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Re-calibration of Sunrise Dam Gold Mine central-discharge thickened tailings system cyanide and salinity operating parameters: re-certification with the International Cyanide Management Code

FINAL REPORT

Report to:
Sunrise Dam Gold MIne
AngloGold Ashanti
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DES
DONATO ENVIRONMENTAL SERVICES

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Executive Summary

This report is to be read in the context of:

- Donato, D. B., Gillespie, C. G., and Griffiths, S. R. 2006, ACMER Research Project: 58. A risk assessment of the effects of goldmining cyanide-bearing tailings solutions on wildlife. Sponsor's Report Case Study C, National Research Centre for Environmental Toxicology and ACMER, Brisbane [1], referred to as the Causational Report; and
- Donato, D.B., and Smith, G.B., 2007, Summary of Findings: ACMER Project 58, Sunrise Dam Gold Mine Sponsor's Report, Anglogold Ashanti Australia, Donato Environmental Services [2], referred to as the Summary of Findings Report.

A spreadsheet of the WAD cyanide discharge concentration data is made available to peer reviewers for analysis.

The hypotheses, arguments and recommendations presented in these reports have been peer-reviewed and accepted and are not duplicated here. A summary of hypotheses is provided in this report for completeness.

Sunrise Dam Gold Mine (SDGM) has implemented an International Cyanide Management Code (Code)-compliant wildlife and cyanide monitoring protocol at the central-thickened discharge (CTD) tailings system.

This monitoring protocol, coupled with additional third-party monitoring, formed the basis of constructing the peer-reviewed argument (Causational Report [1]) of hypersaline tailings providing a protective mechanism for wildlife to mine waste solutions in excess of 50 mg/L WAD cyanide concentration.

That report did not contradict the currently described toxicity threshold of 50 ppm WAD cyanide concentration that was derived from fresh water peripheral discharge tailings systems. This report demonstrates that there are protective mechanisms occurring at SDGM CTD that identified the limitations of applying the threshold to a central-discharge hypersaline system.

No toxicity threshold was determined in the Causational Report since no cyanide-related wildlife deaths were recorded. Taking into account this limitation and Code compliance requirements, safe operating parameters to maintain the protective mechanisms were recommended. These operating parameters are based on site-specific empirical data. These recommendations (and operating parameters) were provided in an adaptive management context to allow re-calibration derived from ongoing monitoring data. On a second review [3] of the conditions of the Causational Report it was found that WAD cyanide discharge concentrations to the tailings system was above those prescribed operating parameters.

The ongoing daily wildlife-monitoring program coupled with carcass detection blind tests provides the evidence that the tailings system continues to be benign to wildlife despite the apparent increase of WAD cyanide discharge concentration.

This report provides the WAD re-calibrated operating parameters derived from the data collected since the Code audit site visit (1 June 2006). These parameters are 100 mg/L for the 80 percentile and 125.5 mg/L for other operational days. A precedent exists of Code-compliant mine waste solutions at St Ives Gold Mine with equivalent cyanide parameters of 112 mg/L and 132 mg/L respectively.

The re-calibrated operating parameters are provided as an adaptive management context, with associated recommendations. The recommendations as provided in this report are intended to necessitate the maintenance of the protective mechanisms and provide the necessary monitoring data and regime. These recommendations supersede all those originally provided in the peer-reviewed Causational Report [1].

Background

AngloGold Ashanti Sunrise Dam Gold Mine (SDGM) and other gold producers in Australia and Africa sponsored a three-year project under the auspices of then Australian Centre for Mine and Environment Research, Project 58 (ACMER P58). This project produced a series of site-specific sponsor's reports and published papers [4-6].

The findings from this work identified that the International Cyanide Management Code (Code) guideline of "to limit the concentration of cyanide in open impoundments to a maximum of 50 mg/L WAD as being protective of most wildlife and livestock" [7] is valid at the point of discharge to tailings systems.

The work also discovered that the guideline was not applicable to hypersaline tailings at SDGM. The arguments were presented in the ACMER P58 SDGM site-specific report (Causational Report) in the context of the Code and with causal arguments and was peer-reviewed. A set of cyanide and salinity operating parameters for the tailings system were established with additional conditions as part of Code compliance. These operating parameters were based on site-specific empirical data and were provided in an adaptive management context to allow a continual-improvement scenario and re-calibration derived from ongoing monitoring data. A summary of this report (referred to as the Summary of Findings Report [2]) was lodged on the Code website with certification of the SDGM. The hypersalinity arguments were further defined, peer-reviewed and accepted at Kanowna Belle and St Ives gold mines, which were investigated during the Minerals and Energy Institute of Western Australia (MERIWA M398) study [8].

After two annual reviews of the operating parameters at SDGM [9] since compliance, it was recently statistically identified [3] that the tailings system is operating outside the prescribed parameters regarding weak-acid-dissociable (WAD) cyanide discharge concentrations. These annual reviews also identified that despite these increases in cyanide discharge concentrations the tailings systems continue to be benign to wildlife.

Scope of this work

SDGM engaged Donato Environmental Services (DES) to reassess the cyanideoperating parameters and make recommendations in the context of the Code given the tailings system continues to be benign to wildlife.

This scope forms the basis of this report.

