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Water quality objectives for Magela Creek – revised November 2004

M Iles

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Contents

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1 Background

1.1 The review process

Water quality objectives, in the form of a hierarchy of trigger values[1], have previously been set for key variables in the Magela Creek on the Ranger Project Area (Klessa 2001a & b) and Ngarradj (Swift Creek) in the Jabiluka Mineral Lease (Jabiluka Minesite Technical Committee minutes 21/09/2001).

A report on the progress of reviewing the trigger values in Magela Creek, Gulungul Creek and Ngarradj (Iles 2003) was circulated to stakeholders for comment in late 2003. That report included:

- a description of the creeks and existing water quality (chemistry) monitoring programs,
- a review of the Australian and New Zealand Water Quality Guidelines (ANZECC & ARMCANZ 2000) approach to deriving water quality objectives and an interpretation of that approach,
- a review of the methods and data used to set existing trigger values,
- a quality assessment of the historic datasets available,
- an assessment of the usefulness of reference site data parameters as guidelines for managing water quality, and
- recommendations for alternative approaches to deriving trigger values.

Written and verbal feedback from stakeholders on that report highlighted/reinforced the following important points.

- Because the trigger values for most parameters are based on a value that falls within the natural range of values at the reference site, it is expected that the triggers will be occasionally exceeded. In fact, the purpose of using values within the natural range is to draw attention to any potential change in water quality as soon it may be statistically noticeable. A single exceedance of a trigger based on reference site percentiles does not mean the value is outside the normal range of values and should not cause alarm or responses inappropriate to the event.
- Recognising the above point, there is a need to educate stakeholders and the public about the use of the trigger value system and appropriate reactions (management and stakeholder/public interpretations) to any exceedances.
- There is a need to interpret measurements with greater reference to the hydrological conditions at the time, especially for turbidity, which is highly variable across the hydrograph. Sampling of the reference site (and test site) has commonly occurred

[1] Trigger values are numerical water quality objectives that, when exceeded, trigger a management response.

during the low stages of the hydrograph thus the turbidity data that make up the reference dataset have a narrow range of values compared to that which occurs naturally across the entire hydrograph.

- The focus of the Australian and New Zealand Water Quality Guidelines, and their justification for relaxing trigger values beyond reference site conditions, is ecosystem protection. In addition to ecosystem protection, the Traditional Owners want to have, as a management aim, no change to the natural water quality.
- The underlying principle of ERA's water quality management is to keep perturbations downstream of the mine (as measured at the compliance point 'MG009') to a minimum when practical.
- A detectable signal from mining, on the water quality downstream of Ranger, was always expected (Fox 1977). Therefore, effectively, the political and economic aspects of water quality changes (compared to reference site conditions) were considered when the government granted approval for mining[2].
- Achieving reference site conditions during the life of the mine is not realistic for some parameters and the numerical triggers based on reference site conditions need to be relaxed if the system is to be used to manage water quality in a meaningful way.

1.2 Water quality objective versus trigger value

To reconcile the above issues, the current system of having numerical values alone as water quality objectives needs to be expanded. The term 'Water Quality Objective' can encompass more than a numerical value used to assess 'compliance' or interpret changes in water quality. So, for those key variables where it is necessary to relax the numerical trigger values beyond the guideline provided by reference site conditions (ie where reference site conditions do not provide good management guidelines due to an existing change to downstream water quality) a narrative statement has been coupled to the trigger value to describe what the water quality objective should be with respect to that variable.

A coupled numerical and narrative water quality objective supports both the scientific objectives of data interpretation and assessment of ecosystem protection while also supporting the management aim of minimising perturbations downstream of the mine where practical.

1.3 Limit versus guideline

At the Ranger Minesite Technical Committee meeting on the 17th October 2003 it was agreed that when the trigger values are based on the natural range of values at a reference site, the upper (and lower in the case of pH) trigger value would be a guideline, rather than a limit. Therefore, the upper trigger value is a limit for uranium and radium, and a guideline for all other parameters.

1.4 Actions invoked by an exceedance of a trigger value

While some recommendations on possible investigative actions are included in the discussion on turbidity, the official reporting and management responses invoked when an exceedance of a trigger value occurs are described in Appendix 1, *"Actions invoked by an exceedance of a trigger value"*. The original requirements for reporting and management response were prescribed in Klessa 2001b.

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2 The NLC reiterates that the traditional owners did not agree with the Government decision to approve mining at Ranger.

1.5 Water quality objectives for Gulungul Creek and Ngarradj

Stakeholder feedback on Iles 2003 indicated that setting or changing trigger values for Gulungul Creek and Ngarradj should be supported by further investigations. Particular comments were along the lines of:

- Basing trigger values on downstream data collected to date at Ngarradj was not acceptable without further work to understand the nature of the difference between the upstream and downstream sites (ERA, NLC, Ray Evans – ARRTC)
- The geochemistry of Gulungul Creek catchment needs to be better understood in order to ascertain if the upstream site is truly indicative of pre-mining conditions that could have been expected at the downstream site (ERA, Ray Evans – ARRTC)

These comments, the changed status of the Jabiluka site and the time constraints imposed by other commitments during the year lead to the focus of this review being on Magela Creek. Investigations into the chemistry of Gulungul Creek will begin this coming wet season and stakeholders and ARRTC are reassessing research priorities for Ngarradj.

2 Methodology

The ERA and SSD 2003–04 wet season data have been added to the upstream site (reference site) and downstream site (test site) datasets that were described in Iles 2003. Laboratory[3] EC, pH and turbidity were used rather than insitu measurements for reasons described previously (Iles 2003 and Klessa 2001b).

For all parameters (except uranium and radium) a reference site dataset spanning from 1993 to present was used and the following steps were taken.

1. Reference site datasets were checked for outliers[4]. Each datum identified as an outlier was checked. Outliers were only removed if comments in the database or quality control measurements indicated that the result might be unreliable. Outliers that were removed are listed in the relevant sections below.
2. Reference site data were plotted as time series to evaluate seasonal patterns.
3. Reference site percentiles were calculated and displayed over the downstream historic data on a control chart with the previous trigger values and/or updated reference site percentiles. The chart axis identifies the date range of the historic datasets used. The historic datasets include all data present in the ERA LIMS database and in the *eriss* database – no ERA data were removed even though some of the older data are of suspect quality.
4. The downstream data were examined to determine the number of times (expressed as a percentage) that the downstream data had historically exceeded the revised upstream reference site percentiles. This provides an indication of whether the revised triggers would be exceeded with the frequency statistically expected. If so, then the reference site percentiles provide a good management tool and it is recommended that they be adopted as numerical water quality objectives in the form of focus, action and guideline trigger values.

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3 Once a reliable reference dataset of insitu measurements is established insitu measurements will replace laboratory-based measurements.

4 Results more than 1.5 times the interquartile range (the middle 50% of the data) were identified as outliers by MINITAB™ Release 13.20.

5. In the case of those parameters where a signal from the mine is already present (uranium, EC, magnesium and sulfate) the water quality has changed from reference site conditions and so reference site percentiles no longer provide good management aids. For these parameters an alternative approach to setting water quality objectives is used, including adopting a narrative objective.

For uranium, the recommended trigger values are based on ecotoxicity testing. Iles (2003) applied the above approach to uranium data and found that if the triggers were based on reference site percentiles they would be constantly exceeded and therefore not useful for providing early warning of potentially detrimental[5] changes in the water quality.

For radium-226, the previous trigger values are based on human health protection. The derivation of the limit is described in Klessa 2001b. A change to the way the test value (the wet season average difference) is calculated and removal of the focus and action triggers are recommended here.

For magnesium, all data were rounded to one decimal place for histogram presentation.

3 Data analyses and recommendations

3.1 pH

3.1.1 Upstream pH

Figure 1 shows the outliers identified in the pH data from the reference site (MCUS) since 1993. Of the outliers identified only 3 data were removed, leaving 365 data in the reference site dataset. The data removed were:

- pH = 3.97 on 15/3/00 (ERA) – comment re “odd EC” in database; Mg & SO_4 values low for given EC.
- pH = 3.37 on 19/1/01 (eriss) – QC pH very low also.
- pH = 5.20 on 29/1/02 (eriss) – QC pH very low also.

Figure 2 shows the pH distribution after outlier removal. The slightly longer left-side tail on the pH histogram reflects the lower pHs often measured at the beginning of the wet season at the upstream site (figure 3).

The revised reference site percentiles are shown in table 1 along with the previous trigger values for pH in Magela Creek.

5 Uranium concentrations at the downstream site have been elevated for many years without detriment to the ecosystem (Supervising Scientist 2004).

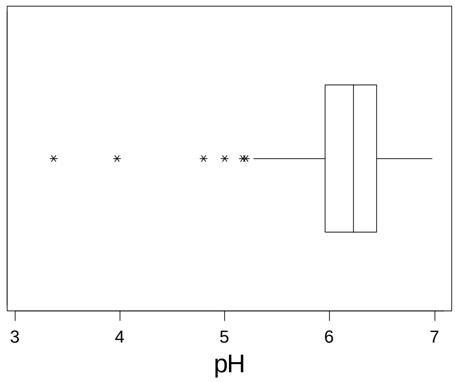

Figure 1 Box plot of MCUS pH since 1993

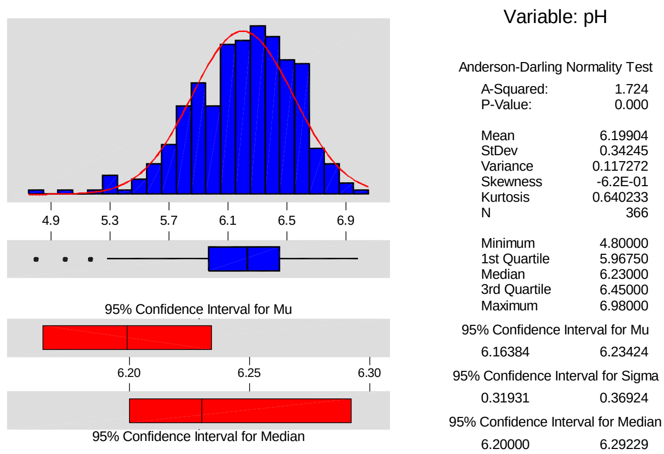

Figure 2 Descriptive statistics for MCUS pH since 1993 (after outlier removal)

