8.0 Surface Water - Water and Sediment Quality

8.1 Summary

This section discusses the following issues raised in the PER guidelines regarding water and sediment quality.

- *Risk of Metal Transport*

Risk	Mitigation Measures	Monitoring	Contingency
Transport of metals into the aquatic environment	Internal clay cores of the OEF, TSF and flood protection bund will be protected by a rock-fill face to prevent erosion of the core from both direct rainfall runoff and flooding Only durable NAF material to be used on the outer rock-fill Runoff from the outer faces will be channelled by contoured drainage to sediment ponds prior to being discharged.	Water and sediment in sediment ponds to be monitored Water and sediment in McArthur River and Barney and Surprise Creeks to be monitored Trigger levels to be set to determine if there is a risk to the aquatic environment	Undertake a risk assessment to identify contingency actions which could include increasing sediment pond storage capacity or pumping pond water back for reuse on site

- *Fate of Metals in the Receiving Environment*

  The fate of metal species from the mining operations could be that they settle on the McArthur River bed and/or accumulate in biota. However, monitoring to date has not shown any detectable downstream metal effects from the existing mine. Potential sources of metals in the river from the Open Cut Project would be from water or sediment discharge. However the risk of metal contamination in downstream sediments or biota is minimal because the mine water management system prevents the discharge of contaminated water, and the rock armouring and sediment ponds surrounding the mine structures prevent the discharge of contaminated sediments.

- *Sediment Data*

  Sediment data for the McArthur River upstream and downstream of the mine are available for lead, zinc, cadmium and copper from 1994 to 2005. These data show that metal concentrations are all less than the relevant ANZECC guidelines (2000b). The existing monitoring program will continue and will be augmented by including additional parameters and sampling sites.

- *Tailings Storage Facility Discharge*

  Modelling has shown that a strategic release of excess water from the water management dam at the TSF is not required. However, the existing licensed emergency procedure for a controlled discharge will remain. The risk of an uncontrolled discharge from the TSF is 1 in 500 years at which time the dilution would be such that no adverse impacts on the downstream environment would occur.

- *Marine Monitoring*

  The existing marine monitoring at Bing Bong includes annual monitoring of shellfish and seagrass and monthly monitoring of water and sediment. In 2003 the McArthur River estuary was sampled for sediment, seagrass, oysters and water quality. The existing program will be expanded to include: migratory birds at Bing Bong (Section 11.4.4); annual sediment, oyster and seagrass sampling in the McArthur River estuary; and sampling for sediment and biota to be agreed with the local community at Sir Edward Pellew Islands. An independent expert will be engaged to review and explain the results of the monitoring program to the community.

8.2 Transport of Metals

8.2.1 Existing Water Quality

An assessment of existing surface water quality in the receiving waters around the McArthur River Mine is presented in Appendix C. This assessment provides a detailed evaluation of the specific risks of bio-available metal concentrations determined with hardness modified trigger values (HMTV) in accordance with 'Water Quality Guidelines for Fresh and Marine Waters' (ANZECC, 2000a).

The assessment utilised recent water quality data (2003-2005) to provide an assessment of current conditions of the receiving waters with statistical methods in accordance with the ANZECC guidelines.

The assessment has shown that the existing mining operations have not caused any toxic metal impacts on downstream aquatic ecosystems.

McArthur River

The water quality assessment (Appendix C) demonstrates that the aquatic ecosystems in the McArthur River have not been adversely impacted by copper, lead, or zinc from the existing mining operation. There is low risk of metals toxicity to McArthur River aquatic ecosystems because copper, lead, and zinc concentrations are within ANZECC HMTV water quality criteria (ANZECC, 2000a).

Surprise and Barney Creeks

The water quality data (Appendix C) for both Surprise and Barney Creeks show that copper and lead concentrations are within copper and lead ANZECC hardness modified trigger values (HMTV) criteria.

In Surprise Creek the zinc concentrations are below zinc ANZECC HMTV criteria. However, in Barney Creek zinc concentrations are higher due to the natural geology of this catchment. This is a natural occurrence, as evidenced by zinc concentrations upstream of the mine where water quality is not affected by mining activity. The upstream zinc concentrations in Barney Creek exceed zinc ANZECC HMTV criteria. Barney Creek also has naturally soft water (low hardness) as indicated by concentrations of $CaCO_3$.

If there were permanent aquatic ecosystems in the Barney Creek reach adjacent to the mine, the natural occurrence of elevated zinc concentrations and soft water could be considered a concern for toxicity to aquatic ecosystems. However, the reach of Barney Creek adjacent to the mine does not support permanent aquatic ecosystems.

The natural occurrence of elevated zinc concentrations in Barney Creek has not affected downstream permanent aquatic ecosystems in McArthur River as evidenced by downstream McArthur River zinc concentrations being within zinc ANZECC HMTV criteria. The typical flows in the McArthur River are approximately 15 times those of Barney Creek (Table 12.1, Draft EIS (URS, 2005a)), thus significant dilution of the naturally elevated zinc levels in Barney Creek occurs following confluence with the McArthur River.

8.2.2 Potential Risks of Metals Transport

The potential for toxicity impacts on the aquatic ecosystems due to on-going transport of metals from the materials used to construct the major components of the Open Cut Project (flood protection bund, TSF, and the OEF) has been assessed.

Toxicity impacts are a risk only if all of the following conditions occur:

- The materials contain metals that can leach at bio-available concentrations exceeding ANZECC HMTV criteria
- The controls for erosion (direct rainfall runoff or flooding) are inadequate
- The controls to contain eroded sediment are inadequate.

8.2.3 Metals Transport Risk Assessment and Mitigation

The actual risk of the Open Cut Project causing toxicity to aquatic ecosystems due to erosion of materials is extremely low, because not all of the above criteria are met. McArthur River Mine has evaluated the materials used to construct the major project components and has developed measures to ensure the protection of aquatic ecosystems from eroded sediment, and consequent potential metal toxicity impacts.

Flood Protection Bund

The external face of the flood protection bund will be rock-filled (average rock diameter of 300 mm) to provide geotechnical stability and to protect its internal clay core against erosion. Initially the rock-fill material will be a combination of the Breccias, Shale and Dolomitic sandstone excavated from the river diversion channel.

