REVISED ENVIRONMENTAL QUALITY CRITERIA REFERENCE DOCUMENT (Cockburn Sound)

A supporting document to the draft Environmental Protection (Cockburn Sound) Policy 2002

Environmental Protection Authority
Report 20
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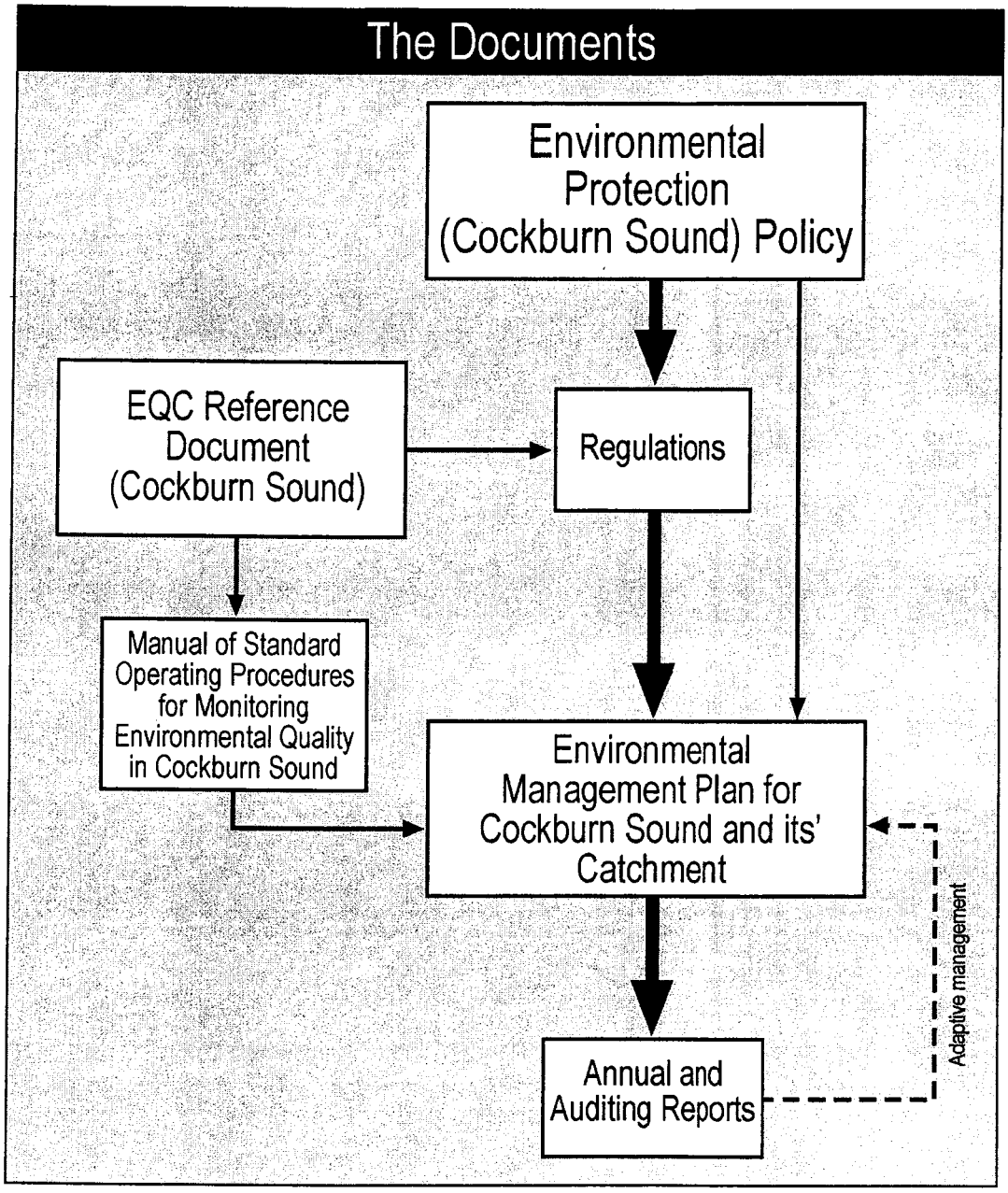

The *Cockburn Sound Environmental Quality Management Framework* documents and how they relate

PREAMBLE

Cockburn Sound is a sheltered marine embayment located to the south-west of the Perth metropolitan region. Its relatively calm waters have attracted a wide range of commercial activities that must 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 have the potential to impact on the quality of the Sound and these also need to be managed appropriately.

State Cabinet, in recognition of the need for effective multiple use management, established the Cockburn Sound Management Council (CSMC) to prepare an Environmental Management Plan (EMP) for the Sound. The EPA agreed to prepare an Environmental Protection Policy (EPP) to set the common goals for management and provide the authority for implementing the plan.

The focus of the EPP is to declare, protect and maintain the Environmental Values of Cockburn Sound, protecting them from the adverse effects of pollutants, waste discharges and deposits. Environmental quality criteria have been specifically developed for Cockburn Sound to tell whether or not the environmental quality meets the objectives that have been set for it in the EPP. A comprehensive suite of environmental quality criteria are provided in this Revised EQC Reference Document. *Environmental quality guidelines* and *environmental quality standards* also appear in Regulations under the EPP. The diagram on the opposite page gives an overview of how the various documents that make up the management framework for Cockburn Sound link together.

1 INTRODUCTION

Both Government and the 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 Revised Draft Environmental Protection (Cockburn Sound) Policy (EPA, 2002). The framework is underpinned by established environmental values and clearly expressed and spatially defined environmental quality objectives to guide decision-making and provide the common goals for management. The objectives have been developed in consultation with the community and are intended to 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 if necessary, to restore environmental quality to the levels defined by the EQC.

The EQC are provided in this document and support the Environmental Protection (Cockburn Sound) Policy and the EMP. They are based on known current and historical contaminant inputs and are relevant to the potential issues/pressures in the Sound. Those EQC that are guidelines and standards will be incorporated into regulations under the policy. All the EQC, and the decision schemes which explain how the EQC should be applied, are included in this reference document. The decision schemes are also included in the EPP. If in future other contaminants are considered to pose a potential threat to the environmental values of the Sound then guidance should be sought from the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ, 2000), the *Western Australian Shellfish Quality Assurance Program* (HDWA & FWA, 1999) and the *Australian New Zealand Food Standards* (ANZFA, 2000) to establish additional EQC.

Development of the EQC was predominantly 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 EPA has adopted the concept of using water quality guidelines to trigger a risk-based approach for determining the risk of a significant environmental impact. This risk-based approach integrates the more traditional chemical and physical indicators with biological indicators of environmental quality. Where necessary, expert scientific advice was sought through technical workshops and working groups to provide guidance on the selection of appropriate indicators and criteria.

Sources of additional information used for the development of the EQC were *HDWA & FWA (1999), ANZFA (2000)* and advice from the Health Department of Western Australia.

A *Manual of Standard Operation Procedures for Monitoring Environmental Quality in Cockburn Sound* has also been prepared to complement this document. The manual specifies how samples should be collected and the results assessed against the EQC. This has been done to further reduce uncertainty associated with environmental monitoring and decision-making. It also allows data generated in accordance with the standard operating procedures to be temporally and spatially integrated to assess the quality of Cockburn Sound.

2 THE ENVIRONMENTAL QUALITY MANAGEMENT FRAMEWORK

2.1 An overview

The objective of the environmental quality management framework 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 adopted for the environmental quality management framework (Figure 1). Following extensive consultation one ecological and three social *environmental values* have been identified for protection in Perth's coastal waters (EPA, 2000). 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 ecological 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 in some areas. The boundaries for each environmental quality objective, and the different levels of ecological protection, are defined in the Revised Environmental Protection (Cockburn Sound) Policy 2002 (EPA, 2002).

For each environmental quality objective a set of *environmental quality criteria (EQC)* have been established to provide the environmental quality benchmarks against which environmental quality and 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 are 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.

An essential step in the environmental quality management framework is the implementation of appropriate monitoring strategies to provide data for measuring environmental performance against the EQC. Monitoring should primarily focus on those indicators or contaminants that are 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. Early warning of potential risks to environmental quality may then be identified through environmental exposure modelling. This may 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 frequent 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).

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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.

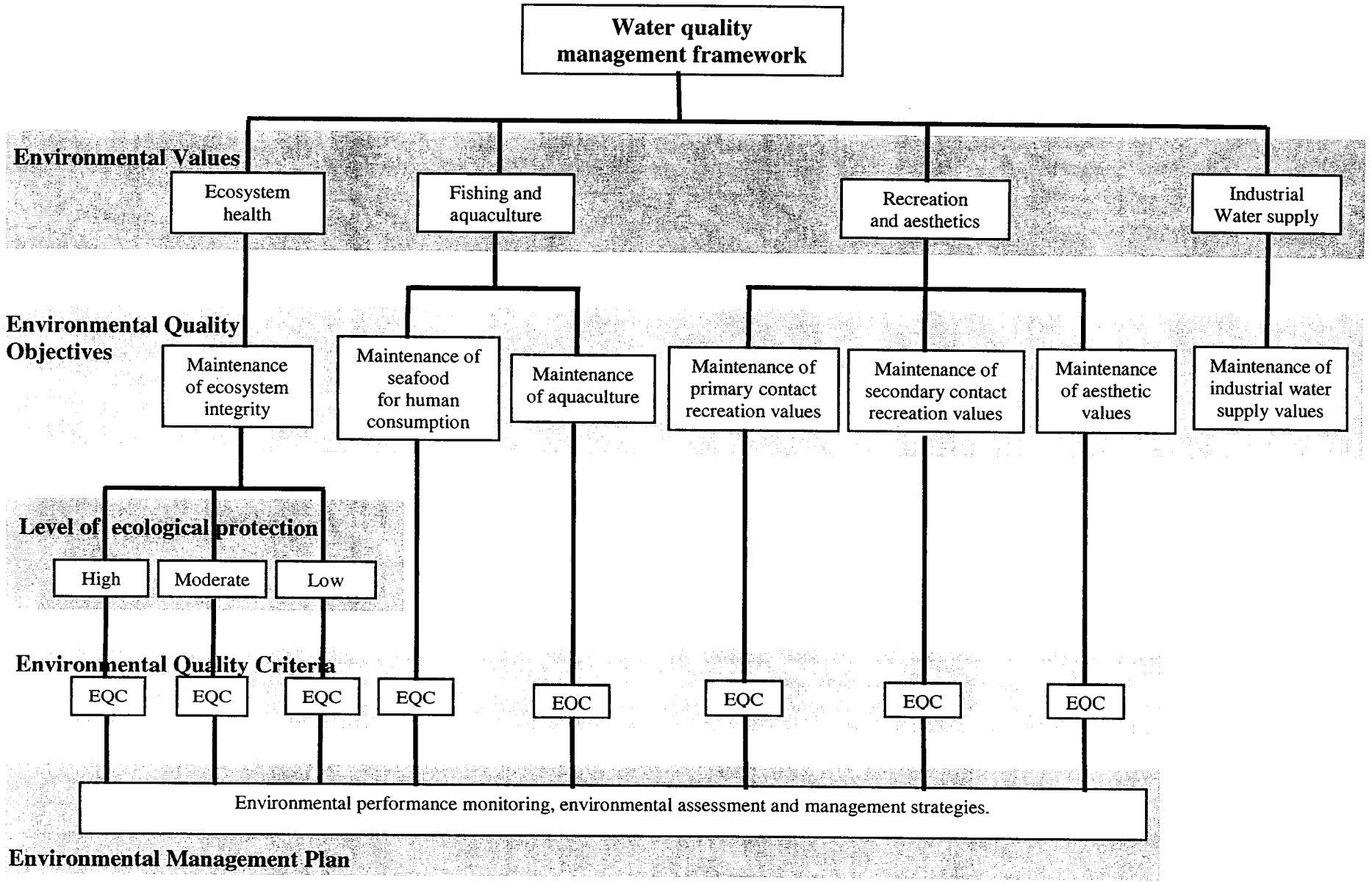


Figure 1 The environmental quality management framework for Cockburn Sound.

Figure 2. The Environmental Values and their corresponding Environmental Quality Objectives 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 ecological protection shall apply to Cockburn Sound (High, Moderate, and Low).
Fishing and Aquaculture	***Maintenance of seafood for human consumption.*** Seafood is safe for human consumption when collected or grown in Cockburn Sound. ***Maintenance of aquaculture.*** Water is of a suitable quality for aquaculture purposes.
Recreation and Aesthetics	***Maintenance of primary contact recreation values*** Primary contact recreation (eg. swimming) is safe to undertake in Cockburn Sound.
	Maintenance of secondary contact recreation values Secondary contact recreation (eg. boating) is safe to undertake in Cockburn Sound.
	Maintenance of aesthetic values The aesthetic values of Cockburn Sound is protected.
Industrial water supply	***Maintenance of industrial water supply values*** Water in Cockburn Sound is of a suitable quality for industrial water supply purposes.

2.2 The EQC and their application

2.2.1 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 using one of four possible approaches (listed in order of preference):

- locally developed biological effects data;
- ecological models;
- reference sites; or
- refining default trigger values for local environments using a risk-based approach.