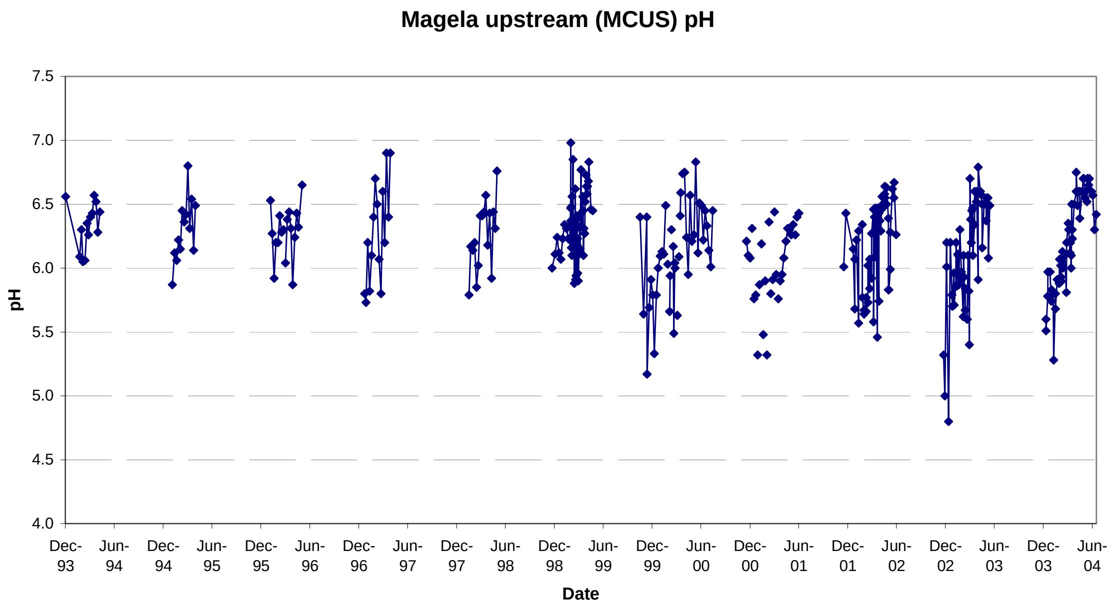

Figure 3 Magela Creek upstream pH data (outliers retained)

Table 1 Reference site pH percentiles

Trigger	Statistic	Previous trigger guidelines	Revised lower percentiles	Revised upper percentiles
Focus	20th and 80th percentiles	5.8 – 6.5	5.9	6.5
Action	5th and 95th percentiles	5.5 – 6.8	5.6	6.7
Guideline	0.3rd and 99.7th percentiles	5.2 – 7.2	5.0	6.9

3.1.2 Downstream pH

Figure 4 shows the historic downstream pH data plotted on a control chart with previous upper and lower guideline trigger values and the revised reference site percentiles.

The percentage of the historic downstream (MG009) data that has exceeded the revised reference site percentiles is

- > upper 80th %ile = 16.5%, > upper 95th %ile = 5.5%, > upper 99.7th %ile = 1.8%
- < lower 20th %ile = 25.5%, < lower 95 th %ile = 4.8%, < lower 0.3rd %ile = 0.8%

This percentage of exceedances is similar to that expected statistically indicating that the pH at both sites is similar and that reference site percentiles provide a useful guideline for managing pH in Magela Creek.

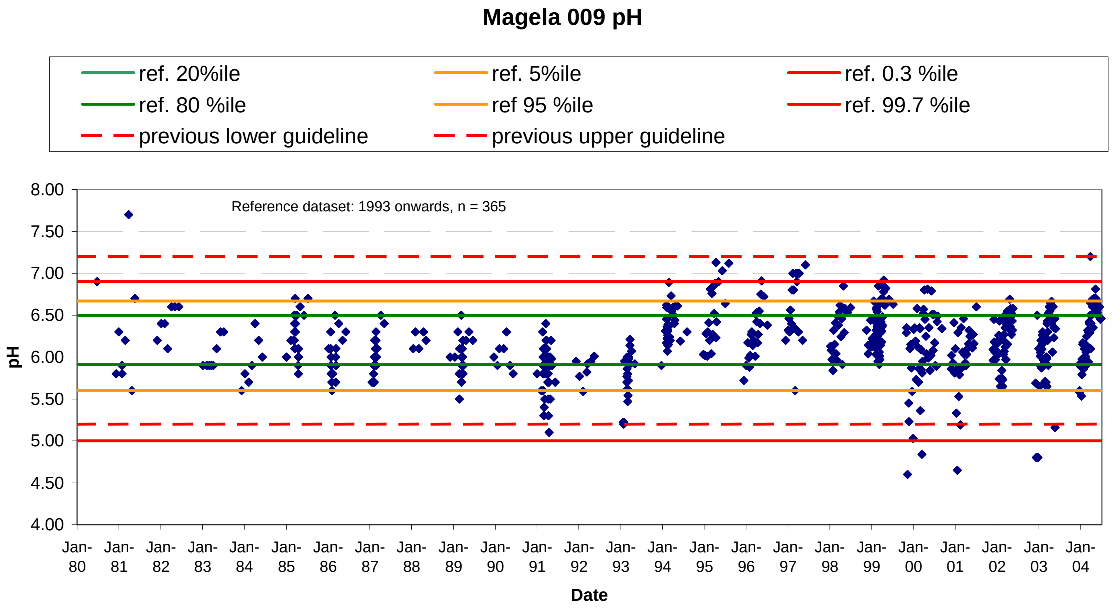

Figure 4 Magela Creek downstream pH data plotted against reference site percentiles and previous upper and lower guideline triggers

3.1.3 Recommended water quality objective for pH in Magela Creek

The 80th, 95th and 99.7th percentiles of the MCUS dataset should be adopted as the pH focus, action and guideline trigger values.

- The water quality objective for pH in Magela Creek is **to retain the natural distribution of pH in Magela Creek and report and act on any trigger value exceedances at MG009, where the trigger values are:**
  - **Focus: lower = 5.9, upper = 6.5,**
  - **Action: lower = 5.6, upper = 6.7,**
  - **Guideline: lower = 5.0, upper = 6.9.**
- The measure of the success of meeting this objective is that the focus, action and upper guideline trigger values are not exceeded at the downstream site alone (ie exceedance not reflected at the upstream site) more often than statistically expected. And, all exceedances are reported and investigated as outlined in Appendix 1 "*Actions Invoked by Trigger Value Exceedances*".

3.2 Turbidity

3.2.1 Upstream turbidity

Figures 5 and 6 show the outliers and distribution of turbidity data at the reference site (MCUS) since 1993. Of the outliers identified none were removed. The number of data in the reference site dataset is 328. The revised reference site percentiles are shown in table 2 along with the previous trigger values for turbidity in Magela Creek.

The long right-side tail on the turbidity histogram reflects the occasional high turbidities, which appear to be randomly distributed (figure 7) throughout the wet seasons. The reference dataset consists of discrete measurements not continuous measurements.

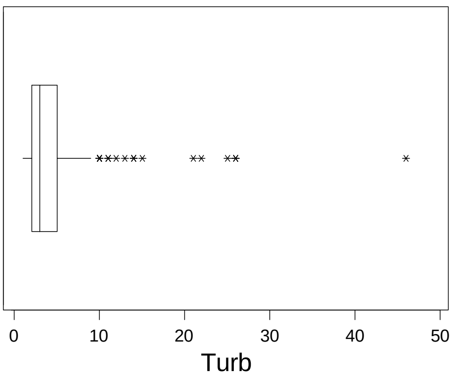

Figure 5 Box plot of MCUS turbidity since 1993

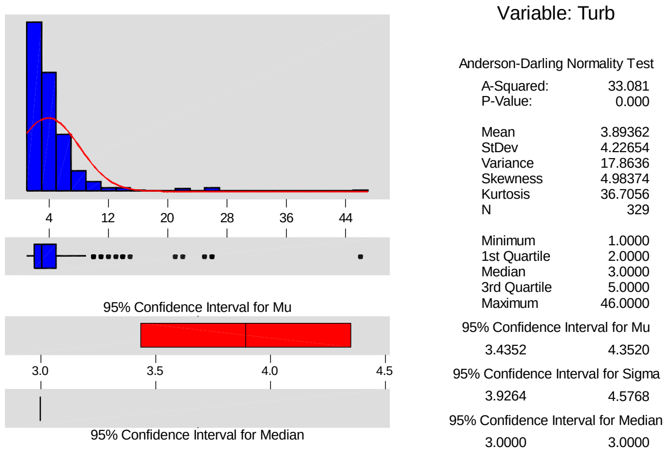

Figure 6 Descriptive statistics for MCUS turbidity since 1993

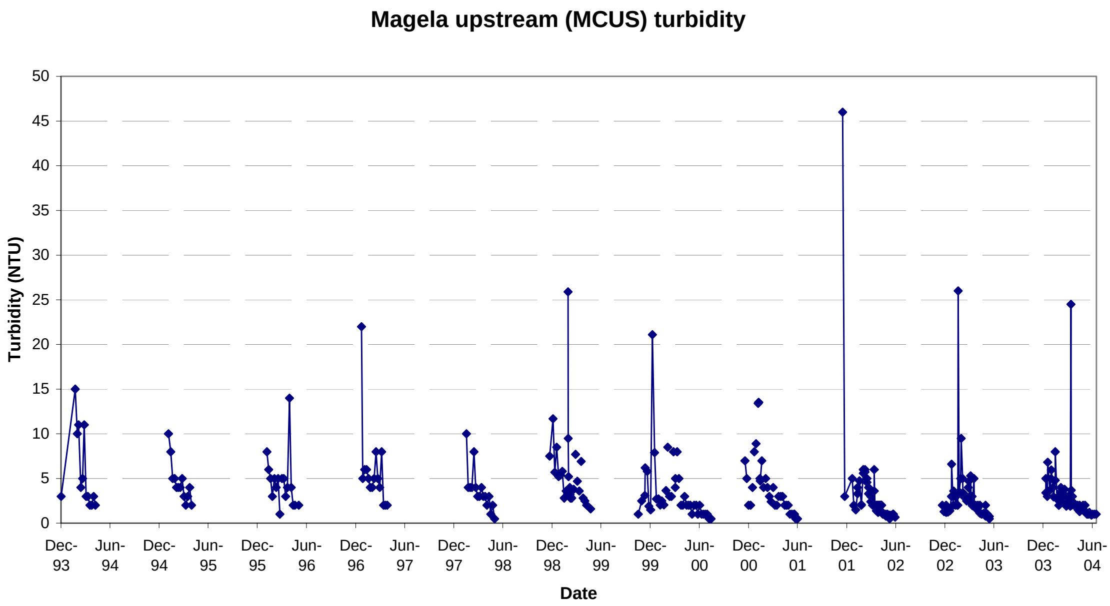

Figure 7 Magela Creek upstream turbidity data (outliers retained)

Table 2 Reference site turbidity percentiles

Trigger	Percentile	Previous trigger values (NTU)	Revised percentiles (NTU)
Focus	80^{th}	10	5
Action	95^{th}	24	10
Guideline	99.7^{th}	56	26

3.2.2 Downstream turbidity

Figure 8 shows the historic downstream turbidity data plotted on a control chart with previous action and limit trigger values and the revised reference site percentiles.

