Draft Environmental Quality Criteria Reference Document (Cockburn Sound)

A supporting document to the draft Environmental Protection (Cockburn Sound) Policy 2001

DECEMBER 2001

Environmental Protection Authority

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Tables

PREAMBLE

Cockburn Sound is a sheltered marine embayment located to the south-west of the Perth metropolitan region. The relatively calm waters have attracted a wide range of commercial activities that need to be managed to maintain the recreational and ecological attributes that are highly valued by the community. Land-use activities in the catchment to Cockburn Sound also have the potential to impact on the quality of the Sound and these also need to be managed appropriately.

In recognition of the need for effective multiple use management State Cabinet established the Cockburn Sound Management Council (CSMC) as a coordinating body for the management of Cockburn Sound. The CSMC was to prepare an Environmental Management Plan (EMP) for the Sound and the EPA agreed to prepare an Environmental Protection Policy (EPP) providing the authority for implementing the management plan.

The focus of the EPP is to declare, protect and maintain the Environmental Values of Cockburn Sound from the effects of pollutants, waste discharges and deposits. Environmental quality criteria have therefore been developed for Cockburn Sound to give effect to the EPP and enable environmental quality to be assessed under the EMP.

1. INTRODUCTION

Both Government and community have shown a desire to maintain a high level of quality in Perth's coastal waters in perpetuity. The EPA is establishing an environmental quality management framework for Cockburn Sound through the development of a draft Environmental Protection (Cockburn Sound) Policy (EPA, 2000b). The framework is underpinned by established environmental values and clearly expressed and spatially defined environmental quality objectives that guide decision-making and become the common goals for management. It is intended that the objectives reflect the values held by the community for the Cockburn Sound marine environment.

Implementation of the management framework will be through the Environmental Management Plan (EMP) developed by the Cockburn Sound Management Council and requires a cooperative approach that involves all stakeholders. Environmental quality criteria (EQC) play an important role in the management framework by providing the quantitative benchmarks for measuring success in achieving the environmental quality objectives. The goal of environmental management would therefore be to ensure that direct and indirect sources of contaminants are managed such that the EQC are met and the environmental quality objectives achieved. If exceeded, then the regulator, manager and discharger must cooperatively develop and implement management strategies, with timelines and interim objectives, to restore environmental quality to the levels defined by the EQC.

The EQC are provided in this document to support the Environmental Protection (Cockburn Sound) Policy and the EMP, and are relevant to the issues and potential pressures that currently exist in the Sound. Both the EQC, and the decision schemes explaining how the EQC should be applied, are included in this reference document. The decision schemes are also included in the EPP.

Development of the EQC has mainly been based on the guidelines and approaches recommended in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ 2000). In particular, the concept of using water quality guidelines for triggering a risk-based approach to determining whether a significant environmental impact is likely has been adopted. This risk-based approach integrates the more traditional chemical and physical indicators with biological indicators of environmental quality. Where necessary expert advice was also sought through the use of technical workshops and working groups to provide guidance on the development of specific criteria.

Sources of additional information used for the development of the EQC were the *Western Australian Shellfish Quality Assurance Program (HDWA & FWA, 1999)*, the *Australian and New Zealand Food Standards (ANZFA, 2000)* and advice from the Health Department of Western Australia.

In this reference document EQC have only been provided for contaminants considered relevant to Cockburn Sound based on known current and historical contaminant inputs. If other contaminants are likely to pose a potential threat to the environmental values of the Sound in the future then guidance should be sought from ANZECC & ARMCANZ (2000), HDWA & FWA (1999) and ANZFA (2000) to establish additional EQC.

1.1 The environmental quality management framework

The objective of the environmental quality management framework established for Cockburn Sound is to maintain a level of environmental quality that will protect both the integrity and biodiversity of the marine ecosystems as well as current and projected future societal uses of the Sound from the effects of pollution, waste discharges and deposits. The management framework is based on, and consistent with, the National Water Quality Management Strategy (NWQMS) and is underpinned by the principles of the National Strategy for Ecologically Sustainable Development (ESD Steering Committee, 1992). The management framework will be applied in consultation with the community and stakeholders.

Consistent with the NWQMS (ANZECC & ARMCANZ, 2000), a tiered approach has been used to develop the environmental quality management framework (Figure 1). One ecological and three social *environmental values* have been identified for protection in Perth's coastal waters (EPA, 2000a). Environmental Values include ecosystem health condition[1] and beneficial uses[2]. To support the four environmental values, seven *environmental quality objectives* have been defined (Figure 2) that form the primary management objectives. They signal the environmental quality needed to protect the Environmental Values that the community wants protected. For the first environmental quality objective *'Maintenance of ecosystem integrity'* three levels of protection have been recognised for Cockburn Sound. The acceptance of different levels of ecological protection is based on a recognition that other societal benefits also need to be considered (eg. use of marine waters for receiving waste and economic benefits of industrial development) when managing environmental quality and these may preclude a high level of quality being achieved. The boundaries for each environmental quality objective, and the different levels of protection, are defined in the draft Envirnomental Protection (Cockburn Sound) Policy 2001 (EPA, 2001).

For each environmental quality objective a set of *environmental quality criteria* have been established to provide the environmental quality benchmarks against which the performance of environmental management can be measured. Unlike the environmental values and environmental quality objectives, which are largely qualitative and described narratively, the criteria are more quantitative and usually described numerically. The key to successful environmental management is to maintain environmental quality within the bounds described by the EQC, thereby achieving the environmental quality objectives and ensuring the environmental values continue to be supported.

The final step in the management framework is the implementation of appropriate monitoring strategies to provide data for measuring environmental performance against the EQC. Monitoring should focus only on the environmental quality indicators for contaminants that were considered to pose a potential threat to achieving the environmental quality objectives and will need to be conducted at two levels. Firstly, the contaminant source should be monitored on an on-going basis to provide information on contaminant inputs and early warning of potential risks to environmental quality through environmental exposure modelling. This may

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[1] Means a condition of the ecosystem which is relevant to the maintenance of ecological structure, function or process.

[2] Means use of the environment, which is conducive to public benefit, public amenity, public safety, public health or aesthetic enjoyment.

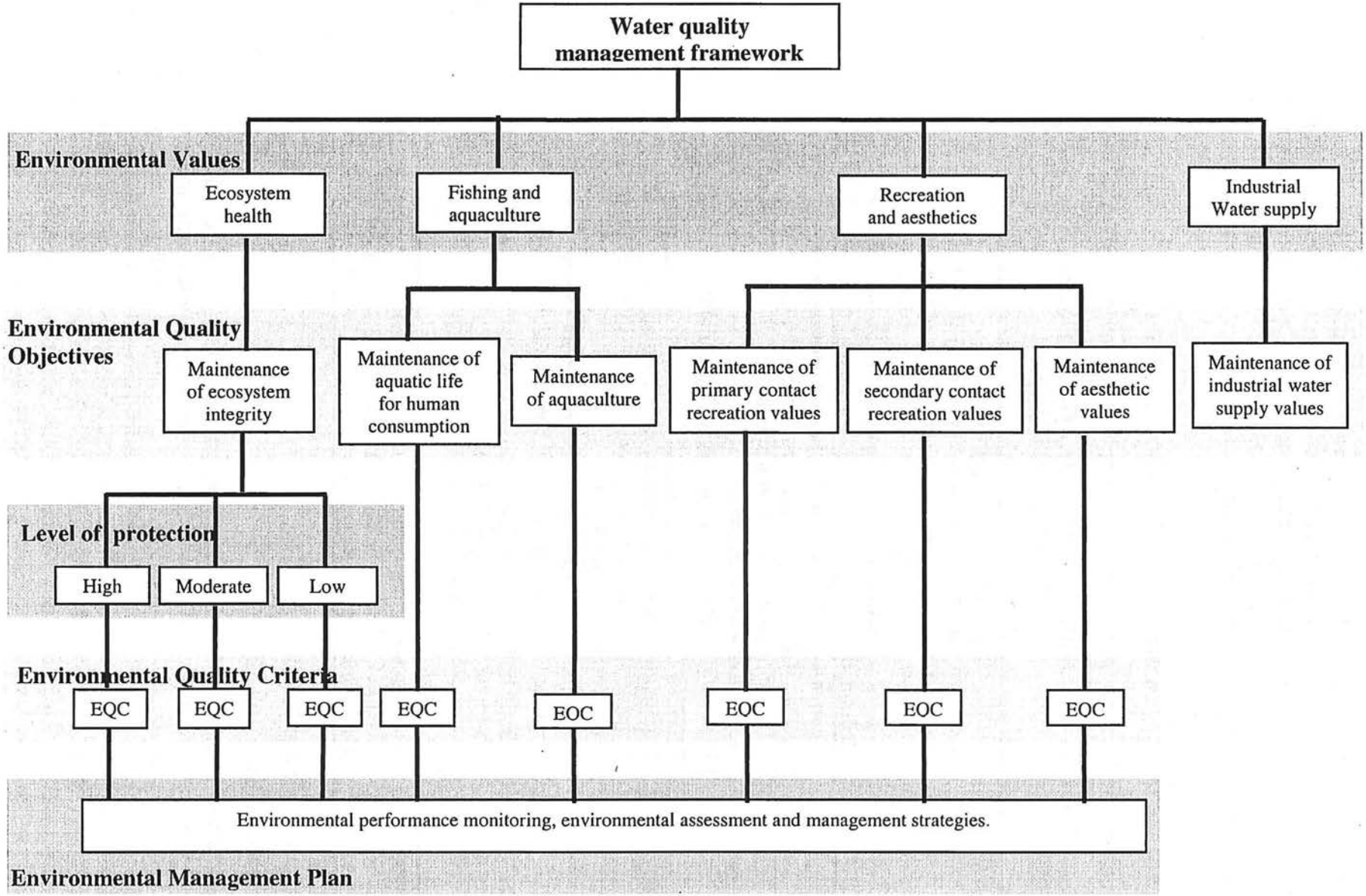


Figure 1 The environmental quality management framework for Cockburn Sound.

involve sampling an effluent stream, groundwater, stormwater drains or any other potential sources. Secondly, a program for monitoring the quality of the ambient environment is required. Sampling would be required on a less regular basis than at the contaminant source, and environmental quality assessment is likely to rely primarily on more integrative measures of exposure such as sediment and biota quality, phytoplankton, and the health of key components of the ecosystem (eg. seagrass).

Figure 2. *The EVs and their corresponding EQOs for Perth's coastal waters.*

ENVIRONMENTAL VALUES	ENVIRONMENTAL QUALITY OBJECTIVES AND THEIR DESCRIPTIONS
Ecosystem Health	***Maintenance of ecosystem integrity.*** Ecosystem integrity is considered in terms of structure (eg. the biodiversity, biomass and abundance of biota) and function (eg. food chains and nutrient cycles). Three levels of protection shall apply to Cockburn Sound (High, Medium, and Low).
Fishing and Aquaculture	***Maintenance of aquatic life for human consumption.*** Seafood will be safe for human consumption when collected or grown in Cockburn Sound. ***Maintenance of aquaculture.*** Water will be of a suitable quality for aquaculture purposes.
Recreation and Aesthetics	***Maintenance of primary contact recreation values*** Primary contact recreation (eg. swimming) will be safe to undertake in Cockburn Sound.
	Maintenance of secondary contact recreation values Secondary contact recreation (eg. boating) will be safe to undertake in Cockburn Sound.
	Maintenance of aesthetic values The aesthetic values of Cockburn Sound will be protected.
Industrial water supply	***Maintenance of industrial water supply values*** Water in Cockburn Sound will be of a suitable quality for industrial water supply purposes.

1.2 The EQC and their application

1.2.1 Environmental quality criteria

The Australian and New Zealand Guidelines for Fresh and Marine Waters (ANZECC & ARMCANZ, 2000) have recognised the inherent variability that exists within broad ecosystem types and that specific guidelines for a contaminant may need to be tailored to local environmental conditions when protecting ecosystem integrity. They have therefore recommended an approach where EQC are derived either using locally developed biological effects data, ecological models, reference sites, or by refining default trigger values using a risk-based approach that takes into account local environmental factors that modify the effect of a contaminant. The framework adopted for applying EQC to Cockburn Sound has been developed to be consistent with the recommended approaches in ANZECC & ARMCANZ 2000.

Two main types of EQC have been developed to remain consistent with ANZECC & ARMCANZ (2000).

Environmental quality guidelines (EQG) are threshold numerical values or narrative statements which if met indicate there is a high degree of certainty that the associated environmental quality objective has been achieved. If the guideline is not met then it is uncertain that the associated environmental quality objective has been achieved and a more detailed assessment against an environmental quality standard is triggered. This assessment will be risk-based and investigative in nature. EQG are generally equivalent to the water quality guidelines described in ANZECC & ARMCANZ (2000).

Environmental quality standards (EQS) are threshold numerical values or narrative statements that indicate a level beyond which there is a significant risk that the associated environmental quality objective has not been achieved and a management response is triggered. The response would focus on reducing loads of the contaminant of concern (ie. source control) but may also require *in-situ* remedial work to be undertaken. EQS are generally equivalent to the water quality objectives described in ANZECC & ARMCANZ (2000).

EQG are generally relatively simple and easy to measure indicators of environmental quality. If exceeded there is an increased risk that the associated environmental quality objective may not be met and this signals the need for a more comprehensive assessment against the EQS. This involves a risk-based approach that considers multiple lines of evidence and integrates more refined measures of the surrogate indicators (eg. bioavailable contaminant concentrations) with more direct measures of the environmental quality objective (eg. toxicity testing, in-situ biological effects or reduced growth of aquaculture stock). The conceptual framework for applying environmental quality guidelines and standards is illustrated in Figure 2.

Like all natural systems, the marine environment is subject to a high degree of natural variability and some indicators of environmental quality may vary significantly from season to season and/or between sites (eg. turbidity and light attenuation coefficient are generally greater inshore than offshore, or inshore nutrient concentrations may increase significantly over winter as a result of river flow). Much of this variability has been minimised by deriving EQC for specific seasons. For example, in Cockburn Sound the main period for nutrient related monitoring is the summer months when river flow is minimal. Nevertheless, seasonal and/or spatial variability is minimal for most indicators and the criteria for these indicators would apply throughout the year.

1.2.2 Applying the EQC

Both the numerical and narrative EQC for Cockburn Sound are provided in the tables in Section 2.8 below. They need to be considered within the context of the associated decision schemes and guidance notes also provided in the same section. The EQC, decision schemes and guidance notes together are a complete package and should not be used in isolation of each other.

The decision schemes have been developed to guide users through each step of this risk-based approach for implementation of the guidelines and standards. It should be noted that it may not always be necessary to complete all the steps in the decision schemes. In general each step of the decision scheme is more difficult to undertake and a cost/benefit analysis may need to be undertaken before proceeding. If the cost of proceeding to the next step outweighs the cost of implementing a management response, stakeholders could agree that the EQS has been exceeded and implement an appropriate management response to ensure the relevant environmental quality objective is achieved. Simplified pictorial representations of each decision scheme have been included to help illustrate the sequence of the steps involved.

One of the first steps to resolve when applying the EQC for a particular contaminant is to determine which of the criteria, from the range of environmental quality objectives established for the site,

should be compared against the monitoring data. In general the lowest EQG for a particular contaminant would be selected for this purpose and then investigations appropriate to the relevant EQS would be undertaken if the guideline was exceeded. However, for some EQOs there are only EQS for certain contaminants and routine monitoring data should be compared with these. It is also possible that for a particular contaminant the guideline for a second environmental quality objective is exceeded, in which case consideration should be given to whether exceedance of the second associated EQS needs investigation. Where EQG or EQS exist for a range of media (eg. concentrations in water vs. concentrations in organisms or sediment) monitoring programs may need to measure contaminants in each media type.

The EQC that have been developed for Cockburn Sound are comprehensive and quite detailed. Although decision schemes and guidance notes have been provided for their implementation, it is not possible to predict all likely scenarios that may arise. A commonsense approach to applying the EQC will therefore be required by all stakeholders for those circumstances where little guidance has been provided, but always bearing in mind the intent of providing surety that the environmental quality objective is achieved. For example, EQG should never be below natural background concentrations; and the chemistry and fate of rapidly degraded contaminants (eg. chlorine) should not be assumed to be conservative when considering the results of contaminant distribution modelling. Also, there may be circumstances where an EQG has been exceeded, but additional investigations indicate that the EQS has been met. In this situation the guideline should be modified whenever possible in light of the results so that an endless loop of unnecessary triggering further investigations is avoided.

An important point to remember regarding the management framework is that the EQC define the limits of acceptable change to environmental quality. They do not represent pollution levels that trigger enforcement action if exceeded.

1.2.3 Comparing monitoring data against the EQC

Whether or not monitoring is focussed on a particular season or region, there will still be a certain amount of variability in any monitoring data which can create a degree of uncertainty about whether or not the EQC has been exceeded. It is important to ensure that monitoring programs are designed to provide the appropriate level of temporal and spatial coverage to adequately characterise the area in question to minimise this uncertainty. Insufficient coverage can artificially bias the results leading to an apparent exeedance of a guideline or standard when in fact it was insignificant. Similarly, a poorly designed monitoring program can result in data that indicate a guideline or standard has not been exceeded, when in fact a significant exceedance has occurred and a response should have been triggered. Balancing these two errors (Type I and Type II error) is an important part of monitoring program design and sufficient effort must be allocated to ensuring enough samples are being taken for comparison to the EQC, and that these samples are representative of the site.

For comparing monitoring data with the EQC, and determining when a significant and unacceptable change has occurred, a relatively simple approach has been adopted that is consistent with the approaches in ANZECC/ARMCANZ (2000).

For toxicants and bacteriological indicators the preferred approach is to compare the 95th percentile of the monitoring data with the EQC.

For nutrients and physical stressors (eg. dissolved oxygen, light attenuation coefficient, temperature, salinity and pH) the approach for high protection areas is to compare the median of the test-site data with the 20th and/or 80th percentiles (depending upon the stressor under consideration) of an equivalent reference distribution, or with the default guideline trigger values provided in ANZECC & ARMCANZ (2000).

