5. APPENDIX 5: SPECIALIST CLOSURE STUDIES

5.1 Appendix 5.1: FIMISTON WRD Landform Stability Outcomes

TOOWOOMBA
PO Box 57 HARLAXTON QLD 4350
Phone 07 4613 1825 | Fax 07 4613 1826

PERTH
PO Box 5175 SOUTH LAKE WA 6164
Phone 08 9494 2835 | Fax 08 9494 2837

NEWCASTLE
PO Box 1102 WARNERS BAY NSW 2282
Phone 02 4965 7717 | Fax 07 4613 1826

19 December 2014

2088.14h

Kalgoorlie Consolidated Gold Mines
Black Street
PMB 27
Kalgoorlie WA 6433

Memorandum: Review of landform stability project outcomes

Attention: Janine Cameron – Senior Environmental Coordinator

1. Introduction

Landloch Pty Ltd has completed a range of projects for Kalgoorlie Consolidated Gold Mines (KCGM) focussed on the development of a functional waste dump batter design that can be used on new rehabilitation works. This memorandum seeks to summarise the work done in this regard and focuses on works that included:

- Characterisation of soils and wastes from a plant growth perspective.
- Refinement of internal processes to balance the available growth media volumes to the volume required, while also considering closure aspects including visual amenity, plant growth, and erosional stability.
- Characterisation of soils and wastes from an erosion perspective.
- Development of batter designs to be used on rehabilitated landforms.

This memo is structured such that it outlines the work performed in these three areas.

2. Characterisation of soils and wastes – plant growth potential

A revision of KCGM's existing growth media classification scheme was completed because the scheme:

- Included wastes such as potentially acid forming materials that are not rehabilitation materials.

- Made assumptions concerning erosional stability of materials and subsequent erosion assessment work (discussed below) completed can be used to more robustly consider erosion.
- included many characterisation parameters, and a rationalisation of the number of properties would streamline the process.
- Did not clearly describe the actual values used to define the boundaries between classes.

2.1 Review of previous scheme

The previous scheme included assessment of: salinity, pH, sodicity, dispersion and hardsetting, fertility, gravel content, permeability, erodibility, and acid forming potential. Important changes include:

- The salinity criteria was based on agricultural crops and varied with texture. The revised scheme sets salinity threshold criteria based on available plant response data to salinity (salt tolerant species) for soils and oxides in the Kalgoorlie region. Given that the soils at KCGM are largely loam in texture, variation of threshold $EC_{1:5}$ with texture was not deemed necessary.
- Assessment of topsoil and subsoil pH showed values were similar for topsoils and subsoils. Given this similarity, pH values were not deemed a useful differentiator of materials. Therefore, it was established that materials with $pH_{1:5}$ values that varied significantly from the typical range of topsoils would be classed as of concern.
- Previously the scheme used exchangeable cations data, the Emerson dispersion test and a measure of hardsetting to determine the effects of sodicity, dispersion, and hardsetting. These factors are now assessed by consideration of clay content, Exchangeable Sodium Percentage (ESP), Cation Exchange Capacity (CEC) and Exchangeable Sodium concentrations. This offers a robust framework from which to define dispersion and tunnel potential and issues of hardsetting.
- Fertility was not considered necessary for inclusion in the updated scheme for the following reasons:
    - The nutrient store in a plant root zone will be variable, with levels changing not only with material, but also with the depth of material applied and the combinations in which the materials are used.
    - Disturbance of soils and removal of vegetation will remove nutrient from the nutrient balance that will render the soils less fertile than they were before disturbance.
    - Fertiliser can be readily added to address deficiencies.
    - Fertiliser needs should be defined on a case by case basis at the time of rehabilitation.
- Acid forming potential was removed as the scheme's intent is to only consider rehabilitation materials. Black flag shales (PAF) are not rehabilitation materials and are managed separately.

2.2 Revised scheme

A revised classification scheme was developed and is shown in Table 1. The scheme enables rehabilitation materials to be classed into five categories:

Class A is reserved for soils, and these materials represent the best quality materials, having low salinity, pH levels within normal bounds, low sodicity, and moderate-moderately high permeability. These materials can be expected to support vegetation provided fertility is sufficient at the time of rehabilitation (assessment of fertiliser requirements form part of rehabilitation planning). They can be used both on flat or sloping surfaces provided sufficient erosion stability is achieved through the addition of rock. They can be used on highly visible areas.

Class B is also reserved for soils, and these materials are suitable once their sodicity is amended (establishing amendment requirements form part of rehabilitation planning). If amended these materials could be used on highly visible areas. These materials can be expected to support vegetation, provided fertility is sufficient at the time of rehabilitation (assessment of fertiliser requirements form part of rehabilitation planning). They can be used both on flat or sloping surfaces provided sufficient erosion stability is achieved through the addition of rock. If managed properly, they can be used on highly visible areas.

Class C can include both soils and oxide materials and these materials are characterised by their elevated salinity. They are preferably used on flat areas, but can also be used on less visible sloping areas provided sufficient erosional stability is achieved through addition of rock. Growth of vegetation will be limited to salt sensitive species, particularly in the early stages of rehabilitation.

Class D can also include both soils and oxides, and these materials are characterised by their elevated salinity and sodicity. Use of these materials requires the amendment of the high sodicity values, and their use is limited to less visible areas. Growth of vegetation on these materials will be limited to salt sensitive species, particularly in the early stages of rehabilitation.

Class E materials are oxides that are only to be used in flat and less visible areas where vegetation is not required. There are characterized by pH values that differ from the pH values normally measured for soils at KCGM.

Table 1: Revised KCGM Rehabilitation Materials Classification Scheme

Material Classification	General Characteristics
Class A	Topsoil material for use as a surface rehabilitation material on highly visible areas. Can be used for outer slopes or flat surfaces provided sufficient erosional stability is achieved through addition of rock.
	• Non-saline or low salinity, and • Soil pH within normal bounds, and • Non-sodic, and • Moderate-moderately high permeability.
Class B	Topsoil material for use as a surface rehabilitation material when its sodicity is amended. If amended, this material could be used on highly visible areas. Can be used for outer slopes or flat surfaces provided sufficient erosional stability is achieved through addition of rock.
	• Non-saline or low salinity, and • Soil pH within normal bounds, and • Sodic or hardsetting or slow-moderately slow permeability.
Class C	Oxide or soil material for use as a surface material on less visible areas. Preferably used on flat areas, but could be used for less visible outer slopes provided sufficient erosional stability is achieved through addition of rock. Growth of salt sensitive species will be limited in these materials, particularly in the early stages of rehabilitation.
	• Saline, and • Soil pH within normal bounds or less than 1 pH unit from being with normal bounds, and • Non-sodic or hardsetting.
Class D	Oxide or soil material for use on less visible areas. The sodicity of this material should be amended. Preferably used on less visible flat areas. Growth of salt sensitive species will be limited in these materials if saline, particularly in the early stages of rehabilitation.
	• Saline, and • Soil pH within 1 pH unit of being with normal bounds, and • Sodic or highly sodic and hardsetting or very slow permeability. OR • ·Non-saline, and • ·Soil pH within 1 pH unit of being with normal bounds, and • ·Highly sodic and hardsetting or very slow permeability.
Class E	Oxide material for use on low visibility, flat areas where vegetation growth is not required. The sodicity of this material should be amended. Growth of vegetation will be limited in these materials due to low pH. High salinity may also limit growth.
	• Non-saline or saline • Non-sodic, sodic, or highly sodic, and • Oxide pH greater than 1 pH unit outside of normal bounds

3. Materials balance

As a result of the revised classification scheme, the existing materials balance also required adjustment. Landloch has reclassified soils across KCGM using the existing characterisation data augmented with new sampling sites and targeted sampling to infill the existing data where it was lacking. Additional sampling sites were assessed where sampling intensity for a stockpile was low.

This classification information has now been coupled internally by KCGM with the volume of the available resource in each class. This information can be used to optimise the use of different rehabilitation materials on different rehabilitation domains. The aim is to ensure that the best quality material is used in highly visible areas, with lower quality resources to be used on areas of lower visual amenity. Other factors such as consideration of materials required for tailings storage facility closure design and haul distance for each landform can also be considered when scheduling materials for rehabilitation.

4. Characterisation of erosion potential of soils and wastes

KCGM instigated a body of work in 2012 to more robustly define the erosion potential of their soils and oxides. The intent was to:

- Define erosion potential of soils and oxides of different classes (based on the previous classification scheme and not the revised scheme).
- Classify different materials in terms of their erodibility.
- Establish a landform design that can be used for future rehabilitation works.
- Provide a scientific basis to consider the long term erosional stability of existing rehabilitation to assist in rehabilitation monitoring and closure studies.

Erodibility has been defined for the following materials thus far at KCGM:

- Class 1[1] soil from Orica 2 stockpile;
- Class 1 soil from Fimiston 2 Stockpile 4;
- 1:2 mixture of Class 1 soil from Orica 2 and blocky Class 5[2] waste rock;
- 1:2 mixture of Class 1 Fimiston 2 Stockpile 4 and blocky Class 5 waste rock;
- 1:2 mixture of Class 1 soil and Class 3[3] material;
- 1:2:6 mixture of Class 1 soil, Class 3 material, and Class 5 waste rock;
- Class 3 oxide;
- Class 4 oxide;
- 1:2 mixture of Class 3 oxide and blocky Class 5 waste rock; and
- 1:2 mixture of Class 4[4] oxide and blocky Class 5 waste rock.

[1] Class 1 in the previous scheme is broadly equivalent to a Class A material in the revised scheme.
[2] Class 5 in the previous scheme was a class that defined benign waste rock.
[3] Class 3 in the previous scheme is broadly equivalent to Class C or D in the revised scheme.

The Water Erosion Prediction Project (WEPP) runoff and erosion model was used to assess long-term batter slope stability. Landloch's use of WEPP in assessing the erosion potential of materials and producing rehabilitation designs has been shown to produce landforms that erode in the field in accordance with the erosion rates predicted.

4.1 Soils

Regardless of the rehabilitation material classification, when soils and oxides were assessed without the addition of blocky waste rock, the resultant predicted erosion rates for typical landform batters used on KCGM were high, and erosion via rilling and gullying are highly likely (Figure 1). Evidence of rilling and gullying have already been observed on site within completed rehabilitation where rock is absent at the surface.

The stability of landforms at KCGM will require the incorporation of rock into the surface. With this in mind, erodibility was considered separate from growth media suitability, with the types of soils to be used in different areas driven not by stability but by other factors such as visual amenity.



Figure 1: Rilling of laboratory plot packed with soil subjected to an overland flow.

4.2 Soil-rock mixtures

[4] Class 4 in the previous scheme is broadly equivalent to Class C or D in the revised scheme.

When benign waste rock was incorporated into soils to create a soil-rock mixture, erosion resistance was increased, and stable landform shapes were predicted to be possible for batter height and gradients required by KCGM.

4.3 Oxides and oxide-rock mixtures

The oxides assessed for erosion potential are saline, of variable pH, and potentially dispersive. Their use on slopes for rehabilitation should be avoided from a plant growth perspective, and also on slopes underlain by oxides or where water is allowed to pond and/or concentrate.

If a thin layer (less than 200mm) of oxide is sufficiently mixed into benign, blocky waste rock, and is then underlain by more benign, blocky waste rock, the risk on dispersion causing tunnel erosion is low. However, vegetation growth will be limited.

Erosion rates of the oxides (not mixed into rock) predicted by WEPP are likely to cause extensive rilling. When sufficiently mixed with rock the predicted erosion rates are very low, and the material is predicted to be stable on slopes up to 20m high (Figure 2). However, it is important to note that vegetation growth will be limited due to the saline, hardsetting characteristics.



Figure 2: Rainfall simulation plots of oxides: without rock (left), mixed with rock (right).

4.4 Field verification

The constructability of the batter designs have been discussed by Landloch, site environment staff, and machinery operators. Field trials of down-slope soil pushing and cross-slope ripping have been undertaken. Conventional ripping of soil into underlying rock has been adopted by site staff as it is the most practical method to meet rock cover criteria.

Field-based rainfall simulations (Figure 3) was also completed to confirm that mixing materials with the available machinery and using the construction methods developed can

achieve surfaces that are sufficiently rocky to minimise erosion in the long-term. Cover levels of ~30% were achieved and this value is consistent with cover levels generated in the Landloch soil laboratory, from which erodibility parameters were derived, and from which predictions of stability and the generic batter design were developed.



Figure 3: Field-based assessment of rock cover levels on a rain-armoured surface.

5. Rehabilitation batter design

Using the knowledge gained from the erosion assessment of the various materials, a generic landform batter design was developed. The batter design requires development of a soil/rock sheeting mixture with rocky bands placed at strategic zones to increase infiltration, reduce slope runoff, and reduce erosion rates (Figure 4). The design assumes that the underlying material is benign, blocky waste rock (not oxide).

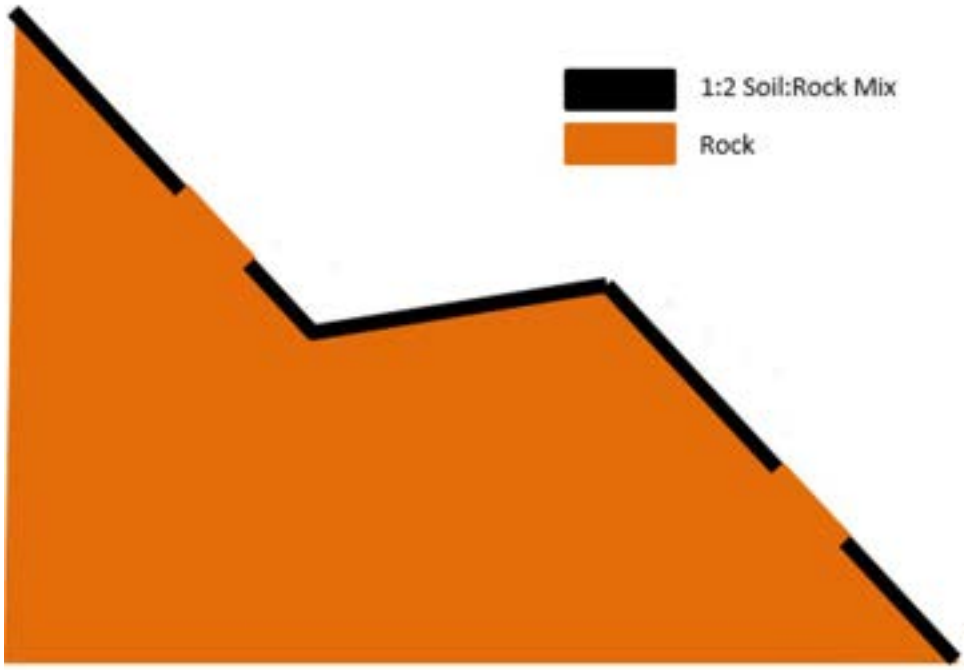


Figure 4: Generic batter design.

Where berms are required, their dimensions have been established to be able to manage sediment accumulation for in the long-term while still providing storage to contain rare rainfall events (storm return period of 200 years).

Implementation of this design has been trialled on the Northern Waste Dump.

In summary, the design developed is based on:

- Consideration of the prevailing climate and its erosivity;
- Known factors critical for stability of natural and disturbed surfaces;
- Characterisation of the erodibility of the typical surface materials present using well-validated procedures;
- Computer simulations of runoff and erosion on the range of typical slopes and surface materials; and
- Landform development simulations to consider the interactions between dump shape, material properties, and flow concentration.

Regards

Mr Evan Howard

PRINCIPAL ENVIRONMENTAL CONSULTANT

5.2 Appendix 5.2: FIMISTON Water Balance and Pit Lake Geochemistry

KCGM Fimiston Operations

Closure Water Balance and Pit Lake Geochemistry: Technical Summary

1 August 2022

J-AU0175-001-R-Rev1

MINE WASTE MANAGEMENT
GREENROAD GROUP

GROUNDWATER
RESOURCE MANAGEMENT

NORTHERN STAR

KCGM Fimiston Operations

Closure Water Balance and Pit Lake Geochemistry: Technical Summary

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Prepared for:

Northern Star Resources Limited

Level 1, 388 Hay Street, Subiaco, Western Australia 6008

Prepared by:

Mine Waste Management Pty Ltd

Suite 2, 435 Vincent Street W, West Leederville, WA 6007 AUSTRALIA

+61 8 9381 2938

www.minewaste.com.au

in collaboration with:

Groundwater Resources Limited Pty Ltd (GRM)

PO Box 442, Bayswater, WA 6933

+61 8 9433 2222

www.g-r-m.com.au

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1 INTRODUCTION

Kalgoorlie Consolidated Gold Mines Pty Ltd (KCGM), a wholly-owned subsidiary of Northern Star Resources, has operations situated adjacent to the city of Kalgoorlie-Boulder in the Eastern Goldfields Region of Western Australia. KCGM's Fimiston Operations comprise the Fimiston Pit (commonly referred to as the 'Super Pit'), Mt Charlotte Underground Mine, the Fimiston and Gidji Processing Plants, and associated Tailings Storage Facilities (TSFs) and waste rock dumps (WRDs) as shown in Figure 1. Process water is supplied from borefields intercepting the Roe palaeochannel system while potable water is supplied via the Goldfields Water Supply Scheme.

KCGM is currently preparing for submission of approvals for an extension of the Fimiston Pit. For these submissions, KCGM required an updated pit lake model and closure water balance model, which incorporates the proposed pit shell at closure and post-closure management of water from the WRDs and TSFs.

Mine Waste Management (MWM), in collaboration with Groundwater Resource Management Pty Ltd (GRM), were engaged to update the closure water balance and hydrogeochemical model for the pit lake that will develop in the Fimiston Pit at mine closure, building on a study completed in 2021 (MBS, 2021). This update reflects the proposed expansion of the open pit, plans for an in-pit WRD, a revised closure schedule, and incorporation of additional TSF cells that will provide seepage inputs to the pit lake post-closure. Hydrological aspects of this work (i.e. revised closure water balance, assessment of overtopping risk, elevation-area-volume stage curve for the pit) were completed by GRM. Hydrogeochemical modelling and report preparation were completed by MWM.

This report presents a technical summary covering the key aspects of the approaches and outcomes of the work undertaken by MWM and GRM during 2021 and 2022.

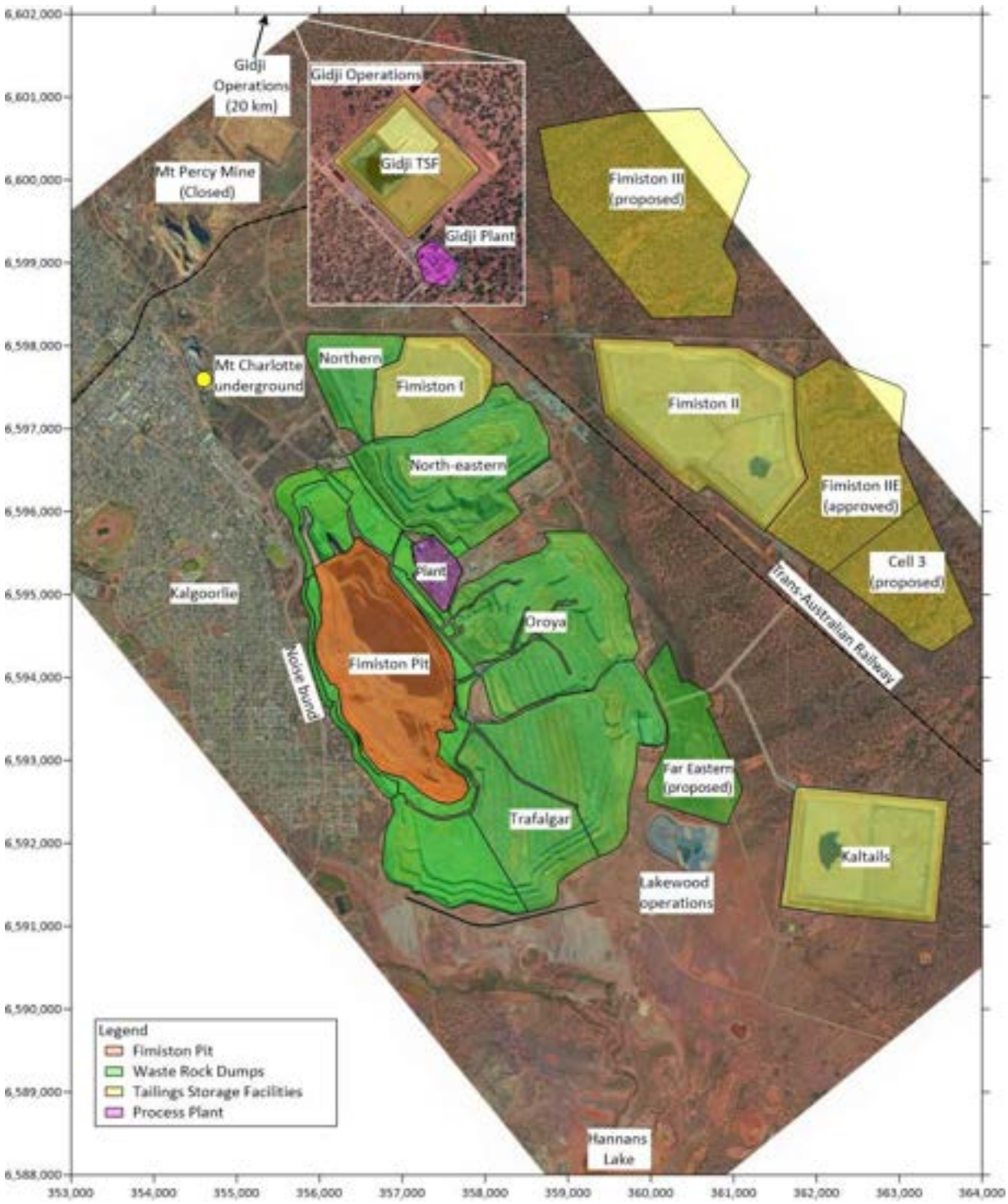


Figure 1: Current and proposed mining activities.

Source: Provided by GRM as part of this scope of work.

2 ENVIRONMENTAL SETTING

The environmental setting of the KCGM operations is described in detail in MBS (2021) and provided in summary form herein.

The Kalgoorlie region has a semi-arid climate with hot summers and mild winters. Annual rainfall varies between 108 and 530 mm with an average of 266 mm. Rainfall occurs during all months of the year. The region is experiencing a distinctive long-term change in rainfall patterns characterised by reduced winter rainfall and a greater number of extreme rainfall events in summer. Climate studies by the CSIRO (2015) indicate that the decreasing winter rainfall trend will be continuing due to climate change with higher probabilities of extreme summer rainfall events.

The KCGM mine is located on an elevated topographic area, which forms a topographic divide between two major palaeodrainage systems that occupy the lower part of the subdued landscape features typical of the Kalgoorlie area. KCGM is situated in the salt lake hydrological region and comprises numerous drainage systems flowing to terminal salt lake systems, clay pans, and other natural surface depressions. KCGM is situated in the Hannan catchment which is associated with the Roe palaeovalley system. The Hannan catchment drains an area of about 230 km^2 and runoff flows to the Hannan Lake, situated south of the operations.

There are three major active groundwater systems in the KCGM area namely:

- Palaeochannel systems: A localised but extensive network of alluvial sands at around 60 m depth. This system is well defined and is the primary source of process water for KCGM and for other mining operations.
- Ferricrete and alluvial sedimentary system: Sand, gravel and fractured ferricrete within clay deposits. These deposits are present in the lower elevation areas at the centre of the surface water catchments.
- Fractured bedrock system where groundwater flow occurs in fractured and weathered zones within the basement rocks at depth. The Fimiston Pit is entirely situated within the fractured bedrock zone.

In general, groundwater at KCGM is naturally saline with TDS (total dissolved solids) concentrations ranging between 75,000 and 170,000 mg/L with higher TDS concentrations observed in monitoring bores near to the TSFs. Groundwater pH is circum-neutral to slightly alkaline in fractured bedrock groundwater systems. Groundwater pH in the ferricrete, paleochannel and alluvial groundwater system is naturally low with an observed range typically between 2.8 to 4.

3 HYDROLOGICAL MODEL DEVELOPMENT

A probabilistic, dynamic systems modelling approach was followed to simulate the closure and post-closure mine water conditions. The GoldSim™ software was used to represent the closure water flow conditions. GoldSim is a graphical, object orientated program for performing dynamic, deterministic or stochastic simulations. The software is frequently used for water balance studies and is well suited for operational and closure water balance studies.

3.1 Inputs from Existing Models

A historical operational model, representing the operational period at KCGM for 1996 to 2019, was developed previously (MBS, 2021). The historical operational model was calibrated to measured dewatering rates and water levels in the underlying historical mine workings. A comparison of calibrated modelled water levels versus measured water levels for the Fimiston Pit is shown in Figure 2. As part of the calibration, model input parameters were derived including groundwater inflow rates and pit wall rainfall runoff coefficients. These model parameters were used in the closure water balance to predict the pit filling rate after closure.

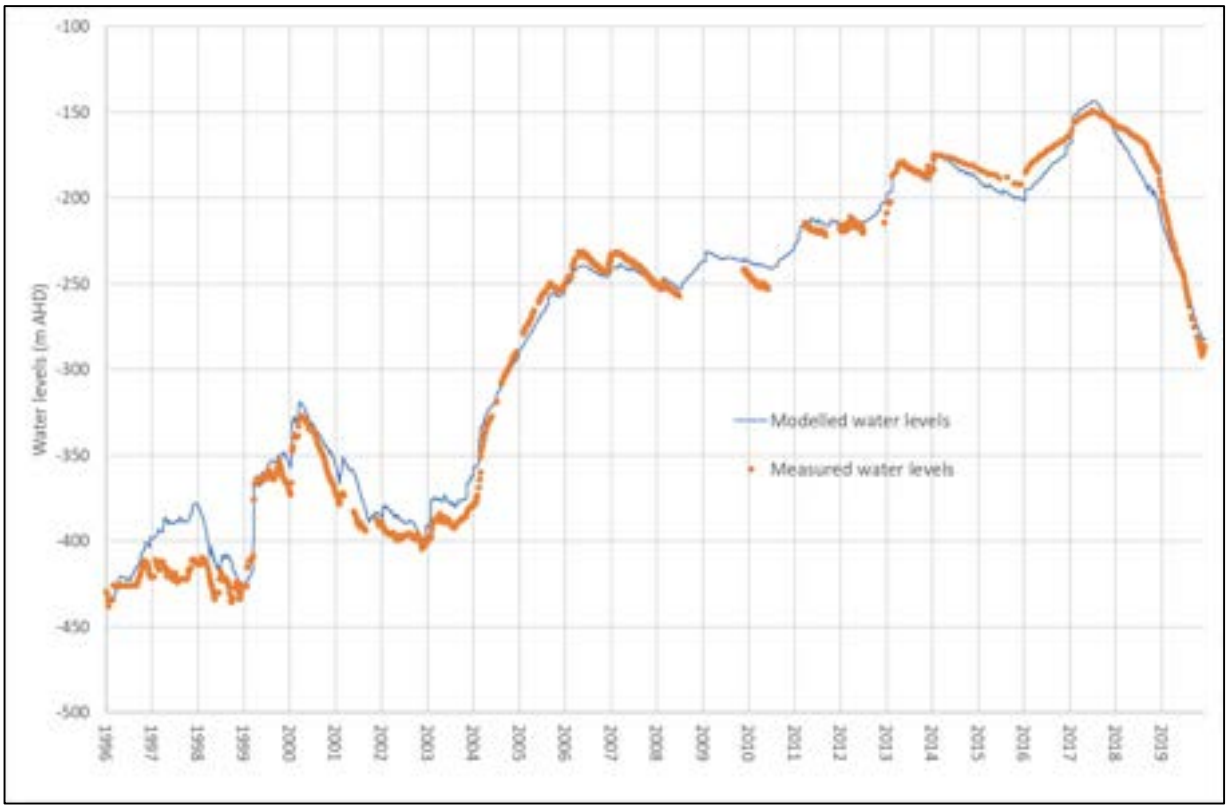


Figure 2: Measured and modelled water levels for Fimiston Pit.

Source: MBS (2021).

Previous work described in MBS (2021) also included developing stochastic rainfall and evaporation datasets for base case conditions and those reflecting changes in the Goldfields climate due to climate change. These datasets were relied upon to predict inflows to the pit related to rainfall (e.g. runoff from pit walls, rainfall to the lake surface) and evaporation from the lake surface.

Climate change projections were also used to develop an alternative closure water balance to assess the sensitivity of the base case model predictions to increased long-term rainfall and evaporation rates, based on the "Australian Climates Futures" decision support tool (CSIRO, 2015).

3.2 Closure Water Balance Model

A revised predictive closure model was developed for this study, which simulates the development of the Fimiston Pit lake over a period of 566 years after closure. The following sections describe the methods, input data and assumption used in developing this model.

During operations, several TSFs and waste dumps will reach their capacity and will be closed and rehabilitated. Both the Mt Charlotte underground workings and Fimiston Pit will be closed, and water levels will be allowed to recover. The sequence of closure at KCGM is as follows:

- 2023: Fimiston II TSF will almost reach its capacity and deposition of tailings will occur occasionally. After closure of the processing plant, the TSF will be closed and rehabilitated over several years, allowing for the settlement of the tailings and drying of the TSF surface to be accessible for the placement of the cover. Seepage from the TSF will require active management for several years post-closure. Thereafter, the TSF is not expected to have significant water release to the environment other than occasional small amounts of runoff from the embankments.
- 2026: Fimiston I and Kaltails TSFs will almost reach capacity and deposition of tailings will occur occasionally. As with the other TSFs, Fimiston I and Kaltails will be closed when processing stops and rehabilitated over several years. Seepage will require active management for several years after which no significant water release to the environment is expected other than occasional small amounts of runoff from the embankments.
- 2027: Waste rock will be managed using both in-pit and ex-pit dumping, allowing for the rehabilitation of some of the completed dump surfaces and slopes.
- 2034: All mining and processing at KCGM will cease. Both the Fimiston and Gidji plants will be decommissioned and rehabilitated. Tailings deposition on Fimiston IIE and Fimiston III are planned to cease and the TSFs will be rehabilitated over several years. As with all the TSFs, seepage will require active management for several years post-closure. Since the process plant will be decommissioned and seepage recovery water will no longer be used as supply water for this, KCGM is planning to pump recovered decant and seepage-affected groundwater from the TSF borefields to the Fimiston Pit for several years, until the seepage impacts on the groundwater have been reduced.

The conceptual model for the post-closure flow balance is shown in Figure 3. At this stage, the borefields and process plants will have been decommissioned and rehabilitated. Landforms will be rehabilitated, including TSFs and WRDs. Pit and underground workings dewatering will have ceased.

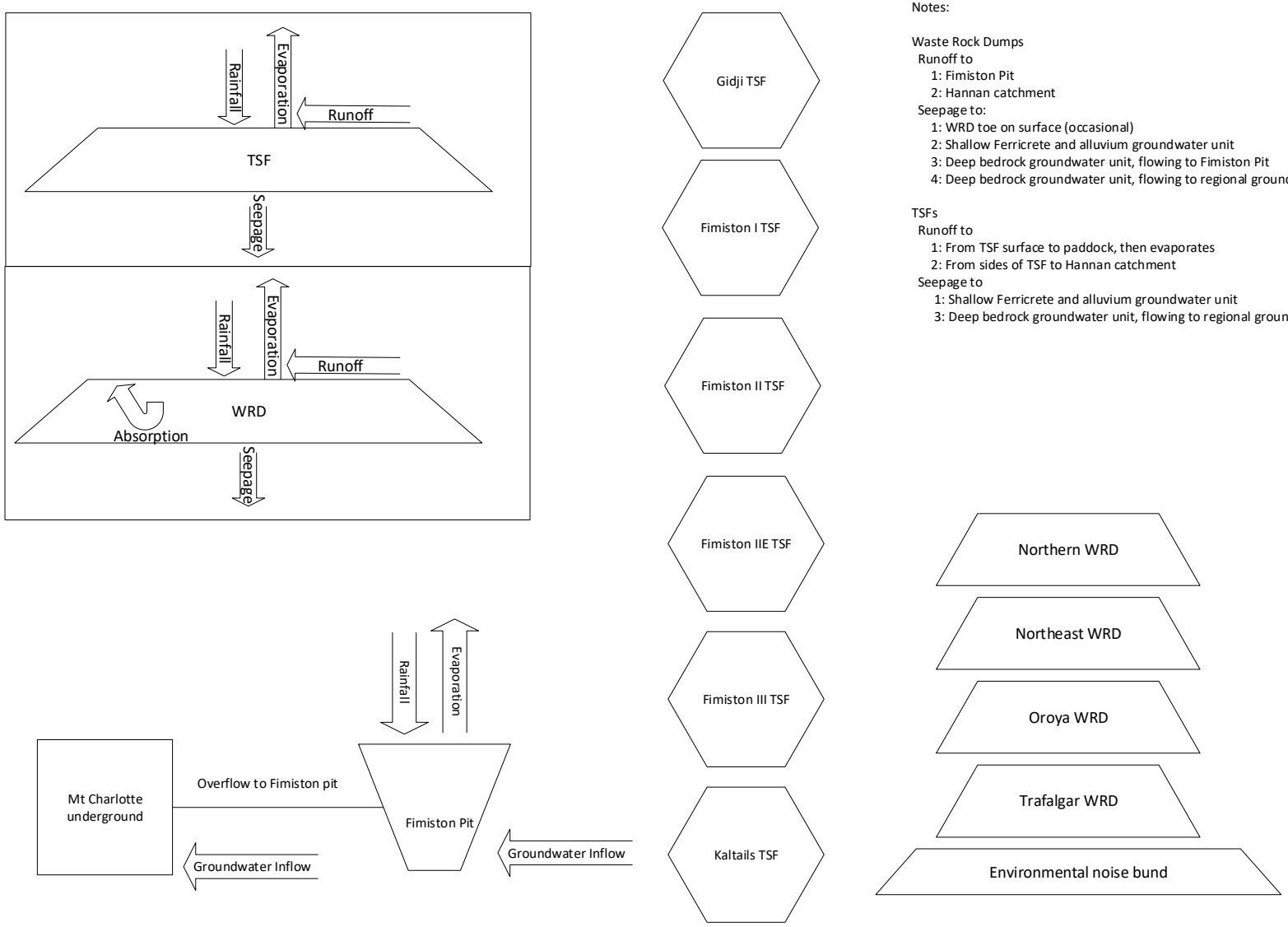


Figure 3: Conceptual flow diagram at closure.

Source: Provided by GRM as part of this scope of work.

3.2.1 Tailings Storage Facilities

TSFs will be rehabilitated to be internal draining, i.e. rainfall runoff from the rehabilitated TSF surfaces will be collecting in the centre of each TSF paddocks, from where it will evaporate. Evaporation rates exceed rainfall by a significant margin, hence TSF surfaces are expected to be dry for most of the time with some water accumulation following large rainfall events. Side slopes of the TSFs will be rehabilitated with runoff reporting to the Eastern Floodway and ultimately Hannans Lake (Figure 4).

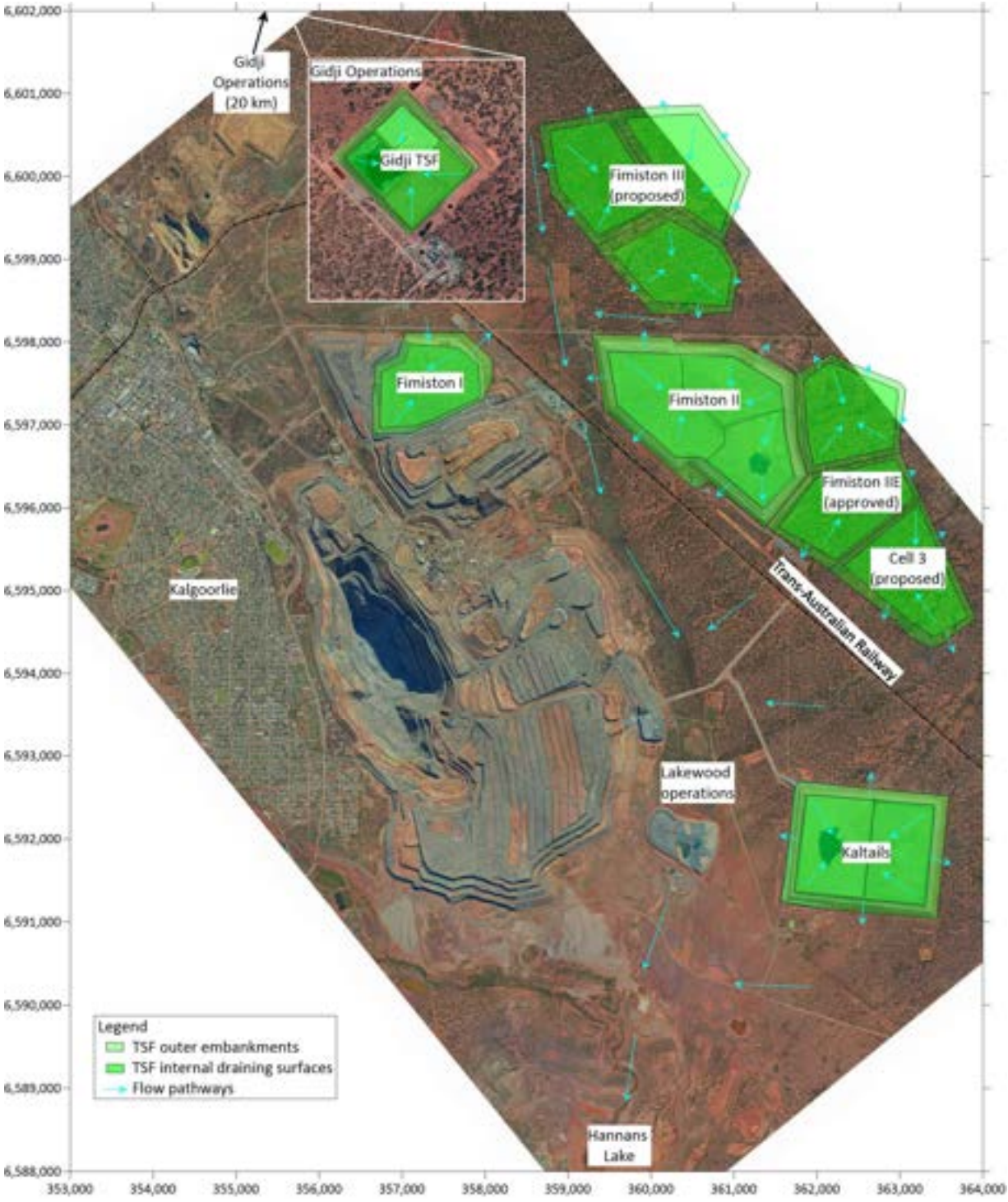


Figure 4: Surface water flow pathways from rehabilitated TSFs.

Source: Provided by GRM as part of this scope of work.

Seepage from the TSFs during the drain-down period is expected to require active management to avoid groundwater level rises around the TSFs over a period of between 10 and 15 years (conservative approach). Cover modelling indicates that minimal seepage will occur from the rehabilitated TSF surfaces after the drain-down period (Big Dog Hydrogeology, 2022).

During the active management period, seepage interception pumping will continue. Seepage is currently intercepted in accordance with the Seepage and Groundwater Management Plan (SGMP) (KCGM, 2020a). This management plan will be revised for the management of seepage during the drain-down period. Tailings deposition will mostly cease on Fimiston I and Fimiston II TSFs during the operational period, though the TSFs might be used occasionally up to closure of the process plants. After closure of the process plants, all TSFs will also be closed and intercepted seepage will be pumped to the Fimiston Pit.

An estimated 75 L/s of recovered seepage and underdrainage will be pumped to Fimiston Pit over 2 years, decreasing to 10 L/s over the following 8 years (Table 1). If the drain-down period is longer than expected (15 years), then 115 L/s of recovered seepage and underdrainage will be pumped to Fimiston Pit for 3 years, falling to between 105 and 12 L/s for the following 12 years (Big Dog Hydrogeology, 2022).

Table 1: Base case tailings seepage and underdrainage inflow rates after closure (L/s)

YEARS POST CLOSURE	CALENDAR YEAR	RECOVERED SEEPAGE			UNDERDRAINAGE			TOTAL
		FIM. I	KALTAILS	FIM. IIE	FIM. III	FIM. IIE	FIM. III	
0	2034	10	15	10	15	10	15	75
1	2035	10	15	10	15	10	15	75
2	2036	10	15	10	15	10	15	75
3	2037	0	0	1	4	1	4	10
4	2038	0	0	1	4	1	4	10
5	2039	0	0	1	4	1	4	10
6	2040	0	0	1	4	1	4	10
7	2041	0	0	1	4	1	4	10
8	2042	0	0	1	4	1	4	10
9	2043	0	0	1	4	1	4	10
10	2044	0	0	1	4	1	4	10

3.2.2 Waste Rock Dumps

The WRDs are progressively rehabilitated during operations. Both in-pit and ex-pit waste rock placement will occur from 2027. Waste rock dumps will be rehabilitated over several years during operations and rehabilitation could be completed by the time processing stops in 2034. The rehabilitation comprises the placement of a topsoil cover on the surfaces and sides of the waste dumps.

A numerical model was developed to determine the infiltration, evapotranspiration, and rainfall runoff from the rehabilitated WRD surface (KCGM, 2020b) as illustrated in Figure 5. Cover modelling indicates that most of rainfall on the rehabilitated WRDs will infiltrate the waste rock (80%). However, significant losses are predicted to occur as rainfall percolates through the waste rock due to absorption and

vaporisation. Runoff rates from the rehabilitated WRDs are estimated to be small, ranging between 2% of rainfall on the waste dump surface to 5% of rainfall on the side-slopes.

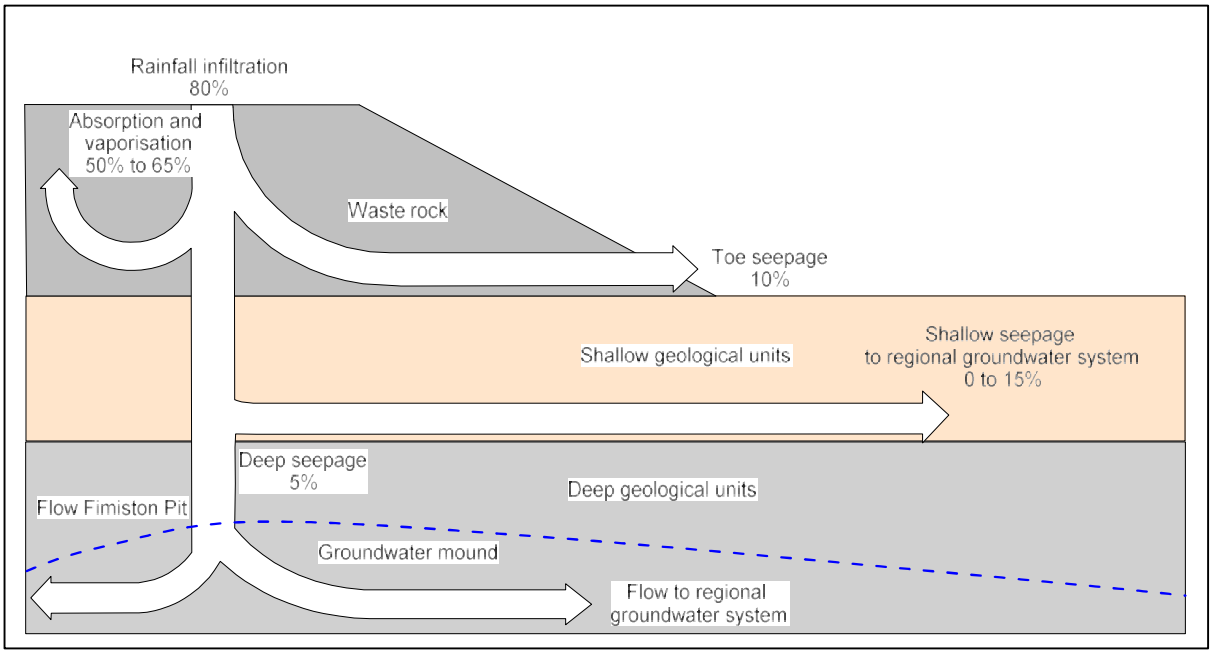


Figure 5: Conceptual flow model for the waste rock dump body and base.

Source: Provided by GRM as part of this scope of work.

Runoff from the WRD surfaces will be conveyed to the Fimiston Pit via drains aligned to existing haul roads, while runoff from the WRD side slopes will flow onto the Eastern Floodway and Gribble Creek sub-catchments, respectively (Figure 6 shows the delineated WRD catchments). The eastern side slopes report to the Eastern Floodway. The western side of the Northern and Trafalgar WRDs and a small western portion of the noise bund report to Gribble Creek (separate landforms are identified in Figure 1).

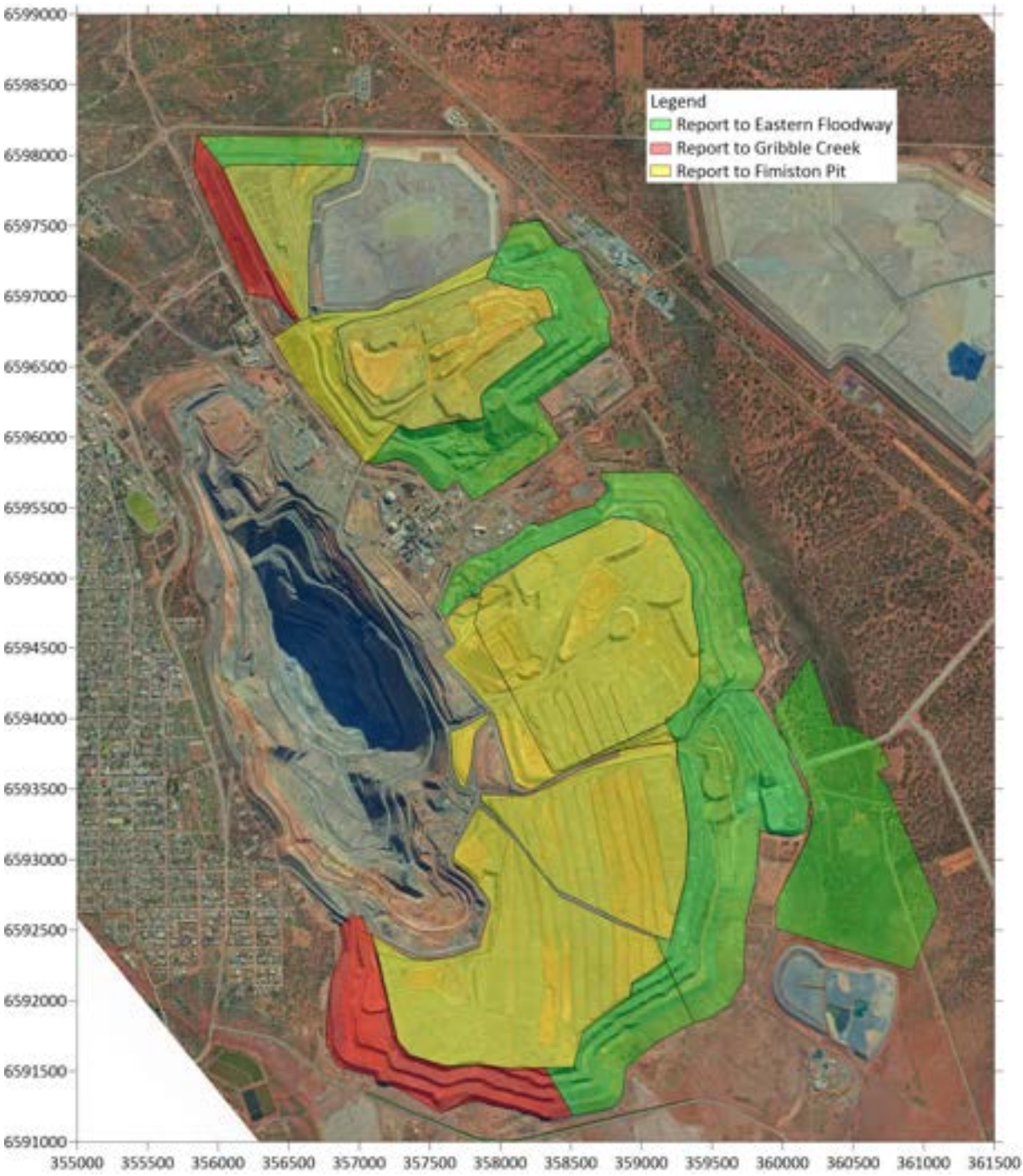


Figure 6: Waste dump surface water catchments at closure.

Source: Provided by GRM as part of this scope of work.

It is possible that some seepage could occur along the toe of the WRD following large rainfall events, discharging down-gradient at the southeastern side of the WRD. During large rainfall events, macropores in the WRD form preferential pathways with rainfall infiltration rapidly percolating through the waste rock material. During such events, rainfall may discharge along the toe of the dump to the ground surface.

Once percolating water reaches the base of the WRD, water that does not seep from WRD toes would generally infiltrate the ground and flow into the underlying ferricrete and alluvium groundwater system, where present, or enter the fractured bedrock aquifer where it can flow either towards the pit or to the regional groundwater system associated with the Hannan groundwater catchment as illustrated in Figure

7 and Figure 8. Estimated seepage flows at WRD toes and to the alluvium and fractured bedrock aquifers were based on GRM professional judgement and experience with the Fimiston Operations and are subject to refinement as part of detailed mine closure planning (pers com. Jan Vermaak, GRM, email dated 18 July 2022).

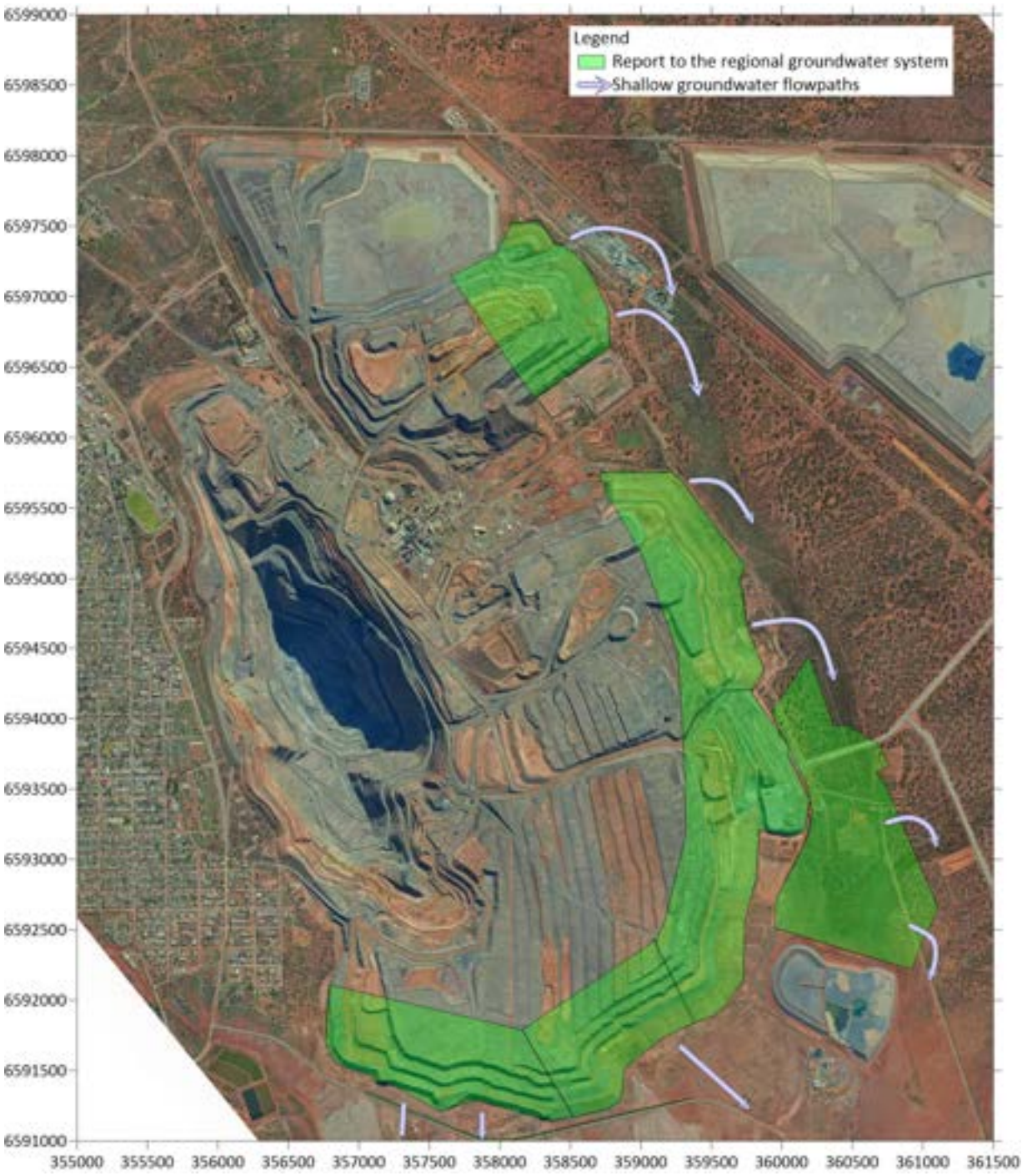


Figure 7: Catchments contributing to seepage to the ferricrete and alluvium groundwater system.

Source: Provided by GRM as part of this scope of work.

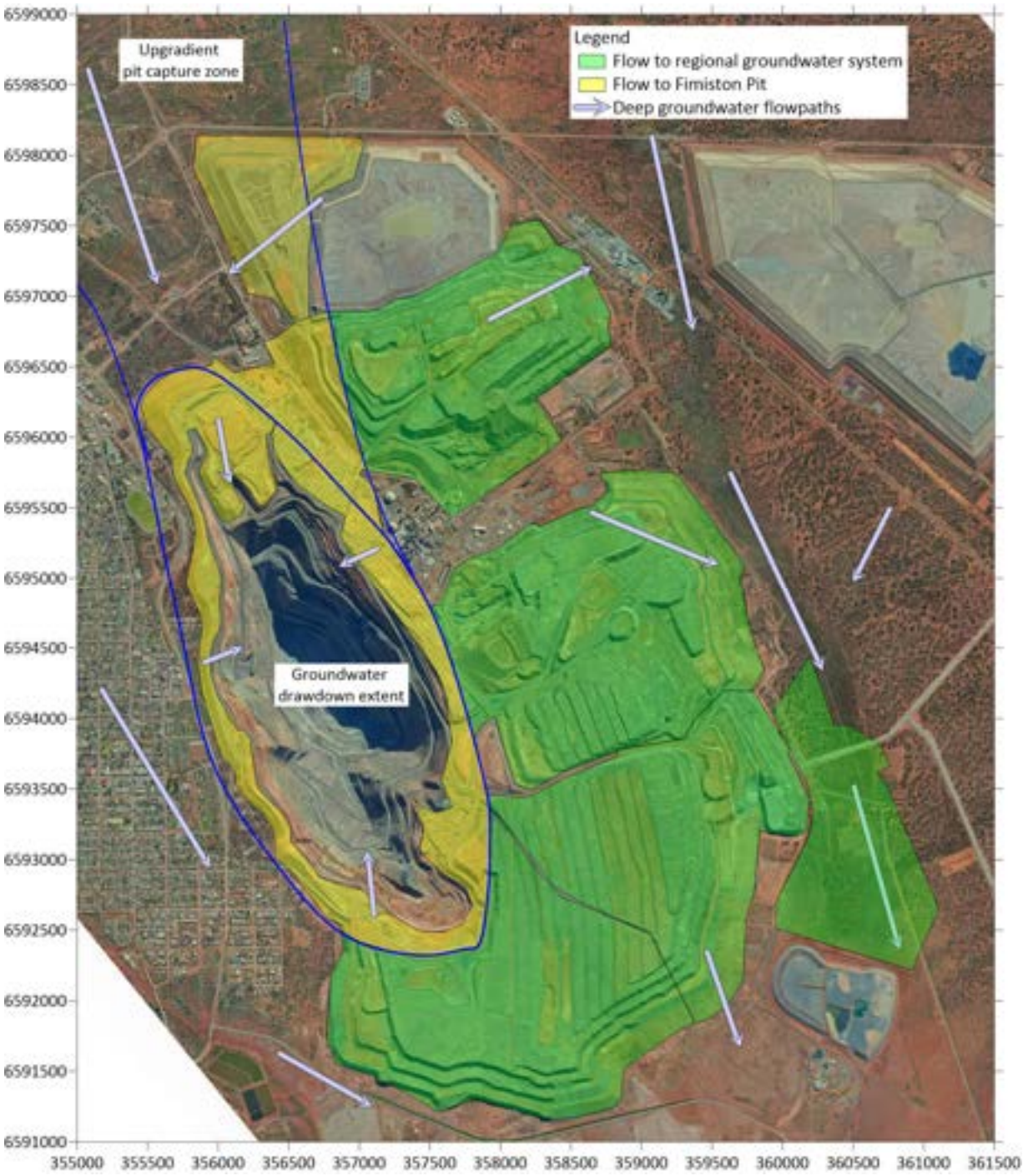


Figure 8: Catchments contributing to seepage to the fractured bedrock groundwater system.

Source: Provided by GRM as part of this scope of work.

3.2.3 Mt Charlotte Underground Working

Peter Clifton and Associates (2014) carried out a hydrogeological assessment of the Mt Charlotte underground workings after closure.

The Mt Charlotte Underground mine used to be accessed via the Sam Pearce Decline, which is located at the northern end of the Fimiston Open Pit. The decline tracks to the northwest and joins the main underground workings of Mt Charlotte on the 9 Level (9L), which is at an elevation of -106 mAHD.

Numerical modelling indicated that the voids in the underground mine workings will slowly fill with groundwater after closure. Initially, groundwater inflow rates are expected to remain constant, but as groundwater levels rise, groundwater inflow rates are expected to decrease because of the lower hydraulic gradient.

Eventually, groundwater levels are expected to reach the Sam Pearce Decline and then overflow into Fimiston Pit. The numerical model indicated that groundwater levels will reach the decline 99 years after closure and the rate of overflow would be 33 kL/d (0.4 L/s). Mt Charlotte is planned to be closed by 2034, which means overflow to Fimiston Pit is predicted to potentially occur by 2133.

3.2.4 Fimiston Pit

The Fimiston Pit will gradually fill with water, mainly from groundwater inflow, rainfall and pit wall runoff in the long-term. However, during the initial stages of closure the pit will also receive relatively substantial volumes of water pumped from the TSF seepage interception bores as well as underdrainage systems installed in Fim IIE and Fim III cells.

As the pit fills with water, the pit lake area will increase, thereby exposing a larger water body surface to evaporation losses. When total inflow rates are the same as the water losses through evaporation, the pit lake will reach equilibrium conditions, pit lake water levels will stabilise, and only seasonal fluctuations are expected thereafter. The pit lake modelling was developed based on the final pit shell design (Pit Design for s38 plus Inpit Dumps Single Surface.dxf) provided by KCGM (pers. com. Stephen Kable, Senior Strategic Planning Engineer, Northern Star Resources, email dated 1 April 2022).

GRM used this pit shell to develop the elevation-area-volume stage curve for the pit. The stage curve was used to determine the pit water levels and pit lake areas as the pit fills with water. The maximum capacity of the pit void (i.e., the capacity to the lowest pit crest elevation at 351 m AHD) is 975 GL and the total area of the pit void is about 479 ha. The final pit void has a strike length of about 3,780 m and a width of about 1,610 m. The pit floor has an elevation of -390 m AHD. The crest elevation ranges from 351 m AHD at the southwestern corner of the pit to 390 m AHD along the northern corner of the pit (average about 360 m AHD). The depth of the pit from the average pit crest elevation is 750 m. Figure 9 shows a 3D rendering of the final pit shell without in-pit backfill.

The oxide interface occurs at elevations ranging between 280 m AHD along the southern and southwestern parts of the pit to 330 m AHD along the remaining sections of the pit. The oxide interface is at a higher elevation than the inferred pre-mining groundwater levels and much higher than the predicted equilibrium pit lake water levels described in more detail later. As such, the oxide layer does not affect the pit water balance significantly, nor is the presence of the pit lake expected to affect the stability of the upper pit slopes.

KCGM is planning to partially backfill the pit void with an in-pit WRD commencing in 2027 over a period of six years. The in-pit waste rock will significantly reduce the capacity of the pit void and this was taken in consideration during the development of the model. The in-pit WRD will occupy around 68 GL of volume within the portion of the void to be occupied by the lake (to -122 m AHD at equilibrium level), which is 58% of the total void volume to this depth. Figure 10 shows a 3D rendering of the final pit shell with in-pit backfill.

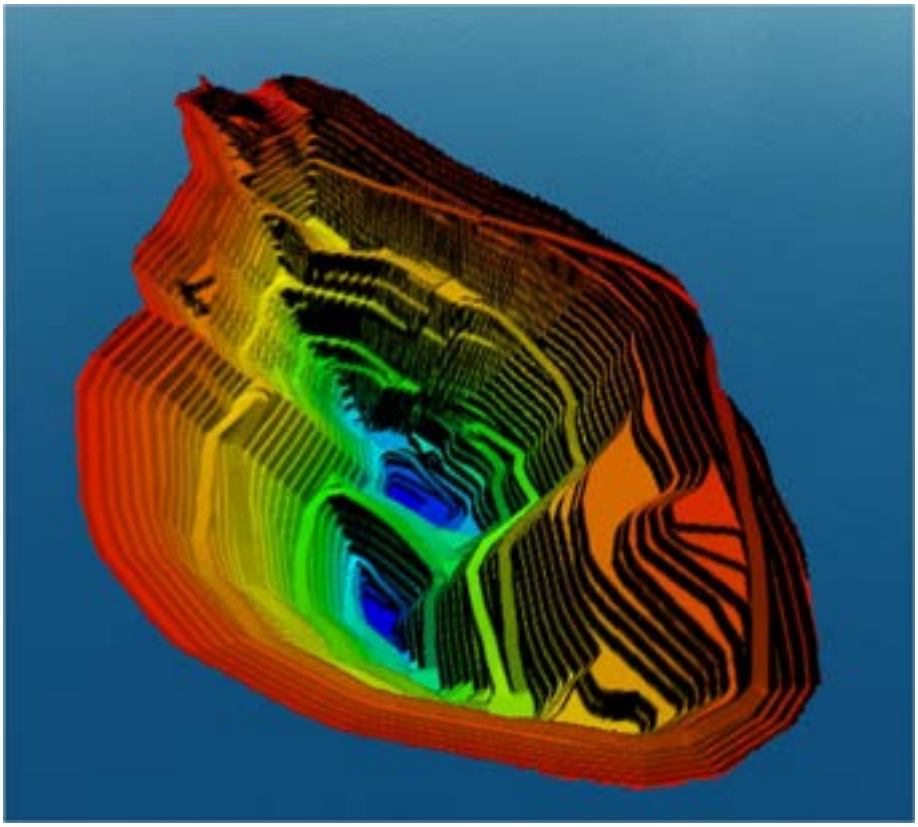


Figure 9: 3D rendering of the Fimiston Pit final pit void without in-pit backfill.

Source: Provided by GRM as part of this scope of work.

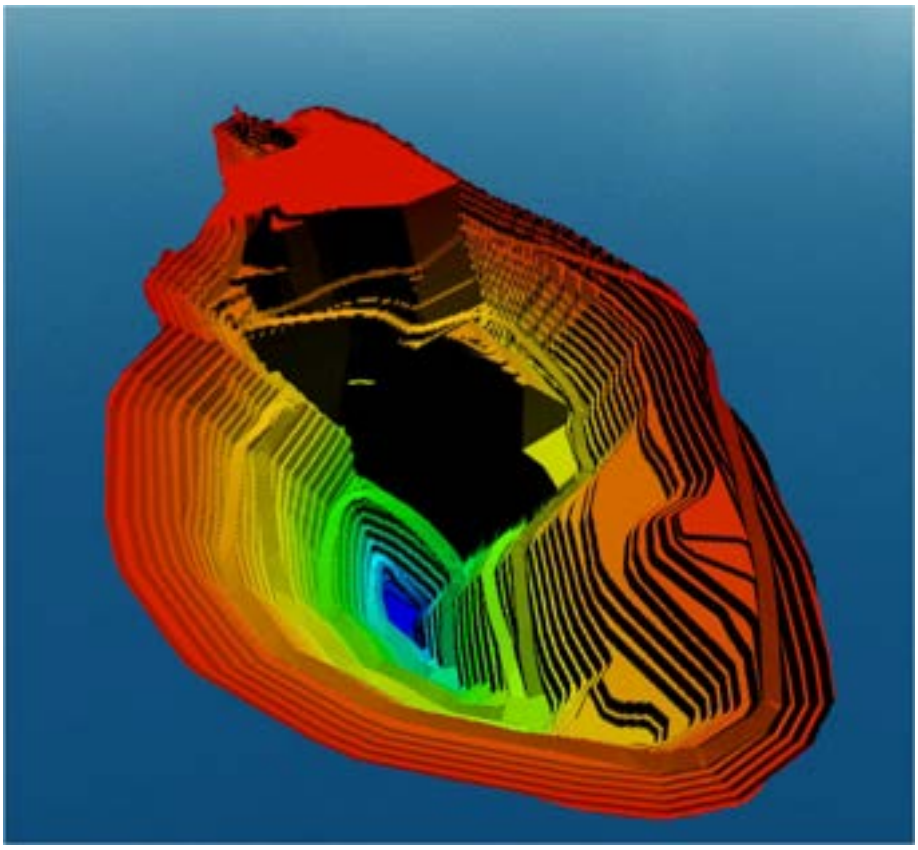


Figure 10: 3D rendering of the Fimiston Pit final pit void showing in-pit backfill .

Source: Provided by GRM as part of this scope of work.

The modelled inflows and outflows to the pit lake during the closure period are summarised in Table 2. Groundwater pumping and elevation data suggest that groundwater inflow rates reached near equilibrium conditions and groundwater inflow rates are unaffected by the pit lake levels up to an elevation of about -100 m AHD. The equilibrium conditions exist because bedrock below -100 m AHD is almost impermeable and groundwater inflow mainly occurs from the more permeable units above -100 m AHD, which flow into historical mine workings below the pit floor level.

The predicted Fimiston Pit lake areas after closure are presented in Figure 11. The results show the pit lake areas over a period of 566 years after closure and were developed by applying the stochastic rainfall and evaporation rates and running the GoldSim flow model for 1,000 realisations. Results are expressed in terms of probability of non-exceedance.

The model shows that the Fimiston pit lake is predicted to reach equilibrium approximately 400 years after closure. There is some variation of pit lake areas ranging between 38 ha and 66 ha at equilibrium with a median equilibrium value of 48 ha. The variation is mainly due to the uncertainties of the rate of evaporation, given effects such as wind shielding, shading, the effect of the lake area, salinity and increased solar radiation due to the higher pit wall albedo.

The predicted pit lake elevations are shown in Figure 12. Equilibrium (nominally 400 years post closure) pit lake level ranges between -159 m AHD to -69 m AHD with a median value of -122 m AHD. Equilibrium pit lake levels are about 473 to 493 m below the pit crest and 453 m deeper than the pre-mining groundwater level. The deep equilibrium pit lake levels are indicative of the high evapotranspiration potential in the region and the relatively low groundwater inflow rates. The maximum water depth at equilibrium is about 290 m. Figure 14 presents a 3D rendering of the pit lake with a water level at -122 m AHD. The model predicts that the lake will reach around 30% of the equilibrium depth after the first year post-closure and around three quarters (73%) of the equilibrium depth of the lake is attained during the first 50 years post-closure, after which the pit lake level rises steadily before reaching equilibrium levels. Seasonal water fluctuations are about 0.5 m though larger fluctuations will occur following large rainfall events.

Figure 13 shows the range in predicted pit lake volumes. Equilibrium pit lake volumes range between 51 GL to 110 GL with the median value of 72 GL. The large range of predicted pit lake volumes is mainly a function of the stage curve whereby a relatively small change in pit lake areas could cause a substantial change in pit lake volume. The predicted pit lake volumes are substantially smaller than the Fimiston Pit capacity of 975 GL. Whilst most of the equilibrium lake depth is attained 50 years post-closure, 55% of the equilibrium lake volume is attained at this time due to the quasi-inverse conical morphology of the void.

Table 2: Estimated inflows and outflows from the Fimiston Pit lake.

INFLOW/OUTFLOW	APPROACH	NOTES
Groundwater inflow	Based on estimated groundwater inflows as determined through calibration.	Assumed to be constant until it reached -100 m AHD, then gradually decreases.
Direct rainfall	Stochastic rainfall applied to the pit lake surface.	Pit lake surface area was modelled dynamically, i.e., lake surface increases as pit fills up with water.
Pit wall runoff	Based on estimated pit wall runoff coefficients as determined through calibration.	Includes pit wall runoff coefficients for both normal and high rainfall events.
Backfill runoff	Surface area of backfill estimated from the backfill schedule. Runoff assumed to be similar to runoff from WRDs	
Backfill seepage	Seepage assumed to be similar to toe seepage rates from WRDs	It has been assumed that a cover system will not be installed on the in-pit WRD.
TSF seepage interception and underdrainage	Post closure pumping rates from the seepage interception system estimated based mainly on monitoring data.	TSF seepage interception will be required for a relatively short period (10 to 15 years) and will have a small effect on pit water levels.
Mt Charlotte Underground Mine	Based on an earlier study.	Small inflows predicted.
Runoff from the WRDs	Based on Hydrus modelling of the rehabilitated WRD surfaces.	
Toe seepage from the WRDs	Based on the pre-mining surface contours and assumption of seepage rates.	Only a small section of WRDs produces toe seepage flowing to the pit.
Seepage from the WRDs flowing to the fractured bedrock groundwater system	Estimates based on observed groundwater levels responses from groundwater monitoring data.	Seepage rates are small.
Evaporation	Based on the stochastic evaporation applied over the pit lake surface.	Included a pan factor (0.63 with standard deviation of 0.05) to account for lower evaporation rates over a lake surface.

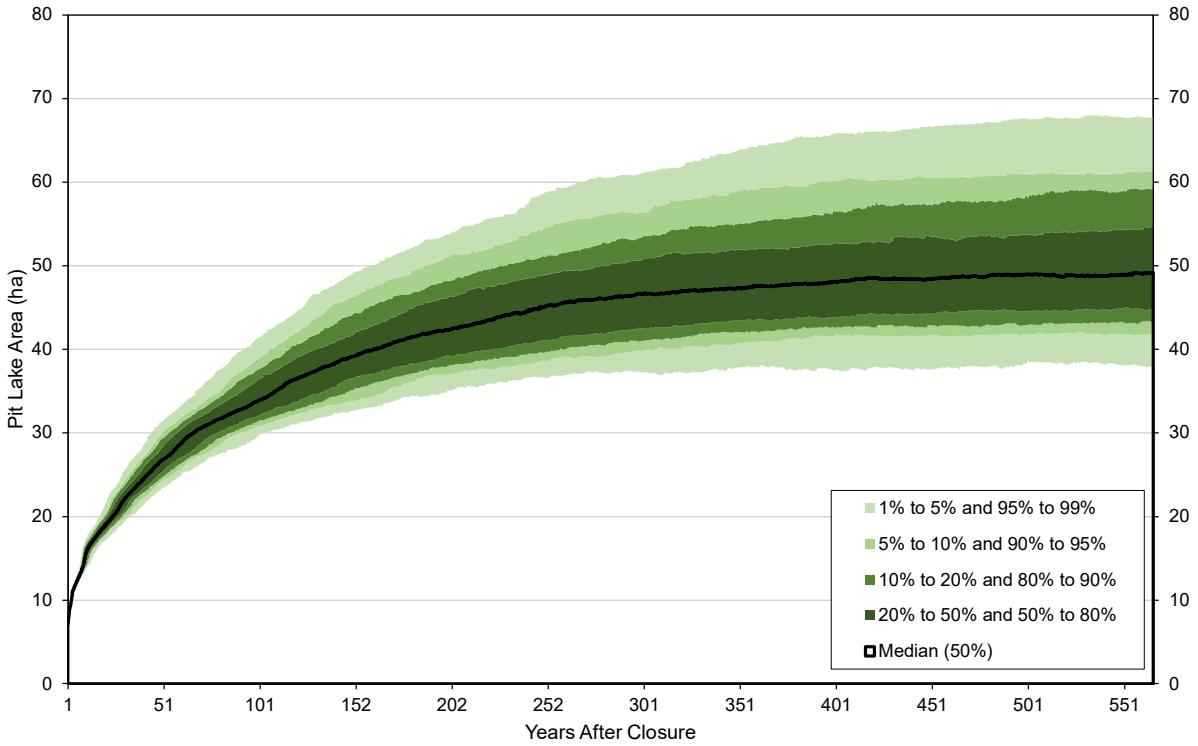


Figure 11: Predicted Fimiston Pit lake surface area (base case conditions).

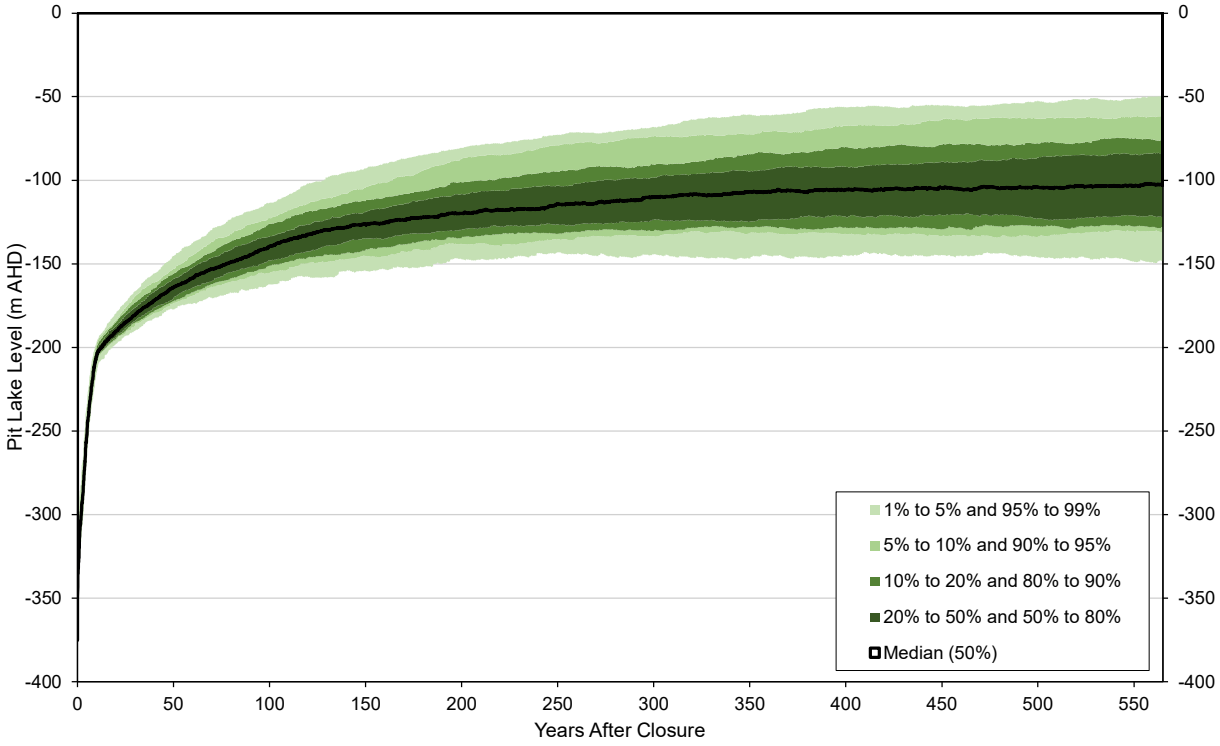


Figure 12: Predicted Fimiston Pit lake elevation (base case conditions).

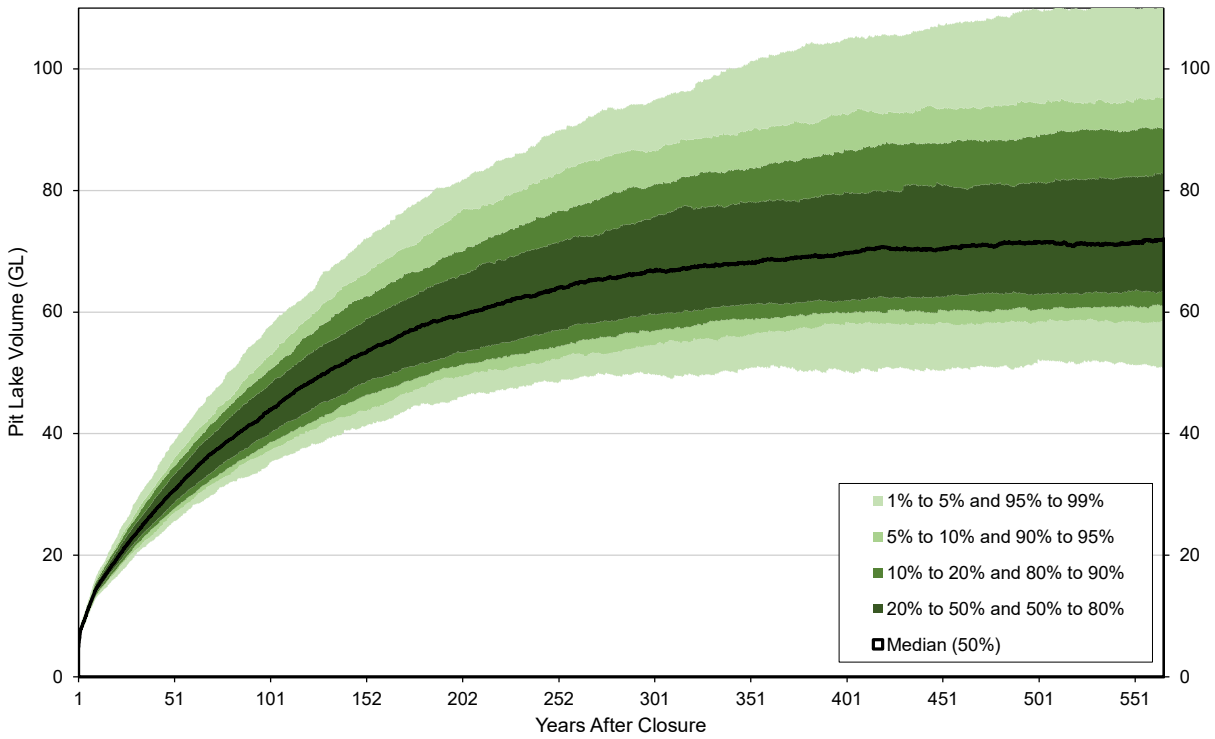


Figure 13: Predicted Fimiston Pit lake volume (base case conditions).

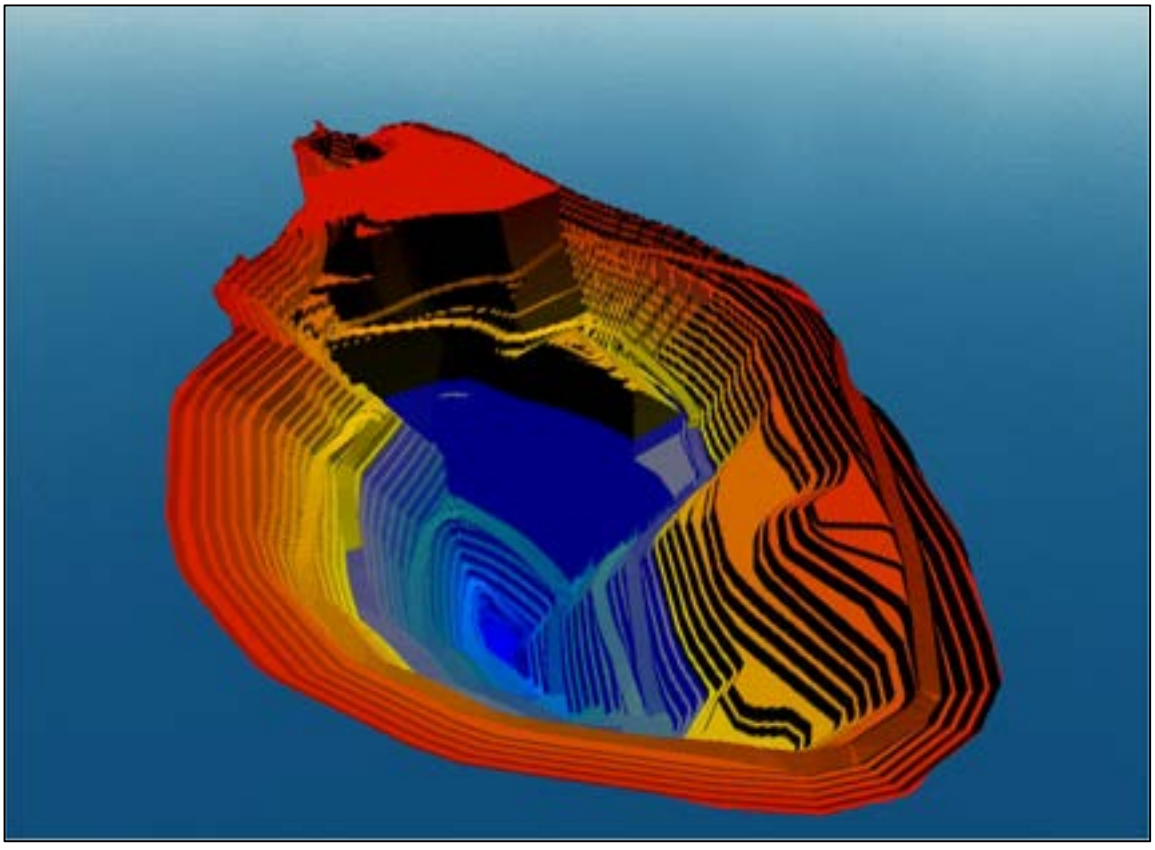


Figure 14: 3D rendering of the pit lake surface at -122 m AHD.

Source: Provided by GRM as part of this scope of work.

Figure 15 shows the contribution of inflows to the pit lake (base case conditions). Initially, intercepted TSF seepage and underdrainage inputs (tailings water) will be the largest inflow to the pit, representing up to 62% of water entering the pit lake in the first ten years after closure (nominally 2044). The next most substantial inflows at this time are groundwater (23%) and pit wall runoff (7%). With time, groundwater inflow and pit wall runoff will become the larger contributors to the pit lake. At 100 years after closure, groundwater inflow and pit wall runoff will comprise 51% and 14% of the pit lake inputs to date, respectively. Because tailings water inputs cease ten years after closure under base case conditions, their relative contribution to the total inflow volume during the first 100 years post-closure will be reduced to 14%. After 400 years post-closure groundwater represents over half (53%) of the total inflow volume to the lake, followed by pit wall runoff (14%), direct rainfall (13%) and runoff/seepage from the in-pit WRD (12%). All other inflows, including tailings water, represent less than 3% of the cumulative inflows up to that point in time.

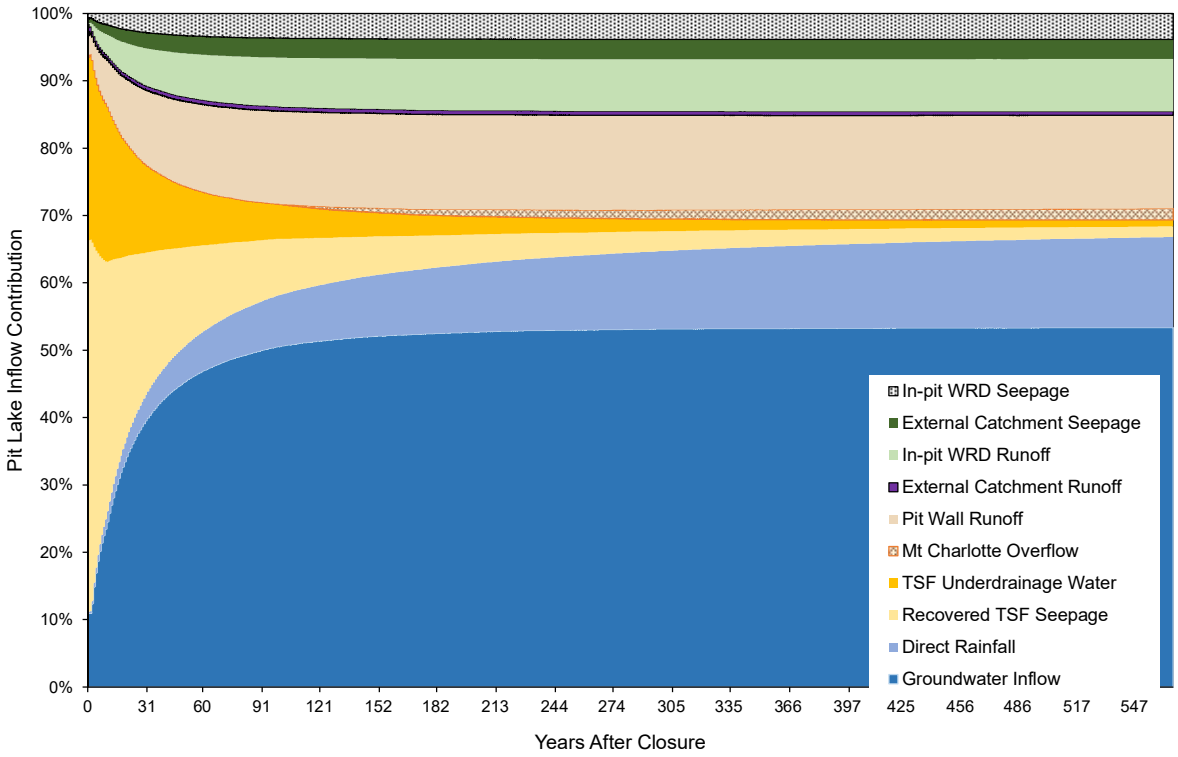


Figure 15: Predicted Fimiston Pit lake inflow contribution (base case conditions).

GRM carried out a sensitivity and uncertainty analysis to assess which model parameters could affect the future outcome of the model predictions as related to the pit lake water balance. An initial, qualitative assessment was undertaken to identify the key parameters which could affect the model outcome and required further assessment. Based on the initial assessment, two additional water balance model runs were undertaken, namely:

- A climate change scenario, whereby both long-term rainfall and evaporation rates increase in accordance with the latest climate projection models (Section 3.1); and
- A scenario whereby seepage and underdrainage interception water is pumped to the Fimiston Pit over a longer time period as discussed in Section 3.2.1. This scenario is considered to represent worst-case tailings water inflow estimates, based on observed draindown trends at the Kaltails TSF and the Fimiston I TSF during the operating period.

Results for the climate change scenario indicated that the range of predicted water levels at 400 years post-closure (between -145 m AHD and -60 m AHD) was slightly higher than those for the base case scenario (between -160 m AHD and -76 m), with a median level (-110 m AHD) around 12 m higher than the base case prediction. Compared to base case conditions at 400 years post-closure, cumulative proportional inflows from groundwater, rainfall and pit wall runoff were slightly higher (~ 2 percentage points) and evaporation rates from the pit lake surface are also higher. Predicted pit lake levels were similar because the increased average rainfall, which causes higher equilibrium water levels, would be being offset by the increased evaporation rates.

The results from the extended TSF inputs model scenario indicated that extending the duration of tailings water inputs from 10 years to 15 years post-closure will have a negligible influence on pit lake level and volume at 400 years post-closure (equilibrium) compared with the base case scenario. However, the predicted make-up of the pit lake water would be affected, especially during the early period of pit filling. The cumulative proportion of total inflow volume from recovered TSF seepage and underdrainage water at 100 years post-closure (30%) is higher than the equivalent for the base case scenario (14%). The difference is still notable at 400 years post-closure, whereby tailings water comprises 9.4% of total inflows for the extended TSF inputs scenario, compared with 3.6% for the base case scenario.

4 FIMISTON PIT LAKE HYDROGEOCHEMICAL MODEL

An integrated solute accounting, mixing, stratification and geochemical speciation model was developed for the Fimiston Pit lake, based on water balance and flow modelling described previously, as well as materials characterisation data and water quality monitoring data. Models were developed for baseline scenario, climate change scenario, and extended TSF inputs (seepage and underdrainage recovery) scenario.

4.1 Derivation of Hydrochemical Source Terms

Hydrochemical source terms were developed to represent the chemical characteristics of each pit lake inflow (e.g., groundwater inflow, TSF seepage) using a combination of water quality monitoring data and results from materials characterisation studies as summarised in Table 3. The chemical compositions of the resulting source terms are presented in Table 4 through to Table 6.

Table 3: Summary of source terms, data sources and considerations.

INPUT	DATA SOURCES AND CONSIDERATIONS
Groundwater	Water quality monitoring data from several bores intersecting voids beneath the Fimiston Pit, collected between 2005 and 2020. Using this monitoring data is likely conservative as water from the voids may already be affected by mining activities.
Rainwater	Data from rainfall composition monitoring network established by the CSIRO (Crosbie *et al*., 2012), using data from the Meekatharra monitoring site.
Pit wall runoff (dolerite and basalt lithologies)	Data from geochemical characterisation studies (e.g., static leachate testing data) of the main lithologies to be present on the pit walls at closure as reported in MBS (2020).
Pit wall runoff (Black Flag shale)	Synthesised leachate and acid base accounting (ABA) data from field-based kinetic weathering trials (MBS, 2017; 2020) and geochemical characterisation studies (MBS, 2017; GCA, 2010). Consideration given to the variable potential for exposed shale to generate acid and metalliferous drainage (AMD) and neutral metalliferous drainage (NMD), estimates of sulfide oxidation rates from kinetic trials and potential weathering (sloughing) rate of pit wall shale (pers. com. Charlotte Woolley, Geotechnical Superintendent, Northern Star Resources, email dated 17 August 2021). Source term is conservative given apparent evapoconcentration of leachates from kinetic weathering trials (i.e. dilution can reasonably be expected to reduce concentrations in pit wall runoff under high rainfall event conditions).
Reactive pit wall carbonate	Data from geochemical characterisation studies as summarised in MBS (2020) and GCA (2010). Assumptions around pit wall weathering depth were used to estimate carbonate potentially available to neutralise pit water acidity.

INPUT	DATA SOURCES AND CONSIDERATIONS
Reactive carbonate from in-pit WRD	Data from geochemical characterisation studies as summarised in MBS (2017; 2020) and GCA (2010). Assumptions around reactive ANC availability based on estimated median waste rock particle diameter and reaction depth, and a nominal volume (2 m^3 per m^2 exposed to lake water) of in-pit waste providing neutralising capacity to the pit water.
TSF seepage recovery water	Water quality monitoring data from process plant (mill) inputs from bore fields collecting seepage-affected groundwater at Kaltails, Fimiston I and II TSFs collected between February 2013 and April 2020.
TSF underdrainage recovery water	Water quality analysis (metals, metalloids etc.) for decant from Fimiston II TSF (MBS, 2016) and cyanide monitoring data for decant from Fimiston II TSF (September 2021 – March 2022) provided by KCGM (pers. com. Genevieve Tait, Environmental Advisor, email dated 16 March 2022).
Mt Charlotte underground floodwater	Water quality monitoring data from samples reflecting dewatering the underground workings and various groundwater inflow seepage locations, between January 2014 and February 2016.
Waste rock runoff and seepage	Water quality data for samples collected from ramps leading into the pit (May 2020) and reflecting inputs of WRD toe seepage at several locations between July 2009 and February 2020. Adjustments to salinity and major ion composition were made to account for inputs of saline water used for dust suppression (where not reflective of closure conditions).

Table 4: Source term composition for groundwater, rainfall, Mt Charlotte floodwater and waste rock runoff and seepage.

PARAMETER (mg/L)	GROUNDWATER	RAINFALL	MT CHARLOTTE FLOODWATER	WASTE ROCK RUNOFF AND SEEPAGE
TDS	64,344	11.6	36,960	10,883
pH	7.4	-	6.9	6.9
Density (kg/L)	1.03	1.00	1.03	1.00
Alkalinity as HCO_3	342	2.4	183	39
Ag	0.01	-	0.0005	0.1
Al	0.05	0.03	0.02	0.05
As	0.02	-	0.001	0.02
B	5.5	-	5	3.5
Ba	0.08	-	0.07	0.2
Ca	1500	0.95	1,500	70
Cd	-	-	0.0005	0.008
Cl	35,000	2.4	19,834	6,300
Cyanide (total)	-	-	-	-
Co	0.1	-	0.05	0.28
Cr	0.005	-	0.0025	0.03
Cu	0.2	-	0.01	0.26
F	0.2	0.03	0.2	0.2
Fe	7	-	0.02	-
K	200	0.2	160	32
Mg	2,600	0.4	1,500	470
Mn	4	0.04	0.3	5.8
Mo	0.02	-	0.007	0.2
Na	19,000	1.9	10,000	3,300
Ni	0.015	-	0.03	0.05
Pb	0.005	-	0.001	0.005
Sb	0.005	-	0.002	0.005
Se	-	-	0.002	-
SO_4	6,000	1.6	3,700	550
Sr	20	-	-	-
U	-	-	-	-
Zn	0.1	0.09	0.05	0.1

Values presented in mg/L unless otherwise stated. Dashes indicate that no value has been defined (i.e., not indicated as present based on laboratory analysis).

Table 5: Source term composition for runoff from key lithologies exposed on the final pit walls.

PARAMETER (mg/L)	DOLERITE	BASALT	OXIDE ZONE BLACK FLAG SHALE	OXDISED UNWEATHERED/TRANSITION ZONE BLACK FLAG SHALE
TDS	104	137	95	44,055
pH	8.7	8.8	8.8	2.6
Density (kg/L)	1.00	1.00	1.00	1.00
Alkalinity as HCO_3	26	46	6.6	-512*
Acidity as $CaCO_3$	-	-	-	3,500*
Ag	0.025	-	0.26	0.007
Al	1.1	1.0	0.7	542
As	0.002	0.02	0.03	0.13
B	-	-	-	3.8
Ba	0.002	0.001	0.003	0.026
Ca	13	13	9.8	518
Cd	-	-	-	2.3
Cl	45	46	41	10,929
Co	-	-	-	21
Cr	-	-	-	1.1
Cu	-	-	-	170
F	0.09	0.07	0.12	-
Fe	-	-	-	141
K	4	5	14	68
Li	0.008	0.007	0.004	-
Mg	6	4	5	5,206
Mn	0.004	0.01	0.001	99
Mo	-	-	0.006	0.004
Na	7	20	5	5,054
Ni	-	-	-	24
Pb	-	-	-	0.26
Sb	0.004	0.015	0.12	0.002
Se	-	-	-	0.45
SO_4	2	2	13	21,694
Sr	0.04	0.03	0.08	-
U	-	-	-	0.028
V	-	-	-	0.82
Zn	-	-	-	80

**Negative alkalinity predictions by PHREEQC are not analogous to acidity. Acidity was estimated from aluminium (assuming Al^{3+}), iron (assuming Fe^{2+}), manganese concentrations and pH. Note that acidity estimates are presented for reference purposes and were not explicitly used in the PHREEQ model.*

Table 6: Source term composition for recovered groundwater seepage and underdrainage water.

PARAMETER (mg/L)	RECOVERED TSF SEEPAGE		TSF UNDERDRAINAGE: FIMISTON I/II/III
	KALTAILS	FIMISTON II/II/III	
TDS	81,622	111,580	142,284
pH	2.8	2.9	7.9
Density (kg/L)	1.1	1.1	1.07
Alkalinity as HCO_3	-133*	-82*	183
Acidity as $CaCO_3$	1,300*	1,460*	-
Ag	0.01	0.01	0.24
Al	215	249	2.3
As	0.005	0.005	0.006
B	8.8	8	10
Ba	0.03	0.04	0.49
Ca	1,100	2,500	2,827
Cd	-	-	-
Cl	46,241	65,733	78,153
Cyanide (total)	1.1	0.7	30
Co	2.9	1.5	2.8
Cr	0.1	0.04	0.06
Cu	0.13	0.02	32
F	0.3	0.3	0.26
Fe	4.4	0.7	1.8
K	130	300	568
Hg	-	-	0.046
Mg	3,429	2,690	4,130
Mn	8.8	5.5	0.69
Mo	-	-	0.17
Na	24,491	35,860	47,762
Ni	0.5	0.25	1.3
Pb	0.1	0.2	0.03
Sb	0.005	0.005	0.13
Se	0.05	0.05	0.3
SO_4	6,123	4,283	8,579
Sr	24	38	-
U	0.01	0.05	0.001
Zn	0.05	0.07	0.06

**Negative alkalinity predictions by PHREEQC are not analogous to acidity. Acidity was estimated from aluminium (assuming Al^{3+}), iron (assuming Fe^{2+}), manganese concentrations and pH. Note that acidity estimates are presented for reference purposes and were not explicitly used in the PHREEQ model.*

4.2 Potential for Stratification

Limnological modelling was undertaken as part of the previous study for the Fimiston Pit lake (MBS, 2021), using the one-dimensional General Lake Model (GLM Version 3) to predict whether a stratified lake is likely to form. Given the close similarity between the closure conditions for the previous and current studies, the findings were used to inform the solute accounting and mixing components of the model. The outcomes of the limnological modelling are summarised herein.

The GLM computes vertical profiles of temperature, salinity and density by accounting for the effect of inflows/outflows, mixing and meteorological factors. Meteorological parameters were derived from rainfall data for Kalgoorlie-Boulder Airport (1989 – 2020, BoM 2020) and others (solar radiation, cloud cover, air temperature, humidity and windspeed) were derived using data from the SILO database (Queensland Department of Environment and Science). The 1-D approach adopted by GLM resolves a vertical series of layers that capture the variation in water column properties, which is suitable for a wide range of lakes (including pit lakes) and climatic conditions (Hipsey et al. 2019).

For up to 50 years post-closure, the lake was predicted to be stratified whereby a layer of less saline water (less than 20 m deep) was predicted to form above a deeper, more saline and denser body of water (Figure 16). The salinity of the surface layer was predicted to be in the order of 10,000 – 30,000 mg/L TDS (total dissolved solids) compared with the underlying water with salinity in the order of 60,000 – 100,000 mg/L TDS. After this initial period, the salinity stratification was predicted to break down, resulting in a fully mixed lake for the remainder of the projection period (up to 566 years post-closure).

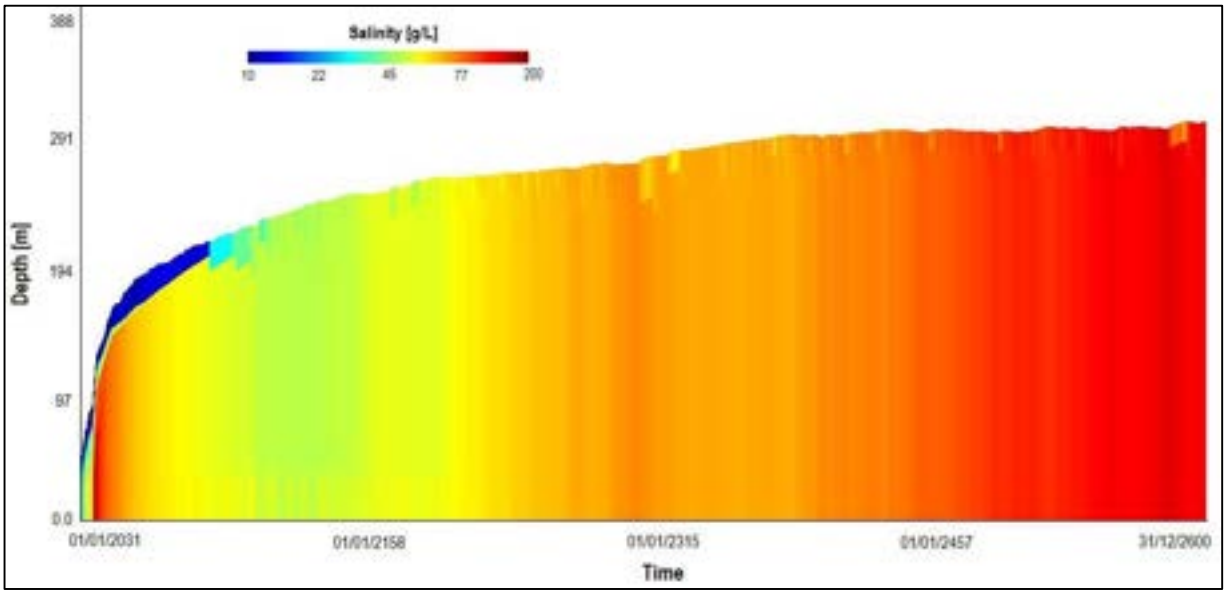


Figure 16: Modelled vertical distribution of salinity.

Source: MBS (2021)

The prediction of a temporary 'lens' of lower salinity water during the early development of the pit lake is attributable to several factors:

- Inputs of pit wall runoff, which was characterised as having low salinity (most of the pit walls were assigned a salinity equivalent to <140 mg/L TDS excepting minor proportions of more concentrated runoff from Black Flag shale), are expected to comprise a substantial proportion of

the inflow during early stage lake filling due to the large, exposed pit wall catchment relative to the volume of the lake;

- Inputs of highly saline TSF seepage recovered from multiple TSFs (up to 112,000 mg/L TDS) was predicted during this phase of the lake development;
- Contrasting salinity and temperature (hence density) of these two inputs was considered to drive the predicted formation of the surface lens; and
- The density disparity driving the formation of the lens was expected to diminish once inputs of recovered TSF seepage cease and inflows of saline groundwater (64,000 mg/L TDS) make a larger proportion of the lake volume relative to pit wall runoff and rainfall.

Predicted surface (top 20 m of the lake) and sub-surface (>20 m) water temperatures (Figure 17) indicated a stable subsurface temperature of approximately 16 ºC. The temperature at the lake surface was predicted to fluctuate with annual seasonal cycles, ranging between 13 ºC to 28 ºC. The lack of temperature disparity between surface and subsurface water on the annual timescale is consistent with the lack of salinity stratification on the timescale of the model.

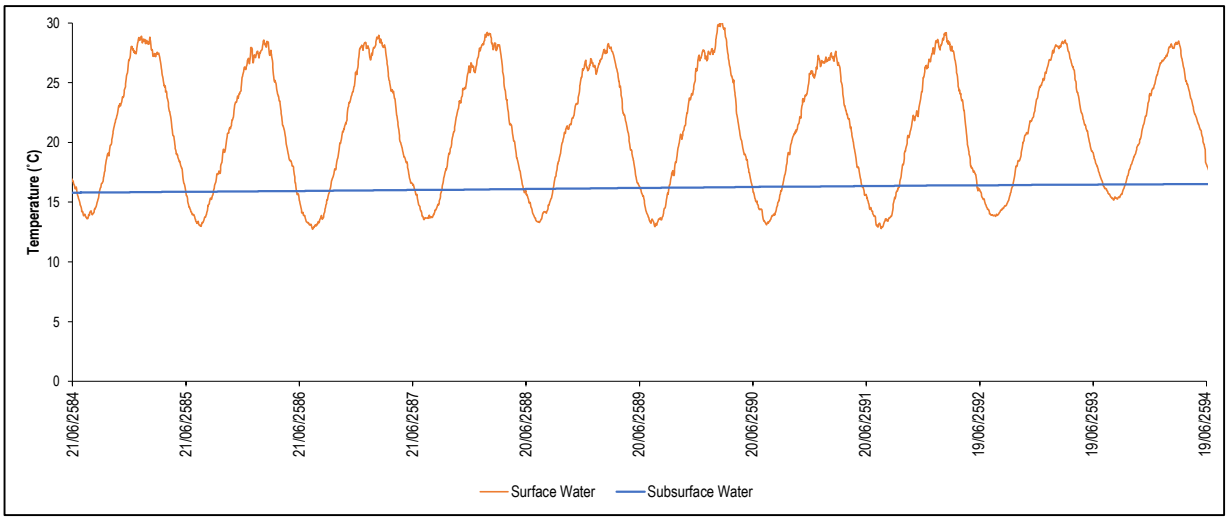


Figure 17: Surface and subsurface temperature variations.

Source: MBS (2021)

4.3 Solute Accounting, Mixing and Geochemical Speciation

Solute accounting (i.e., attribution of hydrochemical source terms to pit lake inflows), mixing and geochemical speciation were integrated into a single PHREEQC geochemical speciation model (USGS 2021), including sequential mixing and geochemical reactivity of lake water in ten intervals spanning the time from mine closure and when an equilibrium pit lake level is expected to be attained (up to 566 years post-closure). The model intervals are shown alongside predicted pit lake depth in Figure 18.

For the water in each mixing interval (base case model), the model incorporated:

- Mixing of each source term in proportions equivalent to the inflows calculated for the closure water balance model;
- Concentration of the resulting mixed lake water by removal of pure water, representing evapoconcentration as calculated from the closure water balance;

- Geochemical speciation modelling of the mixed, evapoconcentrated water to account for mechanisms including:
    - Equilibration with atmospheric gases (O_2 and CO_2);
    - Precipitation of secondary minerals, principally hydrated oxides, predicted to be oversaturated in the mixed lake water; and
    - Adsorption of dissolved metals and metalloids to hydrous ferric oxide (HFO) as represented by precipitated iron (hydr)oxide minerals.

The solution composition and mineral phase assemblages from each mixing interval were incorporated into the subsequent mixing interval. In this way, the model was a reactive mixing model simulating geochemical reactivity and evapoconcentration as a sequential, dynamic process.

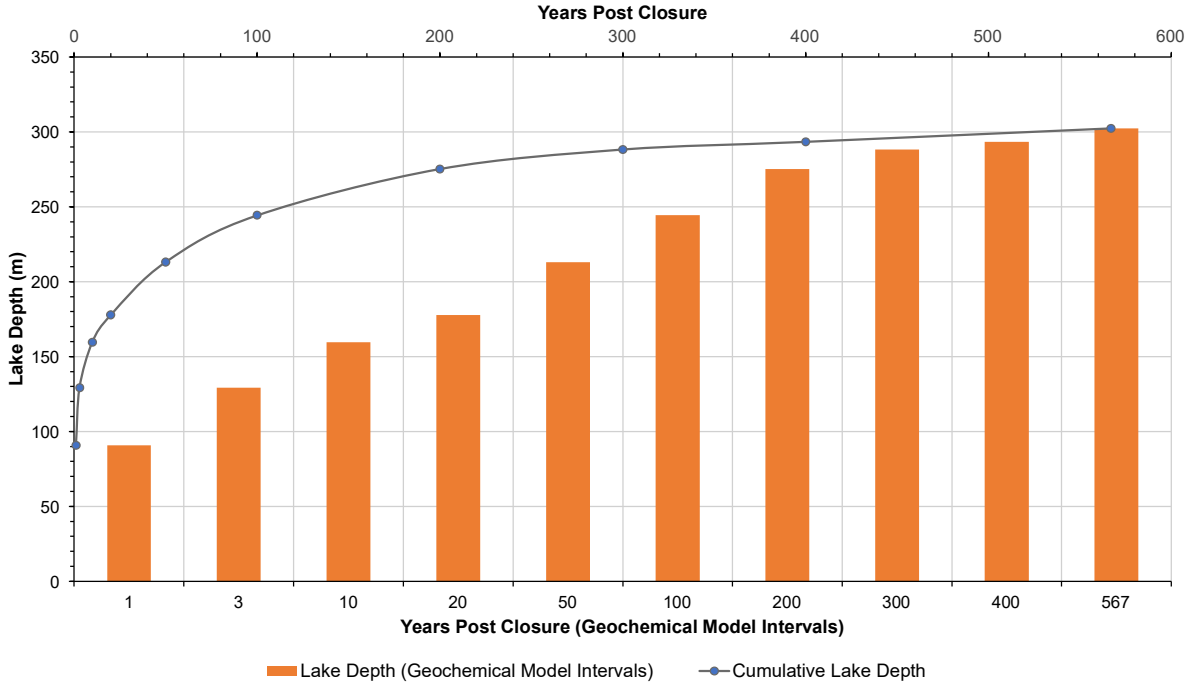


Figure 18: Cumulative lake depth and model intervals vs. year post-closure.

Based on the limnological model findings (Section 4.2), two bodies of water were defined in the base case hydrogeochemical model (upper and lower strata) for the initial five projection intervals, which covered the period up to 50 years post-closure:

- The upper stratum received most of the inflow from less saline, less dense inputs (direct rainfall, runoff from pit catchment) and was subject to evaporation. All rainfall was assigned to the upper stratum as well as 90% of the pit wall runoff and ex-pit catchment runoff to maximise consistency between hydrogeochemical and limnological model predictions;
- The lower stratum received all inflows from more saline, denser water sources (TSF seepage and underdrainage water and groundwater) but was not subjected to evaporation loss; and
- At the point where the stratification was predicted to diminish (nominally 75 years post-closure), the two bodies of water were completely mixed. The mixing model from this point onwards reflected a fully mixed lake.

Given that an unstratified model provides a satisfactory long-term representation of the lake geochemistry, unstratified models were developed for the two sensitivity scenarios (climate change, extended TSF inputs – refer to Section 3.2.4). The results were compared with an unstratified base case model to identify sensitivity of the model outcomes with respect to these three scenarios.

4.4 Limitations and Assumptions

The following assumptions and limitations apply to the solute balance and geochemical speciation modelling and the adopted conceptual pit lake model:

- All reports and data provided to MWM and GRM were accepted as accurate and representative.
- The outputs of water balance models developed by GRM and provided to MWM were accepted as accurate and fit for purpose.
- Modelling did not explicitly account for the rates (i.e. kinetics) of gas exchange, mineral dissolution and mineral precipitation, which are processes occurring simultaneously. Rates of these processes will affect the accuracy of pH predictions over time and consequently pit lake solute composition. Results from more extensive kinetic trials would be required to define solute release rates.
- Thermodynamic speciation codes such as PHREEQC rely on solution equilibria data generated by laboratory studies of solutes for low to moderate ionic strength solutions, corresponding with fresh to slightly saline conditions. Modelling highly saline solutions represents an extrapolation of solution equilibria data, which may affect the accuracy of predictions for various metals and metalloids.
- The geochemical model does not simulate biochemical processes; therefore, concentrations of biologically important species (nitrate, phosphate, and silicon) were not adjusted for biochemical processes.
- The geochemical model does not simulate oxidative degradation of cyanide (i.e. cyanide is treated as a conservative ion); therefore, predicted concentrations are overestimated. Cyanide (e.g. from tailings water inflows) will break down when exposed to circum-neutral water, oxidants and ultraviolet light. Given these limitations, predicted cyanide concentrations should be interpreted as maximum potential concentrations rather than likely concentrations.
- The GLM 3.0 limnological model is one-dimensional and assumes no horizontal variability in lake water temperature, density or salinity. As such, only variations in the vertical dimension of the lake (depth) are predicted. The model is considered fit for purpose, given the long timescale for the model predictions and level and quality of available input data.
- Parameters used to estimate quantities of reactive pit wall and in-pit WRD carbonate, which provide acid neutralisation for the pit lake, were nominal and based on reference information and estimates. Whilst intentionally conservative values were adopted, the actual reactive carbonate quantity was not determined by geochemical measurements.

4.5 Long Term Pit Lake Quality Predictions

4.5.1 Salinity and pH

Predicted pit lake pH, salinity and major ion concentrations for base case conditions (stratified) are presented in Table 7. Equivalent results for the sensitivity analysis scenarios are provided in Appendix A.

The trend for predicted pit lake pH was consistent for the three model scenarios (Figure 19). During the first three years post-closure a substantial proportion of the inflow volumes will be acidic TSF seepage recovered from groundwater and moderately acidic runoff from Black Flag shale exposed on the lower levels of the pit walls. Throughout this early stage the lake is predicted to be moderately acidic (pH 4.0 – 4.1) which reflects the rapid inflow of acidic water, limited availability of acid buffering capacity attributed to the pit walls and limited time for acid buffering reactions with the pit wall to occur (note that the in-pit WRD, which also provides buffering capacity, will not directly interact with the lake during this time).

After ten years post-closure, circumneutral conditions (pH 6.7 – 7.2) are predicted under all model scenarios (comparisons between scenarios refer to unstratified conditions). This reflects additional acid buffering capacity available from the pit walls and the in-pit WRD (dolomite and basalt), which will be largely submerged, as well as alkalinity associated with more substantial proportions of inflows such as groundwater. Whilst buffering capacity provided by pit walls and in-pit waste rock have a significant influence on lake pH during the first 100 years post-closure, the effect of dilution and alkalinity associated with long-term groundwater inflows means that the lake is predicted to become circumneutral within 100 years even if those lithologies provide no buffering capacity (Figure 20). Apart from levels of acidity, the key influence of acid buffering on water quality in the lake during the first 100 years post-closure is the constraint that increased pH places on concentrations of metals with highly pH-dependent solubility (aluminium, copper, and manganese).

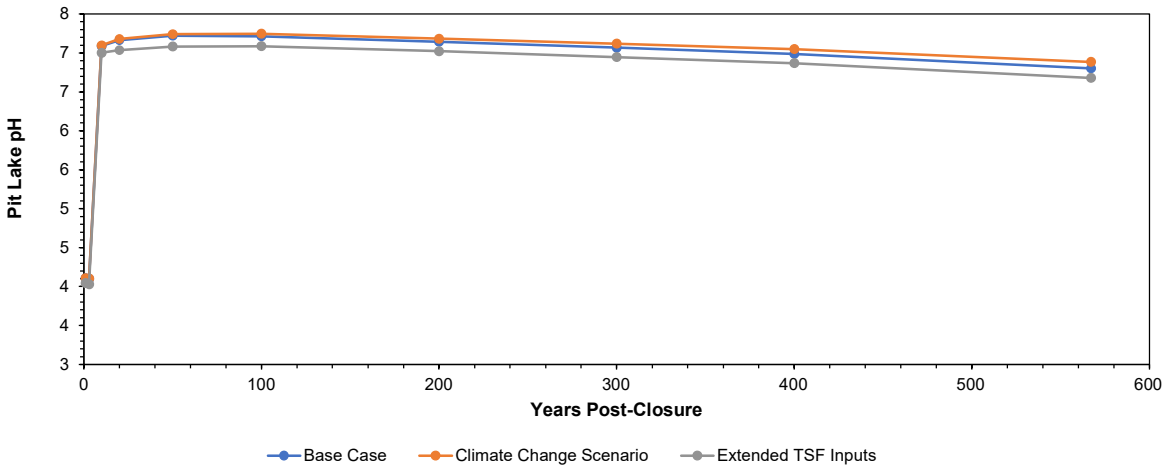


Figure 19: Comparison of lake pH for base case and sensitivity scenarios – unstratified conditions.

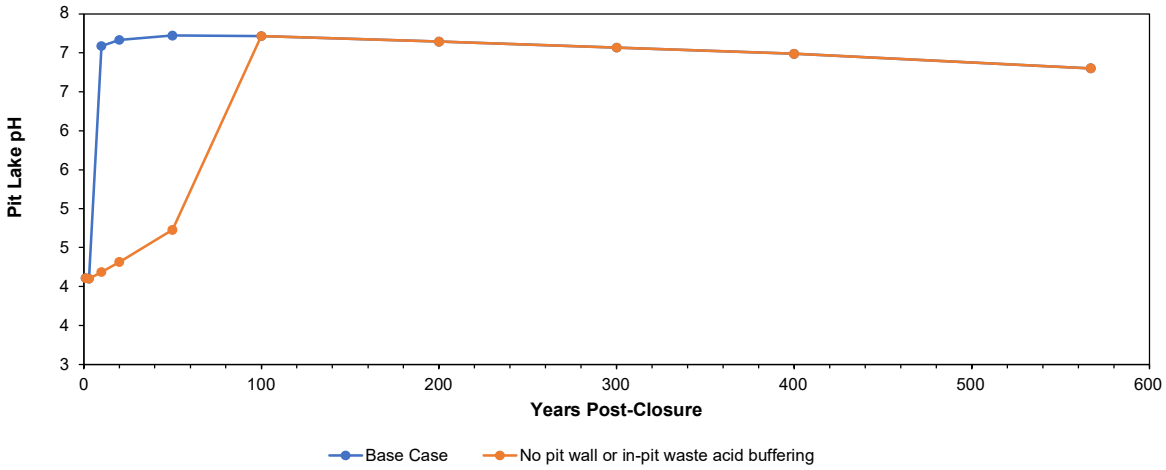


Figure 20: Effect of acid buffering capacity from pit walls and in-pit waste work on lake pH evolution.

Pit lake salinity (expressed as TDS) is predicted to follow the same overall trend for the three model scenarios (Figure 21). Due to the initial inputs of saline TSF seepage and underdrainage water stored in the lake after closure, the lake will have high salinity from the early stages of filling. In the first 10 years post-closure, salinity is expected to be in the order of 100,000 mg/L TDS (hypersaline) regardless of model scenario. In each scenario salinity is predicted to decrease from 10 to 20 years post-closure as inflows of less saline water begin to comprise a larger proportion of the lake volume. From 200 years post-closure onwards, salinity is predicted to start increasing due to evapoconcentration effects and continual inflow of saline groundwater. The final (566 years post-closure) salinity is expected to be in the order of 130,000 – 170,000 mg/L TDS depending on the model scenario. The climate change scenario yields the lowest overall salinity, which can be attributed to slightly larger inputs of less-saline inflows (i.e., rainwater), whilst the extended TSF inputs scenario yields the highest salinity owing to more substantial volumes of highly saline seepage/underdrainage water.