The percentage of the historic downstream (MG009) data that has exceeded the revised reference site percentiles is

- > upper 80^{th} %ile = 22.2%, > upper 95^{th} %ile = 6.6%, > upper 99.7^{th} %ile = 1.2%

Although the reference site percentiles seem very low the frequency of exceedances of these percentiles at the downstream site is similar to that expected statistically (except for slightly higher than expected number of exceedances of the 99.7^{th} percentile). In the cases where the historic downstream data exceeded the revised reference site percentiles the upstream data (when available) was also elevated in most cases. For example, paired data exist for 15 occasions where the revised 95^{th} percentile at the downstream site was exceeded. Of those 15 occasions, turbidities higher than the revised 95^{th} percentile were also recorded at the upstream site.

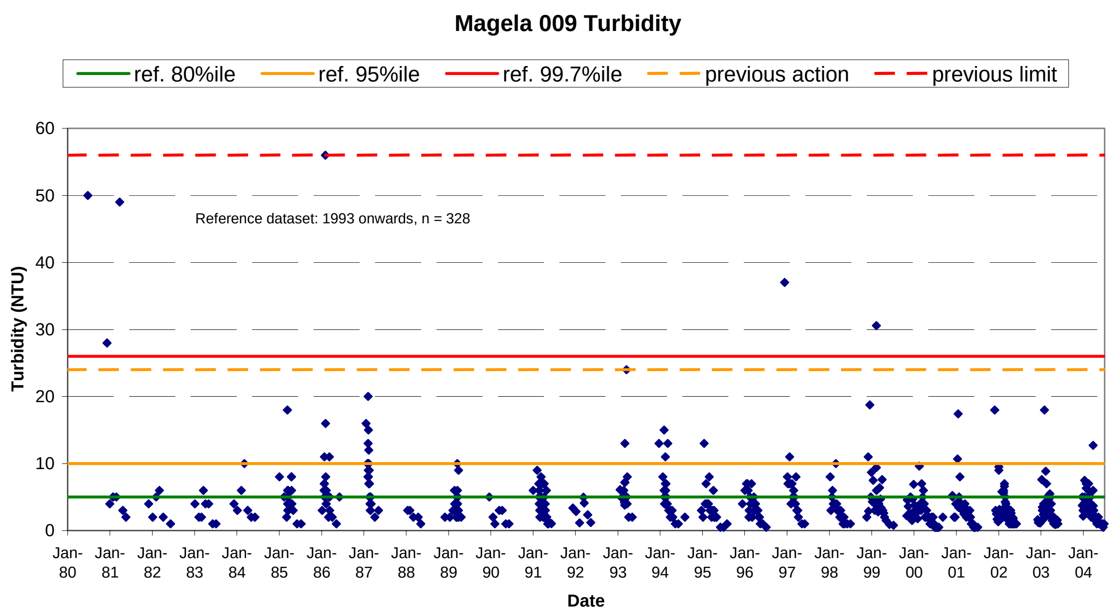

Figure 8 Magela Creek downstream turbidity data plotted against reference site percentiles and previous action and limit triggers

3.2.3 Recommended water quality objective for turbidity in Magela Creek

The turbidity data for both sites is similar and reference site percentiles provide a useful guideline for managing and interpreting downstream turbidity in Magela Creek when that data is collected at a similar stage of the hydrograph as the majority of the reference dataset was (ie in the morning which is usually at the base of the hydrograph).

The 80th, 95th and 99.7th percentiles of the MCUS dataset should be adopted as the turbidity focus, action and guideline trigger values for data collected under the above conditions[6].

- The water quality objective for turbidity in Magela Creek is **to retain the natural distribution of turbidity in Magela Creek and report and act on any trigger value exceedances at MG009, where the trigger values are**:
  - **Focus = 5 NTU,**
  - **Action = 10 NTU,**
  - **Guideline = 26 NTU.**
- The measure of the success of meeting this objective is that the focus, action and upper guideline trigger values are not exceeded at the downstream site alone (ie exceedance not reflected to the upstream site) more often than statistically expected. And, all exceedances are reported and investigated as outlined in Appendix 1 *"Actions Invoked by Trigger Value Exceedances"*.

A protocol will be developed to assist in interpreting exceedances not mirrored at the upstream site. This shall include steps such as checking ERA insitu monitoring of turbidity at GC2 and RP1, taking account of time of sampling, storm events and stage of hydrograph[7], and additional sampling.

3.3 Electrical Conductivity (EC)

3.3.1 Upstream EC

Figures 9 and 10 show the outliers and distribution of EC data at the reference site (MCUS) since 1993. Figure 11 shows the seasonal nature of EC at the upstream site, that is elevated EC at the beginning and end of the wet seasons compared to the middle part of the season.

Of the three outliers identified only one was removed, leaving 368 data in the reference site dataset. The datum removed was,

- EC = 47 µS/cm on 15/3/00 (ERA) – comment in database re "odd EC", pH also outlier and Mg & SO4 data lower than expected for this EC.

The revised reference site percentiles are shown in table 3 along with the previous trigger values for EC in Magela Creek.

Table 3 Reference site EC percentiles

Trigger	Previous trigger values (µS/cm)	Percentile	Revised percentiles (µS/cm)
Focus	21	80	15
Action	30	95	18
Guideline	43	99.7	22

6 These trigger values only apply to measurements made at similar time of day to majority of reference data, ie mornings. Do not apply to continuous data that are collected over the entire hydrograph.

7 The historic data should be reviewed to identify the relationship between hydrograph, rainfall intensity and turbidity data

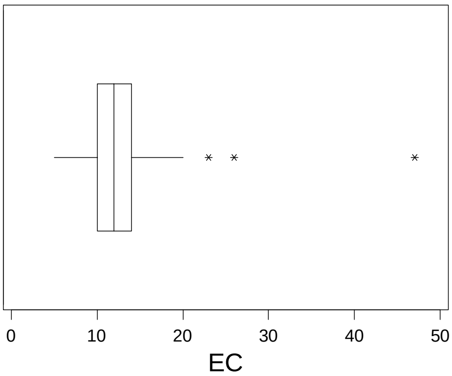

Figure 9 Box plot of MCUS EC since 1993

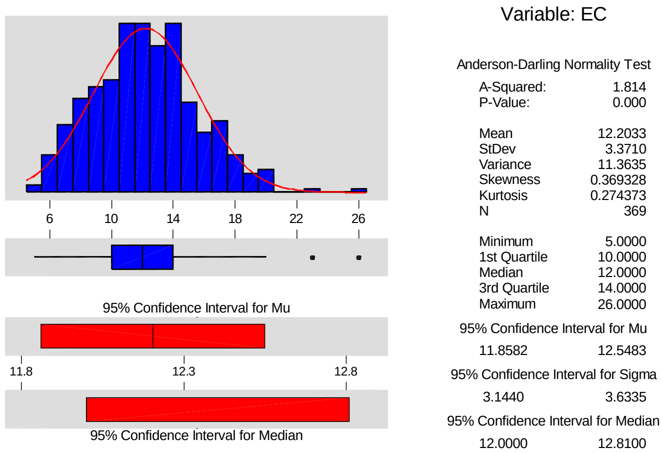

Figure 10 Descriptive statistics for MCUS EC since 1993 (after outlier removal)

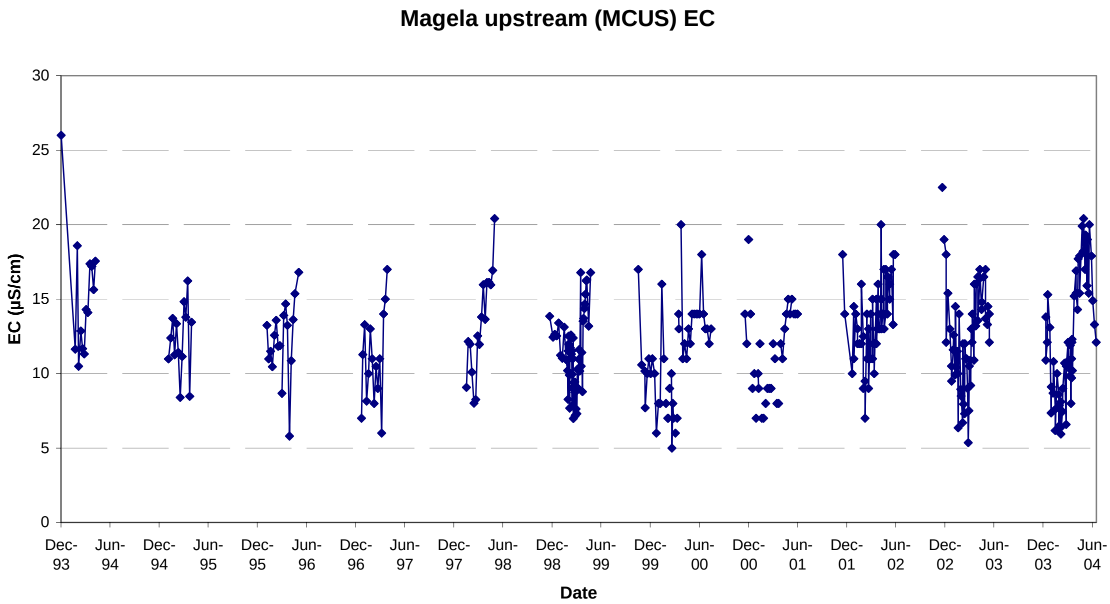

Figure 11 Magela Creek upstream EC data (outliers retained)

3.3.2 Downstream EC

Figure 12 shows the historic downstream EC data plotted on a control chart with previous trigger values and the revised reference site percentiles.

The percentage of the historic downstream (MG009) data that has exceeded the revised reference site percentiles is,

for all historic EC data;

- > upper 80th %ile = 61%, > upper 95th %ile = 37%, > upper 99.7th %ile = 19%

for 02/03 – 03/04 data;

- > upper 80th %ile = 41%, > upper 95th %ile = 13%, > upper 99.7th %ile = 0.9%

The MCUS percentiles do not provide a good management aid for EC in Magela Creek, as EC at the downstream site is elevated compared to the upstream site.

