Government of **Western Australia**
Department of **Water and Environmental Regulation**

# Murujuga Rock Art: Environmental Quality Management Framework

Department of Water and Environmental Regulation
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# Contents

# 1 The Environmental Quality Management Framework

## 1.1 Proposed approach

The Murujuga Rock Art Strategy (Department of Water and Environmental Regulation 2019) establishes the framework for the long-term management and monitoring to protect the rock art (petroglyphs) on Murujuga from the impacts of anthropogenic emissions.

An Environmental Quality Management Framework (EQMF) will be implemented to provide a transparent, risk-based and adaptive framework for monitoring and managing environmental quality to protect the rock art on Murujuga from anthropogenic emissions. The EQMF will establish common and agreed Environmental Quality Objectives (EQO) and scientifically-based limits of 'acceptable' change.

The intent of the EQMF is to achieve a balance between certainty and responsiveness and to ensure the best and most up-to-date scientific information is used to inform decision-making while recognising that there are currently knowledge gaps. This approach has been successfully applied in other situations in Western Australia (and other jurisdictions), including where there are no established guidelines as triggers for management responses.

The key elements of the EQMF are shown in Figure 1.

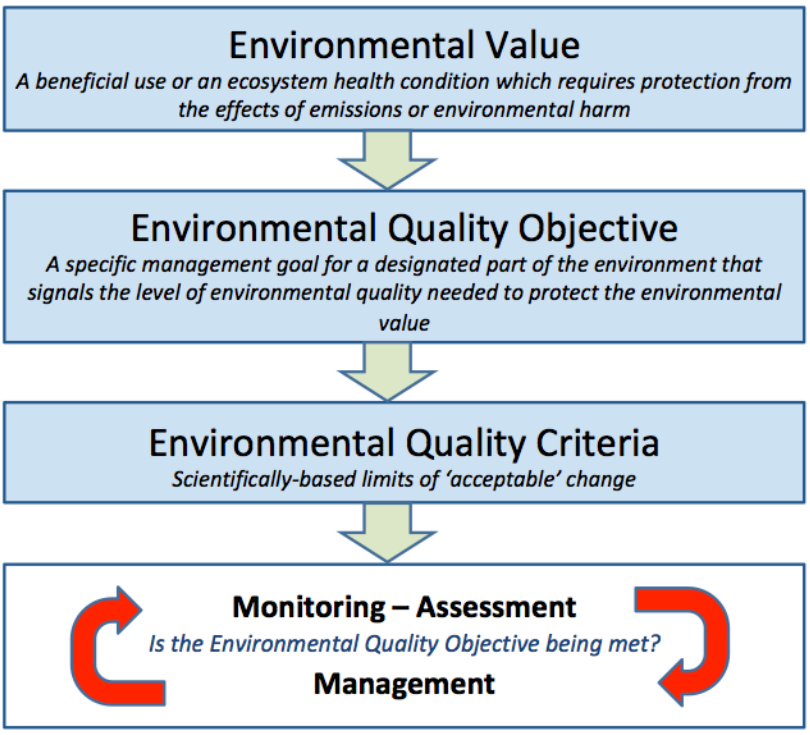


**Figure 1: Structural elements of the Environmental Quality Management Framework**

The EQMF comprises:

- **Environmental Values**, which form the basis of the EQMF. Environmental values include 'beneficial uses'[1] or 'ecosystem health conditions'.[2]
- **Environmental Quality Objectives** (EQO), which are the primary management objectives that describe the environmental quality that must be achieved to protect the environmental values. EQO are measureable and should be incorporated into the key objectives for environmental quality monitoring.
- **Environmental Quality Criteria** (EQC), which are the scientifically-based limits of 'acceptable' change to a measurable environmental quality indicator that is important for the protection of the associated environmental value (i.e. environmental quality thresholds). 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.

  EQC are benchmarks against which environmental monitoring data are compared in order to determine the extent to which the EQOs have been met and triggering an appropriate management response if an EQC is exceeded. EQC should be developed for a range of environmental quality indicators to assess the responses to the main pressures.

  A fundamental requirement of EQC is that they should be clear, readily measurable and auditable. Wherever possible there should be a standardised approach to the measurement of the indicator and comparison of the resulting data against the EQC.

