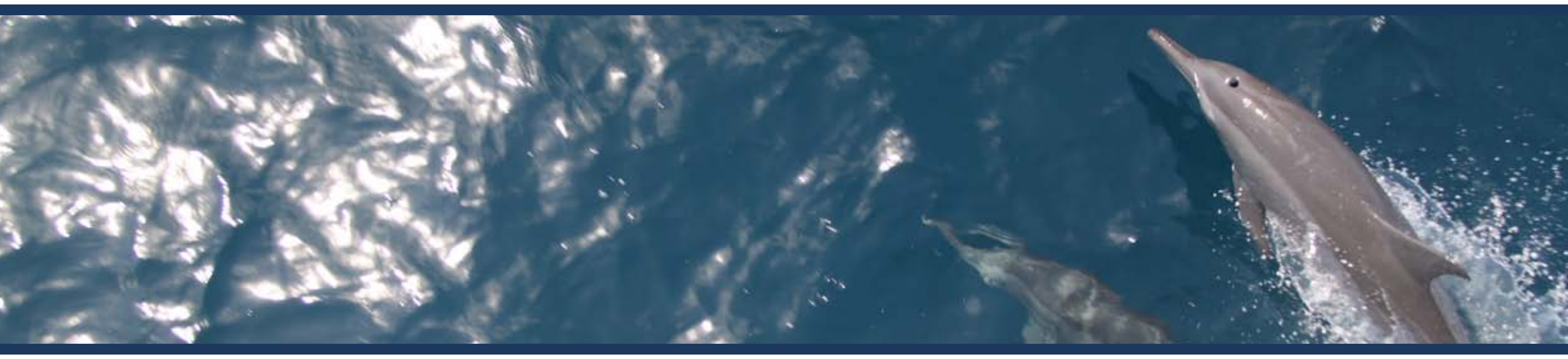
Technical Guidance

Protecting the Quality of Western Australia's Marine Environment



Environmental Protection Authority

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1 Purpose and scope

The purpose of this technical guidance is to:

- assist proponents to design fit-for-purpose modelling and monitoring programs to spatially define, assess and manage potential impacts of their proposal on marine environmental quality, and
- ensure proposals that have the potential to significantly affect marine environmental quality are described and assessed in a sound and consistent manner that demonstrates how the EPA's objective for the Factor 'marine environmental quality' will be met.

The approaches outlined in this Guidance are not new. They have been applied to all significant and relevant proposals subject to formal environmental impact assessment for over a decade.
This Guidance sets out the approach that has been refined and consolidated over this period in a single coherent document.

This document sets out the context for the guidance, describes the structure of the environmental quality management framework and how it is to be applied through environmental impact assessment to maintain a high level of quality in Western Australia's marine waters. WA marine waters extend from the outer boundary of the State's Coastal Waters through estuaries and inland to the limit of tidal influence where salinity is influenced by seawater, including marinas and canals that are contiguous with the marine environment. Although tailored to marine waters, the general approach is applicable to other estuaries and inland waters, but there are likely to be a different set of pressures and issues to be considered.

The appendices provide more detailed guidance on how specific environmental quality criteria are established for ecosystem health and for modelling of wastewater discharges including dredge plumes.

Proponents are provided with the necessary background and guidance on how to present the potential impacts of their proposals on the quality of the marine environment in a spatially-defined and consistent manner. Consistent application of this framework will enhance the timeliness, efficiency and effectiveness of the environmental impact assessment and Ministerial authorisation processes.

> This guidance has been tailored for **Western Australian marine waters**, including any constructed harbours, marinas and canals that are contiguous with marine waters.

Application of the framework reduces uncertainty around the predictions of environmental impact and establishes the aims for monitoring and management plans designed to ensure that the EPA's objectives for marine environmental quality are achieved.

One of the key strengths of the framework is that it provides a consistent and standardised approach for measuring and reporting on marine environmental quality across projects and regions. As such it could be used to provide a spatially-defined and objective basis to facilitate the regulation of wastewater discharges under Part V of the *Environmental Protection Act 1986* (the Act) and to facilitate cumulative impact assessments and trend analyses by activity, sector and/or region (which in turn can be aggregated for state of environment reporting).

2 Background and rationale

The EPA has developed a contemporary environmental quality management framework (EQMF) for protecting and maintaining the quality of the State's marine environment. Environmental values form the basis of the framework from which broad environmental quality objectives, including levels of ecological protection, are established and spatially defined. Environmental quality criteria that represent environmental quality thresholds of 'acceptability' are then established based on scientific, social and political imperatives. These thresholds are benchmarks against which environmental monitoring data are compared in order to determine the extent to which environmental quality objectives have been met.

This EQMF is risk-based and flexible, and can be fine-tuned to address specific issues or management of entire areas. It can also be used to address cumulative effects of point and non-point source discharges on marine environmental quality. While it may not be possible to be definitive about all the discharges or contaminant sources in an area, cumulative effects can be addressed to some extent by:

- modelling the effects of the proposed discharge in addition to the effects of any existing discharges in the area; and
- monitoring and managing the quality of the receiving marine environment rather than the individual discharges.

Because our marine waters are generally in good condition, the focus of the approach is not on restoration of environmental quality but around maintenance of existing environmental quality. In cases where the objectives are not met it helps identify where management and/or restoration may be needed and to measure the effectiveness of either. It also recognises those small areas where some values will not be protected and/or a lower level of ecological protection is acceptable (e.g. the immediate vicinity of a wastewater outfall).

Unplanned events or discharges such as oil or chemical spills can also have severe consequences on marine ecosystems and the environmental values and uses they support. These impacts can extend significant distances from the actual spill location and cross jurisdictional boundaries (e.g. from Commonwealth waters to State waters). Unfortunately, there are limited options for managing these unplanned events and efforts need to focus on prevention and ensuring appropriate response arrangements are in place. So, in addition to providing guidance on the assessment and management of chronic or planned discharges, the environmental quality plans established through this framework could be used to provide spatially-defined and measurable performance objectives for spill contingency plans and spill environmental impact monitoring programs where State waters are at risk.

The framework has been progressively implemented through the environmental impact assessment process, and direct community and stakeholder consultation. It provides a mechanism for allowing seemingly incompatible uses to coexist and provides a common and agreed environmental quality plan for all to work towards. The architecture and application of this framework are set out in more detail in Sections 4 and 5 of this guidance respectively.

3 Context

The framework is based on the principles and guidelines of the National Water Quality Management Strategy (NWQMS), with particular regard to the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ, 2000) (the Guidelines). The Guidelines document takes a concentration-based approach to the management of marine environmental quality and as a result this Guidance has a similar focus. However, proponents and managers are advised to also consider contaminant loads and the potential fate and consequences of increased loads to the receiving environment (e.g. excessive plant biomass caused by increased nutrient loads or the accumulation of toxicants in biota and sediments). Contaminant input inventories can be used to assess any trends in contaminant loads. The EPA recommends that proponents include load-based monitoring techniques in their monitoring and management programs for marine environmental quality wherever appropriate.

The NWQMS was developed in the 1990s through the collaboration of the Commonwealth, State and Territory governments and provides a blueprint for a nationally consistent approach to water quality management. All Australian State and Territory Governments and the Federal Government endorsed the NWQMS and in Western Australia a State Water Quality Management Strategy (SWQMS) was developed to guide implementation at the State level. The relevance of the NWQMS has recently been reconfirmed through COAG, but with some revision to bring it in line with the National Water Reform agenda.

The EQMF is based on the recommendations and approaches in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ, 2000a).

Two examples of where the this framework has been used to guide the assessment of new proposals, and/or to maintain marine environmental quality at acceptable levels, are the *State Environmental (Cockburn Sound) Policy 2015* and *Perth's Coastal Waters: Environmental Values and Objectives* (2000).

4 An outline of the Environmental Quality Management Framework

The key structural elements of the EQMF are shown in Figure 1. The Environmental Values (EVs), Environmental Quality Objectives (EQOs) and, for the EQO 'maintenance of ecosystem integrity', Levels of Ecological Protection (LEPs) constitute the primary management objectives and represent the community's and other stakeholder's desired outcome for marine environmental quality. They can be represented spatially for a defined area (the Environmental Quality Plan (EQP)). The operational elements are the Environmental Quality Criteria (EQC) and the Environmental Quality Management Plan (EQMP). The first three elements of the EQMF (EVs, EQO/LEPs and EQC) are discussed in this Section. EQMPs are discussed in Section 6.

The EPA encourages the establishment of EVs and EQOs through an adequate public consultation process. Where this is not feasible then the default approach is through the application of the principles and approaches outlined in this Technical Guidance (see Section 5).

The EQC must be both measurable and auditable. They are the numerical benchmarks that are used to interpret model outputs to determine if the objectives are likely to be met, and environmental monitoring results to determine if the objectives have been met.

4.1 Environmental Values

Under the NWQMS, Environmental Values (EVs) are defined as particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health and which require protection from the effects of pollution, waste discharges and deposits (ANZECC & ARMCANZ, 2000). This definition is consistent with the definition for Environmental Value contained in the Act. A list of possible EVs is set out in the NWQMS.

In the marine environment five of the NWQMS EVs are recognised and would generally apply throughout WA coastal waters:

- Ecosystem health
- Fishing and aquaculture
- Recreation and aesthetics
- Industrial water supply
- Cultural and spiritual.

EVs do not necessarily reflect all uses that are currently allowed in an area. For example there may be areas within a harbour where a Port Authority has declared a 'Restricted Zone' that excludes recreational boating, swimming and/or fishing for safety or operational reasons. However, the prohibition of these activities within an area is not a reason for excluding the environmental values of 'Fishing and Aquaculture' and 'Recreation and Aesthetics' and allow the uncontrolled discharge of some contaminants to the point where it could be unsafe to swim or consume seafood from the area if the Restricted Zone were lifted in the future.

Alternatively, water quality may not currently meet the level required for an environmental value, or a particular level of ecological protection, but this should not necessarily exclude that value or level of protection from being the long-term management goal.

The EVs that are relevant to a particular area should be identified in consultation with the community and stakeholders.

4.2 Environmental Quality Objectives

Environmental quality objectives (EQOs) are high level management objectives that describe what must be achieved to protect each EV. They are measurable and should be incorporated into the key objectives for environmental quality monitoring and management plans. The EQOs that apply to each EV are listed in Table 1.

It should be noted that for the environmental value 'Ecosystem Health' there are effectively four different EQOs based on whether a low, moderate, high or maximum level of protection is to be applied (refer to Table 2). In the context of the EP Act these four levels equate to four levels of ecosystem health condition.

Although all environmental values are expected to apply to an area, there may be some small sections of the area where one or more EQOs, apart from the maintenance of ecosystem integrity, could be specifically excluded.

> All environmental values and environmental quality objectives should apply throughout the State's coastal waters except small areas around discharges containing faecal pathogens where it can be demonstrated that some human health related environmental values cannot be reasonably achieved.

For example, there may be some small areas around domestic treated wastewater discharges where the risk of disease from pathogens makes it unsafe for people to recreate or catch and eat seafood. In these areas there would be defined zones around the outfalls based on modelling or *in-situ* measurements where it would not be necessary to meet the EQOs for primary and secondary contact recreation and/or seafood safe for eating.

The EQO to protect cultural and spiritual values applies to Aboriginal cultural and spiritual values. In the absence of any specific environmental quality requirements for protection of this value it is assumed that if water quality is managed to protect ecosystem integrity, protect primary contact recreation, protect the quality seafood for eating and maintain aesthetic values, then this may go some way toward maintaining cultural values. However, it is more problematic to define spiritual value in terms of environmental quality requirements.