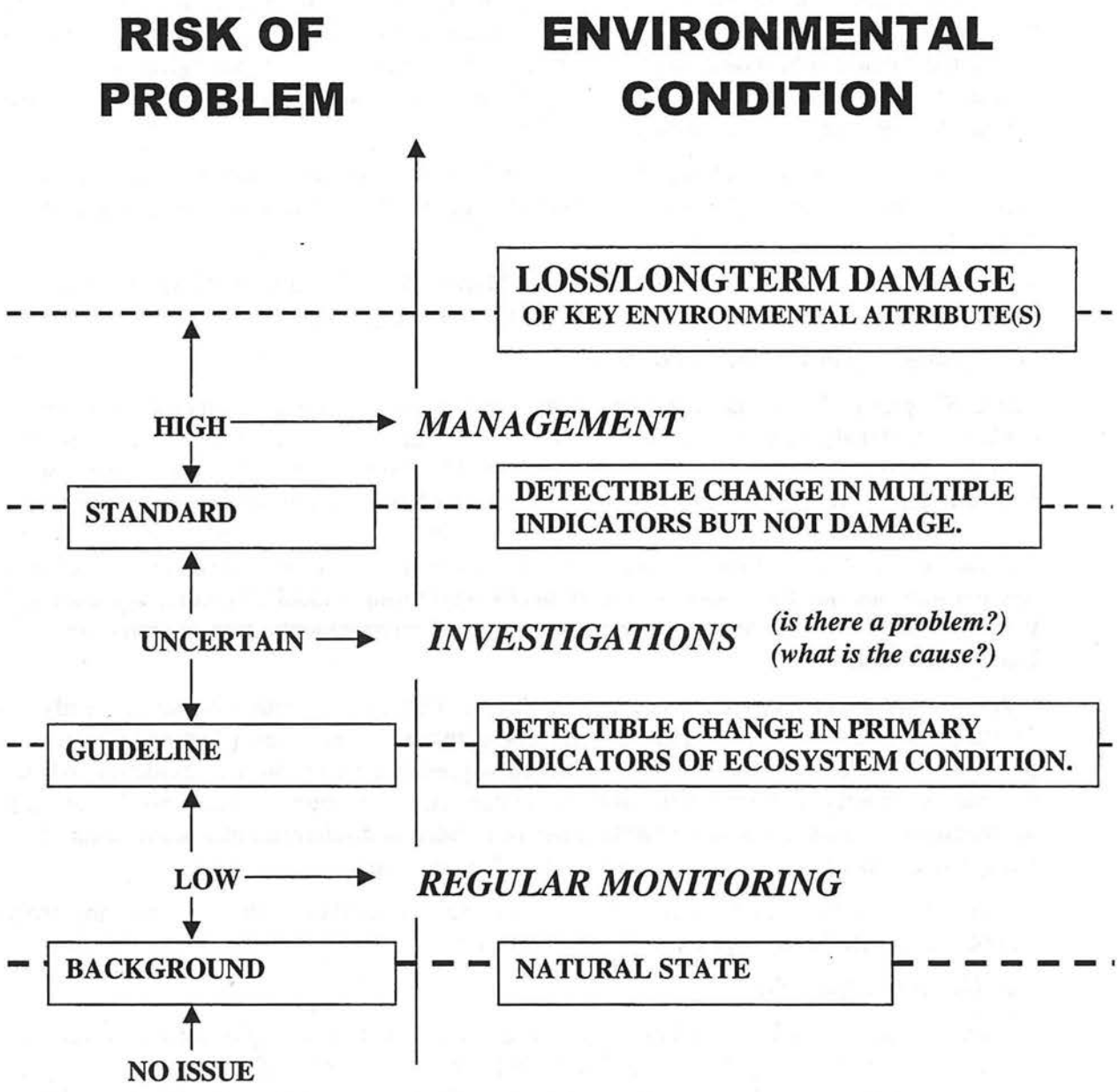


Figure 3. Conceptual diagram showing the relationship between the two types of EQC on the left hand side with the associated environmental condition on the right hand side. The diagram shows that the intensity of management response triggered by exceeding an EQC depends on which type of EQC has been exceeded which in turn reflects the level of risk of whether or not there is an environmental problem.

Again a common sense approach is required when selecting monitoring sites for comparison with the EQC. For example, if a number of sites were to be located around the boundary of a low protection zone to determine whether the moderate protection EQC were being met, then sampling would need to be undertaken on a number of occasions over a minimum of a month. If only one sampling run were conducted it could conceivably occur at a time when very unusual meteorological conditions prevailed. These conditions could cause the discharge plume to extend beyond the low protection zone boundary, albeit for a very short period of time.

For biological indicators control sites will be required to be compared with impact sites, and hence acceptable effect sizes (ie. the amount of change considered acceptable in a biological indicator) established.

The revised NWQMS Guidelines for Fresh and Marine Water Quality should be referenced for a more detailed discussion on comparing monitoring data with EQC.

1.2.4 Selecting indicators of concern

The EQC presented in the tables cover a wide range of environmental quality indicators (including contaminants) that can be used to assess environmental quality. The environmental quality indicators selected for routine monitoring would be determined by the relevant stakeholders on a case by case basis and are likely to be a small subset of the full list of criteria. The selection of indicators would be based on an assessment of the potential threats to environmental quality (past, current and future) and knowledge of the cause-effect pathways. Information that might be used to determine potential threats to environmental quality include: results of *in situ* monitoring, modelled predictions, contaminant input inventories and the nature of the contaminant (eg. environmental fate, potential for biomagnification).

Indicators that exceed, or are predicted to exceed, the EQGs continuously or intermittently would be selected for monitoring by default. Other factors to be considered when selecting indicators to be monitored include: whether there is an observed or predicted trend toward a guideline; whether there is some uncertainty associated with ambient concentrations or impacts; indicators that are at levels approaching the guidelines; demonstrated risk of accidental discharges; characterisation of background concentrations prior to an anticipated future threat.

The selected environmental quality indicators that are measured through the monitoring program are compared against the appropriate EQC.

1.3 Updating the EQC

As national guidelines and standards are updated and our understanding of the environmental processes and ecological pathways in Cockburn Sound improves it will be necessary to update the EQC in this document. The mechanism for revising the EQC is a public process undertaken by the EPA and is described in Schedule 6 of the Environmental Protection (Cockburn Sound) Policy (EPA, 2001). The EQC will be revised at least once in the first two years following their initial release and then as required.

2 THE ENVIRONMENTAL QUALITY CRITERIA

This section contains the numerical and narrative EQC and the risk-based decision schemes (outlining how the EQC should be applied) for the following six environmental quality objectives (see sub-sections below):

- Maintenance of ecosystem integrity;
- Maintenance of aquatic life for human consumption;
- Maintenance of aquaculture;
- Maintenance of primary contact recreation values;
- Maintenance of secondary contact recreation values;
- Maintenance of aesthetic values.

EQC for the maintenance of ecosystem integrity have been further subdivided into those that apply to nutrients and physical stressors, toxicants in water and toxicants in sediment. Where additional information was required to assist with interpretation of the EQC it was provided under the heading 'Guidance notes'.

In the sections below a brief summary is provided for each environmental quality objective outlining the main sources of information used to develop the EQC and the rationale underpinning them. The tables containing the actual EQC (and their associated decision schemes) have been incorporated into Section 2.8 as shown in Figure 4.

Figure 4. *An overview of the tables of EQC..*

Environmental value	**Environmental quality objective**	**Environmental quality criteria**
Ecosystem health	Ecosystem integrity	Tables 1 & 1a (physical/chemical indicators) Table 2 (Toxicants in water and sediment pore waters) Table 3 (Toxicants in sediment)
Fishing and aquaculture	Seafood safe for eating	Table 4
	Aquaculture production	Table 5
Recreation and aesthetics	Primary contact	Table 6
	Secondary contact	Table 7
	Aesthetic values	Table 8
Industrial water supply	Industrial water supply	(no environmental quality criteria)

2.1 Maintenance of ecosystem integrity

The EQC for the EQO of maintaining ecosystem integrity have only been included for those contaminants thought to have been discharged to Cockburn Sound through groundwater, surface waters or licensed effluent disposal, and for which guidelines were available through the NWQMS.

The Draft Environmental Protection (Cockburn Sound) Policy (EPA, 2001) describes three levels of ecological protection and where they apply in Cockburn Sound so that overall ecological integrity can be maintained. This enables impacts from landuse activities in the adjacent catchment to be accommodated without unduly compromising the high level of environmental quality that currently exists over the majority of the Sound. EQC have been developed for each level of protection with the aim of achieving the following broad objectives:

High protection: To allow small changes in the quality of water, sediment or biota (*eg. small changes in contaminant concentrations with no resultant detectable changes beyond natural variation in the diversity of species and biological communities, ecosystem processes and abundance/biomass of marine life*).

Moderate protection: To allow moderate changes in the quality of water, sediment and biota (*eg. moderate changes in contaminant concentrations that cause small changes beyond natural variation in ecosystem processes and abundance/biomass of marine life, but no detectable changes from the natural diversity of species and biological communities*).

Low protection: To allow for large changes in the quality of water, sediment and biota (*eg. large changes in contaminant concentrations causing large changes beyond natural variation in the natural diversity of species and biological communities, rates of ecosystem processes and abundance/biomass of marine life, but which do not result in bioaccumulation/biomagnification in near-by high protection areas*).

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000) has been the key reference document and all of the numerical EQC, or the approaches for deriving these values, have been drawn from this reference. Accordingly, EQG have been allocated to each level of protection.

Although areas along the west side of Cockburn Sound are likely to be in slightly disturbed condition or better, the environmental quality of the majority of the Sound is considered to be in a slightly to moderately disturbed condition and has been provided a high level of protection. The EQG for this level of protection have been developed in accordance with the recommendations of ANZECC & ARMCANZ (2000) as follows:

- The recommended combination of 95% and 99% species protection guideline trigger levels for toxicants in water;
- The ISQG-low guideline trigger levels for toxicants in sediments;
- 80th percentile of the data distribution for a suitable relatively unmodified reference site for the physical and chemical stressors.

The area along the eastern side of Cockburn Sound adjacent to the industrial area and also Careening Bay on Garden Island has been designated a moderate level of protection and a lower level of environmental quality can be expected. EQG for these areas have been developed in accordance with the ANZECC & ARMCANZ (2000) recommendations as follows:

- Application of the default 90% species protection guideline trigger levels for toxicants in water;

- The ISQG-low guideline trigger levels for toxicants in sediments;
- The 95th percentile of the data distribution for a suitable relatively unmodified reference site for the physical and chemical stressors.

For the few small areas located around outfalls that have been designated low protection, EQG have only been proposed for those toxicants identified as having the potential to adversely bioaccumulate or biomagnify. These EQG are the default 80% species protection guideline trigger values from ANZECC & ARMCANZ (2000).

The reference sites selected for determining environmental quality guidelines for the physical and chemical stressors may vary according to the parameter being measured. The intent is for the reference to be as similar as possible to the water body being managed in terms of physical setting, hydrodynamics and biology, but as far as possible it should be unaffected by anthropogenic influences.

The nutrient-related EQG for seagrass and periphyton collectors have been based on reference data collected from the western and northern sides of Cockburn Sound at sites distant from known nutrient sources. A site in Warnbro Sound was also used as a reference for periphyton collectors. The Cockburn Sound sites for these indicators were considered acceptable because they tend to be affected by long-term chronic stress and tend not to respond significantly to short-term fluctuations in the stressors that affect them. Nutrient effects at the western and north-western ends of Cockburn Sound over summer are minor and intermittent with only occasional elevations in phytoplankton caused by currents translocating algal blooms from the eastern side of the Sound. It was also recognised that periphyton can be strongly influenced by proximity to, and types of habitats that provide sources of propagules.

Data from the western side of Cockburn Sound were not used to develop the chlorophyll *a* and light attenuation criteria. There was considered to be a high likelihood that parcels of water from the eastern margin, high in chlorophyll *a,* would be detected (albeit infrequently) on the western side, thus biasing the higher percentiles of the reference data set from which the EQG are derived. The reference site for deriving these EQG needed to be independent of Cockburn Sound because of this. The EQG selected for chlorophyll *a* and light attenuation in Cockburn Sound are based on data collected from a reference site in Warnbro Sound during 'typical' summer conditions. The chlorophyll *a* and light attenuation data were collected at one site in central Warnbro Sound between December and March (the non river flow period) at irregular intervals between 1977/78 and 1993/94. The 1991/92 summer data set was omitted from the analysis on the basis that it represented 'atypical' conditions. Phytoplankton studies conducted between 1991 and 1994 found that a winter bloom of a very distinctive phytoplankton called a silicoflagellate persisted into the summer of 1991/92 resulting in very high chlorophyll *a* concentrations. This pattern was not repeated and phytoplankton species composition and chlorophyll *a* levels returned to normal in the two subsequent summer periods. Investigations concluded that the high chlorophyll *a* levels in Warnbro Sound during the summer of 1991/92 were 'atypical' (DEP, 1996). Inclusion of these 'atypically high' values would have significantly raised the higher order percentiles and any criteria derived from them.

The methods described through the decision schemes for applying the EQC have also been developed from the risk-based and integrated assessment approaches recommended in ANZECC/ARMCANZ (2000) for assessing environmental quality. They begin with simple chemical measures which if exceeded lead to ever more sophisticated monitoring and analytical steps that consider bioavailability of the contaminant and then actual impacts on the biota or ecological processes.

ANZECC/ARMCANZ (2000) also provided *low reliability values* for a number of toxicants where there was insufficient toxicological data to develop high or moderate reliability guideline trigger levels. These were provided to give guidance in the absence of any higher reliability guidelines being

available. Low reliability values were derived by applying larger application (safety) factors to the limited toxicological data for the toxicant to account for the greater uncertainty. Where low reliability values were available for chemicals that may potentially have entered Cockburn Sound (eg. Arsenic), they have also been included in Table 2, for guidance only. Low reliability values are not EQG and do not establish recommended benchmarks for the management of water quality (eg. through the licensing process). Exceedance of low reliability values does not trigger mandatory assessments against environmental quality standards, but it does signal to stakeholders that the possibility of ecological impact needs consideration if further increases beyond the low reliability values are likely. In these situations strategies should be developed in consultation with key stakeholders to ensure unacceptable impacts are avoided. It is also possible to upgrade the low reliability values into EQG by undertaking the additional ecotoxicological tests necessary to meet the minimum data requirements recommended by Anzecc & Armcanz for moderate or high reliability guideline trigger values.

2.2 Maintenance of aquatic life for human consumption

The two primary reference documents for development of the environmental quality guidelines and standards for this EQO are the *Western Australian Shellfish Quality Assurance Program* (HDWA & FWA, 1999) and the *Australian and New Zealand Food Standards Code (ANZFA, 2000).*

These EQC set a level of environmental quality that will ensure there is a low risk of any affect on the health of human consumers of seafood. They can therefore be applied to environments where both commercial and amateur harvesting of wild fish populations occurs, or to areas where aquaculture activities are undertaken. They do not protect the fish populations, or aquaculture species, themselves. To protect the wild fish populations from the affects of environmental contamination the environmental quality guidelines and standards for maintaining ecosystem integrity (Section 2.1) are recommended. These should protect the harvested species as well as the foodwebs, habitats and other environmental processes that support them. Application of the guidelines and standards in Section 2.3 should maintain the health and productivity of aquaculture species.

The environmental quality guidelines are relatively easily measured indicators of a potential threat to human health and are therefore intended to be used as triggers that initiate a program of monitoring and assessment against the relevant environmental quality standards. The standards are intended to confidently predict whether there is a significant risk to the health of human consumers and are therefore based on contaminant levels in the flesh of the seafood species and have been taken from the Food Standards Code. For copper, selenium and zinc guidelines based on the 90^{th} percentile of contaminant levels that would typically be expected in the flesh of food species have been provided. These are the Generally Expected Levels (GELs) provided by ANZFA for guidance in the document *Generally Expected Levels (GELs) for Metal Contaminants: Additional guidelines to maximum levels in Standard 1.4.1 – Contaminants and Natural Toxicants* (ANZFA, 2001).

The EQC are provided in Table 4. Included with the table are guidance notes clarifying particular aspects of EQC application and the Decision Scheme detailing how the EQC should be applied.

2.3 Maintenance of aquaculture

The EQC for the maintenance of aquaculture have been developed from ANZECC/ARMCANZ (2000). The environmental quality guidelines have been taken directly from this document while the environmental quality standards are adapted from the suggested risk-based approach that is triggered if these guidelines are exceeded. Reference to ANZECC/ARMCANZ (2000) will be necessary when comparing water quality with guidelines for specific species groups (step 6 of the decision scheme). Aquaculture species have been divided into a number of related groups and, if available, guidelines

are provided for each group individually. The species groups are: freshwater fish, marine fish, brackish water fish, freshwater crustaceans, marine crustaceans, edible bivalves, pearl oysters and gastropod molluscs.

The EQC are provided in Table 5 and have been developed to maintain the health and productivity of aquaculture species. Included with the table are guidance notes clarifying particular aspects of EQC application and the Decision Scheme detailing how the EQC should be applied. To maintain this environmental quality objective an important focus for management will be to ensure that these EQC are met at the boundary of aquaculture leases in Cockburn Sound.

To protect the health of human consumers of seafood grown in Cockburn Sound, the EQC in Section 2.2 should be applied.

2.4 Maintenance of primary contact recreation

Primary contact recreation includes all recreational activities where the participant comes into frequent direct contact with the water, either as part of the activity or accidentally (eg. swimming, water skiing, wind surfing or diving). The EQC included under this section are intended to protect people undertaking these activities from ill effects caused by poor water quality.

The EQC for primary contact recreation have been drawn primarily from ANZECC/ARMCANZ (2000), but with modification based on advice from the Health Department of Western Australia.

The environmental quality guidelines and standards for faecal pathogens, and the standards for radionuclides and toxic chemicals, were derived in consultation with the Health Department of Western Australia. The approaches used for deriving the EQC are outlined below.

