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Revised environmental quality criteria reference document for Cockburn Sound

A supporting document to the
State Environmental
(Cockburn Sound)
Policy 2013

Environmental Protection Authority

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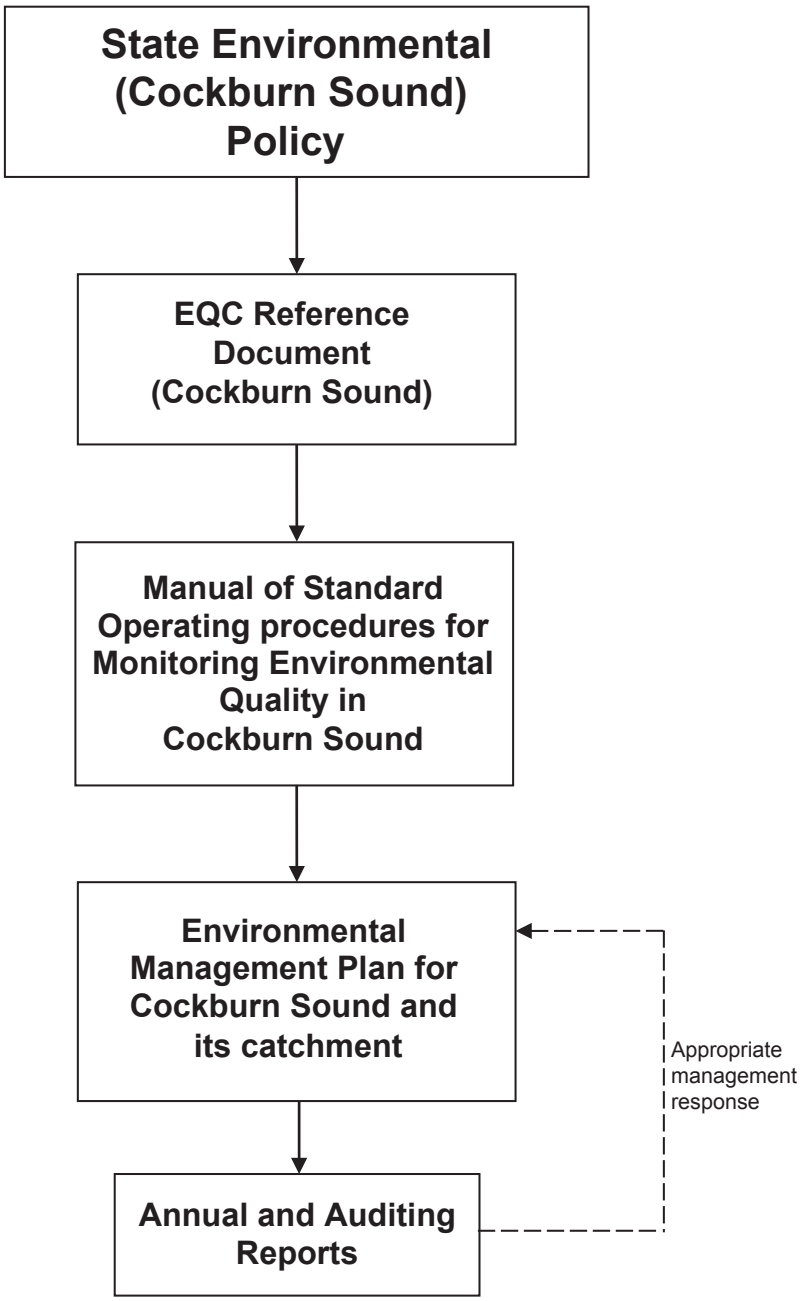


The *Cockburn Sound Environmental Quality Management Framework* documents and how they relate

Preamble

Cockburn Sound is a sheltered marine embayment located to the south-west of the Perth metropolitan region. Cockburn Sound is protected from the prevailing winds and seas by Garden Island and 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 their quality and therefore 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. In 2005 the Environmental Protection Authority (EPA) prepared the State Environmental (Cockburn Sound) Policy 2005 (SEP 2005) to set the common goals for management and provide a mechanism for implementing the management plan. The SEP 2005 was subsequently endorsed by the State Government with the understanding that it would be reviewed in seven years. Following a report into the performance of the environmental management framework for Cockburn Sound in 2010 by the WA Auditor General the EPA revised the SEP 2005 to strengthen the management framework and reporting mechanisms and to update the supporting documents. The State Environmental (Cockburn Sound) Policy 2013 (SEP 2013) supercedes the SEP 2005.

The focus of the Policy 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 in the SEP. A comprehensive suite of environmental quality criteria are provided in this Revised EQC Reference Document. 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 (EPA, 2000). The EPA has established an environmental quality management framework for Cockburn Sound, which has been given effect through the State Environmental (Cockburn Sound) Policy 2013 (SEP, 2013). 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 marine environment of Cockburn Sound.

Implementation of the management framework is 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 the EQC are 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.

All the EQC that support the SEP and the EMP, and the decision schemes which explain how they should be applied, are included in this reference document. They are based on known current and historical contaminant inputs and are relevant to the potential issues/pressures in the Sound (GHD, in draft). The decision schemes are also included in the SEP. 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* (WASQAP, 2011) and the *Australia New Zealand Food Standards Code* <http://www.foodstandards.gov.au/foodstandards/foodstandardscode.cfm> 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) using the implementation framework recommended for WA through the State Water Quality Management Strategy Report 6 (Government of WA, 2004). In particular, the EPA has adopted the concept of using water and sediment quality guidelines to trigger a risk-based approach for determining the risk of an unacceptable environmental impact. If the guidelines are exceeded then there is a significant risk that the contaminant may be causing an environmental impact and further investigation is required to determine whether the level of impact is acceptable. These additional investigations usually involve measuring the bioavailability of contaminants and/or assessing biological or ecological indicators further along the cause/effect pathway. This risk-based approach integrates the more traditional chemical and physical indicators with biological indicators of environmental quality. Sources of additional information used for the development of the EQC were the Australian Shellfish Quality Assurance Program (WASQAP, 2011), *Australia New Zealand Food Standards Code* <http://www.foodstandards.gov.au/foodstandards/foodstandardscode.cfm> and advice from the WA Department of Health. Where necessary, expert scientific advice was sought through technical workshops and working groups to provide guidance on the selection of appropriate indicators and criteria. The current set of EQC are a refinement of the guidelines and standards that have been applied to Cockburn Sound since the SEP 2005 was first released 7 years ago.

The *Manual of Standard Operating Procedures for Environmental Monitoring Against the Cockburn Sound Environmental Quality Criteria* (EPA, 2005), which complements this document, will also be updated to reflect any changes in the EQC. The manual specifies how samples should be collected and analysed, and how the results should be 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 the waters of 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 these waters 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 was developed in consultation with the community and stakeholders and is largely implemented through the Cockburn Sound Management Council.

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 four social *environmental values* have been identified for protection in Cockburn Sound (Table 1 and Figure 2). To support the five environmental values, eight measureable *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 want protected. For the first environmental quality objective *'Maintenance of ecosystem integrity',* three levels of ecological protection have been recognised for areas within Cockburn Sound. The acceptance of different levels of ecological protection is based on a recognition that other societal benefits also need to be considered (e.g. 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 shown in Schedules 2 and 3 of the SEP <www.epa.wa.gov.au/Policies_guidelines/envpol/Pages/1567_StateEnvironmentalCockburnSoundPolicy2005.aspx?pageID=3&url=Policies_guidelines/envpol>.

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 (e.g. seagrass).

2.2 Selecting indicators of concern

The EQC presented in the tables cover a wide range of environmental indicators (including health of biota and concentrations of contaminants) that can be used to assess environmental quality. The environmental quality indicators selected for routine monitoring would be determined on a case by case basis following consultation with the relevant stakeholders and are likely to be a small subset of the full list of criteria in this document. 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, an understanding of natural background contaminant concentrations, modelled predictions, contaminant input inventories and the nature of the contaminant (e.g. environmental fate, potential for biomagnification).

Indicators that exceed or are predicted to exceed the EQC 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 characterisation of effluent; and demonstrated risk of accidental discharges.

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

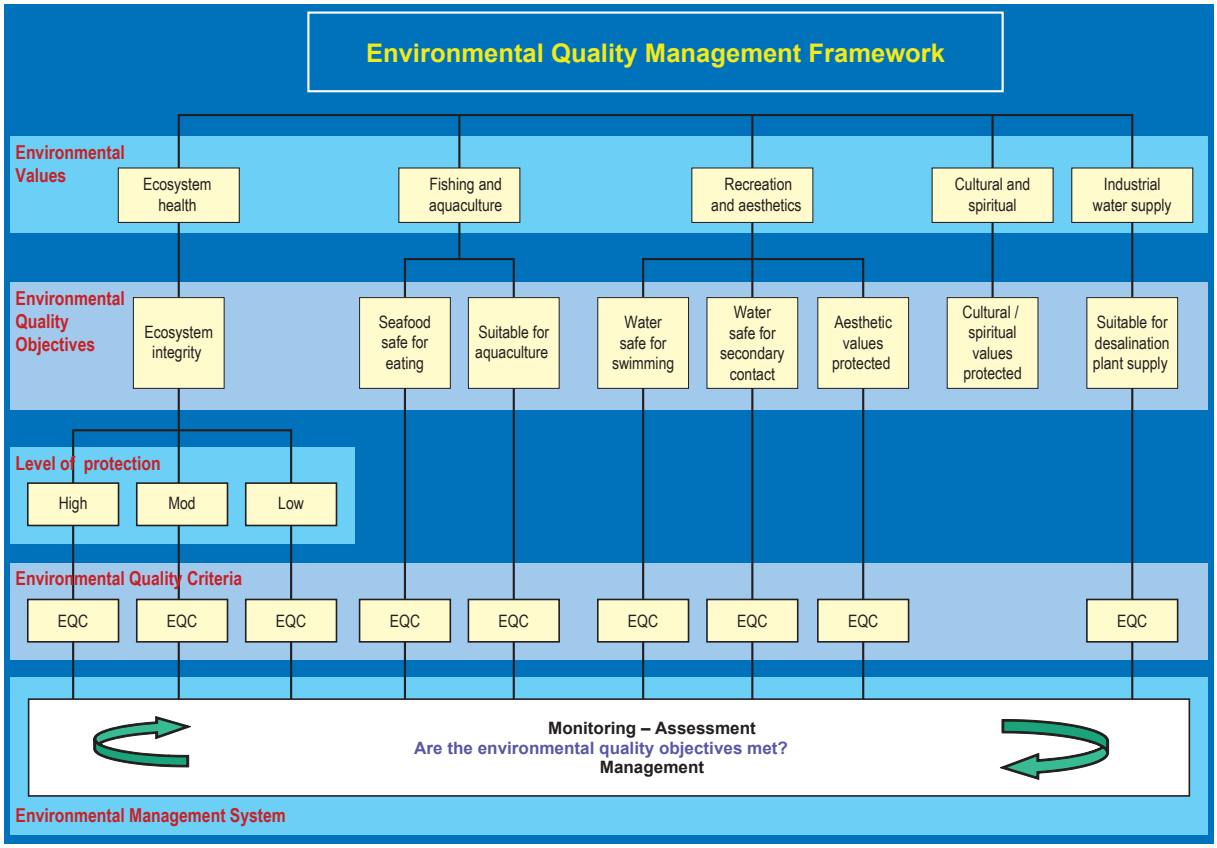


Figure 1 The environmental quality management framework for Cockburn Sound

Environmental Values	Environmental Quality Objectives and their descriptions
Ecosystem Health	***Maintenance of ecosystem integrity.***
	Ecosystem integrity is considered in terms of structure (e.g. the biodiversity, biomass and abundance of biota) and function (e.g. 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 safe for human consumption.***
	Seafood is safe for human consumption when collected or grown.
	Maintenance of aquaculture.
	Water is of a suitable quality for aquaculture purposes.
Recreation and Aesthetics	***Maintenance of primary contact recreation values.***
	Primary contact recreation (e.g. swimming) is safe to undertake.
	Maintenance of secondary contact recreation values.
	Secondary contact recreation (e.g. boating) is safe to undertake.
	Maintenance of aesthetic values.
	The aesthetic values are protected.
Cultural and Spiritual	***Cultural and Spiritual values of the marine environment are protected.***
	Indigenous cultural and spiritual values are not compromised.
Industrial water supply	***Maintenance of water quality for desalination plant operation.***
	Marine water quality is suitable for intake to the Perth desalination plant.

Figure 2 The Environmental Values and their corresponding Environmental Quality Objectives for Cockburn Sound

2.3 What are Environmental Quality Criteria

The 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 (i.e. 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). As discussed earlier, this is a risk-based approach that relies on increasing levels of evidence of an impact before a management response is triggered.

EQG are generally relatively simple and easy to measure indicators of environmental quality. If met there is a low risk that the environmental quality objectives are not being achieved. If an EQG is 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 and evidence-based assessment against the EQS. This approach provides increased confidence to support decision making and is based on evidence using indicators further down the cause/effect pathway. The approach integrates more refined measures of the surrogate indicators (e.g. bioavailable contaminant concentrations) with more direct measures of the environmental quality objective (e.g. 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. 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.

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 that may require some form of surveillance and possibly management intervention but 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 (e.g. Water temperature is strongly seasonal, 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). To address this variability EQC for some indicators have been derived for specific seasons. For example, in Cockburn Sound the main period for nutrient-related monitoring is over summer when river flow is minimal and nutrient concentrations are most stable, while guidelines for temperature have been provided for each season. Nevertheless, most environmental quality indicators are relatively stable, both seasonally and/or spatially, and for these indicators the EQC remain the same throughout the year and the region.

Their Application

Both numerical and narrative EQC for each environmental quality objective in the protected area 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.

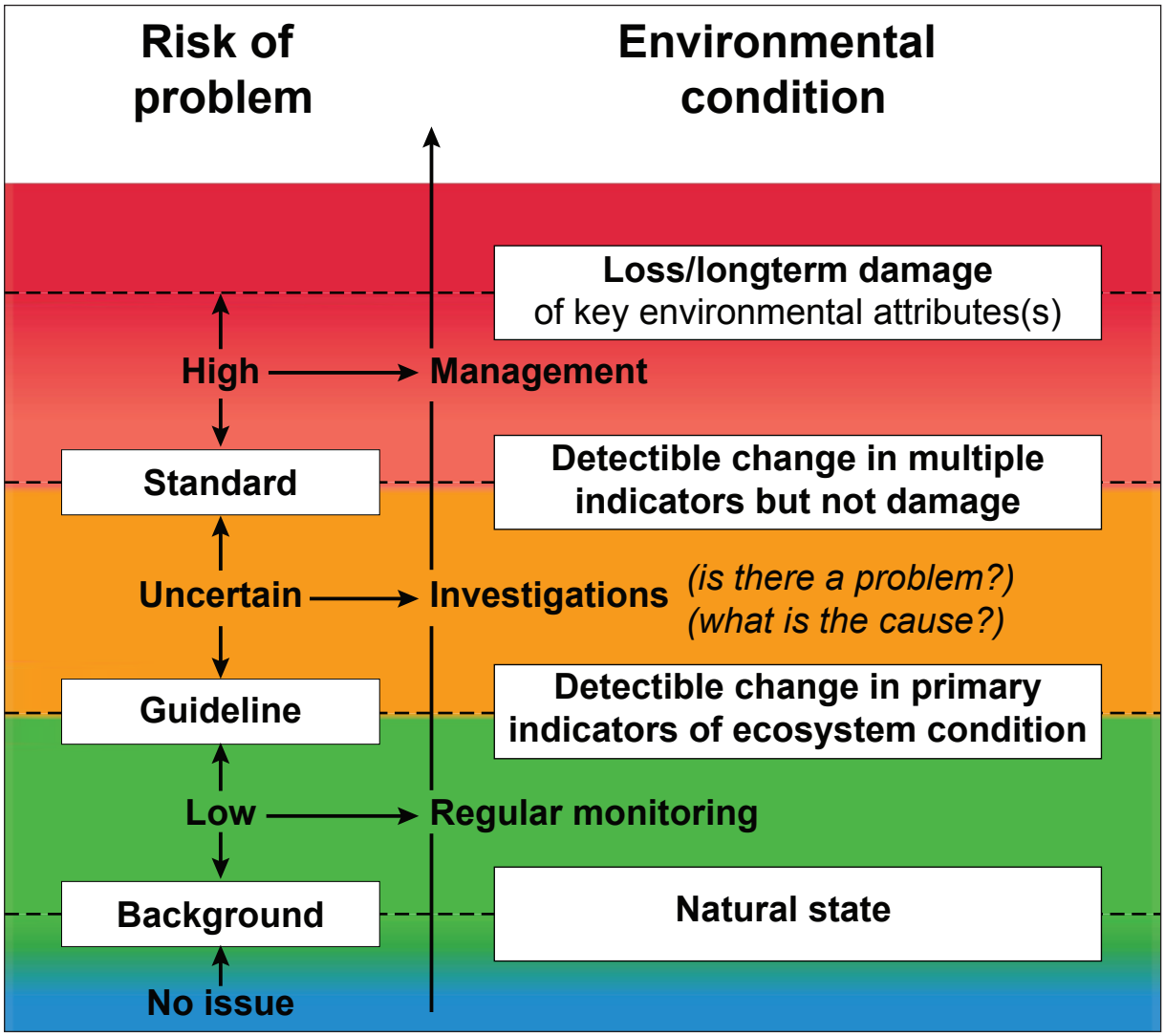


Figure 3 Conceptual diagram showing the relationship between the two types of EQC on the left hand side with the associated environmental condition on the right hand side

The 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 to cease the investigation and divert resources to implement an appropriate management response (e.g. 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 for that contaminant should be compared against the monitoring data. In general the lowest (i.e. most restrictive) 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. The EQG for maintenance of ecosystem integrity are generally the lowest, however, for some environmental quality objectives there are no EQG and only EQS have been provided for specific contaminants. In these circumstances routine monitoring data should be compared with the EQS. It is also possible that the EQG for more than one environmental quality objective may be exceeded, in which case the associated EQS for each environmental quality objective would need to be investigated. Where EQG or EQS exist for a range of media (e.g. 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 Operation Procedures for Environmental Monitoring Against the Cockburn Sound Environmental Quality Criteria* (EPA, 2005).

The EQC developed for Cockburn Sound are comprehensive and quite detailed. Although decision schemes and guidance notes have been provided to assist with implementation of the EQC, it is not possible to predict all likely scenarios that may arise. A common sense approach will therefore be required by all stakeholders when applying the EQC in circumstances where little guidance is available, but always bearing in mind that the intent is to provide surety that the environmental quality objective is achieved. For example, EQG should never be below natural (un-impacted) background concentrations; and the chemistry and stability of rapidly degraded contaminants (e.g. chlorine) should not be assumed to be conservative (remain unchanged) when modelling the distribution and fate of these chemicals in a discharge. 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.