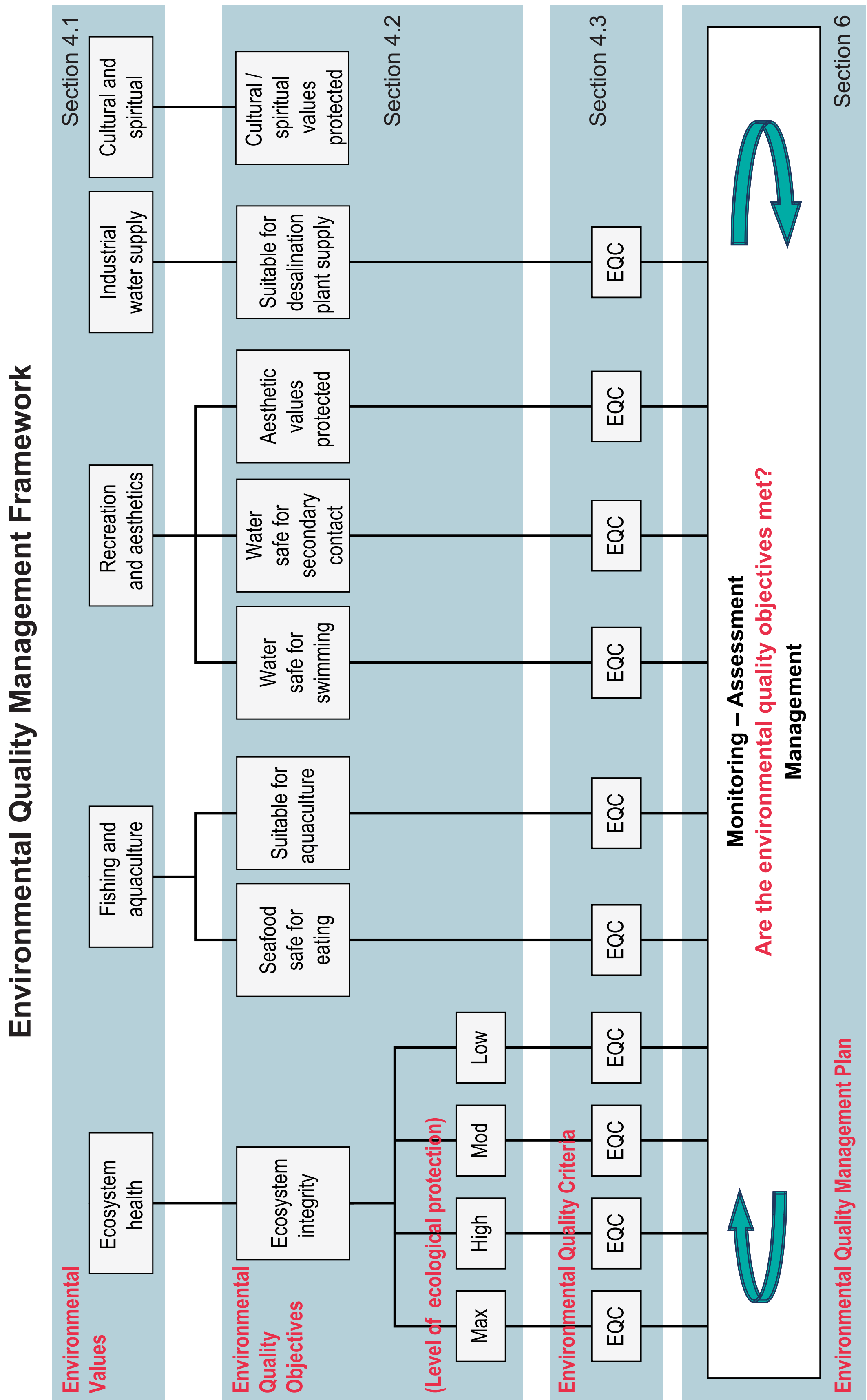

Figure 1: Environmental quality management framework for Western Australian marine waters

Table 1: Environmental Values and Environmental Quality Objectives for the marine waters of Western Australia

Environmental Values (from ANZECC 2000)	Environmental Quality Objectives
Ecosystem Health (ecological value)	**Maintain ecosystem integrity at a maximum level of ecological protection.** **Maintain ecosystem integrity at a high level of ecological protection.** **Maintain ecosystem integrity at a moderate level of ecological protection.** **Maintain ecosystem integrity at a low level of ecological protection.** This means maintaining the structure (e.g. the variety and quantity of life forms) and functions (e.g. the food chains and nutrient cycles) of marine ecosystems to an appropriate level (see Section 4.2.1).
Recreation and Aesthetics (social use value)	**Water quality is safe for primary contact recreation (e.g. swimming and diving).** **Water quality is safe for secondary contact recreation (e.g. fishing and boating).** **Aesthetic values of the marine environment are protected.**
Cultural and Spiritual (social use value)	**Cultural and spiritual values of the marine environment are protected.**
Fishing and Aquaculture (social use value)	**Seafood (caught or grown) is of a quality safe for eating.** **Water quality is suitable for aquaculture purposes.**
Industrial Water Supply (social use value)	**Water quality is suitable for industrial use.**

Table 2: Levels of change in the key elements of ecosystem integrity that define the four levels of ecological protection.

Key elements of ecosystem integrity and their limits of acceptable change		Level of protection for maintenance of ecosystem integrity			
Key elements	**Limits of acceptable change**	**Maximum**	**High**	**Moderate**	**Low**
Ecosystem processes (e.g. primary production, nutrients cycles, food chains)	Ecosystem processes are maintained within the limits of natural variation (no detectable change)	✓	✓		
	Small changes in rates, but not types of ecosystem processes			✓	
	Large changes in rates, but not types of ecosystem processes				✓
Biodiversity (e.g. variety and types of naturally occurring marine life)	Biodiversity as measured on both local and regional scales remains at natural levels (no detectable change)	✓	✓	✓	
	Biodiversity measured on a regional scale remains at natural levels although possible change in variety of biota at a local scale				✓
Abundance and biomass of marine life (e.g. number or density of individual animals, the total weight of plants)	Abundances and biomasses of marine life vary within natural limits (no detectable change)	✓	✓		
	Small changes in abundances and/or biomasses of marine life			✓	
	Large changes in abundances and/or biomasses of marine life				✓
The quality of water, biota and sediment (e.g. types and levels of contaminants such as heavy metals, dissolved oxygen content, water clarity)	Levels of contaminants and other measures of quality remain within limits of natural variation (no detectable changes)	✓			
	Small detectable changes beyond limits of natural variation but no resultant effect on biota		✓		
	Moderate changes beyond limits of natural variation but not to exceed specified criteria			✓	
	Substantial changes beyond limits of natural variation				✓

While the EQO for Aquaculture would generally apply to all marine waters, it is operationalized by applying the EQC at the boundary of the approved aquaculture lease and targeted to the species that are grown there.

The water quality requirements for Industrial Water Supply are specific to the industry and the industrial process used. In most cases the industry is able to treat intake water to the quality required. However, with the recent increase in the use of desalination to augment fresh water supplies, EQC for this EQO may need to be applied at approved salt water intakes to protect the desalination process.

> While it is likely that all environmental values will apply to all State coastal waters, the EQC for aquaculture production only need to be applied at the boundary of an aquaculture lease and the EQC for industrial water supply should only be applied at the approved water intake.

4.2.1 Levels of ecological protection

Four levels of ecological protection (LEPs) are provided for the EQO *maintenance of ecosystem integrity* so that areas identified as important for conservation and biodiversity protection can be maintained in their natural state while recognising that in other parts of the marine environment there are societal uses that may preclude a high level of ecological protection from being achieved (e.g. use of marine waters for waste disposal and other activities such as port operations).

Ideally LEPs would be considered when consulting with the public for establishing EVs and EQOs. Although LEPs partly reflect community desires for an area, the allocation of LEPs is relatively straightforward and largely determined by established uses and by some important principles incorporated in this guidance. As for EVs and all EQOs, LEPs aren't defined by current condition, but are intended to represent long-term objectives for environmental quality. In order to ensure the EV of Ecosystem Health is maintained overall, the cumulative size of the areas where lower levels of ecological protection apply should be proportionally small compared to the areas designated high and maximum. The practical application of this principle is set out below.

4.2.2 Guidance for applying levels of ecological protection

A *maximum level of ecological protection* would require activities to be managed so that there were no changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota. This LEP would generally apply to marine areas considered to be of high conservation value. Obvious examples include most zones within gazetted marine parks, marine nature reserves and conservation zones of marine management areas, but other special areas may also be considered including marine areas that support important world heritage values or areas recognised by the EPA as having high conservation value, Fish Habitat Protection Areas and sanctuary zones in the Rottnest Island Reserve. It would be unreasonable to apply this LEP within five kilometres of large commercial/population centres (e.g. large towns or cities or industrialised ports) because of the constraints it would apply to discharges and other activities.

> The maximum LEP would generally apply to areas with declared high conservation value, but it may also be applied to other areas that are identified by the EPA as warranting special protection. However, it would be impractical to apply a maximum LEP within five kilometres of large commercial or population centres.

The objective for a *high level of ecological protection* is to allow for small measurable changes in the quality of water, sediment and biota, but not to a level that changes ecosystem processes, biodiversity or abundance and biomass of marine life beyond the limits of natural variation. This LEP would apply to all areas that weren't assigned a low, moderate or maximum LEP, which is anticipated to be the majority of the State's coastal waters.

The marine waters around WA are in a near pristine condition apart from some relatively small areas around urban and industrial centres or river mouths draining agricultural catchments. A high LEP will be easily achieved in the majority of the State's marine waters.

A *moderate level of ecological protection* may be applied to relatively small areas within inner ports and adjacent to heavy industrial premises where waste discharges and contamination from current and/or historical activities may have compromised a high level of ecological protection. It may also be used to accommodate any accumulation of contaminants from anti-foulant paints, typically extending up to 250 m from ship turning basins and berths. This level of ecological protection is also considered relevant for marinas and harbours and could be considered for other localised areas if justified with sound technical arguments (e.g. around some treated wastewater discharges). Similarly this level of protection may apply to some sea cage aquaculture where sediments can become organically enriched. In areas assigned a moderate level of ecological protection moderate changes in environmental quality may be acceptable provided there are only small changes in abundance and biomass of marine life and in the rates, but not types, of ecosystem processes. There should be no detectable and persistent changes in biodiversity due to waste discharges or contamination.

Areas allocated the EQO 'Maintenance of ecosystem integrity at a *moderate level of ecological protection*' should be few in number and small compared to the area being managed.

Areas assigned a *low level of ecological protection* should be as small as reasonably practicable and would generally only be considered to accommodate the zone of initial dilution around specific wastewater discharges. The zone of initial dilution for even large volume discharges is generally of the order of tens of metres from the diffuser outlets. The general expectation is that wastewater streams are treated to best practice levels and diffusers designed and located so that contaminants are sufficiently diluted within the low ecological protection zone to meet a high level of ecological protection at the edge of that zone. There can be substantial changes in the quality of water, sediments and/or biota in these areas provided there is no bioaccumulation/bioconcentration of contaminants in the adjacent high ecological protection area. There can also be large changes in abundance and biomass of marine life, biodiversity and rates of ecosystem processes, but only within this confined area.

A *low level of ecological protection* should only be considered around a wastewater discharge where the need can be technically justified. They should be as small as possible and linked to the zone of initial dilution where reasonably practicable to do so, usually extending no more than 70 m from the diffuser. These areas should be located within moderate ecological protection areas where available.

4.3 Environmental Quality Criteria

Environmental quality criteria (EQC) represent scientifically based limits of acceptable change to a measureable environmental quality indicator that is important for the protection of the associated environmental value. A fundamental requirement of EQC is that they should be clear, readily measurable and auditable. Wherever possible there should be a standardised approach to measurement of the indicator and for comparison of the resulting data against the EQC.

A public consultation program is not required for the development of EQC as they are scientifically derived.

In order to determine which are the relevant water quality indicators for monitoring, and hence for the development of EQC, a conceptual model of the ecosystem should be developed that represents the pressures on the system, the energy and nutrient flows and cycles, the contaminant flow paths and the interrelationships between these components. The model should also show the key threats to environmental quality and associated pressure/response relationships. The level of knowledge about the area will determine the level of detail and confidence in the model. An example of a simple conceptual model is provided in Figure 2.

The key environmental quality indicators can be selected based on the assessment of threats and risks from the pressure/response pathways identified in the conceptual model.

