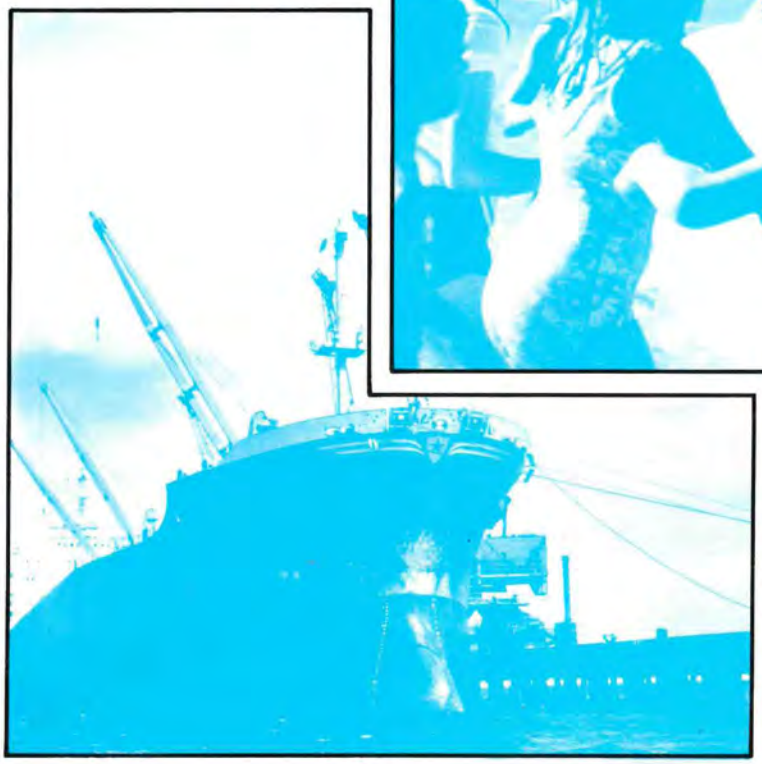
WATER QUALITY CRITERIA for MARINE AND ESTUARINE WATERS of WESTERN AUSTRALIA

Report of the Working Group
established by the Environmental Protection Authority



Department of
Conservation & Environment
Perth Western Australia

BULLETIN No 103
APRIL 1981

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Department of CONSERVATION and ENVIRONMENT

MARINE AND ESTUARINE WATER QUALITY CRITERIA WORKING GROUP

Mr. P.R. Adams, CMG, QC
Chairman
Environmental Protection Authority
BP House
1 Mount Street
PERTH WA 6000

your ref:
our ref:
enquiries:

Dear Mr. Adams,

I am pleased to forward to you the Report of the Marine and Estuarine Water Quality Criteria Working Group.

The Report presents water quality criteria for various beneficial uses of the State's marine and estuarine waters.

The Group reviewed the literature widely and sought the advice of individuals and other authorities in setting these criteria. In some cases, because of the lack of consistent data and information available from Australian and overseas sources, the Group exercised its own judgement and collective expertise in setting appropriate criteria. It must be stressed that these criteria are not absolute and unchanging yardsticks and should be used with considered judgement in the light of various factors which need to be taken into account. In accordance with its terms of reference the Working Group has recommended on water quality criteria rather than standards which are the legally enforceable levels established by an appropriate authority.

This Report also contains several recommendations, including the establishment of a Standing Committee to review and update the State's water quality criteria for marine and estuarine waters.

Yours faithfully,

M. Liveris

M. Liveris
Chairman

1 April 1981

1 Mount Street, Perth, W.A. 6000 tel. 322 2477

SWAN RIVER ESTUARY

Perth, the capital of Western Australia, with its 900 000 inhabitants, is situated on the banks of the Swan River estuary some 20 km upstream of the Port of Fremantle. The estuary is a major recreation area and heavily used, particularly on summer weekends. Water quality is compatible with both direct contact recreation and harvesting of fish, crabs and prawns.

COCKBURN SOUND

Some ten kilometres south of the Port of Fremantle, Cockburn Sound is a popular swimming, boating, commercial and amateur fishing area which also provides naval and commercial shipping port facilities. An extensive environmental investigation has been carried out on these waters.

Industrial and municipal wastewater discharges have caused significant changes to water quality, especially through nutrient enrichment.

Reference: "Cockburn Sound Environmental Study, 1976-1979". (October 1979). Department of Conservation and Environment, Report No. 2. Perth, Western Australia.

CONTENTS

FOREWORD

Following a decision of the Environmental Protection Authority to develop marine and estuarine water quality criteria for Western Australia, the Chairman of the Authority, Mr. C.F. Porter in June 1979 invited several scientists to form an advisory committee "to examine criteria developed elsewhere and their relevance to marine and estuarine waters in the State, and to make recommendations to this Authority". The committee was duly established as the Marine and Estuarine Water Quality Criteria Working Group with the following membership and terms of reference:

Membership

M. Liveris, B.Sc (Hons), Ph.D (W.A.), FACE, FCS, FRACI.
Dean, School of Health Sciences, Western Australian Institute of Technology. (Chairman).

A.W. Chiffings, B.Sc (W.A.).
Cockburn Sound Study Group.

R.C. Gorman, B.Sc (W.A.), FRACI, MAIAS.
Director, Government Chemical Laboratories.

H.E. Jones, B.Sc (Hons) (Birmingham), Ph.D (Reading).
Department of Fisheries and Wildlife.

R.S.W. Lugg, B.Sc, M.B., B.S. (W.A.), M.P.H.
Department of Health and Medical Services.

C.D. Shilkin, B.Sc (Hons) (W.A.).
Confederation of Western Australian Industry (Incorporated).

D. Drake-Brockman, B.Sc (W.A.), Dip. Inst. Adv. Eur. St. (Fr.).
Department of Conservation and Environment. (Technical Secretary).

Terms of Reference

To examine relevant marine and estuarine water quality criteria from Australian authorities and overseas sources and to recommend to the Environmental Protection Authority appropriate criteria for Western Australia, taking into account the various beneficial uses of the waters.

Meetings

The Group had its first meeting on 9 July 1979 and met for a total of seven formal meetings to the end of September 1979. An Interim Report was compiled at this time so that those concerned with reporting the activities of the Cockburn Sound Study Group would have a provisional guide to the criteria proposed for marine waters. The Working Group met a further seven times to 31 March 1980 and compiled a report, which also incorporated estuarine water quality criteria, for presentation to the Environmental Protection Authority on 1 May 1980. The EPA referred the Report to the Conservation and Environment Council for consideration and advice with respect to the future declaration of a State Environmental Protection Policy (SEPP). Joint meetings between the Working Group and the CEC Sub-committee on Water Quality Criteria and also the Marine Studies Branch (DCE) were held. Some modifications resulted and are included in this final Report. In all, seventeen formal meetings were held.

Information Sources

The data available from Australian authorities and overseas sources are in many cases inadequate or inconsistent and have demonstrated the need for further study to establish quantitative criteria and for research into toxicological effects of water contaminants on local marine life. The water quality criteria presented in this report are regarded by the Group as being the most reliable on the basis of the information available from credible sources in Australia and overseas.

ACKNOWLEDGEMENTS

The work of the Group was facilitated by advice and support of officers of the agencies of the members and by information services which assisted in the provision of relevant literature sources. In particular, the help of the Librarian, Library Assistant and typists of the Department of Conservation and Environment was indispensable in the preparation of this report.

The Working Group is also appreciative of advice given by other government and non-government organisations with which it consulted in the process of determining marine and estuarine water quality criteria.

In particular, mention should be made of assistance received from staff of the Water Quality Branch of the Victorian EPA who made available a draft copy of "Manual of Recommended Water Quality Criteria (1978)" from which the Working Group borrowed parts of the Introduction pertaining to the beneficial uses concept and also a significant portion of the preamble to the Schedules of criteria for the maintenance and preservation of aquatic ecosystems. Elsewhere the Working Group derived considerable assistance from the Draft Manual and wishes to express its gratitude to the Victorian EPA.

I. INTRODUCTION

(a) Introductory Remarks

Water quality criteria have a key role in the management of marine and estuarine waters. Such criteria when established permit the formulation of environmental protection policies through which may be made the decisions relating to the management of the water quality in a given area. The need for water quality criteria has emerged as a result of the present, proposed and possible future developments along the coastline of Western Australia.

(b) The EPA and Water Quality Management

The Environmental Protection Authority, established under the Environmental Protection Act, 1971-1980, has as its duties (Section 28):

(a) to enhance the quality of the environment; and

(b) to control and wherever practicable to prevent any act or omission which causes, or is capable of causing, pollution.

"Pollution" is defined in the Act as *any direct or indirect alteration of the environment to its detriment or degradation.*

In undertaking its duties the Environmental Protection Authority has as a primary function (Section 29a):

to consider and initiate the means of enhancing the quality of the environment and the means of preventing, controlling, abating or mitigating pollution.

To this end the Environmental Protection Authority has the power to declare policies with regard to environmental matters. These powers and the method of implementing them are contained in Sections 35 to 53 of the Act.

More particularly, Sections 35 to 38 lay down the manner in which such a policy shall be advertised, made available for public comment and be the subject of a public inquiry if necessary; Section 39 states that once the policy has been published by the Government in the Gazette, it . . . *has the force of law as though it had been enacted as part of this Act* . . . (i.e. the Environmental Protection Act); Section 40 considers the content of a declaration of policy; Section 41 outlines the conditions under which a declared policy may and will be reviewed; and Sections 43 to 53 outline an appeals procedure.

Such policies are not intended as simple statements of intent or to provide only philosophical guidelines. State environmental protection policies (as declared under Section 39 of the Act) *establish the basis upon which the Authority will act to preserve or enhance the environment to which that declaration relates* (Section 40(1)). To this end a policy:

- *may specify beneficial uses that the Authority will endeavour to protect or promote, and detrimental uses or practices that the Authority is empowered to prohibit or control, and may set out the measures by which those objectives are to be attained and maintained.*
- *may delineate programmes for the improvement or restoration of the environment and the prevention, abatement or control of pollution.*
- *may relate to any activity for the enhancement or protection of the environment, whether related to land, air, sea or other waters, noise, vibration, or the discharge of waste, or otherwise.*
- *may empower the Authority, or any other person or body authorised by the Authority, with the approval of the Governor, to make regulations for the purposes of the enforcement of the provisions of the declaration including a power to impose pecuniary and other penalties.*

(c) The Beneficial Uses Concept

The successful management of water quality, or in fact, any other resource, involves the consideration of social, economic, technological, scientific and political factors. In all of these areas the value judgements made at one point in time may well differ from those made at a later point in time. This will be as a result of new scientific knowledge, technological advances and changes in social and political values. The formulation, administration and amendment of policies need to be undertaken so that not only are all of the above considerations taken into account, but changes in the same may also be allowed for.

The most effective means of achieving some sort of control of water quality is through the setting of ambient water standards. These standards need to be set in accordance with the management objectives set out in the policy. Management objectives (expressed as water quality standards) are based on the scientifically derived water quality criteria which ensure the protection of a body of water for any stated beneficial uses. The term "beneficial use" is not defined in the Environmental Protection Act, but is clearly intended to imply uses which require positive management to prevent alteration or degradation to the point where the water is no longer suitable for such a use. As a result, this Committee has adopted the following definition of "beneficial use":

"A beneficial use is any use of the environment or any element or segment of the environment that is conducive to public benefit, welfare, safety or health. A beneficial use will require protection from the detrimental effects of any direct or indirect alteration of the environment."

This is consistent with the duties and functions of the Environmental Protection Authority as given in the Act (Sections 28 and 29) and the definitions of "environment" and "pollution" also given in the Act (Section 4).

When dealing with environmental management through environmental protection policy reference is often made to "Criteria", "Objectives", and "Standards".

To avoid any ambiguity here they have been defined according to Harding (1976) as follows:

"Criteria" means the scientific yardsticks upon which a decision or judgement may be made concerning the ability of water of a given quality to support a designated beneficial use.

"Objectives" represent the desirable, possibly long-term aims or goals of a water quality management programme. Such objectives are often derived after consideration of water quality criteria in the light of economic, social or political factors.

"Standards" are current legally enforceable levels established by an authority. Standards are not necessarily based upon sound scientific knowledge or ideal environmental requirements, but may in fact be established quite arbitrarily in the absence of technical data, and often with a marginal factor of safety.

The criteria in this document are not absolute and unchanging yardsticks of water quality in relation to the various beneficial uses. They should be used with considered judgement and due awareness of other factors which may need to be taken into account, including the natural quality of the water concerned, the kinds of organisms it contains and the local hydrological conditions.

The water quality criteria selected for any beneficial use or level or class of protection within a beneficial use can only be refined in the light of new scientific knowledge. Social, economic, and political considerations can play no part in the selection of such criteria. These factors must be taken into account in the selection of the beneficial uses for which any particular water body is to be protected and the level of protection to be applied.

The decisions and judgements which may be called for on the basis of criteria in this document are often particularly complex when issues of public health are involved. Additional factors requiring consideration may include the origin of bacterial pollution of recreational waters or the methods of food preparation and patterns of consumption of various seafoods. The information may not be readily ascertainable without appropriate investigation.

For these reasons the most valuable function of certain health criteria is to indicate the need for further investigation before a final judgement as to appropriate action is made. Such criteria are designated in this document as "health investigation levels" and set out, in respect of certain parameters that may affect human health directly or indirectly, levels above which the appropriate authority should be notified so that it may investigate the circumstances and advise on any action necessary to prevent the occurrence of a situation potentially dangerous to health.

Health investigation levels are thus set below those levels at which a health risk would actually occur. The appropriate authority to be notified, should these levels be exceeded, will normally be the local health authority or the Department of Health and Medical Services.

The criteria for the various toxicants have been derived from toxicity data accumulated from tests involving single toxic substances only.

It is well recognised by the Working Group that synergistic effects due to the simultaneous presence of more than one toxicant may occur. However, in the absence of experimental data it can only be assumed that a sufficient safety margin has been allowed.