The criteria for faecal pathogens are based on the outcomes of the World Health Organisation Expert Consultation at Farnham, UK, convened in April 2001 to revise Volume 1, Chapter 4 of the draft WHO *Guidelines for Safe Recreational-water Environments* (WHO, 1998). The draft report of the Farnham Consultation, *Bathing Water Quality and Human Health: Faecal Pollution* (WHO, 2001) is expected to be available late in 2001. The approach taken in deriving these criteria is expected to be consistent with the approach that will be taken by the National Health and Medical Research Council when updating the *Australian Guidelines for Recreational Use of Water* (NHMRC 1990).

For radionuclides the preferred approach of the Health Department was for it to be advised of any monitoring that is to be undertaken and that all results should be referred to the Radiological Council for advice. Currently there are no internationally accepted standards for radionuclides in water used for recreational purposes.

The environmental quality guideline values for toxic chemicals were derived by multiplying the Australian Drinking Water Guidelines (NHMRC & ARMCANZ, 1996) by a factor of 20. This is based on an assumption that swimmers in marine waters will not consume more than 0.1 litres of water in a day during a normal swimming session compared to the assumed consumption of 2 litres per day used for the development of drinking water guidelines.

2.5 Maintenance of secondary contact recreation

Secondary contact recreation includes recreational activities in which the participant comes into direct contact with the water infrequently, either as part of the activity or accidentally (eg. boating, canoeing or fishing). The EQC included under this section are intended to protect people undertaking these types of activities from ill effects caused by poor water quality.

The EQC for secondary contact recreation have been drawn primarily from ANZECC/ARMCANZ (2000), although the criteria for faecal pathogens have been based on advice from the Health Department of Western Australia. For faecal pathogens the guidelines and standards have been set at an order of magnitude higher than the equivalent criteria for primary contact recreation.

2.6 Maintenance of aesthetic values

Cockburn Sound is the most intensively used marine embayment in Western Australia and is highly valued by the community for its ecological, recreational and aesthetic attributes. These EQC have been developed to protect the aesthetic values of the Sound. The criteria focus mainly on maintaining the visual amenity of its waters and ensuring that fish harvested for human consumption (by recreational or commercial activities) are not tainted.

The environmental quality guidelines have mainly been taken from ANZECC/ARMCANZ (2000) with some modification based on the outcomes of a workshop on aesthetic values held by the Cockburn Sound Management Council (Cleary, 2001).

The guidelines for fish tainting substances are based on levels of contaminants that may make water or edible marine life unpalatable (but not toxic) to people. In ANZECC/ARMCANZ (2000) they are found in the section on Aquaculture and human consumption of aquatic foods (under Primary Industries) and remain unrevised since their initial release in 1992. To develop the fish tainting substance guidelines for Cockburn Sound the guidelines contained in ANZECC/ARMCANZ (2000) were revised against the latest USEPA criteria for organoleptic effects (USEPA, 1999). The levels for 2,4-dichlorophenol, 2,5-dichlorophenol, 2,6-dichlorophenol, 3-methyl-4-chlorophenol and phenol have been revised accordingly.

The EQS for the visual indicators is based on the results of a community survey undertaken to determine whether the objective of maintaining aesthetic values has been met. The survey should focus on perceived changes in the parameters listed under the EQGs.

2.7 Maintenance of industrial water supply

Industrial water supply has a high economic benefit to the community and is recognised as an important environmental value that must be given adequate consideration in the planning and management of Cockburn Sound. ANZECC & ARMCANZ (2000) did not provide any specific guidance for industrial water supply because water quality requirements vary considerably between (and within) industries, and because management of the water resource tends to be driven by other coincidental environmental values that require better quality water. Therefore no guidelines have been developed for industrial water supply in Cockburn Sound.

2.8 Tables of EQC and the Decision Schemes for their application

The following tables contain the draft environmental quality guidelines and draft environmental quality standards for Cockburn Sound that support the draft Environmental Protection (Cockburn Sound) Policy. Included with the tables are the decision schemes guidance notes to guide how these EQC are applied. The table in Figure 4 (Section 2) summarises where the EQC for each environmental quality objective or environmental value are found.

Table 1. Narrative environmental quality criteria for protecting the marine ecosystem from the effects of physical and chemical stressors

Definitions:

Ambient Value is the median value of individual sample data for a defined area

Defined Area is the area to be characterised for environmental quality against pre-determined environmental quality objectives and levels of protection. The defined area can be equivalent to the entire EQO1 level of protection zone, or a subset of that zone.

Non river-flow period is the period December to March inclusive and when river and estuarine flows are weak.

	Environmental Quality Guideline		Environmental Quality Standard	
	High protection	**Moderate protection**	**High protection**	**Moderate protection**
	Water Quality Measures		**Water Quality Measures**	
	Chlorophyll a and Light Attenuation			
A	Ambient value of the defined area during the non river-flow period is not to exceed the value for that indicator as specified in Table 1a	Ambient value of the defined area during the non river-flow period is not to exceed the value for that indicator as specified in Table 1a		

	Dissolved Oxygen Concentration			***Dissolved Oxygen Concentration*** *Further work required on EQS.*	
B	Ambient value for dissolved oxygen concentration in bottom waters is greater than the value for that indicator as specified in Table 1a at any site.	Ambient value for dissolved oxygen concentration in bottom waters is greater than the value for that indicator as specified in Table 1a at any site.	**B**	Ambient value for dissolved oxygen concentration in bottom waters is greater than the value for that indicator as specified in Table 1a at any site and No significant change in any ecological or biological indicators beyond natural variation that can be demonstrably linked to poorly oxygenated waters. and No deaths of marine organisms resulting from deoxygenation.	Ambient value for dissolved oxygen concentration in bottom waters is greater than the value for that indicator as specified in Table 1a at any site and No persistent (ie, ≥4 weeks) and significant change in any ecological or biological indicators beyond natural variation that can be demonstrably linked to poorly oxygenated waters. and No deaths of marine organisms resulting from deoxygenation.
	Water Temperature			***Water Temperature*** *Further work required on EQS.*	
C	Median temperature at individual site over any season, measured according to SOP, not to exceed: - the 80%ile of the natural temperature range over the same period or - the median temperature at a reference site over the same period by more than the temperature values specified in Table 1a for that indicator.	Median temperature at individual site over any season, measured according to SOP, not to exceed: - the 95%ile of the natural temperature range over the same period or - the median temperature at a reference site over the same period by more than the temperature values specified in Table 1a for that indicator	**C**	No significant change in any ecological or biological indicators beyond natural variation that can be demonstrably linked to anthropogenically-sourced thermal stress. and No deaths of marine organisms resulting from anthropogenically-sourced thermal stress.	No persistent (ie, ≥4 weeks) and significant change in any ecological or biological indicators beyond natural variation that can be demonstrably linked to anthropogenically-sourced thermal stress. and No deaths of marine organisms resulting from anthropogenically-sourced thermal stress.

Table 1 Continued.

	Environmental Quality Guideline		Environmental Quality Standard	
	High protection	**Moderate protection**	**High protection**	**Moderate protection**
	In-direct Biological Measures	**In-direct Biological Measures**	**In-direct Biological Measures**	**In-direct Biological Measures**
	Algal Growth Potential			
D	Ambient value for periphyton biomass during the non river-flow period does not exceed the value for that indicator as specified in Table 1a at any site	Ambient value for periphyton biomass during the non river-flow period should not exceed the value for that indicator as specified in Table 1a at any site		
	Direct Biological Measures		**Direct Biological Measures**	
	Phytoplankton Blooms		***Phytoplankton Blooms***	
E	Ambient value for phytoplankton biomass measured as chlorophyll *a* does not exceed the value for that indicator, as specified in Table 1a, on any occasion during the non river-flow period, and Phytoplankton biomass measured as chlorophyll *a* at any site does not exceed the value for that indicator, as specified in Table 1a, on 25% or more occasions	Ambient value for phytoplankton biomass measured as chlorophyll *a* does not exceed the value for that indicator, as specified in Table 1a, on more than one occasion during the non river-flow period and Phytoplankton biomass measured as chlorophyll *a* at any site does not exceed the value for that indicator, as specified in Table 1a, on 50% or more occasions	**E** Ambient value for phytoplankton biomass measured as chlorophyll *a* does not exceed the value for that indicator, as specified in Table 1a, on more than one occasion during the non river-flow period and in two consecutive years and Phytoplankton biomass measured as chlorophyll *a* at any site does not exceed the value for that indicator, as specified in Table 1a, on 25%	Ambient value for phytoplankton biomass measured as chlorophyll *a* does not exceed the value for that indicator, as specified in Table 1a, on more than three occasions during the non river-flow period and in two consecutive years and Phytoplankton biomass measured as chlorophyll *a* at any site does not exceed the value for that indicator, as specified in Table 1a, on 50%

during the non river-flow period	during the non river-flow period		or more occasions during the non river-flow period and in two consecutive years	or more occasions during the non river-flow period and in two consecutive years
			Seagrass	
		F	**Ambient values for seagrass meadow shoot density during January and in two consecutive years is:** - greater than the 20th percentile of seagrass meadow shoot density at an appropriate reference site or - greater than the value for that indicator as specified in Table 1a, and Ambient values for seagrass meadow shoot density in any one year is: - greater than the 5th percentile of seagrass meadow shoot density at an appropriate reference site or - greater than the value for the minimum shoot density indicator as specified in Table 1a and The upper and lower depth limit of seagrass meadows must not show a statistically significant retreat relative to baseline distribution	Ambient values for seagrass meadow shoot density during January and in two consecutive years is: - greater than the 5th percentile of seagrass meadow shoot density at an appropriate reference site or - greater than the value for that indicator as specified in Table 1a and Ambient values for seagrass meadow shoot density in any one year is: - greater than the 1st percentile of seagrass meadow shoot density at an appropriate reference site or - greater than the value for the minimum shoot density indicator as specified in Table 1a and The upper and lower depth limit of seagrass meadows must not show a statistically significant retreat relative to baseline distribution

TABLE 1a. Numerical environmental quality criteria for protecting the marine ecosystem from the effects of physical and chemical stressors

Footnotes	Environmental Quality Indicators	Environmental Quality Guidelines		Environmental Quality Standards		- notes -
		High protection	Moderate protection	High protection	Moderate protection	
	Water Quality Measures					
	Physical and Chemical					
A	Chlorophyll *a* ($\mu g\ L^{-1}$)	0.802	1.031			
B	Light Attenuation Coefficient (m^{-1})	0.087	0.124			
C	Dissolved Oxygen	90% saturation*	90% saturation*	5 mg L^{-1}.	4 mg L^{-1}.	Further work required on EQS.
D	Temperature (°Centigrade)					
	Season	*Value*	*Value*			Further work required on EQS.
	Summer	0.8	1.6			
	Autumn	1.9	3.1			
	Winter	0.5	1.5			
	Spring	1.2	3.0			
	In-direct Biological Measures					
	Algal Growth Potential					
E	Periphyton (mg chl *a* m^{-2})					
	2.0 - 2.5 m depth	35	41			
	7.0 - 8.0 m depth	30	43			

	Direct Biological Measures					
	Phytoplankton Blooms					
F	Chlorophyll *a* ($\mu g\ L^{-1}$)	1.72	2.41	1.72	2.41	
G	*Seagrass*					
	- median shoot density (shoots m^{-2})					
	2.0 - 2.5 m depth			600	450	
	7.0 - 8.0 m depth			400	300	
	- minimum shoot density (shoots m^{-2})					
	2.0 - 2.5 m depth			450	330	
	7.0 - 8.0 m depth			300	260	

Footnotes:

A Measured spectrophotometrically. Sites should be sampled weekly. Refer to SOP for detailed sampling and analytical requirements.

B Preferably measured using data loggers according to SOP; expressed on $\log_{10}$ basis.

C Dissolved oxygen measured in daylight hours. Bottom waters is 0-50 cm from sediment surface. Significant is defined by key stakeholders; persistent is ≥4 weeks.

D Temperature measured at 50 centimetres below the water surface and 50 centimetres above the sediment surface and seasonal median compared with EQC in table 1a. The preferred approach for measuring temperature is to use integrated data loggers according to SOP.

E Measured as chlorophyll *a* concentration of total growth on vertically-oriented rigid substrate, 28 day deployments (check). Chlorophyll *a* determinations same as for phytoplankton chlorophyll *a*, after grinding and extraction in 90% acetone extraction. (SL for methods)

F Values are three times median chlorophyll *a* concentration of reference site for high protection areas; three times 80^{th} percentile of reference site for moderate protection areas, during the non river-flow period. Samples to be measured spectrophotometrically Data should be omitted if *Oscillatoria erythraea* is abundant (ie >10% composition) or visible as surface slicks

G Measured non-destructively, re-locatable sampling points preferred. Where site depths other than 7-8 m or 2-2.5 m are monitored, the criteria should be based on values derived from modelling scenarios or from other appropriate reference site data.

Narrative decision scheme for applying the EQC for physical and chemical stressors

1. Conduct routine monitoring program covering the area to be assessed using Standard Operating Procedures. Monitoring program should be designed to allow assessment of environmental quality against EQG (A,B,C,D and E) ..... go to step 2

2. Determine whether nutrient-related EQG (A, D or E) has been exceeded
   [N] ..... go to step 3
   [Y] ..... go to step 5 unless back-up samples or immediate resampling does not confirm exceedance of the EQG.

3. Determine whether dissolved oxygen-related EQG (B) has been exceeded
   [N] ..... go to step 4
   [Y] ..... go to step 8 unless immediate re-measurement does not confirm exceedance of the EQG.

4. Determine whether temperature-related EQG (C) has been exceeded
   [N] ..... go to step 1
   [Y] ..... go to step 9

The EQG is exceeded triggering more intensive investigation. Ambient quality is now monitored and assessed against the Environmental Quality Standard

5. Revise monitoring program as appropriate and implement to allow assessment of environmental quality against EQS (E and F) ..... go to step 6

6. Determine whether EQS (E or F) has been exceeded
   [N] ..... go to step 1
   [Y] ..... go to step 7

7. Determine whether EQG (A or D) has been exceeded

[N] ..... go to step 1, and investigate possible non nutrient-related causes of exceedence of EQS

[Y] ..... **Management response required** **go to step 10**

8. Determine whether EQS (B) has been exceeded

[N] ..... go to step 1

[Y] ..... **Management response required** **go to step 10**

9. Determine whether EQS (C) has been exceeded

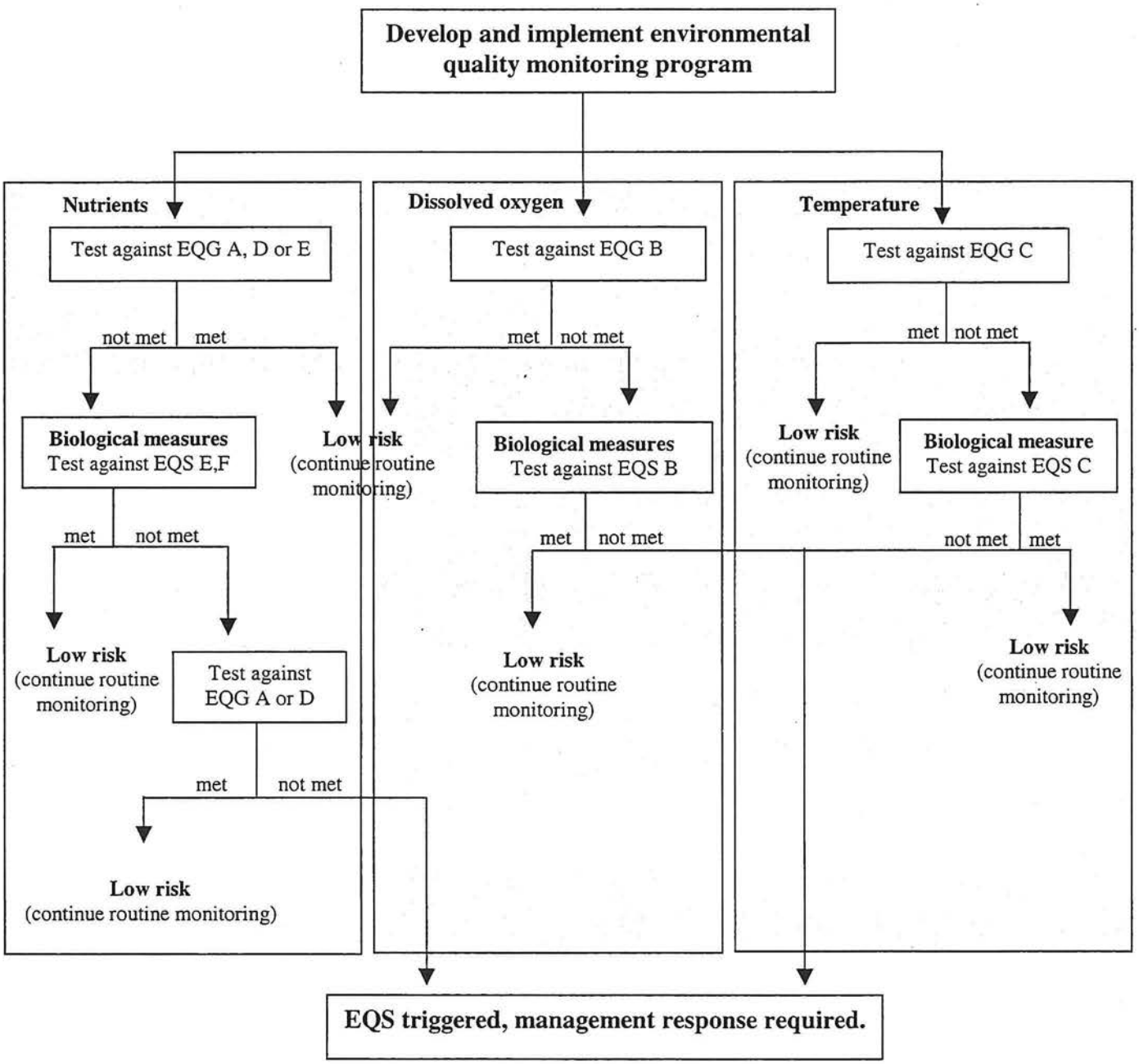
[N] ..... go to step 1

[Y] ..... **Management response required** **go to step 10**

The EQS is exceeded triggering a management response.

10. Initiate management response to reduce contaminant loads and restore environmental quality to comply with the objectives within specified timeframes.