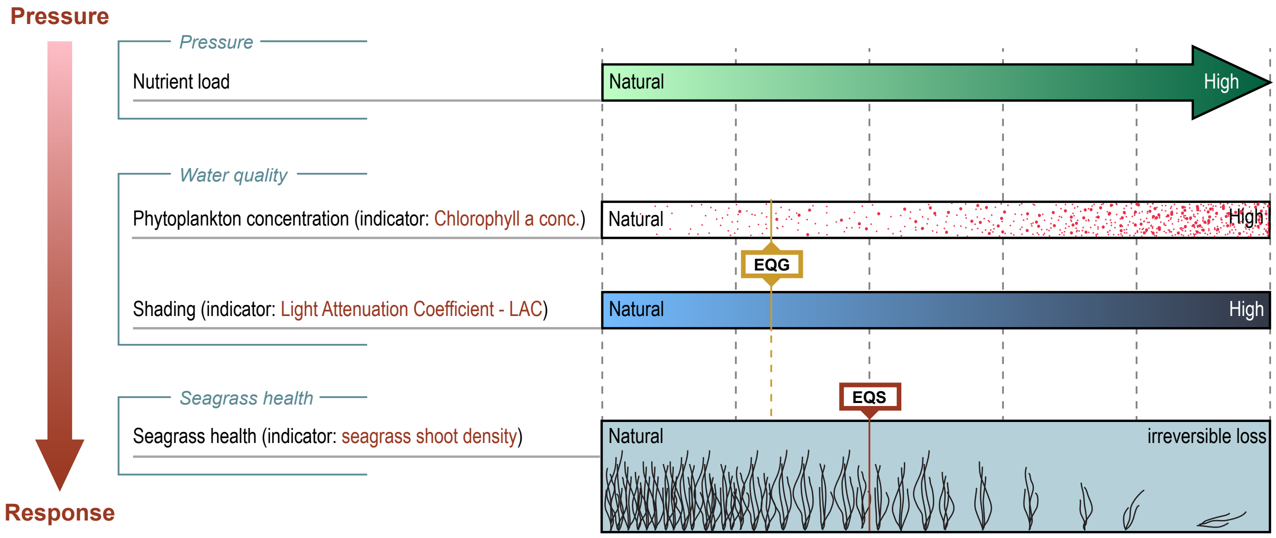

Figure 2: A simple conceptual model of a nutrient pressure/response relationship for a perennial seagrass meadow

EQC should be developed for the range of environmental quality indicators selected for each EQO to assess the responses to the main pressures associated with the development or activity. Most EQC can be derived from existing guideline trigger values, however some may need to be developed from pre-impact baseline or un-impacted local reference site data and take into account seasonal variability (Appendix 1). It should be noted that the more comprehensive the dataset, the more reliable the EQC. They should also be developed to assess and manage environmental quality over time scales appropriate to the pressure, for example EQC derived from annual or seasonal reference site data may be relevant for assessing impacts on much longer time scales than EQC derived from shorter-term ecotoxicological tests generally undertaken over a few days. In this way monitoring programs can be developed that are tightly focussed and 'fit for purpose'. Environmental quality indicators generally relate to water, sediment or biota quality, environmental/ecological processes, abundance and biomass and/or biodiversity measures and are selected according to our best understanding of the likely pressure/response pathways.

For indicators that relate to human health (e.g. indicators for recreational values and for seafood safe for human consumption) the EQC in EPA (2015) provide an accepted approach for WA waters, but up-to-date advice should be sought from the Western Australian Department of Health which has primary responsibility for protecting public health in WA. Guidance on suitable environmental indicators and guidelines for some aspects of human health can be found on the following Department of Health web page: **http://www.public.health.wa.gov.au/3/1287/2/publications.pm** For the environmental value 'ecosystem health' different EQC will apply depending on the level of ecological protection to be met (Refer Appendix 1).

The environmental quality criteria are divided into relatively simple and easy to measure environmental quality guidelines (EQG) and more robust environmental quality standards (EQS). Indicators for the development of EQG should be closer to the pressure end of the pressure/response relationship (e.g. chlorophyll a concentration in Figure 2) and give early warning of a potential problem. The EQS are generally more difficult to measure and based on indicators located at the response end of the relationship (e.g. seagrass shoot density in Figure 2). These are set at a level that gives greater certainty of an impact occurring before implementing management action (see Figure 3). This certainty can be significantly improved by increasing the number of indicators assessed that are directly relevant to a particular threat or issue ('multiple lines of evidence').

Environmental quality guidelines 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.

Environmental quality standards are threshold numerical values or narrative statements that indicate a level which if not met indicates there is a significant risk that the associated environmental quality objective has not been achieved and a management response is required. 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.

The EQC are applied through a risk-based approach that is intended to be cost-effective but still capture any uncertainty around the level of impact by staging monitoring and management responses according to the degree of risk to environmental quality. The approach provides a level of confidence that management responses are not triggered too early (i.e. when there is no actual impact) or too late after significant or irreversible damage to the surrounding ecosystem, or there are effects on human health.

Environmental quality criteria should be established using a *risk-based* approach with EQG providing early warning of potential environmental effects and EQS located further along the cause/effect pathway indicating when the level of risk is no longer acceptable and triggering management to prevent environmental harm or pollution.

Where there is some uncertainty around the specific threshold value of an EQG or EQS then a precautionary approach is recommended where the benefit of doubt is weighted toward protection of the environmental value.

If an EQG is met then the probability of an environmental problem occurring is minimal and routine monitoring would continue. However, if the EQG is exceeded it indicates uncertainty and triggers further investigation against a different threshold or suite of indicators for the EQS, and at potentially different sampling frequencies, to determine whether the respective environmental value is likely to be compromised.

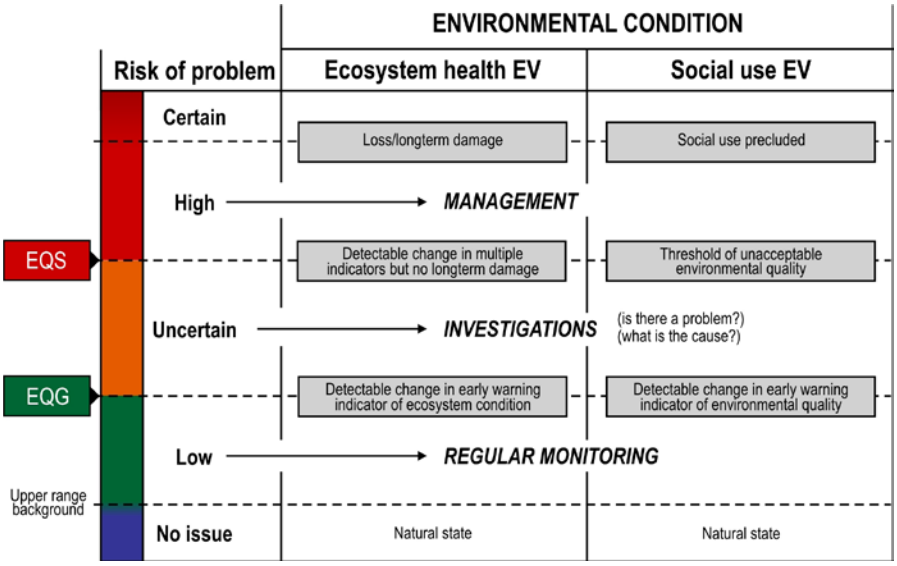

Figure 3: A conceptual diagram showing the relationship between the two types of EQC on the left hand side with the associated environmental conditions on the right hand side.

If assessment of the monitoring data indicates that an EQS has been exceeded then it signifies an unacceptable risk to the value (Figure 3) and therefore a management response should be implemented to restore environmental quality to within acceptable levels. Timeframes for restoring acceptable environmental quality will need to be determined on a case-by-case basis, but should be as short as reasonably practicable.

In cases where 'short-term' non-compliance with an EQO or level of ecological protection over a 'small' area is predicted and appears to be unavoidable, proponents could consider proposing temporary exclusion of an EQO or lower level of ecological protection for the small area. However, the proposal would need to be supported by additional monitoring and management to confirm that the desired long-term EQP and EQC have been reinstated following completion of the impacting activity. When determining the acceptability of such a proposal the EPA would consider the nature and reversibility of the effects, the spatial extent of the impact, timeframes for recovery and any other relevant matters.

In keeping with the risk-based approach, several EQS could be established for any particular environmental issue to give greater certainty that an effect has or has not occurred (multiple lines of evidence). Each consecutive EQS would be for an indicator situated further along the pressure/response pathway and provide greater certainty of environmental effect, and hence ensure that a management response is not triggered too early or too late. Good examples of this approach are found in the *Environmental Quality Criteria Reference Document for Cockburn Sound* (EPA, 2015) which is a supporting document to the *State Environmental (Cockburn Sound) Policy 2015* (Gov of WA, 2015).

Once the relevant indicators, and associated EQC, have been identified an environmental quality monitoring program can be designed to measure the selected indicators and assess performance against the EQC.

5 Guidance to proponents on applying the framework

This section contains the more detailed considerations for applying the EQMF to specific areas in the State's coastal waters. It has been divided into three sections that address:

1. how the framework is used in EIA,
2. key considerations for applying the framework to State marine waters, and
3. general guidance for stakeholder consultation.

When applying the EQMF in EIA there are two other key marine guidances related to the factor Benthic Communities and Habitats that may also need to be considered in the context of environmental quality:

- Technical Guidance - Protection of Benthic Communities and Habitats; and
- Technical guidance - Environmental Impact Assessment of Marine Dredging Proposals .

Technical Guidance - Protection of Benthic Communities and Habitats sets out a framework for proponents to present information to the EPA on the cumulative loss of benthic communities and habitats in an area. If a reduction in environmental quality caused by a proposal is predicted to cause significant and permanent losses of benthic communities and/or habitats then this guidance may also be relevant for EIA of the proposal.

Technical guidance - Environmental Impact Assessment of Marine Dredging Proposals is an activity based guidance that sets out an approach for presenting and managing the predicted impact of suspended sediment from dredging operations on benthic habitats and communities (shading, abrasion, sedimentation and clogging of feeding mechanisms), and the uncertainty associated with these predicted impacts. While this technical guidance only considers impacts over the limited time frames associated with individual projects, the EQMF is more focussed on the monitoring and management of longer term, more chronic effects on environmental quality. Nevertheless, the assessment and management of potential toxic effects from contaminants released during dredging, or of dredging impacts on the social environmental values (e.g. recreation and aesthetics or fishing and aquaculture) would be under the Marine Environmental Quality factor using this guidance, not the *Technical Guidance - Protection of Benthic Communities and Habitats*. This would require the inclusion of an EQP as well as environmental quality criteria for the relevant indicators as a component of the dredge and spoil disposal monitoring and management program.

5.1 Application through EIA

The EPA's objective for the environmental factor 'Marine Environmental Quality' is:

To maintain the quality of water, sediment, and biota so that the environmental values, both ecological and social, are protected.

To assess potential impacts on the Factor 'Marine Environmental Quality' proponents should consider and document all anticipated impacts in the context of the environmental values and environmental quality objectives (including levels of ecological protection) established, or proposed, for the area (see Section 4).

> Proponents should consider and assess the cumulative effects of their proposal which means considering their proposal as an addition to any effects of adjacent approved activities.

If there is an existing approved EQP (e.g. the *State Environmental (Cockburn Sound) Policy 2015*) that has established EQOs and the proponent's predictions suggest that after incorporation of mitigation strategies the cumulative effect of the proposed development is unlikely to meet the EQOs, then the proponent should provide maps highlighting where and over what area the EQOs are unlikely to be met if the new proposal was implemented.

If there is no existing approved EQP established for the area then the proponent should develop an EQP using the principles and approaches outlined in this Guidance. Proponents should engage with the community and relevant stakeholders in developing the EQP. The proposed EQP sets out the extent and severity of the predicted environmental impact of the proposal on the key environmental factor 'Marine Environmental Quality'. The proponent would therefore identify the environmental values to be protected and provide maps showing where the different EQOs are proposed to apply spatially. Proponents should therefore identify any areas where an EQO is proposed not to apply, or where a lower level of ecological protection may be proposed, with supporting rationale. This should include a consideration of cumulative effects from adjacent influences.

The spatial data sets used to prepare the maps will also need to be provided.

If a proposal is approved by the Minister for Environment, the Ministerial Statement will usually formally establish the EQP for the area if an EQP does not exist already. If an EQP for the area has already been established through Government policies, EPA position statements or decision making on proposals, or through approved management plans, any Ministerial Statement that varies the EQP will be considered as a formal amendment of the EQP. Where the OEPA holds existing spatial data sets showing the contemporary EQP for the area, proponents should request these data sets and use them as the base for showing any additional effects of their proposals.

Where another regulatory authority has accepted an EQP as a basis for its assessment of a discharge and the issuing of an approval or license, then that EQP should be considered established in the interim and proponents should use this for informing the EIA of subsequent proposals in the area.

> The EPA will consider the acceptability of a proposed EQP, or a proposed amendment to an existing EQP (and associated EQC), and advise Government through the environmental impact assessment process.

Environmental Quality Management Plans (EQMP) set out the details of monitoring, assessment and management programs that will be undertaken to ensure the EQOs, and hence the EPA's objective for the Factor, are met. Proponents are encouraged to consider and present EQMPs as part of the assessment process. Alternatively, EQMPs may be required through Ministerial conditions.

EQMPs may also be established for marine parks and reserves through the *Conservation and Land Management Act 1984* (CALM Act) or they may be developed outside a legislative framework as a tool for managing potential impacts in a defined area such as a port or marina.

EQMPs developed for monitoring and managing a specific project, or the construction of marine infrastructure, may have only local application and/or relatively short lifespans compared to EQMPs developed for broader regions and long-term operations. Nevertheless, where these two types of EQMP overlap they must still mesh with each other. Any departures from the regional EQMP should only be interim and agreed after consultation with key stakeholders. This would generally be achieved through the EIA process. It is implementation of the EQMF through the broader EQMP that goes some way toward ensuring that the cumulative impacts of individual discharges and activities are appropriately managed.