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 there is uncertainty as to whether the associated environmental quality objective has been achieved and a more detailed assessment against an environmental quality standard is triggered. This assessment is 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 normally focus on identifying the cause (or source) of the exceedance and then reducing loads of the contaminant of concern (ie. source control) and 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 3.

Two additional types of EQC provided in this document only relate to the maintenance of ecosystem integrity. Low reliability values (LRV) have been provided for chemicals where there was insufficient information on toxicity to derive an environmental quality guideline. Initial Management Triggers (IMT) assist in assessing the urgency of implementing a management response in areas where water quality has been significantly contaminated. Neither LRVs or IMTs are recommended benchmarks for assessing environmental performance, but they do provide information that can assist environmental quality management decisions in Cockburn Sound.

Like all natural systems, the marine environment is subject to a high degree of natural variability and some indicators of environmental quality will 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 over summer when river flow is minimal. Nevertheless, for most indicators seasonal and/or spatial variability is minimal and the criteria would apply throughout the year.

2.2.2 Applying the EQC

Both numerical and narrative EQC for each environmental quality objective in Cockburn Sound are incorporated into tables in Section 3.8 below. They need to be considered within the context of the associated decision schemes and guidance notes provided with the tables. The EQC, decision schemes and guidance notes form a complete package and should not be used in isolation of each other.

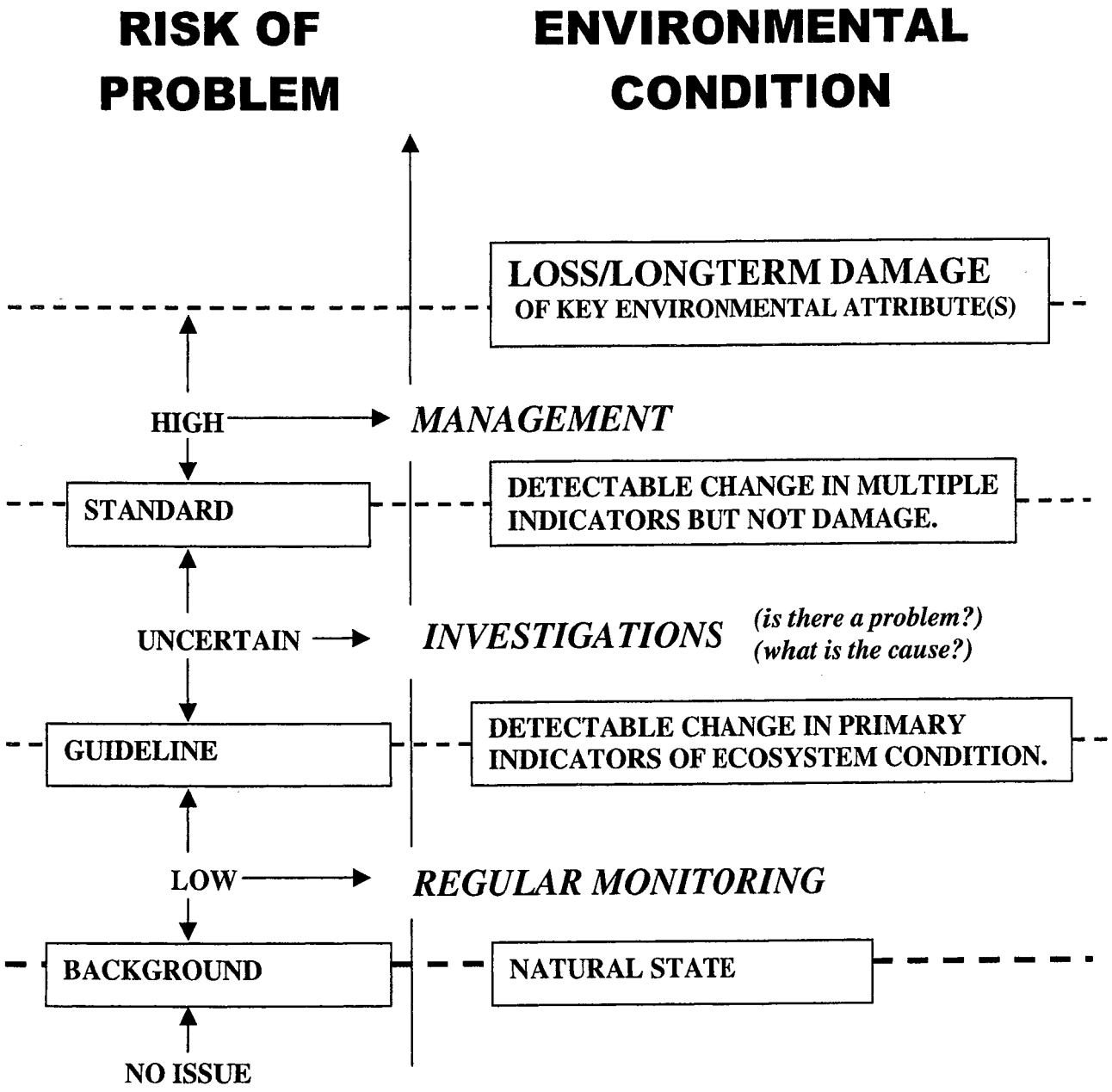


Figure 3. Conceptual diagram showing the relationship between the two types of EQC on the left hand side with the associated environmental condition on the right hand side. The diagram shows that the intensity of management response triggered by exceeding an EQC depends on which type of EQC has been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

The decision schemes have been developed to guide users through each step in the risk-based approach for implementing the guidelines and standards. It should be noted that all the steps of the decision scheme may not always need to be completed. In general each successive 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 (eg. contaminant load reduction) 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.

Given the range of environmental quality objectives established for the site, one of the first steps when applying the EQC for a particular contaminant is to determine which of the criteria 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 environmental quality objectives there are no EQG and only EQS have been provided for specific 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 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. Guidance on designing environmental quality monitoring programs, the collection and storage of samples from each media type and interpretation of results against EQG and EQS is provided in the EPA's companion document, *Manual of Standard Operating Procedures for Monitoring Environmental Quality in Cockburn Sound.*

The EQC that have been developed for Cockburn Sound are comprehensive and quite detailed. Although decision schemes and guidance notes have been provided for applying the EQC, 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 (unimpacted) 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, if there is a high degree of certainty that an EQO has been achieved even though an EQG is exceeded, consideration could be given to modifying the EQG to avoid unnecessarily triggering further investigations against the EQS.

An important point to remember regarding the environmental quality 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. Nor do they infer it is acceptable to load up the ecosystem to these levels – waste avoidance/minimisation strategies should always be adopted and reinforced.

2.2.3 Comparing monitoring data against the EQC

The extent of the area from which environmental quality data is to be collected and compared against the EQC will need to be established on a case-by-case basis and clearly defined in the monitoring program. The EQC themselves have been drafted so that they can be applied to a broad area incorporating a number of sampling sites, or to an individual sampling site. Hence environmental quality can be assessed at a range of spatial scales.

Whether or not monitoring is focussed on a particular region or season, 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 and minimise this uncertainty. Insufficient coverage can artificially bias the results leading to an apparent exceedance of a guideline or standard when in fact it was met. 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 taken for comparison with the EQC, and that these samples are representative of the site.

For comparing monitoring data with the EQG, 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 most toxicants and bacteriological indicators the 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 ecological 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 this document.

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 ecological protection zone to determine whether the moderate ecological protection EQC were being met, then sampling would need to be undertaken on a number of occasions over a minimum of a month to capture temporal variability. If only one sampling run were conducted it could conceivably occur at a time when 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, reference sites will be required for comparison with potential impact sites, and hence a threshold of acceptable change must be established (eg. the 20th and/or 80th percentiles of the measured distribution of the indicator at the reference site for high ecological protection areas).

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

2.2.4 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 following consultation with 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 prioritised for monitoring. 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; an expected increase in contaminant inputs; poor resolution of effluent;

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.

2.3 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 and in the regulation to the Revised Draft Environmental Protection (Cockburn Sound) Policy 2002 (EPA, 2002). The mechanism for revising the EQC is a public process undertaken by the EPA and is described in Schedule 6 of the Revised Draft Policy (EPA, 2002). The EQC will be revised at least once in the first two years following their initial release and then as required.

The nutrient related EQC are exceptions and will be updated annually to incorporate each year's monitoring results from the reference site (see section 3.1.2).

3 THE ENVIRONMENTAL QUALITY CRITERIA

An outline of the main sources of information used to develop the EQC for each environmental quality objective, and the rationale underpinning them has been provided in Sections 3.1 to 3.7. The tables containing the actual EQC (and their associated decision schemes) have been incorporated into Section 3.8. It should be noted that the pictorial decision schemes provide a summary of the narrative decision schemes and hence may not contain all the steps. Additional information required for interpreting the EQC is provided in the footnotes to the tables and under the heading 'Guidance notes'.

EQC for the maintenance of ecosystem integrity have been further subdivided into EQG and EQS for nutrients and physical stressors, EQG and EQS for toxicants in water, initial management triggers for toxicants in water, low reliability guidelines for toxicants in water and EQG and EQS for toxicants in sediment.

3.1 Maintenance of ecosystem integrity

EQC for the maintenance of ecosystem integrity only include 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 ANZECC & ARMCANZ (2000). ANZECC & ARMCANZ (2000) should be referenced if EQC are required for contaminants other than those listed in the tables in this document.

3.1.1 Levels of protection

The Revised Draft Environmental Protection (Cockburn Sound) Policy (EPA, 2002) describes three levels of ecological protection and where they apply spatially in Cockburn Sound so that overall ecological integrity can be maintained. This enables landuse activities to be accommodated without unduly compromising the high level of environmental quality that currently exists over the majority of the Sound. The levels of ecological protection represent the minimum acceptable level of environmental quality to be achieved through management of the Sound. They do not describe the current, or preferred, environmental condition 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 ecological protection areas*).

* ***Detectable change beyond natural variation nominally defined by the median of a test site parameter being outside the 20th and 80th percentiles of the measured distribution of that parameter from a suitable reference site.***

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000) recognises and provides guidelines for three levels of ecological protection: undisturbed; slightly to moderately disturbed; and highly disturbed.

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 assigned a high level of ecological protection to be achieved. 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 or the default guideline trigger value provided.

The area along the eastern side of Cockburn Sound adjacent to the industrial area, and also Careening Bay on Garden Island, is considered to be 'highly disturbed' and has been designated a moderate level of ecological protection. This area includes several existing and proposed harbours and marinas which should be assessed individually. Environmental quality data from the harbours and marinas should not be used to assess performance in the overall moderate ecological protection area. EQG for moderate ecological protection 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 a low level of ecological 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 total area occupied by low ecological protection areas is 1% or less of the protected area in Cockburn Sound.

3.1.2 Derivation of nutrient related EQC

The reference sites selected for deriving 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 EQC [chlorophyll *a*, light attenuation coefficient (LAC), phytoplankton biomass and seagrass shoot density] were derived while giving consideration to achieving the following three important objectives:

- Protection of the remaining seagrass meadows in Cockburn Sound;
- Ensure a level of water quality that would enable seagrass meadows to re-establish along the eastern side of Cockburn Sound, including the Jervoise Shelf, to depths of up to 10 metres; and
- Minimise the occurrence and extent of phytoplankton blooms in Cockburn Sound.

Phytoplankton biomass, and hence chlorophyll *a* concentration and water clarity, in Cockburn Sound is primarily affected by nutrient availability and water residence time. A primary determinant of seagrass survival in Cockburn Sound is whether the plants are receiving sufficient light at the leaf epidermis for net growth over a full year. Decreases in water clarity (measured as LAC) and shading by excessive epiphytic growth are the two main influences on seagrass light availability. For example, LAC is thought to have increased to approximately 0.13 m^{-1} in the early 1970's when the seagrass meadows were lost from the majority of the eastern margin of Cockburn Sound (DEP 1996).

The EQC for chlorophyll *a*, LAC and phytoplankton biomass were derived using data collected from one reference site in the central basin of Warnbro Sound (site 4) during 'typical' summer conditions at intervals between 1987 and 2002. Water quality in Warnbro Sound is high and is independent of Cockburn Sound water quality. The decision to use only one reference site in Warnbro Sound minimises the additional sampling effort required to collect the reference data and was made following an analysis of data from all Warnbro sites showing that site 4 data was representative of all sites. It was recognised that the quality of the water in the northwest corner of Cockburn Sound may predominantly be similar to Warnbro Sound, however, data from this area 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 chlorophyll *a* and light attenuation data were collected between December and March (the non river-flow period) at irregular intervals between 1977/78 and 2001/2. The 1991/92 summer chlorophyll *a* 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 found in Cockburn Sound and was not repeated again in Warnbro Sound, with phytoplankton species composition and chlorophyll *a* levels returning 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 significantly raised the higher order percentiles providing an irrational bias to any criteria derived from them (DEP, in prep).

The resulting EQG for chlorophyll *a* and LAC are at levels that approximate the current water quality in the high protection area of Cockburn Sound, but suggest further reductions in chlorophyll *a* should be a focus for management in the moderate protection area. The LAC levels in both areas approximate

the EQG and if these can be improved slightly then the re-establishment of seagrass along the eastern margin of Cockburn Sound would no longer be limited by water clarity.