The dominant ions in the lake are predicted to be sodium, chloride and sulfate, reflecting the composition of the major inflows (e.g., groundwater and pit wall runoff). Calcium and magnesium concentrations are expected to be lower since they are likely to be constrained by precipitation of dolomite ($CaMg(CO_3)_2$).

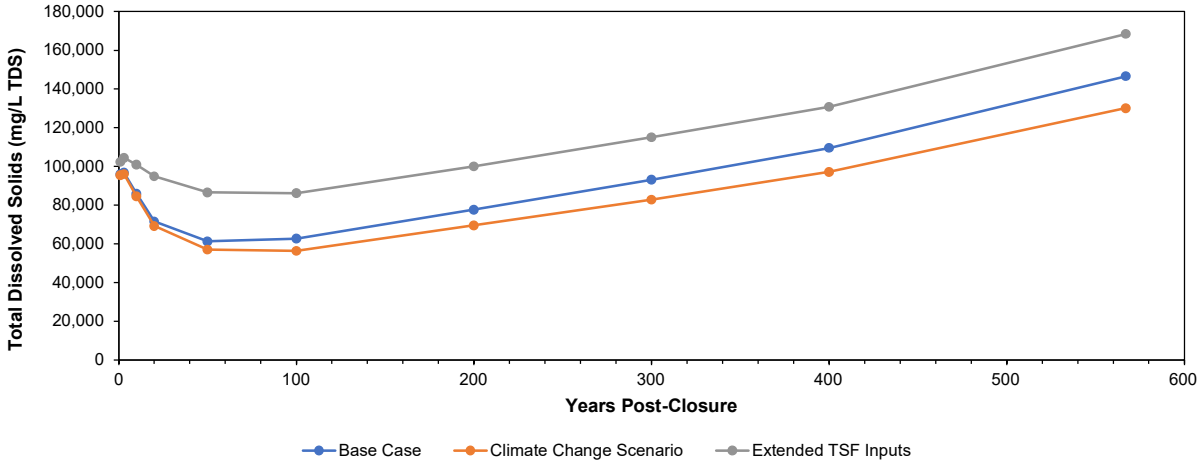


Figure 21: Comparison of lake salinity (TDS) for base case and sensitivity scenarios.

The predicted effects of stratification on salinity during the first 50 years of the pit lake development, as shown for the base case model in Figure 22, include:

- Water in the upper stratum is predicted to be saline, in the order of 8,000 – 17,000 mg/L TDS for the first 50 years post-closure, reflecting the accumulation of water from relatively less saline inflows (i.e. pit wall runoff, rainwater) above a denser lower stratum. Increases in salinity reflect evapoconcentration from this stratum as well as the salinity of the inflows;
- Water in the lower stratum is predicted to be hypersaline (order of 100,000 mg/L TDS) within the first 3 years post closure, due to the accumulation of highly saline and dense TSF seepage/underdrainage inputs in this deeper portion of the lake. Salinity is predicted to decrease to around 75,000 mg/L between 10 and 50 years post-closure, as inflows of less saline water (i.e., groundwater) start to comprise a larger proportion of the volume in this stratum; and
- The strata are predicted to converge (nominally 70 years post-closure), from which time relatively linear increases in salinity are expected due to continual inflows of saline groundwater and evapoconcentration.

Stratification effects related to pH are not expected to be significant, with the upper stratum pH being up to 0.4 units higher than the lower stratum for the first 50 years post-closure.

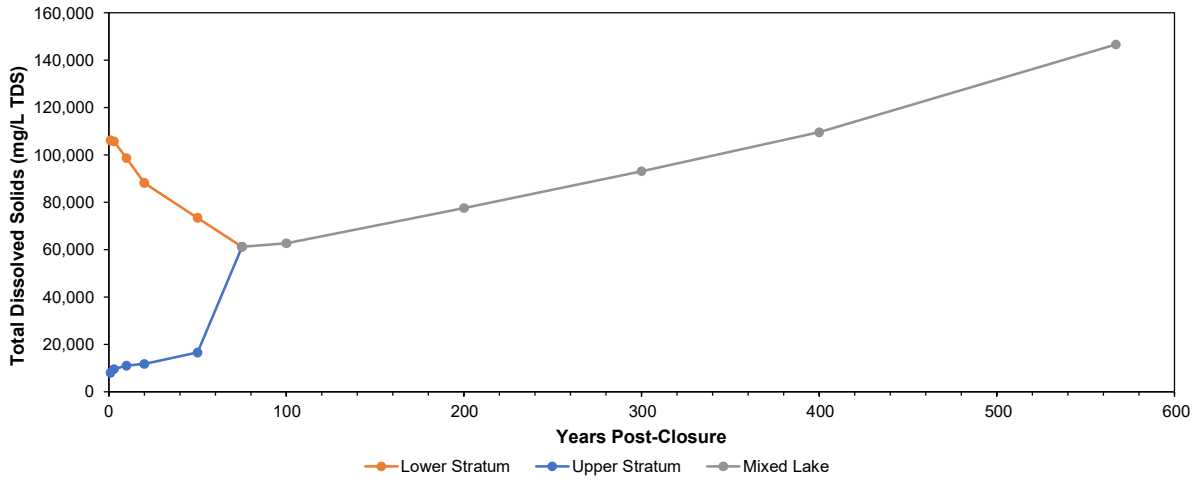


Figure 22: Predicted lake salinity under stratified and unstratified base case conditions.

4.5.2 Metals, Metalloids and Trace Ions

Predicted concentrations of metals and metalloids for the stratified base case model, over the projected timeframe of 566 years post-closure, are presented in Table 8.

To identify potential water quality hazards, concentrations were compared to livestock drinking water Default Guideline Values (DGVs, ANZECC 2000/ANZG 2018) and Non-Potable Groundwater Use (NPUG) guideline values (DER, 2014). Note these guideline values were used for comparison/screening purposes only and are conservative since pit lake water (and local groundwater) has no identified beneficial uses other than mining due to high salinity.

Comparison against screening values indicated that concentrations of arsenic, barium, cobalt, chromium, fluoride, iron, lead, lithium, manganese, strontium, uranium, vanadium and zinc are predicted to remain relatively low during the 566 year projection period, indicating these elements are of limited environmental significance within the lake post-closure.

Despite being overestimated (i.e., breakdown through photooxidation was not accounted for in the model), predicted cyanide concentrations are low at the lake surface (<0.1 mg/L total cyanide). The model predicts more elevated cyanide concentrations in the lower stratum (up to 50 years post-closure) and then continual decreases for the remainder of the projection period because cyanide is only significant in TSF underdrainage water to be stored in the lake during the first decade post-closure (Table 6). In the long-term dilution from other inflows exceeds the effect of evapoconcentration, although more realistically the cyanide would not be environmentally stable over such a long period and levels would be expected to diminish much more rapidly than predicted by the model. Cyanide complexation also increases metal/metalloid solubility, indicating that modelling cyanide conservatively also results in some overestimation of dissolved metal/metalloid concentrations in the lake.

Elevated concentrations of aluminium (9-117 mg/L) and copper (4-10 mg/L) were predicted to exist within the lake during the first 3 years post-closure, which can be attributed to high concentrations of these elements present within TSF seepage/underdrainage inflows and the acidic conditions (pH 4) expected to prevail for this short period (Figure 23 and Figure 24). After 10 years post-closure, predicted concentrations of these elements diminish to essentially negligible levels as they are sparingly soluble under circumneutral conditions expected from this time and precipitate with secondary minerals (i.e. gibbsite) or chemisorb to surfaces of minerals such as iron oxyhydroxides.

Trends for dissolved metals and metalloids that are expected to become more concentrated in the upper stratum of the lake versus the lower stratum (those exceeding screening values), which includes cadmium, molybdenum and nickel, are shown in Figure 25 to Figure 27. The accumulation of these elements in the upper stratum can be attributed to their presence in pit wall runoff (particularly runoff from unweathered Black Flag shale), which is apportioned to the upper stratum in the stratified model. Whilst cadmium and nickel concentrations are expected to remain relatively stable under unstratified conditions, due to a balance between dilution (by inflows containing less of these elements) and evaporation, molybdenum concentrations are predicted to continually increase with evaporation since molybdenum is present in multiple inflows contributing to the lake over the long-term.

Similar long-term trends are also observed for metals and metalloids predicted to accumulate predominantly in the lower stratum in the stratified model (antimony, boron, mercury, and selenium) as shown in Figure 28 to Figure 31. The model predicts that these elements will be present in relatively high concentrations in the lower stratum during the first few years of the lake filling due to inputs of acidic and metal/metalloid enriched TSF seepage and underdrainage water. In each case, concentrations are expected to decrease until at least 50 years post-closure as other inflows with lower metal/metalloid content effectively dilute that tailings water. As noted above, the model predicts antimony and boron concentrations will continue to increase over time due to evapoconcentration whilst concentrations of mercury and selenium are projected to decrease because these are only significant in early tailings water inflows and the effect of subsequent dilution by other inflows exceeds that of evapoconcentration over time.

Concentrations of major ions, trace ions, metals and metalloids are presented for the base case, climate change scenario and extended TSF inputs scenario in Appendix A.

The extended TSF inputs scenario model predicts that extending the duration during which tailings water (recovered seepage and underdrainage) is stored in the mine void from 10 years to 15 years after closure would increase concentrations of some metals and metalloids in the lake over the long-term. Levels of cobalt, fluoride, lithium, molybdenum, antimony and vanadium are predicted to increase by factors of 2 to 3 versus the base case scenario. Chromium concentrations are predicted to increase by factors of 3 to 5 compared with the base case scenario, whilst projected iron concentrations increase markedly (by

a factor of 50 to 500 – up to 0.5 mg/L). These differences are clearly attributed to the presence of these elements at elevated concentrations in the tailings water versus other inflows.

Results for the climate change sensitivity scenario model indicate that metal and metalloid concentrations would be generally similar to those expected under base case conditions. The only notable deviations from the base case predictions are for cobalt (~30% reduction), iron (~30% reduction) and molybdenum (~25% reduction).

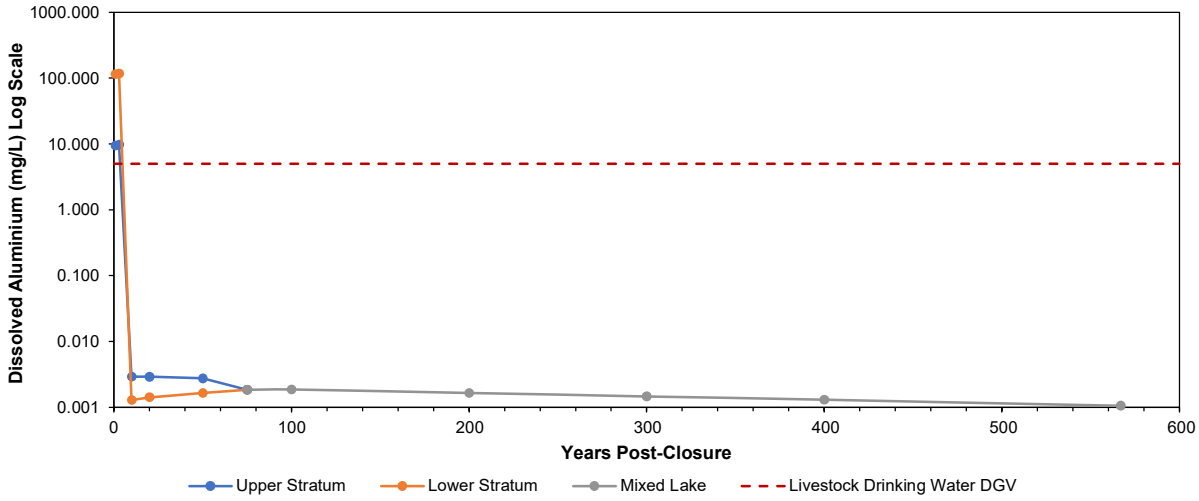


Figure 23: Predicted dissolved aluminium concentrations (base case model)

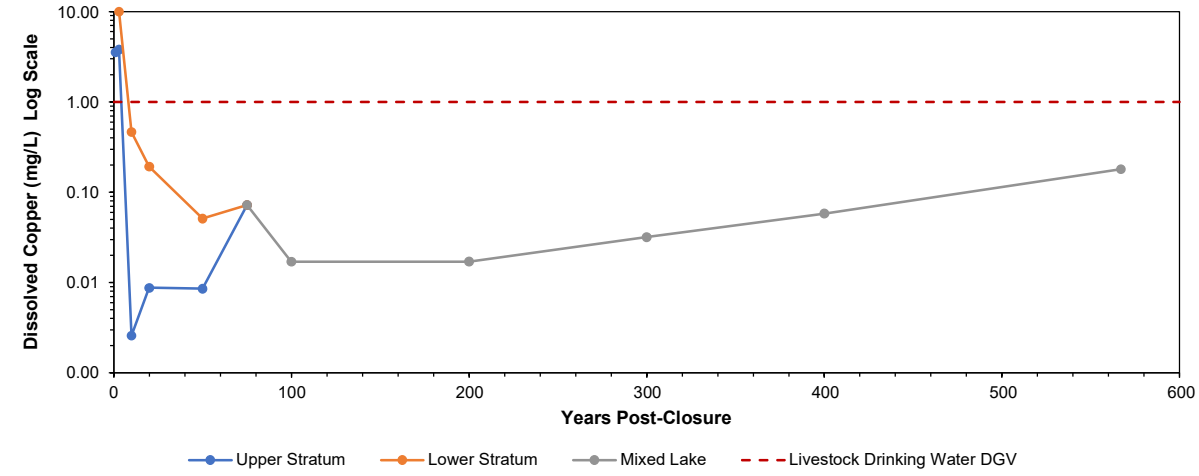


Figure 24: Predicted dissolved copper concentrations (base case model).

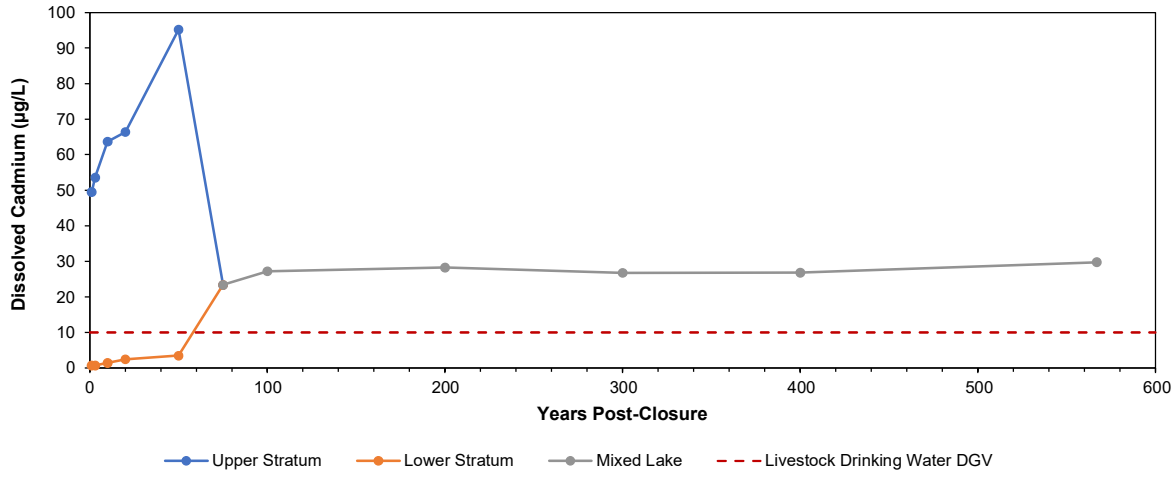


Figure 25: Predicted dissolved cadmium concentrations (base case model).

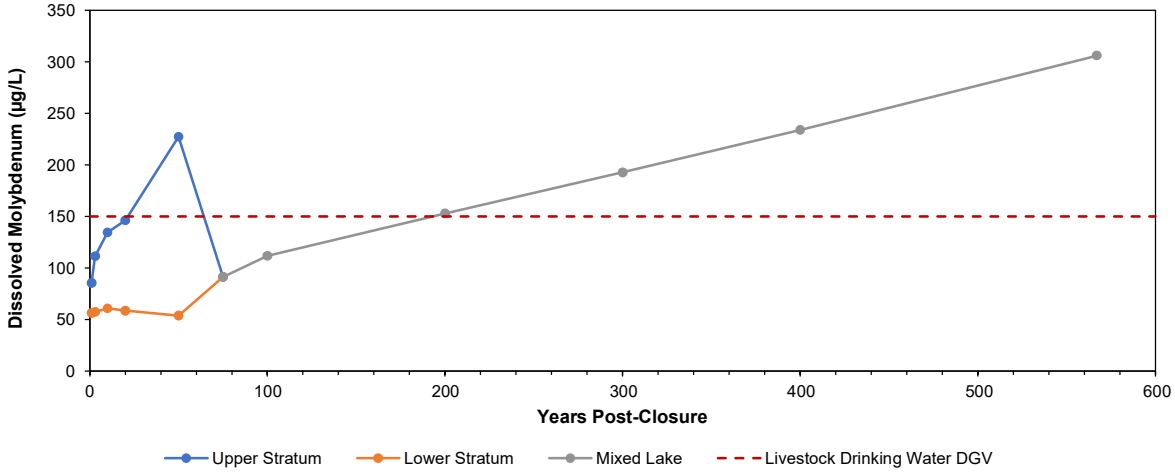


Figure 26: Predicted dissolved molybdenum concentrations (base case model).

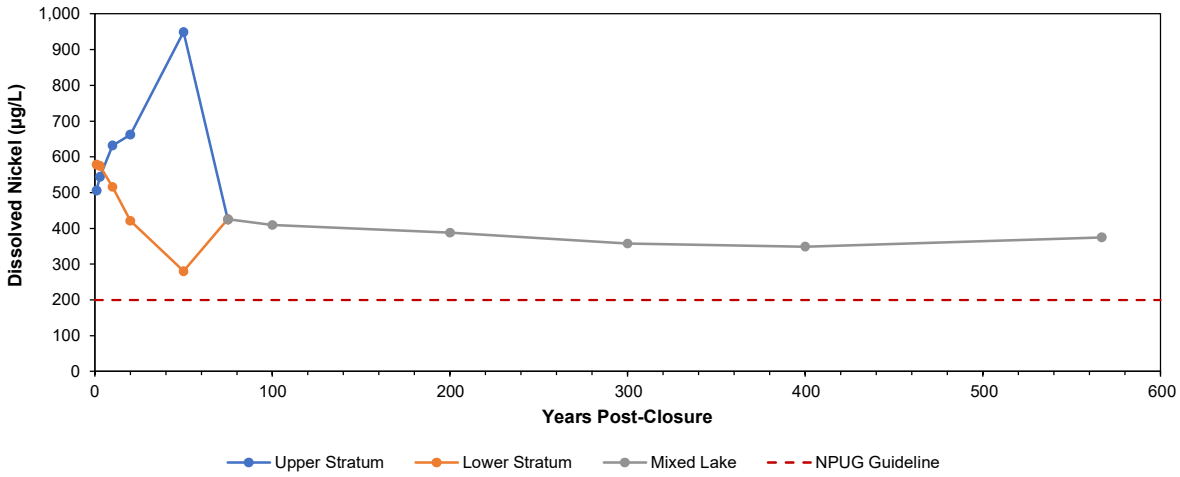


Figure 27: Predicted dissolved nickel concentrations (base case model).

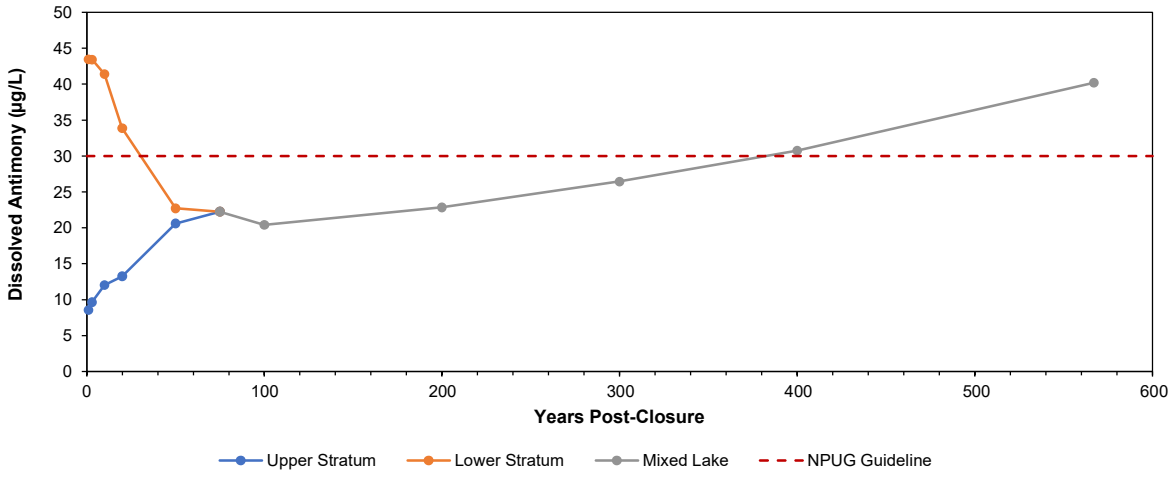


Figure 28: Predicted dissolved antimony concentrations (base cade model).

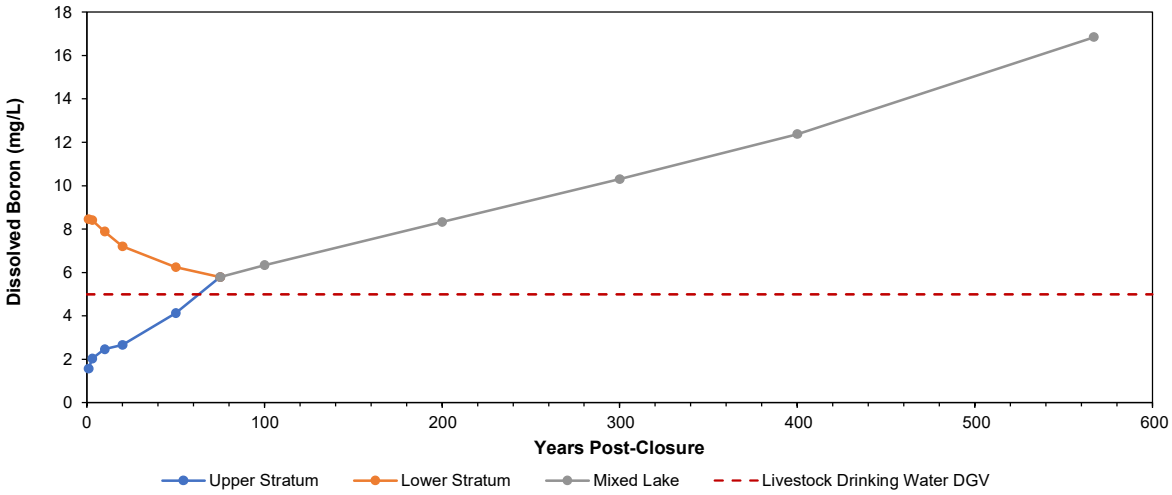


Figure 29: Predicted dissolved boron concentrations (base case model).

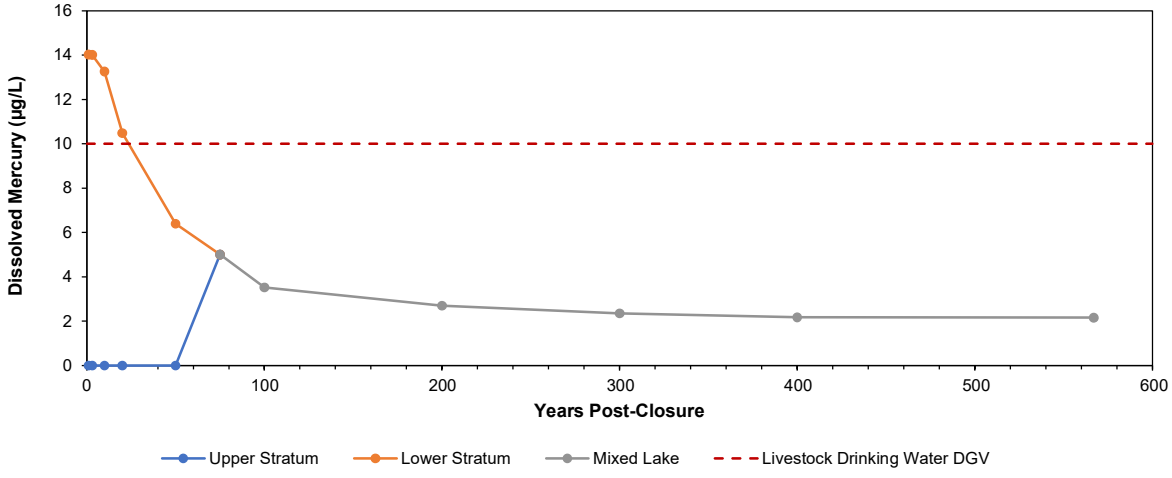


Figure 30: Predicted dissolved mercury concentrations (base case model).

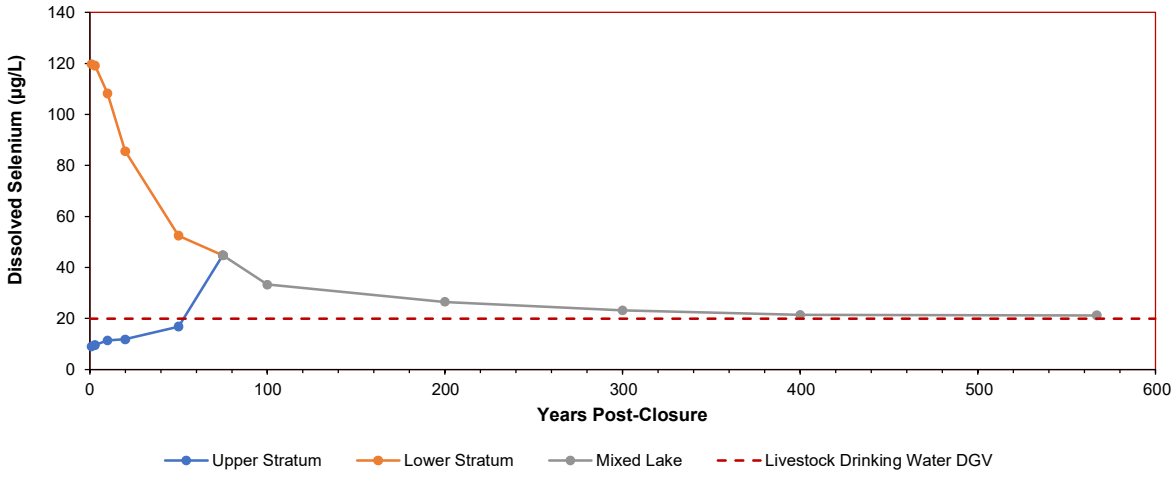


Figure 31: Predicted dissolved selenium concentrations (base case model).

Table 7: Key parameters and major ions for base case model.

STRATUM	YEARS POST CLOSURE	pH	ALKALINITY (mg/L AS HCO_3^-)	CYANIDE (mg/L)	Cl (mg/L)	Ca (mg/L)	K (mg/L)	Mg (mg/L)	Na (mg/l)	Sulfate (mg/L)	TDS (mg/L)
Upper	1	4.6	-	<0.1	2,944	794	18	309	1,521	2,461	8,063
	3	4.6	-	<0.1	3,777	825	23	378	1,956	2,609	9,583
	10	7.4	50	<0.1	4,583	850	28	470	2,372	2,737	11,096
	20	7.5	50	<0.1	4,957	859	30	502	2,567	2,798	11,769
	50	7.4	49	<0.1	7,659	895	46	757	3,969	3,240	16,624
Lower	1	4.1	-	10	61,823	1,389	336	3,210	35,161	4,011	106,107
	3	4.1	-	10	61,536	1,386	335	3,195	35,009	4,019	105,659
	10	7.0	56	9	57,352	1,341	323	3,104	32,676	3,776	98,667
	20	7.1	54	7	50,914	1,266	287	2,868	28,855	3,894	88,175
	50	7.1	50	4	41,870	1,161	237	2,549	23,464	4,090	73,451
Mixed	75	7.2	50	3	34,443	1,132	196	2,159	19,234	3,978	61,218
	100	7.2	50	2	35,224	1,075	201	2,347	19,467	4,307	62,699
	200	7.1	52	2	44,047	1,023	252	3,064	24,121	4,988	77,583
	300	7.1	56	2	53,268	992	306	3,765	29,050	5,608	93,084
	400	7.0	64	1	63,057	970	363	4,497	34,308	6,252	109,550
	566	6.8	93	1	85,052	941	490	6,117	46,175	7,685	146,601
Livestock drinking water DGV (ANZECC, 2000)				NG	NG	1,0000	NG	NG	NG	1,000	4,000 (Cattle)
NPUG (DER, 2014)				0.8	250	NG	0.8	NG	NG	1,000	NG

NG No guideline applicable.

Table 8: Metal and metalloid concentrations for base case model.

STRATUM	YEARS POST CLOSURE	Al (mg/L)	As (µg/L)	B (mg/L)	Ba (µg/L)	Cd (µg/L)	Co (µg/L)	Cr (µg/L)	Cu (mg/L)	F (mg/L)	Fe (µg/L)	Hg (µg/L)	Li (µg/L)	Mn (µg/L)	Mo (µg/L)	Ni (µg/L)	Pb (µg/L)	Sb (µg/L)	Se (µg/L)	Sr (mg/L)	U (µg/L)	V (µg/L)	Zn (mg/L)
Upper	1	9	18	2	7	50	<0.1	35	4	0.1	1	<0.1	5	12	86	506	7	9	9	0.02	1	17	2
	3	10	21	2	8	54	<0.1	40	4	0.2	1	<0.1	6	14	111	544	8	10	10	0.03	1	18	2
	10	<0.01	0.4	2	8	64	<0.1	43	<0.01	0.2	<0.1	<0.1	7	<0.1	135	632	1	12	11	0.03	1	1	2
	20	<0.01	1	3	8	66	<0.1	47	0.01	0.2	<0.1	<0.1	8	<0.1	146	662	1	13	12	0.04	1	2	2
	50	<0.01	2	4	8	95	<0.1	71	0.01	0.4	<0.1	<0.1	12	<0.1	227	949	2	21	17	0.1	1	3	3
Lower	1	115	7	8	12	1	753	52	10	0.3	<0.1	14	0.1	4,420	57	578	106	43	120	21	22	0.2	0.1
	3	117	7	8	12	1	725	51	10	0.3	<0.1	14	0.1	4,396	57	574	105	43	119	21	22	0.2	0.1
	10	<0.01	9	8	12	1	193	43	0.5	0.3	<0.1	13	0.1	<0.1	61	516	87	41	108	19	18	0.4	0.1
	20	<0.01	11	7	11	2	<0.1	36	0.2	0.2	295	10	0.2	<0.1	59	421	70	34	86	18	14	1	0.1
	50	<0.01	9	6	11	3	<0.1	26	0.1	0.2	17	6	0.4	<0.1	54	280	44	23	53	17	9	1	0.2
Mixed	75	<0.01	8	6	10	23	<0.1	36	0.1	0.3	1	5	3	<0.1	91	425	35	22	45	13	7	1	1
	100	<0.01	8	6	10	27	<0.1	37	0.02	0.3	0.1	4	4	<0.1	112	409	26	20	33	15	5	2	1
	200	<0.01	11	8	9	28	<0.1	41	0.02	0.4	<0.1	3	5	<0.1	153	388	23	23	27	19	4	1	1
	300	<0.01	14	10	9	27	<0.1	45	0.03	0.5	<0.1	2	7	<0.1	193	358	23	26	23	18	3	1	1
	400	<0.01	19	12	8	27	<0.1	50	0.1	0.6	<0.1	2	9	<0.1	234	349	25	31	21	18	3	0.4	1
	566	<0.01	35	17	7	30	<0.1	64	0.2	0.8	<0.1	2	12	0.1	306	375	29	40	21	16	3	0.3	1
Livestock drinking water DGV (ANZECC, 2000)		5	500	5	NG	10	1,000	1,000	1	2	NG	2	2,500*	NG	150	1,000	100	NG	20	NG	200	NG	20
NPUG (DER, 2014)		0.2	100	40	20,000	20	NG	500	20	15	300	10	NG	5,000	500	200	100	30	100	NG	170	NG	3

NG No guideline applicable.

** ANZECC (2000) STV/LTV irrigation water*

5 SUMMARY AND KEY FINDINGS

Integrated water balance and hydrogeochemical models developed for the Fimiston Pit lake (MBS, 2021) were revised and augmented to reflect the proposed extension of the Fimiston Pit, changes to in-pit waste rock backfill design and associated changes to mine closure schedules (i.e. bringing cessation of pit dewatering and processing forward from 2035-2038 to 2034) and water management strategies.

The revised closure water balance was based on the probabilistic, dynamic systems modelling approach used in previous studies for the Fimiston Pit (MBS, 2021), and was completed using GoldSim™. The updated closure water balance was developed from existing historical and operational water balances with consideration of predictions for borefield production, processing demand and tailings water management reflecting a revised mine and closure plan (Big Dog Hydrogeology, 2022).

A revised hydrogeochemical model for the Fimiston Pit lake was based on updated water balance predictions (i.e. inflow rates to the pit), revised assessment of lithologies to remain exposed after mine closure and additional consideration of reactive lithologies on the pit walls (Black Flag shale) and in-pit waste rock.

An assessment of post-closure water management requirements (Big Dog Hydrogeology, 2022) indicates that active management of seepage from the TSFs is required over a period between 10 and 15 years (15 years if extended recovery is necessary) to avoid impacts related to rising groundwater levels from mounding, during the tailings drain-down period. Seepage interception and underdrainage water will be pumped to the Fimiston Pit using the existing seepage interception water infrastructure. After the drain-down period, no further outflows to the environment are predicted from the TSFs.

The revised closure water balance predictions indicate that the equilibrium pit lake water elevations will be between -159 m AHD and -69 m AHD (median level of -122 m AHD), which will be reached about 400 years after closure. Pit lake water levels will be substantially lower than the estimated pre-mining water levels. As such, the pit lake will be a groundwater sink with no outflows to the surrounding environment and no risk of overtopping. Equilibrium water levels are predicted to be between 473 m and 493 m below the pit crest. The oxide weathering interface is much higher than the predicted equilibrium pit lake water levels and therefore does not significantly affect the pit water balance, nor is the presence of the pit lake expected to significantly affect the stability of the upper pit slopes.

The hydrogeochemical modelling predicted that in the long-term (up to circum-600 years post closure), the Fimiston Pit lake will:

- Be unstratified, hypersaline (>100,000 mg/L TDS) and circum-neutral (pH 6.7 – 6.9). Stratification is predicted for the initial 50 years post-closure only.
- Contain marginally elevated dissolved concentrations of some potentially environmentally significant metals and metalloids (antimony, boron, cadmium, molybdenum, nickel and selenium), noting that the water has no known beneficial use, is considered too saline for significant consumption by fauna and will be physically inaccessible; and
- Continue to accumulate solutes over time due to evapoconcentration (i.e., in perpetuity), noting that halite (NaCl) precipitation will eventually limit salinity to <300,000 mg/L TDS.

The lake is predicted to be moderately acidic (pH 4.0 – 4.1) during the first three years post-closure, owing to the storage of substantial volumes of acidic TSF seepage recovered from groundwater in the void and moderately acidic runoff from Black Flag shale exposed on the lower levels of the pit walls. After ten years post-closure, circumneutral conditions (pH 6.7 – 7.2) are predicted under all model scenarios, reflecting additional acid buffering capacity available from the pit walls and the in-pit WRD (dolomite and basalt), which will be largely submerged, as well as alkalinity associated with more substantial proportions of inflows such as groundwater.

Sensitivity analysis, examining the potential impacts of climate change, indicated that:

- Median equilibrium pit lake level under the climate change scenario was about 15 m higher than the base case scenario prediction. Predicted pit lake levels were similar because the increased average rainfall, which causes higher equilibrium water levels, would be offset by the increased evaporation rates under the climate change model conditions; and
- Predictions for pit lake pH, salinity and concentrations of metals, metalloids and trace ions were very consistent with those for the base case scenario.

Another alternative model scenario reflecting an extended period of TSF seepage/underdrainage discharge (15 years vs. 10 years) into the pit, indicated that:

- Extended tailings water inputs would not significantly affect long-term pit lake level, volume and area versus the base case model;
- Extending tailings water inputs would increase concentrations of some metals/metalloids and ions in the lake, typically by factors of between 2 and 5. These elements, which are present in the tailings water at much higher levels than in other inflows to the lake, include: cobalt, chromium, fluoride, iron, lithium, molybdenum, antimony, and vanadium. Increased concentrations of this magnitude are not considered to significantly alter the overall environmental risk profile of the pit lake.

The hypersalinity of the pit lake is unlikely to pose a threat to the surrounding environment since the lake is expected to remain a terminal groundwater sink, the pit void exists in association with hypersaline groundwater, and the pit lake surface will be far below ambient ground level. These factors also limit the environmental significance of elevated concentrations of some metals and metalloids.

Access to the pit lake for terrestrial fauna is likely to be extremely limited due to the steep gradients from ground level and substantial freeboard, as access via ramps and roads will be limited at closure. Whilst flying fauna (e.g., birds and bats) may be able to access the lake surface, the water is unlikely to remain palatable for more than 50 years due to increasing salinity. Furthermore, consumption of the brackish to saline water is unlikely to be substantial where more attractive freshwater sources are available to avifauna.

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7 LIMITATIONS

Attention is drawn to the document “Limitations”, which is included in Appendix C of this report. The statements presented in this document are intended to provide advice on what the realistic expectations of this report should be, and to present recommendations on how to minimise the risks associated with this project. The document is not intended to reduce the level of responsibility accepted by Mine Waste Management, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in doing so.

APPENDIX A PREDICTED WATER QUALITY RESULTS - SENSITIVITY ANALYSIS SCENARIOS

Table A1: Key parameters and major ions for base case and sensitivity analysis scenario models (unstratified).

MODEL SCENARIO	YEARS POST CLOSURE	pH	ALKALINITY (mg/L as HCO_3^-)	Cl (mg/L)	CYANIDE (mg/L)	Ca (mg/L)	K (mg/L)	Mg (mg/L)	Na (mg/L)	SULFATE (mg/L)	TDS (mg/L)
Base Case	1	4.1	-	55,675	9	1,359	303	2,909	31,650	3,920	95,973
	3	4.1	-	56,143	9	1,359	306	2,933	31,922	3,944	96,767
	10	7.1	53	49,592	8	1,305	279	2,717	28,220	3,711	85,910
	20	7.2	51	40,860	6	1,226	231	2,351	23,105	3,774	71,627
	50	7.2	50	34,449	3	1,134	196	2,160	19,234	3,979	61,227
	100	7.2	50	35,229	2	1,076	201	2,348	19,468	4,307	62,707
	200	7.1	52	44,054	2	1,023	252	3,065	24,121	4,988	77,592
	300	7.1	57	53,272	2	993	306	3,766	29,052	5,608	93,091
	400	7.0	64	63,060	2	970	363	4,498	34,310	6,252	109,558
	566	6.8	94	85,059	2	941	490	6,119	46,178	7,685	146,613
Climate Change Scenario	1	4.1	-	55,363	9	1,357	301	2,894	31,471	3,915	95,457
	3	4.1	-	55,736	9	1,357	304	2,912	31,689	3,937	96,095
	10	7.1	53	48,720	8	1,301	274	2,671	27,719	3,700	84,472
	20	7.2	50	39,385	5	1,222	223	2,271	22,263	3,748	69,191
	50	7.2	49	31,907	3	1,130	181	2,011	17,803	3,906	57,014
	100	7.2	50	31,410	2	1,076	179	2,108	17,339	4,158	56,345
	200	7.2	51	39,225	2	1,029	225	2,743	21,455	4,758	69,520
	300	7.1	54	47,124	1	1,001	271	3,344	25,671	5,284	82,786
	400	7.0	59	55,651	1	979	321	3,982	30,243	5,837	97,110
	566	6.9	79	75,256	1	947	434	5,426	40,812	7,094	130,093
Extended TSF Inputs	1	4.0	-	59,784	9	1,470	323	2,969	33,917	3,750	102,394
	3	4.0	-	61,039	9	1,479	330	3,023	34,632	3,779	104,474
	10	7.0	56	59,043	8	1,437	314	3,096	33,361	3,511	100,860
	20	7.0	54	55,314	7	1,389	298	2,949	31,239	3,580	94,862
	50	7.1	53	50,109	6	1,283	273	2,833	28,119	3,830	86,537
	100	7.1	53	49,719	5	1,197	273	2,988	27,703	4,194	86,165
	200	7.0	58	57,895	4	1,115	323	3,704	31,977	4,921	100,034
	300	6.9	65	66,811	3	1,069	376	4,414	36,717	5,583	115,078
	400	6.9	76	76,149	3	1,037	430	5,133	41,711	6,241	130,824
	566	6.7	120	98,464	3	1,006	560	6,779	53,753	7,683	168,416

Table A2: Predicted metal and metalloid concentrations for base case and sensitivity analysis scenario models (unstratified)

MODEL SCENARIO	YEARS POST CLOSURE	Ag (µg/L)	Al (mg/L)	As (µg/L)	B (mg/L)	Ba (µg/L)	Cd (µg/L)	Co (µg/L)	Cr (µg/L)	Cu (mg/L)	F (mg/L)	Fe (µg/L)	Hg (µg/L)	Li (µg/L)	Mn (µg/L)	Mo (µg/L)	Ni (µg/L)	Pb (µg/L)	Sb (µg/L)	Se (µg/L)	Sr (mg/L)	U (µg/L)	V (µg/L)	Zn (mg/L)
Base Case	1	80	102	8	8	12	6	574	50	9	0.3	<0.1	13	1	4,427	60	571	96	40	108	19	20	2	0.3
	3	82	105	8	8	12	6	564	50	9	0.3	<0.1	13	1	4,486	62	571	96	40	109	19	20	2	0.2
	10	82	0.001	12	7	12	11	<0.1	44	0.3	0.3	17	11	1	<0.1	72	535	76	37	94	17	16	3	0.4
	20	74	0.002	15	6	11	16	<0.1	39	0.1	0.2	47	8	2	<0.1	78	476	57	29	69	14	11	5	1
	50	71	0.002	21	6	11	23	<0.1	37	0.1	0.3	1	5	3	<0.1	92	428	38	22	45	13	7	7	1
	100	78	0.002	27	6	10	27	<0.1	38	0.1	0.3	0.1	4	4	<0.1	113	411	30	20	33	15	5	9	1
	200	100	0.002	39	8	9	28	<0.1	42	0.1	0.4	<0.1	3	5	<0.1	154	390	27	23	27	19	4	8	1
	300	123	0.001	50	10	9	27	<0.1	47	0.1	0.5	<0.1	2	7	<0.1	196	359	27	26	23	18	3	7	1
	400	149	0.001	61	12	8	27	<0.1	53	0.1	0.6	<0.1	2	9	<0.1	240	350	28	31	21	18	3	7	1
	566	201	0.001	84	17	7	30	<0.1	67	0.2	0.8	<0.1	2	12	0.1	328	376	33	40	21	16	3	7	1
Climate Change Scenario	1	80	101	8	8	12	6	565	50	9	0.3	<0.1	12	1	4,425	60	570	95	40	108	19	20	2	0.3
	3	82	104	8	8	12	6	554	50	9	0.3	<0.1	13	1	4,487	63	570	95	40	108	19	20	2	0.3
	10	81	0.001	12	7	12	11	<0.1	43	0.3	0.3	44	11	1	<0.1	72	533	75	37	92	16	15	4	0.4
	20	74	0.002	15	6	11	17	<0.1	39	0.1	0.2	33	8	2	<0.1	79	473	55	29	67	14	11	6	1
	50	70	0.002	21	5	11	25	<0.1	36	0.1	0.2	0.4	5	3	<0.1	93	429	36	21	42	12	7	8	1
	100	78	0.002	27	6	10	29	<0.1	38	0.1	0.3	<0.1	3	4	<0.1	115	412	27	19	30	13	5	9	1
	200	103	0.002	39	8	9	30	<0.1	43	0.1	0.4	<0.1	2	6	<0.1	161	395	25	22	24	17	4	9	1
	300	128	0.002	49	10	9	29	<0.1	48	0.1	0.5	<0.1	2	8	<0.1	205	361	25	26	21	19	3	8	1
	400	155	0.001	60	11	8	29	<0.1	54	0.1	0.6	<0.1	2	9	<0.1	252	352	26	30	19	18	3	7	1
	566	212	0.001	83	16	8	32	<0.1	69	0.2	0.8	<0.1	2	13	0.1	347	378	30	40	19	17	3	7	1
Extended TSF Inputs	1	78	122	7	8	13	4	792	48	9	0.3	<0.1	12	0.4	4,379	55	556	113	39	110	22	25	1	0.2
	3	80	130	7	8	13	4	840	49	9	0.3	<0.1	13	0.4	4,447	57	562	116	40	113	22	26	1	0.2
	10	75	0.001	9	8	13	5	603	50	0.3	0.3	<0.1	11	1	<0.1	58	547	111	37	104	22	24	2	0.2
	20	77	0.001	11	8	13	9	233	48	0.3	0.3	<0.1	10	1	<0.1	67	538	99	35	95	21	21	3	0.4
	50	79	0.001	17	8	12	17	<0.1	47	0.1	0.3	80	8	2	<0.1	85	519	80	30	76	20	17	5	1
	100	87	0.001	25	8	11	23	<0.1	48	0.1	0.3	21	7	3	<0.1	109	510	67	29	62	20	14	7	1
	200	111	0.001	38	10	10	26	<0.1	53	0.1	0.4	11	6	5	<0.1	156	500	61	31	54	21	12	8	1
	300	136	0.001	49	12	9	26	<0.1	58	0.1	0.6	10	5	7	<0.1	200	470	58	34	48	19	10	7	1
	400	161	0.001	61	14	9	26	<0.1	63	0.2	0.7	10	5	8	0.1	246	459	57	38	45	18	10	7	1
	566	214	0.001	84	19	8	29	<0.1	78	0.5	0.9	21	5	11	0.5	335	487	62	48	45	17	10	7	1

APPENDIX B DEFINITIONS

NAME	DESCRIPTION
AHD	Altitude relative to Australian Height Datum
Circum-neutral	Approximating to acid-base neutrality (typically pH 6.5 to 7.5).
Deterministic Simulation	A simulation where input parameters are represented using single values (i.e. they are determined or assumed to be known with certainty).
EC	Electrical conductivity, an indicator of salinity.
Elapsed-time Simulation	A simulation that tracks time using the time since the start of the model run.
Element	A GoldSim component that forms the basic model building blocks.
Entrainment (water)	Water that occurs within the pores of a granular matrix such as tailings.
HDPE	High density polyethylene. A plastic commonly used to manufacture water-proof sheeting.
Hydraulic Conductivity (K) [Permeability]	The volume of water that will flow in a unit time under a unit hydraulic gradient through a unit area. Analogous to the permeability with respect to fresh water (units commonly m/d or m/s).
Hypersaline	Significantly saltier than typical seawater (37 g/L).
Limnological	The study of limnology includes aspects of the biological, chemical, physical, and geological characteristics and functions of inland waters.
mbgl	Metres below ground level
Mean	The expected value of a distribution or first moment of the distribution.
Median	The 50th percentile of a distribution.
Monte Carlo Simulation	A method of propagating uncertainties in model inputs into uncertainties in model results, by using random or pseudo-random sampling of distributions over a number of realisations.
Percentile	An amount on a scale from 1 to 100 that indicates the percent of a distribution that is equal to or below a certain value.
PHREEQC	A chemical thermodynamic equilibrium speciation model developed by the United Stated Geological Survey.
Probabilistic (Stochastic) Simulation	A simulation in which the uncertainty in input parameters is explicitly represented by defining them as probability distributions.
Probability Distribution	A mathematical representation of the relative likelihood of a variable having certain specific values.

NAME	DESCRIPTION
Realisation	A single model run within a Monte Carlo simulation. It represents one possible path a system might follow through time.
Seepage	Water that has percolated through a waste landform (e.g. waste rock dump or tailings storage facility).
SILO (database)	A database of Australian climate data from 1989 to present.
Source term	Describes the characteristic chemical composition (e.g. of a pit lake inflow source).
Stochastic	An element that can be used to quantitatively represent the uncertainty in a model input.
Supernatant	Liquid remaining after setting of tailings solids.
TDS	Total Dissolved Solids (contained within a water sample), expressed in mg/L.
Time-Step	A discrete interval of time used in dynamic simulations.

APPENDIX C LIMITATIONS

This Document has been provided by Mine Waste Management Pty Ltd (MWM) subject to the following limitations:

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MINE WASTE MANAGEMENT

GREENROAD GROUP

5.3 Appendix 5.3: FIMISTON Pit Lake Ecosystem Review

Memo

To: Janine Cameron, Jessica Li

From: Volker Framenau

CC:

Date: 8 February 2018

Subject: **Expected biota of Fimiston Pit Lake**

1 INTRODUCTION

Kalgoorlie Consolidated Gold Mines Pty Ltd (KCGM) operates the Fimiston open pit, commonly known as the Superpit, adjacent to the city of Kalgoorlie Boulder in the Eastern Goldfields Region of Western Australia. KCGM is the operating company for the mining operations and is jointly owned by Newmont and Barrick. Mining operations in the Fimiston Pit are estimated to cede in 2026, with the Fimiston Pit filling with water from different sources and changing over time (e.g. direct precipitation into the lake, pit wall run-off, groundwater inflow, borefield dewatering post closure) forming a permanent lake.

The pit lake elevation is predicted to reach equilibrium at approximately 150 years after closure at -52 mAHD (meter Australian Height Datum) around 467 m below the pit crest elevation resulting in a depth of the lake of approximately 250 m. Potential seasonal movement in the elevation of the pit lake for average conditions is predicted to be small at about approximately 1.5 m. The water balance model indicates that there is no potential for the pit lake elevation to rise above the pit rim (Schlumberger 2015).

Pit inflows will be dominated by pit wall run-off generated during rainfall events followed by groundwater inflows that will decrease as pit lake elevation increases. Due to the maintenance of a groundwater sink, solute inflows will tend to accumulate within the pit lake. Water losses are mainly through evaporation which will lead to solute evapo-concentration over time, although high precipitation events may occasionally dilute concentrations temporarily. The pit lake water will tend to develop to hypersaline, and will become a brine in the very long term (Schlumberger 2015).

The preliminary model (which is based on full mixing with all solutes conserved (i.e. no precipitation or stratification) indicates that solute concentrations will steadily increase at a rates between 340 mg/L/year and 400 mg/L/year. Pit lake TDS values will attain 129,000 and 139,000 mg/L, within a 90% confidence interval over a period of around 180 years after closure (Schlumberger 2015).

The water quality will be of slightly alkaline in the early closure stages and will deteriorate considerably. During this period pH is forecast to decrease to around 4, Al to increase to around 90 mg/L, and trace metals to increase. Once the pit lake has reached equilibrium, pH would have increased slightly although still forecast to maintain moderately acidic conditions around 4. Metals/metalloids would be within solution due to the mineralogy of the pit and chemistry of recharge waters. Nutrients, nitrate and phosphorous, were modelled below limits of detection, however, could possibly be introduced in very small quantities over time via runoff and animal/bird visitations (Schlumberger 2015).

2 OBJECTIVE AND SCOPE OF WORKS

As part of mine closure planning, KCGM aims to demonstrate if there are any possible receptors/pathways for metals in solution to be transported from the lake into the surrounding environment.

To address this objective, KCGM commissioned Phoenix Environmental Sciences (Phoenix) to assess if the future Fimiston Pit lake will be able to support life/an ecosystem in its terminal stage (email to V.W. Framenau, 3 August 2016).

3 METHODS

This assessment is based on a desktop review of the biota of salt lakes, in particular deeper saline waters. To that extent, it included a review of:

- similar aquatic systems in Australia and world-wide (i.e. deep, hypersaline and acidic lakes)
- known aquatic biota of saline wetlands in Western Australia (commonly known from shallow lakes) and their potential to persist in deeper lakes (i.e. required micro habitats)

The assessment included a review of scientific literature and reports and the consultation of experts (S. Helleren, Dalcon Environmental, algae).

Three trophic levels are considered within the ecology of inland lakes (Moss 1998):

- primary producers (algae and photosynthetic bacteria)
- consumers (mainly micro- and macroinvertebrates)
- higher trophic predators (birds, fish).

The assessment is here restricted to the modelled terminal conditions of Fimiston Pit lake at about 150–180 years after closure and does not consider the varying conditions before.

4 RESULTS

Our review suggests, that a lake with conditions to that of the terminal Fimiston Pit lake, i.e. deep, hypersaline, and of moderate acidity, does not exist in Australia. A lake somewhat similar to that modelled for the Fimiston Pit is Lake Kepwari near Collie (Western Australia), also a pit lake, with a depth of 65 m and with moderate acidity (pH 4) (Kumar *et al.* 2011). Somewhat similar systems may exist in the Western District of Victoria, where, for example, Lake Gnotuk is described as a deep, hypersaline lake; however, in 2008 the lake was only 18 m deep and with a salinity of 80,000 mg/L (Leahy *et al.* 2010). The nearby Lake Keilambete, was less than 10 m deep with salinity slightly in excess of 100,000 mg/L (Leahy *et al.* 2010). Non-withstanding, some results of Leahy *et al.*'s (2010) study are considered here.

There are numerous deep, hypersaline lakes around the world, with the Dead Sea (Israel) the most famous. The lake is more than 300 m deep with average salinity of 340,000 mg/L (Stiller & Nissenbaum 1999). The Great Salt Lake (Utah) is at its maximum about 33 m deep and salinities vary between 135,000 mg/L and 290,000 mg/L (Stiller & Nissenbaum 1999). There are a number of studies on smaller lakes, for example Lake Burdur (Turkey) is described as 100 m deep and saline (up to 50,000 mg/L); however, in contrast to the terminal Fimiston Pit lake, it is highly alkaline (Girgin *et al.* 2004).

There are numerous studies on inland wetlands in south-western Australia and the effects of increasing salinity have been studied extensively (Gregory *et al.* 2009; Halse *et al.* 2003; James *et al.* 2003; Nielsen *et al.* 2003). Some of these studies considered halotolerances of the inhabiting biota (Colmer *et al.* 2009; Geddes 1981; Nielsen *et al.* 2008; Pinder *et al.* 2005; Pinder *et al.* 2009; Timms *et al.* 2009) and these are considered here when discussing potential inhabitants of a terminal Fimiston Pit lake. Overall, species richness in inland saline waters decreases with increasing salinity (Hammer 1986).

However, the comparison of the Fimiston Pit lake with regional wetlands is hampered by two main factors:

- the shallow nature of natural saline wetlands in Western Australia; and
- their generally ephemeral nature with hydroperiods restricted to after high rainfall events.

A deep lake may not provide the necessary microhabitats for the persistence of biota common in salt lakes of the Goldfields. For example, benthic microbial communities (BMC; or 'algal mats'), typical for shallow ephemeral salt lakes, cannot persist beyond a certain depth where light cannot penetrate and muddy substrate required for *Parartemia* brine shrimps to lay their eggs, may not be available.

The expected thermal stratification and its temporal pattern of the terminal Fimiston Pit lake are difficult to predict, as they are dependent on water temperature, salinity gradients within the lake and wind conditions. Effects of stratification were explicitly not included in the hydrological model for the lake (Schlumberger 2015). Deep lakes generally stratify on a seasonal basis. For those in warm, semi-arid regions, the warm monomictic pattern is characteristic, with mixing once a year. The lakes stratify thermally during the warmer season and mix during other seasons (Girgin *et al.* 2004). However, with no annual lake turnover, most of the nutrient inputs, including any internal recycling that may occur, will be potentially lost to the deep lake bottom and the lake will always be low in nutrients (S. Helleren, pers. comm.).

Hydroperiod appears to be an important factor determining wetland biota in Western Australia. Fewer than half of the invertebrates, and a much smaller portion of plants using salt lakes have been found in permanent salinized wetlands (Halse *et al.* 2003). It appears likely that changed salinity and flooding patterns provide unfavourable cues and conditions for hatching and development of invertebrates in Western Australian wetland (Pinder *et al.* 2002).

Some naturally acidic wetlands occur in southwestern Western Australia, but few invertebrate species occurring in saline Avon Wheatbelt wetlands are also acidophilic, including the brine shrimp *Parartemia contracta*, the copepod *Calamoecia trilobata* and undescribed ostracod in the genus *Reticypris* (Halse *et al.* 2003).

In summary, due to a number of unknown parameters it is very difficult to predict the biota of a terminal Fimiston Pit lake as hydrologically modelled by Schlumberger (2015), as no comparable system exists in Australia or world-wide. Our assessment is therefore largely based on the known limitations within the three trophic levels of a lake.

4.1 PRIMARY PRODUCTION

Microflora responsible for primary production through photosynthesis have been found in most types of saline waters, indicating that halophilic microorganisms tolerate high salinity and can adapt to different stressors like high pH or extreme temperatures (Kunte *et al.* 2002). The primary producers in a lake are either planktonic (i.e. occur the water column; phytoplankton) or benthic (living on the bottom).

Phytoplankton are generally dominated by algae and a few bacterial species. In saline lakes, e.g. the Great Salt Lake in Utah, these are commonly diatoms and/or green algae (Chlorophyceae), such as species of *Dunaliella*. *Dunaliella salina* is one of the most environmentally tolerant eukaryotic organisms known and can cope with a salinity range from seawater (*ca*. 35,000 mg/L) to NaCl saturation (310,000 mg/L), and a temperature range from < 0°C to > 38°C. This halophilic species produces beta-carotene in such large quantity that the water it inhabits may become quite red in colour (http://faculty.weber.edu/sharley/AIFT/GSL-Life.htm; accessed 30 August 2016). However,

salinity more than 15,000 mg/L decreases its growth rate. This physiological restriction, for example, ensures that red *Dunaliella* blooms in the Dead Sea only after periodic freshwater influxes that create suitable conditions in the surface layers of the lake (Oren & Ben-Yosef 1997).

The benthic habitat of salt lakes is generally dominated by blue-green algae (cyanobacteria) and some diatoms with the occasional green algae. They often form dense BMC's. These primary producers are especially active when the phytoplankton (and micro- and macroinvertebrate) numbers decline and the resulting clear water allows light to penetrate further to the bottom. In Australia, much all of the primary production in hypersaline systems (which are typically shallow) is benthic, in the form of microbial mats (bacteria, cyanobacteria, diatoms). In deeper hypersaline systems there is usually very little primary productivity in the water column (S. Helleren, pers. comm.).

In lakes of the Western District in Victoria, algae seem generally more able to tolerate extreme high salinities as compared with other biological groups. Algal diversity correlated significantly with salinity; however, below 200,000 mg/L the relationship was weak or non-existent. The correlation largely arose from the lower algal diversity at salinities greater than 300,000 mg/L (Leahy *et al.* 2010). Extremely high salinities did not seem to impact on algal densities with no significant relationship being detected between salinity and algal cell count; high algal densities were recorded even at near saturated salinity levels of 320,000 mg/L (Leahy *et al.* 2010). Diatom species diversity declined with increasing salinity at the Victorian lakes. Above a salinity of 80,000 –100,000 mg/L, diatom diversity was noticeably lower (Leahy *et al.* 2010). In contrast, in Western Australian wetlands, algal diversity is reduced in salinities between 100,000–200,000 mg/L with *Dunaliella* being dominant, and with species of *Ruppia*, *Lepilaena* and *Lamprothamnium* occurring occasionally (Halse *et al.* 2003).

Whilst salinity does not seem to be a limiting factor for algal diversity and densities, low nutrient levels and acidity will reduce primary production (Gimmler 2001). It is not clear whether acidity, water toxicity or nutrient limitation or a combination of all are the impediments for limited algal growth at Lake Kepwari. However, it appears possible that nutrient additions may be able to lift algal biomass in the lake (Kumar *et al.* 2011).

In summary, primary productivity in a hypersaline, acidic and deep lake such as the Fimiston Pit lake would be very low due to the a limited phytoplankton algal mass and a limited amount of shallow areas where BMC can develop. If BMCs do develop, water temperatures in the lake would be significantly lower than they are in the salt lakes of the region further reducing productivity. There could be situations after heavy rains, where a freshwater layer develops on top of the hypersaline water. If this layer contains nutrients and persists for a short time (ideally under warm and still conditions), this could result in an algal bloom which will create a short-lived burst of productivity (as reported for the Dead Sea), with all the biomass ultimately being lost to the deep water.

4.2 CONSUMERS

Algae provide the food source for the consumers of the second trophic level and in saline wetlands these are often dominated by a variety of crustaceans and some insect larvae, mainly those of flies (Diptera). In the Great Salt Lake, phytoplanktonic algae provide the food for the grazing brine shrimp (*Artemia franciscana*). Diatoms, though valuable, are tougher for the brine shrimp to digest because of their thick silica cell walls (Stephens & Gardner 2007). The algal mats that develop are important as the food for two species of brine fly (genus *Ephydra*). These small insects spend their larval developmental stage grazing on this benthic community, later form pupae and emerge as adults in early summer (Stephens & Gardner 2007).

In the lakes of the Victorian Western District, high numbers of invertebrate species are typically found in lakes with low salinity (Leahy *et al.* 2010). Species diversity declines rapidly as waters become more saline. Many freshwater lakes are intolerant of salinity above 3,000 mg/L and species diversity drops markedly once salinity becomes greater than 5,000 mg/L. In lakes ranging from approximate 50,000 to 200,000 mg/L, the trend of declining diversity with increasing salinity is weak. The invertebrates that do occur in such hypersaline lakes are generally tolerant of a broad salinity range and species diversity does not change much with increasing salinity in this range (Leahy *et al.* 2010; Pinder *et al.* 2005). At the extreme end of the salinity spectrum (>300,000 mg/L), very few invertebrate species are able to survive. In Western Australia, halotolerant or halophile aquatic micro- and macroinvertebrates that have been found in salinities similar to the terminal Fimiston Pit lake or above include brine shrimp (e.g. *Parartemia*, *Artemia*), some ostracods (e.g. *Australocypris*, *Reticypris*), copepods (e.g. *Calamoecia*, *Metacyclops*) and some insect larvae, in particular flies (Diptera) (Pinder *et al.* 2005). For example, *Calamoecia salina* has a salinity tolerance of up to around 140,000 mg/L (Dalcon 2010) and *Parartemia* species have been found in salinities nearing saturation (>300,000 mg/L) (Pinder *et al.* 2005).

The low acidity as modelled for the Fimiston Pit lake represents an important limiting factor for the presence of aquatic micro- and macroinvertebrates. Few halotolerant invertebrate species occurring in saline Avon Wheatbelt wetlands are also acidophilic or acidotolerant, including the brine shrimp *Parartemia contracta*, the copepod *Calamoecia trilobata* and ostracods in the genus *Reticypris* (Halse *et al.* 2003).

In particular brine shrimp are well adapted to varying hydrological circumstances. *Parartemia* produce both non-resting eggs (for maintenance of populations during a filling event) and drought resistant resting eggs (for surviving between filling events). The latter require a period of drying before they will hatch. These strategies mean that *Parartemia* should be able to maintain populations in permanent wetlands (Timms *et al.* 2009). However, *Parartemia* eggs appear to be primarily laid into the mud of saline wetlands (Campagna 2007), and it is unknown if the steep and rocky Fimiston Pit lake banks provide a suitable or large enough microhabitat for reproduction.

In summary, low primary production and acidity, high salinity, and a potential lack of habitat for reproduction are limiting factors for the establishment of an aquatic micro- and macrofauna assemblage at Fimiston Pit lake. This assemblage will be dominated by halo- and acidotolerant crustaceans such as *Parartemia*, *Calamoecia* and *Reticypris*, and possibly some larval Diptera, but these will likely occur only in low densities.

4.3 PREDATORS

Very few fish can survive acidity levels as modelled for Fimiston Pit lake (Dunson *et al.* 1977) and therefore these are not further considered here. Waders and shorebirds can often been found in large numbers on shallow salt lakes taking advantage of the high productivity after rain (Kingsford *et al.* 1999; Roshier *et al.* 2002). This productivity is in particular high for salt lakes with an initial freshwater phase that triggers high algal growth rates and is followed by a boom in aquatic micro- and macroinvertebrates on which the birds feed on. In contrast, Lake Lefroy, which lacks a freshwater phase, does not have abundant bird fauna after fill events (SIGM 2011). Some species may be particularly adapted to high salinity levels, for example, Hooded Plovers (*Thinornis rubricollis*) have increased in numbers at Warden Lake near Esperance with increasing salinity, despite other waders reducing heavily in numbers (Department of the Environment 2014). Few waterbird utilize acidic wetlands, although Red-necked Avocets (*Recurvirostra novaehollandiae*) have been found breeding in wetlands with pH 2.8 (Halse et al. 2003).

In summary, Fimiston Pit lake will likely be utilised by water birds to rest, but based on expected low primary production and low numbers of aquatic invertebrates, the lake will not be an important food source and it is unlikely that birds will breed. Within this context it also needs to be considered that the lake will be too deep for wading birds to forage.

5 SUMMARY

In summary, it is difficult to predict the aquatic biota of a terminal Fimiston Pit lake due to a lack of comparative aquatic systems, although acidic pit lakes are general nutrient poor and have low primary production. Similarly, Fimiston Pit lake will likely be of low productivity. Steep lake walls are likely to limit the establishment of BMC's, the most common primary producers in shallow hypersaline lakes. Planktonic primary producers such as *Dunaliella* green algae may persist, but if permanent thermal (and possibly salinity) stratification occurs nutrient cycling will be reduced with nutrients accumulating at the bottom of the lake. Aquatic micro- and macroinvertebrates will be limited to halotolerant/-phil and acidotolerant/-phil groups, such as brine shrimp (e.g. *Parartemia*, possibly introduced *Artemia*), ostracods (*Reticypris*), and copepods (e.g. *Calamoecia*) and some insect larvae, in particular flies (Diptera). However, the lack of primary production and microhabitats characteristic of regional shallow lakes will limit their numbers. Consequently, the lake will provide little food for waders or shorebirds, although some have frequently been found on hypersaline and acidic lakes.

With respect to the objective of this assessment, it is unlikely that there are any major pathways for contaminants in solution to be transported from the lake into the surrounding environment if the nutrient levels and acidity of the terminal Fimiston Pit lake are not managed to provide for higher primary production.

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5.4 Appendix 5.4: FIMISTON Waste Geochemical Characterisation

FRESH ROCK WASTE GEOCHEMICAL CHARACTERISATION FOR FIMISTON OPEN PIT

PREPARED FOR:

KALGOORLIE CONSOLIDATED GOLD MINES

NOVEMBER 2017

PREPARED BY:

Martinick Bosch Sell Pty Ltd
4 Cook Street
West Perth WA 6005
Ph: (08) 9226 3166
Fax: (08) 9226 3177
Email: info@mbsenvironmental.com.au
Web: www.mbsenvironmental.com.au

FIMISTON OPEN PIT
FRESH ROCK WASTE GEOCHEMICAL CHARACTERISATION

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1. INTRODUCTION

1.1 BACKGROUND

Kalgoorlie Consolidated Gold Mines (KCGM) operates the Fimiston Open Pit, Mt Charlotte Underground Mine and the Fimiston and Gidji Processing Plants (Figure 1), located adjacent to the City of Kalgoorlie-Boulder approximately 600 km east of Perth, Western Australia.

Mining and mineral processing has occurred along an area known as the Golden Mile since gold was first discovered in 1893. The Golden Mile is one of the world's richest gold-bearing reefs and gave rise to a multitude of mining operations. In 1989, all mines, processing plants and leases along the Golden Mile were merged into one integrated operation, KCGM.

Ore for gold production at KCGM is today sourced from two primary mining locations; the Fimiston Open Pit (commonly known as the Super Pit) located on the Golden Mile and the Mt Charlotte Underground Mine approximately 2 km north of the Fimiston Open Pit (Figure 1). The Fimiston Open Pit mining rate is approximately 69 million tonnes per annum (Mt/a) (comprising ore and waste), of which approximately 12 Mt/a will be processed at the Fimiston Mill. On completion, the Fimiston Open Pit will measure 3.5 km in length, 1.5 km in width and up to 700 m in depth.

The majority of waste rock from the Fimiston Open Pit is placed in waste rock dumps (WRDs) to the south and northeast of the mine (Figure 1). Waste rock from Fimiston Open Pit is comprised of three main identified lithologies – Golden Mile Dolerite (GM Dolerite) (80%), Paringa Basalt (14%) and Black Flag Shale (BF) (4.5%) (Table 1).

Table 1: Fimiston Waste Rock Breakdown

Weathering Zone	Lithology	Percentage of Total Waste
Oxide	GM Dolerite	11.6
	Paringa Basalt	3.3
	Black Flag Shale	0.9
	Devon Consols Basalt	0.4
	Williamstown Dolerite	0.1
Transition	GM Dolerite	6.3
	Paringa Basalt	1.3
	Black Flag Shale	0.5
Fresh	GM Dolerite	62.9
	Paringa Basalt	9.6
	Black Flag Shale	3.1
Total Across Weathering Zones	GM Dolerite	80.8
	Paringa Basalt	14.2
	Black Flag Shale	4.5

The BF bed occurs as a partially mineralised, near vertical dipping bed hosted within GM Dolerite. The mineralising event on the Golden Mile has led to an overall geochemical enrichment in arsenic (As), tellurium (Te), mercury (Hg), lead (Pb), vanadium (V) and boron (B). This enrichment is largely confined to the main lode

systems with lower levels of enrichment in the surrounding host BFs and significantly lower enrichment in the host GM Dolerite and Paringa Basalt.

Mine waste from Fimiston Open Pit is selectively placed in dumps with waste BF managed by placement away from the outer 50 m of the WRD and covered by at least 5 m of benign material (GM Dolerite/Paringa Basalt) on the uppermost surface of the WRD. A minor proportion of ore grade BF (1.2 grams per tonne (g/t) gold) is stockpiled for later processing in defined areas. Small volumes of waste rock are also:

- Crushed and used for backfilling of the underground stopes at Mt Charlotte (approximately 500,000 t/a).
- Supplied to external sources for production of crushed rock products (approximately 265,000 t/a).

Waste rock produced during mining at Mt Charlotte remains underground as backfill material.

At Fimiston, marginal grade ore (0.9 g/t to 1.2 g/t) and low grade ore (0.5 g/t to 0.9 g/t) is selectively stockpiled on the North East and Oroya WRDs near the mill to allow for processing after mining of ore has ceased. Should reprocessing not occur, the marginal and low grade ore stockpiles will be rehabilitated to blend in with the adjoining WRDs.

Management of the large volumes of waste mined from the Fimiston Open Pit requires sound knowledge of the geochemistry of the three primary fresh rock lithologies to inform mine closure planning. The purpose of this report is to briefly compile the available geochemical information for Fimiston Open Pit waste rock and in particular to incorporate additional sampling and analysis of BF as the key lithology of interest to address gaps in knowledge, previously identified in a site wide review conducted by MBS in 2016 (MBS 2016).



Figure 1: KCGM Fimiston Open Pit and Key Mine Waste Landforms

1.2 OBJECTIVE AND SCOPE OF WORK

The objectives and scope of works for the additional waste rock characterisation were to:

- A review of previous geochemical characterisation for the three major lithologies based on information within reports.
- Liaise with KCGM staff for provision of available sulfur assay data (percentage sulfur) by lithology for Fimiston Open Pit waste.
- Liaise with KCGM staff for collection of additional pit wall samples for laboratory analysis of exposed BF transect samples within the Fimiston Open Pit.
- Liaise with KCGM staff for collection of three representative rock samples (surface, mid-section and near base) from each of five BF IBC (Intermediate Bulk Container or 'Bulkie') field trials established in 2005/2006 together with any liquid from the base generated by rainfall.
- Analysis of these samples for Acid Base Accounting (ABA) parameters and composition as follows:
  - Total sulfur, sulfate sulfur and chromium reducible sulfur (CRS).
  - Acid Neutralising Capacity (ANC).
  - Total carbon and total inorganic carbon.
  - Net Acid Generation (NAG) test on samples containing >0.2% CRS.
  - Elemental analysis of four acid digest solutions for Ag, Al, As, Au, Ba, Ca, Cd, Co, Cu, Cr, Fe, K, Mg, Mn, Mo, Na, Ni, Pb, Sb, Se, Te, U, V and Zn.
  - Gold content assay.
- Assessment of the additional Black Flag Shale transect samples for acid and metalliferous drainage (AMD) potential and geochemical enrichment based on the sulfur assay data and results of static testing for ABA and elemental composition above.
- Assessment of the IBC trials results and projection for neutral and AMD potential based on field exposure on site over approximately 11 years.
- Overall assessment of geochemical properties for the three major lithologies based on all available information in previous and current waste characterisation work.

2. GEOCHEMICAL CHARACTERISATION METHODS

2.1 ACID FORMING WASTE CLASSIFICATION METHODOLOGY

There is no simple method to define whether mine waste containing small quantities of sulfur will produce sulfuric acid. Sulfide minerals are variable in their behaviour under oxidising conditions and not all forms will produce sulfuric acid (H_2SO_4). Instead, a combination of approaches is often applied to more accurately classify mine waste. These approaches are listed below in order of increasing data requirements (and therefore increased reliability):

- The "Analysis Concept", which only requires data for total sulfur content. Its adoption is based on long term experience of wastes from Western Australian mine sites in arid and semi-arid conditions. Experience has shown that waste rock containing very low sulfur contents (less than 0.2 to 0.3%) rarely produces significant amounts of acidic seepage.
- The "Ratio Concept", which compares the relative proportions of acid neutralising minerals (measured by the Acid Neutralising Capacity (ANC)) to acid generating minerals (measured by the Maximum Potential Acidity (MPA)). Experience has shown that the risk of generating acidic seepage is generally low when this ratio (the Neutralisation Potential Ratio – NPR) is above a value of two.
- Acid-Base Accounting, in which the calculated value for Nett Acid Producing Potential (NAPP) is used to classify the acid generating potential of mine waste. NAPP is equal to the MPA minus the ANC.
- Procedures recommended by AMIRA (2002), which take into consideration measured values provided by the Nett Acid Generation (NAG) test and calculated NAPP values.
- Kinetic leaching column test data, which provides information for the relative rates of acid generation under controlled laboratory conditions, intended to simulate those within a waste rock dump or tailings storage facility.

A sound knowledge of geological and geochemical processes must also be employed in the application of the above methods.

Classification of wastes in this report uses procedures recommended by AMIRA (2002) based on NAPP and NAGpH results. However results are also compared to the Analysis Concept (total sulfur) and Ratio Concept models and a modification of the AMIRA procedure by determination of the following:

- Analysis for total sulfur (Tot_S) and sulfate sulfur (SO_4_S), both reported as sulfur, as a measure of oxidisable sulfur. Alternatively, Chromium Reducible Sulfur (CRS) can be used a direct measure of oxidisable sulfur.
- Analysis for ANC (quoted in kg H_2SO_4/t).
- Calculation of carbonate neutralising potential (CarbNP) (quoted in kg H_2SO_4/t) from measured concentrations of Total Inorganic Carbon (TIC).
- Calculation of Acid Production Potential (AP) = [(Tot_S – SO_4_S) * 30.6] kg H_2SO_4/t. Chromium Reducible Sulfur (CRS) can be used in place of total sulfur minus sulfate sulfur in this calculation of AP.
- Calculation of NAPP = [AP – ANC] kg H_2SO_4/t.
- Calculation of Effective NAPP = [AP – CarbNP] kg H_2SO_4/t.
- Analysis for NAG (quoted in kg H_2SO_4/t).
- Analysis for NAGpH.
- Calculation of NPR = ANC/AP.

This AMIRA approach is more conservative than either the Analysis Concept or the Ratio Concept alone, but assumes the absence of sulfur present as barium sulfate. The AMIRA approach of using NAG testing is particularly useful for PAF-LC materials or where there is very low ANC in the host rock. A combined acid generation classification scheme based on NAPP and NAG determinations is presented in Table 2.

Table 2: Waste Classification Criteria

Primary Geochemical Waste Type Class	NAPP Value kg H_2SO_4/t	NAGpH	Sulfide S Content
Potentially Acid Forming (PAF)	≥10	< 4.5	≥ 0.3%
Potentially Acid Forming – Low Capacity (PAF-LC)	0 to 10	< 4.5	0.16 to 0.3%
Uncertain (UC)	0 to 5	> 4.5	Not important
Uncertain (UC)	-10 to 0	< 4.5	Not important
Non Acid Forming (NAF)	-100 to 0	> 4.5	Not important
Acid Consuming (AC)	< -100	> 4.5	Not important

Table 2 is based on the Australian Government's Guidelines on Managing Acidic and Metalliferous Drainage (DIIS 2016) and is in turn based on an earlier classification system included within the AMIRA ARD Test Handbook (AMIRA 2002), which is advocated by the Global Acid Rock Drainage Guidelines (GARD) published by the International Network for Acid Prevention (INAP 2009). This classification system, based on static acid base accounting procedures and used in conjunction with geological, geochemical and mineralogical analysis can still leave materials classified as 'uncertain' where there is conflicting NAGpH and NAPP results. Uncertain materials demonstrating a NAGpH above 4.5 may be tentatively assigned as potentially NAF and those below pH 4.5 as potentially PAF – however in such cases, further assessment, such as the use of kinetic leaching columns may be required to provide a definitive classification.

2.2 LABORATORY METHODS

2.2.1 Acid Base Accounting

Sample analysis was performed by Intertek Genalysis. All samples underwent analysis for ABA parameters and total metals composition using a four acid digestion. Full ABA analysis (namely CRS and NAG analysis) was only conducted on samples containing greater than or equal to 0.2% total sulfur (Analysis Concept).

ANC was measured by a modified Sobek procedure (AMIRA 2002), which involves addition of dilute hydrochloric acid to the sample, followed by gentle simmering (two hours) to complete the reaction. The ABA scheme relies on measurement of oxidisable sulfur. The value of this fraction of sulfur in mine waste samples is calculated as the difference between total sulfur and sulfate-sulfur, which is present in a fully oxidised form and therefore not capable of generating additional acidity. Sulfate-sulfur content was determined by a heated hydrochloric acid extraction and Inductively Coupled Plasma – Optical Emission Spectrometry (ICP-OES) finish. CRS was also measured on samples in conjunction with total sulfur and sulfate-sulfur. CRS provides a direct measurement of sulfide-sulfur (instead of calculation of oxidisable sulfur as the difference between total sulfur and sulfate sulfur).

When assessing data for the MPA and NAPP, it must be noted that both parameters are based on the assumption that all sulfur contained in the sample is acid producing (sourced from pyrite (FeS_2) and other iron sulfide minerals). However, this represents a worst case scenario as not all minerals containing sulfur will result in acid production. Conversely, the NAPP calculation also assumes that the acid neutralising material measured in ANC is rapid-acting. In practice, some neutralising capacity is supplied by silicate and aluminosilicate minerals which can be much slower to react. Further still, iron carbonate minerals such as siderite ($FeCO_3$) have limited or no capacity to neutralise acidity due to acid producing reactions resulting from oxidation of the dissolved ferrous iron

component. Despite these assumptions, NAPP remains a suitable conservative prediction of potential acid generation when used in conjunction with mineralogical data.

The NAG test involves the addition of hydrogen peroxide, a strong oxidising agent, to a sample of mine waste to oxidise reactive sulfides. After cooling the sample pH is measured (NAGpH) and any acidity generated measured by back titrating with sodium hydroxide solution to a pH of 4.5 (NAG to pH 4.5) and pH 7 (NAG to pH 7). NAG is expressed in units of kg H_2SO_4/t. A significant NAG result (i.e. final NAGpH less than 4.5) generally indicates that the sample is PAF (Table 2) and the test provides a direct measure of the NAG potential. A NAGpH of 4.5 or more generally indicates that the sample is NAF, but may still be capable of generating metalliferous drainage following oxidation of the sulfide minerals. Results for titrations of aliquots of the NAG solution to endpoint pH values of 4.5 and 7.0 allow estimation by the difference between these results of the relative amounts of non-acid producing base metal (such as copper) and iron sulfides in the sample.

2.2.2 Elemental Composition

Environmentally significant metals and metalloids were measured following digestion of a finely ground sample with a mixture of four acids (hydrochloric, nitric, perchloric and hydrofluoric acids) which is a near total determination for the elements measured.

From this data, the global abundance index (GAI) for each element was calculated by comparison to the average earth crustal abundance (Bowen 1979 and AIMM 2001). The main purpose of the GAI is to provide an indication of any elemental enrichment that could be of environmental significance. The GAI (based on a log-2 scale) is expressed in integer increments from zero to six (GARD Guide). A GAI of zero indicates that the content of the element is less than or up to three times the average crustal abundance; a GAI of one corresponds to a three to six fold enrichment; a GAI of two corresponds to a six to 12 fold enrichment and so forth, up to a GAI of six which corresponds to a 96-fold, or greater, enrichment above average crustal abundances. A GAI of more than three is considered significant and may warrant further investigation. Results have been truncated to show no more than a GAI of six.

3. PREVIOUS FIMISTON PIT GEOCHEMICAL STUDIES

Based on observations and recommendations from an overview undertaken by HAL-Environsciences Pty Limited (HAL) in August 2006, there has been two main previous reports and one field study of AMD potential on Fimiston Open Pit lithologies. These comprise:

- Graeme Campbell and Associates Pty Ltd 2010 (GCA 2010). A study of 77 samples including 27 GM Dolerite, 9 Paringa Basalt and 15 BF from the fresh rock 'primary' zone for static ABA testing, pH and EC and selected samples for mineralogy by X-Ray Diffraction (XRD).
- Soilwater Group 2013 (Soilwater Group 2013). A static and 52 week kinetic study of two BF and three Paringa Basalt samples.
- A KCGM field trial of five IBC's filled with BF material either from a transect of the exposed BF or from waste rock from the Lakewood waste rock dump. Records of the sample selection, initial or any subsequent analysis or exact date of the establishment of this trial are not available other than being believed to have been established in either 2005 or 2006, possibly on the basis of preliminary recommendations from HAL-Environsciences. These were sampled and assessed for current work as described in Section 5.2.

A brief description of the combined results of GCA 2010 and Soilwater Group 2013 studies is given below.

3.1 SAMPLE BREAKDOWN

A summary of samples assessed in the two previous studies are presented in Table 3. The following are key points in relation to samples selected:

- BF samples taken for GCA 2010 were hand sampled (15 samples) at intervals of approximately 1 m from within and adjacent to an available pit exposure within the fresh rock zone, as this lithology was not intersected during the drilling program.
- Soilwater Group collected two samples of BF from the main mineralised zone and three samples of Paringa Basalt comprising one sample (marked "High Grade") from the eastern contact of the mineralised orebody and samples (marked "Low Grade") from either side of the mineralised orebody.

The primary potential for generation of AMD exists within the fresh rock zone and in particular the higher sulfide, lower ANC BF. All samples from weathered (transition and oxide) zones characterised by Graeme Campbell and Associates were found to be NAF and essentially inert and are not discussed further. Additional information on this weathered material can be found in GCA 2010 and MBS 2016.

Table 3: Fimiston Open Pit Waste Rock Sample Summary

Weathering Zone	Lithology	Number of Samples	Study
Oxide	Mottled Zone	3	GCA 2010
	Upper Saprolite	4	GCA 2010
	Lower Saprolite	2	GCA 2010
	BF	3	GCA 2010
Transition	Upper Saprolite	2	GCA 2010
	Lower Saprolite	2	GCA 2010
	Not known/undifferentiated	7	GCA 2010
	GM Dolerite	1	GCA 2010
	Paringa Basalt	4	GCA 2010
Fresh	GM Dolerite (drill core)	27	GCA 2010
	Paringa Basalt (drill core)	9	GCA 2010
	BF (transect across exposed material)	15	GCA 2010
	BF	2	SWG 2013
	Paringa Basalt	3	SWG 2013

3.2 SUMMARY OF RESULTS FOR FRESH BF

3.2.1 Mineralogy (GCA 2010)

BF samples were found to contain pyrite in accessory amounts (2 to 10%) within a matrix dominated by quartz, muscovite and accessory amounts of plagioclase (feldspar). The dominant carbonate mineral was ankerite (10 to 20%) with trace to accessory amounts (up to 10%) of siderite. Ankerite composition average was $(Mg_{0.39}Fe_{0.16}Ca_{0.48})CO_3$ and can therefore be expected to provide substantial ANC to neutralise acid formation. Higher siderite content samples relative to ankerite will provide less ANC.

Sphalerite (ZnS), chalcopyrite ($CuFeS_2$) and graphite were also detected in trace amounts in various BF samples.

3.2.2 Acid Base Accounting

The 17 BF analysed were found to have moderate to high levels of sulfide-sulfur (0.24 to 5.1%), but within a background matrix (ankerite) of moderate to high ANC (65 to 140 kg H_2SO_4/t). Fresh samples of BF recorded alkaline pH values ranging from 6.8 to 8.5. NAGpH values following oxidation ranged from 2.3 to 9.0. Analysis of acid base buffering characteristic curves (ABCC) indicated approximately 10 to 20 kg H_2SO_4/t readily available alkalinity to buffer acid production, which is approximately equal to 0.5% as sulfur.

On the basis of classification used in this report (Table 2), only one sample (GCA 2010 - sample 8503) would be classified as PAF as it had a NAGpH of less than 4.5 (2.3). Three classify as uncertain (GCA 2010 sample number 8510 and both Soilwater Group samples) on the basis of having a positive NAPP, but NAGpH of more than 4.5. The remainder would be classified as NAF or acid consuming.

Gold content was not assayed on previous samples – it is assumed that all samples selected were waste material.

3.2.3 Elemental Composition

BF samples were geochemically enriched in a number of elements with significant spatial variation across intersections. Highest concentrations of metals and metalloids were found in the middle of intersections near the primary zone (Table 4, reproduced from Graeme Campbell and Associates 2010).

Table 4: Black Flag Shale Enriched Metals and Metalloids

Metal	Concentration Range (mg/kg)
Silver	<0.2 to 1.4
Copper	10 to 540
Cadmium	<0.2 to 9.9
Lead	7 to 330
Boron	61 to 110
Mercury	0.07 to 2.7
Arsenic	38 to 290
Antimony	11 to 140
Bismuth	0.04 to 0.73
Selenium	0.28 to 3.8
Zinc	34 to 5,400

3.2.4 Sulfide Oxidation and Solute Release Rates

The two BF samples assessed were not found to undergo any significant sulfide oxidation during the course of a 52 week kinetic leaching experiment (Soilwater Group 2013). An initial flush of sulfate from previous oxidation only was observed, but diminished rapidly. These samples would be classified according to Table 2 as UC because of a positive NAPP of 12 kg/t H_2SO_4 but NAGpH values of greater than 4.5. The pH remained stable at approximately pH 7.4. Apart from initial flushing effects, solute release of metals and metalloids was found to be limited to molybdenum in one of the two samples studied. This sample recorded a solute release rate for molybdenum of approximately 1 mg/kg/week, but less than 10% of total molybdenum present was leached at the end of the 52 week trial.

3.3 FRESH MAFIC ROCK (PARINGA BASALT AND GM DOLERITE)

3.3.1 Mineralogy (GCA 2010)

The only sulfide mineral detected by XRD in GM Dolerite (four samples) and Paringa Basalt (two samples) was pyrite in trace to accessory abundance. The dominant carbonate (ANC source) mineral was ankerite with some calcite and siderite. Ankerite composition varied from $(Mg_{0.40}Fe_{0.15}Mn_{0.02}Ca_{0.51})CO_3$ (low iron) to $Mg_{0.27}Fe_{0.27}Mn_{0.01}Ca_{0.49})CO_3$ (high iron) and is therefore expected to provide substantial ANC.

Common rock forming minerals were quartz, plagioclase, chlorite, biotite/muscovite micas, all of which are consistent with mafic igneous lithologies.

3.3.2 Acid Base Accounting

All Paringa Basalt and GM Dolerite samples were classified as NAF on the basis of generally low sulfide-sulfur (most less than 0.2%) and generally high ANC sufficient to be classed as acid consuming. GM Dolerite waste

rock had higher ANC (average 171 kg H_2SO_4/t) than Paringa Basalt (average 98 kg H_2SO_4/t) (GCA 2010 data). ABCC analysis indicated 120-150 kg H_2SO_4/t of available alkalinity in GM Dolerite and 70 to 140 kg H_2SO_4/t in Paringa Basalt samples which also indicates this ANC is readily available. The pH of samples ranged from 7.8 to 8.6 and EC 0.16 to 1.4 mS/cm, indicating mildly alkaline conditions and low to moderate levels of soluble salts.

3.3.3 Elemental Composition

Examination of results indicates variable enrichment in silver (<0.2 to 1.1 mg/kg) and antimony (1.4 to 9.1 mg/kg) for both lithologies, with some GM Dolerite samples also having elevated concentrations of mercury (maximum 0.44 mg/kg) and arsenic (10 to 260 mg/kg).

3.3.4 Sulfide Oxidation and Solute Release Rates

Basalt samples used in 52 week kinetic leaching experiments (Soilwater Group 2013), did not exhibit any significant oxidation during the course of the experiment. Leachate pH remained stable at approximately pH 7.8. Apart from initial flushing effects, only arsenic in one of the three samples tested was found to be released at any significant level in comparison to relevant water quality criteria. A maximum arsenic concentration of 0.38 mg/L (0.068 mg/kg/week release rate) was recorded in week eight, which is slightly below a Livestock Drinking Water Guideline of 0.5 mg/L (ANZECC 2000). The average arsenic release rate was approximately 0.03 mg/kg/week and less than 10% of total arsenic present was leached at the end of the 52 week trial. This indicates that enriched species such as arsenic are not expected to be significantly soluble in fresh rock material and only released extremely slowly with appropriate dilution over time with weathering.

4. REVIEW OF AVAILABLE FIMISTON OPEN PIT SULFUR ASSAY DATA

Sulfur assay data by X-Ray Fluorescence (XRF) from drilling programmes for Fimiston Open Pit were provided to MBS for review as part of this report. Summaries for the significantly lithologies (>1 % of waste rock) of fresh Paringa Basalt, GM Dolerite and fresh BF are provided in the following sections.

4.1 PARINGA BASALT AND GM DOLERITE

A summary of XRF data for Paringa Basalt and GM Dolerite mafic rocks from the Fimiston Pit (which may include some ore material as gold content was not indicated) is provided in Table 5 below. The GM Dolerite data includes all the associated mafic units U1 to U9. A histogram of sulfur content for GM Dolerite and Paringa Basalt is shown below in Chart 1 and Chart 2, respectively.

Data indicated that the majority (54%) of GM Dolerite samples were below 0.3% sulfur threshold of the Analysis Concept, while for Paringa Basalt the proportion was approximately one third (28%). Calculated maximum potential acidity based on the 90th percentile sulfur contents (55 kg H_2SO_4/t for GM Dolerite and 96 kg H_2SO_4/t for Paringa Basalt) is still less than the average ANC values for samples tested (171 kg H_2SO_4/t and 98 kg H_2SO_4/t respectively). This indicates an extremely low risk of AMD generation from these lithologies and indeed that the majority of this material (in particular the GM Dolerite) can be considered acid consuming for the purposes of mine closure. No further assessment of these lithologies was deemed necessary.

Table 5: Sulfur (%) Summary for GM Dolerite and Paringa Basalt Assay Data

Type	# Samples	Average	Median	90th Percentile	Maximum
GM Dolerite	101,751	0.69	0.26	1.81	22.4
Paringa Basalt	38,201	1.23	0.63	3.14	26.0

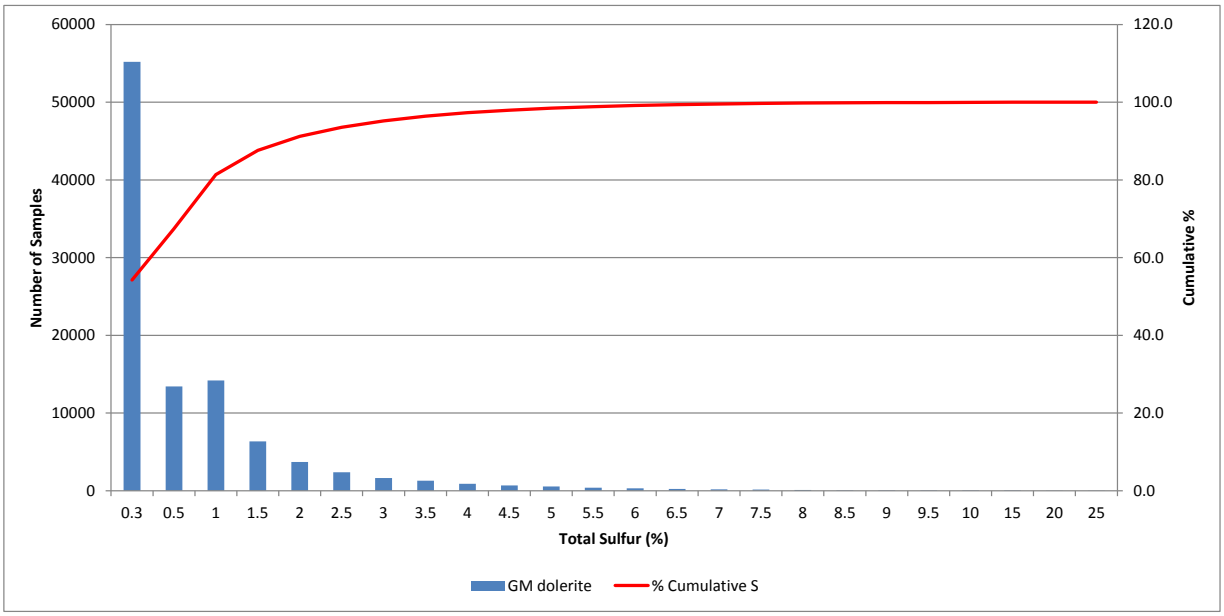


Chart 1: Frequency Histogram of Total Sulfur in GM Dolerite Assay Samples

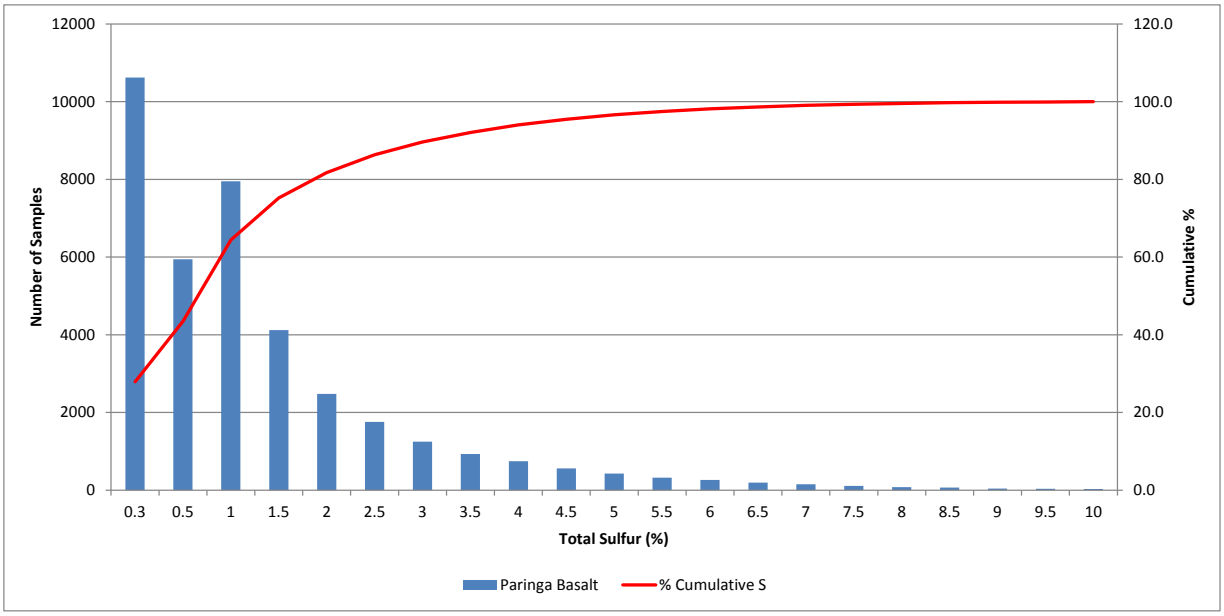


Chart 2: Frequency Histogram of Total Sulfur in Paringa Basalt Assay Samples

4.2 FRESH ROCK BF

Sulfur assay data by XRF for BF were segregated into ore vs waste based on an ore grade cutoff of 1.2 g/t and is summarised in Table 6. A histogram of sulfur content for the BF waste samples is shown in Chart 3.

Table 6: Sulfur (%) Summary for BF Assay Data

Type	# Samples	Average	Median	90th Percentile	Maximum
BF Ore	210	4.68	4.14	8.10	19.1
BF Waste	2,687	2.58	1.98	5.49	17.4

As expected, ore grade samples were slightly higher on average in sulfur content than waste samples. Data indicated that nine percent of samples of BF waste were above the 0.3% Analysis Concept criterion for potential acid generation. However, BF also contains organic sulfur forms which contributes to the total sulfur result. Approximately 75% of BF waste samples had a total sulfur content of less than the 3.2% average (two samples) studied for kinetic leaching by Soilwater Group and found not to be non-acid generating (Soilwater 2013).

However, it was also noted that the spread of sulfur contents by assay was much larger than has been captured in the 17 samples of static and two samples of kinetic testing performed to date and may be prone to bias as they related to only two sampling events. A greater number of BF samples for analysis of AMD potential and examination of the IBC field kinetic trial samples were therefore warranted for current work.

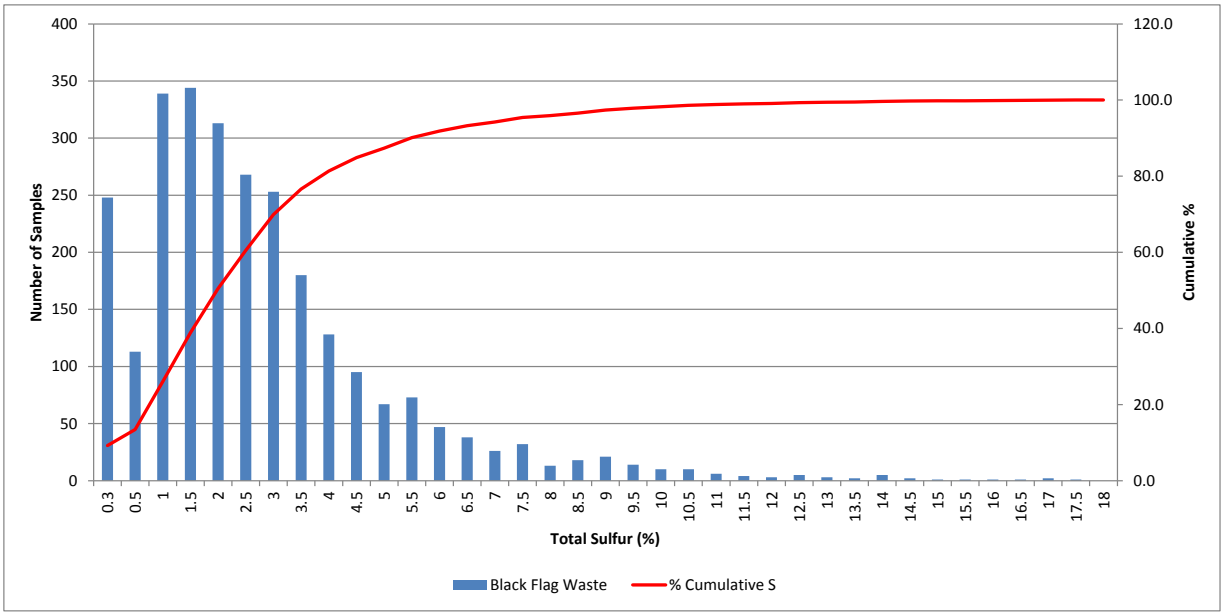


Chart 3: Frequency Histogram of Total Sulfur in Waste BF Samples

5. DESCRIPTION OF ADDITIONAL SAMPLES

5.1 BLACK FLAG SHALE FROM FIMISTON PIT WALL (STATIC)

KCGM staff collected 15 representative samples of BF along a transect of the exposed BF bed in the northern corner of Fimiston Open Pit. Sampling by transect allowed comparison to previous data (GCA 2010) and the distribution of sulfur and composition by position within the BF bed. Samples were collected every 1 metre extending out from the centre of the bed in both directions (sampling in a similar fashion to GCA 2010) in order to cover the entire width of visible BF material. A summary of transect samples is given in Table 7.

Table 7: Transect Sample Descriptions

Field ID	Sample Type	Distance From Centre of Transect (m)	Direction From Centre
T1 - 7mR	BF	7	Right/East
T1 - 6mR	BF	6	Right/East
T1 - 5mR	BF	5	Right/East
T1 - 4mR	BF	4	Right/East
T1 - 3mR	BF	3	Right/East
T1 - 2mR	BF	2	Right/East
T1 - 1mR	BF	1	Right/East
T1 Central	BF	0	Central
T1 - 1mL	BF	1	Left/West
T1 - 2mL	BF	2	Left/West
T1 - 3mL	BF	3	Left/West
T1 - 4mL	BF	4	Left/West
T1 - 5mL	BF	5	Left/West
T1 - 6mL	BF	6	Left/West
T1 - 7mL	BF	7	Left/West

5.2 IBC CONTAINERS OF BLACK FLAG SHALE (KINETIC)

At some point in either 2005 or 2006, a series of field trials of exposure of BF and/or surrounding metasedimentary rock lithologies were established on site in five IBCs with the tops removed to allow exposure to rainfall and weathering (Plate 1 to Plate 6 below). This approach allows collection of long term data on waste rock material as mined (without crushing) and under site conditions as suggested by the GARD guide (INAP 2009). In essence, these are larger scale field kinetic trials similar to the experiments conducted by Soilwater Group in 2013, but with only incident rainfall and without reduction of the rock size by crushing. The key benefits to the previous kinetic work is that these samples are more representative of the site conditions for BF and have been exposed for much longer (approximately 11 years) than the 12 months used in the Soilwater Group study.

Details of the origin of the samples and timing of this trial no longer exist, but field observations in September 2016 by MBS indicated that all samples comprised BF/metasediment and that one in particular showed visual evidence of oxidation and acid formation (IBC3). A further 15 waste rock samples were collected for laboratory analysis from each IBC at surface, 0.5 m and 1 m depths. This sampling strategy was employed in order to determine the degree of weathering over the past 10 to 11 years and to indicate any differences in oxidation by depth. Three

pooled water (effectively pore water) samples were also collected from IBCs that had sufficient liquid in the base to sample. A summary of IBC samples is given in Table 8. After comparison of these samples to the pit wall transect samples (this report and GCA 2010), MBS considers that it is likely the IBC samples were also taken as a transect across the BF bed with IBC3 representing the central and most reactive section of the BF bed. The direction of sampling (west to east or east to west) is uncertain, however results were generally suggestive of a west to east transect from IBC1 to IBC5. IBC1 contained material with very low sulfur content (<0.1%) compared to the other IBC materials and is considered to be more metasedimentary material (a minor lithology for the Fimiston Open Pit) rather than shale, although it may be sourced from the edges of the BF bed.

Table 8: IBC Waste Rock and Leachate Sample Descriptions

Field ID	Sample Type	Depth (m)
IBC1 0 m	Waste Rock	0
IBC1 0.5 m	Waste Rock	0.5
IBC1 1m	Waste Rock	1
IBC2 0 m	Waste Rock	0
IBC2 0.5m	Waste Rock	0.5
IBC2 1 m	Waste Rock	1
IBC3 0 m	Waste Rock	0
IBC3 0.5 m	Waste Rock	0.5
IBC3 1m	Waste Rock	1
IBC4 0 m	Waste Rock	0
IBC4 0.5 m	Waste Rock	0.5
IBC4 1m	Waste Rock	1
IBC5 0 m	Waste Rock	0
IBC5 0.5 m	Waste Rock	0.5
IBC5 1 m	Waste Rock	1
IBC 2 - liquid	Water	N/A
IBC 3 - liquid	Water	N/A
IBC 4 - liquid	Water	N/A



Plate 1: IBCs Outside KCGM Site Office



Plate 2: Surface Material IBC1



Plate 3: Surface Material IBC2



Plate 4: Surface Material IBC3



Plate 5: Surface Material IBC4



Plate 6: Surface Material IBC5

6. RESULTS AND DISCUSSION OF ADDITIONAL SAMPLES

6.1 STATIC ACID BASE ACCOUNTING

Laboratory results for total sulfur, CRS, ANC, NAG testing and calculated acid base accounting parameters of the transect and IBC waste rock samples are collated in Table A1-1 and Table A1-2 of Appendix 1. The original laboratory reports are included in **Error! Reference source not found.**

6.1.1 Sulfur Forms

A summary of results for the three sulfur forms assessed is provided in Table 9.

Table 9: Sulfur (%) Forms Summary

Sample Type	# Samples	SO_4_S Range	SO_4_S Mean	CRS Range	CRS Mean	Total S Range	Total S Mean
BF Transect	15	0.02-0.30	0.13	0.51-10.7	4.5	0.61-13	5.46
IBC Field Trial	15	0.06-1.8	0.41	0.02-7.2	1.6	0.08-8.2	2.11

Based on the data in Table 9, and Tables A1-1 and A1-2 (Appendix 1), the following are noted as key points:

- CRS was found to be a better indication of oxidisable sulfide content due to the presence of organic sulfur species measured as part of total sulfur determinations, which biases the latter determination high in calculations of AP. For this reason, calculations of AP and NAPP were based on the measured CRS.
- For fresh transect samples the proportion of total sulfur present as CRS averaged 84%. IBC trial samples from IBC containers 4 and 5 were similar with an average of 86% of total sulfur present as CRS. This indicates a general lack of significant reaction for IBC 4 and IBC 5, despite the long period of exposure.
- Consistent with sulfide oxidation having occurred, the proportion of CRS to total sulfur was much lower in samples from IBC1 to IBC3 (average 33%) with a corresponding increasing in the proportion of sulfate sulfur.

6.1.2 Acid Neutralisation Capacity

ANC was measured directly by acid addition, heating and back-titration, but also an estimate of effective carbonate neutralisation as 'Carb-NP' was calculated from the measured inorganic carbon. A summary of results for ANC and Carb-NP is provided in Table 10.

Table 10: ANC (kg H_2SO_4/t) and Carb-NP (kg H_2SO_4/t) Summary

Location	# Samples	ANC Minimum	ANC Maximum	ANC Mean	Carb-NP Minimum	Carb-NP Maximum	Carb-NP Mean
BF Transect	15	9	180	79	7	235	91
IBC Field Trial	15	-23	124	38	0	119	36

Based on the data in Table 10, and Tables A1-1 and A1-2 (Appendix 1), the following are noted as key points:

- For most samples there was good agreement between the measured ANC and the calculated Carb-NP, which is consistent with readily available carbonates contributing to the ANC. The exceptions for transect samples were samples T1-7mR and T1-4mR where the 2.9% and 2.7% inorganic carbon respectively (the two highest results) resulted in Carb-NP being significantly higher than the measured ANC. This result

indicates presence of siderite in these samples which does not contribute to ANC. Reports of a colour change in the laboratory report during ANC determinations (**Error! Reference source not found.**) are also consistent with this explanation.

- Overall, the highest levels of inorganic carbon (carbonates) were found in samples on the eastern (right) side of the transect, but this was variable (only 0.1 % in T1-5mR for example). This was also consistent with GCA 2010 results and suggests an essentially vertical fingering of carbonates in the beds to the east/right of the central section.
- The western most transect samples from 4 to 7 m had relatively consistent levels of inorganic carbon and ANC. These observations are also consistent with trends observed in GCA 2010 reported results.
- The central section of the BF bed comprising the central sample and three metres either side of this had generally the lowest levels of inorganic carbon and hence lowest ANC/Carb-NP ratios. These samples also had the highest content of total carbon (i.e. a high proportion of organic carbon and/or graphite) consistent with the strongest presence of shale lithology.
- Samples from IBC4 and IBC5 had similar levels of ANC and Carb-NP to unreacted transect samples. As for sulfur content, this again indicates a lack of sulfide oxidation despite prolonged exposure from these samples. Samples from IBC2 and IBC3 reported negative ANC values as these samples have exhausted available ANC and had become acidic.

6.1.3 Acid Drainage Classification – Current Data

AMD classifications based on criteria in Table 2 are outlined in Table A1-1 and Table A1-2 of Appendix 1. These classifications are represented as a plot of NAPP (based on CRS) versus NAGpH for the transect samples grouped by position in the BF bed and for IBC samples of BF samples in Chart 4 and Chart 5, respectively. The four quadrants are labelled as NAF, PAF and two UC (uncertain) according to the classification criteria in Table 2. Based on examination of these results, the following can be noted:

- All pit wall sampled material from the central six metres of BF with generally higher CRS sulfur contents as well as lower ANC were classified as PAF high capacity (PAF-HC), with NAPP values of 81 to 294 kg H2SO4/t.
- The western most of transect samples were all classified as NAF, while eastern samples were variable due to the apparent fingering of sulfidic lenses on this side. Three of the four eastern samples were classified as NAF (and two as acid consuming) and one was PAF-HC with a NAPP of 213 kg H2SO4/t.
- IBC trial samples (Chart 5) were more variable. IBC1 contained entirely NAF material and IBC3 (believed from central BF bed) entirely PAF-HC material at all depths. IBC2, IBC4 and IBC5 were mixed in classification between NAF and PAF, with one sample (IBC5 0.5 m) classifying as uncertain (UC) due to negative calculated NAPP but NAGpH slightly below 4.5 (4.3). This variable nature will however reflect the mixture of material reporting to the waste rock dump for BF.
- Despite a classification of PAF-low capacity (PAF-LC) for sample IBC4 0 m (surface) with a CRS content of 2.99%, this material remained circum-neutral (pH 7.60 on 1:5 extract) despite exposure at surface for the period of the trial.
- Samples IBC4 1 m and IBC5 1 m were classified as PAF-HC, but were also circum-neutral (both pH 6.80 on 1:5 extract) after exposure. The depth of these materials in the profile versus oxidised and acidic PAF-HC samples in IBC3 and IBC4 suggest that even a 1 m waste rock cover was sufficient to prevent any significant oxidation during the period of the trial (approximately 11 years).

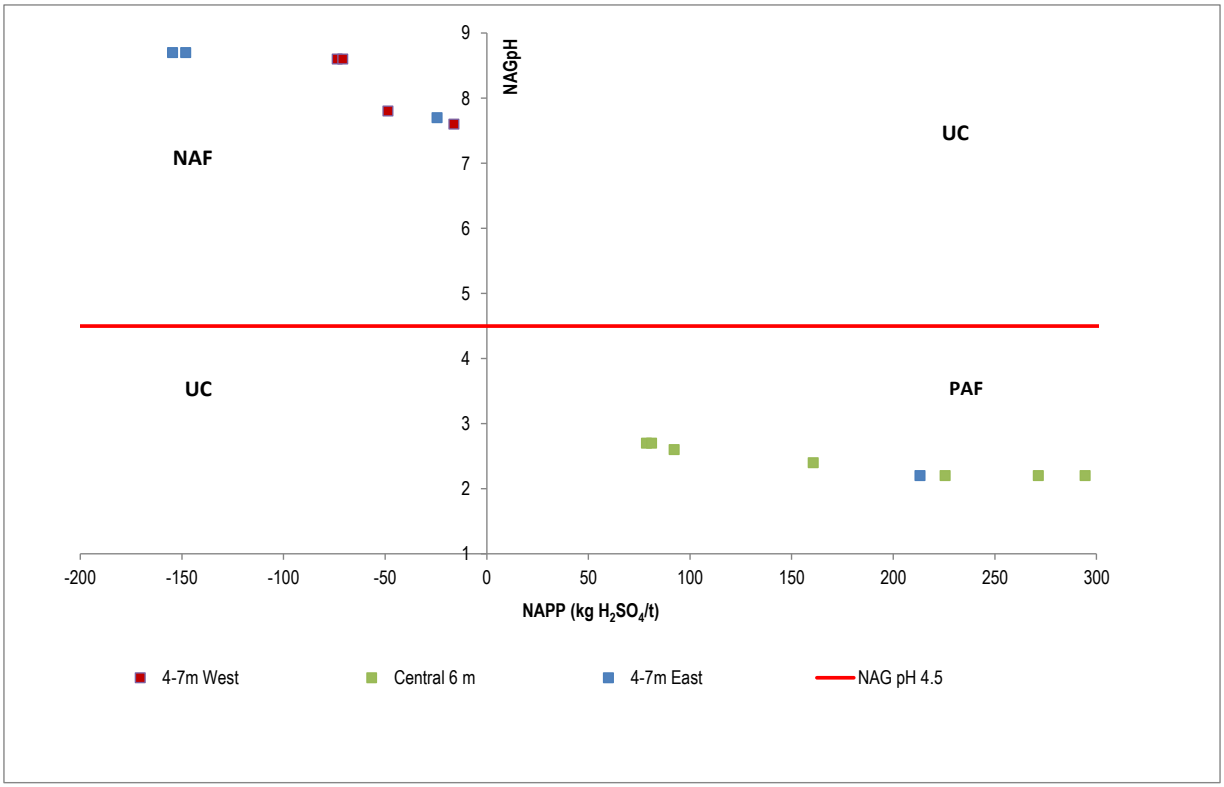


Chart 4: AMD Plot Classifications of Transect Samples

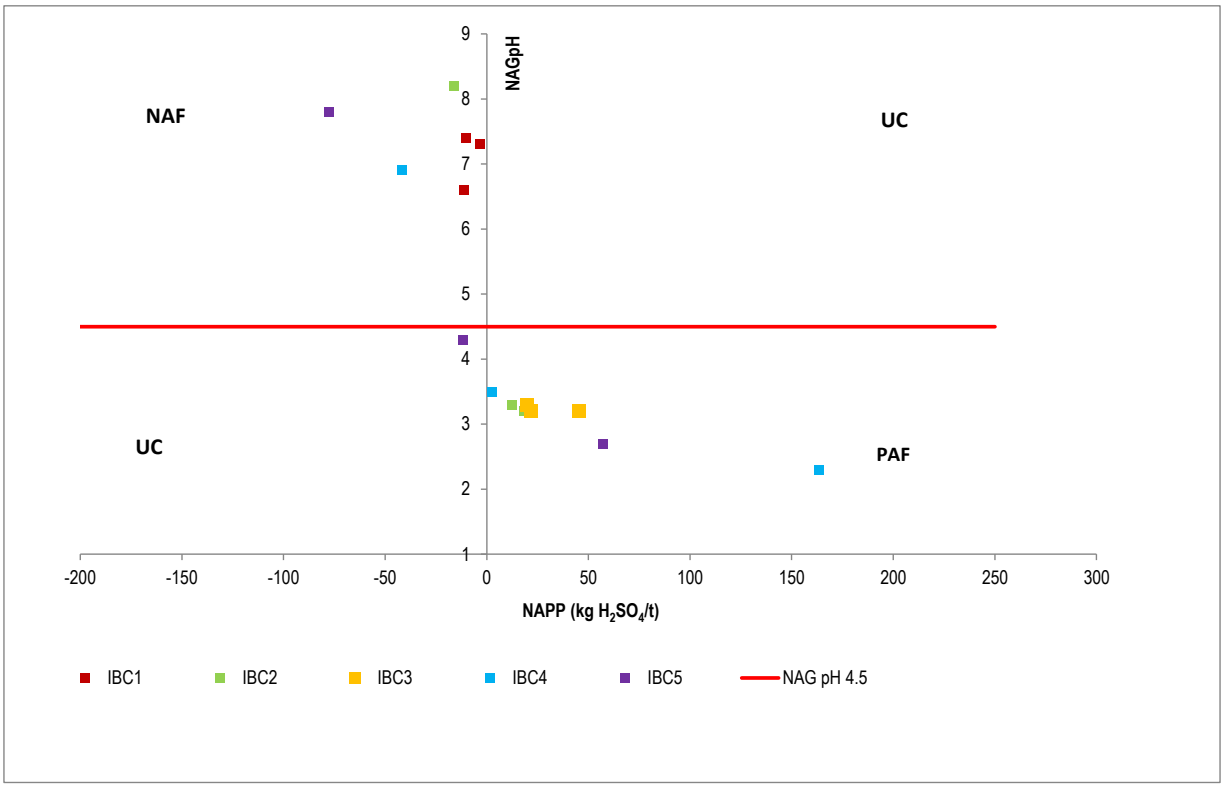


Chart 5: AMD Plot Classification of IBC Samples

6.1.4 AMD Potential Relative to Total Sulfur

An examination of all data from all studies to date was made for total sulfur content (as CRS was not measured by Graeme Campbell and Associates) versus the resultant NAGpH, which is considered as the most reliable indicator of potential for net acid generation. Data from the BF transect from GCA 2010 was grouped into central, western and eastern locations as done in Section 6.1.3 as well as data from the IBC trial and Soilwater Group study. A plot of total sulfur (% on a logarithmic scale) versus NAGpH for the combined data is shown below in Chart 6 and the following was noted in comparison of the data:

- Data for the current study relative to GCA 2010 samples agreed well in relation to western and eastern transect samples (18 of the 19 samples all having NAGpH >4.5 and being classed NAF) but differed markedly for the central transect section. GCA 2010 samples of central BF bed had much lower sulfur contents than current transect samples and only one GCA 2010 sample (4.2% total sulfur) had a NAGpH of less than 4.5 (i.e. PAF).
- The significantly lower sulfur content of IBC1 samples is evident from Chart 6, as well as the range of sulfur contents and NAGpH for samples from IBC5.