The EPA encourages proponents to regularly and publicly report on the assessment of environmental quality monitoring results against the EQC. Where exceedances of environmental quality criteria are identified, the reporting should be more frequent and include proposed management responses and timelines. Proponents are also encouraged to ensure monitoring data are collected using standard methods and are collated and stored in a location and format that maximises availability and utility for other uses.

5.2 Application to State marine waters

When applying the EQMF to marine waters there are a number of key steps that need to be undertaken.

Firstly, the marine system needs to be characterised to build understanding of the system. This may involve collating information on components and aspects of the system such as hydrodynamics, meteorology, biological communities, catchments, energy and nutrient inputs and flows, uses and threats to environmental quality and incorporating the information into a conceptual model of the system that shows the interrelationship between the various components.

The next step involves determining the primary management aims (EVs and EQOs/LEPs), preferably through community and stakeholder consultation as discussed in Section 4.

The EPA has already established environmental quality plans (EQPs) through its guidance documents and position statements for the coastal waters off the Perth metropolitan region (EPA, 2000) and for the Pilbara coastal waters (**http://epa.wa.gov.au/policies-guidance/pilbara-coastal-water-quality-consultation-outcomes**). At a more ad hoc level, the EPA has also endorsed EQPs for localised areas around specific development proposals that it has assessed.

The EQMF has also been applied more comprehensively to the heavily used waters of Cockburn Sound and given effect through the Government's *State Environmental (Cockburn Sound) Policy 2015* (Gov. of WA, 2015). To support this policy the EPA released two supporting documents: *Environmental Quality Criteria Reference Document for Cockburn Sound* (EPA, 2015) and the *Manual of Standard Operating Procedures for Environmental Monitoring against the Cockburn Sound Environmental Quality Criteria* (EPA, 2005). Through this package the environmental values, environmental quality objectives, levels of ecological protection and the specific environmental quality guidelines and standards are identified and spatially allocated. It also provides standard methods for measuring environmental indicators in the field to ensure that data collected by all stakeholders is compatible and comparable. The *State Environmental (Cockburn Sound) Policy 2015* is non-statutory and implementation is largely coordinated through the Cockburn Sound Management Council. The approaches outlined in this Technical Guidance for implementing the EQMF are used by the CSMC to prepare annual reports on the health of Cockburn Sound, formulate advice to Government, and to develop community engagement programs.

However, the majority of the State's marine waters are not covered by an existing EQP, including those significant areas given protection for conservation related purposes under the *Conservation and Land Management Act 1984*, the *Fish Resources Management Act 1994* and the *Rottnest Island Authority Act 1987*, and also some of the most intensively used sections of the coastline where multiple uses are not always compatible. The main benefit of having an agreed EQP for these waters is the common framework it provides for coordinating the monitoring and management of multiple, sometimes mutually exclusive, activities to a standard consistent with community expectations. The impacts of development activities and waste discharges, both individually and cumulatively, are able to be managed according to a single plan and it puts the focus onto those areas where environmental quality may be threatened or need improvement.

The following sections outline relatively simple and sound guidance and recommendations that should be used to apply the EQMF to marine waters in other parts of the State. Table 3 also summarises several key issues that should be considered when developing EQPs and how they have been addressed in previous assessments.

5.2.1 Marine protected areas

At the time of preparing this Guidance, Western Australia had a total of sixteen marine conservation reserves. Management plans are developed for all marine parks and reserves. They set out the ecological and social values to be protected and establish the specific objectives and associated long-term targets for each of those values.

Table 3: Some key issues and how they have generally been addressed in previous assessments.

Type of marine area	Environmental values expected to be protected	Indicative level of ecological protection	Areal extent	Environmental quality criteria	Comments
Adjacent to wastewater discharges (except treated sewage)	All	Low	Individually: very small (usually ~ 70m radius of outfall)	See Appendix 1.	If available, all low ecological protection areas should ideally be located within a moderate ecological protection zone. MEPAs should not be created for the sole purpose of locating LEPAs within them.
Adjacent to treated sewage discharges	All except Recreation and Fishing	Low	Cumulatively: very small, typically <1% of marine waters within a 10 km radius of the outfall.		Boundaries of the areas where the EVs 'Recreation' and 'Fishing' would not be protected need to be well justified.
Immediately adjacent to heavy industrial areas with current, or historical, waste discharges.	All	Moderate	As small as reasonably practicable to accommodate unavoidable impacts that preclude a high level of ecological protection. Typically < 10% of marine waters within a 10 km radius of the centre.	See Appendix 1.	
Ship berthing areas and turning basins within ports	All	Moderate	Typically ≤ 250 m from the edge of the infrastructure.	See Appendix 1.	To allow for accumulation of toxic contaminants from anti-foulant paints.
Marinas and harbours	All	Moderate	Entire marina or harbour, inside the entrance.	See Appendix 1.	
Aquaculture cages	All	Moderate	Portion of a lease that will contain actively fed sea cages. Cumulative area to be as small as reasonably practicable, typically <10% of marine waters within a 10 km radius of the lease.	See Appendix 1.	In some situations (eg. passive fed sea cages) impacts on environmental quality may be minimal and a moderate level of ecological protection may not be required.

Type of marine area	Environmental values expected to be protected	Indicative level of ecological protection	Areal extent	Environmental quality criteria	Comments
Fish habitat protection areas (conservation, fish protection, fish breeding or aquatic ecosystems)	All	Maximum, except for areas within 5 km of a major urban or industrial centre where a high LEP would apply (e.g. Cottesloe FHPA).	Boundary of the area allocated to the identified purpose.	See Appendix 1.	
Fish habitat protection areas (all other purposes)	All	High, although lower levels may be considered for fish culture and propagation	Boundary of the area allocated to the identified purpose.	See Appendix 1.	Boundaries for lower levels of protection will need to be well justified.
Rottnest Island waters	All	High	Boundary of Rottnest Island Marine Reserve.	See Appendix 1.	
Marine parks and reserves	All	Maximum, except for non-conservation areas in Marine Management Areas	Marine park or reserve boundary	See Appendix 1.	
Areas supporting World Heritage Value(s) that can be affected by waste discharges	All	Maximum, unless it can be demonstrated that a lower level will not impact the value(s).	Boundary of the world heritage area or a defined section of it.	See Appendix 1.	
General coastline except for marine parks and reserves	All	High	All State marine waters except areas identified above.	See Appendix 1.	

The values, management objectives and long-term targets described in marine park and reserve management plans can be readily aligned with the primary management objectives and EQC of the EQMF. Because the EQMF only considers 'values' that can be affected by pollution, waste discharges or deposits, the environmental values are a subset of the broader list of ecological and social values identified in marine parks and reserves. Environmental Quality Objectives under the EQMF are equivalent to Management Objectives for marine parks and reserves and different levels of ecological protection for the 'maintenance of ecosystem integrity' may be applied to different zones within marine parks and reserves consistent with the Conservation and Parks Commission long-term targets. The specific environmental quality targets for each marine reserve, or management zone/category within reserves, are provided in the relevant marine reserve management plan available from the Department of Parks and Wildlife.

A maximum level of ecological protection may be appropriate for most zones within Conservation and Parks Commission marine parks and reserves. In Marine Management Areas a high level of ecological protection may be appropriate for non-conservation areas. However, management plans sometimes allow for smaller areas in some zones to be managed to a lower level of ecological protection as specified in the plan or where approved by the appropriate government regulatory authority. Appropriate levels of ecological protection for these smaller areas are established on a case by case basis by using the EQMF to establish EQG and EQS that define a lower level of ecological protection without compromising the broader ecological or social values of that zone or the marine park/reserve as a whole.

Fish Habitat Protection Areas (FHPAs) are established under section 115 of the *Fish Resources Management Act 1994* by the Department of Fisheries for one or more of the following three purposes:

- the conservation and protection of fish, fish breeding areas, fish fossils or the aquatic ecosystem;
- the culture and propagation of fish and experimental purposes related to that culture and propagation; or
- the management of fish and activities relating to the appreciation or observation of fish.

All environmental values are expected to apply to FHPAs, but for 'Ecosystem Health' the relevant level of ecological protection for the EQO will be dependent on the purpose outlined in the Plan of Management. A maximum level of ecological protection may be considered appropriate where the purpose is conservation and protection of fish, fish breeding areas or aquatic ecosystems. A high level of ecological protection should provide a sufficient level of environmental quality for achieving the remaining purposes, although lower levels of ecological protection may need to be considered for small areas where fish culture and propagation is being undertaken. It should be noted that a FHPA may have more than one purpose assigned within it and that more than one level of ecological protection may therefore need to be allocated.

The Rottnest Island Reserve has been established under the *Rottnest Island Authority Act 1987* and within the reserve a number of sanctuary zones have been defined for the protection of representative marine habitats and functioning ecosystems for tourism, recreational activities, research and education programs. Management of the reserve is the responsibility of the Rottnest Island Authority in accordance with the Act.

The combined pressures of boating, people and proximity to the city and mouth of the Swan River suggests that an EQO with maximum level of ecological protection may not be achievable for the Rottnest sanctuary zones and that a high level of ecological protection may be more appropriate. For all Rottnest Island waters outside the sanctuary zones an EQO for a high level of ecological protection should be the aim for management.

5.2.2 General marine waters

Responsibility for developing an environmental quality plan (EQP) for new sections of State marine waters generally rests with the relevant management authority (e.g. Port Authority), or with proponents of development proposals. For canal estates Development Control Policy 1.8 (WAPC, 2012) sets out the roles and responsibilities of the different stakeholders. The community and relevant stakeholders should be consulted early in the process. Proponents are recommended to seek advice from the OEPA early in the pre-referral stage to ensure all issues are adequately addressed.

Where potentially significant risks to the marine environment exist in offshore State waters, the EQMF could be used to establish measureable performance objectives for contingency plans and environmental impact monitoring programs. It could also be used to guide the design of environmental monitoring programs for routine and/or accidental discharges in either State or adjacent Commonwealth waters (e.g. offshore islands and reefs on the north-west shelf and Timor Sea).

Formal establishment of an EQP can occur through various mechanisms such as the EIA process. In all cases, reporting against the relevant environmental quality guidelines and standards is expected to be a public process.

> The key recommendations that should be considered when developing an EQP for specific areas in State marine waters are outlined in Section 4 and in the text boxes throughout this document.

As outlined earlier in this guidance, the environmental values and environmental quality objectives for an area should reflect broader community uses, aspirations and desires, and hence be based on the outcomes of a consultation program. The consultation program should include all relevant community interest groups and stakeholders to ensure that - in addition to the strictly 'environmental' considerations - social, economic and other implications are properly understood and help inform the final decisions on these high level management aims. A broad consultation program is considered essential for engendering a shared ownership of the environmental quality management plan by the community and stakeholders, which in turn will facilitate implementation. Some broader guidance on undertaking consultation is provided in NWQMS Report 3 *Implementation Guidelines* (ARMCANZ & ANZECC, 1998).

Guidance has been provided in Appendix 2 for a consistent approach to modelling wastewater discharges (including dredging related plumes) that ensures model outputs, where required, are suitable for assessing against EQG established for the receiving waters. By considering the EQMF early in the proposal design phase it enables proponents to identify information gaps early in the process, to re-design as necessary their proposal to minimise impacts on environmental quality and to develop supporting management strategies that can be applied during the construction and/or operational phases to reduce impacts further.

Proponent impact predictions on environmental quality should be based around changes to key environmental quality indicators for each environmental value. Subsequent EQMPs should be focussed and designed around measuring and assessing any residual environmental concerns that remain after implementation of any mitigation management strategies. The final EQP and EQMP would be endorsed by the EPA for implementation and may be incorporated into Ministerial Conditions.

5.2.3 Ports

Western Australian ports range in size from relatively small single commodity export facilities such as Useless Loop up to the largest bulk commodity export port in the world at Port Hedland.

Ports are multiple use environments that are often associated with heavy industrial activities. Nevertheless, water and sediment quality surveys suggest that water quality in outer port areas (i.e. distant from inner ports and industrial or urban contaminant sources) is likely to be at near background levels (McAlpine *et al*, 2005a; McAlpine *et al*, 2005b; Wenziker *et al*, 2006; McAlpine *et al*., 2006; McAlpine *et al*., 2007 and McAlpine *et al*, 2012). Only a relatively small proportion of the broader port area is heavily utilised and requires careful planning, oversight and management to ensure that an acceptable level of environmental quality is maintained for the protection of all environmental values.