Subsequently, during the development of the open cut, the slope of the internal and external faces of the bund will be reduced by the addition of more rock-fill by using NAF rocks from the mine pit. Details of the bund design are given in Section 9.

Material Excavated from River Diversion

As discussed in the Draft EIS (URS, 2005a), static testing of the rocks to be excavated from the river diversion was used to determine their soluble metals concentration. The results of this analysis show that for all the material types to be excavated from the river diversion, soluble metals concentrations are all below analytical detection limits (ICP-AES instrumentation), indicating a very low risk of metal contamination of surface water or seepage water from these materials. All of the rock material types were categorised as NAF.

In addition to the soluble metals analysis from the static tests, all material types likely to be excavated from the river realignment and used in the flood protection bund are now being subjected to kinetic leach tests. Such tests are designed to indicate the time-dependent solubility of metals in these materials and the likely rate of generation of metals, salts and acidity in runoff.

As discussed in Section 6.3, kinetic leach testing has indicated the runoff from materials to be excavated as part of the river diversion will be pH neutral, fresh-to-brackish with concentrations of metals and salts below ANZECC (2000a) and NEPC (1999) livestock drinking water guidelines. These results are consistent with the initial static test findings.

Material Excavated from Mine Pit

As discussed in the Draft EIS (URS, 2005a), kinetic leach testing of the overburden rocks to be excavated from the mine pit was undertaken to identify which rocks were NAF and which were PAF.

The results of this analytical work showed that the Lower Dolomitic Shale, W-Fold Shale and Teena Dolomite are all NAF, and that soluble metals in runoff from these materials will remain within ANZECC (2000a) livestock drinking water guidelines. It is these materials that will be used to reduce the slopes of the flood protection bund.

As discussed in Section 6.3, additional dynamic leach testing of the overburden rock types has been undertaken. This has confirmed the findings of the Draft EIS (URS, 2005a) that runoff from the NAF materials will be pH neutral, fresh-to-brackish with concentrations of metals and salts below ANZECC (2000a) and NEPC (1999) livestock drinking water guidelines. The only exception to this was the Upper Pyritic Shale material which, while categorised as NAF, has shown initial indications of elevated concentrations of metals and salts. Because of this, Upper Pyritic Shale will not be used on the external faces of the OEF, flood protection bund or the TSF.

Erosion Protection

The proposed design of the flood protection bund is shown on drawings BEE508-C-DWG-301, 302, 303 and 308 in Appendix B. The alluvial clay material from the river and creek excavations will be placed into the core of the flood protection bund to provide a watertight seal. The bund core will be protected from erosion by an armoured rock cover of NAF material as discussed above.

At the commencement of mine operations, the rock cover will be a minimum thickness of 6 m at the crest of the bund extending to 30 m at the base with finer material against the core and the larger rocks on the outside.

This thickness of armoured rock will subsequently be increased with placement of additional NAF rock from the open cut excavations to reduce the slope of the bund's internal and external walls. The final width of the outside base of the rockfill will increase to 80 m from the core of the bund.

The armoured rock cover for the flood protection bund will provide a high level of protection from erosion cause by direct rainfall and runoff. In effect, the bund will not be eroded by direct rainfall and runoff.

The armoured rock cover for the flood protection bund will also protect the bund from erosion against river flooding. The average rock diameter (D_{50}) will be 300 mm, which will resist erosion from flow velocities up to 2.6 m/s. Flood modelling results show that the maximum flood velocity at the bund will be 1.5 m/s from all flood events including up to a 500-year ARI flood.

Sediment Retention

Runoff from the external face of the flood protection bund will be channelled by contoured drainage to sediment ponds prior to being discharged. These ponds will be designed according to engineering guidelines for soil erosion and sediment control (Institution of Engineers Australia and the Australian Institute of Agricultural Scientists, 1996).

Where practicable, procedures for the construction and maintenance of the sediment ponds will include the following:

- Sediment ponds will be preferably excavated below the natural ground surface. Where it is necessary to construct embankments to form a sediment pond, embankments will be adequately compacted with batter slopes commensurate with the available materials
- Sediment ponds will include a high flow 'spillway' outlet to safely pass floods without breaching the basin. Spillways will be sized to cater for 10-year ARI events
- Sediment ponds will include adequate provisions for access for regular monitoring and maintenance to clean out captured sediments
- Subject to constraints of available space and topography, sediment ponds will be constructed with a plan shape aspect ratio of at least 3 to 1 (length measured from inlet to outlet in relation to width)
- Sediment ponds will be sized with sufficient sediment storage capacity to match the combination of the rate of incoming sediment quantities and planned frequency of sediment removal from the basin
- Clean water diversion drains will be installed to divert clean stormwater flow from undisturbed areas away from the sediment ponds. Diversion drains will also be installed as necessary to direct runoff from the external bund face to the sediment ponds. Diversion drains will to be sized for 5-year ARI storm events with flow velocities limited to 1 m/s

- The sediment levels in surface runoff are expected to drop significantly after the first wet season following construction. After assessing two years of water quality data from the sediment ponds, the need for their ongoing operation will be reviewed in consultation with the Northern Territory Government.

Risk Assessment

The above discussion demonstrates how each of the conditions listed in Section 8.2.2 that could potentially contribute to the transport of metals into the aquatic environment from the flood protection bund will be managed.

Implementation of the control strategy as outlined above will provide a triple level of protection by ensuring that:

- Only NAF materials that do not leach metals at bio-available concentrations exceeding ANZECC HMTV criteria will be exposed
- The bund's clay core will be protected by a rock-fill face of NAF material to prevent erosion of the core from both direct rainfall runoff and flooding
- Runoff from the bund's external face will pass through contoured drainage to sediment ponds, to retain any sediment which might be generated.

Implementation of this strategy will ensure that the risk of ongoing transport of metals into the aquatic environment from the flood protection bund will be minimal.

Tailings Storage Facility

The TSF embankment will be designed as a water retention structure in a similar manner to the flood protection bund. It will consist of a low permeability clay core that will be keyed into the underlying foundation material, and which will be covered with a rock-fill embankment to enhance its structural integrity and to provide erosion protection.