Excluding the IBC results in order to compare only data from fresh rock (non-exposed) samples, then the resulting plot of total sulfur versus NAGpH is shown in Chart 7 together with a line of best fit (co-efficient of determination of 0.72). This suggests crushed rock samples require a total sulfur content of approximately 3 to 4% in order to generate a NAGpH of less than 4.5. IBC trial samples were variable but suggest approximately 2% sulfur as a minimum for acid generation. Overall, based on the sulfur assay data from Section 4.2 a range of 2 to 4% sulfur content is assessed as the minimum required to potentially generate acid under worst case scenario conditions and this represents between 19 and 50% of BF waste.

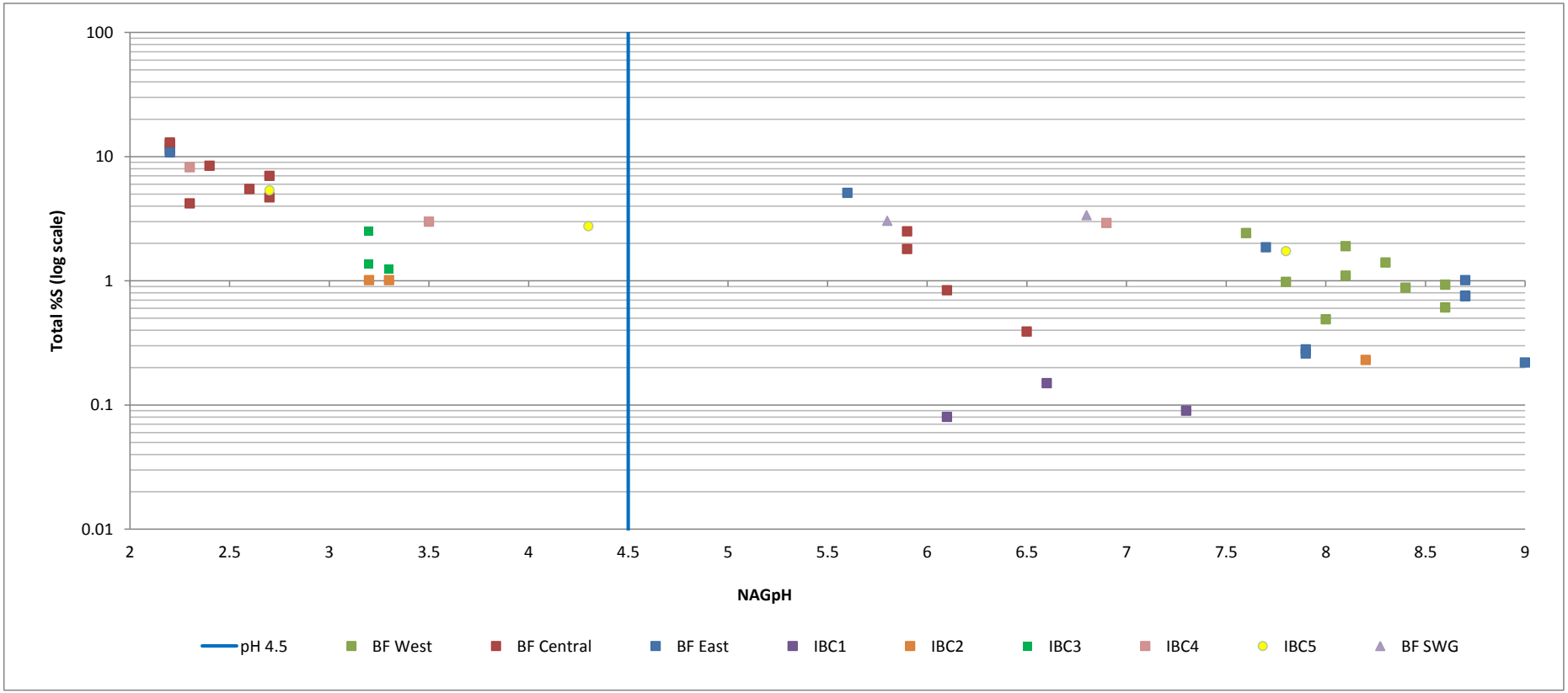


Chart 6: Total Sulfur (Log Scale) Versus NAGpH for all BF Samples

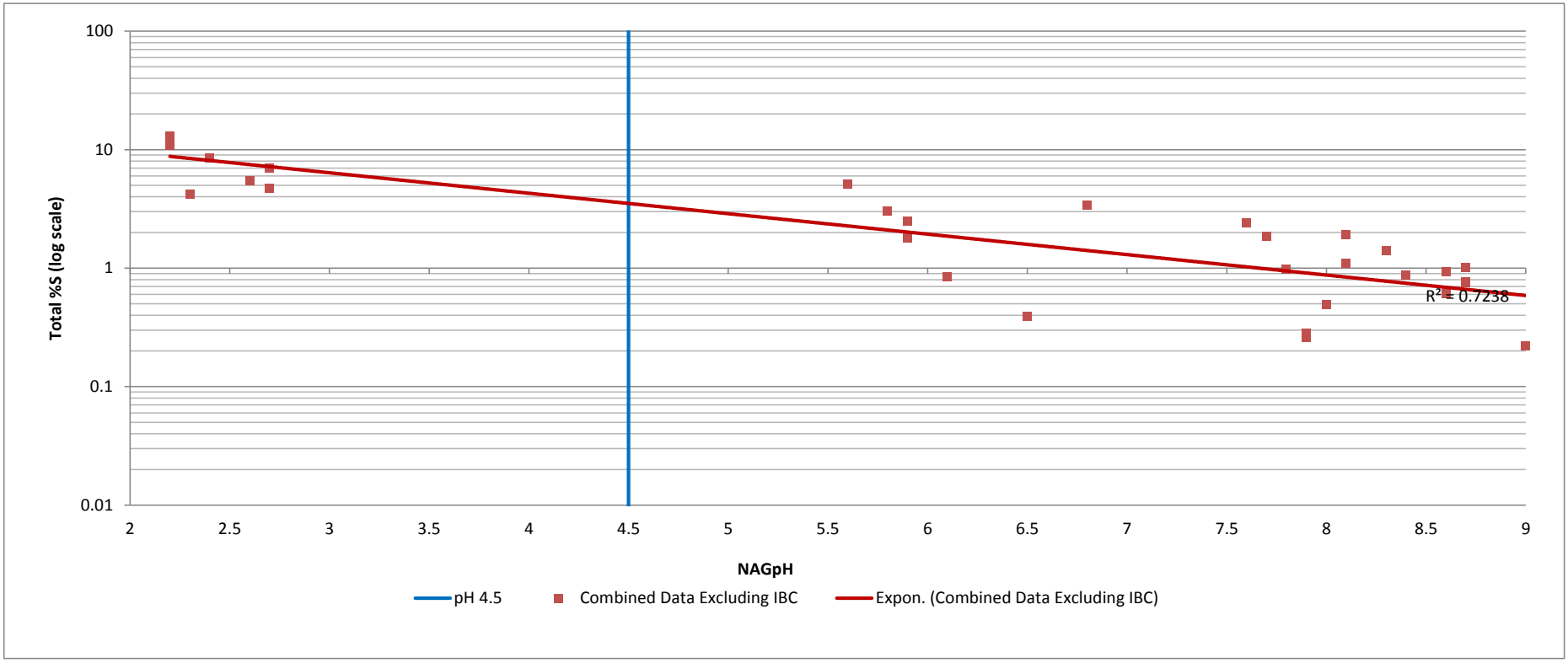


Chart 7: Total Sulfur (Log Scale) Versus NAGpH for BF Samples Excluding IBC Trial

6.2 ELEMENTAL COMPOSITION

Tables A1-3 and A1-4 of Appendix 1 present heavy metal and metalloid compositions for transect and IBC samples, respectively. Tables A1-5 and A1-6 of Appendix 1 presents calculated GAI values for these samples, as outlined in Section 2.2.2. A summary of current results for the primary enriched samples is provided in Table 11.

Key points noted are as follows:

- Gold concentrations in particular but also silver (which are expected to be enriched in samples from this mineralised zone) were highest in transect samples in the central and eastern/right hand side of the central shale bed, which corresponds with the lode zone side of mineralisation. IBC samples 1 to 3 were all enriched in gold. It should be noted that IBC3 (believed central bed area) may actually be considered low grade ore for mining and would thus not report as waste.[1]
- The other elements significantly enriched in approximately half or more of samples of BF were cadmium, copper, zinc, mercury, tellurium, antimony and selenium, with the latter four elements being the most consistently enriched across all samples. Sample T1-5 mR reported the highest concentrations of mercury and tellurium for all samples.
- Tellurium was not assessed in previous waste rock studies, but the Golden Mile deposit is well known to contain tellurides of mercury, gold and silver. Consistent with enrichment by both mercury and tellurium and on the basis of mercury speciation results in Gidji tailings (CSIRO 2013), mercury and tellurium present in samples of BF is considered to be primarily present as coloradoite (HgTe), which is highly insoluble.
- Arsenic was reported as being enriched by Graeme Campbell and Associates (GCA 2010) based on a global crustal average of 1.5 mg/kg. MBS have applied the average soil concentration of 25 mg/kg, which is considered to be more representative for material from the Yilgarn Craton. No samples were enriched in arsenic on this basis.
- Lead, molybdenum, bismuth and tin were enriched (exception of bismuth) only in single samples.

Overall, BF were geochemically enriched in a number of elements which are associated with the mineralisation of the Golden Mile deposit.

Table 11: Black Flag Shale Enriched Metals and Metalloids

Metal	Concentration Range (mg/kg)	Maximum GAI
Gold	<0.001 to 0.74	6
Silver	<0.05 to 28	6
Copper	27 to 1,897	5
Cadmium	0.1 to 15	6
Lead	12 to 143	3
Boron	<50 to 233	4
Mercury	0.07 to 61	6
Molybdenum	0.8 to 103 mg/kg	6
Antimony	5.3 to 374	6
Bismuth	0.0.09 to 2.7	3

[1] Measured gold content was approximately 0.25 g/tonne for IBC 3 but the analysis was for single small weight (25 gram) samples by aqua regia not preferred fire assay technique for gold using a large sample weight and gold concentration.

Metal	Concentration Range (mg/kg)	Maximum GAI
Selenium	<0.5 to 7.1	6
Tellurium	<0.2 to 86	6
Tin	1.0 to 15 mg/kg	3
Zinc	151 to 8,021	6

6.3 ANALYSIS OF IBC LIQUIDS

Collected runoff/leachate water was available in and collected from IBC2, IBC3 and IBC4. IBC containers 1 and 2 contained no rainwater leachate – possibly due to a leak in the IBC, but these IBC trial samples also did not indicate acid formation. It is important to note that concentrations of species in these collected liquids represent the concentrated result of 10 to 11 years of incident rainfall runoff and therefore care should be taken in drawing conclusions from them. The presence or absence of species (in particular metals and metalloids) however is a reasonable indication of the potential for leaching of those species to occur under worst case exposure conditions of the BF.

6.3.1 Soluble Salts and pH

Results for pH, EC, sulfur, calcium and magnesium on liquids collected from IBC2, IBC3 and IBC4 are collated in Table A1-7 of Appendix 1. These results indicate that:

- IBC3 was strongly acid (pH 2.1) while IBC2 was marginally acidic (pH 4.1) and IBC4 was circum-neutral. These results are consistent with field observations indicating a strong oxidation and reactions for PAF-HC material in IBC3, marginal oxidation in IBC2 and minimal overall oxidation of material in IBC4.
- The EC values of IBC3 and IBC4 were similar (64.8 and 69.4 mS/cm respectively), but sulfur content in IBC3 liquid was approximately double that of the circum-neutral IBC4. This result, and a higher concentration of sodium in IBC4, suggests a greater proportion of sodium chloride in IBC4 from general concentration of salts by evaporation versus IBC3, which has a significant contribution from sulfur oxidation of the material above. The EC value of IBC2 (2.8 mS/cm) and sulfur content (336 mg/L) was significantly lower and indicated only brackish water.
- Magnesium rather than calcium was the dominant cation associated with the sulfur (sulfate) in the liquids. Ankerite ($Ca(Fe,Mg,Mn)(CO_3)_2$) was the primary carbonate mineral determined by Graeme Campbell and Associates, but results indicate that the liquids in IBC3 and IBC4 are saturated with respect to gypsum and thus magnesium is the dominant cation.

6.3.2 Soluble Metals and Metalloids

Results for metals and metalloids are also collated in Table A1-7 of Appendix 1. These results indicate that:

- Under the circum-neutral and evapo-concentrated conditions established in IBC4, slightly elevated concentrations of selenium (0.7 mg/L), chromium (0.8 mg/L), cadmium (0.6 mg/L) and zinc (5.6 mg/L) were noted.
- Under slightly more acidic conditions of IBC2, chromium and selenium were not detectable, but aluminium (32 mg/L), copper (18 mg/L), manganese (7.1 mg/L), nickel (2.1 mg/L) and zinc (7.8 mg/L) were the most notable metals and metalloids released.
- Strongly acidic and evapo-concentrated conditions of IBC3 indicated aluminium (2,007 mg/L), iron (528 mg/L), copper (622 mg/L), manganese (365 mg/L), nickel (7.6 mg/L), cobalt (76 mg/L) and zinc (7.8 mg/L) would be the dominant metals and metalloids released under these worst-case conditions. Nickel and cobalt were released under these conditions, despite not being enriched in the bulk material.

- Mercury, tellurium, gold, silver and antimony were not found to be released in soluble forms regardless of pH despite their geochemical enrichment, with most of these elements not detected or just above detection limits in the liquid samples. This confirms the environmentally insoluble nature of the forms of these elements (e.g. as coloradoite).

6.4 ESTIMATION OF KINETIC OXIDATION RATE FROM IBC TRIALS

Initial results for (in particular) CRS are not available for the IBC trial samples to calculate the degree of oxidation in the samples during the approximately 11 year exposure. However an approximation of sulfide oxidation rate can be made based on the sulfate content of the IBC samples if it is assumed minimal net leaching of sulfate has occurred – due to low rainfall and the limited solubility of gypsum. Sulfate concentrations were very low in unexposed fresh rock (Section 6.1.1).

Sulfate sulfur results in the 0.5 m depth samples of the IBCs, where it is expected that the majority of sulfate formed should remain in-situ, ranged from 0.24 to 0.97%. This corresponds to an AP of 7.3 to 30 kg H_2SO_4/t or averaged over 11 years an acid production rate of 0.7 to 2.7 kg H_2SO_4/t per annum. The maximum sulfate content observed in any sample was due to the surface oxidation of PAF-HC material in IBC3 at 1.77%. This corresponds to formation of 54 kg H_2SO_4/t or a rate of 4.9 kg H_2SO_4/t per annum. Given these acid production rates and the typical available ANC content of BFs tested (50 to 100 kg H_2SO_4/t), the material can be classified as PAF long lag with the 'long lag' sub classification indicating that a delay period of several years before significant acid formation and leachate is likely, even for PAF-HC samples (Glossary, Section 9).

7. CONCLUSIONS AND IMPLICATIONS FOR MANAGEMENT

7.1 CONCLUSIONS

The results of a review of all geochemical testing and sulfur assay data available to date indicate that fresh mafic waste rock (Paringa Basalt and GM Dolerite) is:

- Classified as NAF with neutral to alkaline pH and low to moderate salinity levels. GM Dolerite is further classified as being primarily acid consuming (AC) for the majority of samples tested with low sulfur content (more than half of all assay samples being less than 0.3% sulfur of the analysis concept) and high ANC content.
- Very low in concentrations of environmentally significant metals and metalloids, with enrichment noted for the expected gold, silver, antimony and some for mercury (tellurium would also be expected to be enriched in such samples). These metals and metalloids, however, were not been found to be soluble under simulated weathering/kinetic testing conditions and as such are not of any concern for biological uptake or seepage into the receiving hypersaline groundwater at KCGM.
- Suitable for rock armouring and other construction purposes, given the benign geochemical nature and physical competence of this material. In particular GM Dolerite is also suitable as high ANC (acid consuming) waste rock in which to encapsulate PAF material (namely BF).

The results of a review of sulfur assay data, static testing, and kinetic testing including current additional testwork on BF waste rock indicate that:

- A review of BF sulfur assay results from 2,687 samples indicated a median sulfur content of 1.98% and 90th percentile sulfur content of 5.49%. Due to the presence of organic sulfur, total sulfur concentrations tend to overestimate the amount of oxidisable sulfur content and CRS was found to be a better measure of oxidisable sulfur. The proportion of CRS to total sulfur was however relatively consistent for fresh rock samples at an average of 84%.
- Strong correlations of oxidisable sulfur (in the form of pyrite) and ANC (in the form of ankerite) were found by position within the BF bed. The central six metres of the BF bed was found to be the dominant sulfide and lower ANC zone, but 'fingers' of sulfides and carbonates were found to occur outside this zone as well. Siderite (iron carbonate) was also present in various samples, but does not contribute to ANC.
- Due to the spatial variability of the BF material in composition, some inherent variability in the nature of the material and its potential to oxidise and generate AMD was observed - particularly as seen in IBC field trials over 11 years (Section 6.3).
- Study of all static and kinetic results including field IBC trials indicate that a period of several (5 to 10) years full exposure is expected prior to material potentially producing AMD (i.e. there is a significant 'lag' between exposure and generation of AMD). Additionally, oxidation rates were seen to decrease below a depth of 1 m from the surface. Sulfide oxidation rates of 0.7 to 2.7 kg H_2SO_4/t per annum were estimated for material under worst case (fully exposed) conditions. It is noted though that not all samples of BF appear to react significantly under field or laboratory kinetic conditions – the above is an estimation of sulfide oxidation rates from the most reactive materials tested.
- Overall, based on estimations from total sulfur content and measured NAGpH, it is predicted that BF waste with between 2 and 4% sulfur content is required in order to potentially generate AMD and be classified as PAF - long lag. Given the median sulfur content of all assay samples was 1.98% this indicates the waste unit as a whole is at the tipping point of classification. Assay results from 2 to 4% sulfur relate to a potential of 19 to 50% of BF waste being PAF -long lag under worst case scenario conditions.
- BF material is enriched in various metals and metalloids (Au, Ag, Hg, Te, Sb, Se, Cd, Cu, Zn in particular) at levels significantly higher than found for surrounding GM Dolerite and Paringa Basalt, as expected for material within or approaching the lode zone. However, samples of fresh BF material have low

concentrations of soluble metals and metalloids, and leachates are circum-neutral to alkaline with low to moderate salinity. Extreme weathering under worst case exposure conditions of PAF-HC material in IBC trials still do not release soluble Hg, Te or Sb, however with Al, Mn, Fe, Cu, Ni, Co and Zn instead being the primary metals of environmental significance released.

7.2 IMPLICATIONS FOR BF MANAGEMENT

Applying the above results to management of waste rock at KCGM, it has been determined that the overall proportion of fresh rock BF is minor (3.1%) in relation to total rock volume and at most half (50% conservative maximum) of this waste material would actually be capable of generating AMD (i.e. PAF) if left fully exposed. Inherent sulfide oxidation rates are very slow, with a significant lag period of years for acid generation. There is also significant ANC within the host rock such that net acid generation and associated metals leaching from open exposure to rainfall should only be possible after very prolonged exposure. Therefore, current waste dumping operating guidelines at KCGM which ensure encapsulation of BF within surrounding mafic waste rock (Paringa Basalt and GM Dolerite) is deemed entirely adequate to minimise the potential for AMD during operations. In particular GM Dolerite is very high ANC and mostly classified acid consuming in nature such that when used to encapsulate BF waste will provide an excess buffering capacity for any acid formation. Final waste dump design with a store and release cover which prevents water infiltration and sufficiently minimises potential oxidation of the BF is deemed an adequate long term management strategy.

Other management strategies, such as backfill and inundation of BF waste material within the final pit lake at closure are also considered to be a viable alternative for management, should waste dumping become undesirable from a mine planning perspective. This (backfilling) is not however considered to be required simply on the basis of risk management for BF waste.

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9. GLOSSARY OF TECHNICAL TERMS

Term	Explanation
AC	Acid consuming material.
ANC	Acid Neutralising Capacity. A process where a sample is reacted with excess 0.5 m HCl at a pH of about 1.5, for 2-3 hours at 80-90ºC followed by back-titration to pH=7 with sodium hydroxide. This determines the acid consumed by soluble materials in the sample.
ankerite	A calcium, iron, magnesium, manganese carbonate mineral of general formula $Ca(Fe,Mg,Mn)(CO_3)_2$. In composition it is closely related to dolomite, but differs from this in having magnesium replaced by varying amounts of iron(II) and manganese(II).
AP	Acid Potential. Similar to MPA, but only is based on the amount of sulfide-sulfur (calculated as the difference between total sulfur and sulfate-sulfur (SO_4-S), or directly as CRS) rather than total sulfur. AP (kg H_2SO_4/t) = (Total S – SO_4-S) x 30.6
Basalt	A dark coloured fine grained mafic extrusive igneous rock composed chiefly of calcium plagioclase and pyroxene. Extrusive equivalent of gabbro, underlies the ocean basins and comprises oceanic crust.
Carb NP	Carbon Neutralising Potential. The amount of ANC provided by carbonate minerals. Carb NP (kg H_2SO_4/t) = TIC (%) x 81.7
CIL	Carbon in Leach – the process of extracting gold from crushed rock by extraction with sodium cyanide solution and adsorption onto activated charcoal.
Circum-neutral pH	pH value near 7.
CRS	Chromium Reducible Sulfur. A measurement of reactive sulfide sulfur normally applied to acid sulfate soils using reaction with metallic chromium and hydrochloric acid to liberate hydrogen sulfide gas which is trapped and then measured by iodometric titration. For certain sample types, it is considered to be a more accurate estimate of oxidisable sulfur for iron sulfides than the difference between total sulfur and sulfate-sulfur (SO_4-S) for calculating Acid potential (AP).
Dolerite	A mafic, holocrystalline, subvolcanic rock equivalent to volcanic basalt or plutonic gabbro
dolomite	Calcium magnesium carbonate $CaMg(CO_3)_2$.
EC	Electrical conductivity. A measurement of solution salinity. Conversion: 1000 µS/cm = 1 dS/m = 1 mS/cm
felsic	Silicate minerals, magma, and rocks which are enriched in the lighter elements such as silicon, oxygen, aluminium, sodium, and potassium.
mafic	Descriptive of igneous rock containing a high content of ferromagnesian silicate minerals, but less than those present in ultramafic rocks. Common mafic rocks include basalt, dolerite and gabbro.
MPA	Maximum Potential Acidity. A calculation where the total sulfur in the sample is assumed to all be present as pyrite. This value is multiplied by 30.6 to produce a value known as the Maximum Potential Acidity reported in units of kg H_2SO_4/t. MPA should include only the non-sulfate sulfur to avoid over-estimation of acid production in which case it may be referred to as AP.
NAF	Non Acid Forming
NAG	Net Acid Generation. A process where a sample is reacted with 15% hydrogen peroxide solution at pH = 4.5 to oxidise all sulfides and then time allowed for the solution to react with acid soluble materials. This is a direct measure of the acid generating capacity of the

	sample but can be affected by the presence of organic materials.
NAPP	Net Acid Producing Potential. NAPP (kg H_2SO_4/t) = AP – ANC. NAPP (kg H_2SO_4/t) = AP – ANC
effective NAPP	NAPP calculated using CarbNP rather than traditional ANC. Effective NAPP (kg H_2SO_4/t) = AP – CarbNP
PAF	Potentially Acid Forming. A sample is classified as PAF if the NAGpH is less than 4.5 and NAPP is positive (i.e. AP is greater than ANC).
PAF-LC	Potentially Acid Forming – Low Capacity. Waste rock classification for samples with NAPP values less than or equal to 10 kg H_2SO_4/t.
PAF-HC	Potentially Acid Forming – High Capacity. Waste rock classification for samples with NAPP values greater than 10 kg H_2SO_4/t.
PAF short lag PAF long log	Sub classifications of PAF which reflects the relative time required for acid formation being generally taken as short (< 2 years) or long (> 2 years) under field exposed conditions. The lag period before acid formation is controlled by the amount and reactivity of available ANC to neutralise acid as it is formed by oxidation.
pyrite	Iron (II) sulfide, FeS_2. Pyrite is the most common sulfide minerals and the major acid forming mineral oxidising to produce sulfuric acid.
siderite	Iron(II) carbonate $FeCO_3$. Siderite reacts with acid to release ferrous ions (pale green) which then oxidise to ferric (brown) and this in turn generates acidity equal to the initial acid consumption by carbonate. It therefore does not overall contribute to ANC.
TIC	Total Inorganic Carbon.
XRD	X-Ray Diffraction. A laboratory technique used to identify and quantify crystalline mineral phases in geological materials measuring diffraction angles and patterns from a finely ground sample.
XRF	X-Ray Fluorescence. An analytical technique that measures elemental composition by the detection of fluorescent (or secondary) X-rays emitted from the elements after irradiation by an X-ray source.

APPENDICES

APPENDIX 1: COLLATED RESULTS

Table A1-1: Transect Samples - Acid-Base Accounting

Sample	pH (1:5)	EC (1:5)	Total S	CRS	Sulfate-S	Total C	Inorg.C	AP	ANC	Carb-NP	NAPP	NAG (pH 7)	NAG (pH 4.5)	NPR	NAGpH	Class
	pH units	µS/cm	%	%	%	%	%	kg H_2SO_4/tonne						(ANC/AP)	pH units	
T1 - 7mR	8.80	838	1.01	0.83	0.06	2.9	2.9	25	180	235	-155	0	0	7.1	8.7	NAF (AC)
T1 - 6mR	9.10	257	1.86	1.62	0.07	1.0	0.9	50	74	73	-24	0	0	1.5	7.7	NAF
T1 - 5mR	4.80	885	10.82	7.26	0.19	2.9	0.1	222	9	7	213	285	243	0.0	2.2	PAF-HC
T1 - 4mR	9.00	406	0.75	0.62	0.02	2.7	2.7	19	167	218	-148	0	0	8.8	8.7	NAF (AC)
T1 - 3mR	5.60	2670	12.64	10.60	0.30	5.4	0.6	324	53	51	271	278	227	0.2	2.2	PAF-HC
T1 - 2mR	6.90	1902	6.99	6.13	0.22	4.2	1.4	188	109	113	79	73	60	0.6	2.7	PAF-HC
T1 - 1mR	7.80	629	4.69	4.35	0.17	1.5	0.6	133	52	50	81	83	66	0.4	2.7	PAF-HC
T1 Central	8.10	1051	5.48	4.68	0.18	1.5	0.7	143	51	54	92	107	93	0.4	2.6	PAF-HC
T1 - 1mL	7.20	1561	8.45	7.31	0.07	6.1	0.7	224	63	59	161	172	145	0.3	2.4	PAF-HC
T1 - 2mL	7.20	1449	11.32	9.20	0.16	8.0	0.6	282	56	51	226	254	208	0.2	2.2	PAF-HC
T1 - 3mL	6.80	1936	12.99	10.70	0.16	9.7	0.3	327	33	26	294	298	241	0.1	2.2	PAF-HC
T1 - 4mL	8.90	282	0.98	0.80	0.06	1.2	1.0	24	73	80	-49	0	0	3.0	7.8	NAF
T1 - 5mL	9.40	314	0.61	0.51	0.03	1.4	1.4	16	89	110	-73	0	0	5.7	8.6	NAF
T1 - 6mL	9.20	259	2.42	2.35	0.15	1.4	1.3	72	88	107	-16	0	0	1.2	7.6	NAF
T1 - 7mL	9.20	328	0.93	0.76	0.05	1.6	1.5	23	94	124	-71	0	0	4.1	8.6	NAF

Denotes PAF classification

Denotes Uncertain classification

Denotes NAF classification

Table A1-2-: IBC Samples - Acid-Base Accounting

Sample	pH (1:5)	EC (1:5)	Total S	CRS	Sulfate-S	Total C	Inorg. C	AP	ANC	Carb-NP	NAPP	NAG (pH 7)	NAG (pH 4.5)	NPR	NAGpH	Class
	pH units	mS/cm	%	%	%	%	%	kg H_2SO_4/tonne						(ANC/AP)	pH units	
IBC1 0 m	6.60	166	0.15	0.06	0.09	2.17	0.0	2	13	0	-11	N/A	N/A	7.6	N/A	NAF
IBC1 0.5 m	7.30	2820	0.09	0.03	0.06	1.52	0.0	1	4	0	-3	N/A	N/A	5.2	N/A	NAF
IBC1 1m	7.40	2330	0.08	0.02	0.06	1.65	0.0	1	11	0	-10	N/A	N/A	17.1	N/A	NAF
IBC2 0 m	6.10	722	0.23	0.07	0.16	1.98	0.2	2	18	13	-16	0	0	9.0	8.2	NAF
IBC2 0.5m	3.80	1372	1.01	0.46	0.48	1.08	0.0	14	-4	2	18	13	5	-0.3	3.2	PAF-HC
IBC2 1 m	4.50	1453	1.01	0.54	0.42	0.90	0.1	17	4	11	13	7	3	0.2	3.3	PAF-HC
IBC3 0 m	4.10	5300	2.49	0.74	1.77	0.87	0.0	23	-23	0	46	33	18	-1.0	3.2	PAF-HC
IBC3 0.5 m	4.10	3140	1.24	0.22	0.97	0.81	0.0	7	-13	1	20	7	3	-1.9	3.3	PAF-HC
IBC3 1m	3.80	3720	1.37	0.39	0.89	0.68	0.0	12	-10	0	22	10	4	-0.8	3.2	PAF-HC
IBC4 0 m	7.60	271	2.99	2.83	0.09	2.72	1.0	87	84	78	3	20	10	1.0	3.5	PAF-LC
IBC4 0.5 m	7.50	1069	2.92	2.65	0.24	2.83	1.4	81	123	113	-42	1	0	1.5	6.9	NAF
IBC4 1m	6.80	2036	8.22	7.21	0.32	5.16	0.6	221	57	49	164	179	151	0.3	2.3	PAF-HC
IBC5 0 m	7.90	391	1.73	1.52	0.18	2.37	1.5	47	124	119	-77	0	0	2.7	7.8	NAF
IBC5 0.5 m	7.10	513	2.75	2.66	0.26	2.84	1.1	81	93	91	-12	4	1	1.1	4.3	UC
IBC5 1 m	6.80	1078	5.35	4.59	0.23	3.55	0.7	140	83	60	57	78	59	0.6	2.7	PAF-HC

Denotes PAF classification

Denotes Uncertain classification

Denotes NAF classification

Table A1-3: Transect Samples - Metals and Metalloids

Sample	Au	Ag	Al	As	B	Ba	Be	Bi	Ca	Cd	Co	Cr	Cu	Fe	Hg
	mg/kg	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	%	mg/kg
T1 - 7mR	0.08	0.2	7.0	89	<50	536	1.9	0.18	4.1	0.23	27	89	34	6.7	0.33
T1 - 6mR	0.03	0.5	7.9	160	58	670	3.1	0.29	1.7	0.36	9.6	24	43	2.2	0.55
T1 - 5mR	0.29	28	6.4	276	53	238	3.1	1.31	0.2	4.4	76	81	685	10	61
T1 - 4mR	0.02	0.2	7.7	150	<50	145	0.7	0.10	5.3	0.52	57	164	110	7.2	0.22
T1 - 3mR	0.02	8.9	5.5	260	<50	314	3.4	1.57	1.1	10.4	120	68	1,213	12	7.6
T1 - 2mR	0.04	6.0	5.3	176	<50	362	2.9	0.98	2.4	4.9	62	45	549	6.7	3.4
T1 - 1mR	0.02	0.3	6.7	91	<50	452	1.7	0.45	1.1	0.45	31	34	290	5.0	0.27
T1 Central	0.05	0.5	6.4	79	<50	415	1.4	0.61	1.0	0.60	30	30	216	5.6	0.60
T1 - 1mL	0.01	2.3	6.7	227	188	450	1.4	1.42	1.3	9.2	88	72	1,049	8.0	4.20
T1 - 2mL	0.01	2.9	6.0	269	233	308	1.3	1.90	1.1	12	129	64	1,382	11	5.3
T1 - 3mL	0.001	3.4	5.9	343	101	334	1.3	2.66	0.5	15	159	77	1,897	11	5.8
T1 - 4mL	0.003	0.1	7.8	45	79	531	1.1	0.09	1.1	1.3	10	36	74	2.2	0.67
T1 - 5mL	<0.001	<0.05	8.0	41	109	570	1.1	0.09	1.7	0.24	8.2	31	27	1.9	0.12
T1 - 6mL	0.003	0.1	7.4	27	97	540	1.1	0.29	1.3	1.2	14	24	99	3.9	0.63
T1 - 7mL	0.001	<0.05	8.1	45	<50	607	1.2	0.11	1.4	0.50	10	29	47	2.7	0.30
Crustal Average	**0.004**	**0.07**	**8.2**	**25**	**10**	**425**	**2.8**	**0.17**	**4.1**	**0.11**	**20**	**100**	**50**	**4**	**0.08**

Table A1-3: Transect Samples - Metals and Metalloids Continued...

Sample	K	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Si	Sn	Te	U	V	Zn
	%	%	mg/kg	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
T1 - 7mR	2.8	2.4	1,186	2.9	0.7	74	21	10	0.8	25	1.1	0.5	0.9	78	187
T1 - 6mR	3.6	1.1	217	1.8	0.3	17	19	12	1.1	31	2.3	0.7	1.5	41	174
T1 - 5mR	2.9	0.3	113	103	0.2	122	113	374	11	28	6.9	86	1.9	293	2,080
T1 - 4mR	0.5	1.5	1,790	0.9	1.6	107	15	6.6	0.7	24	1.2	0.3	0.6	273	303
T1 - 3mR	2.5	0.9	243	9.8	0.2	145	115	416	12	24	15	22	2.3	431	5,134
T1 - 2mR	2.4	1.6	363	6.0	0.2	95	69	239	7.1	28	8.9	11	2.4	317	2,446
T1 - 1mR	3.1	0.8	240	1.7	0.2	38	63	18	4.8	31	4.4	0.7	1.7	35	198
T1 Central	2.8	0.8	223	2.1	0.2	41	63	22	5.6	31	4.5	1.5	1.5	56	309
T1 - 1mL	2.9	1.0	264	6.1	0.3	127	91	103	11	26	15	3.3	2.2	75	4,748
T1 - 2mL	2.6	0.9	290	7.1	0.2	159	109	131	15	25	15	4.1	2.5	69	6,137
T1 - 3mL	2.6	0.7	128	7.6	0.2	209	143	165	19	24	19	4.1	2.4	67	8,021
T1 - 4mL	3.4	1.4	489	1.2	0.2	19	12	6.2	1.6	34	5.1	<0.2	1.2	40	708
T1 - 5mL	3.5	1.4	681	0.8	0.2	18	16	7.3	<0.5	32	1.0	<0.2	1.2	40	138
T1 - 6mL	3.2	1.6	645	0.9	0.2	26	34	5.3	1.9	31	1.3	<0.2	1.1	37	730
T1 - 7mL	3.6	1.8	728	0.9	0.2	21	21	5.3	0.5	31	1.3	<0.2	1.0	42	330
Crustal Average	**2.1**	**2.3**	**950**	**1.5**	**2.3**	**75**	**14**	**0.2**	**0.2**	**N/A**	**2**	**0.001**	**2.7**	**135**	**75**

Table A1-4: IBC Samples - Metals and Metalloids

Sample	Au	Ag	Al	As	B	Ba	Be	Bi	Ca	Cd	Co	Cr	Cu	Fe	Hg
	mg/kg	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	%	mg/kg
IBC1 0 m	0.7	1.0	6.8	109	<50	536	1.0	0.61	0.04	0.20	9.6	47	212	5.2	1.4
IBC1 0.5 m	0.1	1.4	7.3	38	<50	746	1.1	0.49	0.1	0.07	3.4	29	37	2.4	0.84
IBC1 1m	0.2	1.3	7.1	57	<50	629	1.0	0.61	0.1	0.15	6.8	34	58	3.5	0.79
IBC2 0 m	0.3	1.3	7.3	81	<50	597	1.1	0.42	0.3	1.0	16	47	212	5.7	1.3
IBC2 0.5m	0.2	0.5	7.3	54	<50	504	1.0	0.34	0.2	0.46	8.7	49	125	3.0	0.86
IBC2 1 m	0.2	0.3	8.1	70	<50	516	1.0	0.29	0.5	0.50	12	55	137	3.9	0.66
IBC3 0 m	0.2	0.3	7.6	62	<50	439	1.1	0.34	0.1	5.6	56	47	791	3.1	0.81
IBC3 0.5 m	0.1	0.4	7.4	58	<50	510	0.9	0.34	0.3	1.2	13	44	197	3.0	0.71
IBC3 1m	0.09	0.3	8.0	55	<50	489	1.0	0.35	0.3	1.5	20	78	216	2.9	0.66
IBC4 0 m	0.01	0.6	6.7	83	<50	523	0.9	0.36	1.3	2.4	42	43	971	5.5	1.5
IBC4 0.5 m	0.02	0.6	6.0	57	<50	509	0.8	0.41	2.1	2.7	32	43	340	5.1	1.7
IBC4 1m	0.002	1.6	6.3	127	<50	533	1.0	1.32	0.8	5.3	88	57	854	9.7	3.6
IBC5 0 m	0.01	0.4	7.0	42	<50	534	0.8	0.26	2.1	1.2	24	53	164	4.8	1.0
IBC5 0.5 m	0.01	0.6	6.8	63	<50	584	1.1	0.44	1.6	2.0	38	139	359	5.2	1.5
IBC5 1 m	0.003	1.0	6.7	109	<50	587	0.9	1.02	1.3	3.3	59	47	431	7.0	2.4
Crustal Average	**0.004**	**0.07**	**8.2**	**25**	**10**	**425**	**2.8**	**0.17**	**4.1**	**0.11**	**20**	**100**	**50**	**4**	**0.08**

Table A1-4: IBC Samples - Metals and Metalloids Continued…

Sample	K	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Si	Sn	Te	U	V	Zn
	%	%	mg/kg	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
IBC1 0 m	2.2	0.4	62	2.4	0.4	38	28	23	2.9	32	3.5	0.9	1.6	75	382
IBC1 0.5 m	2.5	0.2	27	1.2	0.5	16	17	9.2	2.5	35	4.7	0.6	1.7	49	151
IBC1 1m	2.4	0.3	57	1.3	0.5	30	17	9.0	3.0	35	3.9	0.7	2.1	49	275
IBC2 0 m	2.4	0.5	105	2.1	0.4	42	20	8.4	1.8	30	3.0	0.7	2.3	83	356
IBC2 0.5m	2.4	0.2	67	2.0	0.6	23	23	11	2.4	34	3.6	0.5	1.1	66	224
IBC2 1 m	2.4	0.3	118	1.6	0.6	31	23	11	2.7	31	3.0	0.5	1.2	94	388
IBC3 0 m	2.3	0.8	405	1.9	0.9	80	25	12	3.8	29	3.3	0.7	1.3	51	490
IBC3 0.5 m	2.4	0.3	89	1.3	0.7	25	20	10	2.6	32	3.2	0.4	1.0	72	154
IBC3 1m	2.2	0.3	153	1.3	1.7	36	22	8.7	2.1	31	2.6	0.4	1.1	74	189
IBC4 0 m	1.9	2.2	334	1.4	0.9	49	36	6.1	4.7	28	4.3	0.5	1.5	57	1,285
IBC4 0.5 m	1.9	2.2	511	1.6	0.7	47	30	7.6	4.1	26	3.4	0.7	1.2	58	1,513
IBC4 1m	2.1	1.7	232	3.3	0.5	116	66	20	9.6	24	8.5	1.8	1.8	50	3,444
IBC5 0 m	2.1	2.4	543	1.6	0.9	43	20	7.0	1.7	26	3.5	0.3	1.5	88	629
IBC5 0.5 m	2.0	2.2	353	1.7	1.0	85	28	7.0	3.5	27	4.1	0.6	1.7	67	1,050
IBC5 1 m	2.2	2.0	315	2.5	0.5	70	43	15	5.9	26	6.2	1.3	2.0	52	1,743
Crustal Average	**2.1**	**2.3**	**950**	**1.5**	**2.3**	**75**	**14**	**0.2**	**0.2**	**N/A**	**2**	**0.001**	**2.7**	**135**	**75**

Table A1-5: Transect Samples - Global Abundance Index

Sample	Au	Ag	Al	As	B	Ba	Be	Bi	Ca	Cd	Co	Cr	Cu	Fe
T1 - 7mR	4	1	0	0	1	0	0	0	0	0	0	0	0	0
T1 - 6mR	3	2	0	0	2	0	0	0	0	1	0	0	0	0
T1 - 5mR	6	6	0	0	2	0	0	2	0	5	1	0	3	1
T1 - 4mR	2	1	0	0	1	0	0	0	0	2	1	0	1	0
T1 - 3mR	2	6	0	0	1	0	0	3	0	6	2	0	4	1
T1 - 2mR	3	6	0	0	1	0	0	2	0	5	1	0	3	0
T1 - 1mR	2	2	0	0	1	0	0	1	0	1	0	0	2	0
T1 Central	3	2	0	0	1	0	0	1	0	2	0	0	2	0
T1 - 1mL	1	4	0	0	4	0	0	2	0	6	2	0	4	0
T1 - 2mL	0	5	0	0	4	0	0	3	0	6	2	0	4	1
T1 - 3mL	0	5	0	0	3	0	0	3	0	6	2	0	5	1
T1 - 4mL	0	0	0	0	2	0	0	0	0	3	0	0	0	0
T1 - 5mL	0	0	0	0	3	0	0	0	0	1	0	0	0	0
T1 - 6mL	0	0	0	0	3	0	0	0	0	3	0	0	0	0
T1 - 7mL	0	0	0	0	1	0	0	0	0	2	0	0	0	0

Table A1-5: Transect Global Abundance Index Continued...

Sample	Hg	K	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Sn	Te	U	V	Zn
T1 - 7mR	1	0	0	0	0	0	0	0	5	1	0	6	0	0	1
T1 - 6mR	2	0	0	0	0	0	0	0	5	2	0	6	0	0	1
T1 - 5mR	6	0	0	0	6	0	0	2	6	5	1	6	0	1	4
T1 - 4mR	1	0	0	0	0	0	0	0	4	1	0	6	0	0	1
T1 - 3mR	6	0	0	0	2	0	0	2	6	5	2	6	0	1	6
T1 - 2mR	5	0	0	0	1	0	0	2	6	5	2	6	0	1	4
T1 - 1mR	1	0	0	0	0	0	0	2	6	4	1	6	0	0	1
T1 Central	2	0	0	0	0	0	0	2	6	4	1	6	0	0	1
T1 - 1mL	5	0	0	0	1	0	0	2	6	5	2	6	0	0	5
T1 - 2mL	5	0	0	0	2	0	0	2	6	6	2	6	0	0	6
T1 - 3mL	6	0	0	0	2	0	1	3	6	6	3	6	0	0	6
T1 - 4mL	2	0	0	0	0	0	0	0	4	2	1	6	0	0	3
T1 - 5mL	0	0	0	0	0	0	0	0	5	0	0	6	0	0	0
T1 - 6mL	2	0	0	0	0	0	0	1	4	3	0	6	0	0	3
T1 - 7mL	1	0	0	0	0	0	0	0	4	1	0	6	0	0	2

Table A1-6: IBC Samples - Global Abundance Index

Sample	Au	Ag	Al	As	B	Ba	Be	Bi	Ca	Cd	Co	Cr	Cu	Fe
IBC1 0 m	6	3	0	2	1	0	0	1	0	0	0	0	2	0
IBC1 0.5 m	4	4	0	0	1	0	0	1	0	0	0	0	0	0
IBC1 1m	5	4	0	1	1	0	0	1	0	0	0	0	0	0
IBC2 0 m	5	4	0	1	1	0	0	1	0	3	0	0	1	0
IBC2 0.5m	5	2	0	1	1	0	0	0	0	1	0	0	1	0
IBC2 1 m	5	1	0	1	1	0	0	0	0	2	0	0	1	0
IBC3 0 m	5	1	0	1	1	0	0	0	0	5	1	0	3	0
IBC3 0.5 m	5	2	0	1	1	0	0	0	0	3	0	0	1	0
IBC3 1m	4	2	0	1	1	0	0	0	0	3	0	0	2	0
IBC4 0 m	1	2	0	1	1	0	0	0	0	4	0	0	4	0
IBC4 0.5 m	1	3	0	1	1	0	0	1	0	4	0	0	2	0
IBC4 1m	0	4	0	2	1	0	0	2	0	5	2	0	4	1
IBC5 0 m	1	2	0	0	1	0	0	0	0	3	0	0	1	0
IBC5 0.5 m	1	3	0	1	1	0	0	1	0	4	0	0	2	0
IBC5 1 m	0	3	0	2	1	0	0	2	0	4	1	0	3	0

Table A1-6: IBC Samples - Global Abundance Index Continued...

Sample	Hg	K	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Sn	Te	U	V	Zn
IBC1 0 m	4	0	0	0	0	0	0	0	6	3	0	6	0	0	2
IBC1 0.5 m	3	0	0	0	0	0	0	0	5	3	1	6	0	0	0
IBC1 1m	3	0	0	0	0	0	0	0	5	3	0	6	0	0	1
IBC2 0 m	3	0	0	0	0	0	0	0	5	3	0	6	0	0	2
IBC2 0.5m	3	0	0	0	0	0	0	0	5	3	0	6	0	0	1
IBC2 1 m	2	0	0	0	0	0	0	0	5	3	0	6	0	0	2
IBC3 0 m	3	0	0	0	0	0	0	0	5	4	0	6	0	0	2
IBC3 0.5 m	3	0	0	0	0	0	0	0	5	3	0	6	0	0	0
IBC3 1m	2	0	0	0	0	0	0	0	5	3	0	6	0	0	1
IBC4 0 m	4	0	0	0	0	0	0	1	4	4	1	6	0	0	4
IBC4 0.5 m	4	0	0	0	0	0	0	0	5	4	0	6	0	0	4
IBC4 1m	5	0	0	0	1	0	0	2	6	5	2	6	0	0	5
IBC5 0 m	3	0	0	0	0	0	0	0	5	3	0	6	0	0	2
IBC5 0.5 m	4	0	0	0	0	0	0	0	5	4	0	6	0	0	3
IBC5 1 m	4	0	0	0	0	0	0	1	6	4	1	6	0	0	4

Table A1-7: Analysis of IBC Leachates

Sample	pH	EC	Au	Ag	Al	As	B	Ba	Ca	Cd	Co	Cr	Cu	Fe	Hg	K
		mS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
IBC 2 - liquid	4.1	2.8	<0.001	0.002	32	<0.01	<1	0.01	130	0.2	1.9	<0.2	18	0.3	<0.01	3
IBC 3 - liquid	2.1	69.4	<0.001	0.005	2,007	0.5	6	0.01	605	7.2	76	2.4	622	528	<0.01	37
IBC 4 - liquid	7.3	64.8	<0.001	0.01	1	<0.01	4	0.04	622	0.6	0.01	0.8	<0.2	0.2	<0.01	109

Sample	Mg	Mn	Mo	Na	Ni	Pb	S	Sb	Se	Si	Te	U	V	Zn
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
IBC 2 - liquid	172	7.1	<0.005	205	2.1	0.3	336	0.002	<0.05	4	<0.01	<0.001	<0.5	7.8
IBC 3 - liquid	8,946	365	<0.005	3,199	88	0.3	13,397	0.004	0.3	102	0.02	0.1	2.1	282
IBC 4 - liquid	5,329	<0.1	0.007	7,949	<0.2	0.2	6,862	<0.001	0.7	4	<0.01	0.003	0.5	5.6

APPENDIX 2: LABORATORY RESULTS

ANALYTICAL REPORT

KALGOORLIE CONSOLIDATED GOLD MINES PTY
Private Mail Bag 27
KALGOORLIE, W.A. 6430
AUSTRALIA

JOB INFORMATION

JOB CODE	: 163.0/1705314
No. of SAMPLES	: 15
No. of ELEMENTS	: 46
CLIENT O/N	: 3100456 (Job 1 of 0)
SAMPLE SUBMISSION No.	:
PROJECT	: BLACK FLAG PIT SAMPLES
STATE	: Rock Chip
DATE RECEIVED	: 19/04/2017
DATE COMPLETED	: 25/05/2017
DATE PRINTED	: 25/05/2017
ANALYSING LABORATORY	: Intertek Genalysis Perth

LEGEND

X	= Less than Detection Limit
N/R	= Sample Not Received
*	= Result Checked
( )	= Result still to come
I/S	= Insufficient Sample for Analysis
E6	= Result X 1,000,000
UA	= Unable to Assay
>	= Value beyond Limit of Method
OV	= Value over-range for Package

MAIN OFFICE AND LABORATORY NATA: 3244 3273
15 Davison Street, Maddington 6109, Western Australia
PO Box 144, Gosnells 6990, Western Australia
Tel: +61 8 9251 8100 Fax: +61 8 9251 8110
Email: genalysis@intertek.com
Web Page: www.genalysis.com.au

KALGOORLIE SAMPLE PREPARATION DIVISION
12 Keogh Way, Kalgoorlie 6430, Western Australia
Tel: +61 8 9021 6057 Fax: +61 8 9021 3476

ADELAIDE LABORATORY NATA: 3244 18645
11 Senna Road, Wingfield, 5013, South Australia
Tel: +61 8 8162 9714 Fax: +61 8 8349 7444

JOHANNESBURG LABORATORY
43 Malcolm Moodie Crescent,
Jet Park, Gauteng, South Africa 1459
Tel: +27 11 552 8149 Fax: +27 11 552 8248

TOWNSVILLE LABORATORY NATA: 3244 20462
9-23 Kelli Street, Mt St John, Bohle, Queensland, Australia 4818
Tel: +61 7 4774 3655 Fax: +61 7 4774 4692

Results are not intended for commercial settlement purposes

SAMPLE DETAILS

DISCLAIMER

Intertek Genalysis wishes to make the following disclaimer pertaining to the accompanying analytical results.

All work is performed in accordance with the Intertek Minerals Standard Terms and Conditions of work http://www.intertek.com/terms/

This report relates specifically to the sample(s) that were drawn and/or provided by the client or their nominated third party. The reported result(s) provide no warranty or verification on the sample(s) representing any specific goods and/or shipment and only relate to the sample(s) as received and tested. This report was prepared solely for the use of the client named in this report. Intertek accepts no responsibility for any loss, damage or liability suffered by a third party as a result of any reliance upon or use of this report.

The results provided are not intended for commercial settlement purposes.

SIGNIFICANT FIGURES

It is common practice to report data derived from analytical instrumentation to a maximum of two or three significant figures. Some data reported herein may show more figures than this. The reporting of more than two or three figures in no way implies that the third, fourth and subsequent figures may be real or significant.

Intertek Genalysis accepts no responsibility whatsoever for any interpretation by any party of any data where more than two or three significant figures have been reported.

SAMPLE STORAGE DETAILS

GENERAL CONDITIONS

SAMPLE STORAGE OF SOLIDS

Bulk Residues and Pulps will be stored for 60 DAYS without charge. After this time all Bulk Residues and Pulps will be stored at a rate of $4.00 per cubic metre per day until your written advice regarding collection or disposal is received. Expenses related to the return or disposal of samples will be charged to you at cost. Current disposal cost is charged at $150.00 per cubic metre.

SAMPLE STORAGE OF SOLUTIONS

Samples received as liquids, waters or solutions will be held for 60 DAYS free of charge then disposed of, unless written advice for return or collection is received.

ANALYSIS

ELEMENTS	Au	Au-Rp1	Ag	Al	ANC	As
UNITS	ppb	ppb	ppm	ppm	kgH2SO4/t	ppm
DETECTION LIMIT	1	1	0.05	50	1	0.5
DIGEST	AR25/	AR25/	4A/	4A/	ANCx/	4A/
ANALYTICAL FINISH	MS	MS	MS	MS	VOL	MS
SAMPLE NUMBERS						
0001 T1 Central	46		0.45	6.36%	51	78.5
0002 T1 - 1mR	20		0.30	6.73%	52	91.2
0003 T1 - 2mR	36		6.01	5.30%	109	176.0
0004 T1 - 3mR	24		8.87	5.53%	53	260.1
0005 T1 - 4mR	20		0.16	7.71%	167	150.0
0006 T1 - 5mR	267	293	28.43	6.40%	9	275.6
0007 T1 - 6mR	34		0.53	7.89%	74	160.4
0008 T1 - 7mR	84		0.20	7.02%	180	88.8
0009 T1 - 1mL	9		2.25	6.72%	63	226.6
0010 T1 - 2mL	7		2.94	5.96%	56	269.1
0011 T1 - 3mL	1		3.40	5.92%	33	343.2
0012 T1 - 4mL	3		0.09	7.75%	73	45.4
0013 T1 - 5mL	X		X	7.97%	89	41.3
0014 T1 - 6mL	3		0.14	7.41%	88	26.9
0015 T1 - 7mL	1		X	8.14%	94	45.2
CHECKS						
0001 T1 - 5mL			X	7.96%		41.7
0002 T1 - 2mR						
0003 T1 - 2mR	36					
0004 T1 - 6mR						
0005 T1 - 3mR					52	
STANDARDS						
0001 CaCO3					981	
0002 OREAS 45d						
0003 PD-1						
0004 OREAS 45e			0.28	6.95%		16.3
0005 SARM48						
0006 HgSTD-8						
0007 NAG Std 3						
0008 OREAS 907	103					
0009 TOC-1						
0010 MPL-5			28.11	3.25%		964.6
0011 OREAS 121			0.06	4.70%		4.2
BLANKS						
0001 Control Blank						
0002 Control Blank					0	
0003 Control Blank	X					

ANALYSIS

ELEMENTS	B	Ba	Be	Bi	C	Ca
UNITS	ppm	ppm	ppm	ppm	%	ppm
DETECTION LIMIT	50	0.1	0.05	0.01	0.01	50
DIGEST	FP1/	4A/	4A/	4A/		4A/
ANALYTICAL FINISH	OE	MS	MS	MS	/CSA	MS
SAMPLE NUMBERS						
0001 T1 Central	X	415.1	1.41	0.61	1.51	1.01%
0002 T1 - 1mR	X	451.5	1.71	0.45	1.52	1.06%
0003 T1 - 2mR	X	362.3	2.94	0.98	4.23	2.42%
0004 T1 - 3mR	X	313.9	3.43	1.57	5.35	1.13%
0005 T1 - 4mR	X	145.0	0.67	0.10	2.71	5.31%
0006 T1 - 5mR	53	238.3	3.09	1.31	2.88	1719
0007 T1 - 6mR	58	670.2	3.14	0.29	1.01	1.66%
0008 T1 - 7mR	X	536.3	1.88	0.18	2.92	4.12%
0009 T1 - 1mL	188	450.1	1.43	1.42	6.13	1.31%
0010 T1 - 2mL	233	308.2	1.25	1.90	8.03	1.07%
0011 T1 - 3mL	101	334.1	1.33	2.66	9.71	5365
0012 T1 - 4mL	79	530.7	1.10	0.09	1.16	1.14%
0013 T1 - 5mL	109	569.7	1.08	0.09	1.38	1.74%
0014 T1 - 6mL	97	540.0	1.09	0.29	1.36	1.31%
0015 T1 - 7mL	X	607.3	1.24	0.11	1.57	1.39%
CHECKS						
0001 T1 - 5mL	105	569.9	1.02	0.09		1.78%
0002 T1 - 2mR						
0003 T1 - 2mR						
0004 T1 - 6mR						
0005 T1 - 3mR					5.30	
STANDARDS						
0001 CaCO3						
0002 OREAS 45d					1.03	
0003 PD-1						
0004 OREAS 45e		251.7	0.62	0.29		626
0005 SARM48	55					
0006 HgSTD-8						
0007 NAG Std 3						
0008 OREAS 907						
0009 TOC-1						
0010 MPL-5		576.8	21.22	38.00		4.15%
0011 OREAS 121		1009.6	1.45	0.04		777
BLANKS						
0001 Control Blank						
0002 Control Blank					X	
0003 Control Blank						

ANALYSIS

ELEMENTS	Cd	Co	ColourChange	Cr	Cu	EC
UNITS	ppm	ppm	NONE	ppm	ppm	uS/cm
DETECTION LIMIT	0.02	0.1	0	1	0.5	10
DIGEST	4A/	4A/	ANCx/	4A/	4A/	Ws/
ANALYTICAL FINISH	MS	MS	QUAL	MS	MS	MTR
SAMPLE NUMBERS						
0001 T1 Central	0.60	29.8	No	30	215.9	1051
0002 T1 - 1mR	0.45	30.6	No	34	289.5	629
0003 T1 - 2mR	4.91	61.8	No	45	549.3	1902
0004 T1 - 3mR	10.42	120.0	No	68	1212.9	2670
0005 T1 - 4mR	0.52	57.0	Yes	164	109.5	406
0006 T1 - 5mR	4.41	75.8	No	81	685.2	885
0007 T1 - 6mR	0.36	9.6	No	24	43.0	257
0008 T1 - 7mR	0.23	27.1	Yes	89	33.7	838
0009 T1 - 1mL	9.16	88.3	No	72	1049.0	1561
0010 T1 - 2mL	11.68	128.9	No	64	1382.0	1449
0011 T1 - 3mL	14.81	159.4	No	77	1897.0	1936
0012 T1 - 4mL	1.31	10.0	No	36	74.3	282
0013 T1 - 5mL	0.24	8.2	Yes	31	27.0	314
0014 T1 - 6mL	1.16	13.8	Yes	24	98.5	259
0015 T1 - 7mL	0.50	10.4	Yes	29	47.4	328
CHECKS						
0001 T1 - 5mL	0.21	8.1		31	26.6	
0002 T1 - 2mR						
0003 T1 - 2mR						1875
0004 T1 - 6mR						
0005 T1 - 3mR			No			
STANDARDS						
0001 CaCO3						
0002 OREAS 45d						
0003 PD-1						
0004 OREAS 45e	0.04	61.0		982	788.5	
0005 SARM48						
0006 HgSTD-8						
0007 NAG Std 3						
0008 OREAS 907						
0009 TOC-1						
0010 MPL-5	2.89	132.0		807	1879.1	
0011 OREAS 121	X	4.2		43	3.3	
BLANKS						
0001 Control Blank						
0002 Control Blank						
0003 Control Blank						X

ANALYSIS

ELEMENTS	Fe	Final-pH	Fizz-Rate	Hg	K	Mg
UNITS	ppm	NONE	NONE	ppb	ppm	ppm
DETECTION LIMIT	50	0.1	1	1	20	20
DIGEST	4A/	ANCx/	ANCx/	AR01/	4A/	4A/
ANALYTICAL FINISH	MS	MTR	QUAL	CV	MS	MS
SAMPLE NUMBERS						
0001 T1 Central	5.58%	0.8	X	598	2.79%	8253
0002 T1 - 1mR	5.04%	0.9	X	274	3.06%	8122
0003 T1 - 2mR	6.73%	0.9	X	3366	2.44%	1.60%
0004 T1 - 3mR	11.51%	0.9	X	7551	2.51%	8801
0005 T1 - 4mR	7.17%	1.4	2	224	4949	1.49%
0006 T1 - 5mR	10.27%	0.9	X	61257	2.90%	2602
0007 T1 - 6mR	2.16%	0.9	1	547	3.59%	1.09%
0008 T1 - 7mR	6.67%	1.3	2	331	2.84%	2.40%
0009 T1 - 1mL	7.98%	0.9	X	4204	2.94%	9772
0010 T1 - 2mL	11.00%	0.9	X	5270	2.62%	8823
0011 T1 - 3mL	11.45%	0.9	X	5793	2.60%	6910
0012 T1 - 4mL	2.22%	1.0	1	670	3.40%	1.38%
0013 T1 - 5mL	1.94%	1.0	2	124	3.46%	1.41%
0014 T1 - 6mL	3.94%	1.0	1	632	3.18%	1.56%
0015 T1 - 7mL	2.73%	1.0	1	298	3.56%	1.79%
CHECKS						
0001 T1 - 5mL	1.96%				3.47%	1.40%
0002 T1 - 2mR				3346		
0003 T1 - 2mR						
0004 T1 - 6mR						
0005 T1 - 3mR		0.9	X			
STANDARDS						
0001 CaCO3		1.1				
0002 OREAS 45d						
0003 PD-1						
0004 OREAS 45e	24.44%				3295	1584
0005 SARM48						
0006 HgSTD-8				3055		
0007 NAG Std 3						
0008 OREAS 907						
0009 TOC-1						
0010 MPL-5	3.55%				1.05%	8825
0011 OREAS 121	1.61%				2.62%	2416
BLANKS						
0001 Control Blank						
0002 Control Blank		0.8				
0003 Control Blank						

Results are not intended for commercial settlement purposes

ANALYSIS

ELEMENTS	Mn	Mo	C-Acinsol	MPA	Na	NAG
UNITS	ppm	ppm	%	kgH2SO4/t	ppm	kgH2SO4/t
DETECTION LIMIT	1	0.1	0.01	0.01	20	1
DIGEST	4A/	4A/	C71/		4A/	NAGx/
ANALYTICAL FINISH	MS	MS	CSA	/CALC	MS	VOL
SAMPLE NUMBERS						
0001 T1 Central	223	2.1	0.85	167.75	2079	107
0002 T1 - 1mR	240	1.7	0.91	143.49	1690	83
0003 T1 - 2mR	363	6.0	2.85	213.83	1854	73
0004 T1 - 3mR	243	9.8	4.73	386.78	2448	278
0005 T1 - 4mR	1790	0.9	0.04	23.00	1.62%	0
0006 T1 - 5mR	113	102.7	2.79	330.91	1756	285
0007 T1 - 6mR	217	1.8	0.12	56.79	2579	0
0008 T1 - 7mR	1186	2.9	0.04	30.96	7445	0
0009 T1 - 1mL	264	6.1	5.41	258.42	2692	172
0010 T1 - 2mL	290	7.1	7.41	346.26	2373	254
0011 T1 - 3mL	128	7.6	9.39	397.46	2398	298
0012 T1 - 4mL	489	1.2	0.18	29.97	1768	0
0013 T1 - 5mL	681	0.8	0.03	18.72	1909	0
0014 T1 - 6mL	645	0.9	0.05	73.88	1858	0
0015 T1 - 7mL	728	0.9	0.05	28.42	2138	0
CHECKS						
0001 T1 - 5mL	685	0.9			1903	
0002 T1 - 2mR						
0003 T1 - 2mR						74
0004 T1 - 6mR			0.11			
0005 T1 - 3mR				390.65		
STANDARDS						
0001 CaCO3						
0002 OREAS 45d				1.81		
0003 PD-1						
0004 OREAS 45e	553	2.4			565	
0005 SARM48						
0006 HgSTD-8						
0007 NAG Std 3						23
0008 OREAS 907						
0009 TOC-1			1.43			
0010 MPL-5	2214	20.3			5346	
0011 OREAS 121	765	7.5			2382	
BLANKS						
0001 Control Blank			X			
0002 Control Blank				0.17		
0003 Control Blank						5

ANALYSIS

ELEMENTS	NAGpH	NAG(4.5)	NAPP	Ni	Pb	pH
UNITS	NONE	kgH2SO4/t	kgH2SO4/t	ppm	ppm	NONE
DETECTION LIMIT	0.1	1	1	0.5	0.5	0.1
DIGEST	NAGx/	NAGx/		4A/	4A/	Ws/
ANALYTICAL FINISH	MTR	VOL	/CALC	MS	MS	MTR
SAMPLE NUMBERS						
0001 T1 Central	2.6	93	117	40.9	63.1	8.1
0002 T1 - 1mR	2.7	66	92	37.5	63.2	7.8
0003 T1 - 2mR	2.7	60	105	95.1	69.0	6.9
0004 T1 - 3mR	2.2	227	334	144.5	114.9	5.6
0005 T1 - 4mR	8.7	0	-144	107.2	14.8	9.0
0006 T1 - 5mR	2.2	243	322	121.5	113.1	4.8
0007 T1 - 6mR	7.7	0	-17	16.6	19.0	9.1
0008 T1 - 7mR	8.7	0	-149	73.7	20.5	8.8
0009 T1 - 1mL	2.4	145	195	127.3	90.7	7.2
0010 T1 - 2mL	2.2	208	290	158.7	108.5	7.2
0011 T1 - 3mL	2.2	241	365	208.5	142.9	6.8
0012 T1 - 4mL	7.8	0	-43	19.0	11.9	8.9
0013 T1 - 5mL	8.6	0	-70	18.3	15.8	9.4
0014 T1 - 6mL	7.6	0	-14	25.5	34.1	9.2
0015 T1 - 7mL	8.6	0	-65	21.0	20.7	9.2
CHECKS						
0001 T1 - 5mL				18.4	15.5	
0002 T1 - 2mR						
0003 T1 - 2mR	2.7	65				6.9
0004 T1 - 6mR						
0005 T1 - 3mR			339			
STANDARDS						
0001 CaCO3						
0002 OREAS 45d						
0003 PD-1						
0004 OREAS 45e				455.5	20.8	
0005 SARM48						
0006 HgSTD-8						
0007 NAG Std 3	2.5	19				
0008 OREAS 907						
0009 TOC-1						
0010 MPL-5				2368.2	2065.5	
0011 OREAS 121				9.7	20.7	
BLANKS						
0001 Control Blank						
0002 Control Blank			0			
0003 Control Blank	4.6	0				5.7

ANALYSIS

ELEMENTS	pH Drop	S	S	S-SO4	Sb	Se
UNITS	NONE	%	%	%	ppm	ppm
DETECTION LIMIT	0.1	0.01	0.005	0.01	0.05	0.5
DIGEST	ANCx/		SCR/	S71/	4A/	4A/
ANALYTICAL FINISH	MTR	/CSA	VOL	OE	MS	MS
SAMPLE NUMBERS						
0001 T1 Central	3.5	5.48	4.680	0.18	22.47	5.6
0002 T1 - 1mR	3.7	4.69	4.350	0.17	18.16	4.8
0003 T1 - 2mR	3.6	6.99	6.130	0.22	239.10	7.1
0004 T1 - 3mR	3.3	12.64	10.600	0.30	415.62	11.9
0005 T1 - 4mR	2.9	0.75	0.617	0.02	6.58	0.7
0006 T1 - 5mR	3.5	10.82	7.260	0.19	374.26	11.1
0007 T1 - 6mR		1.86	1.620	0.07	12.38	1.1
0008 T1 - 7mR	3.0	1.01	0.831	0.06	10.03	0.8
0009 T1 - 1mL	3.7	8.45	7.310	0.07	103.44	11.2
0010 T1 - 2mL	3.3	11.32	9.200	0.16	131.16	15.4
0011 T1 - 3mL	3.9	12.99	10.700	0.16	164.74	19.3
0012 T1 - 4mL	3.4	0.98	0.799	0.06	6.22	1.6
0013 T1 - 5mL	3.3	0.61	0.507	0.03	7.29	X
0014 T1 - 6mL	3.3	2.42	2.350	0.15	5.31	1.9
0015 T1 - 7mL	3.2	0.93	0.757	0.05	5.34	0.5
CHECKS						
0001 T1 - 5mL					7.47	X
0002 T1 - 2mR						
0003 T1 - 2mR						
0004 T1 - 6mR						
0005 T1 - 3mR	3.3	12.77		0.31		
STANDARDS						
0001 CaCO3						
0002 OREAS 45d		0.06				
0003 PD-1				4.14		
0004 OREAS 45e					1.04	2.8
0005 SARM48						
0006 HgSTD-8						
0007 NAG Std 3						
0008 OREAS 907						
0009 TOC-1						
0010 MPL-5					336.40	127.8
0011 OREAS 121					0.16	X
BLANKS						
0001 Control Blank						
0002 Control Blank		X		X		
0003 Control Blank						

Results are not intended for commercial settlement purposes

ANALYSIS

ELEMENTS	Si	Sn	Te	U	V	Zn
UNITS	%	ppm	ppm	ppm	ppm	ppm
DETECTION LIMIT	0.1	0.1	0.2	0.01	1	1
DIGEST	FP1/	4A/	4A/	4A/	4A/	4A/
ANALYTICAL FINISH	OE	MS	MS	MS	MS	MS
SAMPLE NUMBERS						
0001 T1 Central	30.8	4.5	1.5	1.49	56	309
0002 T1 - 1mR	31.2	4.4	0.7	1.65	35	198
0003 T1 - 2mR	27.9	8.9	10.9	2.38	317	2446
0004 T1 - 3mR	23.7	15.2	22.2	2.27	431	5134
0005 T1 - 4mR	24.4	1.2	0.3	0.58	273	303
0006 T1 - 5mR	28.3	6.9	85.9	1.94	293	2080
0007 T1 - 6mR	31.0	2.3	0.7	1.48	41	174
0008 T1 - 7mR	24.7	1.1	0.5	0.85	78	187
0009 T1 - 1mL	26.2	15.0	3.3	2.24	75	4748
0010 T1 - 2mL	24.6	15.4	4.1	2.50	69	6137
0011 T1 - 3mL	24.0	19.4	4.1	2.40	67	8021
0012 T1 - 4mL	33.5	5.1	X	1.22	40	708
0013 T1 - 5mL	31.8	1.0	X	1.16	40	138
0014 T1 - 6mL	30.9	1.3	X	1.12	37	730
0015 T1 - 7mL	30.6	1.3	X	0.98	42	330
CHECKS						
0001 T1 - 5mL	29.7	1.0	X	1.14	40	135
0002 T1 - 2mR						
0003 T1 - 2mR						
0004 T1 - 6mR						
0005 T1 - 3mR						
STANDARDS						
0001 CaCO3						
0002 OREAS 45d						
0003 PD-1						
0004 OREAS 45e		1.3	X	2.41	322	47
0005 SARM48	32.2					
0006 HgSTD-8						
0007 NAG Std 3						
0008 OREAS 907						
0009 TOC-1						
0010 MPL-5		6.1	29.7	10.79	194	1299
0011 OREAS 121		0.6	X	219.21	21	12
BLANKS						
0001 Control Blank						
0002 Control Blank						
0003 Control Blank						

Results are not intended for commercial settlement purposes

ANALYSIS

ELEMENTS	Au	Au-Rp1	Ag	Al	ANC	As
UNITS	ppb	ppb	ppm	ppm	kgH2SO4/t	ppm
DETECTION LIMIT	1	1	0.05	50	1	0.5
DIGEST	AR25/	AR25/	4A/	4A/	ANCx/	4A/
ANALYTICAL FINISH	MS	MS	MS	MS	VOL	MS
BLANKS						
0004 Control Blank			X	336		X
0005 Control Blank						

ANALYSIS

ELEMENTS	B	Ba	Be	Bi	C	Ca
UNITS	ppm	ppm	ppm	ppm	%	ppm
DETECTION LIMIT	50	0.1	0.05	0.01	0.01	50
DIGEST	FP1/	4A/	4A/	4A/		4A/
ANALYTICAL FINISH	OE	MS	MS	MS	/CSA	MS
BLANKS						
0004 Control Blank	X	X	X	X		X
0005 Control Blank						

ANALYSIS

ELEMENTS	Cd	Co	ColourChange	Cr	Cu	EC
UNITS	ppm	ppm	NONE	ppm	ppm	uS/cm
DETECTION LIMIT	0.02	0.1	0	1	0.5	10
DIGEST	4A/	4A/	ANCx/	4A/	4A/	Ws/
ANALYTICAL FINISH	MS	MS	QUAL	MS	MS	MTR
BLANKS						
0004 Control Blank	X	X		X	X	
0005 Control Blank						

ANALYSIS

ELEMENTS	Fe	Final-pH	Fizz-Rate	Hg	K	Mg
UNITS	ppm	NONE	NONE	ppb	ppm	ppm
DETECTION LIMIT	50	0.1	1	1	20	20
DIGEST	4A/	ANCx/	ANCx/	AR01/	4A/	4A/
ANALYTICAL FINISH	MS	MTR	QUAL	CV	MS	MS
BLANKS						
0004 Control Blank	106				135	58
0005 Control Blank				2		

Results are not intended for commercial settlement purposes

ANALYSIS

ELEMENTS	Mn	Mo	C-Acinsol	MPA	Na	NAG
UNITS	ppm	ppm	%	kgH2SO4/t	ppm	kgH2SO4/t
DETECTION LIMIT	1	0.1	0.01	0.01	20	1
DIGEST	4A/	4A/	C71/		4A/	NAGx/
ANALYTICAL FINISH	MS	MS	CSA	/CALC	MS	VOL
BLANKS						
0004 Control Blank	X	X			X	
0005 Control Blank						

ANALYSIS

ELEMENTS	NAGpH	NAG(4.5)	NAPP	Ni	Pb	pH
UNITS	NONE	kgH2SO4/t	kgH2SO4/t	ppm	ppm	NONE
DETECTION LIMIT	0.1	1	1	0.5	0.5	0.1
DIGEST	NAGx/	NAGx/		4A/	4A/	Ws/
ANALYTICAL FINISH	MTR	VOL	/CALC	MS	MS	MTR
BLANKS						
0004 Control Blank				X	X	
0005 Control Blank						

ANALYSIS

ELEMENTS	pH Drop	S	S	S-SO4	Sb	Se
UNITS	NONE	%	%	%	ppm	ppm
DETECTION LIMIT	0.1	0.01	0.005	0.01	0.05	0.5
DIGEST	ANCx/		SCR/	S71/	4A/	4A/
ANALYTICAL FINISH	MTR	/CSA	VOL	OE	MS	MS
BLANKS						
0004 Control Blank					X	X
0005 Control Blank						

ANALYSIS

ELEMENTS	Si	Sn	Te	U	V	Zn
UNITS	%	ppm	ppm	ppm	ppm	ppm
DETECTION LIMIT	0.1	0.1	0.2	0.01	1	1
DIGEST	FP1/	4A/	4A/	4A/	4A/	4A/
ANALYTICAL FINISH	OE	MS	MS	MS	MS	MS
BLANKS						
0004 Control Blank	X	X	X	X	X	X
0005 Control Blank						

METHOD CODE DESCRIPTION

Method Code	Analysing Laboratory NATA Laboratory Accreditation	NATA Scope of Accreditation
/CALC	Intertek Genalysis Perth 3244 3237	

No digestion or other pre-treatment undertaken. Results Determined by calculation from other reported data.

/CSA	Intertek Genalysis Perth 3244 3237	MPL_W043, CSA : MPL_W043

Induction Furnace Analysed by Infrared Spectrometry

4A/MS	Intertek Genalysis Perth 3244 3237	4A/ : MPL_W002, MS : ICP_W003

Multi-acid digest including Hydrofluoric, Nitric, Perchloric and Hydrochloric acids in Teflon Tubes. Analysed by Inductively Coupled Plasma Mass Spectrometry.

ANCx/MTR	Intertek Genalysis Perth 3244 3237	

Acid Neutralizing Capacity Digestion Procedure. Analysed with Electronic Meter Measurement

ANCx/QUAL	Intertek Genalysis Perth 3244 3237	

Acid Neutralizing Capacity Digestion Procedure. Analysed by Qualitative Inspection

ANCx/VOL	Intertek Genalysis Perth 3244 3237	

Acid Neutralizing Capacity Digestion Procedure. Analysed by Volumetric Technique.

AR01/CV	Intertek Genalysis Perth 3244 3237	

Aqua-Regia digest. Analysed by Cold Vapour Generation Atomic Absorption Spectrometry.

AR25/MS	Intertek Genalysis Perth 3244 3237	

Aqua-Regia digest. Analysed by Inductively Coupled Plasma Mass Spectrometry.

C71/CSA	Intertek Genalysis Perth 3244 3237	

Digestion by hot acid(s) and Induction Furnace Analysed by Infrared Spectrometry

FP1/OE	Intertek Genalysis Perth 3244 3237	FP1/ : MPL_W011, OE : ICP_W004

Sodium peroxide fusion (Zirconia crucibles) and Hydrochloric acid to dissolve the melt. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.

NAGx/MTR	Intertek Genalysis Perth 3244 3237	

Net Acid Generation Extraction of samples with H2O2 Analysed with Electronic Meter Measurement

NAGx/VOL	Intertek Genalysis Perth 3244 3237	

Net Acid Generation Extraction of samples with H2O2 Analysed by Volumetric Technique.

METHOD CODE DESCRIPTION

Method Code	Analysing Laboratory NATA Laboratory Accreditation	NATA Scope of Accreditation
S71/OE	Intertek Genalysis Perth **3244 3237**	

Digestion to eliminate sulphides. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.

SCR/VOL	Intertek Genalysis Perth **3244 3237**	

Chromium Reducible Suplhur Analysed by Volumetric Technique.

Ws/MTR	Intertek Genalysis Perth **3244 3237**	

Water Extraction using a sample:water ratio of 1:5 or to client request. Analysed with Electronic Meter Measurement

ANALYTICAL REPORT

KALGOORLIE CONSOLIDATED GOLD MINES PTY
Private Mail Bag 27
KALGOORLIE, W.A. 6430
AUSTRALIA

JOB INFORMATION

JOB CODE	:	163.0/1705306
No. of SAMPLES	:	15
No. of ELEMENTS	:	46
CLIENT O/N	:	3100456 (Job 1 of 0)
SAMPLE SUBMISSION No.	:	
PROJECT	:	BULKIE SAMPLES
STATE	:	Rock Chip
DATE RECEIVED	:	19/04/2017
DATE COMPLETED	:	25/05/2017
DATE PRINTED	:	25/05/2017
ANALYSING LABORATORY	:	Intertek Genalysis Perth

LEGEND

X	= Less than Detection Limit
N/R	= Sample Not Received
*	= Result Checked
( )	= Result still to come
I/S	= Insufficient Sample for Analysis
E6	= Result X 1,000,000
UA	= Unable to Assay
>	= Value beyond Limit of Method
OV	= Value over-range for Package

MAIN OFFICE AND LABORATORY NATA: 3244 3273

15 Davison Street, Maddington 6109, Western Australia
PO Box 144, Gosnells 6990, Western Australia
Tel: +61 8 9251 8100 Fax: +61 8 9251 8110
Email: genalysis@intertek.com
Web Page: www.genalysis.com.au

KALGOORLIE SAMPLE PREPARATION DIVISION

12 Keogh Way, Kalgoorlie 6430, Western Australia
Tel: +61 8 9021 6057 Fax: +61 8 9021 3476

ADELAIDE LABORATORY NATA: 3244 18645

11 Senna Road, Wingfield, 5013, South Australia
Tel: +61 8 8162 9714 Fax: +61 8 8349 7444

JOHANNESBURG LABORATORY

43 Malcolm Moodie Crescent,
Jet Park, Gauteng, South Africa 1459
Tel: +27 11 552 8149 Fax: +27 11 552 8248

TOWNSVILLE LABORATORY NATA: 3244 20462

9-23 Kelli Street, Mt St John, Bohle, Queensland, Australia 4818
Tel: +61 7 4774 3655 Fax: +61 7 4774 4692

Results are not intended for commercial settlement purposes

SAMPLE DETAILS

DISCLAIMER

Intertek Genalysis wishes to make the following disclaimer pertaining to the accompanying analytical results.

All work is performed in accordance with the Intertek Minerals Standard Terms and Conditions of work http://www.intertek.com/terms/

This report relates specifically to the sample(s) that were drawn and/or provided by the client or their nominated third party. The reported result(s) provide no warranty or verification on the sample(s) representing any specific goods and/or shipment and only relate to the sample(s) as received and tested. This report was prepared solely for the use of the client named in this report. Intertek accepts no responsibility for any loss, damage or liability suffered by a third party as a result of any reliance upon or use of this report.

The results provided are not intended for commercial settlement purposes.

SIGNIFICANT FIGURES

It is common practice to report data derived from analytical instrumentation to a maximum of two or three significant figures. Some data reported herein may show more figures than this. The reporting of more than two or three figures in no way implies that the third, fourth and subsequent figures may be real or significant.

Intertek Genalysis accepts no responsibility whatsoever for any interpretation by any party of any data where more than two or three significant figures have been reported.

SAMPLE STORAGE DETAILS

GENERAL CONDITIONS

SAMPLE STORAGE OF SOLIDS

Bulk Residues and Pulps will be stored for 60 DAYS without charge. After this time all Bulk Residues and Pulps will be stored at a rate of $4.00 per cubic metre per day until your written advice regarding collection or disposal is received. Expenses related to the return or disposal of samples will be charged to you at cost. Current disposal cost is charged at $150.00 per cubic metre.

SAMPLE STORAGE OF SOLUTIONS

Samples received as liquids, waters or solutions will be held for 60 DAYS free of charge then disposed of, unless written advice for return or collection is received.

ANALYSIS

ELEMENTS	Au	Au-Rp1	Ag	Al	ANC	As
UNITS	ppb	ppb	ppm	ppm	kgH2SO4/t	ppm
DETECTION LIMIT	1	1	0.05	50	1	0.5
DIGEST	AR25/	AR25/	4A/	4A/	ANCx/	4A/
ANALYTICAL FINISH	MS	MS	MS	MS	VOL	MS
SAMPLE NUMBERS						
0001 Bulkie 1 - surface	744	757	0.99	6.77%	13	108.8
0002 Bulkie 1 - 0.5m	100		1.42	7.30%	4	37.9
0003 Bulkie 1 - 1m	243		1.31	7.07%	11	56.7
0004 Bulkie 2 - surface	266		1.34	7.33%	18	80.8
0005 Bulkie 2 - 0.5m	178		0.48	7.30%	-4	54.4
0006 Bulkie 2 - 1m	171		0.25	8.08%	4	70.3
0007 Bulkie 3 - surface	248		0.25	7.60%	-23	61.6
0008 Bulkie 3 - 0.5m	143		0.40	7.44%	-13	58.1
0009 Bulkie 3 - 1m	88		0.31	8.04%	-10	54.7
0010 Bulkie 4 - suface	14		0.57	6.75%	84	82.8
0011 Bulkie 4 - 0.5m	16		0.60	6.05%	123	56.6
0012 Bulkie 4 - 1m	2		1.59	6.34%	57	126.5
0013 Bulkie 5 - surface	11		0.36	6.95%	124	42.2
0014 Bulkie 5 - 0.5m	10		0.63	6.83%	93	63.1
0015 Bulkie 5 - 1m	3		0.96	6.69%	83	108.5
CHECKS						
0001 Bulkie 4 - suface			0.71	6.53%	92	80.3
0002 Bulkie 4 - 1m	2					
0003 Bulkie 4 - suface						
0004 Bulkie 2 - surface						
STANDARDS						
0001 HgSTD-8						
0002 SARM1						
0003 ANC-2					120	
0004 NAG Std 3						
0005 OREAS 45e			0.32	6.17%		15.4
0006 OREAS 600						
0007 PD-1						
0008 OREAS 45e	52					
0009 TOC-1						
0010 MPL-5			35.45	3.19%		1019.4
0011 OREAS 121			X	4.73%		4.9
BLANKS						
0001 Control Blank	X					
0002 Control Blank						
0003 Control Blank			X	X	0	X
0004 Control Blank						

ANALYSIS

ELEMENTS	B	Ba	Be	Bi	C	Ca
UNITS	ppm	ppm	ppm	ppm	%	ppm
DETECTION LIMIT	50	0.1	0.05	0.01	0.01	50
DIGEST	FP1/	4A/	4A/	4A/		4A/
ANALYTICAL FINISH	OE	MS	MS	MS	/CSA	MS
SAMPLE NUMBERS						
0001 Bulkie 1 - surface	X	536.0	1.00	0.61	2.17	444
0002 Bulkie 1 - 0.5m	X	746.2	1.06	0.49	1.52	610
0003 Bulkie 1 - 1m	X	629.2	1.04	0.61	1.65	921
0004 Bulkie 2 - surface	X	596.9	1.13	0.42	1.98	3201
0005 Bulkie 2 - 0.5m	X	504.0	1.02	0.34	1.08	1557
0006 Bulkie 2 - 1m	X	515.9	0.98	0.29	0.90	4557
0007 Bulkie 3 - surface	X	438.5	1.06	0.34	0.87	1062
0008 Bulkie 3 - 0.5m	X	509.8	0.94	0.34	0.81	3449
0009 Bulkie 3 - 1m	X	488.8	1.01	0.35	0.68	2794
0010 Bulkie 4 - suface	X	522.5	0.85	0.36	2.72	1.27%
0011 Bulkie 4 - 0.5m	X	508.8	0.82	0.41	2.83	2.09%
0012 Bulkie 4 - 1m	X	533.4	1.04	1.32	5.16	8493
0013 Bulkie 5 - surface	X	534.2	0.83	0.26	2.37	2.14%
0014 Bulkie 5 - 0.5m	X	583.6	1.07	0.44	2.84	1.61%
0015 Bulkie 5 - 1m	X	586.7	0.93	1.02	3.55	1.34%
CHECKS						
0001 Bulkie 4 - suface		512.9	0.92	0.34	2.74	1.23%
0002 Bulkie 4 - 1m						
0003 Bulkie 4 - suface						
0004 Bulkie 2 - surface	X					
STANDARDS						
0001 HgSTD-8						
0002 SARM1	X					
0003 ANC-2						
0004 NAG Std 3						
0005 OREAS 45e		228.6	0.58	0.25		596
0006 OREAS 600					0.50	
0007 PD-1						
0008 OREAS 45e						
0009 TOC-1						
0010 MPL-5		572.5	20.50	35.58		4.13%
0011 OREAS 121		984.2	1.46	0.07		883
BLANKS						
0001 Control Blank						
0002 Control Blank						
0003 Control Blank		0.2	X	X	X	X
0004 Control Blank	X					

Results are not intended for commercial settlement purposes

ANALYSIS

ELEMENTS	Cd	Co	ColourChange	Cr	Cu	EC
UNITS	ppm	ppm	NONE	ppm	ppm	uS/cm
DETECTION LIMIT	0.02	0.1	0	1	0.5	10
DIGEST	4A/	4A/	ANCx/	4A/	4A/	Ws/
ANALYTICAL FINISH	MS	MS	QUAL	MS	MS	MTR
SAMPLE NUMBERS						
0001 Bulkie 1 - surface	0.20	9.6	No	47	212.2	166
0002 Bulkie 1 - 0.5m	0.07	3.4	No	29	37.0	2820
0003 Bulkie 1 - 1m	0.15	6.8	No	34	58.0	2330
0004 Bulkie 2 - surface	1.01	15.9	No	47	212.1	722
0005 Bulkie 2 - 0.5m	0.46	8.7	No	49	125.1	1372
0006 Bulkie 2 - 1m	0.50	12.4	Yes	55	136.8	1453
0007 Bulkie 3 - surface	5.56	56.4	No	47	790.6	5300
0008 Bulkie 3 - 0.5m	1.18	13.0	Yes	44	196.9	3140
0009 Bulkie 3 - 1m	1.45	19.5	Yes	78	216.3	3720
0010 Bulkie 4 - suface	2.39	41.6	No	43	970.5	271
0011 Bulkie 4 - 0.5m	2.66	31.9	No	43	339.7	1069
0012 Bulkie 4 - 1m	5.31	88.1	No	57	854.4	2036
0013 Bulkie 5 - surface	1.21	23.6	No	53	164.4	391
0014 Bulkie 5 - 0.5m	2.00	37.6	No	139	358.8	513
0015 Bulkie 5 - 1m	3.34	58.9	No	47	431.2	1078
CHECKS						
0001 Bulkie 4 - suface	2.33	39.8	No	44	956.4	267
0002 Bulkie 4 - 1m						
0003 Bulkie 4 - suface						
0004 Bulkie 2 - surface						
STANDARDS						
0001 HgSTD-8						
0002 SARM1						
0003 ANC-2						
0004 NAG Std 3						
0005 OREAS 45e	0.02	52.7		923	716.9	
0006 OREAS 600						
0007 PD-1						
0008 OREAS 45e						
0009 TOC-1						
0010 MPL-5	2.89	129.5		728	1851.0	
0011 OREAS 121	0.03	4.3		45	4.4	
BLANKS						
0001 Control Blank						
0002 Control Blank						
0003 Control Blank	X	X		2	X	X
0004 Control Blank						

Results are not intended for commercial settlement purposes

ANALYSIS

ELEMENTS	Fe	Final-pH	Fizz-Rate	Hg	K	Mg
UNITS	ppm	NONE	NONE	ppb	ppm	ppm
DETECTION LIMIT	50	0.1	1	1	20	20
DIGEST	4A/	ANCx/	ANCx/	AR01/	4A/	4A/
ANALYTICAL FINISH	MS	MTR	QUAL	CV	MS	MS
SAMPLE NUMBERS						
0001 Bulkie 1 - surface	5.20%	0.7	X	1446	2.18%	4140
0002 Bulkie 1 - 0.5m	2.42%	0.9	X	844	2.51%	1698
0003 Bulkie 1 - 1m	3.54%	0.8	X	787	2.36%	3076
0004 Bulkie 2 - surface	5.67%	0.7	X	1298	2.37%	4617
0005 Bulkie 2 - 0.5m	2.95%	1.0	X	855	2.36%	1877
0006 Bulkie 2 - 1m	3.90%	1.0	X	658	2.42%	2601
0007 Bulkie 3 - surface	3.11%	1.0	X	809	2.27%	7948
0008 Bulkie 3 - 0.5m	2.97%	1.0	X	705	2.41%	2755
0009 Bulkie 3 - 1m	2.94%	1.0	X	662	2.22%	3376
0010 Bulkie 4 - suface	5.49%	0.8	1	1512	1.95%	2.18%
0011 Bulkie 4 - 0.5m	5.09%	0.9	1	1748	1.87%	2.16%
0012 Bulkie 4 - 1m	9.74%	0.8	X	3648	2.13%	1.66%
0013 Bulkie 5 - surface	4.81%	1.0	1	979	2.08%	2.41%
0014 Bulkie 5 - 0.5m	5.16%	0.9	1	1472	1.99%	2.23%
0015 Bulkie 5 - 1m	6.95%	0.9	1	2429	2.18%	2.03%
CHECKS						
0001 Bulkie 4 - suface	5.35%	0.9	1		1.90%	2.08%
0002 Bulkie 4 - 1m						
0003 Bulkie 4 - suface						
0004 Bulkie 2 - surface				1365		
STANDARDS						
0001 HgSTD-8				2962		
0002 SARM1						
0003 ANC-2		1.4				
0004 NAG Std 3						
0005 OREAS 45e	22.85%				3195	1468
0006 OREAS 600						
0007 PD-1						
0008 OREAS 45e						
0009 TOC-1						
0010 MPL-5	3.58%				1.11%	8931
0011 OREAS 121	1.65%				2.78%	2500
BLANKS						
0001 Control Blank						
0002 Control Blank						
0003 Control Blank	X	0.9			X	X
0004 Control Blank				X		

Results are not intended for commercial settlement purposes

ANALYSIS

ELEMENTS	Mn	Mo	C-Acinsol	MPA	Na	NAG
UNITS	ppm	ppm	%	kgH2SO4/t	ppm	kgH2SO4/t
DETECTION LIMIT	1	0.1	0.01	0.01	20	1
DIGEST	4A/	4A/	C71/		4A/	NAGx/
ANALYTICAL FINISH	MS	MS	CSA	/CALC	MS	VOL
SAMPLE NUMBERS						
0001 Bulkie 1 - surface	62	2.4	2.17	4.67	3658	
0002 Bulkie 1 - 0.5m	27	1.2	1.53	2.78	5444	
0003 Bulkie 1 - 1m	57	1.3	1.66	2.37	4837	
0004 Bulkie 2 - surface	105	2.1	1.82	7.08	3831	0
0005 Bulkie 2 - 0.5m	67	2.0	1.06	30.94	6319	13
0006 Bulkie 2 - 1m	118	1.6	0.77	30.96	5727	7
0007 Bulkie 3 - surface	405	1.9	0.87	76.14	8720	33
0008 Bulkie 3 - 0.5m	89	1.3	0.80	37.87	6936	7
0009 Bulkie 3 - 1m	153	1.3	0.68	41.85	1.67%	10
0010 Bulkie 4 - suface	334	1.4	1.77	91.47	9084	20
0011 Bulkie 4 - 0.5m	511	1.6	1.45	89.29	6936	1
0012 Bulkie 4 - 1m	232	3.3	4.56	251.58	4930	179
0013 Bulkie 5 - surface	543	1.6	0.91		9183	0
0014 Bulkie 5 - 0.5m	353	1.7	1.73	84.23	9668	4
0015 Bulkie 5 - 1m	315	2.5	2.82	163.76	4725	78
CHECKS						
0001 Bulkie 4 - suface	327	1.4			8643	21
0002 Bulkie 4 - 1m			4.51			
0003 Bulkie 4 - suface						
0004 Bulkie 2 - surface						
STANDARDS						
0001 HgSTD-8						
0002 SARM1						
0003 ANC-2						
0004 NAG Std 3						23
0005 OREAS 45e	521	2.2			543	
0006 OREAS 600						
0007 PD-1						
0008 OREAS 45e						
0009 TOC-1			1.41			
0010 MPL-5	2239	19.8			5313	
0011 OREAS 121	780	7.1			2464	
BLANKS						
0001 Control Blank			X			
0002 Control Blank						
0003 Control Blank	X	X			X	6
0004 Control Blank						

Results are not intended for commercial settlement purposes

ANALYSIS

ELEMENTS	NAGpH	NAG(4.5)	NAPP	Ni	Pb	pH
UNITS	NONE	kgH2SO4/t	kgH2SO4/t	ppm	ppm	NONE
DETECTION LIMIT	0.1	1	1	0.5	0.5	0.1
DIGEST	NAGx/	NAGx/		4A/	4A/	Ws/
ANALYTICAL FINISH	MTR	VOL	/CALC	MS	MS	MTR
SAMPLE NUMBERS						
0001 Bulkie 1 - surface			-8	37.6	28.4	6.6
0002 Bulkie 1 - 0.5m			-1	16.4	16.9	7.3
0003 Bulkie 1 - 1m			-9	29.9	16.9	7.4
0004 Bulkie 2 - surface	8.2	0	-11	42.4	19.5	6.1
0005 Bulkie 2 - 0.5m	3.2	5	35	23.1	23.2	3.8
0006 Bulkie 2 - 1m	3.3	3	27	31.4	22.9	4.5
0007 Bulkie 3 - surface	3.2	18	99	79.7	25.2	4.1
0008 Bulkie 3 - 0.5m	3.3	3	51	24.5	20.1	4.1
0009 Bulkie 3 - 1m	3.2	4	52	35.7	22.0	3.8
0010 Bulkie 4 - suface	3.5	10	8	48.9	35.7	7.6
0011 Bulkie 4 - 0.5m	6.9	0	-34	47.0	29.5	7.5
0012 Bulkie 4 - 1m	2.3	151	195	116.2	65.7	6.8
0013 Bulkie 5 - surface	7.8	0		43.3	20.1	7.9
0014 Bulkie 5 - 0.5m	4.3	1	-9	84.9	27.7	7.1
0015 Bulkie 5 - 1m	2.7	59	81	69.7	42.9	6.8
CHECKS						
0001 Bulkie 4 - suface	3.5	11		48.8	36.1	7.6
0002 Bulkie 4 - 1m						
0003 Bulkie 4 - suface						
0004 Bulkie 2 - surface						
STANDARDS						
0001 HgSTD-8						
0002 SARM1						
0003 ANC-2						
0004 NAG Std 3	2.5	18				
0005 OREAS 45e				414.5	20.3	
0006 OREAS 600						
0007 PD-1						
0008 OREAS 45e						
0009 TOC-1						
0010 MPL-5				2345.6	1989.3	
0011 OREAS 121				12.3	17.8	
BLANKS						
0001 Control Blank						
0002 Control Blank						
0003 Control Blank	4.7	0		X	X	5.8
0004 Control Blank						

Results are not intended for commercial settlement purposes

ANALYSIS

ELEMENTS	pH Drop	S	S	S-SO4	Sb	Se
UNITS	NONE	%	%	%	ppm	ppm
DETECTION LIMIT	0.1	0.01	0.005	0.01	0.05	0.5
DIGEST	ANCx/		SCR/	S71/	4A/	4A/
ANALYTICAL FINISH	MTR	/CSA	VOL	OE	MS	MS
SAMPLE NUMBERS						
0001 Bulkie 1 - surface	3.5	0.15	0.056	0.09	22.96	2.9
0002 Bulkie 1 - 0.5m		0.09	0.025	0.06	9.16	2.5
0003 Bulkie 1 - 1m		0.08	0.021	0.06	9.03	3.0
0004 Bulkie 2 - surface		0.23	0.065	0.16	8.35	1.8
0005 Bulkie 2 - 0.5m	3.3	1.01	0.461	0.48	10.79	2.4
0006 Bulkie 2 - 1m	3.3	1.01	0.541	0.42	11.03	2.7
0007 Bulkie 3 - surface	3.7	2.49	0.740	1.77	12.19	3.8
0008 Bulkie 3 - 0.5m	3.4	1.24	0.222	0.97	10.36	2.6
0009 Bulkie 3 - 1m	3.3	1.37	0.392	0.89	8.73	2.1
0010 Bulkie 4 - suface	3.1	2.99	2.830	0.09	6.09	4.7
0011 Bulkie 4 - 0.5m	3.1	2.92	2.650	0.24	7.64	4.1
0012 Bulkie 4 - 1m	3.1	8.22	7.210	0.32	20.16	9.6
0013 Bulkie 5 - surface	3.0	1.73	1.520	0.18	6.97	1.7
0014 Bulkie 5 - 0.5m	3.1	2.75	2.660	0.26	7.04	3.5
0015 Bulkie 5 - 1m	3.2	5.35	4.590	0.23	14.70	5.9
CHECKS						
0001 Bulkie 4 - suface	3.1	2.98			5.73	4.8
0002 Bulkie 4 - 1m						
0003 Bulkie 4 - suface				0.10		
0004 Bulkie 2 - surface						
STANDARDS						
0001 HgSTD-8						
0002 SARM1						
0003 ANC-2						
0004 NAG Std 3						
0005 OREAS 45e					0.87	2.5
0006 OREAS 600		1.72				
0007 PD-1				4.24		
0008 OREAS 45e						
0009 TOC-1						
0010 MPL-5					326.68	123.6
0011 OREAS 121					0.32	X
BLANKS						
0001 Control Blank						
0002 Control Blank				X		
0003 Control Blank		X			X	X
0004 Control Blank						

Results are not intended for commercial settlement purposes

ANALYSIS

ELEMENTS	Si	Sn	Te	U	V	Zn
UNITS	%	ppm	ppm	ppm	ppm	ppm
DETECTION LIMIT	0.1	0.1	0.2	0.01	1	1
DIGEST	FP1/	4A/	4A/	4A/	4A/	4A/
ANALYTICAL FINISH	OE	MS	MS	MS	MS	MS
SAMPLE NUMBERS						
0001 Bulkie 1 - surface	32.1	3.5	0.9	1.62	75	382
0002 Bulkie 1 - 0.5m	35.4	4.7	0.6	1.70	49	151
0003 Bulkie 1 - 1m	34.6	3.9	0.7	2.08	49	275
0004 Bulkie 2 - surface	30.3	3.0	0.7	2.29	83	356
0005 Bulkie 2 - 0.5m	33.6	3.6	0.5	1.09	66	224
0006 Bulkie 2 - 1m	31.1	3.0	0.5	1.20	94	388
0007 Bulkie 3 - surface	28.6	3.3	0.7	1.27	51	490
0008 Bulkie 3 - 0.5m	31.5	3.2	0.4	0.95	72	154
0009 Bulkie 3 - 1m	30.6	2.6	0.4	1.09	74	189
0010 Bulkie 4 - suface	27.6	4.3	0.5	1.50	57	1285
0011 Bulkie 4 - 0.5m	26.3	3.4	0.7	1.21	58	1513
0012 Bulkie 4 - 1m	24.3	8.5	1.8	1.75	50	3444
0013 Bulkie 5 - surface	26.1	3.5	0.3	1.46	88	629
0014 Bulkie 5 - 0.5m	26.9	4.1	0.6	1.71	67	1050
0015 Bulkie 5 - 1m	26.0	6.2	1.3	2.03	52	1743
CHECKS						
0001 Bulkie 4 - suface		4.2	0.5	1.51	54	1251
0002 Bulkie 4 - 1m						
0003 Bulkie 4 - suface						
0004 Bulkie 2 - surface	29.9					
STANDARDS						
0001 HgSTD-8						
0002 SARM1	35.0					
0003 ANC-2						
0004 NAG Std 3						
0005 OREAS 45e		1.1	0.2	2.16	296	50
0006 OREAS 600						
0007 PD-1						
0008 OREAS 45e						
0009 TOC-1						
0010 MPL-5		6.3	30.4	10.37	201	1299
0011 OREAS 121		0.7	X	210.59	25	17
BLANKS						
0001 Control Blank						
0002 Control Blank						
0003 Control Blank		X	X	X	2	2
0004 Control Blank	X					

Results are not intended for commercial settlement purposes

METHOD CODE DESCRIPTION

Method Code	Analysing Laboratory NATA Laboratory Accreditation	NATA Scope of Accreditation
/CALC	Intertek Genalysis Perth **3244 3237**	

No digestion or other pre-treatment undertaken. Results Determined by calculation from other reported data.

/CSA	Intertek Genalysis Perth **3244 3237**	**MPL_W043, CSA : MPL_W043**

Induction Furnace Analysed by Infrared Spectrometry

4A/MS	Intertek Genalysis Perth **3244 3237**	**4A/ : MPL_W002, MS : ICP_W003**

Multi-acid digest including Hydrofluoric, Nitric, Perchloric and Hydrochloric acids in Teflon Tubes. Analysed by Inductively Coupled Plasma Mass Spectrometry.

ANCx/MTR	Intertek Genalysis Perth **3244 3237**	

Acid Neutralizing Capacity Digestion Procedure. Analysed with Electronic Meter Measurement

ANCx/QUAL	Intertek Genalysis Perth **3244 3237**	

Acid Neutralizing Capacity Digestion Procedure. Analysed by Qualitative Inspection

ANCx/VOL	Intertek Genalysis Perth **3244 3237**	

Acid Neutralizing Capacity Digestion Procedure. Analysed by Volumetric Technique.

AR01/CV	Intertek Genalysis Perth **3244 3237**	

Aqua-Regia digest. Analysed by Cold Vapour Generation Atomic Absorption Spectrometry.

AR25/MS	Intertek Genalysis Perth **3244 3237**	

Aqua-Regia digest. Analysed by Inductively Coupled Plasma Mass Spectrometry.

C71/CSA	Intertek Genalysis Perth **3244 3237**	

Digestion by hot acid(s) and Induction Furnace Analysed by Infrared Spectrometry

FP1/OE	Intertek Genalysis Perth **3244 3237**	**FP1/ : MPL_W011, OE : ICP_W004**

Sodium peroxide fusion (Zirconia crucibles) and Hydrochloric acid to dissolve the melt. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.

NAGx/MTR	Intertek Genalysis Perth **3244 3237**	

Net Acid Generation Extraction of samples with H2O2 Analysed with Electronic Meter Measurement

NAGx/VOL	Intertek Genalysis Perth **3244 3237**	

Net Acid Generation Extraction of samples with H2O2 Analysed by Volumetric Technique.

METHOD CODE DESCRIPTION

Method Code	Analysing Laboratory NATA Laboratory Accreditation	NATA Scope of Accreditation
S71/OE	Intertek Genalysis Perth **3244 3237**	

Digestion to eliminate sulphides. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.

SCR/VOL	Intertek Genalysis Perth **3244 3237**	

Chromium Reducible Suplhur Analysed by Volumetric Technique.

Ws/MTR	Intertek Genalysis Perth **3244 3237**	

Water Extraction using a sample:water ratio of 1:5 or to client request. Analysed with Electronic Meter Measurement

5.5 Appendix 5.5: FIMISTON Tailings Geochemistry Summary

(2 documents)

Northern Star Resources Limited

February 2025

Fimiston Tailings Geochemical Characterisation



Question today
Imagine tomorrow
Create for the future

Fimiston Tailings Geochemical Characterisation

Northern Star Resources Limited

WSP
Lvl 3, Mia Yellagonga Tower 2, 5 Spring St
Perth WA 6000
PO Box 7181
Cloisters Square WA 6850

Tel: +61 8 9489 9700
Fax: +61 8 9489 9777
wsp.com

Rev	Date	Details
0	17 February 2025	Final report
1	18 February 2025	Updated final report

	Name	Date	Signature
Prepared by:	Bernarda Leon Alan Levett	18/02/2025	
Reviewed by:	Gert du Plessis	18/02/2025	
Approved by:	Gert du Plessis	18/02/2025	

WSP acknowledges that every project we work on takes place on First Peoples lands.
We recognise Aboriginal and Torres Strait Islander Peoples as the first scientists and engineers and pay our respects to Elders past and present.

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Appendix B Collated results
Appendix C Laboratory certificates
Appendix D Limitation statement

Glossary

AC	Acid Consuming
AD	Acid/acidic Drainage
AMD	Acid and Metalliferous Drainage
ANC	Acid Neutralising Capacity
ASLP	Australian Standard Leaching Procedure
COC	Chain of Custody
CRS	Chromium Reducible Sulfur
CT	Combined Tailings
DGV	Default Guideline Value
DI	Deionised
EC	Electrical Conductivity
GAI	Geochemical Abundance Index
FO	Fimiston Operation
KCGM	Kalgoorlie Consolidated Gold Mines Pty Ltd
LOCC	Large Oxygen Consumption Cells
LOR	Limit of Reporting
MPA	Maximum Potential Acidity
NAF	Non-Acid Forming
NAG	Net Acid Generation
NAPP	Net Acid Producing Potential
NATA	National Association of Testing Authorities
NMD	Neutral (pH) and Metalliferous Drainage
NSR	Norther Star Resources Limited
OCR	Oxygen Consumption Rates
PAF	Potentially Acid Forming
QXRD	Quantitative X-Ray Diffraction
SD	Saline Drainage
S/L	Solid to Liquid (ratio)
TDS	Total Dissolved Solids
TN	Total Nitrogen
TSF	Tailings Storage Facility
UC	Uncertain
UFG	Ultra Fine Grind
WAD	Weakly Acid Dissociable (cyanide)
WSP	WSP Australia Pty Ltd

Executive summary

The Fimiston Operation is a gold mine located in Kalgoorlie, Western Australia, which is owned and operated by Northern Star Resources Limited (NSR). WSP Australia Pty Ltd (WSP) was engaged by NSR to undertake a static geochemical characterisation of tailings produced from the Fimiston processing plant.

The scope of work undertaken by WSP involved the following:

- Desktop review of previous geochemical assessments for Fimiston tailings.
- Liaise with NSR for collection of representative tailings samples from Fimiston processing plant.
- Prepare Chain of Custody (COC) documentation for NSR to supplement the samples to the nominated analytical laboratory.
- Review, collate and interpret laboratory data.
- Prepare a technical report (this report) that addresses the following to the appropriate level:
  - Risk of acid and metalliferous drainage (AMD), neutral and metalliferous drainage (NMD) and/or saline drainage (SD) generation from Fimiston tailings.
  - Discussion on acid neutralisation capacity (ANC) of the tailings and potential mechanisms.
  - Preliminary identified management measures and implications for operations and mine closure.
  - Recommendations for future work (if identified).

Six (6) Fimiston tailings slurry samples were collected from the Fimiston process plant over a six (6) day operational period between 27 February 2024 and 3 March 2024. Individual tailings slurry samples were collected by NSR site personnel during each operational day, with generally a good distribution between the samples collected on day shift (DS) and night shift (NS). Separate samples of dried tailings solids and filtered supernatant were provided to WSP. Three master composite samples were then prepared by NSR for tailings slurry to produce the final tailings solids and supernatant samples. The three (3) master composite samples (i.e., 3 solids and 3 liquids) were provided to WSP for laboratory testing.

The geochemical characterisation methodology employed in this assessment followed those outlined in common practice guidelines, including mineralogy, multi-element composition, acid-base accounting (ABA), net acid generation (NAG), deionised (DI) water leach, net acid generation (NAG) liquor analysis, and supernatant chemical screening.

Key findings from the geochemical assessment of the Fimiston tailings are:

- The findings in from the current assessment are broadly consistent with previous studies on Fimiston tailings.
- The major mineral phases include quartz, dolomite, albite, and mica; dolomite is capable of effective acid neutralisation. Minor pyrite (iron sulfide mineral) is present, which is capable of acid generation
- Multi-element composition analysis shows geochemical enrichment of arsenic, sulfur, antimony, selenium, tellurium and tungsten in the Fimiston tailings.
- The potential for AMD generation is negligible for Fimiston tailings. Despite containing low levels of sulfide sulfur, the tailings are classified as non-acid forming (NAF), and may further be classed as NAF acid consuming (AC). The tailings contain sufficient and readily available acid neutralisation capacity (ANC) to neutralise any acid generated by sulfide oxidation.
- Drainage from the Fimiston TSF is expected to be represented by the supernatant composition, and hence, expected to have a near-neutral to slightly alkaline pH, be hypersaline, and contain certain cyanide-associated metal(loid)s at concentrations surpassing the selected guidelines for assessment (antimony, cadmium, cobalt, copper, iron, nickel, and thallium).

- Short-term tailings leaching due to natural rainfall, as simulated by a static DI water leach, is indicated to be of better quality than the supernatant/processing water. Runoff and seepage from tailings (once the supernatant no longer dominates the pore-water chemistry) are expected to be circum-neutral, brackish, and contain predominantly low concentrations of soluble metal(loid)s.
- Drainage from completely oxidised Fimiston tailings, as simulated by the NAG liquor test, is indicated to be similar in comparison to drainage from fresh tailings (i.e., the drainage composition is not expected to vary significantly between fresh and oxidised tailings). Based on the NAG liquor results, it is unlikely that sulfide oxidation will be a major contributor to NMD and SD.

Recommendations from the study are:

- Routine tailings geochemical testing is recommended to develop an inventory of mine wastes produced and stored onsite to support closure preparedness.
- Additional geochemical characterisation should be undertaken if there are any anticipated or confirmed changes to the orebody geology or processing method(s).

1 Introduction and scope

The Fimiston Operation is a gold mine located in Kalgoorlie, Western Australia, which is owned and operated by Northern Star Resources Limited (NSR). WSP Australia Pty Ltd (WSP) was engaged by NSR to undertake a static geochemical characterisation of tailings produced from the Fimiston processing plant to support environmental approvals.

The scope of work undertaken by WSP involved the following:

- Desktop review of previous geochemical assessments for Fimiston tailings.
- Liaise with NSR for collection of representative tailings samples from the Fimiston processing plant.
- Prepare Chain of Custody (COC) documentation for NSR to supplement the samples to the nominated analytical laboratory.
- Review, collate and interpret laboratory data.
- Prepare a technical report (this report) that addresses the following to the appropriate level:
  - Risk of acid and metalliferous drainage (AMD), neutral and metalliferous drainage (NMD) and/or saline drainage (SD) generation from Fimiston tailings.
  - Discussion on acid neutralisation capacity (ANC) of the tailings and potential mechanisms.
  - Preliminary identified management measures and implications for operations and mine closure.
  - Recommendations for future work (if identified).

2 Desktop review

WSP has reviewed the provided geochemical test work reports on the Fimiston tailings to date (Table 2.1).

Table 2.1 Previous geochemical studies – Fimiston tailings

Reference	Author	Date	Title
(GCA, 2003)	Graeme Campbell and Associates Pty Ltd	January 2003	Geochemical Characterisation of Profile-Samples from Tailings-Bed ("Static Testwork") – Implications for Process-Tailings Management
(GCA, 2010)	Graeme Campbell and Associates Pty Ltd	28 July 2010	KCGM: Geochemical Characterisation of Process-Tailings Samples (Fimiston Mill and Gidji Roaster) – Implications for Process-Tailings Management
(MBS, 2016a)	MBS Environmental Pty Ltd	13 April 2016	Geochemical Tailings Characterisation
(MBS, 2016b)	MBS Environmental Pty Ltd	5 October 2016	Tailings Geochemistry Overview

Based on the previous work completed on the characterisation of the Fimiston tailings, the key geochemical results are as follows:

- **Semi-quantitative mineralogy** (GCA, 2010):
  - Major minerals (>10%): ankerite, quartz, plagioclase, chlorite, and muscovite.
  - Trace minerals (<10%): pyrite, siderite, titanium, and magnetite.
- **Acid-base accounting (ABA)** (GCA, 2010; MBS, 2016a):
  - Fimiston tailings were classified as non-acid forming (NAF) based on:
    - Low to moderate sulfide-sulfur content (0.05 - 1.06 %).
    - High acid neutralisation capacity (ANC, 133 - 200 kg·H_2SO_4/t).
- **Multi-element composition**:
  - Slight enrichment in mercury, arsenic, antimony and tellurium (MBS, 2016a).
- **Solubility testing** (MBS, 2016a; MBS, 2016b):
  - Supernatant:
    - Supernatant is slightly alkaline (pH 7.9) and hypersaline (electrical conductivity (EC) ~150,000 µS/cm).
    - Supernatant soluble metal and metalloid concentrations are linked with in cyanide and/or ammonia complex formation.
    - Cyanide concentrations are 21 - 25 mg/L, mostly in the form of weakly acid dissociable (WAD) cyanide.
    - Supernatant contains moderate but variable concentrations of copper, lead, nickel cobalt, mercury and antimony.
  - Water leach (modified Australian Standard Leaching Procedure (ASLP) using 1:5 S/L ratio with deionised (DI) water):
    - Leachate is slightly alkaline (pH 7.8 - 8.5) with a brackish salinity (EC = 3,000 - 5,500 µS/cm).

- Mercury was consistently present at concentrations that surpassed the ANZECC & ARMCANZ (2000) livestock default guideline value (DGV) (0.005 - 0.08 mg/L). High soluble concentrations of cobalt (0.69 mg/L), copper (1.6 mg/L), and hexavalent chromium (0.32 mg/L) were also noted for one of the Fimiston tailings samples.
- High metal concentrations in the single Fimiston sample are regarded to be associated with cyanide complexes.

- Acetic acid leach:
  - Three tailings solids assessed against the ASLP (1:20 S/L ratio) using acetic acid as the extractant fluid.
  - Higher concentrations (relative to the DI leach) of certain metal(loid)s due to the increased solubility of cyanide complexes (e.g., Fe, Pb, and Zn).
  - Lower concentrations (relative to the DI leach) of certain metal(loid)s likely due to adsorption processes (e.g., As, Co, Mo, and Sb).
- Net acid generation (NAG) liquor:
  - Trace metal and metalloid concentrations in fully oxidised solutions were very low.
  - Aluminium concentrations (0.05 - 0.75 mg/L) were elevated in the NAG liquor, which is still below ANZECC & ARMCANZ (2000) livestock DGV when adjusted to a nominal 1:20 S/L extraction ratio.

3 Assessment details

3.1 Sample descriptions

Six (6) Fimiston tailings slurry samples were collected from the Fimiston process plant over a six (6) day operational period between 27 February 2024 and 3 March 2024. Individual tailings slurry samples were collected by NSR site personnel during each operational day, with generally a good distribution between the samples collected on day shift (DS) and night shift (NS). A schematic demonstrating the sampling approach undertaken by NSR for each operational day is provided in Figure 3.1.

Separate samples of dried tailings solids and filtered supernatant were provided to WSP. Daily composite samples were prepared by NSR from individual supernatant and tailings solid samples, as follows:

- Equal volumes of each individual supernatant, collected over the operational 24-hour period, were combined to prepare the daily composite supernatant sample.
- Equal amounts of dried tailings solids, collected over the operational 24-hour period, were passed through a riffle splitter, to achieve representative sub-samples, and combined.
- The corresponding supernatant and tailings solids were used to prepare each daily composite sample (i.e., samples from the same operational period were combined).

Three master composite samples were then prepared by NSR for tailings slurry to produce the final tailings solids and supernatant samples, which were provided to WSP for laboratory testing (Table 3.1).