  EQC are applied through a risk-based approach that is intended to capture any uncertainty around the level of impact by staging monitoring and management responses according to the degree of risk to environmental quality. Where there is some uncertainty around the specific threshold value of an EQC, a precautionary approach should be adopted with the benefit of doubt weighted toward protection of the environmental value.

There are two types of EQC:

- **Environmental Quality Guidelines (EQG)** are threshold numerical values or narrative statements that, if met, indicate there is a low risk of adverse

[1] 'Beneficial use' includes a use of the environment, or of any portion thereof, which is conducive to public benefit, public amenity, public safety, public health or aesthetic enjoyment and which requires protection from the effect of emissions or indirect or direct alteration of the environment to its detriment or degradation or potential detriment or degradation (environmental harm) (Section 3 of the *Environmental Protection Act 1986*).

[2] 'Ecosystem health condition' includes a condition of the ecosystem which is relevant to the maintenance of ecological structure, ecological function or ecological process and which requires protection from the effects of emissions or indirect or direct alteration of the environment to its detriment or degradation or potential detriment or degradation (environmental harm) (Section 3 of the *Environmental Protection Act 1986*).

environmental effects and a high degree of certainty that the associated EQO has been achieved. Routine monitoring and assessment would continue.

EQG are generally relatively simple and easy to measure and are based on indicators located closer to the pressure end of the pressure / response (cause / effect) pathway. EQG provide early warning of potential environmental effects.

If the EQG are not met, then there is an increased risk of adverse environmental effects and uncertainty about whether the EQO has been achieved. If an EQG is exceeded, this triggers a more detailed assessment against the Environmental Quality Standard (EQS) to determine if the environmental value is at risk. This assessment is risk-based and investigative in nature. The linkages between the indicators measured for the EQG and the indicators measured for the associated EQS must be clear and logical.

- **Environmental Quality Standards (EQS)** are threshold numerical values or narrative statements which, if not met, indicate there is a high risk of adverse environmental impacts and that the associated EQO has not been achieved.

  EQS are generally more difficult to measure and based on indicators located at the response end of the pressure / response (cause / effect) pathway. Changes in the indicators measured for the EQS suggest 'real' effects and EQS should therefore be set at levels that represent the threshold of an unacceptable level of change.

  To provide greater certainty, a number of indicators should be assessed that are directly relevant to a particular threat or issue. The consistency of interpretation between the different lines of evidence (i.e. 'multiple lines of evidence' approach) will give greater certainty to the assessment and provide the robustness necessary to underpin the decisions regarding whether the EQS is being met and the associated EQO has been achieved.

  If an EQS is exceeded, the assumption is that the environmental value is at risk and a management action is triggered to prevent environmental harm or pollution and restore environmental quality to within acceptable levels.

  The response would normally focus on identifying the cause (or source) of the exceedance and then, if the exceedance is attributable to anthropogenic emissions, reducing the loads of the contaminant of concern (i.e. source control). Timeframes for restoring environmental quality are determined on a case-by-case basis, but should be as short as reasonably practicable.

  The response may also require *in situ* conservation or intervention work to be undertaken.

The overarching goal of environmental management is to ensure that sources of contaminants are managed such that environmental quality is maintained within the bounds described by the EQC (i.e. kept below the EQG and never exceeding the EQS), thereby achieving the EQO and ensuring the environmental value continues to be supported. 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 (i.e. after significant or irreversible damage).

## 1.2 EQMF to protect the rock art on Murujuga

The conceptual framework behind the EQMF to protect the rock art on Murujuga is shown in Figure 2. The environmental value is the rock art, which is one of the physical elements of the Aboriginal cultural heritage of Murujuga. The EQO is "maintenance of environmental quality to protect the rock art", such that weathering of the rock art is not accelerated beyond natural rates by anthropogenic emissions.