2.4 Comparing monitoring data against the EQC

The extent of the area from which environmental quality data are to be collected and compared against the EQC will depend on the objective of the monitoring and reporting program and will therefore need to be established on a case-by-case basis and clearly defined in the monitoring program. For example, data evaluation to inform report cards on the general health of the whole of Cockburn Sound might combine all sites within each broad zone (e.g. levels of ecological protection) to compare against the EQC, whereas evaluation of monitoring data to inform the management of environmental quality in areas of the Sound that might be impacted may require data from individual sites, or a few pooled local sites, to be assessed against the EQC. The EQC themselves have been drafted with this in mind and 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, but in most cases the EPA recommends that monitoring data from individual sites should be assessed against the EQC to identify areas requiring focussed management before the problem spreads into adjacent areas.

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 it had 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 most environmental quality indicators, the approach adopted for comparing monitoring data with the EQG and determining when a significant and unacceptable change has occurred, is consistent with ANZECC & ARMCANZ (2000) and relatively straightforward:

- For most toxicants and bacteriological indicators the approach is to compare the 95th percentile of the monitoring data with the EQC; and
- For nutrients and physical stressors (e.g. 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 locating 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 causing the discharge plume to extend beyond the low protection zone boundary, albeit for a very short period of time. If only one site is to be located on the low ecological protection zone boundary then consideration should be given to sampling on a number of occasions and each time locating the sampling site where modelling predicts the discharge plume will intersect with the zone boundary under the prevailing meteorological conditions (i.e. focus on worse case).

For biological indicators, reference sites will be required for comparison with potential impact sites, and hence a threshold of acceptable change must be established (e.g. the 20th and/or 80th percentiles of the measured distribution of the indicator at the reference site for high ecological protection areas).

The NWQMS Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ, 2000) should be referenced for a more detailed discussion on comparing monitoring data with EQC.

2.5 Deriving EQC for new indicators

There may be situations that call for monitoring of a new indicator in Cockburn Sound, and for which EQC have not been determined. Under these circumstances the first step is to check whether a guideline trigger value has been derived for that contaminant in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ, 2000). However, if the indicator is a physical or chemical stressor in water (e.g. TSS, pH, salinity, nutrients, etc), the default trigger values provided in ANZECC & ARMCANZ (2000) for the protection of ecosystem health should only be used if there are no data available to derive an EQG using biological effects or reference site data (see below).

The preferred approach for deriving an EQC is to use biological/ecological effects data either from the testing of local biota and using local waters (ecosystem health) or from the scientific literature (ANZECC & ARMCANZ, 2000). In most cases this information will not be immediately available and will require significant investigations and research to be undertaken. Alternatively, an EQC can be derived using data collected from an un-impacted local reference site. In this case there will need to be a sufficient temporal spread of data available to determine whether seasonal changes in the indicator require guidelines to be derived seasonally and a sufficient number of data to derive a guideline with statistical confidence. The objective of this approach is to maintain the quality of the target waters within a range that is defined by a reference condition that is considered to be of a suitable quality. Although the approach was developed to protect the environmental value of ecosystem health (ANZECC & ARMCANZ, 2000), there is a high probability that any EQG derived using this approach will also protect the more social environmental values because humans tend to be less sensitive to changes in environmental quality than most marine fauna and flora.

Consistent with ANZECC & ARMCANZ (2000), a new EQG for a water quality indicator would be derived from the 20th percentile and/or 80th percentile of the natural background levels for that indicator for a high level of ecological protection, or the 5th and/or 95th percentiles for a moderate level of ecological protection. If the median for the defined area is within the range specified by these percentiles, then it is reasonable to assume there is a low risk that the EQO of maintaining ecosystem integrity is not being achieved. A new EQG for a sediment contaminant in high and moderate ecological protection areas is derived by multiplying the median natural background concentration of the contaminant in the reference sediments by a factor of 2.

For anthropogenic organic chemicals that don't occur naturally, any detection of the chemical using the lowest LOR available is the recommended EQG.

2.6 Updating the EQC

This version of the Environmental Quality Criteria Reference Document for Cockburn Sound updates the original document released in January 2005. The EQC and decision frameworks in this document will be amended by the EPA from time to time following a process of public consultation and made publicly available. The amendments will be necessary to:

- incorporate improvements in our understanding of the environmental processes and ecological pathways in Cockburn Sound;
- incorporate any relevant updates of national guidelines and standards.

Several of the nutrient related EQC require updating annually to incorporate the latest monitoring results from the reference site (see section 3.1.2). The EQG for chlorophyll *a*, light attenuation and phytoplankton biomass, and the EQS for seagrass meadow shoot density (*P. sinuosa*), leaf and leaf cluster characteristics (*A. griffithii*) and phytoplankton biomass will be recalculated each year and made available on the Cockburn Sound Management Council's website as soon as practicable following completion of the monitoring period (www.csmc.environment.gov.au).

3. The EQC for each environmental quality objective

An outline of the main sources of information used to develop the EQC for each environmental quality objective, and the rationale underpinning them, are provided in Sections 3.1 to 3.8. The tables containing the actual EQC (and their associated decision schemes) are provided in Section 4.

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 SEP describes three levels of ecological protection and where they apply spatially in the protected area so that overall ecological integrity can be maintained. This enables land use 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 necessarily 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 (*e.g. 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 (*e.g. 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 (*e.g. 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.

The majority of Cockburn Sound is expected to be maintained in 'slightly disturbed' condition or better. In recognition of this a high level of ecological protection has been assigned to these areas. The EQG for this level of protection have been developed in accordance with the recommendations of ANZECC & ARMCANZ (2000) as follows:

- The recommended 99% species protection guideline trigger levels for toxicants in water will apply;
- The ISQG-low guideline trigger levels for toxicants in sediments;
- The 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.

Within the protected area two broad areas are considered to be 'moderately to highly disturbed': the area along the eastern side of Cockburn Sound adjacent to the industrial area; and Careening Bay on Garden Island. These areas have been designated a moderate level of ecological protection and should be assessed separately. The moderate level of ecological protection area along the eastern side of Cockburn Sound also 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. A lower level of ecological protection may also be considered for any additional marinas or harbours approved and constructed within the protected 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.

While the methodology for developing EQC for all moderate ecological protection areas should be consistent, it may be appropriate to monitor a subset of indicators for some marinas and harbours depending on potential threats to environmental quality and the benthic habitats present (e.g. monitoring and assessment of light attenuation coefficient and chlorophyll a in a marina may be unnecessary if seagrass is not present). For the few small areas located around outfalls in Cockburn Sound 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 these low ecological protection areas is 1% or less of the protected area in Cockburn Sound.

3.1.2 Derivation of EQC

Cockburn Sound is managed for a mix of industrial, defence, commercial and recreational purposes, all of which have the potential to impact on the marine environment. Achieving the environmental quality objective 'maintenance of ecosystem integrity' largely depends on ensuring that environmental quality is maintained within acceptable levels. The level of environmental quality considered acceptable varies according to the level of ecological protection assigned to the area.

ANZECC & ARMCANZ suggest a range of approaches for deriving EQG depending on the information available for the area or the contaminant. The preferred approach is to derive EQG from local biological/ecological effects data or from the scientific literature. Examples include the guideline trigger values from ANZECC & ARMCANZ (2000) for toxicants in water which

are based on ecotoxicological data or the sediment quality guidelines which are based on ecological effects data. Where insufficient biological or ecological effects data exist then the next preferred method is to determine an acceptable level of change from a reference condition based on a percentile of the reference data distribution (Section 3.1.1). The reference sites selected for deriving these EQC may vary according to the parameter being measured. The intent is for the reference site to be as similar as possible to the water body being managed in terms of physical setting, hydrodynamics and biology, but importantly it should be unaffected by anthropogenic influences. Where there are insufficient information or resources available to derive a site specific EQG for a physical or chemical stressor, then the default regional trigger values provided in Section 3.3 of ANZECC & ARMCANZ (2000) could be used as an interim step until more reliable EQG can be derived.

Further discussion is provided below for those physical and chemical stressors where EQC are derived from local reference site data.

Nutrient-related EQC

The first three groups of EQC (Table 1a A-C) deal with the issue of nutrient enrichment and were derived while giving consideration to achieving the following three important objectives:

- Protection of the remaining seagrass meadows in Cockburn Sound;
- Maintaining 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
- Minimising 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 1970s when the seagrass meadows were lost from the majority of the eastern margin of Cockburn Sound (DEP, 1996).

Warnbro Sound in the Shoalwater Islands Marine Park was selected as the most appropriate reference area for Cockburn Sound. Water quality in Warnbro Sound is high and is practically independent of water quality in Cockburn Sound. The EQC for chlorophyll *a*, LAC and phytoplankton biomass are derived using data collected from one reference site in the central basin of Warnbro Sound (site 4) during 'typical' summer conditions over a rolling 6 year period. The decision to use only one reference site in Warnbro Sound was made following an analysis of data from all Warnbro sites showing that data from site 4 were representative of all Warnbro Sound sites combined. Furthermore it minimises the additional sampling effort required to collect the reference data. It was recognised that the quality of the water in the northwest corner of Cockburn Sound may 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 are collected between December and March (the non river-flow period) and have been collected at irregular intervals between 1977 and 2002 and then every year after that. It should be noted that the 1991/92 summer chlorophyll *a* data set was found to represent atypical conditions and as such was omitted from any analyses of

this dataset. 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).

The resulting EQG for chlorophyll *a* 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 on the eastern side of the Sound. The LAC levels in both high and moderate ecological protection areas approximate the EQG and if these levels can be maintained 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 are based on 'rolling' percentiles and so will be re-calculated and updated each year using the monitoring results collected during the current year and the five previous summers so that the EQC are calculated from a database of approximately 100 values and remain contemporary. 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 (e.g. 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 full historical reference site data set.

b) If the median is between the 20th percentile and the 80th percentile, the new data are incorporated into the historical reference data set, new median, 80th and 95th percentiles are computed from the last 6 years of the data 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. In this case the new data are not incorporated into the historical reference data set or used to recompute a new set of rolling percentile-based EQG. In addition, the comparison of the test site (i.e. Cockburn Sound) data against the reference is not conducted for that year as this finding suggests that the water quality may be responding to non-local forcings. Alternatively, the finding may suggest that Warnbro Sound is responding to increased nutrient inputs from surrounding land uses and its suitability as a reference site should be investigated. In the first instance a trend analysis of the chlorophyll a and LAC data in Warnbro Sound should be undertaken to determine whether there is a statistically significant increasing trend. Other suitable reference sites will need to be investigated if the trend continues over consecutive years. Furthermore, managers of the Shoalwater Islands Marine Park would be alerted and may need to take management intervention to ensure the objectives of the park are maintained.

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.

In addition to the nutrient-related EQG described above, three EQS were developed specifically to identify changes in seagrass health, i.e.:

- Seagrass shoot density (*Posidonia* species);
- Seagrass lower depth limit (*Posidonia* species); and
- Leaf and leaf cluster characteristics *(Amphibolis griffithii).*

Posidonia sinuosa

The EQS for seagrass shoot density using reference site data have been developed for *Posidonia* seagrass meadows generally, although the default numerical EQS in Table 1b (and updated annually on the Cockburn Sound Management Council website: <csmc.environment.wa.gov.au/> are specifically provided for use with *Posidonia sinuosa* shoot density data. The numerical EQS for *P. sinuosa* are derived using data collected from permanent fixed relocatable quadrats placed in *P. sinuosa* beds at Mersey Point, Warnbro Sound. Shoot density is measured at this reference site in January each year and the data added to the historical reference data set. EQS are then re-calculated from the last 100 data points for each monitored depth at the reference site (i.e. rolling 4 year percentiles) and then updated on the Cockburn Management Council website <csmc.environment.wa.gov.au/>. Shoot density percentiles for the first 4 years of monitoring have been provided in Table 1b and represent historical baseline percentile values for seagrass shoot density at the Warnbro Sound reference sites and are termed 'Absolute Minimum Criteria'. To guard against the possibility of a declining trend in seagrass shoot density at the Warnbro Sound reference site influencing the EQS over time, the following three step process is to be implemented prior to evaluating shoot density at individual sites.

i. For each depth, compare the updated rolling 20th percentile and 5th percentile shoot density against the absolute minimum 5th percentile and 1st percentile respectively;

ii. If either the updated rolling 20th percentile or 5th percentile shoot density is greater than the absolute minimum 5th percentile or 1st percentile respectively, then the updated rolling percentiles are used as the EQS;

iii. If either the updated rolling 20th percentile or 5th percentile shoot density is less than the absolute minimum 5th percentile or 1st percentile respectively, then it is assumed that seagrass shoot density at the reference depth has significantly declined and may no longer be a useful reference. In this case the absolute minimum 5th percentile or 1st percentile values are used as the EQS for high and moderate ecological protection areas respectively.

Environmental quality in Warnbro Sound has historically been relatively high and is independent of the environmental quality of Cockburn Sound, however, the Auditor General's report on the Environmental Management of Cockburn Sound (OAG, 2010) expressed concern that seagrass shoot density at the Warnbro Sound reference site may be trending down and that the site may no longer be a suitable reference. In response to this concern the CSMC commissioned a thorough review of the Cockburn Sound seagrass monitoring program, including the on-going suitability of the reference site in Warnbro Sound. The review confirmed the suitability of the

reference site and recommended the above approach to ensure any future decline in shoot density at the reference site does not allow an on-going decline in seagrass meadows to occur in Cockburn Sound without being detected. It was also recommended that consideration be given to establishing one or more additional reference sites to strengthen the approach and guard against the derived EQC from being potentially influenced by degrading seagrass health in Warnbro Sound. The Cockburn Sound Management Council and Department of Environment Regulation (DER) are currently investigating the feasibility of using sites established in the Shoalwater Bay Marine Park and Jurien Bay Marine Park as additional reference sites. As the database for any new reference sites expands over subsequent years it will be possible to assess any trends at the Warnbro Sound reference site at a regional level. If shoot density at the Warnbro Sound reference site is found to be trending down compared to the other regional reference sites then consideration will need to be given to replacing the Warnbro Sound reference site.

The reference site seagrass shoot density data used to derive the default shoot density criteria in Table 1b are collected at depths of 2, 2.6, 3.2, 5.3 and 7.4 metres, consequently the annually updated rolling EQS and the absolute minimum EQS provided in Table 1b are not suitable for use at significantly different depths. To assess seagrass health at depths outside this range, additional reference sites would need to be established at an 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 important that both reference and test sites have the same seagrass species.

An EQS for the lower depth limit of *P. sinuosa* meadows investigates whether there has been a statistically significant retreat of the leading edge of a seagrass meadow into shallower depths compared to its baseline position.

Amphibolis griffithii

The EQC for the indicators ‘leaf extension rate’, number of ‘leaves per cluster’ and number of ‘clusters per stem’ have been developed based on a draft standard operating procedure developed by ECU (Lavery and McMahon 2011) for determining the health of *Amphibolis griffithii* subject to light stress. The three selected indicators of light stress in *A. griffithii* meadows were from a set of 13 sub-lethal indicators of light stress developed by McMahon & Lavery (2008) and Lavery et al. (2009) after taking into account applicability for a monitoring program (e.g. ease and cost of measurement and analysis). The broader suite of stress indicators were developed through applied research undertaken in a monospecific *A. griffithii* meadow at 5 m depth over two years (2005–07) in Jurien Bay. The selected indicators are based on the latest understanding of the pressure-response pathway for light stress in this species, with leaf extension rate and number of leaves per cluster expected to respond first followed by number of clusters per stem. The sampling methodology for *A griffithii* is destructive rather than the *in situ* approach used for *P. sinuosa* meadows, and consideration should therefore be given to the potential for sampling impacts on meadows that are relatively sparse.

Of the three selected indicators, only two (‘leaves per cluster’ and ‘clusters per stem’) have been included in Table 1b for assessment of Amphibolis seagrass beds in Cockburn Sound under the SEP. The values provided in Table 1b for these two indicators are derived from the Jurien Bay data and are to function as default EQC, unless more appropriate site specific EQC are established from data collected at a suitable reference site(s). The default EQC that apply to areas assigned a high level of ecological protection are based on the 20th percentiles for each indicator as calculated from the Jurien Bay data, while those that apply to areas with a moderate level of ecological protection are based on the 5th percentiles. For the indicator ‘leaves per cluster’ the relevant values for the EQC correspond to those published in McMahon and

Lavery 2008 (Figure 12.3). The values for the indicator 'clusters per stem' were re-calculated to suit the different monitoring approach developed for Cockburn Sound where individual *A. griffithii* stems are harvested rather than all stems in a quadrat (Kathryn McMahon, pers. com.).

Leaf extension rate is considered to be the most sensitive indicator of light stress, but because it responds in relatively short time periods it was not considered to be a suitable indicator for the assessment of *A. griffithii* health over 12 month periods as undertaken for the SEP. Nevertheless, the indicator could provide an additional line of evidence for light stress and the EQG may be useful for monitoring shorter term impacts associated with construction pressures from new developments. Trigger values for leaf extension rate are therefore provided in the table below for use as appropriate. These values have been derived from the 20th (HEPA) and 5th (MEPA) percentiles leaf extension rates measured at Jurien Bay and would be triggered if leaf extension rate fell below the values provided.

A. griffithii	High Protection trigger	Moderate protection trigger
Leaf extension rate (mm cluster^{-1} day^{-1})	< 0.67	< 0.4

EQC for other physical and chemical stressors

Changes in dissolved oxygen concentration, water temperature, salinity and pH can have a deleterious impact on biota if the parameters move outside their normal range for the site. The numerical EQG and EQS for dissolved oxygen concentration (Table 1a D) and pH (Table 1a G) are based on the information and recommendations in ANZECC & ARMCANZ (2000) for marine biota. The temporal component of the EQC for dissolved oxygen is based on professional judgement and is intended to ensure that any reductions in DO below the recommended concentrations do not extend for long periods.

Water temperature (Table 1a E) and salinity (Table 1a F) are naturally highly variable between and within ecosystems and also seasonally, so it is not appropriate to apply default guideline trigger levels developed for use across broad regions. It is therefore recommended that EQG for these parameters are developed in accordance with the percentile based approach from ANZECC & ARMCANZ (2000) for developing locally relevant guidelines based on local reference site data (refer Section 3.1.1). If required, default trigger values are provided in the Guidance Notes for interim use until a reference condition has been defined.