Rock for the embankment will be sourced from the river diversion excavation and from mine pit overburden. Only NAF rock will be used. Further details of the TSF design are given in Section 7.2.

As discussed above, geochemical testing has confirmed that the NAF material to be used as rock-fill for the TSF embankment will generate runoff that contains concentrations of metals and salts within ANZECC (2000a) and NEPC (1999) livestock drinking water guidelines. Drainage from the TSF embankment will not result in any toxic effects from metals in downstream aquatic environments.

Similarly, the rock-fill outer layer of the TSF will provide adequate protection against erosion. Typically the rock-fill thickness will be approximately 3 m at the top increasing to 40 m at the base. Average rock diameter (D_{50}) will be 300 mm, which will resist erosion from flow velocities up to 2.6 m/s. Flood modelling results show that the maximum flood velocity at the TSF embankment will be 1 m/s from all flood events up to a 500-year ARI flood.

Runoff from the external face of the TSF embankment will be channelled by contoured drainage to flow through sediment ponds prior to being discharged. These ponds will be designed as described above and will be in accordance with the engineering guidelines for soil erosion and sediment control (Institution of Engineers Australia and the Australian Institute of Agricultural Scientists, 1996).

The sediment levels in surface runoff are expected to drop significantly after the first wet season following construction. After assessing two years of water quality data from the sediment ponds, the need for their ongoing operation will be reviewed in consultation with the Northern Territory Government.

As is the case for the flood protection bund the proposed control strategy for the TSF embankment will provide a triple level of protection by ensuring that:

- Only NAF materials that do not leach at bio-available concentrations exceeding ANZECC HMTV criteria will be exposed
- The embankment's clay core will be protected by a rock-fill face of NAF material, which will vary in thickness from 3 m to 40 m to prevent erosion of the core from both direct rainfall runoff and flooding
- Runoff from the embankment's external face will pass through contoured drainage to sediment ponds to retain any sediment which might be generated.

Implementation of this strategy will ensure that the risk of ongoing transport of metals into the aquatic environment from the TSF embankment will be minimal.

Overburden Emplacement Facility

There will be no risk of on-going transport of metals into aquatic ecosystems from erosion of or runoff from PAF materials in the OEF due to their encapsulation (URS, 2005a).

The OEF materials that could be potentially vulnerable to on-going erosion will be limited to NAF materials used to cover the OEF or from the NAF disposal operations. The cover material for the OEF will comprise competent NAF rock sourced from the mine pit.

The type of rock used for the cover will depend upon what is being mined at any given time and the mechanical and geochemical characteristics of the rock type. Only hard (competent) materials will be selectively used as cover material. Based on the current mine plan, the OEF cover material is expected comprise competent NAF, Teena Dolomite, Dolomitic Sandstone and Breccia.

Kinetic leach column testing has commenced on individual (non-composite) samples of Teena Dolomite and breccia. Test results indicate that leachate from these materials will be pH neutral, fresh and have concentrations of metals and salts below ANZECC (2000a) and NEPM (1999) livestock drinking water guidelines. This confirms the leach test results from the composite samples reported in the Draft EIS (URS, 2005a).

The OEF will be progressively rehabilitated and hence the active dumping area which could be exposed to on-going erosion will be minimised. This will substantially reduce the potential sediment levels in surface runoff generated by erosion.

Runoff from the PAF side of the OEF will discharge to the PAF Pond, which will be designed and operated as part of the site-wide water management system. Water in this pond will not be discharged, but will be pumped to the water management dam at the TSF and reused in the processing plant. The PAF pond has been designed to cater for a 1 in 100-year rainfall event. This procedure will ensure that there is no risk of the transport of metals from the PAF side of the OEF into the aquatic environment.

The sediment ponds that collect all runoff from the NAF zone of the OEF will trap sediment eroded from the OEF. This will occur primarily from the active dumping operation and will provide a safeguard against the potential for transport of metals from the OEF to aquatic ecosystems. The sediment ponds will be designed in accordance with the requirements of the Institution of Engineers Australia and the Australian Institute of Agricultural Scientists (1996). The NAF sediment ponds at the OEF will operate for the life of the mine.

The NAF sediment ponds will occasionally overflow clean runoff water into receiving waters. The quality of overflows will be monitored by sampling and laboratory analysis, and will be supplemented with monitoring of McArthur River receiving waters upstream of the mine to establish trigger levels. The monitoring will include total metals concentrations and filtered metals concentrations.

Trigger levels will establish if the quality of overflow waters (including sediment metals in water) is a potential risk to aquatic ecosystems, in accordance with the following criteria:

- If filtered metals concentrations in NAF sediment pond overflow exceed ANZECC HMTV metals criteria; or
- If total metal in NAF pond overflow exceed corresponding total metal concentrations in upstream McArthur River by more than 10%.

If monitoring shows that either of the above trigger levels is exceeded, one or more of the following corrective actions and safeguards will be implemented:

- Risk assessment studies will be undertaken to quantify the risk of the NAF sediment pond metals load on downstream aquatic ecosystems. This will involve the determination of:
  - The total quantity of metals in the NAF sediment pond discharge (by integration of discharge quantity and metals concentration) to evaluate total metals loads into the McArthur River
  - The total upstream McArthur River metals load
- The relative impact of the sediment pond metals load on McArthur River metals load will be determined to quantify the risk of the NAF sediment pond metals load on downstream aquatic ecosystems
- The risk assessment process and results will be undertaken in consultation with the Northern Territory Government. If the risk assessment identifies potential for adverse risk to downstream

aquatic ecosystems from the sediment pond discharge, corrective actions will be implemented which could include:

- Increasing the capacity of the NAF sediment pond to reduce quantity of pond discharge and increase effectiveness of sediment settling rates or
- Pumping water from the NAF sediment pond to the water management dam at the TSF, to minimise the probability of discharge, and re-evaluating the site water balance modelling to quantify the impact on overflow risk of the TSF. If necessary the capacity of the TSF will be increased to maintain its design criterion of 1 in 500-year overflow risk.

The extensive evaluation of OEF materials, the proposed OEF design, safeguards, and the implementation of the above monitoring and corrective actions will ensure that the potential for on-going transport of metals into aquatic ecosystems from erosion of the OEF materials will be negligible.