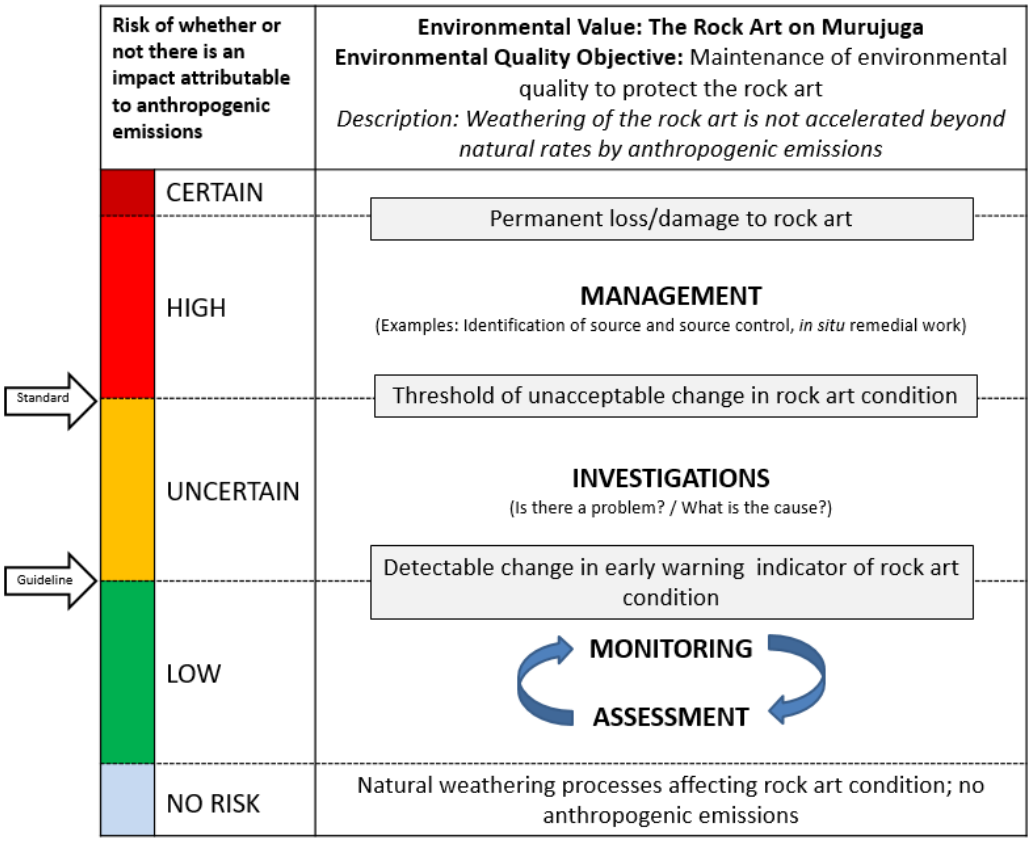


**Figure 2: The Environmental Quality Management Framework for protecting the rock art on Murujuga**

The EQMF applies only to the protection of one of the physical elements (the rock art) of the Aboriginal cultural heritage of Murujuga and does not directly address the protection of the other tangible and intangible Aboriginal cultural heritage values of Murujuga. In the absence of any specific environmental quality requirements for the protection of these values, it is considered that if environmental quality is managed to protect the integrity or condition of the rock art, then this may go some way toward maintaining some of these cultural heritage values.

The EQMF also does not address the other significant ecological and social environmental values of Murujuga. In the future, the EQMF could be extended to incorporate other Aboriginal cultural heritage, social and ecological values.

The focus of the EQMF is on monitoring and managing environmental quality to protect the rock art on Murujuga from anthropogenic emissions. It will be important that the Murujuga site is considered as a 'system' in the broadest sense, with the integrity or condition of the rock art viewed as a response to interactions between multiple extrinsic (e.g. environmental factors) and intrinsic (e.g. the characteristics of the rock and rock art, including its weathering history) components of the system operating over different temporal and spatial scales. Because of the complexity of the system as a whole, weathering of the rock art may not be proportional to an increase in anthropogenic emissions even if the rock is of the same or similar geological characteristics and exposed to the same or very similar micro-environmental conditions. This creates challenges in identifying definitive causal links between changes in environmental quality as a consequence of anthropogenic emissions and the weathering of the rock art. The complexity of the system will need to be carefully considered and addressed in the design of the Murujuga Rock Art Monitoring Program and the derivation of EQC.

All the factors potentially affecting the rock art, which may be interrelated and may exacerbate each other, will need to be considered as part of any investigation into changes in the integrity or condition of the rock art and the development of recommended management options.

## 1.3 Establishing relevant Environmental Quality Criteria

Unlike environmental values and EQO, which are largely qualitative and described narratively, EQC are quantitative and may be numerical values or narrative statements.

