategies within the Catchment Area as a means of improving conditions in the Peel-Harvey System. However, to fully achieve the adopted objective, these initiatives would need to be integrated with continued management and monitoring of the actual estuaries. Certain measures need to be applied and continued throughout the water bodies, dredging of the Mandurah Channel and weed harvesting for example. Increasing human pressures on and around the estuaries will also require continuing management. Monitoring of the estuaries will obviously need to continue and probably be expanded, for example to verify predictions concerning changes nutrient levels, and provide general water quality information for both the Peel Inlet and Harvey Estuary.

6.4 TIMING AND MEANS OF IMPLEMENTATION OF CATCHMENT AND ESTUARY MANAGEMENT

6.4.1 CATCHMENT MANAGEMENT

It is evident that management control over land use activities in the Catchment Area will be needed to achieve the objective of producing and maintaining an estuary system that is visibly clean and healthy and ecologically healthy and resilient. It will also be necessary to develop a mechanism (or mechanisms) to facilitate ongoing implementation of the catchment management plan in the long term. As this will take some time there is an urgent need to establish an interim mechanism to ensure that the gains already made from changes in fertiliser practices are at least maintained.

6.4.2 MECHANISMS FOR IMPLEMENTATION OF CATCHMENT MANAGEMENT

There are various means by which management control over land use activities in the Catchment Area could be achieved, in particular via:

- Government statement of commitment;
- existing legislative controls, for example
  - -provisions under the Rights in Water and Irrigation Act and the Health Act;
  - -pollution control provisions under the Environmental Protection Act;
  - -provisions under the Soil Conservation Act;
  - -land use controls and provisions being implemented through local government authority Town Planning Schemes; and
- development of incentive schemes to encourage cooperation.

These and other possible mechanisms would need to be investigated during the next phase of the study.

6.4.3 ESTUARY MANAGEMENT

A management plan for the Peel-Harvey System, the lower reaches of its tributary rivers, and a limited portion of its catchment already exists, ie the Peel-Inlet Management Programme (Waterways Commission Peel Inlet Management Authority, 1982). Clearly, this plan would represent a means by which on-going requirements applying to the Peel-Harvey System could be implemented. It would be necessary to revise this plan in conjunction with preparation of the land use and management strategies for the Catchment Area.

6.4.4 TIMING OF THE MANAGEMENT ELEMENTS

The development of both the catchment management plan and methods for its implementation will be critical inputs to the Stage 2 ERMP process. Consequently, there is a need to develop the following elements of catchment management for consideration in the Stage 2 ERMP assessment:

- development of integrated use and management programmes for the Peel-Harvey System and its Catchment Area;

- provision of an appropriate ongoing enabling framework for implementation of the programmes; and

- establishment of an interim mechanism as a matter of urgency, to safeguard gains already made from changes to fertiliser practices, pending the development of the catchment and estuary plans and the enabling framework.

7. CONCLUSIONS AND RECOMMENDATIONS

It is clear that the major sources of nutrient input (particularly phosphorus) to the Peel-Harvey System are the Catchment Area (as defined in Figure 1) and the sediment store within the estuaries which, under certain conditions, releases phosphorus into the water column thus making it available for incorporation by phytoplankton and algae (see Figure 3).

In terms of the Catchment Area, it will be necessary to develop a long-term management plan to attain and secure for all time, reductions in nutrient loading to the System that would be of sufficient magnitude to significantly assist in achieving the EPA's objectives, ie "to produce and maintain an estuary system that is visibly clean and healthy, and is ecologically healthy and resilient".

Management of the Catchment Area would have to be achieved in the context of:

- continuing development and land use changes; and
- a dynamic economy and market.