Scientific evidence shows that the ecosystem has not suffered as a result of these elevated EC levels (Supervising Scientist 2004). However, the traditional owners have expressed a wish that no changes in water chemistry occur in the Magela Creek as a result of mining. Such changes have already occurred and cannot be reasonably avoided during the operating life of the mine, although there has been a significant improvement in EC levels achieved over the past two years at MG009 (figure 12).

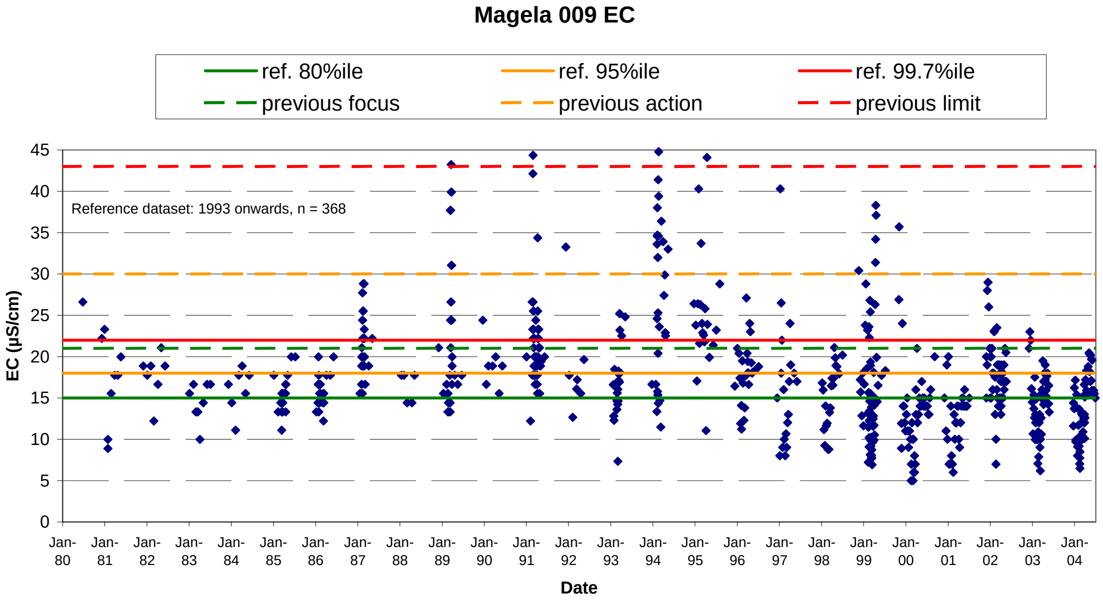

Figure 12 Magela Creek downstream EC data plotted against reference site percentiles and previous trigger values

3.3.3 Recommended water quality objective for EC in Magela Creek

A dual-focus water quality objective is needed to (i) provide a scientific basis for assessing ecosystem protection and (ii) to work toward meeting the wishes of the traditional owners.

This can be achieved by:

(i) retaining the previous EC trigger values for the purposes of interpreting monitoring data (with respect to providing early warning of potential impacts to the ecosystem), and triggering actions, until such time as ecotoxicological work on Mg (Mg:Ca) is reported, and

(ii) sustaining the improved EC levels of the last two wet seasons if practicable[8]. (For example, the last two wet seasons downstream (MG009) data[9] should be used as achievable criteria at MG009 for assessing the design of the process water/pond water treatment plant within a BPT assessment framework.) While this does not fully meet the wishes of the traditional owners for no change in the water quality, it is more stringent than an objective based on scientific evidence of biological effects alone and is recommended to minimise water quality change in respect of the traditional owners wishes.

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8 The amount of rainfall and dilution capacity of Magela Creek is a strong factor in the practicality of achieving this objective.

9 The 80th, 95th and 99.7th percentiles of the last two years downstream EC data are **17**, **20** and **23** respectively.

- The water quality objectives for EC in Magela Creek are:

(i) to report and act on any exceedances of the focus, action and guideline trigger values, where the trigger values are:

  - **Focus = 21 µS/cm,**
  - **Action = 30 µS/cm,**
  - **Guideline = 43 µS/cm**, and

(ii) to sustain the improved water quality seen in the last two wet seasons when practical.

- The measures of success are (i) all exceedances are reported and investigated as outlined in Appendix 1 *"Actions Invoked by Trigger Value Exceedances"*, and (ii) the existing trigger values are not exceeded more often than in the last two wet seasons without reasonable cause.

3.4 Magnesium

3.4.1 Upstream magnesium

Figures 13 and 14 show the distribution of the magnesium data at the reference site (MCUS) since 1993, and that there are no identified outliers in the dataset. The number of data in the reference site dataset is 362. The reference site percentiles are shown in table 4.

The bimodal distribution (2nd peak at 0.8 mg/L) reflects the seasonal elevations of magnesium in the creek, which can be prolonged at the end of the wet season (figure 15).

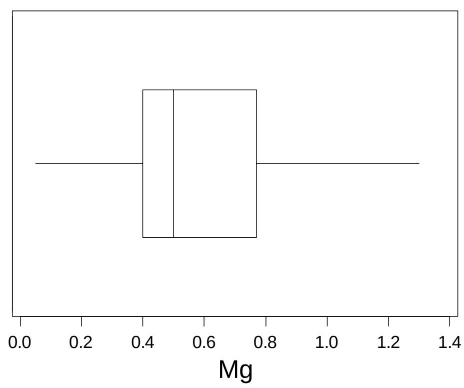

Figure 13 Box plot of MCUS magnesium since 1993

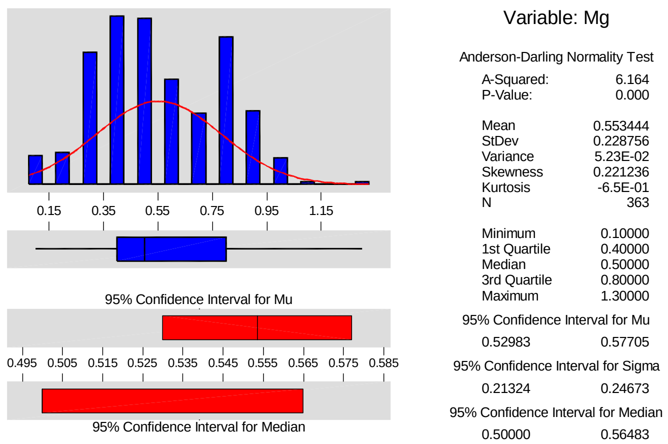

Figure 14 Descriptive statistics for MCUS magnesium since 1993

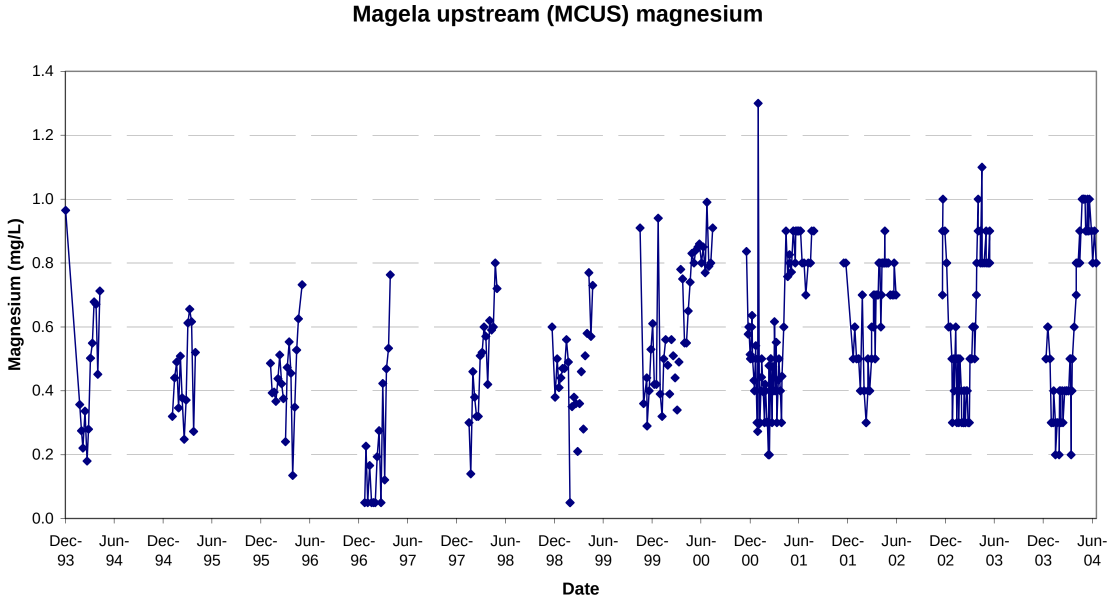

Figure 15 Magela Creek upstream magnesium data

Table 4 Reference site magnesium percentiles

Trigger	Previous trigger values (µg/L)	Percentile	Percentile values (µg/L)
Focus	N/A	80	0.8
Action	N/A	95	0.9
Guideline	N/A	99.7	1.1

3.4.2 Downstream magnesium

Figure 16 shows the historic downstream magnesium concentrations plotted on a control chart with the reference site percentiles.