River and Creek Diversions

There could be potential for adverse impacts on water quality in the McArthur River or Barney Creek if the diversion channels are constructed with materials that leach excessive quantities of metals or sulfates, or create acidic conditions. This risk will be controlled by ensuring that the materials placed in the diversion channels (including bank protection and rehabilitation materials) will be NAF only. They will be classified by geochemical testing to confirm that leachate concentrations of metals are below ANZECC HMTV criteria for the protection of aquatic ecosystems.

Geochemistry investigations (Section 6.3) have shown that the rock to be excavated from the diversion (and the in-situ rock remaining exposed in the channel) will not produce high concentrations of metals. Many of the test results show metal concentrations below levels that can be measured in a laboratory. The conclusion of the geochemistry assessment is that water quality (or leachate) from the rock in the diversion channel will have metal concentrations below ANZECC HMTV criteria.

For the in-situ rock that will remain exposed in the diversion channel, there is a significant degree of conservatism in the geochemical investigation results due to the method used for testing. The kinetic leach testing simulates infiltration through a rock dump by passing water through many small pieces of crushed rock to maximise the surface area of the rock in contact and reacting with water. This type of testing produces a more concentrated leachate (conservative) compared to the quality of water expected in the diversion channel where the surface area of the in-situ rock exposed to the water is considerably less than that in the kinetic leach tests. Hence, the rock material left exposed in the diversion channel is expected to produce concentrations of metals lower than the results of the geochemical investigations.

The same control measures used for the McArthur River channel will be applied to Barney Creek. Rock will be geologically classified by type and then categorised according to the geochemical investigation results. All rock materials placed in the Barney Creek diversion will be NAF and metals concentrations are expected to be below ANZECC HMTV criteria.

With the above control strategies, the rock materials in the diversion channels are not expected to generate acidic conditions or metal contamination, including in the event of neutral drainage. To confirm this conclusion, the following monitoring will be undertaken during and after construction:

- The rock types exposed in the diversion channel excavations (including bed and banks) will be mapped and classified by an experienced geologist. This mapping will be used to provide an as-constructed record of the channel and to guide the water quality testing program.
- Progress inspections will be undertaken by an experienced geologist during placement of rock materials to ensure that PAF rock has not been placed in the diversion channels. Any identified PAF material will be immediately removed and replaced with NAF material. This checking process will be repeated at the completion of construction.
- The rocks placed in the diversion channels for bank lining or armouring, bed armouring, and riffles construction will be classified according to rock type. Plans showing where different types of rocks have been used and their geochemical characteristics will be included in the as-constructed report of the diversion works.
- After construction, water quality monitoring in the McArthur River and Barney Creek will be undertaken to confirm that no diversion materials are leaching metals. The as-constructed mapping of the completed diversion channels will be used to guide the location and number of water quality monitoring sites as necessary to identify any potential sources of contamination.

In the unlikely event that the water quality monitoring identifies elevated metal concentrations from the diversion materials at levels that could be a risk to aquatic biota, or that in-situ materials with the potential to leach elevated metal concentrations are identified, one or more of the following contingency measures will be implemented:

- The water quality monitoring program will be intensified (locations, samples and frequency) to accurately identify the specific area where metals are leaching and/or acidic conditions are occurring, and under what flow conditions
- A detailed geochemical sampling and testing program of the relevant channel materials will be undertaken to confirm that they are the source of the elevated metal concentrations or acidic conditions
- Any installed rock materials (e.g. rock placed on banks or in riffles) that are shown to be creating acidic conditions or elevated metals concentrations will be removed and replaced with NAF rock that has been tested and demonstrated to produce acceptably low concentrations of metals.
- If a section of the in-situ channel bed or bank rock is identified as producing acidic water but is low in metal concentrations, dolomitic NAF rock could be placed over the acid source to neutralise any potentially acidic drainage.
- If a section of the in-situ channel bed or bank is identified as producing high metal concentrations (either acidic or neutral), the in-situ rock could be excavated to a depth of approximately 2 m below the design profile, covered with a minimum of 1 m of compacted clay, and then armoured with 1 m of NAF rock. The compacted clay seal over the in-situ rock will limit its exposure to air thereby

minimising oxidation and limiting the leaching of metals. The armour rock over the clay will prevent it from being washed away. Alternative methods to seal the in-situ rock (such as concrete, epoxy, or tunnel sealing products) may also be considered.

8.3 Fate of Metal Species

The fate of metals in mineralised sediments mobilised by mining activities at McArthur River Mine will be similar to the fate of metals in naturally mineralised sediments from natural erosion processes, which transport sediment from the catchment to the coast. Similar to the natural processes, it is possible that metal species in sediments exposed or mobilised by the Open Cut Project could ultimately bio-accumulate in aquatic biota.

The mobilisation of mineralised sediments must be recognised in the context that the McArthur River has a natural erosion and sediment transport function, and without these on-going long term processes and natural phenomena, the McArthur River would not exist in its current form. The coastal alluvial delta at the mouth of the McArthur River provides evidence that erosion and sediment transport from the catchment to the coast has been occurring over thousands of years.

The assessment of available water quality data also shows that the catchment geology and derived sediments are naturally mineralised with elevated metals concentrations (e.g., water quality data for Barney Creek show that zinc concentrations upstream of the mine are naturally elevated, and water quality in this area is not affected by mining activities (Section 8.2.1)).

The risks of metals toxicity to aquatic biota downstream of the mine would only be of concern if the mine increased quantities of mineralised sediment in the McArthur River above guideline values, or discharged water with high concentrations of bio-available metals at quantities sufficient to increase the quality of receiving waters above guideline values.

With the implementation of the proposed mine water management strategy to contain and reuse all contaminated waters on site, the potential for discharge of mine water with high concentrations of bio-available metals is low. As described previously, the mitigation measures to ensure that the risk of excessively increasing the quantities of mineralised sediment will be low include:

- The geochemical evaluation of all construction materials so that only those that generate runoff within relevant guidelines are classified as NAF
- Designing and constructing the mine works to minimise erosion
- Providing contoured drainage to sediment ponds to contain eroded sediment from works that are potentially vulnerable to erosion.