To reduce the impact of phosphorus within the waters of the Peel-Harvey System a method has to be found to remove phosphorus both from annual input and from release from the sediment store. To achieve an ecologically resilient system, improved flushing mechanisms, such as provision of a new channel (or channels) will have to be developed. This should ensure that the System would become resilient enough to remain in a healthy condition in the face of planned urbanisation and future developments in the Catchment Area. Therefore, in terms of redressing the nutrient enriched condition of the Peel-Harvey System and achieving an ecologically resilient system for well into the future, the requirements are:

- preparation and implementation of integrated use and management programmes for the Peel-Harvey System and its catchment;
- establishment of an appropriate enabling frame-work for these programmes;
- development of interim measures to ensure that the gains already made in the area of nutrient reductions in the catchment are secured whilst the initiatives above are being developed;
- continuation of monitoring programmes within both the Catchment Area and the estuaries, and

of the fertiliser modification programme, commercial development of a sulphur only (non-phosphorus) fertiliser, and farmer extension programmes;

- continued investigations into the size, design, location and implications of the construction of a new channel (or channels) connecting the estuary system to the sea; and

- investigations into the desirability of dredging the channel linking Peel Inlet and Harvey Estuary.

Figure 7 shows how this will all be drawn together in the Stage 2 ERMP.

The Authority, after giving due consideration to the information presently to hand, and subject to the implementation of the following recommendations, is of the opinion that neither management of the Catchment Area nor construction of the Dawesville Channel alone can reduce the level of nutrient enrichment in the System sufficiently to achieve a mesotrophic status, at least in the short term.

RECOMMENDATION 1

The EPA recommends that initiatives already in place, specifically, commitment to long term continuation of the fertiliser management programme, commercial development of a sulphur only (non-phosphorus) fertiliser, farmer extension programme, weed harvesting and monitoring of aspects of the catchment and estuary should be continued.The latter should be designed to meet the following management objectives:

- **verify that the management programme will fulfil the EPA's objective;**

- **verify/improve predictions about the phosphorus rundown in soils and sediments;**

- **indicate what occurs if widespread use of sulphur-only (non-phosphorus) fertiliser commences in 1986;**

- **to allow for prediction of blooms (from measuring the chlorophyll$_a$ level and nutrients in the sediments in the estuaries);**

- **to provide data on whether and how an oxygen collapse develops; and**

- **to provide up-to-date information which will allow for an accurate description of the**

existing environment in the catchments and estuary at any time.

RECOMMENDATION 2

The EPA recommends that in order to protect the Peel-Harvey System from excessive loads of phosphorus (and other nutrients) a Catchment Management Plan and an appropriate mechanism to facilitate its implementation be developed. To secure continuation of gains already achieved in the Catchment Area, an interim mechanism should be instituted as a high priority.

RECOMMENDATION 3

The EPA recommends that the Peel Inlet Management Programme be reviewed and revised to be in accord with the EPA's management objective for the Peel-Harvey System and to be consistent with the Catchment Management Plan and enabling mechanism (see Recommendation 2).

RECOMMENDATION 4

The EPA recommends that if the dredging of both ends of the Mandurah Channel, to improve the flushing in Peel Inlet, is carried out early enough, then the work should be monitored in order to facilitate the following:

- the data obtained from the monitoring of the effects of the above dredging should be used to check the validity of the predictions from the mathematical modelling which has been used to predict the improved flushing of Peel Inlet; and

- the above findings should then be used to further enhance the predictive modelling of solute transport (phosphorus) resulting from the Dawesville Channel and the interactions between the improved flushing characteristics of the dredged Mandurah Channel and the Dawesville Channel.

RECOMMENDATION 5

The EPA recommends that investigations continue into the size, design, location and implications of construction of a channel (or channels) connecting the sea to the Harvey Estuary, specifically in the context of the EPA's objectives and other recommendations in this report.

In addition, there may be an improvement in the pollution problem in the Harvey Estuary if circulation is improved between the Harvey Estuary and the Peel Inlet. Therefore there should be further investigations into the dredging of the channel between Ward Point and Point Grey (see Section 5.3.1. and Figure 2 of this report).