Code Compliance and with Standard of Practice 4.4

The primary objectives of the Code are the protection of human health and the reduction of environmental impacts associated with the use of cyanide in the goldmining industry. As it applies to goldmining operations, the Code is comprised of two major elements. The Code principles broadly state commitments that signatories make to manage cyanide in a responsible manner. Standards of practice follow each principle, identifying the performance goals and objectives that must be met to comply with the principle. Signatories to the Code commit to and demonstrate that they adhere to its principles and meet its standards of practice.

To attain registration as a signatory to the Code, goldmining operations must undergo an independent third-party audit of all procedures and practices relating to the management of cyanide to verify that the standards of practice are met.

It is stipulated in the Code Standard of Practice 4.4 [10] that operations should implement measures to limit the concentration of cyanide in open impoundments to a maximum of 50 mg/L WAD as this is the concentration widely viewed as being protective of most wildlife and livestock [11]. However the Code provides a process for mining operations to prove and demonstrate compliance in excess of this maximum WAD concentration as described on pages 36 and 37 of the International Cyanide Management Institute (ICMI) auditor's guidance document:

> *(An) Operation could demonstrate that a higher concentration of WAD cyanide in open water does not cause wildlife mortality due to site-specific reasons. For example, if there are no birds that drink from the beach of an impoundment in the area of an operation, then the 50 mg/l limit would not apply at the discharge point. Similarly, if the operation could demonstrate that a 50 mg/l concentration of WAD cyanide is not lethal to the specific types of birds and other wildlife that live and pass through the area, then some higher but still protective level would be appropriate. However, making these demonstrations to the auditor's satisfaction will not, and should not, be easy. Anecdotal evidence such as "we've never seen any bird mortality" is not sufficient, although any assertion that the 50 mg/l limit is unnecessary must be supported with comprehensive, daily inspection records demonstrating that there are no deaths. The operation must also present the scientific rationale for the lack of mortality at a cyanide concentration that would otherwise be toxic. This could be a study by an appropriately qualified person concluding, for example, that no wading or shore birds are known to be in the area, or that the local population of birds and wildlife are resistant to this cyanide concentration. In support of such a proposition, comprehensive daily inspection records demonstrating that there are no deaths must be presented in the form of a scientific study; any such study must be peer-reviewed and sufficiently rigorous that a causal relationship is established [10]. Like any competent scientific study, the results must be independently reproducible and predictive [10].*

Establishment of causation essentially requires identification of protective mechanisms (for example, habitat manipulation or natural degradation) that prevent solutions with typically toxic concentrations of cyanide from causing wildlife mortality [10]. Hypotheses must be supported by empirical data collected in a structured manner that withstands the scrutiny of peer review.

Hypersalinity causational argument

The methodology used at SDGM, has been implemented with the ACMER P58 and the MERIWA M398 projects and at other individual operations [12, 13]. The findings at SDGM relate to wildlife ecology and hence exposure has been reproduced at these case studies. The arguments have been peer-reviewed and accepted (on three occasions: SDGM, Kanowna Belle and St Ives gold mines) and need not be re-examined nor presented in this report. For completeness and convenience a briefing of the arguments is presented below.

The SDGM Causational Report [1] did not contradict the currently described toxicity threshold of 50 ppm WAD cyanide concentration that was derived from fresh-water peripheral discharge tailings systems. The report demonstrated that protective mechanisms occur at SDGM central-thickened discharge (CTD) tailings system and identified the limitations of applying the 50 mg/L threshold to a central-discharge hypersaline system.

Considering the recorded cyanide concentrations and lack of recorded wildlife deaths (from the robust monitoring procedure), this system departed from recognised literature and assumptions.

To develop a hypothesis of this result, the following mathematical expression describes wildlife cyanosis impact (or lack of impact) as:

Impact = f Exposure (wildlife interaction) x Hazard (CN concentration) eqn. 1 [14].

Since the cyanide code specifies no wildlife deaths and that 50 ppm WAD cyanide is the recognised hazard threshold then the equation above can be further described. Consider that the 50 ppm WAD cyanide concentration threshold is derived from fresh-water peripheral discharge tailings systems [15-17]. Therefore the risk can be described as:

Impacto = f Exposurefpd x ([CN WAD] < 50 ppm) eqn 2.

Where Impacto is no wildlife deaths, Exposurefpd is the extent of wildlife exposure at a fresh-water peripheral discharge system and the hazard is expressed as the toxicity threshold or less.

At SDGM impact was recorded as zero (Impact0) and the hazard as above 50 ppm WAD cyanide concentration. Therefore wildlife exposure (for whatever mechanism) at SDGM CTD (ExposureSDGM) must be less than experienced at fresh-water peripheral discharge systems.

To explain this phenomenon of reduced or eliminated exposure the following four mechanisms are hypothesised:

1. There are minimal habitat provisions containing bioavailable cyanide (supernatant and wet tails) for at-risk species.
2. The management procedures are maintained to minimise and reduce structural habitat diversity in the CTD.
3. The minimal food provisions in cyanide-bearing substrates reduces the inadvertent ingestion associated with feeding in solutions and wet tails.
4. Hypersalinity eliminates the drinking of solutions.