8.4 NAF Runoff Monitoring

As discussed in Section 8.2, runoff from each of the project components using NAF rock as a construction material (flood protection bund, TSF and OEF) will pass through sediment ponds prior to release from the site. This measure is proposed as an additional safeguard to confirm the results of the project's geochemical testing program.

The proposed water monitoring program for the sediment ponds comprises the following key elements:

- Timing
  - In-situ monitoring undertaken following heavy storm events
  - Samples collected for laboratory analysis monthly (if water present) or following pond discharge
- Analysis
  - In-situ: pH, EC, Redox
  - Acidity/alkalinity
  - TDS/TSS
  - Soluble metals in total and filtered samples (As, Cd, Cu, Fe, Hg, Mn, Pb, Zn)
  - Soluble major cations in total and filtered sample (Ca, Mg, Na, K)
  - Soluble Cl, SO_4
  - Hardness
  - N, P, chlorophyll 'a'.

The proposed sediment sampling program for the sediment ponds comprises the following key elements

- Sediment sample from ponds collected quarterly during the wet season (subject to safe access)
- Analysis to include:
  - Particle size distribution
  - Metals (total fraction and fraction passing 75 micron): As, Cd, Cu, Fe, Hg, Mn, Pb, Zn

Until such time as site-specific trigger levels have been developed, default trigger levels applying to the sediment ponds will be set in accordance with the following criteria:

- Filtered metal concentrations in the sediment pond exceed the ANZEEC HMTV for 95% protection level of freshwater aquatic ecosystems
- The total metals concentration in pond overflow exceeds the total metals concentration in the upstream monitoring site in the McArthur River by more than 10%.

Should either of the above criteria be triggered, a risk assessment will be undertaken to identify the source of the metal contamination. Contingency measures will then be implemented based on the outcome of the risk assessment. Such measures could include increasing the size of the ponds to increase their sedimentation capacity, or pumping the retained water into the closed mine water management system so that the water is reused on site and not discharged.

8.5 Sediment Monitoring Program

Existing Sediment Data

McArthur River Mine has been monitoring sediment quality in the McArthur River downstream and upstream of the mine since 1994. This monitoring has included sampling and analysis for zinc, lead, copper and cadmium. The results of this monitoring are summarised in the following figures. Monitoring site SW7 in upstream of the mine and site SW6 is downstream.

The data show that all samples were well below the relevant ANZECC (2000b) sediment quality guidelines. These results indicate that the existing mining operation is not having any significant effects on downstream sediment quality.