EQC for toxicants

The EQG for toxicants in marine waters and sediment pore waters (Table 2a) and for toxicants in sediments (Table 3) have been mostly developed from the guideline trigger levels provided in ANZECC & ARMCANZ (2000). For contaminants in water the 95th percentile of the contaminant concentration at an impact site is compared with the relevant EQG (Table 2a) to determine whether there is a risk that the EQO may not be met, requiring a more detailed assessment against the EQS. For contaminant concentrations in marine sediments it is the median concentration at an impact site that is compared with the EQG. However, if the sediment concentration at any individual sampling site exceeds the re-sampling trigger then further investigation should be undertaken to determine the extent and severity of contamination. Environmental quality standards for water and sediment quality are also provided in Tables 2a and 3 respectively. The EQS are adapted from the risk-based approaches recommended in ANZECC & ARMCANZ (2000) when guideline trigger values are exceeded.

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 necessarily 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 (e.g. arsenic), while others are discharged at relatively high concentrations (e.g. 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 a 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 water quality (e.g. through the licensing process) in Cockburn Sound. Although exceedance of LRVs do not trigger mandatory assessments against environmental quality standards, it does signal to stakeholders that the possibility of ecological impact needs consideration, particularly 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 (e.g. 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 (i.e. data from a minimum of 5 species from 4 taxonomic groups).

Undertaking investigations to assess environmental quality against an EQS can take a considerable amount of time, potentially delaying management action in situations where contaminants are at levels requiring an urgent response. A set of Initial Management Triggers (IMT) for toxicants in water have therefore been provided (Table 2b) to assist in assessing the urgency of implementing a management response upon discovery of a significant contamination event (e.g. heavy contamination from unlicensed inputs or accidental spills of toxic substances). IMTs can also be used to set a limit to on-going degradation of the water resource while investigations against an EQS are underway.

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.

The 95th percentile of the estimated bioavailable concentration of a contaminant at an impact site is compared with the relevant IMT provided in Table 2b. 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.

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. The initial step triggered by exceedance of an EQG for a toxicant is to investigate bioavailability of the contaminant. If concentrations still present a significant risk (i.e. EQG are still exceeded by the bioavailable concentration), then actual impacts on biota or ecological processes are considered. 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 2.3, 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 developing science in Western Australia, and Australia generally. Toxicological services are offered by a number of laboratories within Western Australia and interstate, although protocols for sediment toxicity assessment are not as well developed in Australia as are protocols for assessing the toxicity of waters. Test protocols have been developed for a range of species across Australia, including Western Australia, but preference should be given to protocols that have been developed for organisms local to the impact area. If there are no toxicity testing protocols available for local species then the feasibility of developing new locally relevant protocols should be considered.

3.2 Maintenance of seafood safe 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* (WASQAP, 2011) and the *Australia New Zealand Food Standards Code (*http://www.foodstandards.gov.au/foodstandards/foodstandardscode.cfm), developed and administered by Food Standards Australia New Zealand (FSANZ). Both documents are regularly updated and users should check the latest versions to determine whether the relevant EQC provided in this document have been revised. The WASQAP Manual can be located on the Department of Health (DoH) WA website <www.public.health.wa.gov.au>.

The EQC for this EQO set a level of environmental quality that will ensure there is a low risk of any effect on the health of human consumers of seafood. For filter feeding shellfish, except scallops and pearl oysters, any assessment against the EQO must be using data that are collected from a comprehensive monitoring program consistent with the requirements of the WASQAP Manual. The primary threats to human consumers of seafood relate to contamination of filter feeding shellfish by faecal pathogens (e.g. bacteria), the accumulation of biotoxins from

toxic algae and/or the accumulation of toxic chemicals in the flesh of the shellfish. Filter feeding shellfish need to filter large quantities of water to obtain their food and in the process they can potentially accumulate significant quantities of pathogens and other contaminants that can cause serious illness in humans. However, for other species of seafood and for those shellfish where only the adductor muscle is eaten (e.g. scallops and pearl oysters) the DoH advises that there is only a low risk of potential impacts on human health and therefore monitoring programs do not need to be as comprehensive as required in the WASQAP Manual and may not need to consider faecal bacteria or toxic algae.

Currently, accredited quality assurance monitoring programs based on the requirements of the WASQAP Manual are only conducted for approved shellfish harvesting areas where shellfish are grown commercially for the food market (e.g. Oyster harbour (Albany), Mistaken Island (Albany) and Southern Flats (Cockburn Sound)). Monitoring and management of shellfish quality for these commercial growing areas is administered under the Food Act by DoH, with monitoring undertaken by the growers and auditing undertaken by the DoH. For people that collect and eat wild shellfish the DoH suggests that they may be putting their health at risk and recommends that the public only eat shellfish harvested commercially under strict quality assurance monitoring programs (DoH, 2010). Any monitoring programs established to determine whether the environmental value 'Seafood is safe for Human Consumption' has been protected in an area where wild shellfish are taken recreationally would need to be based on the WASQAP Manual, but there may be issues concerning liability that should be considered. Where monitoring programs are required around wastewater outfalls that may potentially impact on the environmental value then they may also need to be based on the recommended WASQAP Manual for the relevant contaminants. If shellfish are not in the immediate vicinity of the outfall then the results could be used to show the distance from the outfall at which the risk of the discharge impacting shellfish quality (for human consumption) is deemed to be negligible. Where there are no edible shellfish within the broader region of the outfall then monitoring for this environmental value may not be required. It should be noted that monitoring programs for wastewater outfalls are generally not designed to guarantee the safety of seafood in the vicinity of the outfall. This is because there could be other sources of contamination that affect the safety of the seafood (e.g. toxic algal bloom impacts on shellfish).

It should be noted that these EQC do not protect the fish populations or aquaculture species themselves. To protect the wild seafood populations from the effects 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 food webs, habitats and other environmental processes that support them. Application of the guidelines and standards discussed 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 FSANZ in the document *Generally Expected Levels (GELs) for Metal Contaminants: Additional guidelines to maximum levels in Standard 1.4.1 – Contaminants and Natural Toxicants* <http://www.foodstandards.gov.au/_srcfiles/GELs_0801.pdf>.

The standards are intended to confidently predict whether there is a significant risk to the health of human consumers and are therefore predominantly 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. In particular it is important to note that these EQC are based on contaminant concentrations in hydrated (un-dried) flesh. As such, test sample concentrations need to be expressed per unit 'wet weight' rather than 'dry weight' which is always significantly higher and can generate un-necessary concern when used inappropriately.

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 in the policy area by applying the nutrient-related ecological EQC from tables 1a and 1b. 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 relevant EQS are met adjacent to and within 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 (e.g. 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 primarily based on advice from the Department of Health Western Australia and to a lesser extent on ANZECC & ARMCANZ (2000).

The environmental quality guidelines and standards for faecal pathogens, toxic algae, 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 WHO *Guidelines for Safe Recreational Water Environments*, Volume 1, Chapter 4 (WHO, 2003) and consistent with the *Guidelines for*

Managing Risks in Recreational Water (NHMRC, 2008).

The criteria for toxic algae have been based on the professional judgement of experienced environmental health practitioners in the Department of Health WA and the *Guidelines for Managing Risks in Recreational Water* (NHMRC, 2008).

For radionuclides the Health Department should 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 2011) by a factor of 10 (NHMRC, 2008). This is based on an assumption that swimmers in marine waters will not consume more than 0.2 litres of water in a day during a normal swimming session (WHO, 2003) compared to the assumed consumption of 2 litres per day used for the development of drinking water guidelines. This provides for a simple screening approach in which a substance occurring in recreational water at a concentration of 10 times that stipulated in the drinking water guidelines may merit further investigation.

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 (e.g. 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 and phytoplankton cell count 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 (http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm). The EQS is based on actual tainting of fish flesh.

The EQS for the visual indicators is based on direct measures of the community's 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. Such a survey should focus as much as possible on perceived changes in the parameters listed under the EQGs.

3.7 Maintenance of cultural and spiritual values

Water resources are generally associated with important cultural and spiritual values for the local indigenous people. These values may relate to a range of uses and issues including spiritual relationships, sacred sites, customary use, the plants and animals associated with water, drinking water or recreational activities (ANZECC & ARMCANZ, 2000). Inclusion of this environmental value recognises the cultural and spiritual values of Cockburn Sound to the indigenous peoples of the area, but no specific environmental quality criteria are provided, nor are there any guidelines provided for this value in ANZECC & ARMCANZ (2000). By ensuring that the quality of these waters is sufficient to protect ecosystem integrity, protect the quality of seafood and allow people to recreate safely may go some way toward maintaining cultural values, but it is more difficult to define spiritual value in terms of environmental quality requirements.

3.8 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. The Perth Desalination Plant is an important source of potable water for the Perth metropolitan region and is located in the port industrial zone along the eastern shore of Cockburn Sound with a seawater intake in the Sound itself. There are significant development pressures in this area and this has lead the Water Corporation to put forward a set of water quality criteria for the intake water that will ensure the efficacy of the desalination process is maintained and the potability of the desalinated water is protected. No other guidelines have been proposed for industrial water supply.

4. Tables of EQC and the decision schemes for their application

The environmental quality criteria for Cockburn Sound that support the SEP 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 that guide how the EQC are used to assess and manage environmental quality and protect the environmental values. 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'.

Figure 4 An overview of the tables of EQC

EV	EQO	Group	Subgroup	Variable	EQC						Notes
					EQG			EQS			
Ecosystem Health					**HEPA**	**MEPA**	**LEPA**	**HEPA**	**MEPA**	**LEPA**	
	Maintenance of Ecosystem Integrity										
		Physical and Chemical Stressors									
			Nutrients	Nutrient Enrichment:							
				Chlorophyll a	Table 1a A	Table 1a A	n/a				
				Light attenuation coefficient	Table 1a A	Table 1a A	n/a				
				Seagrass shoot density			n/a	Table 1a A	Table 1a A		
				Leaf & leaf cluster				Table 1a A	Table 1a A		
				Lower depth limit			n/a	Table 1a A	Table 1a A	n/a	
				Algal growth potential	TBD	TBD	n/a	TBD	TBD	n/a	
				Phytoplankton biomass	Table 1a C	Table 1a C	n/a	Table 1a C	Table 1a C	n/a	
			Other	Dissolved oxygen concentration	Table 1a D	Table 1a D	n/a	Table 1a D	Table 1a D	n/a	
				Water temperature	Table 1a E	Table 1a E	n/a	Table 1a E	Table 1a E	n/a	
				Salinity	Table 1a F	Table 1a F	n/a	Table 1a F	Table 1a F	n/a	
				pH	Table 1a G	Table 1a G	n/a	Table 1a G	Table 1a G	n/a	
				Total suspended solids	Table 1a H	Table 1a H	n/a	Table 1a H	Table 1a H	n/a	
		Toxicants (water)									Initial Management Triggers (see Table 2b) & Low Reliability Values (see Table 2c) may also apply
			Metals & metalloids	Various	Table 2a	Table 2a	Table 2a	Table 2a	Table 2a	n/a	
			Non-metallic Inorganics	Various	Table 2a	Table 2a	n/a	Table 2a	Table 2a	n/a	
			Organics	Various	Table 2a	Table 2a	Table 2a	Table 2a	Table 2a	n/a	
			Organochlorine pesticides	Various	Table 2a	Table 2a	Table 2a	Table 2a	Table 2a	n/a	
			Organophosphorus pesticides	Various	Table 2a	Table 2a	Table 2a	Table 2a	Table 2a	n/a	
			Herbicides & fungicides	Various	n/a	n/a	n/a	n/a	n/a	n/a	
			Surfactants	Various	n/a	n/a	n/a	n/a	n/a	n/a	
			Oils & petroleum hydrocarbons		n/a	n/a	n/a	n/a	n/a	n/a	
			Diesel		n/a	n/a	n/a	n/a	n/a	n/a	
			Oil spill dispersants	Corexit 9527	Table 2a	Table 2a	n/a	Table 2a	Table 2a	n/a	
		Toxicants (sediment)									
			Metals & metalloids	Various	Table 3	Table 3	Table 3	Table 3	Table 3	n/a	
			Organometallics	TBT	Table 3	Table 3	Table 3	Table 3	Table 3	n/a	
			Organics	Various	Table 3	Table 3	Table 3	Table 3	Table 3	n/a	

EV	EQO	Group	Subgroup	Variable	EQC						Notes
					EQG			EQS			
Fishing and Aquaculture					**HEPA**	**MEPA**	**LEPA**	**HEPA**	**MEPA**	**LEPA**	
	Seafood Safe for Human Consumption										
		Biological contaminants		Various	Table 4			Table 4			
		Chemicals		Various	Table 4			Table 4			
		Metals		Various	Table 4			Table 4			
		Organic chemicals		Various	Table 4			Table 4			
	Maintenance of Aquaculture Production										
		Physico-chemical stressors		Dissolved oxygen		Table 5			Table 5		
				pH	Table 5			Table 5			
		Toxicants									
			Non-metallic inorganic chemicals	Various	Table 5			Table 5			
			Metals and metalloids	Various	Table 5			Table 5			
			Organic chemicals	Various	Table 5			Table 5			
			Pesticides	Various	Table 5			Table 5			
Recreation and Aesthetics											
	Maintenance of Primary Contact Recreation Values										
		Biological		Faecal pathogens		Table 6			Table 6		
				Toxic algae	Table 6			Table 6			
		Physical		pH		n/a			Table 6		
				Water quality	Table 6			n/a			
		Radiological		Gross alpha and beta activity	n/a			Table 6			
		Toxic chemicals									
			Inorganic chemicals	Various	Table 6			Table 6			
			Organic chemicals	Various	Table 6			Table 6			
			Pesticides	Various	Table 6			Table 6			
	Maintenance of Secondary Contact Recreation Values										
		Biological		Faecal pathogens		Table 7			Table 7		
				Toxic algae	Table 7			Table 7			
		Physical and chemical		pH		n/a			Table 7		
				Toxic chemicals	Table 7			n/a			
	Maintenance of Aesthetic Quality										
		Visual indicators		Various	Table 8			Table 8			
		Fish tainting substances		Various	Table 8			Table 8			
Cultural and Spiritual											
	Cultural and Spiritual Values of the Marine Environment are protected				n/a			n/a			
Industrial Water Supply											
	Maintenance of Water Quality for Desalination Plant Operation										
		Biological		Various	Table 9			Table 9			
		Physical and chemical		Various	Table 9			Table 9			

TTM = Total Toxicity of the Mixture
DTA = Direct Toxicity Assessment
IMT = Initial Management Triggers
LRV = Low Reliability Values
TCC = Total Contaminant Concentration

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 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. A defined area can be as large as an entire zone for which a level of ecological protection is determined or a subset of a zone. For example, if an EQG for a relatively large 'defined area' is exceeded because of impacts at a small number of sites, then consideration should be given to subdividing the area up into smaller 'defined areas' for assessment against the EQC, especially if the sites where the EQG is exceeded are clustered together.

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

or means either one of the two alternative EQC can be used for assessing environmental quality. The choice will generally depend on the availability of quality reference site data.

Roman numerals are used for indicators for which multiple EQC are specified and each one should be considered individually. If any one of the multiple EQC are exceeded then the guideline or standard for that indicator has not been met.

	Environmental Quality Guideline†			Environmental Quality Standard†	
	High protection	Moderate protection		High protection	Moderate protection
	Nutrients			Nutrients	
A	***Nutrient enrichment***		**A**	***Nutrient enrichment***	
	Chlorophyll a and Light Attenuation			*Seagrass (*P. sinuosa*)*	
	Ambient value of the defined area during the non river-flow period is not to exceed the value for that indicator as updated annually on <csmc.environment.wa.gov.au>	Ambient value of the defined area during the non river-flow period is not to exceed the value for that indicator as updated annually on <csmc.environment.wa.gov.au>	**i**	EQG A is not to be exceeded in a second consecutive year	EQG A is not to be exceeded in a second consecutive year
				unless	*unless*
				Median *P. sinuosa* meadow shoot density measured at a site in the defined area during January and in any one of the two consecutive years is:	Median *P. sinuosa* meadow shoot density measured at a site in the defined area during January and in any one of the two consecutive years is:
				– greater than the baseline 5th percentile as specified in Table 1b	– greater than the baseline 1st percentile as specified in Table 1b
				and either	*and either*
				– greater than the 20th percentile of *P. sinuosa* meadow shoot density at an appropriate reference site	– greater than the 5th percentile of *P. sinuosa* meadow shoot density at an appropriate reference site
				or	*or*

Environmental Quality Guideline†		Environmental Quality Standard†	
High protection	Moderate protection	High protection	Moderate protection
Nutrients		Nutrients	
		– greater than the rolling 20th percentile of the Warnbro Sound reference site updated annually on <csmc.environment.wa.gov.au>	– greater than the rolling 5th percentile of the Warnbro Sound reference site updated annually on <csmc.environment.wa.gov.au>
		ii EQG A is not to be exceeded in any year *unless* Ambient values for *P. sinuosa* meadow shoot density in the same year is: – greater than the 5th percentile of *P. sinuosa* meadow shoot density at an appropriate reference site *or* – greater than the rolling 5th percentile of the Warnbro Sound reference site updated annually on <csmc.environment.wa.gov.au>	EQG A is not to be exceeded in any year *unless* Ambient values for *P. sinuosa* meadow shoot density in the same year is: – greater than the 1st percentile of *P. sinuosa* meadow shoot density at an appropriate reference site *or* – greater than the rolling 1st percentile of the Warnbro Sound reference site updated annually on <csmc.environment.wa.gov.au>
		iii EQG A is not to be exceeded in any year *unless* The lower depth limit of seagrass meadows does not show a statistically significant retreat relative to baseline distribution.	EQG A is not to be exceeded in any year *unless* The lower depth limit of seagrass meadows does not show a statistically significant retreat relative to baseline distribution.
		Seagrass (A. griffithii)	
		EQG A is not to be exceeded in a second consecutive year *unless* **iv** Median number of leaves per cluster measured at a site in the defined area during January and in any one of the two consecutive years is: – greater than the 20th percentile of number of leaves per cluster at an appropriate reference site *or, if no local reference site available,* – greater than the value for leaves per cluster specified in Table 1b *and* **v** Median number of clusters per stem measured at a site in the defined area during January and in any one of the two consecutive years is: – greater than the 20th percentile of the number of clusters per stem at an appropriate reference site	EQG A is not to be exceeded in a second consecutive year *unless* Median number of clusters per stem measured at a site in the defined area during January and in any one of the two consecutive years is: – greater than the 5th percentile of the number of clusters per stem at an appropriate reference site *or, if no local reference site available,* – greater than the value for clusters per stem specified in Table 1b