The Warnbro Sound reference site will be monitored weekly for chlorophyll *a* and LAC over each summer season (December to March inclusive) The EQC for chlorophyll *a*, LAC and phytoplankton biomass will then be updated each year to incorporate the results of the previous summer's monitoring data. The following mechanism will also be implemented each year to guard against the EQC being triggered because of regional scale effects rather than pressures within Cockburn Sound (eg. unusually favourable meteorological conditions for phytoplankton growth), and also ensuring that the re-calculated EQC is not biased by unusual regional scale effects. The mechanism involves three steps undertaken on the reference site data prior to its incorporation into the updated EQC:

a) compare the median of the reference site data from the year being assessed against the 80th percentile and the 20th percentile of the historical reference site data (note these values are 0.9 and 0.4 (ug chla/L) respectively).

b) If the median is less than the 80th percentile, and greater than the 20th percentile, the new data are included with the reference data set, new median, 80th and 95th percentiles are computed and the EQG and EQS for high and moderate ecological protection areas are updated. The Cockburn Sound monitoring data for that year are then compared against the updated EQG.

c) If the median of the current year reference site data is greater than the 80th percentile, or lower than the 20th percentile of the historical data set, it is accepted that the reference site has shifted outside its 'normal' bounds and these data are **not** used to recompute a new set of percentile-based EQG. In addition, the comparison of the test site (ie Cockburn Sound) data against the reference is **not** conducted for that year as this finding is taken to indicate there is a significant risk that the water quality is responding to non-local forcings.

In tables 1a and 1b provision has been made for the incorporation of EQG for algal growth potential. This indicator will relate to the growth of non-phytoplankton species and is intended to provide early warning of the potential for excessive epiphytic or unattached macro-algal growth reducing light availability to seagrass meadows. Chlorophyll *a* measurements from periphyton collector plates have been successfully trialled in northern Perth metropolitan waters, but in Cockburn Sound the collectors are significantly affected by competing encrusting fauna and consequently chlorophyll *a* measurements are relatively low. Proximity to sources of algal propagules can also be a significant determinant of the availability of propagules for settlement on the collector plates, and hence chlorophyll *a* measurements. Opportunities for investigating the feasibility of alternative indicators of algal growth potential will therefore be sought, and if a suitable indicator is identified it will be incorporated into tables 1a and 1b.

The nutrient-related EQS for seagrass have been developed for *Posidonia* seagrass meadows and are based on reference data collected from randomly located quadrats at sites distant from known nutrient sources on the western and northern sides of Cockburn Sound. The location of reference sites for seagrass shoot density within Cockburn Sound was considered acceptable because the indicator tends to be affected by long-term chronic stress and tends 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 biomass from the eastern side of the Sound. In the future, the intention is to replace the default shoot density criteria with criteria derived from permanent fixed relocatable quadrats located at each of the reference sites.

The reference sites used to derive the default shoot density criteria in Table 1b were located at depths of 2 metres and 7.5 metres, consequently the default EQC values provided in Table 1b are not suitable for use at significantly different depths. To assess seagrass health at depths other than 2.0 - 2.5 and 7.0 – 8.0 metres additional reference sites will need to be established at the appropriate depth and monitored as part of a monitoring and assessment program. Permanent quadrats should be set up at both reference and potential impact sites and non-destructive sampling techniques used to measure shoot density. It is also preferable that the reference and test sites have the same seagrass species.

3.1.3 Decision schemes for applying the EQC

The methods described through the decision schemes for applying the EQC (see section 2.2.2) have 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 for comparison against the EQG, and which if exceeded lead to ever more sophisticated monitoring and analytical steps for assessment against the EQS. Initially bioavailability of the contaminant (eg. toxicants) would be considered and then actual impacts on the biota or ecological processes. This may involve laboratory-based ecotoxicological investigations that measure biological responses to changes in environmental quality using appropriate organisms (preferably local species) and/or *in situ* measurement of selected indicators of ecological integrity. As discussed in section 2.2.2, it is not necessary to go through each step of a decision scheme sequentially before determining whether a management response is required, stakeholders can agree to by-pass the remaining steps of the scheme at any stage and implement an appropriate management response.

The use of toxicological investigations (including direct toxicity assessment) is a relatively new tool in Western Australia that is still developing. Toxicological services are offered by a number of laboratories within the State and interstate, although protocols for sediment toxicity assessment are not as well developed in Australia as are protocols for assessing the toxicity of waters. In Western Australia there are relatively few test protocols developed using local organisms, but work is currently underway to expand the number of local protocols available. Across Australia, however, test protocols have been developed for a range of species and these could be used in the interim.

3.1.4 Initial management triggers

Undertaking investigations to assess environmental quality against the EQS can take a considerable amount of time, potentially delaying management action in situations where it may be urgently required (eg. heavy contamination from unlicensed inputs or accidental spills of toxic substances). For toxicants in water a set of Initial Management Triggers (IMT) have been provided in Table 2b that can be used to assist in assessing the urgency of implementing a management response upon discovery of a significant contamination event (ie. is there time to investigate against the EQS or is contamination at a level where quick action is required). They can also be used to set a cap to increasing degradation of the water resource while investigations against the EQS are on-going.

The IMT are used to assess the level of contamination by comparing the estimated bioavailable concentration of a contaminant with the value provided. If the IMT is exceeded then management action should be considered to reduce the level of contamination to below the IMT while investigations against the EQS continue.

The IMT values have been arbitrarily drawn from the 90% species protection. (high protection) and 80% species protection (moderate protection) guideline values provided by ANZECC & ARMCANZ (2000). The majority of the values are at levels that do not protect key test species in the laboratory from chronic toxic effects, and in some cases acute toxicity, and so are unlikely to protect organisms in the field from chronic toxicity.

3.1.5 Low reliability values

For a number of toxicants there were insufficient toxicological data to develop reliable guideline trigger levels and so *low reliability values* (LRVs) were derived and provided in ANZECC & ARMCANZ (2000). The intent was 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 toxicological data to account for the greater uncertainty associated with the limited database. The values may therefore be conservative for some chemicals and may not closely reflect concentrations above which toxic effects could occur. Low reliability values for a number of toxicants have been provided in Table 2c. Some of these substances have a high community profile in Cockburn Sound (eg. arsenic), while others are discharged at relatively high concentrations (eg. aluminium). Water quality guidelines from a number of overseas countries have also been provided for the substances listed in Table 2c, where available. These have been provided simply as additional information to be used in conjunction with the LRVs to assist regulators and managers to make informed decisions on acceptable levels of water quality in Cockburn Sound, bearing in mind that the overseas guidelines are generally applied as standards.

ANZECC & ARMCANZ (2000) cautions that LRVs should not be used as default guideline trigger values, but further states that 'it is reasonable to use them in the risk-based decision scheme to determine if conditions at the site increase or decrease potential risk'. In other words, it is reasonable to assume that if ambient concentrations fall below the LRV then there is a low risk of ecological impact. However, if concentrations are above an LRV it does not necessarily mean an impact is likely. Low reliability values therefore are not EQG, and do not establish recommended benchmarks for the management of Cockburn Sound water quality (eg. through the licensing process). However, if ambient concentration meets an LRV then there is a high probability that the ecosystem has not been affected. Although exceedance of LRVs does not trigger mandatory assessments against environmental quality standards, 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. These strategies may include:

- undertaking literature searches or toxicological tests (eg. direct toxicity assessment of effluents or ambient waters) to gather more data of sufficient quality to further assess the likely risk of exposure to the chemical;
- intensified monitoring to observe trends in the toxicant concentration; and
- in situ monitoring of relevant biological or ecological indicators.

Low reliability values can also be upgraded into EQG by undertaking the additional ecotoxicological tests necessary to complement the existing data and meet the minimum data requirements recommended by ANZECC & ARMCANZ (2000) for moderate or high reliability guideline trigger values (data from a minimum of 5 species from 4 taxonomic groups).

3.2 Maintenance of seafood for human consumption

The two primary reference documents for development of the environmental quality guidelines and standards for this objective 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 seafood species occurs, or to areas where aquaculture activities are undertaken. They do not protect the fish populations or aquaculture species themselves. To protect the wild seafood populations from the affects of environmental contamination the

environmental quality guidelines and standards for maintaining ecosystem integrity (Section 3.1) 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 3.3 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 guidelines for copper, selenium and zinc are based on the 90th percentile of contaminant levels that would typically be expected in the flesh of food species. 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 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.

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.

3.3 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 the guidelines are exceeded. ANZECC/ARMCANZ (2000) aquaculture guidelines for nitrate and phosphate have not been included because they relate to the stimulation of algal blooms within the aquaculture environment. Instead this issue is managed by applying the nutrient related ecological EQC from tables 1a and 1b to the whole of Cockburn Sound. The ecological EQC from tables 1a and 1b are also used to manage salinity and water clarity to near natural levels in Cockburn Sound, eliminating the need to address these issues through aquaculture EQC.

Reference to ANZECC/ARMCANZ (2000) will be necessary when comparing water quality with guidelines for specific species groups (step 6 of the decision scheme). In ANZECC/ARMCANZ (2000) 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. Although the EQG apply throughout the area designated to this environmental quality objective the main focus for management if an EQG is exceeded will be to ensure that the EQS 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 3.2 should be applied.

3.4 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 report of the Farnham Consultation, *Bathing Water Quality and Human Health: Faecal Pollution* (WHO, 2001) is available on the WHO website. The approach taken in deriving these criteria is expected to be consistent with the approach that is anticipated to 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.

3.5 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.

3.6 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. EQC for this objective 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 guidelines for fish tainting substances in Cockburn Sound the guidelines contained in ANZECC/ARMCANZ (2000) were reviewed by comparison 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 is based on actual tainting of fish flesh.

The EQS for the visual indicators is based on direct measures of the communities perceptions of the aesthetic values of Cockburn Sound, for example the results of a community survey undertaken to determine whether the objective of maintaining aesthetic values has been met. The survey should focus as much as possible on perceived changes in the parameters listed under the EQGs.

3.7 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.

3.8 Tables of EQC and the Decision Schemes for their application

The environmental quality criteria for Cockburn Sound that support the Revised Draft Environmental Protection (Cockburn Sound) Policy are contained in Tables 1 to 8 of this section. Figure 4 summarises where the EQC for each environmental quality objective or environmental value are found. Included with the tables are the decision schemes and guidance notes to guide how the EQC are applied.

Figure 4. An overview of the tables of EQC.

Environmental value	**Environmental quality objective**	**Environmental quality criteria**	**Page No.**
Ecosystem health	Ecosystem integrity	Physical/chemical indicators	
		Table 1a narrative EQG & EQS	18
		Table 1b numerical values	24
		Toxicants in water/sediment pore waters	
		Table 2a EQG & EQS	32
		Table 2b IMT	35
		Table 2c LRV	36
		Toxicants in sediment	
		Table 3	44
Fishing and aquaculture	Seafood safe for eating	*Table 4*	52
	Aquaculture production	*Table 5*	58
Recreation and aesthetics	Primary contact	*Table 6*	64
	Secondary contact	*Table 7*	77
	Aesthetic values	*Table 8*	82
Industrial water supply	Industrial water supply	*(no environmental quality criteria)*	-

Table 1a. 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 ecological protection. The defined area can be equivalent to the entire high level of ecological 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**	
A	***Chlorophyll a and Light Attenuation***		***Chlorophyll a and Light Attenuation***	
	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 1b	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 1b	If EQS H has been exceeded then EQG A is not to be exceeded in the second consecutive year	If EQS H has been exceeded then EQG A is not to be exceeded in the second consecutive year.

B	*Dissolved Oxygen Concentration*		B	*Dissolved Oxygen Concentration*	
	Ambient value for dissolved oxygen in bottom waters is greater than the value for that indicator as specified in Table 1b at any site for a defined period of not more than 6 weeks.	Ambient value for dissolved oxygen in bottom waters is greater than the value for that indicator as specified in Table 1b at any site for a defined period of not more than 6 weeks.		Ambient value for dissolved oxygen in bottom waters is greater than the value for that indicator as specified in Table 1b at any site for a defined period of not more than 6 weeks. <u>and</u> No significant change in any ecological or biological indicators beyond natural variation that can be demonstrably linked to poorly oxygenated waters. <u>and</u> No deaths of marine organisms resulting from deoxygenation.	Ambient value for dissolved oxygen in bottom waters is greater than the value for that indicator as specified in Table 1b at any site for a defined period of not more than 6 weeks. <u>and</u> 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. <u>and</u> No deaths of marine organisms resulting from deoxygenation.
C	***Water Temperature***		**C**	***Water Temperature***	
	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 <u>or</u> - the median temperature at a reference site over the same period by more than the temperature values specified in Table 1b 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 <u>or</u> - the median temperature at a reference site over the same period by more than the temperature values specified in Table 1b for that indicator		No significant change in any ecological or biological indicators beyond natural variation that can be demonstrably linked to anthropogenically-sourced thermal stress. <u>and</u> 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. <u>and</u> No deaths of marine organisms resulting from anthropogenically-sourced thermal stress.

Table 1a Continued.