The Causational Report established using site-specific data, literature and comparisons with other case studies, a casual relationship that these protective mechanisms reduce wildlife exposure. It was noted that if these protective mechanisms cease or reduce in effectiveness then the risk of cyanosis may occur.

Proposed mechanisms to reduce wildlife exposure at SDGM CTD have resulted in no observable impact and have been developed through close scrutiny of data collected during extensive monitoring over a two-year-plus period. It is not suggested that the exposure-reducing mechanisms detailed at SDGM occur at other mining operations thereby automatically equating to a wildlife protection and resulting in no observable impact to wildlife.

The MERIWA M398 presented similar arguments that tested and confirmed the following hypothesis: Hypersalinity (> 50 000 mg/L total dissolved solids

– TDS) provides some natural barriers for wildlife exposure to WAD cyanide contained in tailings solutions [8].

The MERIWA M398 project, consistent with the SDGM Causational Report, did not identify a toxicity threshold.

Alternatively to prescribing a toxicity threshold, safe operating parameters specific to salinity and cyanide concentration were provided with an ongoing rigorous monitoring program. Considering the lack of known toxicity threshold, the Causational Report found that the operating parameters (and all other recommendations) "need to be considered as an adaptive management process and should be continually reviewed with new information and on-site data" (page 40, Causational Report) [1]. Provided the CTD remains benign to wildlife then it was always likely that the cyanide operating parameter would be recalibrated (up or down) after analysis of three years of data since the previous certification.

Limitations and critical operating parameters

The critical operating parameters of cyanide concentration and salinity for SDGM were set as described in Table 1 as the first study of its kind in 2006. As a comparison the critical operating parameters for Kanowna Belle and St Ives gold mines are provided [8]. It can be noted that the cyanide concentration parameter is below the two other hypersaline Code-compliant tailings systems. The salinity parameter is also significantly higher.

Table 1. Current recommended operating parameters for SDGM (established in 2006), Kanowna Belle and St Ives gold mines

Parameter	SDGM	Kanowna Belle	St Ives
Spigot WAD cyanide mg/L (lower percentile)	< 70 mg/L for 75 (%) percentile	< 78 mg/L 80 (%) percentile	< 112 mg/L 80 (%) percentile
Spigot WAD cyanide mg/L (upper percentile)	Not to exceed 90 mg/L	< 92 mg/L 95 (%) percentile	< 132 mg/L 95 (%) percentile
TDS mg/L	> 90 000	> 50 000	> 50 000
Spigot copper mg/L		50	46
Supernatant copper mg/L		50	44

Sunrise Dam Gold Mine operations

The SDGM operation is located 55 km south of Laverton, Western Australia. The mine is situated immediately to the east of the hypersaline Lake Carey and is surrounded by numerous other smaller saline lakes. The operation is comprised of an open pit and underground mining operations as well as processing operations. SDGM has an annual processing rate of 3.6 million tonnes.

The Natural Environment

The climate in the SDGM region is described as arid with an average annual rainfall of 231 mm. Vegetation in the region is dominated by mulga woodlands (*Acacia aneura*) over mixed understorey shrubs including species of *Eremophila*, *Maireana*, *Atriplex* and *Senna*. Ground cover comprises a suite of grasses and daises, typically species of *Eragrostis*, *Eriachne*, *Triodia* and *Sclerolaena* [18, 19].

The ecology of the saline lakes and waterbirds and general ornithology are in part been described by Smith [20]. These provide a basis for determination of site-specific at-risk wildlife species [21, 22].

Tailings deposition and supernatant solution management

The tailings dam is currently a 320 Ha single-cell CTD facility. Under normal operational conditions there is minimal or no supernatant liquor or associated ponding from tailings discharge. The thickened tailings are deposited at approximately 65% solids through the multi-spigot centrally located discharge system. The tailings dam and associated decant water dam were constructed above the surrounding flat terrain and are not part of any significant drainage system. The central discharge system results in conical stacking of dry tails. The CTD has a circular footprint and is fringed by native vegetation some 50 m from the CTD perimeter. A stock and wildlife-proof electric fence has been erected around the perimeter of the structure.

An open drainage system around the periphery of the CTD removes excess ground water and contains less than 1 ppm WAD cyanide to the perimeter of the CTD for use as dilution and it flows to the adjacent decant water dam. The clay-compacted lined decant pond walls are armoured with coarse rock material. The decant pond is rectangular in shape (45 m x 45 m).

The decant water, usually less than 20 ppm WAD cyanide, is transferred through pumping and underground carriage to the process water dam, which is located in close proximity to the mill.

Since Code compliance the tailings have covered the entire area within the walled perimeter. The perimeter wall has also been lifted. Tailings have leached and consolidated from the centre to these walls and buried all natural landforms, islands and emergent vegetation (a recommendation of the Causational Report).

Findings since certification

Hypotheses validity

As reported in the compliance review [3], WAD cyanide discharge concentrations were found to be above the operating parameters set as conditions on Code compliance.

Four hypotheses were tested in the Causational Report [1] and found to be valid (peer-review), these were:

1. There are minimal habitat provisions containing bioavailable cyanide (supernatant and wet tails) for at-risk species.
2. The management procedures are maintained to minimise and reduce structural habitat diversity in the CTD.
3. The minimal food provisions in cyanide-bearing substrates reduces the inadvertent ingestion associated with feeding in solutions and wet tails.
4. Hypersalinity eliminates the drinking of solutions.