The aim of the present exercise is to establish, for given beneficial uses, criteria which may be used to derive water quality objectives. These criteria should not be used as objectives or standards without further critical examination. The Working Group recognises that for some criteria the levels set may be below the current levels of detection. However, this does not detract from their potential usefulness.

Beneficial uses identified and considered by this Committee are as follows:

1. Direct Contact Recreation (e.g. bathing, swimming, surfing, water-skiing, skin and scuba diving).
2. Harvesting of Aquatic Life (excluding Molluscs) for Food.
3. Harvesting of Molluscs for Food.
4. Harvesting of Aquatic Life for Non-edible Uses (e.g. pearls).
5. Passage of Fish and Other Aquatic Life (e.g. migration).
6. Aquaculture of All Forms (fish, molluscs, crustacea, algae etc.)
   Class 1 — Edible Uses
   Class 2 — Non-edible Uses.

7. Maintenance and Preservation of Aquatic Ecosystems
   Class 1 — Maximum level of protection (i.e. natural state)
   Class 2 — High level of protection
   Class 3 — Minimal level of protection.
8. Maintenance and Preservation of Foreshores and Banks (e.g. protection against erosion of banks).
9. Scientific and Educational Uses.
10. Flushing Water and Water Replenishment (e.g. harbour waters moving further upstream with incoming tide).
11. Agricultural Water Supply (e.g. after desalination or for irrigation).
12. Potable Water Production (desalination).
13. Recovery of Minerals (e.g. salt).
14. Industrial Water Supply
    Class 1 — Food Processing — Washing and cooking procedures.
    Class 2 — Food Processing — In-plant holding procedures.
    Class 3 — Steam Generation, Cooling and Other Processes.
15. Power Generation (e.g. by tides or waves).
16. Navigation and Shipping (e.g. commercial and naval).

Beneficial uses will, of course vary from area to area. Ideally, the indentification of beneficial uses to be protected should take into account the following:

- nature and extent of existing uses,
- anticipated uses and demand pressures,
- factors affecting environmental quality and the degree of use, e.g. land use, point source and diffuse discharges, etc.,
- social and economic consequences of policy objectives, and
- feasibility of attainment.

It should be noted that the sole purpose of identifying beneficial uses for protection is to provide the basis for the derivation of water quality management objectives and not to specify permissible uses, as in land use planning.

(d) Marine and Estuarine Waters

Marine waters will be defined as those comprising the seas surrounding the coastline and which are never measurably diluted with fresh water derived from land drainage. Although generally having salinities typical of sea-water, approximately 33°/oo to 37°/oo, marine waters so defined can be hypersaline in certain embayments, e.g. Hamelin Pool, Shark Bay.

For delineation of estuarine waters the following definition of an estuary given by Pritchard (1967) will be used:

"An estuary is a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea-water is measurably diluted with fresh water derived from land drainage."

Estuaries may be permanently open to the sea, e.g. Swan Estuary; seasonally closed and open at one or more times each rainy season, e.g. Wilson Inlet; or normally closed and only open following unusually heavy rains, e.g. Stokes Inlet. Estuarine systems which are now permanently closed off from the sea nevertheless retain some estuarine characteristics.

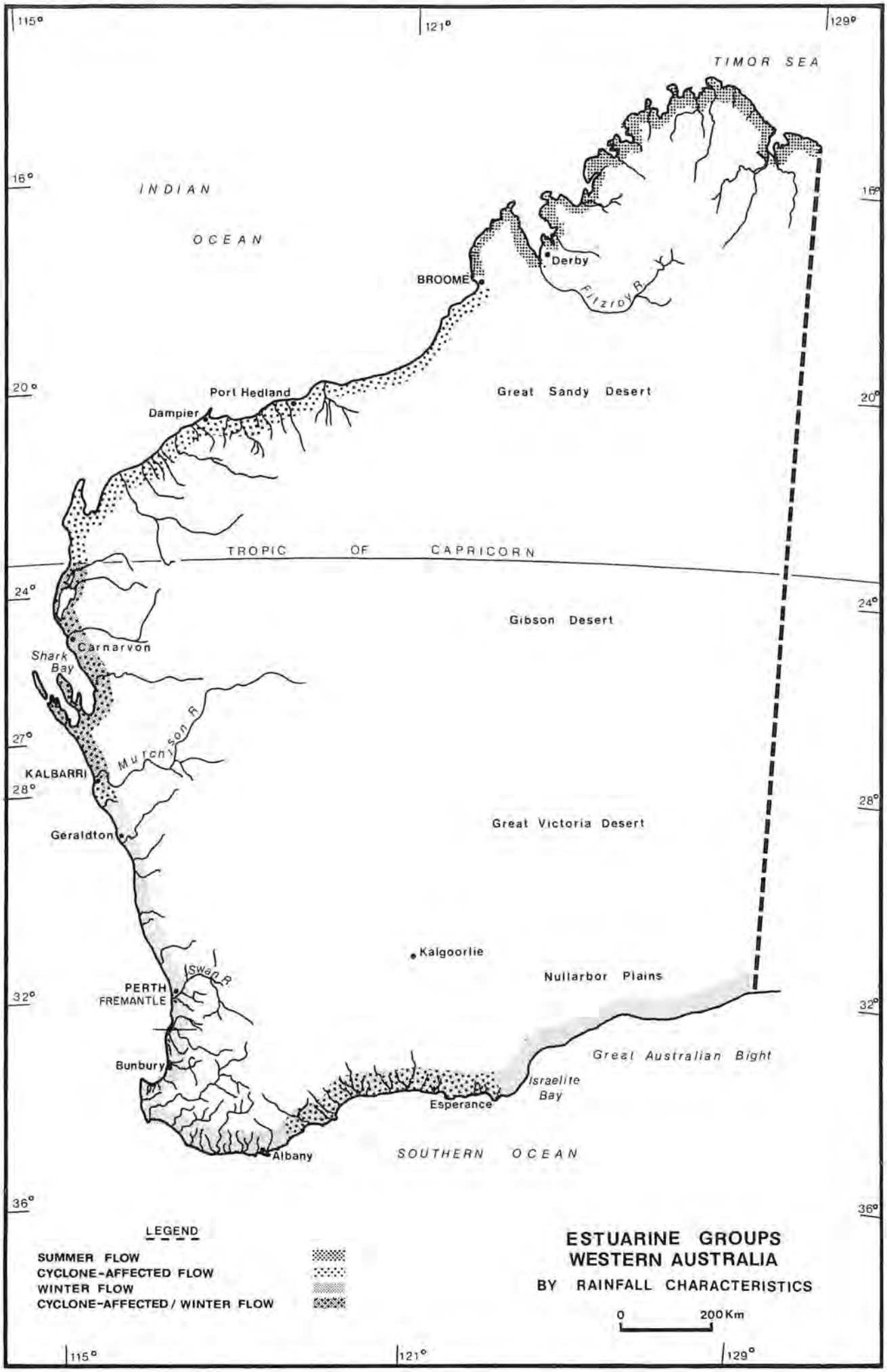
In Western Australia estuaries may be broadly differentiated into three geographical groups by rainfall characteristics (see map on page 4):

Group 1 — North of Broome.
Group 2 — Broome to the Murchison River (Kalbarri).
Group 3 — South of the Murchison River.

In group 1 major freshwater flows occur only in the summer wet season. In group 2 rivers flow intermittently as a result of cyclonic rains in summer, but the Murchison River and other rivers as far north as the Tropic of Capricorn may also flow as a result of winter rainfall. In group 3 major freshwater flows occur principally in the winter wet season, but estuaries east of Albany may also flow as a result of rain-bearing cyclonic depressions.

Hodgkin and Lenanton (in press) recognise approximately eighty estuaries in south-western Australia between the Murchison River and Israelite Bay, all of the bar-built type. They are subject to extreme changes in salinity which may vary from fresh to hypersaline and this is considered the limiting ecological factor for plant and animal communities.

The beneficial uses considered in this report are applicable to both marine and estuarine waters. However, in addition to considerable variations in salinity, many of the other natural parameters relevant to the beneficial uses show extreme differences within and between estuaries. Thus estuaries lack the general uniformity of marine waters and this flux makes difficult the establishment of some normal seasonal values which is so frequently a part of marine water quality criteria.


115°
121°
129°
TIMOR SEA
16°
INDIAN
OCEAN
Derby
BROOME
Fitzroy R.
20°
Port Hedland
Dampier
Great Sandy Desert
TROPIC OF CAPRICORN
24°
Gibson Desert
Carnarvon
Shark Bay
27°
Murchison R.
KALBARRI
28°
Great Victoria Desert
Geraldton
Kalgoorlie
Swan R.
PERTH
FREMANTLE
Nullarbor Plains
32°
Great Australian Bight
Bunbury
Israelite Bay
Esperance
Albany
SOUTHERN OCEAN
36°
LEGEND
SUMMER FLOW
CYCLONE-AFFECTED FLOW
WINTER FLOW
CYCLONE-AFFECTED / WINTER FLOW
ESTUARINE GROUPS
WESTERN AUSTRALIA
BY RAINFALL CHARACTERISTICS
0
200 Km

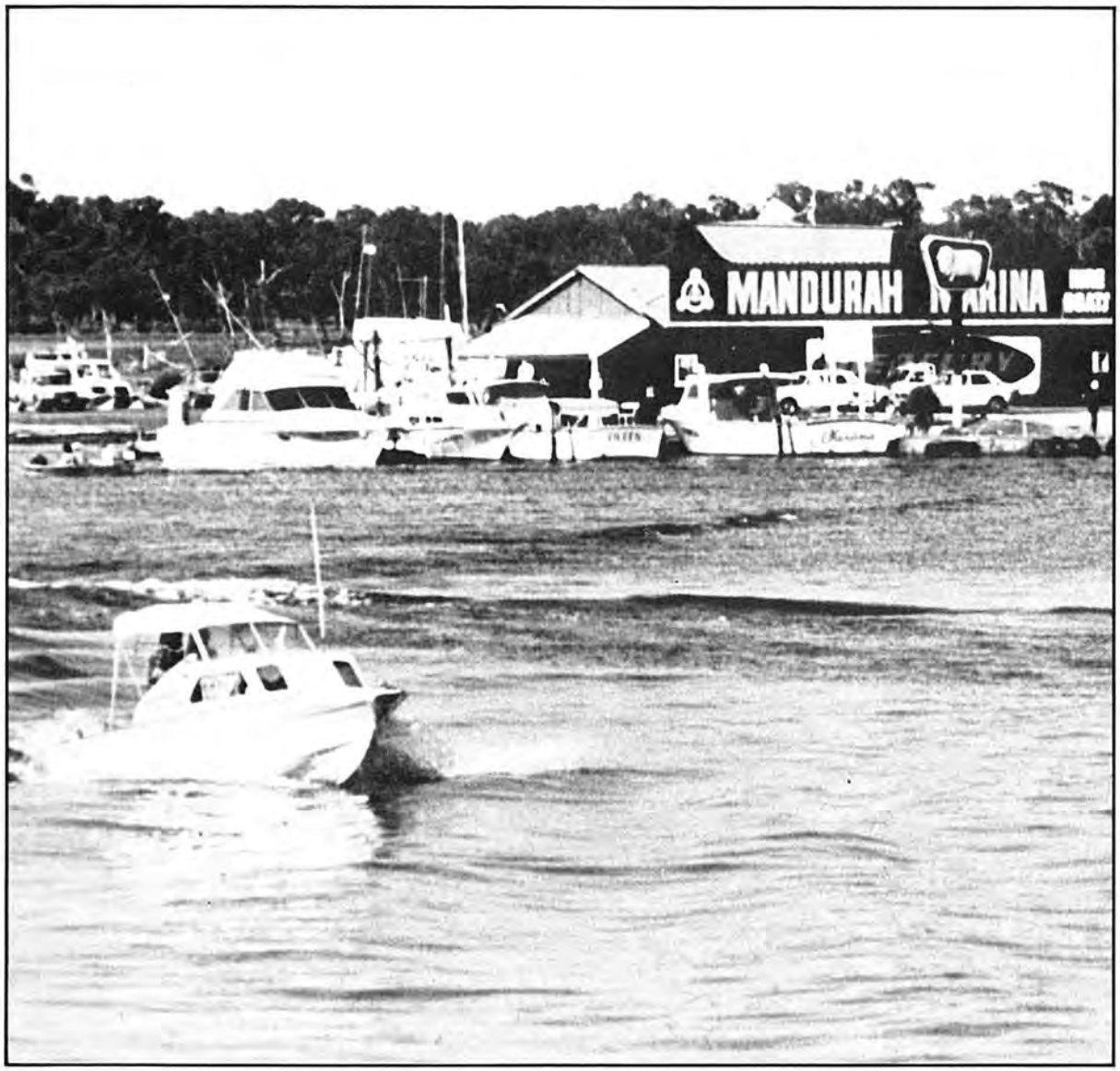
(e) **Radioactive Substances**

When considering criteria for radioactive substances it is necessary to take cognizance of the fact that they comprise a complex group of substances, thus rendering the establishment of criteria for gross radioactivity extremely difficult.

Coupling this difficulty with the lack of information available on the levels of concern of the various radionuclides exacerbates the problem of setting a gross radioactivity limit for organisms in the ecosystem other than man.

Of particular concern is the paucity of data relevant to the effects of these substances on simple or complex ecosystems.

PEEL INLET—HARVEY ESTUARY



Approximately 70 km south of Perth, the Peel Inlet-Harvey Estuary system is a shallow coastal lagoon of 133 square kilometres used extensively by amateur and professional fishermen and boating and yachting enthusiasts.

This estuary, which is the most biologically productive in the south-west of Western Australia, is currently experiencing severe water quality problems associated with nutrient enrichment derived mainly from agricultural sources.