RECOMMENDATION 6

The EPA recommends that environmental review of the management strategy should continue in the State's environmental impact assessment process in the following manner: (see Figure 7)

. the studies aimed at providing specific information to assist in management decisions contained in Recommendations 1-3 and 5 be implemented**;

. the Stage 2 ERMP be prepared when the results and/or data from the above are available to incorporate into that document;

. the Stage 2 ERMP should inter alia:

  - report the results of the implementation of recommendations made in this assessment report;

  - identify the probability of success associated with the management alternatives for meeting the EPA's objectives;

  - give the timetable for the preferred management strategy and the implications thereof;

  - consider the anticipated effects on the Estuaries resulting from the Catchment Management Plan and enabling mechanism;

  - outline a monitoring programme to verify that the management strategy is fulfilling the EPA's objectives;

  - outline a mechanism for review and reporting of the monitoring results; and

  - examine the impacts of the construction of a channel (or channels) and its/their consequences.

**this would also apply to Recommendation 4 if the work is completed early enough.

RECOMMENDATION 6 (continued)

to ensure a meaningful public review phase the following condition would be necessary:

- ongoing EPA involvement in determining the level, nature and timing of assessment required for possible associated developments.

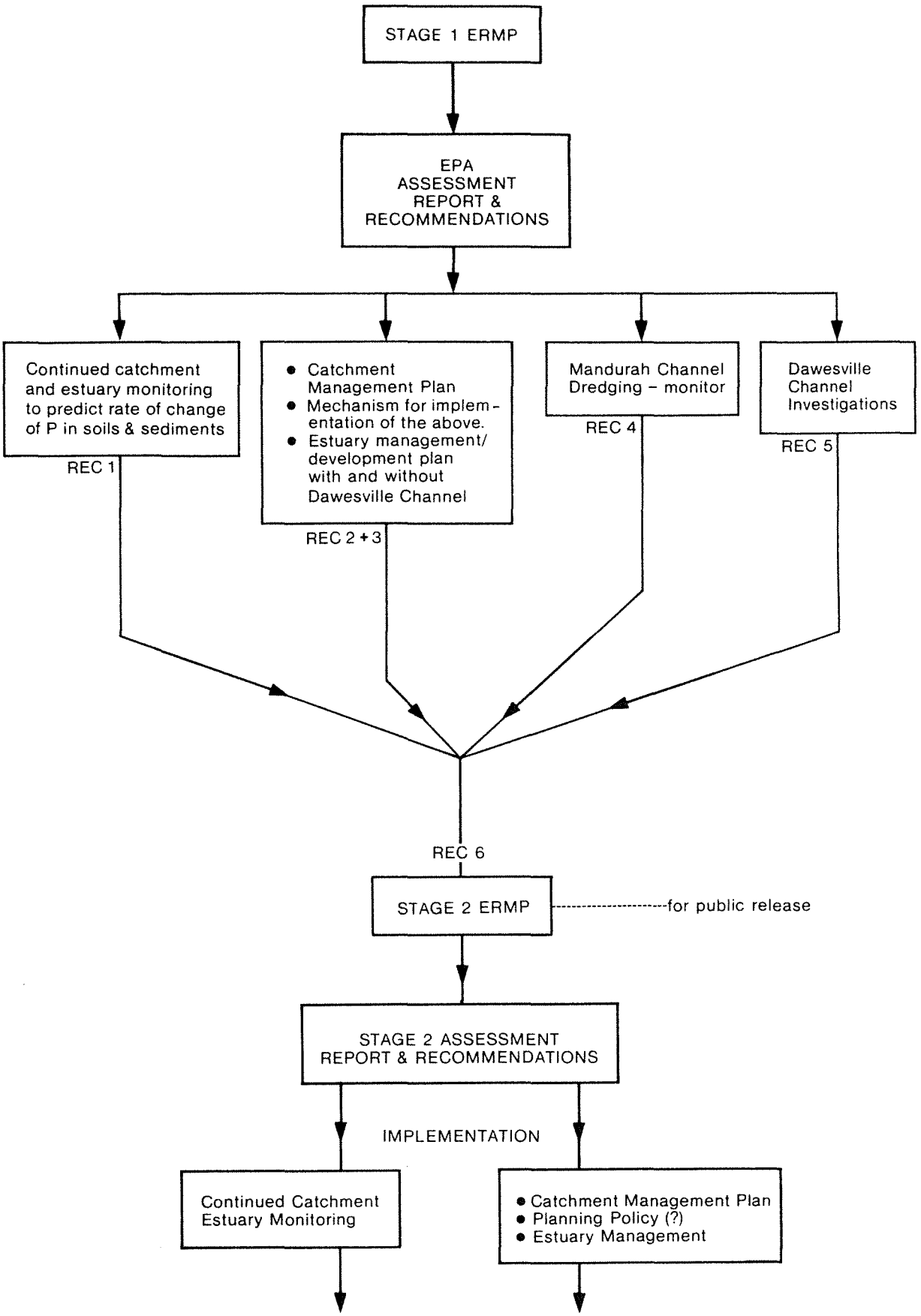


Figure 7 Schematic Illustrating Stage 1 ERMP Assessment and Stage 2 ERMP Process.

8. REFERENCES

Hodgkin, E.P., Birch, P.B., Black, R.E., and Hillman, K., 1985. The Peel-Harvey Estuarine Study Proposals for Management: DCE Report No. 14, December, 1985.

DCE (Department of Conservation and Environment), 1984. Management of Peel Inlet and Harvey Estuary: report of research findings and options for management: DCE Bulletin 170, May, 1984.