The CTD continues to be monitored for wildlife by trained mill technicians on a daily basis and by environment staff weekly. These monitoring regimes are designed to detect if carcasses are present.

After discussions with SDGM staff (May 2008) it was decided to test the efficacy of the mill technician observation (carcass detection) skill by having environment staff conduct blind tests. Decoy carcasses (balloons) were deployed without the knowledge of the wildlife observers (mill technicians). The decoys are black or blue balloons, water-filled to 10 to 15 cm, which partially sink in tailings solutions. Black balloons of this size, mostly submerged in solutions, best replicates dead Grey Teal or Pacific Black Duck, two common species known to be at-risk from cyanide-bearing tailings systems [16]. This test measures the likelihood of detecting a mortality event, not necessarily the extent or size (number of wildlife deaths) of that mortality event.

Table 2. Mill staff efficacy in detecting decoy carcasses (balloons) at the CTD and stormwater pond (SWP)

	Occasions decoys set	Occasions decoys detected	Number set	Number detected
CTD	25	21	57	38

The balloons were detected on 21 of 25 occasions (84%). On one of the occasions the mill technicians did not conduct the observations. When taking this into account, to specifically measure mill technician skill balloons were detected on 21 of 24 observational occasions (87.5%).

Of the 57 balloons set 38 were detected. The balloons are usually set early in the morning by environment staff, before mill technicians conducted observations. The balloons burst, at a variable rate usually dependant on air temperature, so some balloons would have burst before the mill technicians conducted their observations. Having balloons burst during the day replicates how carcasses are scavenged by wildlife.

Considering the balloon detection rates, it is considered that the detection ability of the mill technicians is sufficient to detect carcasses of the most likely species if they were present. The wildlife technicians' ability to detect decoys and lack of wildlife carcasses coupled with environment staff observations provides further evidence that the CTD is benign to wildlife despite WAD cyanide discharge concentrations exceeding the current operating parameters.

The stormwater pond adjacent to the CTD does not receive cyanide solutions approaching 50 mg/L and consequently the efficacy rates are not provided.

Dataset used for analysis

In re-calibrating the WAD cyanide discharge concentration parameters, all the data since the 1 June 2006 (Code audit site visit, 23 June 2006) to September 2009 has been considered for analysis. All WAD cyanide concentration at discharge spigot data analysed by MPL laboratories and as provided to DES was included in the analysis. No data was excluded for statistical or other purpose or reason.

The CTD discharge salinity has remained above the prescribed threshold of 90 000 TDS mg/L since 1 June 2006 except for four occasions. No re-calibration is warranted for salinity as the site has essentially operated within the designated operating parameter of above 90 000 TDS. Salinity data is no longer considered by the report.

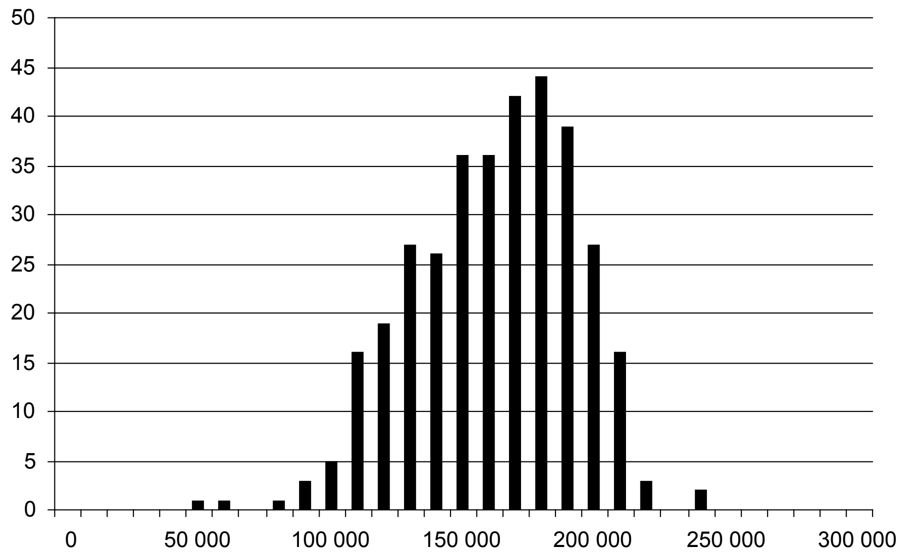

Figure 1. A histogram of the distribution of salinity at discharge into the CTD

Descriptive statistics of WAD cyanide at discharge

To provide an understanding of the cyanide discharge concentrations a descriptive statistical summary is provided.

Table 3. Statistical summary of WAD cyanide discharge concentration as sampled at the discharge spigot. The analysis is conducted by MPL laboratories.

Mean	81.68	Kurtosis	5.60
Standard error	2.15	Skewness	1.40
Median	77.00	Range	222.00
Mode	100.00	Minimum	18.00
Standard deviation	28.00	Maximum	240.00
Sample variance	784.11	Count	170

The distribution of WAD cyanide concentration at discharge into the CTD is provided in Figure 2.