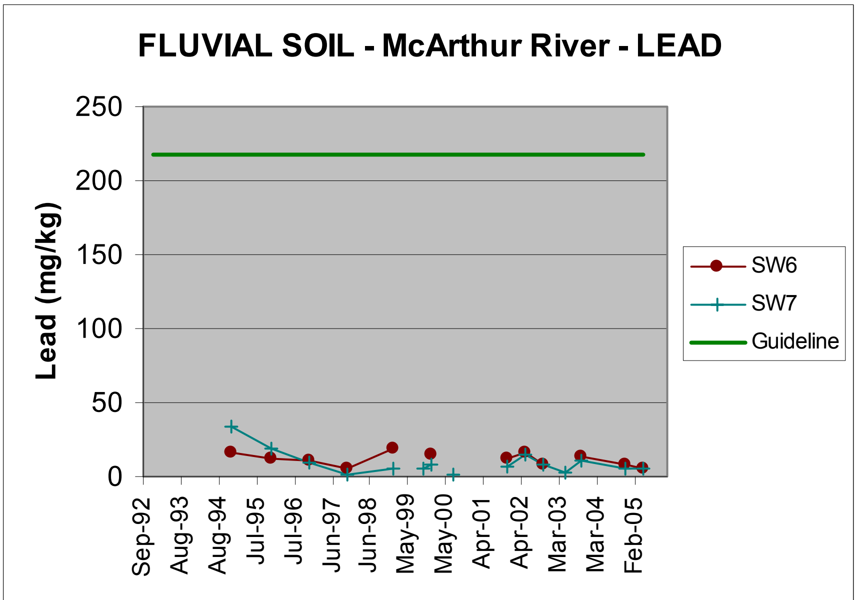

Figure 8.1

Lead Concentrations in McArthur River Sediments

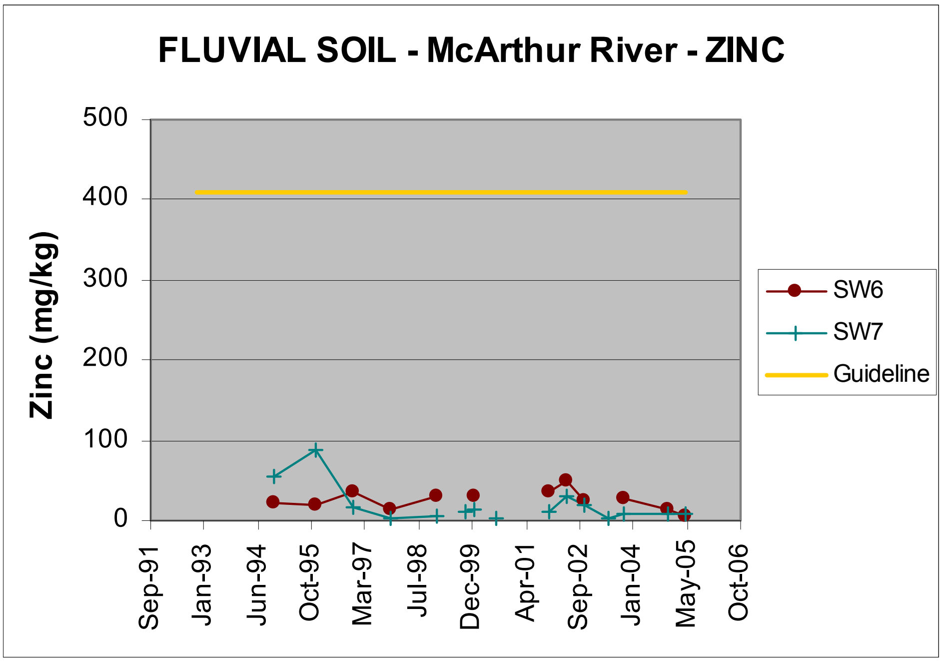

Figure 8.2

Zinc Concentrations in McArthur River Sediments

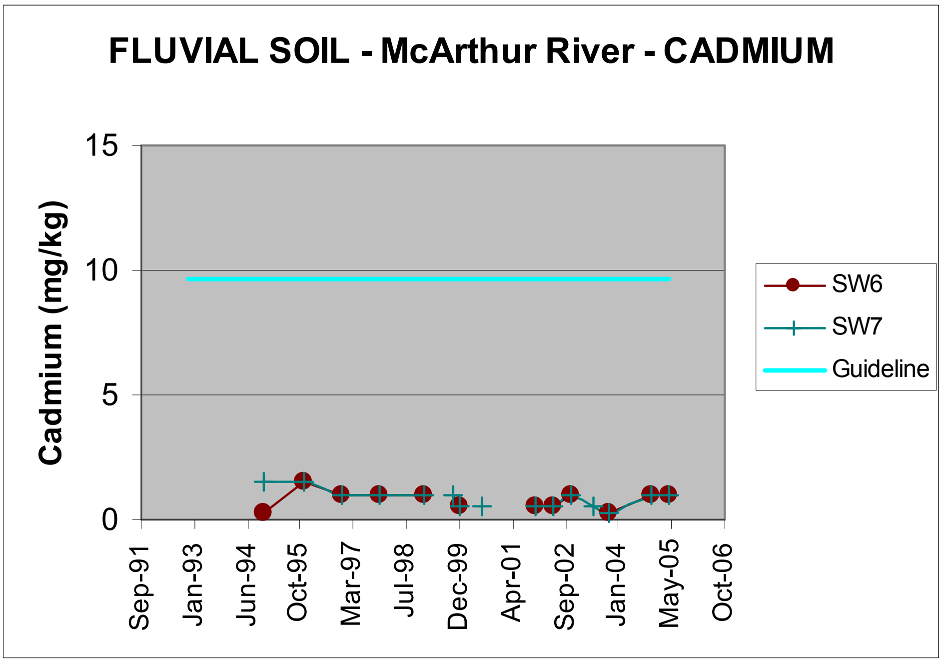

Figure 8.3

Cadmium Concentrations in McArthur River Sediments

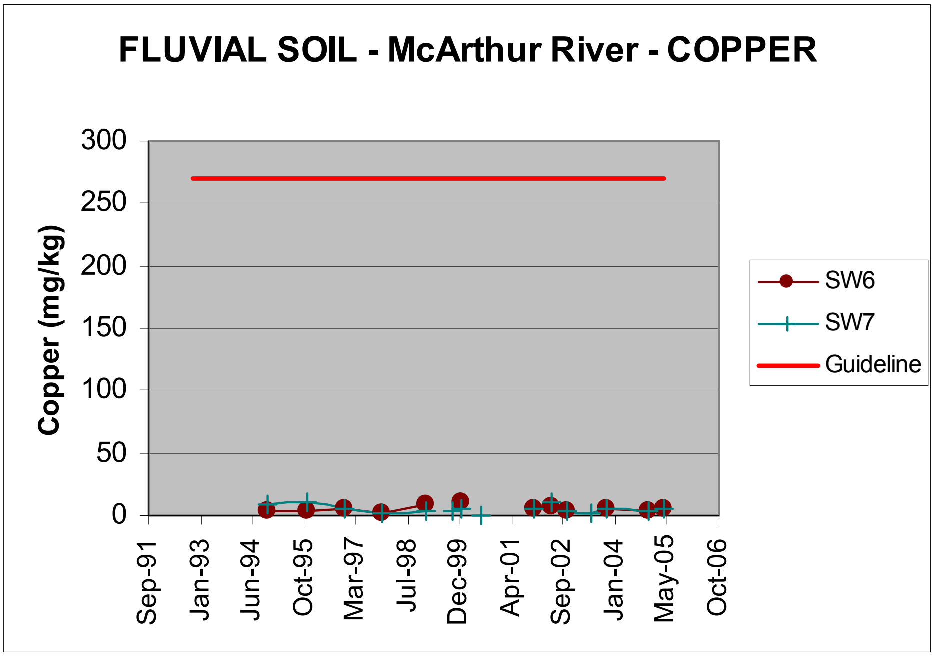

Figure 8.4

Copper Concentrations in McArthur River Sediments

Proposed Sediment Monitoring

With the implementation of the Open Cut Project it is proposed to augment the existing sediment monitoring program. The proposed monitoring program for the McArthur River comprises the following key elements

- Monitoring Locations:
  - Two locations upstream (SW7 and additional site within 100 m in case there is an anomaly with one of the sample results)
  - One location downstream of the Barney Creek diversion but upstream of the point where the McArthur River diversion rejoins the existing river channel
  - One location downstream of the point where the McArthur River diversion rejoins the existing river channel but upstream of the junction with the Glyde River
  - One location downstream of the Glyde River junction
- Timing
  - Monitoring to be undertaken quarterly (subject to safe wet season access)
- Analysis - Sediment
  - Particle size distribution
  - Soluble metals (total and filtered passing 75 micron filter) - (As, Cd, Cu, Fe, Hg, Mn, Pb, Zn)

  - Soluble major cations in total and filtered (passing 75 micron filter) sample - (Ca, Mg, Na, K)
- Analysis – Water (at the same location and the same time as the sediment sampling)
  - In-situ pH, EC, Redox
  - TDS/TSS
  - Soluble metals in total and filtered samples (As, Cd, Cu, Fe, Hg, Mn, Pb, Zn)
  - Soluble major cations in total and filtered sample (Ca, Mg, Na, K)
  - Soluble Cl, SO_4
  - Hardness
  - N, P, chlorophyll 'a'.

8.6 TSF Discharge Regime

Containment of TSF Effluent

The PER guidelines have requested 'Dilution/hydraulic modelling to determine appropriate minimum river flow/stage height requirements for a discharge regime to deal with diluted TSF effluents that may need to be discharged during heavy rainfall events'.

The Open Cut Project will not require controlled discharge from the water management system, and thus discharge limits are not required. It will not be necessary for the controlled discharge of diluted TSF effluent during heavy rainfall events.