DCE (Department of Conservation and Environment), 1985. Mandurah Channel Dredging, Department of Marine and Harbours: Report and Recommendations by the Environmental Protection Authority Parts 1 and 2: DCE Bulletin 231, October 1985 and November, 1985.

Department of Home Affairs and Environment, 1984. A National Conservation Strategy for Australia - Living Resource Conservation for Sustainable Development Proposed by a Conference held in Canberra in June, 1983.

EMAC, 1981. The Peel-Harvey Estuarine System Study. A report by the Estuarine and Marine Advisory Committee to the Environmental Protection Authority: DCE Bulletin No. 88, March 1981.

EPA (Environmental Protection Authority), 1983. Conservation Reserves for Western Australia: The Darling System - System 6: DCE Report No. 13.

Hodgkin, E.P., Birch, P.B., Black, R.E., and Humphries, R.B., 1980. The Peel-Harvey Estuarine System Study (1976-1980): a report to the Estuarine and Marine Advisory Committee: DCE Report No. 9 Dec. 1980.

Humphries, R.B., and Croft, C.M., 1983. Management of the Eutrophication of the Peel Harvey Estuarine System, Report 3: Final Report: DCE Bulletin 165, May 1984.

International Union for Conservation of Nature and Natural Resources, 1980. World Conservation Strategy-Living Resource Conservation for Sustainable Development.

PHSG (Peel-Harvey Study Group), 1985. Peel Inlet and Harvey Estuary Management Strategy - Environmental Review and Management Programme Stage 1.

Reckhow, K.H., 1981. Lake Data Analysis and Nutrient Budget Modeling: US EPA 600/3-81-011.

Waterways Commission: Peel Inlet Management Authority, 1982. Peel Inlet Management Programme.

GLOSSARY

Alga - a simple plant, usually associated with water, which does not have any internal structures for transporting water and nutrients.

Algae - plural of alga

Algicide - a chemical substance that poisons algae either directly or by interfering with their growth.

Catchment Area - the area of the coastal plain catchments as defined in Figure 1.

Chaetomorpha - a type of large green alga (macroalga).