	Environmental Quality Guideline		Environmental Quality Standard	
	High protection	**Moderate protection**	**High protection**	**Moderate protection**
D	***Salinity***		***Salinity***	
	Median salinity at individual site over any period, measured according to SOP, not to deviate beyond: - the 20th and 80th percentile of the natural salinity range over the same period or - the median salinity at a reference site by more than the range specified in Table 1b for that indicator.	Median salinity at individual site over any period, measured according to SOP, not to deviate beyond: - the 5th and 95th percentile of the natural salinity range over the same period or - the median salinity at a reference site by more than the range specified in Table 1b for that indicator	No significant change in any ecological or biological indicators beyond natural variation that can be demonstrably linked to anthropogenically-sourced salinity stress. and No deaths of marine organisms resulting from anthropogenically-sourced salinity 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 salinity stress. and No deaths of marine organisms resulting from anthropogenically-sourced salinity stress.
E	***pH***		***pH***	
	Ambient value for pH of the defined area is within the range specified in Table 1b.	Ambient value for pH of the defined area is within the range specified in Table 1b.	No significant change in any ecological or biological indicators beyond natural variation that can be demonstrably linked to anthropogenic-sourced changes in pH. and No deaths of marine organisms resulting from anthropogenic-sourced changes in pH.	No persistent (ie, =4 weeks) and significant change in any ecological or biological indicators beyond natural variation that can be demonstrably linked to anthropogenic-sourced changes in pH. and No deaths of marine organisms resulting from anthropogenic-sourced changes in pH.

	In-direct Biological Measures	In-direct Biological Measures	In-direct Biological Measures	In-direct Biological Measures
F	***Algal Growth Potential***			
	To be developed.	To be developed		
	Direct Biological Measures		**Direct Biological Measures**	
G	***Phytoplankton Biomass***		**G** ***Phytoplankton Biomass***	
	Ambient value for phytoplankton biomass measured as chlorophyll *a* does not exceed the value for that indicator, as specified in Table 1b, 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 1b, on 25% or more occasions during the non river-flow period	Ambient value for phytoplankton biomass measured as chlorophyll *a* does not exceed the value for that indicator, as specified in Table 1b, 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 1b, on 50% or more occasions during the non river-flow period	Ambient value for phytoplankton biomass measured as chlorophyll *a* does not exceed the value for that indicator, as specified in Table 1b, 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 1b, on 25% or more occasions during the non river-flow period and in two consecutive years	Ambient value for phytoplankton biomass measured as chlorophyll *a* does not exceed the value for that indicator, as specified in Table 1b, 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 1b, on 50% or more occasions during the non river-flow period and in two consecutive years

Table 1a Continued.

Environmental Quality Guideline		Environmental Quality Standard	
High protection	**Moderate protection**	**High protection**	**Moderate protection**
		H *Seagrass*	
		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 1b, 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 1b	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 1b 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 1b

	and The upper and lower depth limit of seagrass meadows must not show a statistically significant retreat relative to baseline distribution and The upper and lower depth limit of seagrass meadows must not show a statistically significant retreat relative to baseline distribution	and The upper and lower depth limit of seagrass meadows must not show a statistically significant retreat relative to baseline distribution and The upper and lower depth limit of seagrass meadows must not show a statistically significant retreat relative to baseline distribution

TABLE 1b. Numerical environmental quality criteria for protecting the marine ecosystem from the effects of physical and chemical stressors (relevant footnotes and Guidance notes should also be read)

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_1	Chlorophyll *a* ($\mu g\ L^{-1}$)	0.9	1.2			
A_2	Light Attenuation Coefficient (m^{-1})	0.09	0.11			
B	Dissolved Oxygen	90% saturation*	80% saturation*	60% saturation*	60% saturation*	
C	Temperature (°Centigrade)					
	Season	*Value*	*Value*			
	Summer	0.8	1.6			
	Autumn	1.9	3.1			
	Winter	0.5	1.5			
	Spring	1.2	3.0			
D	Salinity	± 0.8	± 1.2			
E	pH	± 0.2	± 0.2			
	In-direct Biological Measures					
F	*Algal Growth Potential*					
	To be developed					

	Direct Biological Measures					
G	*Phytoplankton Biomass*					
	Chlorophyll *a* ($\mu g\ L^{-1}$)	1.8	2.7	1.8	2.7	
H	*Seagrass*					
	- median shoot density (shoots m^{-2})					
	2.0 - 2.5 m depth			600	450	
	7.0 - 8.0 m depth			400	300	
	Other depths			*	*	
	- minimum shoot density (shoots m^{-2})					
	2.0 - 2.5 m depth			450	330	
	7.0 - 8.0 m depth			300	260	
	Other depths			*	*	

Footnotes:

* 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 preferably from suitable reference sites established at the appropriate depth. Shoot density measurements should be from permanent relocatable quadrats over seagrass meadows of the same species as at the potential impact site, and each additional years data combined with previous years monitoring data to recalculate and update the criteria as described in EQS H in Table 1a. Reference sites need to be established in areas that are relatively unaffected by anthropogenic influences and with sufficient quadrats to account for natural variability.

A_1 Measured spectrophotometrically. Sites should be sampled weekly. Refer to SOP for detailed sampling and analytical requirements. The numerical value will be updated each year to incorporate the latest reference site data as described in section 3.1.2.

A_2 Preferably measured using data loggers according to SOP; expressed on $\log_{10}$ basis. The numerical value will be updated each year to incorporate the latest reference site data.

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

C Temperature measured either at 50 centimetres below the water surface or 50 centimetres above the sediment surface depending on plume density and seasonal median compared with EQG in table 1b. Measurements are taken at both the potential impact site and a suitable reference site. The preferred approach for measuring temperature is to use semi-permanently located data loggers according to SOP.

D Salinity is referred to without units since it is defined as a ratio of conductivities according to the Practical Salinity Scale. Cockburn Sound has a typical salinity range of 34 – 36. In the past, units of ppt have been ascribed to these salinity measurements. Salinity is measured either at 50 centimetres below the water surface or 50 centimetres above the sediment surface depending on plume density and the median compared with EQG in table 1b. Measurements are taken at both the potential impact site and a suitable reference site.

E pH is measured at 50 centimetres below the water surface and 50 centimetres above the sediment surface and the median for each depth compared with EQG in table 1b. Measurements are taken at both the potential impact site and a suitable reference site.

F An indicator for growth potential for non-phytoplankton algae is to be developed and incorporated in the EQC Reference Document as soon as practicable.

G Values are three times median chlorophyll *a* concentration of reference site for high ecological protection areas; three times 80th percentile of reference site for moderate ecological 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

H Measured non-destructively, re-locatable sampling points preferred. The numerical values for seagrass shoot density apply to seagrasses of the genus *Posidonia*.

Guidance notes

- The EQG for chlorophyll *a* and LAC have been derived from a reference site located in the central basin of Warnbro Sound (site 4) using the recommended approaches of ANZECC & ARMCANZ (2000).
- The EQG for chlorophyll *a* and LAC and EQS for phytoplankton biomass will be recalculated annually as the current seasons water quality data for the Warnbro Sound reference site gets added to the historical database. The new values will become the EQG for the following season.
- The mechanism described in section 3.1.2 should be used to guard against triggering of the EQC caused by regional scale effects (ie those effects forced from outside of Cockburn Sound).
- There is no EQS directly corresponding to the EQG for the chlorophyll *a*, LAC and algal growth potential. Investigation against the seagrass EQS is triggered if these EQG are exceeded.
- The EQG for temperature and salinity and EQS for seagrass health have been derived from reference sites in Cockburn Sound according to the recommended approach in ANZECC & ARMCANZ (2000) (ie. 20^{th} and/or 80^{th} percentiles of reference distribution for high ecological protection and 5^{th} and/or 95^{th} percentiles for moderate ecological protection). Professional judgment has also been used to develop some of the measures for the seagrass EQS.
- The EQG for dissolved oxygen and pH have been derived from the default guideline trigger values provided in ANZECC & ARMCANZ (2000), although the dissolved oxygen EQG for moderate ecological protection is partly based on professional judgment
- When assessing environmental quality in the moderate ecological protection area the performance of harbours and marinas should be assessed individually and not as part of the overall moderate protection area.

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 to G) - go to step 2.

2. Determine whether nutrient-related EQG (A, F or G) has been exceeded
   [N]..... - go to step 3.
   [Y] (EQG A or F). - go to step 7 unless back-up samples or immediate re-sampling does not confirm exceedance of the EQG.
   [Y] (EQG G)..... - go to step 14 unless back-up samples or immediate re-sampling 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 10 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 5.
   [Y] ..... - go to step 11 unless immediate re-measurement does not confirm exceedance of the EQG.

5. Determine whether salinity-related EQG (D) has been exceeded
   [N] ..... - go to step 6.
   [Y] ..... - go to step 12 unless immediate re-measurement does not confirm exceedance of the EQG.

6. Determine whether EQG (E) for pH has been exceeded
   [N] ..... - go to step 1.
   [Y] ..... - go to step 13 unless immediate re-measurement does not confirm exceedance of the EQG.

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

7. Expand monitoring program as appropriate and implement to allow assessment of environmental quality against EQG (A or F) and EQS (G and H) - go to step 8.

8. Determine whether EQS (G or H) has been exceeded
   [N] ..... - go to step 1.
   [Y] ..... - go to step 9.

9. Determine whether EQG (A or F) was exceeded in the current year
   [N] ..... - go to step 1, and
   investigate possible non nutrient-related causes of exceedence of EQS
   [Y] ..... - **EQS triggered** go to step 15.

10. Determine whether EQS (B) has been exceeded
   [N] ..... - go to step 1.
   [Y] ..... - **EQS triggered** go to step 15.

11. Determine whether EQS (C) has been exceeded
   [N] ..... - go to step 1.
   [Y] ..... - **EQS triggered** go to step 15.

12. Determine whether EQS (D) has been exceeded
   [N] ..... - go to step 1.
   [Y] ..... - **EQS triggered** go to step 15.

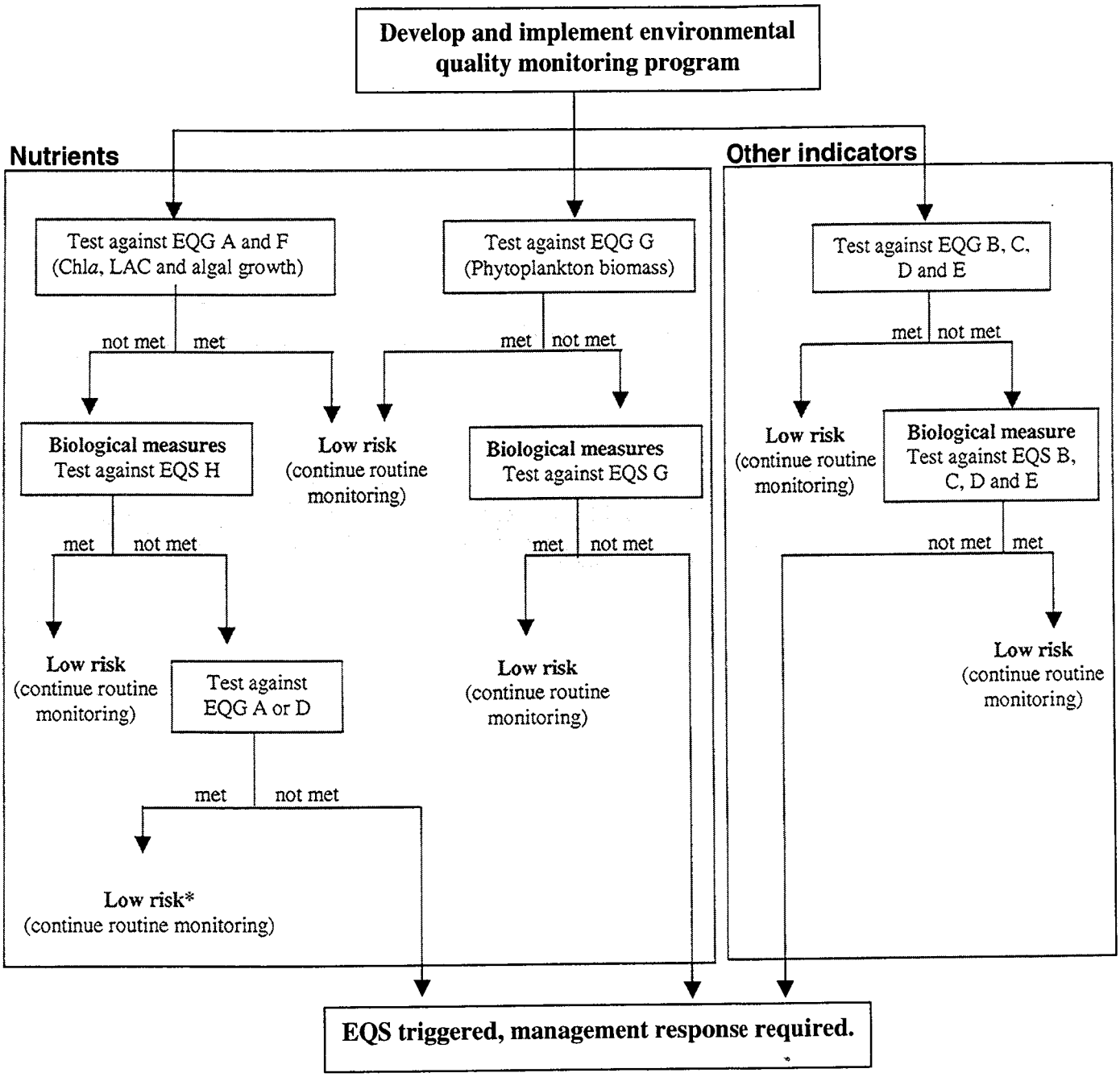
13. Determine whether EQS (E) has been exceeded
   [N] ..... - go to step 1.
   [Y] ..... - **EQS triggered** go to step 15.