The EPA encourages Port Authorities to apply the EQMF to all marine waters within their boundaries and incorporate the resultant EQP into port environmental management systems (EMS) or port environmental management plans. This would facilitate management of the environmental performance of tenants and port service providers, and provide a framework that facilitates the long-term planning and development of ports. There are also a number of other benefits/advantages for the ports, including:

- provides a framework for Port Authorities to use when considering and assessing potential impacts of new developments within the port area against the environmental factor 'Marine Environmental Quality'. This has the potential to improve efficiencies and reduce timelines for the environmental impact assessment process and Ministerial authorisations.
- provides a planning and management framework to guide future proponents in the design of their proposals and their monitoring and management programs and for port authorities to ensure that environmental quality is maintained at levels suitable for all users;
- provides a basis for considering cumulative effects and the environmental impact assessment of port developments in the long-term;
- provides a framework for ensuring tenants and service providers are accountable for their environmental performance;
- allows for monitoring, management and reporting on environmental quality that is meaningful, easily understood, and clearly identifies areas where environmental values are, and are not, being protected;
- focusses attention onto those areas where environmental quality requires improvement, or in the case of development proposals, where predictions suggest that impacts on environmental quality may compromise the established environmental values;
- a mechanism for coordinating the monitoring and management of multiple, sometimes mutually exclusive, activities;
- cost and efficiency benefits through the implementation of one comprehensive port-wide environmental quality management plan that includes performance monitoring and management feedback loops for all relevant activities within the port; and
- the collection, collation and interpretation of monitoring data on a port-wide scale has potentially useful outputs for all parties (e.g. baseline data, calibration and validation data for modelling, etc.).

Port Authorities have management responsibility for the entire area within a port boundary. Although the EQMF should be applied to this broader area, the focus would be on the inner port area where most activities occur. The EPA is also aware that the EQMP may only be one component of a port wide EMS/environmental management plan that may also need to address a range of other issues unrelated to environmental quality (eg. marine fauna, benthic habitats or introduced marine pests – proponents should refer to the Department of Fisheries website for guidance on the regulation and management of introduced marine pests).

Port Authorities are responsible for developing and coordinating the implementation of EMS or environmental management plans for ports, however formal endorsement of the proposed environmental values and environmental quality objectives (including levels of ecological protection) would, where applicable, be through the environmental impact assessment and authorisation process under part IV of the *Environmental Protection Act 1986*. Each lessee could contribute to the implementation of the EMS or plan, which would be the primary tool for the port to assess the environmental performance of each tenant and port service provider as well as the port as a whole. Alternatively, individual monitoring and management programs from all the port users could be integrated through a port EMS or environmental management plan. The Port Authority would be accountable for the general environmental quality of the port and would therefore be responsible for ensuring that each individual tenant and service provider is held accountable for their environmental performance. If environmental quality within port waters is found to be impacted by activities external to the port then the relevant stakeholder(s) should be advised of the problem and encouraged to implement strategies to improve their environmental performance.

5.3 Consultation

The EQMF is fundamentally based on meeting broader community and stakeholder expectations for environmental quality. As set out above, there are a number of existing management frameworks for various parts of the marine environment. In the main these have been developed through extensive community and stakeholder consultation programs and the outcomes presented in the form of management plans.

In considering the extent to which consultation is required the EPA expects proponents and managers to consider the outcomes of previous consultation. For example, in the case of marine protected areas, given the extensive consultation that is involved in establishing the reserves and the zoning scheme within them, and the equivalencies between the marine protected area framework and the EQMF (refer to Section 5.2.1), the EPA does not expect that consultation to be repeated. Consultation is most important if there are proposals to significantly affect the EQOs of an area, including a reduction in the level of ecological protection, or in areas not covered by an existing EQP.

Proponents and managers are advised to take into account the location and associated level of public interest when considering the scope of consultation.

> Where the full list of EVs are proposed, and the levels of ecological protection are consistent with the recommendations set out in this Guidance, consultation can be relatively narrow and limited to local key stakeholders.

6 Monitoring, management and reporting

The protocols and procedures associated with monitoring, management and reporting on achievement of EQOs and protection of EVs are usually established and described in an environmental quality management plan (EQMP). The following section provides some additional guidance for implementing the EQMF through marine EQMPs and should be considered in combination with the *Environmental Impact Assessment (Part IV Divisions 1 and 2) Procedures Manual*.

The key elements of an EQMP should include:

- A description of the system to be monitored;
- The pressures, or threats, to environmental quality;
- An objective outlining the reason for monitoring and management;
- Duration of monitoring program;
- The indicators to be measured with a rationale for their use;
- Monitoring/sampling methodology and rationale (including site locations, frequency, depth, equipment, etc.);
- Analytical methods and limits of reporting for samples;
- Clear, measurable and auditable EQC for each indicator and the statistical methods for interpreting monitoring data against the EQC;
- The actions triggered when an EQG is exceeded;
- Management responses triggered when an EQS is exceeded; and
- Reporting mechanisms and timing.

A considerable amount of information and guidance for designing and implementing EQMPs is also available from the following three documents:

- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Chapter 7 (ANZECC and ARMCANZ, 2000a);
- *Australian Guidelines for Water Quality Monitoring and Reporting* (ANZECC and ARMCANZ, 2000b); and
- *Manual of Standard Operating Procedures for Environmental Monitoring against the Cockburn Sound Environmental Quality Criteria* (EPA, 2005).

While it is preferable that EQMPs are developed for on-going implementation across broad areas of the marine environment, it may also be necessary to develop EQMPs for monitoring and managing specific projects at a local scale and relatively short timeframes. Since implementation of the broader EQMP effectively addresses cumulative impacts in the area it is important that project specific EQMPs mesh with the broader plan and that any departures should only be considered interim for the life of the project and agreed after consultation with key stakeholders.

Objectives

The objectives of the monitoring program should be established early in the design phase and will be determined by the type of monitoring required. The types of issues that a monitoring program might be required to address include: pre-impact monitoring of baseline conditions at monitoring and at un-impacted reference sites; monitoring to determine whether EQG and/or EQS have been exceeded, and hence whether EVs are protected; and/or monitoring to confirm recovery of environmental quality after an impact has occurred. The first two types of monitoring program would generally be required if site-specific EQG and/or EQS needed to be derived (e.g. light attenuation coefficient or chlorophyll a) or if there was uncertainty over whether the EQG were appropriate for the area (i.e. potential mineral enriched area). As recommended in ANZECC & ARMCANZ (2000), proponents should ideally aim to collect 2 years of control site or reference site monitoring data for characterising baseline conditions and deriving locally relevant EQC. Some indicators may be seasonally variable and hence EQC may need to be developed on a seasonal basis. EQC may only need to be developed for those seasons where there is a risk of a significant impact on environmental quality.

> Ideally the collection of two years of reference site data is required for the derivation of site specific EQC. This should be undertaken by proponents prior to completion of assessment documentation to inform impact predictions and facilitate the development of environmental monitoring and management plans.

Design

The EQMP needs to be structured to achieve the objective(s). Selection of the indicators to be measured is based on an assessment of the pressures, threats and risks to maintaining an acceptable level of environmental quality in the area, and the pressure/response pathways identified for the system. The linkages between the indicators measured for the EQG and the indicators measured for the associated EQS must be clear and logical. Construction of a conceptual model of the ecosystem is a useful tool for identifying the energy and nutrient inputs and flow paths to undertake this assessment (see Section 4.3).

The frequency that each indicator is monitored and the lifespan of the EQMP should be determined based on the pressures and risks as well as the objective to be achieved, and may need to be agreed with the regulator.

When selecting un-impacted reference sites care needs to be taken to ensure they are representative of the impact sites, but located well away from the actual zone of influence for any existing pressures as well as the predicted zone of influence for the pressures from the proposed development. Where control sites are required to represent current baseline conditions (i.e. may be affected by existing surrounding pressures, but not the pressures from the proposed development) they need to be located well outside the zone of influence of the development.

> To account for modelling uncertainty reference sites and/or control sites should be located well beyond the boundaries of the modelled zone of influence for the pressure of concern.

For each selected indicator there may be more than one relevant EQG or EQS representing the different levels of quality required for protecting different environmental values. For the EQMP it is the most conservative EQG that should be selected as the focus for monitoring because if this guideline is met then by default the other EQG and EQS will also have been achieved and the associated values protected.

For a discharge with a known dilution gradient around the outfall, and where baseline concentrations have been accurately quantified, it may be more cost effective to measure concentrations of the contaminants of concern in the wastewater and then calculate the expected concentrations of the contaminants at the boundaries of the surrounding zones, using the predicted worst case dilution factor, to determine compliance.

Sampling

Sample analysis/measurement is a critical step and proponents need to ensure that the selected laboratory is NATA accredited and uses analytical methods that can achieve levels of reporting that are below the EQG or EQS. If the objective is to measure actual background concentrations of chemical indicators at ultra-trace levels in the marine environment then a specialist laboratory will be required with appropriate QA/QC methods included in their reporting. Advice should also be sought from the laboratory on appropriate sampling hygiene to ensure no contamination of the samples when sampling in the field or during storage. Similarly, if *in-situ* measurements are being taken then the accuracy and precision of the instrument should be fit for purpose.

Field measurement and/or sampling technique is also critical to obtaining high quality and consistent monitoring data that are comparable spatially and temporally. The use of standardised techniques has the additional advantage of producing data that can be compared across projects. The EPA therefore recommends that its Manual of Standard Operating Procedures for Cockburn Sound (EPA, 2005) is used as a guide when developing field sampling and measurement protocols. Proponents should also give consideration to where and how data are collated and stored (including electronic format) to maximise the availability and utility of the data for other uses.

Interpretation

It is recommended that the statistical methods used to assess monitoring data against the EQC are 'fit for purpose', practical, kept as simple as possible, are consistent with the recommended approaches in ANZECC & ARMCANZ (2000) and are included in the environmental quality management plans.

Measurement and interpretation of EQS based on *in-situ* measurements of biological/ecological indicators is a specialist field and advice should be sought from appropriate experts. A baseline condition will generally need to be established and reference or control sites required. Selection of the indicator and sampling method should be guided by the program objective(s) and consideration given to whether additional indicators should be included (multiple lines of evidence). Some relatively detailed advice on selection of biological/ecological indicators and their measurement can be found in ANZECC and ARMCANZ (2000a and 2000b).

The interpretation of environmental monitoring data against the EQG and EQS can also be a useful tool for refining any EQG where there is a significant degree of uncertainty. This may be an option if monitoring and assessment has consistently shown exceedances of the EQG over a significant period of time, but with no noticeable effect on the indicators that are compared against the associated EQS. Alternatively, in situations where exceedances of both the EQG and EQS occur almost simultaneously it suggests that the EQG has not been set at a level that provides early warning of a potential unacceptable impact and should be modified accordingly. While it may not be necessary to explicitly describe this feedback loop in an EQMP, proponents and regulators alike should recognise that this is a legitimate outcome of monitoring and assessment.

Management

Where an EQS has been exceeded the objective of the management response should be to ensure that there is no irreversible loss or long term damage to key biological/ecological indicators and to return environmental quality to an acceptable condition. If other stakeholders are partially or fully responsible for exceedance of an EQS then they should be made aware of the exceedance and encouraged to address the problem. Management response options should be identified early in the design phase of a development proposal so that any necessary infrastructure can be built into the design (e.g. ability to extend a diffuser). Inclusion of the range of feasible management responses in the EQMP is essential for providing confidence and clarity to all parties on how environmental quality can and will be maintained to protect all relevant environmental values.

The EQMF is a risk-based approach for managing environmental quality. The overarching intent is to keep below the EQG and never exceed the EQS. As such, some proponents may choose to implement management responses before an EQS is triggered, or confirmed to be triggered, so that environmental quality is returned to low risk levels and delays and costs associated with undertaking monitoring and evaluation against the EQS are avoided.

> The EQMF is a risk-based approach and it is recognises that at any point along the cause-effect pathway a decision may be made to implement a management response rather than to undertake a more comprehensive and potentially more costly phase of monitoring against an EQS.

Reporting

Monitoring data should be collated and interpreted against the EQC in accordance with the agreed statistical methods and reported in a timely manner. Routine reporting could be on a regular basis and reports should be publically available. The EPA also encourages proponents to make their environmental monitoring data available publicly to increase transparency and understanding of how the marine environment responds to different pressures. Reporting exceedances of EQG and/or EQS should be as soon as practicable and in accordance with any regulatory requirements. If there are no reporting requirements through regulation then proponents should ensure all relevant public authorities are notified of the exceedances and any proposed management responses as soon as practically feasible.