Reference: Hodgkin, E.P. et al. (December 1980). "The Peel-Harvey Estuarine System Study, 1976-1980". Department of Conservation and Environment, Report No. 9. Perth, Western Australia.

II. MARINE AND ESTUARINE WATER QUALITY CRITERIA FOR RECOGNISED BENEFICIAL USES

For ease of reference and for the sake of completeness, a certain amount of deliberate repetition has occurred in several Schedules corresponding to different beneficial uses. This repetition also permits independent future modification to any given Schedule without perturbation of the others.

GENERAL AESTHETIC CRITERIA

The following general aesthetic criteria should apply to all water bodies regardless of the declaration of beneficial uses unless otherwise specified.

Waters should be:

1. Free from substances which will settle to form putrescent or otherwise objectionable sludge deposits.
2. Free from floating debris, oil, grease, scum, foam and other floating materials, in amounts sufficient to be unsightly or otherwise objectionable.
3. Free from materials which will produce colour, odour, turbidity, or other conditions to such a degree as to be unsightly or otherwise objectionable.

CRITERIA FOR RADIOACTIVE SUBSTANCES

Although the Working Group consulted as widely as it was able in order to obtain specific criteria for radioactive substances, the information provided in most cases was not relevant and lacked specificity.

For example, the World Health Organization figures which are available apply only to drinking water and are not considered applicable to any envisaged beneficial uses of marine and estuarine waters.

Given the nature of the information available the following narrative criteria from the Water Quality Control Plan for Ocean Waters of California is currently adopted and should apply to all water bodies:

> Radioactive substances should not be present in concentrations that are deleterious to human, plant, animal or aquatic life or that result in the accumulation of radioactive substances in the food web to an extent that presents a hazard to human, plant, animal or aquatic life.

BENEFICIAL USE NO. 1
DIRECT CONTACT RECREATION

The criteria in Schedule 1 are intended to protect marine and estuarine waters for direct contact recreation including bathing, diving, water-skiing and other activities in which the human body may come into direct contact with the water to the point of complete immersion.

The waters should conform to the general aesthetic criteria for marine and estuarine waters. They should also be protected against loads of nutrients and other biostimulants capable of causing excessive or nuisance growths of algae or other aquatic plants.

It should be pointed out that for a complete understanding of the criteria in Schedule 1, especially as far as "health investigation levels" are concerned, the relevant passages in the Introduction should be read (see page 2).

SCHEDULE 1

MARINE AND ESTUARINE WATER QUALITY CRITERIA FOR DIRECT CONTACT RECREATION

Parameter	Criterion	Source
Aesthetic Considerations	As on page 8.	USA EPA (Comp)
Physical Hazards	The water in bathing and swimming areas should be free of submerged bodies and other subsurface hazards.	NH&MRC
Light Penetration	A Secchi disc should be visible to a depth of 2m except in "learn to swim" areas where a Secchi disc should be visible on the bottom.	NH&MRC
pH	6.5-8.5, except for waters with a low buffer capacity where a range of pH between 5.0 and 9.0 may be tolerated.	NH&MRC
Chemicals and Biological Materials	The waters should not contain chemicals and biological materials in such concentrations as to be irritating to the skin or mucous membranes of the human body upon brief immersion. In addition, they should not contain chemicals and biological materials in such concentrations as to be toxic to man if small quantities are ingested.	NH&MRC
Faecal Coliforms	A health investigation level for water in open and unenclosed bathing and swimming areas may be established on the basis of a minimum of five samples taken over not more than a 30-day period under conditions representative of the water quality to which users are commonly exposed, and is reached either when the median reading of such samples exceeds 150 organisms/100mL, or when more than 20% of the total samples during this period exceed 500/100mL. For this purpose samples during the wettest quarterly interval may be omitted if users are not commonly exposed during that interval. The water in bathing and swimming areas in which the median reading ordinarily exceeds 50/100mL and/or in which more than 20% of samples ordinarily exceed 150/100mL, should be protected against any degradation in that quality from a new or increased source of pollution. Water of higher quality should be similarly protected against degradation beyond the levels mentioned in this paragraph.	WG
Faecal Material	The water in bathing and swimming areas should be protected against direct contamination with fresh faecal material of human or domesticated animal origin.	WG
Radioactive Substances	The waters should not contain radioactive substances in such concentrations as to be deleterious to man if small quantities are ingested.	DH&MS

BENEFICIAL USE NO. 2
HARVESTING OF AQUATIC LIFE (EXCLUDING MOLLUSCS) FOR FOOD

BENEFICIAL USE NO. 3
HARVESTING OF MOLLUSCS FOR FOOD

BENEFICIAL USE NO. 4
HARVESTING OF AQUATIC LIFE FOR NON-EDIBLE USES

BENEFICIAL USE NO. 5
PASSAGE OF FISH, AND OTHER AQUATIC LIFE

Most measures of the effect of a pollutant upon an aquatic organism employ laboratory tests in which the concentration of the pollutant required to kill 50% of the test population within a specified time is recorded. This concentration is called the LC_{50} or TL_m and is usually for a time of 48 or 96 hours. Its value depends upon the age and physiological condition of the organism, the conditions of the test and the stress suffered by the organism before and during the test.

The toxicity value for a pollutant tested in laboratory conditions may differ in the natural environment where synergistic or antagonistic effects may occur in the presence of other pollutants, or the pollutant may be precipitated, combined with other material or changed into a more or a less harmful chemical form or species.

Besides lethal (acute) effects, the pollutant may cause sublethal (chronic) effects which may be difficult to detect. These may contribute to the death of an organism or a decline in population although such a result would not be evident from laboratory tests. For example, the organism's ability to detect and escape predators or to resist other forms of stress may have been lowered or its reproductive capacity impaired.

Where edible organisms are concerned the pollutant may cause tainting or an unsightly appearance, which renders the organism unsatisfactory to the consumer.

Accumulation of a pollutant within an organism can lead to concentrations harmful to the organism or to its consumer which were not evident from short-term tests. Such concentrations can be passed on through several links in the food chain and may result in public health problems.

In addition to direct effects of a pollutant upon an organism there are indirect effects which result from the complexity of ecosystems. These may be injurious, e.g. the destruction of seagrasses used as breeding areas or as habitats for juvenile fish, the loss of an organism in the food chain of the fish. Because of this interdependency between organisms it may be preferable to test the activity of the pollutant upon the most sensitive species whose loss can influence the success of the organisms of interest.

It is evident that the factors cited above make it difficult to evaluate the water concentration value for a pollutant which will protect an organism in its natural environment, or its consumer. Where accumulation of a pollutant occurs which could cause public health problems it may also be essential to set concentration limits for the pollutant within the organism and perhaps the sediments.

Very little testing of the effects of pollutants upon Australian species has been attempted and there are few or no results for Western Australian species tested in conditions simulating their natural environment. There is a vast array of lethal concentration figures and a smaller array of sublethal concentration figures of pollutants which may be found in overseas publications. These have been reviewed by several national and international agencies such as the U.S. Environmental Protection Agency, the U.S. National Academy of Sciences, the Canadian Department of the Environment, the Australian Water Resources Council and the World Health Organization.

For a large number of pollutants these agencies have formulated protection criteria for marine and freshwater species in general which have been obtained mainly from LC_{50} values by the use of an application (safety) factor. These criteria are necessarily conservative. The individual States of the U.S.A. have mainly classified their waters into several categories based upon their beneficial uses and employed protection criteria for each category which closely follow those set by the U.S. EPA. California has proposed a slightly different approach: It applies a beneficial use system but formulates criteria for the protection of organisms in oceanic waters which take into consideration acute and chronic toxic concentrations of pollutants and their average sea-water concentrations. In brief, a conservative estimate of the acute toxic concentration of a pollutant is calculated as the lower ten percentile of the LC_{50} data reported. A conservative estimate of the chronic toxic

concentration is calculated as the average (log mean) of the lower three chronic concentrations reported. An average sea-water concentration is calculated as the log mean of the data reported. A protection figure is then arrived at by multiplying the acute toxic concentration by the U.S. EPA recommended application factor. If the figure obtained is below the chronic toxic concentration and above the average sea-water concentration it is accepted. However, if it does not satisfy these two conditions it is rejected and an acceptable figure obtained by using the concentration lying half-way (on a log scale) between the chronic toxic and average sea-water concentrations.

If marine and estuarine water quality criteria are to be set in Western Australia, in the absence of toxicity results for local species and conditions it is inevitable that criteria from overseas results be used as a guide. Their conservative nature makes such an extrapolation possible. Because perturbation to one component of an ecosystem may influence other components, criteria to protect fish, crustacea and molluscs in Western Australian marine and estuarine waters will generally be applicable for the protection of the total ecosystem.

In this compilation of criteria for beneficial uses Nos. 2, 3, 4 and 5, criteria have been selected preferentially from the Californian Proposal, 1977 and the U.S. EPA publication Quality Criteria for Water, 1976. Schedules 2, 3, 4 and 5 contain water quality criteria for the protection of the above-mentioned "fisheries" beneficial uses.

SCHEDULE 2

MARINE AND ESTUARINE WATER QUALITY CRITERIA FOR HARVESTING OF AQUATIC LIFE (EXCLUDING MOLLUSCS) FOR FOOD

Parameter	Criterion	Source
Aesthetic Considerations	As on page 8.	USA EPA (Comp.)
Floating and Submerged Litter	No materials should be present which directly or indirectly have an adverse effect upon aquatic organisms, or which interfere with normal fishing or harvesting practices or damage fishing equipment.	WG
Barriers	No barrier should be constructed, substances added nor alterations made to the marine or estuarine environment which will prevent the normal movement and migratory patterns of aquatic organisms to the detriment of their populations or cause changes in the normal water movement pattern which will lead to adverse effects upon them.	WG
Light Attenuation	The combined effects of turbidity and colour should not reduce the depth of the compensation point for photosynthetic activity by more than 10% from the seasonal background value.	USA EPA
Settleable Matter	Unnatural inputs of settleable material should not cause the formation of deposits which are harmful to aquatic organisms.	VIC EPA (M)
Suspended Solids	Upper limit of 80 mg/L and depth of compensation point for photosynthetic activity should not be reduced by more than 10% from the natural seasonal norm.	Hart/USA EPA
Temperature	The maximum acceptable variation in the weekly average temperature due to artificial sources is 1°C for waters north and 2°C for waters south of latitude 27°S during all seasons of the year, provided that no single value exceeds the highest summer maximum recorded over the previous five years inclusive.	USA EPA
Salinity	Unnatural influences should not change the seasonal mean salinity, measured preferably over not less than five years, by more than 0.25 of the standard deviation, nor change the salinity beyond the range recorded over that period.	WG/VIC EPA (G)
Ionic Ratio	The ratios of major ions should not be altered such that this beneficial use is affected.	WG
pH	6.5-8.5 and no change in excess of 0.2 units from normal. For waters of salinity below 5 000 mg/L (5°/oo) the pH range should be 6.0 to 9.0 and no change in excess of 0.5 units.	USA EPA/WG/Hart
Dissolved Oxygen	Not to fall below 4.0 mL/L (5.7 mg/L) for more than 6 consecutive hours, and never to fall below 3.5 mL/L (5.0 mg/L).	WG
Arsenic	6 month median not to exceed 8 μg/L. No more than 20 per cent of readings to exceed 80 μg/L. No single reading to exceed 500 μg/L.	Calif (K&S)
Cadmium	6 month median not to exceed 3 μg/L. No single reading to exceed 8 μg/L.	Calif (K&S)
Chromium (total)	6 month median not to exceed 2 μg/L. No single reading to exceed 7 μg/L.	Calif (K&S)

Copper	6 month median not to exceed 5 μg/L. No single reading to exceed 40 μg/L.	Calif (K&S)
Lead	6 month median not to exceed 8 μg/L. No more than 20 per cent of readings to exceed 80 μg/L. No single reading to exceed 200 μg/L.	Calif (K&S)
Mercury	6 month median not to exceed 0.14 μg/L. No more than 20 per cent of readings to exceed 1.4 μg/L. No single reading to exceed 3 μg/L.	Calif (K&S)
Nickel	6 month median not to exceed 20 μg/L. No more than 20 per cent of readings to exceed 200 μg/L. No single reading to exceed 450 μg/L.	Calif (K&S)
Silver	6 month median not to exceed 0.45 μg/L. No more than 20 per cent of readings to exceed 4.5 μg/L. No single reading to exceed 10 μg/L.	Calif (K&S)
Zinc	6 month median not to exceed 20 μg/L. No single reading to exceed 200 μg/L.	Calif (K&S)
Aldrin	Not to exceed 0.003 μg/L	USA EPA
Azinphosmethyl	Not to exceed 0.01 μg/L	USA EPA
Camphechlor	Not to exceed 0.005 μg/L	USA EPA
Chlordane	Not to exceed 0.004 μg/L	USA EPA
2,4-D	Not to exceed 4 μg/L	NAS/NAE
DDT	Not to exceed 0.001 μg/L	USA EPA
Dieldrin	Not to exceed 0.003 μg/L	USA EPA
Endosulfan	Not to exceed 0.001 μg/L	USA EPA
Endrin	Not to exceed 0.004 μg/L	USA EPA
Heptachlor	Not to exceed 0.001 μg/L	USA EPA
Lindane	Not to exceed 0.004 μg/L	USA EPA
Maldison	Not to exceed 0.1 μg/L	USA EPA
Methoxychlor	Not to exceed 0.03 μg/L	USA EPA
Parathion	Not to exceed 0.04 μg/L	USA EPA
Other Pesticides	Not to exceed 0.01 of the 96-hour LC_{50} value for the selected test species.	WG
Ammonia (expressed as Nitrogen)	6 month median not to exceed 600 μg/L. No single reading to exceed 2000 μg/L.	Calif (K&S)
Chlorine (total residual)	6 month median not to exceed 2 μg/L. No single reading to exceed 10 μg/L.	Calif (K&S)
Cyanide	6 month median not to exceed 5 μg/L. No single reading to exceed 10 μg/L.	Calif (K&S)
Fluoride	6 month median not to exceed 2 mg/L No single reading to exceed 10 mg/L	WG
Hydrogen Sulphide	Not to exceed 2 μg/L	USA EPA
Total Hydrocarbons	Not to exceed 10 μg/L	WG
Aromatic Hydrocarbons	Not to exceed 1 μg/L	WG
Phenolic Compounds	6 month median not to exceed 300 μg/L.	Calif (K&S)
Polychlorinated Biphenyls (PCBs)	Not to exceed 0.001 μg/L	USA EPA
Surfactants	Not to exceed 0.01 of the 96-hour LC_{50} value for the test organisms.	WG

Other Toxic Substances	No material should be present in an amount exceeding 0.01 of the 96-hour LC_{50} value for the test organism.	WG
Metals Accumulation	In addition to the criteria set out above for individual metals in water, a health investigation level may be established for any given metal on the basis of samples of the edible portion of a particular aquatic species, and is reached when more than 10% of such samples exceed the maximum permissible level prescribed for that metal in the Food and Drug Regulations, 1961, as amended, made under the Health Act, 1911-1978.	DH&MS
Tainting Agents	Taste- or odour-producing substances should not be present at concentrations that lead to undesirable tastes or odours in fish flesh or other edible products of aquatic origin. For examples of levels and types of compounds known to taint aquatic organisms see Table I. These are not intended to be criteria.	Calif.
Radioactive Substances	Radioactive substances should not be present in concentrations that are deleterious to human, plant, animal, or aquatic life or that result in the accumulation of radioactive substances in the food web to an extent that presents a hazard to human, plant, animal, or aquatic life.	Calif.
Nutrients and Other Biostimulants	The loads of nutrients and other biostimulants to receiving waters should not cause excessive or nuisance growths of algae or other aquatic plants, or deleterious reductions in dissolved oxygen concentrations in those waters.	VIC EPA (M)

TABLE 1: Concentrations of Chemical Compounds in water that can cause tainting of the flesh of aquatic organisms.