14. Determine whether EQS (G) has been exceeded
   [N] ..... - go to step 1.
   [Y] ..... - **EQS triggered** go to step 15.

The EQS is exceeded triggering a management response.

15. 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 2a. Environmental quality criteria for protecting the marine ecosystem from the effects of toxicants in marine waters and sediment pore waters (relevant footnotes and Guidance notes should also be read)

Environmental Quality Guidelines

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[G].

Chemical	High protection (µg/L)	Moderate protection (µg/L)	Low protection (µg/L)
METALS and METALLOIDS			
Cadmium [B]	0.7	14[C]	36[A]
Chromium III	27.4	49	
Chromium VI	4.4	20[C]	
Cobalt	1	14	
Copper	1.3	3[C]	
Lead	4.4	6.6[C]	
Mercury (inorganic) [B]	0.1	0.7[C]	1.4[C]
Nickel	7	200[A]	
Silver	1.4	1.8	
Tributyltin (as µg/L Sn)	0.006[C]	0.02[C]	
Vanadium	100	160	
Zinc	15[C]	23[C]	
NON-METALLIC INORGANICS			
Ammonia [D, E]	910	1200	
Cyanide [F]	4	7	
ORGANICS			

Environmental Quality Standard

High protection

Narrative

Bioavailable measures

A. The 95%ile of the bioavailable contaminant concentration in the test samples should not exceed the environmental quality guideline value;

and

B. 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[G].

Indirect biological measures

C. Using direct toxicity assessment (DTA) procedures on ambient waters there should not be a statistically significant effect ($P < 0.05$) on lethal or sublethal chronic endpoints for any species, compared to the reference/control water.

D. Using direct toxicity assessment (DTA) procedures on an effluent discharge:

Moderate protection

Narrative

Bioavailable measures

A. The 95%ile of the bioavailable contaminant concentration in the test samples should not exceed the environmental quality guideline value;

and

B. 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[G].

Indirect biological measures

C. Using direct toxicity assessment (DTA) procedures on ambient waters there should not be a statistically significant effect ($P < 0.05$) on lethal acute endpoints, or of greater than 50% on sublethal chronic endpoints, for any species, compared to the reference/control water.

D. Using direct toxicity assessment (DTA) procedures on an effluent discharge:

Benzene	500 [C]	900 [C]	
Naphthalene	50 [C]	90 [C]	
Pentachlorophenol [B]	11	33	55 [A]
Phenol	400	520	
1,2,4-trichlorobenzene [B]	20	140	240
ORGANOCHLORINE PESTICIDES			
Endosulfan [B]	0.005	0.02	0.05 [A]
Endrin [B]	0.004	0.01	0.02
ORGANOPHOSPHORUS PESTICIDES			
Chlorpyrifos [B]	0.009	0.04 [A]	0.3 [A]
Temephos [B]	0.05	0.4	3.6 [A]
OIL SPILL DISPERSANTS			
Corexit 9527	1100	2200	
OTHER CHEMICALS	#	#	#

- the dilution of effluent at the boundary of a high protection zone should be protective of at least 95% of species calculated using the statistical distribution methodology on the results of DTA using sublethal chronic endpoints on 5 species (minimum 4 taxonomic groups);

or

- if only 3 species (from 3 taxonomic groups) are tested, the dilution of effluent (as % effluent) at the boundary of a high protection zone should be greater than that represented by the lowest chronic NOEC (ie. the NOEC for the most sensitive species) divided by a safety factor of 10.

Direct biological/ecological measures

E. No significant* change in any biological or ecological indicator beyond natural variation that can be demonstrably linked to a contaminant.

F. Where TBT concentrations exceed the guideline the incidence of imposex in *Thais orbita* should be $\leq 5\%$.

and

G. 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.

discharge:

- the dilution of effluent at the boundary of a moderate protection zone should be protective of at least 90% of species calculated using the statistical distribution methodology on the results of DTA using sublethal chronic endpoints on 5 species (minimum 4 taxonomic groups);

or

- if only 3 species (from 3 taxonomic groups) are available, the dilution of effluent (as % effluent) at the inner boundary of a moderate protection zone should be greater than that represented by the lowest chronic NOEC (ie. the NOEC for the most sensitive species) divided by a safety factor of 2.

Direct biological/ecological measures

E. The median of the distribution of measurements for any biological or ecological indicator should be within the 10th and 90th percentile of the natural range measured at suitable reference sites;

and

F. No loss of species beyond natural variation;

and

G. No loss in types of ecosystem processes.

* 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.

\# Refer to Low reliability values in Table 2c and the NWQMS Report No.4 (ANZECC & ARMCANZ 2000). For chemicals not listed in tables 2a or 2c, 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 ecological protection EQG; 90% values for moderate ecological protection EQG; and 80% values for low ecological protection EQG. Low ecological protection EQG only provided for chemicals identified as potential bioaccumulators or bioconcentrators.

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 See section 8.3.7 of ANZECC & ARMCANZ (2000) for a detailed discussion on how different environmental factors will affect toxicity of the chemical.

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

G TTM (total toxicity of the mixture) = Σ(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.

Table 2b. Initial Management Triggers for High Protection and Moderate Protection areas

Chemical	High protection (µg/L)	Moderate protection (µg/L)
Initial Management Trigger (IMT)	The 95%ile of estimated bioavailable contaminant concentration in test samples 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 trigger values below.	
METALS and METALLOIDS		
Cadmium [B]	14 [C]	36 [A]
Chromium III	49	91
Chromium VI	20 [C]	85 [C]
Cobalt	14	150 [C]
Copper	3 [C]	8 [A]
Lead	6.6 [C]	12 [C]
Mercury (inorganic) [B]	0.7 [C]	1.4 [C]
Nickel	200 [A]	560 [A]
Silver	1.8	2.6 [C]
Tributyltin (as µg/L Sn)	0.02 [C]	0.05 [C]
Vanadium	160	280
Zinc	23 [C]	43 [C]
NON-METALLIC INORGANICS		
Ammonia [D, E]	1200	1700
Cyanide [F]	7	14
ORGANICS		
Benzene	900 [C]	1300 [C]
Naphthalene	90 [C]	120 [C]
Pentachlorophenol [B]	33	55 [A]
Phenol	520	720
1,2,4-trichlorobenzene [B]	140	240
ORGANOCHLORINE PESTICIDES		
Endosulfan [B]	0.02	0.05
Endrin [B]	0.01	0.02
ORGANOPHOSPHORUS PESTICIDES		
Chlorpyrifos [B]	0.04 [A]	0.3
Temephos [B]	0.4	3.6
OIL SPILL DISPERSANTS		
Corexit 9527	2200	4400
OTHER CHEMICALS	#	#

#	Refer to NWQMS Report No.4 (ANZECC & ARMCANZ 2000). For chemicals not listed in this table guideline trigger values from ANZECC & ARMCANZ (2000) should be applied as follows: 90% guideline trigger values for high ecological protection interim management triggers; and 80% values for moderate ecological protection interim management triggers.
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	See section 8.3.7 for a detailed discussion on how different environmental factors will affect toxicity of the chemical.
F	Cyanide as un-ionised HCN measured as [CN].

Table 2c. Low Reliability Values[A]

(low reliability values should not be used as environmental quality guidelines – see section 3.1.5)

Chemical	High protection (µg/L)	Moderate protection (µg/L)	Low protection (µg/L)	Summary of available overseas guidelines[D] (µg/L)	Comments
METALS and METALLOIDS					
Aluminium	0.5				
Arsenic III	2.3			12	(total) South Africa
				12.5	(total) Canada
Arsenic V	4.5			25	(tot. dissolved) Netherlands
				36	(tot. dissolved) USA
Manganese	80				
Molybdenum	23			290	(tot. dissolved) Netherlands
Selenium IV[B]	3			1	(total) Canada
				5.3	(tot. dissolved) Netherlands
Selenium VI[B]	3			71*	(tot. dissolved) USA
NON-METALLIC INORGANICS					
Chlorine (total residual)	3			2	British Columbia, Alaska.
				7.5	USA
Hydrogen sulfide[C,#]	1			2	British Columbia, Quebec, USA
ORGANICS					
Toluene	110	230		92	New York State
				215	Canada
				730	Netherlands
Ethylbenzene	5			4.5	New York State
				25	Canada
				370	Netherlands
o-xylene[E]	350				
m-xylene[E]	75				
p-xylene[E]	200				
Total xylene				19	(total) New York State
				380	(total) Netherlands
Cumene	20	40			
Anthracene[B]	0.01	1.5	7	0.08	Netherlands
Phenanthrene[B]	0.6	4	8	0.3	Netherlands
Fluoranthene[B]	1	1.7	2	0.3	Netherlands
Benzo(a)pyrene[B]	0.1	0.4	0.7	0.2	Netherlands
Capacitor 21[B]	0.002				
Aroclor 1016	0.009				
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				
Total PCBs				0.03	USA
ORGANOCHLORINE PESTICIDES					
Aldrin[B]	0.003			0.001	Netherlands
Chlordane[B]	0.0001			0.002	Netherlands
				0.004	USA
DDE[B]	0.0005			0.0004	Netherlands

DDT[B]	0.0004		0.0009	Netherlands
			0.001	USA
Dieldrin[B]	0.01		0.0019	USA
			0.039	Netherlands
Heptachlor[B]	0.0004		0.0005	Netherlands
			0.0036	USA
ORGANOPHOSPHORUS PESTICIDES				
Fenitrothion	0.001		0.009	Netherlands
Malathion	0.05		0.013	Netherlands
			0.1	USA
HERBICIDES AND FUNGICIDES				
2,4-D	280		10	Netherlands
2,4,5-T	36		9	Netherlands
Metsulfuron	8			
Amitrole	22			
Atrazine	13		2.9	Netherlands
Simizine	3.2		0.14	Netherlands
Glyphosate	370			
SURFACTANTS				
Linear alkylbenzene sulfonates (LAS)	0.1			
Alcohol ethoxylated sulfate (AES)	650			
Alchohol ethoxylated surfactants (AE)	140			
OILS & PETROLEUM HYDROCARBONS				
Diesel	3			
OIL SPILL DISPERSANTS				
BP 1100 X	25			
Corexit 7664	16			
Corexit 8667	1200			
Corexit 9550	14	400		

* The USEPA suggests that the status of the fish community should be monitored if selenium concentration exceeds 5.0 µg/L because the guideline does not take into account uptake via the food chain.

\# Refer to the 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.

A 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 ecological 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.

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

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

D The overseas guidelines provided in this table have been derived to protect marine ecosystems from the chronic effects of contaminants, and not for triggering further investigations to determine if chronic effects are occurring.

E Toxicity of the xylene isomers can be assumed to be additive.

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 ecological protection area in Cockburn Sound. For moderate ecological protection

areas the 90% values have been selected and for the low ecological 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 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 of ANZECC & ARMCANZ (2000).
- 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 ecological protection area then tissue concentrations of that chemical should be measured in benthic or sessile suspension or deposit feeders from the high ecological protection area (or from the closest high ecological 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 80th percentile of the concentrations calculated. The median tissue concentration from the high ecological protection area test site should not exceed the 80th percentile of the reference site concentrations. (Tissue concentrations in edible seafood should also be compared with the EQC for maintenance of seafood 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. If deriving a safe level of effluent dilution then the statistical extrapolation method can be applied to derive the required level of dilution. However, if only the minimum of 3 species from 3 taxonomic groups are tested then the safe level of dilution is derived by applying a safety factor of x10 to the result of the most sensitive species. The number of species actually tested will need to be tailored according to available test protocols and 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.

Initial Management Trigger

- Bioavailable concentrations of contaminants should be derived using the approaches outlined in section 3.4.3 of ANZECC & ARMCANZ (2000) and compared against the IMT.
- Fresh samples should be used for determining bioavailable contaminant concentrations. Sample preservation can have a significant effect on chemical speciation/bioavailability.

Low reliability values

- ANZECC/ARMCANZ (2000) cautions that LRVs should not be used as default guideline trigger values. However, it is reasonable to assume that if ambient concentrations fall below the LRV then there is a low risk of ecological impact. If an LRV is exceeded the resulting action may be to search for, or test for, more toxicological data of sufficient quality to further assess the likely risk of exposure to the chemical.
- LRVs can be upgraded into guidelines by undertaking additional toxicological studies, that complement the studies already incorporated in the ANZECC & ARMCANZ (2000) database, to meet the minimum data requirements for deriving moderate or high reliability guidelines (ie. 5 species from 4 taxonomic groups).
- The methodology used to derive the LRVs is described in section 8.3.4.4 of ANZECC & ARMCANZ (2000).
- Overseas guidelines have been included in the table to provided additional information for consideration when assessing the potential ecological consequences of any of these contaminants.

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 4.

2. Is it appropriate to establish an EQG by determining the 80th percentile for a high ecological protection area, or 95th percentile for a moderate ecological protection area, of natural background concentration?
   [N]..... - go to step 3.
   [Y]..... - go to step 4.