Pictorial decision scheme for applying the EQC for physical and chemical stressors



* And investigate non nutrient-related causes of exceedances.

TABLE 2. Environmental quality criteria for protecting the marine ecosystem from the effects of toxicants in marine waters and sediment pore waters

Environmental Quality Guidelines (values in bold) **and Low Reliability Values**[□] (values in italics)

Environmental Quality Standard

A. The 95%ile of the sample concentrations from the area of concern (either from one sampling run or all samples over an agreed period of time, or from a single site over an agreed period of time) should not exceed the environmental quality guideline value.

B. Where there are mixtures of toxicants, TTM should not exceed 1 for the area of concern using the total toxicity of mixtures formula[H].

Chemical	High protection (µg/L)	Moderate protection (µg/L)	Low protection (µg/L)	High protection: Initial Management (µg/L)	High protection: Narrative	Moderate protection: Initial Management (µg/L)	Moderate protection: Narrative
					Initial management trigger A. The 95%ile of sample concentrations from the area of concern (either from one sampling run or all samples over an agreed period of time, or from a single site over an agreed period of time) should not exceed the Initial Management Standard. **Bioavailable measures** B. The 95%ile of the bioavailable contaminant concentration in the test samples should not exceed the environmental quality guideline value. and C. TTM should not exceed 1 for chemical mixtures using median bioavailable contaminant concentrations from the area of concern (either from one sampling run or all samples over an agreed period of time, or from a single site over an agreed period of time) and environmental quality guidelines in the total toxicity of mixtures formula[H].		**Initial management trigger** A. The 95%ile of filtered sample concentrations from the area of concern (either from one sampling run or all samples over an agreed period of time, or from a single site over an agreed period of time) should not exceed the initial management standard. **Bioavailable measures** B. The 95%ile of the bioavailable contaminant concentration in the test samples should not exceed the environmental quality guideline. and C. TTM should not exceed 1 for chemical mixtures using median bioavailable contaminant concentrations from the area of concern (either from one sampling run or all samples over an agreed period of time, or from a single site over an agreed period of time) and environmental quality guidelines in the total toxicity of mixtures formula[H].
METALS and METALLOIDS							
Aluminium	*TBC***						
Arsenic III	*2.3*						
Arsenic V	*4.5*						
Cadmium [B]	**0.7**	**14**[C]	**36**[A]	14[C]		36[A]	
Chromium III	**27.4**	**49**		49		91	
Chromium VI	**4.4**	**20**[C]		20[C]		85[C]	
Cobalt	**1**	**14**		14		150[C]	
Copper	**1.3**	**3**[C]		3[C]		8[A]	
Lead	**4.4**	**6.6**[C]		6.6[C]		12[C]	
Manganese	*80*						
Mercury (inorganic) [B]	**0.1**	**0.7**[C]	**1.4**[C]	0.7[C]		1.4[C]	
Molybdenum	*23*						
Nickel	**7**	**200**[A]		200[A]		560[A]	
Selenium IV[B]	*3*						
Selenium VI[B]	*3*						

Silver	**1.4**	**1.8**		1.8
Tributyltin (as µg/L Sn)	**0.006** [C]	**0.02** [C]		0.02 [C]
Vanadium	**100**	**160**		160
Zinc	**15** [C]	**23** [C]		23 [C]
NON-METALLIC INORGANICS				
Ammonia [D, #]	**910**	**1200**		1200
Chlorine [E])	*3*			
Cyanide [F]	**4**	**7**		7
Hydrogen sulfide [G, #]	*1*			
ORGANICS				
Benzene	**500** [C]	**900** [C]		900 [C]
Toluene	*110*	*230*		
Ethylbenzene	*50*	*110*		
o-xylene	*200*	*470*		
m-xylene	*30*	*70*		
p-xylene	*140*	*250*		
cumene	*20*	*40*		
Naphthalene	**50** [C]	**90** [C]		90 [C]
Anthracene [B]	*0.01*	*1.5*	*7*	
Phenanthrene [B]	*0.6*	*4*	*8*	
Fluoranthene [B]	*1*	*1.7*	*2*	
Benzo(a)pyrene [B]	*0.1*	*0.4*	*0.7*	
Pentachlorophenol[B]	**11**	**33**	**55**[A]	33
Phenol	**400**	**520**		520
1,2,4-trichlorobenzene[B]	**20**	**140**	**240**	140
POLYCHLORINATED BIPHENYLS				
Capacitor 21[B]	*0.002*			
Aroclor 1016	*0.009*			

2.6 [C]
0.05 [C]
280
43 [C]
1700
14
1300[C]
120 [C]
55[A]
720
240

|Indirect biological measures

D. Using direct toxicity assessment (DTA) procedures, EC50 values should never be exceeded compared to reference waters at a 0.05 level of probability.

and

E. Using DTA the mortality rate for any species should not exceed LC20 values compared to reference waters at a 0.05 level of probability.

Direct biological/ecological measures

F. The median of the distribution of measurements for any biological or ecological indicator should be within the 20th and 80th percentile of the natural range measured at suitable reference sites;

and

G. No loss of species beyond natural variation;

and

H. no loss in types of ecosystem processes.

Table 2 Continued.

Aroclor 1221	*1.0*				
Aroclor 1232	*0.3*				
Aroclor 1242	*0.3*				
Aroclor 1248	*0.03*				
Aroclor 1254	*0.01*				
4,4'-dichlorobiphenyl	*0.1*				
2,3,4'-trichlorobiphenyl	*0.07*				
2,2'4,5,5'-pentachloro-1,1'-biphenyl	*0.2*				
2,4,6,2',4',6'-hexachlorobiphenyl	*0.15*				
ORGANOCHLORINE PESTICIDES					
Aldrin [B]	*0.003*				
Chlordane [B]	*0.0001*				
DDE [B]	*0.0005*				
DDT [B]	*0.0004*				
Dieldrin [B]	*0.01*				
Endosulfan [B]	**0.005**	**0.02**	**0.05** [^]	0.02	0.05 [^]
Endrin [B]	**0.004**	**0.01**	**0.02**	0.01	0.02
Heptachlor [B]	*0.0004*				
ORGANOPHOSPHORUS PESTICIDES					
Chlorpyrifos [B]	**0.009**	**0.04** [^]	**0.3** [^]	0.04 [^]	0.3 [^]
Fenitrothion	*0.001*				
Malathion	*0.05*				
Temephos [B]	**0.05**	**0.4**	**3.6** [^]	0.4	3.6 [^]
HERBICIDES AND FUNGICIDES					
2,4-D	*280*				
2,4,5-T	*36*				
Metsulfuron	*8*				
Amitrole	*22*				
Atrazine	*13*				
Simizine	*3.2*				
Glyphosate	*370*				

SURFACTANTS					
Linear alkylbenzene sulfonates (LAS)	*0.1*				
Alcohol ethoxylated sulfate (AES)	*650*				
Alchohol ethoxylated surfactants (AE)	*140*				
OILS & PETROLEUM HYDROCARBONS					
Total petroleum hydrocarbons	*7*				
OIL SPILL DISPERSANTS					
BP 1100 X	*25*				
Corexit 7664	*16*				
Corexit 8667	*1200*				
Corexit 9527	**1100**	**2200**	2200	4400 ^	
Corexit 9550	*14*	*400*			
MISCELLANEOUS					
Polyelectrolyte flocculants	*1*				
OTHER CHEMICALS	#				

* Significant means at the level of detection determined by the effects size and statistical decision criteria agreed by the relevant stakeholders on a case-by-case basis. This provides flexibility for stakeholders to account for the wide range in natural variability between different biological indicators and to determine a level of detection that is ecologically meaningful..

** EQC to be confirmed after further investigation of toxicity.

▫ Low reliability values based on low reliability trigger value calculated from limited data (from chapter 8 of ANZECC & ARMCANZ 2000). In most cases low reliability guidelines are only provided for high protection areas because of the relatively conservative assumptions in the calculation. Action is not mandatory if they are exceeded, but regulators and management agencies should be advised and consideration given to developing strategies that will ensure environmental impacts are avoided.

\# Refer to NWQMS Report No.4 (ANZECC & ARMCANZ 2000). See section 8.3.7 for a detailed discussion on how different environmental factors will affect toxicity of the chemical. For chemicals not listed in this table guideline trigger values from ANZECC & ARMCANZ (2000) should be applied as follows: the recommended combination of 99% or 95% values (slightly disturbed systems) for high protection EQG; 90% for high protection EQS and moderate protection EQG; and 80% for moderate protection EQS and low protection EQG.

A Value may not protect key test species from acute and chronic toxicity (see ANZECC & ARMCANZ 2000).

B Chemical for which possible bioaccumulation and biomagnification effects should be considered (log_{10} Kow values >4 and <7).

C Value may not protect key test species from chronic toxicity (see ANZECC & ARMCANZ 2000).

D Total ammonia as [NH_3-N] at pH 8.

E Measured as Total residual chlorine.

F Cyanide as un-ionised HCN measured as [CN].

G Sulfide as un-ionised H_2S, measured as [S] (see ANZECC & ARMCANZ 2000).

H TTM (total toxicity of the mixture) = $\Sigma(Ci / EQGi)$

where Ci is the concentration of the 'i'th component in the mixture and EQGi is the guideline for that component. If TTM exceeds 1, the mixture has exceeded the water quality guideline. ANZECC & ARMCANZ (2000) only recommends use of this formula on mixtures with up to 5 contaminants of concern until further scientific study confirms its relevance to more complex mixtures. The TTM should be analysed for each sampling occasion, and then the median TTM of all sampling occasions compared against the guideline. The effect of different contaminants on biota can be synergistic, antagonistic as well as additive depending on a number of factors, including the species being tested. The use of DTA is recommended for toxicant mixtures of greater than 5 components or of uncertain mixture effects. Where the effect of the different contaminants on each other is unknown, and DTA is not a viable alternative, the assumption that all contaminants have additive toxicity is acceptable.

Narrative decision scheme for applying the EQC for marine waters and sediment pore waters

(Options are provided in the decision tree for skipping steps once an EQG has been triggered (eg. go straight to testing against biological measures, or implement agreed management strategies to reduce contaminant inputs, without undertaking all of the prior steps). This will largely be based on a simple cost/benefit analysis undertaken for each step, and would require the agreement of all key stakeholders.)

1. Determine whether an EQG exists for the contaminants of concern:
   [N]..... - go to step 2
   [Y]..... - go to step 3

2. Is it appropriate to establish an EQG by determining the 80th percentile for a high protection area, or 95th percentile for a moderate protection area, of natural background concentration?
   [N]..... - go to step 14.
   [Y]..... - go to step 3.

3. Undertake routine monitoring program covering the area to be assessed and the contaminants of concern using the standard operating procedures and go to step 4.

4. Was the laboratory practical quantitation limit (PQL) for any of the contaminants above the EQG value?
   [N]..... - go to step 5.
   [Y]..... - if detection of the contaminant is confirmed in a filtered sample go to step 10, otherwise assume the contaminant has not been detected.

5. Determine whether EQG (A) has been met:
   [N]..... - go to step 6.
   [Y]..... - go to step 9.

6. If the exceedance was for the last sampling occasion has it been confirmed by analysing the back-up samples or samples collected immediately from the same sites?
   [N]..... - go to step 9.
   [Y]..... - go to step 7 if high or moderate protection area;
   - go to step 16 if the EQG was established for a low protection area.

7. Was the EQG identified as a low reliability guideline?
   [N]..... - go to step 8 (optional); or
   - go to step 10.
   [Y] - consult with relevant regulators to ensure unacceptable impacts are avoided.

8. For naturally occurring chemicals determine whether the 80th percentile for a high protection area, or 95th percentile for a moderate protection area, of natural background contaminant concentration exceeds the EQG:
   [N]..... - go to step 10.
   [Y]..... - establish the 80th or 95th percentile of background concentration as the new EQG then go to step 4.

9. For the primary contaminants determine whether EQG (B) has been met:
   [N]..... - go to step 13.
   [Y]..... - no toxicity problem, go to step 3.

The EQG is now triggered and ambient quality is compared against the EQS.

10. Determine whether EQS (A) has been met:
   [N]..... - go to step 17
   [Y]..... - go to step 11, or
   - go to step 14 if PQL > EQG.

11. Has the contaminant of concern been identified in Table 2 of the EQC Reference Document as having the potential to adversely bioaccumulate or biomagnify?
   [N]..... - go to step 12 (steps 14 or 15 also an option).
   [Y]..... - go to step 12 (steps 14 or 15 also optional); and
   - go to step 16.

12. Resolve bioavailable concentrations of relevant contaminants and determine whether EQS (B) has been met:
   [N]..... - go to step 14 (steps 15 or 17 also an option).
   [Y]..... - go to step 13.

13. For the primary contaminants determine whether EQS (C) has been met:
   [N]..... - go to step 14 (steps 15 or 17 also an option).
   [Y]..... - environmental quality acceptable, go to step 3.

14. Undertake direct toxicity assessment (DTA) using locally relevant species and determine whether EQS (D) and (E) have been met:
   [N]..... - go to step 15 or step 17.
   [Y]..... - environmental quality acceptable, go to step 3.

15. Undertake detailed field investigation to determine whether EQS (F) and (G) have been met for high protection areas, or EQS (F), (I) and (J) have been met for moderate protection areas:
   [N]..... - **EQS triggered.** Go to step 17.
   [Y]..... - environmental quality acceptable, go to step 3.

16. Determine whether EQS (H) has been met:

[N]..... - **EQS triggered.** Go to step 17.

[Y]..... - chemical not bioaccumulating, go to step 3.

17. Implement management action to reduce contaminant inputs to the ambient environment and achieve the environmental quality objective within an agreed timeframe. Prior to implementing management action procedures such as TIE and CBR might be required to confirm the specific cause of toxicity or the source of contaminants. In extreme circumstances environmental remediation may be considered appropriate.

Guidance notes

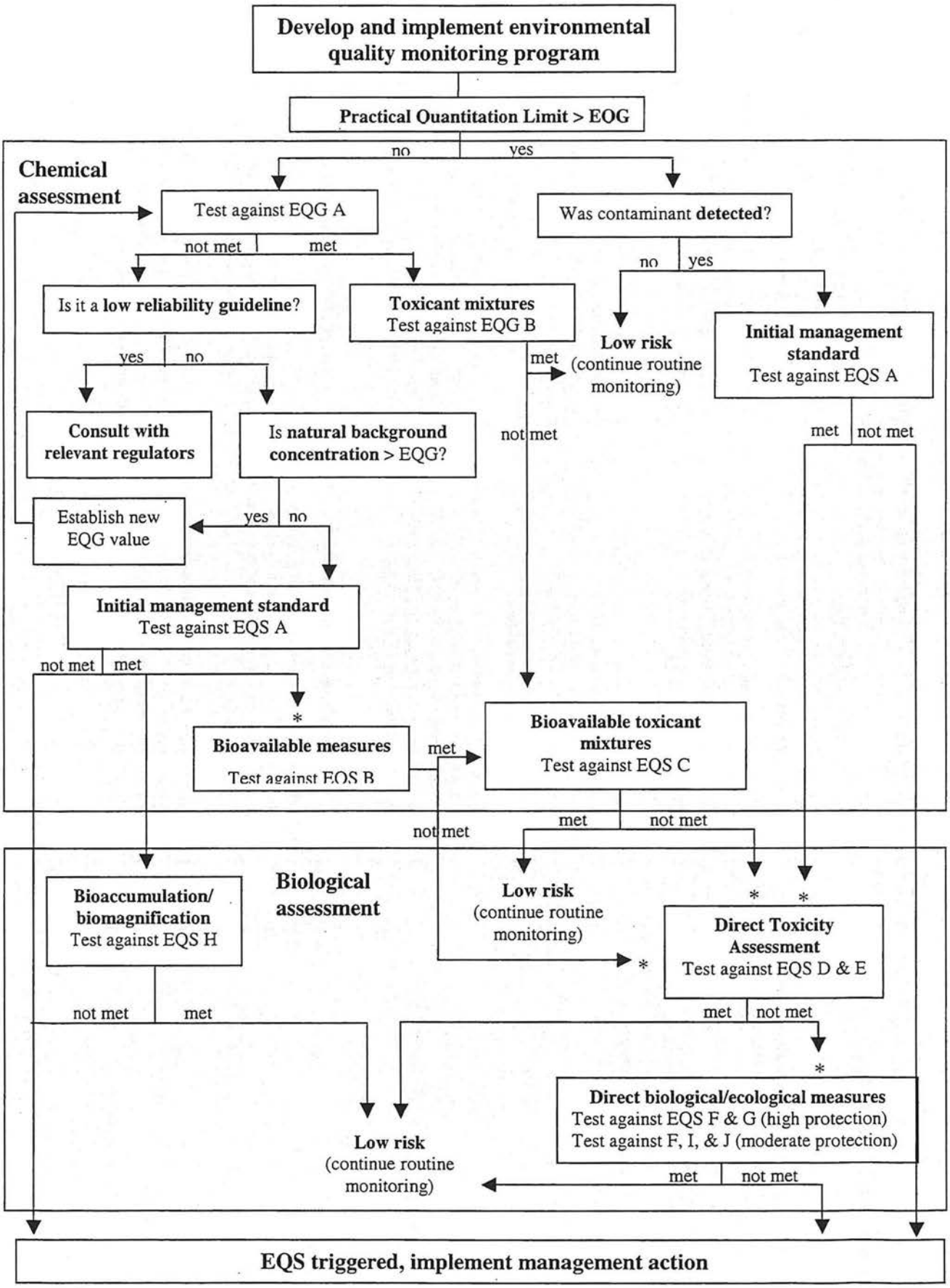
Environmental quality guidelines

- The majority of Cockburn Sound waters are considered to be at the 'slightly disturbed' end of the slight to moderate disturbance spectrum. The ANZECC & ARMCANZ (2000) recommended combination of 99% and 95% guideline trigger values for 'slightly to moderately disturbed' systems have been selected as the environmental quality guidelines for the high protection area in Cockburn Sound. For moderate protection areas the 90% values have been selected and for the low protection areas the 80% values are recommended only for those substances that are identified in the tables as potential biomagnifiers or bioaccumulators.
- If a new environmental quality guideline is established by determining the 80th percentile of natural background concentration then it should be compared against the median of the test samples rather than the 95th percentile.
- A minimum of 5 samples are required for comparison with the environmental quality guideline, and where less than 20 samples have been taken, the maximum sample concentration should be less than the guideline.
- For metal and inorganic toxicants it is preferable, but not necessary, that samples are filtered (ie. 0.45µm teflon or glass fibre filter) in the first instance for comparison with the guidelines. If an unfiltered sample exceeds the guideline then additional samples should be collected and filtered for comparisons against the guideline and initial management standard. For organic toxicants it is not usually necessary to filter the samples before comparing against the environmental quality guidelines or initial management triggers.
- For contaminants that are at very low concentrations in effluent streams, mass balance calculations can be used to estimate contaminant concentrations as an alternative to actual measurement.
- For the toxicity of mixtures formula^{H} a TTM should only be calculated if the mixture is simple (ie. up to 5 toxic components) and their toxicity is additive. The use of DTA is recommended for toxicant mixtures of greater than 5 components or of uncertain mixture effects.
- The environmental quality guidelines in italics, and marked with the footnote symbol $^{\square}$, are low reliability guidelines provided to give guidance in the absence of any other information. It is not mandatory to undertake further assessment against the standards if the low reliability guidelines are exceeded. However, strategies should be developed in consultation with the regulator to ensure unacceptable impacts are avoided.
- The analytical practical quantitation limit is defined by NATA (Tech Note 13) as 'The lowest concentration of an analyte that can be determined with acceptable precision (repeatability) and accuracy under the stated conditions of the test'. It equates to the reporting limit quoted by most analytical laboratories.
- When considering the analytical procedures to be used for sample analysis, consideration must be given to the analytical practical quantitation limit required to compare against the EQG.
- For those few guidelines that are below the best available practical quantitation limit, it will often be possible to control effluent concentrations of these chemicals to ensure that calculated levels in receiving waters do not exceed the guideline. Where DTA is to be undertaken, existing information (eg. ecotoxicological and/or discharge data) should first be assessed to determine whether adverse effects can be expected.