Tainting Agent	µg/L
acetophenone	500
acrylonitrile	18 mg/L
m-cresol	200
o-cresol	400
p-cresol	120
cresylic acids (meta, para)	200
n-butylmercaptan	60
o-sec. butylphenol	300
p-tery. butylphenol	30
o-chlorophenol	1
p-chlorophenol	10
2,3-dichlorophenol	84
2,4-dichlorophenol	1
2,5-dichlorophenol	23
2,6-dichlorophenol	35
2-methyl, 4 chlorophenol	75
2-methyl, 6-chlorophenol	3
o-phenylphenol	1 mg/L
2,4,6-trichlorophenol	3
phenol	1 mg/L
diphenyloxide	50
β,β-dichlorodiethyl ether	90
p-dichlorobenzene	250
ethylbenzene	250
ethanethiol	240
ethylacrylate	600
formaldehyde	95 mg/L
petrol	5
kerosene	100
kerosene plus kaolin	1 mg/L
isopropylbenzene	250
naphtha	100
napthalene	1 mg/L
naphthol	500
2-naphthol	300
dimethylamine	7 mg/L
α-methylstyrene	250
oil, emulsifiable	15 mg/L
pyridine	5 mg/L
pyrocatechol	800
pyrogallol	20 mg/L
quinoline	500
p-quinone	500
styrene	250
toluene	250
outboard motor fuel, as exhaust	500
guaiacol	82

Reference: Water quality criteria, 1972. Washington, DC: National Academy of Sciences — National Academy of Engineering. 1974. p. 148.

SCHEDULE 3

MARINE AND ESTUARINE WATER QUALITY CRITERIA FOR HARVESTING OF MOLLUSCS FOR FOOD

Parameter	Criterion	Source
Aesthetic Considerations	As on page 8.	USA EPA (Comp)
Floating and Submerged Litter	No materials should be present which directly or indirectly have an adverse effect upon molluscs or which interfere with normal fishing or harvesting practices or damage fishing equipment.	WG
Barriers	No barrier should be constructed, substances added nor alterations made to the marine or estuarine environment which will prevent the normal movement and migratory patterns of molluscs to the detriment of their populations or cause changes in the normal water movement pattern which will lead to adverse effects upon them.	WG
Light Attenuation	The combined effects of turbidity and colour should not reduce the depth of the compensation point for photosynthetic activity by more than 10% from the seasonal background value.	USA EPA
Settleable Matter	Unnatural inputs of settleable material should not cause the formation of deposits which are harmful to aquatic organisms.	VIC EPA (M)
Suspended Solids	Upper limit of 80 mg/L and depth of compensation point for photosynthetic activity should not be reduced by more than 10% from the natural seasonal norm.	Hart/USA EPA
Temperature	The maximum acceptable variation in the weekly average temperature due to artificial sources is 1°C for waters north and 2° C for waters south of latitude 27°S during all seasons of the year, provided that no single value exceeds the highest summer maximum recorded over the previous five years inclusive.	USA EPA
Salinity	Unnatural influences should not change the seasonal mean salinity, measured preferably over not less than five years, by more than 0.25 of the standard deviation, nor change the salinity beyond the range recorded over that period.	WG/VIC EPA (G)
Ionic Ratio	The ratio of major ions should not be altered such that this beneficial use is affected.	WG
pH	6.5-8.5 and no change in excess of 0.2 units from normal. For waters of salinity below 5 000 mg/L (5°/oo) the pH range should be 6.0 to 9.0 and no change in excess of 0.5 units.	USA EPA/WG/Hart
Dissolved Oxygen	Not to fall below 4.0 mL/L (5.7 mg/L) for more than 6 consecutive hours, and never to fall below 3.5 mL/L (5.0 mg/L).	WG
Arsenic	6 month median not to exceed 8 μg/L. No more than 20 per cent of readings to exceed 80 μg/L. No single reading to exceed 500 μg/L.	Calif (K&S)
Cadmium	6 month median not to exceed 3 μg/L. No single reading to exceed 8 μg/L.	Calif (K&S)
Chromium (total)	6 month median not to exceed 2 μg/L. No single reading to exceed 7 μg/L.	Calif (K&S)

Copper	6 month median not to exceed 5 μg/L. No single reading to exceed 40 μg/L.	Calif (K&S)
Lead	6 month median not to exceed 8 μg/L. No more than 20 per cent of readings to exceed 80 μg/L. No single reading to exceed 200 μg/L.	Calif (K&S)
Mercury	6 month median not to exceed 0.14 μg/L. No more than 20 per cent of readings to exceed 1.4 μg/L. No single reading to exceed 3 μg/L.	Calif (K&S)
Nickel	6 month median not to exceed 20 μg/L. No more than 20 per cent of readings to exceed 200 μg/L. No single reading to exceed 450 μg/L.	Calif (K&S)
Silver	6 month median not to exceed 0.45 μg/L. No more than 20 per cent of readings to exceed 4.5 μg/L. No single reading to exceed 10 μg/L.	Calif (K&S)
Zinc	6 month median not to exceed 20 μg/L. No single reading to exceed 200 μg/L.	Calif (K&S)
Aldrin	Not to exceed 0.003 μg/L	USA EPA
Azinphosmethyl	Not to exceed 0.01 μg/L	USA EPA
Camphechlor	Not to exceed 0.005 μg/L	USA EPA
Chlordane	Not to exceed 0.004 μg/L	USA EPA
2,4-D	Not to exceed 4 μg/L	NAS/NAE
DDT	Not to exceed 0.001 μg/L	USA EPA
Dieldrin	Not to exceed 0.003 μg/L	USA EPA
Endosulfan	Not to exceed 0.001 μg/L	USA EPA
Endrin	Not to exceed 0.004 μg/L	USA EPA
Heptachlor	Not to exceed 0.001 μg/L	USA EPA
Lindane	Not to exceed 0.004 μg/L	USA EPA
Maldison	Not to exceed 0.1 μg/L	USA EPA
Methoxychlor	Not to exceed 0.03 μg/L	USA EPA
Parathion	Not to exceed 0.04 μg/L	USA EPA
Other Pesticides	Not to exceed 0.01 of the 96-hour LC_{50} value for the selected test species.	WG
Ammonia (expressed as Nitrogen)	6 month median not to exceed 600 μg/L. No single reading to exceed 2000 μg/L.	Calif (K&S)
Chlorine (total residual)	6 month median not to exceed 2 μg/L. No single reading to exceed 10 μg/L.	Calif (K&S)
Cyanide	6 month median not to exceed 5 μg/L. No single reading to exceed 10 μg/L.	Calif (K&S)
Fluoride	6 month median not to exceed 2 mg/L. No single reading to exceed 10 mg/L.	WG
Hydrogen Sulphide	Not to exceed 2 μg/L	USA EPA
Total Hydrocarbons	Not to exceed 10 μg/L	WG
Aromatic Hydrocarbons	Not to exceed 1 μg/L	WG
Phenolic Compounds	6 month median not to exceed 300 μg/L.	Calif. (K&S)
Polychlorinated Biphenyls (PCBs)	Not to exceed 0.001 μg/L	USA EPA
Surfactants	Not to exceed 0.01 of the 96-hour LC_{50} value for the test organisms.	WG

Other Toxic Substances	No material should be present in an amount exceeding 0.01 of the 96-hour LC_{50} value for the test organism.	WG
Metals Accumulation	In addition to the criteria set out above for individual metals in water, a health investigation level may be established for any given metal on the basis of samples of the edible portion of a particular mollusc species, and is reached when more than 10% of such samples exceed the maximum permissible level prescribed for that metal in the Food and Drug Regulations, 1961, as amended, made under the Health Act, 1911-1978.	DH&MS
Tainting Agents	Taste- or odour-producing substances should not be present at concentrations that lead to undesirable tastes or odours in fish flesh or other edible products of aquatic origin. For examples of levels and types of compounds known to taint aquatic organisms see Table 1. These are not intended to be criteria.	Calif.
Radioactive Substances	Radioactive substances should not be present in concentrations that are deleterious to human, plant, animal, or aquatic life or that result in the accumulation of radioactive substances in the food web to an extent that presents a hazard to human, plant, animal, or aquatic life.	Calif.
Nutrients and Other Biostimulants	The loads of nutrients and other biostimulants to receiving waters should not cause excessive or nuisance growths of algae or other aquatic plants or deleterious reductions in dissolved oxygen concentrations in those waters.	VIC EPA (M)
Faecal Coliforms	A health investigation level for water in areas designated for mollusc harvesting may be established on the basis of a minimum of five samples taken over not more than a 30-day period under circumstances in which faecal contamination is most probable, and is reached either when the median reading of such samples exceeds 15 organisms/100 mL, or when more than 20% of such samples exceed 50/100 mL.	NSSP/Maine
Faecal Material	The water in areas designated for mollusc harvesting should be protected against direct contamination with fresh faecal material of human or domesticated animal origin.	DH&MS

SCHEDULE 4

MARINE AND ESTUARINE WATER QUALITY CRITERIA FOR HARVESTING OF AQUATIC LIFE FOR NON-EDIBLE USES.

Parameter	Criterion	Source
Aesthetic Considerations	As on page 8.	USA EPA (Comp)
Floating and Submerged Litter	No materials should be present which directly or indirectly have an adverse effect upon aquatic organisms, or which interfere with normal fishing or harvesting practices or damage fishing equipment.	WG
Barriers	No barrier should be constructed, substances added nor alterations made to the marine or estuarine environment which will prevent the normal movement and migratory patterns of aquatic organisms to the detriment of their populations or cause changes in the normal water movement pattern which will lead to adverse effects upon them.	WG
Light Attenuation	The combined effects of turbidity and colour should not reduce the depth of the compensation point for photosynthetic activity by more than 10% from the seasonal background value.	USA EPA
Settleable Matter	Unnatural inputs of settleable material should not cause the formation of deposits which are harmful to aquatic organisms.	VIC EPA (M)
Suspended Solids	Upper limit of 80 mg/L and depth of compensation point for photosynthetic activity should not be reduced by more than 10% from the natural seasonal norm.	Hart/USA EPA
Temperature	The maximum acceptable variation in the weekly average temperature due to artificial sources is 1°C for waters north and 2° C for waters south of latitude 27°S during all seasons of the year, provided that no single value exceeds the highest summer maximum recorded over the previous five years inclusive.	USA EPA
Salinity	Unnatural influences should not change the seasonal mean salinity, measured preferably over not less than five years, by more than 0.25 of the standard deviation, nor change the salinity beyond the range recorded over that period.	WG/VIC EPA (G)
Ionic Ratio	The ratios of major ions should not be altered such that this beneficial use is affected.	WG
pH	6.5-8.5 and no change in excess of 0.2 units from normal. For waters of salinity below 5 000 mg/L (5°/oo) the pH range should be 6.0 to 9.0 and no change in excess of 0.5 units.	USA EPA/WG/Hart
Dissolved Oxygen	Not to fall below 4.0 mL/L (5.7 mg/L) for more than 6 consecutive hours, and never to fall below 3.5 mL/L (5.0 mg/L).	Hart/Calif (K&S)
Arsenic	6 month median not to exceed 8 μg/L. No more than 20 per cent of readings to exceed 80 μg/L. No single reading to exceed 500 μg/L.	Calif (K&S)
Cadmium	6 month median not to exceed 3 μg/L. No single reading to exceed 8 μg/L.	Calif (K&S)
Chromium (total)	6 month median not to exceed 2 μg/L. No single reading to exceed 7 μg/L.	Calif (K&S)