3. Is it appropriate in the interim to assess water quality against the low reliability values (LRVs) provided in table 2c of the EQC Reference Document?
   [N]..... - go to step 14 if significant threat posed by contaminant, otherwise undertake literature search and derive a suitable LRV.
   [Y]..... - go to step 18.

4. Undertake routine monitoring program covering the area to be assessed and the contaminants of concern using the standard operating procedures and go to step 5.

5. Was the laboratory practical quantitation limit (PQL) for any of the contaminants above the EQG value?
   [N]..... - go to step 6.
   [Y]..... - if detection of the contaminant is confirmed in a backup sample go to step 10, otherwise assume the contaminant has not been detected and go to step 4.

6. Determine whether EQG (A) has been met:
   [N]..... - go to step 7.
   [Y]..... - go to step 9.

7. 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]..... - if high or moderate ecological protection area go to step 8, or to step 10 if EQG derived according to step 2;
   - go to step 16 if the EQG was for a low ecological protection area.

8. For naturally occurring chemicals determine whether the 80th percentile for a high ecological protection area, or 95th percentile for a moderate ecological 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 6.

9. For the primary contaminants determine whether EQG (B) has been met:
   [N]..... - go to step 13.
   [Y]..... - no toxicity problem, go to step 4.

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

10. Give regard to whether the level of contamination requires an urgent response by determining whether the initial management trigger (IMT) from table 2b of the EQC Reference Document has been met while investigations against the EQS are on-going:
   [N]..... - consider management action to reduce the level of contamination below the IMT; and
   - go to step 11.
   [Y]..... - go to step 11.

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), or step 14 if PQL>EQG.
   [Y]..... - go to step 12 (steps 14 or 15 also optional), or step 14 if PQL>EQG; and
   - go to step 16.

12. Resolve bioavailable concentrations of relevant contaminants and determine whether EQS (A) 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 (B) has been met:
   [N]..... - go to step 14 (steps 15 or 17 also an option).
   [Y]..... - environmental quality acceptable, go to step 4.

14. Undertake direct toxicity assessment (DTA) using relevant species and determine whether EQS (C) and (D) have been met:
   [N]..... - go to step 15 or step 17.
   [Y]..... - environmental quality acceptable, go to step 4.

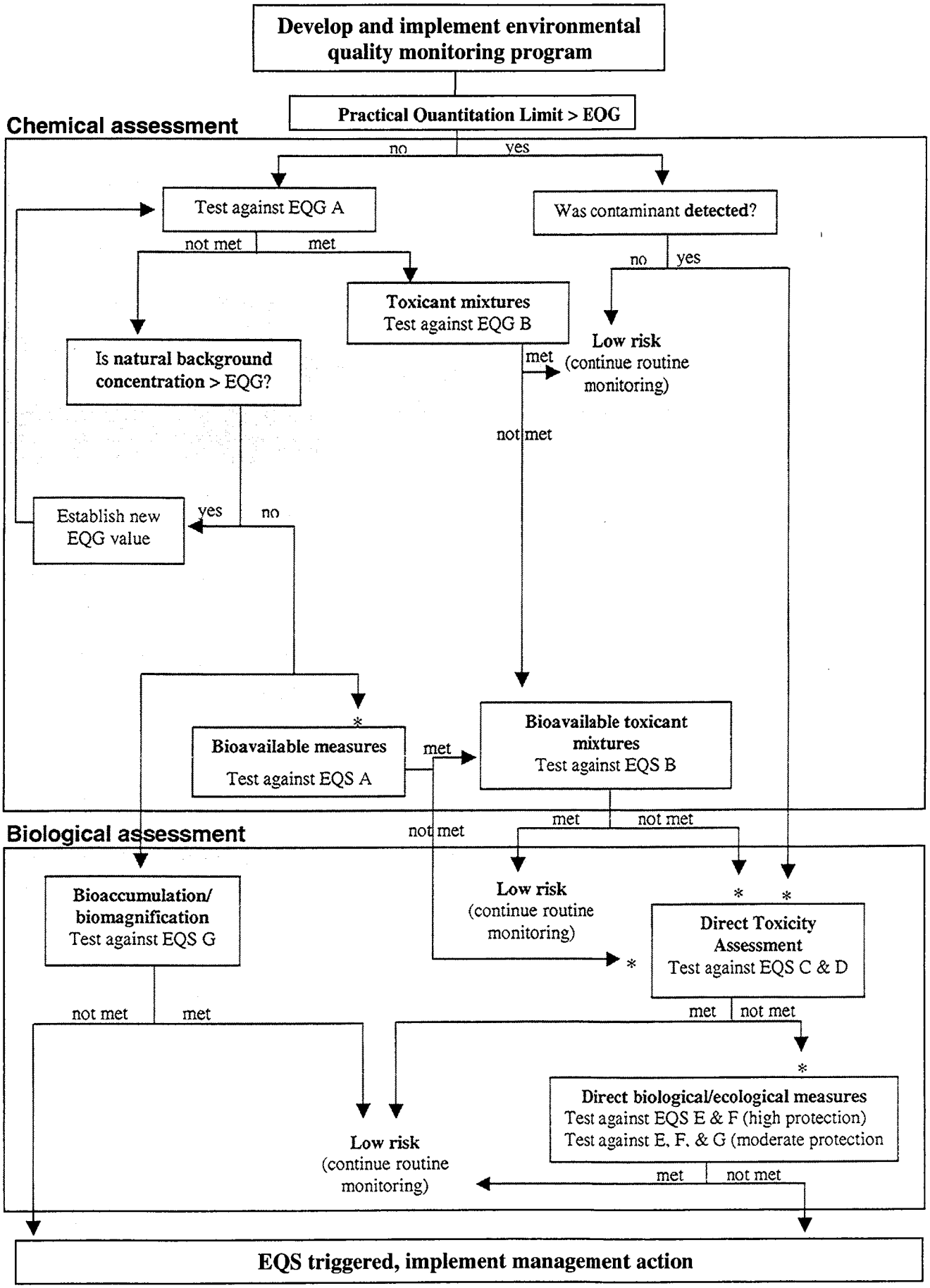
15. Undertake detailed field investigation to determine whether EQS (E) and (F) have been met for high ecological protection areas, and EQS (E), (F) and (G) have been met for moderate ecological protection areas:
   [N]..... - **EQS triggered.** Go to step 17.
   [Y]..... - environmental quality acceptable, go to step 4.

16. Determine whether EQS (G) in high ecological protection areas has been met:
    [N]..... - **EQS triggered.** Go to step 17.
    [Y]..... - chemical not bioaccumulating, go to step 4.

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.

18. Include contaminant in routine monitoring program. If the LRV is not exceeded then environmental quality is acceptable and no management action is required. If the LRV is exceeded, consult with relevant regulators to ensure unacceptable impacts are avoided (this may include undertaking a literature search on effects of the contaminant, undertaking direct toxicity assessment or upgrading the LRV into an EQG).

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 (relevant footnotes and Guidance notes should also be read)

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 ecological protection areas. B. Total contaminant concentration at individual sample sites should not exceed the environmental quality guideline re-sampling trigger (if so, 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.	**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.
Chemical	**Value** (high, moderate and low[A] protection)	**Re-sampling trigger**		
METALS and METALLOIDS [C] (mg/kg dry wt)			**Porewater measure** C. The 95%ile of bioavailable contaminant concentrations in porewater samples from the defined sampling area should not exceed high protection water quality guideline values (Table 2a of EQC Reference document).	**Porewater measure** C. The 95%ile of bioavailable contaminant concentrations in porewater samples from the defined sampling area should not exceed moderate protection water quality guideline values (Table 2a of EQC Reference document).
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			**Indirect biological measures** D. Sediment toxicity tests should not result in a statistically significant effect ($P < 0.05$) on sublethal chronic or lethal acute endpoints for any species, compared to a matched reference sediment.	**Indirect biological measures** D. Sediment toxicity tests should not result in a statistically significant effect ($P < 0.05$) on lethal acute endpoints, or of greater than 50% on sublethal chronic endpoints for any species, compared to a matched reference sediment.
Tributyltin (µg Sn/kg dry wt.)	5	70		
ORGANICS (µg/kg dry wt) [D, E]			**Direct biological/ecological measures** E. No significant[I] change in any biological or	**Direct biological/ecological measures** E. The median of the distribution of

Acenaphthene	16	500	ecological indicator beyond natural variation that can be demonstrably linked to a contaminant;	measurements for any biological or ecological indicator should be within the 20th and 80th percentile of the natural range measured at suitable reference sites;
Acenaphthalene	44	640	F. Where TBT concentrations exceed the guideline the incidence of imposex in *Thais orbita* should be ≤ 5%.	and
Anthracene [B]	85	1100		F. no loss of species beyond natural variation;
Fluorene	19	540		and
Naphthalene	160	2100	G. 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.	G. no loss in types of ecosystem processes.
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]		

* Contaminant concentrations in sediments should be reported as dry weight. For initial assessment of sediment metal concentrations against the EQG a strong acid digestion (eg. nitric acid/perchloric acid mixture) should be used.

A Environmental quality guidelines may be used in low ecological 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 at this time because they are generally considered to have low toxicity 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.

Table 3 Continued.

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.

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).*

Guidance notes

Environmental quality guidelines

- The ISQG-low from ANZECC and ARMCANZ (2000) 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.
- Pore water comparisons should not be undertaken against 'low reliability values'.
- 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 ecological protection area then tissue concentrations of that chemical should be measured in benthic or sessile suspension or deposit feeders from the high ecological protection area (or from the closest high ecological protection area if the exceedance was in a moderate or low ecological 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 ecological 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 seafood 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 and type 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.

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 13.
   [Y]..... - establish the 90th percentile of background concentration as the EQG value then 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 ecological 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. Assess whether EQS (B) has been met:
   [N]..... - go to step 9.
   [Y]..... - no toxicity problem, go to step 3.

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

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 EQG for water (Table 2a or EQC Reference document) 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) has 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 (E) and (F) have been met for high ecological protection areas, or EQS (E), (F) and (G) have been met for moderate ecological protection areas:

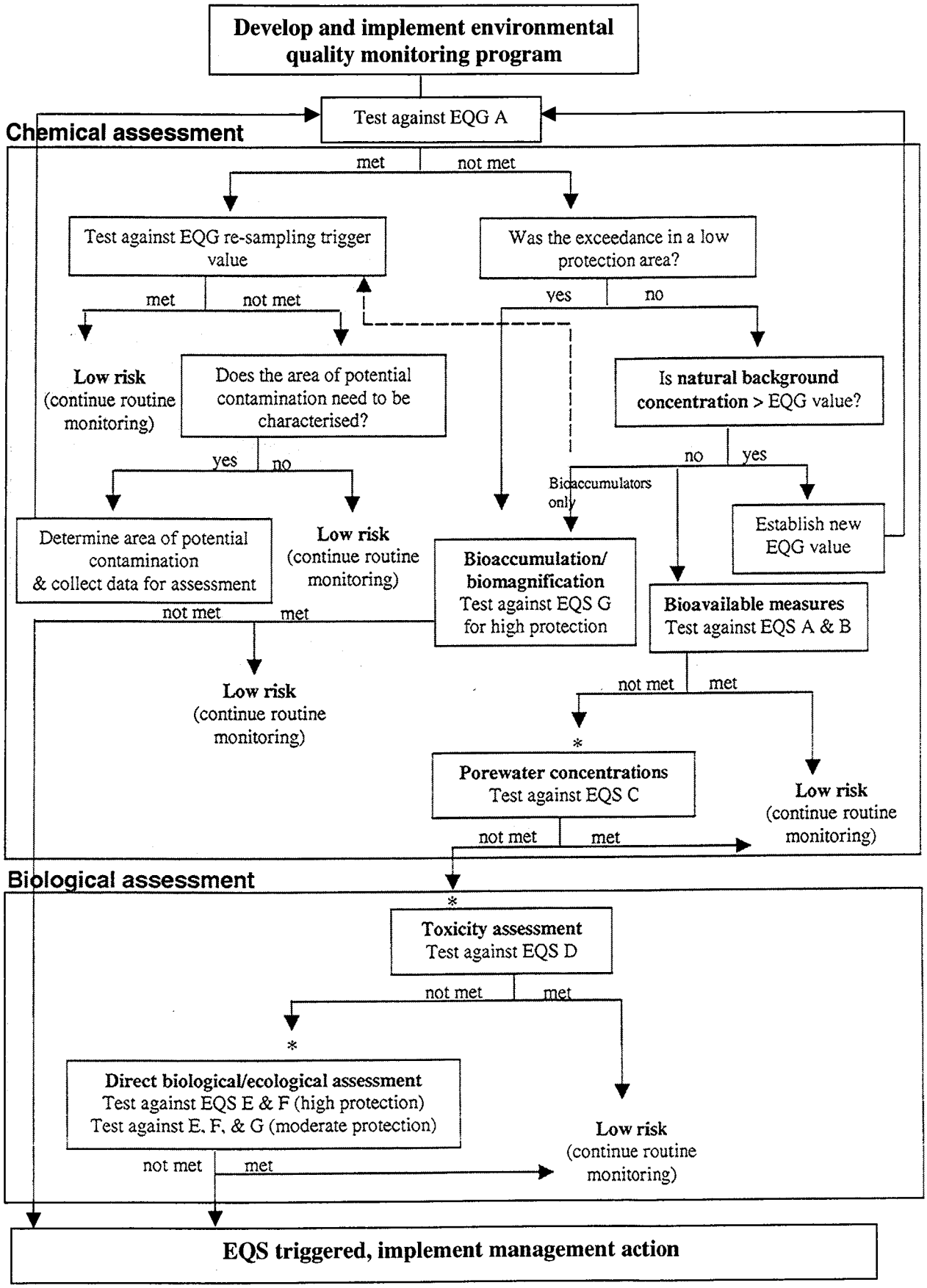
[N]..... - **EQS triggered.** Go to step 16.
[Y]..... - environmental quality acceptable, go to step 3.