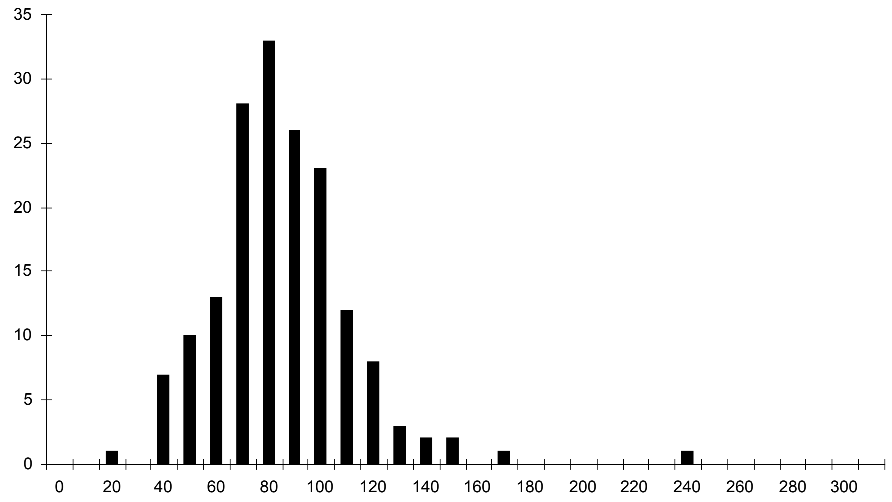

Figure 2. A histogram of the distribution of WAD cyanide concentration at discharge into the CTD

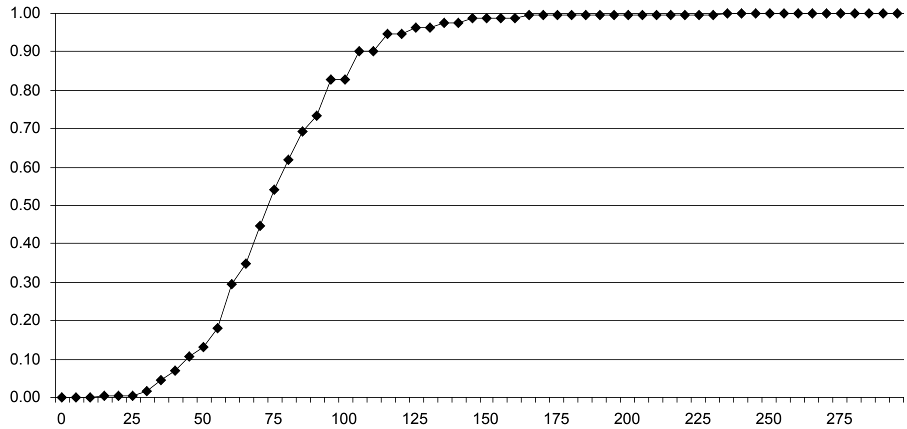

Figure 3. A sigmoid distribution of cumulative percentile WAD cyanide concentration at discharge into the CTD (x-axis)

Figures 2 and 3 illustrate the normal distribution and minimal step-wise nature of the percentiles. This provides for accurate calculation of 80th and 95th percentiles.

80th and 95th percentiles of WAD cyanide at discharge

The 80th and 95th percentiles are calculated using the Microsoft Excel©, which computes percentiles using the following formula.

Percentile (x) = (Rank (x) - 1) / (n - 1) where n is the number of data points. If x does not match one of the values, then the percentage rank function interpolates.

The 80th and 95th percentiles calculated WAD cyanide concentration is 100 and 125.5 mg/L, respectively. These hazard concentrations are within the specifications as recorded at St Ives Gold Mine [8] providing precedent of the benign nature of the hazard under hypersaline conditions.

Supernatant parameters

Tailings disposal is a CTD system and has minimal supernatant contrary to Kanowna Belle and St Ives gold mines. Consequently no supernatant operating chemistry parameters were provided in the Causational Report [1] nor are they provided in this report. The importance of copper as a cyanide attenuator in the supernatants of Kanowna Belle and St Ives gold mines was a well-documented protective mechanism [8]. This is also not pertinent to SDGM CTD.

No observable effect (no deaths) on wildlife

Wildlife observations were conducted by mill technicians on 1 012 of a possible 1 187 (85.3%), totalling 1 354 wildlife observations and four deaths. In addition environment staff conducted observations on 203 days. Two deaths were kangaroos, one was a cat-predated Red-capped Plover [3] and the fourth was a fatigued Australian Pelican (photographs observed). These deaths were not attributed to cyanide, the kangaroos obviously become bogged and a pelican in such an environment was noted as fatigued. Considering 1 354 wildlife observations recorded, the four deaths do not exceed what would be expected for background mortality rates.

Discussion

The established protective mechanisms of reducing cyanide-bearing habitats (by management and tailings system design), hypersalinity, lack of food provisions and minimal water continue to be effective at the increased cyanide concentrations recorded since Code compliance.

As no wildlife cyanosis deaths were recorded since Code compliance, the recommendations address maintenance of the protective measures already in place with modification of WAD cyanide discharge concentration. Since WAD cyanide thresholds would exist but are not known [1, 2, 8], the recommendations include monitoring the protective mechanisms, operating parameters and wildlife at a frequency determined by the Code.