The percentage of the historic downstream (MG009) magnesium data that has exceeded the reference site percentiles is,

for all historic magnesium data:

- > upper 80th %ile = 55%, > upper 95th %ile = 39%, > upper 99.7th %ile = 19%

for 02/03 – 03/04 magnesium data:

- >upper 80th %ile = 42%, > upper 95th %ile = 17%, > upper 99.7th %ile = 0.9%

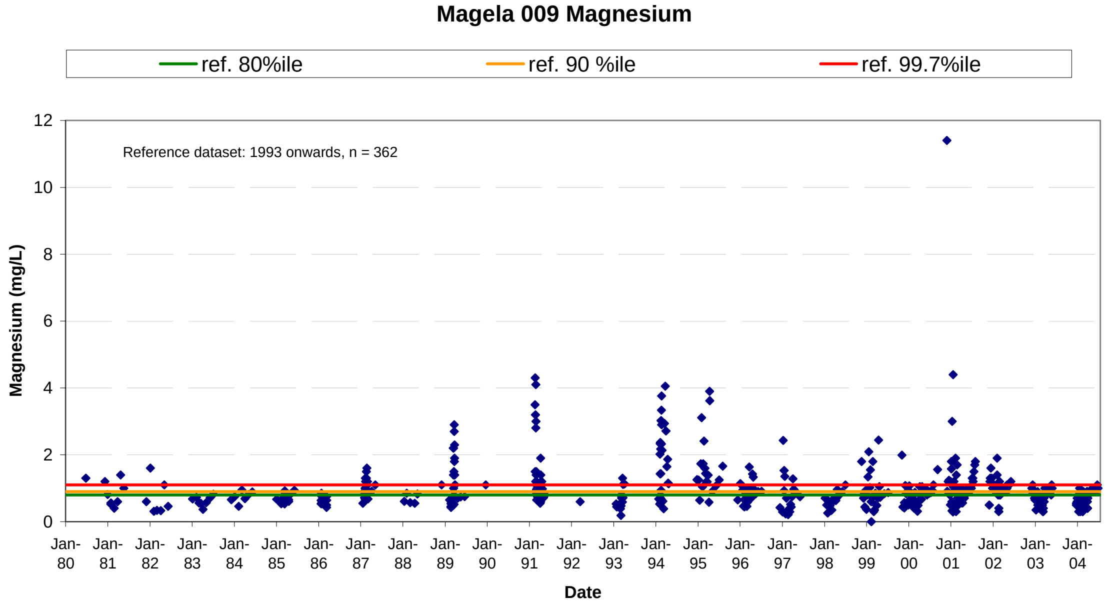

Figure 16 Magela Creek downstream Mg data plotted against reference site percentiles

3.4.3 Recommended water quality objective for magnesium in Magela Creek

The reference site percentiles do not provide a good management tool for magnesium in Magela Creek, as magnesium at the downstream site is elevated compared to the upstream site. Therefore we recommend retaining the status quo of using the existing EC triggers as a proxy for magnesium until ecotoxicity work on magnesium (Mg:Ca) is complete. Early warning for potential magnesium impacts on the ecosystem will be assessed with the EC proxy again this wet season.

Like EC, the magnesium concentrations have improved over the last two wet seasons and the water quality objective should be to sustain that improvement if practicable. (For example, the last two wet seasons downstream (MG009) data[10] should be used as achievable criteria at MG009 for assessing the design of the process water/pond water treatment plant within a BPT assessment framework. The 'safe' Mg:Ca ratio will need to be considered in setting design criteria and may be an overriding factor.) While this does not fully meet the wishes of the traditional owners for no change in the water quality, it is recommended to minimise water quality change in respect of the traditional owners wishes.

- The water quality objective for magnesium in Magela Creek is **to minimise the mine related magnesium signal at the downstream site and sustain the improved water quality seen in the last two wet seasons when practicable**.
- The measure of success of sustaining the improved water quality seen in the last two wet seasons is that the magnesium concentrations this wet season will not significantly differ to those of the last two wet seasons without reasonable cause, and the objectives for EC are met.

[10] The 80th, 95th and 99.7th percentiles of the last two years downstream Mg data are **0.9, 1.0** and **1.2** respectively.

3.5 Sulfate

3.5.1 Upstream sulfate

Figures 17 and 18 show the outliers and distribution of sulfate data at the reference site (MCUS) since 1993. The long right-side tail on the sulfate histogram reflects the occasional higher values recorded which are mostly at the beginning of the wet season (figure 19).

Of the numerous outliers identified only one was removed, leaving 361 data in the reference site dataset. That datum removed was,

- SO_4 = 3.55 mg/L on 5/1/00 (ERA) – EC not elevated for same sample.

The reference site percentiles are shown in table 5.

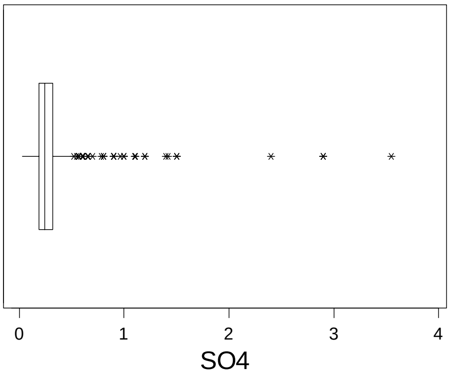

Figure 17 Box plot of MCUS sulfate since 1993

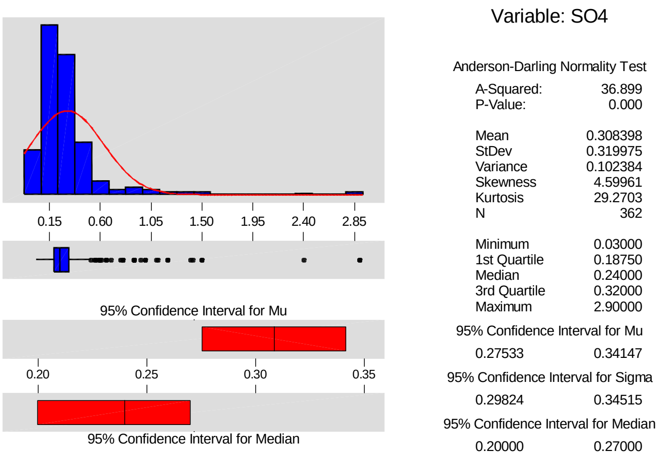

Figure 18 Descriptive statistics for MCUS sulfate since 1993 (after outlier removal)

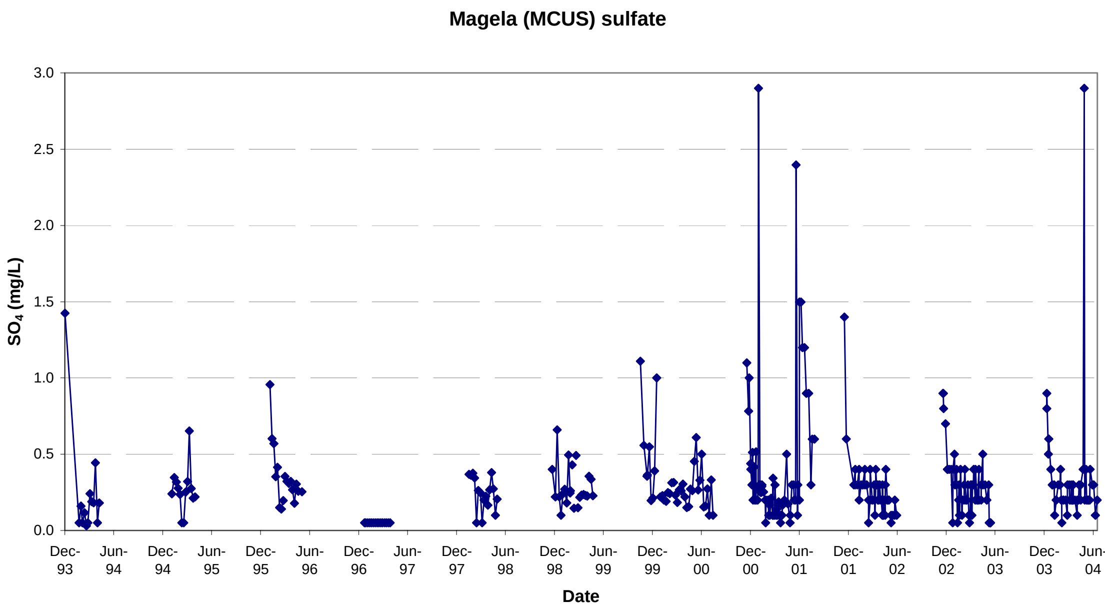

Figure 19 Magela Creek upstream sulfate data

Table 5 Reference site sulfate percentiles

Trigger	Previous trigger values (µg/L)	Percentiles	Revised percentiles (µg/L)
Focus	N/A	80	0.4
Action	N/A	95	0.9
Guideline	N/A	99.7	2.9

3.5.2 Downstream sulfate

Figure 20 shows the historic downstream sulfate concentrations plotted on a control chart with the reference site percentiles.

The percentage of the historic downstream (MG009) data that has exceeded the reference site percentiles is,

for all historic sulfate data:

- > upper 80th %ile = 72%, > upper 95th %ile = 39%, > upper 99.7th %ile = 7%

for 02/03 – 03/04 data:

- >upper 80th %ile = 73%, > upper 95th %ile = 33%, > upper 99.7th %ile = 0%.

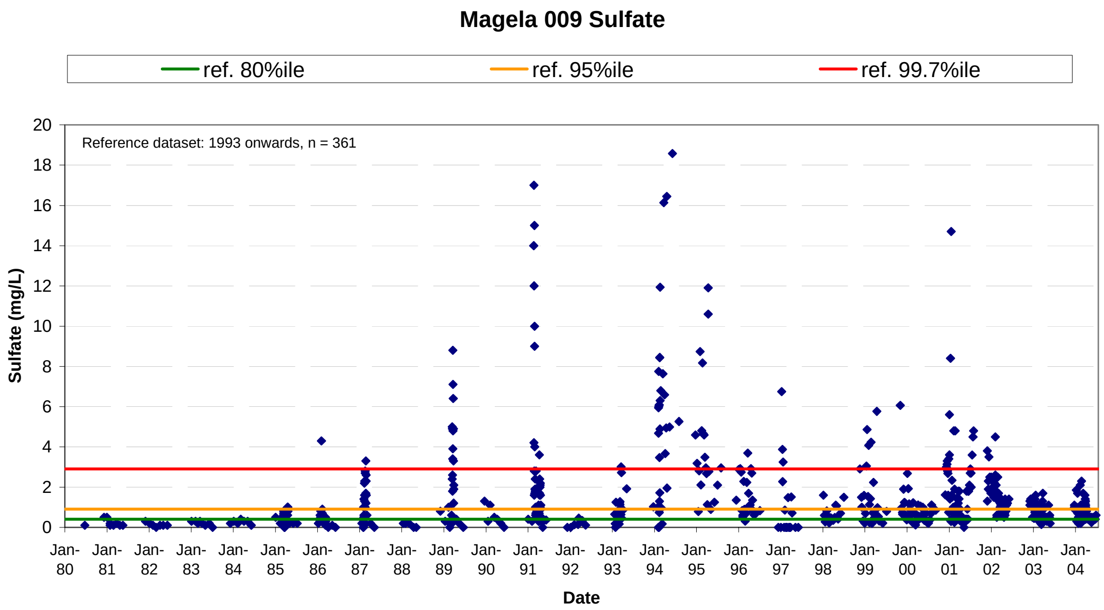

Figure 20 Magela Creek downstream sulfate data plotted against reference site percentiles

3.5.3 Recommended water quality objective for sulfate in Magela Creek

The reference site percentiles do not provide a good management tool for sulfate as sulfate at the downstream site is elevated compared to the upstream site. Recent ecotoxicity work indicates that sulfate is not toxic at levels of about 200 mg/L (several orders of magnitude higher than the concentrations in Magela Creek).