Environmental quality standards

- Bioavailable concentrations of contaminants should be derived using the approaches outlined in section 3.4.3.
- Fresh samples should be used for determining bioavailable contaminant concentrations. Sample preservation can have a significant effect on chemical speciation/bioavailability.
- If the environmental quality guideline for a chemical that adversely bioaccumulates or biomagnifies in organisms (see footnote B) is exceeded in a high, moderate or low protection area then tissue concentrations of that chemical should be measured in benthic or sessile suspension or deposit feeders from the high protection area (or from the closest high protection area if the exceedance was in a moderate or low protection area). Tissue concentrations should also be measured at a suitable reference site with similar characteristics and the 80^{th} percentile of the concentrations calculated. The median tissue concentration from the high protection area test site should not exceed the 80^{th} percentile of the reference site concentrations. (Tissue concentrations in edible seafood should also be compared with the EQC for maintenance of aquatic life for human consumption.)
- DTA (direct toxicity assessment) is discussed in detail in sections 3.4.3.2/12, 8.3.5.19 and 8.3.6 of (ANZECC & ARMCANZ 2000). DTA considers 'whole of effluent toxicity' and can be used on receiving/ambient waters or on effluent diluted with the receiving water. It can be used to determine a safe level of effluent dilution. ANZECC & ARMCANZ (2000) recommend that ideally chronic effects on a minimum of 5 species relevant to the site of concern, and from 4 different trophic levels, should be determined unless DTA is being applied to an effluent stream on a regular and ongoing basis, in which case the minimum requirement is 3 species from different taxonomic groups. The number of tests actually carried out will need to be tailored according to those currently available and/or relevant, through discussion between key stakeholders.
- Direct measurement of biological or ecological indicators is likely to require comparison with reference sites so that natural variability is taken into account. A minimum of two in-situ biological/ecological indicators relevant to the contaminant of concern should be monitored.
- Investigative procedures such as Toxicity Identification Evaluation (TIE) and Contaminant Body Residue (CBR) may be required to establish whether the observed biological effects are caused by specific contaminants or specific sources of contaminants.

Pictorial decision scheme for applying the EQC for toxicants for marine waters and sediment pore waters



* An alternative option to further assessment against the EQS is to go directly to the implementation of management action.

TABLE 3. Environmental quality criteria for protecting the marine ecosystem from the effects of toxicants in sediments

Environmental Quality Guideline		Environmental Quality Standard	
		High protection	Moderate protection
A. Median sediment total contaminant concentration* from a defined sampling area should not exceed the environmental quality guideline value for high, moderate and low protection areas. B. If total contaminant concentration at an individual sample site exceeds the environmental quality guideline re-sampling trigger, a new sampling area should be defined to assess the extent of contamination.		**Bioavailable measures** A. The 80%ile of bioavailable metal or metalloid concentrations [G] (eg. dilute acid extractable metals, SEM/AVS analysis [H]) from the defined sampling area should not exceed the EQG. or B. The median bioavailable concentration for non-metallic contaminants [G] (eg. OC normalisation[D]) from the defined sampling area should not exceed the EQG. **Porewater measure** C. The 95%ile of contaminant concentrations in filtered porewater samples from the defined sampling area should not exceed high protection water quality bioavailable measures (table 2 of EQC document). **Indirect biological measures** D. Sub-lethal chronic toxicity testing should show no effect on any test species relative to a matched reference sediment at a 0.05 level of probability. and E. There should be no increase in mortality rate for any species relative to a matched reference sediment in all toxicity tests at a 0.05 level of probability.	**Bioavailable measures** A. The median bioavailable metal or metalloid concentrations [G] (eg. dilute acid extractable metals, SEM/AVS analysis [H]) from the defined sampling area should not exceed the EQG. or B. The 40%ile of bioavailable concentrations for non-metallic contaminants [G] (eg. OC normalisation) from the defined sampling area should not exceed the EQG. **Porewater measure** C. The 95%ile of contaminant concentrations in filtered porewater samples from the defined sampling area should not exceed moderate protection water quality bioavailable measures (table 2 of EQC document). **Indirect biological measures** D. Sub-lethal chronic toxicity testing should show no more than a 50% effect on any test species relative to a matched reference sediment at a 0.05 level of probability. and E. The mortality rate for any species should not exceed 20% relative to a matched reference sediment in all toxicity tests at a 0.05 level of probability.
Chemical	**Value** (high, moderate and low[A] protection)	**Re-sampling trigger**	
METALS and METALLOIDS [C] (mg/kg dry wt)			
Antimony	2	25	
Arsenic	20	70	
Cadmium	1.5	10	
Chromium	80	370	
Copper	65	270	
Lead	50	220	
Mercury [B]	0.15	1	
Nickel	21	52	
Silver	1	37	
Zinc	200	410	
ORGANOMETALLICS			
Tributyltin (µg Sn/kg dry wt.)	5	70	
ORGANICS (µg/kg dry wt) [D, E]			
Acenaphthene	16	500	

Acenaphthalene	44	640		
Anthracene [B]	85	1100		
Fluorene	19	540		
Naphthalene	160	2100		
Phenanthrene [B]	240	1500		
Low Molecular Weight PAHs [B, F]	552	3160		
Benzo(a)anthracene	261	1600		
Benzo(a)pyrene [B]	430	1600		
Dibenzo(a,h)anthracene	63	260		
Chrysene	384	2800		
Fluoranthene [B]	600	5100		
Pyrene	665	2600		
High Molecular Weight PAHs [B, F]	1700	9600		
Total PAHs [B]	4000	45000		
Total DDT [B]	1.6	46		
p.p'-DDE [B]	2.2	27		
o,p'- + p,p'-DDD	2	20		
Chlordane [B]	0.5	6		
Dieldrin [B]	0.02	8		
Endrin [B]	0.02	8		
Lindane	0.32	1		
Total PCBs [B]	23	180[J]		
			Direct biological/ecological measures	**Direct biological/ecological measures**
			F. No significant[I] change in any biological or ecological indicator beyond natural variation that can be demonstrably linked to a contaminant;	F. The median of the distribution of measurements for any biological or ecological indicator should be within the 20th and 80th percentile of the natural range measured at suitable reference sites;
			G. Where TBT concentrations exceed the guideline the incidence of imposex in *Thais orbita* should be ≤ 5%.	and
				I. no loss of species beyond natural variation;
			H. The median tissue concentration of chemicals that can adversely bioaccumulate or biomagnify should not exceed the 80th percentile of tissue concentrations from a suitable reference site.	and
				J. no loss in types of ecosystem processes.

* For metals in sediments a strong acid digestion (eg. nitric acid/perchloric acid mixture) should be used.

A Environmental quality guidelines may be used in low protection areas, but only for substances that adversely bioaccumulate or biomagnify.

B Substances that may adversely bioaccumulate or biomagnify (Log_{10} Kow values >4 and <7)

C EQG have not been developed for Aluminium, Manganese and Titanium because toxicity is not an issue for these metals in marine sediments. In addition there was insufficient data available to develop EQG for Cobalt, Molybdenum, Selenium and Vanadium. Management of these contaminants should be through cooperative approaches involving the regulating authorities and the organisations that are significant sources of these contaminants.

D Normalised to 1% organic carbon;

E There was insufficient data available to develop EQG for Benzene, Phenol and Total petroleum hydrocarbons. Management of these contaminants should be through cooperative approaches involving the regulating authorities and the organisations that are significant sources of these contaminants.

F Low molecular weight PAHs are the sum of concentrations of acenaphthene, acenaphthalene, anthracene, fluorene, naphthalene and phenanthrene;
High molecular weight PAHs are the sum of concentrations of benzo(a)anthracene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, fluoranthene and pyrene.

Table 3 Continued.

G See NWQMS Report No.4 Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ 2000).

H SEM/AVS analysis appropriate for divalent transition metals that react with sulphide to form insoluble precipitates such as Cd, Cu, hg, Ni, Pb and Zn.

I Significant means at the level of detection determined by the effects size and statistical decision criteria agreed by the relevant stakeholders on a case-by-case basis. This provides flexibility for stakeholders to account for the wide range in natural variability between different biological indicators and to determine a level of detection that is ecologically meaningful.

J The EQG re-sampling trigger for total PCB has been taken from WA Department of Environmental Protection Report 17 *Southern Metropolitan Coastal Waters Study (1991-1994).*

Narrative decision scheme for applying the EQC for toxicants in sediments

(Options are provided in the decision tree for skipping steps once an EQG has been triggered (eg. go straight to testing against biological measures, or implement agreed management strategies to reduce contaminant inputs, without undertaking all of the prior steps). This will largely be based on a simple cost/benefit analysis undertaken for each step, and would require the agreement of all key stakeholders.)

1. Determine whether an EQG value exists for the contaminants of concern:
   [N]..... - go to step 2
   [Y]..... - go to step 3

2. Is it appropriate to establish an EQG value based on natural background concentration:
   [N]..... - go to step 11.
   [Y]..... - go to step 3.

3. Undertake routine monitoring program covering the area to be assessed using the standard operating procedures and go to step 4.

4. Determine whether EQG (A) has been met:
   [N]..... - go to step 5
   [Y]..... - go to step 8..

5. If the exceedance was for the last sampling occasion has it been confirmed by analysing the back-up samples or samples collected immediately from the same sites?
   [N]..... - go to step 8.
   [Y]..... - go to step 6.

6. Was the exceeded EQG established for a low protection area?
   [N]..... - go to step 7 (optional); or
   - go to step 8 to define any 'hot spots'; and
   - to step 10 to assess the entire sampled area against the EQS.
   [Y] - go to step 15.

7. For naturally occurring chemicals determine whether the natural background contaminant concentration exceeds the EQG value (unlikely in most cases, note that test site and reference site must have comparable grain sizes):
   [N]..... - go to step 8 to define any 'hot spots'; and
   - to step 10 to assess the entire sampled area against the EQS.
   [Y]..... - establish the 90%ile of background concentration as the new EQG value then go to step 4.

8. Determine whether sediment contaminant concentration at individual sampling sites exceed the EQG re-sampling trigger:
   [N]..... - no toxicity problem, go to step 3.
   [Y]..... - go to step 9.

9. Determine whether the extent of potential contamination needs to be characterised further (in most cases this will be necessary):

[N]..... - no toxicity problem, go to step 3.
[Y]..... - determine area of potential contamination, if sufficient data for its assessment go to step 4; or
- determine area of potential contamination, design sampling program for this area and go to step 3.

The EQG is now triggered and ambient quality is compared against the EQS.

10. Has the contaminant of concern been identified in Table 3 of the EQC Reference Document as having the potential to adversely bioaccumulate or biomagnify:

[N]..... - go to step 11 (steps 12, 13 or 14 also an option).
[Y]..... - go to step 11 (step 12, 13 or 14 also optional); and
- go to step 15.

11. Resolve bioavailable concentrations (as far as possible) for relevant contaminants and determine whether EQS (A) and (B) have been met:

[N]..... - go to step 12 (steps 13, 14 or 16 also an option).
[Y]..... - environmental quality acceptable, go to step 3.

12. Sample and analyse sediment porewaters for those contaminants of concern that have an initial management standard in water (schedule 3, table 2) and determine whether EQS (C) has been met:

[N]..... - go to step 13 (steps 14 or 16 also an option).
[Y]..... - environmental quality acceptable, go to step 3.

13. Undertake sediment toxicity testing using relevant species and determine whether EQS (D) and (E) have been met:

[N]..... - go to step 14 or step 16.
[Y]..... - environmental quality acceptable, go to step 3.

14. Undertake detailed field investigation to determine whether EQS (F) and (G) have been met for high protection areas, or EQS (F), (I) and (J) have been met for moderate protection areas:

[N]..... - **EQS triggered.** Go to step 16.
[Y]..... - environmental quality acceptable, go to step 3.

15. Determine whether EQS (H) has been met:

[N]..... - **EQS triggered.** Go to step 16.
[Y]..... - chemical not bioaccumulating, go to step 3.

16. Implement management action to reduce contaminant inputs to the ambient environment and achieve the environmental quality objective within an agreed timeframe. Prior to implementing management action procedures such as TIE and CBR might be required to confirm the specific cause of toxicity or the source of contaminants. In extreme circumstances environmental remediation may be considered appropriate.

Guidance notes

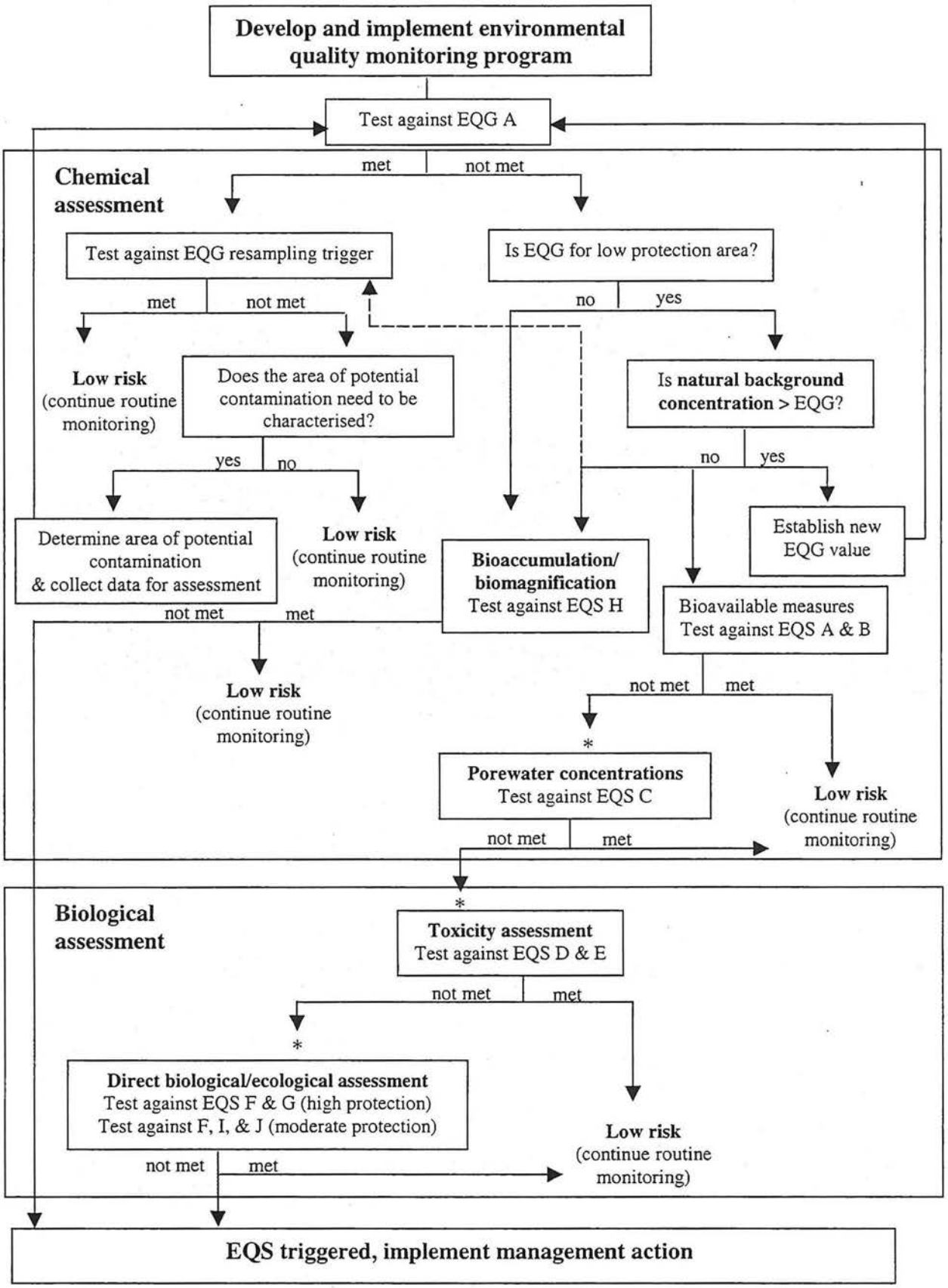
Environmental quality guidelines

- the ISQG-low is the EQG value and the ISQG-high is the EQG re-sampling trigger.
- For metals, the guidelines are based on total metal concentration (strong acid digestion). Ultimately, as more local data becomes available, it is envisaged that guidelines will be based on more bioavailable measurements such as acid soluble analyses.
- Where individual samples exceed the environmental quality guideline re-sampling trigger, additional sampling of that potentially contaminated site will generally be required and the median compared to the environmental quality guideline. This may not be necessary where the original sampling program had adequate spatial coverage to be confident that the area that exceeds the re-sampling trigger has been defined.
- The sampling area may be defined by a boundary, an area of potential contamination or some other defining parameter.