The WAD cyanide concentrations at discharge into the CTD recorded since the Code audit site visit of 23 June 2006 form the basis of the new cyanide operating parameters. These new operating parameters are described in a manner consistent with Kanowna Belle and St Ives gold mines, with target parameters set at 80 and 95 percentiles.

It should be noted that if these protective mechanisms cease or reduce in effectiveness then the risk of cyanosis may occur.

Recommendations

The following recommendations need to be considered as an adaptive management process and should be continually reviewed with new information and on-site data collection. These recommendations apply when WAD cyanide discharge conditions at discharge to the CTD exceed 50 mg/L.

The recommended target operating parameters for WAD cyanide at discharges into the CTD are given as 80 percentile and 95 percentile, which replicate the regime and distribution of WAD concentrations that operated at SDGM since Code certification. This is to be consistent with existing hypersaline Code-compliance mining operations (Kanowna Belle and St Ives gold mines).

Recommendation 1. The target is to discharge WAD cyanide concentration below 100 mg/L on 80% of operational days, and on other operational days below 125.5 mg/L .

On few occasions WAD cyanide concentrations were recorded above the 125.5 mg/L threshold and no wildlife deaths were recorded. Typically there is statistical confidence below the calculated 95th percentile, in this case a WAD cyanide discharge concentration of 125.5 mg/L as benign to wildlife.

If these percentiles and limits are exceeded the operation is to respond and take immediate action to ensure that the situation is adequately addressed by the following day.

Table 4. Re-calibrated recommended target maximum WAD cyanide spigot operating parameters for SDGM. Corresponding recommended target operating parameters for Kanowna Belle and St Ives gold mines are provided for comparison

Parameter	Sunrise Dam	Kanowna Belle	St Ives
Target WAD cyanide 80th percentile mg/L (operate under on 80% of days)	100	78	112
Target maximum WAD cyanide mg/L (operate under on other operational days)	125.5	92	132
TDS mg/L TDS	> 90 000	> 50 000	> 50 000
Copper mg/L		50	44

It is necessary to address limitations of no-determined-hazard threshold under hypersaline conditions. This requires rigorous monitoring of the protective mechanisms to determine any wildlife cyanosis events and providing techniques for simultaneous monitoring of cyanide concentrations and salinity.

Consequently the following recommendations are provided in addition to the operating parameters (recommendation 1). The recommendations have considered the current management stage of the CTD, knowledge gained [8, 12, 13, 23] since production of the Causational Report [1] and supersede those prescribed in the Causational Report. These recommendations are consistent with industry leading practice [8].

Recommendation 2. Maintain discharge salinity above TDS of 90 000 mg/L and monitor daily

Significant rainfall events may result in a decrease in the salinity of tailings discharged to the CTD. Systems, management plans and notifications are required to maintain, monitor and respond accordingly.

Daily salinity samples should be taken to understand the spigot discharge salinity and to determine fluctuations in salinity due to rainfall or other events. The relationship between tailings discharge salinity and the salinity of spigot-derived supernatant should be examined.

Recommendation 3. Daily monitor WAD cyanide concentration at discharge to the tailings system

Daily spigot discharge sampling will be required for Code compliance as a routine procedure as long as discharge concentrations are 50 mg/L WAD cyanide or greater [24].

It would be considered leading practice to also collect superntant, spigot-derived pooling, rainfall-derived pooling, process plant chemistry including salinity and cyanide concentrations, to allow an understanding, adequate and expedient control within the prescribed cyanide concentration parameters as recommended. Such data will allow an understanding between cyanide concentrations and salinity, particularly during rainfall events.

Recommendation 4. Duplicate tailings samples (WAD cyanide and TDS) to be taken from the spigot discharge point

Duplicate tailings samples (WAD cyanide and TDS) should be taken from time to time from the spigot discharge point. Samples should be preserved according to a procedure that is acceptable by a NATA-accredited laboratory.

Both samples should then be sent to a NATA-accredited laboratory for analysis. This procedure will identify errors in sample preservation and analysis.

Recommendation 5. Daily wildlife monitoring by trained staff

While discharge concentration is 50 mg/L WAD cyanide or greater, environment or technician staff trained and qualified in environmental monitoring techniques will need to gather data on a daily basis. The wildlife-monitoring regime for environment and trained technician staff is summarised in the following table. This is identical to the current (routine) wildlife regime implemented by mine staff.

The monitoring regime is designed to collect data to assess the risk (if any) and record impacts (if any). It will document the presence and behaviour of at-risk species, habitat usage and documentation of carcasses. This, coupled with the proposed cyanide and chemistry-monitoring regime, will provide data and allow continual assessment of wildlife cyanosis risk.

The wildlife-monitoring regime to be conducted by environmental or suitably trained technical staff should include the components outlined in Table 5.