Copper	6 month median not to exceed 5 μg/L. No single reading to exceed 40 μg/L.	Calif (K&S)
Lead	6 month median not to exceed 8 μg/L. No more than 20 per cent of readings to exceed 80 μg/L. No single reading to exceed 200 μg/L.	Calif (K&S)
Mercury	6 month median not to exceed 0.14 μg/L. No more than 20 per cent of readings to exceed 1.4 μg/L. No single reading to exceed 3 μg/L.	Calif (K&S)
Nickel	6 month median not to exceed 20 μg/L. No more than 20 per cent of readings to exceed 200 μg/L. No single reading to exceed 450 μg/L.	Calif (K&S)
Silver	6 month median not to exceed 0.45 μg/L. No more than 20 per cent of readings to exceed 4.5 μg/L. No single reading to exceed 10 μg/L.	Calif (K&S)
Zinc	6 month median not to exceed 20 μg/L. No single reading to exceed 200 μg/L.	Calif (K&S)
Aldrin	Not to exceed 0.003 μg/L	USA EPA
Azinphosmethyl	Not to exceed 0.01 μg/L	USA EPA
Camphechlor	Not to exceed 0.005 μg/L	USA EPA
Chlordane	Not to exceed 0.004 μg/L	USA EPA
2,4-D	Not to exceed 4 μg/L	NAS/NAE
DDT	Not to exceed 0.001 μg/L	USA EPA
Dieldrin	Not to exceed 0.003 μg/L	USA EPA
Endosulfan	Not to exceed 0.001 μg/L	USA EPA
Endrin	Not to exceed 0.004 μg/L	USA EPA
Heptachlor	Not to exceed 0.001 μg/L	USA EPA
Lindane	Not to exceed 0.004 μg/L	USA EPA
Maldison	Not to exceed 0.1 μg/L	USA EPA
Methoxychlor	Not to exceed 0.03 μg/L	USA EPA
Parathion	Not to exceed 0.04 μg/L	USA EPA
Other Pesticides	Not to exceed 0.01 of the 96-hour LC_{50} value for the selected test species.	WG
Ammonia (expressed as Nitrogen)	6 month median not to exceed 600 μg/L. No single reading to exceed 2000 μg/L.	Calif (K&S)
Chlorine (total residual)	6 month median not to exceed 2 μg/L. No single reading to exceed 10 μg/L.	Calif (K&S)
Cyanide	6 month median not to exceed 5 μg/L. No single reading to exceed 10 μg/L.	Calif (K&S)
Fluoride	6 month median not to exceed 2 mg/L. No single reading to exceed 10 mg/L.	WG
Hydrogen Sulphide	Not to exceed 2 μg/L	USA EPA
Total Hydrocarbons	Not to exceed 10 μg/L	WG
Aromatic Hydrocarbons	Not to exceed 1 μg/L	WG
Phenolic Compounds	6 month median not to exceed 300 μg/L.	Calif (K&S)
Polychlorinated Biphenyls (PCBs)	Not to exceed 0.001 μg/L	USA EPA
Surfactants	Not to exceed 0.01 of the 96-hour LC_{50} value for the test organisms.	WG

Other Toxic Substances	No material should be present in an amount exceeding 0.01 of the 96-hour LC_{50} value for the test organism.	WG
Radioactive Substances	Radioactive substances should not be present in concentrations that are deleterious to human, plant, animal, or aquatic life.	Calif.
Nutrients and Other Biostimulants	The loads of nutrients and other biostimulants to receiving waters should not cause excessive or nuisance growths of algae or other aquatic plants or deleterious reductions in dissolved oxygen concentrations in those waters.	VIC EPA (M)

SCHEDULE 5

MARINE AND ESTUARINE WATER QUALITY CRITERIA FOR PASSAGE OF FISH AND OTHER AQUATIC LIFE.

Parameter	Criterion	Source
Aesthetic Considerations	As on page 8.	USA EPA (Comp)
Barriers	No barrier should be constructed, substances added nor alterations made to the marine or estuarine environment which will prevent the normal movement and migratory patterns of fish and other aquatic organisms to the detriment of their populations or cause changes in the normal water movement pattern which will lead to adverse effects upon them.	WG
Radioactive Substances	Radioactive substances should not be present in concentrations that are deleterious to human, plant, animal, or aquatic life or that result in the accumulation of radioactive substances in the food web to an extent that presents a hazard to human, plant, animal, or aquatic life.	Calif.

BENEFICIAL USE NO. 6
AQUACULTURE OF ALL FORMS

The protection of waters for aquaculture may be intended for the production of edible (Class 1) or non-edible (Class 2) organisms. It may include all forms such as fish, molluscs, crustacea, algae etc.

As a general rule, whenever waters are to be protected for aquaculture of edible species it is suggested that, in the absence of any more specific criteria, the criteria for beneficial use No. 2, Harvesting of Aquatic Life (Excluding Molluscs) for Food, should apply. However, in the case when molluscan species are to be cultured for human consumption, the criteria for beneficial use No. 3, Harvesting of Molluscs for Food, should be applied.

In the case when aquatic life is to be cultured for non-edible uses, the criteria for beneficial use No. 4, Harvesting of Aquatic Life for Non-edible Uses, are appropriate.

Where it is known that there are specific water quality requirements for any particular aquacultural activity, then these requirements should also be met.

The General Aesthetic Criteria listed on page 8 should also apply.

BENEFICIAL USE NO. 7
MAINTENANCE AND PRESERVATION OF AQUATIC ECOSYSTEMS

An ecosystem comprises a physicochemical environment together with a more or less stable community of evolutionarily adapted organisms, which interact in such a way that there is transportation of energy and materials through the system and recycling of material resources within the system. Thus an ecosystem can be viewed in terms of abiotic elements such as sunlight, temperature, pH, inorganic nutrients, etc., and biotic elements, the interacting organisms and populations which constitute an ecological community. The biotic community of an ecosystem comprises three groups of organisms, distinguished by their trophic status within the system, i.e. the producers, the consumers and the decomposers.

The producers synthesise organic material from inorganic nutrients using abiotic sources of energy. Producers form a fundamental component of an ecosystem since they biologically fix energy in a form which other organisms may utilise. Consumers are those organisms which derive nutrients and energy by assimilation of preconstituted organic material. Various trophic levels may be recognised within this class of organisms on the basis of their positions in food chains. Decomposers are those organisms which derive nutrition from the metabolic waste products of other organisms and their remains. This class of organisms including bacteria plays an important role in the ecosystem since they release inorganic nutrients for re-use by producers, thus completing the cycle.

An important realisation that comes from the recognition of the integrated nature of ecosystems is that interferences with one element or process may have far-reaching repercussions for other parts of the whole ecosystem.

Properly functioning aquatic ecosystems are important to man in a number of ways:

- Aquatic ecosystems are valuable food, recreation and educational resources. In most countries, including Australia, commercial and sport fisheries are economically important, as are other water-based sporting activities.
- Properly constituted marine and freshwater communities are essential to the efficient assimilation of organic matter and recycling of nutrients in the aquatic environment. Such processes are important in maintaining water quality.
- Not only do aquatic communities play an important role in maintaining water quality, they also provide a reliable indicator of the quality of water and hence of its suitability for other beneficial uses by man.

Levels of Protection

Although localised deterioration of an aquatic ecosystem, due to degradation of water quality, may be reversible, in general the recovery of the abused system to its former state is far more costly than prevention of the abuse. Where pollution is widespread and severe, rehabilitation of aquatic communities may be economically, if not practically, impossible.

In order to provide clear alternatives from which to formulate environmental protection policies for particular waters it is useful to delineate various levels of protection to be satisfied by different sets of criteria. Three levels of protection are recognised.

Class 1

This represents maximum protection for ecosystems and corresponds to water quality of a natural or pristine state. Waters subject to such a level of protection should not receive any waste discharges whatsoever, nor be affected by man-made changes within the surface or ground watersheds, nor the body of water itself. (See Schedule 7 (1)).

Class 2

A high level of protection such that any waste discharges or man-made changes which do occur may be readily assimilated or withstood by the system without any detectable effects on the biota or the structure of the ecosystem to which they belong. Water quality criteria for Class 2 protection are given in Schedule 7(2).

Class 3

A minimal level of protection such that any waste discharge or man-made changes which do occur may lead to changes in the present biota, but do not change the nature of the residing biota to the point where it no longer functions as an ecosystem, i.e. has the recognisable components of an ecosystem as discussed above. Water quality criteria for Class 3 protection are given in Schedule 7(3).

The Working Group, whilst appreciating the need for this level of protection, has found some difficulty in setting relaxed levels for many parameters. Where it is known that the level of a particular parameter can be relaxed, then this less stringent level has been used. However, where insufficient data are available, the more conservative values applying to Class 2 protection have been used.

BLACKWOOD RIVER ESTUARY

The Blackwood River catchment drains 23 000 square kilometres of the south-west corner of the State in which a wide range of rural activities takes place. Following mining and dredging claims, the Environmental Protection Authority directed that a study of the ecology of the estuary be made.

Reference: Hodgkin, E.P. (1978). "An Environmental Study of the Blackwood River Estuary, Western Australia, 1974-75". Department of Conservation and Environment, Report No. 1. Perth, Western Australia.

SCHEDULE 7 (1)

MARINE AND ESTUARINE WATER QUALITY CRITERIA FOR MAINTENANCE AND PRESERVATION OF AQUATIC ECOSYSTEMS

Class 1

Water quality parameters should be maintained at pristine or ambient levels where applicable. Waters under this level of protection should not be modified by human activities in any way.

The determination of pristine or ambient values should be based on data from as long a time period as possible but this should not be for a period of less than three years.

The following water quality parameters are the minimum which should be used in establishing the ambient condition for any given location:

- Light Attenuation
- Settleable Matter
- Suspended Solids
- Temperature
- Salinity
- pH
- Dissolved Oxygen
- Trace Metals
- Nutrients
- Hydrocarbons
- Radioactive Substances
- Other likely pollutants

SCHEDULE 7 (2)

MARINE AND ESTUARINE WATER QUALITY CRITERIA FOR MAINTENANCE AND PRESERVATION OF AQUATIC ECOSYSTEMS

Class 2

Parameter	Criterion	Source
Aesthetic Considerations	As on page 8.	USA EPA (Comp)
Floating and Submerged Litter	No materials should be present which directly or indirectly have an adverse effect upon aquatic organisms.	WG
Barriers	No barrier should be constructed, substances added nor alterations made to the marine or estuarine environment which will prevent the normal movement and migratory patterns of marine and estuarine organisms to the detriment of their populations or cause changes in the normal water movement pattern which will lead to adverse effects upon them.	WG
Light Attenuation	The combined effects of turbidity and colour should not reduce the depth of the compensation point for photosynthetic activity by more than 10% from the seasonal background value.	USA EPA
Settleable Matter	Unnatural inputs of settleable material should not cause the formation of deposits which are harmful to aquatic organisms.	VIC EPA (M)
Suspended Solids	Upper limit of 80 mg/L and depth of compensation point for photosynthetic activity should not be reduced by more than 10% from the natural seasonal norm.	Hart/USA EPA
Temperature	The maximum acceptable variation in the weekly average temperature due to artificial sources is 1°C for waters north and 2°C for waters south of latitude 27°S during all seasons of the year, provided that no single value exceeds the highest summer maximum recorded over the previous five years inclusive.	USA EPA
Salinity	Unnatural influences should not change the seasonal mean salinity, measured preferably over not less than five years, by more than 0.25 of the standard deviation, nor change the salinity beyond the range recorded over that period.	WG/VIC EPA (G)
Ionic Ratio	The ratios of major ions should not be altered such that this beneficial use is affected.	WG
pH	6.5-8.5 and no change in excess of 0.2 units from normal. For waters of salinity below 5 000 mg/L (5°/oo) the pH range should be 6.0 to 9.0 and no change in excess of 0.5 units.	USA EPA/WG/Hart
Dissolved Oxygen	Not to fall below 4.0 mL/L (5.7 mg/L) for more than 6 consecutive hours, and never to fall below 3.5 mL/L (5.0 mg/L).	WG
Arsenic	6 month median not to exceed 8 μg/L No more than 20 per cent of readings to exceed 80 μg/L. No single reading to exceed 500 μg/L.	Calif (K&S)
Cadmium	6 month median not to exceed 3 μg/L. No single reading to exceed 8 μg/L.	Calif (K&S)
Chromium (total)	6 month median not to exceed 2 μg/L. No single reading to exceed 7 μg/L.	Calif (K&S)

Copper	6 month median not to exceed 5 μg/L. No single reading to exceed 40 μg/L.	Calif (K&S)
Lead	6 month median not to exceed 8 μg/L. No more than 20 per cent of readings to exceed 80 μg/L. No single reading to exceed 200 μg/L.	Calif (K&S)
Mercury	6 month median not to exceed 0.14 μg/L. No more than 20 per cent of readings to exceed 1.4 μg/L. No single reading to exceed 3 μg/L.	Calif (K&S)
Nickel	6 month median not to exceed 20 μg/L. No more than 20 per cent of readings to exceed 200 μg/L. No single reading to exceed 450 μg/L.	Calif (K&S)
Silver	6 month median not to exceed 0.45 μg/L. No more than 20 per cent of readings to exceed 4.5 μg/L. No single reading to exceed 10 μg/L.	Calif (K&S)
Zinc	6 month median not to exceed 20 μg/L. No single reading to exceed 200 μg/L.	Calif (K&S)
Aldrin	Not to exceed 0.003 μg/L	USA EPA
Azinphosmethyl	Not to exceed 0.01 μg/L	USA EPA
Camphechlor	Not to exceed 0.005 μg/L	USA EPA
Chlordane	Not to exceed 0.004 μg/L	USA EPA
2,4-D	Not to exceed 4 μg/L	NAS/NAE
DDT	Not to exceed 0.001 μg/L	USA EPA
Dieldrin	Not to exceed 0.003 μg/L	USA EPA
Endosulfan	Not to exceed 0.001 μg/L	USA EPA
Endrin	Not to exceed 0.004 μg/L	USA EPA
Heptachlor	Not to exceed 0.001 μg/L	USA EPA
Lindane	Not to exceed 0.004 μg/L	USA EPA
Maldison	Not to exceed 0.1 μg/L	USA EPA
Methoxychlor	Not to exceed 0.03 μg/L	USA EPA
Parathion	Not to exceed 0.04 μg/L	USA EPA
Other Pesticides	Not to exceed 0.01 of the 96-hour LC_{50} value for the selected test species.	WG
Ammonia (expressed as Nitrogen)	6 month median not to exceed 600 μg/L. No single reading to exceed 2000 μg/L.	Calif (K&S)
Chlorine (total residual)	6 month median not to exceed 2 μg/L. No single reading to exceed 10 μg/L.	Calif (K&S)
Cyanide	6 month median not to exceed 5 μg/L No single reading to exceed 10 μg/L.	Calif (K&S)
Fluoride	6 month median not to exceed 2 mg/L. No single reading to exceed 10 mg/L.	WG
Hydrogen Sulphide	Not to exceed 2 μg/L	USA EPA
Total Hydrocarbons	Not to exceed 10 μg/L	WG
Aromatic Hydrocarbons	Not to exceed 1 μg/L	WG
Phenolic Compounds	6 month median not to exceed 300 μg/L.	Calif (K&S)
Polychlorinated Biphenyls (PCBs)	Not to exceed 0.001 μg/L	USA EPA
Surfactants	Not to exceed 0.01 of the 96-hour LC_{50} value for the test organisms.	WG