15. Determine whether EQS (G) for high ecological protection 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.

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 seafood safe for human consumption (relevant footnotes and Guidance notes should also be read)

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 lusitanucum, A. lusitanicum, A minutum, A ostenfeldii, 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	Diarrhoetic shellfish poison (DSP) 0.2 mg/kg
	(*Dinophysis acuminata*) 1000 cells/L	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*Gymnodinium catenatum*	1 000 cells/L	PSP	0.8 mg Saxitoxin eq./kg
	Karenia K. *breve, K. breve-like*, K. mikimotoi	1 000 cells/L	Neurotoxic shellfish poison (NSP)	200 mouse units/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 (see values below). E. Mercury concentration in the flesh of seafood should not exceed the environmental quality standard (see values below) 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 Molluscs and Seaweed	2.0 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

* Standard 1.4.1 clause 6 outlines protocols for sampling and comparing results against the food standards for mercury.

\# Schedules 1 and 2 provide food standards for a long list of pesticides, none of which have been repeated in this table. These schedules will need to be referenced if pesticide concentrations in seafood are considered to be a potential issue.

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 guidelines for copper, selenium and zinc are the Generally Expected Levels (GELs) provided by ANZFA and are based on the 90th percentile of contaminant levels that would typically be expected in the flesh of food species (ANZFA, 2001).
- 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).

Narrative decision scheme for applying the EQC for seafood 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, and 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 step 4 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 is exceeded triggering more intensive investigation. Ambient quality is now monitored and assessed against the Environmental Quality Standard

4. Determine whether EQS (A) has been met:
   [N]..... - go to step 5 (or proceed directly to step 8).
   [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 of seafood and conducting sanitary survey; and
   - go to step 1.

6. Determine whether EQS (C) has been met:

   [N]..... - **EQS triggered**. Go to step 9.
   [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 implementation of appropriate management on advice of the Health Department of WA. If appropriate, environmental remediation may be required.

9. Implement management action to reduce the risk to public health on advice of the Health Department of WA. Determine the cause of the toxic algal bloom and, if appropriate, reduce contaminant inputs.

Pictorial decision scheme for applying the EQC for seafood safe for human consumption

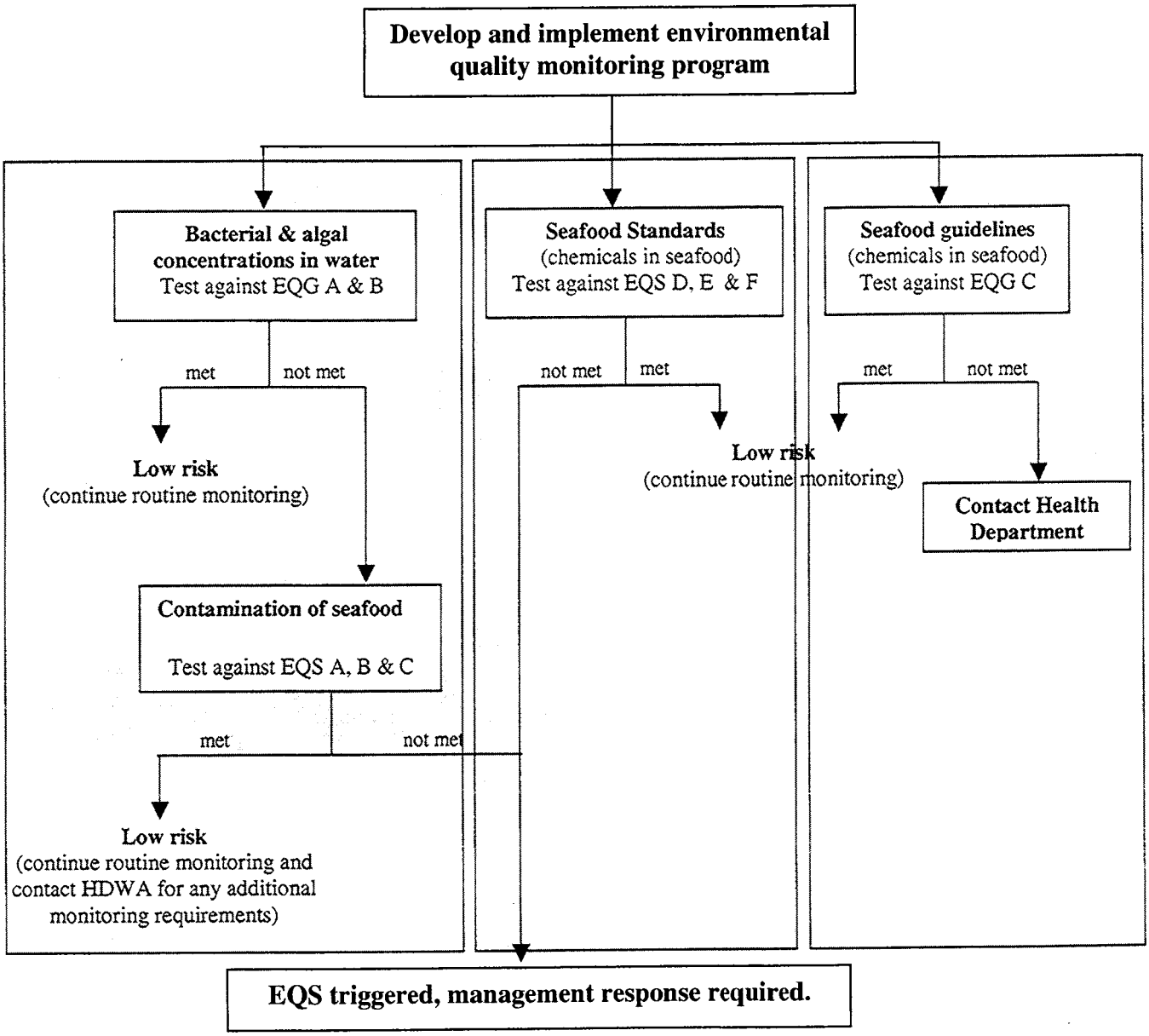


TABLE 5. Environmental quality criteria for the maintenance of aquaculture production (relevant footnotes and Guidance notes should also be read)

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 not be a statistically significant effect ($P<0.05$) 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	
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.	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[#]. if not, then D. Where appropriate, bioavailable contaminant concentration should meet the relevant guideline (environmental quality guideline or species group guideline) in ≥ 95% of samples. if not, then E. Using direct toxicity assessment (DTA) procedures there should not be a statistically significant effect ($P<0.05$) in end-points related to growth or quality of the cultured species (caused by contaminants from external sources) between the aquaculture waters and waters from a suitable reference site. or 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.
Non metallic inorganic chemicals (μg /L)		
Ammonia (total as N)	1000	
Chlorine (as total residual)	3	
Cyanide	5	
Hydrogen sulfide	2	
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 Sn)	0.004	
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).

Guidance notes

Environmental quality guidelines

- 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.
- 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).

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 analysis of back-up samples, or samples collected immediately from the same sites, confirmed the exceedance?
   [N]..... - suitable for aquaculture, go to step 1.
   [Y]..... - go to step 4 if the indicator is naturally occurring; and
   - go to step 8 if the indicator is a xenobiotic chemical.

4. Determine whether the 95th percentile of natural background contaminant concentration exceeds the EQG:
   [N]..... - go to step 6 if EQG A was not met; and
   - go to step 8 if EQG B was not met.
   [Y]..... - go to step 5.

5. Establish the 95th percentile of background concentration as the new EQG then determine whether EQG (A and/or B) have been met:
   [N]..... - go to step 6 if EQG A not met; and
   - go to step 8 if EQG B not met.
   [Y]..... - suitable for aquaculture, go to step 1.

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

6. Determine whether EQS (A) has been met:
   [N]..... - go to step 7 (step 11 is also optional).
   [Y]..... - EQS not triggered, go to step 1.

7. Determine whether EQS (B) has been met:
   [N]..... - **EQS triggered**, go to step 11.
   [Y]..... - EQS not triggered, go to step 1.

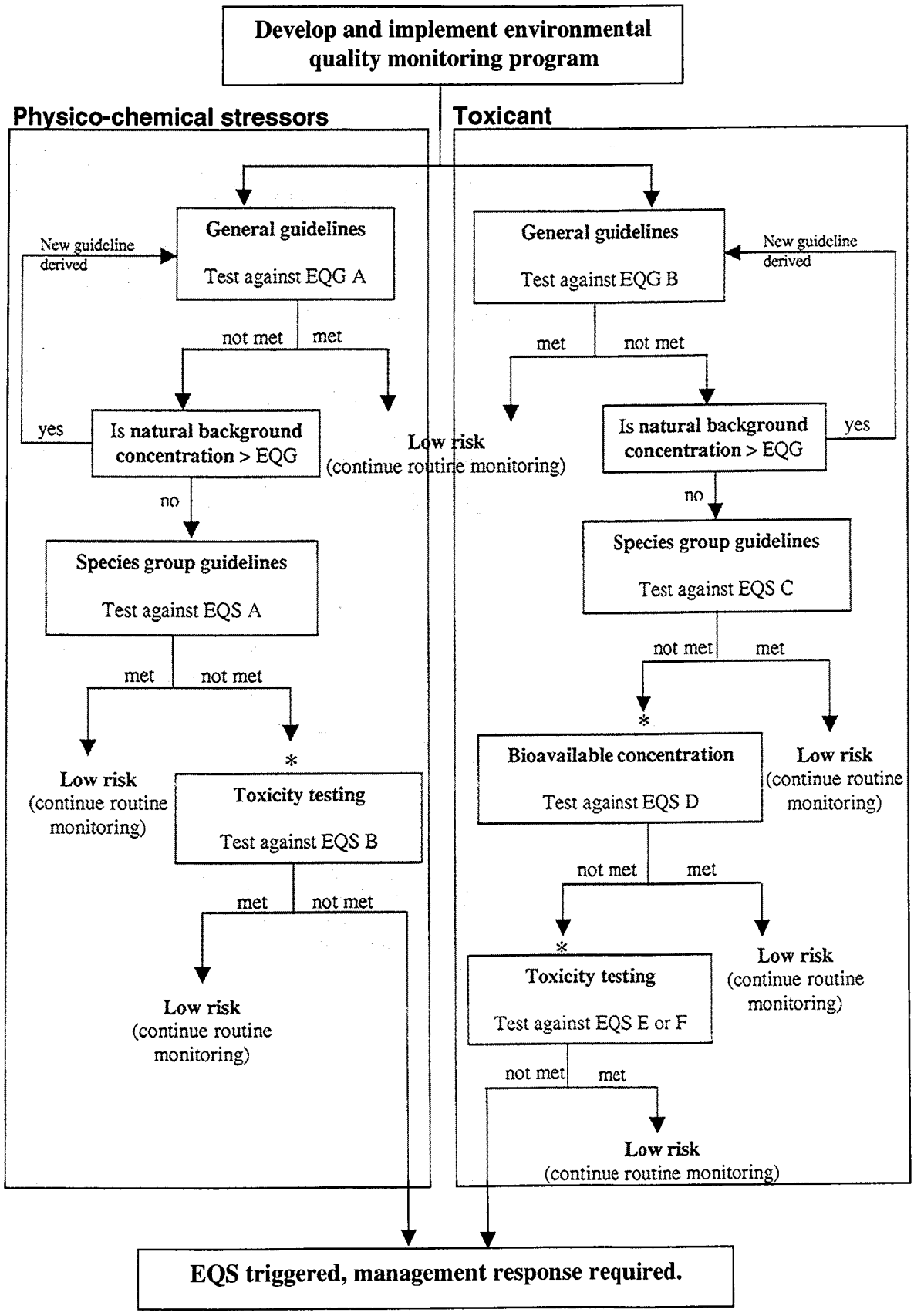
8. Determine whether EQS (C) has been met:
   [N]..... - go to step 9 (steps 10 or 11 also optional).
   [Y]..... - EQS not triggered, go to step 1

9. Determine whether EQS (D) has been met:
   [N]..... - go to step 10 (step 11 also optional).
   [Y]..... - EQS not triggered, go to step 1.

10. Determine whether EQS (E or F) have been met:
    [N]..... - **EQS triggered**, go to step 11.
    [Y]..... - EQS not triggered, go to step 1.

11. 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.

Pictorial decision scheme for applying the EQC for aquaculture production



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

TABLE 6. Environmental quality criteria for the maintenance of primary contact recreation (relevant footnotes and Guidance notes should also be read)

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 *considered by a medical practitioner as potentially resulting from toxic algae* 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 (total residual)	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

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.