Chlorophyll$_a$ - a green pigment present in plants which is esential for photosynthesis.

Cladophora - a type of large green alga (macroalga).

Cyanobacterium - a blue-green bacterium. Cyanobacteria is the plural.

DCE - Department of Conservation and Environment.

EMAC - Estuarine and Marine Advisory Committee.

EPA - Environmental Protection Authority.

ERMP - Environmental Review and Management Programme.

Eutrophic - rich in nutrients and hence having excessive plant growth, which may kill animal life by deprivation of oxygen.

Mesotrophic - Moderately enriched in nutrients with abundant but usually not excessive plant growth, resulting in a healthy, very biologically productive system.

Nodularia spumigena - a blue-green alga (thought by botanists to be strictly a blue-green bacterium or cyanobacterium) which grows as microscopic filaments and produces annual 'blooms'. These have been causing problems in Harvey Estuary for many years.

NOI - Notice of Intent.

PER	- Public Environmental Report.
Phytoplankton	- plankton consisting of plants.
Trophic	- nutrient condition.
Ulva	- a type of large alga (weed) called sea lettuce that is a nuisance weed in Peel Inlet.

APPENDIX 1

ENUMERATION OF POINTS RAISED IN PUBLIC SUBMISSIONS ADDRESSING THE PEEL INLET AND HARVEY ESTUARY MANAGEMENT STRATEGY - ERMP STAGE 1

PUBLIC SUBMISSIONS

A total of 19 submissions was received during the public review period.

A list of issues raised in the submissions follows and is divided up into seven major categories:

1. Estuarine Biology

2. Hydraulic Considerations

3. Amenity

4. Fishing Industry

5. Navigation

6. Soil Amendment

7. Others

The Authority encloses this Appendix for information and passes no judgement on the validity of the points raised. The Authority has considered all these in the preparation of its Assessment Report, wherever relevant.

1. ESTUARINE BIOLOGY

- Support all six points mentioned in the brochure except for the direct need to dredge the Mandurah Channel (perhaps only later if necessary).

- In view of the poor water quality and algae growth in the Peel-Harvey estuary, the Government's six-point action plan is fully supported.

- Support the actions proposed in both reports aimed at improving water quality throughout the estuary system.

- Support, in principle, dredging of the Mandurah Channel, as an increased interchange of water will improve water quality in the estuary.

- The combination of dredging of the estuary entrance channel and the use of slow-release fertiliser will eventually clean up the estuary making a Dawesville Channel unwarranted.

- If the flushing of the estuary via the proposed Dawesville Channel is too effective in removing nutrients, there may be insufficient food for the fish.

- The amount of sand and weed from the sea moving through the Dawesville Channel and being deposited in the estuary will be a problem.

- Dredging will clean up the estuary temporarily, while the Dawesville Channel (with a lot of thought) will provide a permanent solution.

- The combination of the Dawesville Channel and dredging of the Mandurah Channel will lead to a vast improvement in the estuary.

- Further consideration should be given to pumping water into the Harvey Estuary at the required time to suppress the rise in water temperatures.

- Instead of dredging, NAUTEX (fossilized marine algae in the form of chalk) should be used to stimulate the growth of aquatic micro-organisms to destroy the suspended organic matter.

- Disagree with dredging of the Mandurah Channel because of possible destruction of existing sea grasses, fish and marine habitat.

- Before the Dawesville Channel is commenced, a detailed investigation should be carried out to prove that the estuarine environment will not change to a marine environment.

- Only minor dredging work should be carried out until an ERMP on the dredging proposals is prepared.

2. HYDRAULIC CONSIDERATIONS

- The proposed Dawesville Channel may increase the rise and fall of tides from 5 cm to 40 cm each day.

- The Dawesville Channel should be at a 45^{o} angle with a groyne to the south of the ocean entrance - this design will prevent scouring, assist in drawing the water out, and act as a venturi system forcing the water back in on the tide.