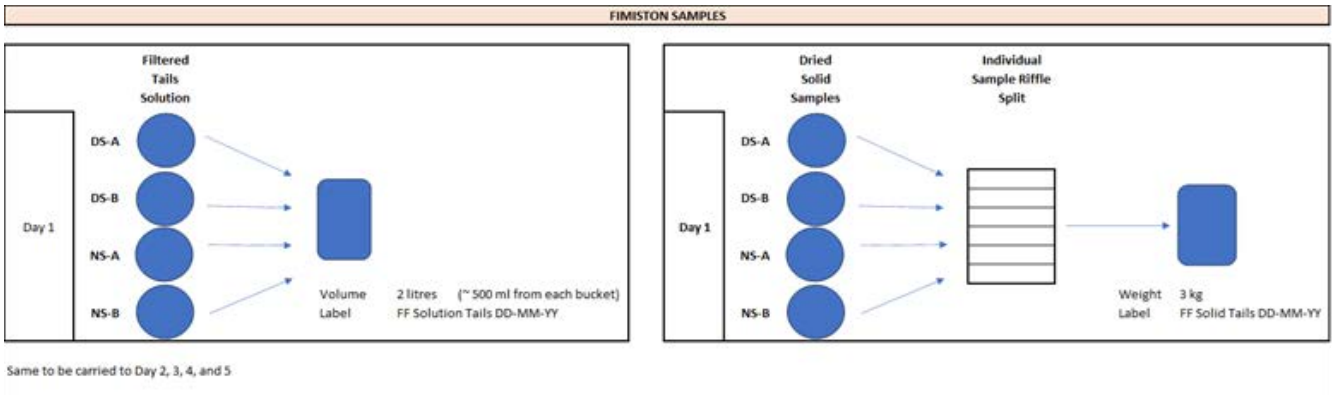


Figure 3.1 Diagram sampling approach for Fimiston tailings samples

Table 3.1 Daily and master composite sample details

Daily composite No.	Date	Master Composites
1	27/02/2024	Fimiston Tailings 1
2	28/02/2024	Fimiston Supernatant 1
3	29/02/2024	Fimiston Tailings 2
4	01/03/2024	Fimiston Supernatant 2
5	02/03/2024	Fimiston Tailings 3
6	03/03/2024	Fimiston Supernatant 3

3.2 Laboratory program

The geochemical characterisation methodology employed in this assessment followed those outlined in AMIRA (2002), DITR (2016), and INAP (2009). Samples were subjected to the suite of laboratory parameters outlined in Table 3.2. Most of the laboratory analyses were performed by ALS Environmental Pty Ltd (ALS), Brisbane, under National Association of Testing Authorities (NATA) accreditation, where applicable. Mineralogical analysis by quantitative X-ray diffraction (QXRD) was subcontracted to Earth Systems, Melbourne.

Table 3.2 Laboratory program

Laboratory test	Test Work Details
ABA	— pH and EC (1:2 S/L ratio) — Sulfur speciation: total sulfur (LECO), sulfide sulfur (chromium reducible sulfur, CRS) and sulfate sulfur (4M HCl-extractable sulfur) — Carbon speciation: total carbon (LECO), TIC and TOC — ANC
NAG	— NAG pH — NAG acidity to pH 4.5 — NAG acidity to pH 7.0
Whole rock multi-element analysis	Strong four-acid mixture digestion and ICP analysis of a standard 48-element suite
Mineralogy	Assessment by QXRD, including amorphous content
ABCC	Acid buffering characteristic curve
DI leach (modified ASLP, 1:5 extraction ratio, 18-hour tumble)	— pH and EC — Alkalinity (hydroxide, carbonate, bicarbonate and total) — Major ions (Ca, Mg, Na, K, Cl, F, SO_4) — Dissolved (filtered, 0.45 um) metal(loid)s by ICP analysis. — Dissolved Hg by FIMS — Nitrogen speciation (NO_2, NO_3, NH_3, total Kjeldahl nitrogen (TKN), total nitrogen (TN)) — Total P and PO_4 — Total cyanide (CN), WAD cyanide and free CN
Supernatant	— Same suite as DI leach, plus total dissolved solids (TDS)
NAG liquor	— pH and EC — Alkalinity (hydroxide, carbonate, bicarbonate and total) — Major ions (Ca, Mg, Na, K, Cl, F, SO_4) — Dissolved (filtered, 0.45 um) metal(loid)s by ICP analysis. — Dissolved Hg by FIMS

Notes: ABA = acid-base accounting | ANC = acid neutralisation capacity | ASLP = Australian Standard Leaching Procedure | CRS = chromium reducible sulfur | EC = electrical conductivity | FIMS = flow injection mercury system | ICP = inductively coupled plasma | NAG = net acid generation | TDS = total dissolved solids | TIC = total inorganic carbon | TOC = total organic carbon | QXRD = quantitative X-ray diffraction

3.3 Laboratory background information and data processing

Full experimental details and background information are provided in Appendix A with brief methodological descriptions outlined in the following sub-sections.

3.3.1 Tailings composition and geochemical abundance index

The measured total concentrations are compared to average crustal concentrations to calculate geochemical abundance index (GAI) values for each element. The GAI values indicate elements that are geochemically enriched and, therefore, may be of environmental importance. A GAI value of greater than or equal to three (GAI ≥3) is generally considered geochemically enriched (i.e., enrichment of >12 times the median soil content).

3.3.2 Acid forming classification

The net acid producing potential (NAPP) calculation was based on the acid potential (AP), which uses the sulfide sulfur concentration determined using the CRS test (as opposed to the maximum potential acidity (MPA), which is calculated using the total sulfur concentration). The calculated carbonate neutralisation potential (Carb-NP) was higher than the measured ANC for all samples, hence, the ANC was used for the NAPP and neutralisation potential ratio (NPR) calculations. The Carb-NP may be overestimated due to the presence of siderite, which contains inorganic carbon but does not contribute to acid neutralisation. Siderite was confirmed to be present in the mineralogy testing (see Section 4.1.1).

3.3.3 Water leach

The DI water leach aims to simulate leaching under normal rainfall conditions and represents the potential ‘at-source’ conditions. This test cannot be used to evaluate transient processes, such as sulfide oxidation, or predict long-term solute release rates. For comparative purposes, the livestock drinking water DGVs (ANZECC & ARMCANZ, 2000) and the non-potable water use guidelines (NPUG) (DER, 2014) were used. These comparison guidelines were selected in keeping consistent with previous studies (Section 2).

4 Results and discussion

The following sections present the results and interpretation of the tailings solids and supernatant samples collected and analysed in this study. A brief description of the laboratory tests performed is provided in Appendix A, along with the relevant context for interpreting the results and the more relevant limitations that should be considered.

Collated results are presented in Appendix B and the compiled laboratory certificates are given in Appendix C.

4.1 Bulk tailings geochemistry

4.1.1 Mineralogical composition

The mineralogical composition of the Fimiston tailings is provided in Table 4.1. The key findings include:

- The major mineral phases of the Fimiston tailings are quartz (20.8 - 30.1%), dolomite (21.1 - 21.8%), albite (13.1 - 16.4%) and mica (muscovite/paragonite, combined 19.0 - 24.0%). These results are broadly consistent with the GCA (2010) study, although it is noted that ankerite (high iron dolomite) may also be present in the current samples.
- Carbonate minerals capable of effective acid neutralisation, including calcite [$CaCO_3$] and dolomite [$(Ca, Mg)_2(CO_3)_2$] are present. The major carbonate mineral present is dolomite (~22%), with minor calcite (0.8 - 3.6%) and siderite [$FeCO_3$] (1.6 - 2.3%). Siderite is not capable of effective acid neutralisation but is present at low concentrations relative to dolomite.
- Minor pyrite (iron sulfide mineral; [FeS_2]) is present in all three Fimiston samples (<2.1%). Iron sulfide minerals (such as pyrite) are very important in the context of AMD as it has the potential to produced sulfuric acid (H_2SO_4) when oxidised.
- Other trace mineral phases include silicate minerals (actinolite, biotite, clinochlore, microcline and paragonite), oxide minerals (magnetite), and amorphous minerals.

4.1.2 Multi-element composition

The multi-element results and calculated GAI values for all metal(loid)s analysed are shown in Appendix B (samples EB2411964-001 to EB2411964-003) with geochemically enriched metal(loid)s presented in Table 4.2. The key results include:

- The Fimiston tailings are primarily composed of iron (~8.0%), aluminium (~6.0%), magnesium (~2.0%), calcium (~5.0%), sodium (~2.0%), and potassium (~1.0%). The abundance of these metals is consistent with the mineralogical composition, with the presence of aluminosilicate minerals, dolomite, pyrite, and siderite. It should be noted that total silicon (Si) was not determined but is expected to be a major element based on the presence of quartz and silicate minerals verified by mineralogy testing (Section 4.1.1).
- The calculated GAI values indicate that arsenic, sulfur, antimony, selenium, tellurium and tungsten are geochemically enriched (GAI ≥3) in the Fimiston tailings.

Table 4.1 Quantitative mineralogical composition results (Q-XRD)

Mineral group		**Tailings sample (%wt)**		
		Fimiston Tailings 1	**Fimiston Tailings 2**	**Fimiston Tailings 3**
Sulfide	Pyrite (FeS_2)	2.1	2.1	1.9
Carbonate	Calcite ($CaCO_3$)	3.6	0.8	0.8
	Dolomite ($CaMg(CO_3)_2$)	**21.1**	**21.8**	**21.7**
	Siderite ($FeCO_3$)	2.3	1.5	1.6
Silicate	Actinolite ($Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$)	0.1	ND	ND
	Albite ($NaAlSi_3O_8$)	**15.2**	**16.4**	**13.1**
	Biotite ($K(Mg,Fe)_3(AlSi_3O_{10})(OH)_2$)	0.6	0.7	0.7
	Clinochlore ($(Mg,Fe^{2+})_5Al_2Si_3O_{10}(OH)_8$)	8.0	7.9	9.9
	Microcline ($KAlSi_3O_8$)	1.0	1.3	0.9
	Muscovite ($KAl_2(AlSi_3O_{10})(OH)_2$)	**17.1**	**15.2**	**14.7**
	Paragonite ($NaAl_2(AlSi_3O_{10})(OH)_2$)	6.9	7.5	4.3
	Talc ($Mg_3Si_4O_{10}(OH)_2$)	ND	ND	ND
Hydroxide/ Oxide	Magnetite (Fe_3O_4)	ND	ND	0.3
	Quartz (SiO_2)	**20.8**	**22.5**	**30.1**
Non-crystalline	Amorphous	1.2	2.3	ND

Notes: Major minerals indicated in **bold** | ND = not detected

Table 4.2 Geochemically enriched metal(loid)s in tailings samples

Element	Crustal Average Concentration* (mg/kg)	Geochemical abundance index (GAI)
As	1.8	4
S	500	2-3
Sb	0.2	4
Se	0.05	4
Te	0.001	6
W	1.5	3

Notes: * (AusIMM, 2001; Smith, K. S., & Huyck, H. L. O., 1997)

4.2 Acid-base accounting (ABA)

Summary statistics of ABA and NAG testing parameters for the Fimiston tailings solids samples are presented in Table 4.3. The AMIRA (2002) cross-plot used for acid formation classification, based on the calculated net acid production potential (NAPP) and NAG pH, is presented in Figure 4.1. The key findings are:

- The paste pH values for the Fimiston tailings samples are within the alkaline range (pH 8.8 - 9.0), with brackish salinity (EC = 4,780 - 5,940 µS/cm).
- The total sulfide sulfur content is low (0.26 - 0.44%) with sulfur predominately present as sulfide (0.24 - 0.41%).
- The ANC for these samples is high, ranging from 196 - 207 kg·H_2SO_4/t, which is expected to be mainly provided by reactive carbonate minerals such as dolomite based on the mineralogy testing.
- The tailings samples are classified as NAF based on alkaline NAG pH values (pH 10.6 - 10.7) and negative NAPP values (-199 to -183 kg·H_2SO_4/t). The NPR is >3 for all Fimiston tailings samples (NPR = 15 - 26). The Fimiston tailings may be classed as NAF (acid consuming; AC) based on the highly negative NAPP values.

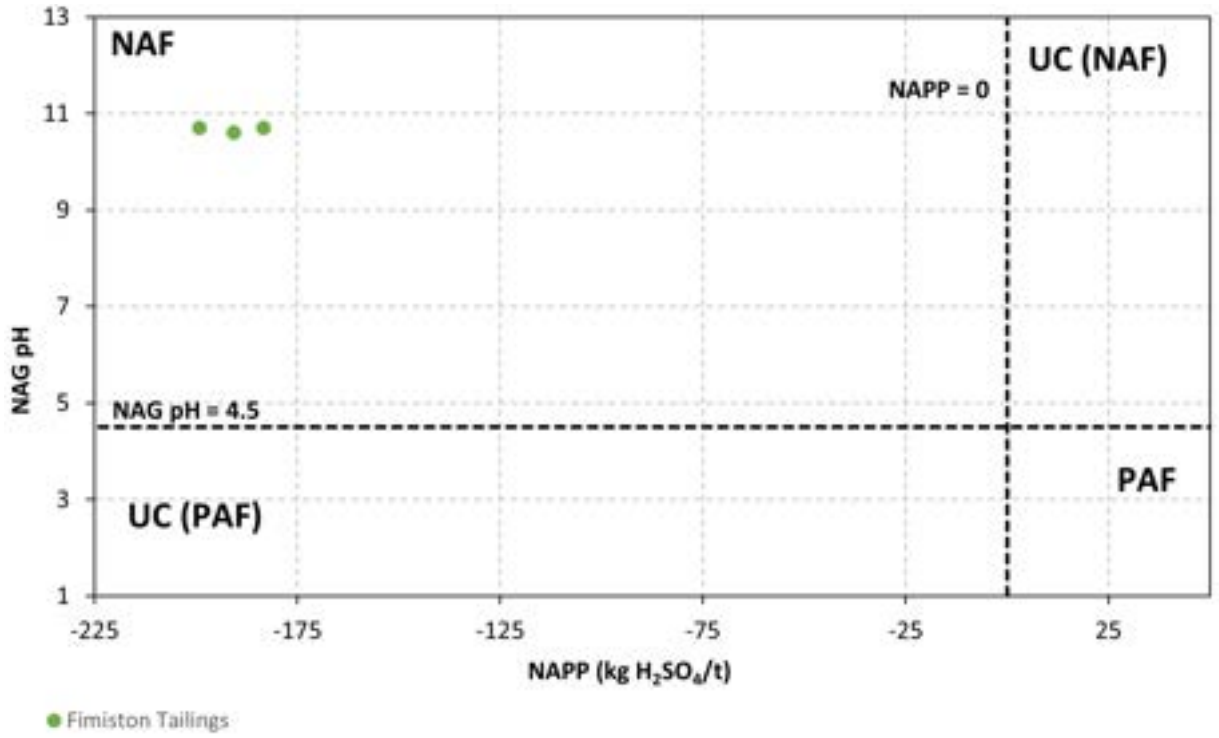
These findings are consistent with the previous MBS (2016b) study report for Fimiston tailings.

Table 4.3 Summary of statistics of acid-base accounting parameters

Parameter	Units	Minimum	Median	Maximum
Measured parameters				
Paste pH	No units	8.8	8.9	9.0
Paste EC	µS/cm	4,780	4,800	5,940
Total Sulfur (TS)	wt.%	0.26	0.28	0.44
Sulfate-S (S_{HCl})	wt.%	0.03	0.03	0.04
Sulfide-S (S_{CR})	wt.%	0.24	0.26	0.41
Total Carbon	wt.%	3.5	3.5	3.8
TIC	wt.%	3.4	3.4	3.8
TOC	wt.%	0.04	0.08	0.08
ANC	kg·H_2SO_4/t	196	198	207

Parameter	Units	Minimum	Median	Maximum
NAG pH	No units	10.6	10.7	10.7
Calculated parameters				
MPA	kg·H_2SO_4/t	8	9	13
AP (using S_{CR})	kg·H_2SO_4/t	7	8	13
$NAPP_{AP-ANC}$	kg·H_2SO_4/t	-199	-191	-183
$NPR_{ANC/AP}$	-	15	26	27
Classification	-	NAF		

Notes: EC: electrical conductivity | ANC: acid neutralisation capacity | AP: acid potential | TIC: total inorganic carbon | TOC: total organic carbon | MPA: maximum potential acidity | NAG: net acid generation | NAPP: net acid production potential | NPR: neutralisation potential ratio | NAF: non-acid forming



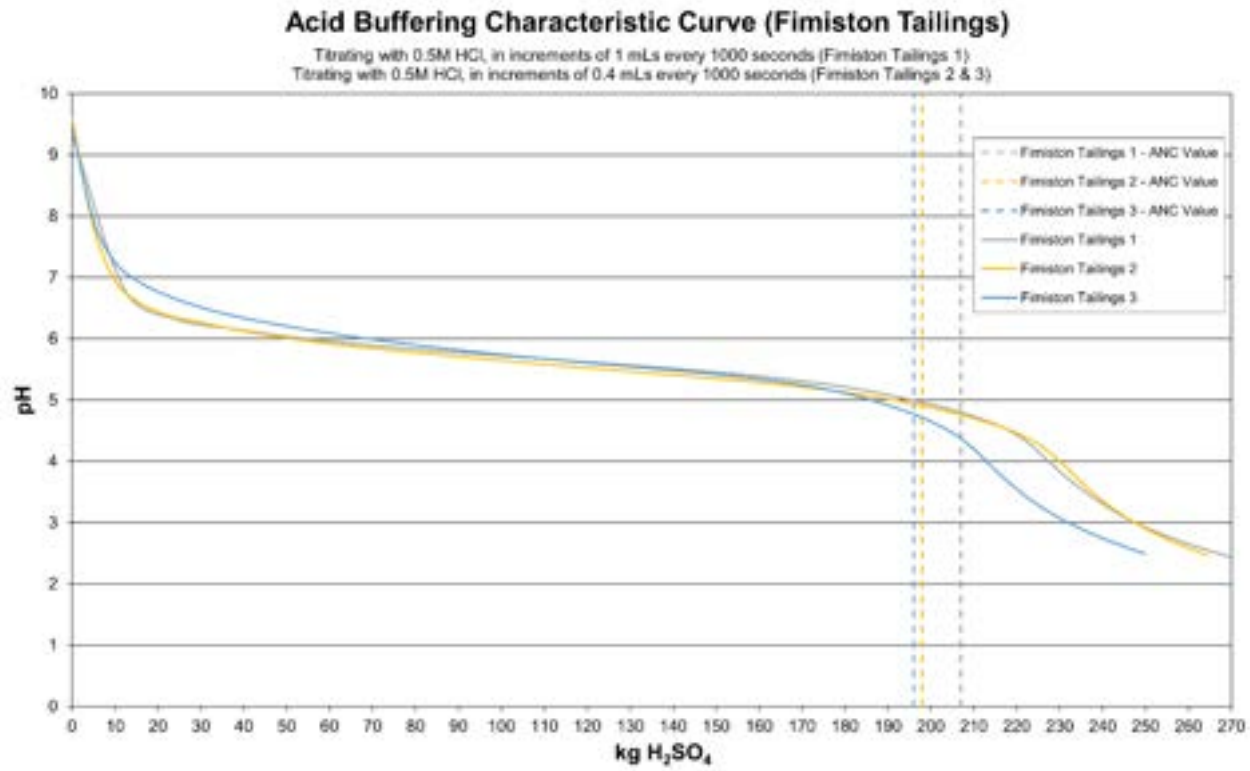
Notes: NAG: Net acid generation | NAF: Non-acid forming | NAPP: Net acid potential production | PAF: Potentially acid forming | UC: uncertain

Figure 4.1 Acid formation cross-plot of Fimiston tailings

4.3 Acid buffering characteristic curve (ABCC)

The ABCC plot for the Fimiston tailings is presented in Figure 4.2. The ABCC results indicate that:

- The Fimiston tailings have an overall high acid buffering capacity, as evidenced by the high ANC values (196 - 207 kg·H_2SO_4/t) and the presence of abundant dolomite confirmed by the mineralogy results.
- The 'effective ANC' (to pH 6) ranges from 49 - 69 kg·H_2SO_4/t, indicating that approximately 25% to 35% of the total ANC is readily available.
- The ABCC results indicate that the most significant acid buffering occurs to pH 5, comprising ~95% of the total ANC.



Notes: ANC: Acid neutralisation capacity

Figure 4.2 Acid buffering characteristic curve (ABCC) for Fimiston tailings samples

4.4 Solubility assessment

The median parameter concentrations for the DI water leachates, the supernatant, and the NAG liquor for the Fimiston tailings are presented in Table 4.3.

4.4.1 Water leach

The key DI water leach results include:

- **pH**: Leachate pH is within the near-neutral pH range (pH 7.5 - 7.9).
- **Salinity and major ions**: The salinity of the DI water leachates is marginally brackish, with EC values ranging from 2,400 - 3,060 µS/cm (equivalent calculated TDS[1] of 1,608 - 2,050 mg/L). The calculated TDS values are within the livestock drinking water DGV (cattle) of 4,000 mg/L. The major ion contributors to the leachate salinity are chloride (766 - 947 mg/L), sodium (399 - 496 mg/L), and sulfate (95 - 140 mg/L). The leachate chloride concentrations exceed the NPUG guideline value (250 mg/L) in all the Fimiston tailings leachates.
- **Alkalinity**: Total alkalinity of the DI water leachates ranges from 34 - 39 mg $CaCO_3$/L and is provided exclusively by bicarbonate (HCO_3).
- **Trace metal(loid)s**: Dissolved metal(loid) concentrations are within the livestock drinking water DGV and NPUG guideline values, and predominately near or below respective laboratory limits of reporting (LOR).
- **Cyanide**: The free cyanide concentrations are within the comparator guideline value of 0.8 mg/L. Total cyanide concentrations range from 0.002 - 0.05 mg/L and WAD from 0.003 - 0.046 mg/L.

[1] TDS calculated from EC using the following expression: TDS = EC*0.67 (ANZECC & ARMCANZ, 2000)

- **Nutrient content**:
  - Total nitrogen (TN) concentrations typically range from 1.0 - 1.4 mg·N/L, with the organic-associated total Kjeldahl nitrogen (TKN) being the main contributor, followed by ammonia, nitrate and nitrite. Leachate nitrate and nitrite concentrations are within the comparator guidelines.
  - Total phosphorus concentrations range from <0.01 - 0.02 mg/L.

Overall, short-term tailings leaching due to natural rainfall is expected to have a near-neutral pH, brackish and contain predominantly low concentrations of soluble metal(loid)s. These findings are broadly consistent with the findings from the MBS (2016a) study report, except for the following (the same modified ASLP method was used between both studies):

- Dissolved mercury concentrations were previously reported as consistently exceeding the ANZECC& ARMCANZ (2000) livestock DGV in DI water leachates (0.005 - 0.08 mg/L), whereas mercury concentrations were below the laboratory LOR for all Fimiston tailings leachate samples (<0.0001 mg/L).
- High soluble concentrations of cobalt (0.69 mg/L), copper (1.6 mg/L), and hexavalent chromium (0.32 mg/L) were previously reported for one of the Fimiston tailings samples. In the current assessment, concentrations of these metals were comparatively lower, with maximum concentrations of 0.02 mg/L, 0.19 mg/L, and <0.001 mg/L recorded for cobalt, copper and chromium (total dissolved), respectively.

4.4.2 Supernatant chemistry

The key Fimiston tailings supernatant results include:

- **pH**: The supernatant pH is within the circum-neutral range (pH 7.5 - 7.9).
- **Salinity and major ions**: The salinity of the supernatant is high (hypersaline), with measured TDS values ranging from 100,000 - 106,000 mg/L, which exceeds the livestock drinking water DGV of 4,000 mg/L (cattle). The major ion contributors to the leachate salinity are chloride (53,300 - 56,400 mg/L), sodium (30,200 - 34,100 mg/L), and sulfate (4,530 - 4,590 mg/L). Concentrations of chloride and sulfate surpass the NPUG guideline values (250 mg/L and 1,000 mg/L respectively). Calcium, magnesium, and sulfate concentrations also exceed their respective livestock drinking water DGV (1,000 mg/L, 2,000 mg/L, and 1,000 mg/L, respectively).
- **Alkalinity**: Total alkalinity ranges from 71 - 98 mg $CaCO_3$/L and is exclusively provided by bicarbonate (HCO_3).
- **Trace metal(loid)s**: Due to the saline nature of the Fimiston supernatants, the laboratory LOR was compromised for several metal(loid)s, resulting in higher LOR values than the corresponding comparison guidelines (i.e., selenium and thallium). Aside from these limitations, soluble metal(loid) concentrations are generally below the comparison criteria, except for the following:
  - Concentrations of antimony (0.07 - 0.08 mg/L), nickel (0.6 - 0.8 mg/L), and iron (15.7 - 22.9 mg/L) exceed the NPUG guideline values in all Fimiston supernatant samples.
  - Concentrations of cobalt (1.0 - 1.1 mg/L), and copper (10.6 - 17.6 mg/L), exceed the livestock drinking water DGV in all samples.
  - Concentrations of cadmium and thallium exceed the comparator guidelines in one sample.
  - These metal(loid)s may be associated with cyanide complexing, as also suggested in previous studies (Section 2).
- **Cyanide**: The Fimiston supernatant contains high total cyanide (68 - 100 mg/L), WAD cyanide (25 - 36 mg/L), and free cyanide (21 mg/L to 30 mg/L). Free cyanide concentrations in all samples exceed the NPUG guideline value of 0.8 mg/L.

- **Nutrients**:
  - TN concentrations typically range from 60.9 - 62.6 mg·N/L, with TKN (i.e., nitrogen of organic origin) being the main contributor, followed by ammonia, nitrate (i.e., inorganic origin), and nitrite. Nitrate and nitrite concentrations are within the comparator guidelines.
  - Total phosphorus concentrations range between <0.05 - 0.08 mg/L.

Overall, drainage from the Fimiston TSF is expected to be represented by the supernatant composition, and hence, expected to have a near-neutral to slightly alkaline pH, be hypersaline, and contain certain metal(loid)s at concentrations surpassing the selected guidelines for assessment. The very high salinity is understood to be from the processing water used. As such, these conditions are likely to prevail at least until the entrained supernatant water has been flushed from the tailings mass (solid).

The Fimiston supernatant compositions are broadly consistent with that previously reported in the MBS (2016a) study, except for the following:

- Dissolved iron concentrations were higher in Fimiston supernatants (up to ~23 mg/L) in comparison to that reported previously (1.6 mg/L). The higher iron concentrations in Fimiston supernatants may be associated with water-soluble cyanide complexes, particularly since the total cyanide content is approximately three-fold higher in the current samples.
- Dissolved mercury concentrations were below the laboratory LOR in the current study compared to a reported concentration of 0.04 mg/L in the previous study.

4.4.3 Net acid generation (NAG) liquor

The NAG liquor composition results, which simulate contact water following completely oxidation. The key results include:

- **pH**: The NAG liquor pH is slightly alkaline (pH 9.8 - 10.1).
- **Salinity and major ions**: The salinity of the NAG liquor is non-saline (calculated TDS ranged from 224 - 263 mg/L), and lower in comparison to the DI leach salinity results. This is likely attributable to the higher S/L extraction ratio of the NAG test.
- **Minor/trace metal(loid)s**:
  - Concentrations of aluminium (0.3 - 0.4 mg/L) are present at higher concentrations in the NAG liquor relative to DI water leachate compositions. However, these concentrations are not considered significant, as they marginally surpass the NPUG guideline value which is based on aesthetics (post-flocculation of aluminium sulfate) and not related to environmental health.
  - Other dissolved metal(loid) concentrations of the NAG liquor leachates are present at similar concentrations to the corresponding DI water leach concentrations.

Overall, drainage from completely oxidised/weathered Fimiston tailings, as simulated by the NAG liquor test, is indicated to be similar in comparison to drainage from fresh tailings (i.e., the drainage composition is not expected to vary significantly between fresh and weathered tailings). Based on the NAG liquor results, it is unlikely that sulfide oxidation will be a major contributor to NMD or SD.

5 Limitations statement

Your attention is drawn to the document titled – “Limitation Statement”, which is included in Appendix D of this report. The statements presented in that document are intended to inform a reader of the report and its proper use. There are important limitations as to who can use the report and how it can be used. It is important that a reader of the report understands and has realistic expectations about those matters. The Limitation Statement document does not alter the obligations WSP has under the contract between it and its client.

6 Conclusions and recommendations

Key findings from the geochemical assessment of the Fimiston tailings are:

- The findings in from the current assessment are broadly consistent with previous studies on Fimiston tailings.
- The major mineral phases include quartz, dolomite, albite, and mica; dolomite is capable of effective acid neutralisation. Minor pyrite (iron sulfide mineral) is present (1.9 – 2.1%), which is capable of acid generation.
- Multi-element composition analysis shows geochemical enrichment of arsenic, sulfur, antimony, selenium, tellurium and tungsten in the Fimiston tailings.
- The potential for AMD generation is negligible for Fimiston tailings. Despite containing low levels of sulfide sulfur, the tailings are classified as NAF, and may further be classed as NAF (AC) based on strongly negative NAPP values. The tailings contain sufficient and readily available ANC to neutralise any acid generated by sulfide oxidation.
- Drainage from the Fimiston TSF is expected to be represented by the supernatant composition, and hence, expected to have a near-neutral to slightly alkaline pH, be hypersaline, and contain certain cyanide-associated metal(loid)s at concentrations surpassing the selected guidelines for assessment (antimony, cadmium, cobalt, copper, iron, nickel, and thallium).
- Short-term tailings leaching due to natural rainfall, as simulated by a static DI water leach, is indicated to be of better quality than the supernatant/processing water. Runoff and seepage from tailings (once the supernatant no longer dominates the pore-water chemistry) are expected to be circum-neutral, brackish, and contain predominantly low concentrations of soluble metal(loid)s.
- Drainage from completely oxidised Fimiston tailings, as simulated by the NAG liquor test, is indicated to be similar in comparison to drainage from fresh tailings (i.e., the drainage composition is not expected to vary significantly between fresh and oxidised tailings). Based on the NAG liquor results, it is unlikely that sulfide oxidation will be a major contributor to NMD and SD.
- Routine tailings geochemical testing is recommended to develop an inventory of mine wastes produced and stored onsite to support closure preparedness.
- Additional geochemical characterisation should be undertaken if there are any anticipated or confirmed changes to the orebody geology or processing method(s).

7 References

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8 Closing

We trust this document meets your expectations. Should you have any queries regarding the content of this report, or if we can be of further assistance, please do not hesitate to contact Gert du Plessis (gert.duplessis@wsp.com).

Appendix A

Geochemical characterisation methodology

1 Geochemical characterisation methodology and classification

The approach to geochemical characterisation and material classification is discussed in the following subsections.

1.1 Acid-base accounting

The most common methods for assessing the acid formation potential of mine waste materials are the acid-base accounting (ABA) and net acid generation (NAG) tests, which are referred to as static methods (AMIRA 2002). The acid generation potential and acid neutralisation capacities of mine wastes are critical to assessing the potential for acid and metalliferous drainage (AMD) formation, as follows:

- **Acid generation:** Acid generation in mine waste is typically a result of iron sulfide (e.g., pyrite [FeS_2]) oxidation, producing an oxidant (Fe^{3+}), acid (H^+) and sulfate (SO_4^{2-}). Iron and aluminium sulfate minerals, such as jarosite [$KFe_3(SO_4)_2(OH)_6$] and alunite [$KAl_3(SO_4)_2(OH)_6$], which are secondary precipitated acid-sulfosalts generated by the oxidation of iron sulfides, may also produce acidity by hydrolysis, rather than oxidation.
- **Neutralisation:** The acidity generated by sulfide oxidation can be buffered by readily reactive carbonate minerals (e.g., calcite [$CaCO_3$]) present in a material. Acid neutralisation can also be provided by silicate minerals; however, this is slow-reacting neutralisation that is dependent on the weathering susceptibility of the minerals present (Table 1.1).

Therefore, quantification of the acid generation potential by sulfide oxidation and neutralisation potential by buffering minerals (such as carbonates) forms the fundamental basis of the ABA assessment. It should also be noted that AMD is not strictly limited to acid drainage but includes potential alternative issues related to sulfide oxidation, such as neutral mine drainage (NMD) or saline drainage (SD).

Table 1.1 Grouping of minerals according to their ANC (Kwong, 1993)

Group name	Typical minerals	Relative reactivity
Dissolving	Calcite, aragonite, dolomite, magnesite, and brucite.	1.0
Fast weathering	Anorthite, nepheline, olivine, garnet, jadeite, leucite, spodumene, diopside, and wollastonite.	0.6
Intermediate weathering	Epidote, zoisite, enstatite, hypersthene, augite, hedenbergite, hornblende, glaucophane, tremolite, actinolite, serpentine, chrysolite, talc, chlorite, and biotite.	0.4
Slow weathering	Albite, oligoclase, labradorite, vermiculite, montmorillonite, gibbsite, kaolinite.	0.02
Very slow weathering	K-feldspar and muscovite.	0.01
Inert	Quartz, rutile, and zircon.	0.004

Total sulfur and total carbon are measured by combusting the sample in oxygen at 1,350°C. Sulfur/carbon present in the sample is evolved as sulfur dioxide/carbon dioxide and swept to a measurement cell for quantification by infrared detection (LECO). The infra-red cell output is calibrated against a standard to determine the total sulfur/carbon of the sample. Total sulfur indicates the amount of sulfur that could potentially contribute to acid generation. Sulfide and sulfate sulfur species are also measured to determine oxidisable and non-oxidisable forms, respectively. Total carbon is typically also accompanied by the measurement of total inorganic carbon (TIC), which is used to estimate the material's neutralising capacity that is associated with carbonate minerals.

Material acid neutralisation capacity (ANC) is commonly measured by the Modified Sobek method (Sobek, et. Al. 1978). This method involves the reaction of a sample with a known volume of standardised hydrochloric acid (HCl) and back-titration with sodium hydroxide (NaOH) to determine the amount of unreacted acid. The amount of acid consumed is calculated and expressed as kg H_2SO_4/t (AMIRA 2002).

The NAG test aims to experimentally determine the potential acid generated after a sample has undergone complete oxidation. During the NAG tests, the samples are mixed with a strong oxidising agent (H_2O_2) to oxidise sulfide minerals present in the sample, generating acidity. In turn, any reactive acid-consuming minerals present may buffer any acid generated. Excess acidity produced during oxidation will decrease the solution pH. A NAG pH of 4.5 is commonly considered the threshold between NAF and potentially acid-forming (PAF) material in combination with a negatively calculated net acid production potential (NAPP) (AMIRA, 2002). The NAG solution can then be neutralised by titration to pH 4.5 and 7.0 to quantify the acidity produced during oxidation.

Additional parameters are calculated based on the ABA test work to support acid formation potential classification, as shown in Table 1.2.

Table 1.2 Formulas for calculation of ABA parameters

Parameter	Formula	Notes
Maximum Potential Acidity (MPA)	MPA = TS * 30.6	Upper limit of acid production based on the total sulfur (TS) concentration. The MPA assumes that all sulfur is present as pyrite and, as such, can be very conservative.
Acid Potential (AP)	AP = CRS (S_{CR}) * 30.6 **OR** AP = TOS (TS – S_{HCl}) * 30.6	Upper limit of acid production based on the total oxidisable sulfur (TOS) content. The TOS can be determined by the chromium reducible sulfur (CRS) method (direct measure of sulfides) or by the difference between TS and sulfate-sulfur (i.e., S_{HCl}, sulfide sulfur). The AP corrects for fully oxidised forms of sulfur, which are non-acid producing.
Carbonate neutralising potential (Carb-NP)	Carb-NP = TIC * 81.63	Neutralisation potential based on the assumption that all inorganic carbon is present as calcite.
Net acid production potential (NAPP)	NAPP = AP – ANC	Net acid production potential, using the MPA, to determine the balance of acid producing and acid neutralising potentials.
Effective net acid production potential ($NAPP_{eff}$)	$NAPP_{eff}$ = AP – Carb-NP	Net acid production potential corrected for sulfide sulfur and readily available ANC.
Neutralisation potential ratio (NPR)	NPR = ANC/AP	Neutralisation potential ratio, which is the ratio of neutralising potential to acid producing potential.
Effective neutralisation potential ratio (NPR_{eff})	NPR_{eff} = Carb-NP/AP	Neutralisation potential ratio corrected for readily available ANC.

Notes: Units for all calculated parameters are in kg H_2SO_4/t.

1.2 Acid forming classification

The acid formation classification scheme used in the current assessment (Table 1.3) is determined using the NAPP and NAG pH values. The classification is assigned in accordance with AMIRA (2002) and DITR (2016) guidelines.

The neutralisation potential ratio (NPR) provides another method of classifying the potential acid generation of samples and is based on the ratio of ANC to the maximum potential acidity (MPA). Generally, materials with NPR values greater than two are considered NAF, whereas materials with NPR values less than two, and especially less than one, are considered PAF (Price, 2009).

Table 1.3 Summary of acid-forming classification scheme (AMIRA 2002, DITR 2016)

Class	Subclass	NAPP (kg H_2SO_4/t)	NAG pH
NAF	NAF	<0	≥ 4.5
	NAF-barren	NAPP < 0 and ANC ≤ 5 kg H_2SO_4/t	≥ 4.5
	AC	< -100	≥ 4.5
PAF	PAF	>10	< 4.5
	PAF-LC	0 to 10	< 4.5
UC	UC(PAF)	Negative	< 4.5
	UC(NAF)	Positive	≥ 4.5

Notes: NAF = Non-acid forming; AC = Acid consuming; NAPP = Net acid production potential; PAF – LC = Potentially acid forming low capacity; UC = Uncertain

1.3 Bulk geochemical composition

1.3.1 Mineralogical composition

Mineralogical composition is a key component of AMD characterisation, since it determines the physical and geochemical stability, and reaction rates of geologic materials and mine wastes (INAP, 2009). Mineralogical composition was determined using quantitative X-ray diffraction (QXRD), which includes amorphous (i.e., non-crystalline) phases.

1.3.2 Multi-element composition

Total multi-element concentrations were determined using a strong four-acid mixture digestion (hydrochloric, hydrofluoric, perchloric and nitric acids) and analysed by inductively-coupled plasma optical emission spectroscopy (ICP-OES) or mass spectrometry (ICP-MS).

Measured concentrations are compared to average crustal concentrations (AusIMM 2001; Smith and Huyck, 1999) to calculate geochemical abundance index (GAI) values for each element. The GAI values indicate elements that are geochemically enriched and, therefore, may be of environmental importance. The GAI is based on a log-2 scale and is expressed in integer increments from 0 to 6, respectively (INAP, 2009), where a GAI value equal to zero indicates that the element is present at a concentration similar to, or lower than, the average crustal concentration, and a GAI value of 6 indicates an approximate 100-fold enrichment or greater. A GAI value equal to, or greater than, three (GAI ≥ 3) is generally considered geochemically enriched (i.e., enrichment of 12 to 24 times the average crustal concentration).

1.4 Solubility assessments

Various solubility assessments are performed to inform the potential for AMD, NMD and SD generation from tailings samples. Common solubility assessments include (1) the Australian Standard Leaching Procedure (ASLP) using deionised (DI) water, (2) the tailings associated water (referred to as the supernatant) and (3) NAG liquor which represents the leachate composition of fully oxidised tailings.

For high-level comparative purposes, the results may be screened against site-specific, local, state, or international water quality criteria to determine the potential drainage hazards associated with the materials. Ultimately, screening criteria are required to be appropriate for the environmental context.

1.4.1 Water leach

A modified Australian Standard Leaching Procedure (ASLP) was employed for the current work, utilising a 1:2 solid-to-liquid (S/L) ratio instead of the 1:20 S/L ratio per the Standard, and using deionized (DI) water as the extraction fluid. Following the addition of DI water to the weighed (dry) sample, it was tumbled/mixed via rotary action for 18 hours. Extractant fluids were decanted, following centrifugation, and analysed.

The DI water leach aims to simulate leaching under normal rainfall conditions and represents the potential 'at-source' conditions. This test cannot be used to evaluate transient processes, such as sulfide oxidation, or predict long-term solute release rates. Kinetic testing is more appropriate for predicting long-term solute release rates.

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Appendix B

Collated results

Appendix B
Collated geochemical results

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Table B.1 Multi-elemental composition results for Fimiston tailings (Part 1 of 3)

Sample ID	Unit	ppm	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm
	Lab ID	**Ag**	**Al**	**As**	**Ba**	**Be**	**Bi**	**Ca**	**Cd**	**Ce**	**Co**	**Cr**	**Cs**	**Cu**	**Fe**	**Ga**	**Ge**
Fimiston Tailings 1	EB2411964001	0.12	6.21	33	160	0.86	0.02	5.58	0.12	17.8	27.5	95	8.44	26.1	7.82	15.8	0.23
Fimiston Tailings 2	EB2411964002	0.30	6.37	45	160	0.89	0.04	5.23	0.13	18.8	32.0	124	8.67	43.8	8.05	16.8	0.25
Fimiston Tailings 3	EB2411964003	0.39	6.12	54	150	0.86	0.06	5.18	0.15	19.5	38.4	147	7.79	51.5	8.22	15.5	0.21
Median (Fimiston tailings)		0.30	6.21	45	160	0.86	0.04	5.23	0.13	18.8	32.0	124	8.44	43.8	8.05	15.8	0.23

Table B.2 Multi-elemental composition results for Fimiston tailings (Part 2 of 3)

Sample ID	Unit	ppm	ppm	%	ppm	ppm	%	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	%
	Lab ID	**Hf**	**In**	**K**	**La**	**Li**	**Mg**	**Mn**	**Mo**	**Na**	**Nb**	**Ni**	**P**	**Pb**	**Rb**	**Re**	**S**
Fimiston Tailings 1	EB2411964001	2.2	0.073	1.2	7.3	56.8	1.9	1,715	0.77	1.8	2.8	56	630	3.3	48.6	0.002	0.29
Fimiston Tailings 2	EB2411964002	2.4	0.078	1.2	7.7	65.1	2.0	1,805	1.3	1.9	2.7	63	630	5.8	50.1	0.002	0.28
Fimiston Tailings 3	EB2411964003	2.3	0.074	1.1	7.7	62.2	2.2	1,745	1.2	1.6	2.7	69	610	7.5	46.5	0.002	0.51
Median (Fimiston tailings)		2.3	0.074	1.2	7.7	62.2	2.0	1,745	1.2	1.8	2.7	63	630	5.8	48.6	0.002	0.29

Table B.3 Multi-elemental composition results for Fimiston tailings (Part 3 of 3)

Sample ID	Unit	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm
	Lab ID	**Sb**	**Sc**	**Se**	**Sn**	**Sr**	**Ta**	**Te**	**Th**	**Ti**	**Tl**	**U**	**V**	**W**	**Y**	**Zn**	**Zr**
Fimiston Tailings 1	EB2411964001	5.13	37.9	<1	0.7	199	0.19	0.69	0.98	0.553	0.45	0.3	269	16.7	10.9	110	90.6
Fimiston Tailings 2	EB2411964002	5.68	38.7	1	0.8	177	0.19	1.9	1.15	0.542	0.52	0.4	279	17.6	11.3	131	93.7
Fimiston Tailings 3	EB2411964003	5.78	36.7	1	0.7	166	0.17	1.5	1.18	0.532	0.49	0.4	257	18.0	10.6	121	88.4
Median (Fimiston tailings)		5.68	37.9	1	0.7	177	0.19	1.5	1.15	0.542	0.49	0.4	269	17.6	10.9	121	90.6

Table B.4 Geochemical abundance index (GAI) results for Fimiston tailings (Part 1 of 3)

Sample ID	Crustal Abundance	0.07	8	1.8	425	2.8	0.17	3	0.2	60	25	100	3	55	5	15	1.5
	Unit	ppm	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm
	Lab ID	**Ag**	**Al**	**As**	**Ba**	**Be**	**Bi**	**Ca**	**Cd**	**Ce**	**Co**	**Cr**	**Cs**	**Cu**	**Fe**	**Ga**	**Ge**
Fimiston Tailings 1	EB2411964001	0	0	4	0	0	0	0	0	0	0	0	1	0	0	0	0
Fimiston Tailings 2	EB2411964002	2	0	4	0	0	0	0	0	0	0	0	1	0	0	0	0
Fimiston Tailings 3	EB2411964003	2	0	4	0	0	0	0	0	0	0	0	1	0	0	0	0

Notes: highlighted cell denotes geochemically enriched elements (GAI ≥3)

Table B.5 Geochemical abundance index (GAI) results for Fimiston tailings (Part 2 of 3)

Sample ID	Crustal Abundance	3	0.1	2.6	30	20	2.1	950	1.5	2.4	20	75	10000	12.5	90	0.0005	0.05
	Unit	ppm	ppm	%	ppm	ppm	%	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	%
	Lab ID	**Hf**	**In**	**K**	**La**	**Li**	**Mg**	**Mn**	**Mo**	**Na**	**Nb**	**Ni**	**P**	**Pb**	**Rb**	**Re**	**S**
Fimiston Tailings 1	EB2411964001	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	2
Fimiston Tailings 2	EB2411964002	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	2
Fimiston Tailings 3	EB2411964003	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	3

Notes: highlighted cell denotes geochemically enriched elements (GAI ≥3)

Table B.6 Geochemical abundance index (GAI) results for Fimiston tailings (Part 3 of 3)

Sample ID	Crustal Abundance	0.2	16	0.05	2	375	2	0.001	10	0.057	0.45	2.7	135	1.5	30	70	165
	Unit	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm
	Lab ID	**Sb**	**Sc**	**Se**	**Sn**	**Sr**	**Ta**	**Te**	**Th**	**Ti**	**Tl**	**U**	**V**	**W**	**Y**	**Zn**	**Zr**
Fimiston Tailings 1	EB2411964001	4	1	-	0	0	0	6	0	0	0	0	0	3	0	0	0
Fimiston Tailings 2	EB2411964002	4	1	4	0	0	0	6	0	0	0	0	0	3	0	0	0
Fimiston Tailings 3	EB2411964003	4	1	4	0	0	0	6	0	0	0	0	0	3	0	0	0

Notes: '-' denotes elements with total concentrations <LOR and therefore GAI values were not calculated | highlighted cell denotes geochemically enriched elements (GAI ≥3)

Table B.7 Acid-base accounting (ABA) and net acid generation (NAG) results for Fimiston tailings

Sample ID	Lab ID	**Physicochemical**			**S Speciation**			**C Speciation**			**Acid Neutralisation Capacity**		**Net Acid Generation**		
		pH units	µS/cm	mg/L	%	%	%	%	%	%	$kg{\cdot}H_2SO_4/t$	% $CaCO_3$	No units	$kg{\cdot}H_2SO_4/t$	$kg{\cdot}H_2SO_4/t$
		0.1	1	1	0.01	0.02	0.005	0.02	0.02	0.02	0.5	0.1	0.1	0.1	0.1
		Paste pH	**Paste EC**	**TDS Calculated**	**S_{TOT}**	**S_{HCl}**	**S_{CR}**	**TC**	**TOC**	**TIC**	**ANC as H_2SO_4**	**ANC as $CaCO_3$**	**NAG pH**	**NAG pH 4.5**	**NAG pH 7.0**
Fimiston Tailings 1	EB2411964001	8.8	4,780	3,203	0.28	0.03	0.26	3.82	0.04	3.78	207	21	10.7	<0.1	<0.1
Fimiston Tailings 2	EB2411964002	8.9	4,800	3,216	0.26	0.04	0.24	3.48	0.08	3.40	198	20	10.6	<0.1	<0.1
Fimiston Tailings 3	EB2411964003	9.0	5,940	3,980	0.44	0.03	0.41	3.47	0.08	3.39	196	20	10.7	<0.1	<0.1

Table B.8 Calculated acid-base accounting results for Fimiston tailings

Sample ID	Lab ID	ABA calculated parameter								
		$kg \cdot H_2SO_4/t$	$kg \cdot H_2SO_4/t$	$kg \cdot H_2SO_4/t$	$kg \cdot H_2SO_4/t$	$kg \cdot H_2SO_4/t$	$kg \cdot H_2SO_4/t$	$kg \cdot H_2SO_4/t$	-	-
		MPA	**TOS**	**AP**	**AP_{TOS}**	**Carb-NP**	**$NAPP_{AP-ANC}$**	**$NAPP_{eff}$**	**NPR**	**Classification**
Fimiston Tailings 1	EB2411964001	8.6	0.25	8.0	8.0	309	-199	-301	26	NAF
Fimiston Tailings 2	EB2411964002	8.0	0.22	7.0	7.0	278	-191	-270	27	NAF
Fimiston Tailings 3	EB2411964003	14	0.41	13	13	277	-183	-264	15	NAF

Table B.9 Chemical composition of supernatant, DI water leachate and NAG liquor for Fimiston tailings sample

Parameter		**Unit**	**LOR**	**NPUG**	**Livestock DGV**	**Tailings water**			**Tailings solid**					
						Supernatant			**Water leachate**			**NAG liquor**		
						Fimiston Tailings 1	Fimiston Tailings 2	Fimiston Tailings 3	Fimiston Tailings 1	Fimiston Tailings 2	Fimiston Tailings 3	Fimiston Tailings 1	Fimiston Tailings 2	Fimiston Tailings 3
Physio-chemical	pH	No units	0.1	NG	6-8.5	7.5	7.7	7.9	7.9	7.5	7.8	10.1	9.8	9.9
	EC	µS/cm	1	NG	NG	121,000	116,000	122,000	2,400	3,060	2,790	392	387	335
	TDS-calculated	mg/L	1	4000 (cattle)	NG	102,000	100,000	106,000	1,608	2,050	1,869	263	259	224
Alkalinity	OH^- Alkalinity	$mg \cdot CaCO_3/L$	1	NG	NG	<1	<1	<1	<1	<1	<1	1	<1	<1
	CO_3 Alkalinity	$mg \cdot CaCO_3/L$	1	NG	NG	<1	<1	<1	<1	<1	<1	46	34	41
	HCO_3 Alkalinity	$mg \cdot CaCO_3/L$	1	NG	NG	71	84	98	39	39	34	<1	4	1
	Total Alkalinity	$mg \cdot CaCO_3/L$	1	NG	NG	71	84	98	39	39	34	47	39	42

Parameter		Unit	LOR	NPUG	Livestock DGV	Tailings water			Tailings solid					
						Supernatant			Water leachate			NAG liquor		
						Fimiston Tailings 1	Fimiston Tailings 2	Fimiston Tailings 3	Fimiston Tailings 1	Fimiston Tailings 2	Fimiston Tailings 3	Fimiston Tailings 1	Fimiston Tailings 2	Fimiston Tailings 3
Cation/ Anions	Sulfur as S	mg/L	1	NG	NG	1,520	1,810	1,690	39	50	41	9	8	11
	Sulfate (SO_4)	mg/L	1	1000	1000	4,530	4,580	4,590	95	140	112	29	26	31
	Chloride (Cl)	mg/L	2	250	NG	54,700	53,300	56,400	766	947	847	43	52	30
	Fluoride (F)	mg/L	0.1	15	2	0.1	<0.5	0.2	0.2	0.3	0.3	<0.1	<0.1	<0.1
	Silicon (Si)	mg/L	0.05	NG	NG	2.94	3.24	2.64	0.94	1.19	1.11	6.79	5.37	7.23
	Calcium (Ca)	mg/L	1	NG	1000	2,640	2,520	2,710	52	64	53	30	21	24
	Magnesium (Mg)	mg/L	1	NG	2000	2,190	1,990	2,140	29	38	32	<1	<1	<1
	Sodium (Na)	mg/L	1	NG	NG	34,100	30,200	33,600	399	496	410	48	54	39
	Potassium (K)	mg/L	1	NG	NG	411	360	383	5	6	5	2	3	2
Dissolved Metal(loid)s	Aluminium (Al)	mg/L	0.01	0.2	5	<0.2	<0.2	<0.2	0.03	0.02	0.02	0.40	0.30	0.33
	Antimony (Sb)	mg/L	0.001	0.03	NG	0.078	0.068	0.072	0.002	0.003	0.004	<0.001	0.001	0.001
	Arsenic (As)	mg/L	0.001	0.1	0.5	<0.02	<0.02	0.053	0.001	0.002	0.002	<0.001	0.001	0.001
	Beryllium (Be)	mg/L	0.001	0.6	NG	<0.02	<0.02	<0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Barium (Ba)	mg/L	0.001	20	NG	0.444	0.371	0.390	0.026	0.036	0.034	0.003	0.003	0.005
	Bismuth (Bi)	mg/L	0.001	NG	NG	<0.02	<0.02	<0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Parameter		Unit	LOR	NPUG	Livestock DGV	Tailings water			Tailings solid					
						Supernatant			Water leachate			NAG liquor		
						Fimiston Tailings 1	Fimiston Tailings 2	Fimiston Tailings 3	Fimiston Tailings 1	Fimiston Tailings 2	Fimiston Tailings 3	Fimiston Tailings 1	Fimiston Tailings 2	Fimiston Tailings 3
	Cadmium (Cd)	mg/L	0.0001	0.02	0.01	<0.002	<0.002	0.0029	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	Chromium (Cr)	mg/L	0.001	0.5	1	<0.02	<0.02	<0.02	<0.001	<0.001	<0.001	0.003	0.001	0.033
	Cobalt (Co)	mg/L	0.001	NG	1	1.000	1.010	1.090	0.011	0.024	0.018	<0.001	<0.001	<0.001
	Copper (Cu)	mg/L	0.001	20	1	10.6	17.6	15.3	<0.001	0.186	0.073	<0.001	<0.001	<0.001
	Lead (Pb)	mg/L	0.001	0.1	0.1	<0.02	<0.02	<0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Lanthanum (La)	mg/L	0.001	NG	NG	<0.02	<0.02	<0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Lithium (Li)	mg/L	0.001	NG	NG	0.063	0.063	0.074	0.009	0.011	0.008	0.003	0.004	0.003
	Manganese (Mn)	mg/L	0.001	5	NG	0.124	0.160	0.427	0.016	0.018	0.014	<0.001	<0.001	<0.001
	Molybdenum (Mo)	mg/L	0.001	0.5	0.15	0.090	0.089	0.090	0.003	0.005	0.005	0.005	0.006	0.007
	Nickel (Ni)	mg/L	0.001	0.2	1	0.621	0.764	0.741	<0.001	0.002	<0.001	<0.001	<0.001	<0.001
	Rubidium (Rb)	mg/L	0.001	NG	NG	0.33	0.321	0.299	0.005	0.011	0.009	0.003	0.006	0.004
	Selenium (Se)	mg/L	0.01	0.1	0.02	<0.2	<0.2	<0.2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Silver (Ag)	mg/L	0.001	NG	NG	0.129	0.150	0.150	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Strontium (Sr)	mg/L	0.001	NG	NG	31.4	29.1	31.7	0.883	0.910	0.701	0.184	0.152	0.137

Parameter		Unit	LOR	NPUG	Livestock DGV	Tailings water			Tailings solid					
						Supernatant			Water leachate			NAG liquor		
						Fimiston Tailings 1	Fimiston Tailings 2	Fimiston Tailings 3	Fimiston Tailings 1	Fimiston Tailings 2	Fimiston Tailings 3	Fimiston Tailings 1	Fimiston Tailings 2	Fimiston Tailings 3
	Tellurium (Te)	mg/L	0.005	NG	NG	<0.1	<0.1	<0.1	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
	Thallium (Tl)	mg/L	0.001	NG	0.002	0.023	<0.02	<0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Thorium (Th)	mg/L	0.001	NG	NG	<0.02	<0.02	<0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Tin (Sn)	mg/L	0.001	NG	NG	<0.02	<0.02	<0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Titanium (Ti)	mg/L	0.01	NG	NG	<0.2	<0.2	<0.2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Uranium (U)	mg/L	0.001	0.17	0.2	<0.02	<0.02	<0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Vanadium (V)	mg/L	0.01	NG	NG	<0.2	<0.2	<0.2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Zinc (Zn)	mg/L	0.005	3	20	<0.1	<0.1	<0.1	<0.005	0.006	<0.005	<0.005	<0.005	<0.005
	Boron (Bo)	mg/L	0.05	40	5	0.52	0.61	0.81	0.11	0.18	0.16	0.98	1.02	1.14
	Iron (Fe)	mg/L	0.05	0.3	NG	15.7	22.9	21.8	<0.05	0.15	0.15	<0.05	<0.05	<0.05
	Tungsten (W)	mg/L	0.001	NG	NG	<0.02	<0.02	<0.02	<0.001	<0.001	<0.001	0.001	0.002	0.002
	Tantalum (Ta)	mg/L	0.001	NG	NG	<0.02	<0.02	<0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Mercury (Hg)	mg/L	0.0001	0.01	0.002	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001
Nutrients	Total Nitrogen	mgN/L	0.1	NG	NG	61.6	60.9	62.6	1.0	1.4	1.3	-	-	-
	Nitrate	mgN/L	0.01	113	90	11.2	12.1	11.6	0.17	0.21	0.18	-	-	-
	Nitrite	mgN/L	0.01	9.1	9.1	0.16	0.21	0.33	<0.01	<0.01	0.01	-	-	-

Parameter		Unit	LOR	NPUG	Livestock DGV	Tailings water			Tailings solid					
						Supernatant			Water leachate			NAG liquor		
						Fimiston Tailings 1	Fimiston Tailings 2	Fimiston Tailings 3	Fimiston Tailings 1	Fimiston Tailings 2	Fimiston Tailings 3	Fimiston Tailings 1	Fimiston Tailings 2	Fimiston Tailings 3
	Nitrite + Nitrate	mg/L	0.01	NG	NG	11.4	12.3	11.9	0.17	0.21	0.19	-	-	-
	Total Kjeldahl Nitrogen	mg/L	0.1	NG	NG	50.2	48.6	50.7	0.8	1.2	1.1	-	-	-
	Ammonia as N	mgN/L	0.01	NG	NG	34.9	34.0	35.2	0.54	0.86	0.80	-	-	-
	Reactive Phosphorus	mg/L	0.01	NG	NG	0.28	0.49	0.42	<0.01	<0.01	<0.01	-	-	-
	Total Phosphorus	mg/L	0.01	NG	NG	<0.05	0.07	0.08	<0.01	<0.01	0.02	-	-	-
Cyanide	Free Cyanide	mg/L	0.002	0.8	NG	21.0	29.6	20.7	0.002	0.050	0.017	-	-	-
	Total Cyanide	mg/L	0.002	NG	NG	67.6	99.7	92.5	0.022	0.155	0.094	-	-	-
	Weak Acid Dissociable	mg/L	0.002	NG	NG	24.8	35.8	25.8	0.003	0.046	0.029	-	-	-

Notes: '-' denotes no analysis undertaken | results highlighted in red denote exceedance to the guideline | *TDS for supernatant is measured by the laboratory

Appendix C

Laboratory certificates

EARTH SYSTEMS

ABN 42 120 062 544
4/290 Salmon Street
Port Melbourne, Victoria, 3207, Australia
Tel: +61 (0)3 9810 7500
Email: enviro@earthsystems.com.au
Web: www.acidmetalliferousdrainage.com
Web: www.earthsystems.com.au
Web: www.esanalytical.com.au

Client WSP
ES Project WSPXRD2443
Client Project Fimiston and Gidji Tailings (PS211564)
Reporting Units weight %[1]

Mineral Group	Sample ID	Fimiston Tailings 1	Fimiston Tailings 2	Fimiston Tailings 3
Sulfide	Pyrite	2.1	2.1	1.9
Sulfate	Gypsum	0	0	0
Carbonate	Calcite	3.6	0.8	0.8
	Dolomite	21.1	21.8	21.7
	Siderite	2.3	1.5	1.6
Silicate	Actinolite	0.1	0	0
	Albite	15.2	16.4	13.1
	Biotite	0.6	0.7	0.7
	Clinochlore	8.0	7.9	9.9
	Microcline	1.0	1.3	0.9
	Muscovite	17.1	15.2	14.7
	Paragonite	6.9	7.5	4.3
	Talc	0	0	0
Hydroxide / Oxide	Magnetite	0	0	0.3
	Quartz	20.8	22.5	30.1
Other	Amorphous	1.2	2.3	0

Note: 1) 0 wt.% = not detected.
2) The amorphous content of the samples has been determined by modelling the background using a disordered tridymite structure.

CERTIFICATE OF ANALYSIS

Work Order	: **EB2411964-AA**	Page	: 1 of 14
Amendment	: **1**		
Client	: **WSP AUSTRALIA PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: GERT DU PLESSIS	Contact	: Carsten Emrich
Address	: LEVEL 3, MIA YELLAGONGA TOWER 2 5 SPRING STREET PERTH	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61 7 3552 8616
Project	: PS211564-Fimiston and Gidji Tailings Geochemical Charcaterisation for the Fimiston Operation	Date Samples Received	: 09-Apr-2024 12:30
Order number	: PS211564	Date Analysis Commenced	: 15-Apr-2024
C-O-C number	: ----	Issue Date	: 12-Feb-2025 10:05
Sampler	: ----		
Site	: ----		
Quote number	: EN/000		
No. of samples received	: 9		
No. of samples analysed	: 9		

Accreditation No. 825
Accredited for compliance with ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Beatriz Llarinas	Senior Chemist - Inorganics	Brisbane Inorganics, Stafford, QLD
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Kirsty Watson	Senior Chemist - Organics	Brisbane Organics, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EK067G (Total Phosphorous as P): Some samples were diluted due to matrix interference. LOR adjusted accordingly.
- It is recognised that EK067G (Total Phosphorus) is less than EK071G (Reactive Phosphorus) for some samples. Results confirmed by re-extaction and re-analysis.
- As per QWI – EN55-3 Data Interpreting Procedures, Ionic balances are typically calculated using Major Anions - Chloride, Alkalinity and Sulfate; and Major Cations - Calcium, Magnesium, Potassium and Sodium. Where applicable and dependent upon sample matrix, the Ionic Balance may also include the additional contribution of Ammonia, Dissolved Metals by ICPMS and H+ to the Cations and Nitrate, SiO2 and Fluoride to the Anions.
- ASS: EA029 (SPOCAS): Analysis is performed as per the Acid Sulfate Soils Laboratory Methods Guidelines (2004) and the updated National Acid Sulfate Soils Guidance: National acid sulfate soils identification and laboratory methods manual, Department of Agriculture and Water Resources, Canberra, ACT (2018)
- ALS is not NATA accredited for the performance of EN35: Miscellaneous Leaching procedure.
- EK040P (Fluoride) - Particular samples required dilution due to matrix interferences. LOR values have been adjusted accordingly.
- Ionic Balance out of acceptable limits for some samples due to analytes not quantified in this report.
- Amendment (12/02/2025):This report has been amended following the split of reports into 2 reports: Report 1: Fimiston report and Report 2: Gidji. All analysis results are as per the previous report
- EG035F (Dissolved Mercury): Some samples were diluted due to matrix interference. LOR adjusted accordingly.
- EG020F (Dissolved Metals by ICP-MS): Limit of reporting raised for some samples due to matrix interference.
- ED093F (Dissolved Major Cations by ICP): Limit of reporting raised for some samples due to matrix interference.
- ED040F (Dissolved Major Anions by ICP-AES): Limit of reporting raised for some samples due to matrix interference.
- EG035F (Dissolved Mercury by FIMS): Positive mercury results have been confirmed by re-extraction and re-analysis.
- It is recognised that EK028SF (WAD Cyanide by SFA) is less than EK025SF (Free Cyanide) for Workorder sample EB2411964-002 (Fimiston Tailings 2 ASLP LEACHATE). However, the difference is within experimental variation of the methods.
- EK055G (Ammonia as N), EK059G (NOx): Sample EB2409949-019 shows poor matrix spike recovery due to sample matrix interference. Confirmed by re-extraction and re-analysis.
- ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.
- ASS: EA029 (SPOCAS): Liming rate is calculated and reported on a dry weight basis assuming use of fine agricultural lime (CaCO3) and using a safety factor of 1.5 to allow for non-homogeneous mixing and poor reactivity of lime. For conversion of Liming Rate from kg/t dry weight to kg/m3 in-situ soil, multiply reported results x wet bulk density of soil in t/m3.
- EA046 ABCC: NATA Acreditation does not cover the performance of this service.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.
- ED045G: The presence of Thiocyanate, Thiosulfate and Sulfite can positively contribute to the chloride result, thereby may bias results higher than expected. Results should be scrutinised accordingly.

Analytical Results

Sub-Matrix: **LEACHATE** (Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Sample ID	Fimiston Tailings 1 ASLP LEACHATE	Fimiston Tailings 2 ASLP LEACHATE	Fimiston Tailings 3 ASLP LEACHATE	Fimiston Tailings 1 NAG LEACHATE	Fimiston Tailings 2 NAG LEACHATE
				Sampling date / time	04-Apr-2024 00:00	04-Apr-2024 00:00	04-Apr-2024 00:00	04-Apr-2024 00:00	04-Apr-2024 00:00
					EB2411964-001	EB2411964-002	EB2411964-003	EB2411964-013	EB2411964-014
					Result	Result	Result	Result	Result
EA005P: pH by PC Titrator									
pH Value	----	0.01	pH Unit		**7.89**	**7.46**	**7.84**	**10.1**	**9.84**
EA010P: Conductivity by PC Titrator									
Electrical Conductivity @ 25°C	----	1	µS/cm		**2400**	**3060**	**2790**	**392**	**387**
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	<1	**1**	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	<1	**46**	**34**
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		**39**	**39**	**34**	<1	**4**
Total Alkalinity as CaCO3	----	1	mg/L		**39**	**39**	**34**	**47**	**39**
ED040F: Dissolved Major Anions									
Sulfur as S	63705-05-5	1	mg/L		**39**	**50**	**41**	**9**	**8**
Silicon	7440-21-3	0.05	mg/L		**0.94**	**1.19**	**1.11**	**6.79**	**5.37**
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		**95**	**140**	**112**	**29**	**26**
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		**766**	**947**	**847**	**43**	**52**
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		**52**	**64**	**53**	**30**	**21**
Magnesium	7439-95-4	1	mg/L		**29**	**38**	**32**	<1	<1
Sodium	7440-23-5	1	mg/L		**399**	**496**	**410**	**48**	**54**
Potassium	7440-09-7	1	mg/L		**5**	**6**	**5**	**2**	**3**
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		**0.03**	**0.02**	**0.02**	**0.40**	**0.30**
Antimony	7440-36-0	0.001	mg/L		**0.002**	**0.003**	**0.004**	<0.001	**0.001**
Arsenic	7440-38-2	0.001	mg/L		**0.001**	**0.002**	**0.002**	<0.001	**0.001**
Beryllium	7440-41-7	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Barium	7440-39-3	0.001	mg/L		**0.026**	**0.036**	**0.034**	**0.003**	**0.003**
Bismuth	7440-69-9	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001

Analytical Results

Sub-Matrix: **LEACHATE** (Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Sample ID	Fimiston Tailings 1 ASLP LEACHATE	Fimiston Tailings 2 ASLP LEACHATE	Fimiston Tailings 3 ASLP LEACHATE	Fimiston Tailings 1 NAG LEACHATE	Fimiston Tailings 2 NAG LEACHATE
				Sampling date / time	04-Apr-2024 00:00	04-Apr-2024 00:00	04-Apr-2024 00:00	04-Apr-2024 00:00	04-Apr-2024 00:00
					EB2411964-001	EB2411964-002	EB2411964-003	EB2411964-013	EB2411964-014
					Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued									
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L		<0.001	<0.001	<0.001	**0.003**	**0.001**
Cobalt	7440-48-4	0.001	mg/L		**0.011**	**0.024**	**0.018**	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L		<0.001	**0.186**	**0.073**	<0.001	<0.001
Lanthanum	7439-91-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Lithium	7439-93-2	0.001	mg/L		**0.009**	**0.011**	**0.008**	**0.003**	**0.004**
Manganese	7439-96-5	0.001	mg/L		**0.016**	**0.018**	**0.014**	<0.001	<0.001
Molybdenum	7439-98-7	0.001	mg/L		**0.003**	**0.005**	**0.005**	**0.005**	**0.006**
Nickel	7440-02-0	0.001	mg/L		<0.001	**0.002**	<0.001	<0.001	<0.001
Rubidium	7440-17-7	0.001	mg/L		**0.005**	**0.011**	**0.009**	**0.003**	**0.006**
Selenium	7782-49-2	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
Silver	7440-22-4	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Strontium	7440-24-6	0.001	mg/L		**0.883**	**0.910**	**0.701**	**0.184**	**0.152**
Tellurium	22541-49-7	0.005	mg/L		<0.005	<0.005	<0.005	<0.005	<0.005
Thallium	7440-28-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Thorium	7440-29-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Tin	7440-31-5	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Titanium	7440-32-6	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
Uranium	7440-61-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium	7440-62-2	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L		<0.005	**0.006**	<0.005	<0.005	<0.005
Boron	7440-42-8	0.05	mg/L		**0.11**	**0.18**	**0.16**	**0.98**	**1.02**
Iron	7439-89-6	0.05	mg/L		<0.05	**0.15**	**0.15**	<0.05	<0.05
Tungsten	7440-33-7	0.001	mg/L		<0.001	<0.001	<0.001	**0.001**	**0.002**
Tantalum	7440-25-7	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001

Analytical Results

Sub-Matrix: **LEACHATE** (Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Sample ID	Fimiston Tailings 1 ASLP LEACHATE	Fimiston Tailings 2 ASLP LEACHATE	Fimiston Tailings 3 ASLP LEACHATE	Fimiston Tailings 1 NAG LEACHATE	Fimiston Tailings 2 NAG LEACHATE
				Sampling date / time	04-Apr-2024 00:00	04-Apr-2024 00:00	04-Apr-2024 00:00	04-Apr-2024 00:00	04-Apr-2024 00:00
					EB2411964-001	EB2411964-002	EB2411964-003	EB2411964-013	EB2411964-014
					Result	Result	Result	Result	Result
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	<0.0001	<0.0010	<0.0010	<0.0010
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		**0.2**	**0.3**	**0.3**	<0.1	<0.1
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		**0.54**	**0.86**	**0.80**	----	----
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N	14797-65-0	0.01	mg/L		<0.01	<0.01	**0.01**	----	----
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N	14797-55-8	0.01	mg/L		**0.17**	**0.21**	**0.18**	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		**0.17**	**0.21**	**0.19**	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		**0.8**	**1.2**	**1.1**	----	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ **Total Nitrogen as N**	----	0.1	mg/L		**1.0**	**1.4**	**1.3**	----	----
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		<0.01	<0.01	**0.02**	----	----
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		<0.01	<0.01	<0.01	----	----

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)				Sample ID	Fimiston Tailings 3 NAG LEACHATE	----	----	----	----
				Sampling date / time	04-Apr-2024 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit		EB2411964-015	--------	--------	--------	--------
					Result	----	----	----	----
EA005P: pH by PC Titrator									
pH Value	----	0.01	pH Unit		**9.85**	----	----	----	----
EA010P: Conductivity by PC Titrator									
Electrical Conductivity @ 25°C	----	1	µS/cm		**335**	----	----	----	----
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		**41**	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		**1**	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L		**42**	----	----	----	----
ED040F: Dissolved Major Anions									
Sulfur as S	63705-05-5	1	mg/L		**11**	----	----	----	----
Silicon	7440-21-3	0.05	mg/L		**7.23**	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		**31**	----	----	----	----
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		**30**	----	----	----	----
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		**24**	----	----	----	----
Magnesium	7439-95-4	1	mg/L		<1	----	----	----	----
Sodium	7440-23-5	1	mg/L		**39**	----	----	----	----
Potassium	7440-09-7	1	mg/L		**2**	----	----	----	----
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		**0.33**	----	----	----	----
Antimony	7440-36-0	0.001	mg/L		**0.001**	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L		**0.001**	----	----	----	----
Beryllium	7440-41-7	0.001	mg/L		<0.001	----	----	----	----
Barium	7440-39-3	0.001	mg/L		**0.005**	----	----	----	----
Bismuth	7440-69-9	0.001	mg/L		<0.001	----	----	----	----

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)				Sample ID	Fimiston Tailings 3 NAG LEACHATE	----	----	----	----
				Sampling date / time	04-Apr-2024 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit		EB2411964-015	--------	--------	--------	--------
					Result	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued									
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L		**0.033**	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L		<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L		<0.001	----	----	----	----
Lanthanum	7439-91-0	0.001	mg/L		<0.001	----	----	----	----
Lead	7439-92-1	0.001	mg/L		<0.001	----	----	----	----
Lithium	7439-93-2	0.001	mg/L		**0.003**	----	----	----	----
Manganese	7439-96-5	0.001	mg/L		<0.001	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L		**0.007**	----	----	----	----
Nickel	7440-02-0	0.001	mg/L		<0.001	----	----	----	----
Rubidium	7440-17-7	0.001	mg/L		**0.004**	----	----	----	----
Selenium	7782-49-2	0.01	mg/L		<0.01	----	----	----	----
Silver	7440-22-4	0.001	mg/L		<0.001	----	----	----	----
Strontium	7440-24-6	0.001	mg/L		**0.137**	----	----	----	----
Tellurium	22541-49-7	0.005	mg/L		<0.005	----	----	----	----
Thallium	7440-28-0	0.001	mg/L		<0.001	----	----	----	----
Thorium	7440-29-1	0.001	mg/L		<0.001	----	----	----	----
Tin	7440-31-5	0.001	mg/L		<0.001	----	----	----	----
Titanium	7440-32-6	0.01	mg/L		<0.01	----	----	----	----
Uranium	7440-61-1	0.001	mg/L		<0.001	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L		<0.01	----	----	----	----
Zinc	7440-66-6	0.005	mg/L		<0.005	----	----	----	----
Boron	7440-42-8	0.05	mg/L		**1.14**	----	----	----	----
Iron	7439-89-6	0.05	mg/L		<0.05	----	----	----	----
Tungsten	7440-33-7	0.001	mg/L		**0.002**	----	----	----	----
Tantalum	7440-25-7	0.001	mg/L		<0.001	----	----	----	----

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)				Sample ID	Fimiston Tailings 3 NAG LEACHATE	----	----	----	----
				Sampling date / time	04-Apr-2024 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit		EB2411964-015	--------	--------	--------	--------
					Result	----	----	----	----
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0010	**----**	**----**	**----**	**----**
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		<0.1	**----**	**----**	**----**	**----**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	Fimiston Tailings 1 ASLP LEACHATE	Fimiston Tailings 2 ASLP LEACHATE	Fimiston Tailings 3 ASLP LEACHATE	----	----
			Sampling date / time	04-Apr-2024 00:00	04-Apr-2024 00:00	04-Apr-2024 00:00	----	----
Compound	CAS Number	LOR	Unit	EB2411964-001	EB2411964-002	EB2411964-003	--------	--------
				Result	Result	Result	----	----
EA002: pH 1:2 (Soils)								
pH Value	----	0.1	pH Unit	**8.8**	**8.9**	**9.0**	**----**	**----**
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-198**	**-190**	**-182**	**----**	**----**
EA010: Conductivity (1:2)								
Electrical Conductivity @ 25°C	----	1	µS/cm	**4780**	**4800**	**5940**	**----**	**----**
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	**10.7**	**10.6**	**10.7**	**----**	**----**
NAG (pH 4.5)	----	0.1	kg H2SO4/t	<0.1	<0.1	<0.1	**----**	**----**
NAG (pH 7.0)	----	0.1	kg H2SO4/t	<0.1	<0.1	<0.1	**----**	**----**
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**207**	**198**	**196**	**----**	**----**
ANC as CaCO3	----	0.1	% CaCO3	**21.1**	**20.2**	**20.0**	**----**	**----**
Fizz Rating	----	0	Fizz Unit	**3**	**3**	**3**	**----**	**----**
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.258**	**0.239**	**0.414**	**----**	**----**
EA029-G: Retained Acidity								
HCl Extractable Sulfur (20Be)	----	0.020	% S	**0.028**	**0.040**	**0.030**	**----**	**----**
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.28**	**0.26**	**0.44**	**----**	**----**
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	**0.04**	**0.08**	**0.08**	**----**	**----**
EP003TC: Total Carbon (TC) in Soil								
Total Carbon	TC	0.02	%	**3.82**	**3.48**	**3.47**	**----**	**----**
EP003TIC: Total inorganic Carbon (TIC) in Soil								
Total Inorganic Carbon	----	0.02	%	**3.78**	**3.40**	**3.39**	**----**	**----**
Sample Preparation Method								
ø Amount	----	0.1	g	**25.0**	**25.0**	**25.0**	**----**	**----**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Sample ID	Fimiston Supernatant 1	Fimiston Supernatant 2	Fimiston Supernatant 3	----	----
				Sampling date / time	04-Apr-2024 00:00	04-Apr-2024 00:00	04-Apr-2024 00:00	----	----
Compound	CAS Number	LOR	Unit		EB2411964-007	EB2411964-008	EB2411964-009	--------	--------
					Result	Result	Result	----	----
EA005P: pH by PC Titrator									
pH Value	----	0.01	pH Unit		**7.50**	**7.70**	**7.85**	----	----
EA010P: Conductivity by PC Titrator									
Electrical Conductivity @ 25°C	----	1	µS/cm		**121000**	**116000**	**122000**	----	----
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		**102000**	**100000**	**106000**	----	----
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	<1	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	<1	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		**71**	**84**	**98**	----	----
Total Alkalinity as CaCO3	----	1	mg/L		**71**	**84**	**98**	----	----
ED040F: Dissolved Major Anions									
Sulfur as S	63705-05-5	1	mg/L		**1520**	**1810**	**1690**	----	----
Silicon	7440-21-3	0.05	mg/L		**2.94**	**3.24**	**2.64**	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		**4530**	**4580**	**4590**	----	----
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		**54700**	**53300**	**56400**	----	----
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		**2640**	**2520**	**2710**	----	----
Magnesium	7439-95-4	1	mg/L		**2190**	**1990**	**2140**	----	----
Sodium	7440-23-5	1	mg/L		**34100**	**30200**	**33600**	----	----
Potassium	7440-09-7	1	mg/L		**411**	**360**	**383**	----	----
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		<0.20	<0.20	<0.20	----	----
Antimony	7440-36-0	0.001	mg/L		**0.078**	**0.068**	**0.072**	----	----
Arsenic	7440-38-2	0.001	mg/L		<0.020	<0.020	**0.053**	----	----
Beryllium	7440-41-7	0.001	mg/L		<0.020	<0.020	<0.020	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Sample ID	Fimiston Supernatant 1	Fimiston Supernatant 2	Fimiston Supernatant 3	----	----
				Sampling date / time	04-Apr-2024 00:00	04-Apr-2024 00:00	04-Apr-2024 00:00	----	----
Compound	CAS Number	LOR	Unit		EB2411964-007	EB2411964-008	EB2411964-009	--------	--------
					Result	Result	Result	----	----
EG020F: Dissolved Metals by ICP-MS - Continued									
Barium	7440-39-3	0.001	mg/L		**0.444**	**0.371**	**0.390**	----	----
Bismuth	7440-69-9	0.001	mg/L		<0.020	<0.020	<0.020	----	----
Cadmium	7440-43-9	0.0001	mg/L		<0.0020	<0.0020	**0.0029**	----	----
Chromium	7440-47-3	0.001	mg/L		<0.020	<0.020	<0.020	----	----
Cobalt	7440-48-4	0.001	mg/L		**1.00**	**1.01**	**1.09**	----	----
Copper	7440-50-8	0.001	mg/L		**10.6**	**17.6**	**15.3**	----	----
Lanthanum	7439-91-0	0.001	mg/L		<0.020	<0.020	<0.020	----	----
Lead	7439-92-1	0.001	mg/L		<0.020	<0.020	<0.020	----	----
Lithium	7439-93-2	0.001	mg/L		**0.063**	**0.063**	**0.074**	----	----
Manganese	7439-96-5	0.001	mg/L		**0.124**	**0.160**	**0.427**	----	----
Molybdenum	7439-98-7	0.001	mg/L		**0.090**	**0.089**	**0.090**	----	----
Nickel	7440-02-0	0.001	mg/L		**0.621**	**0.764**	**0.741**	----	----
Rubidium	7440-17-7	0.001	mg/L		**0.330**	**0.321**	**0.299**	----	----
Selenium	7782-49-2	0.01	mg/L		<0.20	<0.20	<0.20	----	----
Silver	7440-22-4	0.001	mg/L		**0.129**	**0.150**	**0.150**	----	----
Strontium	7440-24-6	0.001	mg/L		**31.4**	**29.1**	**31.7**	----	----
Tellurium	22541-49-7	0.005	mg/L		<0.100	<0.100	<0.100	----	----
Thallium	7440-28-0	0.001	mg/L		**0.023**	<0.020	<0.020	----	----
Thorium	7440-29-1	0.001	mg/L		<0.020	<0.020	<0.020	----	----
Tin	7440-31-5	0.001	mg/L		<0.020	<0.020	<0.020	----	----
Titanium	7440-32-6	0.01	mg/L		<0.20	<0.20	<0.20	----	----
Uranium	7440-61-1	0.001	mg/L		<0.020	<0.020	<0.020	----	----
Vanadium	7440-62-2	0.01	mg/L		<0.20	<0.20	<0.20	----	----
Zinc	7440-66-6	0.005	mg/L		<0.100	<0.100	<0.100	----	----
Boron	7440-42-8	0.05	mg/L		**0.52**	**0.61**	**0.81**	----	----
Iron	7439-89-6	0.05	mg/L		**15.7**	**22.9**	**21.8**	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Sample ID	Fimiston Supernatant 1	Fimiston Supernatant 2	Fimiston Supernatant 3	----	----
				Sampling date / time	04-Apr-2024 00:00	04-Apr-2024 00:00	04-Apr-2024 00:00	----	----
Compound	CAS Number	LOR	Unit		EB2411964-007	EB2411964-008	EB2411964-009	--------	--------
					Result	Result	Result	----	----
EG020F: Dissolved Metals by ICP-MS - Continued									
Tungsten	7440-33-7	0.001	mg/L		<0.020	<0.020	<0.020	----	----
Tantalum	7440-25-7	0.001	mg/L		<0.020	<0.020	<0.020	----	----
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0010	<0.0010	<0.0010	----	----
EK025SF: Free CN by Segmented Flow Analyser									
Free Cyanide	----	0.002	mg/L		**21.0**	**29.6**	**20.7**	----	----
EK026SF: Total CN by Segmented Flow Analyser									
Total Cyanide	57-12-5	0.002	mg/L		**67.6**	**99.7**	**92.5**	----	----
EK028SF: Weak Acid Dissociable CN by Segmented Flow Analyser									
Weak Acid Dissociable Cyanide	----	0.002	mg/L		**24.8**	**35.8**	**25.8**	----	----
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		**0.1**	<0.5	**0.2**	----	----
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		**34.9**	**34.0**	**35.2**	----	----
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N	14797-65-0	0.01	mg/L		**0.16**	**0.21**	**0.33**	----	----
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N	14797-55-8	0.01	mg/L		**11.2**	**12.1**	**11.6**	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		**11.4**	**12.3**	**11.9**	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		**50.2**	**48.6**	**50.7**	----	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		**61.6**	**60.9**	**62.6**	----	----
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		<0.05	**0.07**	**0.08**	----	----
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		**0.28**	**0.49**	**0.42**	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Sample ID	Fimiston Supernatant 1	Fimiston Supernatant 2	Fimiston Supernatant 3	----	----
				Sampling date / time	04-Apr-2024 00:00	04-Apr-2024 00:00	04-Apr-2024 00:00	----	----
Compound	CAS Number	LOR	Unit		EB2411964-007	EB2411964-008	EB2411964-009	--------	--------
					Result	Result	Result	----	----
EN055: Ionic Balance									
ø Total Anions	----	0.01	meq/L		**1640**	**1600**	**1690**	**----**	**----**
ø Total Cations	----	0.01	meq/L		**1800**	**1610**	**1780**	**----**	**----**
ø Ionic Balance	----	0.01	%		**4.85**	**0.37**	**2.71**	**----**	**----**

Analytical Results

Sub-Matrix: ZHE LEACHATE (Matrix: WATER)			Sample ID	Fimiston Tailings 1 ASLP LEACHATE	Fimiston Tailings 2 ASLP LEACHATE	Fimiston Tailings 3 ASLP LEACHATE	----	----
			Sampling date / time	04-Apr-2024 00:00	04-Apr-2024 00:00	04-Apr-2024 00:00	----	----
Compound	CAS Number	LOR	Unit	EB2411964-001	EB2411964-002	EB2411964-003	--------	--------
				Result	Result	Result	----	----
EK025SF: Free CN by Segmented Flow Analyser								
Free Cyanide	----	0.002	mg/L	**0.002**	**0.050**	**0.017**	**----**	**----**
EK026SF: Total CN by Segmented Flow Analyser								
Total Cyanide	57-12-5	0.002	mg/L	**0.022**	**0.155**	**0.094**	**----**	**----**
EK028SF: Weak Acid Dissociable CN by Segmented Flow Analyser								
Weak Acid Dissociable Cyanide	----	0.002	mg/L	**0.003**	**0.046**	**0.029**	**----**	**----**

Australian Laboratory Services Pty. Ltd.

32 Shand Street
Stafford
Brisbane QLD 4053
Phone: +61 7 3243 7222 Fax: +61 7 3243 7218
www.alsglobal.com/geochemistry

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To: **ALS ENVIRONMENTAL**
32 SHAND STREET
STAFFORD QLD 4053

Finalized Date: 7-MAY-2024
Account: ALSENV

CERTIFICATE BR24111646

Project: EB2411964

P.O. No.: ME-MS61

This report is for 6 samples of Pulp submitted to our lab in Brisbane, QLD, Australia on 26-APR-2024.

The following have access to data associated with this certificate:

SUB RESULTS -BRIS		

SAMPLE PREPARATION

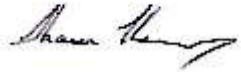
ALS CODE	DESCRIPTION
LOG-24	Pulp Login - Rcd w/o Barcode
LEV-01	Waste Disposal Levy

ANALYTICAL PROCEDURES

ALS CODE	DESCRIPTION	INSTRUMENT
ME-MS61	48 element four acid ICP-MS	

This is the Final Report and supersedes any preliminary report with this certificate number.Results apply to samples as submitted.All pages of this report have been checked and approved for release.
***** See Appendix Page for comments regarding this certificate *****

Signature:



Shaun Kenny, Brisbane Laboratory Manager

Australian Laboratory Services Pty. Ltd.

32 Shand Street
Stafford
Brisbane QLD 4053
Phone: +61 7 3243 7222 Fax: +61 7 3243 7218
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To: **ALS ENVIRONMENTAL**
32 SHAND STREET
STAFFORD QLD 4053

Finalized Date: 7-MAY-2024
Account: ALSENV

Project: EB2411964

CERTIFICATE OF ANALYSIS BR24111646

Sample Description	Method / Analyte / Units / LOD	ME-MS61 Ag ppm 0.01	ME-MS61 Al % 0.01	ME-MS61 As ppm 0.2	ME-MS61 Ba ppm 10	ME-MS61 Be ppm 0.05	ME-MS61 Bi ppm 0.01	ME-MS61 Ca % 0.01	ME-MS61 Cd ppm 0.02	ME-MS61 Ce ppm 0.01	ME-MS61 Co ppm 0.1	ME-MS61 Cr ppm 1	ME-MS61 Cs ppm 0.05	ME-MS61 Cu ppm 0.2	ME-MS61 Fe % 0.01	ME-MS61 Ga ppm 0.05
EB2411964-001		0.12	6.21	33.0	160	0.86	0.02	5.58	0.12	17.75	27.5	95	8.44	26.1	7.82	15.80
EB2411964-002		0.30	6.37	45.2	160	0.89	0.04	5.23	0.13	18.80	32.0	124	8.67	43.8	8.05	16.75
EB2411964-003		0.39	6.12	54.2	150	0.86	0.06	5.18	0.15	19.45	38.4	147	7.79	51.5	8.22	15.45
EB2411964-004		4.86	1.39	1050	40	0.31	1.02	2.48	0.83	8.47	504	278	2.86	396	25.6	3.59
EB2411964-005		14.50	1.63	1225	50	0.34	1.30	2.59	1.22	10.05	559	286	3.92	409	28.7	4.16
EB2411964-006		2.89	1.40	1125	40	0.30	1.12	2.33	1.12	9.68	495	234	2.80	355	25.9	3.60

***** See Appendix Page for comments regarding this certificate *****

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32 SHAND STREET
STAFFORD QLD 4053

Project: EB2411964

CERTIFICATE OF ANALYSIS BR24111646

Sample Description	Method / Analyte / Units / LOD	ME-MS61 Ge ppm 0.05	ME-MS61 Hf ppm 0.1	ME-MS61 In ppm 0.005	ME-MS61 K % 0.01	ME-MS61 La ppm 0.5	ME-MS61 Li ppm 0.2	ME-MS61 Mg % 0.01	ME-MS61 Mn ppm 5	ME-MS61 Mo ppm 0.05	ME-MS61 Na % 0.01	ME-MS61 Nb ppm 0.1	ME-MS61 Ni ppm 0.2	ME-MS61 P ppm 10	ME-MS61 Pb ppm 0.5	ME-MS61 Rb ppm 0.1
EB2411964-001		0.23	2.2	0.073	1.15	7.3	56.8	1.91	1715	0.77	1.76	2.8	55.9	630	3.3	48.6
EB2411964-002		0.25	2.4	0.078	1.15	7.7	65.1	2.00	1805	1.26	1.86	2.7	63.3	630	5.8	50.1
EB2411964-003		0.21	2.3	0.074	1.09	7.7	62.2	2.18	1745	1.17	1.62	2.7	69.2	610	7.5	46.5
EB2411964-004		0.24	1.1	0.102	0.34	6.4	11.3	0.75	1245	15.15	0.45	2.3	402	170	1340	13.2
EB2411964-005		0.24	1.3	0.113	0.38	7.5	14.0	0.92	1290	15.85	0.43	2.4	470	200	1515	15.8
EB2411964-006		0.20	1.1	0.098	0.33	7.0	11.4	0.74	2420	12.55	0.46	2.1	415	180	1350	13.1

***** See Appendix Page for comments regarding this certificate *****

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32 SHAND STREET
STAFFORD QLD 4053

Finalized Date: 7-MAY-2024
Account: ALSENV

Project: EB2411964

CERTIFICATE OF ANALYSIS BR24111646

Sample Description	Method	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61
	Analyte	Re	S	Sb	Sc	Se	Sn	Sr	Ta	Te	Th	Ti	Tl	U	V	W
	Units	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm
	LOD	0.002	0.01	0.05	0.1	1	0.2	0.2	0.05	0.05	0.01	0.005	0.02	0.1	1	0.1
EB2411964-001		0.002	0.29	5.13	37.9	<1	0.7	199.0	0.19	0.69	0.98	0.553	0.45	0.3	269	16.7
EB2411964-002		0.002	0.28	5.68	38.7	1	0.8	177.0	0.19	1.85	1.15	0.542	0.52	0.4	279	17.6
EB2411964-003		0.002	0.51	5.78	36.7	1	0.7	166.0	0.17	1.50	1.18	0.532	0.49	0.4	257	18.0
EB2411964-004		0.011	>10.0	49.3	9.1	11	1.4	141.0	0.11	46.2	0.57	0.355	0.74	0.3	92	22.1
EB2411964-005		0.010	>10.0	50.9	11.3	11	1.5	147.0	0.10	46.8	0.71	0.347	0.84	0.3	100	21.8
EB2411964-006		0.008	>10.0	44.3	10.0	10	1.0	132.0	0.10	36.6	0.66	0.313	0.74	0.3	88	20.1

***** See Appendix Page for comments regarding this certificate *****

Australian Laboratory Services Pty. Ltd.

32 Shand Street
Stafford
Brisbane QLD 4053
Phone: +61 7 3243 7222 Fax: +61 7 3243 7218
www.alsglobal.com/geochemistry

ALS Brisbane is a NATA Accredited Testing Laboratory. Corporate Accreditation No: 825, Corporate Site No: 818.

To: ALS ENVIRONMENTAL
32 SHAND STREET
STAFFORD QLD 4053

Finalized Date: 7-MAY-2024
Account: ALSENV

Project: EB2411964

CERTIFICATE OF ANALYSIS BR24111646

Sample Description	Method / Analyte / Units / LOD	ME-MS61 Y ppm 0.1	ME-MS61 Zn ppm 2	ME-MS61 Zr ppm 0.5
EB2411964-001		10.9	110	90.6
EB2411964-002		11.3	131	93.7
EB2411964-003		10.6	121	88.4
EB2411964-004		12.6	282	43.5
EB2411964-005		13.4	372	48.4
EB2411964-006		12.3	331	43.5

***** See Appendix Page for comments regarding this certificate *****

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To: **ALS ENVIRONMENTAL**
32 SHAND STREET
STAFFORD QLD 4053

Finalized Date: 7-MAY-2024
Account: ALSENV

Project: EB2411964

CERTIFICATE OF ANALYSIS BR24111646

CERTIFICATE COMMENTS

ANALYTICAL COMMENTS

Applies to Method: REEs may not be totally soluble in this method.
ME-MS61

ACCREDITATION COMMENTS

Applies to Method: NATA Accreditation covers the performance of this service but does not cover the performance of ALS Brisbane Sample Preparation. Corporate Accreditation No: 825, Corporate Site No: 818. The Technical Signatory is David Jones,ICPMS Supervising Chemist
ME-MS61

LABORATORY ADDRESSES

Applies to Method: Processed at ALS Brisbane located at 32 Shand Street, Stafford, Brisbane, QLD, Australia. Processed at ALS Brisbane Sample Preparation at 23 Pineapple Street, Zillmere, QLD, 4034, Australia
LEV-01 LOG-24 ME-MS61

ALS Environmental

Acid Buffering Characteristic Curve (ABCC) REPORT

Batch: EB2411964

CONTACT:	GERT DU PLESSIS	**LABORATORY:**	Brisbane
CLIENT:	WSP AUSTRALIA PTY LTD	**DATE SAMPLED:**	4/04/2024
ADDRESS:	LEVEL 3, MIA YELLAGONGA TOWER 2 5 SPRING STREET, PERTH	**DATE RECEIVED:**	9/04/2024
		DATE COMPLETED:	1/05/2024
		SAMPLE TYPE:	Soil
		No. of SAMPLES:	6

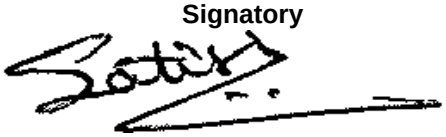
COMMENTS

EA046 : NATA accreditation does not cover performance of this service.

ISSUING LABORATORY: ALS BRISBANE

Address:	2 Byth Street STAFFORD QLD 4053 AUSTRALIA	**Telephone:**	07 3243 7222
		Facsimile:	07 3243 7218
		E-mail:	Satishkumar.Trivedi@alsglobal.com

Signatory



Work Order :	EB2411964	Client ID:	WSP AUSTRALIA PTY LTD

	Sub Matrix			Soil
	Client Sample Identification 1			Fimiston Tailings 1
	Client Sample Identification 2			
	Sample Date			4/04/2024
Method	Analyte	Units	LOR	

	001
	EB2411964

EA046 - A Titration information

HCl Molarity:	**M**	**0.5**
Increments:	**mL**	**1.0**
Weight	**(g)**	**2**
ANC	**kgH2SO4/t**	**207**

EA046 -B - Curve information

Addition	mLs added (total)	kg H2SO4/t	pH	Addition	mLs added (total)	kg H2SO4/t	pH
0	0	0	9.21				
1	1	12.25	7.11				
2	2	24.5	6.46				
3	3	36.75	6.26				
4	4	49	6.11				
5	5	61.25	6.01				
6	6	73.5	5.92				
7	7	85.75	5.85				
8	8	98	5.78				
9	9	110.25	5.72				
10	10	122.5	5.67				
11	11	134.75	5.62				
12	12	147	5.57				
13	13	159.25	5.51				
14	14	171.5	5.45				
15	15	183.75	5.35				
16	16	196	5.19				
17	17	208.25	4.91				
18	18	220.5	4.57				
19	19	232.75	3.84				
20	20	245	3.15				
21	21	257.25	2.72				
22	22	269.5	2.43				

Work Order :	EB2411964	Client ID:	WSP AUSTRALIA PTY LTD

	Sub Matrix			Soil
	Client Sample Identification 1			Fimiston Tailings 1
	Client Sample Identification 2			
	Sample Date			4/04/2024
Method	Analyte	Units	LOR	

001	Check
EB2411964	

EA046 - A Titration information

HCl Molarity:	**M**	**0.5**
Increments:	**mL**	**1**
Weight	**(g)**	**2**
ANC	**kgH2SO4/t**	**207**

EA046 -B - Curve information

Addition	mLs added (total)	kg H2SO4/t	pH	Addition	mLs added (total)	kg H2SO4/t	pH
0	0	0	9.34				
1	1	12.25	6.80				
2	2	24.5	6.31				
3	3	36.75	6.17				
4	4	49	6.04				
5	5	61.25	5.95				
6	6	73.5	5.87				
7	7	85.75	5.80				
8	8	98	5.73				
9	9	110.25	5.67				
10	10	122.5	5.61				
11	11	134.75	5.54				
12	12	147	5.47				
13	13	159.25	5.39				
14	14	171.5	5.29				
15	15	183.75	5.17				
16	16	196	4.99				
17	17	208.25	4.77				
18	18	220.5	4.41				
19	19	232.75	3.67				
20	20	245	3.09				
21	21	257.25	2.71				
22	22	269.5	2.44				

Work Order :	EB2411964	Client ID:	WSP AUSTRALIA PTY LTD

	Sub Matrix			Soil
	Client Sample Identification 1			Fimiston Tailings 2
	Client Sample Identification 2			
	Sample Date			4/04/2024
Method	Analyte	Units	LOR	

	002
	EB2411964

EA046 - A Titration information

HCl Molarity:	**M**	**0.5**
Increments:	**mL**	**0.4**
Weight	**(g)**	**2**
ANC	**kgH2SO4/t**	**198**

EA046 -B - Curve information

Addition	mLs added (total)	kg H2SO4/t	pH	Addition	mLs added (total)	kg H2SO4/t	pH
0	0	0	9.60	36	14.4	176.4	5.16
1	0.4	4.9	7.86	37	14.8	181.3	5.12
2	0.8	9.8	6.98	38	15.2	186.2	5.06
3	1.2	14.7	6.63	39	15.6	191.1	5.00
4	1.6	19.6	6.45	40	16	196	4.94
5	2	24.5	6.34	41	16.4	200.9	4.87
6	2.4	29.4	6.28	42	16.8	205.8	4.78
7	2.8	34.3	6.20	43	17.2	210.7	4.69
8	3.2	39.2	6.14	44	17.6	215.6	4.58
9	3.6	44.1	6.07	45	18	220.5	4.45
10	4	49	6.02	46	18.4	225.4	4.27
11	4.4	53.9	5.98	47	18.8	230.3	3.99
12	4.8	58.8	5.93	48	19.2	235.2	3.65
13	5.2	63.7	5.89	49	19.6	240.1	3.35
14	5.6	68.6	5.86	50	20	245	3.11
15	6	73.5	5.82	51	20.4	249.9	2.91
16	6.4	78.4	5.78	52	20.8	254.8	2.74
17	6.8	83.3	5.76	53	21.2	259.7	2.59
18	7.2	88.2	5.72	54	21.6	264.6	2.47
19	7.6	93.1	5.69				
20	8	98	5.66				
21	8.4	102.9	5.64				
22	8.8	107.8	5.60				
23	9.2	112.7	5.57				
24	9.6	117.6	5.54				
25	10	122.5	5.51				
26	10.4	127.4	5.49				
27	10.8	132.3	5.46				
28	11.2	137.2	5.43				
29	11.6	142.1	5.40				
30	12	147	5.37				
31	12.4	151.9	5.34				
32	12.8	156.8	5.31				
33	13.2	161.7	5.28				
34	13.6	166.6	5.24				
35	14	171.5	5.21				

Work Order :	EB2411964	Client ID:	WSP AUSTRALIA PTY LTD

	Sub Matrix			Soil
	Client Sample Identification 1			Fimiston Tailings 3
	Client Sample Identification 2			
	Sample Date			4/04/2024
Method	Analyte	Units	LOR	

	003
	EB2411964

EA046 - A Titration information

HCl Molarity:	**M**	**0.5**
Increments:	**mL**	**0.4**
Weight	**(g)**	**2**
ANC	**kgH2SO4/t**	**196**

EA046 -B - Curve information

Addition	mLs added (total)	kg H2SO4/t	pH	Addition	mLs added (total)	kg H2SO4/t	pH
0	0	0	9.46	36	14.4	176.4	5.16
1	0.4	4.9	7.95	37	14.8	181.3	5.09
2	0.8	9.8	7.27	38	15.2	186.2	5.00
3	1.2	14.7	6.97	39	15.6	191.1	4.89
4	1.6	19.6	6.78	40	16	196	4.77
5	2	24.5	6.64	41	16.4	200.9	4.62
6	2.4	29.4	6.52	42	16.8	205.8	4.43
7	2.8	34.3	6.43	43	17.2	210.7	4.16
8	3.2	39.2	6.35	44	17.6	215.6	3.82
9	3.6	44.1	6.28	45	18	220.5	3.52
10	4	49	6.22	46	18.4	225.4	3.27
11	4.4	53.9	6.16	47	18.8	230.3	3.06
12	4.8	58.8	6.10	48	19.2	235.2	2.89
13	5.2	63.7	6.05	49	19.6	240.1	2.74
14	5.6	68.6	6.00	50	20	245	2.61
15	6	73.5	5.96	51	20.4	249.9	2.49
16	6.4	78.4	5.91				
17	6.8	83.3	5.87				
18	7.2	88.2	5.83				
19	7.6	93.1	5.79				
20	8	98	5.75				
21	8.4	102.9	5.72				
22	8.8	107.8	5.69				
23	9.2	112.7	5.65				
24	9.6	117.6	5.62				
25	10	122.5	5.59				
26	10.4	127.4	5.56				
27	10.8	132.3	5.53				
28	11.2	137.2	5.50				
29	11.6	142.1	5.47				
30	12	147	5.44				
31	12.4	151.9	5.40				
32	12.8	156.8	5.37				
33	13.2	161.7	5.33				
34	13.6	166.6	5.28				
35	14	171.5	5.23				

Work Order :	EB2411964	Client ID:	WSP AUSTRALIA PTY LTD

	Sub Matrix			Soil
	Client Sample Identification 1			Gidji Tailings 1
	Client Sample Identification 2			
	Sample Date			4/04/2024
Method	Analyte	Units	LOR	

	004
	EB2411964

EA046 - A Titration information

HCl Molarity:	**M**	**0.5**
Increments:	**mL**	**0.2**
Weight	**(g)**	**2**
ANC	**kgH2SO4/t**	**83**

EA046 -B - Curve information

Addition	mLs added (total)	kg H2SO4/t	pH	Addition	mLs added (total)	kg H2SO4/t	pH
0	0	0	8.92	36	7.2	88.2	3.47
1	0.2	2.45	8.50	37	7.4	90.65	3.38
2	0.4	4.9	8.17	38	7.6	93.1	3.31
3	0.6	7.35	7.95	39	7.8	95.55	3.24
4	0.8	9.8	7.79	40	8	98	3.18
5	1	12.25	7.68	41	8.2	100.45	3.11
6	1.2	14.7	7.59	42	8.4	102.9	3.06
7	1.4	17.15	7.52	43	8.6	105.35	3.00
8	1.6	19.6	7.46	44	8.8	107.8	2.95
9	1.8	22.05	7.39	45	9	110.25	2.90
10	2	24.5	7.31	46	9.2	112.7	2.85
11	2.2	26.95	7.22	47	9.4	115.15	2.80
12	2.4	29.4	7.11	48	9.6	117.6	2.75
13	2.6	31.85	6.98	49	9.8	120.05	2.70
14	2.8	34.3	6.82	50	10	122.5	2.65
15	3	36.75	6.66	51	10.2	124.95	2.60
16	3.2	39.2	6.47	52	10.4	127.4	2.55
17	3.4	41.65	6.25	53	10.6	129.85	2.51
18	3.6	44.1	6.01	54	10.8	132.3	2.46
19	3.8	46.55	5.78				
20	4	49	5.55				
21	4.2	51.45	5.34				
22	4.4	53.9	5.18				
23	4.6	56.35	5.04				
24	4.8	58.8	4.90				
25	5	61.25	4.77				
26	5.2	63.7	4.64				
27	5.4	66.15	4.51				
28	5.6	68.6	4.40				
29	5.8	71.05	4.28				
30	6	73.5	4.16				
31	6.2	75.95	4.03				
32	6.4	78.4	3.90				
33	6.6	80.85	3.78				
34	6.8	83.3	3.66				
35	7	85.75	3.56				

Work Order :	EB2411964	Client ID:	WSP AUSTRALIA PTY LTD

	Sub Matrix			Soil
	Client Sample Identification 1			Gidji Tailings 2
	Client Sample Identification 2			
	Sample Date			4/04/2024
Method	Analyte	Units	LOR	

	005
	EB2411964

EA046 - A Titration information

HCl Molarity:	**M**	**0.5**
Increments:	**mL**	**0.2**
Weight	**(g)**	**2**
ANC	**kgH2SO4/t**	**81.1**

EA046 -B - Curve information

Addition	mLs added (total)	kg H2SO4/t	pH	Addition	mLs added (total)	kg H2SO4/t	pH
0	0	0	8.93	36	7.2	88.2	3.38
1	0.2	2.45	8.39	37	7.4	90.65	3.30
2	0.4	4.9	8.11	38	7.6	93.1	3.23
3	0.6	7.35	7.90	39	7.8	95.55	3.17
4	0.8	9.8	7.77	40	8	98	3.10
5	1	12.25	7.66	41	8.2	100.45	3.04
6	1.2	14.7	7.54	42	8.4	102.9	2.98
7	1.4	17.15	7.41	43	8.6	105.35	2.93
8	1.6	19.6	7.28	44	8.8	107.8	2.88
9	1.8	22.05	7.16	45	9	110.25	2.82
10	2	24.5	7.02	46	9.2	112.7	2.77
11	2.2	26.95	6.89	47	9.4	115.15	2.72
12	2.4	29.4	6.74	48	9.6	117.6	2.67
13	2.6	31.85	6.56	49	9.8	120.05	2.62
14	2.8	34.3	6.38	50	10	122.5	2.57
15	3	36.75	6.20	51	10.2	124.95	2.52
16	3.2	39.2	6.04	52	10.4	127.4	2.48
17	3.4	41.65	5.84				
18	3.6	44.1	5.63				
19	3.8	46.55	5.45				
20	4	49	5.28				
21	4.2	51.45	5.14				
22	4.4	53.9	5.01				
23	4.6	56.35	4.88				
24	4.8	58.8	4.76				
25	5	61.25	4.64				
26	5.2	63.7	4.52				
27	5.4	66.15	4.40				
28	5.6	68.6	4.27				
29	5.8	71.05	4.15				
30	6	73.5	4.02				
31	6.2	75.95	3.89				
32	6.4	78.4	3.77				
33	6.6	80.85	3.65				
34	6.8	83.3	3.56				
35	7	85.75	3.46				

Work Order :	EB2411964	Client ID:	WSP AUSTRALIA PTY LTD

	Sub Matrix			Soil
	Client Sample Identification 1			Gidji Tailings 3
	Client Sample Identification 2			
	Sample Date			4/04/2024
Method	Analyte	Units	LOR	

	006
	EB2411964

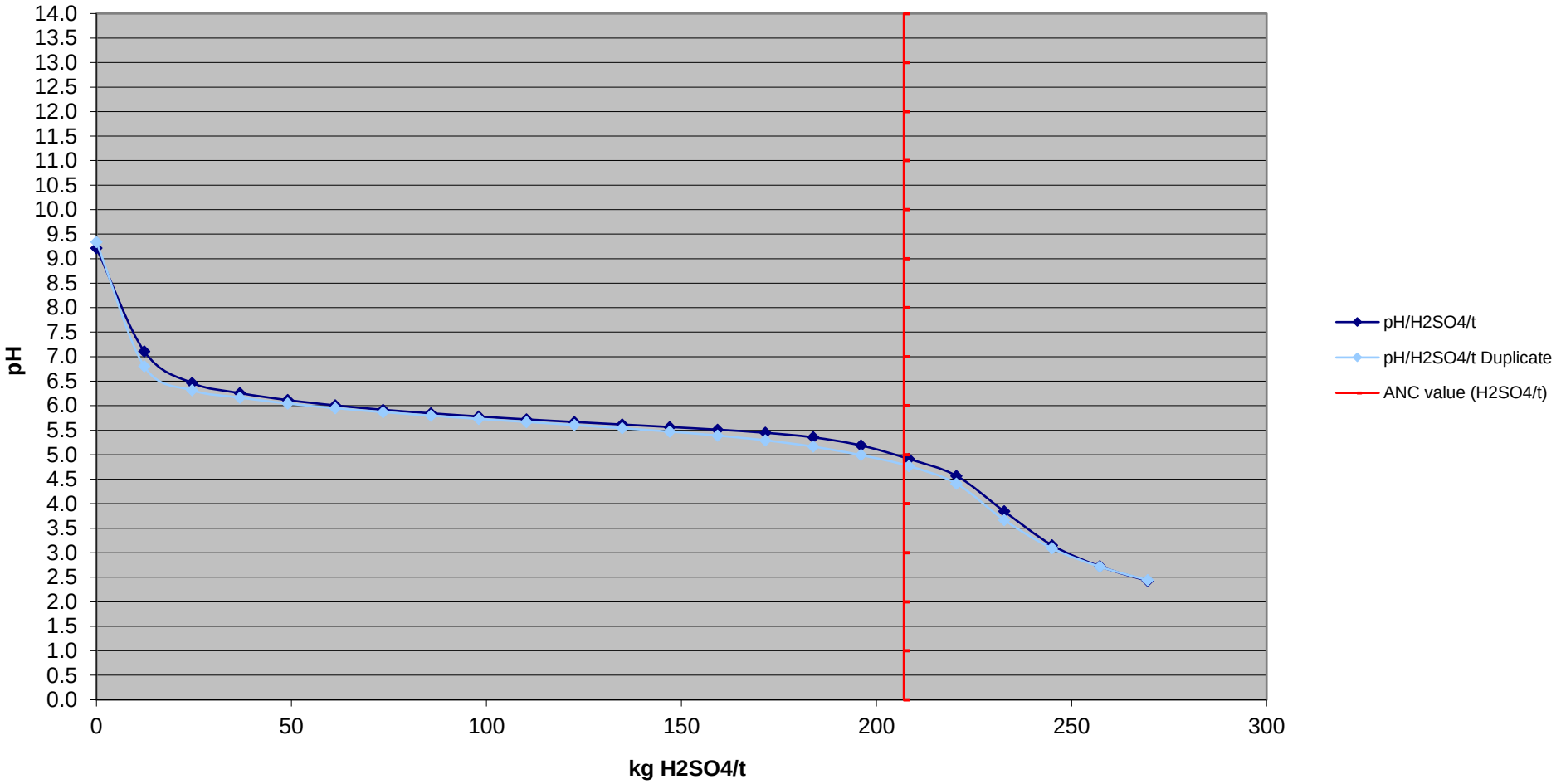
EA046 - A Titration information

HCl Molarity:	**M**	**0.5**
Increments:	**mL**	**0.2**
Weight	**(g)**	**2**
ANC	**kgH2SO4/t**	**79.8**

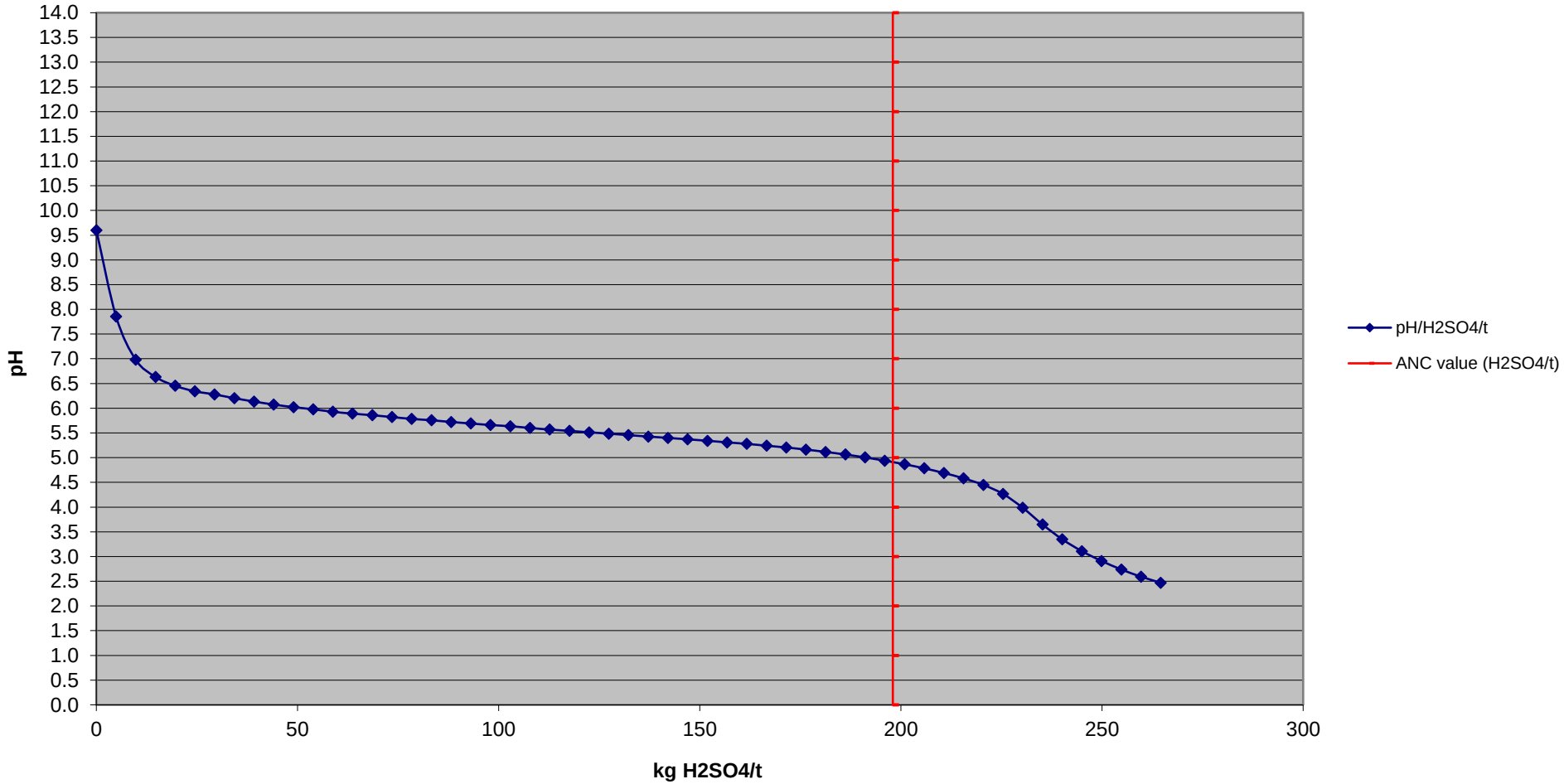
EA046 -B - Curve information

Addition	mLs added (total)	kg H2SO4/t	pH	Addition	mLs added (total)	kg H2SO4/t	pH
0	0	0	8.81	36	7.2	88.2	3.49
1	0.2	2.45	8.37	37	7.4	90.65	3.41
2	0.4	4.9	8.08	38	7.6	93.1	3.32
3	0.6	7.35	7.90	39	7.8	95.55	3.25
4	0.8	9.8	7.80	40	8	98	3.18
5	1	12.25	7.72	41	8.2	100.45	3.12
6	1.2	14.7	7.65	42	8.4	102.9	3.06
7	1.4	17.15	7.58	43	8.6	105.35	3.00
8	1.6	19.6	7.48	44	8.8	107.8	2.94
9	1.8	22.05	7.35	45	9	110.25	2.89
10	2	24.5	7.21	46	9.2	112.7	2.83
11	2.2	26.95	7.06	47	9.4	115.15	2.78
12	2.4	29.4	6.90	48	9.6	117.6	2.72
13	2.6	31.85	6.72	49	9.8	120.05	2.67
14	2.8	34.3	6.55	50	10	122.5	2.62
15	3	36.75	6.38	51	10.2	124.95	2.57
16	3.2	39.2	6.22	52	10.4	127.4	2.52
17	3.4	41.65	6.09	53	10.6	129.85	2.47
18	3.6	44.1	5.91				
19	3.8	46.55	5.75				
20	4	49	5.57				
21	4.2	51.45	5.39				
22	4.4	53.9	5.24				
23	4.6	56.35	5.11				
24	4.8	58.8	4.98				
25	5	61.25	4.86				
26	5.2	63.7	4.72				
27	5.4	66.15	4.60				
28	5.6	68.6	4.47				
29	5.8	71.05	4.34				
30	6	73.5	4.22				
31	6.2	75.95	4.08				
32	6.4	78.4	3.96				
33	6.6	80.85	3.82				
34	6.8	83.3	3.70				
35	7	85.75	3.59				

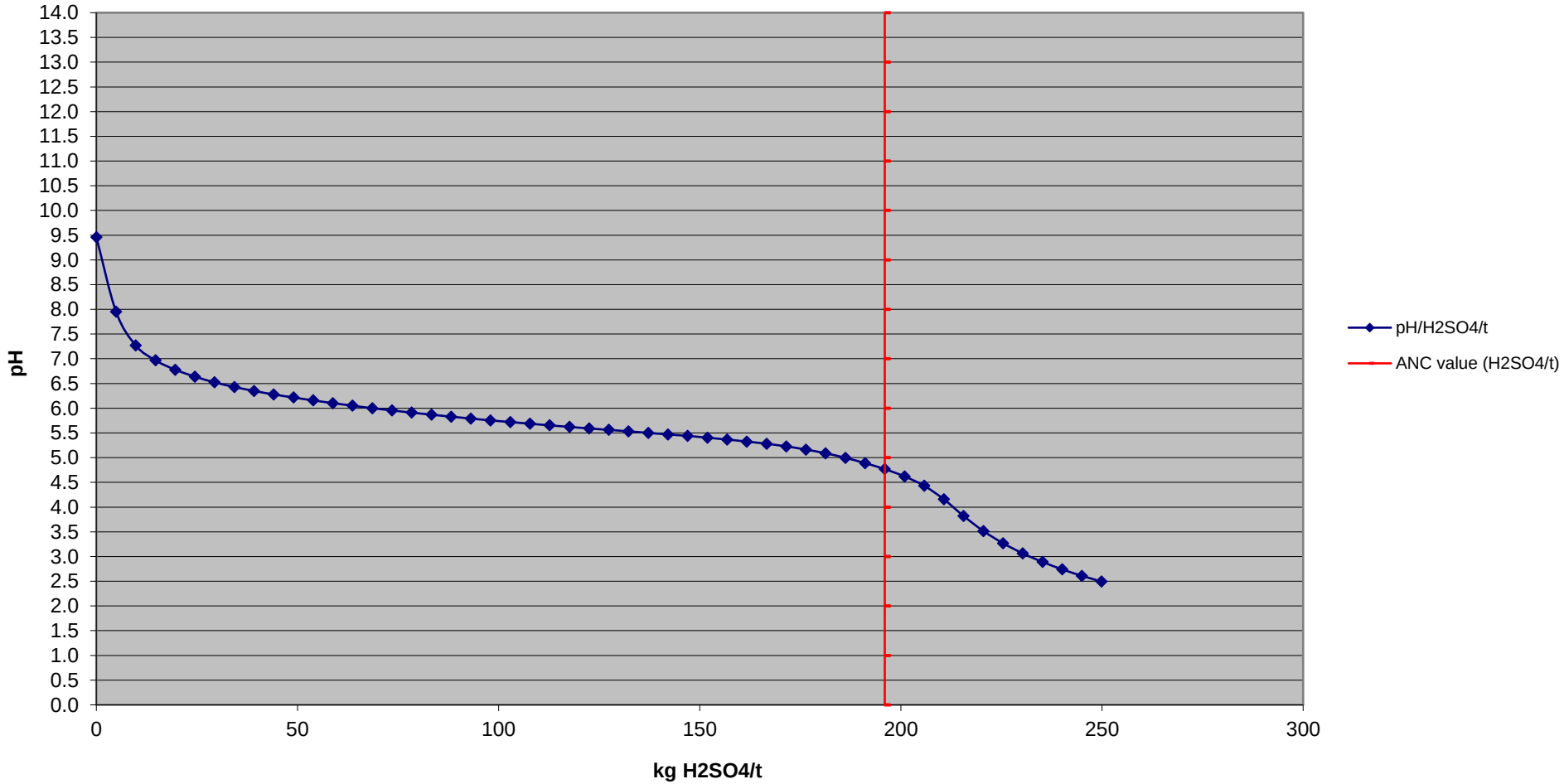
EB2411964 - 001 and Check 001 (Fimiston Tailings 1)
Acid Buffering Characteristic Curve
Titrating with 0.5M HCl, in increments of 1 mLs every 1000 seconds



EB2411964 - 002 (Fimiston Tailings 2)
Acid Buffering Characteristic Curve
Titrating with 0.5M HCl, in increments of 0.4 mLs every 1000 seconds

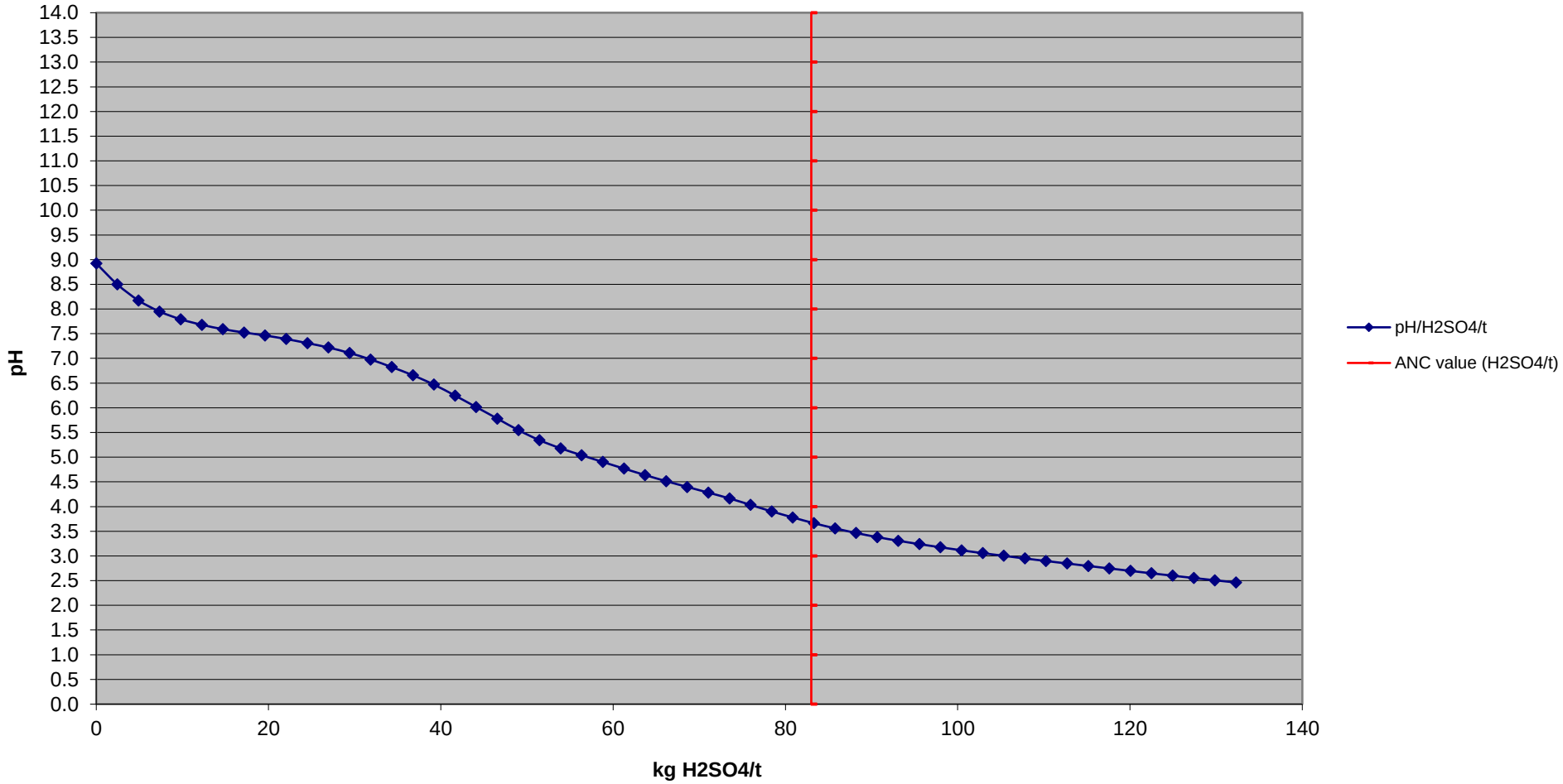


EB2411964 - 003 (Fimiston Tailings 3)
Acid Buffering Characteristic Curve
Titrating with 0.5M HCl, in increments of 0.4 mLs every 1000 seconds



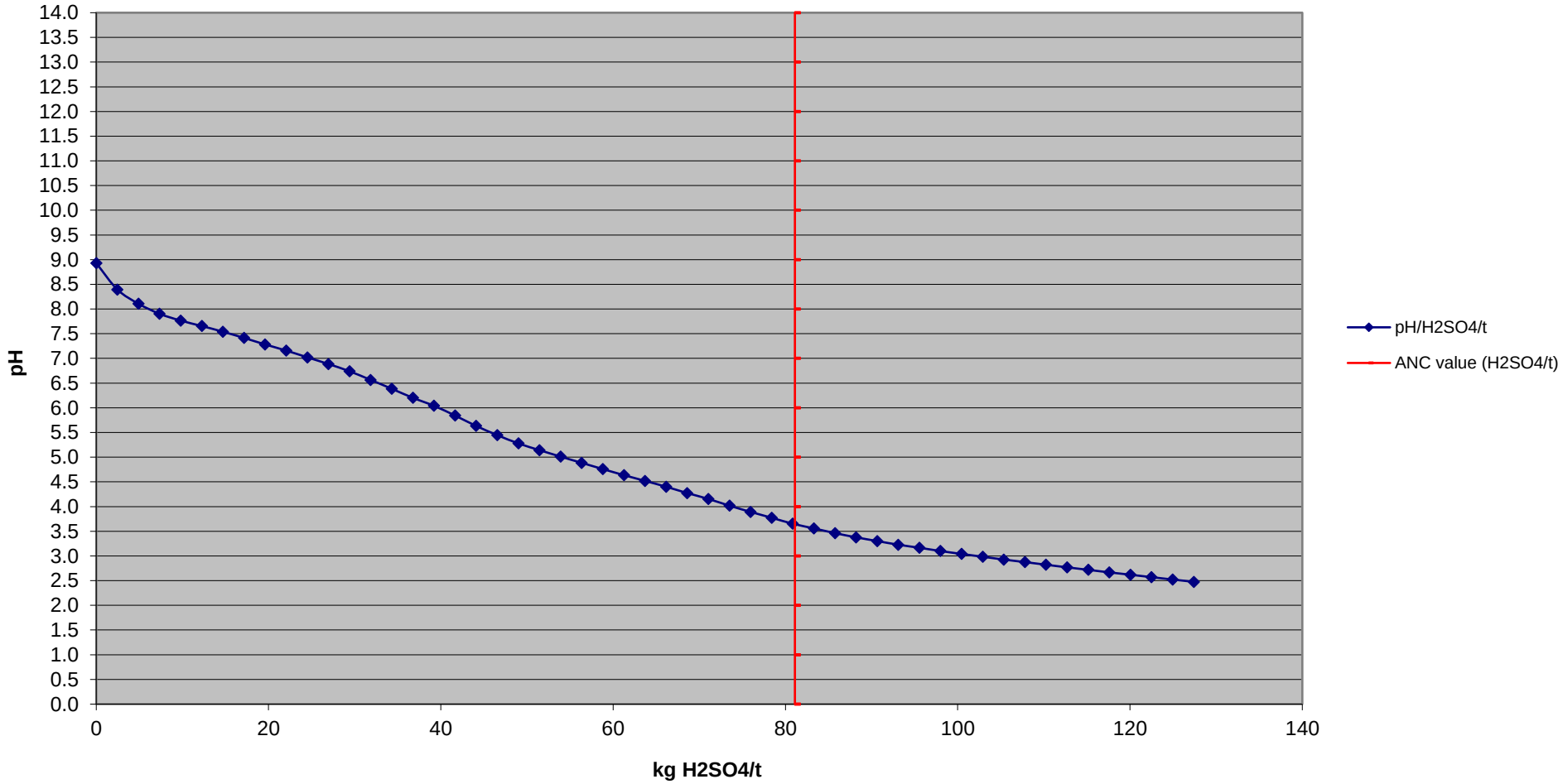
EB2411964 - 004 (Gidji Tailings 1)
Acid Buffering Characteristic Curve

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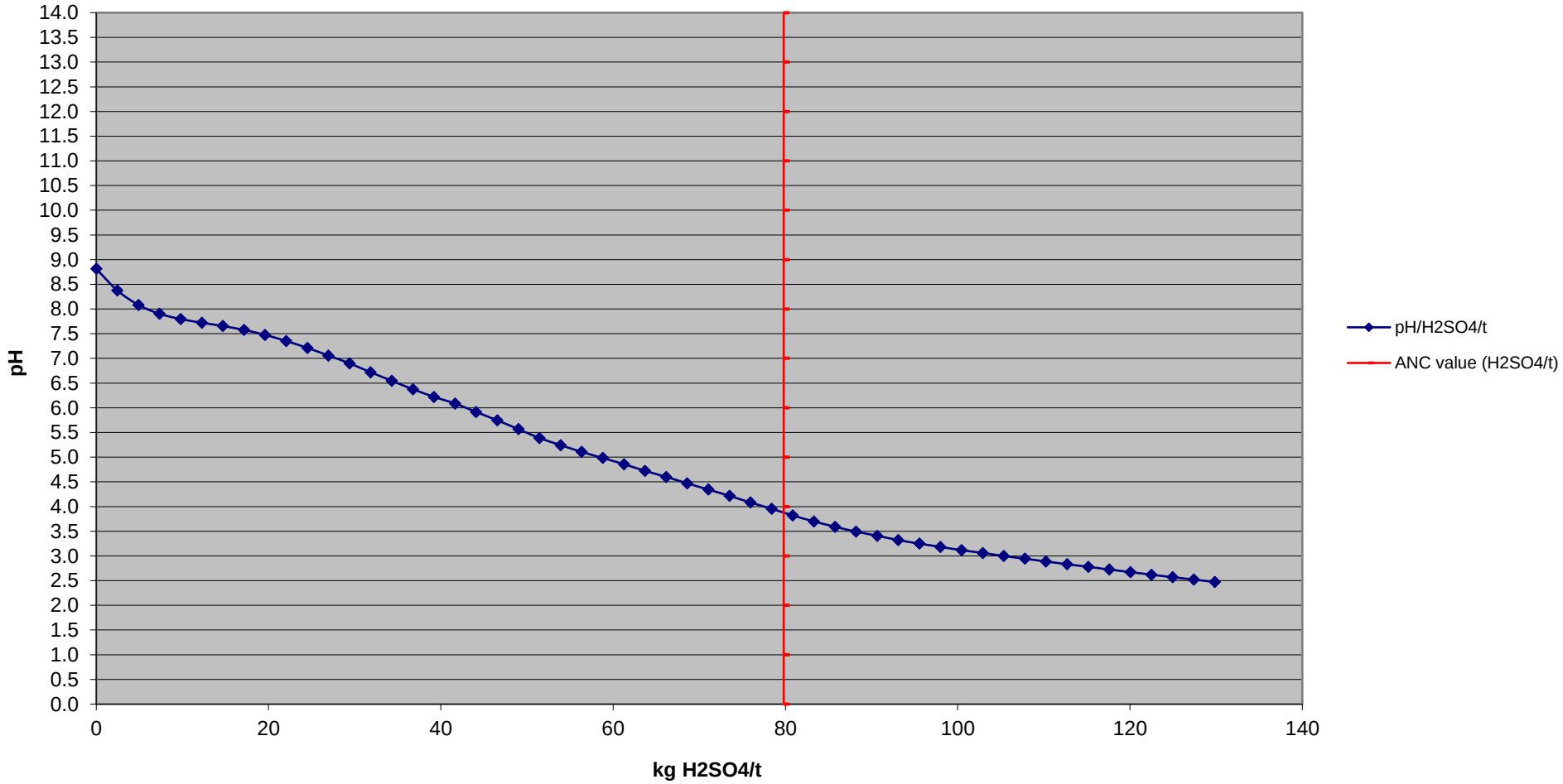


EB2411964 - 005 (Gidji Tailings 2)
Acid Buffering Characteristic Curve

Titrating with 0.5M HCl, in increments of 0.2 mLs every 1000 seconds



EB2411964 - 006 (Gidji Tailings 3)
Acid Buffering Characteristic Curve
Titrating with 0.5M HCl, in increments of 0.2 mLs every 1000 seconds



Appendix D

Limitation statement

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FIMISTON, KALTAILS AND GIDJI TAILINGS GEOCHEMISTRY OVERVIEW

PREPARED FOR:

KALGOORLIE CONSOLIDATED GOLD MINES

FEBRUARY 2018

PREPARED BY:

Martinick Bosch Sell Pty Ltd
4 Cook Street
West Perth WA 6005
Ph: (08) 9226 3166
Fax: (08) 9226 3177
Email: info@mbsenvironmental.com.au
Web: www.mbsenvironmental.com.au

SUPER PIT PROJECT
FIMISTON, KALTAILS AND GIDJI TAILINGS GEOCHEMISTRY OVERVIEW

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1. SCOPE AND PURPOSE

The primary purpose of this report is to collate and summarise key information from previous geochemical characterisation studies of tailings materials produced by Kalgoorlie Consolidated Gold Mines (KCGM) up to mid-2016. This work is to include:

- Collation of sample numbers taken and methodology used in previous assessments of KCGM tailings.
- Collation of key analytical data characterising KCGM tailings materials from previous reports.
- Summary of the overall implications for tailings management and closure based on results to date.