7 Acronyms and definitions

Acronyms

Acronym	Definition for the purpose of this Guidance
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agricultural and Resource Management Council of Australia and New Zealand
BCH	Benthic Communities and Habitats
CALM	Conservation and Land Management
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DER	Department of Environment Regulation
DEP	Department of Environmental Protection
EAG	Environmental Assessment Guideline
EPA	Environmental Protection Authority
EQC	Environmental Quality Criteria
EQG	Environmental Quality Guideline
EQO	Environmental Quality Objective
EQP	Environmental Quality Plan
EQS	Environmental Quality Standard
EQMF	Environmental Quality Management Framework
EQMP	Environmental Quality Management Plan
EV	Environmental Value
FHPA	Fish Habitat Protection Area
LEP	Level of Ecological Protection
MMA	Marine Management Area
NWQMS	National Water Quality Management Strategy
OEPA	Office of the Environmental Protection Authority
QA/QC	Quality Assurance and Quality Control
SWQMS	State Water Quality Management Strategy

Definitions

Word or phrase	Definition for the purpose of this Guidance
Background (conditions)	Natural environmental conditions that are largely un-impacted by anthropogenic influences.
Baseline (conditions)	Environmental conditions prior to being subject to pressures from a development or operation of concern.
Benthic Communities and Habitats (BCH)	Are functional ecological communities that inhabit the seabed and the areas of seabed that support these communities (eg. high relief reef, platform reef, sand, silt and the depth they occur at). The communities may include light dependent taxa (eg. algae, seagrass, corals, some sponges, mangroves) or animals that obtain their energy by consuming live or dead organisms (eg. ascideans, sponges, soft corals).
Contaminant	Biological (e.g. bacterial and viral pathogens) and chemical (see Toxicants) introductions capable of producing an adverse response in a biological system, seriously injuring structure or function or causing mortality.
Control site	A site located in an area that is unaffected by a pressure being monitored (generally up-current) and used for determining baseline conditions/ quality prior to becoming influenced by the pressure of concern.
Detectable change	A measurable change in an indicator (generally beyond the natural variability of that indicator) that is statistically significant.
Environmental Factor	A part of the environment that may be impacted by an aspect of a proposal. There are 14 environmental factors identified as relevant and practical for the EIA process (see the EPA's Statement of Environmental Principles, Factors and Objectives).
Environmental quality criteria	Environmental quality guidelines and/or standards.
Environmental quality guideline	A threshold numerical value or narrative statement which if met indicates there is a high degree of certainty that the associated environmental quality objective has been achieved.
Environmental quality indicator	A specific parameter that can be measured and used to indicate the quality of that part of the environment by comparing the measurements against the associated EQC for that parameter.
Environmental quality management framework	The framework adopted by the EPA and described in this Guidance for managing the quality for the marine environment to meet the EPA's objectives and the community and stakeholder's long-term desires. The main output of the EQMF is the EQP and EQMP.
Environmental quality objective	A specific management goal for a designated part of the environment that signals the level of environmental quality needed to protect the environmental value.
Environmental quality plan	A plan that identifies the environmental values that apply to an area and spatially maps the zones where the environmental quality objectives (including levels of ecological protection) should be achieved.

Word or phrase	Definition for the purpose of this Guidance
Environmental quality standard	A threshold numerical value or narrative statement that indicates a level which if not met indicates there is a significant risk that the associated environmental quality objective has not been achieved and triggers a management response.
Environmental value	Particular value or use of the environment that is important for a healthy ecosystem or for public benefit, welfare, safety or health and that requires protection from the effects of pollution, waste discharges and deposits.
Level of ecological protection	A level of environmental quality desired by the community and stakeholders for the EQO maintenance of ecological integrity.
Irreversible	Lacking a capacity to return or recover to a state resembling that prior to being impacted within a timeframe of five years or less (also see reversible).
Physico-chemical stressor	Refers to physical (e.g. temperature, electrical conductivity, total suspended solids) and chemical characteristics (e.g. dissolved oxygen concentration, nutrient concentrations) of water that can cause changes in biological systems.
Pollution	Where an emission causes direct or indirect alteration of the environment to the detriment of an environmental value.
Reference site	A site located in a similar system, or in a location that experiences similar natural environmental conditions as an area being managed, but largely un-impacted by anthropogenic influences and used as a benchmark for determining the environmental quality to be achieved.
Reversible	A capacity to return or recover to a state resembling that prior to being impacted within a timeframe of five years or less.
State coastal waters	The State coastal waters extend three nautical miles seaward from the territorial sea baseline.
Toxicant	A chemical capable of producing serious injury in an organism(s) or death at concentrations that could be encountered in the environment.
Uncertainty	In relation to prediction is doubt or concern about the reliability of achieving predicted outcomes.
WA Marine Waters	State coastal waters and waters within the limits of the state, excluding estuaries and other inland waters.
Waters within the Limits of the State	Waters on the landward side of the territorial sea baseline.
Xenobiotic	A foreign chemical not produced in nature and not normally considered a constituent of a specified biological system. This term is usually applied to manufactured chemicals.

8 Bibliography

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Technical appendices

Appendix 1 - Establishing relevant environmental quality criteria

A crucial step in developing an EQMP is to identify the relevant indicators and criteria that define acceptable and unacceptable environmental quality. This requires an understanding of the actual pressures and threats to the quality of the marine environment, how they affect environmental processes and ecosystem integrity and the likely initial and secondary signs of these effects. With these elements a conceptual model can be constructed and used to select the appropriate indicators of environmental quality. Clear and measureable EQG and EQS are then identified for the selected indicators. If they are too stringent they may trigger unwarranted concern. If too lax they can fail to identify problems before they become very difficult or too late to rectify.

In simple terms contaminants can be grouped into four broad categories based on the mode of effect.

- Physical contaminants include temperature, suspended sediments and turbidity, all of which can affect ecosystem processes such as respiration and photosynthesis. Physical contaminants can also affect social uses of marine waters by altering the clarity of the water or aesthetic characteristics.
- Biostimulants affect ecosystems by promoting the growth of particular organisms. In the case of plant nutrients such as inorganic nitrogen, the effects of excess nutrient is seen as increased biomass of fast-growing algae. These plants can then shade or smother other slower-growing organisms and cause undesirable effects. Organic material can stimulate the growth of organisms such as worms in sediments and change benthic community structure. In both instances the most reliable indicators of effect are not the biostimulants themselves; rather they are other biota that respond positively or negatively to the biostimulant.
- Toxicants on the other hand affect biological systems by 'poisoning' and the level of toxicity is generally concentration related. Toxic effects can be induced by either direct contact with elevated concentrations of toxicants in the surrounding media or through bioaccumulation/bioconcentration of toxicants in the tissues of marine organisms. Toxicants can cause reductions in growth rates, fecundity and mobility in affected organisms or, in extreme cases, mortality. Sensitivity to toxicants can vary with taxonomic group, trophic level and even between related species. Monitoring and management is initially based on measuring the concentration of the contaminant in water, sediment or biota and comparing the results against relevant criteria for that particular toxicant developed from actual biological effects data.
- Pathogenic contaminants increase the risk of disease and are an important consideration adjacent to sewage discharges, mainly affecting use of the surrounding waters by humans. In most instances risks are proportional to the concentration of these pathogens in water and biota.

For most environmental values numerical criteria for a range of potential indicators can be determined using the default trigger values or recommended approaches in ANZECC and ARMCANZ (2000). For indicators that relate to human health (e.g. indicators for recreational values and for seafood safe for human consumption) the EQC in EPA (2015) provide an accepted approach for WA waters, but up-to-date advice should be sought from the Department of Health which has primary responsibility for protecting public health in Western Australia. Guidance on suitable environmental indicators and guidelines for some aspects of human health can be found on the following Department of Health web page: **http://www.public.health.wa.gov.au/3/1287/2/publications.pm**

More specific advice for deriving EQG and EQS for indicators of ecosystem health is provided in the following sections. In general an EQG is likely to relate to a threshold concentration of a contaminant, or stressor, whereas an EQS is more likely to be based on a level of acceptable change in a biological or ecological indicator (i.e. at the response end of the pressure/response relationship).

1 Physico-chemical stressors (ecosystem health)

The term physico-chemical stressors refers to physical parameters (e.g. water clarity, suspended sediment and temperature), biostimulants (e.g. nutrients), pH, salinity and dissolved oxygen. Often the stressors themselves can be measured and used as an indicator of environmental quality, but in some cases other measures can also be used as an environmental quality indicator for a stressor (e.g. light attenuation coefficient for water clarity, turbidity for suspended sediment concentrations, chlorophyll a for the effects of nutrients).

ANZECC & ARMCANZ (2000) provides generic default guideline trigger values for a number of physico-chemical stressors that could be applied across broad swathes of Australia, and that could be used as EQG. However, when considering a specific area, it strongly recommends deriving more robust and locally relevant guidelines using baseline data from suitable un-impacted reference sites because the natural range of physico-chemical stressor concentrations are often locality specific, and the biological communities found in a locality are generally adapted to these natural background conditions. Reference sites must be located beyond the influence of anthropogenic pressures, ideally in areas allocated a high or maximum level of ecological protection and likely to remain un-impacted over time.

The method for deriving EQG using this approach involves gathering sufficient un-impacted baseline data on each indicator (ideally a minimum of 20 measurements) for the relevant season(s) (if no seasonal variation then data from the entire year can be used). This baseline data set can be used to derive specific numerical values based on percentiles that can then be used as EQG for specific levels of ecological protection. This is shown in Table 1 for the four levels of ecological protection.

The *median* value for an indicator measured at the impact site(s) is then assessed against the relevant EQG.

For areas allocated a maximum level of ecological protection there should be no detectable change from natural variation. This could be determined using statistical techniques for comparing potentially impacted sites with un-impacted reference sites, or for identifying a change in an indicator from historical conditions, and using an appropriate level of statistical significance and statistical power agreed with the key stakeholders. Alternatively, a simpler approach is to use a conservative percentile of an un-impacted baseline data set to derive an EQG as described above.

For the management of nutrient enrichment issues the EPA does not recommend using concentrations of nutrients in marine waters, but instead recommends that productivity indicators are monitored (e.g. chlorophyll a, algal biomass, etc.) as EQG.

Table 1: Preferred methods for deriving EQC for the different indicator types and EQOs for the EV 'Ecosystem Health'. (Based on the recommended approaches and trigger values in ANZECC & ARMCANZ (2000) with some adaptation for the Western Australian marine environment.)

Indicator Type	Max LEP	High LEP	Mod. LEP	Low LEP
EQG for physico-chemical stressors	No detectable change from natural background	20th and/or 80th percentile of natural background, whichever is relevant	5th and/or 95th percentile of natural background, whichever is relevant	No EQG apply
EQG for Toxicants in water	*Naturally occurring*: No detectable change from natural background *Xenobiotic*: No detection using lowest available analytical limits of detection	99% species protection trigger values, except for cobalt where the 95% species protection trigger is recommended.	90% species protection trigger values	80% species protection trigger values for potentially bioaccumulating/ bioconcentrating chemicals
EQG for Toxicants in sediment	*Naturally occurring*: No detectable change from natural background *Xenobiotic*: No detection using lowest available analytical limits of detection	ISQG-low* trigger values	ISQG-low* trigger values	ISQG-low* trigger values but only for potentially bioaccumulating/ bioconcentrating chemicals
Bioaccumulation/ Bioconcentration of toxicants (EQS)	No detectable change from natural background	80th percentile of tissue concentrations in filter or deposit feeder at suitable reference site.	No EQS apply	No EQS apply
Biological indicators (EQS)	No detectable change beyond natural variation	No detectable change beyond natural variation	No detectable change in biodiversity, small changes in abundance and biomass and rates of ecosystem processes (e.g. 95th percentile of background)	No EQS apply

* Interim sediment quality guideline – low range.

2 Toxicants in water (ecosystem health)

Toxic contaminants can be naturally occurring chemicals (e.g. metals, some polycyclic aromatic hydrocarbons, ammonia[1], etc.) or man-made compounds (xenobiotic). For EVs that relate to human health the environmental quality criteria for toxicants are designed to ensure people are protected from any toxic effects. EQG recommended for managing potential environmental effects on ecosystem health are generally based on ecotoxicological studies (measureable biological effects). The guideline trigger values for *toxicants in water* provided in ANZECC and ARMCANZ (2000) are based on actual biological effects data for a range of species and are recommended for use as EQG. Different values are recommended for different levels of species protection (e.g. 90% species protection). Table 1 specifies which level of species protection from ANZECC & ARMCANZ (2000) applies to which level of ecological protection for 'maintenance of ecosystem integrity' in WA marine waters. Of particular note is that the only indicators for which EQG would apply in low ecological protection areas are contaminants that can potentially bioaccumulate/bioconcentrate. If one of these EQG is exceeded then an assessment against an EQS based on bioaccumulation/bioconcentration would be triggered, but only in the adjacent high ecological protection area. The objective of the methodology for evaluating bioaccumulation/bioconcentration in the high ecological protection area should ensure no detectable changes beyond natural variability.