- A sand-by pass system may be necessary to keep the entrance to the Dawesville Channel open.

- The disturbance to long-shore drift of sediment has not been qualified.

- Consideration should be given to the possible movement of spoil after placement which may be induced either naturally or as a result of man's activities.

- The Dawesville Channel should follow a south west to north east course instead of the east to west course because the prevailing tides and winds are from the south west and the sand drift is from south to north.

- Mulberry Harbours could be constructed in the Dawesville Channel and the Mandurah Channel to facilitate clearance.

3. AMENITY

- The fertilizer modification programme must be encouraged by the Government and local authorities at all times.

- To justify the cost of the Dawesville Channel, it should be suitable for use by the boating public, and this would then allow the recovery of part of the costs through the sale of nearby land.

- With the development of the Dawesville Channel, some form of education and interpretive programme will be necessary in regard to changed recreation areas and activities.

- On the Ocean Beach site, the area currently producing reasonable surfing conditions may dissipate with the flow of tidal waters through the proposed Channel. Will other areas be affected?

- Will the Dawesville Channel create dangerous conditions at the point of entry to the ocean which would affect swimmers, boats and surfers?

- The level and type of access to the proposed Channel would require clear definition from both a safety and public access perspective, and boat ramps, carparks, public toilets, picnic areas, jetties (public and private) etc should all be considered.

- Artificial reefs on the ocean side of the proposed channel should be investigated, giving consideration to the marine effects and impact on other recreational uses for the area.

- If the channel is passable, there may be pressure from the public for residential development and tourist/recreational/yachting type developments.

4. FISHING INDUSTRY

- An increase in the rise and fall of the tides (as a result of the proposed Dawesville Channel) would have a definite effect on the fishing industry.

- The Dawesville Channel may cause a decrease in the number of mullet and yellow-eyed mullet which currently form the basis of the crayfish bait industry.

- Even if the prawns are unaffected, it would be uneconomical to catch prawns with half going out the Dawesville Channel and half going out the Mandurah Channel.

- An improvement in water quality could allow the growth of weed and macro-algae to extend to the Harvey Estuary which would foul the beaches and nets, and make it impossible to catch the fish.

- If the estuary is changed to a more constant marine environment, it will no longer be a viable fishing industry.

5. NAVIGATION

- It is essential that the opening of the Dawesville Channel to the ocean be made safe for navigation.

- If the Peel and Harvey Estuaries are separated with a plug of dredge soils, this would defeat the advantage of free navigation through both waterways.

- At what depth and what degree of difficulty will the Dawesville Channel be for recreational boating, and will they vary significantly?

6. SOIL AMENDMENT

- Soil amendment using bauxite residue offers some unique advantages compared to other techniques and is worthy of further consideration.

- The effect of soil amendment may be more immediate than changes in fertilization practice.

- Application rates as low as 20T/ha are sufficient to prevent phosphate leaching, while rates higher than 500T/ha can significantly improve crop yield.

- Soil amendment could be considered as a pre-requisite to intensive farming practices (eg piggery) and also effluent disposal areas.

- The red mud will reduce rates of infiltration to the watertable and will ultimately increase evaporative losses from rainfall or irrigation possibly causing groundwater salinities to rise (reducing utility of groundwater).

- Compared to the Dawesville Channel option, the Bauxite Residue option will involve moving half the amount of material over several years and will be applied over a much larger area.

- The Bauxite Residue option would cost approximately $ 22 million with no maintenance costs while the Dawesville Channel option would cost $ 31 million with an annual maintenance cost of about $ 0.3 million.

7. OTHERS

- Existing wetland vegetation should be retained to provide a biological filter to any future development of lands in proximity to waterways.

- The piggery and sheep holding yards at Serpentine should be relocated.

- Need to assess thermal influences prior to finalising the engineering design.