In preparing this report, information has been taken from the following geochemical reports prepared for KCGM:

- Graeme Campbell and Associates Pty Ltd 2003. *Gidji Roaster Geochemical Characterisation of Profile – Samples from Tailings-Bed (Static Test Work) – Implications for Mine Waste Management*. Report prepared for KCGM January 2003.
- Golder Associates 2008. *Geochemical and Geotechnical Characterisation of the Existing Kaltails Tailings*. Report prepared for KCGM August 2008.
- Graeme Campbell and Associates Pty Ltd 2010. *Geochemical Characterisation of Process Tailings Samples (Fimiston Processing Plant and Gidji Roaster) – Implications for Process – Tailings Management*. Report prepared for KCGM July 2010.
- Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2013. *KCGM Emissions Reduction Project: Mercury Characterisation*. Report prepared for KCGM September 2013.
- MBS Environmental 2016. KCGM Geochemical Tailings Characterisation. Memorandum report prepared for KCGM 13 April 2016.

2. PROJECT DESCRIPTION

The Project is located in Kalgoorlie-Boulder, 600 km east of Perth in the Eastern Goldfields Region of Western Australia (WA). The Project is divided into five operational areas (Figure 1) that encompass all operational and exploration areas managed by KCGM. The five operational areas are:

- Regional.
- Fimiston (and Kaltails).
- Gidji.
- Mount Charlotte (Mt Charlotte).
- Mount Percy (Mt Percy).



Figure 1: KCGM Operational Setting Adjacent to City of Kalgoorlie-Boulder

With the exception of the Gidji operation, all other operations are within close proximity of the City of Kalgoorlie-Boulder. The Gidji operation is located 17 km north of the city.

Mining and mineral processing has occurred along an area known as the Golden Mile, since gold was first discovered in 1893. The Golden Mile is one of the world's richest gold-bearing reefs and gave rise to a multitude of mining operations. In 1989, all mines, processing plants and leases along the Golden Mile were merged into one integrated operation, KCGM.

Gold production at KCGM is today sourced from two primary mining locations; the Fimiston Open Pit (commonly known as the Super Pit) located on the Golden Mile and the Mt Charlotte Underground Mine approximately 2 km north of the Fimiston Open Pit (Figure 2).

The Fimiston Open Pit mining rate is approximately 69 million tonnes per annum (Mt/a) (comprising ore and waste), of which approximately 12 Mt/a will be processed at the Fimiston Processing Plant.

The Mt Charlotte Underground Mine produces ore at the rate of 420,000 tonnes per annum (t/a). Ore is transported to the Fimiston Processing Plant via the Sam Pearce decline.

All ore mined at KCGM is treated at the Fimiston Processing Plant using flotation and conventional carbon in leach (CIL) circuits. Tailings from the Fimiston Processing Plant are currently pumped to the following Tailings Storage Facilities (TSFs); Fimiston I, Fimiston II and Kaltails (Figure 2). These TSFs are located to the north, east and south of the Fimiston Process Plant respectively. Fimiston I was initially constructed in 1988/89, with Fimiston II in 1992. Both have received tailings from processing of ore from the Fimiston Operations and the Golden Mile over their operating lives.

Kaltails was a joint venture project run from 1988 to 1999 between Normandy of Australia Ltd (now Newmont) and the Western Australian Mint which sluice mined (reprocessed) much of the old tailings facilities that were constructed to the south of the Fimiston Operations in the early part of the 20th century. These tailings were treated at a plant adjacent to the Kaltails TSF, where final tailings were deposited until around 1999. The tailings was then decommissioned and the batters rehabilitated. In 2011 KCGM recommissioned the TSF to provide additional tailings capacity for Life of Mine from the Fimiston Operations.

A sulfide concentrate, produced by flotation prior to the CIL process within the Fimiston Mill is transferred to the Gidji operation for further processing to improve extraction. Prior to 2001 the processing of all sulfide concentrate involved roasting (calcining) of the prior to cyanide extraction and this calcined tailings material was deposited to Gidji I TSF(Figure 3), located to the north of the processing facility. From early 2001, tailings deposited were a mixture of ultra-fine grinding (UFG) and calcine tailings. The roasters were decommissioned in 2015, and hence production of any calcined tailings component ceased, with all tailings produced from UFG. In 2012 a new lined facility, Gidji II, was constructed abutting Gidji I to the north to provide further capacity for tailings deposition. Gidji I reached approved capacity in 2013, and is no longer used for active tailings deposition. Tailings from Gidji I have been used to construct upstream lifts of Gidji II.



Figure 2: Key Mine Waste Landforms at KCGM



Figure 3: Gidji Tailings Storage Facility

3. MINE GEOLOGY OF ACTIVE OPERATIONS

The mine pit geology determines the geochemical characteristics of the mine waste materials generated at KCGM.

3.1 FIMISTON OPEN PIT

Approximately 80% of the waste rock sourced from the Fimiston Open Pit is Golden Mile (GM) Dolerite (Table 1). The remaining waste rock is composed primarily of Paringa Basalt (14%) and the Black Flag Beds (4.5%).

Table 1: Fimiston Waste Rock Breakdown

Weathering Zone	Lithology	Percentage of Total Waste
Oxide	GM Dolerite	11.6
	Paringa Basalt	3.3
	Black Flag Shale	0.9
	Devon Consols Basalt	0.4
	Williamstown Dolerite	0.1
Transition	GM Dolerite	6.3
	Paringa Basalt	1.3
	Black Flag Shale	0.5
Fresh	GM Dolerite	62.9
	Paringa Basalt	9.6
	Black Flag Shale	3.1
Total Across Weathering Zones	GM Dolerite	80.8
	Paringa Basalt	14.2
	Black Flag Shale	4.5

The mineralising event on the Golden Mile has led to an overall geochemical enrichment in arsenic (As), tellurium (Te), mercury (Hg), lead (Pb), vanadium (V) and boron (B). This enrichment is largely confined to the main lode systems with lower levels of enrichment in the surrounding host Black Flag Shales and significantly lower enrichment in the host Dolerite and Basalt. Analysis of over 1,200 samples of basalt and dolerite from non-mineralised diamond drill hole core indicates that sulfur grades within the WRDs average approximately 0.38% (by weight) (KCGM, 1990).

3.2 MT CHARLOTTE UNDERGROUND OPERATIONS

Within the vicinity of the Mt Charlotte deposit, the stratigraphy consists of a basal ultramafic unit (Hannans Lake Serpentinite), overlain successively by the Devon Consols Basalt, Kapai Slate, Paringa Basalt and Black Flag Beds. Mafic to ultramafic sills, including the Golden Mile Dolerite, have subsequently intruded the sequence. The Golden Mile Dolerite is the dominant lithology at the Mt Charlotte operations. The Black Flag Beds have historically been intersected through drives at Mt Charlotte, but this is a minor lithology for the area. Gold mineralisation is of the stockwork style (steeply plunging pipe-like quartz veins). The veins contain coarse quartz-carbonate, minor scheelite, tourmaline and albite; extensive wall rock alteration occurs around these veins. The alteration assemblage is quartz-albite-sericite-siderite-ankerite-pyrite. Mineralisation occurs primarily in the Golden Mile Dolerite.

4. PROCESS TAILINGS GEOCHEMISTRY

4.1 STUDIES CONDUCTED

4.1.1 Sample Descriptions

Descriptions of samples included in the studies covered by this report are presented below and summarised in Table 2. Note for Gidji samples all but one sample (reported by GCA 2003) represent UFG Gidji tailings. Reference to fresh tailings refers to un-oxidised/unweathered material (refer Glossary, Section 7).

Graeme Campbell and Associates (2003)

A total of ten samples collected by KCGM comprising:

- One sample of aged in-situ Gidji 'Calcine stream' tailings from production prior to 2001. This material forms the lowest layer of material in the Gidji I TSF.
- Nine samples of Gidji mixed (Calcine plus UFG) tailings collected across the TSF profile from surface to 4 m deep).

Golder Associates (2008)

A total of ten samples comprising:

- One sample of fresh Fimiston Processing Plant tailings solids and supernatant solution (Golder ID 101-10).
- Nine samples of tailings collected from then inactive Kaltails TSF at surface, 2 m and 5.5 m depth from inner (D1), middle (M1) and outer (S1) portions of one TSF cell.

Graeme Campbell and Associates (2010)

A total of five samples collected by KCGM comprising:

- One sample of fresh Fimiston Processing Plant tailings and supernatant solution.
- Four samples of tailings collected from the Gidji site, comprising fresh (plant), beach head (TSF), beach tail (TSF) and a 'high sulfur' sample (plant).

CSIRO (2013)

- One sample of fresh UFG tails collected by KCGM, which was used to prepare a second simulated weathered tails sample under laboratory conditions.

MBS Environmental (2016)

A total of six surface tailings solids and four tailings fluids collected by KCGM comprising:

- Two samples of fresh Fimiston I Mill tailings (decant and outer) and one of Fimiston II tailings. Fimiston I decant sample was considered anomalous for Fimiston tailings as it included some deposition of metals resulting from re-circulating of Gidji process water post cyanide destruction to Fimiston I decant pond.
- One sample of Kaltails tailings.
- One surface UFG tailings sample each of Gidji TSF I and Gidji TSF II.
- Supernatant tailings fluids from Gidji TSF II, Fimiston I, Fimiston II and Kaltails.

Table 2: Tailings Sample Summary

Sample Source		Location	Number of Samples	Study
Fimiston		Fresh tails	1	GCA (2010)
		Fresh tails	1	Golder (2008)
		Fresh tails (decant Fim I, outer Fim I, Fim II)	3	MBS (2016)
Kaltails	Pre KCGM	Surface	3	Golder (2008)
		2 m deep	3	Golder (2008)
		5.5 m deep	3	Golder (2008)
	Post KCGM	Surface (decant)	1	MBS (2016)
Gidji		Fresh UFG tails	1	GCA (2010)
		Beach Head UFG tails	1	GCA (2010)
		Beach UFG tails	1	GCA (2010)
		High Sulfur Sample (UFG)	1	GCA (2010)
		Pre 2001 Calcine tails	1	GCA (2003)
		Post 2001 UFG tails with some calcined tails as deposited to Gidji I (depth profile to 4 m).	9	GCA (2003)
		UFG Leach tails and Simulated Weathered tails prepared from this.	2	CSIRO (2013)
		Fresh UFG tails (Gidji I and II)	2	MBS (2016)
Total Samples			**33 (15 Fimiston/Kaltails, 18 Gidji)**	

4.1.2 Methodology

Summaries of the test methods used by the Golder Associates (2008), Graeme Campbell and Associates (2003 and 2010), CSIRO (2013) and MBS (2016) are discussed below. Despite minor differences in methodology, data from all reports are considered comparable.

Graeme Campbell and Associates (2003)

- Analysis of solids for acid base accounting (ABA) parameters including total sulfur, SO_4-S, carbonate carbon, acid neutralising capacity (ANC), net acid production potential (NAPP), by Australian Environmental Laboratories. Acid Base Characteristic Curve (ABCC) by Graeme Campbell.
- pH and Electrical Conductivity (EC) (1:2 water extract).
- Analysis of 1:10 water extracts for soluble chloride and sulfate.

Golder Associates (2008)

- Analysis of solids for ABA parameters including total sulfur, chromium reducible sulfur (CRS), ANC, net acid generation (NAG) test, by ALS Environmental.
- pH and EC (1:5 soil:water extract).
- Multi-element composition by total acid digestions of seven selected samples by ALS Minerals.
- Mineralogy by X-Ray Diffraction (XRD) of seven selected samples by CSIRO.

- Analysis of supernatant solution or NAG test solution (1:100 solid:liquid ratio) of seven selected samples for pH, EC, Total Dissolved Solids (TDS), Alkalinity/Acidity, major cations, chloride, sulfate and dissolved metals/metalloids by ALS Environmental.

Graeme Campbell and Associates (2010)

- Analysis of solids for ABA parameters including total sulfur, SO_4-S, total carbon, carbonate carbon, ANC and NAG by Genalysis Laboratories. ABCC by Graeme Campbell.
- pH and EC (1:2 water extract).
- Multi-element composition by total acid digestion by Genalysis Laboratories.
- Mineralogy by XRD (Roger Townend).
- Analysis of supernatant for pH, EC, TDS, major ions plus ammonia, dissolved metals/metalloids, Weak Acid Dissociable Cyanide (WAD CN), Total Cyanide (Total CN) and thiocyanate.

CSIRO (2013)

- Mineralogy by XRD and QEMSCAN by CSIRO.
- Analysis of leachate mercury concentrations in multiple media from UFG tails before and after simulated oxidation of the sample with hydrogen peroxide (53% of pyrite oxidised).

MBS Environmental (2016)

- Analysis of solids for ABA parameters including total sulfur, SO_4-S, total carbon, ANC and NAG by Genalysis Laboratories.
- Analysis of a 1:5 water extract of solids for pH, EC, major ions, fluoride, alkalinity and metals/metalloids including hexavalent chromium, antimony and tellurium. Analysis of a 1:20 acetic acid leach for metals and metalloids.
- Multi-element composition by total acid digestion including antimony and tellurium.
- Analysis of supernatant fluids for pH, EC, major ions, fluoride and alkalinity, dissolved metals/metalloids, WAD CN, Total CN and free cyanide.

4.2 FIMISTON/KALTAILS TAILINGS

4.2.1 Mineralogy

The only sulfide mineral detected by XRD (Graeme Campbell and Associates 2010) in Fimiston tailings was pyrite, in trace (<2%) amounts. The dominant carbonate mineral was ankerite (10 to 20%) with trace (<2%) siderite. Ankerite composition average was $(Mg_{0.24}Fe_{0.22}Mn_{0.01}Ca_{0.52})CO_3$ and therefore expected to provide substantial ANC as a consequence of a high ratio of calcium and magnesium (effective acid neutralising properties) to iron and manganese (zero or very low potential for acid neutralisation).

Common rock forming minerals were quartz, plagioclase, chlorite, muscovite/biotite micas, all of which are consistent with mafic igneous lithologies. There was also trace to accessory levels of titanium and iron oxides (magnetite), respectively.

Mineral analysis (CSIRO) in the Golder Associates (2008) of the Kaltails samples indicate composition broadly similar to the above findings for analysis of Fimiston tailings (no sulfide minerals detectable by XRD). The ANC material was indicated tentatively as dolomite rather than ankerite determined in Fimiston tailings.

4.2.2 Acid Base Accounting

All 15 samples of Fimiston and Kaltails tailings examined were classified as NAF on the basis of generally low to moderate sulfide-sulfur (range 0.05 to 1.06%) and high ANC (133 to 200 kg/t H_2SO_4). Essentially all (14 of the 15 samples), had a resulting NAPP value of less than -100 kg H_2SO /t, indicating the material is actually acid consuming (AC) in nature.

Fresh samples of tailings recorded alkaline pH values ranging from 7.8 to 8.5. NAG pH values following oxidation were more alkaline, with pH values ranging from 8.0 to 10.6.

4.2.3 Elemental Composition and Leachate Solubility

Excluding one sample of Fimiston 1 decant solids considered anomalous in 2016 (Section 4.1.1), examination of results for all other Fimiston and Kaltails samples indicates slight enrichment by mercury (0.39 to 1.47 mg/kg versus a crustal average of 0.08 mg/kg) and arsenic (31 to 132 mg/kg versus 1.8 mg/kg crustal average). Significant enrichments versus crustal averages were found for antimony (4.8 to 15.1 mg/kg versus crustal average 0.2 mg/kg) and tellurium (0.99 to 1.93 mg/kg versus crustal average of 0.001 mg/kg). Consistent with enrichment by both mercury and tellurium and on the basis of mercury speciation results in Gidji tailings (CSIRO 2013) which are sourced from the same ore, mercury and tellurium present in Fimiston/Kaltails tailings was determined to be present as coloradoite (HgTe), which is highly insoluble. Tellurium concentrations in 1:5 water or 1:20 acetic acid leaches of Fimiston/Kaltails solids were at or below limits of reporting (<0.0001 to 0.0002 mg/L). Leachable antimony concentrations, despite enrichment, were also extremely low. Concentrations of mercury in extracts of fresh tailings on a 1:20 ratio basis (MBS 2016) were below livestock drinking water guidelines (0.002 mg/L) and not considered at risk of adversely impacting the quality of saline groundwater – leachable concentrations of mercury are also expected to fall post closure as solubility of mercury is considered linked to presence of cyanide in fresh tailings and this cyanide will degrade post-closure.

4.2.4 Supernatant Solution and NAG Solution Analysis

Fresh tailings supernatant solution had pH 7.8 to 7.9, was hypersaline (100,000 to 155,000 µS/cm EC and approximately 84,000 mg/L to 100,000 mg/L TDS) and sodium chloride dominant, but also with high levels of calcium, magnesium and sulfate. In 2016 (MBS 2016), the salinity of Fimiston 1 supernatant fluid was higher (200,000 µS/cm EC) due to temporary mixing with returned Gidji process water. Typical of a gold processing tails solution, solubility of metals and metalloids is considered strongly linked to cyanide and/or ammonia complex formation. In the 2016 assessment (MBS 2016), concentrations of cyanide in Fimiston/Kaltails supernatant ranged from 21 to 25 mg/L – almost entirely present as WAD cyanide. Moderate but variable concentrations of copper, lead, nickel, cobalt, mercury and antimony were noted across the three reports.

NAG test solutions provided by oxidation (1:100 extraction ratio) with hydrogen peroxide (which destroys cyanide species) aims to estimate the long term solubility of metals and metalloids after cyanide complexes have been oxidised or become physically absorbed to tailings surfaces. The concentrations of trace metals and metalloids in these simulated solutions (GCA 2008) were very low, which is to be expected given the strongly alkaline, oxidising conditions. The highest metal concentration was aluminium (0.05 to 0.75 mg/L), which is still below ANZECC 2000 Livestock Drinking Water Guidelines of 5 mg/L when adjusted to a normal 1:20 ratio extraction ratio.

4.3 GIDJI TAILINGS

4.3.1 Mineralogy

Analysis of the four various Gidji tailings (Graeme Campbell and Associates 2010) by XRD indicated the tailings were primarily comprised of gypsum, hematite and pyrite in varying quantities with accessory amounts (2-10%) of ankerite, halite, silicates (plagioclase and micas) and quartz. Traces of Ni-cobaltite and titanium oxides were also present.

Mercury was identified in 2013 (CSIRO 2013), as being present as highly insoluble coloradoite (HgTe).

4.3.2 Acid Base Accounting

Analysis of a single historical sample of the 'calcine stream' tailings from processing prior to 2001 which forms the base layers of Gidji TSF I was found to have less than 0.1% sulfide sulfur, moderate ANC in the form of ankerite and was thus classified as NAF.

All 13 samples of various UFG Gidji tailings (Graeme Campbell 2003 and 2010) analysed were classified as PAF on the basis of high sulfide-sulfur (range 6.1 to 22%) in the form of pyrite and low to moderate ANC (range 44 to 130 kg H_2SO /t $_4$, ABCC determined effective ANC was 40-50 kg H_2SO /t). Fresh surface samples of dried tailings recorded alkaline pH values in 2003 (GCA 2003 pH range 8.7 to 10.0) but were more circum-neutral in 2010 (GCA 2010 pH range 7.6 to 7.8. NAG pH values following peroxide oxidation (GCA 2010) were acidic, with pH values ranging from 1.9 to 2.3.

Analysis of two additional fresh UFG Gidji tailings samples in 2016 (MBS 2016), indicated extremely high sulfide-sulfur contents of 33 to 37% (higher than previous studies), with limited ANC (43 to 56 kg H_2SO /t) and NAGpH values of 1.7 and 1.8. The fresh samples of tailings were alkaline (pH 8.7 to 8.8) but overall the classification was of Gidji tailings being highly PAF in nature.

4.3.3 Elemental Composition

As Gidji tailings are produced from a sulfide concentration float from Fimiston pit ore, an array of primarily sulfur associated elements (chalcophiles) are geochemically enriched compared to Fimiston tailings. The GCA 2010 and MBS 2016 reports indicated significant enrichment in silver, copper, cadmium, lead, cobalt, mercury, arsenic, antimony, bismuth, selenium and molybdenum (Table 3) versus global crustal averages. On the basis of mercury speciation (CSIRO 2013), highly insoluble coloradoite (HgTe) was expected to be the dominant form of both mercury and tellurium although some mercury in processed tails will have been converted to cyanide complexes. Results below summarise data for samples of Gidji UFG tailings (post 2001), data for calcined Gidji tailings (pre 2001, Gidji TDF1) is not available but is expected to be broadly similar.

Table 3: Gidji Tailings Enriched Metals and Metalloids (UFG Tailings)

Metal	Concentration Range (mg/kg) (GCA 2010)	Concentration Range (mg/kg) (MBS 2016)
Silver	4.3 to 11.6	3.5 to 5.4
Copper	1,300 to 2,500	811 to 1,028
Cadmium	1.1 to 1.9	1.9 to 2.0
Lead	240 to 520	852 to 900
Cobalt	540 to 790	429 to 454
Mercury	4.0 to 8.9	13.1 to 16.8
Arsenic	2,000 to 3,300	1,500 to 1,574
Antimony	73 to 120	45.7 to 66.8
Bismuth	0.45 to 0.55	0.55 to 0.56
Selenium	4.5 to 12.1	11.9 to 13.9
Tellurium	Not Analysed	43.6 to 46.3
Molybdenum	23 to 30	20 to 26

4.3.4 Gidji Supernatant Solutions

Graeme Campbell and Associates (2010), reported fresh Gidji tailings supernatant solution had alkaline pH values in the range of 9.7 to 10.6 with high concentrations of cyanide present due to requirements of processing (1,600 to 1,700 g/L total cyanide, 470 to 950 mg/L WAD cyanide, 2,200 to 4,200 mg/L thiocyanate). Another sample in 2016 (MBS 2016) showed slightly lower pH of 8.4, total cyanide of 1,082 mg/L and WAD cyanide of 555 mg/L. All three supernatant solutions analysed were hypersaline (78,000 to 110,000 mg/L TDS, 94,000 to 160,000 µS/cm EC). Sodium chloride was the dominant salt, although high levels of calcium, magnesium and sulfate were present. Concentrations of cyanide associated metals including iron (34 to 184 mg/L), nickel (18 to 50 mg/L), copper (524 to 3,100 mg/L), cobalt (129 to 280 mg/L) and zinc (<0.1 to 60 mg/L) reflect the cyanide based chemistry in the supernatant water during the active lifetime of the TSF. Post closure, the levels of cyanide in the tailings porewater and subsequently potential for groundwater seepage are expected to attenuate by degradation and/or surface absorption and with it the concentrations of these dissolved metals.

4.3.5 Gidji Tailings Leachate Solubility

Leachable concentrations of metals and metalloids in both water and acetic acid solutions were examined in 2016 (MBS 2016). Leachable concentrations in water and acetic acid solutions of tellurium, bismuth, molybdenum, selenium, arsenic and antimony, despite geochemical enrichment, were low to extremely low and considered of low risk to the receiving environment. Water leachates of fresh tailings contained elevated concentrations of metals capable of forming stable cyanide complexes – copper, cobalt, nickel, mercury and silver. These cyanide complexes are not expected however to persist post closure and concentrations of these metals largely decreased under acidic leach conditions (acetic acid) due to partial destruction of the cyanide complexes. Acetic acid leach conditions (simulating partial oxidation of tailings producing acidic conditions), significantly increased solubility for lead, iron and zinc versus fresh tailings, indicating dissolution of oxide forms of these metals. Copper and nickel maintained reasonable solubility under acid leach conditions as well.

Mercury concentrations as reported for Gidji UFG tails in 2013 (CSIRO 2013) indicated that mercury has very low solubility under normal alkaline to circum-neutral conditions with a maximum soluble fraction of 0.05 mg/kg in either fresh or oxidised tailings (equivalent to 0.0025 mg/L in a 1:20 ratio extract). Concentrations of soluble mercury in fresh tails in 2016 (MBS 2016) were found to be significantly higher (2.2 to 3.1 mg/kg in water, 1.5 to 1.75 mg/kg in acetic acid), but had an unknown quantity of residual cyanide present. The solubility of mercury in tailings extracts is considered closely linked to the proportion of available cyanide as the main mercury mineral form (coloradoite) is otherwise highly insoluble. Leachable concentrations of mercury are expected to decrease post closure in line with 2013 results as cyanide degrades.

5. IMPLICATIONS FOR MANAGEMENT AND CLOSURE

5.1 FIMISTON AND KALTAILS PROCESS TAILINGS

The results of geochemical testing to date indicate that Fimiston and former Kaltails process tailings will:

- Remain NAF with alkaline porewater post closure.
- Remain hypersaline with the predicted formation of a surface gypsum crust post closure, which is expected to reduce infiltration rates into underlying tailings.
- During operation the solubility of trace metals and metalloids and any potential for infiltration to groundwater (depending on infiltration rates and surface adsorption reactions) will reflect the cyanide based chemistry of the Fimiston process water. Metals noted in low to moderate concentration in Fimiston supernatant solution include copper, mercury, antimony, lead, nickel and cobalt.
- Post closure potential for leaching of trace metals and metalloids is considered very low as gradual cyanide degradation, surface adsorption (including arsenic as insoluble iron bound species) and the alkaline nature of the tailings will reduce the mobility of most metals and metalloids to very low levels. Simulation of oxidised tailings conditions by analysis of tailings solutions after accelerated laboratory oxidation with peroxide indicate extremely low levels of all environmentally significant metals and metalloids.
- The risk of leachate from stored Fimiston and Kaltails tailings in rehabilitated storages adversely impacting groundwater is considered low.

5.2 GIDJI PROCESS TAILINGS

The results of geochemical testing to date indicate that Gidji process tailings have the following characteristics:

- Hypersaline and likely to remain so in the long-term (post closure) with the formation of a surface gypsum and halite crust. Infiltration rates are predicted to decrease rapidly from those during the operational period.
- Dry UFG tailings, although classified as PAF with very high sulfide-sulfur contents, are circum-neutral to alkaline when fresh. An effective closure design using a store and release cover to limit water infiltration and slow the rate of oxidation (i.e. to keep it within the 'lag' phase of weathering), combined with the arid climate should limit acid formation. Suppression of significant oxidation under these conditions should also be assisted by the formation of surface 'armouring' from material such as gypsum in the tailings material above the saturated zone. Deeper tailings within a water saturated zone due to the high osmotic pressure of the tailings will remain free of oxygen and therefore be prevented from oxidising. Gidji I calcined tailings (pre 2001) were classified as NAF.
- Substantially enriched by metals and metalloids including silver, arsenic, cobalt, copper, mercury, lead, nickel, cadmium, tellurium, antimony, selenium and molybdenum. Chromium was not found to be enriched in tailings samples examined.
- Despite geochemical enrichment, arsenic, antimony, selenium and tellurium had low to very low solubility in water or acetic acid leachates of fresh tailings and are considered of low risk to the receiving environment.
- During operation the solubility of trace metals and metalloids and any potential for infiltration to groundwater (depending on infiltration rates and surface adsorption reactions) will reflect the cyanide based chemistry of the Gidji process water. Metals noted under these conditions include copper, nickel, mercury, cobalt and zinc. Solubility of these metals is expected to decrease gradually over time following closure with attenuation of cyanide levels by various means.
- Predicted leachates of any tailings which may oxidise (and hence become acidic) on the Gidji II TSFs have the potential for significantly elevated concentrations of metals and metalloid toxicants including lead,

copper, zinc, iron and to a lesser degree nickel. The base of Gidji II TSF was fully lined to reduce seepage to groundwater. Gidji I TSF is predominantly comprised of non-acid forming calcined tailings but has not been evaluated for leachable concentrations of metals.

- Post closure potential for long-term leaching of trace metals and metalloids should be limited in suitably covered Gidji TSFs post-closure by degradation and surface adsorption of otherwise soluble cyanide species (copper, nickel, mercury, cobalt and zinc) and the circum-neutral to alkaline pH of pore waters, including a basement layer of NAF calcine tails materials. Final cover design requirements for erosion/seepage control as required (noting the hypersaline receiving groundwater which has no identified beneficial uses), should also include further evaluation of Gidji I calcined tailings.

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7. ABBREVIATIONS AND GLOSSARY OF TECHNICAL TERMS

Term	Explanation/Description
ABCC	Acid Base Characterisation Curve. The ABCC test involves slow titration of a sample with acid while continuously monitoring pH. This data provides an indication of what portion of the ANC measured in a sample is readily available for acid neutralisation.
AC	Acid consuming material. Defined as NAF material which has a NAPP value in excess of – 100 kg H_2SO_4/t.
ANC	Acid Neutralising Capacity. A process where a sample is reacted with excess 0.5 m HCl at a pH of about 1.5, for 2-3 hours at 80-90ºC followed by back-titration to pH=7 with sodium hydroxide. This determines the acid consumed by soluble materials in the sample.
ankerite	A calcium, iron, magnesium, manganese carbonate mineral of general formula $Ca(Fe,Mg,Mn)(CO_3)_2$. In composition it is closely related to dolomite, but differs from this in having magnesium replaced by varying amounts of iron(II) and manganese.
AP	Acid Potential. Similar to MPA, but is only based on the amount of sulfide-sulfur (calculated at the difference between total sulfur and sulfate-sulfur (SO_4-S)) rather than total sulfur. AP (kg H_2SO_4/t) = (Total S – SO_4-S) x 30.6.
basalt	A dark coloured fine grained mafic extrusive igneous rock composed chiefly of calcium plagioclase and pyroxene. Extrusive equivalent of gabbro, underlies the ocean basins and comprises oceanic crust.
calcite	Calcium carbonate $CaCO_3$.
CIL	Carbon in Leach – the process of extracting gold from crushed rock by extraction with sodium cyanide solution and adsorption onto activated charcoal.
circum-neutral pH	pH value near 7.
CRS	Chromium Reducible Sulfur. A measurement of reactive sulfide sulfur normally applied to acid sulfate soils using reaction with metallic chromium and hydrochloric acid to liberate hydrogen sulfide gas which is trapped and then measured by iodometric titration. It is considered to be a more accurate estimate of oxidisable sulfur for iron sulfides than the difference between total sulfur and sulfate-sulfur (SO_4-S) for calculating Acid potential (AP).
dolerite	A mafic, holocrystalline, subvolcanic rock equivalent to volcanic basalt (but larger grained) or plutonic gabbro.
dolomite	Calcium magnesium carbonate $CaMg(CO_3)_2$.
EC	Electrical conductivity. A measurement of solution salinity. Conversion: 1,000 µS/cm = 1 dS/m = 1 mS/cm
Fresh tailings	Tailings which have not been oxidised by exposure to oxygen and hence started to oxidise and produce sulfuric acid (as opposed to weathered or aged tailings which have).
felsic	Silicate minerals, magma, and rocks that are enriched in the lighter elements such as silicon, oxygen, aluminium, sodium, and potassium.
laterite	Highly weathered soils/subsoils developed by extensive leaching of iron and aluminium rich parent rocks in tropical climates to leave soils rich in iron and aluminium oxides/hydroxides.
mafic	Descriptive of igneous rock containing a high content of ferromagnesian silicate minerals, but less than those present in ultramafic rocks. Common mafic rocks include basalt, dolerite and gabbro.

Term	Explanation/Description
MPA	Maximum Potential Acidity. A calculation where the total sulfur in the sample is assumed to all be present as pyrite. This value is multiplied by 30.6 to produce a value known as the Maximum Potential Acidity reported in units of kg H_2SO_4/t.
NAF	Non Acid Forming. A sample is classified as NAF if the NAG pH is greater than 4.5 and NAPP is negative (i.e. ANC is greater than AP).
NAG	Net Acid Generation. A process where a sample is reacted with 15% hydrogen peroxide solution at pH = 4.5 to oxidise all sulfides and then time allowed for the solution to react with acid soluble materials. This is a direct measure of the acid generating capacity of the sample but can be affected by the presence of organic materials.
NAG pH	The pH after the NAG test with hydrogen peroxide and heating is completed i.e. oxidation of all sulfides.
PAF	Potentially Acid Forming. A sample is classified as PAF if the NAG pH is less than 4.5 and NAPP is positive (i.e. AP is greater than ANC).
PAF-LC	Potentially Acid Forming – Low Capacity. Waste rock classification for samples with NAPP values less than or equal to 10 kg H_2SO_4/t.
PAF-HC	Potentially Acid Forming – High Capacity. Waste rock classification for samples with NAPP values greater than 10 kg H_2SO_4/t.
pH_F	pH field of a 1:2 soil:water paste.
pH_{FOX}	pH field after addition of a few drops of strong oxidant (hydrogen peroxide).
porphyry	An igneous rock in which large crystals (phenocrysts) are set in a matrix of relatively finer-grained crystals or of glass.
QEMSCAN	Quantitative Evaluation of Minerals by Scanning Electron Microscopy. An integrated instrumental system for identifying and quantifying mineral phases comprising a Scanning Electron Microscope (SEM), several Energy-dispersive X-ray spectroscopy detectors and propriety software for data acquisition and processing.
saprolite	A rock chemically broken down in its original place by deep weathering of the bedrock surface.
serpentinite	A mineral composed dominantly of the serpentine minerals antigorite, lizardite and chrysotile. It is green to dark green coloured.
siderite	Iron(II) carbonate $FeCO_3$.
TIC	Total Inorganic Carbon.
TSF	Tailings Storage Facility.
ultramafic	An igneous rock with a very low silica content and rich in minerals such as hypersthene, augite and olivine. These rocks are also known as ultrabasic rocks.
XRD	X-Ray Diffraction. A laboratory technique used to identify and quantify crystalline mineral phases in geological materials measuring diffraction angles and patterns from a finely ground sample.

5.6 Appendix 5.6: FIMISTON TSFs Closure Design Report

REPORT

Tailings Storage Facility Closure Design Report

Fimiston I, Fimiston II and Kaltails Tailings Storage Facilities

Submitted to:

Janine Cameron
Kalgoorlie Consolidated Gold Mines
Fimiston Processing Plant
Black Street
KALGOORLIE WA 6430

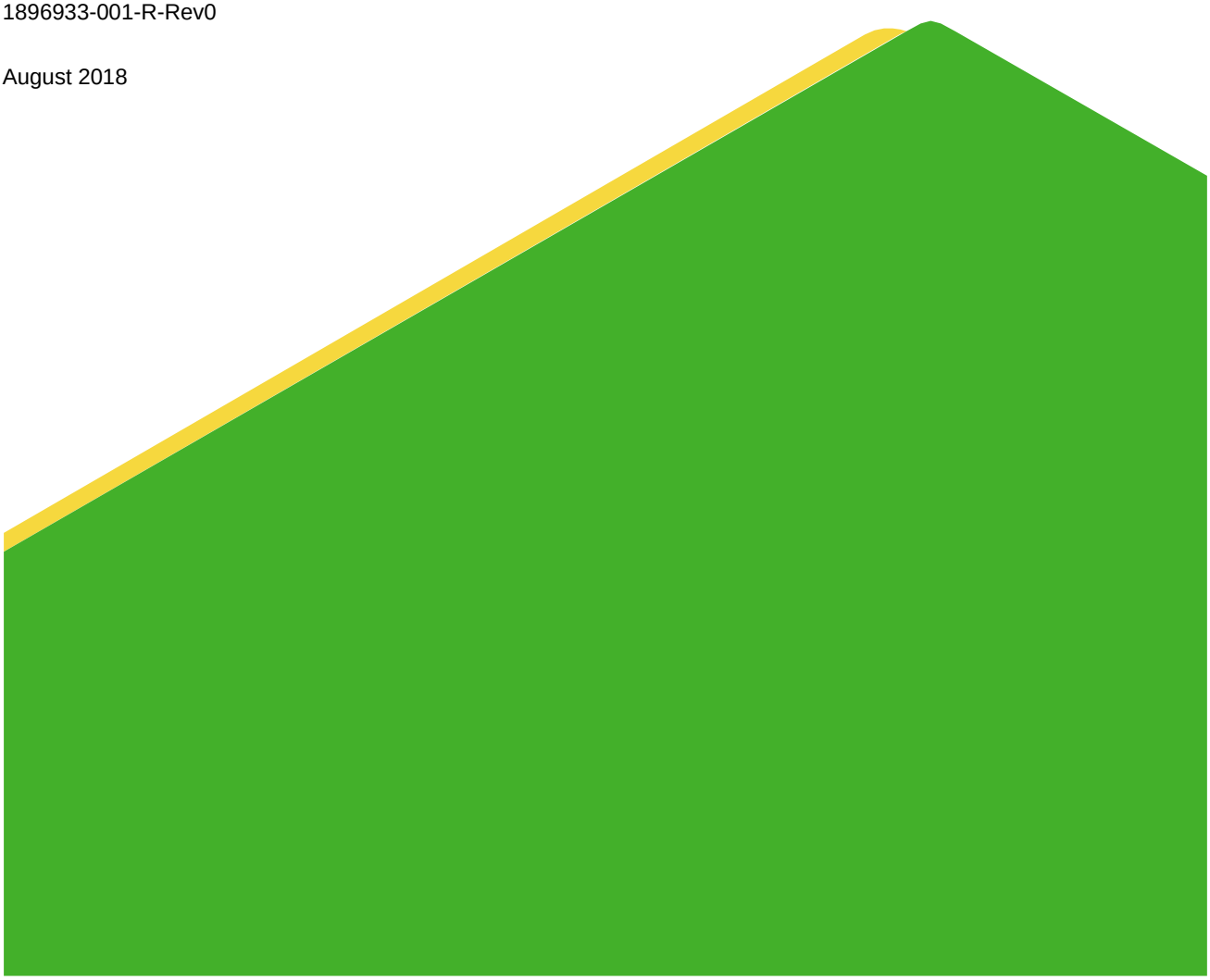
Submitted by:

Golder Associates Pty Ltd
Level 3, 1 Havelock Street West Perth, Western Australia 6005 Australia

+61 8 9213 7600

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1.0 INTRODUCTION

Kalgoorlie Consolidated Gold Mines Pty Ltd (KCGM) is seeking approval via a Mining Proposal for the closure design of the three Tailings Storage Facilities (TSFs), namely Fimiston I, Fimiston II and Kaltails TSFs that store tailings generated at the Fimiston Processing Plant. This document provides a summary of the proposed design for closure of these TSFs. The proposed design is aligned with the latest Mine Closure Plan (MCP) (Document version: KCGM MCP 2018 26032018 Final; KCGM 2018) submitted in March 2018 to the Department of Mines, Industry Regulation and Safety (DMIRS).

This report has been prepared in general accordance with the Guideline for Mining Proposals in Western Australia (Department of Mines and Petroleum, 2016) and presents the outcomes of the design studies undertaken to support closure of the TSFs. The closure design for the TSFs is presented as follows:

- Section 2 presents the basis of design.
- Section 3 presents the site setting, including climatic conditions.
- Section 4 presents an overview of the TSFs that are the subject of the closure design.
- Section 5 presents a summary of the geotechnical and geochemical characteristics of the tailings.
- Section 6 presents a summary of the inherent risks identified for the TSFs at closure, and how they are managed as part of the closure design.
- Section 7 presents an overview of the modelling and trials undertaken to support the closure design.
- Section 8 presents the overall closure design concept for the TSFs and the closure designs for each TSF, with reference to figures as appropriate. Note: the figures show the anticipated configuration at closure. As part of a TSF decommissioning plan, the design will be adjusted taking cognisance of the as-built configuration of the TSFs.

For details on the closure timeline, monitoring, maintenance, stakeholder consultation and management of information, data and records, please refer to the most recent version of the MCP.

2.0 BASIS OF DESIGN

Detailed TSF closure design planning commenced with a workshop in 2014. The subsequent work included a closure and rehabilitation design alternatives assessment for the Fimiston I, Fimiston II and Kaltails TSFs. Table 1 provides the final closure and rehabilitation design criteria that have been developed for KCGM's TSFs through 2014 to 2016.

Table 1: Closure and rehabilitation design criteria for Fimiston I, Fimiston II and Kaltails TSFs

Factor	Closure and Rehabilitation Design Criteria
TSF Top Surface	
Top Surface Geometry (Per Paddock/Cell)	Interior drainage with an engineered perimeter bund designed to provide internal containment for the design storm. If not in place due to the existing beach slope, the outermost 75 m of the top surface perimeter area will be graded to drain away from the outer slopes to promote rainfall runoff flowing away from the perimeter.
Top Surface Cover and Thickness	0.5 m thick benign waste rock or oxide waste placed as a single loose lift over tailings.
Perimeter Bund	Minimum crest width of 1.5 m with slopes 1V:3H. Minimum height to be designed to provided stable containment for the design storm (24-hour PMP) plus 0.3 m freeboard. Bunds to be constructed with low permeability soils (e.g. tailings) and protected from erosion with rock armour.

Factor	Closure and Rehabilitation Design Criteria
Perimeter Bund Construction	Low permeability soils placed in perimeter bunds to be placed in maximum 0.3 m lifts and compacted to a minimum dry density of 95% of the maximum dry density, as determined by AS1289.5.4.1, at a moisture content of ±2% of the optimum moisture content. This is consistent with construction of wall raises. The cover material to be placed over the compacted perimeter bund.
Embankment Slopes	
Embankment Slope Profile	Regrade where required to a nominal 1V:3H continuous slope if currently steeper than 1V:3H, or a continuous slope to meet cut to fill requirements. To be assessed individually for each TSF flank.
Embankment Slope Closure and Rehabilitation Cover	0.5 m thick cover of benign waste rock placed over compacted tailings. Growth media placement in alignment with KCGM Visual Amenity Concept, with placement of 150 to 200 mm of rehabilitation materials, ripped into waste rock.
Toe Sediment Retention Bund	Conversion of the seepage recovery drain and bund to sediment retention structure. Minimum crest width 2 m, height 2 m and outer bund slopes 1V:4H.
Hydrology	
Rehabilitation and Closure Strategy	Contain precipitation from the design containment storm event on the top surface.
Design Storm for Containment	24-hour probable maximum precipitation (PMP) event for upper surface.
Design Storm for Conveyance (downchute and stilling basin)	Capable of managing the 500-year annual recurrence interval (ARI) event.

3.0 SITE SETTING

3.1 Climate

The Kalgoorlie area is characterised by hot summers and mild winters with mean daily temperatures ranging from a maximum of 33.7°C in January to a minimum of 5.0°C in July. Rainfall in the Kalgoorlie area is influenced in summer by the monsoonal systems in the tropics, with occasional cyclonic storms carrying through to the Goldfields. In winter the rainfall generally originates from broad frontal lows moving in from the south-west. The mean annual rainfall for Kalgoorlie[1] is 266.3 mm, distributed fairly evenly throughout the year, although showing a noticeable decrease during the months of September to December. The annual rainfall may be highly variable from one year to the next, with wet years through to drought years.

The mean annual evaporation of 2628 mm (7.2 mm/day) significantly outstrips rainfall by an order of magnitude, with mean daily evaporation ranging from a high of 12.5 mm/day in January to a low of 2.6 mm/day in June.

3.2 Geology and geotechnical characteristics

The typical soil profile is generally characteristic of the surrounding areas including the TSFs, with superficial materials generally being loose and shallow to around 300 mm depth, becoming dense to very dense or very stiff to hard with depth. Calcrete typically occurs in the upper horizons with well-developed ferricrete horizons occurring in the underlying clay. Underlying bedrock horizons consist typically of banded meta-sedimentary rock or massive igneous rock, extensively weathered to depth and lateritised.

[1] Based on data from Bureau of Meteorology station 012038, Kalgoorlie-Boulder Airport

3.3 Surface water characteristics

The TSFs are located within the catchment of Hannan Lake, which is a saline playa lake located about 10 km south of Kalgoorlie. This catchment is about 18 km long and between 8 km and 13 km wide. Surface gradients range between 3 m/km parallel to the central floodway and greater than 10 m/km across the catchment.

3.4 Groundwater characteristics

There are three major groundwater aquifer systems that have been defined during extensive drilling and testing in the vicinity of KCGM:

- The ferricrete and alluvial sedimentary system, an accumulation of sand, gravel and fractured ferricrete within clays, occurring typically from 4 to 40 m depth, which is present in lower elevation areas of the surface water catchments.
- The palaeochannel systems, an extensive network of Tertiary alluvial sands occurring at around 60 m depth in buried river channels. This aquifer system is well understood and is utilised by KCGM and by other mining operations as the primary source of process water supply.
- The bedrock system, where groundwater flow occurs in fractured and weathered zones within the basement rocks at depth (the primary aquifer for Fimiston Open Pit).

The three aquifers are discrete and can be considered independent of one another. Groundwater quality is brackish and ranges from 1,000 to 3,000 mg/L Total Dissolved Solids (TDS).

The maximum thickness of the sedimentary deposits near the TSFs is about 30 m. These deposits typically consist of red-brown clays and gravels, and blue-grey clays and clayey gravels which are partly lateritised. The weathered bedrock beneath the central floodway is mainly pallid or mottled clay. Groundwater flow prior to mining activities was in a southerly direction with an approximate hydraulic gradient of 1:1 000, mirroring the surface water flows.

Groundwater is managed under a Seepage and Groundwater Management Plan through abstraction bores. The target depth is generally 4 to 6 m, except for an area to the south-west of the Kaltails TSF, where a depth of 2 m is the target.

4.0 BACKGROUND TO TSFS

4.1 Current operations

Tailings generated by the Fimiston Processing Plant are stored in the existing Fimiston TSFs comprising Fimiston I (a single cell), Fimiston II (three cells) and Kaltails (two cells) (Figure 1). Currently approximately 12 to 13 million tonnes per annum (Mtpa) of tailings solids are pumped through delivery lines as slurry from the Fimiston Processing Plant to the TSFs, with decant return water pumped back from the TSFs to the Fimiston Processing Plant for reuse. Operation of the Fimiston TSFs is managed through an Operating Licence (Licence No. L6420/1988/14) issued by the Department of Water and Environmental Regulation (DWER) and through several DMIRS approved Mining Proposals (including geotechnical aspects) (REG IDs: 17819, 19075, 15456, 56261, 14131, 15193, 14974, 38617, and 48329), and an Operating Manual developed specifically for the TSFs.

4.1.1 Fimiston I

The smallest of the three TSFs, the Fimiston I TSF covers approximately 120 ha and is located to the south of (and adjacent to) Bulong Road, abuts the eastern side of the Old Croesus TSF (now almost completely encapsulated by the Northern WRD), and is directly north of the North Eastern WRD (Figure 1).

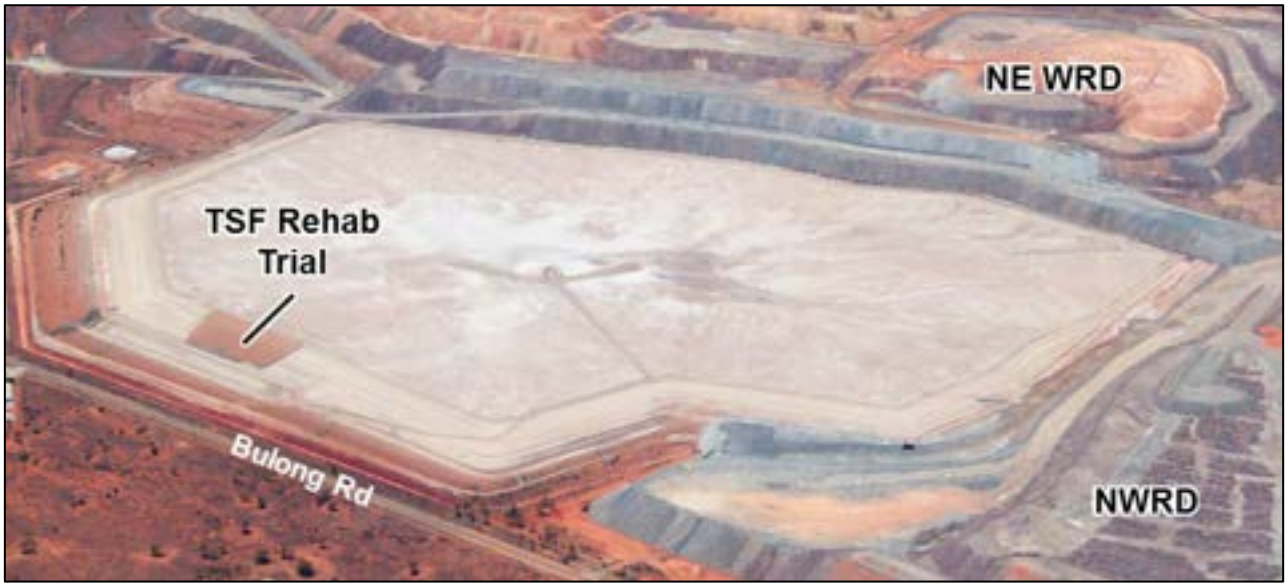


Figure 1: Fimiston I TSF – Facing SE (2018)

The Fimiston I TSF was originally designed by Australian Groundwater Consultants in 1988. The initial layout comprised four roughly equal and square cells (Cells A, B, C, and D) of about 18 ha each. The two westernmost cells (Cells A and B) abutted the pre-existing Croesus TSF, which they replaced as the operational TSF servicing the Fimiston Processing Plant. In 1993, the four cells were formed into two rectangular cells. These were designated as Fimiston I West (from Cells A and B) and Fimiston I East (from Cells C and D). At the same time, a plan was made to combine Fimiston I East and West cells into a single operational cell. At that time, the Fimiston I East cell was some 5 m lower in crest elevation than Fimiston I West. This required the rate of rise on Fimiston I East to be greater than on Fimiston I West for a period of eleven years before they reached a common elevation.

In 2002 the Fimiston I West Cell had reached a height that allowed it to be combined with the adjacent decommissioned Croesus TSF, increasing its usable depositional area to 68 ha. At that time, the maximum height of the facility was 19 m. The two cells (Fimiston I West, including Croesus and Fimiston I East) reached a common elevation in 2004 and were combined into a single cell, which has subsequently been referred to as Fimiston I.

In 2013 Fimiston I reached a crest elevation close to its maximum licensed height of 40 m (approved in 2004) and deposition of tailings was suspended.

The lower outer embankment of the Fimiston I TSF was constructed at 1V:3H and the upper embankment lifts at 1V:4H in the mid-2000s. The outer embankments have not been rehabilitated (except for the north-western flank) and the exposed tailings are prone to water and wind erosion.

The current approved rehabilitation design for the Fimiston I TSF is that no topsoil is required to be placed on the upper slopes and top surface.

4.1.2 Fimiston II

The largest of the three TSFs, the Fimiston II TSF is comprised of three ‘paddocks’ (AB, C and D), covers approximately 378 ha, and is located immediately east of the Trans-Australian Railway Corridor (Figure 2).



Figure 2: Fimiston II TSF – facing south-east (2017)

The Fimiston II TSF has evolved through the progressive development of four tailings cells, originating in 1991 through the design and construction of A Paddock, followed shortly afterwards by B Paddock. These roughly square facilities of some 50 ha each were designed by GHD. To cater for increased throughput at the Fimiston Processing Plant, additional tailings deposition area was required, and in 1994 C Paddock was commissioned (designed by Golder), providing an additional 107 ha of deposition area. In 1995 D Paddock was commissioned (designed by Golder), providing a further 116 ha of depositional area.

Following a risk analysis in 1996, A and B Paddocks were combined into a single cell and an elevated gravity ("floating") decant was installed, allowing the supernatant pond to be located well away from the external embankments to the west, abutting the adjacent wall of D Paddock. This process took three years to complete and the cells were able to be effectively operated as a single cell with a gravity outfall in 1999. Between 2008 and 2009 the gravity decants on the three cells of Fimiston II were replaced with pump-off decant facilities and the gravity outfall pipes were sealed with grout.

Since that time, the three cells on Fimiston II have been raised in sequence through upstream raises of ~1.0 m or ~1.5 m in height at an average rate of rise of about 2.0 m per year. The licensed height of the cells was increased in 2007 through the approval of a Mining Proposal and again in 2015. The currently approved maximum elevations of the Fimiston II cells are ~60 m.

The lower outer embankment of the Fimiston II TSF was constructed at 1V:3H and the upper embankment lifts at 1V:4H in the mid-2000s. The change in the mid-2000s resulted in a marked change in average outer embankment slope. There is also an intermediate bench that reduces the overall average outer embankment slope of the Fimiston II TSF. The recently raised embankments have not been rehabilitated and the exposed tailings are prone to water and wind erosion.

The current approved rehabilitation design for the Fimiston II TSF is that no topsoil is required to be placed on the upper slopes and top surface.

4.1.3 Kaltails

The Kaltails TSF covers approximately 282 ha and is located to the south of the Trans-Australian Railway corridor and to the north-east of Mount Monger Road (Figure 3).

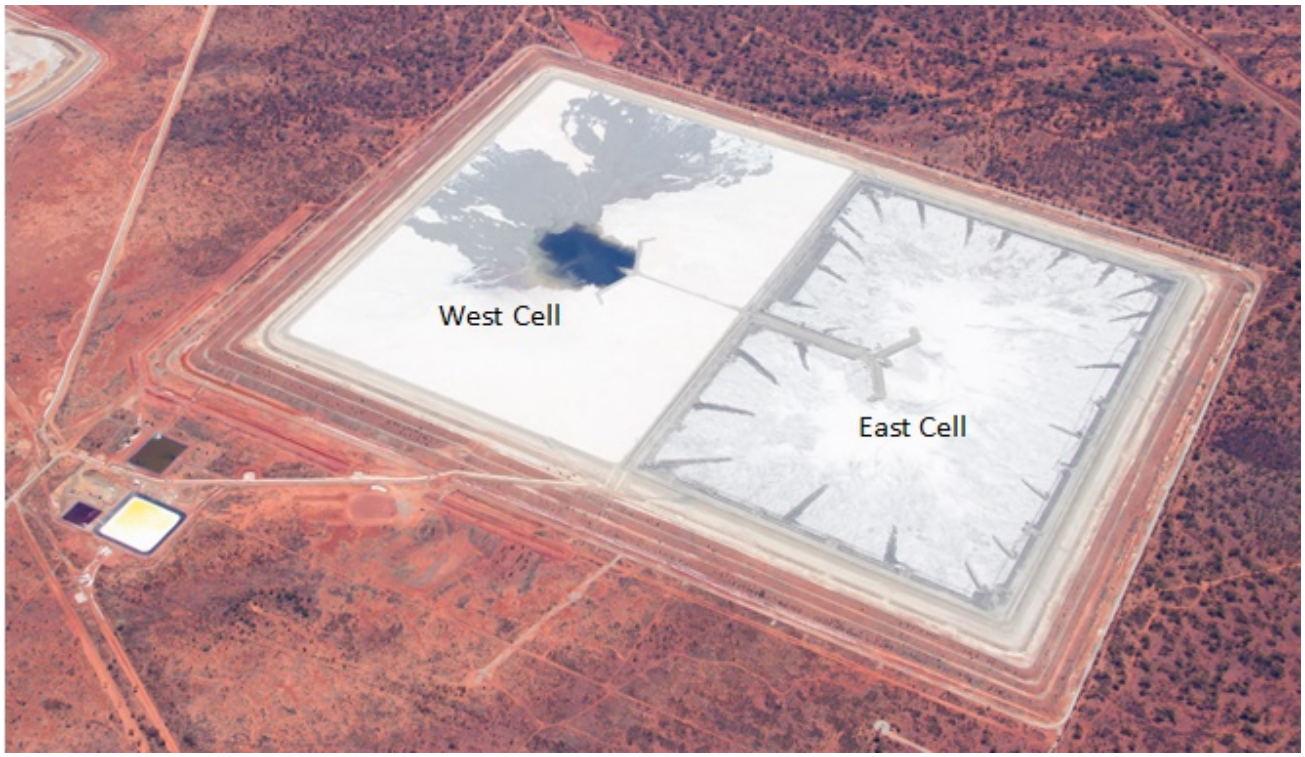


Figure 3: Kaltails TSF – facing north north-east (2017)

The Kaltails TSF was originally developed to store tailings arising from the Kaltails tailings retreatment plant (State Agreement Act) that was established in 1989 to reprocess gold tailings sourced from numerous TSFs in the area. Mulga Mines Pty Ltd designed the TSF, and it originally comprised three equally-sized rectangular paddocks roughly 600 m × 1200 m in areal extent. These three cells were later sub-divided to form six equal and abutting square cells, each roughly 600 m × 600 m in dimension, arranged in a three (west to east) by two (north to south) configuration. The TSF was decommissioned in 1999 at a maximum height of 23 m, following closure of the Kaltails tailings retreatment plant.

KCGM recommissioned the TSF in October 2011 as a “piggy back” facility, with two roughly equal rectangular cells (East Cell and West Cell) of about 800 m × 1200 m formed on top of the original TSF’s six cells. Pump-off decant facilities were provided to both cells and the original gravity outfalls were decommissioned. Golder carried out the piggyback TSF design and the licenced height of the facility was increased to 42.5 m through a Mining Proposal, submitted in 2009. The TSF was recommissioned in 2011 and since then the two cells (East and West) have been raised alternatively through upstream raises of 1.5 m in height at a rate of rise of up to 2.7 m per year. The recently raised embankments have not been rehabilitated and the exposed tailings are prone to water and wind erosion.

The current approved rehabilitation design for the Kaltails TSF is that no topsoil is required to be placed on the upper slopes and top surface.

5.0 TAILINGS CHARACTERISATION

5.1 Reported data

Information on the physical and geochemical characteristics of the tailings has previously been presented to the regulatory authorities in the following documentation:

- Works Approval for the Fimiston II TSF, AB Paddock (GHD 1991)
- Works Approval for the Fimiston II TSF, C and D Paddocks (Golder 1994)
- Notice of Intent addendum for increasing the height of Fimiston I TSF (Golder 2003)
- Notice of Intent addendum for increasing the height of Fimiston II TSF (Golder 2005)
- Annual operational audits and performance reviews since commissioning by Golder Associates.

Reference should be made to the source documents for a more comprehensive discussion of the test data, if required. Additional studies have been carried out to supplement the available Fimiston tailings data, including the following:

- *In situ* piezocone penetration test (CPTu) investigations of the Fimiston TSFs.
- Laboratory testwork to investigate the potential to increase the rate of rise of the tailings (Golder 2004).
- Supplementary laboratory testing of bulk tailings samples, completed in 2017 (Golder 2017b).

5.2 Physical characteristics

Key tailings physical characteristics are summarised in Table 2, consistent with values reported in previous submissions to the regulatory authorities.

Table 2: Key tailings physical characteristics

Material Characteristic	Unit	Value	Source
Particle size distribution	% passing 75 mm	55-85	Tube samples from tailings beach
Atterberg limits	%	Non-plastic	Tailings sample laboratory testing
Slurry concentration	% solids	45 to 55	Fimiston Processing Plant
Particle density	Specific gravity	2.86	Laboratory and CPTu testing
Dry density	t/m^3	~1.6	Tube samples from tailings beach
Bulk density	t/m^3	~2.1	Tube samples from tailings beach
Beach slope	%	0.5 to 0.7	Beach surveys
Shear strength	Undrained strength ratio	0.22 to 0.60	CPTu and laboratory testing
	Peak undrained (kPa)	10 to 200	*In situ* shear vane testing
	Drained (degrees)	30° to 35°	Triaxial testing
Consolidation	M_v (m^2/MN)	0.1 to 0.3.4	Laboratory and CPTu testing
	c_v (m^2/year)	47 to 2429	Laboratory and CPTu testing
Permeability	k_v (m/s)	10^{-8} to 10^{-9}	Laboratory and CPTu testing
	k_h (m/s)	10^{-7} to 10^{-8}	CPTu dissipation testing
Liquefaction resistance	Static yield strength ratio	0.22 to 0.30	Laboratory and CPTu testing
	Cyclic resistance ratio	0.10 to 0.15	Laboratory and CPTu testing
Post liquefaction strength	Strength ratio	0.05 to 0.15	Laboratory and CPTu testing

5.3 Geochemical characteristics

Geochemical analysis of the Fimiston tailings was completed by MBS Environmental in 2016 to better define the geochemical characteristics. Tailings samples underwent Acid Base Accounting (ABA) and analysis of concentrations and geochemical enrichment of elements considered to be potentially geochemically and/or environmentally significant. Tailings were subjected to a water leach, with leachates analysed for final extract pH and EC, major ions, alkalinity, fluoride, the metals and metalloids, including the hexavalent form of chromium (VI). Tailings samples were also subjected to a dilute acetic acid leach to provide indication of the nature of acid neutralising materials present and metals and metalloids that are likely to be leached should acid conditions prevail. Water samples from the supernatant of the TSFs were analysed as for the tailings leachates, and also total, free and weak-acid dissociable (WAD) forms of cyanide.

The analysis of samples taken to date indicates that tailings deposited into the TSFs are characterised by:

- Low total sulfur concentrations, much of which is present in the oxidised (sulfate) form.
- A NAF classification, indicating a very low risk of acid formation and substantial Acid Neutralising Capacity (ANC).
- During operation, the solubility of trace metals and metalloids and any potential for infiltration to groundwater (depending on infiltration rates and surface adsorption reactions) will reflect the cyanide-based chemistry of the Fimiston process water. Metals noted in low to moderate concentration in Fimiston supernatant solution include copper, mercury, antimony, lead, nickel, and cobalt.
- Mercury concentrations in tailings solids and leachates are low.
- Very low concentrations of tellurium in water and acetic acid leachates indicate that most of the tellurium is present as stable, insoluble minerals (namely coloradoite). Given that the only beneficial use of groundwater is mining, and there are no ecological users of groundwater, the very low concentrations found in tailings leachate are unlikely to have an adverse impact.
- Fimiston tailings are not enriched with chromium. Seepage from the Fimiston TSFs is predicted to be circumneutral to alkaline after mine closure, under which conditions trivalent chromium (III) concentrations are predicted to be very low and of no environmental significance.
- Fimiston tailings are not enriched with nickel. Water leachates and tailings fluids of Fimiston tailings contain very low concentrations of dissolved nickel and predicted concentrations are unlikely to increase after mine closure.

Consequently, the post-closure conditions were predicted by MBS as follows:

- Tailings to remain hypersaline with the predicted formation of a surface gypsum crust post closure, which is expected to reduce infiltration rates into underlying tailings.
- Alkaline and brackish to moderately saline tailings leachate in perpetuity.
- Very low concentrations of metals and metalloid in tailings leachate due to gradual cyanide degradation, surface adsorption (including arsenic as insoluble iron bound species) and the alkaline nature of the tailings reducing the mobility of most metals and metalloids to very low levels. Simulation of oxidised tailings conditions by analysis of tailings solutions after accelerated laboratory oxidation with peroxide indicate extremely low levels of all environmentally significant metals and metalloids.

Therefore, the risk of leachate from stored Fimiston tailings in rehabilitated storages adversely impacting groundwater is considered low.

5.3.1 Fimiston I Pre-KCGM

Although deposition of tailings has occurred at Fimiston I since 1988, and geochemical characterisation of Fimiston tailings were conducted in 2010 and 2016, these results are considered to be representative of the entire tailings facility as all tailings are produced as a result of processing ore from the same mineralised area, the Golden Mile.

5.3.2 Kaltails Pre-2011

A report into the geochemical compatibility of tailings deposited in the Kaltails TSF from the Kaltails Retreatment Project prior to 2011 indicated that Fimiston tailings is very similar in terms of acid mine drainage characteristics and metal leaching characteristics (Golder 2008). As such, the geochemical characteristics presented above are considered to be representative of the TSF as a whole.

6.0 INHERENT RISKS

6.1 Overview

Risk assessment is an essential tool to ensure appropriate management of unplanned events that might occur on site during or post closure. A structured risk-based approach allows for a systematic review and analysis of risk and cost benefit in both engineering and environmental terms as well as identification of closure associated opportunities. The KCGM Closure Risk Assessment (outlined further in the MCP) is based on the principles outlined in AS/NZS 4360:2004 Risk Management and uses likelihood, consequence and risk rankings (KCGM 2018). This risk assessment is updated on an annual basis and has been summarised in the 2018 MCP.

Additional feature specific risk assessments have been conducted as required, as part of the closure planning process, for example the TSFs. These assessments were conducted with representation provided by KCGM, Barrick, Newmont, and nominated consultants with the results incorporated into subsequent updates of the KCGM site closure risk register.

The key risks associated with the Fimiston TSFs are:

- Geotechnical slope failure. Geotechnical slope failure is considered to be a low risk by virtue of the requirement for an acceptable factor of safety, in accordance with ANCOLD (2012), to be in place during operations. The phreatic surface is predicted to reduce within a short period post-operations, resulting in an increasing factor of safety over time. Moreover, post-closure infiltration (discussed in Section 7.3.3) is expected to be minor and is not anticipated to result in an increased phreatic surface, and hence a satisfactory factor of safety will be maintained.
- Slope erosion due to overtopping. Whilst this risk is considered to be high due to the potential consequences, allowance has been made to store the PMP, as noted in the basis of design, and hence this risk is considered to be mitigated. The TSF upper surface design is discussed in Section 8.2.
- Slope erosion due to rainfall events. This risk is considered to be high and was therefore the subject of trials and modelling to provide a key input to the design, as noted in the following section. This risk is mitigated through placement of a rock cover, as noted in Section 8.2.2.
- Slope erosion due to wind. This risk is considered to be high but is mitigated by the design solution for the slope erosion due to rainfall item.
- Post-closure seepage. This risk is considered to be moderate, noting that operational controls are in place that provide effective groundwater management. These measures will be maintained in the post-operational period, as noted in Section 7.3.3.

As part of the risk assessment process many inherent risks have been reduced or mitigated by existing controls or the requirement to develop and implement controls. The controls are discussed as part of the closure design presented in Section 8.0. Following implementation of the controls, the residual risks are considered to be low in all cases.

7.0 DATA COLLECTION, MODELLING, AND TRIALS

7.1 Overview

KCGM commissioned Landloch Pty Ltd (Landloch) to undertake studies focussing on the characterisation of available materials for use in rehabilitation, as well as slope configurations that provide acceptable erosion rates (i.e. erosion rates within the agreed closure design criteria). Key outcomes of these studies were used as inputs into the engineering design of the closure and rehabilitation slopes, as follows:

- The likelihood of interface erosion between the rock armour layer and tailings surface was studied. Outcomes indicated that the rock armour material had a higher than expected amount of finer material. Erosion modelling (using WEPP[2]), indicated that 0.5 m was sufficient cover to mitigate the risk of potential erosion.
- Adaption of successful WRD design to TSFs.
- The rocky cover layer thickness, as well as the sponge effect of the rehabilitation materials, reduces infiltration and interface erosion between the rock and tailings.
- Rehabilitation material is planned to be incorporated into waste rock in areas where topsoil is assigned by the 'Visual Amenity' concept. Erosion modelling (using WEPP), using material-specific properties, such as critical shear stress[3], of the candidate topsoil materials will be used to estimate the maximum slope length that these materials can tolerate and dictate the need for rocky bands on the slopes to prevent initiation of rills.

7.2 Rehabilitation material characterisation

The rehabilitation materials classification system and materials balance were updated in 2014 to better reflect erodibility of the rehabilitation materials.

Material characterisation was undertaken for tailings, soil, oxide and waste rock by Golder, Soil Water Consultants, and Outback Ecology from 2007 to 2015. Additional characterisation data were collected by Landloch (2015) for tailings and oxide materials in 2015. Samples were characterised for water retention, saturated hydraulic conductivity, bulk density, particle distribution, pH and salinity. Materials characterisation findings were reviewed and considered during planning and design of the Fimiston TSFs closure and rehabilitation.

The pH values for tailings were relatively consistent, and were similar to those of the oxides, waste rock, and soils. Tailings near the TSF wall from Kaltails had a consistent texture, averaging ~7% clay, ~40% fine sand, and low coarse sand values, those near the decant had higher proportions of clay and silt sized particles and very low sand contents, and those near the TSF wall of Kaltails (closer to the point of discharge) showed higher proportions of coarse sand and fine sand and smaller proportions of silt.

Tailings from Fimiston I and Fimiston II TSFs had comparable textures and were similar to Kaltails, with some variation in the silt and fine sand proportions, indicating that a large proportion of particles were likely to have a diameter similar to the threshold between these two size fractions (~20 µm).

[2] Water Erosion Prediction Project

[3] The dimensionless shear stress required for the initiation of motion, in this case transport of sediment

Salinity (ECse) of the tailings tended to increase near the TSF surface, consistent with capillary rise of salts occurring within the fine-grained tailings when exposed to the atmosphere. The salinity of the surface tended to be approximately three times that measured at 1 m. The profile assessed at Kaltails indicated that below 1 m, salinity increased to values similar to those observed at the surface.

Stockpiled soils have variable salinity, and oxides showed EC1:5 values of 2-4 dS/m. The moisture retention characteristics of the oxides were relatively consistent. The moisture retention characteristics of the tailings were also relatively consistent (Landloch, 2015).

7.3 Trials and Modelling

7.3.1 Erosion trials and modelling

When developing cover configurations for the TSFs, concerns were raised about the potential for erosion at the interface of cover materials and the tailings surface.

Modelling and field simulations were undertaken to assess erosion rates from the interface for a range of TSF cover configurations, using slope lengths of 20, 30 and 40 m and gradients ranging from 12 to 18°. Results indicated that waste rock or screened crushed rock performed well to minimise interface erosion. Moreover, it was concluded that the use of linear profiles up to 20 m high is considered achievable at KCGM where gradients are between 12 and 18 degrees.

7.3.2 Material placement trial

7.3.2.1 Objective

Trials have been undertaken at the Fimiston I TSF with the key objective of the trial of reducing uncertainties in the closure design and hence provide greater accuracy in the design, particularly in relation to the volume of rock that is required to meet the closure design.

The purpose of the trial was to address the following areas of uncertainty:

- The minimum thickness that can be placed with the rock sizes available, while avoiding the potential for expression of tailings during the subsequent ripping process
- Earthmoving aspects of placement of armouring on the TSF slope
- The amount of penetration of the cover material into the tailings.

7.3.2.2 Approach

The following approach was undertaken to place the material:

- The windrow at the crest of the TSF was removed and waste rock, sourced from the nearby waste rock facility, was placed on the crest in the approximate quantities required to place the three panels: 0.5 m, 0.75 m and 1 m (the base case) on trial slopes – see Figure 4.
- The rock was pushed down the slope, as shown in Figure 5 – two pieces of equipment were used, namely a D8 dozer and a D10 dozer.
- Once the rock had been pushed down to the approximate depth targeted for each section, the area was surveyed. Of note was the relatively ‘fine’ waste rock particles observed along the slope (see Figure 6).
- For trial purposes, topsoil was then imported and placed on the surface, before being pushed down over the rock and ripped.



Figure 4: Waste rock placed in preparation for dozing



Figure 5: Waste rock being pushed down slope



Figure 6: Waste rock particle sizes

7.3.2.3 Trial Outcomes

The trial provided valuable insight into the way in which the closure operations could be undertaken, particular in relation to the extent of embedment, the particle size of the waste rock and the placed thickness.

Test pits were excavated into the cover material, with the following observations made:

- The extent of penetration of rock into the tailings slope was estimated to be minimal, in the order of 50 mm. In the context of the thickness of the layers placed, this is considered to be negligible. The extent of compaction of the tailings surface due to trafficking with heavy equipment was considered to be minimal.
- The waste rock generally had a finer median particle size than anticipated, which would result in a lower infiltration rate.

The following list provides the key outcomes from the trial:

- The extent of penetration of rock into the tailings slope was estimated to be minimal, in the order of 50 mm. In the context of the thickness of the layers placed, this is considered to be negligible.
- There was no visual evidence of tailings on the surface or in the cover profile of any of the three panel after ripping had occurred.
- The waste rock generally had a finer median particle size than anticipated – this would result in a lower infiltration rate.
- Observations in the test pits indicated a clear transition between the tailings and the waste rock.

These outcomes have been incorporated into the closure design.

7.3.3 Post-closure infiltration and long-term seepage

7.3.3.1 Approach

Post-closure infiltration fluxes for the following closure cover systems were modelled by Landloch and provided to Golder by KCGM for post-closure seepage modelling:

- Oxide soil cover, 0.5 m thick (OXIDE)
- Rock fill cover, 0.5 m thick (ROCK)
- Oxide soil and rock fill cover, 0.5 m thick (OXIDEROCK)
- Soil and rock fill cover, 0.5 m thick (SOILROCK)
- No cover, i.e. post-closure infiltration through an exposed tailings beach (TAILS), as a base case.

A comparison of the five post-closure infiltration fluxes provided by KCGM (from Landloch) is presented in Figure 7. The fluxes provided extend for 10 years, matching a 10-year climate record. For modelling purposes, the fluxes were conservatively applied three times (i.e. 30 years post operations).

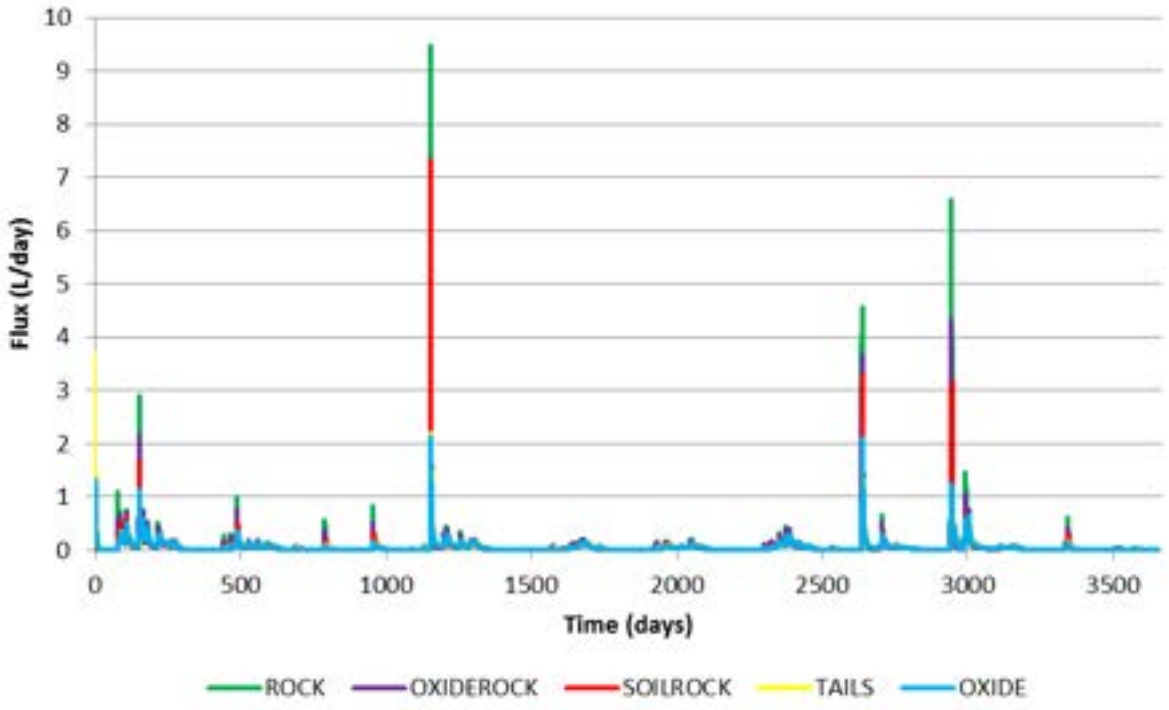


Figure 7: Post-closure infiltration fluxes provided by Landloch

The seepage models were originally developed with the primary aim of estimating fluxes through the bases of the TSFs, and the resulting influence of seepage on groundwater levels during the operational phases. These models were updated to enable the modelling of post-closure infiltration, as follows:

- Application of a pre-closure infiltration flux (i.e. 'no cover' flux), provided by Landloch, to the model for the first two years following cessation of operations. This fallow period corresponds to the post-operational drying period, before the selected cover system would be installed.
- Application of each post-closure infiltration flux scenario, provided by Landloch, to the model after the two-year fallow period.
- Implementation of a hydraulic head boundary at the location of the existing bores, generally <100 m downstream of the TSFs, to simulate the groundwater abstraction required to maintain groundwater levels below those stipulated by TSF operating licence conditions (6 m below ground level for Fimiston I and Fimiston II, 4 m below ground level for Kaltails), following cessation of operations.

7.3.3.2 Outcomes of Modelling

The seepage fluxes through the base of the TSFs are presented in the following figures. The results indicate that the seepage flux will remain well below 5 L/s following the draindown period. The draindown period is the period immediately following cessation of operations, approximately two years in duration, during which the flux through the base of the TSFs reduces rapidly from the rate of flux during operations to the rate of flux post-closure.

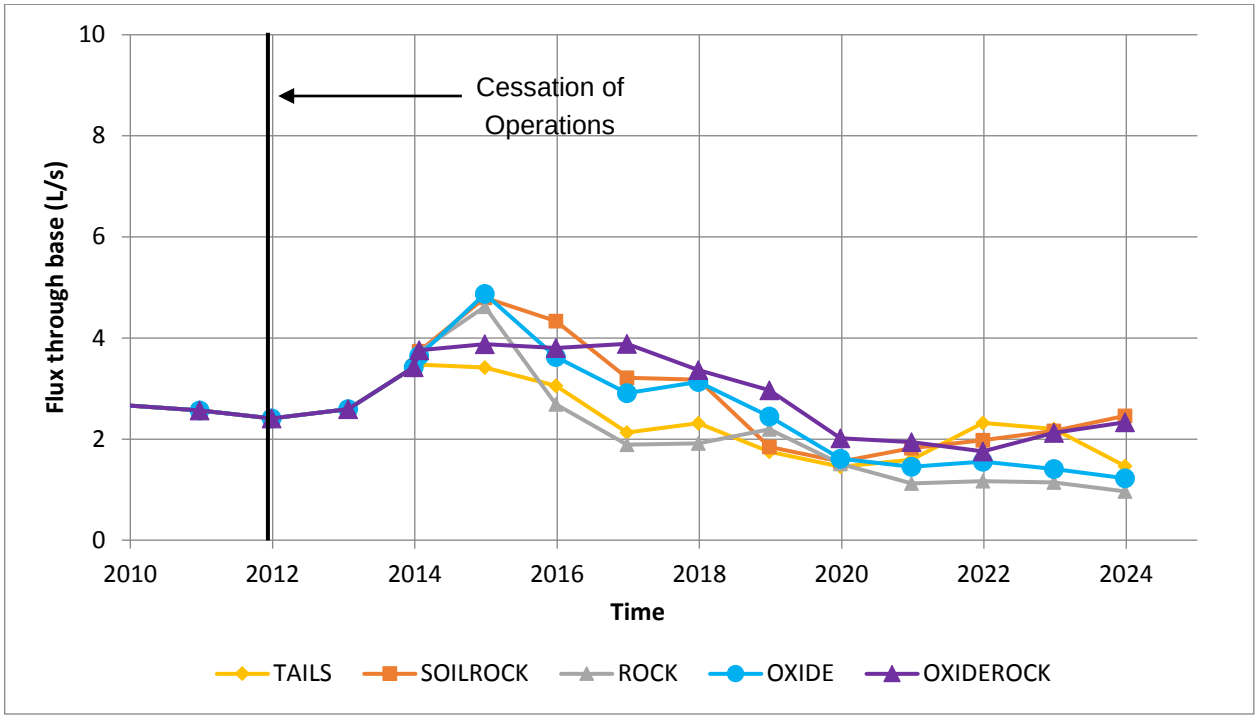


Figure 8: Comparison of seepage fluxes through base of Fimiston I

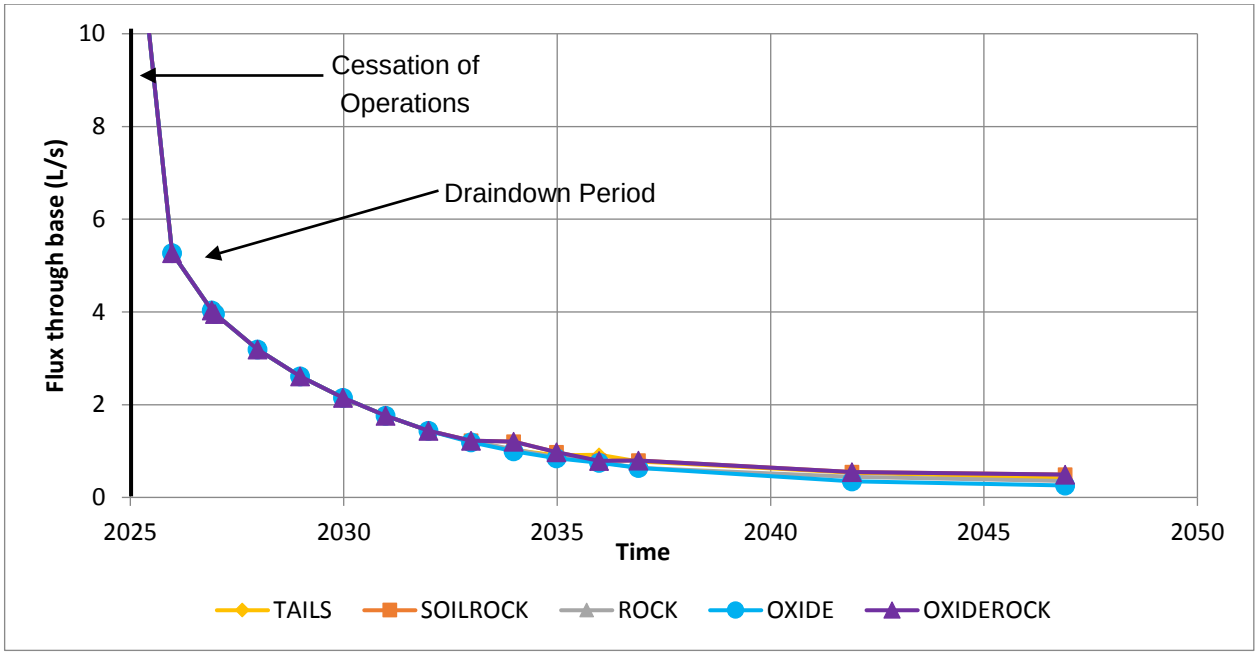


Figure 9: Comparison of seepage fluxes through base of Fimiston II AB Paddock

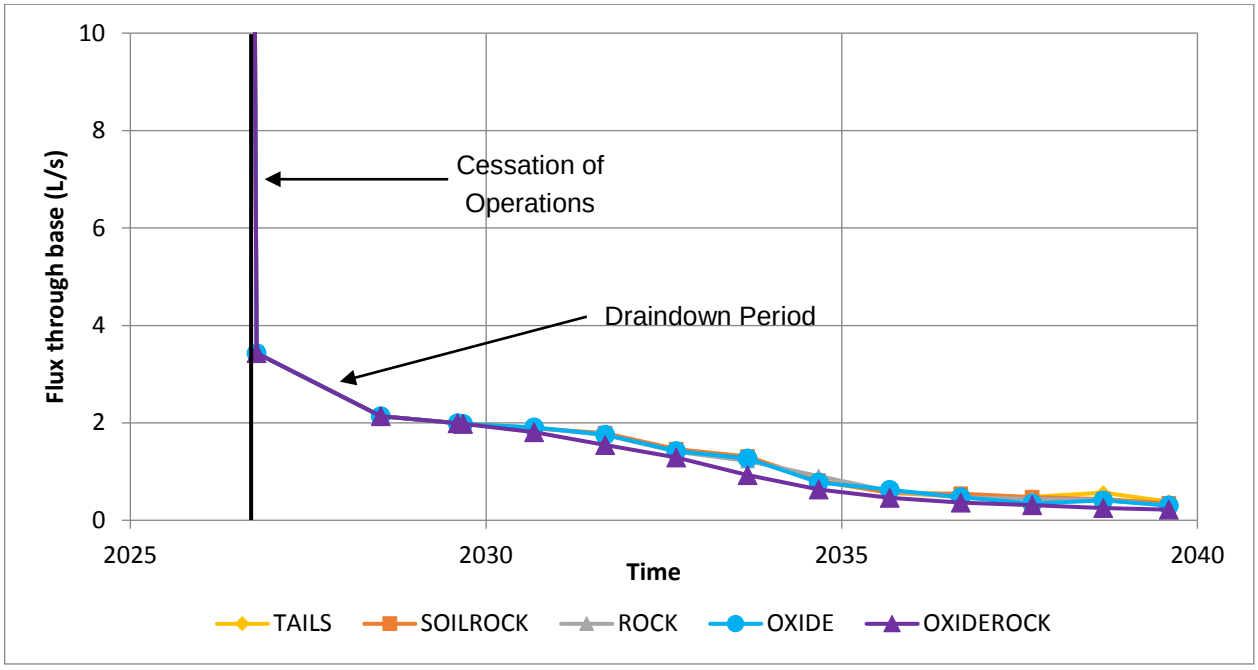


Figure 10: Comparison of seepage fluxes through base of Fimiston II C Paddock

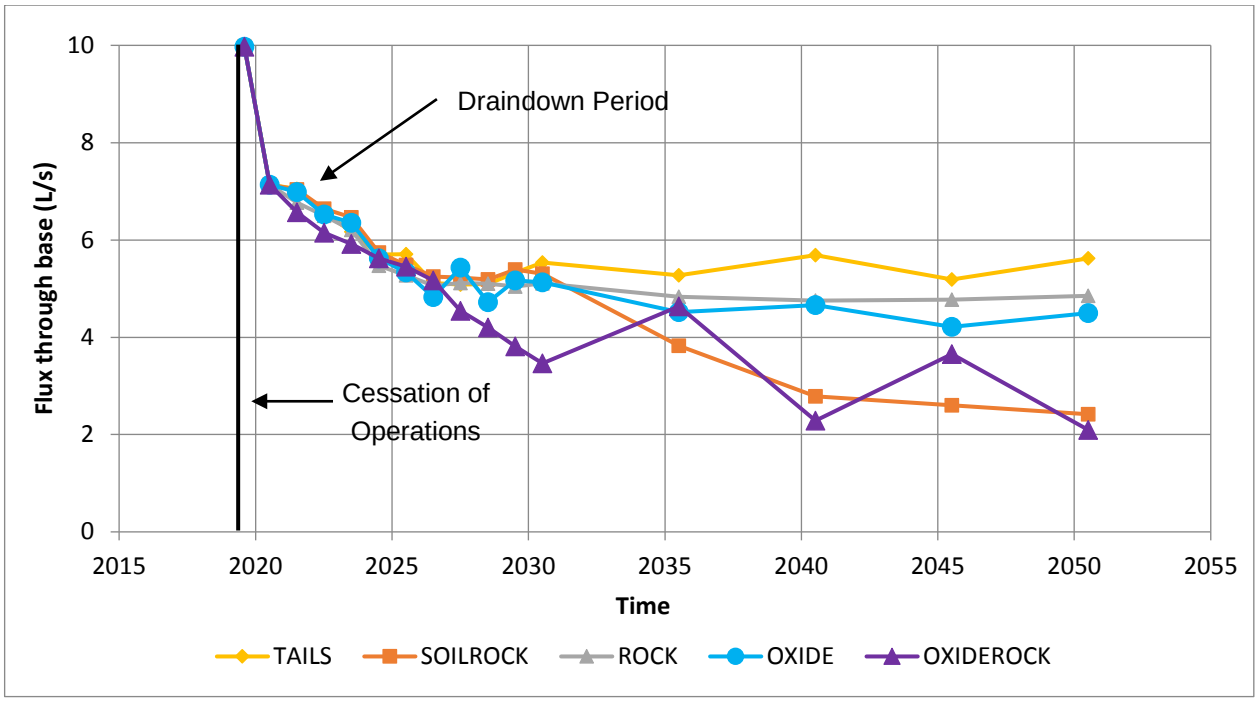


Figure 11: Comparison of seepage fluxes through base of Kaltails TSF

The main driver during the initial post-closure period was identified as draindown of the stored interstitial water from the tailings. Regardless of the cover type, a portion of flux infiltrates and contributes to ongoing drainage through the base at the rate that the tailings will allow it to be released (i.e. the flow through the base is restricted by the permeability of the tailings). Hence, placement of a thin waste rock cover is considered to be acceptable to manage the potential for wind erosion, without impacting post-closure infiltration.

Seepage modelling has also been undertaken to confirm the influence of ponding from large rainfall events on the post-closure seepage rate for the TSFs. The results indicate that, due to the low infiltration noted above, the groundwater level is largely unaffected by ponding of large rainfall events, acknowledging that the ponded water would evaporate within a few months and hence there would be limited potential for a sustained hydraulic connection to be (re)formed. Post-closure rainfall events are therefore not considered to be a significant contributor to seepage.

8.0 TSF CLOSURE DESIGN

8.1 Overview

TSF closure designs have been progressed based on results of material characterisation, trials and engineering assessment. The following general TSF closure design information is applicable to all three of the Fimiston TSFs. Site-specific closure design information is also provided.

8.2 General Design Summary

8.2.1 TSF Upper Surface

The tailings surface will be covered with minimum 0.5 m of suitable material (waste rock and/or oxide) sourced from Fimiston WRDs, which will protect the surface of the TSF against water and wind erosion by acting as an energy dissipater and forming a barrier on the tailings surface. There will likely be temporary ponding of incident rainfall on top of the TSFs until the water is evaporated. Due to high potential evaporation and low rainfall in the area, it is expected this will be a short-term occurrence and because of de-saturation of the underlying tailings, will not result in any long-term hydraulic connection between ponding on the TSF surface and the groundwater system below the facility. Some infiltration into the tailings from surface will occur (see Section 7.3.3), and in the long term, ongoing seepage rates in the range 2 to 5 L/s have been modelled to occur from each paddock into the underlying groundwater system. The modelling indicates that the groundwater elevation will not be influenced by this minor seepage.

A competent engineered and rock armoured perimeter crest bund will be built around the upper crest of the TSFs. Engineering assessment of the upper surface of the TSF has confirmed the design capacity of 24-hour PMP, without the crest bund. The bund will add additional capacity and ensure no overtopping to the external slopes.

8.2.2 TSF Slopes

8.2.2.1 Geotechnical stability

Geotechnical slope failure is considered to be a low risk by virtue of the requirement for an acceptable factor of safety, in accordance with ANCOLD (2012), to be in place during operations. The phreatic surface is predicted to reduce within a short period post-operations, resulting in an increasing factor of safety over time.

8.2.2.2 Erosional stability

In line with the outcomes of the modelling completed by Landloch (2018a and 2018b), the external slopes above the existing rehabilitated benches will be regraded to form a single continuous slope where possible, as this is deemed to be the best option from an erosion management perspective. A rock cover will be placed on the external embankments to minimise the potential for water erosion, and to minimise wind erosion (i.e. dust generation). The thickness of the rock cover required is anticipated to be minimum 0.5 m, allowing for some contingency in thickness as noted in the outcome of the material placement trial (see Section 7.3.2). The addition of growth medium will be guided by the 'Visual Amenity' concept. To minimise erosion these slopes will have outer surface designs similar to the erosion resistant design used for the Fimiston WRDs, with rocky bands placed horizontally at key locations to manage water erosion. As noted by Landloch (2018a), the use of linear profiles up to 20 m high is considered achievable at KCGM where gradients are between 12 and 18 degrees. Moreover, Landloch (2018b) indicated that while the benches will need to be removed (as part of forming a single continuous slope), the existing micro-relief (minor variations in elevation on the slope) will not cause significant increases in long-term erosion potential.

The specific location of the rocky bands will be determined on a case by case basis for each flank, based on several factors, including slope lengths, current TSF wall geometry and practical implementation aspects. The erosion resistant design will also assist with reducing infiltration of rainwater to the interface between the cover material and the TSF surface, as noted by Landloch (2018a).

8.2.2.3 Bench drains and downchutes

A bench drain is required on the benches above the existing rehabilitated zone on the lower slopes of the TSFs. These lateral drainage structures will provide conveyance of upslope stormwater runoff to the downchutes prior to release to the downstream environment. The bench drain provides protection to the existing rehabilitated areas from runoff and potential erosion impacts.

The drains have been sized to convey the critical 500-year ARI design storm runoff with at least 0.5 m freeboard. The shallow gradients of the bench drains, approximately 0.5%, will limit the flow velocity and energy of the conveyed runoff below the critical level required to cause significant erosion. A typical section of the proposed bench drain is shown in Figure 12.

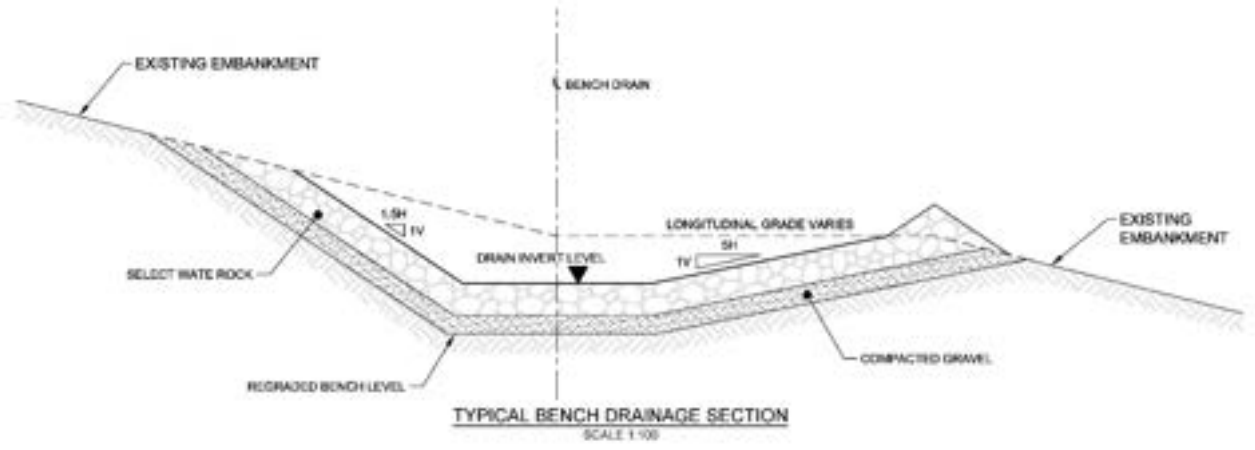


Figure 12: Bench drain design

It has been assumed that the proposed bench drain geometry can be accommodated in the existing bench width. Where the adoption of the proposed geometry is potentially constrained by smaller bench widths then further refinements to the design and/or upslope gradients may be required.

Engineered downchutes will control the conveyance of stormwater runoff from the higher elevation bench drains to the downstream environment, while minimising potential erosion impacts to the existing rehabilitated slopes. The proposed downchutes have been assessed as a single, uninterrupted channel and have been sized to convey the 500-year critical design storm runoff with at least 0.5 m freeboard. A consistent downchute slope of 1:3 (V:H) has been assumed for the hydraulic modelling assessments.

The dimensions of the chutes have been estimated with the objective of minimising peak flow depths and increasing the hydraulic radius thereby reducing maximum flow velocity. The downchute channel sizing and recommended engineered channel construction materials have been assessed with the objective of achieving a peak flow velocity for the critical 500-year ARI design event of below 3.5 m/s, to enable the use of rip rap as a construction material and avoiding the need to construct the downchutes from other materials such as articulated concrete blocks. Consideration has also been given for the potential for rocks within the channel to eventually becoming covered with sediment or vegetation over time, therefore reducing the assumed roughness coefficients.

The downchute has been designed such that the same channel dimensions and geometry can be constructed on each flank of the TSFs. A typical section of the recommended engineered downchute is shown in Figure 13.

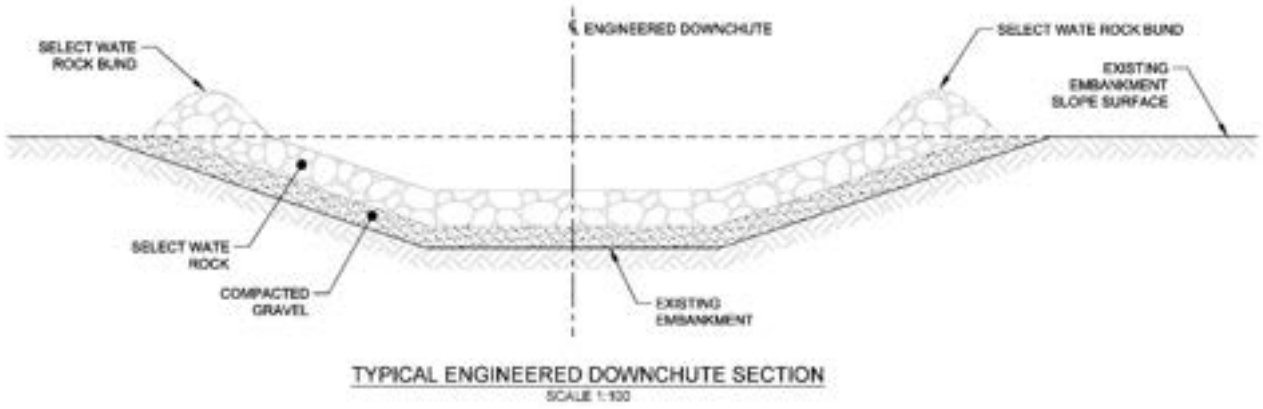


Figure 13: Engineered downchute structure design

The number of engineered downchutes required per flank has been estimated based on the conveyance capacity of the downchute geometry, as per Figure 13.

8.2.3 TSF Toe

8.2.3.1 General

At closure, the outlets of the engineered downchutes will direct rainfall runoff into the natural environment at a flow rate at which the receiving environment can accept the water. Energy dissipation and erosion protection will be required at the toe of each downchute. In addition, where a shallow toe drain exists near the existing toes, this will be converted to a bund to provide sediment retention from slope erosion. The deeper seepage interception trenches will be made safe and stable post-dewatering.

8.2.3.2 Energy Dissipation Structure

The results of the hydraulic modelling indicate that under the critical peak design flood conditions the hydraulic jump will occur close to the base of the downchute; therefore the objective of the energy dissipation structure is to limit erosion and provide protection at the toe of each of the engineered downchutes. The geometry of the energy dissipation structure will enable the flow within the downchute to transition to subcritical flow prior to discharge of the stormwater runoff to the downstream environment, thereby reducing erosion potential.

A typical section of the minimum geometry requirements of the energy dissipation structure is shown in Figure 14.

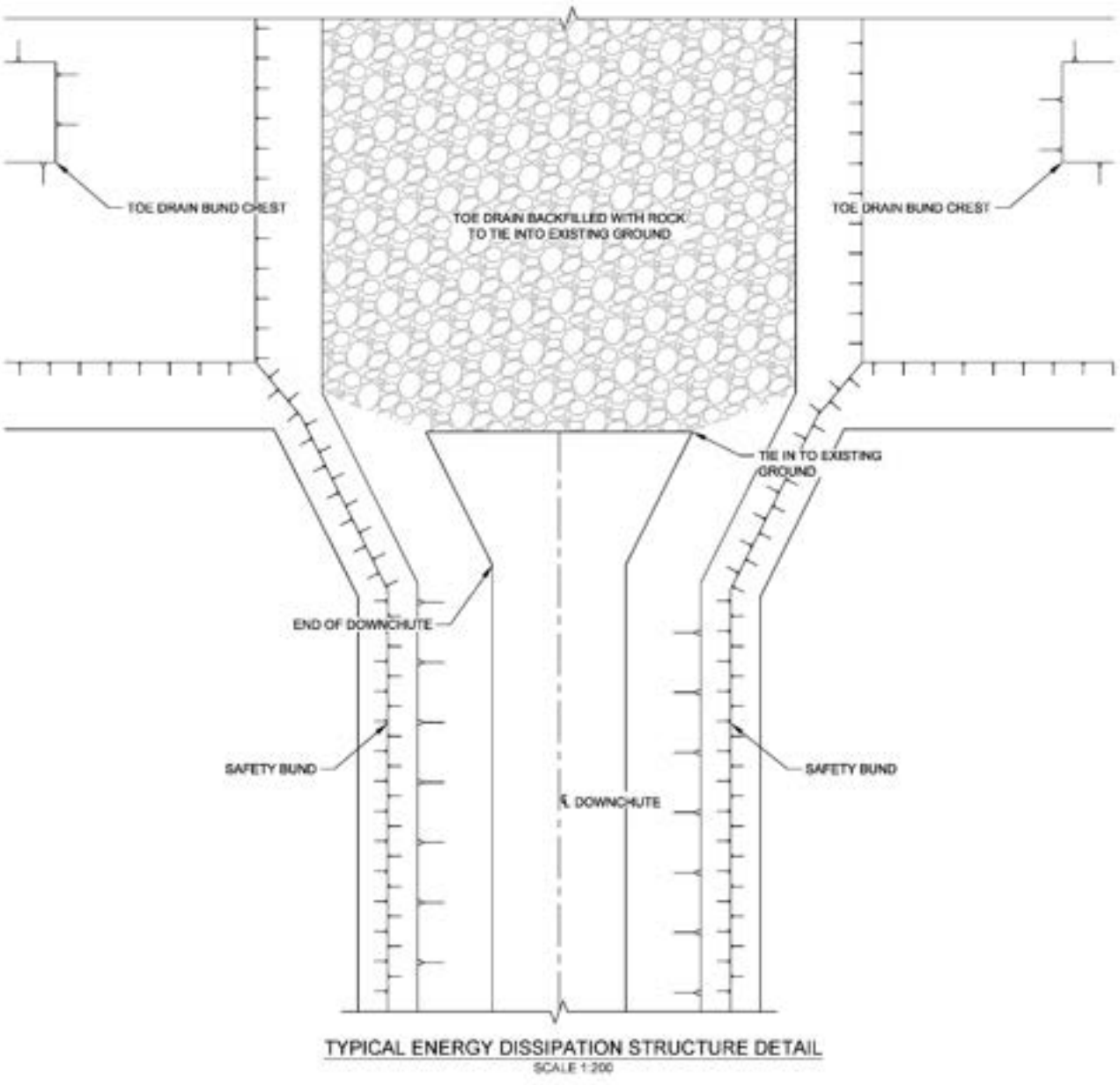


Figure 14: Energy dissipation structure design

8.2.4 Toe Drain Rehabilitation and Sediment Bund

During or shortly after the post-closure monitoring period, the existing shallow toe drain will be filled with waste rock and the bund will be constructed to contain any further sediment that is conveyed down the slopes of the TSFs during precipitation and storm events. Sediment that is conveyed down the slopes during the post-closure monitoring period will be collected in the existing drains.