Environmental quality standards

- The environmental quality guidelines for metals are based on biological effects data that were compared to total concentrations of metals, a large fraction of which is generally mineralised and non-bioavailable. Adjustments have therefore been made to the acceptance criteria for bioavailable concentration of metals to ensure that potentially adverse concentrations are detected.
- Porewater comparisons should not be undertaken against 'low reliability values' EQGs which are based on low reliability guideline trigger levels from ANZECC & ARMCANZ (2000).
- If the environmental quality guideline for a chemical that adversely bioaccumulates or biomagnifies in organisms (see footnote B) is exceeded in a high, moderate or low protection area then tissue concentrations of that chemical should be measured in benthic or sessile suspension or deposit feeders from the high protection area (or from the closest high protection area if the exceedance was in a moderate or low protection area). Tissue concentrations should also be measured at a suitable reference site with similar characteristics and the 80^{th} percentile of the concentrations calculated. The median tissue concentration from the high protection area test site should not exceed the 80^{th} percentile of the reference site concentrations. (Tissue concentrations in edible seafood should also be compared with the EQC for maintenance of aquatic life for human consumption.)
- When undertaking sediment bioassays, bioavailable contaminant concentrations should be measured. ANZECC & ARMCANZ (2000) recommend that sediment bioassays should include a minimum of 4 studies on at least 2 locally relevant invertebrate species, both sediment ingesting and water only species, and should use relevant end-points such as mortality, growth and fecundity. The number of tests actually carried out will need to be tailored according to those currently available and/or relevant, through discussion between key stakeholders.
- Direct measurement of biological or ecological indicators is likely to require comparison with reference sites so that natural variability is taken into account. A minimum of two in-situ biological/ecological indicators relevant to the contaminant of concern should be monitored.
- Investigative procedures such as Toxicity Identification Evaluation (TIE) and Contaminant Body Residue (CBR) may be required to establish whether the observed biological effects are caused by specific contaminants or specific sources of contaminants.

Pictorial decision scheme for applying the EQC for toxicants in sediments



* An alternative option to further assessment against the EQS is to go directly to the implementation of management action.

TABLE 4. Environmental quality criteria for the maintenance of aquatic life safe for human consumption

Indicator	Environmental quality guideline (units as stated)	Environmental quality standard (EQS) (units as stated)
Biological contaminants		
Thermotolerant faecal coliforms in water	A. The median thermotolerant faecal coliform bacterial concentration should not exceed 14 CFU/100 mL, with no more than 10% of the samples exceeding 21 CFU/100 mL measured using the membrane filtration method. or The median thermotolerant faecal coliform bacterial concentration should not exceed 14 MPN/100 mL, with no more than 10% of the samples exceeding 43 MPN/100 mL measured using the multiple tube analytical method.	A. The median thermotolerant faecal coliform bacterial concentration should not exceed 70 CFU/100 mL, with no more than 10% of the samples exceeding 85 CFU/100 mL using the membrane filtration method.
Thermotolerant faecal coliforms in fish flesh		B. Fish destined for human consumption should not exceed a limit of 2.3 MPN *E. coli* /g of flesh (wet wt.) in four out of five representative samples, and the fifth sample should not exceed 7 MPN *E. coli* /g,with a maximum total plate count of 250 000 organisms/g
Algal biotoxins	B. Concentrations of toxic algae should not exceed the following environmental quality guideline values in any samples.	C. Toxin concentration in seafood should not exceed the environmental quality standards in any samples.
	Alexandrium (*A. acatenella, A. catenella, A. cohorticula, A. fundyense, A. lusitanicum, A. tamiyavanichi, A. Tamarense*) 100 cells/L	Paralytic shellfish poison (PSP) 0.8 mg Saxitoxin eq./kg
	Dinophysis (*D. acuta, D. fortii, D. norvegica*) 500 cells/L (*Dinophysis acuminata*) 5000 cells/L	Diarrhoetic shellfish poison (DSP) 0.2 mg/kg DSP 0.2 mg/kg
	Prorocentrum (*P. lima, P. mexicanum* 500 cells/L	DSP 0.2 mg/kg

Indicator	Environmental quality guideline (units as stated)		Environmental quality standard (EQS) (units as stated)	
	Gymnodinium			
	(G. *breve, G. breve-like*)	1 000 cells/L	Neurotoxic shellfish poison (NSP)	200 mouse units/kg
	(*Gymnodinium catenatum*)	1 000 cells/L	PSP	0.8 mg Saxitoxin eq./kg
	Pseudonitzchia			
	(*P. australis, P. pungens, P. turgidula, P. fraudulenta, P. delicatissima, P. pseudodelicatissima*)	5 000 cells/L (>50% total phytoplankton); 50 000 cells/L (<50% total phytoplankton).	Amnesic shellfish poison (ASP) (domoic acid)	20 mg/kg
Chemicals	C. Median chemical concentration in the flesh of seafood should not exceed the environmental quality guideline value.		D. Chemical concentrations (except for mercury) in the flesh of seafood should not exceed the environmental quality standard value. E. Mercury concentration in the flesh of seafood should not exceed the environmental quality standard value in accordance with Standard 1.4.1 clause 6 of the revised Australian and New Zealand Food Standards Code. F. Pesticide residue concentrations in the flesh of seafood should not exceed the maximum residue limits and extraneous residue limits in schedules 1 and 2 respectively of the revised Australian and New Zealand Food Standards Code.	
Metals (mg/kg)				
Arsenic (inorganic)			Crustacea and Fish	2.0
			Molluscs and Seaweed	1.0
Cadmium			Molluscs	2.0

Table 4 Continued.

Indicator	Environmental quality guideline (units as stated)		Environmental quality standard (EQS) (units as stated)	
Copper	Crustacea	20		
	Fish	2.0		
	Molluscs	30		
Lead			Fish	0.5
			Molluscs	2.0
Mercury			Billfish (including Marlin), Southern bluefin tuna, Rays and Shark	1.0 (mean level)
			Crustacea, Molluscs and Other Fish	0.5 (mean level)
Selenium	Crustacea and Molluscs	1.0		
	Fish	2.0		
Zinc	Crustacea	40		
	Fish	15		
	Oysters	290		
Organic chemicals (mg/kg)			*Chemical*	
Acrylonitrile			All food	0.02
Polychlorinated biphenyls			Fish	0.5
Vinyl chloride			All food	0.01

Narrative decision scheme for applying the EQC for aquatic life safe for human consumption

1. Conduct routine monitoring program covering the area to be assessed and the contaminants of concern using the standard operating procedures and go to step 2.

2. Determine whether EQG (A, B and/or C) have been met, or whether EQS (D, E or F) have been met:
   [N]..... - go to step 3.
   [Y]..... - seafood suitable for consumption, go to step 1.

3. Are any of the exceedances confirmed by analysing the back-up samples or samples collected immediately from the same sites?
   [N]..... - seafood suitable for consumption, go to step 1.
   [Y]..... - go to steps 4 and 7 if EQG A not met; and
   - go to step 6 if EQG B not met; and
   - go to step 7 if EQG C not met; and
   - go to step 8 if EQS (D, E or F) not met.

The EQG may now be triggered and ambient quality is compared against the EQS.

4. Determine whether EQS (A) has been met:
   [N]..... - go to step 5 (step 8 also an option).
   [Y]..... - go to step 7 for advice on conducting sanitary survey; and
   - go to step 1.

5. Determine whether EQS (B) has been met:
   [N]..... - **EQS triggered**. Go to step 8.
   [Y]..... - go to step 7 for advice on further monitoring and conducting sanitary survey; and
   - go to step 1.

6. Determine whether EQS (C) has been met:
   [N]..... - **EQS triggered**. Go to step 8.
   [Y]..... - EQS not triggered, go to step 7; and
   - go to step 1.

7. Contact the Health Department of WA with the results and seek advice on any additional monitoring or management requirements to ensure human health risks are managed at an appropriate level.

8. Implement management action to reduce contaminant inputs, or if this is not practically feasible, then reduce risk to public health through appropriate management on advice of the Health Department of WA. If appropriate, environmental remediation may be required.

Guidance notes

Environmental quality guidelines

- Two methods for the measurement of thermotolerant faecal coliforms have been accepted by the Australian Shellfish Quality Assurance Advisory Committee. The membrane filtration method is not as widely available but has greater accuracy at lower cost.
- The measurement of chemical contaminants in seafood should be for hydrated foods only.

Environmental quality standards

- Where an environmental quality guideline has been exceeded it is strongly recommended that the monitoring results are referred to the Health Department for advice before undertaking further assessment against the environmental quality standard. This is particularly important for thermotolerant faecal coliforms because a comprehensive sanitary survey is triggered to classify the site and determine appropriate management strategies to reduce human health risk to acceptable levels (eg. depuration, prediction of high risk periods).

Pictorial decision scheme for applying the EQC for aquatic life safe for human consumption

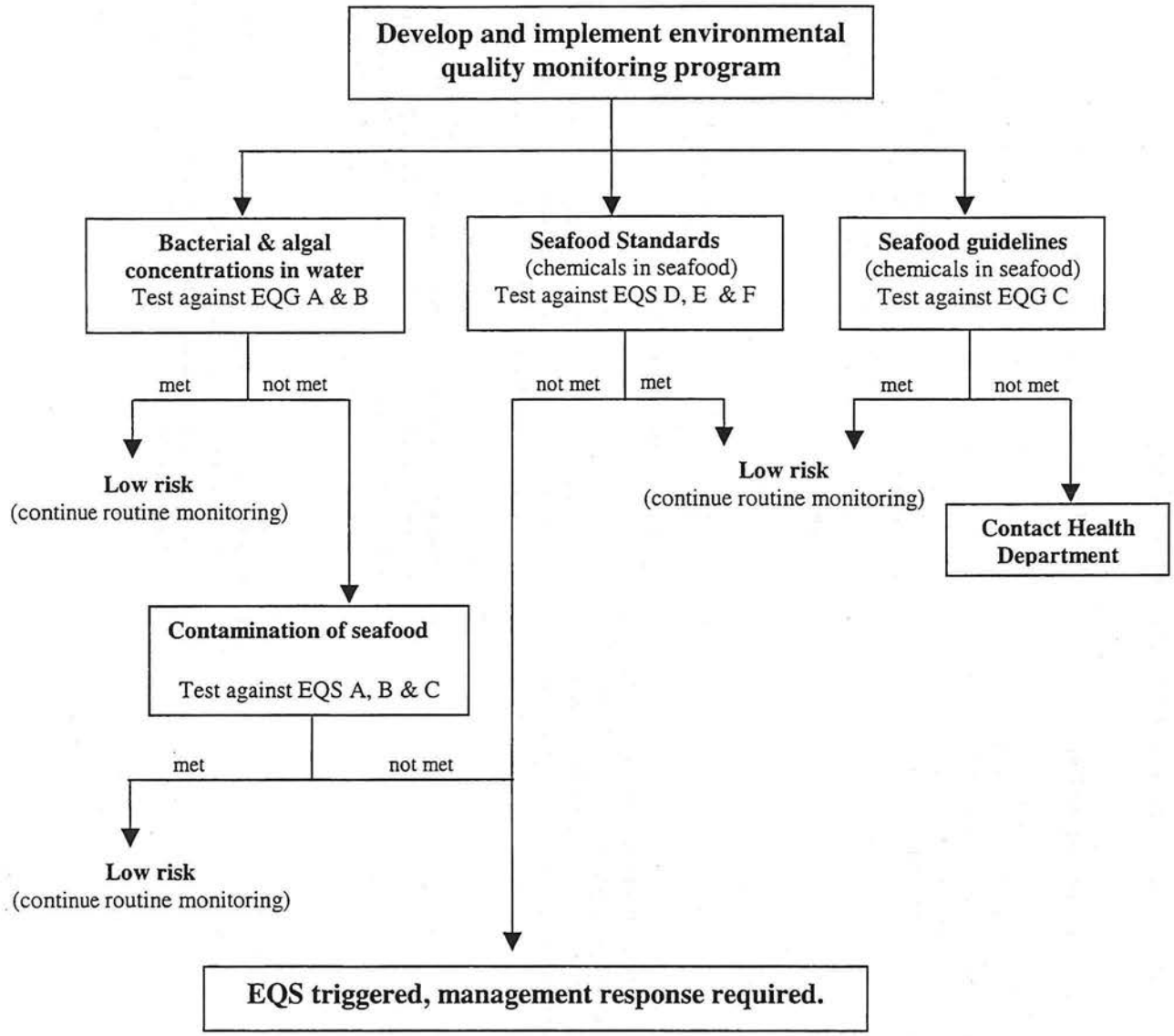


TABLE 5. Environmental quality criteria for the maintenance of aquaculture production

Indicator	Environmental quality guideline	Environmental quality standard (EQS)
PHYSICO-CHEMICAL STRESSORS	A. The median of the sample concentrations from the area of concern (either from one sampling run or all samples over an agreed period of time, or from a single site over an agreed period of time) should not exceed the environmental quality guideline value.	A. The median of the sample concentrations should meet the appropriate species group guidelines provided in Chapter 9 of NWQMS Report No. 4[#] B. Using direct toxicity assessment (DTA) procedures there should be no significant difference in end-points related to growth or quality of the cultured species (caused by externally forced changes in physico-chemical stressors) between the aquaculture waters and a suitable control.
Dissolved oxygen	≥5 mg/L	
pH	6 - 9	
Phosphates	0.05 mg/L	
Salinity (TDS)	33 – 37 mg/L	
Suspended solids	10 mg/L	C. Toxicant concentration (from external sources) in ≥95% of samples should meet the appropriate species group guidelines provided in Chapter 9 of NWQMS Report No. 4[#].
TOXICANTS	B. The 95%ile of the sample concentrations from the area of concern (either from one sampling run or all samples over an agreed period of time, or from a single site over an agreed period of time) should not exceed the environmental quality guideline value.	<u>if not, then</u> D. Where appropriate, bioavailable contaminant concentration should meet the relevant guideline (environmental quality guideline or species group guideline) in ≥ 95% of samples.
Non metallic inorganic chemicals (μg /L)		<u>if not, then</u>
Ammonia (un-ionised)	100	E. Using direct toxicity assessment (DTA) procedures there should be no significant difference in end-points related to growth or quality of the cultured species (caused by contaminants from external sources) between the aquaculture waters and a suitable reference site.
Chlorine	3	
Cyanide	5	
Hydrogen sulfide	2	<u>or</u>
Nitrate-N	100 000	F. Contaminant concentration (from external sources) in ≥95% of samples should be less than the NOEC value (calculated from toxicity tests using end-points relevant to growth or quality) for the cultured species.
Nitrite-N	100	

Indicator	Environmental quality guideline	Environmental quality standard (EQS)
Metals and metalloids (µg /L)		
Aluminium	10	
Arsenic	30	
Cadmium	5	
Chromium	20	
Copper	5	
Iron	10	
Lead	7	
Manganese	10	
Mercury	1	
Nickel	100	
Selenium	10	
Silver	3	
Tributyltin (as µg/L TBT)	0.01	
Total available nitrogen (TAN)	1000	
Vanadium	100	
Zinc	5	
Organic chemicals (µg /L)		
Methane	65 000	
Polychlorinated biphenyls (PCBs)	2	
Pesticides (µg /L)		
Chlordane	0.004	
Endosulfan	0.001	
Lindane	0.004	
Paraquat	0.01	

see NWQMS Report No 4 Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2001).

Narrative decision scheme for applying the EQC for aquaculture production

(Options are provided in the decision tree for skipping steps once an EQG has been triggered (eg. go straight to testing against biological measures, or implement agreed management strategies to reduce contaminant inputs, without undertaking all of the prior steps). This will largely be based on a simple cost/benefit analysis undertaken for each step, and would require the agreement of all key stakeholders.)

1. Conduct routine monitoring program covering the area to be assessed and the contaminants of concern using the standard operating procedures and go to step 2.

2. Determine whether EQG (A and/or B) have been met:
   [N]..... - go to step 3
   [Y]..... - suitable for aquaculture, go to step 1.

3. If the exceedance was for the last sampling occasion has it been confirmed through the analysis of back-up samples or samples collected immediately from the same sites?
   [N]..... - suitable for aquaculture, go to step 1.
   [Y]..... - go to step 4 if EQG A not met; and
   - go to step 6 if EQG B not met.

The EQG may now be triggered and ambient quality is compared against the EQS.

4. Determine whether EQS (A) has been met:
   [N]..... - go to step 5 (step 9 is also optional).
   [Y]..... - EQS not triggered, go to step 1.

5. Determine whether EQS (B) has been met:
   [N]..... - **EQS triggered**, go to step 9.
   [Y]..... - EQS not triggered, go to step 1.

6. Determine whether EQS (C) has been met:
   [N]..... - go to step 7 (steps 8 or 9 also optional).
   [Y]..... - EQS not triggered, go to step 1

7. Determine whether EQS (D) has been met:
   [N]..... - go to step 8 (step 9 also optional).
   [Y]..... - EQS not triggered, go to step 1.

8. Determine whether EQS (E or F) have been met:
   [N]..... - **EQS triggered**, go to step 9.
   [Y]..... - EQS not triggered, go to step 1.

9. Implement management action to reduce contaminant inputs to the ambient environment and achieve the environmental quality objective within an agreed timeframe. Prior to implementing management action procedures such as TIE and CBR might be required to confirm the specific cause of toxicity or the source of contaminants. In extreme circumstances environmental remediation may be considered appropriate.

Guidance notes

Environmental quality guidelines

- It is preferable, but not necessary, that samples for toxicant analyses are filtered (ie. 0.45µm teflon or glass fibre filter) in the first instance for comparison with the guidelines. If an unfiltered sample exceeds the guideline then additional samples should be collected and filtered for comparison against the guideline.