	Environmental Quality Guideline†		Environmental Quality Standard†	
	High protection	Moderate protection	High protection	Moderate protection
	Nutrients		Nutrients	
			or,if no local reference site is available, – greater than the value for clusters per stem specified in Table 1b	
B	***Algal Growth Potential***		***Algal Growth Potential***	
	To be developed.	To be developed	To be developed.	To be developed.
C	***Phytoplankton Biomass***		***Phytoplankton Biomass***	
i	Ambient value for phytoplankton biomass measured as chlorophyll a does not exceed the value for that indicator, as updated annually at <csmc.environment.wa.gov.au> on any occasion during the non river-flow period	Ambient value for phytoplankton biomass measured as chlorophyll a does not exceed the value for that indicator, as updated annually at <csmc.environment.wa.gov.au>, on more than one occasion during the non river-flow period	Ambient value for phytoplankton biomass measured as chlorophyll a does not exceed the value for that indicator, as updated annually at <csmc.environment.wa.gov.au>, on more than one occasion 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 updated annually at <csmc.environment.wa.gov.au>, on more than three occasions during the non river-flow period and in two consecutive years
ii	Phytoplankton biomass measured as chlorophyll a at any site does not exceed the value for that indicator, as updated annually at <csmc.environment.wa.gov.au>, on 25% or more occasions during the non river-flow period	Phytoplankton biomass measured as chlorophyll a at any site does not exceed the value for that indicator, as updated annually at <csmc.environment.wa.gov.au>, on 50% or more occasions during the non river-flow period	Phytoplankton biomass measured as chlorophyll a at any site does not exceed the value for that indicator, as updated annually at <csmc.environment.wa.gov.au>, on 25% or more occasions during the non river-flow period and in two consecutive years	Phytoplankton biomass measured as chlorophyll a at any site does not exceed the value for that indicator, as updated annually at <csmc.environment.wa.gov.au>, on 50% or more occasions during the non river-flow period and in two consecutive years
	Other Physical and Chemical Stressors		**Other Physical and Chemical Stressors**	
D	***Dissolved Oxygen Concentration***		***Dissolved Oxygen Concentration***	
	The median dissolved oxygen concentration in bottom waters at a site, calculated over a period of no more than one week, is greater than the value for that indicator as specified in Table 1b.	The median dissolved oxygen concentration in bottom waters at a site, calculated over a period of no more than one week, is greater than the value for that indicator as specified in Table 1b.	i The median dissolved oxygen concentration in bottom waters at a site, calculated over a period of no more than one week, is greater than the value for that indicator as specified in Table 1b.	The median dissolved oxygen concentration in bottom waters at a site, calculated over a period of no more than one week, is greater than the value for that indicator as specified in Table 1b.
			ii No significant change beyond natural variation in any ecological or biological indicators that are affected by poorly oxygenated water unless that change can be demonstrably linked to a factor other than oxygen concentration.	No persistent (i.e. ≥ 4 weeks) and significant change beyond natural variation in any ecological or biological indicators that are affected by poorly oxygenated water unless that change can be demonstrably linked to a factor other than oxygen concentration.
			iii No deaths of marine organisms resulting from deoxygenation.	No deaths of marine organisms resulting from deoxygenation.

	Environmental Quality Guideline†			Environmental Quality Standard†	
	High protection	Moderate protection		High protection	Moderate protection
E	***Water Temperature*** †		**E**	***Water Temperature*** †	
	Other Physical and Chemical Stressors			**Other Physical and Chemical Stressors**	
	Median temperature at an individual site over any season, measured according to SOP, not to exceed the 80th percentile of the natural temperature range measured at a suitable reference site for the same season†.	Median temperature at an individual site over any season, measured according to SOP, not to exceed the 95th percentile of the natural temperature range measured at a suitable reference site for the same season†.	**i**	No significant change beyond natural variation in any ecological or biological indicators that are affected by water temperature unless that change can be demonstrably linked to a factor other than water temperature.	No persistent (i.e. ≥ 4 weeks) and significant change beyond natural variation in any ecological or biological indicators that are affected by water temperature unless that change can be demonstrably linked to a factor other than water temperature.
			ii	No deaths of marine organisms resulting from anthropogenically-sourced thermal stress.	No deaths of marine organisms resulting from anthropogenically-sourced thermal stress.
F	***Salinity*** †		**F**	***Salinity*** †	
	Median salinity at an individual site over any period, measured according to SOP, not to deviate beyond the 20th and 80th percentiles of the natural salinity range measured at a suitable reference site for the same period†.	Median salinity at an individual site over any period, measured according to SOP, not to deviate beyond the 5th and 95th percentiles of the natural salinity range measured at a suitable reference site for the same period†.	**i**	No significant change beyond natural variation in any ecological or biological indicators that are affected by changing salinity unless that change can be demonstrably linked to a factor other than salinity stress.	No persistent (i.e. = 4 weeks) and significant change beyond natural variation in any ecological or biological indicators that are affected by changing salinity unless that change can be demonstrably linked to a factor other than salinity stress.
			ii	No deaths of marine organisms resulting from anthropogenically-sourced salinity stress.	No deaths of marine organisms resulting from anthropogenically-sourced salinity stress.
G	***pH***		**G**	***pH***	
	Median pH at an individual site over any period, measured according to SOP, not to deviate beyond:	Median pH at an individual site over any period, measured according to SOP, not to deviate beyond:	**i**	No significant change beyond natural variation in any ecological or biological indicators that are affected by changes in pH unless that change can be demonstrably linked to a factor other than altered pH.	No persistent (i.e. =4 weeks) and significant change beyond natural variation in any ecological or biological indicators that are affected by changes in pH unless that change can be demonstrably linked to a factor other than altered pH.
	– the 20th and 80th percentile of the natural pH range measured at a suitable reference site for the same period	– the 5th and 95th percentile of the natural pH range measured at a suitable reference site for the same period			
	or	or	**ii**	No deaths of marine organisms resulting from anthropogenic-sourced changes in pH.	No deaths of marine organisms resulting from anthropogenic-sourced changes in pH.

Environmental Quality Guideline†		Environmental Quality Standard†	
High protection	Moderate protection	High protection	Moderate protection
– the median pH at a suitable reference site by more than the range specified in Table 1b for that indicator.	– the median pH at a suitable reference site by more than the range specified in		

† default trigger values are provided in the guidance notes for interim use when undertaking tasks such as modelling prior to reference site data being available.

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)

Key to Guidance Notes	Environmental Quality Indicators	Environmental Quality Guidelines		Environmental Quality Standards	
		High protection	Moderate protection#	High protection	Moderate protection#
	Nutrients				
A	*Nutrient enrichment*				
A1	Chlorophyll a (µg L^{-1})	For the updated annual value go to: <csmc.environment.wa.gov.au> or contact CSMC on: (08) 9591 3837			
A2	Light Attenuation Coefficient (m^{-1})	For the updated annual value go to: <csmc.environment.wa.gov.au> or contact CSMC on: (08) 9591 3837			
	P. sinuosa				
A3	Current reference site seagrass shoot density			Rolling percentiles	
	1.5–2.0 m depth			For the updated annual values for the established depths go to: <csmc.environment.wa.gov.au> or contact CSMC on: (08) 9591 3837	
	2.0–3.0 m depth				
	3.0–4.0 m depth				
	5.0–6.0 m depth				
	6.0–7.0 m depth				
	Other depths*				
A4	Absolute minimum seagrass shoot density			(baseline 5th percentile)	(baseline 1st percentile)
	1.5–2.0 m depth			666	412
	2.0–3.0 m depth			500	275
	3.0–4.0 m depth			171	100
	5.0–6.0 m depth			419	324
	6.0–7.0 m depth			59	25
	A. griffithii				
A5	Number of leaves per cluster			2	nc
A6	Number of clusters per stem			3	1
B	Algal Growth Potential				
	To be developed				
C	Phytoplankton Biomass				

	Chlorophyll a (µg L^{-1})	For the updated annual value go to: <csmc.environment.wa.gov.au> or contact CSMC on: (08) 9591 3837		For the updated annual value go to: <csmc.environment.wa.gov.au> or contact CSMC on: (08) 9591 3837	
	Other physical and chemical stressors				
D	Dissolved Oxygen	90% saturation	80% saturation	60% saturation	60% saturation
G	pH	± 0.2	± 0.2		

Footnotes:

* Where site depths other than 1.5–4 m or 5–7 m are monitored, the criteria should be based, in order of preference, on values derived from suitable reference sites established at the appropriate depth, the default *P. sinuosa* shoot densities provided in Table 1b above for the next shallowest depth or modelling scenarios. 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 Section 3.1.2. Reference sites need to be established in areas that are relatively unaffected by anthropogenic influences and with sufficient quadrats to account for natural variability.

\# When assessing environmental quality in moderate ecological protection areas the performance of harbours and marinas should be assessed individually and not as part of the overall moderate protection area. Similarly, Careening Bay should also be assessed separately from the eastern side of Cockburn Sound.

nc No criteria

Guidance notes

A_1 Measured spectrophotometrically. Sites should be sampled weekly. Refer to SOP for detailed sampling and analytical requirements. The EQG have been derived from reference sites located in Warnbro Sound using the recommended approaches of ANZECC & ARMCANZ (2000). As described in section 3.1.2, the numerical values will be updated each year to incorporate the latest reference site data and these will replace the respective criteria from the previous year. Updated numerical values will be published annually on the CSMC website <csmc.environment.wa.gov.au>.

A_2 Light measurements should only be made within the period from 2 hours after sunrise to 2 hours before sunset. Preferably measured using data loggers according to SOP; expressed on $\log_{10}$ basis. The EQG have been derived from reference sites located in Warnbro Sound using the recommended approaches of ANZECC & ARMCANZ (2000). The numerical values will be updated each year to incorporate the latest reference site data and these will replace the respective criteria from the previous year. Updated numerical values will be published annually on the CSMC website (csmc.environment.wa.gov.au).

A_3 Measured non-destructively, re-locatable sampling points preferred. The numerical values for seagrass shoot density apply to the seagrass species *Posidonia sinuosa*. The reference site approach may be used on any meadow forming species of the genus *Posidonia*. The EQS are derived from reference sites located in Warnbro Sound using the recommended approaches outlined in Section 3.1.2 and consistent with ANZECC & ARMCANZ (2000). The EQS for *P. sinuosa* shoot density are updated and published annually on the CSMC website (csmc.environment.wa.gov.au). The numerical EQS in Table 1b represent the absolute minimum shoot density for each depth range.

A_4 Absolute minima seagrass shoot densities represent a baseline condition at the Warnbro Sound reference sites during the first four years of monitoring prior to 2005.

A_5 The number of leaves per cluster specified in Table 1b are derived from the 20th percentile (HEPA) calculated from data collected in *A. griffithii* meadows at Jurien Bay and may be used as default EQS until more appropriate site-specific EQS can be derived from local reference site data.

A_6 The number of clusters per stem specified in Table 1b are derived from the 20th (HEPA) and 5th (MEPA) percentiles calculated from data collected in *A. griffithii* meadows at Jurien Bay and may be used as default EQS until more appropriate site-specific EQS can be derived from local reference site data.

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

C 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. Note that there are two components to this EQG and EQS: site scale assessment; and broader regional scale assessment. Samples to be measured spectrophotometrically. Data should be omitted if *Oscillatoria erythraea* is abundant (ie >10% composition) or visible as surface slicks. The numerical values will be updated each year to incorporate the latest reference site data and these will replace the respective criteria from the previous year. Updated numerical values will be published annually on the CSMC website (csmc.environment.wa.gov.au).

D Dissolved oxygen measured in daylight hours. 'Bottom waters' means waters within 50 cm from the sediment surface. Significant is defined by key stakeholders; persistent is ≥4 weeks. The EQG and EQS for dissolved oxygen 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.

E This indicator has been developed for use at the local scale (e.g. around an outfall) rather than broader scales. Temperature is measured either at 50 centimetres below the water surface or 50 centimetres above the sediment surface, depending on plume density, and the seasonal median is compared with the EQG (or the default trigger values discussed below). 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. To assess the significance of changes in temperature for tasks undertaken prior to the availability of suitable reference site data (e.g. early modelling projects) a set of default trigger values are provided for interim use. These are not EQG, but are calculated using the ΔT values which have been derived from reference sites in Cockburn Sound according to the recommended approach in ANZECC & ARMCANZ (2000) (i.e. 80th percentiles of reference distribution for high ecological protection and 95th percentiles for moderate ecological protection). The default trigger value is the seasonal median of suitable reference site data plus the ΔT provided in the table below.

	High protection ΔT (°C)	**Moderate protection ΔT** (°C)
Summer	+1.5	+1.9
Autumn	+2.6	+4.0
Winter	+1.6	+3.6
Spring	+2.7	+3.7

F This indicator has been developed for use at the local scale (e.g. around an outfall) rather than broader scales. 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 is compared with the EQG (or the default trigger values discussed below). Measurements are taken at both the potential impact site and a suitable reference site. 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. To assess the significance of changes in salinity for tasks undertaken prior to the availability of suitable reference site data (e.g. early modelling projects) a set of default trigger values are provided for interim use. These are not EQG, but are calculated using the ΔS values which have been derived from reference sites in Cockburn Sound according to the recommended approach in ANZECC & ARMCANZ (2000) (i.e. 20th and/or 80th percentiles of reference distribution for high ecological protection and 5th and/or 95th percentiles for moderate ecological protection). The default trigger value is the median of suitable reference site data ± the ΔS provided in the table below.

	High protection	Moderate protection
*Salinity (*ΔS)	± 1.3	± 1.4

G This indicator has been developed for use at the local scale (e.g. around an outfall) rather than broader scales. 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. The EQG for pH have been derived from the default guideline trigger values provided in ANZECC & ARMCANZ (2000).

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 steps 2 - 6.

2. Determine whether nutrient-related EQG (A, B and C) have been exceeded

   [N]…… – go to step 3.

   [Y] (EQG A or B). – go to step 7 unless back-up samples or immediate re-sampling does not confirm exceedance of the EQG.

   [Y] (EQG C)……. – go to step 9 unless back-up samples or immediate re-sampling does not confirm exceedance of the EQG.

3. Determine whether dissolved oxygen-related EQG (D) 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 (E) has been exceeded

   [N] …… – go to step 5.

   [Y] …… – go to step 11 unless immediate re-measurement does not confirmexceedance of the EQG.

5. Determine whether salinity-related EQG (F) 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 (G) 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 and/or B) and EQS (A and/or B)

   – go to step 8.

8. Determine whether EQS (A or B) has been exceeded

   [N] …… – go to step 1.

   [Y] …… - **EQS triggered** go to step 14.

9. Determine whether EQS (C) has been exceeded

   [N] …… – go to step 1.

   [Y] …… – **EQS triggered** go to step 14.

10. Determine whether EQS (D) has been exceeded

    [N] …… – go to step 1.

    [Y] …… – **EQS triggered** go to step 14.

11. Determine whether EQS (E) has been exceeded

    [N] …… – go to step 1.

    [Y] …… – **EQS triggered** go to step 14.

12. Determine whether EQS (F) has been exceeded

    [N] …… – go to step 1.

    [Y] …… – **EQS triggered** go to step 14.

13. Determine whether EQS (G) has been exceeded

    [N] …… – go to step 1.

    [Y] …… – **EQS triggered** go to step 14.

The EQS is exceeded triggering a management response.

14. Initiate management response to identify the source of contamination and reduce contaminant loads and restore environmental quality to comply with the objectives within specified timeframes.

Simplified pictorial decision scheme for applying the EQC for physical and chemical stressors

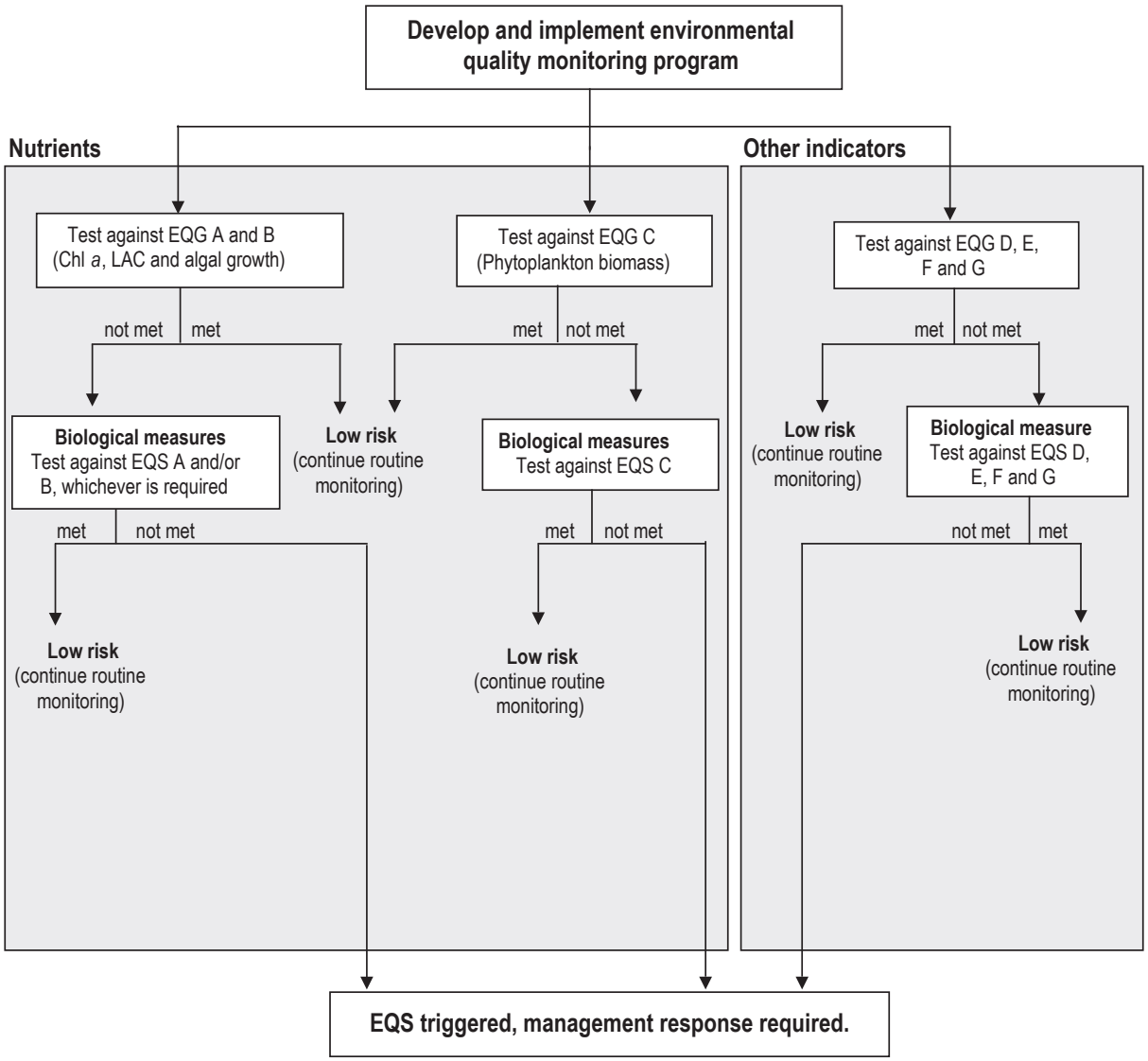


Table 2a Environmental quality criteria for protecting the marine ecosystem from the effects of toxicants in marine waters and sediment pore waters (*relevant footnotes and Guidance notes should also be read*)