Breaks in the backfilled seepage interception trench will be required at the toe of each engineered downchute to provide a path for water to flow into the natural environment, after flowing through the energy dissipation structure.

8.3 Closure Design – Fimiston I TSF

The closure design for the Fimiston I TSF is shown on Figure A1 and A2 included in Appendix A of this report. On the eastern side of the Fimiston I TSF, the lower flank has been rehabilitated, with a wide bench above the completed rehabilitation. Stormwater from this bench drain will be diverted to ground level through an engineered downchute, consistent with existing practice on the Fimiston TSFs, and a simple diversion trench to guide this stormwater water to suitable entry point in the catchment.

Two sides (western and southern) of the TSF will be encapsulated by WRDs at closure. The remaining slopes will be regraded and rehabilitated, with waste rock sourced from the nearby waste dump used as the cover material to form a continuous slope. Allowance has been made for a minimum 0.5 m thickness rock cover over the tailings slopes based on full scale trials undertaken at the site. In alignment with the Visual Amenity concept, the outer surface designs will be similar to the erosion resistant design used for the Fimiston WRDs, with rocky bands placed at key locations to manage water erosion.

One or more rocky bands will be required on the northern flank of the Fimiston I TSF. Modelling indicates that rocky bands will be required more frequently at Fimiston I due to the rehabilitation material properties. However, due to the presence of the bench above the rehabilitation trial on the north-eastern flank, a rocky band is not required but stormwater on this flank will need to be managed. Provision has been made for a bench drain and downchute system to manage stormwater on this flank. A simple diversion trenches will guide this stormwater water to suitable entry points in the catchment.

The existing infrastructure would need to be carefully considered as there would be limited room for construction equipment to traffic the area. Traffic management plans will need to be developed and smaller equipment used initially, where space is constrained.

The design concept for Fimiston I TSF is summarised below:

- Regrade to form a continuous slope on the northern flank and on the upper lift on the eastern flank.
- If in alignment with the ‘Visual Amenity’ concept, placement of waste rock topsoil mix on the slopes including the placement of a rocky band (see Figures A2 and A7).
- Construction of a bench drain on the bench on the eastern flank, draining to a downchute.
- Construction of a bund around the perimeter of the TSF crest (see Figure A7 for details).
- Placement of 0.5 m of waste rock or oxide across the tailings beach.

8.4 Closure Design – Fimiston II TSF

The lower flanks of Fimiston II have been previously rehabilitated, with a substantial step in bench above the rehabilitated flanks (see Figures A3 and A4 in Appendix A). The remaining slopes above the existing rehabilitated zones will be regraded and rehabilitated to form a consistent slope angle arrangement on the Fimiston II TSF embankments, the extent of which are indicated on Figure A3, with cross-sections presented in Figure A4.

Stormwater from the bench drain will be diverted to ground level through engineered downchutes, consistent with existing practice on the Fimiston TSFs. If required, further stormwater management systems such as simple diversion trenches will guide this stormwater water to suitable entry points in the catchment. Further information on stormwater management is provided in the following section.

The specific regrade requirements and location of the rocky bands on Fimiston II TSF will be determined on a case by case basis for each flank, based on several factors, including slope lengths, final TSF wall geometry, physical properties of the rehabilitation materials and practical implementation aspects.

The design concept for Fimiston II TSF is summarised below:

- Regrade to form the continuous slopes on the TSF embankments, above the previously rehabilitated zones.
- Place excess cut on the benches to form an operational drain.
- Place waste rock on the slopes (see Figures A4 and A7 for details).
- Construction of engineered downchutes as required.
- Construction of a bund around the perimeter of the TSF crest (see Figure A7 for details).
- Placement of 0.5 m of waste rock across the tailings beach.

8.5 Closure Design – Kaltails TSF

The lower flanks of Kaltails TSF have been rehabilitated by previous owners, with a substantial step in bench above the rehabilitated flanks (see Figures A5 and A6 in Appendix A). Stormwater from this bench drain will be diverted to ground level through engineered downchutes, consistent with existing practice on the Fimiston TSFs, and a simple diversion trench to guide this stormwater water to suitable entry point in the catchment.

The remaining slopes above the previously rehabilitated zones (benches) will be regraded and rehabilitated to form a continuous slope, as this is deemed to be the best option from an erosion management perspective. Cross-sections of the Kaltails TSF are shown on Figure A6 and indicate that only minor regrading is likely to be required.

A rock cover will be placed on the external embankments to minimise the potential for water erosion of the tailings used, and to minimise wind erosion (i.e. dust generation). Allowance has been made for 0.5 m thickness of rock over the tailings.

8.5.1 Kaltails design summary

The design concept for Kaltails TSF is summarised below.

- Regraded to form a continuous slope on the TSFs embankments.
- Place waste rock on the slopes (see Figures A6 and A7 for details).
- Construction of operational drains and downchutes as required.
- Construction of a bund around the perimeter of the TSF crest (see Figure A7 for details).
- Placement of 0.5 m of waste rock across the tailings beach.

8.6 Management of Surface Water from TSFs

Surface water modelling was undertaken to consider the impacts of water flowing off the TSFs via the downchutes on the existing catchments. The flood modelling within the project area was undertaken using a 2-dimensional (2D) hydraulic model developed in the XPStorm software package. This software package provides an efficient and effective assessment of flood extents, depth and velocity along river systems and interactions with surrounding floodplain areas when flows exceed the channel conveyance capacity.

Engineered downchute inflow locations to the hydraulic model are based on downchute alignments defined as part of the closure design (see Figure 15 and Figure 16). Estimated peak discharge flow rates, for both the Kaltails and Fimiston TSFs, were based on modelling of the 500-year ARI event and included in relevant model scenarios as a steady state inflow condition.



Figure 15: Engineered downchute hydraulic model inflow locations for Kaltails



Figure 16: Engineered downchute hydraulic model inflow locations for Fimiston II

The results of the modelling indicate that, although localised stormwater discharge impacts on the TSF slopes and toes will need to be mitigated through drainage designs and erosion protection measures, the discharge of stormwater from the TSF sites is not expected to significantly influence or modify downstream flood levels or flow velocities, and is not expected to have a significant impact on the railway line culverts. At Kaltails, it is not expected that the contribution of stormwater from the TSF will result in changes to the natural flood response at Mt Monger Road directly downstream of the facility.

8.7 Other Considerations

Post operations, a period of two to three years will be allowed to ensure the tailings is sufficiently dried out to allow safe access to the tailings beaches which form on the upper surface prior to commencement of rehabilitation earthworks. The blanket toe drains around the perimeter of TSF impoundments will remain in place and will continue to recover seepage water, which will be pumped to the Fimiston Open Pit once the Fimiston Plant is no longer operational. All tailings pipelines and pump stations will be flushed prior to decommissioning of systems and tailings lines and pumps will be removed.

In the post closure period, the three TSF areas are likely to be designated as zones of restricted access for safety purposes as well as to protect established vegetation. The TSFs are surrounded by a wire fence.

9.0 CONCLUSION

The closure designs for the Fimiston I, Fimiston II and Kaltails TSFs, as presented in this report, have been based on site trials, modelling, engineering judgement and site knowledge. The designs address the risks identified and modelling suggest that the risks will be sufficiently limited to provide long-term (design life) tailings encapsulation.

10.0 IMPORTANT INFORMATION

Your attention is drawn to the document titled – “Important Information Relating to this Report”, which is included in Appendix B of this report. The statements presented in that document are intended to inform a reader of the report about its proper use. There are important limitations as to who can use the report and how it can be used. It is important that a reader of the report understands and has realistic expectations about those matters. The Important Information document does not alter the obligations Golder Associates has under the contract between it and its client.

Golder Associates Pty Ltd



André Kemp
Principal Closure Consultant



Dr Peter Chapman
Principal Tailings Engineer

SP/AK-PJC/ds

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GLOSSARY

Term	Description
ABA	Acid Base Accounting
ANC	Acid Neutralising Capacity
ARI	Annual Recurrence Interval
cm	Centimetre
DMIRS	Department of Mines, Industry Regulation and Safety
DWER	Department of Water and Environmental Regulation
Fimiston TSFs	Fimiston Processing Plant Tailings Storage Facilities
Golder	Golder Associates Pty Ltd
ha	Hectares
KCGM	Kalgoorlie Consolidated Gold Mines Pty Ltd
L	Litre
Landloch	Landloch Pty Ltd
LOM	Life of Mine
m	Metre
mm	Millimetre
MCP	Mine Closure Plan
Mtpa	Million tonnes per annum
PMP	Probable Maximum Precipitation
Report	Closure Design Report
RL	Reduced Level
TSFs	Tailings Storage Facilities
WA	Western Australia
WAD	Weak-Acid Dissociable
WRD	Waste Rock Dump

REFERENCES

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Landloch (2018b). *Memo: Erosion Assessment of the Fimiston II Slopes*. Project number 2088.18a, Rev 1 dated 25 May 2018.

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APPENDIX A

Figures

MGA94, ZONE 51

357,000 m E

357,500 m E

358,000 m E

358,500 m E

6,598,000 m N

6,597,500 m N

6,597,000 m N

A

FA2

EXTENT OF EXISTING REHABILITATION

BATTERY LIMIT FOR CLOSURE MEASURES

ZONE OF WASTE ROCK DUMP EXPANSION

CURRENT HEIGHT RL 399 m

MAXIMUM HEIGHT RL. 419 m (~60 m)

EXISTING WASTE ROCK PLACED AS PART OF PREVIOUS REHABILITATION

SURFACE WATER POND

DECANT POND

BATTERY LIMIT FOR DESIGN

TSF WASTE ROCK DUMP

365 370 375 380 385 390 395 400 405 410 415 420 425 430 435 440

LEGEND

- ZONE OF WASTE ROCK DUMP EXPANSION
- EXTENT OF EXISTING REHABILITATION
- PROPOSED DOWNCHUTE LOCATIONS
- BENCH DRAIN

NOTE(S)

SURVEY DATA SUPPLIED BY KCGM IN JULY 2017.

0 100 200

1:5,000 METRES

CLIENT
KALGOORLIE CONSOLIDATED GOLD MINES

PROJECT
KCGM FIMISTON TSF CLOSURE DESIGN REPORT

CONSULTANT
GOLDER

YYYY-MM-DD	2018-07-31
DESIGNED	A. KEMP
PREPARED	H. OO
REVIEWED	P. CHAPMAN
APPROVED	P. CHAPMAN

TITLE
FIMISTON I TSF CLOSURE DESIGN OVERVIEW

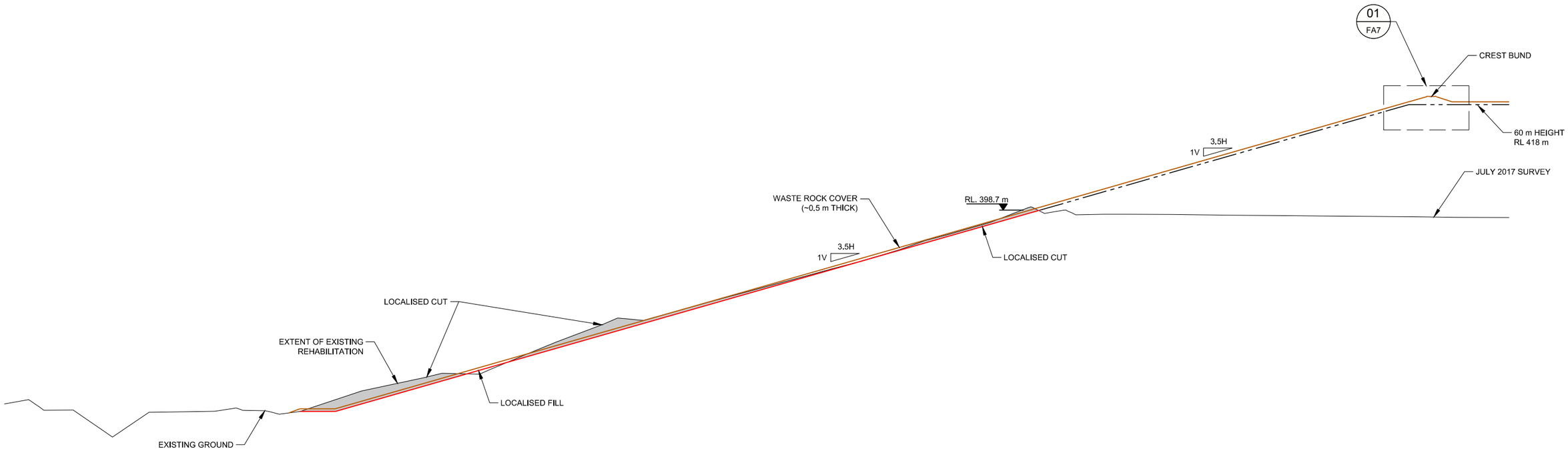
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SCALE 1:750 A FA1 FIMISTON I EMBANKMENT SECTION

0 12.5 25
1:750 METRES

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- LOCALISED CUT
- CONTINUOUS SLOPE DESIGN
- EXISTING GROUND
- PROJECTION TO HEIGHT
- FINAL DESIGN SLOPE

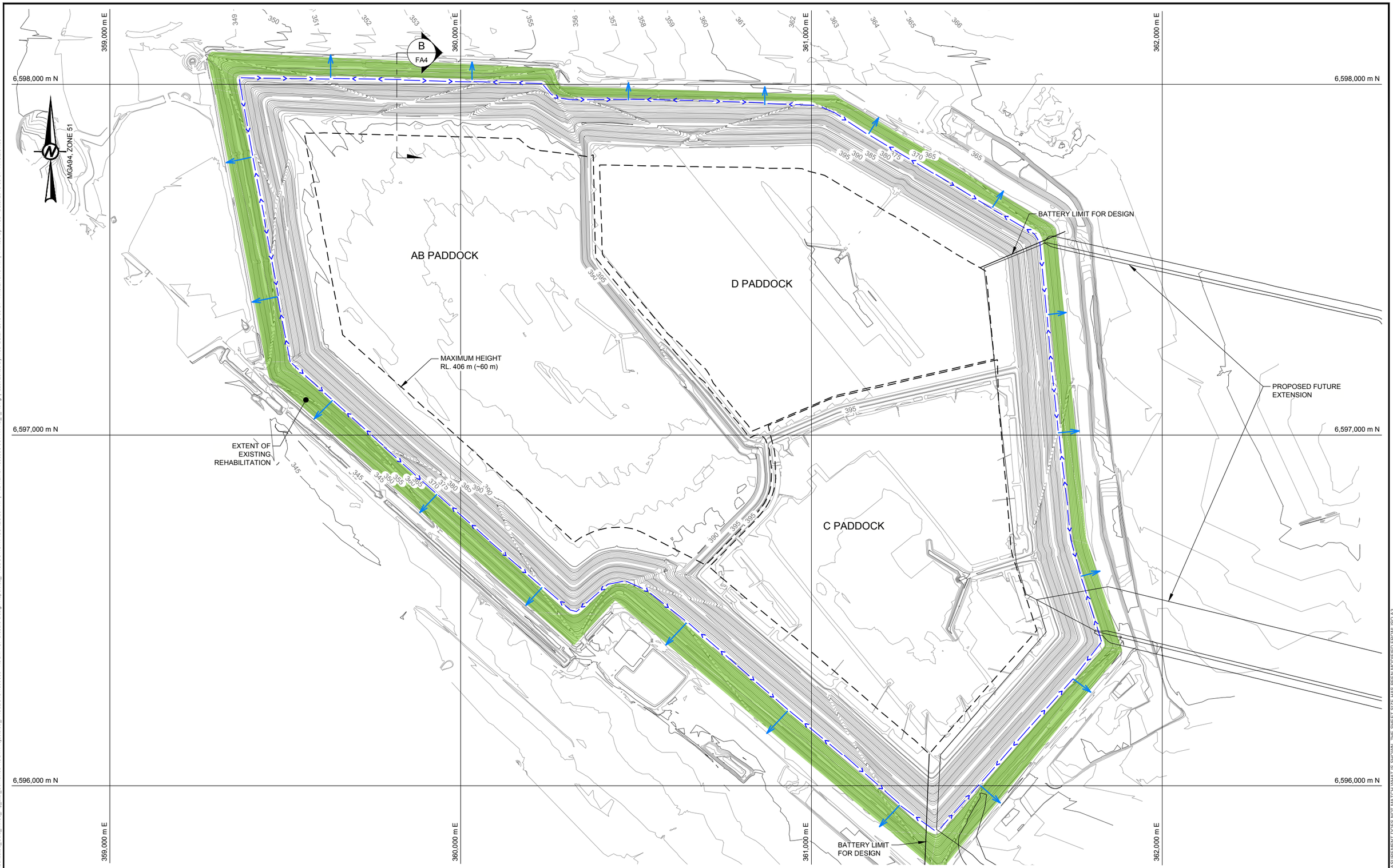
CLIENT
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PROJECT
KCGM FIMISTON TSF CLOSURE DESIGN REPORT

TITLE
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LEGEND

- EXTENT OF EXISTING REHABILITATION
- PROPOSED DOWNCHUTE LOCATIONS
- BENCH DRAIN

NOTE(S)

SURVEY DATA PROVIDED BY KCGM IN JULY 2017.

0 250 500

1:10,000 METRES

CLIENT
KALGOORLIE CONSOLIDATED GOLD MINES

PROJECT
KCGM FIMISTON TSF CLOSURE DESIGN REPORT

CONSULTANT
GOLDER

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REVIEWED	P. CHAPMAN
APPROVED	P. CHAPMAN

TITLE
FIMISTON II TSF CLOSURE DESIGN OVERVIEW

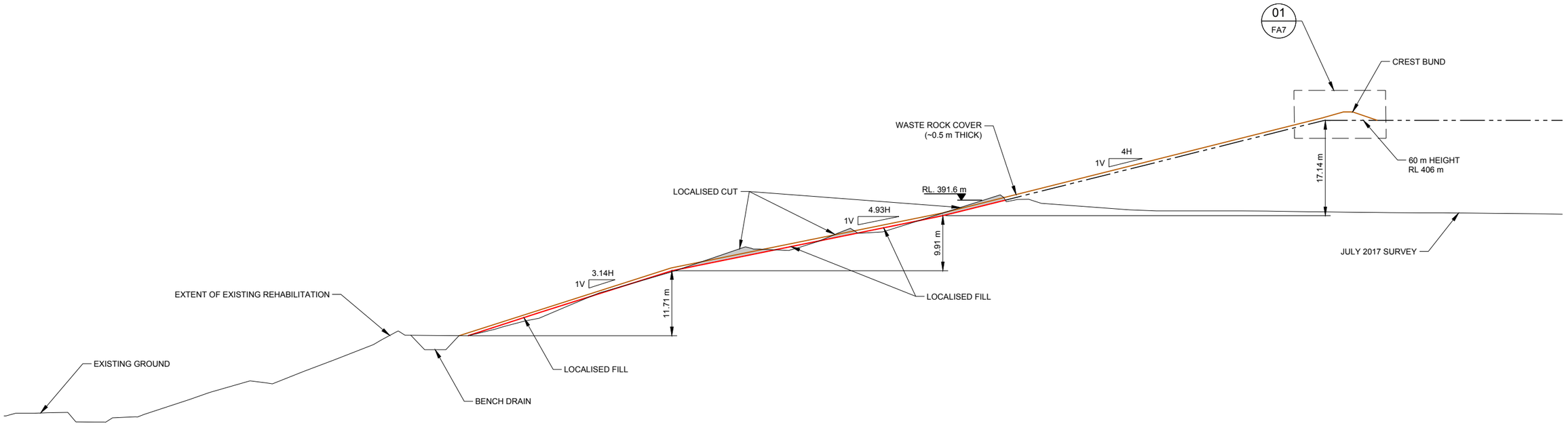
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SCALE 1:750 B FA3 FIM II EMBANKMENT SECTION

0 12.5 25
1:750 METRES

LEGEND

- LOCALISED CUT
- EXISTING GROUND
- MULTI-SLOPE DESIGN SURFACE
- PROJECTION TO HEIGHT
- FINAL DESIGN SLOPE

CLIENT
KALGOORLIE CONSOLIDATED GOLD MINES

PROJECT
KCGM FIMISTON TSF CLOSURE DESIGN REPORT

CONSULTANT
GOLDER

YYYY-MM-DD	2018-07-31
DESIGNED	A. KEMP
PREPARED	H. OO
REVIEWED	P. CHAPMAN
APPROVED	P. CHAPMAN

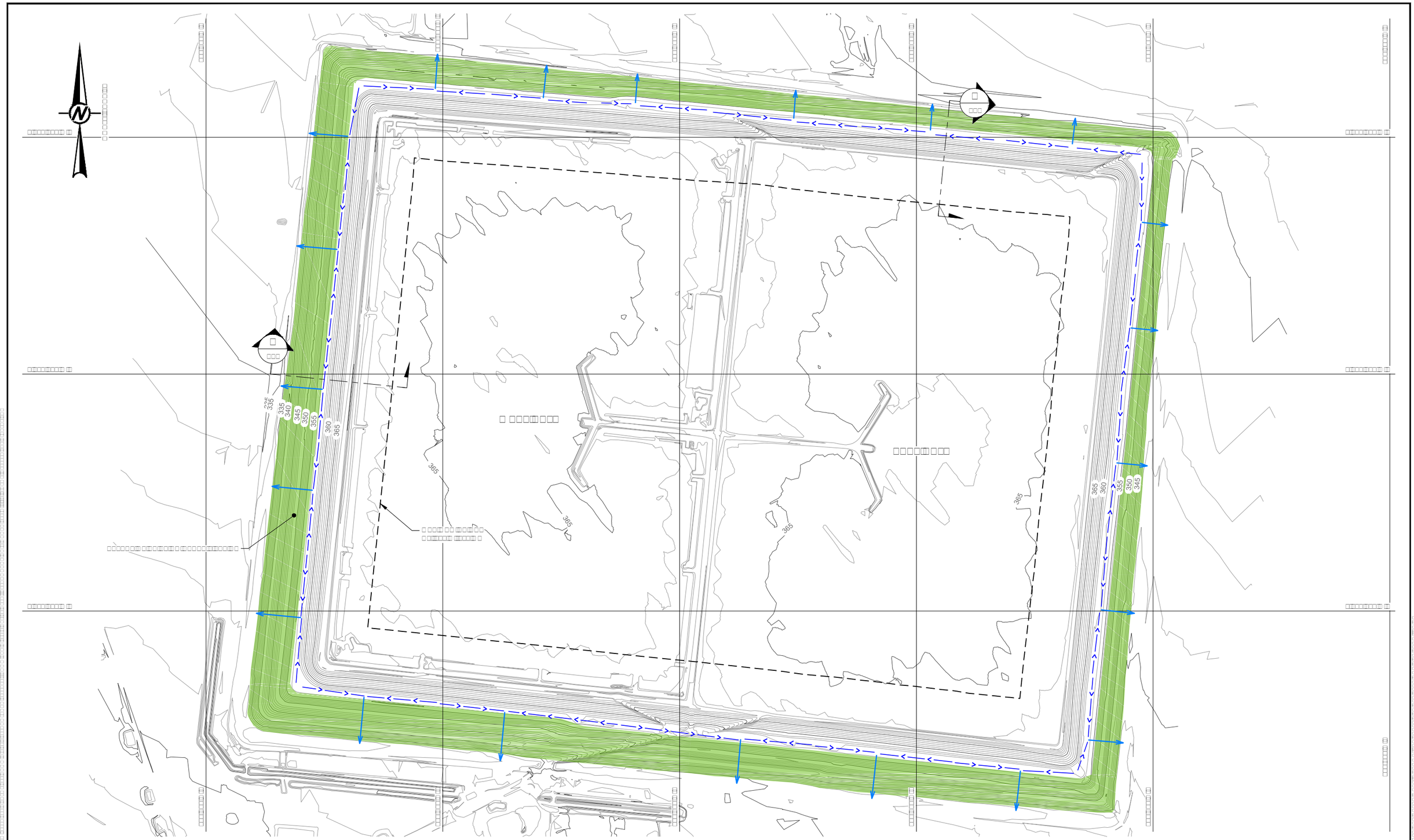
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TYPICAL EMBANKMENT SECTION

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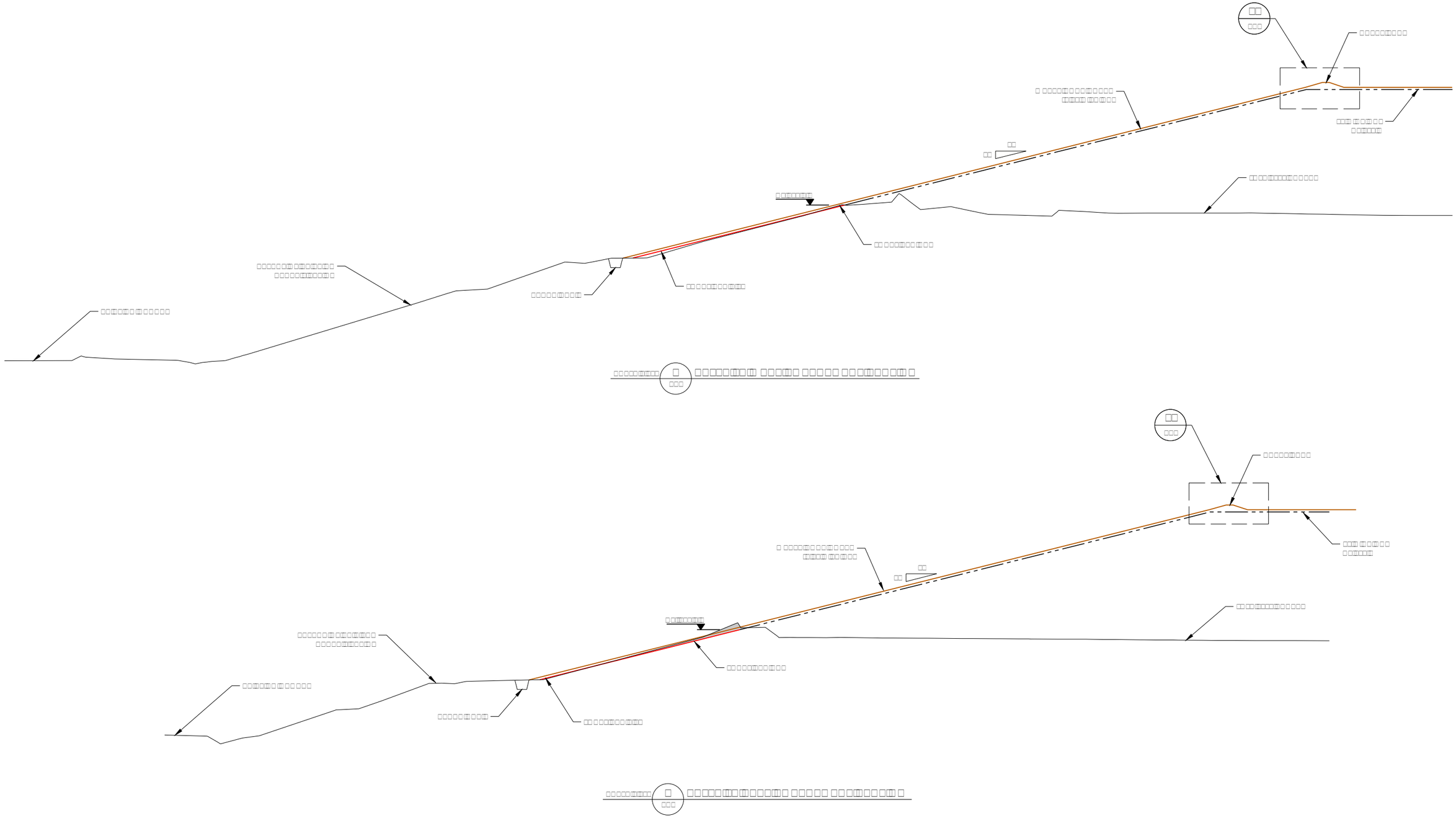


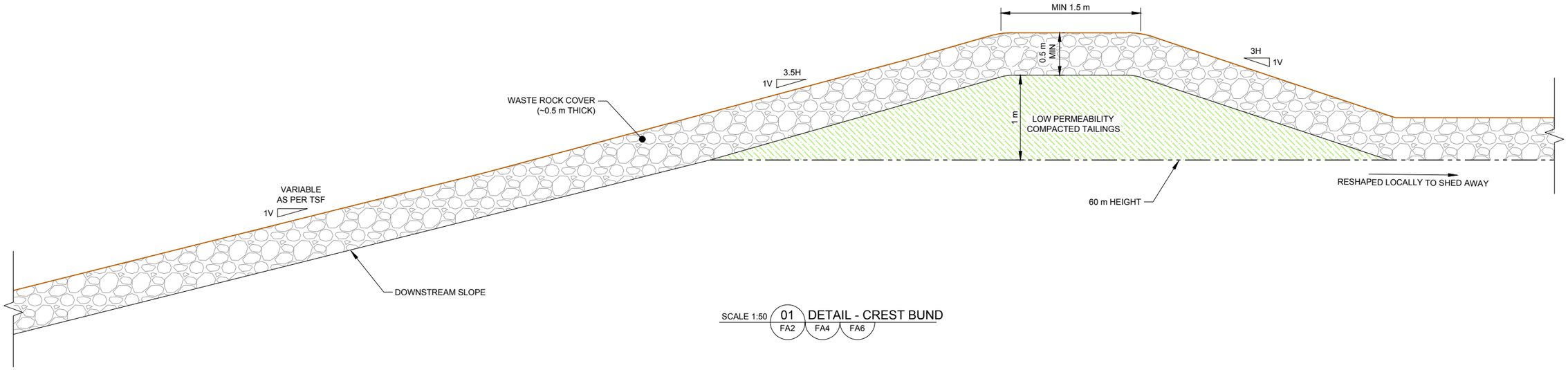
LEGEND

NOTE(S)

GOLDER

KALTAILS TSF CLOSURE DESIGN OVERVIEW


EXISTING GROUND
EXISTING GROUND
EXISTING GROUND



SCALE 1:50 — 01 FA2 — DETAIL - CREST BUND (FA4, FA6)

LOW PERMEABILITY COMPACTED TAILINGS

ROCKY BAND AND WASTE ROCK COVER (NO SOIL MIXED IN)

FINAL DESIGN SLOPE

0 1 2

1:50 METRES

CLIENT
KALGOORLIE CONSOLIDATED GOLD MINES

CONSULTANT
GOLDER

YYYY-MM-DD	2018-07-31
DESIGNED	A. KEMP
PREPARED	H. OO
REVIEWED	P. CHAPMAN
APPROVED	P. CHAPMAN

PROJECT
KCGM FIMISTON TSF CLOSURE DESIGN REPORT

TITLE

PROJECT NO.	DOC No	REV.	FIGURE
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APPENDIX B

Important Information

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5.7 Appendix 5.7: FIMISTON TSF Groundwater Closure Criteria

Big Dog Hydrogeology Pty Ltd
135 Burgoyne Rd Albany WA 6330
simon@bigdoghydrogeology.com.au
+61408230235

Ms Janine Cameron
Closure Specialist
KCGM

11 December 2020

Updated Proposed Groundwater Closure Criteria for the Eastern Floodway

Dear Janine,

As requested, please find following a discussion of proposed groundwater closure criteria for the Eastern Floodway.

1 INTRODUCTION

The Eastern Floodway forms a catchment to Hannan Lake, which is a saline playa lake located about 10 km south of Kalgoorlie (Figure 1). The Eastern Floodway catchment is around 18 km long and between 8 km and 13 km wide. Significant amounts of surface water flow through the Eastern Floodway only after very heavy rainfall events. A shallow groundwater system is known to be present within most of the Eastern Floodway, comprising ferricrete and alluvial sediments within clays.

KCGM current mine facilities which have been constructed within the Eastern Floodway comprise the Fimiston I TSF, the Fimiston II TSF, the Trafalgar Borefield and the Kaltails TSF. An additional TSF, the Fimiston II E TSF is planned to be constructed in the location marked in Figure 1. Seepage from the TSFs has caused changes in groundwater chemistry and rises in groundwater levels near the TSFs, and this seepage is mitigated by the operation of the Seepage and Groundwater Management Plans (SGMPs), which include operation of the Eastern Borefield and the Kaltails TSF Borefield to control groundwater levels, as marked in Figure 1. The closed Oroya TSF also caused large changes in groundwater levels and groundwater chemistry, but was decommissioned in 1996, is now under the Oroya WRD (Figure 1), and is no longer a source of groundwater mounding.

During the KCGM operational period, the facilities in the Eastern Floodway are operated under a licence issued by the WA Department of Water and Environmental Regulation (L6420/1988/14). That licence sets targets for groundwater depths, and includes required management actions linked to groundwater depths. It is accepted by KCGM and by stakeholders that once KCGM commence closure, and tailings deposition to the TSFs is terminated, continued operation of the SGMPs will be required to manage responses of the groundwater system to ongoing drain-down and residual seepage from the facilities in early closure. Currently closure planning allows for the SGMPs to operate at reducing pumping rates for 10 years post deposition. However closure criteria for groundwater conditions in the Eastern Floodway, which define when operation of the SGMPs will be terminated in closure, have not been developed or agreed with stakeholders. This document provides a proposed approach for setting closure criteria for groundwater in the Eastern Floodway. The approach has been developed from an assessment of environmental values for the groundwater system, and using the results of numerous hydrogeological investigation and monitoring programs conducted in the Eastern Floodway.

2 HYDROGEOLOGICAL REGIME AND ENVIRONMENTAL VALUES

The shallow groundwater system in the Eastern Floodway is well understood from multiple drilling, monitoring and modelling investigations, and comprises ferricrete and alluvial sediments overlying weathered bedrock, which correlate with similar deposits around Hannan Lake and elsewhere in the Eastern Goldfields. These deposits are greater than 30 m thick in the central parts of the catchment, and pinch out to the east and west towards the bedrock ridges which form the catchment divides, as confirmed by investigation drilling for the planned Fimiston II E TSF. The deposits are continuous and connected between the borefields identified in Figure 1 and act as a single regional groundwater unit.

The shallow groundwater system is recharged naturally after significant rainfall events that cause surface water to collect and migrate as sheetflow down the Eastern Floodway. Smaller amounts of recharge would also occur by infiltration of surface water in stream channels in the flanks of the catchment. Seepage from the TSFs also recharges the shallow groundwater system below the footprints of the facilities. Pre-mining groundwater flow was generally from north to south, parallel to the surface water flow directions. Groundwater in the vicinity of the TSFs is naturally saline to hypersaline (pre-mining TDS concentrations are indicated to be in the range 30,000 mg/L to 40,000 mg/L at the Fimiston TSFs and 50,000 mg/L to 60,000 mg/L at the Kaltails TSF) and acidic (due to naturally occurring ferrolysis reactions which result in a groundwater pH around 3).

There are no Groundwater Dependent Ecosystems (GDEs) associated with the shallow groundwater system, and the only beneficial use recognised for the saline groundwater is abstraction for mineral processing. Vegetation in the region survives on the infiltration of precipitation in the unsaturated zone above the water table and is not phreatophytic.

Figure 2 contours groundwater elevations in the shallow groundwater system measured in October 2020 at the Eastern Borefield, Trafalgar Borefield, Kaltails TSF Borefield and in investigation bores completed at Morrisons Flats. Groundwater flow directions have been automatically calculated from the contours and are included in Figure 2. On a regional scale, groundwater flow directions remain consistent with the inferred pre-mining conditions, with groundwater slowly migrating from the KCGM mine facilities towards Hannan Lake. Locally, significant mounding is evident around each of the active TSFs, and the monitoring data suggest that mounding between the Fimiston I and Fimiston II TSFs is acting as a hydraulic barrier, preventing groundwater flow from the northern part of the catchment reaching the southern part.

Figure 3 contours the estimated depth of groundwater below topographic surface, generated by comparing the groundwater surface in Figure 2 with digital topographic models. Operation of the SGMPs results in groundwater near the mine facilities being held a safe depth below surface. Groundwater depth is typically being held at more than 10 m downgradient of the embankment toe at the Fimiston I and Fimiston II TSFs, and more than 5 m at the toe of the embankment at the Kaltails TSF. The minimum groundwater depths in compliance bores of around 3 m are measured at MB K01, MB K46 and MB K02, all of which are located to the southwest of the Kaltails TSF where groundwater is naturally shallow.

Figure 3 illustrates that groundwater approaches surface, and discharge may potentially occur within branches of the Eastern Floodway to the south of the Golden Mile Milling operation, along Gribble Creek in Morrisons Flats, and in the area around 1 km distant from the Kaltails TSF towards Hannan's Lake. These shallow groundwater depths are a natural phenomenon, and groundwater discharge to surface has been observed to occur on occasions during monitoring by KCGM, when the Lakewood Supply Trenches overflow across Mt Monger Road. Saline groundwater may therefore contribute to the hydrochemistry of shallow pooling which occasionally occurs in Hannan Lake and may potentially influence ephemeral aquatic ecosystems or halo-tolerant vegetation at the lake. The greatest contribution to discharge at Hannan Lake would be the naturally saline groundwater present in the shallow groundwater system at Morrisons Flats. However in long term closure there would potentially be a small contribution of groundwater migrating to the south towards Hannan Lake from the closed KCGM facilities.

Environmental values and beneficial groundwater use in the Eastern Floodway requiring protection in closure are therefore:

1. Local non phreatophytic vegetation, the health of which would be impaired if the naturally saline groundwater were to rise into the root zone.
2. The potential hydrochemical contributions of groundwater discharge and other sources to the surface environment at Hannan Lake.
3. Potential future use of groundwater for mineral processing.

3 RATIONALE FOR SETTING CLOSURE CRITERIA

Groundwater chemistry

Seepage influences on groundwater hydrochemistry clearly do not impact on the potential beneficial use for mineral processing, as demonstrated during the KCGM operating period when the groundwater and seepage have been a significant proportion of process water use. The natural salinity of the groundwater makes it toxic to vegetation, regardless of the other hydrochemical constituents. Therefore, no closure criteria for groundwater hydrochemistry near the mine facilities are proposed for the protection of non phreatophytic vegetation. This is consistent with the compliance aspects of the operational Prescribed Premises Licence which includes targets and triggered actions for groundwater depths but not for groundwater hydrochemistry.

However it is possible that monitoring of groundwater quality upgradient of potential discharge zones may be required to confirm that the environment at Hannan Lake is being protected in long term closure. As illustrated by the groundwater flow directions in Figure 2, potential monitoring locations for groundwater hydrochemistry which are 1) downgradient of and outside the existing influences of the TSFs; 2) upgradient of the potential influence of the Golden Mile Milling TSF; and 3) close to the KCGM boundary where groundwater flows into the receiving environment at Morrisons Flats, then potential monitoring locations would be:

- Production and monitoring bores in the Trafalgar Borefield. Candidates would be existing production bores TR 2 or TR 4, or existing monitoring bore MB-TR4 which are circled in Figures 4 and 5. Figure 2 illustrates that these bores are located at the downgradient margin of the Trafalgar Borefield, are downgradient of the Fimiston I and Fimiston II TSFs and are downgradient of most of the KCGM waste rock storage facilities. Selection of the most appropriate bore would first entail a review of local groundwater elevations to identify any potential groundwater mounding associated with the Golden Mile Milling operation.
- Kaltails TSF Borefield monitoring bore MB K67 which is circled in Figures 4 and 5. Figure 2 illustrates that this location is downgradient of the Kaltails TSF and Figure 3 illustrates that it is upgradient of potential groundwater discharge zones.

Given the naturally saline hydrochemistry of groundwater in these locations, and the background variation in TDS concentrations and pH which have been observed during KCGM monitoring in the Eastern Floodway and within Morrisons Flats, closure criteria would need to be based around detecting any changes in hydrochemistry which are a statistically significant departure from the background conditions.

Groundwater depths

Protection of the environmental values defined in Section 2 requires that naturally saline groundwater remains below the potential vegetation root zone. It is therefore proposed that closure criteria be set for groundwater depths as follows:

- Criteria will be defined as groundwater depth below surface, not as groundwater elevations, as depth is the controlling parameter for potential impacts to vegetation.
- Criteria will be set for the compliance bores defined in the operational licence, for ease of transitioning between operations and closure. The existing compliance locations have been demonstrated to be suitably located to be protective of vegetation during the operating period.
- The Fimiston II E TSF is not currently included in the operational licence. Construction will require decommissioning of compliance bores MB F43, MB F45 and MB F47. KCGM plan to propose that existing bore MB F100 be added as a compliance location, and four new bores be constructed as compliance locations (110, 111, 112 and 113 as marked in Figure 2). For the purposes of developing draft criteria these are assumed to be the compliance bores in the licence. This assumption will need to be revisited once the license has been reissued.
- Depth criteria will be set individually for each compliance bore, and will be calculated as the depth which would be protective of vegetation in that location, plus an allowance for rebound associated with ongoing residual seepage from the TSFs, plus an allowance for the maximum likely temporary rise in groundwater levels associated with natural recharge from unusually large precipitation events.
- If the resulting depth criterion at a bore is comparable to the estimated pre-mining groundwater depth in that location (where available), the bore should continue to be monitored, but should be switched from compliance to interpretation status, and groundwater depth should be subject to ongoing review. The objective of this action is to avoid setting a target which is below the naturally occurring depth, which would potentially require artificial manipulation of groundwater depths (active pumping) in perpetuity.
- Taking account of the natural variation in groundwater depths, and of the time period over which seepage pulses travel through the groundwater system, the management actions linked to the defined groundwater depth criteria would potentially be:
    - Once all compliance bores in an area have been below the criteria for 6 months, pumping bores upgradient of that area will be switched off, but not decommissioned.
    - Ongoing monitoring will be undertaken. If the observed rebound is higher than was assumed in the calculation of the closure criteria in the following section, it may be necessary to recommence pumping temporarily.
    - Once all compliance bores in that area have been below the criteria for 12 months, the pumping bores will be decommissioned.

4 CALCULATION OF CLOSURE CRITERIA FOR GROUNDWATER DEPTHS

Depth protective of vegetation

The current SGMPs include limits for saline groundwater depth which are considered to be protective of local vegetation. Operation of the SGMPs, including vegetation monitoring over more than 15 years has confirmed these depths to be suitably protective. Linking the closure objectives to the operating limits allows any learnings or refinement in the operational period to be immediately transferred to the closure period. It is therefore proposed that closure criteria be calculated from and linked to the operating licence limits, which at the current time are:

- 4 m below surface for compliance bores in the Eastern Borefield.
- 4 m below surface for compliance bores in Zone A of the Kaltails TSF Borefield.
- 1 m below surface for compliance bores in Zone B of the Kaltails TSF Borefield.
- Noting that the boundary between Zone A and Zone B at the Kaltails TSF Borefield was adjusted in the most recent issue of the licence, and could be adjusted again during the operating period, which would require the closure criteria to be reassessed.

These values have been applied to the criteria calculations in Table 1.

Allowance for recharge events

The response of the shallow groundwater system to natural recharge events has been examined in detail (BDH, 2016). Key conclusions from this study were:

- Changes in groundwater level can be most reliably predicted from weekly precipitation totals (more diagnostic than daily, three day or monthly totals).
- Responses are regionally consistent and can be interpolated across the Eastern Floodway.
- Data are available defining responses to events with weekly precipitation totals up to 160 mm (Annual Exceedance Probability or AEP of 3%).
- Once weekly precipitation exceeds a response threshold of around 40 mm, groundwater level changes are generally proportional to precipitation, although some scatter is present in the relationships, likely due to differing daily precipitation distributions contributing to the same weekly total.
- Recovery from precipitation events occurs rapidly and consistently at an average linear rate of 0.2 m/month.
- Because recovery occurs rapidly, the maximum change in groundwater level is controlled by individual large precipitation events, rather than by multiple closely spaced smaller events.
- These findings allow the construction of observational models to predict groundwater level responses, which have been generated using 76 years of observed precipitation trends for Kalgoorlie Boulder (BDH, 2016).
- Regional responses to an AEP 3% recharge event (160 mm) are reproduced in Figure 4. Changes in groundwater level range from zero to the northeast of the Fimiston II TSF to 2.8 m in the middle of the Eastern Floodway. Responses to an AEP 1% event (238 mm) can be factored from this contour map.

Based on these conclusions, Table 1 calculates the potential recharge response at each compliance bore in two ways:

1. The modelled response to an AEP 3% event, plus a further allowance of 0.5 m to account for the observed scatter between the predicted response and the actual response (see Figures 17 and 18 in BDH, 2016). This scatter results from the differing intensities and distributions which contribute to similar weekly precipitation totals.
2. The modelled response to an AEP 1% event, plus a further 0.5 m to account for the observed scatter between the predicted response and the actual response.

Closure criteria have been calculated at each compliance bore using both methods in Table 1. Assuming post closure SGMP operation continues for a period of 5 years, the probability of one or more events with an AEP of 3% occurring in that period is 14%, while the probability of one or more events with an AEP of 1% occurring in that period is 5%. Application of the AEP 1% calculation is therefore proposed for the criteria as a conservative approach.

Allowance for rebound

When groundwater production is switched off, groundwater depths in the downgradient environment will potentially rebound, driven by:

1. An initial rebound reflecting recovery from any localised pumping influences (effectively an evening out or averaging of the groundwater surface which previously consisted of a large number of overlapping drawdown cones), and
2. A long term rebound reflecting the influence of ongoing residual seepage from the upgradient TSFs.

The magnitude of rebound will vary depending on the location of the monitoring bore (primarily distance from the TSFs and from the groundwater production bores), and will vary depending on how much residual seepage is occurring from the TSFs at the time pumping is shut down. Consequently potential rebound is difficult to model or predict accurately. This does not compromise the closure approach, as the borefields will remain equipped and pumping will be restarted if the observed rebound is greater than the estimated values discussed following.

Both modelling of TSF draindown and observations of groundwater depth responses during temporary decommissioning of the Kaltails TSF and the Fimiston I TSF identify that seepage rates from the TSFs greatly reduce once the decant pond is removed. As long as pumping operates for several years following the termination of tailings deposition, the long term rebound associated with TSF seepage will be a small component in the groundwater system.

The potential for an initial rebound has been investigated by KCGM in a practical manner. In 2016, maintenance works resulted in the Fimiston plant being shut down for around 2 weeks, and caused seepage and groundwater recovery to temporarily cease at the Eastern Borefield and the Kaltails TSF Borefield. KCGM undertook a comprehensive groundwater depth monitoring round while the pumps were operating immediately prior to the shut down, and undertook another monitoring round immediately prior to pumping recommencing. Comparisons of the two sets of groundwater depths identified that:

- The initial rebound was greatest in monitoring bores in the Operational Area close to production bores, where a rebound of up to 2 m was observed at the Kaltails TSF and up to 4 m was observed at the Fimiston TSFs.

- For compliance bores, the initial rebound was up to 0.7 m in monitoring bores located close to production bores, and was more typically in the range 0 m to 0.4 m.

It is therefore proposed that the closure criteria set at the compliance bores include an allowance of 1 m to account for potential rebound influences.

Modelled closure criteria

Table 1 summarises the resulting closure criteria for groundwater depths at all compliance bores. Applying the AEP 1% allowance, the depth criteria range from 3.5 m at MB K46 where shallow rooted vegetation is present, to 9.6 m at MB F27 which is highly responsive to recharge events. Figure 5 contours the modelled closure criteria groundwater depths, and identifies that:

- Target closure criteria depths are around 5.5 m in most locations.
- The target depths reduce to around 4 m in Zone A at the Kaltails TSF where only shallow rooted vegetation is present due to the naturally occurring shallow groundwater depths.
- The target depths increase to a maximum of 9.6 m in the Eastern Floodway where a larger allowance is required for recharge events.

Comparison with estimated pre-mining groundwater depths

The difference between the closure criteria modelled for an AEP 1% allowance and the interpolated pre-mining groundwater depth is calculated in Table 1. The pre-mining groundwater depth has been interpolated in each case from contours of prior groundwater elevations generated by Peter Clifton and Associates (PCA, May 2008 for the Eastern Borefield and PCA, October 2008 for the Kaltails TSF Borefield). Eight locations are identified where the calculated closure criteria are below, or within 1 m of the interpolated pre-mining depth. All of these bores are located close to the middle of the Eastern Floodway where strong recharge responses occur. Taking account of the potential uncertainty in the estimated pre-mining elevations, it is proposed that the modelled criteria should not apply in these locations. This would be achieved by continuing to monitor groundwater depths, but with all eight bores being migrated from compliance to interpretation status for closure, to avoid potentially being required to hold groundwater depths below the naturally occurring levels.

Comparison with current groundwater depths

The difference between the measured depth to groundwater in October 2020 at each compliance bore and the criteria calculated for an AEP 1% is calculated in Table 1. In most locations across the Eastern Floodway, the current groundwater depth is currently between 1 m and 17 m lower than the criteria (negative values in Table 1), and would potentially be sufficient to allow SGMP operation to be terminated, if it were the case that tailings deposition had been terminated for long enough for residual rates of seepage to be low. Areas where groundwater is currently above the proposed criteria are in the middle of the Eastern Floodway near MB F27 and to the southwest of the Kaltails TSF. Most but not all of these locations represent bores proposed to be migrated to interpretation status. The implications of these comparisons are that if the proposed criteria in Table 1 are adopted, the required period of operation of the SGMPs in closure is likely to be less than the 10 years currently assumed for planning and closure costing purposes.

Table 1 Proposed closure criteria

Compliance Bore	Vegetation Limit	3% AEP Recharge	1% AEP Recharge	3% AEP Criteria	1% AEP Criteria	Pre-mining Depth	Pre-mining Less 1%AEP target	Oct-20 Depth	1%AEP target less Oct 20 depth
	mBGL	m	m	mBGL	mBGL	mBGL	m	mBGL	
MB F01	4	0.3	0.4	5.8	5.9	21.7	15.8	13.8	-7.9
MB F02	4	0.1	0.1	5.6	5.6	22.9	17.2	15.2	-9.6
MB F03	4	0.1	0.1	5.6	5.6	16.1	10.5	9.8	-4.2
MB F04	4	0.5	0.7	6.0	6.2	16.4	10.1	12.0	-5.8
MB F06	4	0.9	1.3	6.4	6.8	13.7	6.9	11.0	-4.2
MB F07	4	1.4	2.0	6.9	7.5	12.7	5.2	11.3	-3.8
MB F08	4	1.2	1.8	6.7	7.3	11.8	4.6	8.7	-1.4
MB F09	4	0.8	1.2	6.3	6.7	12.9	6.2	8.6	-1.9
MB F19	4	0.4	0.6	5.9	6.1	11.9	5.8	10.3	-4.2
MB F20	4	0.3	0.4	5.8	5.9	12.4	6.5	12.3	-6.4
MB F21	4	1.0	1.5	6.5	7.0	10.2	3.3	8.4	-1.4
MB F23	4	0.8	1.2	6.3	6.7	18.3	11.6	12.5	-5.8
MB F27	4	2.8	4.1	8.3	9.6	7.7	-1.9	6.4	3.2
MB F30	4	1.0	1.5	6.5	7.0	7.2	0.3	6.8	0.2
MB F31	4	1.3	1.9	6.8	7.4	10.4	3.0	9.3	-1.9
MB F32	4	1.2	1.8	6.7	7.3	11.5	4.2	10.2	-2.9
MB F33	4	0.6	0.9	6.1	6.4	10.5	4.2	8.6	-2.2
MB F38	4	0.1	0.1	5.6	5.6	29.5	23.8	13.3	-7.7
MB F43	4	0.1	0.1	5.6	5.6	24.5	18.8	20.6	-15.0
MB F45	4	0.1	0.1	5.6	5.6	20.2	14.5	11.6	-6.0
MB F47	4	0.2	0.3	5.7	5.8	17.4	11.6	11.4	-5.6
MB F49	4	0.3	0.4	5.8	5.9	17.1	11.2	11.2	-5.3
MB F54	4	0.4	0.6	5.9	6.1	14.2	8.1	11.7	-5.6
MB F55	4	0.4	0.6	5.9	6.1	14.5	8.4	11.1	-5.0
MB F56	4	0.3	0.4	5.8	5.9	14.2	8.3	10.8	-4.9
MB F57	4	0.4	0.6	5.9	6.1	13.6	7.5	10.4	-4.3
MB F60	4	0.1	0.1	5.6	5.6	20.7	15.1	18.1	-12.5
MB F61	4	0.0	0.0	5.5	5.5	21.2	15.7	20.0	-14.5
MB F65	4	1.0	1.5	6.5	7.0	11.4	4.5	9.6	-2.6
MB F66	4	1.4	2.0	6.9	7.5	10.0	2.5	8.9	-1.4
MB F67	4	0.9	1.3	6.4	6.8	18.0	11.2	12.4	-5.6
MB F72	4	0.7	1.0	6.2	6.5	35.0	28.5	7.4	-0.9
MB F73	4	0.4	0.6	5.9	6.1	29.4	23.4	16.1	-10.0
MB F74	4	0.0	0.0	5.5	5.5	22.7	17.2	21.4	-15.9
MB F75	4	0.1	0.1	5.6	5.6	31.8	26.2	16.5	-10.9
MB F77	4	0.1	0.1	5.6	5.6	29.0	23.3	12.4	-6.8
MB F79	4	0.2	0.3	5.7	5.8	17.0	11.2	13.9	-8.1
MB F80	4	0.0	0.0	5.5	5.5	22.5	17.0	20.9	-15.4
MB F81	4	0.7	1.0	6.2	6.5	21.6	15.0	11.3	-4.8
MB F82	4	1.2	1.8	6.7	7.3	17.8	10.5	12.5	-5.2
MB F83	4	1.2	1.8	6.7	7.3	10.9	3.7	9.5	-2.2
MB F84	4	0.4	0.6	5.9	6.1	14.2	8.1	11.8	-5.7
MB F85	4	0.4	0.6	5.9	6.1	23.9	17.8	10.6	-4.5
TRE	4	1.6	2.3	7.1	7.8	6.9	-0.9	6.0	1.8
TRP 2	4	2.3	3.4	7.8	8.9	7.7	-1.2	6.6	2.3
MB F106	4	0.0	0.0	5.5	5.5	>20	>15	26.8	-21.3
MB F110	4	0.0	0.0	5.5	5.5	>20	>15	NA	NA
MB F111	4	0.0	0.0	5.5	5.5	>20	>15	NA	NA
MB F112	4	0.0	0.0	5.5	5.5	>20	>15	NA	NA
MB F113	4	0.1	0.1	5.6	5.6	>15	>10	NA	NA
MB K01	1	1.0	1.5	3.5	4.0	2.9	-1.0	2.7	1.3
MB K02	1	1.2	1.8	3.7	4.3	3.1	-1.1	3.0	1.3
MB K03	1	1.0	1.5	3.5	4.0	4.8	0.9	4.6	-0.6
MB K04	1	1.0	1.5	3.5	4.0	5.0	1.0	4.2	-0.2
MB K05	1	0.9	1.3	3.4	3.8	6.8	3.0	6.0	-2.2
MB K06	4	0.7	1.0	6.2	6.5	10.0	3.5	10.0	-3.5
MB K11	4	0.2	0.3	5.7	5.8	18.6	12.8	14.2	-8.4
MB K13	4	0.2	0.3	5.7	5.8	18.7	12.9	13.6	-7.8
MB K14	4	0.2	0.3	5.7	5.8	16.4	10.6	11.8	-6.0
MB K15	4	0.2	0.3	5.7	5.8	13.7	7.9	11.7	-5.9
MB K21	1	0.7	1.0	3.2	3.5	6.1	2.5	4.4	-0.9
MB K46	1	0.7	1.0	3.2	3.5	4.7	1.2	3.4	0.1
		Proposed interpretation status							
		Currently above proposed criteria							
		Currently below proposed criteria							
		Removed during Fim II E construction							
		Potentially added during Fim II E construction							

5 CONCLUSIONS

Draft closure criteria for groundwater in the Eastern Floodway have been compiled and are presented for review. Criteria for groundwater chemistry near the TSFs are not proposed, however it is possible that hydrochemical monitoring at the Trafalgar Borefield and at MB K67 may be required for closure. In this case closure criteria would be defined to detect changes in groundwater chemistry which represent a statistically significant departure from the background conditions.

It is proposed that groundwater depth closure criteria be set individually at each of the operational compliance bores, based on the depth that would be protective of vegetation, plus an allowance for rebound, plus an allowance for temporary natural recharge events. Natural recharge events are proposed to be quantified as the modelled influence of an AEP 1% event, plus a further 0.5 m safety buffer. The rebound allowance at compliance bores is proposed to be 1 m based on responses observed at compliance bores during operations. The resulting groundwater depth criteria range from 3.5 m at MB K46, to 9.6 m at MB F27. In two locations shaded in Figure 5, the modelled criteria are below or close to the estimated pre-mining groundwater elevation. It is proposed that the modelled criteria should not apply in these locations. This would be achieved by continuing to monitor groundwater depths, but with eight bores located in these areas migrated from compliance to interpretation status for closure, to avoid potentially being required to hold groundwater depths below the naturally occurring levels.

Yours sincerely



Simon Barrett
Principal
Big Dog Hydrogeology Pty Ltd
ABN 158 858 087

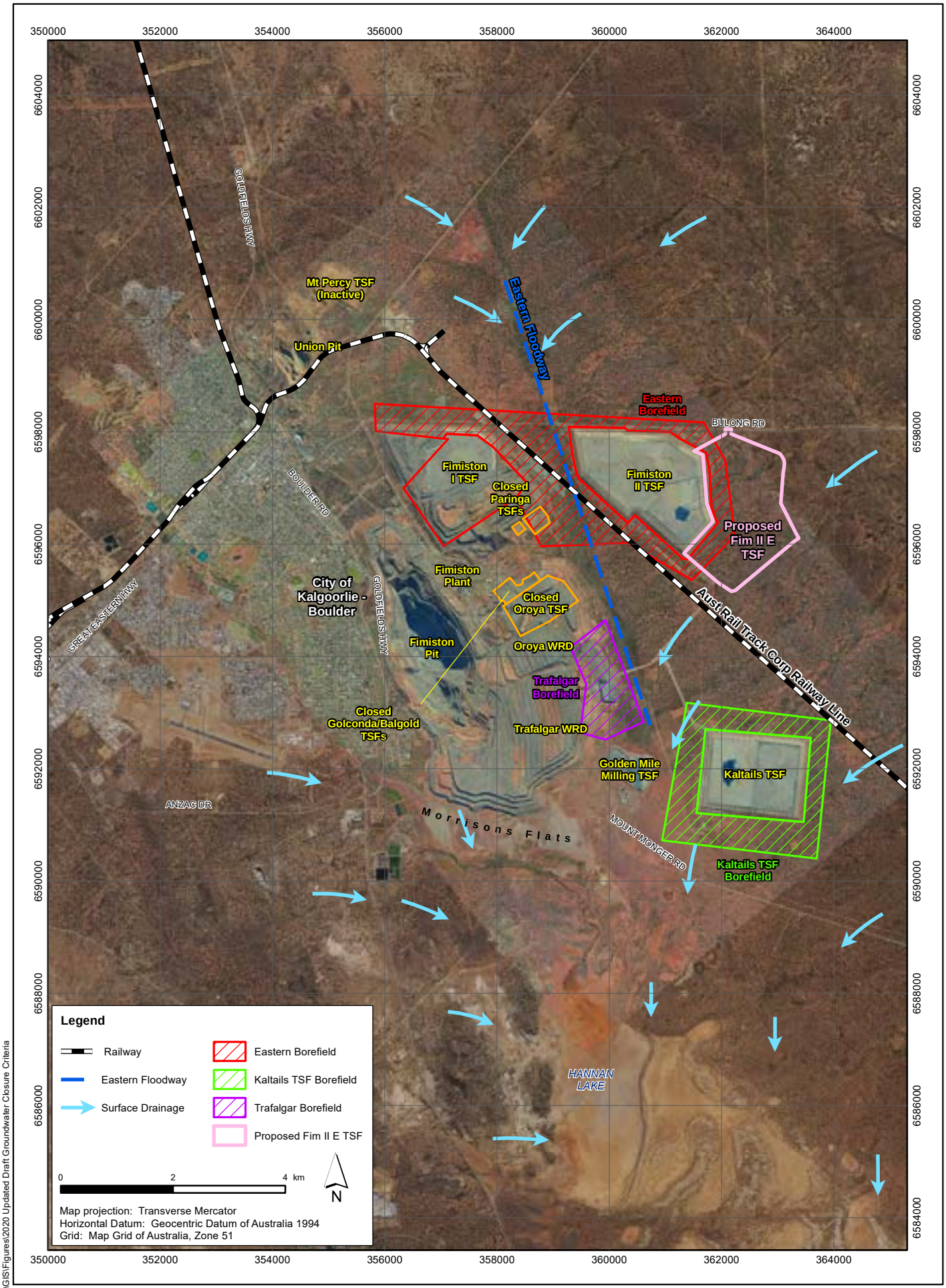
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FIGURES



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BIG DOG HYDROGEOLOGY

Eastern Floodway hydrology

Figure 1

Date: December 2020

Report: 2020 Updated Draft Groundwater Closure Criteria

354000 356000 358000 360000 362000 364000

6602000 6600000 6598000 6596000 6594000 6592000 6590000

Mt Percy TSF (Inactive)
Eastern Floodway
Union Pit
NSURCH3140
CSURCH3141
Mt Charlotte underground mining operation
Fimiston I TSF
Fimiston II TSF
Eastern Borefield
Closed Paringa TSFs
Proposed Fim II E TSF
Fimiston Plant
Closed Golconda/Balgold TSFs
Closed Oroya TSF
Oroya WRD
Fimiston Pit
Trafalgar Borefield
Trafalgar WRD
Golden Mile Milling TSF
Kaltails TSF
Kaltails TSF Borefield
Trans Australian Railway
BHGC007
PAGC212
GGGC027
NORTH KALGURLI MAIN
PAGD022
IDGD015
IDGD013
ORGD028
EUGC005
NKGC137
GGGC028
ENGD060
ORGC252
ORGC250
ENTERPRISE
VICTORIA
ORGC246
ORGD014
ORGD010
TRGC001
CSGC001
PERSEVERANCE
ORGD018
ORGD022
HMGD039
REGC037
HOGD012
LAKEVIEW
LVGC325
CTGC048
CTGD049
PAGC209
JUGC074
LSGC054
JUGC090
JUGD042
LSGC327
LSGC328
CHAFFERS
Chaffers Bore
Chaffers Replacement Bore
ALGC084
ADGC042
ADGC039
ADGC040
ADGC041
LOM 1
LOM 2
HSGC247
HSGC248
HSGC249
ECGC061
TRP 2
TRE
MB-TR1
TR 1
TR 2
TR 4
TR 5
MB-TR4
MF60
MF64
MF61
MF62
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MB K55
MB K66
MB K67
MB K68

Legend

- Standpipe piezometer
- Dry standpipe piezometer
- Decommissioned standpipe piezometer
- Pumping bore
- Decommissioned pumping bore
- Shaft
- VWP installation
- Decommissioned VWP installation
- Proposed compliance bores
- Mt Charlotte underground mining operation
- Eastern Borefield
- Kaltails TSF Borefield
- Trafalgar Borefield
- Proposed Fim II E TSF
- Drawdown cone
- Trans Australian Raliway
- Eastern Floodway
- Surface Drainage
- Groundwater elevation 2020 (mAHD)
- Interpolated groundwater flow directions

0 0.5 1 km

N

Map projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 51

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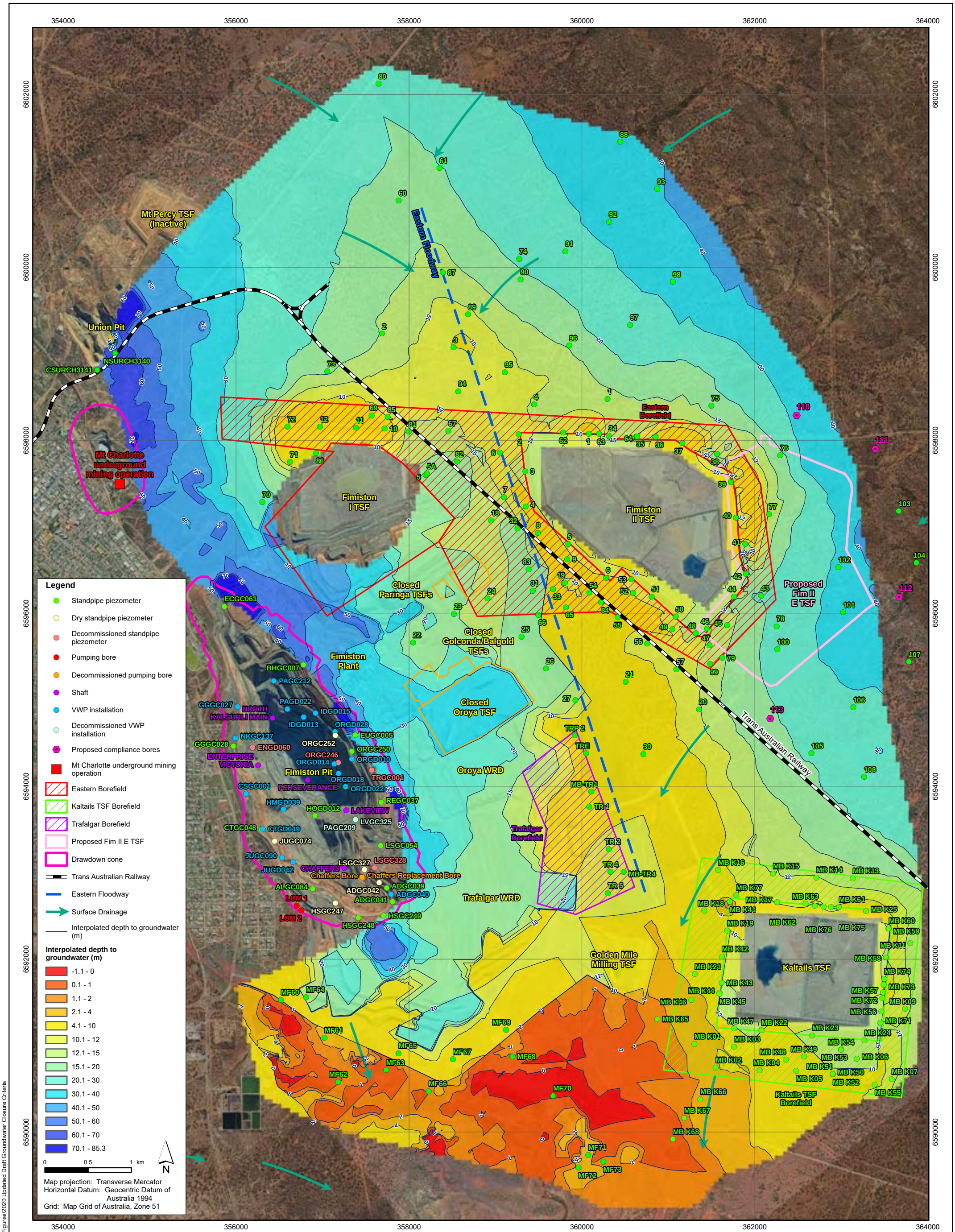
BIG DOG HYDROGEOLOGY

Groundwater elevations and flow directions October 2020

Figure 2

Date: December 2020

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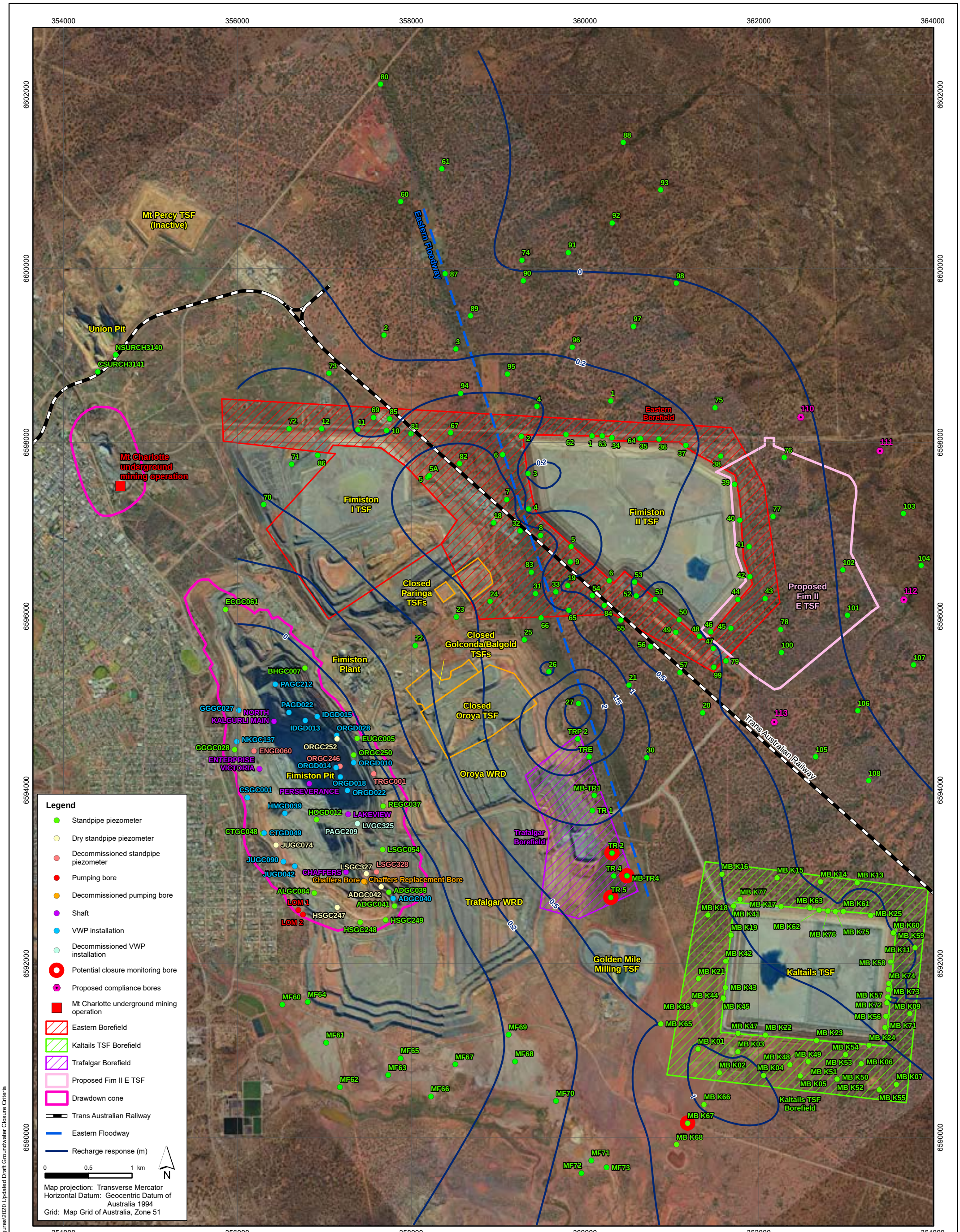
BIG DOG HYDROGEOLOGY

Interpolated depth to groundwater October 2020

Figure 3

Date: December 2020

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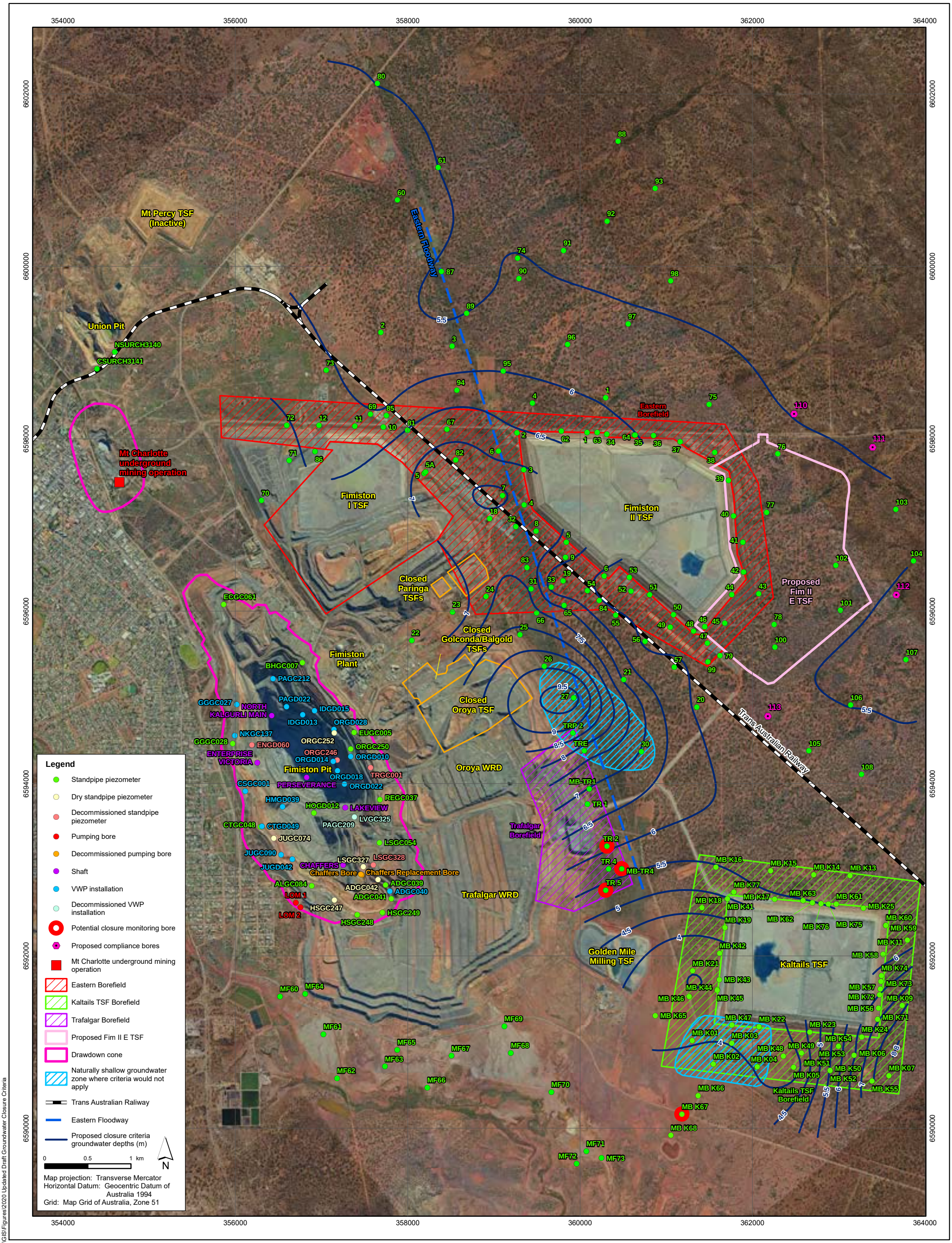
BIG DOG HYDROGEOLOGY

Averaged recharge response for a AEP 3% event

Figure 4

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BIG DOG HYDROGEOLOGY

Distribution of modelled closure criteria for groundwater depths

Figure 5

Date: December 2020

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5.8 Appendix 5.8: FIMISTON TSF Erosion Studies

Landloch

LONG-TERM EROSION POTENTIAL OF SOIL/ROCK MIXTURES USED ON REHABILITATION OF THE FIMISTON 2 TSF





Kalgoorlie Consolidated Gold Mines

May 2018

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TOOWOOMBA
PO Box 57
HARLAXTON QLD 4350
Phone (07) 4613 1825

PERTH
PO Box 5175
SOUTH LAKE WA 6164
Phone (08) 9494 2835

NEWCASTLE
PO Box 7017
Redhead NSW 2290
Phone (02) 4965 7717

Landloch Pty Ltd
A.C.N. 011 032 803
A.B.N. 29 011 032 803

Web site: www.landloch.com.au
Email: admin@landloch.com.au

Project Number: 2088.17f

Report Title: LONG-TERM EROSION POTENTIAL OF SOIL/ROCK MIXTURES USED ON REHABILITATION OF THE FIMISTON 2 TSF

Client: Kalgoorlie Consolidated Gold Mines (KCGM)

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1 INTRODUCTION

Rehabilitation and closure studies are being undertaken by Kalgoorlie Consolidated Gold Mines (KCGM) for the Fimiston 2 Tailings Storage Facility (Fim 2 TSF).

Landloch Pty Ltd has been engaged by KCGM to undertaken erosion and landform design studies on 7 rehabilitation surfaces as part of closure planning for the Fim 2 TSF. In addition to the assessment of 7 rehabilitation surfaces, results of erosion studies conducted in 2014 using soils from the Fim 2 TSF soil stockpiles are to be included in this report (Landloch 2014).

The overall objective of the study is to develop rehabilitation surface shapes that are erosionally stable in the long-term. In order to achieve this aim, Landloch has completed the following:

- Characterisation of a range of soil and waste rock materials that are to be present near the surface of the rehabilitated TSF.
- Water erosion studies including application of both simulated rain and overland flows to the soil and wastes.
- Development of batter profiles with erosionally stable surfaces using runoff/erosion model parameters derived from these studies.

2 EROSION STUDY OVERVIEW

2.1 Material selection

This study is focused on assessment of mixtures of durable, run of mine wastes when mixed with topsoils from the various topsoil stockpiles positioned at the base of the Fim 2 TSF. Seven topsoils were selected for assessment, and their locations are given in Figure 1. The location of the sample assessed in 2014 (Landloch 2014) is also shown and is labelled F24G. A summary of the sample locations in given in Table 1.

Table 1: Location of soil samples used to mix with durable run of mine waste.

Sample ID	Coordinates (GDA 94)		Stockpile No.	KCGM Classification
	Easting (m)	Northing (m)		
B1	361,440	6,597,808	1	A
B7	361,794	6,597,050	1	A
B14	361,897	6,596,180	1	A
F2 S1 G7	361,974	6,596,415	1	A
F2 S1 10	361,784	6,597,548	1	A
B16	360,956	6,595,968	2	A
F2 4H	358,849	6,597,743	4	B
F2 4G^	358,807	6,597,740	4	B

^ F2 4G was sampled and assessed for erosion potential as part of the 2014 studies.

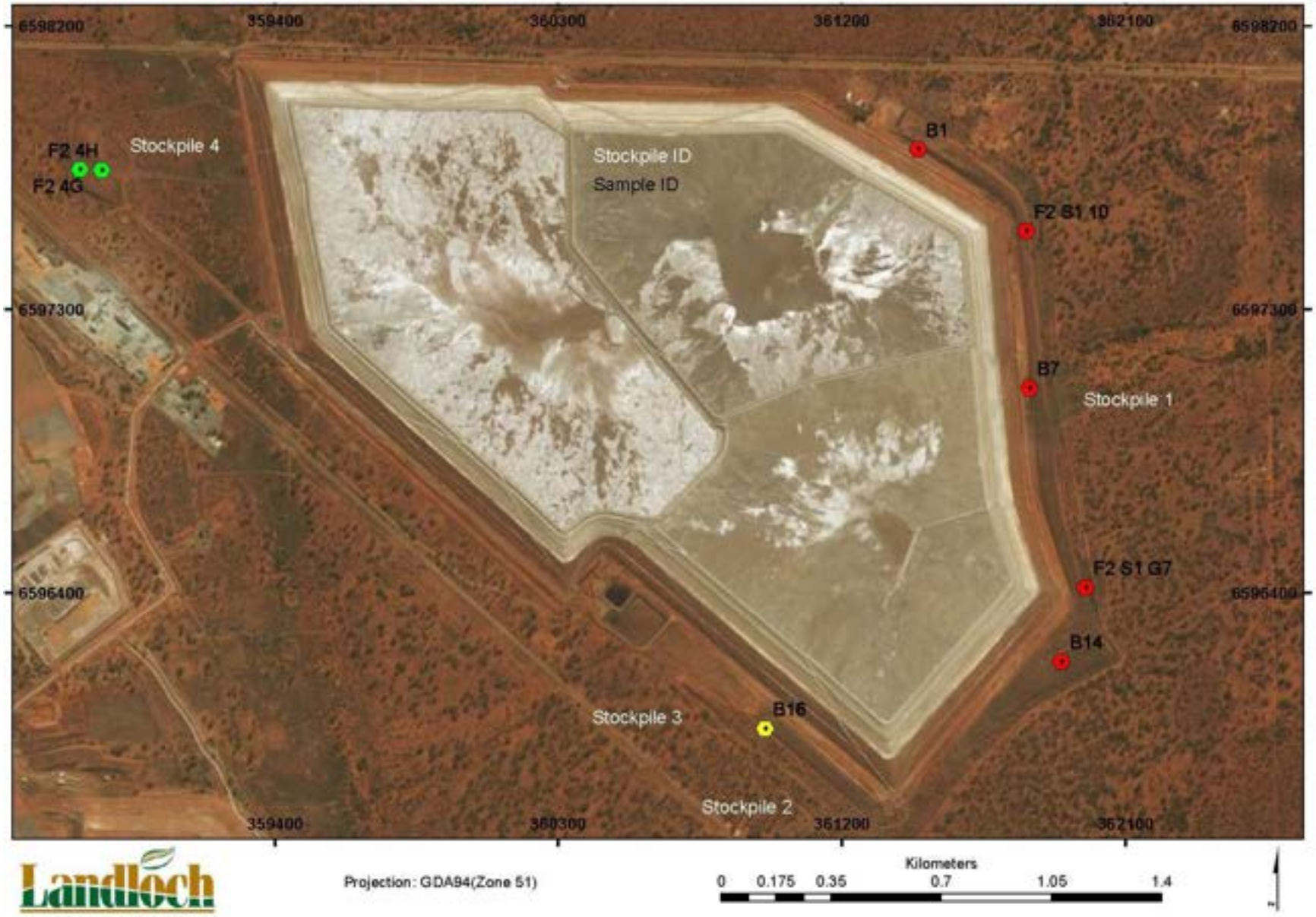


Figure 1: Location of soil samples collected

Sample locations were selected so that the bulk samples were reasonably spread out across the major topsoil stockpiles, and so that they aligned with locations that had been previously assessed using smaller samples and shown to be suitable for use as a growth medium on steep slopes.

Durable run of mine waste rock was sourced from the batters of the Central Waste Dump. Samples were selectively taken from waste that did not contain significant visible oversize material (>~300mm) as the particle size distribution of the waste once pushed to the final rehabilitation gradient will likely contain higher proportions of smaller rock than rock sourced from an active tip head.

At the sampling location the materials were placed into four 200L steel drums. The bulk drum materials were then transported to Landloch's Perth-based erosion assessment facility for detailed material characterisation and subsequent erosion modelling.

The surfaces assessed for erodibility and sediment properties consisted of a mixture of 1 part soil to 2 parts run of mine waste. Packing theory for a binary mixture (i.e. fine-grained soil mixed with coarser rock) indicates that minimum soil void ratios are associated with soil mixtures that contain ~30-40% of fines and ~60-70% coarse by volume (Bodman and Constantin 1965; Coughlan *et al.* 1978). This mixing ratio tends to produce a particle size distribution (once mixed) that contains enough fines to fill the voids created by the rock. If there is too much fines, the rocks tend to 'float' within the fine-grained soils and remain erodible as the soil can erode from around the rocks. If there is too much rock, the fines tend to fall through the voids created by the rock, leaving a surface that is rocky, but with a low proportion of fines to assist in the growth of vegetation.

2.1.1 Baseline material properties

Subsamples of the fine fraction (particles with diameters <2mm) of each of the seven newly collected bulk samples were sent to a third-party NATA accredited laboratory of analysis for:

- Soil $pH_{1:5}$ (H_2O);
- Electrical Conductivity ($EC_{1:5}$);
- Total N and P;
- Organic C;
- Available (Colwell) P and K, and available (KCl) S;
- DTPA Extractable Nutrients (Fe, Mn, Zn);
- Exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} and Al^{3+});
- Effective Cation Exchange Capacity;
- Exchangeable Sodium Percentage;
- Particle size distribution (gravel, sand, silt, clay); and
- Emerson class number.

Once mixed with the run of mine waste, the mixtures were also assessed for particle size distribution.

2.2 WEPP erodibility parameters

Although the concept of "erodibility" is broadly understood, its precise meaning can vary considerably within the framework of some erosion prediction models. In the Water Erosion Prediction Project (WEPP) model (Flanagan and Livingston 1995) used in assessing erosion potential of batters for waste landforms presented in this report, erodibility is described via a number of specific parameters:

- Interrill erodibility (K_i);
- Rill erodibility (K_R);
- Critical shear for rill initiation (τ_c); and
- Effective hydraulic conductivity (K_e).

These WEPP erodibility parameters were derived from data collected using laboratory-based experimental methods involving the application of:

- Simulated rain to a surface and measurement of runoff and sediment in runoff to obtain estimates of K_i and K_e; and
- Surface water flows to obtain estimates of K_R and τ_c.

Those parameters were then used in computer simulations of runoff and erosion in determining a range of landform design options that are presented in this report.

Interrill and rill erosion were determined by employing the following methodology:

- Interrill erosion was measured by applying a simulated "storm" with known rainfall intensity to test plots. Runoff rates sediment loads were recorded and used to derive rainfall related parameters. Loch *et al.* (2001) presents a detailed description of the rainfall simulator configuration as used in this report.
- Rill erosion was measured by applying overland flow to flumes. Sediment in runoff was taken and used to derive rill related parameters.

2.3 WEPP sediment properties

Estimates of erosion rates are sensitive to the particle size and density distributions of the eroded sediment.

Landloch's version of WEPP specifically allows input of detailed sediment particle size and density data and consequently, can more accurately predict erosion.

Settling columns were used to develop equivalent sand size distributions for the sediment (Loch 2001). This approach is particularly useful as it integrates both particle size and density, and the data can be readily entered into WEPP. Nine samples of the rain-impacted surface (three from each of the triplicate rainfall simulation plots) were taken using sampling and handling methods described by Loch (1994).

2.4 Properties of rain-armoured surfaces

Application of simulated rain produces a rain-armoured surface with properties approaching that of surfaces that are likely to be achieved by normal rainfall over several years. Definition of the characteristics of the rain-armoured surface can be useful when monitoring batter slope stability and whether or not the necessary rockiness of the surface has been achieved by the mixing and ripping methods adopted. The rain-armoured surface of each rainfall simulation plot was also assessed for percent rock cover and particle size distribution. In particular, the mean rock size and largest rock size were recorded. Both were measured from orthorectified images to enable accurate scaling of the rocks. For the purpose of this assessment, rocks were defined as particles with diameters 20mm or greater.

2.5 Computer simulation of runoff and erosion from landform batters

2.5.1 The WEPP model

The Water Erosion Prediction Project (WEPP) model was used for simulations of runoff and erosion. It was developed by the United States Department of Agriculture (USDA) to predict runoff, erosion, and deposition for hillslopes and catchments.

WEPP has a daily input time step, although internal calculations use shorter time steps. Plant and soil characteristics important to erosion processes are updated every day. When rainfall occurs, those plant and soil characteristics are considered in determining the likelihood of any runoff. If runoff is predicted to occur, the model computes sediment detachment, transport, and deposition at points along the slope profile.

The erosion component of the WEPP model uses a steady-state sediment continuity equation as the basis for erosion computations. Soil detachment in interrill areas is calculated as a function of the effective rainfall intensity and runoff rate. Soil detachment in rills is predicted to occur if the flow hydraulic shear stress is greater than the soil's critical shear stress, and when the sediment load of the flow is below transport capacity. Deposition in rills is computed when the sediment load is greater than the capacity of the flow to transport it.

2.5.2 Climate sequence

Climate input files are needed to simulate runoff and soil loss with the WEPP model. For each day of simulation, WEPP requires ten daily weather variables:

- Precipitation (mm),
- Precipitation duration (hr),
- Peak storm intensity,
- Time to storm peak,
- Average minimum temperature,
- Average maximum temperature,
- Dew point temperature,
- Solar radiation,
- Wind speed, and
- Wind direction.

Of these, the four precipitation-related variables (underlined in list above) are of particular importance because previous studies have shown that predicted runoff and soil loss are most sensitive to these precipitation variables (Nearing *et al.* 1990).

For most sites around the world, complete historical weather data on these variables are not available. To use WEPP for runoff and erosion prediction, synthetic weather sequences that statistically preserve the mean and variations in the historical observations are required.

CLIGEN is a stochastic weather generator that can be used to provide WEPP climate input files. CLIGEN has been extensively assessed for a wide range of climates in Australia, and it was found that CLIGEN was most suitable to provide the required climate input for WEPP to predict runoff and soil loss in Australia (Yu 2003).

Daily climate data for Kalgoorlie-Boulder Airport (station number 12038) and Kalgoorlie Post Office (station number 12039) were sourced from the Australian Bureau of Meteorology (BoM). The effective record length for rainfall is 112 years. Rainfall intensity (6-minute pluviograph) data were also sourced from the Bureau of Meteorology for the Kalgoorlie-Boulder weather station. This site contains pluviograph data from January 1966 until March 2011, with an effective record length of approximately 43.1 years.

Using these two data sets, the following parameter values were computed and used to develop the synthetic climate sequence for KCGM:

- Mean daily rainfall on wet days for each month,
- Standard deviation and skewness coefficient of daily rainfall for each month,
- Probability of a wet day following a dry day for each month,
- Probability of a wet day following a wet day for each month,
- Mean daily max. temperature for each month,
- Standard deviation of daily max. temperature for each month,
- Mean daily min. temperature for each month,
- Standard deviation of daily min. temperature for each month,
- Mean maximum 30-min rainfall intensity for each month, and
- Probability distribution of the dimensionless time to peak storm intensity.

These parameter values were assembled to create a CLIGEN parameter file for the site. Wind data (used to calculate soil evaporation) were not synthesised by CLIGEN because Priestley-Taylor's method for estimating the potential evaporation will automatically be used by WEPP.

A 100-year climate sequence was generated using CLIGEN version 5.1 (Yu 2002). The climate file shows that there is considerable variation in rainfall from year to year (Figure 2). Additionally, significant variability in the intensity and duration of individual rainfall events, along with soil and landscape factors, create even greater variation in predicted runoff and erosion rates. It is for these reasons that simulations of erosion in the prevailing climate should be made using long-term climate sequences (rather than short term sequences or individual storm events). Use of shorter sequences can lead to both over-estimates and under-estimates of erosion depending on the sequence used.

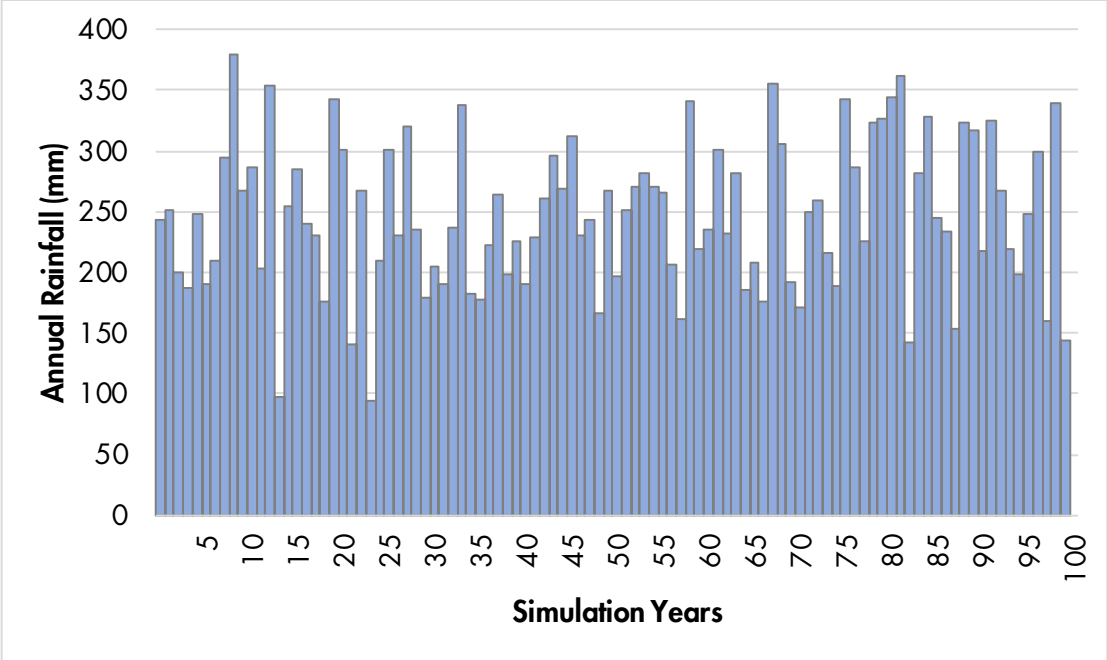


Figure 2: Annual rain for the 100-year climate file used in simulations.

2.5.3 Definition of acceptable erosion

The concept of "acceptable erosion" is widely mentioned in soil erosion literature, but it appears to have little relevance to mine site rehabilitation. Acceptable erosion is often defined as a rate of erosion such that land productivity is not reduced, and is therefore of greatest relevance to agricultural situations. It also ignores the pronounced temporal variations in erosion rates evident in arid regions.

Landloch's approach to landform design aims to create slopes on which rilling will be minimal or absent. Such slopes will have little potential to become heavily gullied, and any interrill erosion that occurs will be relatively insignificant relative to potential rates of erosion by rilling that could develop on long, steep slopes. If rilling and gullying is avoided, the slope should be sustainable.

Landloch has considerable experience in modelling erosion, and assessing erosion processes and rates in the field. In the northern WA Goldfields area, landforms designed with a predicted average erosion rate (averaged over the whole slope) less than 5t/ha/y, together with a predicted maximum erosion rate at any point on the slope less than 10t/ha/y exhibit a low tendency to rill. These erosion threshold values were adopted as acceptable for this report. To date, observations made by Landloch on several sites indicate that this erosion threshold definition has produced batters with low rilling potential that have been consistent with rehabilitation success (DRET 2009).

2.5.4 Model runs and standard input conditions

Each of the materials were used in several simulations of runoff and erosion. WEPP was run for uniform gradient batter slopes with a range of heights (10-30m) and gradients

(12-18°). All batters considered did not contain berms. Batters that contained zones of higher levels of rock cover (i.e. 'rocky bands') were also considered.

WEPP runoff/erosion simulations were conducted on the eight materials with the following model settings:

a) No allowance was made for vegetation effects on erosion. This is consistent with observations of cover levels achieved on site; cover levels in the arid zone tend to be too low to effectively contribute to reducing erosion of steep batter slopes.
b) Light cross-slope ripping will be applied to the rehabilitated batter surface.
c) No allowance was made for water from the top of the landform to discharge onto the batter slopes. Retention of water on top of the landform will considerably reduce potential erosion rates.

3 RESULTS

3.1 Soil and waste properties

The results of the characterisation of the soils and waste supplied are shown in Table 2. The pH and electrical conductivity (EC) were measured using a one part soil to five parts deionised water solution. The pH of the soils and waste is alkaline, consistent with values measured for other soils and wastes on site.

The EC of the topsoil was lower than for the waste. However, all materials had salinity values that are unlikely to limit plant germination or growth. As an indication, germination of some salt sensitive species' may be impacted at $EC_{1:5}$ levels of >1dS/m.

Total N is very low in the waste compared to the soil (as is expected). Total N values of the soils appear satisfactory, and the presence of vegetation on the stockpiles is very likely contributing to this satisfactory result. The plant available nutrients, P and K, are all higher in the soil than the waste. Available S is higher in the waste, though it is not present at toxic levels. The available Cu, Mn, and Zn are higher in the wastes than the soils; the levels for both the waste and the soils appears satisfactory.

The effective cation exchange capacity (ECEC) is a measure of the material's ability to adsorb and hold cations, and can reflect clay content and mineralogy. The ECEC values measured indicate that the soils contain clays that are potentially prone to shrinking and swelling when wet and dried. The soils have a loamy texture and ESP values are typically <6%, indicating that there is a low risk of dispersion and tunnelling. Soil F2-4G does have ESP >6%, and could be prone to some clay dispersion. However, when hydrochloric acid was applied to the aggregates, the material fizzed, indicating the presence of calcium carbonate, a source of calcium that will act to counter the tendency of the soils to disperse. Further, when mixed with waste rock, any dispersion that may occur is unlikely to result in structural instability and tunnel erosion.

The fresh rock has high rock particle density values and low water absorptions values, indicating that the rock is durable and not prone to rapid weathering. This is supported by site observations that indicate that the durable fresh dolerite wastes remain durable in the long-term.

Table 2: Material characterisation data for 8 soils and run of mine waste

Analyses		Unit	Waste Rock	Soil B1	Soil B7	Soil B14	Soil B16	Soil F2 S1 10	Soil F2 S1 G7	Soil F2 4H	Soil F2 4G^
KCGM Classification		-	-	A	A	A	A	A	A	B	B
$pH_{1:5}$ (H_2O)		pH units	7.79	8.00	8.47	8.42	8.40	8.35	8.60	8.39	8.88
Electrical Conductivity ($EC_{1:5}$)		dS/m	1.02	0.70	0.61	0.37	0.34	0.51	0.29	0.92	0.85
Total Nitrogen		mg/kg	74.4	497	545	435	718	535	561	599	-
Total Phosphorus		mg/kg	195	140	136	127	157	159	164	164	-
Organic Carbon		%	1.75	0.30	0.53	0.71	0.79	0.34	0.96	0.5	-
Plant Available Nutrients	Phosphorus - Colwell	mg/kg	3.00	21.0	9.14	4.51	9.14	9.97	8.87	10.5	-
	Potassium - Colwell	mg/kg	89	263	340	419	416	395	348	452	-
	Sulphur - KCl	mg/kg	522	106	101	71.9	34.3	71.9	48.4	144	-
	Copper – DTPA	mg/kg	16.0	0.94	1.47	1.29	1.69	1.39	1.62	1.84	-
	Iron – DTPA	mg/kg	28.4	0.61	1.18	1.2	1.24	2.00	1.48	1.61	-
	Manganese – DTPA	mg/kg	4.50	1.47	2.19	2.18	1.96	2.62	2.85	2.89	-
	Zinc – DTPA	mg/kg	63	0.32	0.3	0.37	0.35	0.50	0.37	0.51	-
Cation Extraction Method		Rayment& Lyons	15A2	15A2	15A2	15A2	15A2	15A2	15C1	15A2	15A2
Exchangeable Cations	Calcium	meq/100g	8.98	22.23	20.14	19.69	22.94	19.86	3.05	21.71	5.40
	Magnesium	meq/100g	0.65	5.08	5.01	4.23	3.23	4.03	1.44	5.35	2.10
	Potassium	meq/100g	0.08	0.45	0.59	0.78	0.84	0.70	0.38	0.86	0.40
	Sodium	meq/100g	0.17	0.94	0.73	0.50	0.40	0.55	0.47	1.12	1.50
	Aluminium	meq/100g	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
	ECEC	meq/100g	9.88	28.71	26.47	25.21	27.41	25.14	5.34	29.03	9.40
	ESP	%	1.8	3.3	2.8	2.0	1.4	2.2	8.8	3.9	15.6

Table 2 cont'd: Material characterisation data for 8 soils and run of mine waste

Analyses		Unit	Waste Rock	Soil B1	Soil B7	Soil B14	Soil B16	Soil F2 S1 10	Soil F2 S1 G7	Soil F2 4H	Soil F2 4G^
Particle Size Distribution of Fine Fraction*	Coarse Sand	%	70.6	36.5	25.6	27.6	29.1	29.7	27.1	24.2	46.4
	Fine Sand	%	17.9	41.2	45.0	40.1	41.7	42.3	41.5	45.0	34.2
	Silt	%	7.1	10.1	11.8	10.7	9.8	9.4	9.8	11.5	1.9
	Clay	%	4.4	12.2	17.7	21.5	19.4	18.7	21.6	19.3	17.4
Coarse Fragments > 2.0mm		%	91.5	-	-	-	-	-	-	-	-
Emerson Class		Class	6	4	4	4	4	4	4	4	4
Particle Size Distribution of Coarse Fraction+	Rock	%	23.6	-	-	-	-	-	-	-	-
	Pebbles	%	26.3	-	-	-	-	-	-	-	-
	Coarse gravel	%	32.2	-	-	-	-	-	-	-	-
	Fine gravel	%	9.5	-	-	-	-	-	-	-	-
	Fines	%	8.5	-	-	-	-	-	-	-	-
Rock Particle Density		g/cm^3	3.0	-	-	-	-	-	-	-	-
Rock Water Absorption		%	0.2	-	-	-	-	-	-	-	-

^ Only some data is available for F2 4G that was characterised in 2014. * Coarse sand: 0.2-2.0mm; Fine sand: 0.02-0.2mm; Silt: 0.002-0.02mm; Clay: <0.002mmm. + Rock: >45mm; Pebble: 25-45mm; Coarse gravel: 5-25mm; Fine gravel: 2-5mm; Fines: <2mm.

3.2 Material erodibility

WEPP erodibility parameters were derived using data collected from the rainfall and overland flow simulations. The derived WEPP erodibility parameters are provided in Table 3. The WEPP parameters for the F2 4G soil without mixing into rock is given in Table 4.

All material mixes had quite consistent measured erodibility parameters. This is to be expected given that the rock is of a similar character (particularly in size distribution), and that the properties of the soils do not vary considerably.

Without addition of rock, the soil has a rill erodibility that is an order of magnitude higher than measured for the mixes, the critical shear is 25-50% lower, and the interrill erodibility value is almost double. These factors combined make the soil considerably more erodible that the material mixes, and highlights the importance of thorough mixing and incorporation of rock into the rehabilitated surface layers of the Fim 2 TSF batters.

Table 3: WEPP parameters derived from laboratory testing for soils mixed with rock at a ratio of 1 part soil to 2 parts rock.

Material Mix	KCGM Classification	Effective hydraulic conductivity, K_e	Interrill erodibility, K_i	Rill erodibility, K_R	Critical shear, τ_c
		mm/h	kg.s/m^4	s/m	Pa
B1	A	15	474,104	0.00195	31
B7	A	15	446,790	0.00183	29
B14	A	11	421,793	0.00261	38
B16	A	15	432,915	0.00100	40
F2 S1 10	A	15	354,264	0.00298	31
F2 S1 G7	A	11	408,604	0.00114	41
F2 4H	B	7	416,259	0.00145	31
F2 4G	B	13	382,885	0.00090	35

Table 4: WEPP parameters derived from laboratory testing for the F2 4G soil not mixed with rock.

Soil	KCGM Classification	Effective hydraulic conductivity, K_e	Interrill erodibility, K_i	Rill erodibility, K_R	Critical shear, τ_c
		mm/h	kg.s/m^4	s/m	Pa
F2 4G	B	13	992,810	0.01080	21

3.3 Sediment properties

Equivalent sand particle size distribution curves for each material is provided in Appendix A[1]. The average distributions for each material were inputted to the WEPP model to inform the sediment transport equation. The sediment for all materials assessed contains only small proportions (~10%) of sediment that could be considered difficult to settle and hence highly mobile in flowing surface water. Hence, the risk of the mobilisation of large volumes of sediment and its movement to significant distances from the toe of the Fim 2 TSF could be considered low.

3.4 Properties of rain-armoured surfaces

Values for percent rock cover, mean rock size ($D_{50(20)}$), and the largest rock size for the different material mixes are given in Table 5. All calculations excluded particles less than 20mm in diameter. Particle size distribution curves for the rain-armoured surfaces are given in Appendix B[2].

The data show that the rock within the rain-armoured surfaces is of a consistent size and cover level across all the plots assessed. This is consistent with the erodibility parameters that also show little variation among the values measured for the material mixes.

Table 5: Properties of the rain-armoured surfaces for soils mixed with waste rock.

Material Mix	KCGM Classification	Rock Cover	Mean Rock Size, $D_{50(20)}$	Largest Rock Size
		%	mm	mm
B1	A	40	40	85
B7	A	35	40	100
B14	A	30	50	95
B16	A	30	50	110
F2 S1 10	A	40	40	85
F2 S1 G7	A	30	40	85
F2 4H	B	30	40	80
F2 4G	B	45	50	100

4 SIMULATIONS OF RUNOFF AND EROSION

4.1 Comparative erosion potential

In order to compare the relative erosion potential of the eight different material mixes (and the one sample of soil that was not mixed with waste rock), WEPP was used to predict long-term erosion for a 20m high linear batter with a gradient of 16°. The results are shown in Figure 3.

[1] Sediment size distribution curves are not available for the F2 4G material that was tested in 2014.

[2] Particle size distribution curves are not available for the F2 4G material that was tested in 2014.

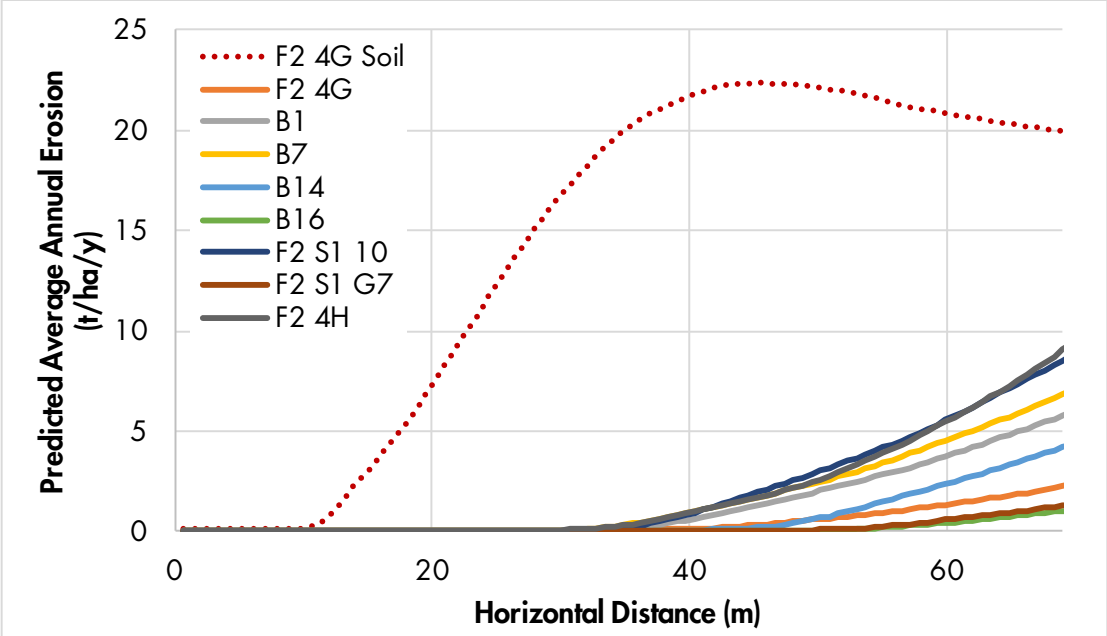


Figure 3: WEPP-predicted average annual erosion for 8 soil/rock mixes and a soil not mixed with rock. Predictions are for a 20m high linear batter with gradient of 16°.

Erosion of the soil (F2 4G Soil) was initiated at very short slope lengths (~15m) compared to the soil/rock mixes (~35m). The mean average annual erosion for the soil was 14t/ha/y, compared to values ranging from 0.2-2.0t/ha/y for the soil/rock mixes.

The soil has a different erosion pattern down the slope, reaching a maximum erosion value, and then maintaining relatively constant erosion for the remainder of the slope. Erosion for this slope is strongly controlled by the ability of the surface runoff to transport the detached material. In contrast, erosion for the soil/rock mixes is strongly controlled by the detachability of material from the surface. This finding is consistent with materials that have relatively high critical shear and low rill detachment values (Table 3).

Erosion potential of the soil/rock mixes does vary from material to material, though overall, the predicted rates are low. The different predicted erosion potentials are strongly controlled by the critical shear of the material, and to some extent the rill erodibility (rill erodibility will become more important as slope length increases). Critical shear in turn is controlled by the rockiness of the surface, and in particular the percent rock cover and the size distribution of the rock.

In summary:

- Soil/rock mixes are more erosion resistant than soil without any addition of durable waste rock.
- All soil/rock mixes are predicted to erode with a similar pattern, becoming increasingly prone to erosion as slope length increases. In contrast the erosion of the soil from the batter occurs relatively uniformly over a lot of the slope.
- Critical shear is a strong predictor of erosion potential, with higher critical shear values leading to lower erosion potential.
- Critical shear is related to the rockiness of the surface. This rockiness is described by both the percent rock cover, and the size distribution of the rocks in the rain-armoured surface.

4.2 Linear batter slopes

The WEPP modelling results for linear batters are presented in Table 6 (Class A materials) and Table 7 (Class B materials). Cells shaded green indicate combinations of dump height and gradient that achieve acceptably low erosion potential. Cells shaded orange have combinations of dump height, gradient, and cover that do not achieve acceptably low erosion potential.

Table 6: WEPP-predicted erosion rates for a range of batter heights and gradients for each Class A material mixed with fresh rock.

Linear Batter Height (m)	Linear Batter Gradient (°)	Slope Length (m)	WEPP-Predicted Mean and Peak Average Annual Erosion (t/ha/y) for These Material Mixed With Fresh Rock:					
			B1 (Class A)		B7 (Class A)		B14 (Class A)	
			Mean	Peak	Mean	Peak	Mean	Peak
10	12	48	0.1	0.6	0.1	0.9	0.1	0.1
10	15	39	0.2	1.0	0.2	1.4	0.1	0.1
10	16	36	0.2	1.1	0.3	1.5	0.1	0.3
10	18	32	0.2	1.3	0.3	1.7	0.1	0.3
20	12	96	0.8	4.0	1.1	4.7	0.4	2.3
20	15	77	1.2	5.6	1.5	6.6	0.7	4.0
20	16	73	1.4	6.0	1.7	7.1	0.8	4.4
20	18	65	1.6	6.9	1.9	7.9	0.9	5.1
30	12	144	1.9	7.2	2.3	8.5	1.3	6.7
30	15	116	2.7	10	3.2	12	2.1	9.8
30	16	109	3.0	11	3.6	13	2.4	11
30	18	97	3.6	13	4.2	15	2.8	13

Linear Batter Height (m)	Linear Batter Gradient (°)	Slope Length (m)	WEPP-Predicted Mean and Peak Average Annual Erosion (t/ha/y) for These Material Mixed With Fresh Rock:					
			B16 (Class A)		F2 S1 10 (Class A)		F2 S1 G7 (Class A)	
			Mean	Peak	Mean	Peak	Mean	Peak
10	12	48	0.1	0.1	0.1	0.9	0.1	0.1
10	15	39	0.1	0.1	0.2	1.5	0.1	0.1
10	16	36	0.1	0.1	0.2	1.7	0.1	0.1
10	18	32	0.1	0.1	0.3	1.9	0.1	0.1
20	12	96	0.1	0.6	1.2	5.8	0.1	0.7
20	15	77	0.1	1.0	1.8	8.2	0.2	1.2
20	16	73	0.2	1.1	2.0	8.8	0.2	1.4
20	18	65	0.2	1.3	2.3	10	0.3	1.6
30	12	144	0.3	1.8	2.7	10	0.4	2.3
30	15	109	0.5	2.5	4.0	15	0.6	3.4
30	16	116	0.6	2.8	4.4	17	0.8	3.9
30	18	97	0.7	3.2	5.2	19	0.9	4.5

Table 7: WEPP-predicted erosion rates for a range of batter heights and gradients for each Class B material mixed with fresh rock.

Linear Batter Height (m)	Linear Batter Gradient (°)	Slope Length (m)	WEPP-Predicted Mean and Peak Average Annual Erosion (t/ha/y) for These Material Mixed With Fresh Rock:			
			F2 4H (Class B)		F2 4G (Class B)	
			Mean	Peak	Mean	Peak
10	12	48	0.1	0.9	0.1	0.1
10	15	39	0.2	1.3	0.1	0.3
10	16	36	0.2	1.4	0.1	0.3
10	18	32	0.3	1.6	0.1	0.4
20	12	96	1.2	6.2	0.3	1.5
20	15	77	1.8	8.9	0.5	2.2
20	16	73	2.0	9.4	0.5	2.4
20	18	65	2.3	10	0.6	2.7
30	12	144	3.1	14	0.8	3.5
30	15	116	4.6	19	1.2	5.1
30	16	109	5.1	21	1.3	6.0
30	18	97	5.8	23	1.5	6.6

The values shown are WEPP-predicted mean and peak average annual erosion rates. The difference between these two values are described diagrammatically in Figure 4. The mean average annual erosion rate is equal to the average long-term erosion that occurs over the entire batter slope. The peak average annual erosion rate is equal to the maximum long-term erosion rate predicted on the test batter slope.

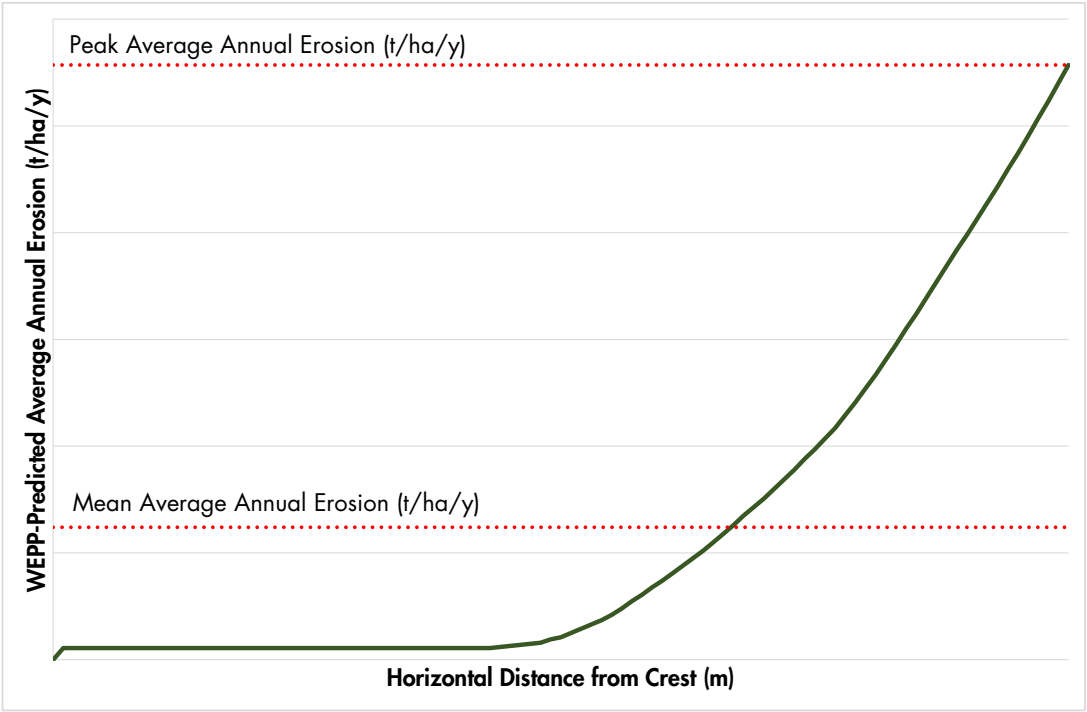


Figure 4: Diagrammatic representation of key erosion values.

5 DISCUSSION

5.1 Suitable batter configurations

Batter heights of 30m are only acceptably stable (for all gradients considered) in three of the eight materials assessed. Batter heights of 20m are acceptably stable in all eight of the materials assessed. Therefore, use of linear profiles up to 20m high is considered achievable at KCGM where gradients are between 12 and 18 degrees.

Rehabilitation of taller batter slopes would require the adoption of a more complex slope configuration. This may include use of concave shapes, or the use of 'rocky bands' strategically placed on the surface to increase erosion resistance and reduce erosion potential.