The TSF will be managed as part of the site water balance, and any runoff from the TSF will be contained within the site water management system. Water in this system will not be discharged, but will be reused in the process plant, with any excess water stored in the decommissioned underground workings. OPSIM water balance modelling of the site has shown that the water management system can be operated as a closed system that will not require discharge.

The key objective of the proposed water management strategy is to ensure that adequate containment is available for extreme rainfall conditions (up to 1 in 500 years at the TSF and 1 in 100 years at the OEF PAF pond). The water management system will continue to be adapted and tested with the OPSIM water balance modeling to ensure that the management strategy complies with the defined overflow risk criteria.

As part of further project planning and refinement, several additional contingency measures for water management have been proposed that could add additional sources of water to the water management system. These additional sources include runoff in the sediment ponds surrounding the flood protection bund and the TSF, and the OEF NAF sediment pond. Water from these ponds (which will be from NAF rocks only) will only be diverted to the water management system in the unlikely event that monitoring shows that it poses a risk to downstream aquatic ecosystems. Geochemical investigations have shown that such a risk is unlikely. However, in the event that these precautionary safeguards need to be implemented, MRM will evaluate, optimise and implement necessary changes to the water management strategy to ensure that the additional water can be managed to comply with the defined overflow risk criteria.

Water from the TSF seepage recovery bores will also be a source of additional water to the mine water management system. As part of detailed design of the seepage recovery bore system, MRM will evaluate and optimise the preferred management strategy for seepage recovery using OSPIM modeling to ensure that the system can continue to comply with the defined overflow risk criteria.

Using the OPSIM water balance modeling to evaluate performance and to assess overflow risk will continue to form a key part of MRM's on-going evaluation of water management risk and adaptation of the water management strategy. Regular reviews and updates of the water balance modeling will be undertaken to account for actual quantities of all contained water from all sources and the contingency measures proposed. Such contingency measures to contain any additional water could include increasing the volume of water stored in the decommissioned underground workings, increasing the capacity of the existing water storage ponds, or constructing new storage or evaporation ponds. All assessments of the predicted water management performance (overflow risk) from updates of the OPSIM modeling and the strategies to be implemented to ensure the overflow risk criteria are maintained will be reported to the Northern Territory Government through the Mine Management Plan.

Waste Discharge Licence

McArthur River Mine has a licensed emergency discharge procedure, and it is proposed that this licensed procedure will continue to apply for the Open Cut Project subject to negotiations with the DPIFM. The emergency discharge procedure allows for controlled discharges via pumps and siphons at a rate that must be limited to ensure that the zinc concentration monitored at the downstream McArthur River surface water monitoring site (SW6) does not exceed the concentration at the upstream monitoring site (SW7) by more than 50 μg/L.

Specific monitoring and reporting procedures are invoked for the emergency discharge procedure, including monitoring at SW4, SW8 and the clean water dam. Controlled discharge is not permitted when river flows at the existing DIPE stream gauge are below the 4 m gauge level (a flow of approximately 100 m^3/s).

A controlled emergency discharge from the water management dam could only occur for storm events greater than or equal to a 1 in 500-year ARI.

Uncontrolled Discharge

In extreme rainfall conditions that exceed the containment capacity of the TSF, overflow from the TSF could occur and may not be controlled. This occurrence would be extremely rare and is not a controlled discharge that could be licensed. This is different to the emergency discharge licence where the discharge is controlled and the license is based on the quality of discharge.

It is not feasible to license the quality or quantity of an uncontrolled discharge when the cause (extreme rainfall) is beyond the control of MRM. However, it is possible for MRM to ensure that the water management system has sufficient containment capacity (demonstrated by OPSIM water balance modelling) to limit the probability of an uncontrolled discharge. Hence, the criteria developed for an uncontrolled discharge in an extreme rainfall event have been based on the risk of the discharge occurring (which can be controlled) rather than quality or quantity of the discharge (which cannot be controlled).

The proposed criteria for the probability of an uncontrolled discharge (1 in 500 years for the TSF, and 1 in 100 years for the OEF PAF pond) are acceptable criteria to ensure minimal risk to the receiving environment. This recognises that it is neither possible nor practical to estimate and contain all implausible, but possible, extreme probable maximum rainfall that could cause uncontrolled discharge. The proposed water management criteria are therefore based on an acceptable minimisation of the risk of overflow. The proposed uncontrolled discharge risk criteria for the TSF are more stringent than the ANCOLD Tailings Guidelines (ANCOLD, 1999) risk criteria for containment.

Any uncontrolled discharge would be unlikely to produce adverse impact on downstream aquatic ecosystems. The quantity of an uncontrolled discharge from the TSF would be an immeasurably small component (<0.02%) of the flow in the McArthur River near the mine when such an overflow might occur. It would be much less and not detectable in the aquatic ecosystems in the McArthur River estuary further downstream. In simple terms, this extremely low risk can be considered as being similar to adding a teaspoon of sugar to an olympic swimming pool once every 500 years. Should it occur, the impact would be so small that it would not be measurable, and it would occur so infrequently that there would be no permanent effect on the health or sustainability of the aquatic ecosystems.

8.7 Marine Monitoring Program

8.7.1 Bing Bong

Existing Monitoring Program

An extensive environmental monitoring program has been undertaken at Bing Bong since 1998. This program has included the following:

- Monthly monitoring of water quality and sediments.
- Annual monitoring of shellfish and seagrass.

The monitoring program has identified levels of lead and zinc elevated above background in surface sediments on the beach and mangrove area immediately west of Bing Bong. Investigations of the lead isotope ratios show that the elevated levels are attributed to the McArthur River Mine concentrate.

However, while the metal concentrations have been identified as elevated compared to background levels east of the channel and in offshore sediments, the concentrations are substantially lower than the ANZECC 2000 ISQG – Low levels (Table 8.1). As the metals levels are below the ISQG Low levels, there is a low probability of effects on benthic biota.