Other Toxic Substances	No material should be present in an amount exceeding 0.01 of the 96-hour LC_{50} value for the test organism.	WG
Radioactive Substances	Radioactive substances should not be present in concentrations that are deleterious to human, plant, animal, or aquatic life or that result in the accumulation of radioactive substances in the food web to an extent that presents a hazard to human, plant, animal, or aquatic life.	Calif.
Nutrients and Other Biostimulants	The loads of nutrients and other biostimulants to receiving waters should not cause excessive or nuisance growths of algae or other aquatic plants or deleterious reductions in dissolved oxygen concentrations in those waters.	VIC EPA (M)
General Provision	Should any individual species or component of the ecosystem be known to have lower tolerances than those specified in the above criteria, then these levels should be those used in setting water quality objectives.	VIC EPA (M)

SCHEDULE 7 (3)

MARINE AND ESTUARINE WATER QUALITY CRITERIA FOR MAINTENANCE AND PRESERVATION OF AQUATIC ECOSYSTEMS

Class 3

Parameter	Criterion	Source
Aesthetic Considerations	As on page 8.	USA EPA (Comp)
Light Attenuation	The combined effects of turbidity and colour should not reduce the depth of the compensation point for photosynthetic activity by more than 50% from the seasonal background value.	USA EPA
Settleable Matter	Unnatural inputs of settleable material should not cause the formation of deposits which are harmful to aquatic organisms.	VIC EPA (M)
Suspended Solids	Upper limit of 80 mg/L and depth of compensation point for photosynthetic activity should not be reduced by more than 20% from the natural seasonal norm.	Hart/WG
Temperature	The maximum acceptable variation in the weekly average temperature due to artificial sources is 2°C for waters north and 4°C for waters south of latitude 27°S during all seasons of the year, provided that no single value exceeds by more than 2°C the highest summer maximum recorded over the previous five years inclusive.	WG
Salinity	Unnatural influences should not change the seasonal mean salinity, measured preferably over not less than five years, by more than 0.25 of the standard deviation, nor change the salinity beyond the range recorded over that period.	WG/VIC EPA (G)
Ionic Ratio	The ratios of major ions should not be altered such that this beneficial use is affected.	WG
pH	6.5-8.5 and no change in excess of 0.5 units from normal. For waters of salinity below 5 000 mg/L (5°/oo) the pH range should be 6.0 to 9.0 and no change in excess of 1.0 units.	USA EPA/WG/Hart
Dissolved Oxygen	Not to fall below 3.5 mL/L (5.0 mg/L) for more than 6 consecutive hours, and never to fall below 3.0 mL/L (4.3 mg/L).	WG
Arsenic	6 month median not to exceed 8 μg/L No more than 20 per cent of readings to exceed 80 μg/L. No single reading to exceed 500 μg/L.	Calif (K&S)
Cadmium	6 month median not to exceed 3 μg/L. No single reading to exceed 8 μg/L.	Calif (K&S)
Chromium (total)	6 month median not to exceed 2 μg/L. No single reading to exceed 7 μg/L.	Calif (K&S)
Copper	6 month median not to exceed 5 μg/L. No single reading to exceed 40 μg/L.	Calif (K&S)
Lead	6 month median not to exceed 8 μg/L. No more than 20 per cent of readings to exceed 80 μg/L. No single reading to exceed 200 μg/L.	Calif (K&S)

Mercury	6 month median not to exceed 0.14 μg/L. No more than 20 per cent of readings to exceed 1.4 μg/L. No single reading to exceed 3 μg/L.	Calif (K&S)
Nickel	6 month median not to exceed 20 μg/L. No more than 20 per cent of readings to exceed 200 μg/L. No single reading to exceed 450 μg/L.	Calif (K&S)
Silver	6 month median not to exceed 0.45 μg/L. No more than 20 per cent of readings to exceed 4.5 μg/L. No single reading to exceed 10 μg/L.	Calif (K&S)
Zinc	6 month median not to exceed 20 μg/L. No single reading to exceed 200 μg/L.	Calif (K&S)
Aldrin	Not to exceed 0.003 μg/L	USA EPA
Azinphosmethyl	Not to exceed 0.01 μg/L	USA EPA
Camphechlor	Not to exceed 0.005 μg/L	USA EPA
Chlordane	Not to exceed 0.004 μg/L	USA EPA
2,4-D	Not to exceed 4 μg/L	NAS/NAE
DDT	Not to exceed 0.001 μg/L	USA EPA
Dieldrin	Not to exceed 0.003 μg/L	USA EPA
Endosulfan	Not to exceed 0.001 μg/L	USA EPA
Endrin	Not to exceed 0.004 μg/L	USA EPA
Heptachlor	Not to exceed 0.001 μg/L	USA EPA
Lindane	Not to exceed 0.004 μg/L	USA EPA
Maldison	Not to exceed 0.1 μg/L	USA EPA
Methoxychlor	Not to exceed 0.03 μg/L	USA EPA
Parathion	Not to exceed 0.04 μg/L	USA EPA
Other Pesticides	Not to exceed 0.01 of the 96-hour LC_{50} value for the selected test species.	WG
Ammonia (expressed as Nitrogen)	6 month median not to exceed 600 μg/L. No single reading to exceed 2000 μg/L.	Calif (K&S)
Chlorine (total residual)	6 month median not to exceed 2 μg/L. No single reading to exceed 10 μg/L.	Calif (K&S)
Cyanide	6 month median not to exceed 5 μg/L. No single reading to exceed 10 μg/L.	Calif (K&S)
Fluoride	6 month median not to exceed 2 mg/L. No single reading to exceed 10 mg/L.	WG
Hydrogen Sulphide	Not to exceed 2 μg/L.	USA EPA
Total Hydrocarbons	Not to exceed 10 μg/L.	WG
Aromatic Hydrocarbons	Not to exceed 1 μg/L.	WG
Phenolic Compounds	6 month median not to exceed 300 μg/L.	Calif (K&S)
Polychlorinated Biphenyls (PCBs)	Not to exceed 0.001 μg/L.	USA EPA
Surfactants	Not to exceed 0.01 of the 96-hour LC_{50} value for the test organisms.	WG
Other Toxic Substances	No material should be present in an amount exceeding 0.01 of the 96-hour LC_{50} value for the test organism.	WG
Radioactive Substances	Radioactive substances should not be present in concentrations that are deleterious to human, plant, animal, or aquatic life or that result in the accumulation of radioactive substances in the food	Calif.

	web to an extent that presents a hazard to human, plant, animal, or aquatic life.	
Nutrients and Other Biostimulants	The loads of nutrients and other biostimulants to receiving waters should not cause excessive or nuisance growths of algae or other aquatic plants, or deleterious reductions in dissolved oxygen concentrations in those waters.	VIC EPA (M)

BENEFICIAL USE NO. 8
MAINTENANCE AND PRESERVATION OF FORESHORES AND BANKS

The continued existence of certain physical features of water bodies, such as banks and foreshores, may be directly dependent upon the maintenance of the water quality surrounding them, and upon the maintenance of the existing geography of the area. For example, the erection of groynes, bridges or causeways may alter water flows in such a way that banks are eroded, removed or established or the shoreline altered. Such structures may also alter water flows so that the self-cleaning characteristics of the water body are adversely affected. The result of the erection of groynes etc, will be reflected in the speed and direction of water flows and levels of suspended solids, these characteristics being in themselves physical water quality parameters. The maintenance of the quality of waters surrounding a submerged bank, for example, may be vital to the aquatic growth which stabilises it. Quite possibly no intervention by man will be as successful as aquatic growth in protecting and maintaining a submerged bank. The same may also apply to the stabilisation of foreshores.

However, no universal numerical criteria can be drawn up for this beneficial use. Whenever waters are to be protected for the maintenance and preservation of foreshores and banks, it is suggested that in the absence of any more specific criteria, the criteria for beneficial use No. 7, Maintenance and Preservation of Aquatic Ecosystems, Class 2 protection, should be applied in conjunction with close attention to the effects of alterations to the physical features of the area. Where it is known that there are specific water quality requirements for any particular area, then these should also be met.

The General Aesthetic Criteria listed on page 8 should also apply.

BENEFICIAL USE NO. 9
SCIENTIFIC AND EDUCATIONAL USES

The educational uses of water depend on the availability of a range of bodies of water demonstrating, as far as possible, naturally occurring variations in water quality. The natural variations may be between different bodies of water at a given time by virtue of its natural environment or for the same body of water at different points in time. In addition it is advantageous to have available bodies of water which are being used for specific purposes, for example, aquaculture, or which have been used in the past for specific purposes, for example, depositing waste. From an educational point of view the benefits arise from students from schools, technical schools and tertiary institutions being able to observe and study the range of bodies of water and the quality of water present.

A similar range of water bodies is necessary for scientific studies and research purposes. It is important for future planning and development, whether for recreational or industrial purposes, to have data available on the following:

- How water bodies and water quality change with time, independent of man's activities, i.e. to observe and monitor a changing baseline;
- How the water quality changes as a result of a carefully managed programme of beneficial uses, i.e. to continually monitor changes resulting from a specific approved use;
- How the water quality changes as a result of the discontinuing of a specific use — for example, the recovery from a specific form of pollution.

These scientific uses will provide the data upon which informed predictions can be made regarding the likely alterations in water quality as a result of particular uses which may be made of a particular body of water.

In the case of a nominated body of water which has been designated for given use, from a scientific and educational point of view consideration should be given to designating a control area which resembles as closely as possible the area to be used. In this way any changes in water quality can be assessed in the context of changes which may have occurred naturally or as a result of regional rather than local effects.

The criteria for protection of this beneficial use are stated in Schedule 9.

SCHEDULE 9

MARINE AND ESTUARINE WATER QUALITY CRITERIA FOR SCIENTIFIC AND EDUCATIONAL USES

Criteria

Waters designated for scientific and educational uses should be protected against factors which adversely affect scientific and educational studies.

During the course of a specified study no disruption likely to render meaningless the data accumulated for scientific or educational purposes should occur.

BENEFICIAL USE NO. 10
FLUSHING WATER AND WATER REPLENISHMENT

Waters which move under the influence of tides, currents, winds or by virtue of other influences can be termed flushing or replenishment waters. Naturally they may have either a beneficial or detrimental effect upon the water quality of the zone into which they move.

In the case when there is movement of waters of inferior quality into a zone where higher water quality is required some provision must be made so that the more stringent requirements are still attainable.

The actual values of criteria for flushing waters cannot be determined in advance, but must be determined on a case-by-case basis. Hence narrative criteria only can be stated (see Schedule 10).

SCHEDULE 10

MARINE AND ESTUARINE WATER QUALITY CRITERIA FOR FLUSHING WATER AND WATER REPLENISHMENT

Criteria

When flushing and replenishment waters arrive in a zone of defined beneficial use or uses, their effect should not be detrimental to the beneficial use or uses defined for that zone.

Consequently, specific water quality criteria for flushing and replenishment waters can only be determined on a case-by-case basis bearing in mind both the degree of mixing which will occur and the criteria established for the waters that they will be mixing with or replenishing.

The free movement of flushing waters should not be impeded in any way which will be detrimental to this beneficial use.

BENEFICIAL USE NO. 11
AGRICULTURAL WATER SUPPLY

At present the agricultural use of saline waters from the ocean and estuaries is only of an experimental nature.

If and when marine and estuarine waters are likely to be used commercially in Western Australia for agricultural water supplies, water quality criteria will be established.

BENEFICIAL USE NO. 12
POTABLE WATER PRODUCTION (DESALINATION)

Water quality criteria for production of potable water by distillation, reverse osmosis or other means have not been found. The suggested criteria in Schedule 12 have been derived from those established for other beneficial uses which are judged relevant.

For the protection of this beneficial use, it will be necessary to avoid undesirable bacteria, algae, plants, floating objects and materials and settleable materials. Furthermore, levels of contaminants should be such that the water produced conforms to drinking water standards.