Because the trigger values for EC, will, by the nature of its relationship with sulfate, keep the concentration of sulfate well below toxic concentrations we recommend retaining the status quo, ie use the existing EC triggers to report and interpret changes the ionic composition (including sulfate).

However, like EC and magnesium, the sulfate concentrations have improved over the last two wet seasons and the water quality objective should be to sustain that improvement if practicable. (For example, the last two wet seasons downstream (MG009) data[11] should be used as achievable criteria at MG009 for assessing the design of the process water/pond water treatment plant within a BPT assessment framework.) While this does not fully meet the wishes of the traditional owners for no change in the water quality, it is recommended to minimise water quality change in respect of the traditional owners wishes.

- The water quality objective for sulfate in Magela Creek is **to minimise the mine related sulfate signal at the downstream site and sustain the improved water quality seen in the last two wet seasons when practicable**.
- The measure of success of sustaining the improved water quality seen in the last two wet seasons is that the sulfate concentrations this wet season will not significantly differ to those of the last two wet seasons without reasonable cause, and the objectives for EC are met.

3.6 Manganese

3.6.1 Upstream manganese

Figures 21 and 22 show the outliers and distribution of manganese data at the reference site (MCUS) since 1993. Of the numerous outliers identified none were removed. The number of data in the reference site dataset is 364. The revised reference site percentiles are shown in table 6 along with the previous trigger values for manganese in Magela Creek.

The long right-side tail on the manganese histogram reflects the high values often measured at the beginning of the wet season (figure 23).

Table 6 Reference site manganese percentiles

Trigger	Previous trigger values (µg/L)	Percentiles	Revised percentiles (µg/L)
Focus	10	80	6.8
Action	18	95	11
Guideline	32	99.7	26

[11] The 80th, 95th and 99.7th percentiles of the last two years downstream sulfate data are **1.1, 1.7** and **2.2** respectively.

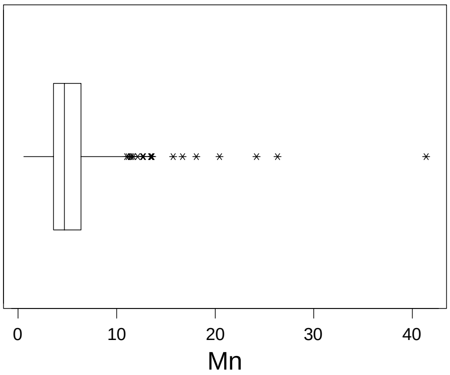

Figure 21 Box plot of MCUS manganese since 1993

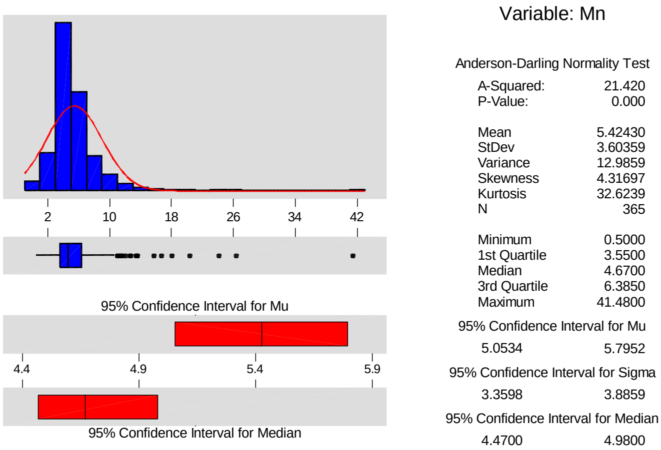

Figure 22 Descriptive statistics for MCUS manganese since 1993

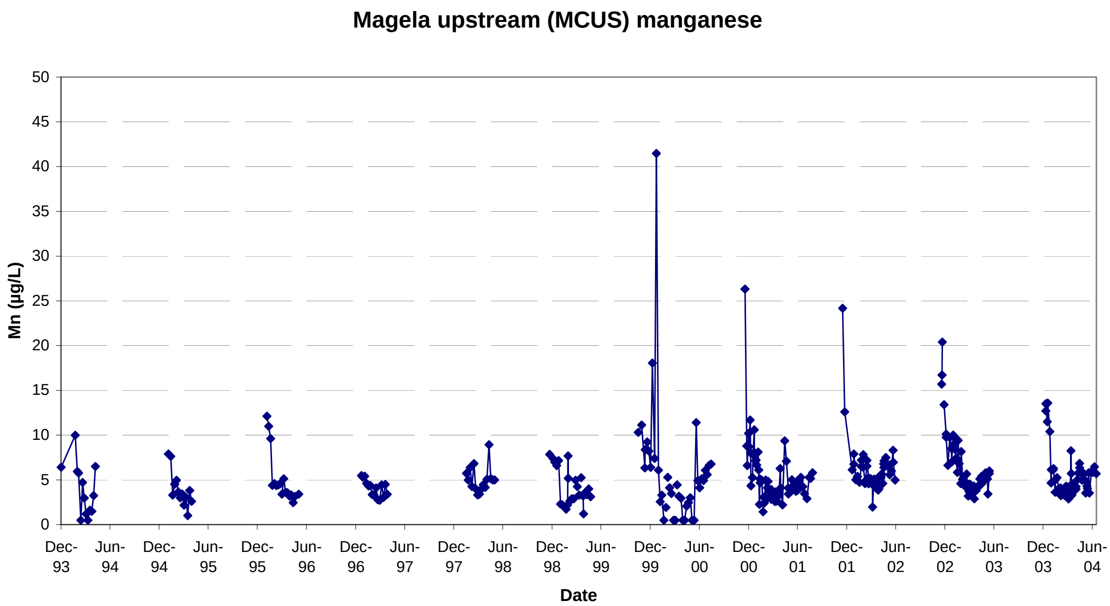

Figure 23 Magela Creek upstream manganese data

3.6.2 Downstream manganese

Figure 24 shows the historic downstream sulfate concentrations plotted on a control chart with the previous trigger values and revised reference site percentiles.

The percentage of the historic downstream (MG009) data that has exceeded the revised reference site percentiles is

- upper 80th %ile = 44%, > upper 95th %ile = 18%, > upper 99.7th %ile = 2%

This is more exceedances than are statistically expected. However, it is clear, especially from the last five years of data (figures 23 & 24) that manganese concentrations vary over the wet season in a predictable manner. Most of the high concentrations that exceed the reference site percentiles occur at the beginning and end of the wet season. It is believed that these elevated manganese values are related to groundwater input (personal communication David Klessa[12]). The variability in manganese concentrations is reduced when the flow reaches five cumecs and greater (figures 25 & 26).

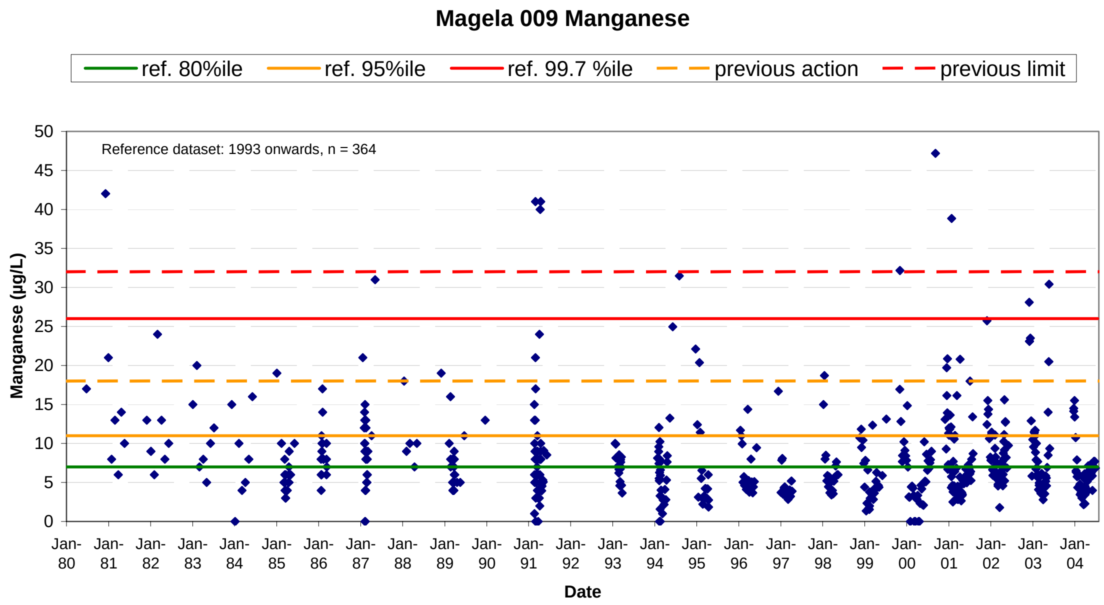

Figure 24 Magela Creek downstream manganese data plotted against reference site percentiles and the previous action and limit trigger values

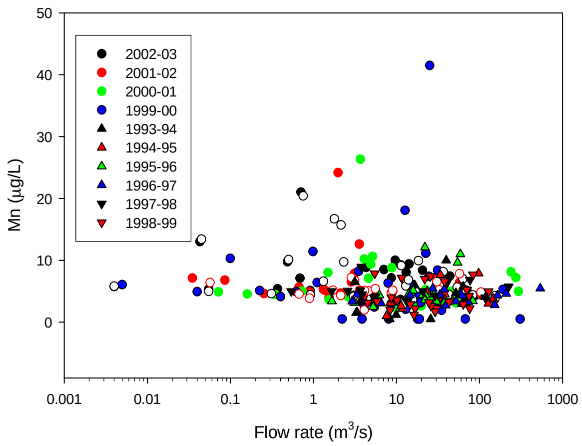

Figure 25 Variation of Mn with flow rate at MCUS

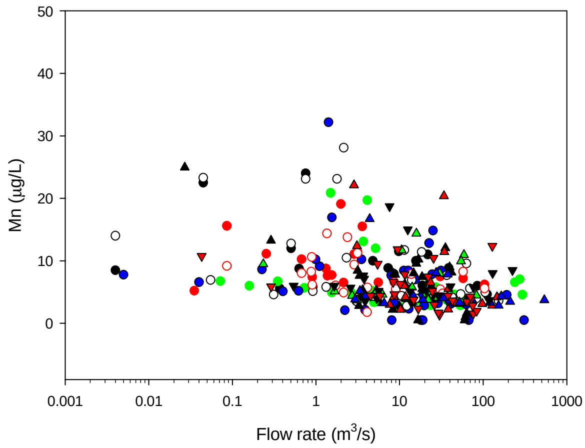

Figure 26 Variation of Mn with flow rate at MG009

(Figures provided by D. Klessa, EWLS. Open symbols denote ***eriss*** data)

12 Work in progress reported to Alligator Rivers Region Technical Committee 14th meeting September 2004.

3.6.3 Recommended water quality objective for manganese in Magela Creek

ARRTC, the expert advisory body overseeing research in the Alligator Rivers Region, has assigned a low priority to the investigation of manganese toxicity in light of international knowledge of manganese toxicity and the relatively low concentrations of manganese in the Magela Creek. Hence, local biological effects data for manganese will not be available in the near future so we recommend adopting the revised reference percentiles as trigger values to be applied in the middle of the wet season (when flow is greater than five cumecs) when any excursions are not expected to be groundwater related.