5.2 Other considerations

It is important to note that the adoption of a soil/rock mixture as the surface layer is necessary not only for erosional stability of the rehabilitated surface. It is also a key component to minimising the risk of erosion of the underlying tailings at the interface between the tailings and the cover layer and the capillary rise of salts from the underlying tailings (Landloch 2015).

5.3 Concave profiles

Given that low erosion rates were predicted for the soil/rock mixes, development of concave profiles as a means of reducing erosion was not necessary. Application of concave slopes to batters sheeted in soil will be of limited value due to the low critical shear value and very high detachment value (Table 4) for the soil.

5.4 Key landform requirements

For the batter profiles provided to be stable and sustainable, it will be critical to retain runoff on the top of the TSF. Discharge of concentrated flows from the top of TSF onto the outer batter slopes is a very common cause of gullying and landform failure. The risk of uncontrolled discharge of surface water from the dump top can be managed by:

- Installing appropriate crest bunding,
- Installing appropriate cross-bunding; and
- Increasing the infiltration capacity and water use of vegetation on the dump top.

Uncontrolled discharge of runoff from the tops of landforms is a major cause of gullying on the outer batter slopes. The perimeter bunds should be:

- Engineered to be able to store at least a 1 in 1,000-year rainfall event;
- Thoroughly compacted and constructed of stable (non-dispersive) material;
- Have their outer face continuous with the outer batter profile and have the same surface treatments applied to it;
- Have a width across the top of the bund of at least 2m; and
- Have their inner face sloping gradually inwards at a gradient of 1V:10H.

The gentle inward gradient ensures that any water that ponds will be ponded well away from the outer batter slope, thereby minimising the potential for any sink-hole that may form to reach the outer batter slope and create an "instant gully".

It is critical to ensure that any runoff generated on the top of a constructed landform does not travel significant distances to create zones where water can pond at significant depth. Cross-bunding should be used to prevent surface water flow concentrations on the flat areas of the waste dump top. These should be constructed such that:

- compacted bunds are 0.5m high – 1m wide across the top – to create cells of 1-3 ha in area on the top of the landform;
- the land surface within each cell is as close to level as possible; and
- surface ripping will hold rainfall excess close to its point of origin. For dump tops, greater depths of rip lines (and heights of mounds between them) can be tolerated, as there is not the concern of rip lines increasing the distance between rill lines or rip lines ponding excess water and causing batter failure.

5.5 Key surface material properties

The WEPP modelling results indicate all soils produce similar erosion potential when mixed with fresh run of mine waste. The usefulness of adding rock for erosion control is a function of the rock size distribution. Larger-sized rocks tend to increase runoff but reduce erosion at higher rock contents. However, as rock content decreases and the spaces between the rock increases, erosion potential can increase. Rocks should not all be the same size, and the size distribution should be well graded. For KCGM, mean rock diameters should be approximately 50mm or greater. As a general rule, a suitable rocky material would have no more than 10% of rock by weight with diameters exceeding 200mm, and only 10-20% of the rock with median rock diameters less than 20mm. The rain-armoured surface created should have a rock cover percentage greater than ~30%. The run of mine waste should be durable, not prone to weathering, and benign (i.e. not potentially acid forming or able to generate metalliferous drainage)

Given the lower erosion risk present on the TSF top, topsoil without added waste rock could be considered, provided the risk of capillary rise of salts is managed. If capillary rise of salts is possible, adoption of a rocky capillary break on the TSF top may be required.

5.6 Batter slopes

Batter slopes should be sheeted with a 1:2 soil/rock mix to a thickness of ~750mm. Seeding rates and species selected should seek to encourage rapid establishment of grasses, with fewer shrub and tree species. To achieve long-term stability of batter slopes on this landform, it is critical that flow concentration be minimised. Concentration of overland flow can be prevented by:

a) Minimising the size of cross-slope rip lines; and
b) Ensuring the thorough mixing of the rock into the soil on the batter slopes.

Rip lines should be no deeper than 300mm (from top of rip line to base of rip line once settlement has occurred). Ripping will be desirable to remove compaction and track marks that can lead to erosion. Given the extreme importance of minimising flow concentration on the batter slopes, it will be essential that construction does not create flow-concentrating features. Of particular concern are:

- Rip lines off contour;
- Irregular batter slope shapes; and
- Sharp corners which render ripping on the contour extremely difficult.

If possible, equipment used for rehabilitation works should have precision guidance systems installed. Operators should be highly skilled and experienced. It is noted that rehabilitation earthworks are significantly different to earthworks typically conducted by mining staff, and requires great precision and adherence to the specified designs if successful rehabilitation is to be achieved.

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APPENDIX A: PSD CURVES FOR THE RAIN-ARMOURED SURFACES

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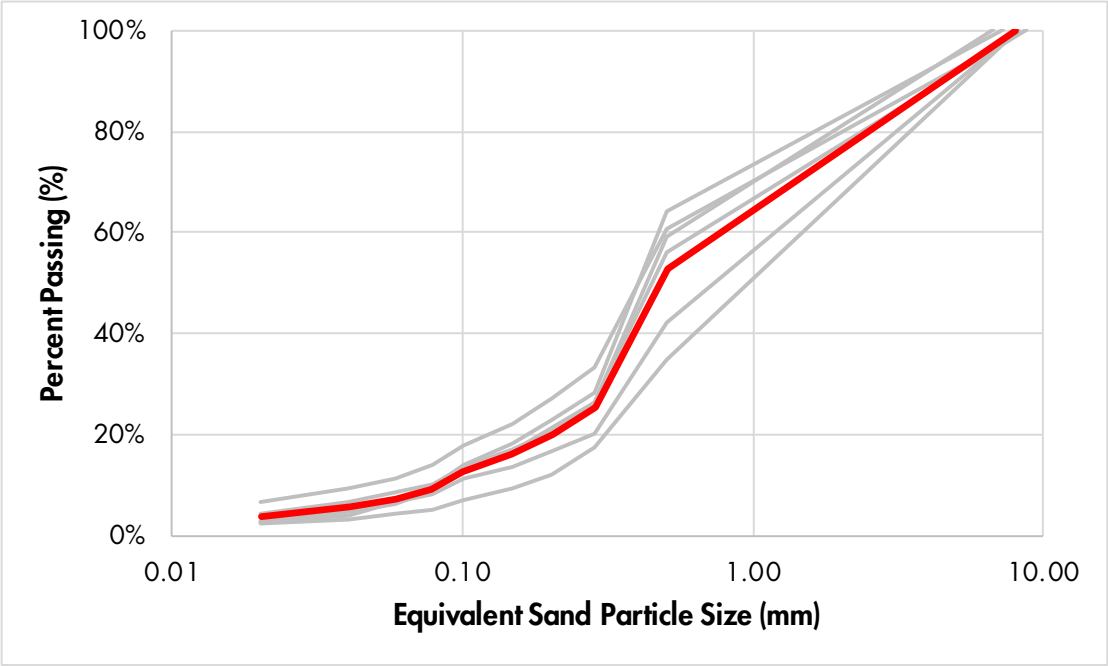


Figure A-1: Equivalent sand PSD curves for the B1 mix. Average line shown in red.

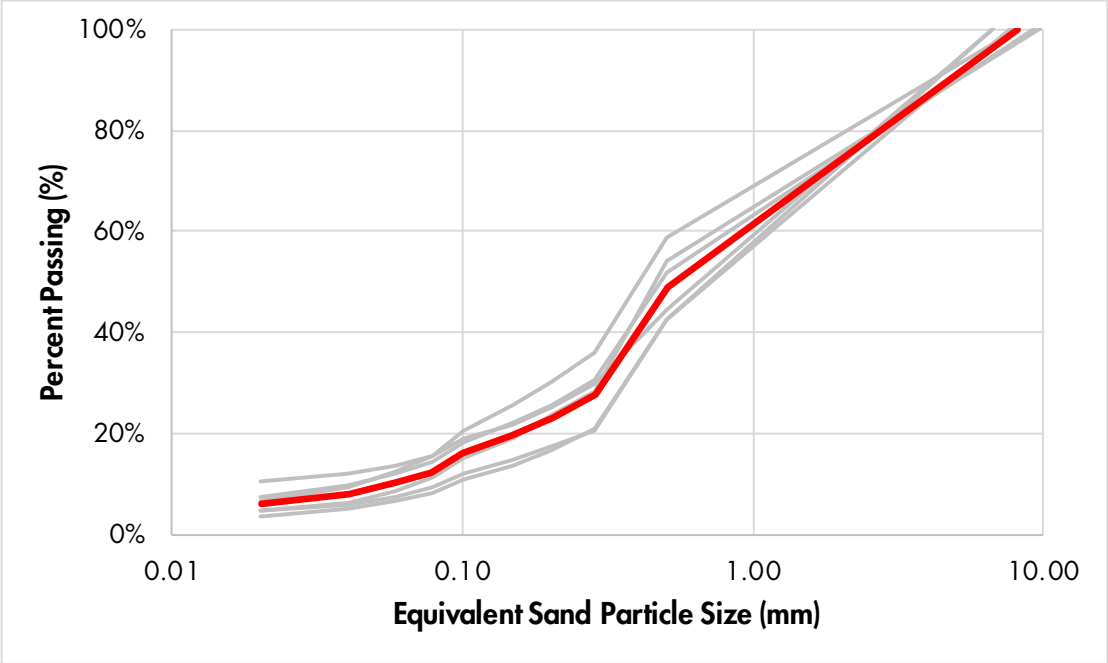


Figure A-2: Equivalent sand PSD curves for the B7 mix. Average line shown in red.

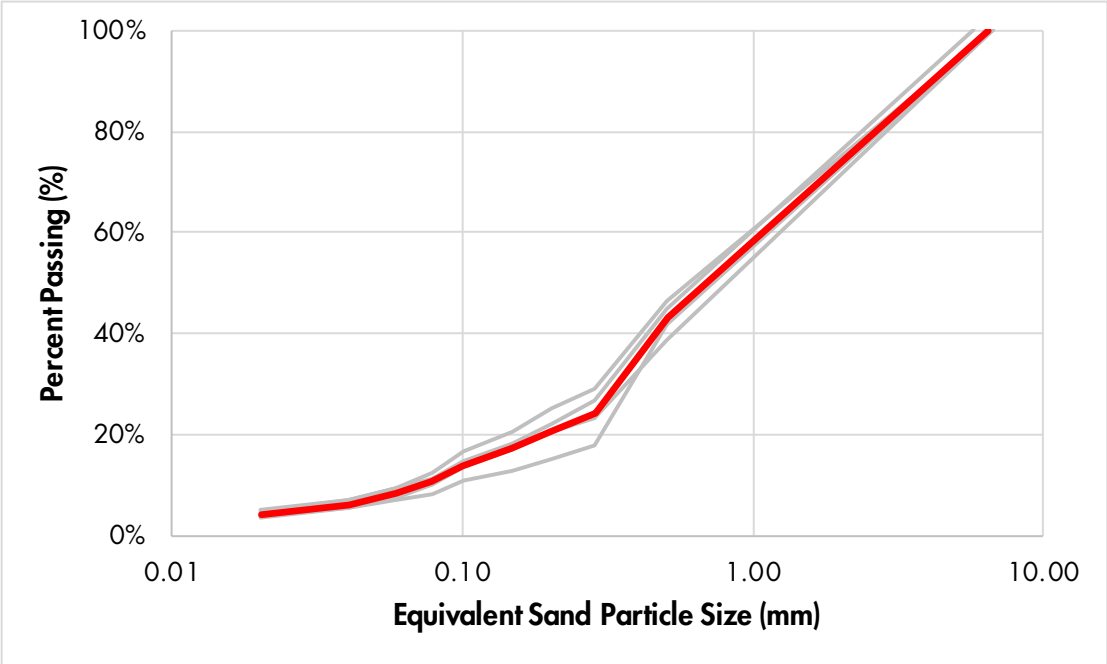


Figure A-3: Equivalent sand PSD curves for the B14 mix. Average line shown in red.

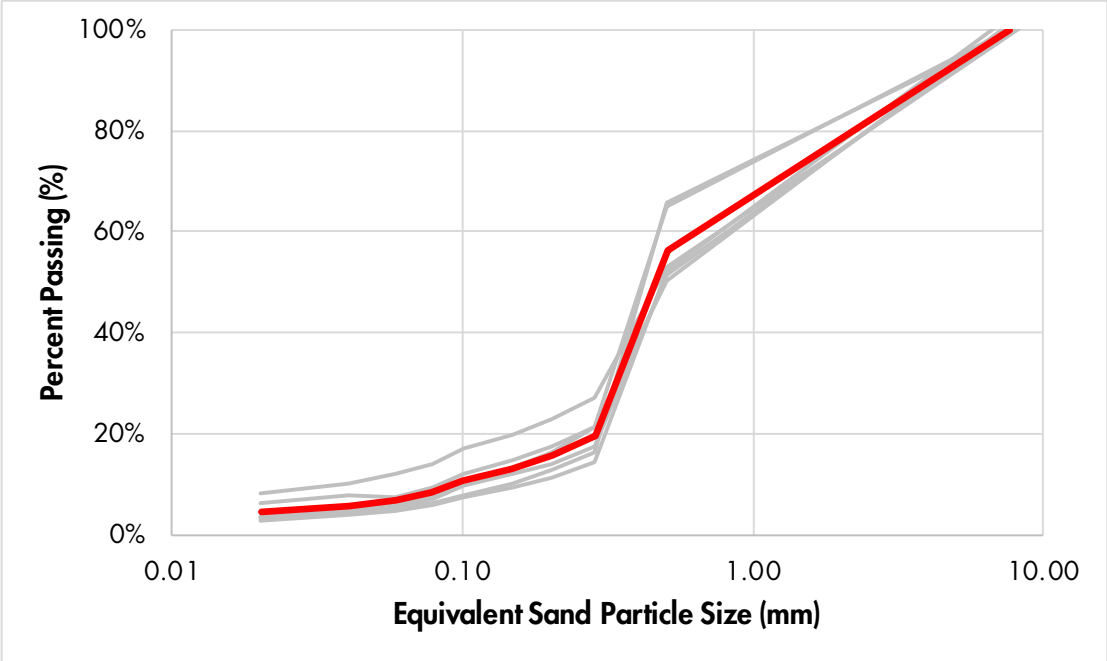


Figure A-4: Equivalent sand PSD curves for the B16 mix. Average line shown in red.

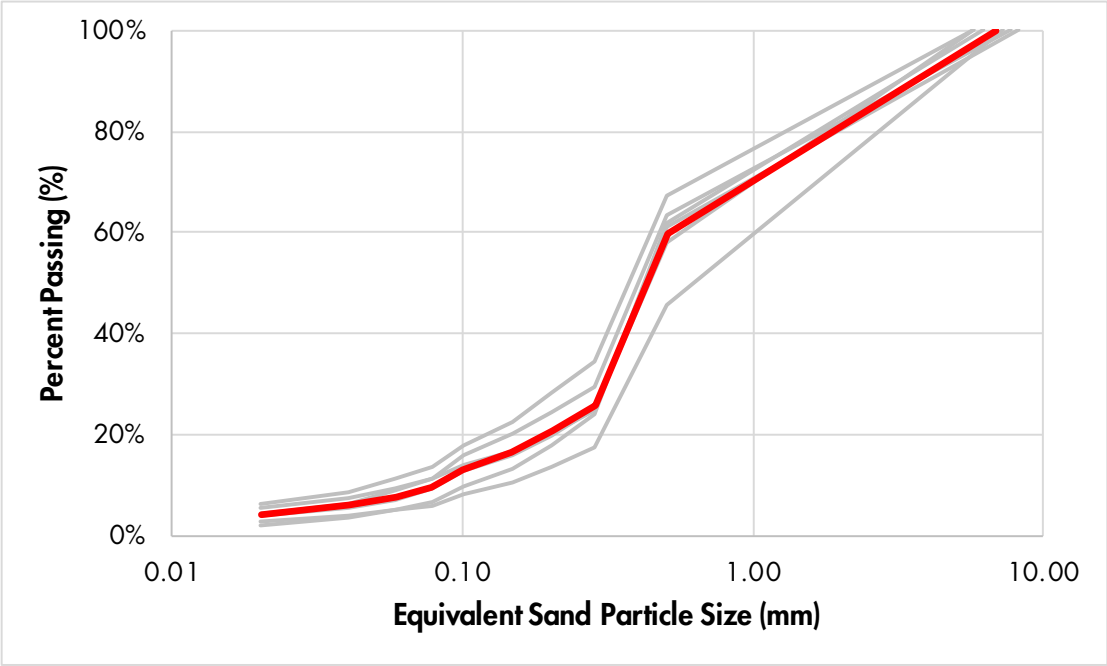


Figure A-5: Equivalent sand PSD curves for the F2 4H mix. Average line shown in red.

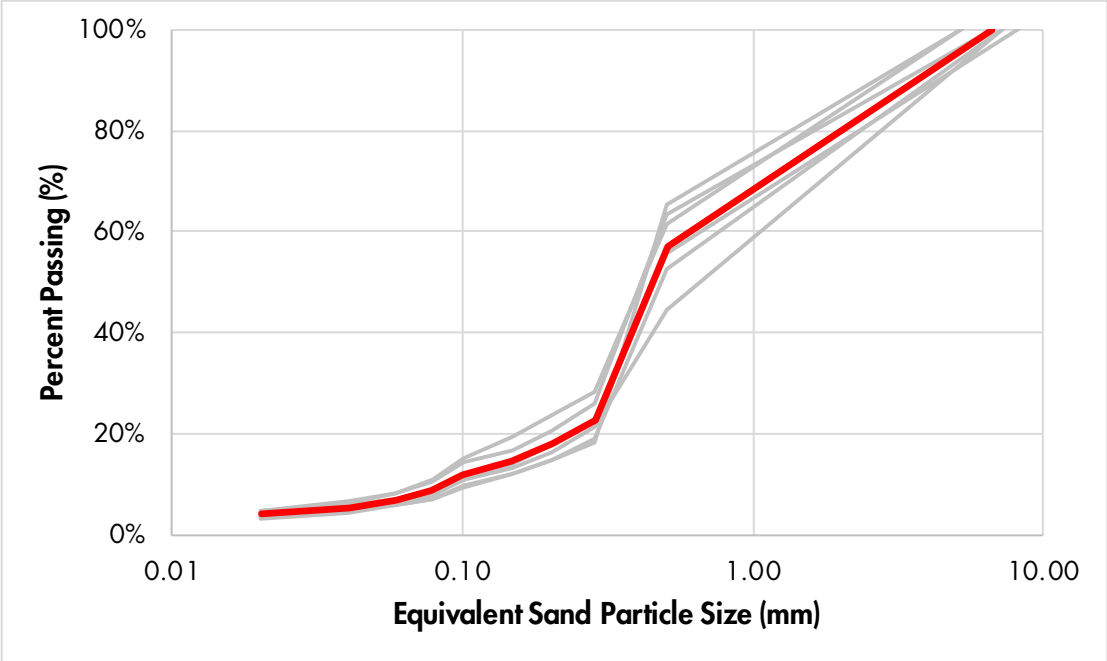


Figure A-6: Equivalent sand PSD curves for the F2 S1 G7 mix. Average line shown in red.

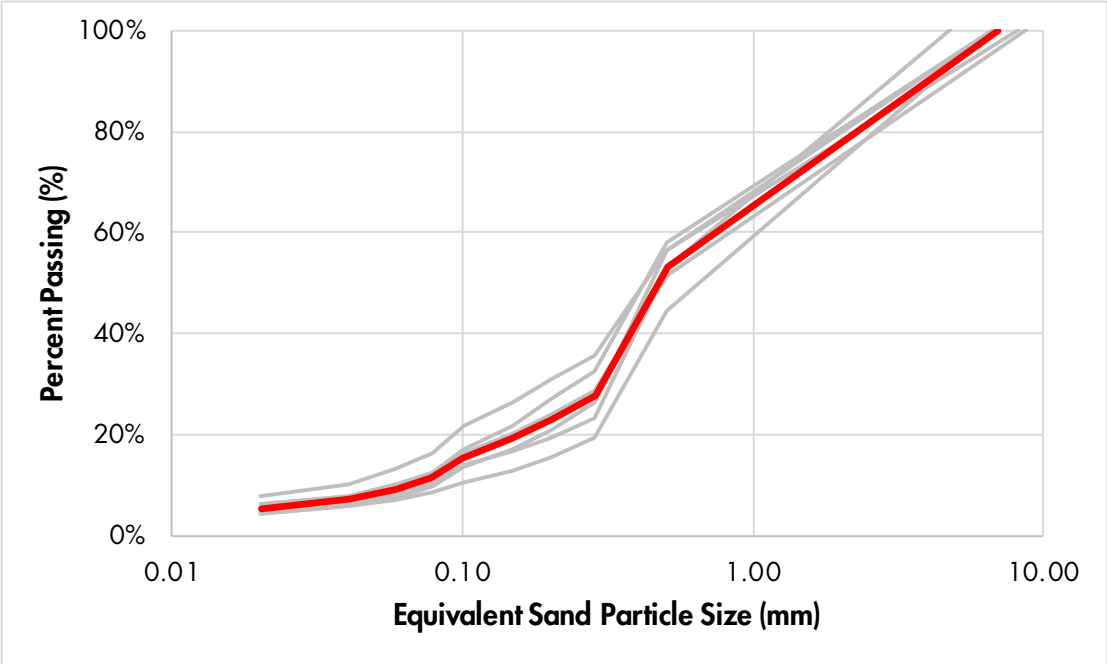


Figure A-7: Equivalent sand PSD curves for the F2 S1 10 mix Average line shown in red.

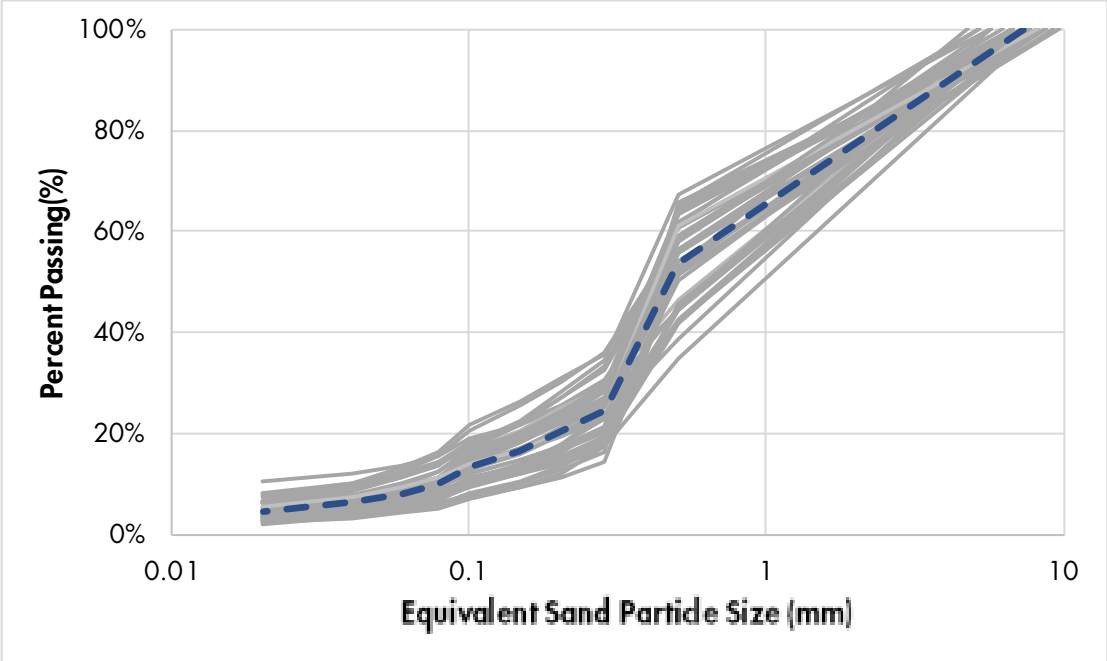


Figure A-8: Equivalent sand PSD curves for all mixes assessed. Average curve shown by blue dotted line.

APPENDIX B: PSD CURVES FOR THE RAIN-ARMOURED SURFACES

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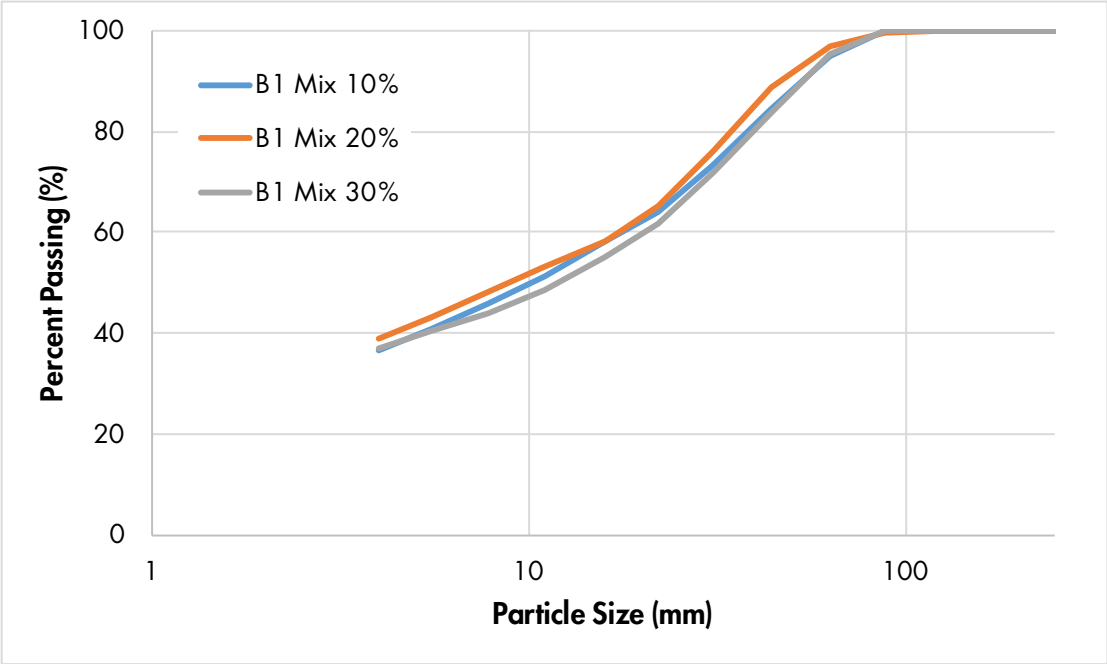


Figure B-1: PSD curves for rain-armoured surfaces, B1 mix

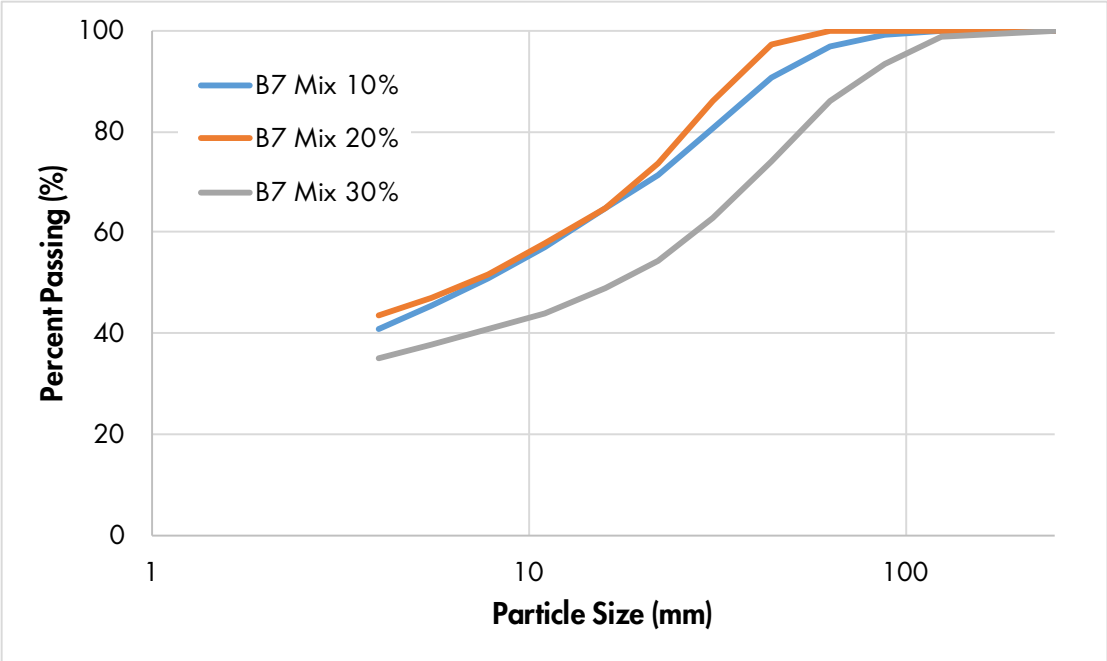


Figure B-2: PSD curves for rain-armoured surfaces, B7 mix

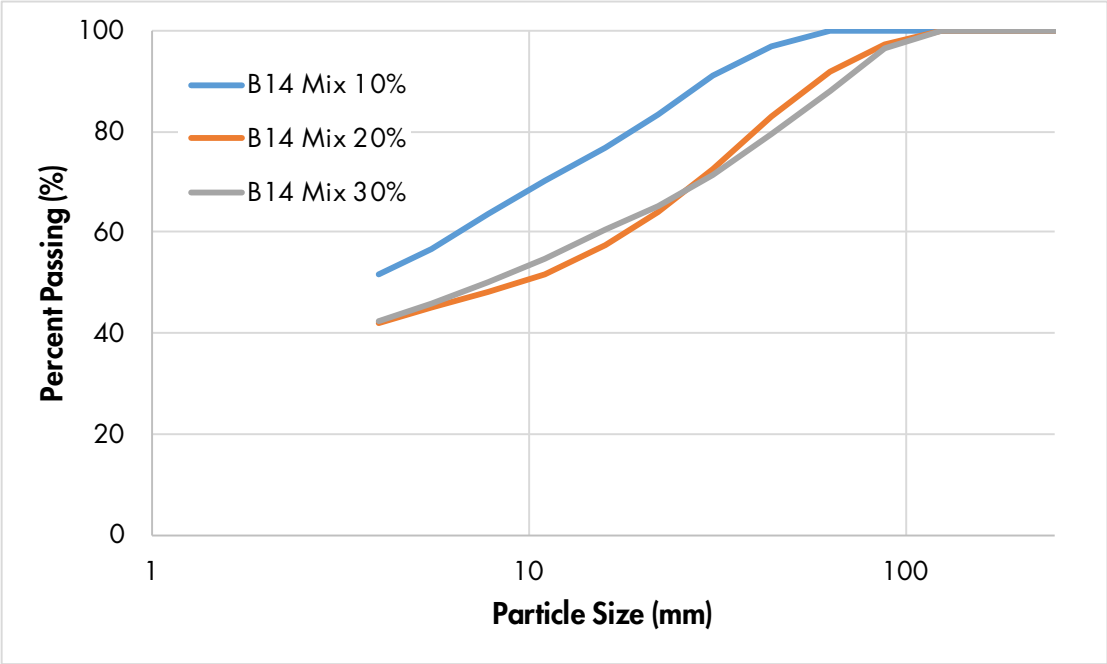


Figure B-3: PSD curves for rain-armoured surfaces, B14 mix

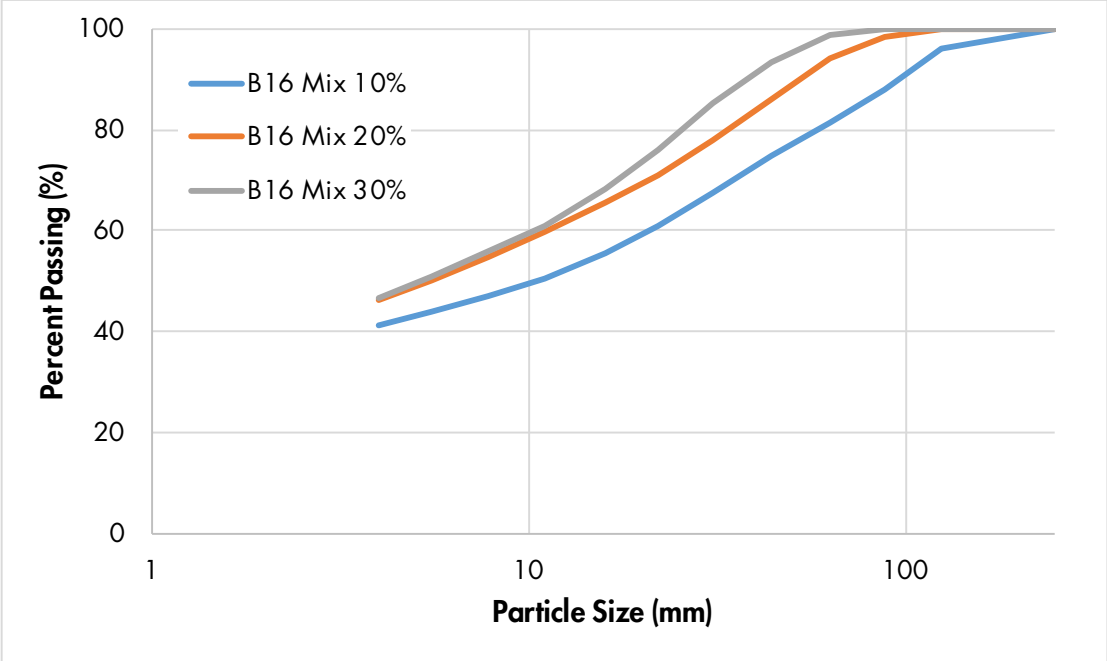


Figure B-4: PSD curves for rain-armoured surfaces, B16 mix

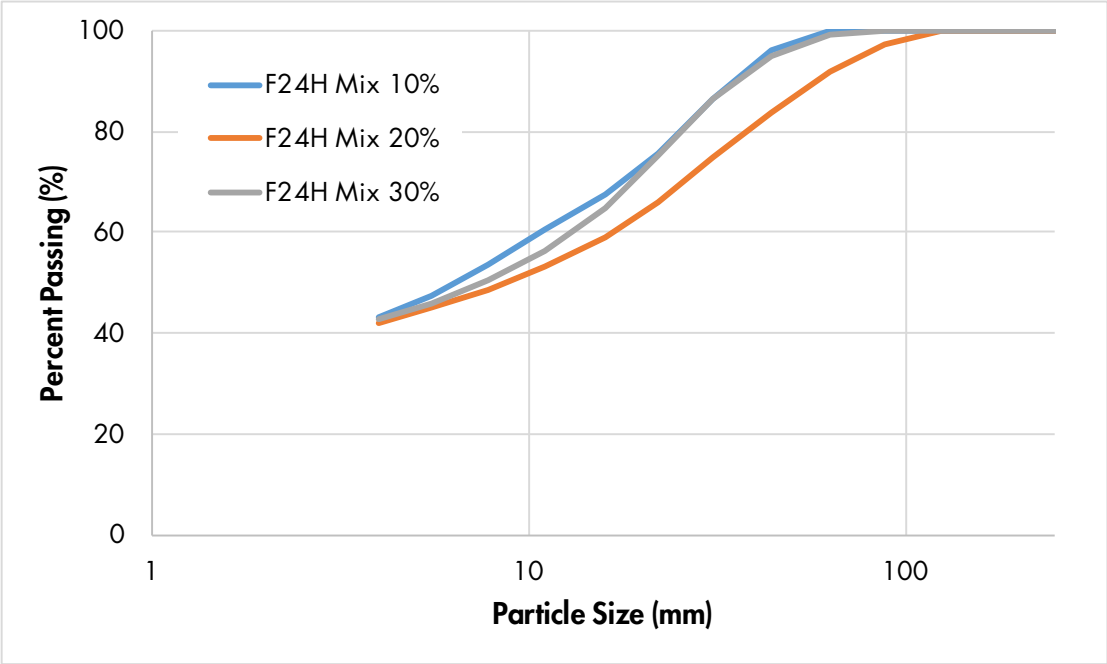


Figure B-5: PSD curves for rain-armoured surfaces, F2 4H mix

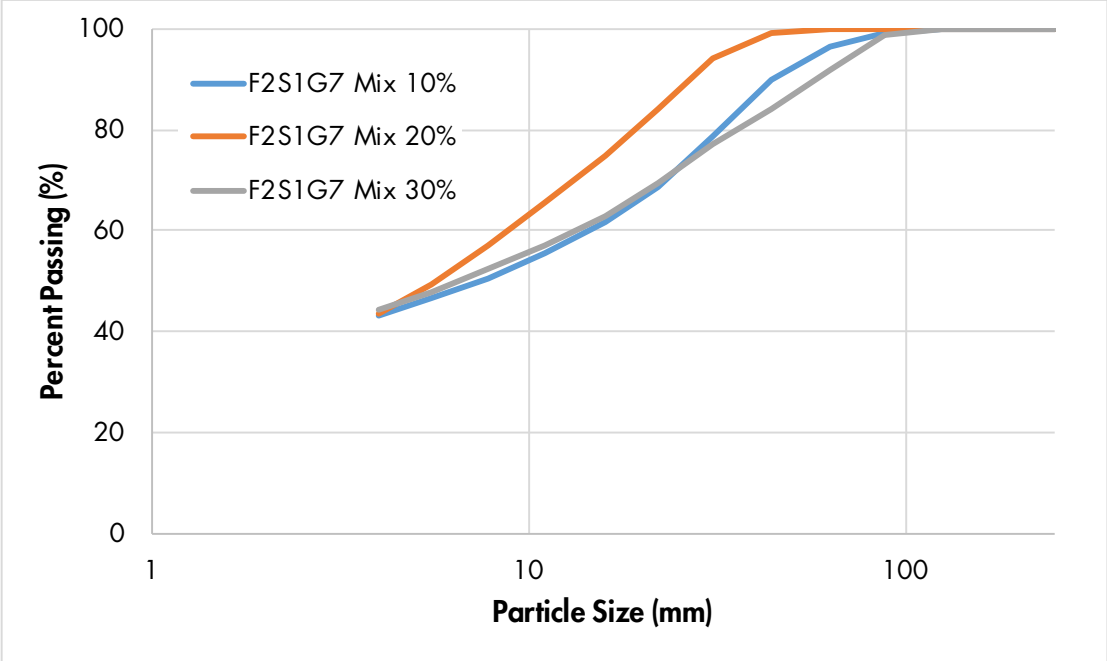


Figure B-6: PSD curves for rain-armoured surfaces, F2 S1 G7 mix

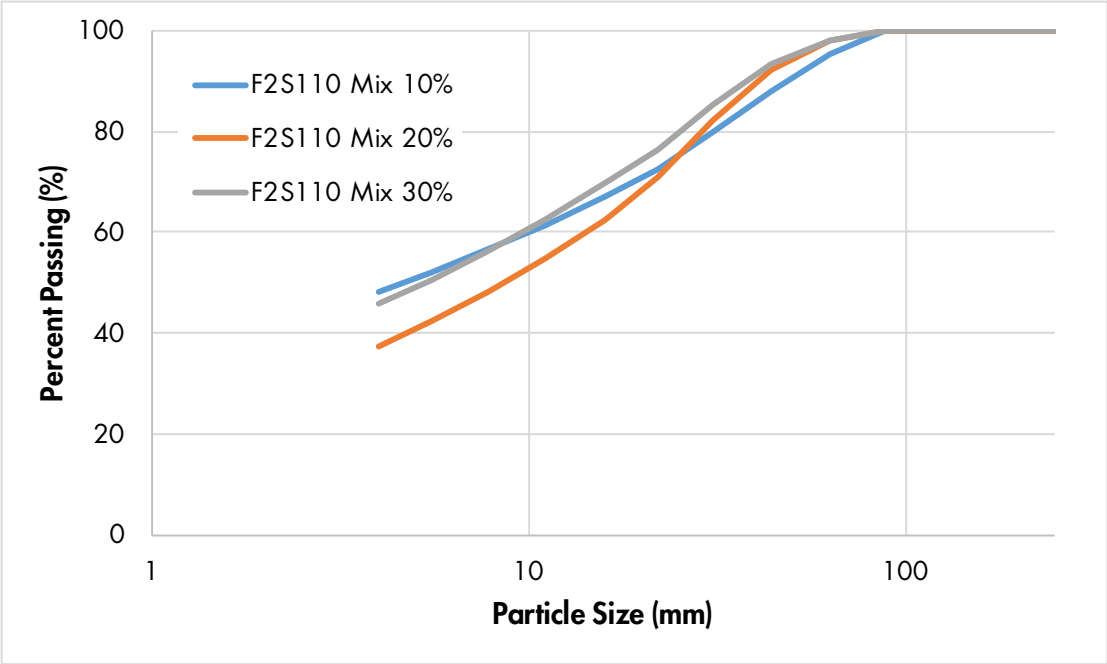


Figure B-7: PSD curves for rain-armoured surfaces, F2 S1 10 mix

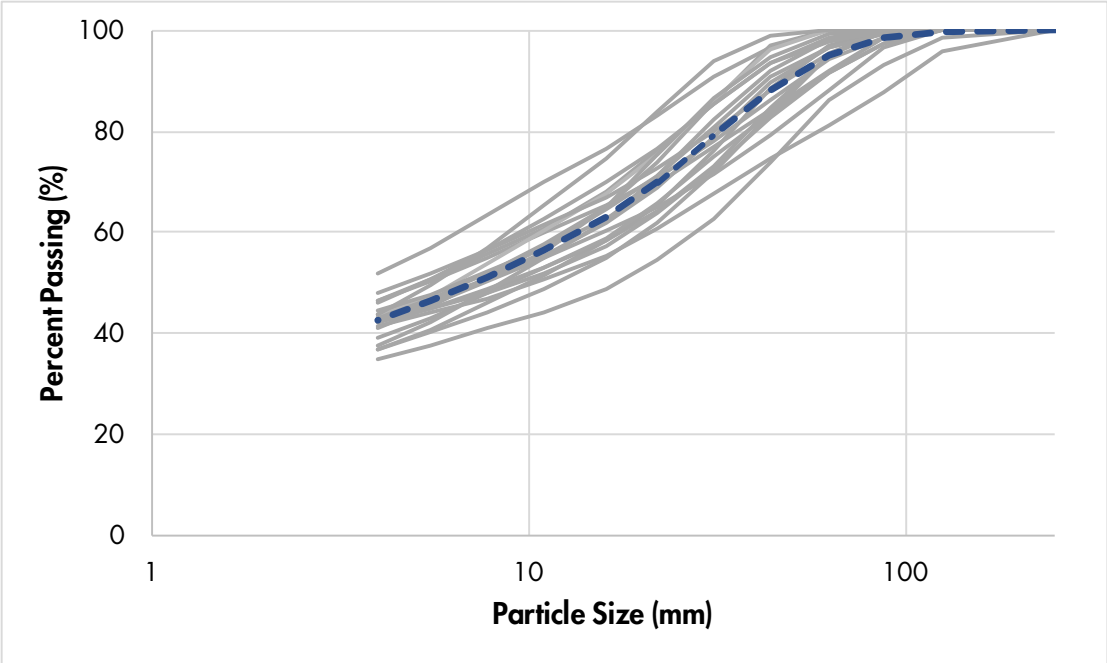


Figure B-8: PSD curves for rain-armoured surfaces, all curves, with average curve shown by blue dotted line.

TOOWOOMBA
PO Box 57 HARLAXTON QLD 4350
Phone 07 4613 1825 | **Fax** 07 4613 1826

PERTH
PO Box 5175 SOUTH LAKE WA 6164
Phone 08 9494 2835 | **Fax** 08 9494 2837

NEWCASTLE
PO Box 7017 REDHEAD NSW 2290
Phone 02 4965 7717 | **Fax** 07 4613 1826

28 May 2018

Kalgoorlie Consolidated Gold Mines
Black Street
Kalgoorlie WA 6430

2088.18a (Rev 2)

Attn: Janine Cameron – Closure Specialist

Memo: Erosion assessment of the Fimiston II TSF slopes

1. Introduction

Landloch has conducted an erosion assessment of 56 lifts from 22 cross sections across the Fimiston II TSF surface. The intent of the assessment is to consider the impact of small variations in surface shape on long-term erosion rates. This work is to guide decisions on whether these existing variations in the surface microtopography should be removed prior to application of the rocky-soil growth media layer over the tailings at closure.

2. Cross sections

The location of the cross sections is shown in Figure 1. Cross sections were not provided on the south-eastern batters because this section of the wall will be reworked as part of the planned TSF extension. Each cross section consists of 2-4 (typically 3) individual lifts that are separated by a small berm. The cross-sections as provided by KCGM were separated into individual lifts, and denoted as 'upper', middle' and 'lower' lifts to mark their position relative to each other for the purposes of modelling. The lift cross sections provided and the individual lifts considered are shown in Figure 2.

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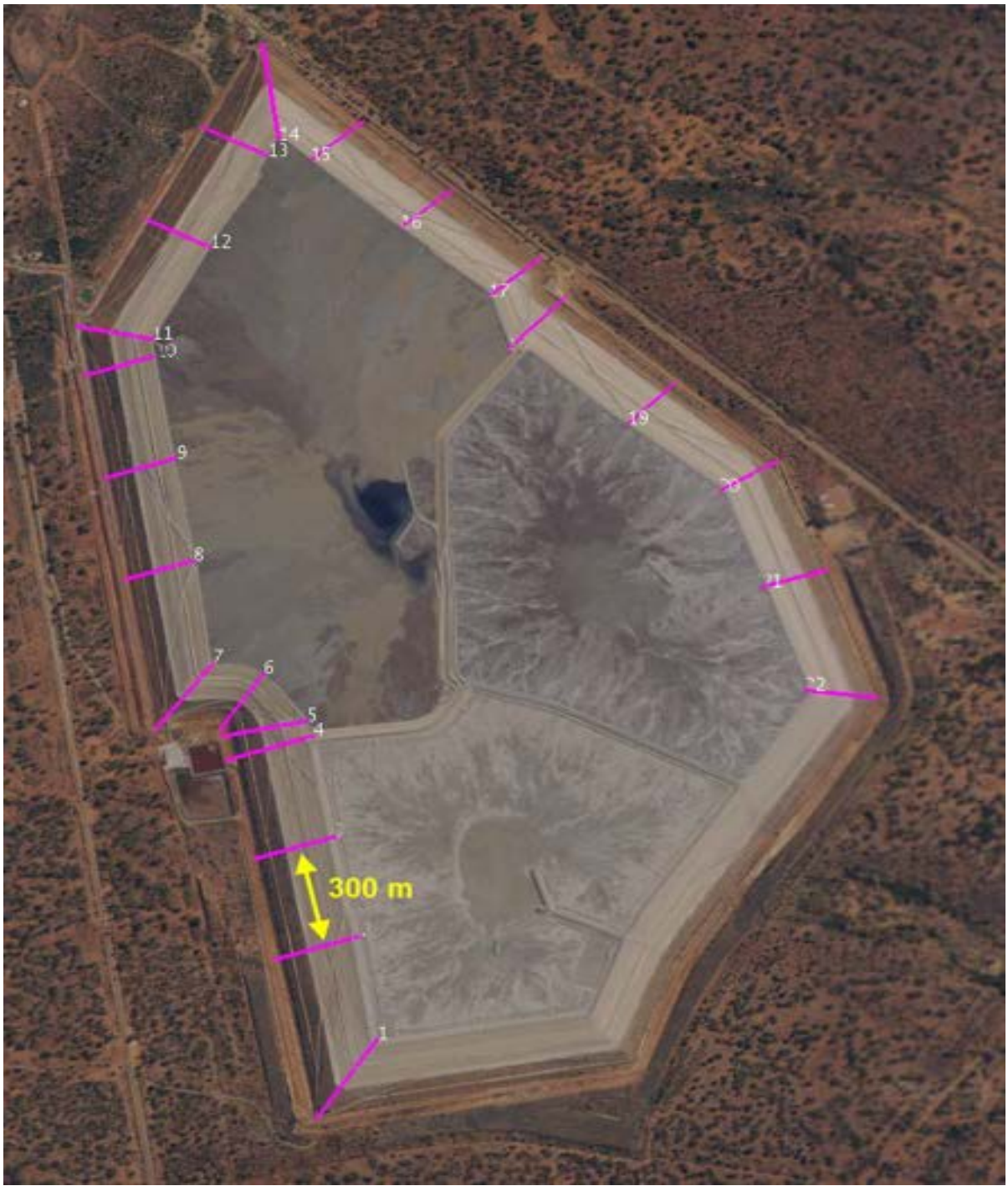
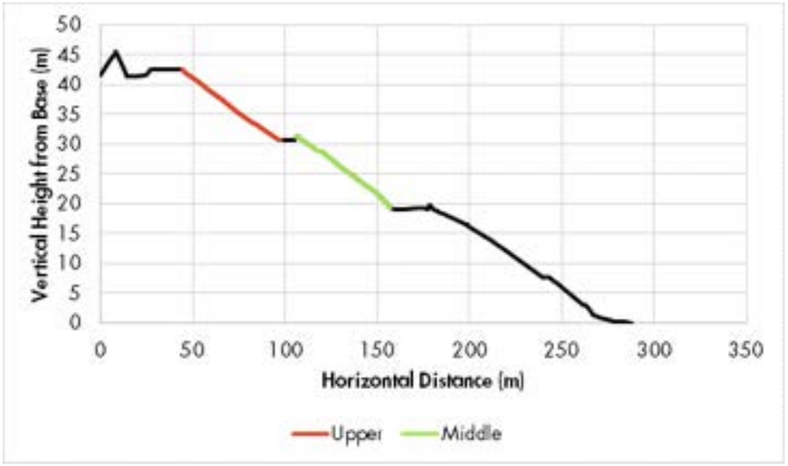
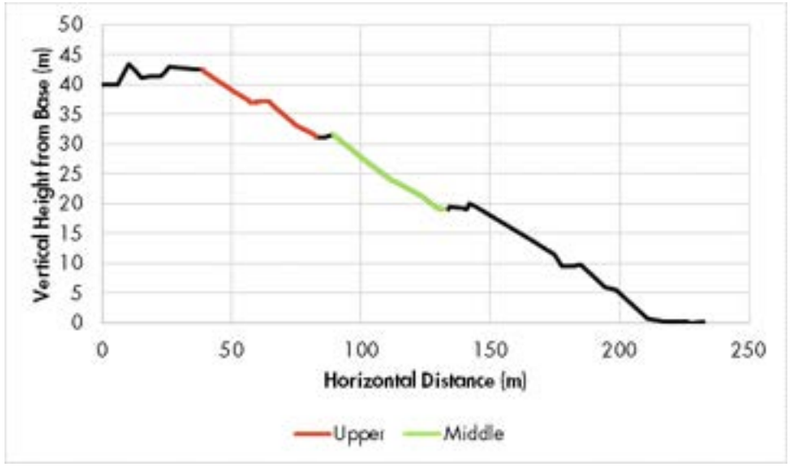


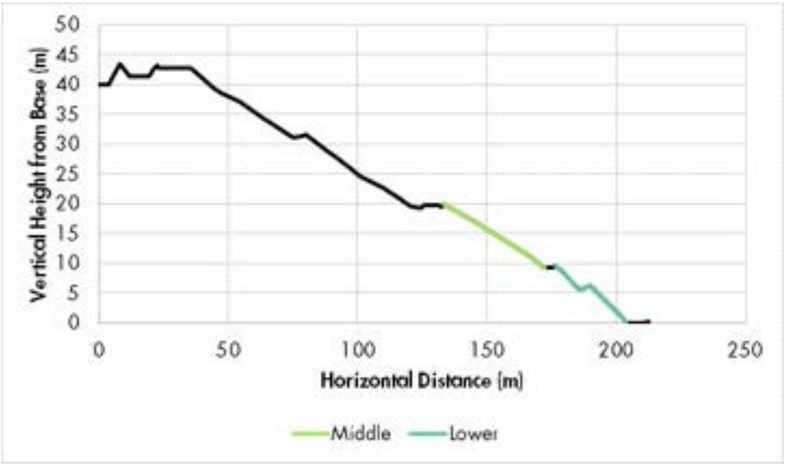
Figure 1: Cross section locations.



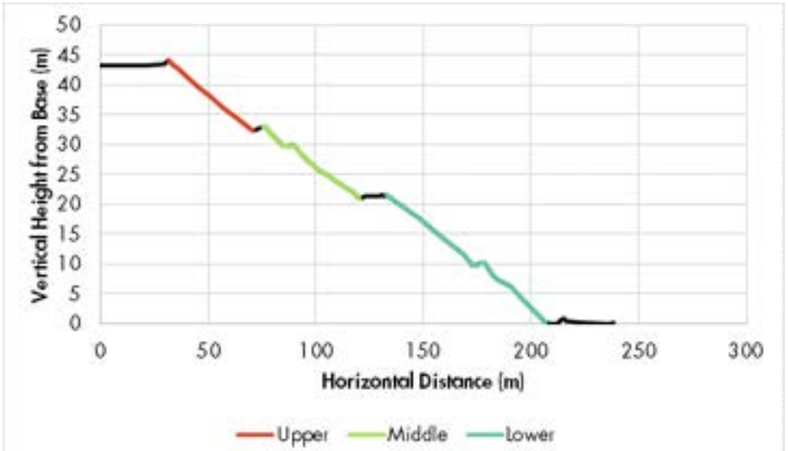
Cross Section 01



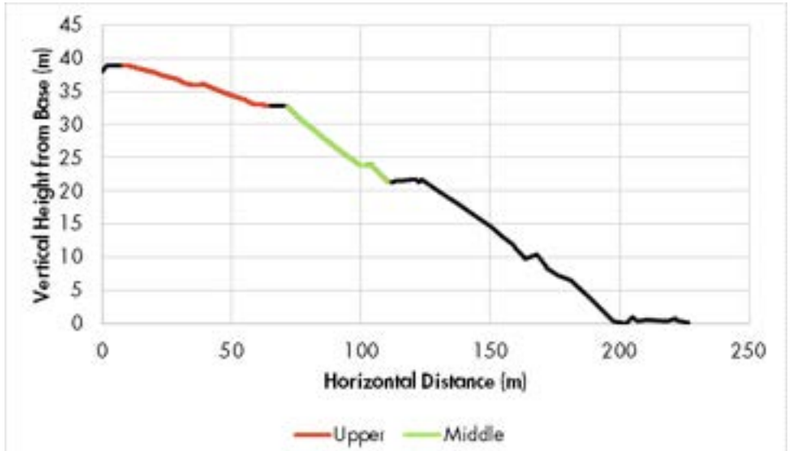
Cross Section 02



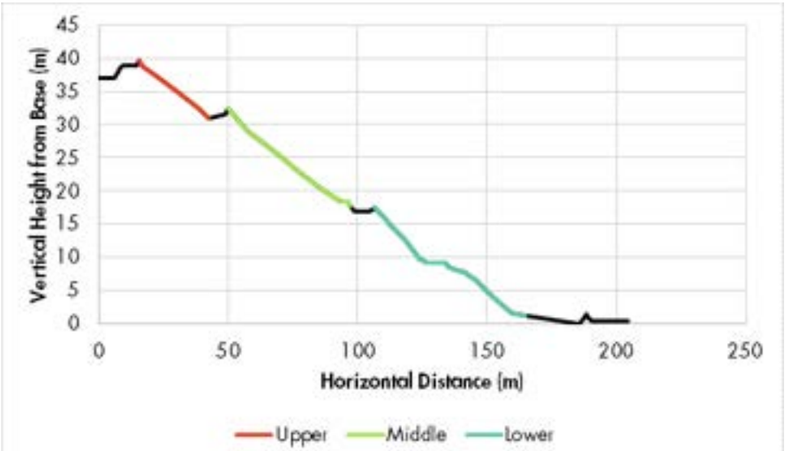
Cross Section 03



Cross Section 04

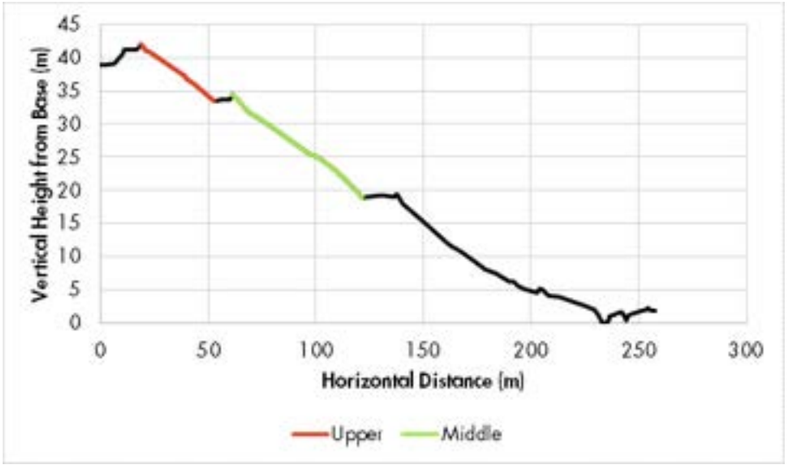


Cross Section 05

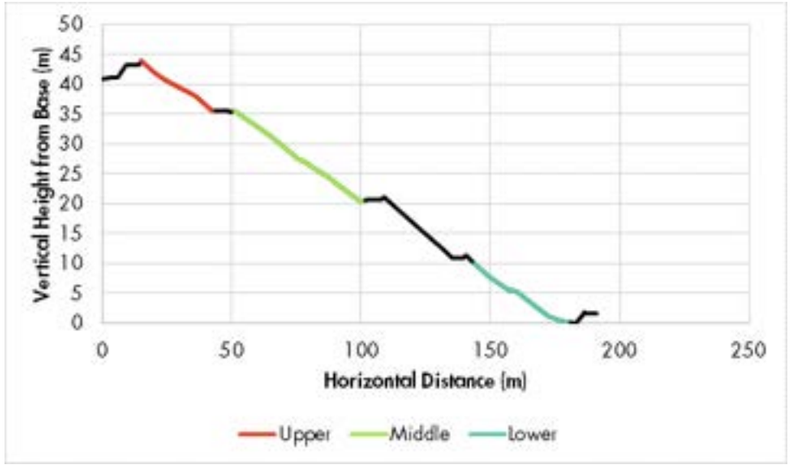


Cross Section 06

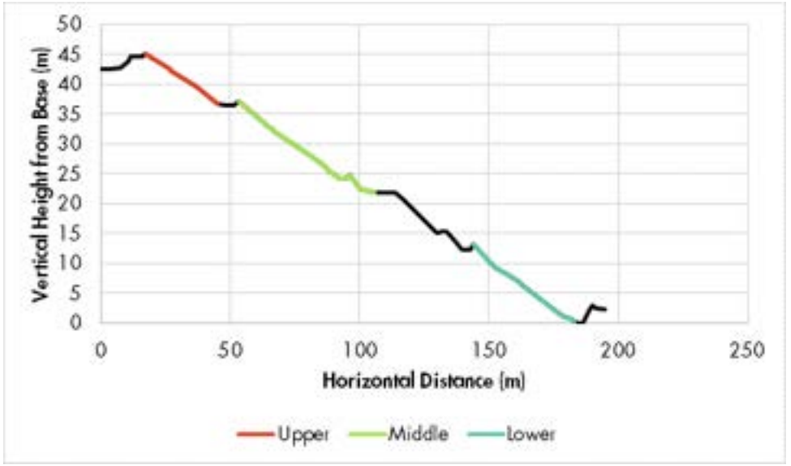
Figure 2: Cross-sections assessed for erosion potential.



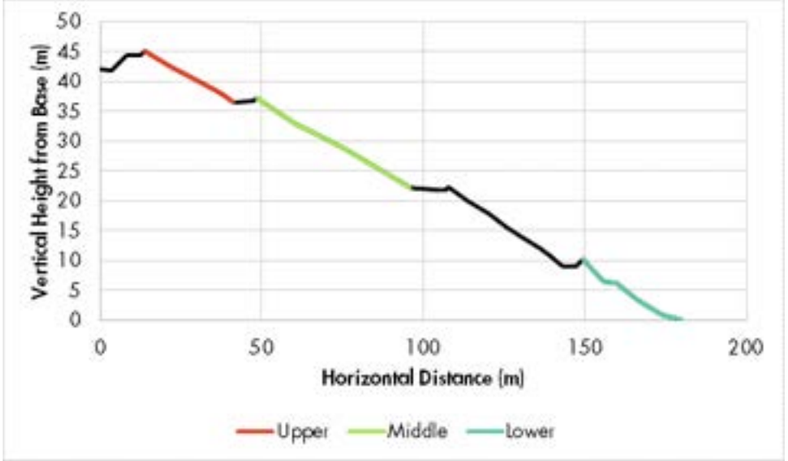
Cross Section 07



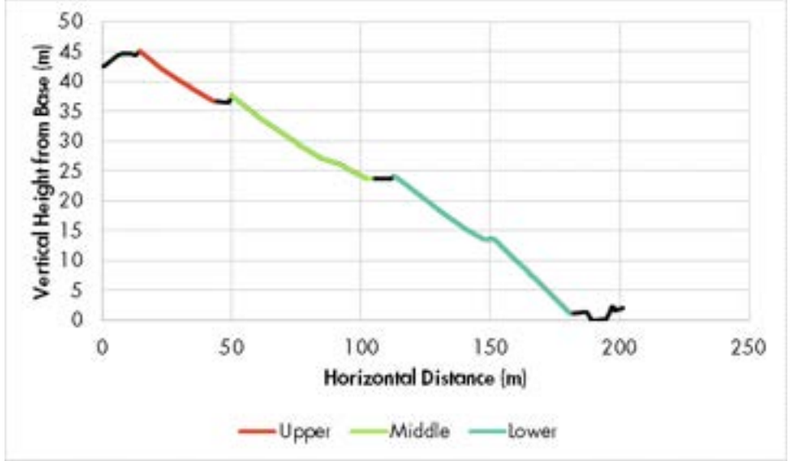
Cross Section 08



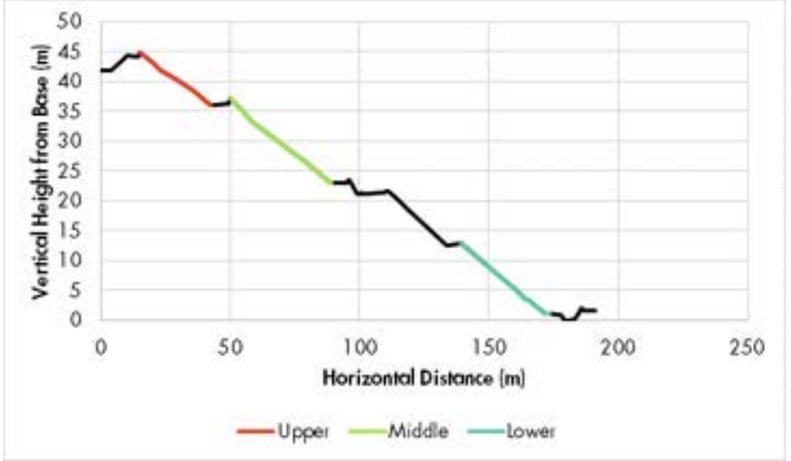
Cross Section 09



Cross Section 10

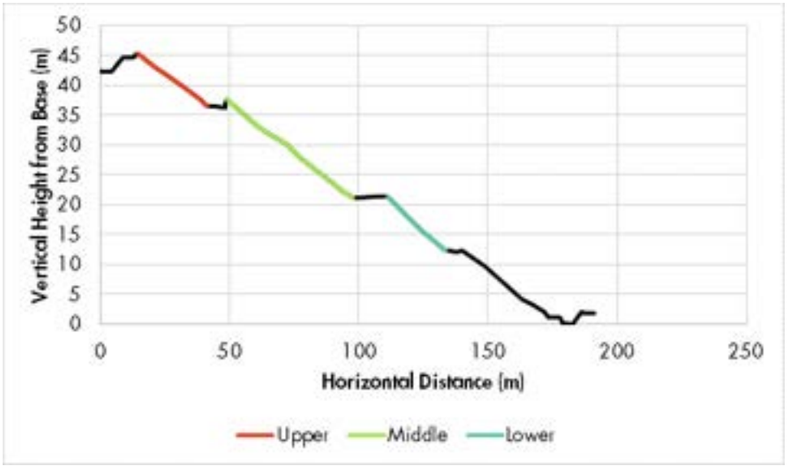


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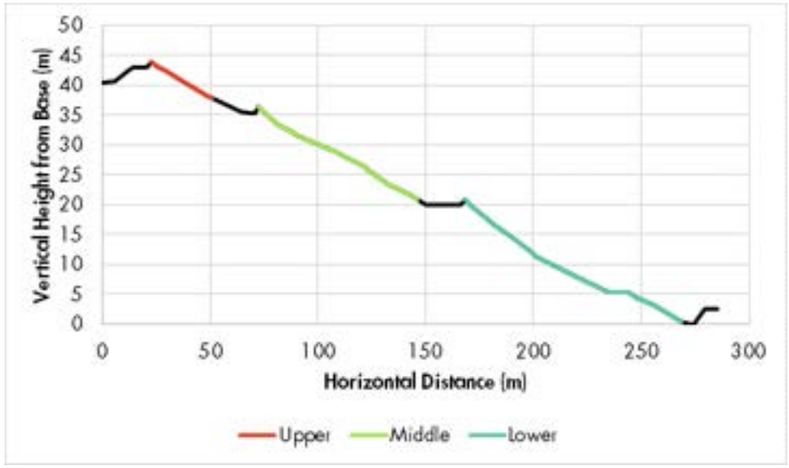


Cross Section 12

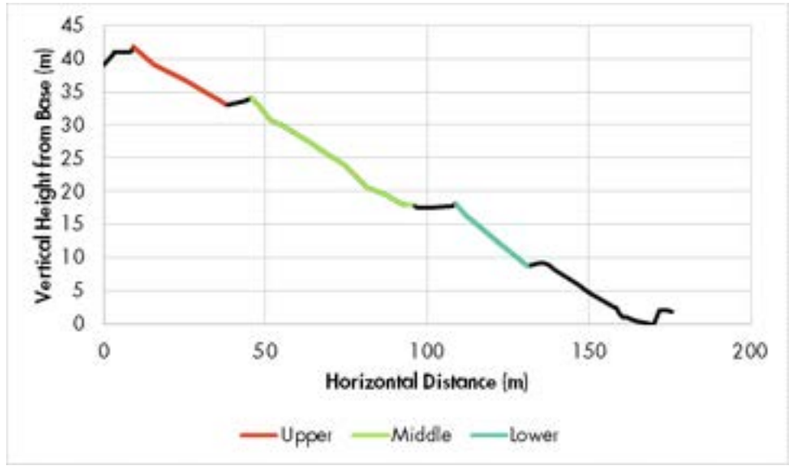
Figure 2 cont'd: Cross-sections assessed for erosion potential.



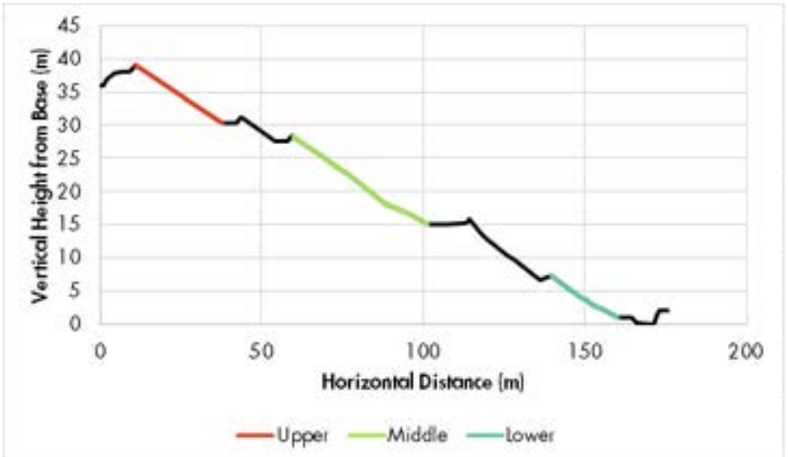
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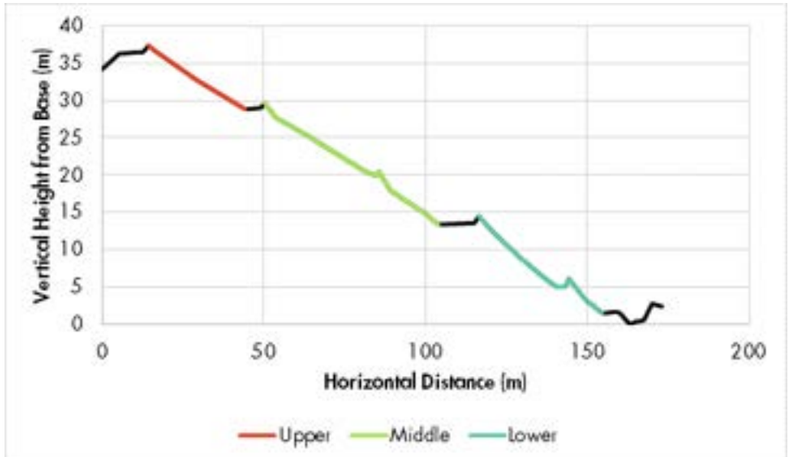
Cross Section 14



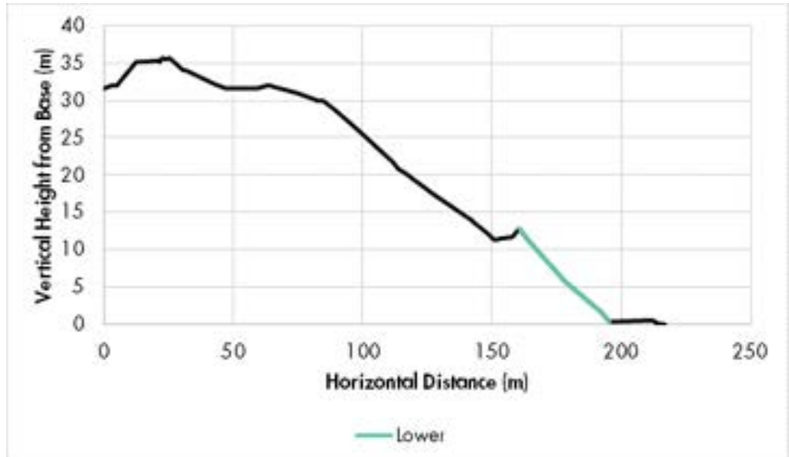
Cross Section 15



Cross Section 16

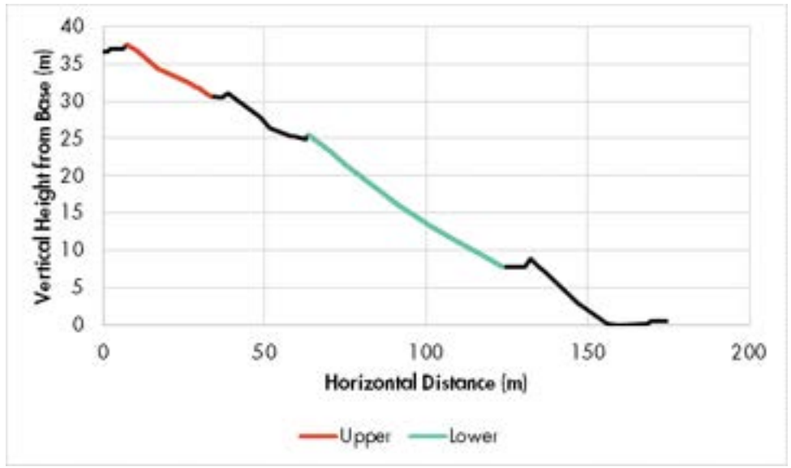


Cross Section 17

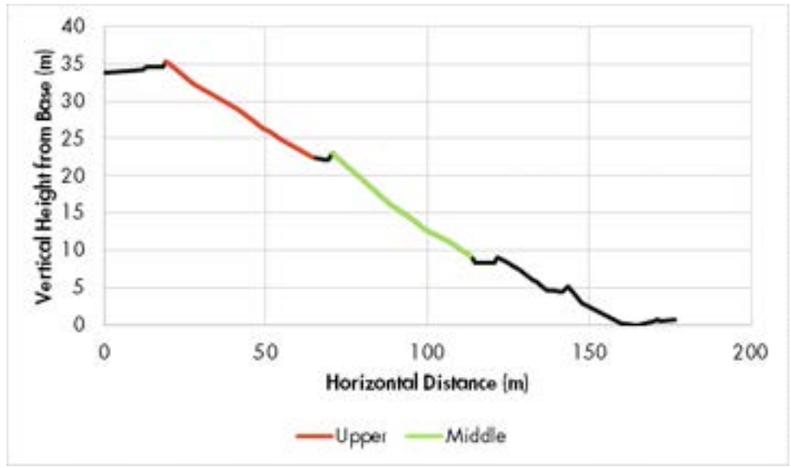


Cross Section 18

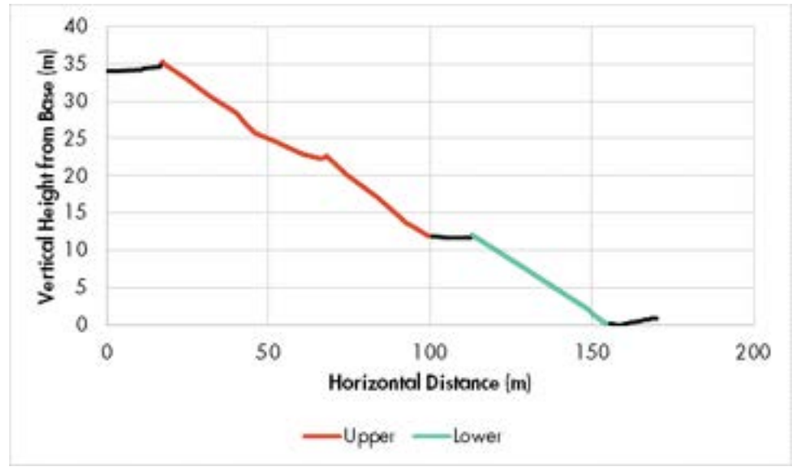
Figure 2 cont'd: Cross-sections assessed for erosion potential.



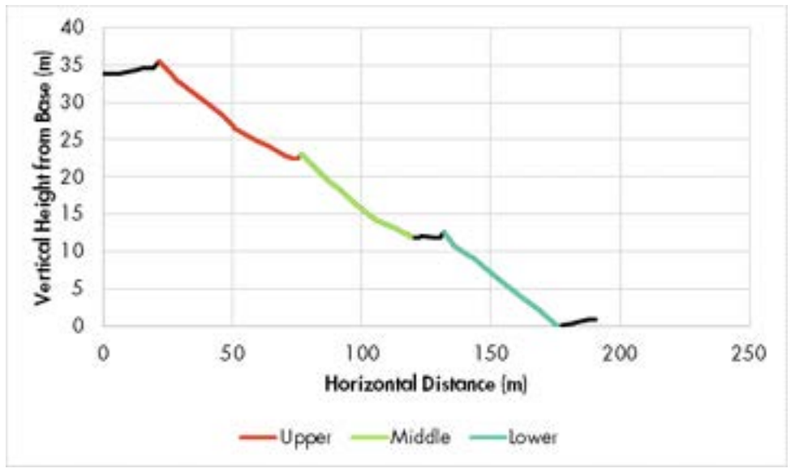
Cross Section 19



Cross Section 20



Cross Section 21



Cross Section 22

Figure 2 cont'd: Cross-sections assessed for erosion potential.

3. Erosion modelling

The erosion assessment used the WEPP runoff and erosion model. The model has been described in detail in previous studies[1]. The model utilised:

- A 100-year climate sequence for Kalgoorlie-Boulder;
- 1:2 soil:rock mixture, with the soil being from the stockpiled soils to the south east of the TSF, and the waste rock being run of mine, fresh, durable dolerite[2]; and
- Cross sections of lifts provided to Landloch by KCGM.

WEPP simulations were conducted on the sections using the following model settings:

a) Rill spacing was set at 2m for the soil/rock mixes;

b) Surface roughness was set at 3cm for all materials, consistent with the value used when calibrating the model runoff predictions using the rainfall simulator infiltration data;

c) No allowance was made for vegetation effects on erosion. This is consistent with observations of cover levels achieved on site; cover levels in the arid zone tend to be too low to effectively contribute to reducing erosion of steep batter slopes;

d) Light cross-slope ripping will be applied to the rehabilitated batter surface; and

e) No allowance was made for water from above the slopes discharging onto the batter slopes and causing increased erosion on the modelled slopes as a result. In essence, the model assumed that each lift was hydraulically disconnected from any upslope lift that may be present.

f) Where berms were present[3], they are reshaped to be outward sloping to model the condition where a berm fails in the long-term.

The WEPP model was run using the cross sections provided to Landloch by KCGM to predict long-term erosion rates for the lifts in their current state. The WEPP model was then re-run for the cross section once the variations in micro-relief were removed (i.e. a linear batter with the same average gradient). The results were compared and used to provide recommendations on the need to remove these variations in micro-relief as part of rehabilitation.

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[1] Landloch (2017) Long-term erosion potential of soil/rock mixtures used on rehabilitation of the Fimiston 2 TSF, Draft report prepared for Kalgoorlie Consolidated Gold Mines.
[2] ibid.
[3] Lifts that contain benches include: Section 2 Upper (2U), 3L, 4L, 5U, 5M, 6L, 9M, 10L, 11L, 14L, 17M, 17L, and 21U.

4. Results and discussion

The results of the WEPP modelling are given in Table 1. Results for both the *in situ* surfaces and the surfaces with the variations in micro-relief removed are shown.

Table 1: WEPP results

Slope	Section	Slope Height (m)	Hor. Slope Length (m)	Avg. Slope Gradient (%)	Erosion (Existing Slope) (t/ha/y)		Erosion (Micro-relief Smoothed) (t/ha/y)	
					Mean	Peak	Mean	Peak
1	Upper	11.9	53.5	22.2	0.1	0.1	0.1	0.3
	Middle	11.9	50.8	23.4	1.4	23	0.1	0.3
2	Upper	11.4	44.5	25.6	0.5	6.3	0.1	0.3
	Middle	12.4	43.5	28.5	0.1	1.8	0.1	0.9
3	Middle	10.8	39.2	27.6	0.4	5.2	0.1	0.4
	Lower	9.5	27.8	34.2	0.1	0.8	0.1	0.3
4	Upper	11.7	39.3	29.8	0.1	0.1	0.1	0.7
	Middle	11.9	44.9	26.5	0.7	1.3	0.1	0.6
	Lower	21.5	74.3	28.9	74	809	0.9	5.3
5	Upper	6.1	55.7	11.0	17	179	0.1	0.1
	Middle	11.4	39	29.2	0.1	1.3	0.1	0.6
6	Upper	8.6	26.9	32.0	0.1	0.1	0.1	0.1
	Middle	14.7	47.1	31.2	0.5	13	0.3	2.1
	Lower	16.4	58.5	28.0	28	447	0.4	2.5
7	Upper	8.5	34.1	24.9	0.1	0.1	0.1	0.1
	Middle	15.4	60.8	25.3	1.4	10	0.2	1.7
8	Upper	8.4	27.6	30.4	0.1	0.1	0.1	0.1
	Middle	15.1	28.7	52.6	0.1	0.1	0.5	3.2
	Lower	9.7	35.8	27.1	2.3	23	0.1	0.2
9	Upper	8.3	27.9	29.7	0.1	0.1	0.1	0.1
	Middle	15.4	52.9	29.1	19	146	0.3	2.2
	Lower	13.1	39.3	33.3	1.2	10	0.2	1.5
10	Upper	8.6	27.6	31.2	0.1	0.1	0.1	0.1
	Middle	14.7	82	17.9	1.3	8.1	0.1	0.3
	Lower	10.1	30.6	33.0	0.1	0.1	0.1	0.4
11	Upper	8.4	28.5	29.5	0.1	0.1	0.1	0.1
	Middle	13.9	54.3	25.6	0.1	2.8	0.1	1.1
	Lower	23	68.1	33.8	7.6	571	1.5	7.7
12	Upper	8.9	27.7	32.1	0.1	0.6	0.1	0.2
	Middle	14.3	39.6	36.1	0.1	1.8	0.3	2.3
	Lower	11.8	34.3	34.4	0.1	10	0.1	1
13	Upper	8.8	27.1	32.5	0.1	0.1	0.1	0.2
	Middle	16.5	49	33.7	0.2	1.6	0.5	3.3
	Lower	9.1	22.5	40.4	0.1	0.1	0.1	0.3

Table 1 cont'd: WEPP results.

Slope	Section	Slope Height (m)	Hor. Slope Length (m)	Avg. Slope Gradient (%)	Erosion (Existing Slope) (t/ha/y)		Erosion (Micro-relief Smoothed) (t/ha/y)	
					Mean	Peak	Mean	Peak
14	Upper	6.1	28.9	21.1	0.1	0.1	0.1	0.1
	Middle	15.5	73.7	21.0	0.1	2	0.1	1
	Lower	20.3	100.5	20.2	108	695	0.3	2.6
15	Upper	8.5	28	30.4	0.1	0.1	0.1	0.1
	Middle	16.3	49.6	32.9	0.7	5.3	0.5	3.1
	Lower	9.4	22.8	41.2	0.1	0.1	0.1	0.3
16	Upper	8.7	27.1	32.1	0.1	0.1	0.1	0.2
	Middle	13.3	41.9	31.7	0.1	0.4	0.2	1.5
	Lower	6.2	20.7	30.0	0.1	0.1	0.1	0.1
17	Upper	8.4	30	28.0	0.1	0.1	0.1	0.1
	Middle	16.1	53.6	30.0	33	250	0.4	2.7
	Lower	12.9	38.3	33.7	0.3	3.2	0.2	1.5
18	Lower	12.5	35.2	35.5	0.1	0.1	0.2	1.4
19	Upper	6.9	26	26.5	0.1	0.1	0.1	0.1
	Lower	17.7	59.9	29.5	0.1	0.5	0.5	3.3
20	Upper	12.8	45.2	28.3	0.1	1	0.1	1
	Lower	13.7	42.8	32.0	0.3	13.4	0.2	1.7
21	Upper	23.3	82.7	28.2	38	181	1.1	6.3
	Lower	11.9	41.5	28.7	0.2	2.3	0.1	0.7
22	Upper	13.1	53.8	24.3	0.1	0.1	0.1	0.7
	Middle	11.1	42.7	26.0	0.1	1	0.1	0.4
	Lower	12.5	44	28.4	0.1	0.1	0.1	0.9

Cross sections that contain a berm (shaped to ensure they breached) and have lift heights greater than ~10-15m[4] show significant increases in erosion when compared against profiles with the same height and average gradient (i.e. with the breached berm and other micro-relief variations removed). An increase in erosion is still predicted for lifts with berms, but with heights less than 15m[5]. However, the size of the increase is smaller, and does not result in a lift having unacceptable erosion[6]. The exception was 5U that had unacceptable erosion rates. It had a height of 6m, but quite a long slope length (55.7m) and low gradient (11%).

[4] 4L, 6L, 8L 9M, 11L, 14L, 17M, and 21U.
[5] 2U, 3L, 5M, 10L, and 17L.
[6] Acceptable erosion rates: Mean average annual erosion <5t/ha/y, and peak average annual erosion rates <10t/ha/y.

Cross sections that do not contain berms and have lift heights less than ~10-12m[7] are predicted erode at similar rates with and without the presence of variable micro-relief. This suggests that for these lift heights, the existing micro-relief will not cause significant increases in long-term erosion potential.

For lift heights greater than ~12m and less than ~23m[8] the degree to which micro-relief changes erosion potential is variable. Within this range of lift heights, those profiles than maintain a broadly linear or concave lift profile[9] are predicted to remain acceptably stable with the micro-relief present. However, for profiles in the same height range with convex lift profiles or sections of the lift that are convex in shape[10], the predicted erosion rates are elevated and can become unacceptable. Therefore, it appears that the broad profile shape is a stronger determinant of erosion than the presence of different levels of micro-relief.

The results can be summarised as follows:

- Micro-relief and the profile shape (concave, linear or slight convex) do not impact on erosion potential of rocky soil batters that are less than ~10m in height[11].
- The presence of a breached berm is predicted to cause unacceptably high erosion rates for lifts greater than 10m in height
- The micro-relief present on the cross sections considered is not predicted to cause unacceptable erosion if the broad shape of the profile is linear or concave.
- Lifts with a convex shape have higher erosion potential and this can be exacerbated by the presence of micro-relief.
- Control of the broad lift shape is critical to producing erosion-resistant surfaces on the Fimiston II TSF batters, with convex shapes being less resistant than linear or concave profile shapes.
- Where berms exist, it is critical that they are sufficiently sized to not overtop and breach.

This assessment has not considered lateral movement of water along structures such as roads that transect the batters on an angle. These structures must also be removed (or made considerably more erosion resistant) as part of rehabilitation and will be a major risk to successful rehabilitation if not properly managed.

[7] 3M, 6U, 7U, 8U, 9U, 10U, 11U, 12U, 13U, 13L, 14U, 15U, 15L, 16U, 16L, 17U, 19U, and 22M.
[8] 23m is the maximum lift height assessed.
[9] 1U, 2M, 4M, 4U, 8M, 11M, 12M, 13M, 14M, 16M, 18L, 19L, 20U, 21L, 22U, and 22L.
[10] 1M, 6M, 7M, 9L, 10M, 15M, 12L, and 20L.
[11] There would be a limit to the degree of convexity that is allowable, but the convexity that is present on some of the low lifts on the Fimiston II TSF is not predicted to cause unacceptable erosion.

Regards



Mr EVAN HOWARD
PRINCIPAL CONSULTANT

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5.9 Appendix 5.9: FIMISTON & REGIONAL Historic Tailings Geochemistry

GEOCHEMICAL ASSESSMENT OF HISTORICAL/LEGACY TAILINGS AT KCGM

PREPARED FOR:

KALGOORLIE CONSOLIDATED GOLD MINES PTY LTD

MARCH 2018

PREPARED BY:

Martinick Bosch Sell Pty Ltd
4 Cook Street
West Perth WA 6005
Ph: (08) 9226 3166
Fax: (08) 9226 3177
Email: info@mbsenvironmental.com.au
Web: www.mbsenvironmental.com.au

MBS ENVIRONMENTAL

MINE CLOSURE PLANNING
GEOCHEMICAL ASSESSMENT OF HISTORICAL/LEGACY TAILINGS

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Appendix 1: Sample Location Photographs

Appendix 2: Collated Data Tables

1. INTRODUCTION AND SCOPE

As part of ongoing investigations to inform mine closure planning, Kalgoorlie Consolidated Gold Mines (KCGM) has requested MBS Environmental (MBS) provide a geochemical assessment of tailings samples collected by KCGM between November 2015 and October 2016 from historical/legacy Tailings Storage Facilities (TSFs) in the area around Fimiston Super Pit and Fimiston Mill, the Mt Percy TSF as well the hand constructed Mullingar TSF approximately 5.5 km to the northwest of the Fimiston Operations. This work was identified as a knowledge gap in a recent review of geochemical characteristics of KCGM tailings conducted by MBS (MBS 2016) as well as in hydrochemical modelling of the Fimiston Super Pit (Schlumberger 2016).

This report provides an assessment of laboratory data for 15 samples of tailings solids collected from historical TSFs and submitted to Intertek Genalysis laboratories by KCGM in November 2015 (eight samples) and October 2016 (seven samples).

The objectives of this assessment were to:

- Describe the geochemical characteristics, including classification of their potential to generate acid metalliferous drainage (AMD), of 15 samples of tailings from historical/legacy TSF's (pre KCGM ownership in 1989) to further inform mine closure planning and strategies.
- Determine the risk of any potential for seepage from tailings materials to be contaminated by acid, salts, metals or metalloids

2. SAMPLE DESCRIPTIONS

KCGM staff collected 15 samples of tailings from seven historical TSF's for analysis by Intertek Genalysis laboratories. The samples were identified as follows:

- Paringa TSF (1).
- Paringa TSF (2).
- Balgold Oroya TSF (Behind Workshop Area).
- Morrison (Calcine) TSF.
- Mt Percy.
- Old Croesus (Fim I).
- Croesus (Pit Shell).
- Mullingar (eight samples identified as MULL1 to MULL8).

The location of the above sampling sites in relation to the current overlying KCGM Fimiston operations is illustrated in Figure 1 (sample locations marked in red). Photographs of various sample locations are shown in Appendix 1. The Mt Percy TSF and Mullingar TSF's are located approximately 5.5 km to the north and northwest respectively of Fimiston operations area and not shown on Figure 1. Samples for the current assessment were taken from near surface (0 to 0.2 m) depth. The sample from the exposed portion of the Balgold Oroya TSF (refer photographs Appendix 1) was taken based on accessibility but it is known that this area (marked as Oroya, Balgold and Galconda in Figure 1) is highly variable in nature and contains many former facilities including leach pads. Therefore this single sample should not be considered representative of this entire area.

In particular it should be noted that the Morrison (Calcine) TSF (shown as 'Calcine' in Figure 1) and Croesus TSF store calcined tailings (tailings that have undergone a high temperature roast to oxidise sulfides) and are deep red in colour as a result (refer photographs at end of report). The remaining tailings samples assessed and current Fimiston tailings are not calcined.

Future management options for Croesus (Pit Shell) material may be limited by safe access as much of this TSF lies within the zone of instability of the pit. The small volume of Morrison (Calcine) TSF material is within an area of proposed southern cutback (Morrison cutback) pit extension and therefore KCGM is considering management options for this material.



Figure 1: Sample Locations Layout (Source KCGM)

3. METHODOLOGY

3.1 ACID BASE ACCOUNTING

Acid Base Accounting (ABA) was used to classify tailings samples as Potentially Acid Forming (PAF), Non Acid Forming (NAF), Acid Consuming (AC) or 'Uncertain' using procedures similar to those used in earlier studies of KCGM mine waste (e.g. MBS 2016). ABA for this assessment involves:

- Measurement of "oxidisable" or "non-sulfate-sulfur" as the difference between total sulfur and sulfate-sulfur provided by an acid extraction procedure.
- Calculation of Acid Potential (AP) by multiplying the "oxidisable" sulfur concentration by 30.6, reported with units of kg H_2SO_4/t.
- Measurement of Acid Neutralising Capacity (ANC), also reported with units of kg H_2SO_4/t.
- Calculation of Net Acid Production Potential (NAPP), defined as the difference between AP and ANC.
- Measurement of NAG pH, which is the pH of a solution obtained by oxidation of a finely ground sample with hydrogen peroxide under conditions of the Net Acid Generation (NAG) laboratory test.
- Classification of mine waste based on NAPP and NAG pH values according to the criteria presented in Table 1.
- Calculation of the neutralisation potential ratio (NPR), defined as ANC divided by AP, where a ratio greater than two indicates a significant excess of neutralisation capacity versus potential for acid generation (MEND 2009).

The samples were also analysed for total carbon. The corresponding acid neutralising capacity (kg H_2SO_4/t) attributed to the carbonate minerals, designated as Carb-NP, was calculated by multiplying the reported result (%C) by 81.7. This calculation assumes all of the total carbon is present as reactive calcium and magnesium carbonate minerals such as calcite ($CaCO_3$), dolomite ($CaMg(CO_3)_2$) and low iron ankerite ($(Ca,Mg,Fe)CO_3$).

Table 1: Combined AMIRA NAPP and NAG Classification of Acid Rock Drainage[1]

Primary Geochemical Waste Type Class	NAPP Value kg H_2SO_4/t	NAG pH	Sulfur Content*
Potentially Acid Forming – High Capacity (PAF-HC)	≥ 10	< 4.5	≥ 0.3%
Potentially Acid Forming – Low Capacity (PAF-LC)	0 to 10	< 4.5	0.16 to 0.3%
Uncertain possibly NAF	0 to 5	> 4.5	Not important
Uncertain possibly PAF	-10 to 0	< 4.5	Not important
Non Acid Forming (NAF)	-100 to 0	> 4.5	Not important
Acid Consuming (AC)	< -100	> 4.5	Not important

1 Table 1 is based on the Australian Government's Guidelines on Managing Acidic and Metalliferous Drainage (DFAT 2016) and is in turn based on an earlier classification system included within the AMIRA ARD Test Handbook (AMIRA 2002), which is advocated by the Global Acid Rock Drainage Guidelines (GARD) published by the International Network for Acid Prevention (INAP 2009).

*Total sulfur analysis by combustion or XRF analysis.

3.2 ELEMENTAL CONCENTRATIONS AND GEOCHEMICAL ENRICHMENT

Based on existing knowledge of the mineralogy of ore and the geological setting at KCGM, the following elements were considered to be potentially geochemically and/or environmentally significant for the tailings samples or major elements required for general characterisation: gold (Au), silver (Ag), aluminium (Al), arsenic (As), barium (Ba), bismuth (Bi), calcium (Ca), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe,) mercury (Hg), potassium (K), magnesium (Mg), manganese (Mn), molybdenum (Mo), sodium (Na), nickel (Ni), lead (Pb), sulfur (S), antimony (Sb), selenium (Se), tellurium (Te), uranium (U), vanadium (V) and zinc (Zn).

All of these elements were measured simultaneously by inductively coupled plasma – atomic emission spectroscopy (ICP-AES) and ICP-MS following digestion of a finely ground sample with the 'four acid' or 'A' digest method by Intertek Genalysis laboratories. Mercury was measured by an alternate low temperature digestion to avoid loss of volatile mercury.

From this data, the global abundance index (GAI) for each element was calculated by comparison to the average earth crustal abundance (AIMM 2001). The main purpose of the GAI is to provide an indication of any elemental enrichment that could be of environmental significance. The GAI (based on a log-2 scale) is expressed in integer increments from zero to six (GARD Guide). A GAI of zero indicates that the content of the element is less than or up to three times the average crustal abundance; a GAI of one corresponds to a 3 to 6 fold enrichment; a GAI of two corresponds to a 6 to 12 fold enrichment and so forth, up to a GAI of six, which corresponds to a 96-fold, or greater, enrichment above average crustal abundances. A GAI of three or more is generally considered significant and may warrant further investigation.

3.3 WATER LEACHATE ANALYSIS

All tailings samples were subjected to a water leach at a sample to solution ratio of 1:5 (weight/volume) using deionised water as typically applied for assessments of soils which represents the typical subsurface saturated water concentrations. A 1:20 ratio as defined in Australian Standards Leaching Procedure (ASLP) 4439.3 is sometimes often used for assessment of potential concentrations in seepage but this can also be estimated by adjustment of results (division by four) from the 1:5 extraction ratio applied in this investigation. A 1:5 extraction ratio allows for better reporting limits of trace metals and is more indicative of porewater type concentrations.

Water leachates were analysed for final extract pH and electrical conductivity (EC), major ions, alkalinity, fluoride (F), boron (B), and the metals and metalloids listed in Section 3.2.

3.4 ACETIC ACID LEACHATE ANALYSIS

Tailings samples were also extracted using dilute acetic acid as the leaching fluid (initial pH 2.9) according to ASLP 4439.3 specification. Analytical finish of the filtered (0.45 µm) extract was via ICP-OES or ICP-MS finish, as necessary, for a range of elements as listed in Section 3.2. This test provides an indication of the nature of acid neutralising materials present and metals and metalloids that are likely to be leached should acid conditions prevail; either by oxidation of sulfide minerals in the tailings being assessed or by co-storage with other sources of PAF mine waste or contact with acidic water.

4. RESULTS AND DISCUSSION

Results for analysis of the historical tailings solids from KCGM leases are presented in Tables A1 to A5 in Appendix 2.

4.1 STATIC ACID BASE ACCOUNTING

Results for pH, EC, total sulfur, sulfate sulfur, ANC, total carbon, NAG and NAG pH are presented in Table A1 of Appendix 2. Calculated parameters, AP, NAPP and Carb-NP, as well as the classification based on criteria presented in Table 1, are also presented.

All samples examined had moderate levels of total sulfur, ranging from 0.55% to 2.37%. Sulfate-sulfur (non-oxidisable form), however, was a significant proportion of total sulfur in most of the samples analysed — in particular for Morrison TSF and Croesus (Pit Shell) (approximately 75%). The latter is consistent with those tailings having undergone a roasting process, which would oxidise contained sulfides to sulfates. Mt Percy tailings had a lower proportion (8%) of sulfate-sulfur as estimated from the acetic acid ASLP (Section 4.3.4). Estimates of sulfate-sulfur are also likely underestimated due to the mild extraction conditions and insoluble forms of sulfate such as barium or strontium sulfates. As a result of the generally high proportions of sulfate-sulfur, the calculated AP values of the samples were low to moderate (8.4 to 58 kg H_2SO_4/t).

Tailings samples had moderate to very high ANC, with values ranging from 37 (Croesus Pit Shell) to 200 kg H_2SO_4/t (Mt Percy). ANC and Carb-NP values were similar for most samples, indicating that the ANC is present in readily available acid neutralising carbonate forms. Carb-NP was just slightly higher than ANC in eight of the 15 tailings samples indicating the presence of carbon in forms which do not contribute to net acid neutralisation — these may include graphitic carbon (from carbonaceous ore including Black Flag Shales) or iron carbonate minerals such as high-iron ankerite ($(Ca,Mg,Fe)(CO_3)_2$) or siderite ($FeCO_3$).

As a result of low to moderate AP values and moderate to high ANC, all historical tailings samples were classified as NAF, with negative NAPP values and alkaline NAG pH values of 8 to 9.6. Nine of the 15 samples (Table A1 of Appendix 2) were further classified as acid consuming (AC). The NAF classifications according to Table 1 are illustrated in Chart 1. Chart 2illustrates all samples have NPR values of greater than two.

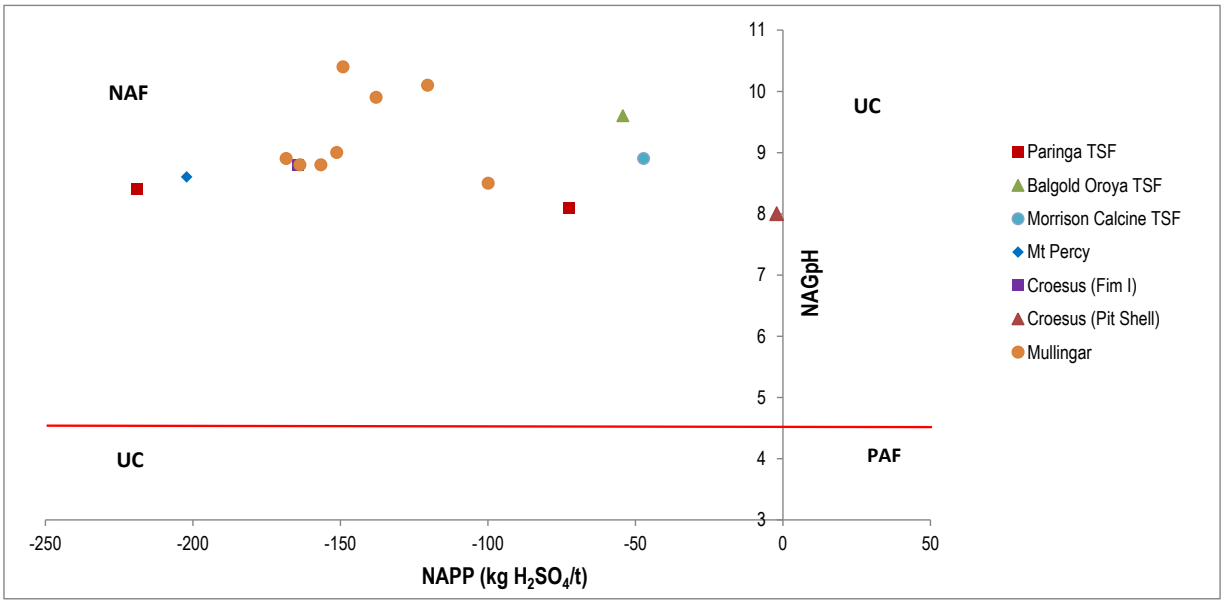


Chart 1: ABA Classification Cross Plot

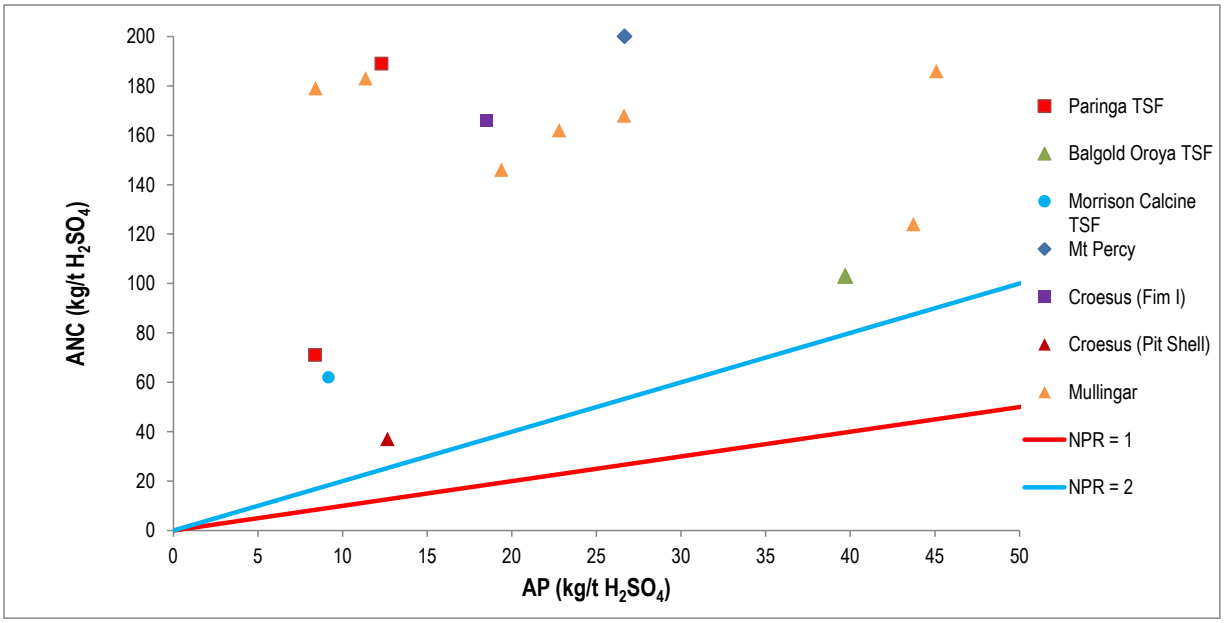


Chart 2: Historical/Legacy Tailings NPR Plot

4.2 ELEMENTAL CONCENTRATIONS AND GEOCHEMICAL ENRICHMENT

Results for analysis of the tailings solids for 26 environmentally significant metals and metalloids are presented in Table A2 of Appendix 2. Calculated GAI values are presented in Table A3 of Appendix 2, with values equal to greater than three highlighted by yellow shading.

Examination of results indicates:

- All samples were substantially enriched in gold, with the two calcined tailings (Morrison TSF and Croesus (Pit Shell), having ore grade levels of approximately 3.2 mg/kg (3.2 g/t) versus the global crustal average of 0.005 mg/kg. The eight Mullingar samples were not analysed for gold. All samples analysed had calculated GAI values of six for gold.
- The associated metal silver was also significantly enriched in all samples except Mt Percy and Mullingar, with highest concentrations of 26 mg/kg and 15 mg/kg being found in Morrison TSF and Croesus (Pit Shell) (GAI 6 versus the global average of 0.07 mg/kg).
- All samples were substantially enriched in the metalloid antimony with GAI values of 3 to 6, corresponding to concentrations of antimony of 3.3 to 86 mg/kg versus the global average of 0.2 mg/kg.
- Although selenium is usually associated with the presence of antimony, selenium was only considered enriched in the Morrison TSF and Croesus (Pit Shell) samples with a GAI of 3.
- Tellurium was significantly enriched in all samples with concentrations of 1.2 to 13.9 mg/kg versus a very low crustal average of 0.001 mg/kg. Samples from Morrison TSF and Croesus (Pit Shell) with elevated gold, silver and tellurium suggest the tellurium is present in the form of telluride minerals calaverite ($AuTe_2$) and slyvanite $(Ag,Au)Te_2$, which are known to occur in the Golden Mile deposit and are insoluble under normal conditions.
- Mercury was enriched (1.1 mg/kg, GAI 3) in the Balgold Oroya TSF sample exposed behind the workshop. As per other KCGM investigations, higher concentrations of both mercury and tellurium at this site (13.9 mg/kg tellurium) suggest the presence of coloradoite (HgTe), which is also insoluble under normal conditions. Marginal mercury enrichment was also observed for two Mullingar samples (MULL1 and MULL8, GAI 3).

- Morrison TSF and Croesus (Pit Shell) samples were also significantly enriched in arsenic (maximum 2,615 mg/kg, GAI 6), cobalt (maximum 369 mg/kg, GAI 3), copper (maximum 764 mg/kg, GAI 3) and molybdenum (maximum 124 mg/kg, GAI 6). The similarity and nature of these tailings materials is consistent with a different pre-treatment of the ore (sulfide flotation and calcining prior to gold extraction) compared to other historical tailings samples. Molybdenum was also marginally enriched (GAI 3) in the Old Croesus (FIM I) sample, and significantly enriched (GAI 4) in all Mullingar samples.
- The Croesus (Pit Shell) sample was also found to be marginally enriched in lead (117 mg/kg, GAI 3), as were two Mullingar samples (110 and 149 mg/kg for samples MULL4 and MULL8, respectively). The source of elevated lead concentrations in these tailings may result from the presence of lead sulfide minerals (galena, PbS) in the source ore, or use of lead nitrate added during cyanidation.
- No historical tailings samples were enriched in barium, bismuth, nickel, chromium, cadmium, manganese, uranium, vanadium, zinc or the common rock-forming elements (aluminium, calcium, magnesium sodium and potassium).

These results clearly demonstrate all tailings samples are enriched in gold, silver, antimony and tellurium. This combination of elements is considered to be associated with the particular nature of the gold/gold telluride deposit. Morrison TSF and Croesus (Pit Shell) tailings samples are more metalliferous than the other samples, also being enriched with environmentally significant elements arsenic, cobalt, copper, molybdenum and lead (Croesus Pit Shell only). In addition to gold, silver, antimony and tellurium, the historical Balgold Oroya TSF and two of the Mullingar samples was the only samples enriched in mercury – likely in the form of coloradoite.

4.3 WATER LEACHATE ANALYSIS

Results for analysis of water leachates of the tailings solids are presented in Table A4 of Appendix 2. Included for comparison purposes are livestock drinking water guidelines (ANZECC 2000) which are commonly applied for comparison of general water quality, although it should be noted that the only the major beneficial users of groundwater in the Goldfields region are for mine process water as groundwater is too saline for livestock use.

4.3.1 pH

Water leachates of all samples were circum-neutral to moderately alkaline, with pH values ranging from 7.2 to 9.1. The highest pH was recorded for the calcined Croesus (Pit Shell) sample.

As all samples were classified as NAF and contained an excess of calcium and magnesium carbonate minerals (Section 4.1), tailings porewater and TSF seepage from rainfall leaching are predicted to remain slightly alkaline in perpetuity.

4.3.2 Salinity and Major Ions

Water leachates of tailings solids were brackish to saline, as indicated by EC values ranging from 1.7 to 20.4 mS/cm. Croesus (Pit Shell) in particular, but also Morrison TSF and Paringa TSF (1), were more saline with calculated total dissolved solids (TDS) concentrations of 8,400 to 13,600 mg/L on a 1:5 solid/liquid basis, compared to a livestock drinking water guideline of 5,000 mg/L for cattle.

Major ion composition was variable with Paringa TSF (1) and Croesus (Pit Shell) leachates being dominated by sodium and chloride ions, while other samples contained increasing amounts of sulfate ions. The 1:5 solid/liquid extracts for Paringa TSF, Morrison TSF, Balgold Oroya and Croesus (Pit Shell) were also saturated or supersaturated with respect to gypsum. Although tailings samples assessed in the current work are not expected to be placed on slopes, the higher concentrations of calcium, magnesium and brackish to saline EC values suggests the tailings materials should not in any event be dispersive. Salinity in the tailings materials is expected to remain for some time after closure due to capillary action - particularly if final placement involves overlying waste rock cover. Residual salinity in the oldest and fully exposed Mullingar TSF samples is evidence of this.

Fluoride concentrations were very low in all samples, ranging from <0.1 to 0.8 mg/L. As these concentrations are well below the livestock drinking water guideline of 2 mg/L, fluoride is not considered a contaminant of potential concern (CoPC) in these historic KCGM tailings.

4.3.3 Metals and Metalloids

Despite enrichment in several metals and metalloids, water leachates of the tailings samples for the Paringa, Balgold Oroya, Mt Percy and Old Croesus (Fim I) TSFs did not contain significant concentrations of any metals or metalloids tested due the insoluble nature of the minerals or elements under neutral conditions. Although geochemically enriched, mercury, tellurium, selenium, antimony, copper, lead and silver in all water extracts were present at very low or less than detectable (e.g. tellurium) concentrations and all were well below livestock drinking water guidelines (ANZECC 2000) and WA Department of Health non-potable groundwater use guidelines (DoH 2014).

The following metal and metalloid concentrations in Morrison TSF and Croesus (Pit Shell) leachate samples were above livestock drinking water guidelines (on a 1:5 extract basis):

- Arsenic (2.52 and 1.75 mg/L respectively) versus a livestock guideline of 0.5 mg/L.
- Cobalt in Croesus (Pit Shell) of 9.0 mg/L versus a livestock guideline of 1 mg/L.
- Molybdenum (0.70 and 0.81 mg/L respectively) versus a livestock guideline of 0.15 mg/L.

With the exception of arsenic in the Croesus (Pit Shell) sample, all above results also marginally exceed the livestock drinking water guideline if compared on a 1:20 extract basis (division of results by four). The 1:20 dilution ratio would be more typical for any potential seepage.

Slightly elevated (>0.01 mg/L, above non-potable groundwater re-use guidelines) concentrations of mercury were recorded in three Mullingar samples (MULL1, MULL3 and MULL8, maximum 0.025 mg/L in MULL1). No samples exceeded the non-potable groundwater use guideline of 0.01 mg/L if adjusted for a 1:20 ratio extraction. Three samples also reported molybdenum (maximum 0.40 mg/L) concentrations above the livestock drinking water guideline.

Chart 3 shows the fractions, as percentages, of the total concentrations of arsenic, cobalt, molybdenum and mercury that are soluble in water. Mercury is the most soluble for particular (not consistent) samples – especially Mullingar. As above the concentrations of soluble mercury are still relatively low and total mercury also low as evidenced by only marginal enrichment (maximum concentration 1.1 mg/kg in MULL1). Molybdenum is the next most soluble, as expected, given its normal presence as the molybdate oxyanion and the alkaline nature of the water extract. Cobalt was found to be particularly soluble (essentially at saturation levels given the alkaline pH) in the Croesus (Pit Shell) sample with 12.2% of the total cobalt being water soluble – perhaps as the cobalt (II) tetrachloride complex which is stable at higher chloride concentrations. Approximately 0.5% of the arsenic present in Morrison TSF and Croesus (Pit Shell) samples was soluble, despite the higher iron content of these two samples (>33% Fe) versus other samples. Arsenate/arsenite oxyanions present from previous oxidation of arsenopyrite are likely being displaced from the surface of the iron oxides by the higher salinity and pH also associated with these samples.

Concentrations of soluble aluminium, boron, barium, bismuth, iron, chromium, manganese, nickel, uranium, vanadium and zinc were very low and therefore considered to be of no environmental consequence.

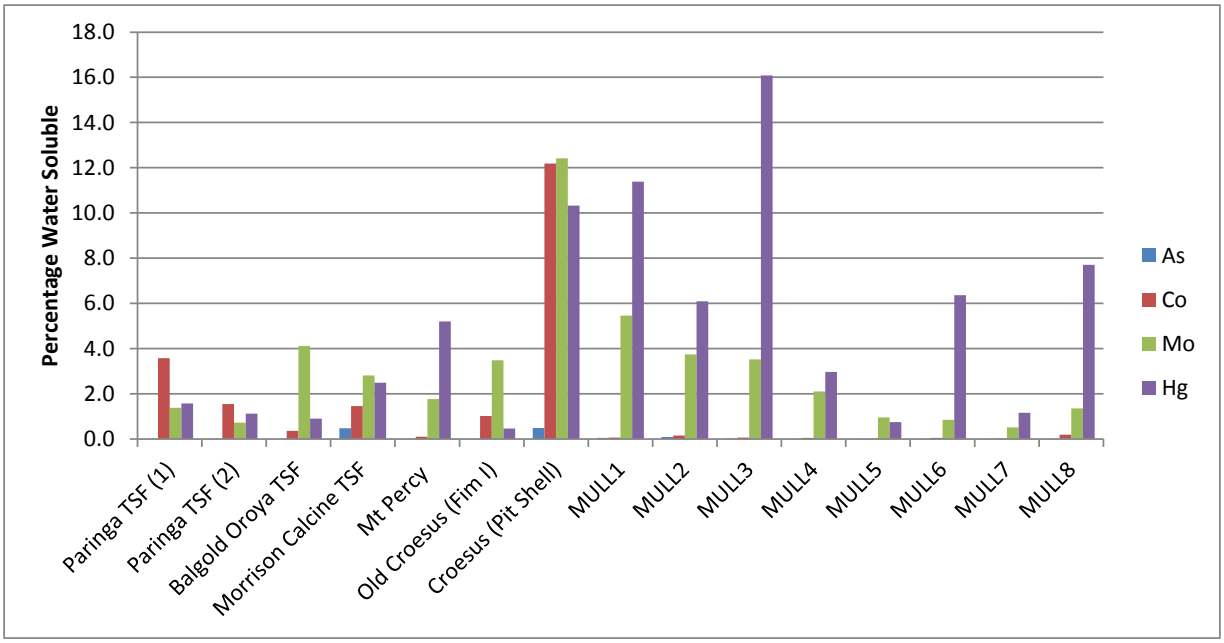


Chart 3: Solubility of Arsenic, Cobalt, Molybdenum and Mercury as Percentages of Total Concentrations

4.3.4 Acetic Acid Leachate Analysis

Results for analysis of acetic acid leachates of the tailings solids are presented in Table A5 of Appendix 2. Comparison of water leachate concentrations presented in Table A4 of Appendix 2 was made with acetic acid leachate concentrations. It should be noted that water leachate was provided by a 1:5 sample to solution leach, while the acid leachate was provided by a 1:20 leach. Comparison on this basis indicates:

- Higher concentrations of calcium and magnesium and iron in acetic acid leachates - a result of partial dissolution of calcium and magnesium carbonates and iron hydroxides or carbonates (e.g. siderite) by acetic acid.
- Higher concentrations of manganese from dissolution of manganese oxides or carbonates by acetic acid.
- Slightly higher concentrations of aluminium, barium, copper, cadmium, nickel and uranium, which reflects the higher concentrations of oxide, hydroxide and carbonate minerals of these elements, all of which are soluble under acidic conditions.
- Generally similar concentrations of mercury, antimony, selenium and tellurium, although tellurium did become slightly more soluble (maximum 0.019 mg/L at 1:20) in the Croesus (Pit Shell) sample under the acidic leachate conditions.
- Only slightly higher concentrations of arsenic in acetic acid leachates, likely from partial dissolution of iron hydroxides and release of the adsorbed oxyanions.
- Significantly lower concentrations of soluble molybdenum and lower concentrations of cobalt in the Croesus (Pit Shell) sample in particular.
- All Mullingar samples contained detectable concentrations of soluble mercury, ranging from 0.002 mg/L to 0.007 mg/L in sample MULL4. There was no significant relationship between water-soluble mercury (Section 4.3.3) and acetic acid soluble mercury; the highest water-soluble concentration was 0.025 mg/L for sample MULL1, whereas the acetic acid solution concentration for this sample was 0.003 mg/L (0.012 mg/L if adjusted to the same 1:5 ratio). These observations suggest that mercury is expected to occur in different mineral forms, ranging from insoluble minerals such as coloradoite to salts of the mercuric (Hg^{2+}) ion.

5. CONCLUSIONS AND IMPLICATIONS FOR MINE CLOSURE

5.1 ALL HISTORICAL TAILINGS

Based on analysis of 15 samples of historical tailings facilities at various surface locations on the KCGM Fimiston lease area the following conclusions can be made:

- The tailings samples had low to moderate theoretical acid production potential and correspondingly moderate to high levels of ANC, with a significant portion of sulfur in most samples being in the already oxidised form (sulfate). As a result all samples were classified as NAF, with Paringa TSF (2), Mt Percy, Old Croesus (Fim I) and six Mullingar samples being further classified as acid consuming.
- Leachate and hence any potential for seepage (depending on closure design) from these tailings is predicted to be alkaline and brackish to moderately saline in perpetuity. Mt Percy TSF, Old Croesus (Fim I) and the Balgold Oroya TSF were lower in salinity (brackish leachate), while Paringa TSF, Morrison TSF and Croesus (Pit Shell) TSFs were approximately four fold more saline. Variable levels of salinity were recorded for the eight Mullingar samples.
- All tailings samples were found to be geochemically enriched in gold, silver, antimony and tellurium as a result of the nature of the particular gold mineralisation, but none of these elements were found to be soluble in water extracts or dilute acetic acid extracts to any extent considered to be of environmental concern post-closure when covered.
- The Balgold Oroya TSF sample was also found to be marginally enriched in mercury (1.1 mg/kg) along with a higher concentration of tellurium (13.9 mg/kg). Mullingar samples were also marginally enriched in mercury and, to a lesser degree, tellurium. Tellurium was highly insoluble and mercury in Balgold Oroya TSF also highly insoluble. Mercury from Mullingar tailings was marginally more soluble than other samples but remained below the non potable groundwater use guideline of 0.01 mg/L if adjusted to a 1:20 ratio extraction. In addition, the net rate of leaching (as evidence from retained salinity) and total concentrations of mercury are low (maximum 1.1 mg/kg). Again, as these elements were found to have low solubility in water extracts they are not considered to pose a risk to the environment when covered with waste rock to prevent water and wind erosion.
- The Paringa, Mt Percy, Mullingar and Old Croesus TSFs are therefore considered to contain geochemically benign tailings, with only moderate levels of salinity in leachates and/or potential seepage, which will remain alkaline. The sample of exposed Balgold Oroya tailings material assessed in this work is also geochemically benign but as previously noted, other materials within the Balgold, Oroya and Galconda operations area is expected to be significantly different and variable in nature.
- Geochemical assessment indicates that for materials other than Morrison and Croesus (Pit Shell) TSF material, a suitably designed waste rock cover to prevent wind and water erosion will be sufficient post-closure to prevent negative impacts on the surrounding environment.