Environmental quality standards

- Guideline values are provided for specific species groups in section 9.4.2 of the ANZECC/ARMCANZ Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000).
- Fresh samples should be used for determining bioavailable contaminant concentrations. Sample preservation can have a significant effect on chemical speciation/bioavailability.
- Toxicity testing or Direct Toxicity Testing[#] (DTA) may be considered for futher investigation if single contaminants are of concern. Where mixtures of contaminants are an issue then DTA procedures are more appropriate. End points for these tests should be relevant to production of the cultured species.
- There is potential for some aquaculture activities to reduce the quality of their production water if management is inadequate. Investigation of the source of any reductions in water quality is therefore essential.
- Investigative procedures such as Toxicity Identification Evaluation (TIE) and Contaminant Body Residue (CBR) may be required to establish whether the observed effects are caused by specific contaminants or come from specific sources.

see NWQMS Report No 4 Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000).

Pictorial decision scheme for applying the EQC for aquaculture production

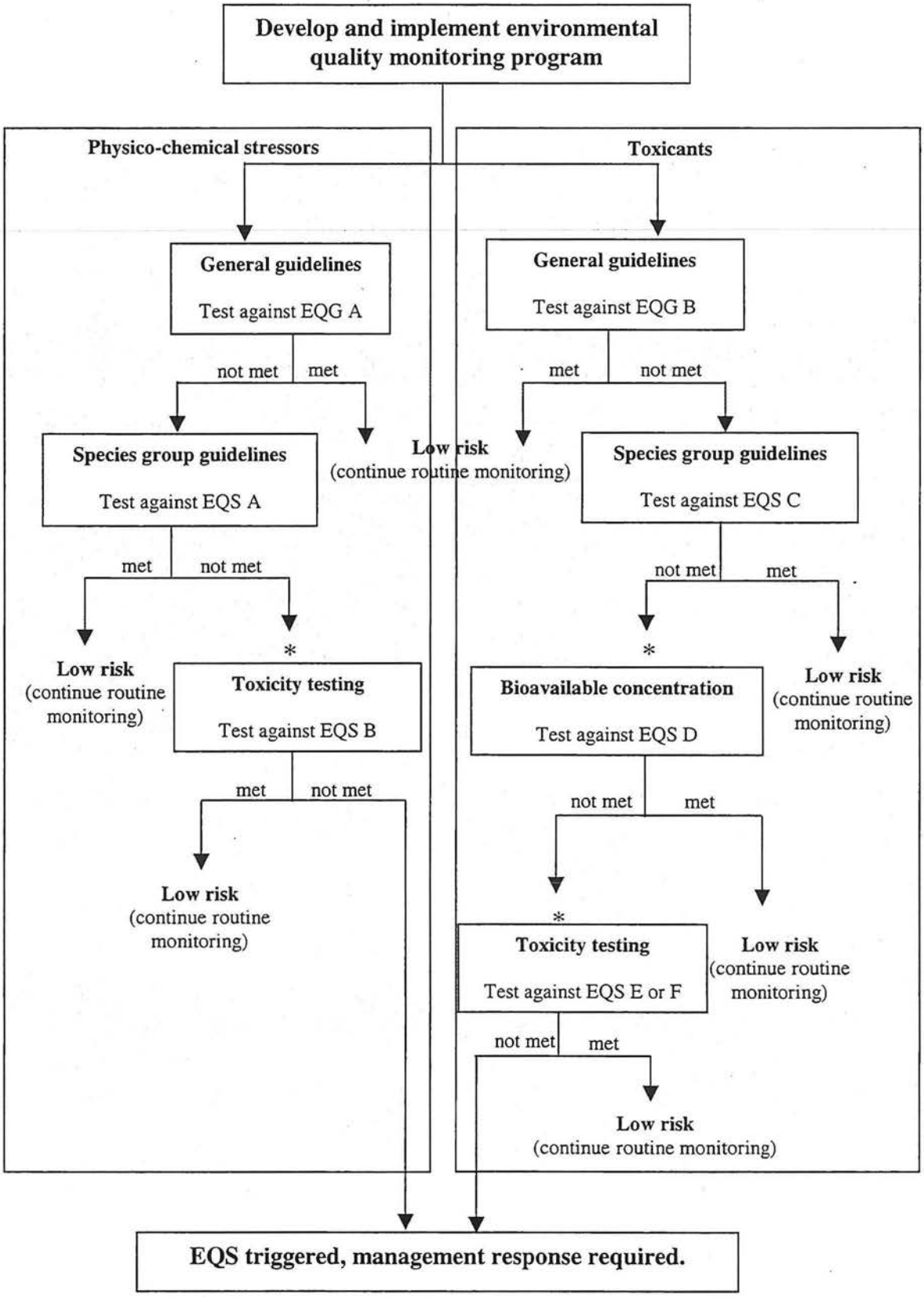


TABLE 6. Environmental quality criteria for the maintenance of primary contact recreation

Indicator	Environmental quality guideline µg/L (unless otherwise stated)	Environmental quality standard (EQS) µg/L (unless otherwise stated)
BIOLOGICAL		
Faecal pathogens	A. The 95%ile bacterial content of marine waters should not exceed 200 enterococci/100mL.	A. The 95%ile bacterial content of marine waters should not exceed 500 enterococci/100mL..
Toxic algae	B. The median phytoplankton cell count for the area of concern (either from one sampling run or from a single site over an agreed period of time) should not exceed 15 000 cells/mL or There should be no reports of skin or eye irritation or potential algal poisoning in swimmers when less than 15 000cells/mL is present in water column.	B. There should be no confirmed incidences (by the Health Department of WA) of skin or eye irritation caused by toxic algae, or of algal poisoning in recreational users.
PHYSICAL		
pH		C. The median of the sample concentrations from the area of concern (either from one sampling run or from a single site over an agreed period of time) should not exceed the range of 5 – 9 pH units.
Water clarity	C. To protect the visual clarity of waters used for swimming, the horizontal sighting of a 200 mm diameter black disc should exceed 1.6 m.	
RADIOLOGICAL		
Gross alpha and beta activity		D. Radionuclide measurements should be at levels that are satisfactory to the Radiological Council.
TOXIC CHEMICALS	D. The 95%ile of the sample concentrations from the area of concern (either from one sampling run or from a single site over an agreed period of time) should not exceed the environmental quality guideline values provided below.	E. The Health Department of WA should be consulted for advice on setting an appropriate environmental quality standard that protects recreational users and any further investigations that would be necessary.

Inorganic chemicals	
Antimony	60
Arsenic	140
Barium	14 000
Boron	6 000
Bromate	400
Cadmium	40
Chlorine	100 000
Chlorine dioxide	20 000
Chlorite	6 000
Chromium	1 000
Copper	40 000
Cyanide	1 600
Fluoride	30 000
Iodide	2000
Lead	200
Manganese	10 000
Mercury	20
Molybdenum	1 000
Monochloramine	60 000
Nickel	400

Table 6 Continued.

Indicator	Environmental quality guideline µg/L (unless otherwise stated)	Environmental quality standard (EQS) µg/L (unless otherwise stated)
Nitrate (as nitrate)	1000 000	
Nitrite (as nitrite)	60 000	
Selenium	200	
Silver	2 000	
Sulfate	10 000 000	
Organic Chemicals		
Acrylamide	4	
Benzene	20	
Benzo(*a*)pyrene	0.2	
Carbon tetrachloride	60	
Chloroacetic acid	3 000	
Chlorobenzene	6 000	
1,2-Dichlorobenzene	30 000	
1,4-Dichlorobenzene	800	
Cyanogen chloride (as cyanide)	1 600	
Dichloroacetic acid	2 000	
Trichloroacetic acid	2 000	
1,1-Dichloroethene	600	
1,2-Dichloroethene	1 200	
1,2-Dichloroethane	60	

Dichloromethane	80
Epichlorohydrin	10
Ethylbenzene	6 000
Ethylenediamine tetraacetic acid (EDTA)	5 000
Formaldehyde	10 000
Hexachlorobutadiene	14
Nitrilotriacetic acid	4 000
Tetrachloroethene	1 000
Trichloroacetaldehyde (chloral hydrate)	400
Trihalomethanes (THMs) (total)	5 000
2-Chlorophenol	6 000
2,4-Dichlorophenol	4 000
2,4,6-Trichlorophenol	400
Tributyltin oxide	20
Di(2-ethylhexyl) phthalate	200
Styrene (vinylbenzene)	600
Toluene	16 000

Table 6 Continued.

Indicator	Environmental quality guideline µg/L (unless otherwise stated)	Environmental quality standard (EQS) µg/L (unless otherwise stated)
Trichlorobenzenes (total)	600	
Vinyl chloride	6	
Xylene	12 000	
Pesticides		
Acephate	200	
Aldicarb	20	
Aldrin (and Dieldrin)	6	
Ametryn	1 000	
Amitrole	200	
Atrazine	400	
Azinphos-methyl	60	
Benomyl	2 000	
Bentazone	600	
Bioresmethrin	2 000	
Bromazil	6 000	
Bromophos-ethyl	200	
Bromoxynil	600	
Carbaryl	600	
Carbendazim	2 000	

Carbofuran	200
Carbophenothion	10
Carboxin	6 000
Chlordane	20
Chlorphenvinphos	100
Chlorothalonil	600
Chloroxuron	200
Chlorfenvinphos	200
Chlorsulfuron	2 000
Clopyralid	20 000
2,4-D	600
DDT	400
Diazinon	60
Dicamba	2 000
Dichlobenil	200
Dichlorvos	20
Diclofop-methyl	100
Dicofol	60
Dieldrin (see Aldrin)	6
Difenzoquat	2 000
Dimethoate	1 000
Diphenamid	6 000
Diquat	100

Table 6 Continued.

Indicator	Environmental quality guideline µg/L (unless otherwise stated)	Environmental quality standard (EQS) µg/L (unless otherwise stated)
Disulfoton	60	
Diuron	600	
DPA (2,2-DPA)	10 000	
EDB	20	
Endosulfan	600	
Endothal	2 000	
EPTC	600	
Ethion	60	
Ethoprophos	20	
Etridiazole	2 000	
Fenamiphos	6	
Fenarimol	600	
Fenchlorphos	600	
Fenitrothion	200	
Fenoprop	200	
Fensulphothion	200	
Fenvalerate	1 000	
Flamprop-methyl	60	
Fluometuron	1 000	
Formothion	1 000	

Fosamine	600
Glyphosate	20 000
Heptachlor (including its epoxide)	6
Hexaflurate	600
Hexazinone	6000
Lindane	400
Maldison	1 000
Methidathion	600
Methiocarb	100
Methomyl	600
Methoxychlor	6 000
Metolachlor	6 000
Metribuzin	1000
Metsulfuron-methyl	600
Mevinphos	100
Molinate	100
Monocrotophos	20
Napropamide	20 000
Nitralin	10 000
Norflurazon	1 000
Oryzalin	6 000
Oxamyl	2 000

Table 6 Continued.

Indicator	Environmental quality guideline µg/L (unless otherwise stated)	Environmental quality standard (EQS) µg/L (unless otherwise stated)
Paraquat	600	
Parathion	200	
Parathion-methyl	2 000	
Pebulate	600	
Pendimethalin	6 000	
Pentachlorophenol	200	
Permethrin	2 000	
Picloram	6 000	
Piperonyl butoxide	2 000	
Pirimicarb	100	
Pirimiphos-ethyl	10	
Pirimiphos-methyl	1 000	
Profenofos	6	
Promecarb	600	
Propachlor	1 000	
Propanil	10 000	
Propargite	1 000	
Propazine	1 000	
Propiconazole	2 000	
Propyzamide	6 000	

Pyrazophos	600
Quintozene	600
Simazine	400
Sulprofos	200
2,4,5-T	2 000
Temephos	6 000
Terbacil	600
Terbufos	10
Terbutryn	6 000
Tetrachlorvinphos	2 000
Thiobencarb	600
Thiometon	60
Thiophanate	100
Thiram	60
Triadimefon	40
Trichlorofon	100
Triclopyr	200
Trifluralin	1 000
Vernolate	600

* (MBAS) Methylene blue active substances

Narrative decision scheme for applying the EQC for primary contact recreation

1. Conduct routine monitoring program covering the area to be assessed and the contaminants of concern using the standard operating procedures and go to step 2.

2. Determine whether EQG (A, B, C and/or D) have been met, or whether EQS (C or D) have been met:

   [N]..... - go to step 3 if EQG B or D or EQS C exceeded.
   - go to step 4 if EQG A not met and
   - go to step 7 if EQG C not met and
   - go to step 8 if EQS D not met.

   [Y]..... - suitable for recreation, go to step 1.

3. If the exceedance was for the last sampling occasion has it been confirmed (eg. through the analysis of back-up samples or samples collected immediately from the same sites)?

   [N]..... - suitable for recreation, go to step 1.

   [Y]..... - go to step 6 if EQG B not met and
   - go to step 8 if EQG D not met and
   - go to step 9 if EQS C not met.

The EQG may now be triggered and the EQS need to be considered.

4. Determine whether EQS (A) has been met:

   [N]..... - go to step 5 and
   - go to step 9.

   [Y]..... - go to step 5.

5. Undertake a sanitary inspection of the site in liaison with the Health Department of WA to further assess the risk to recreational users. Develop predictive approaches to give early warning of periods or events likely to result in poor microbiological water quality and increase sampling frequency in these areas then: - go back to step 1.

6. Intensify monitoring of potentially toxic algal species to assess human health risk and determine whether EQS (B) has been met:

   [N]..... - go to step 9;

   [Y]..... - No issue identified, go to step 1.

7. Swimmers should be urged to use caution when swimming in these waters. Signage may be an option.

8. Contact the Health Department of WA with the results and seek advice on setting an appropriate environmental quality standard that protects recreational users and on any additional monitoring or management requirements to ensure human health risks are managed at an appropriate level.

9. Implement management action to reduce contaminant inputs, or if this is not practically feasible, then reduce risk to public health through appropriate management on advice of the Health Department of WA. If appropriate, environmental remediation may be required.

Guidance notes

Environmental quality guidelines

Faecal pathogens

- The 95%ile bacterial content should be calculated from a minimum of 100 samples taken over a maximum 5 year period.

Toxic algae

- The numerical environmental quality guideline for toxic algae was largely developed for inland waters and should be used as an indicative guideline until sufficient marine data have been gathered for its revision.
- Because of the uncertainty associated with the numerical guideline a watching brief should also be maintained for human health impacts at algal concentrations below the guideline.
- The median of the total algal cell counts for the test site samples should be compared with the environmental quality guideline.

Radiology and Chemicals

- All radiological monitoring results should be referred to the Radiological Council for assessment.
- Environmental quality guidelines for chemicals are derived by multiplying the NH&MRC Drinking Water Guidelines by a factor of 20 (assumes up to 100mL of marine water may be consumed while swimming compared to the assumption of 2L consumed when deriving drinking water guidelines.
- For chemical indicators the 95%ile concentrations of the test site samples are compared with the environmental quality guideline.

Environmental quality standards

Faecal pathogens

- Sanitary inspections should identify the sources of faecal contamination, the conditions or activities that reduce microbiological water quality (eg. runoff) and determine an appropriate sanitary inspection category.
- The 95%ile bacterial content for each site should be calculated from a minimum of 100 samples taken over a maximum 5 year period.

Toxic algae

- To further assess the risk from potentially toxic species, sampling should be intensified with cell counts performed on each species present. Sampling should be at regular intervals for at least one year to identify whether toxic species are present at potentially harmful concentrations. Advice should be sought from the Health Department of WA.
- Consideration should be given to refining the guideline value in light of the monitoring results.

Chemicals

- If chemical concentrations exceed the environmental quality guidelines then the monitoring results should be referred to the Health Department of WA and their advice sought for further investigation.