SCHEDULE 12

MARINE AND ESTUARINE WATER QUALITY CRITERIA FOR POTABLE WATER PRODUCTION (DESALINATION)

Parameter	Criterion	Source
Aesthetic Considerations	As on page 8.	USA EPA (Comp)
Floating Material or Objects	Waters should not contain floating material or objects which would cause nuisance or interfere with this use.	Calif.
Odour	Waters should not contain odorous or odour-producing substances in concentrations that would cause nuisance or render them unsuitable for use.	Calif.
Settleable Matter	Waters should not contain settleable matter in concentrations that cause deposits that would adversely affect this beneficial use.	Calif/VIC EPA (Y)
Suspended Solids	Waters should not contain suspended matter in concentrations that would render them unsuitable for use.	Calif.
pH	Maximum variation of 0.5 units from natural level.	WG
Surfactants	Waters should not contain surfactants or other similar materials in quantities that give rise to foam or otherwise interfere with their use.	WG/Calif.
Oil and Grease	Waters should not contain oil, grease, wax or other similar materials in concentrations that result in a visible film or coating on the surface of the water, that cause nuisance or render the waters unsuitable for use.	Calif.
Toxic Substances, Radioactive Substances and Bacteria	Levels should not cause product water to exceed the relevant desirable current criteria set out in the Department of Health document "Desirable Quality for Drinking Water in Australia", published by the A.G.P.S., Canberra, (1980).	WG
Nutrients and Other Biostimulants	Added nutrients or growth stimulants should not cause excessive or nuisance algal or other plant growth.	VIC EPA (Y)

BENEFICIAL USE NO. 13
RECOVERY OF MINERALS

No specific water quality criteria for recovery of minerals (e.g. salt) have been found. The suggested criteria in Schedule 13 have been derived from those established for other beneficial uses which are judged relevant.

For the protection of this beneficial use, it may be necessary to avoid variations from the normal chemical composition of sea-water, and also to avoid algal and other plant growths, undesirable floating objects and materials and settleable materials occurring in amounts or concentrations that are greater than those normally expected in marine and estuarine waters.

SCHEDULE 13

MARINE AND ESTUARINE WATER QUALITY CRITERIA FOR RECOVERY OF MINERALS

Parameter	Criterion	Source
Aesthetic Considerations	As on page 8.	USA EPA (Comp)
Floating or Submerged Material or Objects	Waters should not contain floating or submerged material or objects which would cause nuisance or interfere with this use and which arise from other than natural origins.	Calif.
Settleable Matter	Waters should not contain settleable matter in concentrations that cause deposits that would adversely affect this beneficial use.	Calif/ VIC EPA (Y)
Suspended Solids	Waters should not contain suspended matter in concentrations that would render them unsuitable for use.	Calif.
pH	Maximum variation of 0.5 units from natural seasonal level.	WG
Oil and Grease	Waters should not contain oil, grease, wax or other similar materials in concentrations that result in a visible film or coating on the surface of the water, that cause nuisance or render the waters unsuitable for use.	Calif.
Other Chemicals	No chemical, other than those naturally occurring, should be present in concentrations that would adversely affect this beneficial use. The waters should not contain any toxicant or other material that would endanger personnel or those consuming the end-product.	WG
Nutrients and Other Biostimulants	Added nutrients or growth stimulants should not cause excessive or nuisance algal or other plant growth.	VIC EPA (Y)
Radioactive Substances	Radioactive substances should not be present in concentrations that are deleterious to this beneficial use.	WG

BENEFICIAL USE NO. 14
INDUSTRIAL WATER SUPPLY

This beneficial use comprises a wide range of water qualities ranging from industrial cooling waters on the one hand to waters required for food processing on the other.

Waters required by food processing industries may have either short or long term contact with foods. The short term exposure occurs in washing and cooking procedures (Class 1), whereas longer exposures occur when, for example, live crustacea are kept in holding tanks (Class 2).

No specific water quality criteria for steam generation, cooling and other processes (Class 3) have been found. There is no known widespread use of marine water by industry other than as cooling water and any use would require criteria specific to the industry concerned. Any criteria set must therefore be sufficiently general so as to cover any future uses and emphasis should be placed on maintaining waters set aside for this beneficial use in a state suitable for existing and future users. The criteria in Schedule 14 have been derived from those established for other beneficial uses which are judged relevant.

SCHEDULE 14 (1)

MARINE AND ESTUARINE WATER QUALITY CRITERIA FOR INDUSTRIAL WATER SUPPLY

Class 1

Food Processing — Washing and Cooking Procedures

Where waters are to be protected for this beneficial use, the applicable criteria in respect of physical, toxicological, radiological and microbiological parameters should be those set out as desirable current criteria in the Department of Health document "Desirable Quality for Drinking Water in Australia", published by the A.G.P.S. Canberra, (1980).

Furthermore, the General Aesthetic Criteria listed on page 8 should also apply.

SCHEDULE 14 (2)

MARINE AND ESTUARINE WATER QUALITY CRITERIA FOR INDUSTRIAL WATER SUPPLY

Class 2

Food Processing — In-plant Holding Procedures

Parameter	Criterion	Source *
Aesthetic Considerations	As on page 8.	USA EPA (Comp)
Suspended Solids	Upper limit of 160 mg/L	WG
Temperature	The maximum acceptable variation in the weekly average temperature due to artificial sources is 2°C for waters north and 4°C for waters south of latitude 27°S during all seasons of the year, provided that no single value exceeds by more than 2°C the highest summer maximum recorded over the previous five years inclusive.	WG
Salinity	Unnatural influences should not change the seasonal mean salinity, measured preferably over not less than five years, by more than 0.25 of the standard deviation, nor change the salinity beyond the range recorded over that period.	WG/VIC EPA (G)
Ionic Ratio	The ratios of major ions should not be altered such that this beneficial use is affected.	WG
pH	6.5-8.5	WG
Dissolved Oxygen	Not to fall below 3.5 mL/L (5.0 mg/L) for more than 6 consecutive hours, and never to fall below 3.0 mL/L (4.3 mg/L).	WG
Arsenic	6 month median not to exceed 40 μg/L. No single reading to exceed 500 μg/L.	Calif (K&S)
Cadmium	6 month median not to exceed 15 μg/L. No single reading to exceed 40 μg/L.	Calif (K&S)
Chromium (total)	6 month median not to exceed 10 μg/L. No single reading to exceed 35 μg/L.	Calif (K&S)
Copper	6 month median not to exceed 25 μg/L. No single reading to exceed 40 μg/L.	Calif (K&S)
Lead	6 month median not to exceed 40 μg/L. No single reading to exceed 200 μg/L.	Calif (K&S)
Mercury	6 month median not to exceed 0.7 μg/L. No single reading to exceed 3 μg/L.	Calif (K&S)
Nickel	6 month median not to exceed 100 μg/L. No single reading to exceed 450 μg/L.	Calif (K&S)
Silver	6 month median not to exceed 2.25 μg/L. No single reading to exceed 10 μg/L.	Calif (K&S)
Zinc	6 month median not to exceed 100 μg/L. No single reading to exceed 200 μg/L.	Calif (K&S)
Aldrin	Not to exceed 0.015 μg/L	USA EPA
Azinphosmethyl	Not to exceed 0.05 μg/L	USA EPA
Camphechlor	Not to exceed 0.025 μg/L	USA EPA
Chlordane	Not to exceed 0.02 μg/L	USA EPA
2,4-D	Not to exceed 20 μg/L	NAS/NAE
DDT	Not to exceed 0.005 μg/L	USA EPA
Dieldrin	Not to exceed 0.015 μg/L	USA EPA
Endosulfan	Not to exceed 0.005 μg/L	USA EPA

Endrin	Not to exceed 0.02 μg/L	USA EPA
Heptachlor	Not to exceed 0.005 μg/L	USA EPA
Lindane	Not to exceed 0.02 μg/L	USA EPA
Maldison	Not to exceed 0.5 μg/L	USA EPA
Methoxychlor	Not to exceed 0.15 μg/L	USA EPA
Parathion	Not to exceed 0.2 μg/L	USA EPA
Other Pesticides	Not to exceed 0.05 of the 96-hour LC_{50} value for the selected test species.	WG
Ammonia (expressed as Nitrogen)	6 month median not to exceed 3 mg/L. No single reading to exceed 5 mg/L.	Calif (K&S)
Chlorine (total residual)	6 month median not to exceed 10 μg/L. No single reading to exceed 30 μg/L.	Calif (K&S)
Cyanide	6 month median not to exceed 25 μg/L. No single reading to exceed 40 μg/L.	Calif (K&S)
Fluoride	6 month median not to exceed 2 mg/L. No single reading to exceed 10 mg/L.	WG
Hydrogen Sulphide	Not to exceed 10 μg/L.	USA EPA
Total Hydrocarbons	Not to exceed 50 μg/L.	WG
Aromatic Hydrocarbons	Not to exceed 5 μg/L.	WG
Phenolic Compounds	6 month median not to exceed 300 μg/L.	WG
Polychlorinated Biphenyls (PCBs)	Not to exceed 0.005 μg/L.	USA EPA
Surfactants	Not to exceed 0.05 of the 96-hour LC_{50} value for the test organisms.	WG
Metals Accumulation	In addition to the criteria set out above for individual metals in water, a health investigation level may be established for any given metal on the basis of samples of the edible portion of a particular aquatic species, and is reached when more than 10% of such samples exceed the maximum permissible level prescribed for that metal in the Food and Drug Regulations, 1961, as amended, made under the Health Act, 1911-1978.	DH&MS
Other Toxic Substances	No levels set. Action to be taken when appropriate.	WG
Tainting Agents	Taste- or odour-producing substances should not be present at concentrations that lead to undesirable tastes or odours in fish flesh or other edible products of aquatic origin. For examples of levels and types of compounds known to taint aquatic organisms see Table 1. These are not intended to be criteria.	Calif.
Radioactive Substances	Radioactive substances should not be present in concentrations that are deleterious to human, plant, animal, or aquatic life or that result in the accumulation of radioactive substances in the food web to an extent that presents a hazard to human, plant, animal or aquatic life.	Calif.
Faecal Coliforms	For molluscs held in tanks the median reading of samples tested for faecal coliform organisms should not exceed 5 organisms/100 mL, nor should more than 20% of readings exceed 15 organisms/100 mL when a minimum of five samples taken over not more than a thirty-day period are tested.	WG

* The values of the criteria in this Schedule are, in most cases, five times the values quoted in the sources and are believed to contain a sufficient safety margin for this beneficial use.

SCHEDULE 14 (3)

MARINE AND ESTUARINE WATER QUALITY CRITERIA FOR INDUSTRIAL WATER SUPPLY

Class 3

Steam Generation, Cooling and Other Processes

Parameter	Criterion	Source
Aesthetic Considerations	As on page 8.	USA EPA (Comp)
Floating or Submerged Material or Objects	Waters should not contain floating or submerged material or objects which would cause nuisance or or interfere with this use.	Calif.
Odour	Waters should not contain odorous or odour-producing substances in concentrations that would cause nuisance or render them unsuitable for use.	Calif.
Settleable Matter	Waters should not contain settleable matter in concentrations that cause deposits that would adversely affect this beneficial use.	Calif/VIC EPA (Y)
Suspended Solids	Waters should not contain suspended matter in concentrations that would render them unsuitable for use.	Calif.
Temperature	Ambient $\pm$ 2°C	VIC EPA (G)
pH	Maximum variation of 0.5 units from natural level.	WG
Surfactants	Waters should not contain surfactants in quantities that give rise to foam or otherwise interfere with their use.	Hart/WG
Oil and Grease	Waters should not contain oil, grease, wax or other similar materials in concentrations that result in a visible film or coating on the surface of the water, that cause nuisance or render the waters unsuitable for use.	Calif.
Other Chemicals	No chemical, other than those naturally occurring, should be present in concentrations that would adversely affect this beneficial use. The waters should not contain any toxicant or other material that would endanger personnel.	WG
Nutrients and Other Biostimulants	Added nutrients or growth stimulants should not cause excessive or nuisance algal or other plant growth.	VIC EPA (Y)
Radioactive Substances	Radioactive substances should not be present in concentrations that are deleterious to this beneficial use.	WG

BENEFICIAL USE NO. 15
POWER GENERATION

No specific water quality criteria for power generation by tides, waves, etc. have been found. The suggested criteria in Schedule 15 have been derived from those established for other beneficial uses which are judged relevant.

The prime requirements for the protection of this beneficial use are avoidance of corrosion, algal and other plant growths, undesirable floating objects and materials and settleable materials occurring in amounts or concentrations that are greater than those normally expected in marine and estuarine waters.

SCHEDULE 15

MARINE AND ESTUARINE WATER QUALITY CRITERIA FOR POWER GENERATION

Parameter	Criterion	Source
Aesthetic Considerations	As on page 8.	USA EPA (Comp)
Floating or Submerged Materials or Objects	Waters should not contain floating or submerged material or objects which cause nuisance or interfere with this use.	Calif.
Settleable Matter	Waters should not contain settleable matter in concentrations that cause deposits that would adversely affect this beneficial use.	Calif/VIC EPA (Y)
Suspended Solids	Waters should not contain suspended matter in concentrations that would render them unsuitable for use.	Calif.
pH	Maximum variation of 0.5 units from natural level.	USA EPA
Oil and Grease	Waters should not contain oil, grease, wax or other similar materials in concentrations that result in a visible film or coating on the surface of the water, that cause nuisance or render the waters unsuitable for use.	Calif.
Other Chemicals	No chemical, other than those naturally occurring, should be present in concentrations that would adversely affect this beneficial use. The waters should not contain any toxicant or other material that would endanger personnel.	WG
Nutrients and Other Biostimulants	Added nutrients or growth stimulants should not cause excessive or nuisance algal or other plant growth.	VIC EPA (Y)
Radioactive Substances	Radioactive substances should not be present in concentrations that are deleterious to this beneficial use.	WG

BENEFICIAL USE NO. 16
NAVIGATION AND SHIPPING

Waters for navigation and shipping should satisfy the following three requirements:

- Suitability for unobstructed passage of shipping and boats.
- Satisfactory physical and chemical properties for intake for engine room, motors and other uses.
- Physical, chemical and biological properties which will afford reasonable protection of port facilities, installations and equipment, and not cause unpleasant or unsafe conditions for crew, manpower, passengers and the general public.