There are currently no existing or default guideline 'trigger values' for protecting the rock art from anthropogenic emissions that could be used as EQC. There is also a knowledge gap with respect to developing suitable EQC that would apply to the rock art on Murujuga as there are no clearly defined relationships between the integrity or condition of the rock art and environmental quality – specifically atmospheric emissions, atmospheric deposition and contaminants interaction.

There are also few examples in the literature where scientifically-based limits of 'acceptable' change have been identified that could be used to protect materials of cultural heritage at specific sites. For example, a study of lichens on inscription panels at Inscription Rock, El Morro National Monument in New Mexico to determine if air pollution is influencing the patterns of substrate degradation, identified 14 lichen species sensitive to one or more air pollutants (Knight *et al.* 2004). The study also found that within a specific location, any number of pollution-sensitive species over 10 suggested low pollution impact.

Scientific investigations and research are required to establish the links between atmospheric emissions, atmospheric deposition and contaminants interaction, and the integrity or condition of the rock art on Murujuga and support the derivation of EQC. Given the complexities of rock art weathering, the number of system variables

involved and the interactions (both synergistic and non-synergistic) between these variables, the derivation of appropriate EQC will not be without its challenges.

In the absence of existing guideline 'trigger values' or narrative statements for scientifically-based limits of 'acceptable' change, the level of important change can be evaluated using data collected from appropriate un-impacted reference (control) sites and statistical techniques, with an appropriate level of statistical significance and statistical power. The objective of this approach is to maintain environmental quality at the monitoring sites within a range that is considered to be of a suitable quality.

Some examples of approaches that have been implemented for deriving scientifically-based limits of 'acceptable' change include:

- Comparison of a potentially impacted site median with percentiles (e.g. $1^{st}/5^{th}$ and/or $99^{th}/95^{th}$ percentiles) of the measured data distribution of that parameter from un-impacted reference sites or baseline data (e.g. Environmental Protection Authority 2017).

  If the potentially impacted site median is within the range specified by these percentiles, then it is assumed there is a low risk that the EQO is not being achieved.

- Application of 'statistical process control charts', which provide a means of displaying the variability of measurements over time, as well as the closeness of individual data points (or groups) to expected values (e.g. Chevron Australia 2016a, b, 2018).

  If a pattern emerges in the line chart (e.g. a consistent magnitude and direction of trajectory of change), or if a data point falls outside pre-specified limits (e.g. at some statistically defined distance above and below the mean [e.g. three standard deviations]), this indicates that a change or trend in the measured parameter is occurring beyond normal sampling variability and it is assumed there is a risk that the EQO is not being achieved, triggering further investigation.

Statistical analysis, such as trend analysis and comparison with un-impacted reference sites, has been used to determine whether there has been a significant change at potentially impacted sites (e.g. Data Analysis Australia 2018). If there is no significant change at the potentially impacted site, then it is assumed there is a low risk that the EQO is not being achieved. Trend analysis and comparisons will also assist in assessing the validity and appropriateness of the EQC and the continuing use of selected reference sites as valid reference sites.

The development of Interim EQC, based on the best available scientific information at the time, will be informed by the monitoring studies undertaken to underpin the design of the Murujuga Rock Art Monitoring Program.

It is anticipated that the Interim EQC will be refined over time. As more data and information become available, the interpretation of the monitoring data against the EQC will be an important step in refining the EQC where there is a significant degree

of uncertainty. If EQC are too stringent, they may trigger unwarranted concern; if too lax, they may fail to identify problems before they become very difficult or too late to rectify. Incorporating this feedback loop will be an important outcome of monitoring and assessment.

## 1.4 Management response framework

The EQMF will provide managers and decision-makers with information to support the implementation or amendment of management actions prior to permanent loss or damage to the rock art occurring, thereby ensuring the rock art is protected from the impacts of anthropogenic emissions in the long-term. The conceptual framework in Figure 2 shows that the intensity of the management response triggered by exceeding an EQC depends on whether an EQG or EQS has been exceeded, which in turn reflects the level of risk of adverse environmental effects.

If the EQO is met, the management focus should be on maintaining the existing environmental quality through continuous improvement (e.g. through identifying and implementing methods of reducing current levels of emissions) and emission minimisation (e.g. management of new and expanding emission sources with a focus on emission minimisation).