Environmental Quality Guidelines*				Environmental Quality Standard*	
A. The 95th percentile of the sample concentrations from a single site or a defined area (either from one sampling run or all samples over an agreed period of time) should not exceed the environmental quality guideline value. **B.** Where there are mixtures of toxicants, TTM at a single site or for a defined area (either from one sampling run or all samples over an agreed period of time) should not exceed 1 using the total toxicity of mixtures formula[G].				**High protection** **Narrative** **Bioavailable measures** **A.** The 95th percentile 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 a single site or a defined area (either from one sampling run or all samples over an agreed period of time) and relevant 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 or sublethal chronic endpoints for any species, compared to the reference/control water. **D.** Using direct toxicity assessment (DTA) procedures on an effluent discharge: – the dilution of effluent at the boundary of a high protection zone should be protective of at least 99% of species calculated using the statistical distribution methodology on the results of DTA using sublethal chronic endpoints on 5 species (minimum 4 taxonomic groups);	**Moderate protection** **Narrative** **Bioavailable measures** **A.** The 95th percentile 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 a single site or a defined area (either from one sampling run or all samples over an agreed period of time) and relevant 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: – 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);

Chemical	High protection (µg/L)	Moderate protection (µg/L)	Low protection (µg/L)
Metals and Metaloids			
Cadmium [B]	0.7	14[C]	36[A]
Chromium III	7.7	49	
Chromium VI	4.4	20[C]	
Cobalt	1	14	
Copper	0.3	3[C]	
Lead	2.2	6.6[C]	
Mercury (inorganic) [B]	0.1	0.7[C]	1.4[C]
Nickel	7	200[A]	
Silver	0.8	1.8	
Tributyltin (as µg/L Sn)	0.0004[C]	0.02[C]	
Vanadium	50	160	
Zinc	7[C]	23[C]	
Non-Metallic Inorganics			
Ammonia [D, E]	500	1200	
Cyanide [F]	2	7	
Organics			
Benzene	500[C]	900[C]	
Naphthalene	50[C]	90[C]	
Pentachlorophenol[B]	11	33	55[A]

Environmental Quality Guidelines*				Environmental Quality Standard*	
Chemical	**High protection** (µg/L)	**Moderate protection** (µg/L)	**Low protection** (µg/L)	**High protection** **Narrative**	**Moderate protection** **Narrative**
Organo-chlorine Pesticides				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 No Observed Effect Concentration (NOEC) (i.e. the NOEC for the most sensitive species) divided by a safety factor of 10.	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 (i.e. the NOEC for the most sensitive species) divided by a safety factor of 2.
Endosulfan [B]	0.005	0.02	0.05 [A]		
Endrin [B]	0.004	0.01	0.02		
Organo-phosphorus Pesticides					
Chlorpyrifos [B]	0.0005	0.04 [A]	0.3 [A]		
Temephos [B]	0.0004	0.4	3.6 [A]		
Oil Spill Dispersants				**Direct biological/ecological measures**	**Direct biological/ecological measures**
Corexit 9527	230	2200		**E.** No significant[H] change in any biological or ecological indicator beyond natural variation that can be demonstrably linked to a contaminant.	**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;
Other Chemicals	#	#	#	**F.** Where TBT concentrations exceed the guideline the incidence of imposex in *Thais orbita* should be ≤ 5%.	**F.** Where TBT concentrations exceed the guideline the incidence of imposex in *Thais orbita* should be ≤ 10%.
				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 of species or types of ecosystem processes.

* EQG and EQS may be applied to a single site or to a 'defined area'. A 'defined area' is the area to be assessed and can be equivalent to an entire high level of ecological protection zone, but care should be taken to ensure that the area is not so large that the analysis becomes meaningless. For example, if an EQG is consistently exceeded in a small portion of a large defined area then consideration should be given to subdividing the area up into smaller 'defined areas' for assessment against the EQC.

\# 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 99% species protection trigger values for high ecological protection EQG; 90% trigger values for moderate ecological protection EQG; and 80% trigger values for low ecological protection EQG. Low ecological protection EQGs are only applied for chemicals identified as potential bioaccumulators or bioconcentrators.

A Trigger 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 compared against the EQG, 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.

H 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.

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 95th percentile of estimated bioavailable contaminant concentration in test samples from a single site or a defined area (either from one sampling run or all samples over an agreed period of time) should not exceed the trigger values below.	
Metals and Metaloids		
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]

Chemical	High protection (µg/L)	Moderate protection (µg/L)
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 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].

Table 2c Low Reliability Values[A]

(low reliability values should not be used as environmental quality guidelines – see section 3.1.2)

Chemical	High protection (µg/L)	Moderate protection (µg/L)	Low protection (µg/L)	Summary of available overseas guidelines[D] (µg/L)	Comments
Metals and Metaloids					
Aluminium	0.5				
Arsenic III	2.3			12	(total) South Africa
Arsenic V	4.5			12.5	(total) Canada
				36	(total dissolved) USA
Manganese	80				
Molybdenum	23				
Selenium IV[B]	3			71*	(total dissolved) USA
Selenium VI[B]	3				
Non-Metallic Inorganics					
Chlorine (total residual)	3			2	British Columbia
				7.5	USA
Hydrogen sulfide[C, #]	1			2	USA
Organics					
Toluene	110	230		215	Canada
Ethylbenzene	5			25	Canada
Nonylphenol	1			0.3	EU
				0.7	Canada
				1.7	USA
o-xylene[E]	350				
m-xylene[E]	75				
p-xylene[E]	200				
Total xylene					
Cumene	20	40			
Anthracene[B]	0.01	1.5	7	0.1	EU
Phenanthrene[B]	0.6	4	8		
Fluoranthene[B]	1	1.7	2	0.1	EU
Benzo(a)pyrene[B]	0.1	0.4	0.7	0.05	EU
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				

Chemical	High protection (µg/L)	Moderate protection (µg/L)	Low protection (µg/L)	Summary of available overseas guidelines[D] (µg/L)	Comments
2,4,6,2',4',6'-hexachlorobiphenyl	0.15			0.03	USA
Total PCBs				0.0001	British Columbia
Organochlorine Pesticides					
Aldrin [B]	0.003				
Chlordane [B]	0.0001			0.004	USA
DDE [B]	0.0005				
DDT [B]	0.0004			0.001	USA
Dieldrin [B]	0.01			0.0019	USA
Heptachlor [B]	0.0004			0.0036	USA
Organophosphorus Pesticides					
Fenitrothion	0.001				
Malathion	0.05			0.1	USA
Herbicides and Fungicides					
2,4-D	280				
2,4,5-T	36				
Metsulfuron	8				
Amitrole	22				
Atrazine	13			0.6	EU
Simazine	3.2			1	EU
Diuron	1.8				
Glyphosate	370				
Surfactants					
Linear alkylbenzene sulfonates (LAS)	0.1				
Alcohol ethoxylated sulfate (AES)	650				
Alchohol ethoxylated surfactants (AE)	140				
Oils & Petroleum Hydrocarbons					
Diesel	3				
Total petroleum hydrocarbons	7				
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 should be 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 marine waters off the Perth metropolitan region, including Cockburn Sound, have been found to be of a very high quality with background contaminant concentrations well below the ANZECC & ARMCANZ, (2000) guideline trigger values for 99% species protection(DoE, 2005). The 99% guideline trigger values have therefore 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 as described in Table 2a.

– 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 (i.e. 0.45µm teflon or glass fibre filter) in the first instance for comparison with the guidelines. If an unfiltered sample exceeds the guideline then step 1 of the EQS requires additional samples to be collected and filtered for comparison 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 (i.e. up to 5 dominant toxicants) and their toxicity is additive. The use of DTA is recommended for toxicant mixtures where greater than 5 toxicants may be dominant or where there are uncertain mixture effects.

– 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. 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 limit of reporting quoted by most analytical laboratories.

– 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 (e.g. 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 safe 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.

– 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.

– 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.

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 (i.e. 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 (e.g. 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 19.

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 8.

   [Y]…….. – if high or moderate ecological protection area go to step 7, or if EQG derived according to steps 2 or 7 go to step 9;

   – if EQG for TBT was exceeded go to step 15;

   – go to step 16 if the EQG was for a low ecological protection area.

7. 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 9.

   [Y]…….. – establish the 80th or 95th percentile of background concentration as the new EQG then go to step 6.

8. For the primary contaminants determine whether EQG (B) has been met:

   [N]…….. – go to step 12.

   [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

9. 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 10.

   [Y]…….. – go to step 10.

10. 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 11 (steps 13 or 14 also an option), or step 13 if PQL > EQG.

    [Y]…….. – go to step 11 (steps 13 or 14 also optional), or step 13 if PQL > EQG; and

    – go to step 16.

11. Resolve bioavailable concentrations of relevant contaminants and determine whether EQS (A) has been met:

    [N]…… – go to step 13 (steps 14 or 17 also an option).

    [Y]……... – go to step 12.

12. For the primary contaminants determine whether EQS (B) has been met:

    [N]…… – go to step 13 (steps 14 or 17 also an option).

    [Y]…….. – environmental quality acceptable, go to step 4.

13. Undertake direct toxicity assessment (DTA) using relevant species and determine whether EQS (C) and/or (D) have been met:

    [N]…….. – go to step 14 or step 17.

    [Y]…….. – environmental quality acceptable, modify EQG accordingly and go to step 4.

14. Undertake detailed field investigation to determine whether EQS (E) has been met for high ecological protection areas, and EQS (E) and (G) have been met for moderate ecological protection areas:

    [N]…….. – **EQS triggered.** Go to step 17.

    [Y]…….. – environmental quality acceptable, modify EQG accordingly and go to step 4.

15. If a guideline for TBT has been exceeded then undertake detailed field investigation to determine whether EQS (F) has been met:

    [N]…….. – **EQS triggered.** Go to step 17

    [Y]…….. – environmental quality acceptable, go to step 4.

16. If a guideline for TBT has been exceeded then undertake detailed field investigation to determine whether EQS (F) has been met:

    [N]…….. – **EQS triggered.** Go to step 17.

    [Y]…….. – environmental quality acceptable, go to step 4.

17. Determine whether EQS (G) for high protection has been met in adjacent high ecological protection areas:

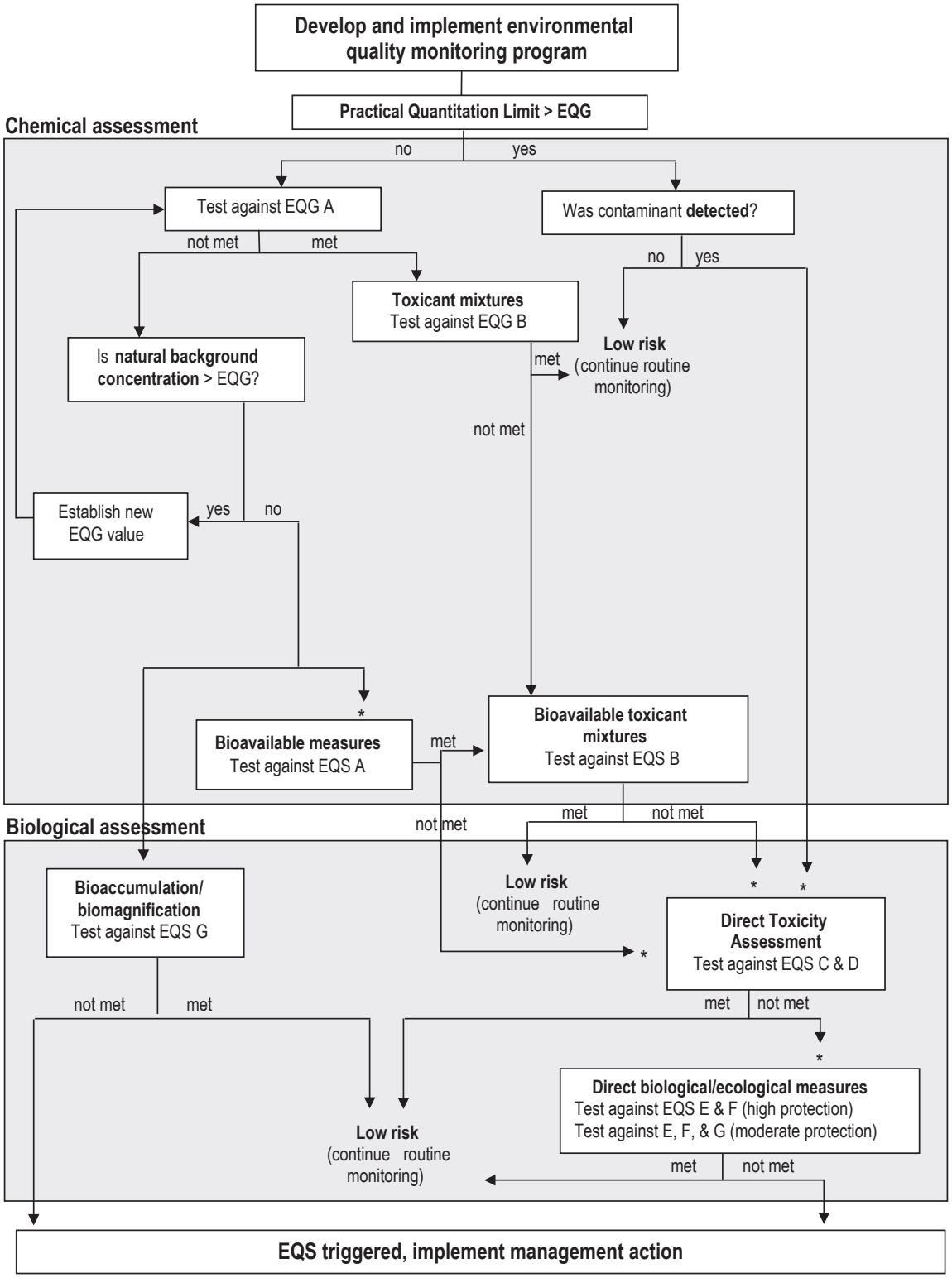
    [N]…….. – **EQS triggered.** Go to step 17.

    [Y]…….. – chemical not bioaccumulating, go to step 4.

18. 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. If EQC for the maintenance of safe seafood have been listed in Table 4 for the problem contaminant(s) then consideration should be given to monitoring the contaminant in seafood to assess risk to human health.

19. 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).

Simplified 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	
A. Median total contaminant concentration in sediments* from a single site or 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).			**High protection**	**Moderate protection**
Chemical	**Value** (high, moderate and low[A] protection)	**Re-sampling trigger**		
Metals and Metaloids[C] (mg/kg dry wt)			**Bioavailable measures** **A.** The 80th percentile of bioavailable metal or metalloid concentrations G (e.g. 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 organometallic or organic contaminants (e.g. OC normalisation or equilibrium partitioning)[G] from the defined sampling area should not exceed the EQG.	**Bioavailable measures** **A.** The median bioavailable metal or metalloid concentrations[G] (e.g. dilute acid extractable metals, SEM/AVS analysis[H]) from the defined sampling area should not exceed the EQG. or **B.** The 40th percentile of bioavailable concentrations for oganometallic or organic contaminants (e.g. OC normalisation or equilibrium partitioning)[G] from the defined sampling area should not exceed the EQG.
Antimony	2	25		
Arsenic	20	70		
Cadmium[B]	1.5	10		
Chromium	80	370		
Copper	65	270		
Lead	50	220		
Mercury [B]	0.15	1		
Nickel	21	52		
Silver	1	3.7		
Zinc	200	410		
Organometallics[K]				
Tributyltin (µg Sn/kg dry wt)[E]	5	70		
Organics (µg/kg dry wt)[D,K]				
Acenaphthene	16	500		
Acenaphthalene	44	640		
Anthracene[B]	85	1100		
Fluorene	19	540		
Naphthalene	160	2100		
Phenanthrene [B]	240	1500		
Low Molecular Weight PAHs[B, F]	552	3160		
Benzo(a) anthracene	261	1600		
			Porewater measure **C.** The 95th percentile 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 95th percentile 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).
			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.
			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 ≤ 5%.	**Direct biological/ecological measures** **E.** The median of the distribution of measurements for any indicators of organism abundance or biomass or rates of ecosystem processes should be within the 10th and 90th percentile of the natural range measured at suitable reference sites;

Environmental Quality Guideline			Environmental Quality Standard	
Chemical	**Value** (high, moderate and low[A] protection)	**Re-sampling trigger**	**High protection**	**Moderate protection**
Benzo(a)pyrene[B]	430	1600	**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.	**F.** Where TBT concentrations exceed the guideline the incidence of imposex in *Thais orbita* should be ≤ 10%; **G.** No loss of species or types of ecosystem processes.
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 (e.g. nitric acid/perchloric acid mixture) should be used and concentrations of organic contaminants should ideally be normalised to 1% organic carbon where appropriate (see footnote K below). In sediments where total contaminant concentrations are already documented an alternative approach could be to by-pass EQG A for routine monitoring programs and instead undertake the initial assessment of sediment quality against EQS A and/or B. If EQS A and/or B are met then sediment quality is acceptable, if not met, then further investigation against the subsequent EQS should be undertaken.

\# EQG and EQS may be applied to a single site or to a 'defined area'. A 'defined area' is the area to be assessed and could be a specific location or a general locality, but because sediment quality is heterogeneous care should be taken to ensure that the area is not so large that the analysis becomes meaningless (e.g. the entire high level of ecological protection zone),

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 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.

E Analysis of sediments for TBT should also include analysis and reporting of the concentrations of the break-down products DBT and MBT. This provides an additional line of evidence for the interpretation and assessment of TBT contamination.

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).*

K Total organic carbon should also be measured in sediment samples analysed for organometallic and organic contaminants. The concentrations of the organometallic/organic contaminants should be normalised to 1% organic carbon before assessing against EQS B and ideally before assessing against EQG A, but only if total organic carbon concentrations fall within the range of 0.5 to 10% TOC.

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.

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 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 safe for human consumption.)

– When undertaking sediment toxicity testing, 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.

– 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.

– 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.

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 (e.g. 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 an EQG based on 2 × the median natural background concentration 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 7.
5. Was the exceeded EQG established for a low ecological protection area?