- There is an urgent need for continued and further testing of the complete system by Civil Engineers to inform you of future improvements and to draw attention to eventual setbacks.

- Further consideration should be given to changes in current land use in the Harvey Catchment Area.

- Land users in the Harvey Catchment Area should be prepared to accept a share of the responsibility for alleviation of the existing problems, possibly through land resumption.

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APPENDIX 2

BASIS OF CALCULATIONS SUPPORTING TABLE 1

APPENDIX 2

Basis of calculations supporting Table 1

1. **DATA BASE**

1.1 FLUSHING COMPONENTS from Hodgkin et al. (1980), Table_6.5

1.1.1 HARVEY ESTUARY

Tidal 0.2/week (5 weeks) : 10.4 vols/yr
River 230 x 10^6 m^3/yr 3.13 vols/yr(1977-1984)
Total 13.53 vols/yr(3.84 weeks)
Area 56 x 10^6 m^2, Volume 73.4 x 10^6 m^3

1.1.2 PEEL INLET

Tidal 0.24/week (4.17 weeks) : 12.5 vols/yr
River 390 x 10^6 m^3/yr 4.96 vols/yr(1977-84)
Total 17.46 vols/yr(2.98 weeks
Area 75.6 x 10^6 m^2 Volume 78.6 x 10^6 m^3

1.2 WATER LOADING

Harvey estuary: $\frac{13.53 \times 73.4 \times 10^6 \ m^3/yr}{56.0 \times 10^6 \ m^2} = 17.73$ m/yr

Peel Inlet: $\frac{17.46 \times 78.6 \times 10^6 \ m^3/yr}{75.6 \times 10^6 \ m^2} = 18.15$ m/yr

1.3 MAXIMUM PERMISSIBLE LOADING FOR MESOTROPHIC CONDITION

From Figure A1 in this Appendix, given the water loadings for each water body, the maximum areal P loading can be read-off. Thus:-

Harvey estuary: water loading qs = 17.73 m/yr
then areal P loading maximum is
L = 0.5 $g/m^2/yr$
Total P load is L x Area,
therefore Total P=0.5 $g/m^2/yr$ x 56 x 10^6 m^2 = 28 t/yr

Peel Inlet: water loading qs = 18.15 m/yr
then areal P loading maximum is
L = 0.6 $g/m^2/yr$.
therefore Total P = 0.6 x 75.6 = 45 t/yr

1.4 LOADING FOR NON-EUTROPHIC STATUS WITH DAWESVILLE CUT

With the increased water flushing it is necessary to recalculate the flushing components and water loading factors. Thus:-

Harvey estuary: expected flushing 0.7 vols/wk
(Hodgkin et al. (1985))

Peel Inlet: expected flushing 0.41 vols/wk
(Hodgkin et al. (1985))

Therefore water loading is

Harvey estuary:

$$\frac{0.41 \times 52 \times 73 \times 10^6 \text{ m}^3}{56 \times 10^6 \text{ m}^2} = 27.94 \text{m/yr}$$

Peel Inlet:

$$\frac{0.7 \times 52 \times 78.6 \times 10^6 \text{ m}^3}{75 \times 10^6 \text{ m}^3} = 38.15 \text{ m/yr}$$

Therefore areal P loading becomes (from Figure A1)

Harvey estuary: $0.8 \text{ gm}^{-2} \text{ yr}^{-1}$
Peel Inlet: $0.9 \text{ gm}^{-2} \text{ yr}^{-1}$

Thus total P loading is:-

Harvey estuary: $0.8 \times 56 \times 10^6 \text{ m}^3 = 44.8$ t/yr
Peel Inlet: 67 t/yr