If the EQO is not met, the management focus should be on improving environmental quality to meet the EQO through the implementation of management processes to avoid and reduce anthropogenic emissions. The response may also require *in situ* conservation or intervention work to be undertaken.

If the EQC are exceeded, stakeholders must cooperatively develop and implement management strategies, with timelines, and, if necessary, interim objectives, to restore environmental quality defined by the EQC.

It is important to note that the EQC define the scientifically-based limits of ‘acceptable’ change to environmental quality. They do not represent pollution levels that trigger enforcement action if exceeded; nor do they infer it is acceptable to ‘load up’ the environment to these levels. Avoidance and minimisation strategies should always be adopted and reinforced.

### 1.4.1 Exceedance of an EQG

If an EQG is exceeded, this triggers a more detailed assessment against the EQS to determine if the environmental value is at risk. This assessment is risk-based and investigative in nature.

### 1.4.2 Exceedance of an EQS

If an EQS is exceeded, a management action is triggered to prevent environmental harm or pollution and restore environmental quality to within acceptable levels.

The response would normally focus on identifying the cause (or source) of the exceedance and then, if the exceedance is attributable to anthropogenic emissions, reducing the loads of the contaminant of concern (i.e. source control). An

understanding of the weathering processes that are naturally affecting the rock art, how anthropogenic emissions may alter these naturally occurring processes or potentially trigger other processes that are not naturally occurring, will be important in determining whether changes documented through the monitoring program are due to natural weathering processes or are the result of anthropogenic emissions, and in turn in identifying appropriate management measures.

The response may also require *in situ* conservation or intervention work to be undertaken.

## 1.5 Implementation of the EQMF

The successful implementation of the EQMF will require:

1. The application of EQC that are based on sound scientific information.
2. A monitoring program that is appropriately designed and implemented to make the necessary measurements, to analyse the data and to report on the integrity or condition of the rock art and change in that integrity.
3. A governance process that enables information to be assessed and appropriate management actions to be implemented.

# 2 The Murujuga Rock Art Monitoring Program

## 2.1 Background

An essential step in the Environmental Quality Management Framework (EQMF) is the implementation of an appropriate monitoring program to provide the data for measuring and assessing environmental performance against the Environmental Quality Criteria (EQC). This will require:

1. Identification of relevant environmental quality indicators.
2. Identification of clear, readily measurable and auditable EQC for each indicator that define acceptable and unacceptable environmental quality conditions; and the statistical methods for interpreting the monitoring data against the EQC.
3. Standardisation of procedures for the measurement of indicators and procedures to compare, interpret, understand and evaluate the results against the EQC.

This will require an understanding of:

- the natural geological, chemical, physical / mechanical and biological weathering / alteration / degradation processes, as well as the interaction mechanisms between these processes, that affect the surface and near-surface of the rock art and the surrounding rock surface;
- the pressures and threats to maintaining an acceptable environmental quality to protect the integrity or condition of the rock art, how these affect the natural weathering / alteration / degradation processes or trigger other processes that are not naturally occurring, the interrelationships between these processes and the integrity of the rock art (i.e. the pressure / response relationships and linkages); and
- the likely initial and secondary signs of these effects.

## 2.2 Purpose and objectives of the Murujuga Rock Art Monitoring Program

The purpose of the Murujuga Rock Art Monitoring Program is to monitor, evaluate and report on changes and trends in the integrity or condition of the rock art and whether the rock art is being subject to accelerated change; specifically to determine whether anthropogenic emissions are accelerating the natural weathering / alteration / degradation of the rock art. This will enable timely and appropriate management responses by the Western Australian Government, industry and other stakeholders to emerging issues and risks.

The objectives of the monitoring program are to:

- obtain data for comparison against the EQC to ascertain whether the Environmental Quality Objective (EQO) is being achieved and the environmental value (the rock art) protected;
- provide the Western Australian Government, the Murujuga Aboriginal Corporation, industry and the community with robust, replicable and reliable information on changes and trends in the integrity or condition of the rock art on Murujuga;
- ensure decisions regarding the protection of the rock art are based on the best available science; and
- inform the evaluation of the effectiveness of any measures taken to mitigate adverse effects on the rock art, including efforts to protect the rock art.

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