   [N]…… – if EQG for TBT was exceeded go to step 14; and

   – for other EQG go to step 6 (optional); or

   – go to step 7 to define any ‘hot spots’; and

   – to step 9 to investigate against the EQS

   [Y]……. – go to step 15.
6. 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 7 to define any ‘hot spots’; and

   – to step 9 to investigate against the EQS.

   [Y]…….. – establish an EQG based on 2 × the median natural background concentration then go to step 4.
7. Assess whether EQG (B) has been met:

   [N]…….. – go to step 8.

   [Y]…….. – no toxicity problem, go to step 3.
8. 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
9. 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 10 (steps 11, 12 or 13 also an option).

   [Y]…… – go to step 10 (step 11, 12 or 13 also optional);

   and

   – go to step 15.
10. Resolve bioavailable concentrations (as far as possible) for relevant contaminants and determine whether EQS (A) and (B) have been met:

[N]…… – go to step 11 (steps 12, 13 or 16 also an option).

[Y]……... – environmental quality acceptable, go to step 3.

11. Sample and analyse sediment porewaters for those contaminants of concern that have an EQG for water (Table 2a of EQC Reference document) and determine whether EQS (C) has been met:

    [N]…… – go to step 12 (steps 13 or 16 also an option).

    [Y]…….. – environmental quality acceptable, go to step 3.

12. Undertake sediment toxicity testing using relevant species and determine whether EQS (D) has been met:

    [N]…….. – go to step 13 or step 16.

    [Y]…….. – environmental quality acceptable, modify EQG accordingly and go to step 3.

13. Undertake detailed field investigation to determine whether EQS (E) has been met for high ecological protection areas, or EQS (E) and (G) have been met for moderate ecological protection areas:

    [N]…….. – **EQS triggered.** Go to step 16.

    [Y]…….. – environmental quality acceptable, modify EQG accordingly and go to step 3.

14. If a guideline for TBT has been exceeded then undertake detailed field investigation to determine whether EQS (F) has been met:

    [N]…….. – **EQS triggered.** Go to step 16.

    [Y]…….. – environmental quality acceptable, go to step 3.

15. Determine whether EQS (G) for high protection has been met in adjacent high ecological protection areas:

    [N]…….. – **EQS triggered.** Go to step 17

    [Y]…….. – environmental quality acceptable, go to step 4.

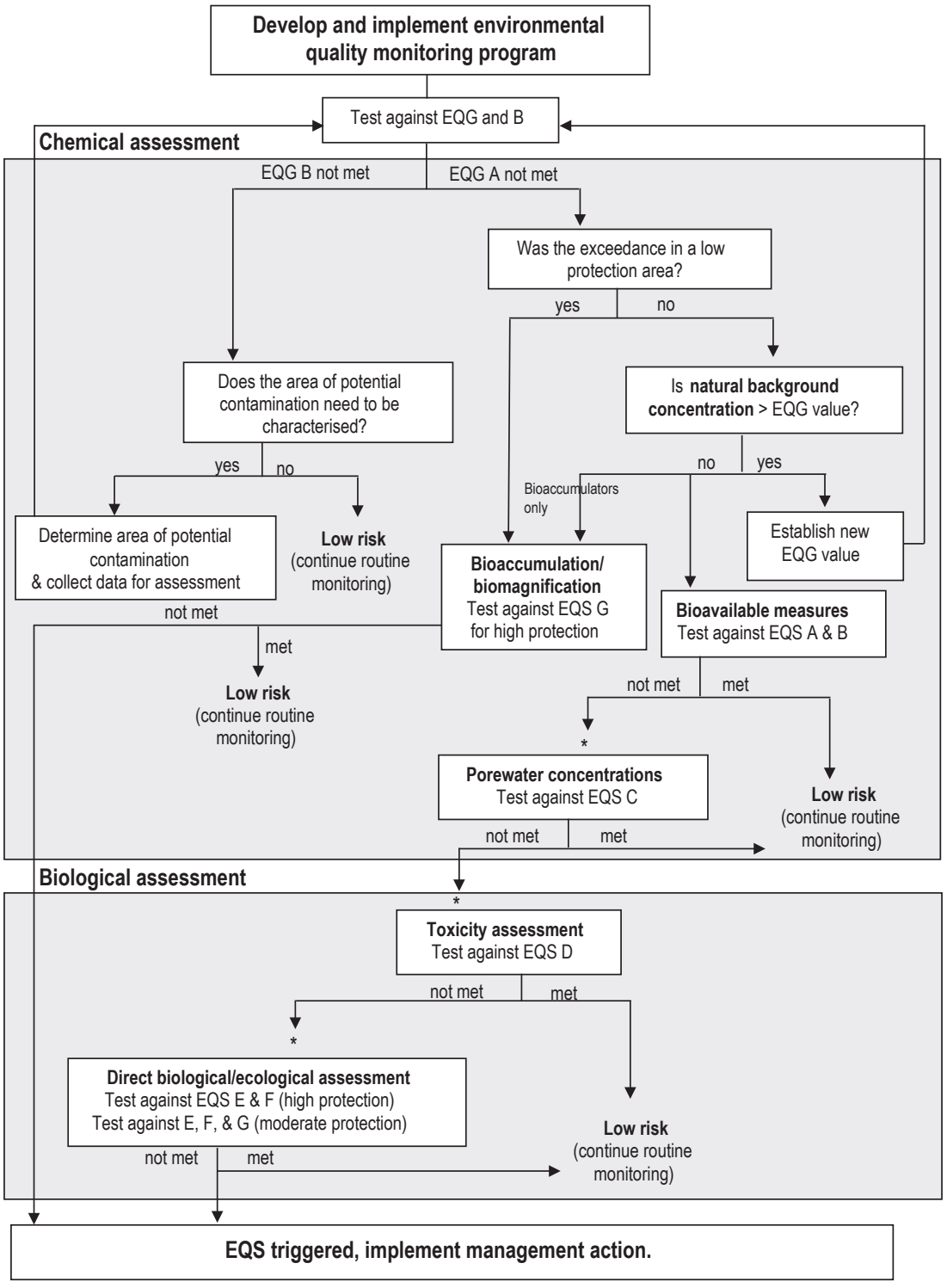
16. Determine whether EQS (G) for high protection has been met in adjacent high ecological protection areas:

    [N]…….. – **EQS triggered.** Go to step 16.

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

17. Implement management action to reduce contaminant inputs to the ambient environment and achieve the environmental quality objective within an agreed timeframe. Prior to implementing management action procedures such as TIE and CBR might be required to confirm the specific cause of toxicity or the source of contaminants. In extreme circumstances environmental remediation may be considered appropriate. If EQC for the maintenance of safe seafood have been listed in Table 4 for the problem contaminant(s) then consideration should be given to monitoring the contaminant in seafood to assess risk to human health.

Simplified 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		
Faecal pathogens in water‡	**A.** The median or geometric mean faecal coliform concentration in samples from a single site must not exceed 14 CFU/100 mL and the estimated 90th percentile must not exceed 21 CFU/100 mL measured using the membrane filtration method. or The median or geometric mean faecal coliform concentration in samples from a single site must not exceed 14 MPN/100 mL and the estimated 90th percentile must not exceed 43 MPN/100 mL measured using a 5 tube decimal dilution test, or 49 MPN/100 mL measured using a 3 tube decimal dilution test. or The median or geometric mean total coliform concentration in samples from a single site must not exceed 70 MPN/100 mL and the estimated 90th percentile must not exceed 230 MPN/100 mL measured using a 5 tube decimal dilution test, or 330 MPN/100 mL measured using a 3 tube decimal dilution test.	**A.** The median or geometric mean faecal coliform concentration in samples from a single site must not exceed 70 CFU/100 mL and the estimated 90th percentile must not exceed 85 CFU/100 mL measured using the membrane filtration method. or The median or geometric mean faecal coliform concentration in samples from a single site must not exceed 88 MPN/100 mL and the estimated 90th percentile must not exceed 260 MPN/100 mL measured using a 5 tube decimal dilution test, or 300 MPN/100 mL measured using a 3 tube decimal dilution test. or The median or geometric mean total coliform concentration in samples from a single site must not exceed 700 MPN/100 mL and the estimated 90th percentile must not exceed 2300 MPN/100 mL measured using a 5 tube decimal dilution test, or 3300 MPN/100 mL measured using a 3 tube decimal dilution test.
Escherichia coli (E. coli) 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 two or more representative samples out of five, and no single sample should exceed 7 MPN *E. coli*/g.
Algal biotoxins ‡	**B.** Concentrations of toxic algae should not exceed the following environmental quality guideline values in any samples. Alexandrium *(A. acatenella, A. catenella, A. cohorticula, A. fundyense, A. lusitanucum, A. minitum, A. ostenfeldii, A. tamiyavanachi, A. tamarense)* 100 cells/L Dinophysis *(D. acuta, D. fortii, D. norvegica)* 500 cells/L *(Dinophysis acuminata)* 3000 cells/L	**C.** Toxin concentration in seafood should not exceed the following environmental quality standards in any samples. Paralytic shellfish poison (PSP) 0.8 mg Saxitoxin eq./kg Diarrhoetic shellfish poison (DSP) 0.2 mg/kg DSP 0.2 mg/kg

Indicator	Environmental quality guideline (units as stated)		Environmental quality standard (EQS) (units as stated)	
	Prorocentrum *(P. lima)*	500 cells/L	DSP	0.2 mg/kg
	Gymnodinium *Gymnodinium catenatum*	1 000 cells/L	PSP	0.8 mg Saxitoxin eq./kg
	Karenia *K. brevis, K. brevis-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)*	250 000 cells/L	Amnesic shellfish poison (ASP) (domoic acid)	20 mg/kg
	Gonyaulax cf. *Spinifera*	100 cells/L	Yessotoxins	1 mg Yessotoxin eq./kg
	Protoceratium reticulatum (Gonyaulax grindley)	500 cells/L	Yessotoxins	1 mg Yessotoxin eq./kg
Chemicals				
	C. Median chemical concentration in the flesh of seafood should not exceed the environmental quality guideline (see values below).		**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 Australia 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 Food Standards of Australia and New Zealand.	
Metals (mg/kg)				
Arsenic (inorganic)			Crustacea and Fish Molluscs and Seaweed	2.0 1.0
Cadmium			Molluscs	2.0
Copper	Crustacea Fish Molluscs	20 2.0 30		
Lead			Fish Molluscs	0.5 2.0

Indicator	Environmental quality guideline (units as stated)		Environmental quality standard (EQS) (units as stated)	
Mercury			Billfish (including Marlin), Southern bluefin tuna, Barramundi, Ling, Orange Roughy, 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.

‡ EQC for faecal pathogens in water and for algal biotoxins are based on protecting human consumers of most filter feeding shellfish (except scallops and pearl oysters where only the adductor muscle is eaten). Managing water quality to a level that ensures shellfish are suitable for human consumption is expected to ensure that other seafoods will also be suitable for human consumption.

Guidance notes

Environmental quality guidelines

– Two methods for the measurement of faecal coliforms have been accepted by the Australian Shellfish Quality Assurance Advisory Committee, the Membrane Filtration method (AS 4276.7) and the multiple tube decimal dilution method (AS 4276.6). 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 FSANZ and are based on the 90th percentile of contaminant levels that would typically be expected in the flesh of food species (FSANZ, 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 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 (e.g. depuration, prediction of high risk periods).

– EQS A is from the WASQAP (2011) and is not an enforceable standard, however EQS B is a Food Standard (FSANZ, 2013) and is enforceable.

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

1. Conduct approved monitoring program (based on WASQAP 2011 if for filter feeding shellfish) covering the area to be assessed and the contaminants of concern using the recommended 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.

Simplified pictorial decision scheme for applying the EQC for seafood safe for human consumption

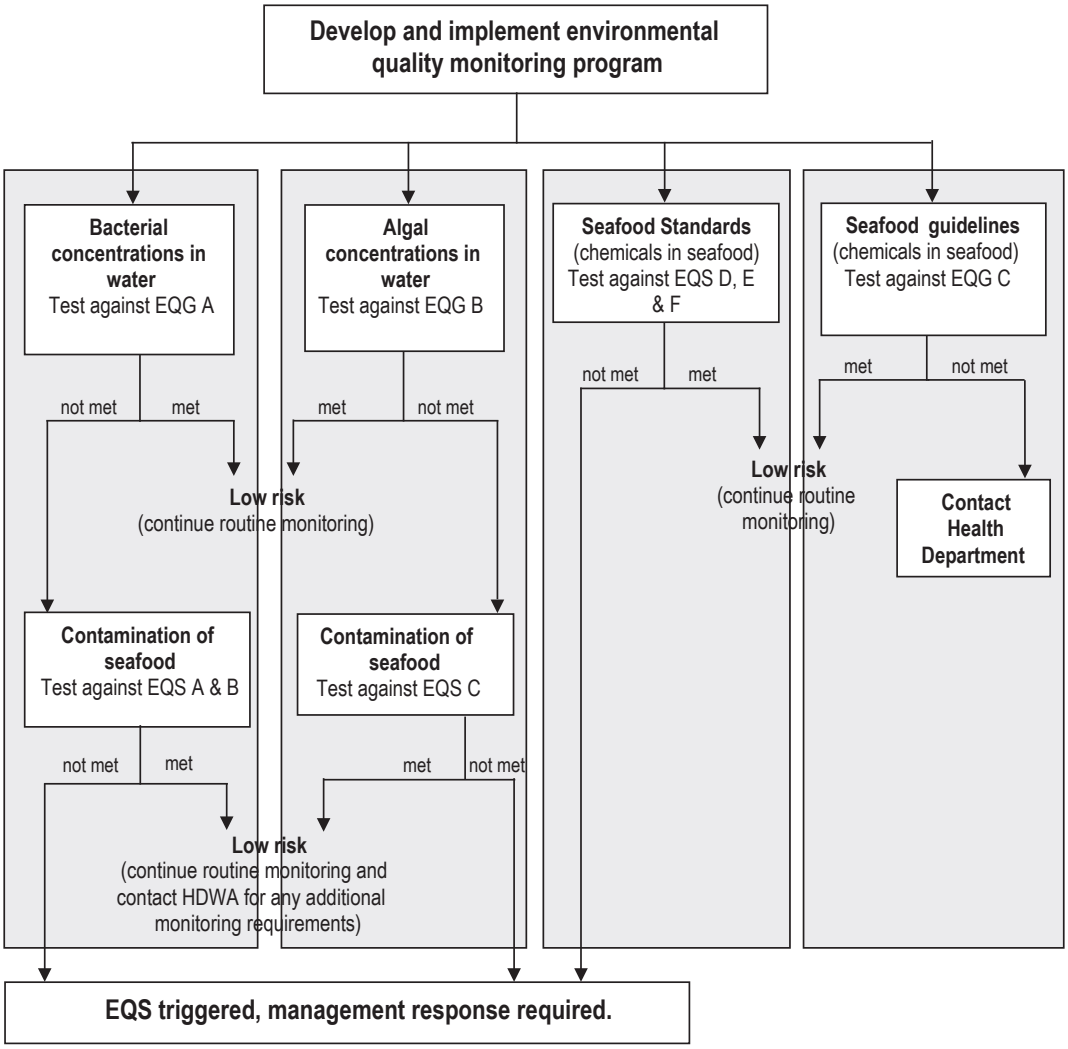


Table 5 Environmental quality criteria for the maintenance of aquaculture production (*relevant footnotes and Guidance notes should also be read*)

Indicator	Environmental quality guideline	Environmental quality standard (EQS)
Physico-chemical stressors	A. The median of the sample concentrations from the defined sampling area (either from one sampling run or all samples 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[#]
Dissolved oxygen	≥ 5 mg/L	**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.
pH	6–9	
Toxicants	**B.** The 95th percentile of the sample concentrations from the defined sampling area (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[#].
Non metallic inorganic chemicals (µg /L)		if not, then
Ammonia (total as N)	1000	**D.** Where appropriate, bioavailable contaminant concentration should meet the relevant guideline (environmental quality guideline or species group guideline) in ≥ 95% of samples.
Chlorine (as total residual)	3	if not, then
Cyanide	5	**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.
Hydrogen sulfide	2	or
Nitrite-N	100	**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.
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	

Indicator	Environmental quality guideline	Environmental quality standard (EQS)
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).

* Total Al and Total Fe can be found naturally at relatively high levels due to terrestrial inputs. The relatively stringent aquaculture EQG for these two metals should not be applied in mixing zones unless approved aquaculture is being undertaken in that zone.

Guidance notes

Environmental quality guidelines

– These EQC relate to maintaining production at an aquaculture facility and as a consequence they may be applied just to the area around the facility, or to Cockburn Sound more broadly, depending on the objectives of the monitoring program.

– If a new environmental quality guideline is established by determining the 80th percentile of natural background concentration (as discussed in Section 2.5) then the median of the test samples, rather than the 95th percentile, should be compared against the newly established EQG.

– It is preferable, but not necessary, that samples for toxicant analyses are filtered (i.e. 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 further 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 own production water if not managed adequately. 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 (e.g. 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 80th or 95th percentile of natural background contaminant concentration, for physico-chemical stressors and toxicants respectively, 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. Determine whether the 80th or 95th percentile of natural background contaminant concentration, for physico-chemical stressors and toxicants respectively, 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.
6. 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

7. 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.

8. Determine whether EQS (B) has been met:

   [N]…….. – **EQS triggered**, go to step 11.

   [Y]…….. – EQS not triggered, go to step 1.

9. 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

10. Determine whether EQS (D) has been met:

    [N]…… – go to step 10 (step 11 also optional).

    [Y]…….. – EQS not triggered, go to step 1.