- The water quality objective for manganese is that **when flow is dominated by surface flow (> 5 cumecs) the reference site distribution is achieved and any trigger value exceedances at MG009 are reported and acted on, where the trigger values are:**
  - **Focus = 7 μg/L,**
  - **Action = 11 μg/L,**
  - **Guideline = 26 μg/L.**
- The measure of the success of meeting this objective is that the focus, action and upper guideline trigger values are not exceeded at the downstream site alone (ie exceedance not reflected to the upstream site) more often than statistically expected during periods where flow exceeds 5 cumecs. And, all exceedances are reported and investigated as outlined in Appendix 1 *"Actions Invoked by Trigger Value Exceedances"*

Research into the seasonal nature of manganese concentration increases will be undertaken to provide information on the causes of the excursions and to assist in the interpretation of the data. And the approach of flow related triggers and the validity of the 5 cumecs will be assessed throughout, and after, the wet season.

3.7 Uranium

3.7.1 Upstream uranium

Figures 27 & 28 show the outliers and distribution of uranium data at the reference site (MCUS) since 23/5/01 for ERA data (when detection limit became 0.005 μg/L[13]) and since the 2000–2001 wet season for ***eriss*** data. Of the outliers identified none were removed. The number of data in the reference site dataset is 202.

The long right-side tail on the uranium histogram reflects the higher values often measured at the beginning of the wet season (figure 29).

The revised reference site percentiles are shown in table 7 along with the previous trigger values for uranium in Magela Creek.

[13] The significance of the changed detection limit and history of sample contamination to the reference site dataset is discussed in Iles 2003.

Table 7 Reference site uranium percentiles

Percentile	Revised percentiles (µg/L)	Trigger	Previous trigger values (µg/L)	Recommended trigger value (µg/L)
80th	0.03	**Focus**	0.2 [a]	0.5
95th	0.04	**Action**	1.4 [b]	0.9
99.7th	0.09	**Limit**	5.8 [c]	6.

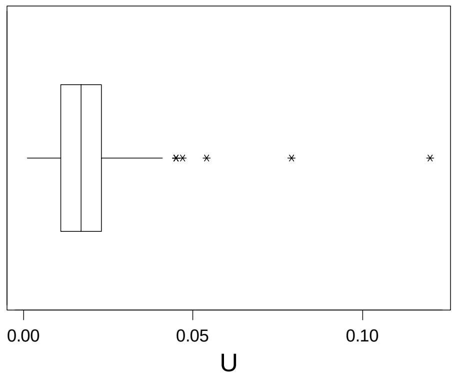

Figure 27 Box plot of MCUS uranium since 1993

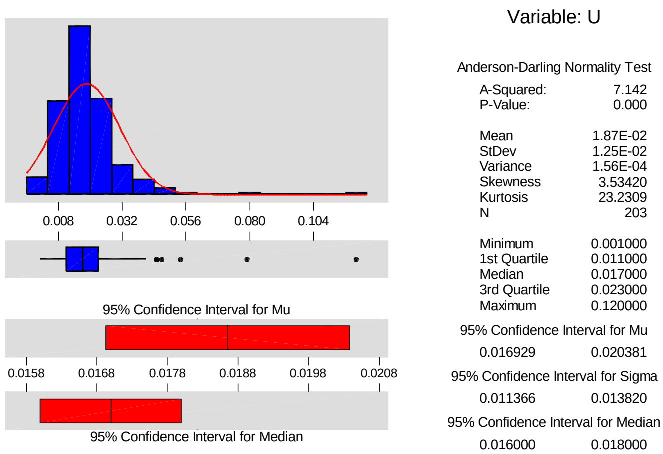

Figure 28 Descriptive statistics for MCUS uranium since 1993

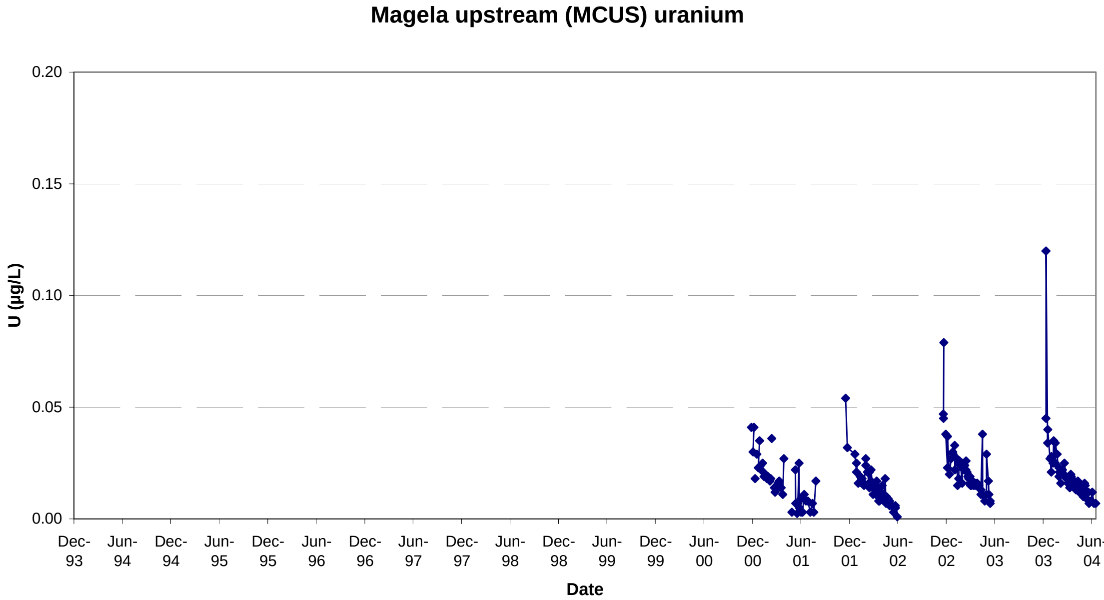

Figure 29 Magela Creek upstream uranium data (outliers retained)

3.7.2 Downstream uranium

A review of the frequency of historic exceedances of the trigger values is not meaningful for uranium as (i) much of the historic uranium data is high due to sample contamination and analytical detection limits that were several orders of magnitude higher than is currently achievable, and (ii) the uranium concentrations being measured at MG009 in the last two years is greatly reduced due to changed management practices on site (figure 28). However, for consistency the historic downstream uranium concentrations are plotted on a control chart with previous and new action and focus trigger values in figure 30.

NOTE: this chart differs from the others as the 'control lines' are not upstream percentiles, they are ecotoxicological confidence limits

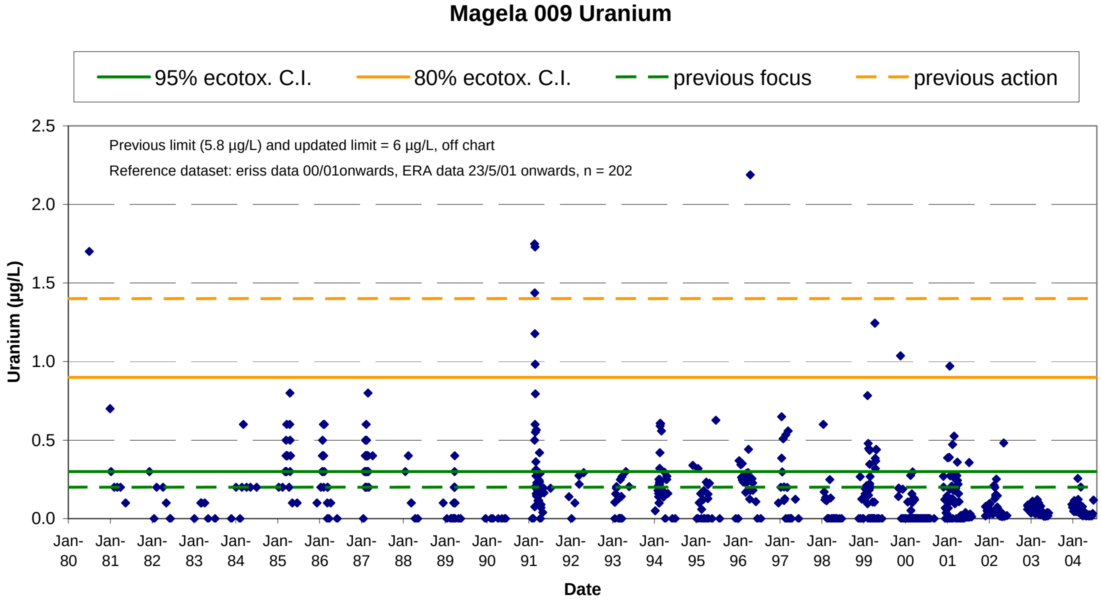

Figure 30 Magela Creek downstream uranium data plotted against the 80% and 95% lower confidence limits (the new focus and action trigger values) of the ecotoxicological limit and the previous focus and action trigger values

3.7.3 Recommended water quality objective for uranium in Magela Creek

The MCUS percentiles (table 7) do not provide a good management aid for uranium in Magela Creek, as uranium at the downstream site is elevated compared to the upstream site[14]. So a different approach is recommended for uranium based on ecotoxicological effects. The recommendation is to adopt the lower 80 and 95% confidence limits of the ecotoxicological limit as focus and action triggers, ie 0.3 and 0.9 µg/L respectively.