The recommended approach for assessing toxicant levels in water is more conservative than that recommended for physico-chemical stressors because the EQG are based on actual biological effects data and so exceedance of the EQG implies there is potential for an effect. For toxicants in water it is not the median that is compared against the criterion, instead it is the 95th percentile of the data from the impact site(s) that is calculated and compared against the EQG.

Where no guideline trigger values are available for naturally occurring toxicants in water then an interim EQG can be derived from the 95th percentile of natural background concentrations and applied to high ecological protection areas (and could be considered for moderate ecological protection areas). But in this case it would be the median of the impact site(s) that is assessed against the interim EQG. For xenobiotic chemicals any detection at the lowest analytical limit of reporting should trigger an assessment against a relevant EQS. Alternatively, ecotoxicological studies could be undertaken to determine a suitable criterion.

For maximum ecological protection areas, appropriate statistical techniques should be used to determine whether there has been a statistically significant change at a potential impact site compared with an un-impacted reference site, or for identifying a change from historical concentrations. The level of statistical significance and statistical power should be 'fit for purpose' and agreed with the key stakeholders.

It should be noted that background water quality surveys undertaken by the OEPA in collaboration with the CSIRO have consistently found background levels of naturally occurring toxicants dissolved in seawater to be extremely low along the West, Pilbara and Kimberley coasts of WA, similar to levels found in oceanic waters (McAlpine *et al*, 2005a; McAlpine *et al*, 2005b; Wenziker *et al*, 2006; McAlpine *et al*, 2012). No concentrations were found to exceed the most stringent ANZECC and ARMCANZ water quality guidelines for the EV 'Ecosystem health' (99% species protection) outside ports and harbours, with the exception of cobalt. The 99% species protection trigger value for cobalt is extremely low, approximating actual measured natural background concentrations, and is considered to be an artefact of the limited dataset available for its derivation. Apart from cobalt, the available evidence suggests that dissolved concentrations of toxicants are not expected to naturally exceed the 99% species protection trigger values anywhere in WA marine waters. For cobalt the 95% species protection trigger value is recommended for use in areas of high ecological protection until the trigger level is revised.

[1] It should be noted that ammonia can also be a bio-stimulant at low concentrations.

Where proponents don't have accurate ultra-trace analyses for the marine waters surrounding their proposal they are encouraged to use the data from the studies referred to above. Furthermore, the EPA expects proponents that claim ANZECC and ARMCANZ guideline trigger values are exceeded by local natural conditions to present a strong case based on quality assured sampling and analysis techniques and supported by independent expert review.

3 Toxicants in sediment (ecosystem health)

The sediment quality guidelines for *toxicants in sediment* (ANZECC and ARMCANZ, 2000) are recommended to be used as EQG. It should be noted that these guidelines are based on semi-quantitative biological effects data from North America and are therefore considered to be less reliable than the trigger values for toxicants in water. The median of impact site data are therefore used to compare against the sediment quality EQG to assess sediment quality. Recommended EQG for the different levels of ecological protection are provided in Table 1.

For maximum ecological protection areas, appropriate statistical techniques should be used to determine whether there has been a statistically significant change at a potential impact site compared with an un-impacted reference site, or for identifying a change from historical concentrations. The level of statistical significance and statistical power should be 'fit for purpose' and agreed with the key stakeholders.

Where no ISQG-low are available for naturally occurring toxicants in sediment then interim EQG can be derived for high and moderate ecological protection areas by multiplying the median of natural background concentrations by a factor of two. For xenobiotic chemicals in sediments, any detection at the lowest analytical limit of reporting should trigger an assessment against a relevant EQS. Alternatively, ecotoxicological studies could be undertaken to determine a suitable criterion.

It should be noted that background sediment quality surveys undertaken by OEPA staff have found concentrations of arsenic, nickel and chromium in sediments at levels approximating the ISQG-low sediment quality guidelines in some very localised areas along the Pilbara coast (McAlpine *et al*, 2006). All other contaminants tested were either well below the relevant sediment quality guidelines, or below the analytical limit of reporting (McAlpine *et al*., 2006; and McAlpine *et al*., 2007).

4 Biological indicators (ecosystem health)

Biological indicators are the most relevant indicators for establishing EQS since they are located towards the response end of the pressure/response pathway and provide an evidence-base to support decision-making. Changes in biological indicators suggest 'real' effects and EQS can therefore be set at levels that represent the threshold of an unacceptable level of change. However, as mentioned previously, biological indicators are particularly recommended for managing nutrient-related pressures and may be used to establish both EQG and EQS.

Depending on the indicator being measured, assessment against the EQS may be undertaken *in-situ* (e.g. community composition), in the laboratory (e.g. toxicological testing) or using samples collected *in-situ* but measured in the laboratory (e.g. chlorophyll *a*). There is a considerable amount of guidance provided in ANZECC and ARMCANZ (2000) for the selection, monitoring and assessment of biological indicators, although the EPA suggests keeping the approaches as simple as possible and with quick turn-around times. Also there should be a preference for monitoring methodologies that are efficient and effective, and that do not involve destructive sampling. Guidance for establishing EQS for biological indicators in the different levels of ecological protection is provided in Table 1.

The objective for maximum and high ecological protection areas is no detectable change beyond natural variation. For some indicators of seagrass health (eg. seagrass shoot density) the 20th percentile at a suitable reference site has been taken to represent the limit of natural variability and so is assessed against the median of potential impact site data to represent an EQS as part of a multiple lines of evidence approach (e.g. EPA, 2015). Seagrass health, primarily measured as seagrass shoot density in perennial meadows, is commonly used as a nutrient-related EQS in the south-west of the State. This can be replaced by indicators of coral health (eg. bleaching and partial mortality) where corals dominate. Where macroalgal reefs dominate, persistent shifts in species composition to more opportunistic species can provide a useful line of evidence for decision making. A similar approach can be taken for chlorophyll a concentrations, but this indicator may more suitable as an EQG.

Alternatively, appropriate statistical techniques could be used to determine if there has been a statistically significant change in a biological indicator at a potential impact site compared with an un-impacted reference site, or to identify a change in the indicator from a historical baseline. The level of statistical significance and statistical power should be ‘fit for purpose’ and agreed with the key stakeholders.

5 References

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Appendix 2 - Guidelines for modelling environmental quality variables affected by wastewater discharges for the purposes of EIA

Introduction

In Western Australia an environmental quality management framework (EQMF) has been developed specifically for use in the State's marine coastal waters for the protection of five fundamental environmental values from the effects of pollution, waste discharges and deposits. A key environmental quality objective (EQO) of this framework is 'Maintenance of Ecosystem Integrity' which may be defined in terms of four different levels of ecological protection (LEPs) that apply spatially, each corresponding to a different environmental health condition. The levels of ecological protection are designated:

- Maximum;
- High;
- Moderate, and
- Low

Environmental quality criteria (EQC) quantitatively specify the environmental quality conditions that are required for the achievement of each EQO, or for each LEP in the case of 'Ecosystem Integrity'. EQC for each EQO have been defined for many contaminants and physico-chemical parameters of ecological concern (ANZECC & ARMCANZ, 2000) and guidance on how these would be applied to each LEP for the EQO 'Maintenance of Ecosystem Integrity' can be found in Appendix 1 of this Technical Guidance and to some extent EPA (2015), McAlpine *et al* (2006), McAlpine *et al* (2007).

The environmental quality management framework may be applied to environmental impact assessment of development proposals involving point source wastewater discharges to the marine environment, including dredge plumes. In this context numerical simulation models are used to predict the spatial extent, temporal variability and concentration (or magnitude) of contaminants in waste dispersion fields or of significant physico-chemical parameters (e.g. dissolved oxygen concentrations and TSS) that may be adversely affected by certain wastewater discharges. It should be noted however, that the modelling guidance offered in this appendix is not relevant for predicting the impacts of suspended sediment on marine biota. This issue is addressed through the approaches and recommendations in *Technical guidance - Environmental Impact Assessment of Marine Dredging Proposals*.

The model output predictions are delivered as the outcome of numerical computations based on a spatial grid which divides the marine space being modelled into small cells, and in a time series for each cell with a fixed time increment. The model output provides a value for the modelled parameter for each cell, and for each incremental time step.

In some cases where vertical variation in the waste dispersion field is important (e.g. a heated water discharge forming a buoyant surface plume) it may be necessary to select the maximum or minimum for each cell and time step, or some depth-weighted average of the concentrations modelled within the water column for each cell and time step (depending on which of these induces the greatest environmental effect).

For each cell, using the time-series data generated by the model, the relevant percentile for the modelled parameter can then be determined and assessed against the relevant EQC. The location and spatial extent of the areas where the different EQOs (including LEPs) are predicted to be met can then be defined in horizontal space and represented on a scaled map of the area.

It can then be determined whether:

- the water quality predicted as a consequence of the proposed waste discharge or dredge plume is consistent with the EQOs and LEPs that have been assigned by managers to the areas surrounding the source of the stress and, if not,
- the spatial extent and severity with which each EQO/LEP is predicted not be met.

Various EQC may be used (as appropriate) to assess model output data and predict the boundaries of the areas where each of the relevant EQOs and LEPs are likely to be met.

It has been noted that although proponents are applying the environmental quality management framework, the approach to describing the outcomes of the modelling, and/or depicting the outputs of the simulation models, often differs between proposals. The intent of this appendix is to impart consistency to the presentation of model outputs showing predicted zones of environmental effect and to the terminology used.

The following section illustrates, with reference to a specific wastewater discharge example, the process of analysing the criteria, selecting appropriate dispersion model output metrics, comparing these metrics with the criteria, and presenting the spatial distribution about the wastewater discharge of predicted levels of ecological protection.

Presentation of predicted ecological protection levels about a contaminant discharge - an example

Consider the discharge and dispersion of a toxicant such as dissolved copper. The concentration of dissolved copper in the dispersion field generally decreases with distance from the source. The level of ecological protection increases (i.e. ecological effect decreases) with *decreasing* concentration.

A brief discussion of percentile statistics is provided in Appendix 1 of this Technical Guidance, since specified percentile values of the model outputs are frequently employed in environmental quality criteria for the levels of ecological protection.

In the present example the assessment would take the general form “95^{th} percentile value of the stressor concentration < = EQC”. This means that for *most of the time* the concentration should be *below* the specified environmental quality criterion for that level of ecological protection. “95^{th} percentile value = EQC” defines the inner (i.e. closest to the source) boundary of the zone where that level of ecological protection is predicted to be achieved. The outer boundary for that zone coincides with the inner boundary of the adjacent zone where a more highly protected (less impacted) category is predicted to be achieved.

Table 1 sets out the key elements of the EQC for copper. Table 1 also illustrates a number of decisions that must be made in preparing (or post-processing) model output data for comparison against the environmental quality criteria. For example:

- the units of the modelled copper concentration data need to be consistent with the units used in the criteria;
- the modelled copper concentration data need to incorporate (or account for) background concentrations;
- the model needs to simulate the copper concentration field for specified periods agreed with environmental managers; and
- if the modelled copper concentrations have significant vertical variation, then it may be appropriate to output the maximum water column concentration for each model cell and time step to ensure that the extent of the zones of low and moderate LEP are not underestimated.

The model output data then need to be processed to determine the 95th percentile values of the simulated copper concentration time-series that will be used to predict the extent and location of the zones. For each model cell the 95th percentile value needs to be assessed against the environmental quality criteria values to determine which level of ecological protection can be met in the small geographical area corresponding to that cell.

Figure 1 illustrates a small portion of the model grid and, for each grid cell, shows the 95th percentile values for the maximum copper concentration throughout the water column of that grid cell calculated over the agreed simulation period. At some of these grid cells the values are less than 3 μg/L and therefore meet the Moderate Ecological Protection guideline for copper. At some other cells they are greater than 3 μg/L and do not meet this guideline. The white shading in Figure 1 indicates the areas where the Moderate LEP can be met. The pink shading indicates the areas where the Moderate LEP is predicted not to be met and these areas would therefore have a Low LEP.

Table 1: Example of criteria analysis and selection of model output metrics to ensure that they are compatible with (and valid for comparisons against) the environmental quality criteria.

Elements of EQC to consider[2]	Example – toxicant stressor
Severity of Ecological Effect	Moderate Ecological Protection
Stressor Variable	Dissolved copper concentration
Stressor-related model output variable[3]	As above (it is assumed that dissolved copper behaves as a conservative tracer)
Units of stressor-related model variable	μg/L
Excess (above background) or absolute value?	Absolute value[4]
Water column representation	Maximum value in water column at each model cell
Ecological response type	Ecological effect increases with increasing copper concentration
Metric of stressor-related model output variable	95th percentile
Magnitude of the threshold for the stressor-related model variable metric	< 3 μg/L
Time period over which metric is calculated	To be agreed with regulator (e.g. six successive periods of two months duration spanning a full calendar year[5]) A model output time step of one hour would be appropriate.