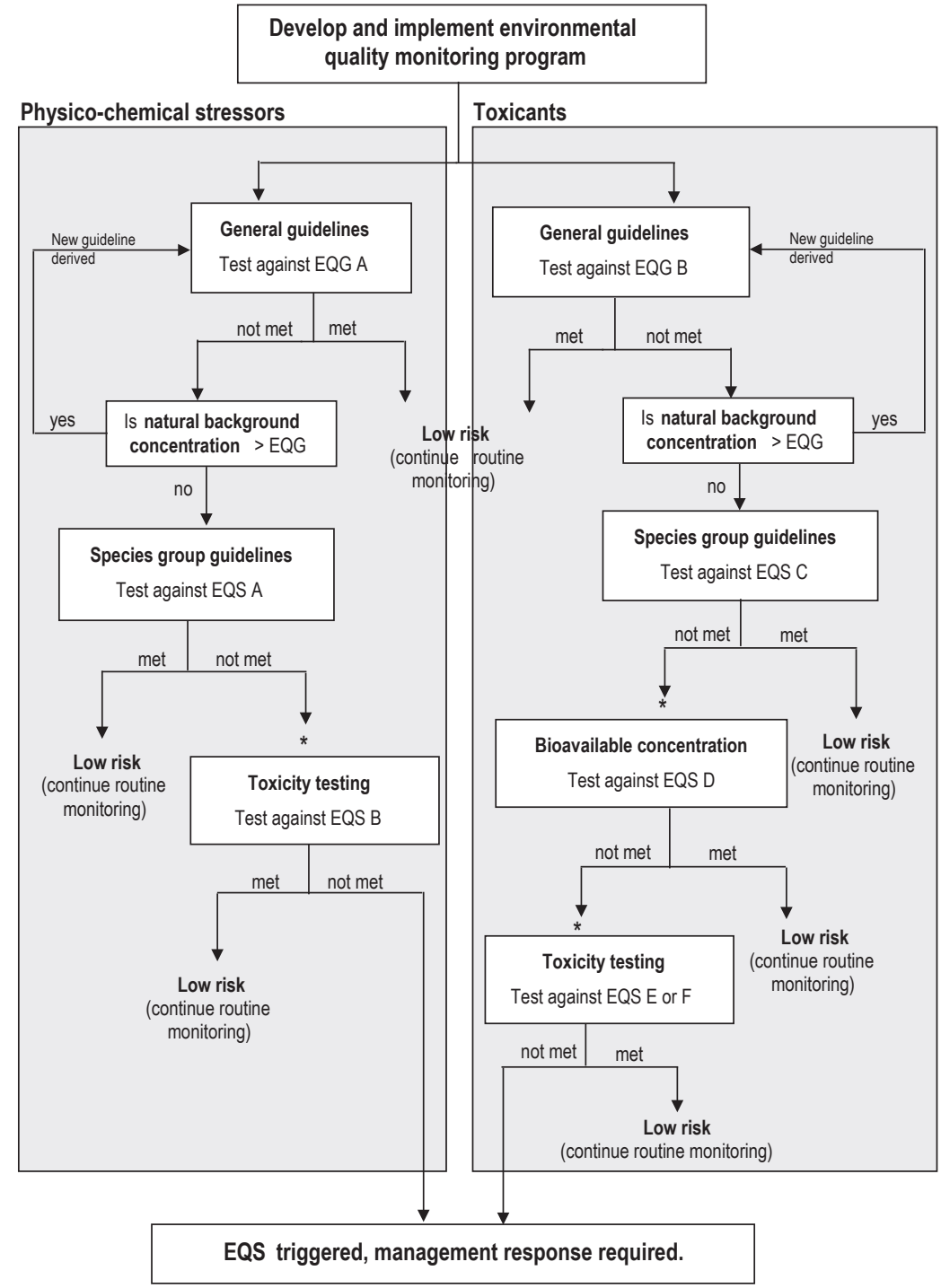
11. Determine whether EQS (E or F) have been met:

    [N]…… – **EQS triggered**, go to step 11.

    [Y]…….. – EQS not triggered, go to step 1.

12. 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.

Simplified 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 95th percentile bacterial content of marine waters should not exceed 200 enterococci/100 mL.	**A.** The 95th percentile bacterial content of marine waters should not exceed 500 enterococci/100 mL.
Toxic algae	**B.** The phytoplankton cell count* from a single site, should not: – exceed 10,000 cells/mL; or – detect DOHWA watch list species or exceed their trigger levels.[#]	**B.** The phytoplankton cell count* from a single site should not: – exceed 50,000 cells/mL; or – detect or exceed DOHWA Watch List action levels.
	C. There should be no reports of skin, eye or respiratory irritation or potential algal poisoning of recreational users considered by a medical practitioner as potentially resulting from toxic algae when less than 10,000 cells/mL is present in the water column.	**C.** There should be no visual presence of algal scums[+] or relatively widespread visible presence of *Lyngbya majuscula* filaments (NHMRC 2008). **D.** There should be no confirmed incidences by report from a medical practitioner, of skin, eye or respiratory irritation, caused by toxic algae or of algal poisoning of recreational users.
Physical		
pH		**E.** 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	**D.** 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		**F.** Radionuclide measurements should be at levels that are satisfactory to the Radiological Council.
Toxic chemicals		
	E. The 95th percentile 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.	**G.** 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	30	
Arsenic	70	
Barium	7 000	
Boron	40 000	

Indicator	Environmental quality guideline µg/L (unless otherwise stated)	Environmental quality standard (EQS) µg/L (unless otherwise stated)
Bromate	200	
Cadmium	20	
Chlorite	3 000	
Chromium	500	
Copper	20 000	
Cyanide	800	
Fluoride	15 000	
Iodide	1000	
Lead	100	
Manganese	5 000	
Mercury	10	
Molybdenum	500	
Monochloramine	30 000	
Nickel	200	
Nitrate (as nitrate)	500 000	
Nitrite (as nitrite)	30 000	
Selenium	100	
Sulfate	5 000 000	
Organic Chemicals		
Acrylamide	2	
Benzene	10	
Benzo(a)pyrene	0.1	
Carbon tetrachloride	30	
Chloroacetic acid	1 500	
Chlorobenzene	3 000	
1,2-Dichlorobenzene	15 000	
1,4-Dichlorobenzene	400	
Cyanogen chloride (as cyanide)	800	
Dichloroacetic acid	1 000	
Trichloroacetic acid	1 000	
1,1-Dichloroethene	300	
1,2-Dichloroethene	600	
1,2-Dichloroethane	30	
Dichloromethane	40	
Epichlorohydrin	5	
Ethylbenzene	3 000	
Ethylenediamine tetraacetic acid (EDTA)	2 500	
Hexachlorobutadiene	7	

Indicator	Environmental quality guideline µg/L (unless otherwise stated)	Environmental quality standard (EQS) µg/L (unless otherwise stated)
Nitrilotriacetic acid	2 000	
Tetrachloroethene	500	
Trichloroacetaldehyde (chloral hydrate)	200	
2-Chlorophenol	3 000	
2,4-Dichlorophenol	2 000	
2,4,6-Trichlorophenol	200	
Tributyltin oxide	10	
Styrene (vinylbenzene)	300	
Toluene	8 000	
Trichlorobenzenes (total)	300	
Vinyl chloride	3	
Xylene	6 000	
Pesticides		
Acephate	100	
Aldicarb	10	
Aldrin (and Dieldrin)	3	
Ametryn	500	
Amitrole	100	
Atrazine	400	
Azinphos-methyl	30	
Benomyl	1 000	
Bentazone	300	
Bioresmethrin	1 000	
Bromazil	3 000	
Bromophos-ethyl	100	
Bromoxynil	300	
Carbaryl	300	
Carbendazim	1 000	
Carbofuran	100	
Carbophenothion	5	
Carboxin	3 000	
Chlordane	10	
Chlorphenvinphos	50	
Chlorothalonil	300	
Chloroxuron	100	
Chlorfenvinphos	50	
Chlorsulfuron	1 000	
Clopyralid	10 000	

Indicator	Environmental quality guideline µg/L (unless otherwise stated)	Environmental quality standard (EQS) µg/L (unless otherwise stated)
2,4-D	300	
DDT	200	
Diazinon	30	
Dicamba	1 000	
Dichlobenil	100	
Dichlorvos	10	
Diclofop-methyl	50	
Dicofol	30	
Dieldrin (see Aldrin)	3	
Difenzoquat	1 000	
Dimethoate	500	
Diphenamid	3 000	
Diquat	50	
Disulfoton	30	
Diuron	300	
DPA (2,2-DPA)	5 000	
EDB	10	
Endosulfan	300	
Endothal	1 000	
EPTC	300	
Ethion	30	
Ethoprophos	10	
Etridiazole	1 000	
Fenamiphos	3	
Fenarimol	300	
Fenchlorphos	300	
Fenitrothion	100	
Fenoprop	100	
Fensulphothion	100	
Fenvalerate	500	
Flamprop-methyl	30	
Fluometuron	500	
Formothion	500	
Fosamine	300	
Glyphosate	10 000	
Heptachlor (including its epoxide)	3	
Hexaflurate	300	
Hexazinone	3000	

Indicator	Environmental quality guideline µg/L (unless otherwise stated)	Environmental quality standard (EQS) µg/L (unless otherwise stated)
Lindane	200	
Maldison	500	
Methidathion	300	
Methiocarb	50	
Methomyl	300	
Methoxychlor	3 000	
Metolachlor	3 000	
Metribuzin	500	
Metsulfuron-methyl	300	
Mevinphos	50	
Molinate	50	
Monocrotophos	10	
Napropamide	10 000	
Nitralin	5 000	
Norflurazon	500	
Oryzalin	3 000	
Oxamyl	1 000	
Paraquat	300	
Parathion	100	
Parathion-methyl	1 000	
Pebulate	300	
Pendimethalin	3 000	
Pentachlorophenol	100	
Permethrin	1 000	
Picloram	3 000	
Piperonyl butoxide	1 000	
Pirimicarb	50	
Pirimiphos-ethyl	5	
Pirimiphos-methyl	500	
Profenofos	3	
Promecarb	300	
Propachlor	500	
Propanil	5 000	
Propargite	500	
Propazine	500	
Propiconazole	1 000	
Propyzamide	3 000	
Pyrazophos	300	

Indicator	Environmental quality guideline µg/L (unless otherwise stated)	Environmental quality standard (EQS) µg/L (unless otherwise stated)
Quintozene	300	
Simazine	200	
Sulprofos	100	
2,4,5-T	1 000	
Temephos	3 000	
Terbacil	300	
Terbufos	5	
Terbutryn	3 000	
Tetrachlorvinphos	1 000	
Thiobencarb	300	
Thiometon	30	
Thiophanate	50	
Thiram	30	
Triadimefon	20	
Trichlorofon	50	
Triclopyr	100	
Trifluralin	500	
Vernolate	300	

* Phytoplankton cell counts include cyanobacteria and eukaryotic organisms.

\# Detection or exceedance of DOHWA watchlist trigger levels should trigger re-sampling and a visual assessment of the site within 48 hours for assessment against EQS B and C.

+ Algal scums are defined as dense accumulations of algal cells at or near the surface of the water forming a layer of distinct discolouration (green, blue, brown or red) (Gov QLD, 2002).

Guidance notes

Environmental quality guidelines

Faecal pathogens

– The 95th percentile bacterial content should be calculated from a minimum of 65–100 samples taken over a maximum 5 year period. In certain areas local resources make it difficult to collect 20 samples in a designated sampling season and consequently the Department of Health accepts a minimum of 13 samples a season over five consecutive years, i.e. a total of 65 samples, for the calculation of the 95th percentile bacterial content. A minimum of 100 samples is expected where sampling is required throughout the year rather than seasonally.

– Samples should be collected at the time of year when most people participate in recreational activities i.e. summer and warmer months of spring and autumn, e.g. November to May.

Toxic algae

– Historical numerical environmental quality guidelines for toxic algae have primarily been developed for inland/fresh waters. In the absence of any known numerical guideline for marine waters, the numerical guidelines referred to in this document are generally indicative and conservative, and thus designed to protect public health. These numerical guidelines are based upon an understanding, that recreational contact and exposure to potentially toxic algae may pose a low level public health risk; whereby some people could experience mild health effects which cause temporary discomfort or difficulty e.g. skin or respiratory irritation.

– DOHWA Watch list for potentially toxic algae in recreational waters

Algal Group	Algal Genus / Complex	Key Species	DOHWA Watch List Trigger Levels (cells/L)	DOHWA Watch List Action Levels (cells/L)
Cyanobacteria	*Lyngbya*	*majuscula*	Detected	relatively widespread visible presence of algal filaments (NHMRC 2008)
	Trichodesmium		Detected	presence of algal scums (NHMRC 2008)
	Other		5,000	15,000
Dinoflagellates	*Noctiluca*		Detected	presence of algal scums (NHMRC 2008)
Raphidophytes	*Heterosigma*		Detected	presence of algal scums (NHMRC 2008)

Please refer to the following hyperlinks for the current updated DOHWA Watch list:

http://www.public.health.wa.gov.au/3/1287/2/publications.pm

http://www.public.health.wa.gov.au/3/661/2/algalblooms.pm

– Detection or exceedance of a DOHWA Watch list trigger level should trigger an increase in monitoring frequency to weekly sampling and an accompanying visual assessment of the site for assessment against EQS B and C. Weekly monitoring will continue until 2 consecutive all-clear results are achieved i.e. samples and visual assessment do not trigger EQG or EQS criteria.

– The resample taken within 48 hours of detection or exceedance of a DOHWA watch list trigger level shall be analysed to determine algal groups and cell counts and shall be reported to the Department of Health WA. This information will assist the Department of Health WA to assess and communicate the potential impacts that detection or exceedance may pose to primary contact recreational water activities.

– Visual assessments are to be undertaken at the time of day when meteorological and oceanographic conditions are expected to be calmest).

– A watching brief should be maintained to consider any reports of human health illness/ disease that may be attributable to potentially toxic algae.

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 NHMRC Drinking Water Guidelines by a factor of 10 (assumes up to 200 mL of marine water may be consumed while swimming compared to the assumption of 2L consumed when deriving

drinking water guidelines.

– For chemical indicators the 95th percentile 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 (e.g. runoff) and determine an appropriate sanitary inspection category. This approach for bacterial water quality risk assessment has been adopted from Chapter 5 of the *Guidelines for Managing Risks in Recreational Water* (NHMRC 2008).

– The 95th percentile bacterial content for each site should be calculated from a minimum of 65–100 samples taken over a maximum 5 year period. Samples should be collected at the time of year when people participate in recreational activities in the area i.e. summer and warmer months of spring and autumn,. In certain areas where sampling is seasonal, local resources may make it difficult to collect 20 samples in a designated sampling season (e.g. November to May) and consequently the Department of Health accepts a minimum of 13 samples a season over five consecutive years, i.e. a total of 65 samples, for the calculation of the 95th percentile bacterial content. A minimum of 100 samples is expected where sampling is required throughout the year rather than seasonally.

Toxic algae

– Historical numerical environmental quality guidelines for toxic algae have primarily been developed for inland/fresh waters. In the absence of any known numerical guideline for marine waters, the numerical standard referred to in this document is indicative and designed to provide an understanding of when recreational exposure to potentially toxic algae is likely to pose a medium-high level risk to public health i.e. a greater proportion of people who undertake primary contact water recreation will be more likely to experience some health compromising effects (e.g. more severe intense skin and respiratory reactions or gastrointestinal/other illness).

– Upon exceedance of an EQS, sampling shall be undertaken at regular intervals (fortnightly minimum and more frequently for apparently significant events) for the duration of the exceedance/detection event to determine whether toxic species are present at potentially harmful concentrations. Weekly sampling at a minimum will be required in the event of a press release. Phytoplankton cell counts should be performed for each potentially toxic species present.

– If an EQS is exceeded the exceedance should be referred to the Department of Health WA for advice on the appropriate management actions to be implemented. If the exceedance involves a potentially toxic algal species at elevated levels, or if algal scums are present at moderate to high risk levels as determined by the Department of Health WA, management action will likely include the erection of warning signs, the issue of a press release and ongoing monitoring at increased frequency (including daily visual assessment of algal bloom location, movement, density and total area of coverage).

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, D and/or E) have been met, and whether EQS (E or F) have been met:

   [N]…….. – go to steps 3 and 4 if EQG A not met; and
   – go to step 6 if EQG B is not met; and
   – go to steps 3 and 8 if EQG D not met; and
   – go to steps 3 and 9 if EQG E or EQS F not met; and
   – go to steps and 10 if EQS E is not met.

   [Y]……. – go to step 3.
3. Seek information to determine whether EQG C has been met:

   [N]……. – go to step 7.

   [Y]…….. – no issues for recreation, go to step 1.

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 10.

   [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 and C have been met:

   [N]…….. – go to step 9.

   [Y]…….. – no issue identified, maintain increased monitoring intensity until EQG met on two consecutive occasions then go to step 1.
7. Contact the Department of Health and determine whether EQS D has been achieved:

   [N]……. – go to step 10.

   [Y]……. – maintain increased monitoring intensity until all relevant EQG are achieved.
8. Swimmers should be urged to use caution when swimming in these waters. Signage may be an option.
9. 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.

10. 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.

Simplified pictorial decision scheme for applying the EQC for primary contact recreation

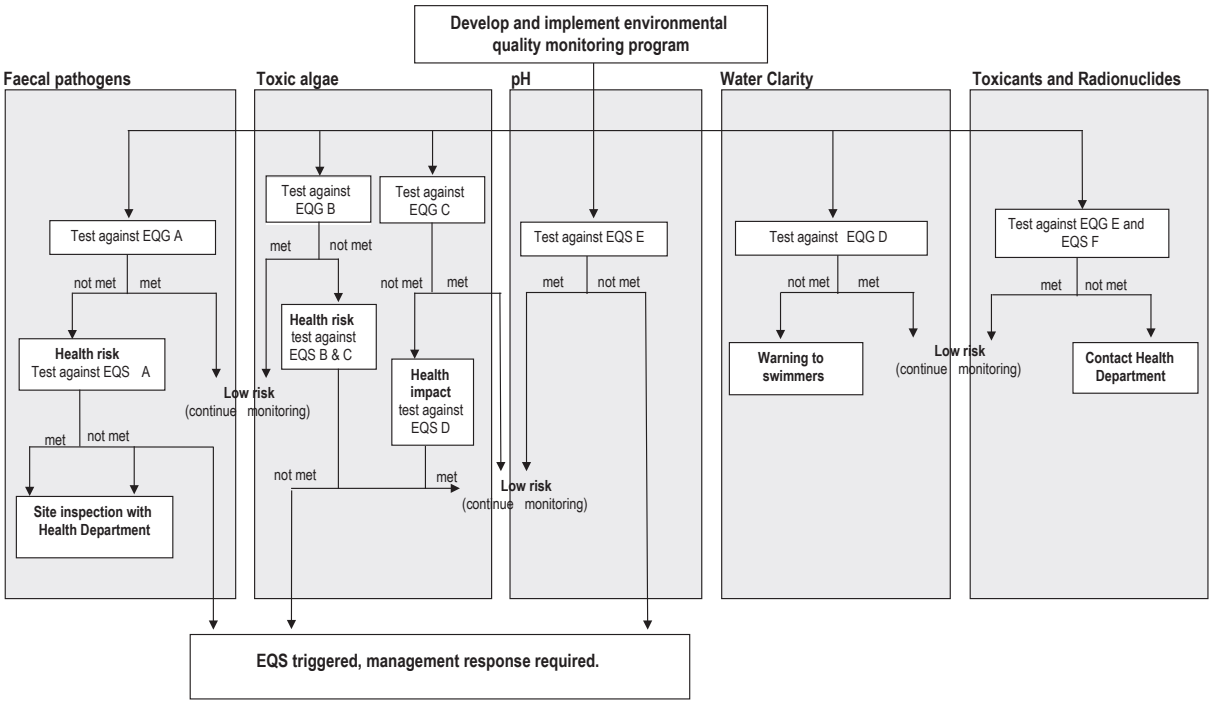


Table 7 Environmental quality criteria for the maintenance of secondary contact recreation
(*relevant Guidance notes should also be read*)

Indicator	Environmental quality guideline	Environmental quality standard (EQS)
Biological		
Faecal pathogens	**A.** The 95th percentile bacterial content of marine waters should not exceed 2000 enterococci/100 mL.	**A.** The 95th percentile bacterial content of marine waters should not exceed 5000 enterococci/100 mL.
Toxic algae	**B.** The median phytoplankton cell count* for a defined sampling area (either form one sampling run or from a single site over an agreed period of time) should not exceed 25,000 cells/mL; **C.** There should be no reports of skin, eye or respiratory irritation or potential algal poisoning of recreational users considered by a medical practitioner as potentially resulting from toxic algae when less than 25 000 cells/mL is present in the water.	**B.** There should be no confirmed incidences, by report from a medical practitioner, of skin, eye or respiratory irritation or poisoning in secondary contact recreational users caused by toxic algae or chemical contaminants.
Physical and chemical		
Toxic chemicals	**D.** Water should contain no chemicals at concentrations that can irritate the skin of the human body.	
pH	**E.** The median of the sample concentrations from a defined sampling area (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.	