However, as ERA has managed to achieve uranium concentrations lower than this over the last several wet seasons the aim of water management should be to sustain this improved water quality. To achieve this any deliberate actions that might affect the downstream water quality should aim to achieve the lower uranium concentrations seen recently, unless a BPT assessment indicates it is not the best option. (For example, the last two seasons downstream

14 Scientific evidence shows that the ecosystem has not suffered as a result of these elevated uranium levels (Supervising Scientist 2004).

(MG009) data[15] should be used as achievable criteria at MG009 for assessing the design of the process water/pond water treatment plant within a BPT assessment framework.) While this does not fully meet the wishes of the traditional owners for no change in the water quality, it is more stringent than an objective based on scientific evidence of biological effects alone and is recommended to minimise water quality change in respect of the traditional owners wishes.

A dual-focus water quality objective is needed to (i) provide a scientific basis for assessing ecosystem protection and (ii) to work toward meeting the wishes of the traditional owners. This can be achieved by (i) implementing the ecotoxicologically based trigger values for the purposes of interpreting monitoring data (with respect to providing early warning of potential impacts to the ecosystem), and triggering actions, and (ii) sustaining the improved uranium concentrations of the last two wet seasons if practicable.

- The water quality objectives for uranium in Magela Creek are:
    i. **to report and act on any trigger value exceedances at MG009, where the trigger values are:**
        - **Focus = 0.3 μg/L,**
        - **Action = 0.9 μg/L,**
        - **Limit[16] = 6 μg/L, and**

    ii. **to sustain the lower uranium concentrations measured in the last two wet seasons when practicable.**
- The measures of success of meeting the objectives are that:
    i. 100% of downstream uranium concentrations are below the limit and there are no sustained increases above the focus and action triggers. And, all exceedances are reported and investigated as outlined in Appendix 1 *"Actions Invoked by Trigger Value Exceedances"*.

    ii. The uranium concentrations this wet season will not significantly differ to those of the last two wet seasons without reasonable cause.

3.8 Radium-226

The existing trigger values for ^{226}Ra are based on human health protection. The limit is a wet season mean arithmetic difference between downstream and upstream locations of 10 mBq/L. The focus level is a difference of >10mBq/L for a sample pair. The action level is >10mBq/L difference between downstream and upstream locations sustained over 90 days. Details are given in Klessa 2001b.

Because radium analyses are slow (in the order of several weeks to months) assessing results against the focus and action levels would not trigger any management action in an appropriate response time. Other key variables are more sensitive parameters for aiding quicker management response and identifying changes in trends. Therefore, dropping the focus and action levels is recommended.

The current limit should be retained with a small change to the way the wet season difference is calculated. This has been calculated in the past (2 years) as the mean of the differences

[15] The 80th, 95th and 99.7th percentiles of the last two years downstream uranium data are **0.08, 0.11** and **0.24** respectively.

[16] Note the limit for uranium has been revised to 6 μg/L (Hogan et al 2003).

(downstream minus upstream) for paired samples. A hydrographic time lag between the upstream downstream sites may differ from the difference in sampling time lag. Therefore, as recommended by Sauerland et al (2004), it is more appropriate to use a difference value between the data populations of upstream and downstream sites for the whole of the wet season rather than comparing individual paired data. The recommended change to the calculation of the wet season difference is to subtract the median of the downstream data for the whole of the wet season from the median of the upstream data. The name of the parameter would become the 'wet season median difference'. The limit for that parameter would still be 10 mBq/L.

3.8.1 Recommended water quality objective for radium-226 in Magela Creek

No focus or action trigger values will apply for ^{226}Ra. The limit will be a wet season median difference of 10 mBq/L calculated as the median of the downstream data for the wet season subtracted from the median of the upstream data for the wet season.

- The water quality objective for ^{226}Ra in Magela Creek is **that the median total ^{226}Ra activity concentration for the wet season at the downstream site will not be more than 10 mBq/L greater than that at the upstream site.**
- The measure of success of meeting this objective is that the downstream median total ^{226}Ra activity concentration for the wet season minus the upstream median total ^{226}Ra activity concentration for the wet season is not greater than 10 mBq/L.

4 Summary of objectives

Table 8 The Water Quality Objectives for Magela Creek and the measures of success of meeting those objectives

Parameter	Objective	Trigger values				Measure of success
		Focus	Action	Guideline	Limit	
pH	To retain the natural distribution of pH in Magela Creek and report and act on any trigger value exceedances at MG009.	5.9 – 6.5	5.6 – 6.7	5.0 – 6.9	N/A	The focus, action and guideline trigger values are not exceeded at the downstream site alone (ie exceedance not reflected at the upstream site) more often than statistically expected. And, all exceedances are reported and investigated as outlined in Appendix 1 "*Actions Invoked by Trigger Value Exceedances"*.
Turbidity	To retain the natural distribution of turbidity in Magela Creek and report and act on any trigger value exceedances at MG009.	5 NTU	10 NTU	26 NTU	N/A	The focus, action and guideline trigger values are not exceeded at the downstream site alone (ie exceedance not reflected to the upstream site) more often than statistically expected. And, all exceedances are reported and investigated as outlined in Appendix 1 *"Actions Invoked by Trigger Value Exceedances"*.
Electrical Conductivity	To (i) report and act on any exceedances of the focus, action and guideline trigger values, and (ii) to sustain the improved water quality seen in the last two wet seasons when practical.	21 µS/cm	30 µS/cm,	43 µS/cm	N/A	(i) All exceedances are reported and investigated as outlined in Appendix 1 *"Actions Invoked by Trigger Value Exceedances"*. (ii) The existing trigger values are not exceeded more often than in the last two wet seasons without reasonable cause
Magnesium	To minimise the magnesium mine signal at the downstream site and sustain the improved water quality seen in the last two wet seasons when practicable.	Use EC as proxy	Use EC as proxy	Use EC as proxy	N/A	The magnesium concentrations this wet season will not significantly differ to those of the last two wet seasons without reasonable cause.
Sulfate	To minimise the mine related sulfate signal at the downstream site and sustain the improved water quality seen in the last two wet seasons when practicable.	Use EC as proxy	Use EC as proxy	Use EC as proxy	N/A	The sulfate concentrations this wet season will not significantly differ to those of the last two wet seasons without reasonable cause.

Parameter	Objective	Trigger values				Measure of success
		Focus	Action	Guideline	Limit	
Manganese	When flow is dominated by surface flow (> 5 cumecs) the reference site distribution is achieved and any trigger value exceedances at MG009 are reported and acted on.	7 µg/L	11 µg/L	26 µg/L	N/A	The focus, action and upper guideline trigger values are not exceeded at the downstream site alone (ie exceedance not reflected to the upstream site) more often than statistically expected during periods where flow exceeds 5 cumecs. And, all exceedances are reported and investigated as outlined in Appendix 1 *"Actions Invoked by Trigger Value Exceedances"*
Uranium	To (i) report and act on any trigger value exceedances at MG009, and (ii) to sustain the lower uranium concentrations measured in the last two wet seasons when practicable.	0.3 µg/L	0.9 µg/L	N/A	6. µg/L	(i) 100% of downstream uranium concentrations are below the limit and there are no sustained increases above the focus and action triggers. And all exceedances are reported and investigated as outlined in Appendix 1 *"Actions Invoked by Trigger Value Exceedances"*. (ii) The uranium concentrations this wet season will not significantly differ to those of the last two wet seasons without reasonable cause.
Radium-226	The median total ^{226}Ra activity concentration for the wet season at the downstream site will not be more than 10 mBq/L greater than that at the upstream site.	N/A	N/A	N/A	10 mBq/L wet season median difference	The downstream median total ^{226}Ra activity concentration for the wet season minus the upstream median total ^{226}Ra activity concentration for the wet season is not greater than 10 mBq/L.

5 References

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Supervising Scientist 2004. *Annual report 2003–2004*. Supervising Scientist, Darwin NT.

Appendix 1 Actions invoked by exceedance of a trigger value

The responses invoked by an exceedance of a trigger value are described below.

For manganese, action is not necessary unless an exceedance of the manganese trigger occurs when flow at the compliance point is greater than five cumecs.

In the case of pH, a trigger exceedance shall be interpreted with regard to the values of other key variables.

Interpretation of notifiable high values should take account of the composition of samples taken upstream.

Exceedance of a focus trigger

Statistically expected ~20% of the time when triggers are based on the natural range of values measured at a reference site.

Values that are higher than the *focus level* but lower than the *action level* will result in a *watching brief*. A watching brief involves keeping an eye on the data in the coming weeks, or further sampling, to verify whether an upward trend is occurring.

An exceedance of a focus trigger does not have to be reported immediately but shall be reported in the *Weekly Water Quality Report* provided by the company to the Supervising Authorities and the Northern Land Council.

Exceedance of an action trigger

Statistically expected ~5% of the time when triggers are based on the natural range of values.

Values that are higher than the *action* level but lower than the *guideline/limit* must be reported[17] to the Supervising Authorities and the Northern Land Council immediately.

Confirmation of such a value by virtue of

- an abrupt change away from background values, or
- a trend away from background values,

will result in an *investigation* of the cause and *correction* of the cause if mining related.

An explanation of the cause (and any corrective action taken) shall be reported in the *Weekly Water Quality Report* provided by the company to the Supervising Authorities and the Northern Land Council.

Exceedance of a guideline

Statistically expected ~0.3% of the time when triggers are based on the natural range of values.

The company shall treat values in excess of the *guideline* the same as a *limit* exceedance except when there is a corresponding increase at the upstream site, and for manganese, when the flow is less than five cumecs. Under these circumstances a *guideline* exceedance will be treated as for an *action* exceedance.

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[17] Reporting by way of verbal communication is acceptable (Ranger Minesite Technical Committee 17/10/2003).

Exceedance of a limit

Company action

Values in excess of the *limit* must be reported both verbally and in writing to the Supervising Authorities and the Northern Land Council immediately. The company will also provide a detailed written report as soon as practical to the Supervising Authorities and the Northern Land Council detailing

- all relevant data,
- the circumstances surrounding the exceedance of the *limit*,
- the corrective actions taken to date; and
- options for further corrective action.

Supervising Scientist action

If in the opinion of the Supervising Scientist the exceedance of a limit is due to operations at Ranger the Supervising Scientist will advise the Minister with regard to

- *the circumstances surrounding the exceedance of the limit, and*
- *whether there has been a breach of the Ranger ERs.*

In drawing a conclusion that the exceedance of the limit for ^{226}Ra constitutes a breach of the ERs, the Supervising Scientist must be convinced that the anthropogenic dose to the critical group has exceeded 1mSv in one year.