Pictorial decision scheme for applying the EQC for primary contact recreation

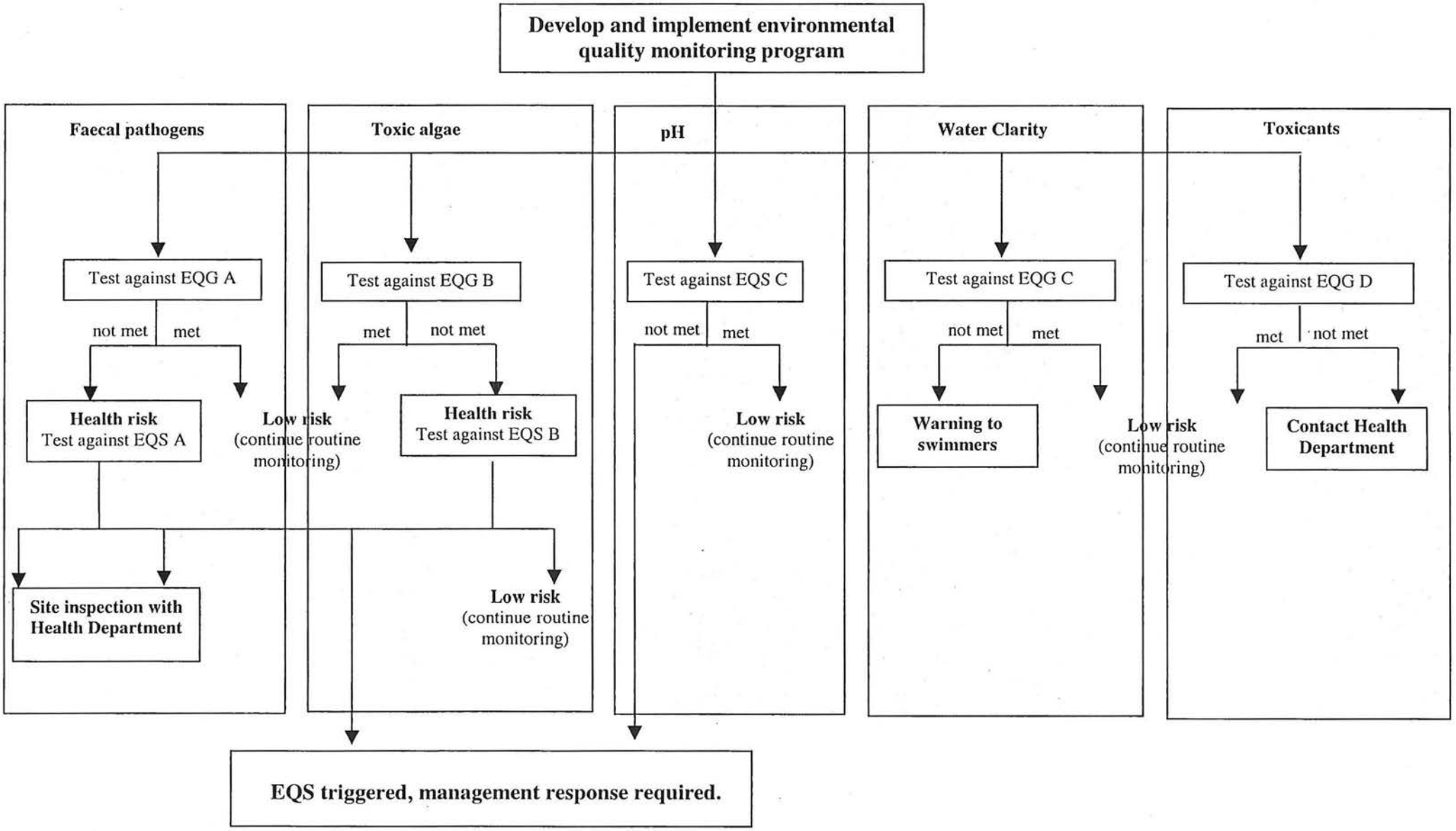


TABLE 7. Environmental quality criteria for the maintenance of secondary contact recreation

Indicator	Environmental quality guideline	Environmental quality standard (EQS)
Biological		
Faecal pathogens	A. The 95%ile bacterial content of marine waters should not exceed 2000 enterococci/100mL.	A. The 95%ile bacterial content of marine waters should not exceed 5000 enterococci/100mL.
Toxic algae	B. The median phytoplankton concentration for the area of concern (either from one sampling run or from a single site over an agreed period of time) should not exceed 15 000 cells/mL or There should not be any reports of skin or eye irritation, or potential algal poisoning, in recreational users when phytoplankton concentration is less than 15 000cells/mL.	B. There should be no confirmed incidences (by the Health Department of WA) of skin or eye irritation caused by toxic algae, or of algal poisoning in recreational users.
Physical and chemical		
pH		C. The median of the sample concentrations from the area of concern (either from one sampling run or from a single site over an agreed period of time) should not exceed the range of 5 – 9 pH units.
Toxic chemicals	C. Recreational water should contain no chemicals at concentrations that can irritate the skin of the human body.	

Narrative decision scheme for applying the EQC for secondary contact recreation

1. Conduct routine monitoring program covering the area to be assessed and the contaminants of concern using the standard operating procedures and go to step 2.

2. Determine whether EQG (A, B and/or C) have been met, or whether EQS (C) have been met:
   [N]..... - go to step 3 if EQG B or EQS C not met and
   - go to step 4 if EQG A not met and
   - go to step 7 if EQG C not met.
   [Y]..... - suitable for secondary contact recreation, go to step 1.

3. If the exceedance was for the last sampling occasion has it been confirmed (eg. through the analysis of back-up samples or samples collected immediately from the same sites)?
   [N]..... - suitable for recreation, go to step 1.
   [Y]..... - go to step 6 if EQG B not met and
   - go to step 8 if EQS C not met.

The EQG may now be triggered and the EQS need to be considered.

4. Determine whether EQS (A) has been met:
   [N]..... - go to step 5 and
   - go to step 8.
   [Y]..... - go to step 5.

5. Undertake a sanitary inspection of the site in liaison with the Health Department of WA to further assess the risk to recreational users. Develop predictive approaches to give early warning of periods or events likely to result in poor microbiological water quality and increase sampling frequency in these areas then:
   - go back to step 1.

6. Determine whether EQS (B) has been met:
   [N]..... - go to step 8;
   [Y]..... - No issue identified, go to step 1.

7. Contact the Health Department of WA with the results and seek advice on setting an appropriate environmental quality standard that protects recreational users and on any additional monitoring or management requirements to ensure human health risks are managed at an appropriate level.

8. Implement management action to reduce contaminant inputs, or if this is not practically feasible, then reduce risk to public health through appropriate management on advice of the Health Department of WA. If appropriate, environmental remediation may be required.

Guidance notes

Environmental quality guidelines

Faecal pathogens

- The 95%ile bacterial content should be calculated from a minimum of 100 samples taken over a maximum 5 year period.

Toxic algae

- The numerical environmental quality guideline for toxic algae was largely developed for inland waters and should be used as an indicative guideline until sufficient marine data have been gathered for its revision.
- Because of the uncertainty associated with the numerical guideline a watching brief should also be maintained for human health impacts at algal concentrations below the guideline.

Environmental quality standards

Faecal pathogens

- The 95%ile bacterial content should be calculated from a minimum of 100 samples taken over a maximum 5 year period.

Pictorial decision scheme for applying the EQC for secondary contact recreation

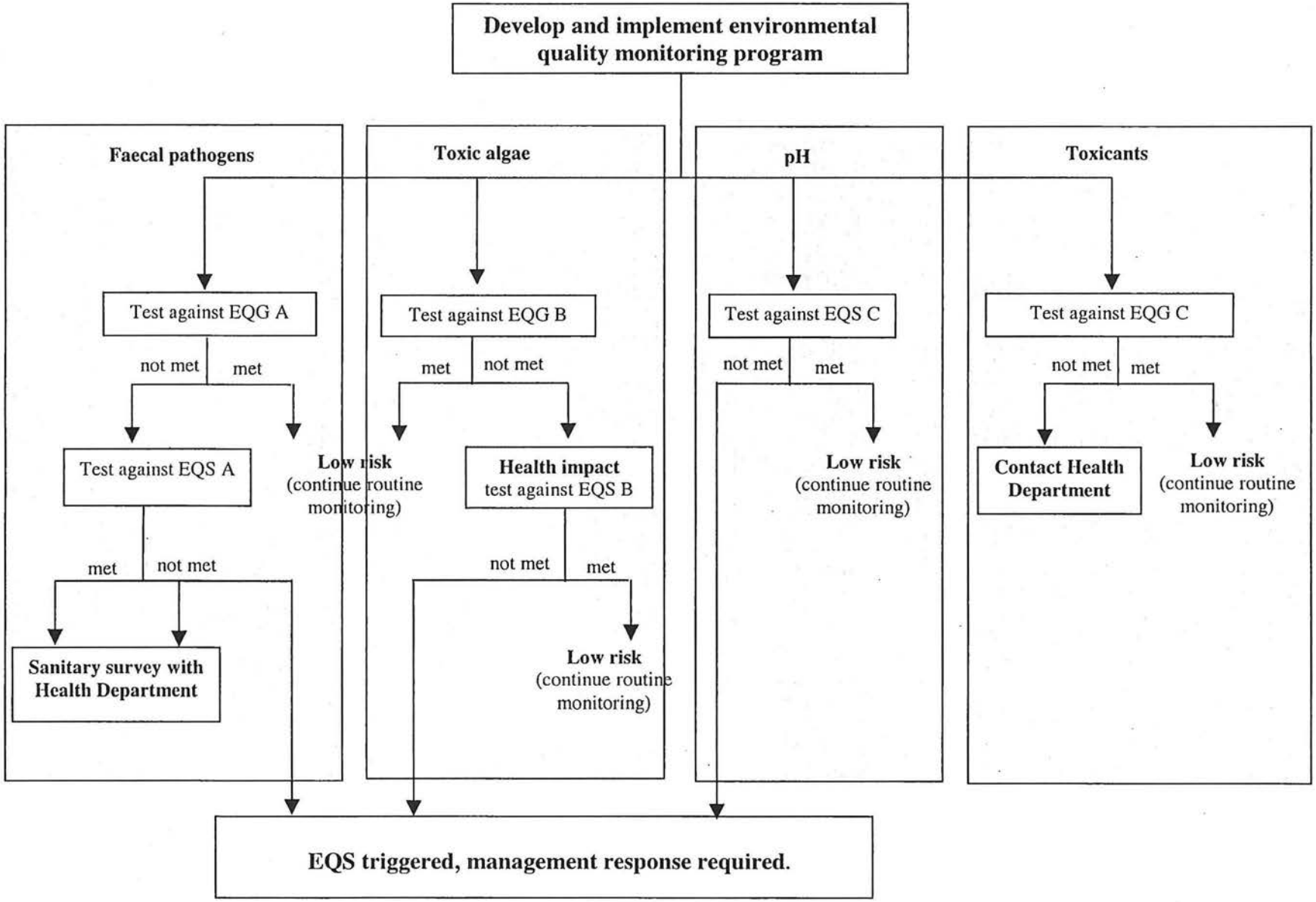


TABLE 8. Environmental quality criteria for Aesthetic quality

Indicator	Environmental quality guideline	Environmental quality standard (EQS)
Visual indicators		
Nuisance organisms	A. Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae and sewage fungus should not be present in excessive amounts.	A. There should be no overall decrease in aesthetic water quality values of Cockburn Sound as measured through a broad community survey.
Faunal deaths	B. There should be no reported incidents of large-scale deaths of marine organisms resulting from un-natural causes.	
Water clarity	C. The natural visual clarity of the water should not be reduced by more than 20%. Seagrass should generally be visible in up to 10m of water under calm conditions in summer.	
Colour	D. The natural hue of the water should not be changed by more than 10 points on the Munsell Scale.	
Reflectance	E. The natural reflectance of the water should not be changed by more than 50%.	
Surface films	F. Oil and petrochemicals should not be noticeable as a visible film on the water or detectable by odour..	
Surface debris	G. Water surfaces should be free of floating debris, dust and other objectionable matter, including substances that cause foaming.	
Submerged debris	H. Benthic habitats should be free from debris of anthropogenic origin.	
Odour	I. There should be no detectable objectionable odours.	
Fish tainting substances (mg/L)		
	J. The 95%ile of the sample concentrations from the area of concern (either from one sampling run or all samples over an agreed period of time, or from a single site over an agreed period of time) should not exceed the environmental quality guideline value provided below.	B. There should be no detectable tainting of edible fish harvested from Cockburn Sound.

Chemical	value
Acenaphthene	0.02
Acetophenone	0.5
Acrylonitrile	18.0
Copper	1.0
m-cresol	0.2
o-cresol	0.4
p-cresol	0.1
Cresylic acids (meta, para)	0.2
Chlorobenzene	0.02
n-butylmercaptan	0.06
o-sec. butylphenol	0.3
p-tert. butylphenol	0.03
o-chlorophenol	0.0001*
p-chlorophenol	0.0001
2,3-dinitrophenol	0.08
2,4,6-trinitrophenol	0.002
2,4-dichlorophenol	0.0003
2,5-dichlorophenol	0.0005
2,6-dichlorophenol	0.0002
3,4-dichlorophenol	0.0003

Table 8 Continued.

Indicator	Environmental quality guideline	Environmental quality standard (EQS)
2-methyl-4-chlorophenol	2.0	
2-methyl-6-cholorophenol	0.003	
3-methyl-4-chlorophenol	3.0	
o-phenylphenol	1.0	
Pentachlorophenol	0.03	
Phenol	0.3	
2,3,4,6-tetrachlorophenol	0.001	
2,3,5-trichlorophenol	0.001	
2,4,6-trichlorophenol	0.002	
2,4-dimethylphenol	0.4	
Dimethylamine	7.0	
Diphenyloxide	0.05	
B,B-dichlorodiethyl ether	0.09*	
o-dichlorobenzene	0.25	
Ethylbenzene	0.25	
Ethanethiol	0.2	
Ethylacrylate	0.6	
Formaldehyde	95.0	
Gasoline	0.005	
Guaicol	0.08	

Kerosene	0.1
Kerosene plus kaolin	1.0
Hexachlorocyclopentadiene	0.001
Isopropylbenzene	0.25
Naphtha	0.1
Naphthalene	1.0
Naphthol	0.5
2-Naphthol	0.3
Nitrobenzene	0.03
a-methylstyrene	0.25
Oil, emulsifiable	15.0
Pyridine	5*
Pyrocatechol	0.8*
Pyrogallol	20*
Quinoline	0.5*
p-quinone	0.5
Styrene	0.25
Toluene	0.25
Outboard fuel as exhaust	7.2
Zinc	5.0

* Lower end of range provided in ANZECC & ARMCANZ 2000.

Narrative decision scheme for applying the EQC for aesthetic quality

1. Conduct routine monitoring program covering the area to be assessed and monitor public complaints. Go to steps 2 and 3.

2. Determine whether all of EQG (A to I) have been met:
   [N]..... - go to step 5.
   [Y]..... - go to step 1.

3. Determine whether EQG (J) has been met:
   [N]..... - go to step 4
   [Y]..... - aesthetic values not compromised, go to step 1.

4. If the exceedance was for the last sampling occasion has it been confirmed through analysis of back-up samples or samples collected immediately from the same sites?
   [N]..... - aesthetic values not compromised, go to step 1.
   [Y]..... - go to step 6.

The EQG may now be triggered and the EQS need to be considered.

5. Undertake community survey and determine whether EQS (A) has been met:
   [N]..... - go to step 7;
   [Y]..... - aesthetic values not compromised, go to step 1.

6. Determine whether EQS (B) has been met:
   [N]..... - go to step 7;
   [Y]..... - aesthetic values not compromised, go to step 1.

7. Identify the causes for the loss of aesthetic value in Cockburn Sound and implement management actions to prevent further reduction of, and if possible to enhance, the aesthetic value within an agreed timeframe.

Guidance notes

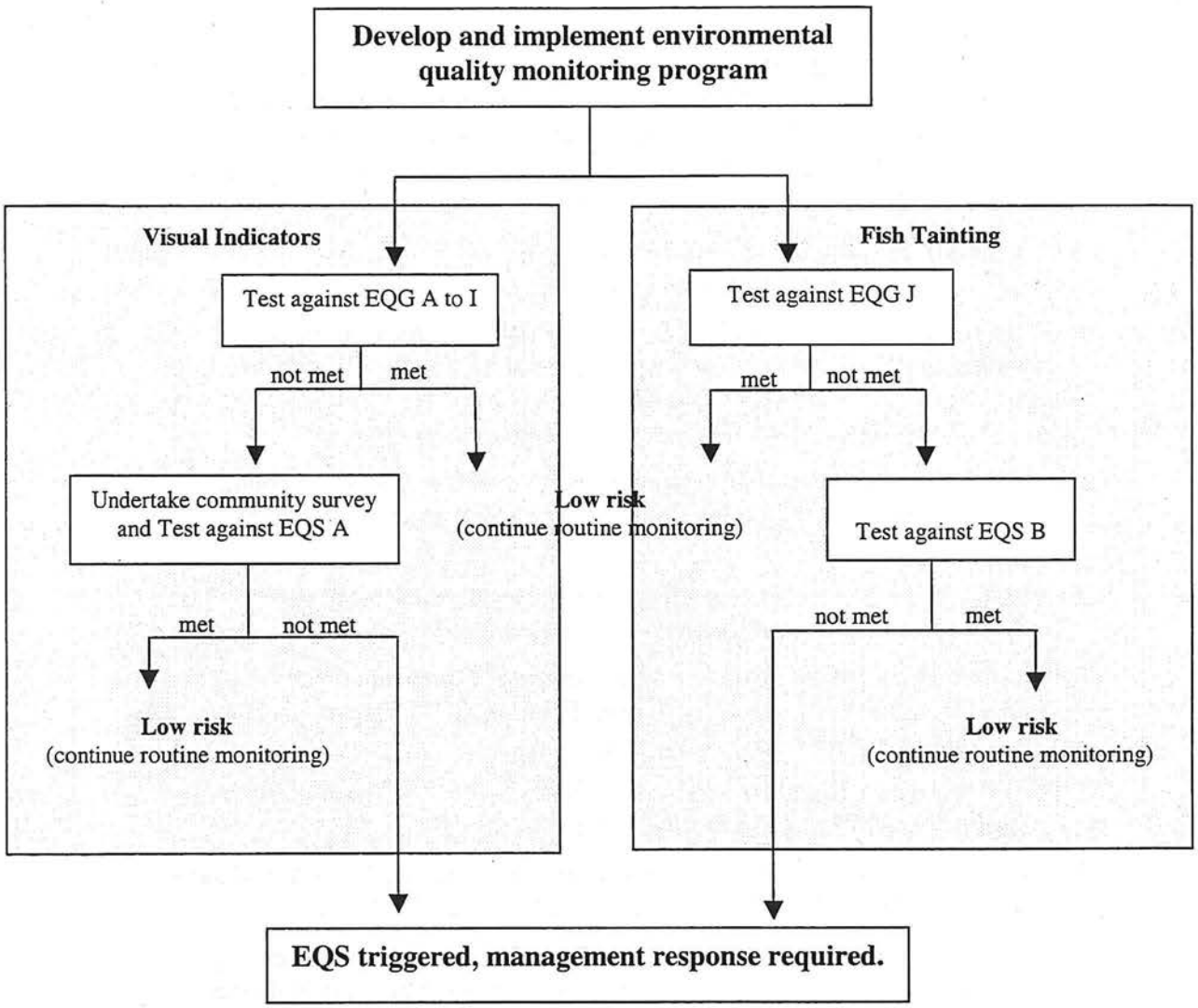
Environmental quality guidelines

- Many of the guidelines for aesthetic quality are subjective and relate to the general appreciation and enjoyment of Cockburn Sound by the community as a whole. Consequently, when using these criteria to determine if aesthetic value is being maintained, consideration should be given to whether the observed change is in a location, or of an intensity, likely to trigger community concern and to whether the changes are transient, persistent or regular events.

Environmental quality standards

- Further investigation involves direct measures of aesthetic value to determine whether there has been a perceived loss of value. Regular surveys (minimum 12 months apart) can be used to show trends in community perception of aesthetic value over time.
- If a guideline for a fish tainting substance has been exceeded, then the source of the potential contamination should be identified and edible fish sampled from around the source for taste testing.

Pictorial decision scheme for applying the EQC for aesthetic quality



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