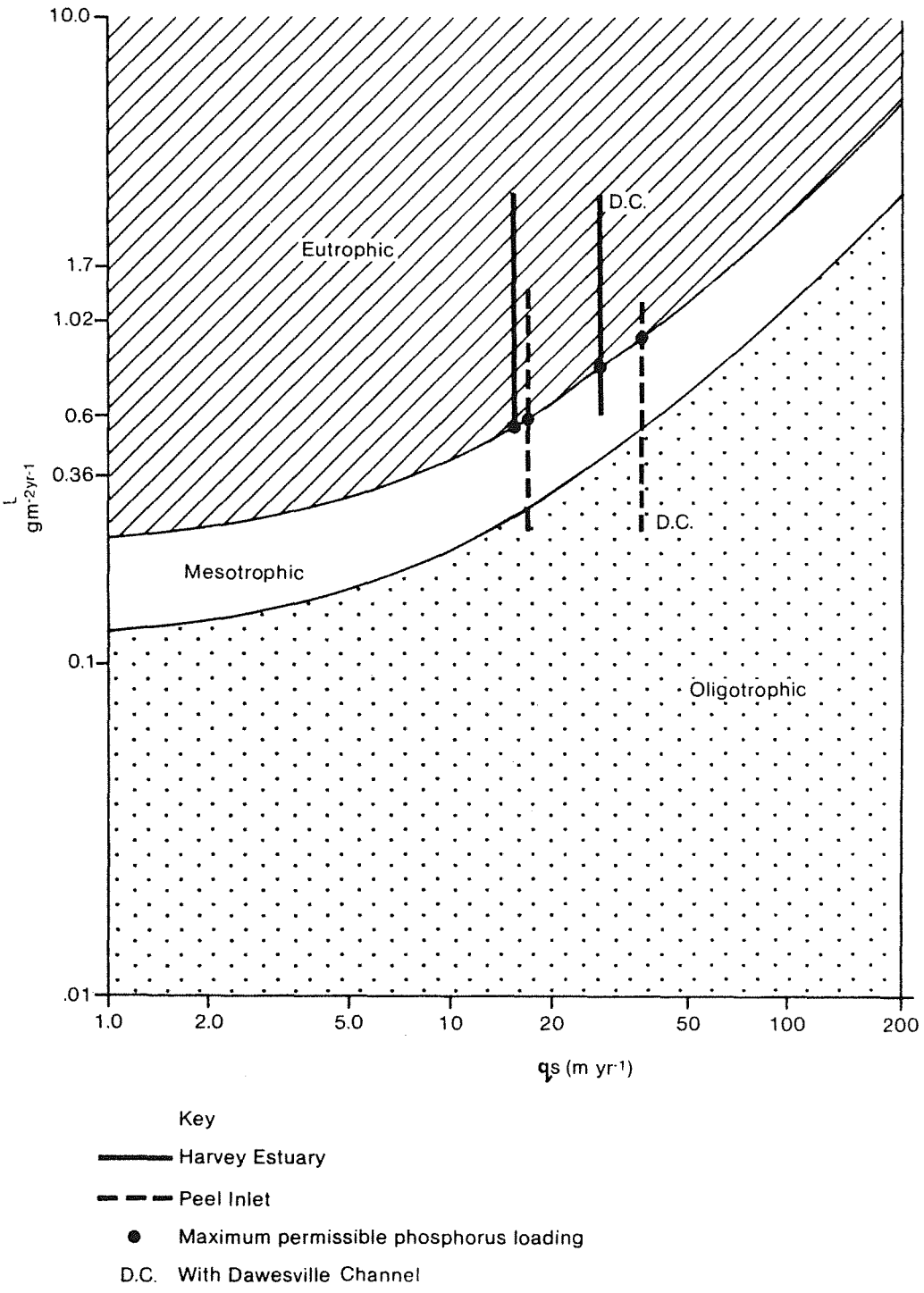

Figure A1 Maximum permissible phosphorus loadings with and without Dawesville Channel, and their relationship to trophic state of the Harvey Estuary and Peel Inlet. Modified after Vollenweider's model (Reckhow, 1981)