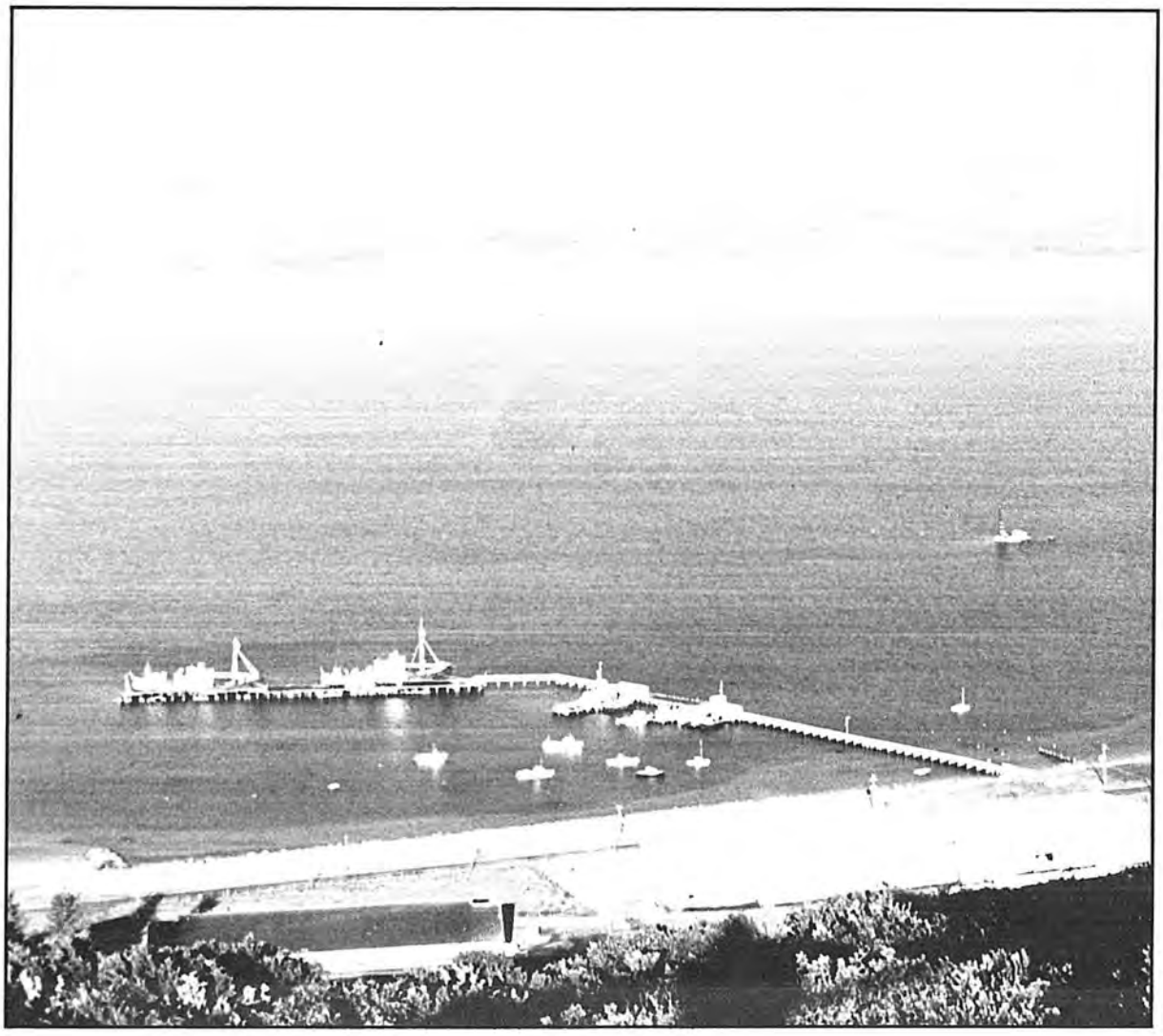
The criteria set out in Schedule 16 are designed to give a reasonable level of protection to shipping, port facilities, installations and equipment and also to personnel. They are mostly derived from water quality criteria for ocean waters published by the State Water Resources Control Board, California, USA.

SCHEDULE 16

MARINE AND ESTUARINE WATER QUALITY CRITERIA FOR NAVIGATION AND SHIPPING

Parameter	Criterion	Source
Aesthetic Considerations	As on page 8.	USA EPA (Comp)
Floating or Submerged Material or Objects	Waters should not contain floating or submerged material, or objects including solids, liquids, foams, and scum, in concentrations or amounts that cause nuisance or adversely affect this beneficial use.	Calif.
Odour	Waters should not contain odour-producing substances, in concentrations that cause nuisance or adversely affect this beneficial use.	Calif.
Settleable Matter	Waters should not contain substances in concentrations that result in deposition of material that causes nuisance or adversely affects this beneficial use.	Calif.
Suspended Solids	Waters should not contain suspended material in concentrations that cause nuisance or adversely affect this beneficial use.	Calif.
pH	6.0-9.0	WG
Surfactants	Waters should not contain surfactants in quantities that give rise to foam resulting from movement or use of the waters.	Hart/WG
Oil and Grease	Waters should not contain oil, grease, wax or other materials in concentrations that result in a visible film or coating on the surface of the water or on objects in the water, that cause nuisance, or that otherwise adversely affect this beneficial use.	Calif.
Chemical Constituents	Waters should not contain chemical constituents in concentrations that result in deterioration, excessive scale-formation or corrosion in or on vessels, port installations and structures, that cause nuisance, or that otherwise adversely affect this beneficial use.	FPA/WG
Radioactive Substances	Waters should not contain radioactive substances in concentrations that would cause their use as ballast water to be unacceptable or that would endanger the crews of vessels.	WG
Nutrients and Other Biostimulants	Waters should not contain nutrients or growth stimulants in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect this beneficial use.	Calif.

PRINCESS ROYAL HARBOUR



The southern port of Albany is situated on Princess Royal Harbour. Recreational use is made of these waters which also receive industrial discharges. A water quality study of the harbour highlighted the need for certain improvements.

Reference: Atkins, R.P. et al. (July 1980). "A Technical Report on the Water Quality of Princess Royal Harbour, Albany". Department of Conservation and Environment, Bulletin No. 74. Perth, Western Australia.

III. CONCLUDING STATEMENT AND RECOMMENDATIONS

The examination of relevant marine and estuarine water quality criteria from Australian and overseas authorities has enabled the Working Group to tabulate, for a range of parameters, corresponding criteria for various beneficial uses of the waters. During its investigation the Group found in many cases either a paucity of quantitative data or indeed a lack of consistency in data from different sources. Further, data from sources outside Western Australia are usually based on investigations under local conditions and may not be entirely relevant in the Western Australian context. This is especially significant in consideration of beneficial uses relating to aquatic life.

The Working Group at times exercised its own judgement and collective expertise in setting appropriate criteria. In recognition of the importance of accurate information and data for an effective environmental protection policy enabling the management of marine and estuarine waters, the Marine and Estuarine Water Quality Criteria Working Group recommends that:

1. The Report of this Working Group be submitted to public review.
2. The appropriate State and Federal authorities be advised of the Working Group's view on the need for toxicological studies, including radioactive substances, on Australian marine and estuarine species.
3. In view of the significant consequences of the presence of nutrients in the marine and estuarine environment, further concerted research aimed at quantifying nutrient criteria be undertaken, especially in those areas where anthropogenic nutrient contributions are greatest.
4. The Environmental Protection Authority establish a Standing Committee on Water Quality Criteria, with similar representation to that of this Working Group, with the following terms of reference:
   i) To review and update, in the light of new information and scientific knowledge, the State's water quality criteria for marine and estuarine waters.
   ii) To recommend on research and investigation priorities in marine and estuarine water quality.
   iii) To advise on the interpretation of criteria specified in its reports.

IV. GLOSSARY

antagonistic effect:	causing reduction of the effect of another chemical.
application factor:	a factor applied to the results of a short-term toxicity test to arrive at the concentration of a substance or mixture of substances which is considered acceptable.
beneficial use:	any use of the environment or any segment or element of the environment that is conducive to public benefit, welfare, safety or health. A beneficial use will require protection from the detrimental effects of any direct or indirect alteration of the environment.
bioaccumulation:	uptake and retention of environmental substances by an organism from its environment.
biostimulants:	those chemical compounds which lead to an increase in the rates or extent of metabolic processes in living organisms.
biota:	living organisms.
compensation point:	where the available light is such that the rate of synthesis of organic compounds equals the rate of respiratory breakdown.
consumer (heterotrophic organism):	an organism that consumes either other organisms or organic food material.
criteria:	the scientific yardsticks upon which a decision or judgement may be made concerning the ability of water of a given quality to support a designated beneficial use.
decomposers:	organisms, usually bacteria and fungi, which break down the organic compounds of dead organisms, utilising some of the products themselves and releasing inorganic nutrients for use by the primary producers.
direct contact recreation:	any recreational water use in which there is prolonged and intimate contact with the water, e.g. swimming and water skiing.
ecosystem:	a biological community together with the physical and chemical resources it requires to maintain its integrity.
environment:	the physical factors prevailing in the State, including the land, and the coastal waters, sea-bed and subsoil adjacent thereto, water, atmosphere, sound, odours, tastes and radiation, the social factor of aesthetics and all factors affecting animal and plant life.
estuary:	a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea-water is measurably diluted with fresh water derived from land drainage. An estuary may be permanently open to the sea; seasonally closed and open at one or more times each rainy season; or normally closed and only open following unusually heavy rains. Estuarine systems which are now permanently closed off from the sea nevertheless retain some estuarine characteristics.
faecal coliforms:	a group of micro-organisms normally found in the gut of warm-blooded animals, and whose presence in the environment is used as an indicator that faecal pollution has taken place.
food web:	a series of interconnecting food chains.
health investigation levels:	criteria which set out, in respect of certain parameters that may effect human health directly or indirectly, levels above which the appropriate authority should be notified so that it may investigate the circumstances and advise on any action necessary to prevent the occurrence of a situation potentially dangerous to health.
heterotrophic organism:	see "Consumer".
LC_{50}:	see "median lethal concentration".
marine waters:	those waters comprising the seas surrounding the coastline and which are never measurably diluted with fresh water derived from land drainage.
median lethal concentration:	the concentration of a toxicant which is lethal to 50 percent of the organisms tested under the test conditions in a specified time.
objectives:	the desirable, possibly long-term aims or goals of a water quality management programme. They are often derived after consideration of water quality criteria in the light of economic, social or political factors.
PCBs:	polychlorinated biphenyls, a group of organic compounds; may be confused with DDT since they exhibit many of the same characteristics in the environment.
pesticide:	any substance used to kill organisms; includes herbicides, insecticides, algicides, fungicides and others.

pollution:	any direct or indirect alteration of the environment to its detriment or degradation.
producers:	organisms which synthesise organic substances from inorganic substances using abiotic sources of energy.
salinity:	the concentration of dissolved mineral constituents, of all kinds, in waters.
Secchi disc:	a matt black disc, 150mm in diameter, used to measure the clarity of water.
six month median upper limit:	the concentration limit applied to the median of all samples taken within any six-month period.
standards:	current legally enforceable levels of parameters established by an authority. They may be arbitrarily established in the absence of technical data and may include a marginal factor of safety.
surfactant:	a surface active agent or detergent.
synergistic effect:	the combination of the effects of separate substances such that the total effect is greater than the sum of the individual effects.
TL_m:	see "median lethal concentration".
toxic substances:	substances which are harmful to living organisms.
trophic level:	position in the food chain (i.e. producer, consumer, etc.).
$\mu g/L$:	micrograms per litre.
°/oo:	parts per thousand.

V. SOURCES OF CRITERIA

Abbreviations used in Schedules

Calif.	State Water Resources Control Board, California. Water Quality Control Plan for Ocean Waters of California. **In:** A Compilation of State Water Quality Standards for Marine Waters, U.S. EPA, Office of Water Planning and Standards, Washington DC, April 1978. Page IX - 54.
Calif. (K&S)	L. Klapow and H. Schueller, Draft: Initial study to describe the environmental impact of proposed amendments to the "Water Quality Control Plan for Ocean Waters of California". Sacramento, California, State Water Resources Control Board, August 1977.
DH&MS	Various communications from Department of Health and Medical Services, Perth, Western Australia.
FPA	Communication from Fremantle Port Authority, Fremantle, Western Australia, 18 September, 1979.
Hart	B.T. Hart, A Compilation of Australian Water Quality Criteria, Technical Paper No. 7, Australian Water Resources Council, Canberra, Australia, 1974.
Maine	Department of Environmental Protection, Maine, Water Quality Criteria for tidal or marine waters, USA (no date). **In:** A Compilation of State Water Quality Standards for Marine Waters, U.S. EPA, Office of Water Planning and Standards, Washington DC, April 1978, page I-7.
NAS/NAE	Water Quality Criteria, 1972. National Academy of Sciences — National Academy of Engineering U.S. EPA, Washington, DC, 1973.
NH&MRC	National Health and Medical Research Council. Report of the 84th Session, Appendix XVI — Waters to be used for recreational purposes within designated areas, Canberra, Australia, November, 1977.
NSSP	Proceedings of the 8th National Shellfish Workshop, Sanitation Workshop, New Orleans, 1974. U.S. Department of Health, Education and Welfare.
USA EPA	Quality Criteria for Water, U.S. Environmental Protection Agency, Washington, DC, July 1976.
USA EPA (Comp)	A Compilation of State Water Quality Standards for Marine Waters, U.S. EPA Office of Water Planning and Standards, Washington, DC, April 1978.
VIC EPA (G)	State Environment Protection Policy (The Waters of Port Phillip Bay). Victoria Government Gazette No. 25, 10 April 1975.
VIC EPA (M)	Draft Manual of Recommended Water Quality Criteria. Environment Protection Authority, East Melbourne, Victoria, Australia, 1978.
VIC EPA (Y)	Draft State Environment Protection Policy — Waters of the Yarra River and Tributaries — with Explanatory Notes. Report no. W-29 (Draft 2). Environment Protection Authority, East Melbourne, Victoria, Australia, 1980.
WG	Marine and Estuarine Water Quality Criteria Working Group, Environmental Protection Authority, Perth, Western Australia.

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