Table 5. Proposed environmental and trained technical staff routine wildlife monitoring program for the TSFs and supernatant ponds

Frequency	Tailings system	Time	Observations	Description
Daily Note – Daily surveys are required as long as discharge concentrations are ≥50 mg/L WAD cyanide. If discharge concentrations are below 50 ppm WAD then sampling frequency can be reduced (e.g. 2 to 3 surveys per week).	CTD	Within three hours of sunrise	Record: • start and finish times; • species ID number; • habitat usage; • behaviour; condition; • time in contact with water body; • observer's name; and • location. Record zero bird presence on the data sheet if applicable.	Record habitats as: S – supernatant (water body on top of tailings) B/WT – beaches/wet tails B/DT – beach/dry tails B/NL – beach/natural landform B/W – beach/walls A – aerial DT – dry tails WT – wet tails Is – islands Record condition as alive, stressed or dead.
			Carcasses present	Concurrent with wildlife surveys. A thorough search of all habitats on the TSF by walking or driving close to the various habitats and using optics. Record any carcasses (location and species) and photograph them. If any at-risk species are present (alive), attempts should be made to haze them from the TSF.
Same day – if carcasses present	All cyanide-bearing water bodies where carcasses present.	Afternoon	Carcasses present	If carcass detected, then carcass counts to be conducted again in the afternoon on the same day to determine carcass in-situ residence time and fate.

In addition seasonal insectivorous bat monitoring should continue until patterns of use and associated risks are understood. The abovementioned wildlife monitoring protocols should be incorporated into existing environmental monitoring documentation..

Recommendation 6. Incorporate intensive monitoring by external experts in the event of cyanide-related wildlife mortality

Data collected during this project by environment and technical staff's routine wildlife monitoring at SDGM and other sponsor mine sites shows that the monitoring regime is effective in detecting whether or not an impact (cyanide-related wildlife mortality) is occurring. However, routine monitoring by environment and technical staff is not effective in determining the level or extent of the impact. Obtaining data to ascertain the level of the impact (i.e. the number of wildlife deaths per day and the likely total number of deaths) can only be achieved by intensive sampling conducted by expert wildlife monitoring personnel. It is not recommended that autopsies of carcasses are conducted. Wildlife cyanosis could be implied by the presence of carcasses of species identified as high and very high risk.

Recommendation 7. Wildlife monitoring data management

To ensure accurate recording of wildlife monitoring data, both the technicians and environment staff should record the results of their daily wildlife monitoring into a single electronic database or spreadsheet to which all parties have access. This will provide the opportunity to compare daily wildlife observations from each monitoring regime. Data from one regime can be used to validate the data collected by the other. This type of data verification can be input into adaptive management procedures to improve wildlife monitoring protocols and ensure the consistency and robustness of data collected.

Ensure that sufficient data collection is undertaken to enable statistical relationships between monitoring cyanide concentrations and wildlife visitation data.

Recommendation 8. Environmental and technical staff wildlife monitoring training

To ensure that wildlife monitoring data collected by SDGM environment and technical staff is robust and consistent, all staff involved in monitoring must be adequately trained in identifying birds to species level, particularly species common to the region, that are at-risk from cyanosis. Environment and technical staff will not be expected to identify individual species but rather guilds of species, i.e. ducks, waders, swallows and martins. They must be aware of the range of habitats that different guilds of at-risk species are attracted to and which of these habitats represent significant cyanosis risks. All monitoring staff should have some general knowledge of the typical range of 'normal' behaviour displayed by at-risk species so they can identify signs of distress that may indicate birds suffering from cyanosis.

Appropriately qualified staff must conduct training. This may include internal staff members with sufficient avifauna monitoring experience, or external experts [24]. Refresher training should also be provided regularly to ensure all monitoring staff are kept up to date with the necessary skills and knowledge required for wildlife monitoring.

Recommendation 9. Manage supernatant surface area to less than 2 Ha

Reducing and limiting supernatant surface area reduces visitations and interaction of at-risk species. This can be achieved by managing spigot flow, thickening tailings and cutting in drains and sumps. During this project period the supernatant surface area was maintained below 2 Ha. Record the supernatant surface area daily, which could be calculated by estimating the percentage of supernatant cover on the CTD.

Recommendation 10. Minimise infrastructure in the vicinity of cyanide bearing habitats

Infrastructure minimisation is already a management procedure. Continuation of this management reduces habitat structural diversity thereby reducing wildlife diversity and exposure pathways. This includes maintaining the tailings system devoid of waste materials other than tails.

Recommendation 11. Restrict wildlife access by maintaining fencing of cyanide-bearing water bodies.

The CTD is surrounded by a wildlife and stock proof fence. Adequate fencing will largely eliminate the hazard of cyanosis to terrestrial wildlife species and also prevent non-cyanide-related terrestrial wildlife deaths caused by animals (such as kangaroos) becoming bogged in tails slurry. However, it is recognised that absolute prevention of access by some animals may not be possible [3]. Fencing of cyanide-bearing water bodies is also considered appropriate in most cases to prevent unauthorised access and potential exposure to humans [2].

Maintenance and regular routine inspections of the fence is required and should be documented.

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Appendix: Management recommendations of the Causational Report (ACMER P58 study)

The original Causational Report (ACMER P58), Donato, D. B., Gillespie, C. G., and Griffiths, S. 2006, ACMER Research Project 58, provided 20 management recommendations. These recommendations were provided to address any perceived risks of wildlife cyanosis at SDGM and identify requirements for compliance with the Code. Code compliance requirements are derived from interpretation of the documentation provided by the ICMI [1-5].