[2] Time-series outputs for individual model cells will be independently assessed against these criteria.

[3] If the primary stressor variable is not directly simulated by the model then a relationship needs to be developed between the primary stressor variable and a "stressor-related model output variable" that is simulated by the model.

[4] If the model outputs are values "in excess of background" and the reference point values are "absolute", then it will be necessary to add a value for ambient background concentrations to the model output, before assessing model results against the criteria.

[5] In this case an envelope would be drawn around the six realisations of the LEP zone to derive a composite LEP zone.

Figure 2 illustrates (at a broader spatial scale than Figure 1) a plot of the 95th percentile of the copper concentration against horizontal distance from the source along a direction represented by the model grid row A-A' in Figure 1. The dots are values of the 95th percentile calculated at successive cells along a row of the model grid denoted by A-A'. These discrete values, determined by the model, may be interpolated to form a curve. Figure 2 also illustrates how the extent of the different levels of ecological protection can be determined with reference to the environmental quality criteria.

Figure 3 illustrates a plan view of the areas where environmental quality guidelines for high, moderate and low ecological protection are predicted to be met by the modelled copper discharge dispersion field.

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Boundaries between different LEP are defined by contours	
Boundary	**95th Percentile [Cu] (µg/L) Contour level**
Mod / High	= 1.3
Low / Mod	= 3

Environmental Quality Guideline	
LEP	**95th Percentile [Cu] (µg/L)**
High	≤ 1.3
Moderate	≤ 3
Low	Moderate LEP guideline not met

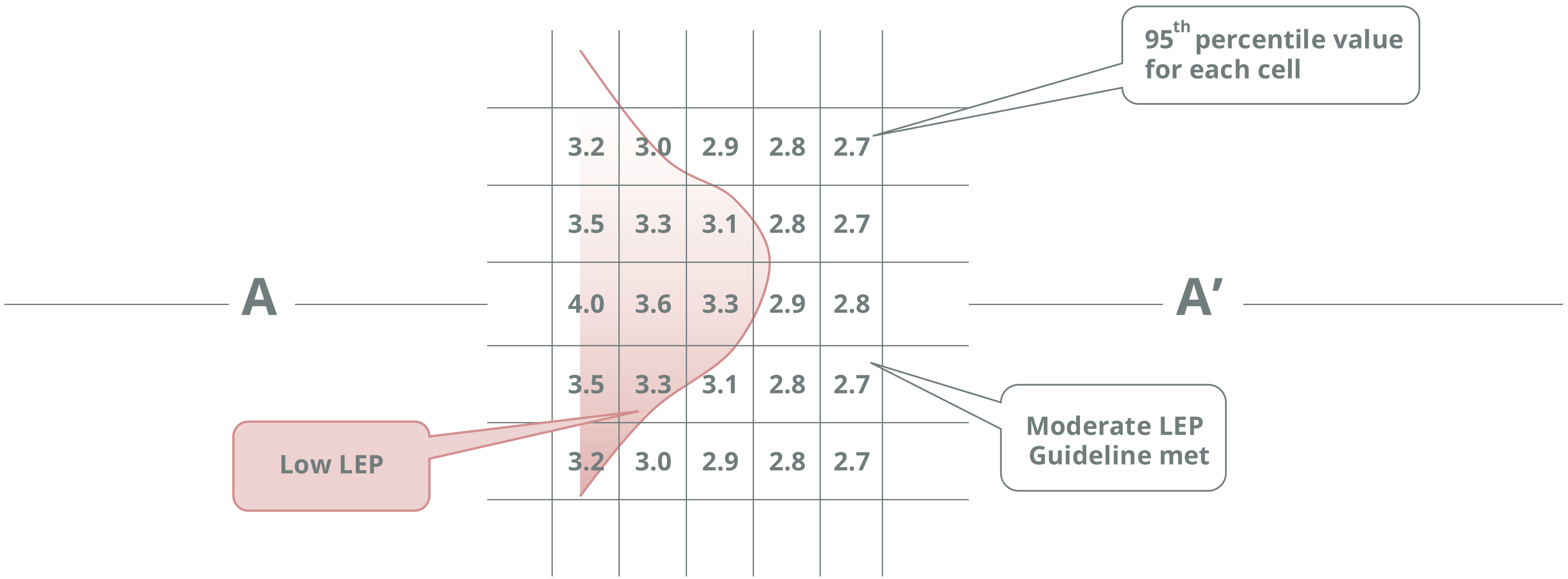
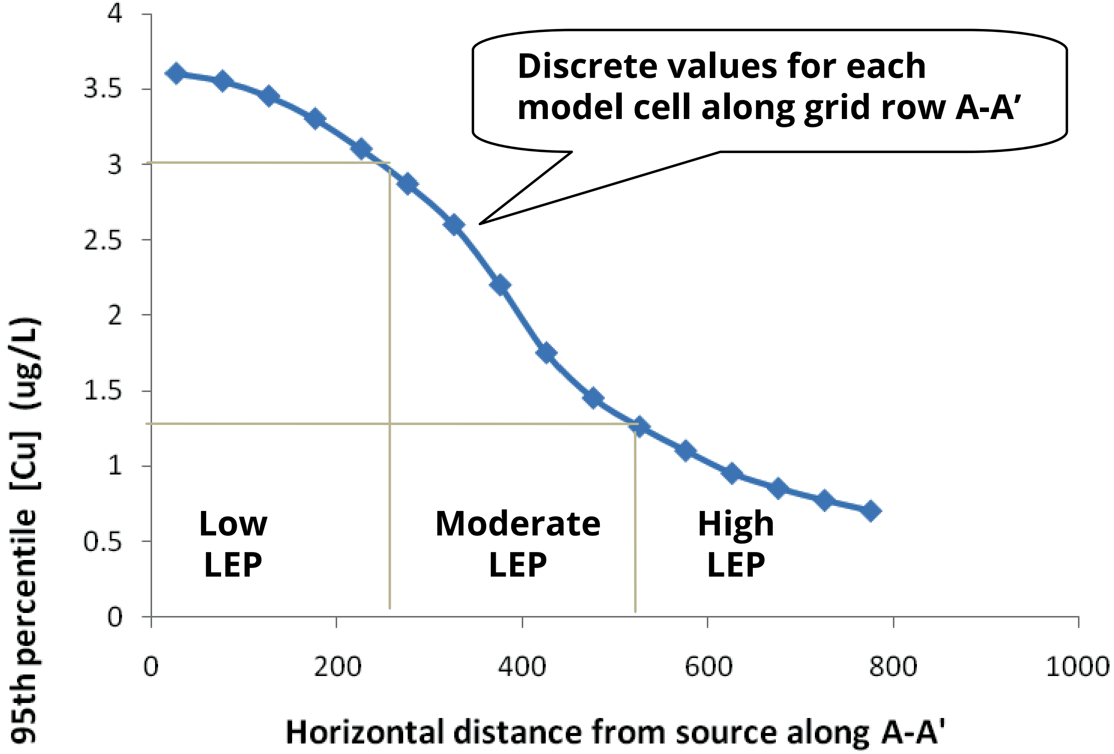


Figure 1: Portion of the model grid, showing the 95th percentile values of copper concentration derived from model output data over the agreed period of simulation for each grid cell. The white shading denotes areas where the moderate LEP guideline is met. The pink shading represents areas where the moderate LEP guideline is not met and would need to be assigned. Model grid row A-A′ is referred to in Figures 2 and 3.



Environmental Quality Guideline	
LEP	**95th Percentile [Cu] (µg/L)**
High	≤ 1.3
Moderate	≤ 3
Low	> 3

Contour values which define LEP area boundaries	
Boundary	**95th Percentile [Cu] (µg/L)**
Mod / High	= 1.3
Low / Mod	= 3

Figure 2: The predicted spatial distribution of *Low*, *Moderate* and *High* Levels of Ecological Protection about a contaminant (dissolved copper) discharge, illustrating the use of Environmental Quality Guidelines and dispersion model outputs to derive the extent of the spatial zones

Environmental Quality Guideline	
LEP	**95th Percentile [Cu] (µg/L)**
High	≤ 1.3
Moderate	≤ 3
Low	> 3

Contour values which define LEP area boundaries	
Boundary	**95th Percentile [Cu](µg/L)**
Contour Level	= 1.3
Mod / High	= 1.3
Low / Mod	= 3

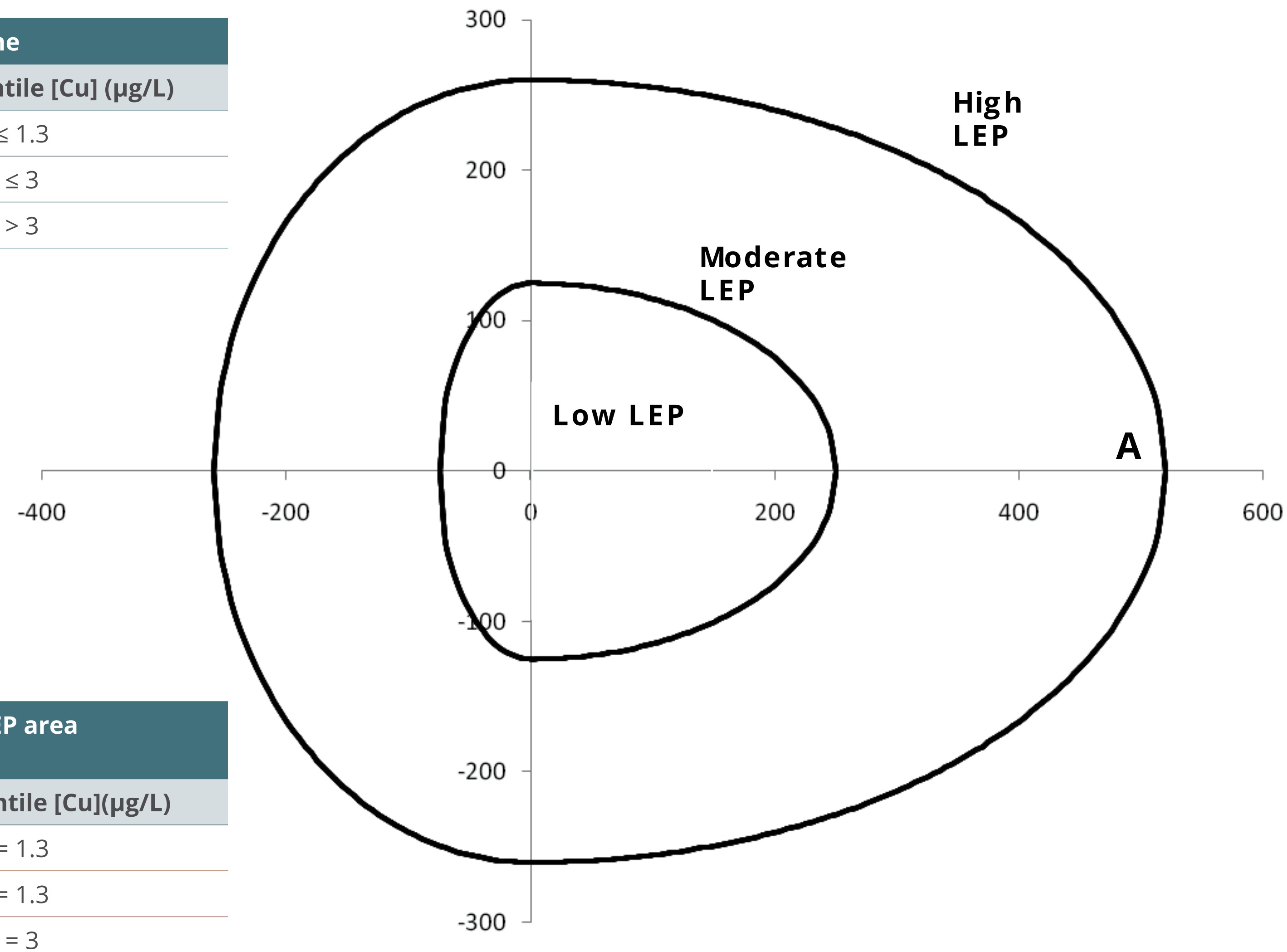


Figure 3: A plan view of the predicted spatial distribution of *Low*, *Moderate* and *High* Levels of Ecological Protection about a contaminant (dissolved copper) discharge located at (0,0).

Environmental Protection Authority 2016, *Technical Guidance – Protecting the Quality of Western Australia's Marine Environment*, EPA, Western Australia.

This document is available in alternative formats upon request.

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