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

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. Contact the Health Department of WA and intensify monitoring of potentially toxic algal species to assess human health risk and determine whether EQS (B) has been met:

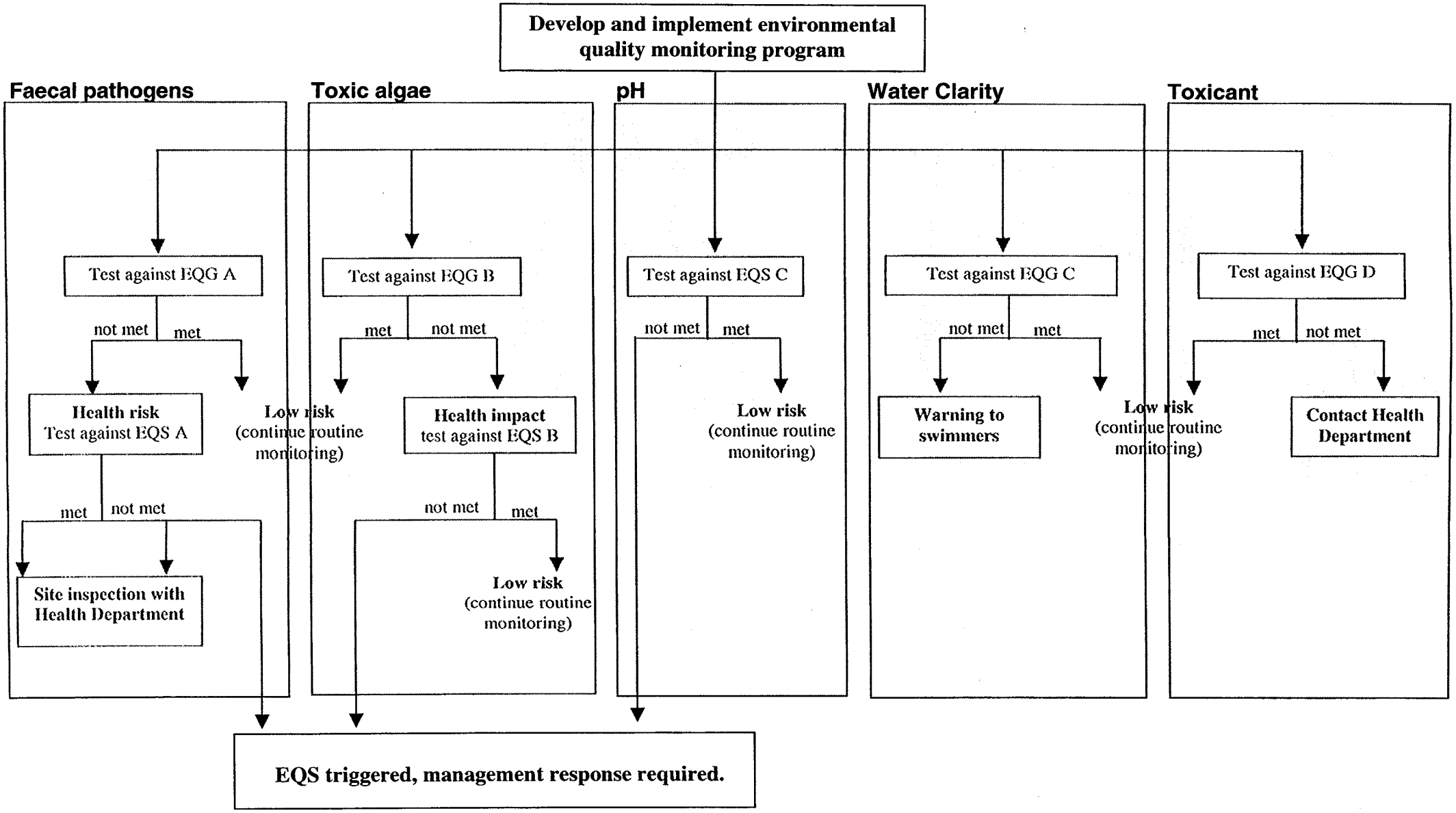
   [N]..... - go to step 9.
   [Y]..... - No issue identified, go to step 1.

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. Reduce risk to public health through appropriate management on advice of the Health Department of WA and implement management action to reduce contaminant inputs where these have been shown to have caused the problem. If appropriate, environmental remediation may be required.

Pictorial decision scheme for applying the EQC for primary contact recreation



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.

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, and whether EQS (C) has 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 is exceeded triggering more intensive investigation. Ambient quality is now monitored and assessed against the Environmental Quality Standard

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

   [N]..... - go to step 5, and
   - go to step 8.

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

TABLE 7. Environmental quality criteria for the maintenance of secondary contact recreation (relevant Guidance notes should also be read)

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 swimmers, *considered by a medical practitioner as potentially resulting from toxic algae,* when less than 15 000cells/mL is present in the water.	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. Water should contain no chemicals at concentrations that can irritate the skin of the human body.	

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.

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, and whether EQS (C) has 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 is exceeded triggering more intensive investigation. Ambient quality is now monitored and assessed against the Environmental Quality Standard

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. Reduce risk to public health through appropriate management on advice of the Health Department of WA and implement management action to reduce contaminant inputs where these have been shown to have caused the problem. If appropriate, environmental remediation may be required.

Pictorial decision scheme for applying the EQC for secondary contact recreation

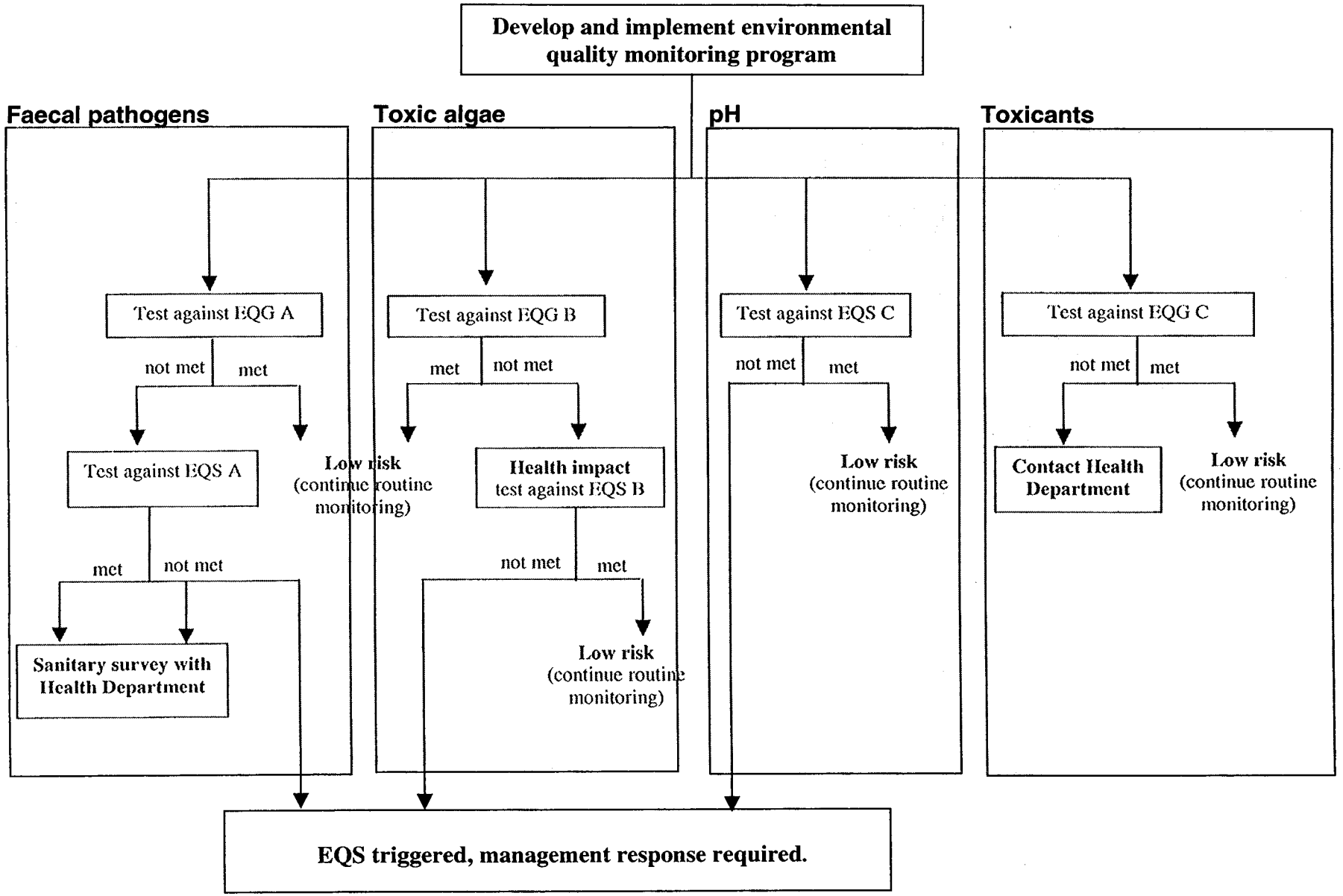


TABLE 8. Environmental quality criteria for Aesthetic quality (relevant footnotes and Guidance notes should also be read)

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 the aesthetic water quality values of Cockburn Sound using direct measures of the communities perception of aesthetic value.
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
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
Zinc	5.0

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

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. For example, 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.

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]..... - aesthetic values not compromised, 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.

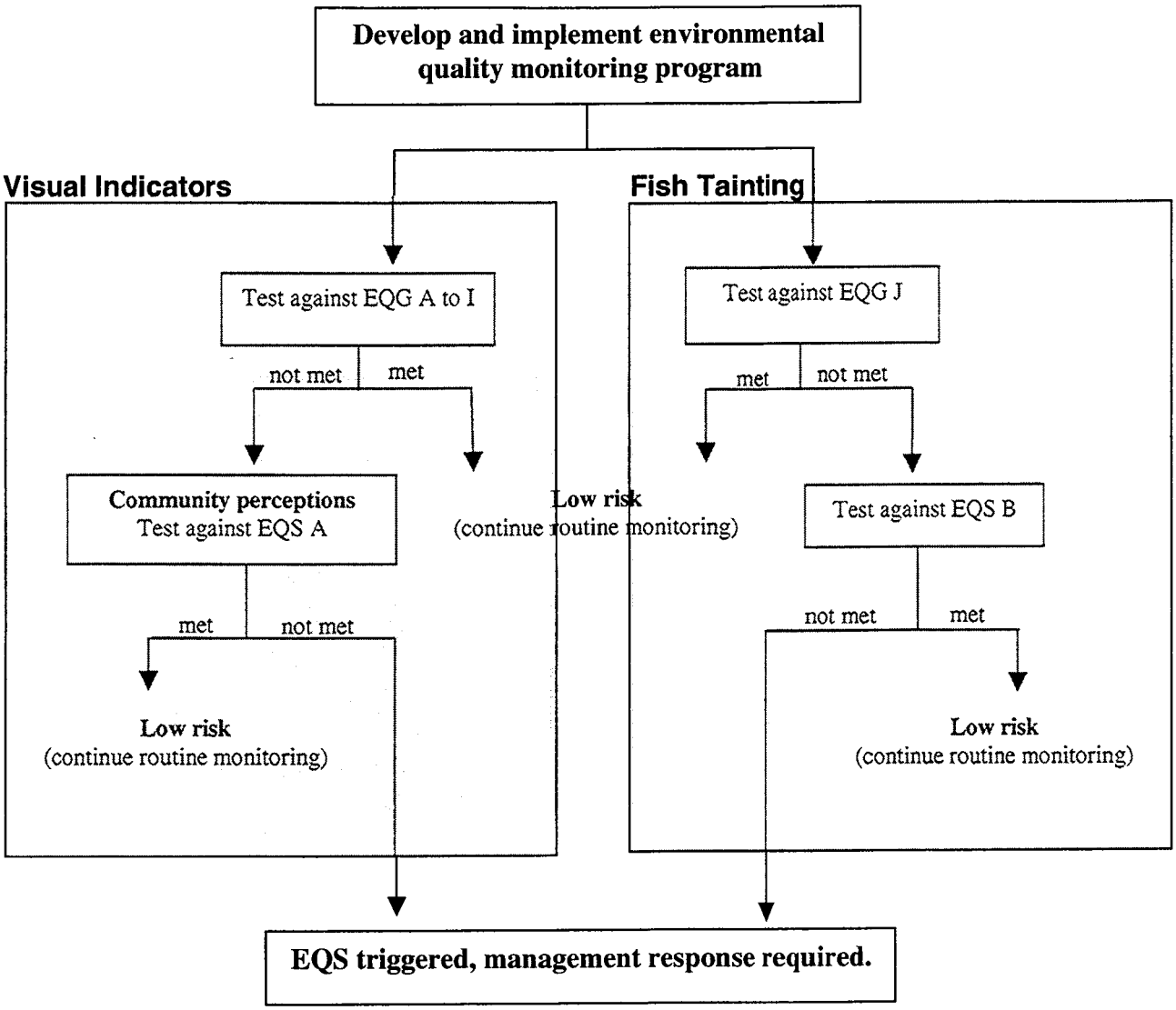
The EQG has been triggered and the EQS need to be addressed.

5. 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 improve, the aesthetic value within an agreed timeframe.

Pictorial decision scheme for applying the EQC for aesthetic quality



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