Since this time literature and research, particularly the MERIWA M398 project, has provided new information and interpretation of the protective mechanisms associated with hypersalinity. Consequently the recommendations (in italics, Table 1) provided in the Causational Report have been superseded. This appendix provides the rational for removing and updating the specific recommendations of the Causational Report.

Table 1. Summary of original recommendations from the Causational Report (AMCER P58) retained or removed from this report.

Original Causation Report recommendation (ACMER P58)	Retained	Removed
Recommendation 1: Manage (tailings) spigot discharge salinity similar to that experienced during this project. It was above 139 000 TDS for 75% of sampled days. It is recommended not to discharge tailings below 90 000 ppm total dissolved solids (TDS) if WAD cyanide discharge concentration is to exceed 50 ppm without protective measures.	This recommendation is retained as recommendation 2 and reworded as follows: Recommendation 2. Maintain discharge salinity above TDS of 90 000 mg/L and monitor daily.	
Recommendation 2: Consider strategically managing spigots to stop the formation of spigot-derived ponding on the periphery of the CTD.		The hypersaline protective mechanisms were found to be effective on spigot-derived pooling and supernatant which was conclusively researched and documented part of the MERIWA project [6]. This recommendation is now superfluous and removed. It is noted that this is good practice and is encouraged.
Recommendation 3: Limit WAD cyanide at the discharge spigot at 70 ppm for 75% of the time and do not to exceed 90 ppm.	The arguments for recalibration of cyanide discharge concentrations are the basis of this report. The recommendation is retained and recalibrated and is now recommendation 1. It is reworded as follows: The target is to discharge WAD cyanide concentration below 100 mg/L on 80% of operational days, and below 125.5 mg/L on 95 % of operational days (as provided in Table 4).	

continued

APPENDIX

Original Causation Report recommendation (ACMER P58)	Retained	Removed
Recommendation 4: Daily salinity monitoring in the mill process circuit.		The critical measure is salinity at discharge to the CTD (now recommendation 2), not the mill process circuit. Although good practice, this recommendation is not necessary to either maintain or monitor the protective mechanisms and therefore is removed.
Recommendation 5: Daily cyanide monitoring at the spigot discharge point.	This recommendation remains unchanged and is now presented as recommendation 3.	
Recommendation 6: Restrict wildlife access by maintaining fencing of cyanide-bearing water bodies.	This recommendation remains unchanged and is now presented as recommendation 11.	
Recommendation 7: Manage supernatant surface area to less than 2 Ha.	This recommendation remains unchanged and is now presented as recommendation 9.	
Recommendation 8: Minimise infrastructure in the vicinity of cyanide-bearing habitats.	This recommendation remains unchanged and is now presented as recommendation 10.	
Recommendation 9: Restrict wildlife access by flattening raised earth and dry tailings piles that form islands in the CTD.		The CTD within its perimeters is completely covered with tailings. Bare ground creating islands no longer exists. This recommendation is redundant and is removed.
Recommendation 10: Daily cyanide monitoring of spigot-derived ponding supernatant.		The hypersaline protective mechanisms were found to be effective on spigot-derived pooling and supernatant which was conclusively researched and documented part of the MERIWA project [6]. This recommendation is now superfluous and removed, however collection of this data is considered useful and mentioned in recommendation 3.
Recommendation 11: Monitor mill cyanide dosage rates daily.		The critical measure is cyanide concentration at discharge to the CTD (now recommendation 3), not the mill process circuit. Although good practice this recommendation is not necessary to either maintain or monitor the protective mechanisms and therefore removed
Recommendation 12: Duplicate tailings samples to be taken from the spigot discharge point.	This recommendation is retained (as recommendation 4) but more tightly and appropriately worded.	

continued

APPENDIX

Original Causation Report recommendation (ACMER P58)	Retained	Removed
Recommendation 13: Monitor rainfall-induced ponding on inactive tailings areas.		The hypersaline protective mechanisms were found to be effective on spigot-derived pooling and supernatant which was conclusively researched and documented part of the MERIWA project [6]. This recommendation is now superfluous and removed, however collection of this data is considered useful and mentioned in recommendation 3.
Recommendation 14: Sample dry tailings.		The recommendation has been completed since certification [7, 8] and is no longer necessary.
Recommendation 15: Daily wildlife monitoring by trained staff.	The recommendation has been retained as recommendation 5.	
Recommendation 16: Incorporate intensive monitoring by external experts in the event of cyanide-related wildlife mortality.	This recommendation has been retained as recommendation 6.	
Recommendation 17: Wildlife monitoring data management.	This recommendation has been retained as recommendation 7.	
Recommendation 18: Preventative wildlife emergency planning.	Emergency procedures for maintaining salinity are best developed by SDGM and a prescriptive recommendation is not necessary and may be counterproductive. The salinity threshold necessary is now provided in recommendation 2. The existence and appropriateness of an emergency is best assessed through the auditing process standard of practice 8 and is consequently removed from this context.	
Recommendation 19: Environment and technical staff wildlife monitoring training.	This recommendation is retained as recommendation 8.	
Recommendation 20: Public dissemination.		Although good practice this recommendation is not necessary to either maintain or monitor the protective mechanisms and therefore removed.