Table 8.1

Range Of Metal Concentrations (Mg/Kg Dry Wt., Averages For Each Year) In <63 µm Fraction of Surface Sediments Compared to ANZECC (2000b) Interim Sediment Quality Guidelines

Metal	Offshore Bing Bong	East of Channel	West of Channel	ISQG – Low*	ISQG-High**
Cu	10-14.6	7.4-13.2	11.5-14.4	65	270
Zn	19.6-37.8	23.1-43.7	58-75	200	410
Cd	0.04-0.15	0.02-0.16	0.06-0.21	1.5	10
Pb	9.4-15.1	10.2-18.4	18.6-28.9	50	220

*ISQG-Low: Interim Sediment Quality Guideline Low value, below which there is a low probability of effects on benthic biota (ANZECC, 2000b).

** ISQG-High: Interim Sediment Quality Guideline. Above this value there is a high probability there will be toxic effects. Between the High and Low values there is an intermediate probability of effects (ANZECC, 2000b).

The results from 1998 to 2005 show no increasing trends for any of the four metals Cu, Zn, Cd and Pb, which may indicate that the levels are largely due to contamination during the first year or so of the load out operation.

Two species of molluscs, *Telescopium telescopium* and *Terebralia semistriata*, have levels of zinc and lead that are elevated above background levels west of the channel (Tables 8.2 and 8.3). However the levels of lead and cadmium have remained substantially below Maximum Levels for Molluscs (Australia and New Zealand Food Standards, 2004).

While there are no reference levels in these food standards for copper and zinc, the copper levels are below the background levels in oysters from the area and zinc is in the same range (Munksgaard and Parry, 2006). As observed for the sediment metal levels, there has been no increasing trend in metal levels from 1998 to 2005 in these two species of molluscs.

Table 8.2

Range of Metal Concentrations (mg/kg wet wt., averages for each year) in *Telescopium telescopium* Compared to Australian Food Standards

Metal	East of Channel	West of Channel	ANZFS ML*
Cu	5.8 – 22.6	3.8 – 19.0	-
Zn	18.4 – 36.2	42.5 – 99.2	-
Cd	0.17 – 0.27	0.17 – 0.35	2
Pb	0.28 – 0.37	0.31 – 0.83	2

* Australia New Zealand Food Standards Code, 2004.- Maximum Level

- : Not established

Table 8.3

Range of Metal Concentrations (mg/kg wet wt., averages for each year) in *Terebralia semistriata* Compared to Australian Food Standards

Metal	East of Channel	West of Channel	ANZFS ML*
Cu	9.5 – 19.1	6.5 – 22.2	-
Zn	15.2 – 28.7	20.3 – 52.2	-
Cd	0.29 – 0.60	0.19 – 0.60	2
Pb	0.14 – 0.44	0.17 – 0.80	2

* Australia New Zealand Food Standards Code, 2004 - Maximum Level

- : Not estabished

The levels of metals in surface sediments east and west of the channel, together with the levels of metals in molluscs, suggest that there would be limited, if any, 'potential impacts to migratory wader birds that might use the adjacent mud flats and mangroves to feed and nest'. The metal levels are below what would be considered to have an impact.

Future Monitoring Program

It is proposed that the existing monitoring program at Bing Bong will continue, and be expanded to further investigate some of the findings from the existing program. The proposed additional work comprises the following key elements:

- Review of species abundance and feeding habits of seabirds, waders and shorebirds during both the dry season and wet season.
- The extent of the elevated metal levels in surface sediments to the west of the channel will be determined, together with depth profiles from cores across the same area, to determine any deposition profiles that may exist from the previous 10 years of operation.
- An investigation will be undertaken as to whether there is any measurable dispersion of metals out of the swing-basin into the water column. The technique of Diffusive Gradients in Thin Films (DGTs) will be used with an array of DGT devices deployed within the swing-basin and channel, and across the front of the load out facility. These devices provide a time integrated concentration of metals that would be potentially bio-available. The DGT device is designed to mimic a biological membrane.

8.7.2 McArthur River Estuary and Sir Edward Pellew Islands

Existing Monitoring Program

The Charles Darwin University was commissioned by McArthur River Mine in 2003 to determine the heavy metal status of marine sediment at the mouth of the McArthur River. The report summarising this study found that:

- At the McArthur River mouth, metal levels in sediments were found to be similar to other river estuaries in the south eastern Gulf. Lead isotope ratio analysis investigation indicates that McArthur River Mine ore-derived lead does not contribute to the lead inventory of these sediments
- Lead isotope ratios in sea grass at McArthur River mouth indicate that McArthur River Mine ore-derived lead makes little or no contribution to lead levels in sea grass
- Metal concentrations in oysters at the McArthur River mouth are all well below food standards (Australia and New Zealand Food Standards, 2004). The lead concentrations in oysters were too low to determine lead isotope ratios.

Future Monitoring Program

The EPA (2006) has indicated that it is satisfied with the findings of the available scientific studies, and acknowledges that there is no scientific evidence to date indicating the estuarine reaches of the river or the Gulf are impacted by the mine.

Nevertheless there is a perception in some sectors of the local community that the Open Cut Project will pose a risk to these areas. Consequently, additional monitoring is proposed at the McArthur River estuary and at the Sir Edward Pellew Islands.

The monitoring program at the McArthur River estuary will be expanded to include further sampling of water quality, sediment, seagrass and oysters for heavy metals in the McArthur River from Borroloola to the river mouth on an annual basis.

Sampling points utilised in the 2003 study would continue to be used, in addition to a transect across the delta of the mouth of the McArthur River. If the sampling within the river and the additional transects show no impact during the two years following commencement of the Open Cut Project, the transect sampling would cease, and monitoring would focus on the river.

In addition, it is proposed that the marine monitoring program will be expanded to include the Sir Edward Pellew Islands. The program will be developed in consultation with members of the local community members, and their advice will be sought on suggested monitoring locations and targets.

It is anticipated that this monitoring will include metals analysis for water, sediment and a range of biota including seagrass, molluscs and fish. Traditional food types used by the local community will be included. In addition, marine animals that are brought to McArthur River Mine showing potential signs of abnormality or stress will be analysed for metals content.

McArthur River Mine has committed to fund the appointment of a mutually agreed scientific specialist to review the scope and results of the monitoring program. This specialist would be able to report separately to the community. It is expected that this approach will assist in:

- Reducing the misconceptions that currently exist within some sectors of the Gulf community
- Generating greater confidence in the monitoring results
- Improving the levels of trust between McArthur River Mine and the community.