* Phytoplankton cell counts include cyanobacteria and eukaryotic organisms.

Guidance notes

Environmental quality guidelines

Faecal pathogens

– The 95th percentile bacterial content should be calculated from a minimum of 65 - 100 samples taken over a maximum 5 year period. The larger number of samples would be expected where monitoring is required throughout the year rather than seasonally.

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 that may be attributable to potentially toxic algae at algal concentrations below the guideline.

Environmental quality standards

Faecal pathogens

– The 95th percentile bacterial content should be calculated from a minimum of 65–100 samples taken over a maximum 5 year period. The larger number of samples would be expected where monitoring is required throughout the year rather than seasonally.

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, D and/or E have been met:

   [N]…….. – go to steps 3 and 4 if EQG A not met; and

   – go to step 6 if EQG B not met; and

   – go to steps 3 and 7 if EQG D or E not met.

   [Y]……. – go to step 3.
3. Seek information to determine whether EQG C has been met:

   [N]……. – go to step 6.
   [Y]…….. – no issues for recreation, go to step 1.

   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. Contact the Department of Health and determine whether EQS B has been achieved:

   [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.

Simplified pictorial decision scheme for applying the EQC for secondary contact recreation

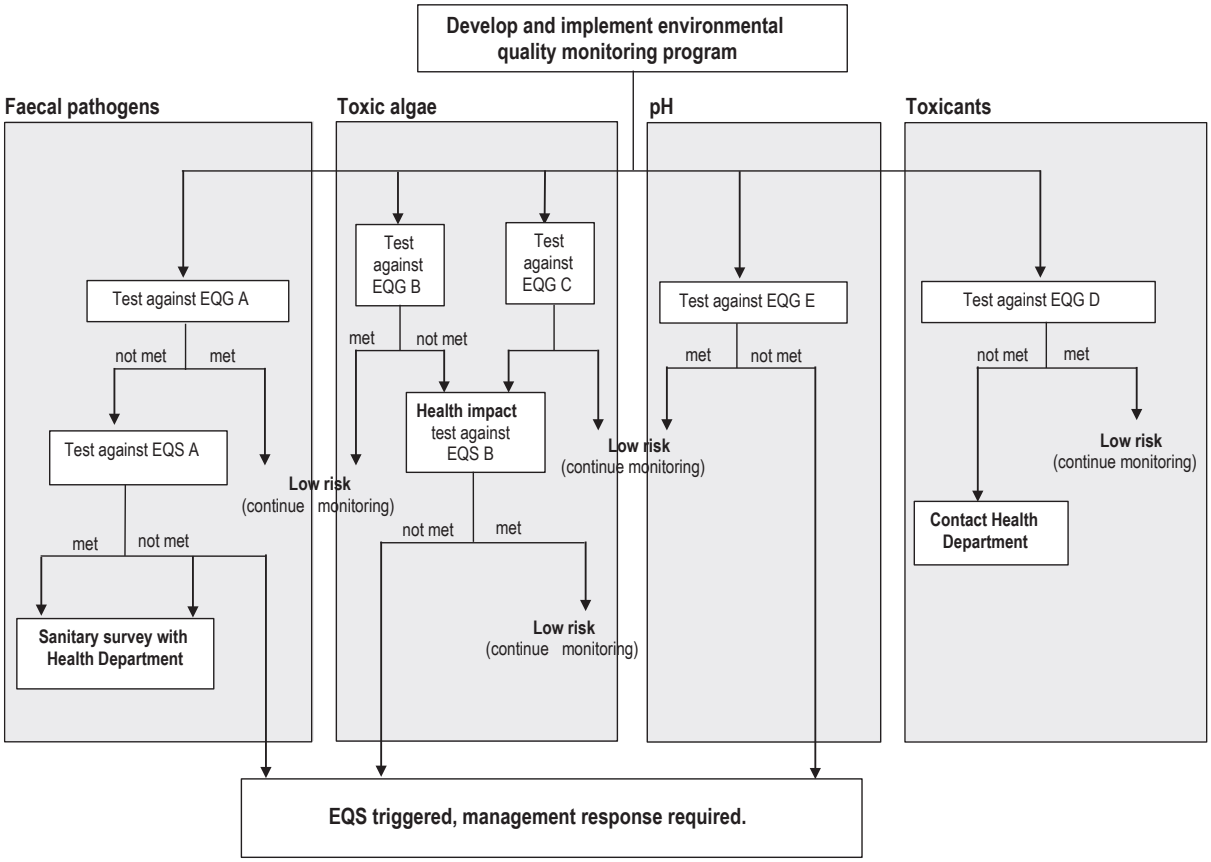


Table 8 Environmental quality criteria for Aesthetic quality (*relevant footnotes and Guidance notes should also be read*)

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 95th percentile of the sample concentrations from a defined sampling area (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

Indicator	Environmental quality guideline	Environmental quality standard (EQS)
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	
2-methyl-4-chlorophenol	1.8	
3-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	

Indicator	Environmental quality guideline	Environmental quality standard (EQS)
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 community 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.

Simplified pictorial decision scheme for applying the EQC for aesthetic quality

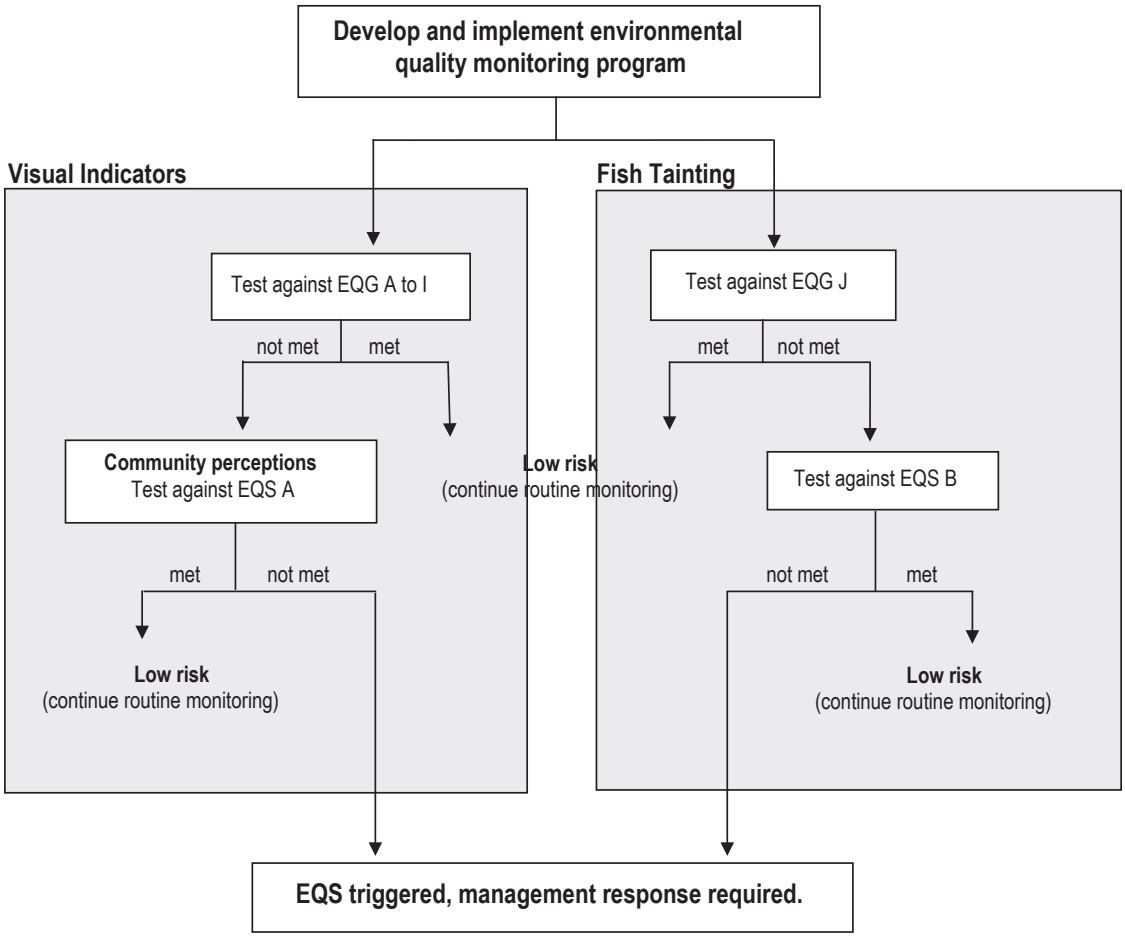


Table 9 Environmental quality criteria for maintenance of water quality for Desalination Plant operation
(*relevant footnotes and Guidance notes should also be read*)

Indicator	Environmental quality guideline (units as stated)	Environmental quality standard (EQS) (units as stated)
Biological		
Faecal streptococci	**A.** The 95th percentile bacterial content of marine waters adjacent to the Perth Seawater Desalination Plant intake over a period not exceeding one month should not exceed 32 CFU faecal streptococci /100 mL	**A.** The bacterial content of Perth Seawater Desalination Plant intake water, as measured by the Water Corporation, should not exceed 32 CFU faecal streptococci/100mL on any occasion
Heterotrophic count	**B.** The 95th percentile heterotrophic bacterial content of marine waters adjacent to the Perth Seawater Desalination Plant intake over a period not exceeding one month should not exceed 150 CFU /100 mL	**B.** The heterotrophic bacterial content of Perth Seawater Desalination Plant intake water, as measured by the Water Corporation, should not exceed 150 CFU /100 mL on any occasion
Physical and Chemical		
Temperature	**C.** The 90th percentile of temperature measurements adjacent to the Perth Seawater Desalination Plant intake over a period not exceeding one month should not exceed 28°C	**C.** The hydrocarbon concentration of Perth Seawater Desalination Plant intake water, as measured by the Water Corporation, should not exceed 10 µg/L on any occasion
pH	**D.** The median pH adjacent to the Perth Seawater Desalination Plant intake over a period not exceeding one month should not exceed 8.5	**D.** A significant reduction in efficiency of the desalination process or a significant increase in the maintenance requirements demonstrably caused by a change(s) in intake water quality
Dissolved oxygen	E. The median dissolved oxygen concentration 5 m above the sea floor adjacent to the Perth Seawater Desalination Plant intake, calculated over a period not exceeding one month, should be ≥ 2 mg/L	
Total dissolved solids	**F.** The median concentration of total dissolved solids adjacent to the Perth Seawater Desalination Plant intake over a period not exceeding one month should not exceed 40,000 mg/L	
Total dissolved solids	**G.** The median concentration of total suspended solids adjacent to the Perth Seawater Desalination Plant intake over a period not exceeding one month should not exceed 10 mg/L	
Hydrocarbons	**H.** The hydrocarbon concentration adjacent to the Perth Seawater Desalination Plant intake should not exceed 10 µg/L on any occasion	
Boron	**I.** The 90th percentile boron concentration adjacent to the Perth Seawater Desalination Plant intake over a period not exceeding one month should not exceed 5.2 mg/L	
Bromide	**J.** The 90th percentile bromide concentration adjacent to the Perth Seawater Desalination Plant intake over a period not exceeding one month should not exceed 77 mg/L	

Guidance notes

Environmental quality guidelines

- The EQG set thresholds that are relevant to the seawater intake but do not necessarily need to be measured at that location if the indicator(s) is expected to be met closer to the source of the pressure.
- The indicators 'faecal streptococci', 'heterotrophic count' and 'boron' are important for ensuring potability of the desalinated water while the remaining indicators relate to the efficacy of the desalination process.
- Exceedance of an EQG must be referred to the Water Corporation for an assessment against the EQS in the intake water or in the operation of the desalination plant.

Environmental quality standards

- Assessment of the EQS must be undertaken by the Water Corporation as operator of the desalination plant.
- Exceedance of an EQS as determined by the Water Corporation should either trigger management at the source to mitigate levels of the contaminant or negotiation with the Water Corporation to investigate the feasibility of treating the intake water to mitigate the impact.

Narrative decision scheme for applying the EQC for Perth Seawater Desalination Plant intake water

1. Conduct routine monitoring program around the pressure source and seawater intake location if necessary. Go to steps 2 and 3.
2. Determine whether all of EQG A to J have been met:

   [N]…….. – go to step 3.

   [Y]……. – intake water quality not compromised, go to step 1.
3. Confirm whether all of EQG A to J have been met at the seawater intake of the Perth Desalination Plant:

   [N]…….. – go to step 4 if EQG A, B or H not met;

   – go to step 5 if EQG C, D, E, F, G, I or J not met;

   [Y]…….. – intake water quality not compromised, go to step 1.

   The EQG has been triggered and the EQS need to be addressed.
4. Depending on which EQG was exceeded, determine whether EQS A, B and/or C have been met:

   [N]…….. – go to step 8;

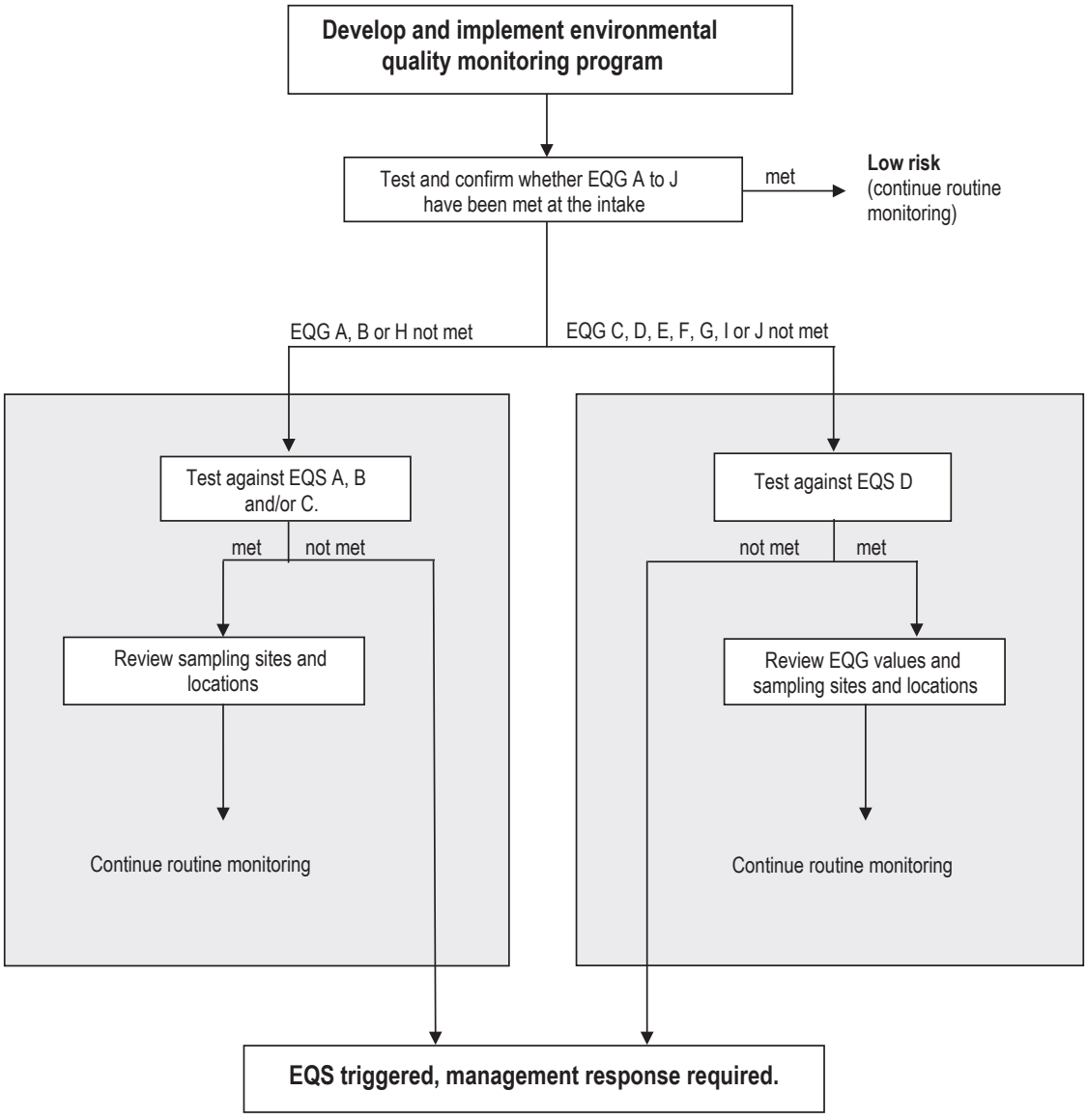
   [Y]…….. – intake water quality not compromised, go to step 6.
5. Determine whether EQS D has been met:

   [N]…….. – go to step 8;

   [Y]…….. – intake water quality not compromised, go to step 7.

6. Given the potential threat to the quality of the intake water, modify the sampling locations and sampling frequency in the monitoring program as necessary then return to step 1.
7. In liaison with the Water Corporation, and in light of contaminant levels in the actual intake water, modify the EQG as necessary and review the sampling frequency and sampling locations in the monitoring program, then return to step 1.
8. Identify the source of the contaminant and implement a management response to either return levels of the contaminant to meet the EQG at the seawater intake of the Perth Seawater Desalination Plant or treat the intake seawater to meet the EQS.

Simplified pictorial decision scheme for applying the EQC for the Perth Seawater Desalination Plant



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