5.2 MORRISON (CALCINE) TSF AND CROESUS (PIT SHELL) TSF

Analysis of the two samples of calcined tailings from Morrison (Calcine) TSF and Croesus (Pit Shell) indicates properties which are somewhat different to the other historical samples - summarised as follows:

- Tailings samples from these historical TSFs were similar in nature and also geochemically enriched in arsenic, cobalt, copper, molybdenum, selenium and lead (Croesus (Pit Shell) only). This difference relates to the different nature of treatment for the production of these tailings.
- Lead and copper in these samples were not found to be soluble under the alkaline conditions expected to prevail post-closure and these elements, despite enrichment, are not considered to pose a risk to the environment.

- Concentrations of arsenic (0.63 mg/L on a 1:20 basis) and molybdenum (0.175 mg/L on a 1:20 basis) in water leachate for the Morrison TSF sample marginally exceeded the livestock drinking water guidelines of 0.5 mg/L and 0.15 mg/L, respectively.
- Concentrations of cobalt (2.25 mg/L on a 1:20 basis), molybdenum (0.202 mg/L on a 1:20 basis) and selenium (0.022 mg/L on a 1:20 basis) in water leachate for the Croesus (Pit Shell) sample were found to marginally exceed the livestock drinking water guidelines of 1 mg/L, 0.15 mg/L and 0.02 mg/L, respectively.
- Any potential post-closure seepage from Croesus (Pit Shell) would eventually report to the Fimiston pit lake and it is noted that this TSF also lies within the zone of instability of the pit. Any potential post closure seepage from the Morrison (Calcine) TSF would report to the underlying groundwater and from there to the pit lake or down gradient palaeochannel aquifer (Schlumberger 2016). Although the potential for impact from both is considered very low given expected seepage rates from finely divided and tightly packed tailings, dilution and receiving environment, the total concentration and solubility of arsenic in both these TSF landforms is sufficient to be classified as Class (III) landfill according to DER landfill waste classifications and waste definitions (DER 2009).

Given these conclusions, it is recommended that KCGM consider the following closure management options for Croesus (Pit Shell) and Morrison TSF tailings:

- Remove and stockpile (as safe access permits) the tailings while the potential for end of mine life or external toll treatment re-processing is investigated based on the measured gold content (up to 3.2 g/t measured in this study).
- Remove tailings and, if not to be re-processed for gold extraction at end of mine, placed within a WRD as a rolled and compacted layer (water shedding), ideally on a sub-base of underlying NAF waste rock (Golden Mile dolerite or Paringa basalt) and covered by at least two metres of additional NAF waste rock or oxide. This may be appropriate for the Morrison TSF tailings in particular but less suitable for Croesus (Pit Shell) TSF given its location and stability.
- Temporarily remove and stockpile Morrison TSF tailings for later placement/backfill within the pit shell along with the Croesus TSF tailings and then cover with a layer of waste rock and (post closure) the pit lake water itself. As the pit lake will remain a groundwater sink in perpetuity (Schlumberger 2016) with no risk of overtopping, there will be no migration of metals and metalloids outside the boundary of the hypersaline (saturated salt) pit lake for the relatively limited metals and metalloid dissolution.

6. REFERENCES

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APPENDICES

APPENDIX 1: SAMPLE LOCATION PHOTOGRAPHS

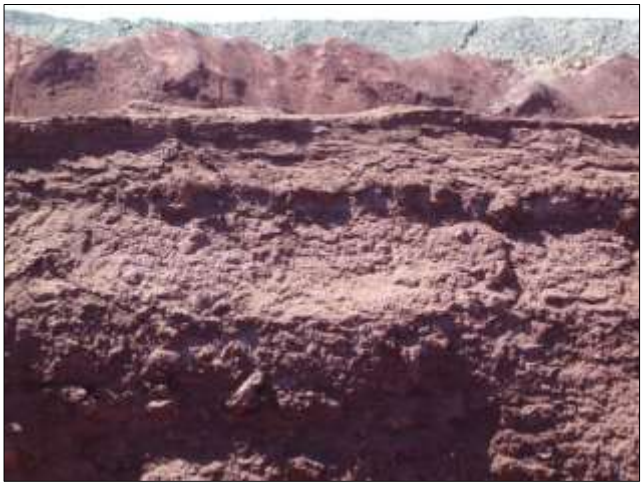
SAMPLE LOCATION PHOTOGRAPHS

KCGM NOVEMBER 2016

Balgold Oroya TSF



Morrison (Calcine) TSF



Morrison (Calcine) TSF



Croesus (Pit Shell)



Croesus (Pit Shell)



APPENDIX 2: COLLATED DATA TABLES

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Table A2-1: Tailings Samples Acid Base Accounting

Sample	pH	EC	Total-S	Sulfate-S*	Total C	AP	ANC	Carb-NP	NAPP	NAG	NPR	NAG pH	Classification
	pH units	µS/cm	%	%	%	kg H_2SO_4/tonne					(ANC/AP)	pH units	
Paringa TSF (1)	8.1	13,270	0.55	0.28*	0.99	8	71	81	-63	0	8.5	8.1	NAF
Paringa TSF (2)	8.3	6,150	0.60	0.20*	2.83	12	189	231	-177	0	15	8.4	AC
Balgold Oroya TSF	8.4	3,430	1.88	0.58*	1.15	40	103	94	-63	0	3.0	9.6	NAF
Morrison (Calcine) TSF	8.6	12,590	1.20	0.90*	0.69	9	62	56	-53	0	6.8	8.9	NAF
4 Mt Percy RAMP	7.9	2,500	0.95	0.08*	2.80	27	200	229	-173	0	7.5	8.6	AC
Old Croesus (Fim I)	8.0	2,920	0.87	0.26*	2.24	19	166	183	-147	0	9.0	8.8	AC
Croesus (Pit Shell)	9.1	2,0360	1.56	1.15*	0.18	13	37	15	-24	0	2.9	8.0	NAF
MULL1	8.4	12,300	1.52	0.89	1.46	19	146	119	-127	0	7.5	8.5	AC
MULL2	7.7	15,400	1.19	0.91	2.02	8	179	165	-171	0	21	8.8	AC
MULL3	7.2	8,200	0.92	0.55	2.20	11	183	180	-172	0	16	8.9	AC
MULL4	8.5	4,200	1.81	0.34	2.24	45	186	183	-141	0	4.1	9.9	AC
MULL5	7.9	1,700	2.37	0.49	2.18	58	153	178	-95	0	2.7	10.1	NAF
MULL6	8.5	6,200	1.35	0.48	2.33	27	168	190	-141	0	6.3	8.8	AC
MULL7	8.5	2,600	1.77	0.34	2.36	44	124	193	-80	0	2.8	10.4	NAF
MULL8	8.1	11,400	1.39	0.64	2.13	23	162	174	-139	0	7.1	9	AC

** Estimate only from acetic acid ASLP not a true (4M HCl) sulfate sulfur determination.*

Denotes PAF classification

Denotes Uncertain classification

Denotes NAF classification

Table A2-2: Tailings Samples Elemental Composition

Sample	Au	Ag	Al	As	Ba	Bi	Ca	Cd	Co	Cr	Cu	Fe	Hg
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	mg/kg
Paringa TSF (1)	0.39	0.80	70,954	151	295	0.12	19,261	0.24	69	134	198	11	0.16
Paringa TSF (2)	0.67	0.76	50,130	126	155	0.05	46,985	0.23	37	58	66	9.9	0.22
Balgold Oroya TSF	0.79	1.7	50,374	156	165	0.11	41,816	0.22	42	72	81	13	1.1
Morrison (Calcine) TSF	3.2	26	24,320	2,615	83	0.19	24,403	0.34	323	9	484	34	0.20
4 Mt Percy RAMP	0.36	0.24	5,6660	154	252	0.09	44,441	0.50	54	645	73	7.0	0.05
Old Croesus (Fim I)	0.56	1.5	55,690	109	236	0.65	41,667	0.25	38	158	83	8.5	0.54
Croesus (Pit Shell)	3.2	15	23,280	1,771	73	0.3	21,571	0.73	369	16	764	33	0.34
MULL1	N/A	0.30	49,415	79	45	0.03	52,460	0.06	57	6	87	11	1.1
MULL2	N/A	0.23	57,036	36	81	0.03	54,738	0.15	36	10	70	11	0.66
MULL3	N/A	0.16	50,828	58	52	0.03	56,143	0.12	49	7	91	11	0.34
MULL4	N/A	0.37	52,819	101	77	0.05	52,688	0.12	57	8	128	11	0.67
MULL5	N/A	0.54	45,505	112	81	0.03	48,262	0.12	53	6	117	10	0.67
MULL6	N/A	0.32	49,076	67	84	0.03	52,588	0.12	42	5	114	9.7	0.39
MULL7	N/A	0.49	48,154	92	82	0.03	52,663	0.13	52	<5	114	11	0.43
MULL8	N/A	0.28	55,318	64	111	0.04	48,751	0.11	38	8	76	9.8	0.78

N/A denotes Not Analysed.

Table A2-3: Tailings Samples Elemental Composition Continued

Sample	K	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Te	U	V	Zn
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Paringa TSF (1)	16,349	10,980	1,044	3.8	20,489	113	10	12	0.9	7.2	0.38	322	153
Paringa TSF (2)	12,805	20,502	1,659	12	16,330	38	7.4	9.6	<0.5	7.1	0.38	260	173
Balgold Oroya TSF	13,857	12,400	1,399	5.3	12,777	52	45	14	0.9	14	0.43	427	211
Morrison (Calcine) TSF	8,178	10,747	604	124	14,688	133	39	86	3.2	9.9	0.20	232	277
4 Mt Percy RAMP	8,784	30,547	1,244	2.4	10,337	282	11	3.3	0.6	1.2	0.40	158	288
Old Croesus (Fim I)	15,518	24,253	1,368	15	12,479	198	24	11	0.9	5.3	0.58	274	144
Croesus (Pit Shell)	7,682	11,301	553	33	24,477	188	117	80	2.7	11	0.31	197	505
MULL1	4,082	21,374	1,443	37	21,549	12	4.7	4.6	0.8	2.1	0.10	492	122
MULL2	9,657	25,617	1,363	47	23,514	17	21	3.4	<0.5	1.8	0.07	606	212
MULL3	6,539	22,286	1,572	32	19,674	18	56	3.6	0.7	1.5	0.09	541	138
MULL4	9,426	20,051	1,457	32	14,184	26	110	4.7	0.8	2.0	0.18	618	141
MULL5	10,790	16,383	1,318	34	9,185	21	79	6.6	0.9	1.8	0.12	533	105
MULL6	10,519	19,283	1,358	37	14,577	19	81	5.6	0.7	1.4	0.10	545	110
MULL7	10,219	18,351	1,454	43	10,843	20	102	8.5	0.8	1.5	0.10	534	113
MULL8	14,631	18,930	1,321	41	15,221	16	149	5.0	0.6	1.6	0.11	572	147

Table A2-4: Tailings Samples Global Abundance Index

Sample	Au	Ag	Al	As	Ba	Bi	Ca	Cd	Co	Cr	Cu	Fe	Hg
Paringa TSF (1)	6	3	0	2	0	0	0	0	1	0	1	1	0
Paringa TSF (2)	6	3	0	2	0	0	0	0	0	0	0	1	1
Balgold Oroya TSF	6	4	0	2	0	0	0	0	0	0	0	1	3
Morrison (Calcine) TSF	6	6	0	6	0	0	0	0	3	0	3	2	1
4 Mt Percy RAMP	6	1	0	2	0	0	0	1	1	2	0	0	0
Old Croesus (Fim I)	6	4	0	2	0	1	0	0	0	0	0	0	2
Croesus (Pit Shell)	6	6	0	6	0	0	0	1	3	0	3	2	1
MULL1	N/A	2	0	1	0	0	0	0	1	0	0	1	3
MULL2	N/A	1	0	0	0	0	0	0	0	0	0	1	2
MULL3	N/A	1	0	1	0	0	0	0	0	0	0	1	2
MULL4	N/A	2	0	1	0	0	0	0	1	0	1	1	2
MULL5	N/A	2	0	2	0	0	0	0	0	0	1	1	2
MULL6	N/A	2	0	1	0	0	0	0	0	0	0	1	2
MULL7	N/A	2	0	1	0	0	0	0	0	0	0	1	2
MULL8	N/A	1	0	1	0	0	0	0	0	0	0	1	3

Denotes GAI values greater than or equal to 3

Table A2-5: Tailings Samples Global Abundance Index Continued

Sample	K	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Te	U	V	Zn
Paringa TSF (1)	0	0	0	1	0	0	0	5	2	6	0	1	1
Paringa TSF (2)	0	0	0	2	0	0	0	5	0	6	0	0	1
Balgold Oroya TSF	0	0	0	1	0	0	1	5	2	6	0	1	1
Morrison (Calcine) TSF	0	0	0	6	0	0	1	6	3	6	0	0	1
4 Mt Percy RAMP	0	0	0	0	0	1	0	3	1	6	0	0	1
Old Croesus (Fim I)	0	0	0	3	0	1	0	5	2	6	0	0	0
Croesus (Pit Shell)	0	0	0	4	0	1	3	6	3	6	0	0	2
MULL1	0	0	0	4	0	0	0	4	1	6	0	1	0
MULL2	0	0	0	4	0	0	0	4	0	6	0	2	1
MULL3	0	0	0	4	0	0	2	4	1	6	0	1	0
MULL4	0	0	0	4	0	0	3	4	1	6	0	2	0
MULL5	0	0	0	4	0	0	2	4	2	6	0	1	0
MULL6	0	0	0	4	0	0	2	4	1	6	0	1	0
MULL7	0	0	0	4	0	0	2	5	1	6	0	1	0
MULL8	0	0	0	4	0	0	3	4	1	6	0	1	0

Denotes GAI values greater than or equal to 3

Table A2-6: Tailings Samples Water Leachate Concentrations

Sample	pH	EC	TDS	Na	K	Ca	Mg	Cl	SO_4	F	Total Alkalinity	HCO_3	CO_3	SAR
	pH units	mS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg $CaCO_3$/L			ratio
Paringa TSF (1)	8.1	13	8,891	2,304	44	403	383	4,259	1,728	0.8	18	18	<1	20
Paringa TSF (2)	8.3	6.2	4,121	781	15	508	188	1,383	1,755	<0.1	15	13	3	7.5
Balgold Oroya TSF	8.4	3.4	2,298	267	11	657	54	464	1,714	0.5	12	9	3	2.7
Morrison (Calcine) TSF	8.6	13	8,435	2,125	32	876	248	3,984	2,308	0.4	13	5	8	16
4 Mt Percy RAMP	7.9	2.5	1,675	318	5	137	44	595	407	0.2	16	16	<1	6.0
Old Croesus (Fim I)	8.0	2.9	1,956	199	17	490	88	219	1,649	<0.1	15	15	<1	2.2
Croesus (Pit Shell)	9.1	20.4	13,641	3,688	71	1,042	782	7,615	3,174	0.5	30	<1	29	21
MULL1	8.4	12	8,241	2,157	21	249	516	3,988	1584	<0.1	23	21	<1	18
MULL2	7.7	15	10,318	2,773	27	311	685	5,176	2,070	<0.1	36	36	<1	20
MULL3	7.2	8.2	5,494	1,461	16	156	251	2,623	738	<0.1	40	40	<1	17
MULL4	8.5	4.2	2,814	626	10	146	115	1,139	531	<0.1	19	9	11	9.4
MULL5	7.9	1.7	1,139	100	22	250	47	173	699	<0.1	47	47	<1	1.5
MULL6	8.5	6.2	4,154	987	13	194	227	1,817	882	<0.1	23	13	10	11
MULL7	8.5	2.6	1,742	385	7	146	55	634	432	<0.1	22	20	<1	6.8
MULL8	8.1	11	7,638	2,111	21	196	362	3,829	1,035	<0.1	28	28	<1	21
Livestock			5,000			1,000			1,000	2				
Non Potable Groundwater								250	1,000	15				

Table A2-7: Tailings Samples Water Leachate Concentrations Continued

Sample	Au	Ag	Al	As	B	Ba	Bi	Cd	Co	Cr	Cu	Fe	Hg
	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Paringa TSF (1)	2.4	0.007	<0.1	0.003	0.1	0.042	<0.05	<0.0002	0.495	<0.1	<0.1	<0.1	<0.001
Paringa TSF (2)	1.8	0.023	<0.1	<0.001	<0.1	0.016	<0.05	<0.0002	0.115	<0.1	<0.1	<0.1	<0.001
Balgold Oroya TSF	11	0.0012	<0.1	0.006	0.2	0.007	<0.05	<0.0002	0.031	<0.1	<0.1	0.1	0.002
Morrison (Calcine) TSF	45	0.264	<0.1	2.5	0.6	0.022	<0.05	<0.0002	0.948	<0.1	<0.1	0.1	0.001
4 Mt Percy RAMP	2.2	0.0004	<0.1	0.005	0.1	0.008	<0.05	<0.0002	0.011	<0.1	<0.1	<0.1	<0.001
Old Croesus (Fim I)	18	<0.0001	<0.1	0.002	0.1	0.016	<0.05	<0.0002	0.079	<0.1	<0.1	0.1	<0.001
Croesus (Pit Shell)	32	0.291	<0.1	1.75	0.2	0.028	<0.05	<0.0002	8.99	<0.1	<0.1	<0.1	0.007
MULL1	N/A	0.0023	0.2	0.008	N/A	0.003	<0.1	<0.0005	0.008	<0.1	<0.1	0.9	0.025
MULL2	N/A	<0.0002	<0.1	0.007	N/A	0.019	<0.1	<0.0005	0.011	<0.1	<0.1	0.6	0.008
MULL3	N/A	0.0008	<0.1	0.004	N/A	0.003	<0.1	<0.0005	0.007	<0.1	<0.1	1.4	0.011
MULL4	N/A	0.0004	<0.1	<0.002	N/A	0.001	<0.1	<0.0005	0.006	<0.1	<0.1	1	0.004
MULL5	N/A	<0.0002	<0.1	<0.002	N/A	0.006	<0.1	<0.0005	<0.002	<0.1	<0.1	0.6	<0.002
MULL6	N/A	0.0014	<0.1	0.002	N/A	0.002	<0.1	<0.0005	0.005	<0.1	<0.1	1.2	0.005
MULL7	N/A	0.0002	<0.1	<0.002	N/A	<0.001	<0.1	<0.0005	0.003	<0.1	<0.1	1.3	<0.002
MULL8	N/A	0.0046	<0.1	<0.002	N/A	0.004	<0.1	<0.0005	0.015	<0.1	<0.1	1.4	0.012
Livestock		1	5	0.5	5			0.01	1	1	1		0.002
Non Potable Groundwater		1	0.2	0.1	40	20		0.02		0.5 (CrVI)	20	0.3	0.01

Denotes a result in 1:5 extract above the Livestock drinking water guideline or Non Potable Groundwater use guideline

Table A2-8: Tailings Samples Water Leachate (1:5) Concentrations Continued

Sample	Mn	Mo	Ni	Pb	Sb	Se	Te	U	V	Zn
	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	µg/L	µg/L	mg/L	mg/L
Paringa TSF (1)	<0.1	0.01	<0.1	<0.005	0.5	<0.005	<1	<0.05	<0.1	<0.1
Paringa TSF (2)	<0.1	0.02	<0.1	<0.005	0.2	<0.005	<1	<0.05	<0.1	<0.1
Balgold Oroya TSF	<0.1	0.04	<0.1	<0.005	0.9	<0.005	<1	<0.05	<0.1	<0.1
Morrison (Calcine) TSF	<0.1	0.70	0.1	<0.005	5.1	0.07	<1	<0.05	<0.1	<0.1
4 Mt Percy RAMP	<0.1	0.009	<0.1	<0.005	0.2	<0.005	<1	<0.05	<0.1	<0.1
Old Croesus (Fim I)	<0.1	0.10	<0.1	<0.005	0.7	0.009	<1	<0.05	<0.1	<0.1
Croesus (Pit Shell)	<0.1	0.81	<0.1	<0.005	24	0.09	<1	<0.05	<0.1	<0.1
MULL1	<0.1	0.40	<0.1	<0.01	0.4	<0.01	<2	<0.1	<0.1	<0.1
MULL2	<0.1	0.35	<0.1	<0.01	2.4	<0.01	<2	<0.1	<0.1	<0.1
MULL3	<0.1	0.22	<0.1	<0.01	0.3	<0.01	<2	<0.1	<0.1	<0.1
MULL4	<0.1	0.13	<0.1	<0.01	<0.2	<0.01	<2	<0.1	<0.1	<0.1
MULL5	<0.1	0.07	<0.1	<0.01	1.2	<0.01	<2	<0.1	<0.1	<0.1
MULL6	<0.1	0.06	<0.1	<0.01	0.3	<0.01	<2	<0.1	<0.1	<0.1
MULL7	<0.1	0.04	<0.1	<0.01	0.5	<0.01	<2	<0.1	<0.1	<0.1
MULL8	<0.1	0.11	<0.1	0.01	0.3	<0.01	<2	<0.1	<0.1	<0.1
Livestock		0.15	1	0.1		0.02		200		20
Non Potable Groundwater	5	0.5	0.2	0.1	30	0.1		170		3

Denotes a result in 1:5 extract above the Livestock drinking water guideline or Non Potable Groundwater use guideline

Table A2-9: Tailings Samples Acetic Acid Leachate (1:20) Concentrations

Sample	pH	Au	Ag	Al	As	B	Ba	Bi	Ca	Cd	Co	Cr	Cu	Fe	Hg
	pH units	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Paringa TSF (1)	4.3	0.7	0.0025	3.9	<0.001	0.3	0.13	<0.05	405	0.003	0.43	<0.1	0.2	78	<0.001
Paringa TSF (2)	4.6	0.5	<0.0001	0.2	<0.001	0.1	0.07	<0.05	582	0.003	0.09	<0.1	<0.1	149	<0.001
Balgold Oroya TSF	4.6	2.3	<0.0001	4.1	0.003	0.3	0.07	<0.05	1,113	0.002	0.04	<0.1	0.2	12	<0.001
Morrison (Calcine) TSF	4.3	8.4	0.03	3.1	2.0	0.6	0.07	<0.05	719	0.003	0.71	<0.1	1.6	46	<0.001
4 Mt Percy RAMP	4.3	1.1	0.0001	0.5	0.004	0.1	0.04	<0.05	342	0.004	0.22	<0.1	<0.1	90	<0.001
Old Croesus (Fim I)	4.8	3.7	<0.0001	0.9	<0.001	0.2	0.09	<0.05	577	0.003	0.10	<0.1	0.2	100	<0.001
Croesus (Pit Shell)	4.1	6.7	0.0955	6.2	3.9	0.3	0.04	<0.05	718	0.01	1.3	<0.1	3.7	2.4	0.002
MULL1	5.1	NA	<0.0001	<0.1	0.001	NA	0.03	<0.05	1,734	0.002	0.24	<0.1	0.1	12	0.003
MULL2	5.3	NA	<0.0001	<0.1	<0.001	NA	0.05	<0.05	1,792	0.003	0.17	<0.1	<0.1	39	0.003
MULL3	5.4	NA	0.0001	<0.1	<0.001	NA	0.04	<0.05	1,533	0.003	0.16	<0.1	<0.1	15	0.004
MULL4	5.3	NA	<0.0001	<0.1	<0.001	NA	0.02	<0.05	1,418	0.004	0.08	<0.1	<0.1	47	0.007
MULL5	5.2	NA	<0.0001	<0.1	<0.001	NA	0.03	<0.05	1,256	0.003	0.10	<0.1	<0.1	192	0.002
MULL6	5.3	NA	<0.0001	<0.1	<0.001	NA	0.02	<0.05	1,376	0.004	0.08	<0.1	<0.1	98	0.002
MULL7	5.3	NA	<0.0001	<0.1	<0.001	NA	0.02	<0.05	1,334	0.003	0.08	<0.1	<0.1	111	0.002
MULL8	5.4	NA	<0.0001	<0.1	<0.001	NA	0.02	<0.05	1,369	0.004	0.12	<0.1	<0.1	53	0.006

Table A2-10: Tailings Samples Acetic Acid Leachate (1:20) Concentrations Continued

Sample	K	Mg	Mn	Mo	Na	Ni	Pb	S	Sb	Se	Te	U	V	Zn
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	µg/L	µg/L	mg/L	mg/L
Paringa TSF (1)	16	233	13	<0.5	630	0.2	<0.005	138	<0.1	<0.005	<1	1.3	<0.1	1.0
Paringa TSF (2)	3	221	16	<0.5	181	0.2	<0.005	99	<0.1	<0.005	<1	0.7	<0.1	2.6
Balgold Oroya TSF	5	135	7.1	<0.5	74	<0.1	<0.005	291	0.8	<0.005	4	1.6	<0.1	1.1
Morrison (Calcine) TSF	8	280	9.2	15	556	0.2	<0.005	450	8.8	0.03	7	0.3	<0.1	4.0
4 Mt Percy RAMP	<1	148	8.4	<0.5	90	0.4	<0.005	39	0.2	<0.005	<1	0.4	<0.1	1.2
Old Croesus (Fim I)	7	164	12	<0.5	55	0.5	<0.005	132	0.2	<0.005	<1	1.4	<0.1	0.8
Croesus (Pit Shell)	19	409	6.6	8.0	1,043	0.1	0.034	573	16	0.02	19	0.7	<0.1	4.2
MULL1	6	211	19	<0.5	562	<0.1	<0.005	407	<0.1	<0.005	<1	0.2	<0.1	0.4
MULL2	9	312	23	<0.5	689	<0.1	<0.005	440	<0.1	<0.005	<1	0.3	<0.1	1.2
MULL3	6	200	23	<0.5	384	<0.1	<0.005	154	<0.1	<0.005	<1	0.08	<0.1	0.3
MULL4	3	216	21	<0.5	190	<0.1	<0.005	167	<0.1	<0.005	<1	0.1	<0.1	0.3
MULL5	3	218	20	<0.5	46	<0.1	<0.005	238	<0.1	<0.005	<1	0.1	<0.1	0.4
MULL6	3	255	19	<0.5	250	<0.1	<0.005	253	<0.1	<0.005	<1	0.1	<0.1	0.3
MULL7	3	206	21	<0.5	99	<0.1	<0.005	168	<0.1	<0.005	<1	0.1	<0.1	0.2
MULL8	6	370	21	<0.5	455	<0.1	<0.005	302	<0.1	<0.005	<1	0.2	<0.1	0.3

5.10 Appendix 5.10: MT CHARLOTTE Hydrological Predictions

Peter Clifton & Associates
Consulting Hydrogeologists
A division of Saguaro Holdings Pty Ltd
ACN 073 231 295; ABN 33 216 640 980

Postal Address: PO Box 186, Floreat WA 6014
Telephone: (08) 9388 9191
Facsimile: (08) 9388 7171
Mobile: 0408 929 964
E-mail: pca@saguaro.com.au

25 March 2021

Kalgoorlie Consolidated Gold Mines Pty Ltd
Private Mail Bag 27
Kalgoorlie WA 6433

Attn: Ms Janine Cameron, Senior Environmental Coordinator

Ref: Mt Charlotte Underground Mine Flooding Predictions

The Mt Charlotte Underground Mine was initially developed to depths of around 130 m prior to the 1930s. The mine was re-opened in 1963, and has since been developed to a depth of around 1.2 km. Current plans are to continue mining until around 2018 and then the mine will be closed.

The mine is accessed either via the Sam Pearce Decline or the Cassidy Shaft. The portal of the Sam Pearce Decline is at the northern end of the Fimiston Open Pit, about 2.5 km SE of the Cassidy Shaft headframe. The decline tracks northwest and joins the main underground workings of Mt Charlotte on the 9 Level (9L). Elevations of these points are:

- Surface at Cassidy Shaft: 390 mAHD
- Portal of Sam Pearce Decline: 316 mAHD
- Intersection of Sam Pearce Decline and 9L: 134 mAHD

There is a small-scale dewatering operation at Mt Charlotte. Water produced by these operations is mostly a mixture of groundwater seepage and water introduced for operating machinery. After dewatering ceases and the mine is closed, the underground voids will slowly fill with water and the level of water in the mine will rise.

A mine flooding model for the Mt Charlotte Underground Mine has been developed to predict the rate of water level rise and likely equilibrium water level in the mine. The flooding model is based on a mine void model which has been developed independently, and inflows from various sources. The flooding model updates earlier predictions of void flooding at Mt Charlotte by Rockwater (2001).

The void model is based on a block model of the mine stopes and other developments produced from data provided by KCGM, and includes all current and proposed mine voids to the end of mining in 2018. The void model is used to estimate the volume of voids between a particular elevation and the base of the mine sump.

The flooding model calculates the incremental volume of water added to the mine from several sources for a given time interval. The level of water in the mine is then determined from the mine void model and the cumulative volume of water in the mine.

Sources of inflow considered by the model are:

- Observed groundwater seepages (maximum 356 kL/day)
- Additional groundwater seepage equivalent to the present discharge of water vapour from the mine ventilation system (average maximum 241 kL/day)
- Additional groundwater seepage equivalent to the rate that water is removed from the mine in wet ore (average 55 kL/day)
- Additional groundwater seepage equivalent to the rate that water is being used for dust suppression (25 kL/day)
- Surface water runoff (average 17 kL/day)

The most significant observed groundwater seepages in the underground are associated with four major steeply dipping structures at depths between -22 mAHD and -540 mAHD.

The flooding model can account for the groundwater inflow components as being either head dependent or head independent. The ambient groundwater level used in head dependent inflow calculations is 335 mAHD, and is based on nearby observations.

Three simulations of the Mt Charlotte mine flooding model have been run:

- Seepage from all inflow components, with head dependent groundwater inflow, and final flood level equal to the ambient groundwater level
- Seepage from all inflow components with no head dependency, and final flood level equal to the ambient groundwater level
- Seepage from all inflow components, with head dependent groundwater inflow, and final flood level equal to the level of the Sam Pearce Decline portal

The first simulation allows groundwater inflow rates to decrease as the flood level rises. This simulation predicts the final equilibrium water level will occur 105 years after closure.

The second simulation assumes seepage rates from all sources remain constant, which is a conservative assumption. The predicted time to flood the mine under these conditions is 34 years after closure.

The third simulation allows flood water to overflow into the Fimiston Pit when the level of water in the mine reaches the portal of the Sam Pearce Decline. This is the most likely of the three scenarios considered, and predicts the final equilibrium flood level will occur 99 years after closure. The predicted inflow rate at this level is 33 kL/day. This is the estimated rate of overflow from the Mt Charlotte Underground into the lake that eventually will develop in the Fimiston Pit after closure of those operations.

Yours faithfully
Peter Clifton & Associates

P M Clifton
9505_L108.DOCX

5.11 Appendix 5.11: MT CHARLOTTE Waste Characterisation

MT CHARLOTTE UNDERGROUND WASTE ROCK GEOCHEMICAL CHARACTERISATION

PREPARED FOR:

KALGOORLIE CONSOLIDATED GOLD MINES PTY LTD

JANUARY 2018

PREPARED BY:

Martinick Bosch Sell Pty Ltd
4 Cook Street
West Perth WA 6005
Ph: (08) 9226 3166
Fax: (08) 9226 3177
Email: info@mbsenvironmental.com.au
Web: www.mbsenvironmental.com.au

MBS ENVIRONMENTAL

MT CHARLOTTE UNDERGROUND
WASTE ROCK GEOCHEMICAL CHARACTERISATION

Distribution List:

Company	Contact name	Copies	Date
KCGM Pty. Ltd.	Janine Cameron – Senior Environmental Coordinator	[01]	12 January 2018
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1. INTRODUCTION

1.1 BACKGROUND

Kalgoorlie Consolidated Gold Mines Pty Ltd (KCGM) operates the Fimiston Open Pit, Mt Charlotte underground mine and the Fimiston and Gidji Processing Plants located adjacent to the City of Kalgoorlie-Boulder approximately 600 km east of Perth, Western Australia (Figure 1).

Mining and mineral processing has occurred in this area, known as the Golden Mile, since gold was first discovered in 1893. The Golden Mile is one of the world's richest gold-bearing reefs and gave rise to a multitude of mining operations. In 1989, all mines, processing plants and leases along the Golden Mile were merged into one integrated operation, KCGM.

Ore for gold production at KCGM is today sourced from two primary mining locations; the Fimiston Open Pit (commonly known as the Super Pit) and the Mt Charlotte underground mine approximately 2 km north of the Fimiston Open Pit (Figure 1). The Fimiston Open Pit mining rate is approximately 69 million tonnes per annum (Mt/a) (comprising ore and waste), of which approximately 12 Mt/a is processed at the Fimiston Mill.

In addition to the above mining locations, development at the Mt Charlotte underground is currently progressing towards two new ore sources:

- Northern Orebody (NOB), a geological extension of the fault line mineralisation seen in the Fimiston Pit.
- Lower Hidden Secret Orebody (LHSO), located approximately 400 m east of Mt Charlotte and within the steeply dipping western limb of the Kalgoorlie Anticline. Mining for LHSO will be between 215 and 440 m underground.

Waste rock generated from NOB and LHSO development will be backfilled to underground mine voids, as has historically been the practice at Mt Charlotte. Waste material will be placed both above and below the final post mining groundwater level.

Waste rock from the NOB extension will comprise almost entirely Golden Mile dolerite (GMD) with minor Black Flag shale lithologies, similar to Fimiston Pit. There is a significant amount of assay data and comprehensive waste characterisation for GMD in particular, as well as Black Flag shale from the Fimiston Pit (MBS 2016, MBS 2017). NOB waste rock is expected to be very similar in nature to these previous samples from Fimiston Pit.

The LHSO development will intercept four fresh rock lithologies: Devons Consol basalt (DCB), Williamstown dolerite (WD), Porphyry (POR) and Kapai slate (KS). The lithology identified as Hannans Lake serpentinite (HLS), which is also in the fresh rock zone, lies below the LHSO and is not part of currently proposed mining. These lithologies are not encountered to any significant degree (only minor Kapai slate is intercepted) in Fimiston Pit and as such, no previous waste characterisation data (if any has been performed), is currently available to support mine closure planning. High sulfur assays recorded for Kapai slate during drilling programs have also indicated this lithology presents a risk of generating acidic and metalliferous drainage (AMD). Although KCGM proposes to backfill waste materials from NOB and LHSO to underground mine voids, additional waste characterisation is required to assess potential impacts to the surrounding environment, particularly post closure leaching of environmentally significant metals and metalloids to the groundwater.



Figure 1: KCGM Fimiston Open Pit and Key Mine Waste Landforms

1.2 OBJECTIVE AND SCOPE OF WORK

The objectives and scope of work for the additional waste rock characterisation were to:

- Liaise with KCGM personnel for provision of drill log data including lithology, sulfur assays (percentage sulfur) and depth for a representative selection of Mt Charlotte underground waste rock types.
- Review the above data to select approximately 24 samples across the fresh waste rock lithologies relevant to Mt Charlotte underground LHSO and NOB orebodies. This includes Kapai slate, Devons Consol basalt, Hannans Lake serpentinite and Williamstown dolerite for the LHSO and the U8 and U9 sequences of Golden Mile dolerite for NOB.
- Visit the Mt Charlotte mine to collect the above samples of drill core, discuss the geology, mine waste planning, available assay results and predicted post-closure groundwater levels.
- Submit samples to a laboratory for determination of the following acid base accounting (ABA) parameters:
  - Total sulfur, sulfate sulfur and (for shale and slate lithologies) chromium reducible sulfur (CRS).
  - Acid Neutralising Capacity (ANC).
  - Total carbon.
  - Net Acid Generation (NAG) test on samples containing >0.2% total sulfur.
- Submit selected samples to the laboratory for the following:
  - Elemental analysis of four acid digest solutions (Ag, Al, As, B, Ba, Ca, Cd, Co, Cu, Cr, Fe, K, Mg, Mn, Mo, Na, Ni, Pb, Sb, Se, Sn, Te, Th, U, V and Zn) and mercury (separate digestion required).
  - Analysis of water and dilute acid leachates of selected samples (based on expected AMD results) for pH, EC, alkalinity/acidity, major ions (Ca, Mg, Na, K, Cl, sulfate) and soluble metals and metalloids (Ag, Al, As, B, Ba, Be, Ca, Cd, Co, Cu, Cr, Fe, K, Hg, Li, Mg, Mn, Mo, Na, Ni, Nb, Pb, Sb, Se, Sn, Ta, U, V and Zn).
  - Mineralogy by X-Ray Diffraction (XRD) (one for each lithology).
- Preparation of a concise geochemical report outlining the properties of the waste rock lithologies and discussing similarities to Fimiston Pit wastes. This does not include an assessment of potential for asbestiform minerals.
- Assessment of the relative risk of neutral and acid drainage potential within waste rock from Mt Charlotte based on available information and current/intended mine practices.

2. PROJECT GEOLOGY AND HYDROLOGY

2.1 MT CHARLOTTE UNDERGROUND GEOLOGY

The Kalgoorlie-Boulder stratigraphy lies within the Archaean aged Norseman-Wiluna Greenstone Belt of WA. Intruded mafic to ultramafic sills contain gold-bearing lodes. Most gold mineralisation in the Golden Mile Deposit (including the NOB extension and Fimiston Pit) is hosted within one of these sills; the Golden Mile dolerite. The Fimiston deposit is dominated by the large Kalgoorlie Anticline/Syncline system which caused deformation of the original stratigraphic sequence. The Golden Mile Fault is the main fault occurring in this system and is directly associated with GMD (KCGM 2014). The GMD layer consisting of mafic-ultramafic rocks is further divided into ten units (designated U1 to U10) which differentiate between mineral concentration and texture of GMD.

The Central Lease area geology, which includes the LHSO deposit, is complex due to multiple overprinting folding events and later crosscutting faults. The general profile of the Central Lease deposits consists of a lower mafic-ultramafic volcanic sequence with sub volcanic sills overlain by a thick sequence of sedimentary and intermediate to felsic volcaniclastic rocks. The lower GMD stratigraphy hosts the LHSO deposit, which also holds the main Mt Charlotte-based Fimiston Deposit, and has expressions in the southern portion of the greenstone belt (Figure 2). Figure 3 is a mine cross-sectional view looking north of Mt Charlotte underground and the LHSO deposit showing drill holes for LHSO which were selected for the current study.

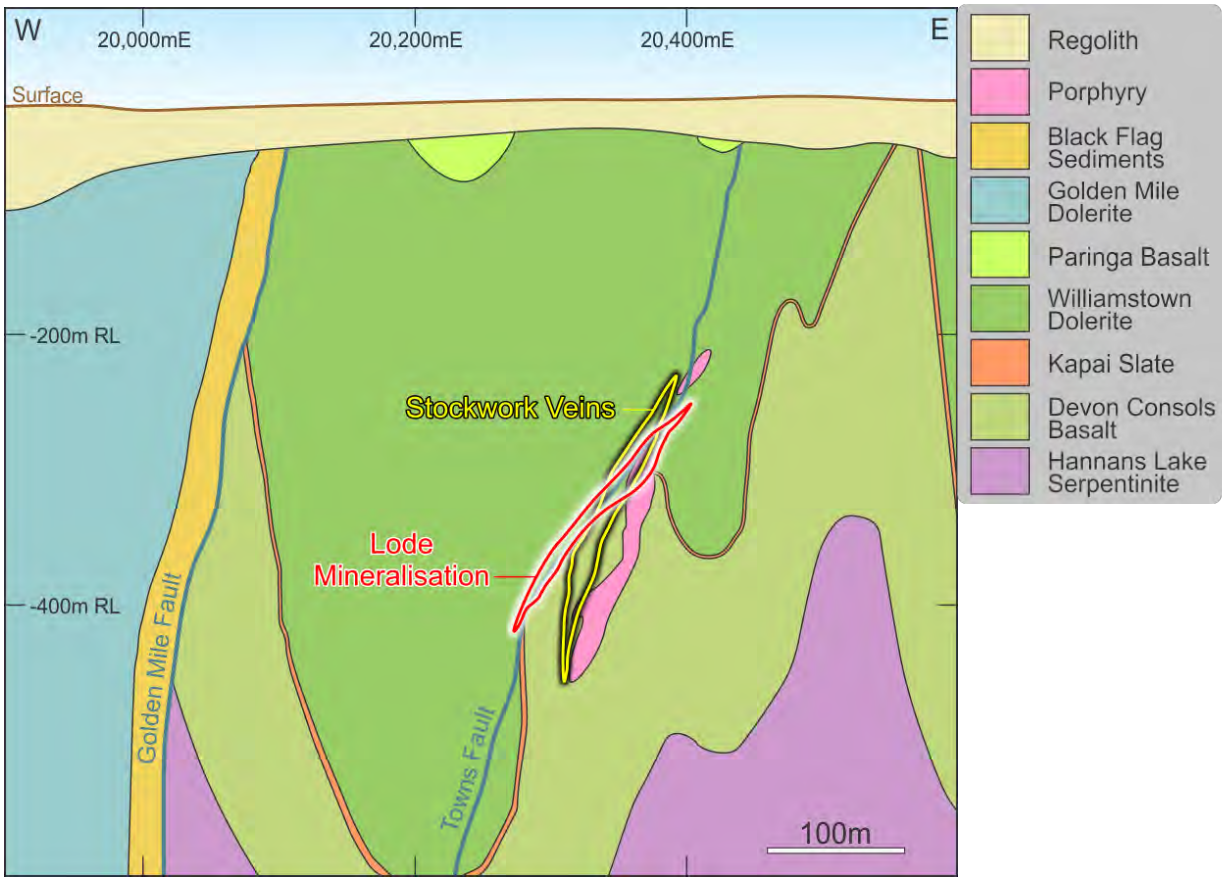


Figure 2: Lower Hidden Secret Orebody Cross-Sectional Geology Schematic

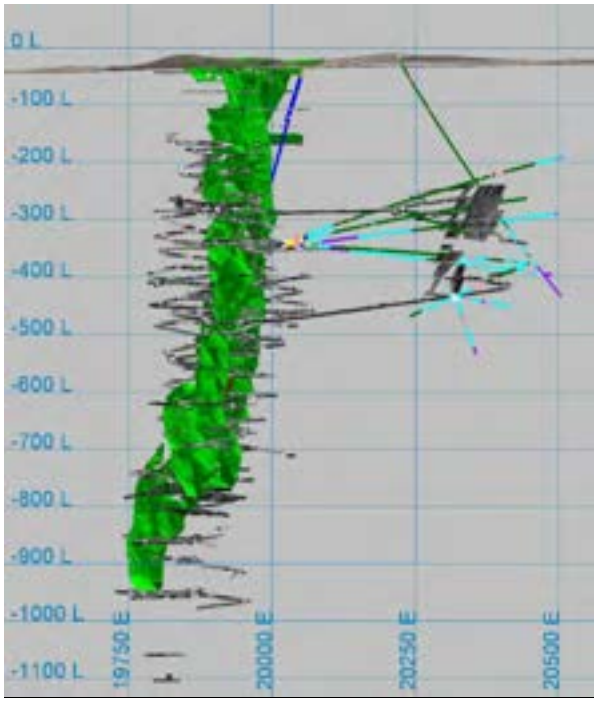


Figure 3: Cross-Sectional View of Mt Charlotte Underground/LHSO Looking North

The mineralising event on the Golden Mile has led to an overall geochemical enrichment in arsenic (As), tellurium (Te), mercury (Hg), lead (Pb), vanadium (V) and boron (B). This enrichment is largely confined to the main lode systems with lower levels of enrichment in the surrounding host BF shales and significantly lower enrichment in the host GMD and Paringa basalt. Gold mineralisation in the LHSO is associated with silver, tellurium, mercury, zinc and copper minerals with a significant presence of hessite (Ag_2Te) in particular (Fitzgerald and Nixon 2016 and references therein).

Estimated waste rock tonnages by lithology for each deposit are given in Table 1.

Table 1: Mt Charlotte Waste Rock Breakdown by Lithology (KCGM Block Model)

Deposit	Lithology (Abbreviation)	Tonnes	Percentage of Total Waste
NOB	Golden Mile dolerite (GMD)	1,961,250	98.7
	Black Flag shale (BF)	26,046	1.3
	Total	**1,987,296**	**100**
LHSO	Williamstown dolerite (WD)	388,727	64
	Devons Consul basalt (DCB)	135,043	22
	Porphyry (POR)	76,694	13
	Kapai slate (KS)	7,469	1.2
	Total	**607,932**	**100**

2.2 REGIONAL AND LOCAL HYDROGEOLOGY

2.2.1 Regional Hydrogeology

There are three major groundwater systems which have been defined during extensive drilling and testing in the vicinity of KCGM:

- The shallow ferricrete and alluvial sedimentary system, an accumulation of sand, gravel and fractured ferricrete within clays, occurring typically from 4 to 40 m depth, which is present in lower elevation areas of the surface water catchments;
- The palaeochannel systems, an extensive network of Tertiary alluvial sands occurring at around 60 m depth in buried river channels. This aquifer system is well understood and is utilised by KCGM and by other mining operations as the primary source of process water supply; and
- The bedrock system hosted primarily within GMD and Paringa basalt, where groundwater flow occurs in fractured and weathered zones within the basement rocks at depth (the primary aquifer for Fimiston Open Pit).

There is no known potable groundwater in the vicinity of Kalgoorlie-Boulder (and by extension, KCGM) within the above systems. Groundwater quality ranges from brackish (1,000 to 3,000 mg/L Total Dissolved Solids (TDS)) in shallow groundwater, to brines approximately five to six times more saline than seawater in paleochannels (up to 200,000 mg/L TDS). The primary influence on the wide variation in TDS concentrations is the topographical location and groundwater age rather than rock type hosting the groundwater system.

2.2.2 Local Hydrogeology

The Mt Charlotte underground mine is not connected to the extensive underground water systems along Kalgoorlie's Golden Mile, which lie beneath the Fimiston Open Pit. Dewatering from Mt Charlotte underground is directed to surface where it is pumped to Fimiston Mill. Minimal (if any) dewatering will need to be carried out at LHSO as a result of dewatering at Mt Charlotte underground (Peter Clifton & Associates 2014) and the observed lack of groundwater flow in mine workings in the area.

Post-closure flood modelling for the Mt Charlotte underground mine was undertaken by Peter Clifton & Associates (2014) to predict long term changes in groundwater levels as the system adjusted to the cessation of mine dewatering. Water entering Mt Charlotte underground post closure will be sourced from a combination of mine surface water runoff (including through the former Glory Hole mine) and underground groundwater from various faults (Charlotte, Flanagan, Neptune and Golden Mile). The natural groundwater level in the area was estimated to be at 335 m Australian height datum (AHD, m above sea level), surface level is approximately 390 m AHD). The most likely modelled scenario considered allowed for flooded mine water in Mt Charlotte underground to reach equilibrium and overflow into the Fimiston Open Pit when the flood level reaches the portal of the Sam Pearce decline at 316 m AHD. This was predicted to occur 99 years after closure of the Mt Charlotte underground mine. The predicted flow rate into Fimiston Pit area (including infiltration into the mine ramp) at the Sam Pearce decline after this time was 33 kL/day.

3. GEOCHEMICAL CHARACTERISATION METHODS

3.1 ACID FORMING WASTE CLASSIFICATION METHODOLOGY

There is no simple method to define whether mine waste containing small quantities of sulfur will produce sulfuric acid. Sulfide minerals are variable in their behaviour under oxidising conditions and not all forms will produce sulfuric acid (H_2SO_4). Instead, a combination of approaches is often applied to more accurately classify mine waste. These approaches are listed below in order of increasing data requirements (and therefore increased reliability):

- The "Analysis Concept", which only requires data for total sulfur content. Its adoption is based on long term experience of wastes from Western Australian mine sites in arid and semi-arid conditions. Experience has shown that waste rock containing very low sulfur contents (less than 0.2 to 0.3%) rarely produces significant amounts of acidic seepage.
- The "Ratio Concept", which compares the relative proportions of acid neutralising minerals (measured by the Acid Neutralising Capacity (ANC)) to acid generating minerals (measured by the Maximum Potential Acidity (MPA)). Experience has shown that the risk of generating acidic seepage is generally low when this ratio (the Neutralisation Potential Ratio – NPR) is above a value of two.
- Acid-Base Accounting, in which the calculated value for Nett Acid Producing Potential (NAPP) is used to classify the acid generating potential of mine waste. NAPP is equal to the MPA minus the ANC.
- Procedures recommended by AMIRA (2002), which take into consideration measured values provided by the Nett Acid Generation (NAG) test and calculated NAPP values.
- Kinetic leaching column test data, which provides information for the relative rates of acid generation under controlled laboratory conditions, intended to simulate those within a waste rock dump (WRD) or tailings storage facility (TSF).

A sound knowledge of geological and geochemical processes must also be employed in the application of the above methods.

Classification of wastes in this report uses procedures recommended by AMIRA (2002) based on NAPP and NAGpH results. However, results are also compared to the Analysis Concept (total sulfur) and Ratio Concept models and a modification of the AMIRA procedure by determination of the following:

- Analysis for total sulfur (Tot_S) and sulfate sulfur (SO_4_S), both reported as sulfur, as a measure of oxidisable sulfur. Alternatively, Chromium Reducible Sulfur (CRS) can be used a direct measure of oxidisable sulfur and is potentially a better method for lithologies with significant organic carbon such as shales and slates.
- Analysis for ANC (quoted in kg H_2SO_4/t).
- Calculation of carbonate neutralising potential (CarbNP) (quoted in kg H_2SO_4/t) from measured concentrations of carbon.
- Calculation of Acid Production Potential (AP) = [(Tot_S – SO_4_S) * 30.6] kg H_2SO_4/t. Chromium Reducible Sulfur (CRS) can be used in place of total sulfur minus sulfate sulfur in this calculation of AP.
- Calculation of NAPP = [AP – ANC] kg H_2SO_4/t.
- Calculation of Effective NAPP = [AP – CarbNP] kg H_2SO_4/t.
- Analysis for NAG (quoted in kg H_2SO_4/t).
- Analysis for NAGpH.
- Calculation of NPR = ANC/AP.

This AMIRA approach is more conservative than either the Analysis Concept or the Ratio Concept alone, but assumes the absence of sulfur present as barium sulfate. The AMIRA approach of using NAG testing is particularly useful for PAF-LC materials or where there is very low ANC in the host rock. A combined acid generation classification scheme based on NAPP and NAG determinations is presented in Table 2.

Table 2: Waste Classification Criteria

Primary Geochemical Waste Type Class	NAPP Value kg H_2SO_4/t	NAGpH	Sulfide S Content
Potentially Acid Forming (PAF)	≥10	< 4.5	≥ 0.3%
Potentially Acid Forming – Low Capacity (PAF-LC)	0 to 10	< 4.5	0.16 to 0.3%
Uncertain (UC)	0 to 5	> 4.5	Not important
Uncertain (UC)	-10 to 0	< 4.5	Not important
Non Acid Forming (NAF)	-100 to 0	> 4.5	Not important
Acid Consuming (AC)	< -100	> 4.5	Not important

Table 2 is based on the Australian Government's Guidelines on Managing Acidic and Metalliferous Drainage (DIIS 2016) and is in turn based on an earlier classification system included within the AMIRA ARD Test Handbook (AMIRA 2002), which is advocated by the Global Acid Rock Drainage Guidelines (GARD) published by the International Network for Acid Prevention (INAP 2009). This classification system, based on static acid base accounting procedures and used in conjunction with geological, geochemical and mineralogical analysis can still leave materials classified as 'uncertain' where there is conflicting NAGpH and NAPP results. Uncertain materials demonstrating a NAGpH above 4.5 may be tentatively assigned as potentially NAF and those below pH 4.5 as potentially PAF – however in such cases, further assessment, such as the use of kinetic leaching columns may be required to provide a definitive classification.

3.2 LABORATORY METHODS

Representative samples from NOB and LHSO were collected by MBS and submitted to Intertek Genalysis which holds accreditation with the National Association of Testing Authorities (NATA). Collated results of all analysis are presented in Appendix 1 and original lab reports attached in Appendix 2.

3.2.1 Acid Base Accounting

All samples collected were screened for total sulfur and carbon as well as ANC. Full ABA analysis (namely sulfate-sulfur and NAG analysis) was only conducted on samples containing greater than or equal to 0.2% total sulfur (Analysis Concept).

ANC was measured by a modified Sobek procedure (AMIRA 2002), which involves addition of dilute hydrochloric acid to the sample, followed by gentle simmering (two hours) to complete the reaction. The ABA scheme relies on measurement of oxidisable sulfur. The value of this fraction of sulfur in mine waste samples is calculated as the difference between total sulfur and sulfate-sulfur, which is present in a fully oxidised form and therefore not capable of generating additional acidity. Sulfate-sulfur content was determined by a heated hydrochloric acid extraction and Inductively Coupled Plasma – Optical Emission Spectrometry (ICP-OES) finish. CRS was also measured on selected samples (Kapai slate) in conjunction with total sulfur and sulfate-sulfur. CRS provides a direct measurement of sulfide-sulfur (instead of calculation of total oxidisable sulfur (TOS) as the difference between total sulfur and sulfate sulfur). Kapai Slate samples are expected to contain organic sulfur forms which do not generate acid upon oxidation. CRS measurement therefore can provide a more accurate prediction of sulfide sulfur and hence acid generation potential compared to calculation of TOS.

When assessing data for the MPA and NAPP, it must be noted that both parameters are based on the assumption that all sulfur contained in the sample is acid producing (sourced from pyrite (FeS_2) and other iron sulfide minerals). However, this represents a worst case scenario as not all minerals containing sulfur will result in acid production. Conversely, the NAPP calculation also assumes that the acid neutralising material measured in ANC is rapid-acting. In practice, some neutralising capacity is supplied by silicate and aluminosilicate minerals which can be much slower to react. Further still, iron carbonate minerals such as siderite ($FeCO_3$) have limited or no capacity to neutralise acidity due to acid producing reactions resulting from oxidation of the dissolved ferrous iron component. Despite these assumptions, NAPP remains a suitable conservative prediction of potential acid generation when used in conjunction with mineralogical data.

The NAG test involves the addition of hydrogen peroxide, a strong oxidising agent, to a sample of mine waste to oxidise reactive sulfides. After cooling the sample pH is measured (NAGpH) and any acidity generated measured by back titrating with sodium hydroxide solution to a pH of 4.5 (NAG to pH 4.5) and pH 7 (NAG to pH 7). NAG is expressed in units of kg H_2SO_4/t. A significant NAG result (i.e. final NAGpH less than 4.5) generally indicates that the sample is PAF (Table 2) and the test provides a direct measure of the NAG potential. A NAGpH of 4.5 or more generally indicates that the sample is NAF, but may still be capable of generating metalliferous drainage following oxidation of the sulfide minerals. Results for titrations of aliquots of the NAG solution to endpoint pH values of 4.5 and 7.0 allow estimation by the difference between these results of the relative amounts of non-acid producing base metal (such as copper) and iron sulfides in the sample.

3.2.2 Water and Dilute Acid Extractable Leach

Selected samples were subjected to a water extraction (deionised, 1:5 extraction ratio) to assess potentially soluble species from waste rock. The Australian Standard Leaching Procedure (ASLP, 1:20 ratio) was also performed on selected samples using dilute acetic acid (pH 2.9) as the extraction fluid. This test was performed to simulate seepage quality expected under mild acidic conditions which may be achieved by severe oxidation of sulfide minerals.

3.2.3 Elemental Composition

Environmentally significant metals and metalloids were measured following digestion of a finely ground sample with a mixture of four acids (hydrochloric, nitric, perchloric and hydrofluoric acids) which is a near total determination for the elements measured.

From this data, the global abundance index (GAI) for each element was calculated by comparison to the average earth crustal abundance (Bowen 1979 and AIMM 2001). The main purpose of the GAI is to provide an indication of any elemental enrichment that could be of environmental significance. The GAI (based on a log-2 scale) is expressed in integer increments from zero to six (GARD Guide). A GAI of zero indicates that the content of the element is less than or up to three times the average crustal abundance; a GAI of one corresponds to a three to six fold enrichment; a GAI of two corresponds to a six to 12 fold enrichment and so forth, up to a GAI of six which corresponds to a 96-fold, or greater, enrichment above average crustal abundances. A GAI of more than three is considered significant and may warrant further investigation. Results have been truncated to show no more than a GAI of six.

3.2.4 Mineralogy

Six samples in total, from both NOB and LHSO, representing each of the fresh lithological units (Williamstown dolerite, Porphyry, Devons Consol basalt, Kapai slate, Hannans Lake serpentinite and Golden Mile dolerite) were chosen for mineralogical determination. These samples were submitted to Intertek Genalysis Laboratory Services for a quantitative powder XRD of the crystalline and amorphous contents. Samples were further ground to a very fine powder in an agate mortar and pestle and subsampled for analysis with and without addition of zinc oxide (solid dilution 10% by weight) to determine amorphous content. XRD patterns were then collected on PANalytical Cubix wavelength dispersive XRD with quantitative analysis performed using an automated Rietveld method of correction. Full experimental details are provided in the mineralogical laboratory report presented in Appendix 2

4. PREVIOUS STUDIES ON GMD AND BF SHALE

GMD and BF shale in NOB occur as part of the same mineralisation event present in Fimiston Pit and results of previous geochemical characterisations for these lithologies within Fimiston Pit are therefore relevant to this study. A summary of previous findings for GMD and BF shale is given below.

4.1 GOLDEN MILE DOLERITE

A review of three previous Fimiston Pit geochemical studies (MBS 2016) and assay data for the GMD lithology (MBS 2017) indicated GMD is geochemically benign. A summary of previous findings for this lithology in Fimiston Pit is provided below:

- Assay data from 101,751 samples indicated the majority (54%) contained total sulfur concentrations of less than 0.3%. The median was 0.26% and 90th percentile 1.81%.
- Calculated MPA based on 90th percentile concentration (1.81%) was 50 kg H_2SO_4/t, which was significantly less than the average ANC of 171 kg H_2SO_4/t measured from 27 samples.
- Mineralogical analysis by XRD identified trace/accessory levels of pyrite in four samples and significant concentrations of ankerite as the dominant carbonate mineral able to provide substantial ANC consistent with the results above.
- All GMD samples were classified as NAF, with the majority being further classified as acid consuming due to low sulfur content and high ANC. Neutral to mildly alkaline pH and low to moderate salinity levels will therefore result in any seepage water generated.
- Environmentally significant metals and metalloids were very low; with enrichment noted for gold, silver, antimony and some samples for mercury. Given the local geology, tellurium was also expected to be enriched, although it was not included in the analysis suite for these studies. Concentrations and expected solubilities of metals and metalloids were not considered a risk to the receiving environment.
- GMD was considered suitable for rock armouring or construction purposes, given its benign geochemical nature and physical competence. Results also indicated it would be suitable for PAF encapsulation on an above ground waste landform given its high ANC content.

4.2 BLACK FLAG SHALE

A review of three previous Fimiston Pit geochemical studies (MBS 2016) and additional characterisation work for the BF shale lithology (MBS 2017) indicated variable total sulfur contents, generally dependant on the material's position within the shale seam. This position therefore determines the AMD properties of this minor lithology which comprises 1.3% of the NOB waste material. A summary of findings for the BF shale lithology in Fimiston Pit is provided below:

- Assay data from 2,687 samples indicated a median sulfur content of 1.98% and 90th percentile sulfur content of 5.49%.
- Due to the presence of organic sulfur, total sulfur concentrations tend to overestimate the amount of oxidisable sulfur and CRS was found to be a better measure of oxidisable sulfur. The proportion of CRS to total sulfur was however relatively consistent for the 15 fresh rock samples assessed for CRS at an average of 84% of total sulfur.
- The ratio of oxidisable sulfur (in the form of pyrite) to ANC (in the form of ankerite) was generally dependant on the material's position within the BF Shale bed. The central six metres of the BF Shale bed was found to be the dominant sulfide/lower ANC zone, but 'fingers' of sulfides and carbonates occurred outside this zone as well. Siderite (iron carbonate) was also present in various samples, but this mineral does not contribute to ANC.

- Due to the spatial and compositional variability of the BF Shale material, some inherent variability in the potential to oxidise and generate AMD was observed across all studies. This included bulk container field trials over 11 years at KCGM.
- Overall, based on estimations from total sulfur content and measured NAGpH, it is predicted that BF shale waste with between 2 and 4% sulfur may be classified as PAF. This represents between 19 and 50% of BF shale waste which, under worst case scenario exposure conditions, may generate AMD.
- BF shale was enriched in various metals and metalloids (Au, Ag, Hg, Te, Sb, Se, Cd, Cu, Zn in particular) at levels significantly higher than present in the surrounding GMD and Paringa basalt. Concentrations were consistent with those expected for material within or approaching the lode zone. Samples of fresh rock BF shale contained low concentrations of soluble metals and metalloids and leachates were circum-neutral to alkaline, with low to moderate salinity. Extreme weathering under worst case exposure conditions of PAF-HC material still did not release soluble Hg, Te or Sb. Primary metals released with acid formation were Al, Mn, Fe, Cu, Ni, Co and Zn.
- Sulfide oxidation rates were very slow, resulting in a significant lag period before acid generation occurs. There was also significant ANC within the host rock, such that net acid generation and associated metals leaching should only be possible after very prolonged exposure.

Operating guidelines at KCGM have been implemented to treat all BF shale as PAF and ensure correct placement and encapsulation within surrounding mafic waste rock within the WRDs. Given this, prolonged exposure of BF Shale leading to acid generation is considered unlikely.

5. REVIEW OF LHSO ASSAY DATA BY LITHOLOGY

LHSO sulfur assay data measured by X-Ray Fluorescence (XRF) during drilling programs were provided to MBS for review as part of this report. A summary of this data for waste rock by lithology is outlined in Table 3. A histogram of sulfur content for key example lithologies of WD and KS are shown in Chart 1 and Chart 2, respectively. Key points noted are as follows:

- GMD assay data was very similar to or slightly lower than previous results from Fimiston Pit (Section 4.1, MBS 2017) which again indicates a low risk of AMD formation, assuming similar levels of ANC.
- HLS (logged in drilling, but not part of waste rock for LHSO) was very low in sulfur with 71% of samples recording concentrations at or below the 0.3% sulfur content (Table 3) stipulated by the 'Analysis Concept'. These samples therefore pose a very low risk of generating AMD.
- WD, DCB and POR, which are the major waste rock lithologies for LHSO, contained similar, relatively low concentrations of sulfur. Approximately 66% of WD samples, for example, contained less than or equal to 0.3 % sulfur. This lithology represents 64% of LHSO waste rock by tonnage.
- Sulfur in KS (Chart 2) was more variable with significantly higher average and 90th percentile concentrations. Although a minor lithology (1.2% of LHSO waste tonnage), this material clearly has significant potential for acid formation.

Table 3: Sulfur (%) Summary for LHSO Drilling Assays

Lithology	# Samples	Average	Median	90th Percentile	Maximum	% At or Below 0.3 %S of Analysis Concept
WD	11,609	0.66	0.11	1.69	36	66
DCB	11,828	0.83	0.13	2.00	58	61
POR	2,918	0.85	0.46	2.03	30	44
KS	601	7.39	6.73	17.9	35	31
HLS	433	0.37	0.08	1.0	5.7	71
GMD	3,395	0.46	0.05	1.3	22	76

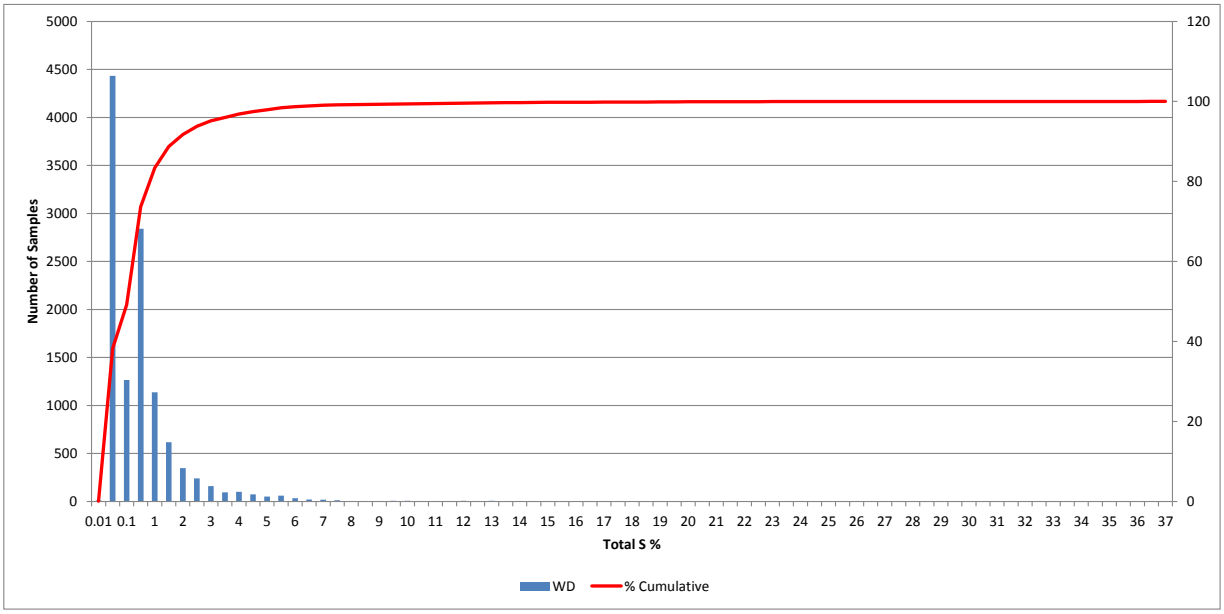


Chart 1: Frequency Histogram of Total Sulfur in WD Assay Samples

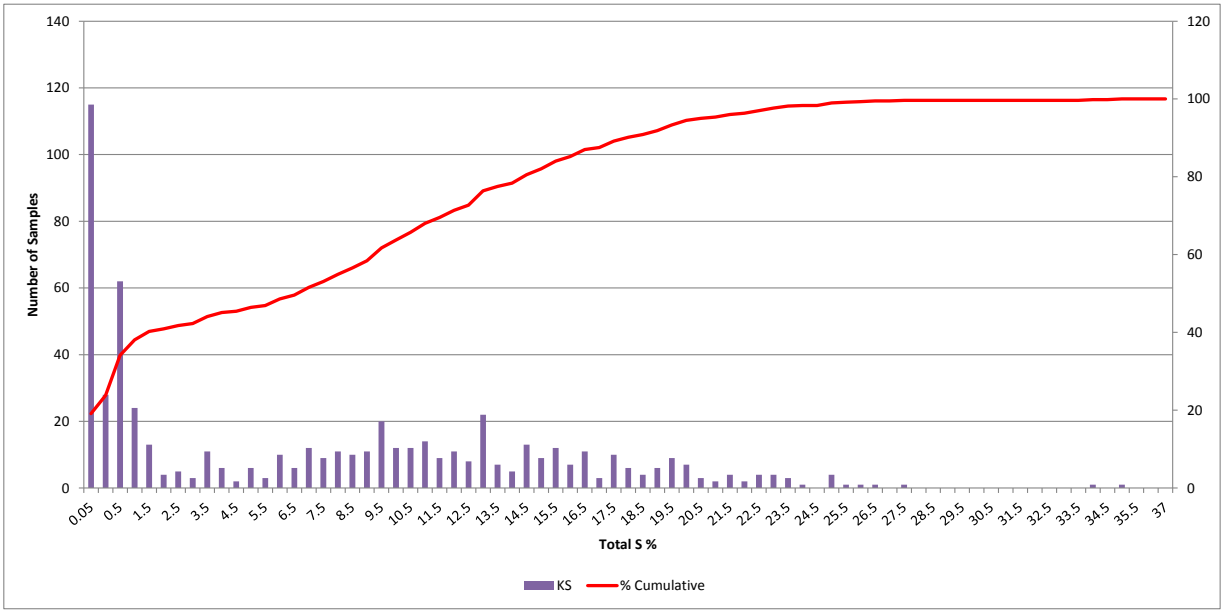


Chart 2: Frequency Histogram of Total Sulfur in KS Assay Samples

6. DESCRIPTION OF SAMPLES

Following a desktop review of available drill log and assay data provided by KCGM personnel, MBS collected 27 representative core samples representing various waste lithologies associated with the LHSO and NOB orebodies at the Mt Charlotte underground mine. Hannans Lake serpentinite, although outside current planned mining zones, was also sampled so as to include all lithologies in the area. NOB waste rock consists entirely of GMD and minor (1.3%) BF shale and is considered geochemically similar to waste rock from Fimiston Pit, properties of which were outlined in Section 4. Consideration of these previous study results thus influenced sampling for current Mt Charlotte waste characterisation with only four samples of GMD from the NOB extension sampled in order to confirm consistency of properties with Fimiston Pit studies. One of these samples (NOBREG), represented weathered regolith – all other samples for the study of NOB and LHSO were of fresh rock consistent with the proposed mining zone. Samples were selected across the range of mining depths, lithologies and sulfur contents considered to be representative of waste rock. A summary of samples collected from the LHSO and NOB by lithology is given in Table 4. Full descriptions are provided in Table A1-1 of Appendix 1.

Table 4: Sample Descriptions

Lithology	Depth Range (m)	Total Samples Collected
Lower Hidden Secret Orebody (LHSO)		
Williamstown dolerite (WD)	28 to 373	5
Porphyry (POR)	55 to 398	4
Devons Consol basalt (DCB)	31 to 330	5
Kapai slate (KS)	70.5 to 502	5
Hannans Lake serpentinite (HLS)	52 to 481	4
Total samples collected from LHSO		**23**
Northern Orebody (NOB)		
Golden Mile dolerite (GMD)	12 to 230	4
Total samples collected from NOB		**4**

7. RESULTS AND DISCUSSION

7.1 ACID BASE ACCOUNTING

Laboratory results for total sulfur, CRS, ANC, NAG testing and calculated acid base accounting parameters of the NOB and LHSO samples are collated in Table A1-2 of Appendix 1. The original laboratory reports are included in Appendix 2.

7.1.1 Sulfur Forms

A summary of results for the three sulfur forms assessed is provided in Table 5.

Table 5: Sulfur (%) Forms Summary

Lithology	# Samples	SO_4_S Range	SO_4_S Mean	Total S Range	Total S Mean	CRS Mean*
WD	5	<0.01 to 0.01	<0.01	0.13 to 3.6	1.1	N/A
DCB	5	<0.01	<0.01	0.55 to 1.4	1.1	N/A
POR	4	<0.01	<0.01	0.12 to 1.4	0.80	N/A
KS	5	0.03 to 0.15	0.07	6.2 to 21.6	12.6	10.0
HLS	4	<0.01	<0.01	0.24 to 1.1	0.50	N/A
NOB GMD	4	<0.01 to 0.02	<0.01	0.02 to 1.09	0.40	N/A

**N/A Indicates not analysed.*

As CRS is considered a better indicator of oxidisable sulfide content for KS samples, the ABA parameters AP and NAPP were calculated from CRS for these samples rather than as total sulfur minus sulfate sulfur in Table A1-2.

Based on the data in Table 5, and Tables A1-1 and A1-2 (Appendix 1), the following are noted as key points:

- CRS, on average, accounted for 79% of the total sulfur present in KS, which was very similar to the 84% observed in BF shale samples (MBS 2017). Total sulfur in these samples includes organic sulfur which does not oxidise to form acid and can therefore result in misleading ABA parameters (high bias).
- Consistent with samples being from the fresh rock zone (apart from NOB REG), levels of sulfate were generally very low to non-detectable.
- Levels of total sulfur were approximately consistent with the overall trends seen from assay analysis (Section 5), with KS having significantly higher total sulfur contents and noted field reactivity versus the others which was reflected in higher sulfate levels for these samples.

7.1.2 Acid Neutralisation Capacity

ANC was measured directly by acid addition, heating and back-titration. Results are provided in Table 6 together with acid production potentials for each lithology, calculated from overall mean sulfur assays (Table 3). Carb-NP results (calculated from the measured total carbon analysis), are given in Table A1-2 (Appendix 1).

Table 6: ANC Versus Mean AP From Total Sulfur Assays (kg H_2SO_4/t)

Lithology	# Samples	ANC Minimum	ANC Maximum	ANC Mean	AP Mean
WD	5	204	422	299	20
DCB	4	216	419	310	16
POR	5	74	179	104	26
KS	5	10	145	84	226
HLS	4	243	480	350	11
NOB GMD	4	21	228	132	14

Based on the data in Table 6, and Table A1-2 (Appendix 1), the following are noted as key points:

- ANC levels were high to very high in all samples from all lithologies, but in particular WD, DCB and HLS. WD and DCB are the dominant waste lithologies by tonnage from LHSO (Table 1).
- KS had the lowest levels of ANC and was the only lithology to have mean ANC levels below the calculated AP from sulfur assay data. For other lithologies, the mean ANC of samples from this work were between 4 and 32 times the level of AP calculated from sulfur assays in the KCGM database.
- For most samples there was very good agreement between the measured ANC and the calculated Carb-NP, which is consistent with readily available carbonates contributing to the ANC. The KS lithology showed marginally more variation which is considered to be due to the presence of organic carbon.

7.1.3 Acid Drainage Classification

AMD classifications based on criteria in Table 2 are outlined in Table A1-2 of Appendix 1. Classifications for samples with more than 0.2% sulfur are represented as a plot of NAPP (CRS used for KS) versus NAGpH for the samples grouped by lithology in Chart 3. The four quadrants are labelled as NAF, PAF and two UC (uncertain) according to the classification criteria in Table 2.

Based on examination of these results, the following can be noted:

- All lithologies other than KS (and BF shale which was previously discussed in section 4.2), from Mt Charlotte were classified as NAF with measured NAGpH values of greater than 4.5 for those measured (more than 0.2% total sulfur). In addition due, to the very high levels of ANC relative to oxidisable sulfur, many were further classified as 'acid consuming' (AC). All samples of WD, DCB and HLS were thus classified as AC. Two of the three fresh rock GMD samples and one of the four POR samples were also classified as AC.
- Four out of the five KS samples were classified as PAF – high capacity. This was a result of high levels of oxidisable sulfur and somewhat lower levels of ANC. One KS sample (KS 2), had a conflicting slightly positive NAPP (35 kg H_2SO_4/t), but a reported NAGpH value of 7.4, resulting in an uncertain classification (UC). As indicated previously, the reactive nature of KS was noted in oxidation and visible acid formation in the drill core trays exposed at KCGM.

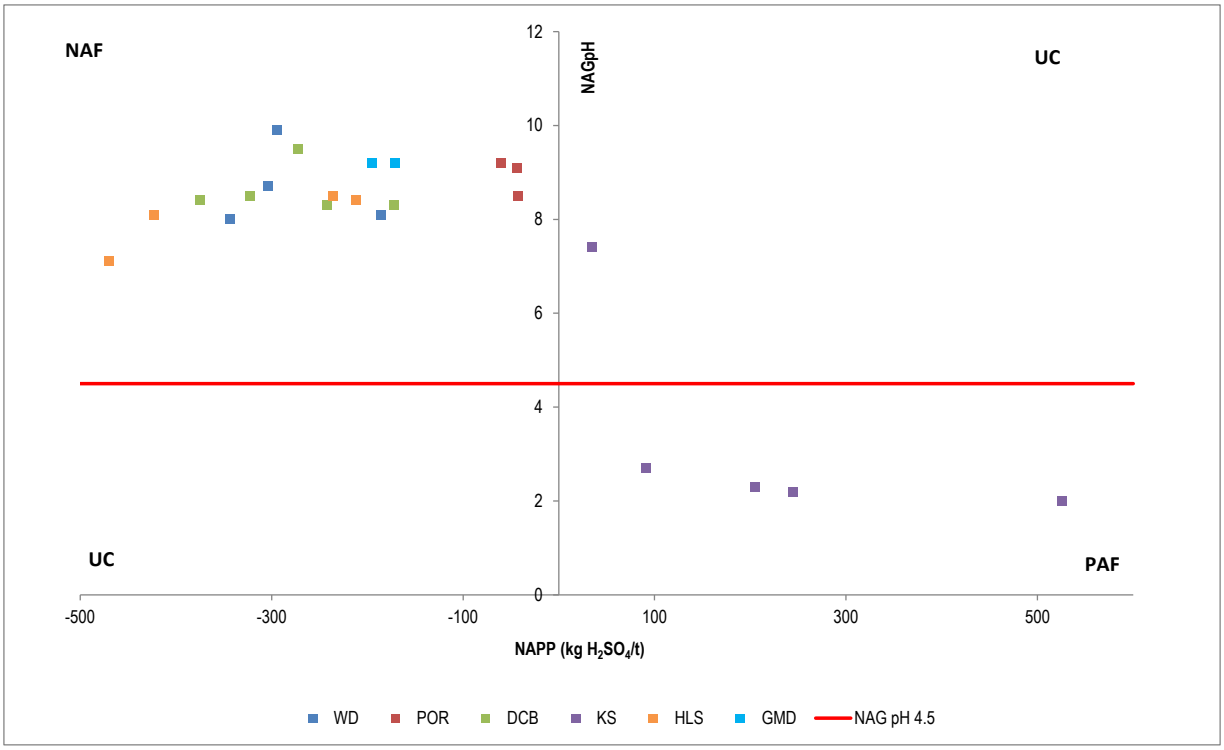


Chart 3: AMD Plot Classifications of Mt Charlotte Lithologies

7.2 ELEMENTAL COMPOSITION

Total elemental composition of selected (, Mt Charlotte waste rock samples (four of each lithology) is presented in Table A1-3 of Appendix 1. Tables A1-4 of Appendix 1 presents calculated GAI values for these samples, as outlined in Section 3.2.3. A summary of results for enriched (GAI of three or more) samples is provided in Table 7.

Key points noted are as follows:

- Consistent with previously discussed observations regarding LHSO mineralisation (Section 2.1), silver, tellurium and antimony were found to be generally enriched across most to all samples. Hessite (Ag_2Te), which is a key mineral associated with gold mineralisation in LHSO (Section 2.1), accounts for the enrichment in silver and tellurium. Gold was not assessed in the current work and lode zone samples were not targeted, but it is expected that concentrations of these and other elements would also be correlated with gold concentration and increase with proximity to the lode zone.
- Mercury, zinc and copper were not found to be enriched within LHSO waste lithologies, indicating these elements are closely associated with the mineralisation event versus the host rock.
- KS was enriched in a number of elements at concentrations generally similar to those observed for BF shale in Fimiston Pit studies. This included arsenic (one sample), cadmium, copper, mercury, selenium and tin. Mercury in BF shale and Fimiston ore is present primarily as coloradoite (HgTe) which is highly insoluble (CSIRO 2013). Coloradoite is also expected to be the dominant form of mercury in KS.
- Consistent with the mafic lithology, chromium and nickel were marginally enriched in HLS samples. Chromium was also elevated in two of the four WD samples (WD 2 and WD 3) and one DCB sample (DCB 2). Cadmium was also enriched in sample WD 1.

Overall, all waste lithologies were generally enriched in silver, tellurium and antimony. KS was geochemically enriched in a similar series of elements to BF shale. With the exception of the KS lithology and minor enrichment in chromium for mafic lithologies, enrichment in other metals and metalloids is closely associated with proximity to mineralisation. As an example, copper and zinc are almost absent in waste rock other than KS.

Table 7: Mt Charlotte Enriched Metals and Metalloids

Metal	Maximum Concentration (mg/kg)	Maximum GAI	Enriched Lithology
Silver	6.9	6	All except HLS
Arsenic	487	4	KS (1 sample)
Cadmium	16	6 (3 in WD)	KS and WD (1 sample)
Chromium	1,889	4	WD, DCB, HLS
Copper	2,524	5	KS
Mercury	23	3	KS
Nickel	1,030	3	HLS
Antimony	17	6	All
Selenium	17	6	KS
Tin	17	3	KS
Tellurium	5.9		All
Zinc	7,256	6	KS and WD

7.3 WATER LEACHATE CHARACTERISATION

7.3.1 Soluble Salts, Alkalinity and pH

Results for pH, EC, alkalinity and major ions in the 1:5 water extracts of selected samples are given in Table A1-5 of Appendix 1. Results for 1:5 extract pH and EC of all samples are also shown in Table A1-2 of Appendix 1.

Samples of fresh waste rock from Mt Charlotte underground were found to have:

- Generally alkaline pH values, ranging from 8.6 to 9.4 in 1:5 extracts of fresh rock. The only exceptions were samples of partially oxidised KS, where pH values ranged from 4.9 to 8.3.
- Moderate to high levels of soluble alkalinity in most samples, with DCB having the highest levels (up to 128 mg/L as $CaCO_3$). Again, the only exception was KS, which contained low concentrations (3 to 30 mg/L as $CaCO_3$).
- Relatively low levels of salinity and soluble salts in fresh rock waste samples with most samples having 1:5 EC values below 200 µS/cm.
- Slightly higher levels of salinity were found in the sample of weathered GMD (GMD REG) with 434 µS/cm and KS 1 and KS 2 (maximum 578 µS/cm), both of which had visible signs of oxidation from field exposure.
- Sulfate was the dominant anion rather than chloride, with significant calcium and magnesium as well as sodium present as the dominant cations.

Overall, results suggest that with the exception of isolated pockets of minor KS lithology, the salinity of waste rock placed underground post mining will remain low and any leachate will be alkaline in nature.

7.3.2 Soluble Metals and Metalloids

Results for water soluble metals and metalloids in the 1:5 extracts of samples are given in Table A1-6 of Appendix 1. ANZECC livestock drinking water guidelines (cattle) are provided for comparison, although it is noted that groundwater is far too saline for use other than as process water.

Key observations are summarised below.

- Despite geochemical enrichment in a variety of elements, no metal or metalloid concentrations in the 1:5 extracts of fresh (non-oxidised) waste rock samples exceeded livestock drinking water guidelines. Concentrations of silver and tellurium which were enriched in the waste rock samples, but have no livestock drinking water guideline, were also very low or not detectable.
- Only low concentrations of antimony were noted in 1:5 extracts (maximum 12 µg/L), despite geochemical enrichment of this element of most samples. There is no corresponding guideline for antimony, but it has a similar or slightly higher toxicity than arsenic, for which the livestock guideline is 500 µg/L. Measured concentrations therefore are not considered to pose any risk to the receiving environment.
- Sample KS 1 which was already partially oxidised by field exposure in the core yard for several years recorded a pH of 4.9 and the 1:5 extract slightly exceeded the ANZECC livestock drinking water guidelines for cadmium (23.6 µg/L) and zinc (28.7 mg/L). However these results:
  - Would not exceed guidelines of 10 µg/L (cadmium) and 20 mg/L (zinc) using the ASLP dilution ratio of 1:20 instead of 1:5. The 1:5 dilution ratio is commonly used to provide better sensitivity for minor elemental concentrations, but obviously magnifies results.
  - Represent samples after several years of exposure to weathering. Such conditions are unlikely to be replicated for such periods of time in the Mt Charlotte underground.
  - Do not reflect placement conditions in the Mt Charlotte underground where surrounding high ANC rock will control pH, generating more alkaline conditions and hence limit solubility of cadmium in particular.

Overall, minimising the rate of oxidation of the minor volume of KS waste rock by placement underground, in conjunction with the high ANC waste rock of other LHSO lithologies, should control any risk to receiving groundwater of soluble metals and metalloids.

7.4 DILUTE ACID LEACHATE CHARACTERISATION

Dilute acetic acid leachate tests provide an indication of the acid neutralising minerals and metals which may be released if management measures for control of oxidation of sulfides and acid formation were not applied. Results for selected samples of Mt Charlotte waste rock are presented in Table A1-7 of Appendix 1.

Under the acidic conditions of this test (starting pH 2.9, final pH 4.1 to 5.2) the following was noted:

- Calcium, iron and magnesium were the major cations solubilised by contact with acid which is consistent with the presence of reactive carbonate minerals such as ankerite, dolomite and calcite. Calcite and ankerite are often observed to be slightly more reactive than dolomite under laboratory conditions and hence will be the first to react to neutralise acid.
- Despite geochemical enrichment in various elements and the acidic conditions of the extract, soluble concentrations of all metals and metalloids of environmental concern were very low. All concentrations were below the livestock drinking water guidelines with the exception of lead in sample KS 2 (148 µg/L versus livestock guideline of 100 µg/L).
- Lead (148 µg/L) and antimony (14 µg/L) in KS 2 were the main notably elevated elements for the acetic acid leachates of samples. However, such concentrations from isolated amounts of KS are considered unlikely given the underground disposal regime, limited exposure to oxygen and buffering capacity of surrounding rock.

Results suggest the most significant metals and metalloids which may be released as a result of uncontrolled oxidation without neutralisation of KS waste rock will be lead, zinc, cadmium and antimony. Mercury was not significantly soluble which is consistent with observations from BF shale (MBS 2017). It is important to reiterate the fact that elemental concentrations presented in Table A1-7 are not a prediction of net expected concentrations

of actual seepage, but an indication of acid neutralisation reactions and species that may be solubilised under acid conditions prior to any neutralisation and precipitation by interactions with surrounding rock.

7.5 MINERALOGICAL ASSESSMENT

Results for the mineralogical assessment of the crystalline and amorphous content of six samples from the fresh rock zone are summarised in Table 8. The quantitative X-ray diffraction analysis report is provided in Appendix 2.

Results indicate the following key points:

- Pyrite was the only acid forming mineral present which confirms the validity of AP calculations based on oxidisable sulfur contents.
- Very high amounts of readily available acid neutralising carbonate minerals were present, namely as ankerite, ferroan magnesite, dolomite and calcite, depending on the lithology (refer Glossary Section 10). With the exception of KS, quantities of these carbonate materials far exceeded the pyrite content which is consistent with the NAF and often acid consuming classification of WD, POR, DCB, HLS and GMD lithologies.
- Other minerals present in significant concentrations included quartz, plagioclase and chlorite which are either non-reactive or mildly acid neutralising (chlorite).

Table 8: Mineralogical Summary

Sample	AMD Class	Mineral Content (%)
WD 3	NAF (AC)	Quartz (29), ferroan magnesite (35), sodium calcium plagioclase (10), chlorite (6), ankerite (13), pyrite (4), illite/muscovite (1), potassium feldspar (1). Amorphous content 3%
POR 1	NAF	Quartz (29), sodium calcium plagioclase (35), dolomite (7), pyrite (2), illite/muscovite (24). Amorphous content 2%
DCB 2	NAF (AC)	Quartz (28), ferroan magnesite (40), sodium calcium plagioclase (9), chlorite (3), dolomite (12), pyrite (2), illite/muscovite (4), potassium feldspar (1). Amorphous content 1%
KS 2	UC	Quartz (67), sodium calcium plagioclase (2), ankerite (14), siderite (4), pyrite (9). Amorphous content 4%
HLS 3	NAF (AC)	Quartz (24), sodium calcium plagioclase (1), chlorite (14), ankerite (27), pyrite (2), paragonite (12), illite/muscovite (7). Amorphous content 12%
NOB GMD 3	NAF (AC)	Quartz (25), sodium calcium plagioclase (17), chlorite (25), calcite (10), ankerite (4), pyrite (1), ilmenite (2). Amorphous content 17%

8. CONCLUSIONS

Results of geochemical characterisation and a review of sulfur assay data for Mt Charlotte underground waste rock lithologies indicated:

- Total sulfur concentrations measured in LHSO samples selected for geochemical characterisation were consistent with those measured by XRF during drilling programs, indicating that samples selected were representative of waste rock to be mined at the site.
- Fresh mafic rock lithologies GMD, WD, DCB, POR and HLS are all classified as NAF with alkaline pH, moderate levels of soluble alkalinity and low salinity levels. WD, DCB, HLS and two of the four GMD samples were further classified as being acid consuming, with very high levels of readily reactive carbonate based ANC relative, to oxidisable sulfur concentrations.
- A general enrichment in silver, tellurium and antimony, which is typical of Golden Mile mineralisation and/or the presence of minerals like hessite within LHSO mineralisation. Fresh mafic rock lithologies GMD, WD, DCB, POR and HLS were low in most environmentally significant metals and metalloids and produced very low concentrations of soluble metals and metalloids in both water and acidic leachates. These materials are considered geochemically benign and seepage from them does not pose a risk to the receiving hypersaline groundwater at KCGM.
- Fresh mafic rock lithologies GMD, WD, DCB and POR are considered suitable for use in construction or rock armouring purposes, given the benign geochemical nature and physical competence of this material. The acid consuming nature of the dominant lithologies of LHSO (WD and DCB) which together account for 86% of LHSO waste rock by mass, is also of note when co-disposed underground as backfill with KS.
- Although a minor lithology (1.2% of LHSO waste mass), KS waste rock contained significant levels of oxidisable sulfur and slightly lower levels of ANC and as such was classified as PAF – high capacity (one sample was uncertain). Levels of CRS KS (5.3 to 17.5%) were significantly higher than those in BF shale from Fimiston Pit (0.51 to 10.7 %), although the proportion of oxidisable sulfur to total sulfur was similar for both (approximately 80%).
- KS was the most geochemically enriched Mt Charlotte waste lithology with enrichment in silver, tellurium, antimony (as for mafics), but also mercury, copper, arsenic, selenium, tin, cadmium and zinc. The concentrations and distribution of enriched elements was broadly similar to BF shale from previous studies (MBS 2017). Despite this enrichment, levels of soluble species released during leaching with both water and weak acid were still comparatively low – likely due to insoluble mineral forms being present such as tellurides. It is noted that extreme weathering of geochemically similar PAF BF shale enriched in mercury, tellurium and antimony still did not release soluble fractions of these three elements.
- Overall, co-disposal of the minor portion of KS lithology (1.2% of LHSO waste mass) with surrounding high ANC lithologies from LHSO underground is considered to pose negligible risk of significant oxidation and metals release to groundwater. The potential for surface oxidation of KS material during the operational phase of mining will likely be constrained by limited air flow in backfilled underground stopes away from active ventilation areas and be readily neutralised by the much larger proportion of highly reactive acid consuming waste rock with moderate to high levels of soluble alkalinity. All oxidisation potential will cease after cessation of mining and the recovery of the water table which is expected to cover all such underground waste rock.

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10. GLOSSARY OF TECHNICAL TERMS

Term	Explanation
AC	Acid consuming material.
ANC	Acid Neutralising Capacity. A process where a sample is reacted with excess 0.5 m HCl at a pH of about 1.5, for 2-3 hours at 80-90ºC followed by back-titration to pH=7 with sodium hydroxide. This determines the acid consumed by soluble materials in the sample.
ankerite	A calcium, iron, magnesium, manganese carbonate mineral of general formula $Ca(Fe,Mg,Mn)(CO_3)_2$. In composition it is closely related to dolomite, but differs from this in having magnesium replaced by varying amounts of iron(II) (ferroan ankerite) and manganese(II).
AP	Acid Potential. Similar to MPA, but only is based on the amount of sulfide-sulfur (calculated as the difference between total sulfur and sulfate-sulfur (SO_4-S), or directly as CRS) rather than total sulfur. AP (kg H_2SO_4/t) = (Total S – SO_4-S) x 30.6
Basalt	A dark coloured fine grained mafic extrusive igneous rock composed chiefly of calcium plagioclase and pyroxene. Extrusive equivalent of gabbro, underlies the ocean basins and comprises oceanic crust.
Carb NP	Carbon Neutralising Potential. The amount of ANC provided by carbonate minerals. Carb NP (kg H_2SO_4/t) = TIC (%) x 81.7
CIL	Carbon in Leach – the process of extracting gold from crushed rock by extraction with sodium cyanide solution and adsorption onto activated charcoal.
Circum-neutral pH	pH value near 7.
CRS	Chromium Reducible Sulfur. A measurement of reactive sulfide sulfur normally applied to acid sulfate soils using reaction with metallic chromium and hydrochloric acid to liberate hydrogen sulfide gas which is trapped and then measured by iodometric titration. For certain sample types, it is considered to be a more accurate estimate of oxidisable sulfur for iron sulfides than the difference between total sulfur and sulfate-sulfur (SO_4-S) for calculating Acid potential (AP).
Dolerite	A mafic, holocrystalline, subvolcanic rock equivalent to volcanic basalt or plutonic gabbro
dolomite	Calcium magnesium carbonate $CaMg(CO_3)_2$.
EC	Electrical conductivity. A measurement of solution salinity. Conversion: 1000 µS/cm = 1 dS/m = 1 mS/cm
felsic	Silicate minerals, magma, and rocks which are enriched in the lighter elements such as silicon, oxygen, aluminium, sodium, and potassium.
mafic	Descriptive of igneous rock containing a high content of ferromagnesian silicate minerals, but less than those present in ultramafic rocks. Common mafic rocks include basalt, dolerite and gabbro.
magnesite	Magnesium carbonate ($Mg(CO_3)_2$) or magnesium iron carbonate (Mg, $Fe(CO_3)_2$), the latter is termed ferroan magnesite.
MPA	Maximum Potential Acidity. A calculation where the total sulfur in the sample is assumed to all be present as pyrite. This value is multiplied by 30.6 to produce a value known as the Maximum Potential Acidity reported in units of kg H_2SO_4/t. MPA should include only the non-sulfate sulfur to avoid over-estimation of acid production in which case it may be referred to as AP.
NAF	Non Acid Forming

Term	Explanation
NAG	Net Acid Generation. A process where a sample is reacted with 15% hydrogen peroxide solution at pH = 4.5 to oxidise all sulfides and then time allowed for the solution to react with acid soluble materials. This is a direct measure of the acid generating capacity of the sample but can be affected by the presence of organic materials.
NAPP	Net Acid Producing Potential. NAPP (kg H_2SO_4/t) = AP – ANC. NAPP (kg H_2SO_4/t) = AP – ANC
effective NAPP	NAPP calculated using CarbNP rather than traditional ANC. Effective NAPP (kg H_2SO_4/t) = AP – CarbNP
PAF	Potentially Acid Forming. A sample is classified as PAF if the NAGpH is less than 4.5 and NAPP is positive (i.e. AP is greater than ANC).
PAF-LC	Potentially Acid Forming – Low Capacity. Waste rock classification for samples with NAPP values less than or equal to 10 kg H_2SO_4/t.
PAF-HC	Potentially Acid Forming – High Capacity. Waste rock classification for samples with NAPP values greater than 10 kg H_2SO_4/t.
pyrite	Iron (II) sulfide, FeS_2. Pyrite is the most common sulfide minerals and the major acid forming mineral oxidising to produce sulfuric acid.
siderite	Iron (II) carbonate $FeCO_3$. Siderite reacts with acid to release ferrous ions (pale green) which then oxidise to ferric (brown) and this in turn generates acidity equal to the initial acid consumption by carbonate. It therefore does not overall contribute to ANC.
TIC	Total Inorganic Carbon.
XRD	X-Ray Diffraction. A laboratory technique used to identify and quantify crystalline mineral phases in geological materials measuring diffraction angles and patterns from a finely ground sample.
XRF	X-Ray Fluorescence. An analytical technique that measures elemental composition by the detection of fluorescent (or secondary) X-rays emitted from the elements after irradiation by an X-ray source.

APPENDICES

APPENDIX 1: COLLATED RESULTS

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Table A1-1: Sample Descriptions

Sample ID	Orebody	Lithology	Grouping	Drill Hole ID	Depth (m)
WD 1	LHSO	Willamstown Dolerite	WD	UGHS144	28-30
WD 2	LHSO	Willamstown Dolerite	WD	UGHS012	280-282
WD 3	LHSO	Willamstown Dolerite	WD	UGHS154	87-89
WD 4	LHSO	Willamstown Dolerite	WD	UGHS007	325-327
WD 5	LHSO	Willamstown Dolerite	WD	UGHS012	371-373
POR 1	LHSO	Porphyry	POR	UGHS012	330-333
POR 2	LHSO	Porphyry	POR	UGHS140	55-57
POR 3	LHSO	Porphyry	POR	UGHS132	56-58
POR 4	LHSO	Porphyry	POR	UGHS010	395-398
DCB 1	LHSO	Devon Consols Basalt	DCB	UGHS012	313-316
DCB 2	LHSO	Devon Consols Basalt	DCB	UNGD010	329-330
DCB 3	LHSO	Devon Consols Basalt	DCB	UGHS140	31-33
DCB 4	LHSO	Devon Consols Basalt	DCB	UGHS140	66-69
DCB 5	LHSO	Devon Consols Basalt	DCB	UGHS132	92-94
KS 1	LHSO	Kapai Slate	KS	UGHS012	356-358
KS 2	LHSO	Kapai Slate	KS	UGHS092	151-154
KS 3	LHSO	Kapai Slate	KS	UGHS010	90-92
KS 4	LHSO	Kapai Slate	KS	UGHS010	500-502
KS 5	LHSO	Kapai Slate	KS	UGHS144	70.5-72
HLS 1	LHSO	Hannans Lake Serpentinite	HLS	UGHS038A	432-434
HLS 2	LHSO	Hannans Lake Serpentinite	HLS	UGHS039	52-54

Sample ID	Orebody	Lithology	Grouping	Drill Hole ID	Depth (m)
HLS 3	LHSO	Hannans Lake Serpentinite	HLS	UGHS039	74-77
HLS 4	LHSO	Hannans Lake Serpentinite	HLS	CKD13m	474-481
GMD REG	NOB	Golden Mile Dolerite Regolith (Transition)	GMD	MC044273	12-13
GMD 1	NOB	Golden Mile Dolerite	GMD	MC04272	40-45
GMD 2	NOB	Golden Mile Dolerite	GMD	MC04273	201-206
GMD 3	NOB	Golden Mile Dolerite	GMD	MC04273	225-230

Table A1-2: Acid Base Accounting

Sample	pH (1:5)	EC (1:5)	Total C	Total-S	CRS	SO4-S	AP	ANC	NAPP	Carb NP	$NAG_{pH4.5}$	NAG_{pH7}	NAGpH	NPR Ratio	Classification
	pH Units	µS/cm	%	%	%	%	kg H_2SO_4/t						pH units		
WD 1	9.4	82	2.61	0.75	N/A	<0.01	23	209	-186	213	0	0	8.1	9	NAF (AC)
WD 2	9.4	129	1.86	0.13	N/A	N/A	4.0	204	-200	152	N/A	N/A	N/A	51	NAF (AC)
WD 3	9.2	87	5.7	2.57	N/A	0.01	78	422	-343	466	0	0	8.0	5	NAF (AC)
WD 4	9.1	159	4.6	0.77	N/A	<0.01	23	318	-294	376	0	0	9.9	13	NAF (AC)
WD 5	9.1	143	4.46	1.29	N/A	<0.01	39	343	-304	364	0	0	8.7	9	NAF (AC)
POR 1	9.3	115	1.18	1.43	N/A	<0.01	44	86	-42	96	0	0	8.5	2	NAF
POR 2	9.2	134	1.15	0.45	N/A	<0.01	14	74	-60	94	0	0	9.2	5	NAF
POR 3	8.6	800	2.33	0.12	N/A	N/A	3.7	179	-175	190	N/A	N/A	N/A	49	NAF (AC)
POR 4	9.0	146	1.1	1.13	N/A	<0.01	34	78	-43	90	0	0	9.1	2	NAF
DCB 1	9.0	187	3.36	1.44	N/A	<0.01	44	216	-172	275	0	0	8.3	5	NAF (AC)
DCB 2	9.2	117	6.06	1.44	N/A	<0.01	44	419	-375	495	0	0	8.4	10	NAF (AC)
DCB 3	9.2	146	4.11	0.55	N/A	<0.01	17	289	-272	336	0	0	9.5	17	NAF (AC)
DCB 4	9.1	139	4.4	1.11	N/A	<0.01	34	276	-242	359	0	0	8.3	8	NAF (AC)
DCB 5	9.1	181	4.88	0.91	N/A	<0.01	28	350	-322	399	0	0	8.5	13	NAF (AC)
KS 1	4.9	578	0.36	21.6	17.5	0.15	536	10	526	29	337	412	2.0	0.0	PAF-HC
KS 2	8.3	114	2.24	6.19	5.32	0.03	163	128	35	183	0	0	7.4	0.7	UC
KS 3	8.3	291	2.49	10.1	7.71	0.03	236	145	91	203	72	102	2.7	0.5	PAF-HC
KS 4	7.6	562	1.54	11.9	8.44	0.11	258	53	205	126	185	232	2.3	0.1	PAF-HC
KS 5	8.1	292	1.62	13.4	10.8	0.04	330	86	244	132	218	242	2.2	0.2	PAF-HC
HLS 1	9.0	206	6.09	0.32	N/A	<0.01	9.6	480	-470	498	0	0	7.1	49	NAF (AC)
HLS 2	9.2	196	3.92	0.24	N/A	<0.01	7.2	243	-236	320	0	0	8.5	33	NAF (AC)

Sample	pH (1:5)	EC (1:5)	Total C	Total-S	CRS	SO4-S	AP	ANC	NAPP	Carb NP	$NAG_{pH4.5}$	NAG_{pH7}	NAGpH	NPR Ratio	Classification
	pH Units	µS/cm	%	%	%	%	kg H_2SO_4/t						pH units		
HLS 3	9.1	172	3.53	1.10	N/A	<0.01	34	246	-212	288	0	0	8.4	7	NAF (AC)
HLS 4	9.2	151	5.42	0.27	N/A	<0.01	8.1	431	-423	443	0	0	8.1	52	NAF (AC)
GMD REG	9.6	434	0.05	0.02	N/A	N/A	0.6	21	-20	4	N/A	N/A	N/A	34	NAF
GMD 1	9.0	198	2.91	1.09	N/A	<0.01	33	228	-195	238	0	0	9.2	7	NAF (AC)
GMD 2	9.3	159	1.02	0.06	N/A	N/A	1.8	100	-98	83	N/A	N/A	N/A	54	NAF
GMD 3	8.9	86	2.12	0.30	N/A	<0.01	9.0	180	-171	173	0	0	9.2	20	NAF (AC)

**As NAGpH is equal to the original pH this samples is already fully oxidised.*
N/A denotes Not Analysed

Denotes PAF classification

Denotes Uncertain classification

Denotes NAF/AC classification

Table A1-3: Total Metals and Metalloids

Sample	Ag	Al	As	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	Hg	K
	mg/kg	%	mg/kg	mg/kg	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	%	mg/kg	%
WD 1	0.36	6.9	7.2	278	0.31	4.5	1.3	59	379	95	8.7	0.1	0.1
WD 2	0.27	4.0	1.7	199	0.50	3.2	0.06	62	1,270	99	7.3	<0.1	1.5
WD 3	5.4	2.4	23	572	1.3	3.0	0.16	57	906	117	6.8	0.1	0.2
WD 4	0.28	7.0	5.1	207	0.66	8.3	0.13	35	348	48	5.0	<0.1	3.8
POR 1	1.2	7.6	22	1,272	1.6	2.1	0.16	7.3	23	88	2.5	0.3	1.9
POR 2	0.15	8.1	4.1	1,183	1.5	2.0	0.07	7.6	22	4	2.4	<0.1	2.2
POR 3	<0.05	7.4	4.0	1,121	1.5	4.2	0.06	28	61	11	4.9	<0.1	1.6
POR 4	1.4	7.8	5.5	1,238	2.2	1.9	0.23	10	37	28	2.3	<0.1	2.4
DCB 1	6.9	7.1	71	227	0.72	4.0	0.65	52	428	61	5.6	0.1	1.9
DCB 2	2.1	2.5	3.5	137	1.2	3.1	0.06	55	1,098	44	6.5	<0.1	0.7
DCB 3	0.24	6.4	1.8	123	0.62	7.0	0.06	48	367	37	7.0	<0.1	1.9
DCB 4	0.47	6.5	9.4	380	0.87	6.2	0.29	45	324	85	6.4	<0.1	2.9
KS 1	1.4	3.9	487	121	0.42	0.2	16	150	119	2,062	23	1.1	1.0
KS 2	1.4	0.2	38	10	0.25	3.2	0.56	11	83	407	9.2	0.6	0.03
KS 4	2.6	5.7	166	234	0.65	1.4	9.6	153	205	2,524	19	1.0	2.2
KS 5	1.9	4.3	179	409	0.97	2.0	2.2	76	184	458	14.9	0.5	2.1
HLS 1	0.13	3.3	67	48	0.15	7.2	0.22	59	1,143	47	6.3	<0.1	0.6
HLS 2	<0.05	7.4	7.7	148	0.46	6.8	0.09	25	157	68	5.2	<0.1	1.2
HLS 3	0.13	7.2	36	189	0.31	6.1	0.13	53	308	100	7.7	<0.1	1.3
HLS 4	0.06	3.6	36	22	0.16	6.0	0.05	75	1,889	32	6.8	<0.1	0.2
GMD REG	<0.05	9.4	20	9.3	0.27	2.8	0.08	50	46	104	7.9	<0.1	0.02
GMD 1	0.13	7.5	24	12	0.31	6.3	0.12	42	28	89	8.8	<0.1	0.3
GMD 2	0.6	7.2	4.7	42	0.53	3.5	0.06	39	29	27	10	<0.1	0.1

Sample	Ag	Al	As	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	Hg	K
	mg/kg	%	mg/kg	mg/kg	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	%	mg/kg	%
GMD 3	0.08	6.0	3.8	12	0.52	6.1	0.07	39	15	36	12	<0.1	0.03
Crustal Average	**0.07**	**8.2**	**25**	**425**	**2.8**	**4.1**	**0.11**	**20**	**100**	**50**	**4.1**	**0.08**	**2.1**

Table A1-3: Total Metals and Metalloids, continued

Sample	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Sn	Te	Th	U	V	Zn
	%	mg/kg	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
WD 1	4.3	2,139	0.5	2.7	150	12	1.8	0.6	0.1	<0.2	0.60	0.15	175	671
WD 2	10.8	1,338	0.3	0.2	291	2.1	0.80	<0.5	0.3	0.3	0.99	0.23	118	60
WD 3	10.2	1,207	0.2	1.0	279	3.0	1.0	0.9	<0.1	5.9	0.78	0.18	126	54
WD 4	3.5	1,151	0.4	0.1	105	3.3	1.2	<0.5	0.3	1.1	1.2	0.27	127	50
POR 1	1.0	316	1.6	3.1	10	13	5.7	<0.5	0.8	0.7	8.9	2.2	60	77
POR 2	0.8	337	0.3	3.1	8	6.5	2.2	<0.5	0.7	<0.2	9.3	2.1	53	64
POR 3	2.7	559	0.1	2.8	69	4.6	2.7	<0.5	0.7	<0.2	6.7	1.4	133	47
POR 4	0.9	343	1.2	2.7	7	21	2.9	<0.5	0.8	0.4	9.7	2.3	52	75
DCB 1	4.0	2,067	0.5	2.1	220	33	4.2	<0.5	1.8	5.6	0.62	0.16	193	304
DCB 2	10.0	1,251	0.2	0.9	257	2.4	1.4	0.5	0.1	2.9	0.81	0.19	106	50
DCB 3	4.3	1,125	0.2	0.8	159	4.2	3.0	<0.5	0.3	<0.2	0.49	0.11	159	55
DCB 4	4.0	1,599	0.6	0.7	170	7.6	3.5	<0.5	0.3	<0.2	0.48	0.13	171	208
KS 1	1.0	511	6.7	0.2	210	99	14	17	12	3.1	4.8	1.3	53	7,256
KS 2	1.5	441	1.9	0.1	11	19	14	4.5	0.3	1.5	0.23	0.07	6	221
KS 4	1.1	708	5.0	0.2	182	45	12	15.1	17	4.5	4.6	1.3	100	4789
KS 5	1.2	452	4.3	0.1	140	33	17	7.2	2.2	4.4	4.2	1.2	69	994
HLS 1	9.8	1,159	0.2	0.1	702	3.3	0.76	<0.5	<0.1	<0.2	0.15	0.05	107	141
HLS 2	2.3	1,227	0.5	1.3	55	3.8	3.4	<0.5	0.7	<0.2	0.63	0.18	201	67
HLS 3	3.9	2,083	0.4	0.6	126	5.3	1.7	0.7	0.3	0.3	0.53	0.15	189	90
HLS 4	11.0	1,129	<0.1	0.04	1,030	0.8	0.44	<0.5	<0.1	<0.2	0.14	0.03	117	68
GMD REG	3.0	1,557	0.1	2.6	55	<0.5	3.5	<0.5	0.2	<0.2	0.26	0.04	247	63
GMD 1	3.3	1,431	0.3	2.3	50	3	4.3	<0.5	0.2	<0.2	0.20	0.05	281	71
GMD 2	3.2	1,468	0.6	2.4	36	1.1	0.61	<0.5	0.2	<0.2	0.56	0.11	326	95

Sample	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Sn	Te	Th	U	V	Zn
	%	mg/kg	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
GMD 3	2.5	1,819	0.7	1.7	24	1.1	0.76	<0.5	1.4	<0.2	0.57	0.14	358	90
Crustal Average	**2.3**	**950**	**1.5**	**2.3**	**75**	**14**	**0.2**	**0.2**	**2**	**0.001**	**10**	**2.7**	**135**	**70**

Table A1-4: Global Abundance Index (GAI)

Sample	Ag	Al	As	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	Hg	K
WD 1	2	0	0	0	0	0	3	1	1	0	1	0	0
WD 2	1	0	0	0	0	0	0	1	3	0	0	0	0
WD 3	6	0	0	0	0	0	0	1	3	1	0	0	0
WD 4	1	0	0	0	0	0	0	0	1	0	0	0	0
POR 1	4	0	0	1	0	0	0	0	0	0	0	1	0
POR 2	1	0	0	1	0	0	0	0	0	0	0	0	0
POR 3	0	0	0	1	0	0	0	0	0	0	0	0	0
POR 4	4	0	0	1	0	0	0	0	0	0	0	0	0
DCB 1	6	0	1	0	0	0	2	1	2	0	0	0	0
DCB 2	4	0	0	0	0	0	0	1	3	0	0	0	0
DCB 3	1	0	0	0	0	0	0	1	1	0	0	0	0
DCB 4	2	0	0	0	0	0	1	1	1	0	0	0	0
KS 1	4	0	4	0	0	0	6	2	0	5	2	3	0
KS 2	4	0	0	0	0	0	2	0	0	2	1	2	0
KS 4	5	0	2	0	0	0	6	2	0	5	2	3	0
KS 5	4	0	2	0	0	0	4	1	0	3	1	2	0
HLS 1	0	0	1	0	0	0	0	1	3	0	0	0	0
HLS 2	0	0	0	0	0	0	0	0	0	0	0	0	0
HLS 3	0	0	0	0	0	0	0	1	1	0	0	0	0
HLS 4	0	0	0	0	0	0	0	1	4	0	0	0	0
GMD REG	0	0	0	0	0	0	0	1	0	0	0	0	0
GMD 1	0	0	0	0	0	0	0	0	0	0	1	0	0
GMD 2	3	0	0	0	0	0	0	0	0	0	1	0	0
GMD 3	0	0	0	0	0	0	0	0	0	0	1	0	0

Table A1-4: Global Abundance Index (GAI) continued

Sample	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Sn	Te	Th	U	V	Zn
WD 1	0	1	0	0	0	0	3	1	0	6	0	0	0	3
WD 2	2	0	0	0	1	0	1	1	0	6	0	0	0	0
WD 3	2	0	0	0	1	0	2	2	0	6	0	0	0	0
WD 4	0	0	0	0	0	0	2	1	0	6	0	0	0	0
POR 1	0	0	0	0	0	0	4	1	0	6	0	0	0	0
POR 2	0	0	0	0	0	0	3	1	0	6	0	0	0	0
POR 3	0	0	0	0	0	0	3	1	0	6	0	0	0	0
POR 4	0	0	0	0	0	0	3	1	0	6	0	0	0	0
DCB 1	0	1	0	0	1	1	4	1	0	6	0	0	0	1
DCB 2	2	0	0	0	1	0	2	1	0	6	0	0	0	0
DCB 3	0	0	0	0	0	0	3	1	0	6	0	0	0	0
DCB 4	0	0	0	0	1	0	4	1	0	6	0	0	0	1
KS 1	0	0	2	0	1	2	6	6	2	6	0	0	0	6
KS 2	0	0	0	0	0	0	6	4	0	6	0	0	0	1
KS 4	0	0	1	0	1	1	5	6	3	6	0	0	0	5
KS 5	0	0	1	0	0	1	6	5	0	6	0	0	0	3
HLS 1	2	0	0	0	3	0	1	1	0	6	0	0	0	0
HLS 2	0	0	0	0	0	0	3	1	0	6	0	0	0	0
HLS 3	0	1	0	0	0	0	2	1	0	6	0	0	0	0
HLS 4	2	0	0	0	3	0	1	1	0	6	0	0	0	0
GMD REG	0	0	0	0	0	0	4	1	0	6	0	0	0	0
GMD 1	0	0	0	0	0	0	4	1	0	6	0	0	0	0
GMD 2	0	0	0	0	0	0	1	1	0	6	0	0	1	0
GMD 3	0	0	0	0	0	0	1	1	0	6	0	0	1	0

Table A1-5: Water Leachate (1:5), Major Ions

Sample	pH	EC	Ca	Mg	Na	K	Cl	SO_4	Total Alkalinity	HCO_3 Alkalinity	CO_3 Alkalinity
		mS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg $CaCO_3$/L		
WD 1	9.4	82	11	4.4	3.2	0.3	4	9.8	34	8	26
WD 3	9.2	87	5.7	7.5	1.7	1.2	2	22	28	5	23
POR 1	9.3	115	13	4.9	7.6	4.9	8	22	65	39	26
DCB 2	9.2	117	6.9	8.1	5.0	2.8	8	20	128	102	26
DCB 4	9.1	139	12	6.1	3.7	8	5	14	114	88	26
KS 1	4.9	578	50	21	7.9	2.8	32	265	3	3	<1
KS 2	8.3	114	17	7.0	1.6	0.4	10	34	30	30	<1
HLS 3	9.1	172	12	5.5	15	5.4	8	19	62	34	28
GMD 3	8.9	86	10	2.7	5.6	0.4	<2	5.0	40	25	15

Table A1-6: Water Leachate (1:5), Metals and Metalloids

Sample	Ag	Al	As	B	Ba	Be	Cd	Co	Cr	Cu	Fe	Hg	Li
	µg/L	mg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	µg/L	µg/L
WD 1	0.03	0.27	0.3	0.12	7.9	<0.1	<0.02	<0.1	<0.01	<0.01	<0.01	<0.1	1.1
WD 3	0.06	0.06	8.7	0.11	175	<0.1	<0.02	<0.1	<0.01	<0.01	<0.01	<0.1	1.1
POR 1	<0.01	0.36	3.0	0.12	9.5	<0.1	<0.02	<0.1	<0.01	<0.01	<0.01	<0.1	1.9
DCB 2	0.02	0.13	1.2	0.11	183	<0.1	<0.02	<0.1	<0.01	<0.01	<0.01	<0.1	1.7
DCB 4	0.01	0.36	2.9	0.12	24	<0.1	<0.02	<0.1	<0.01	<0.01	<0.01	<0.1	2.0
KS 1	<0.01	0.41	7.8	0.14	6.2	0.2	23.6	35	<0.01	0.17	29	<0.1	5.8
KS 2	0.10	<0.01	0.2	0.12	0.90	<0.1	<0.02	<0.1	<0.01	<0.01	<0.01	<0.1	1.0
HLS 3	<0.01	0.43	1.7	0.14	0.93	<0.1	<0.02	<0.1	<0.01	<0.01	<0.01	<0.1	2.7
GMD 3	0.07	0.47	0.4	0.11	0.68	<0.1	<0.02	<0.1	<0.01	<0.01	<0.01	<0.1	0.55
Livestock (ANZECC 2000)	**N/G**	**5**	**500**	**5**	**N/G**	**N/G**	**10**	**1000**	**1**	**1**	**N/G**	**2**	**N/G**

N/G No guideline

Table A1-6: Water Leachate, Metals and Metalloids, continued

Sample	Mn	Mo	Nb	Ni	Pb	Sb	Se	Sn	Ta	Te	Th	U	V	Zn
	mg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L
WD 1	0.009	0.21	<0.005	<0.01	<0.5	2.6	<0.5	<0.1	0.002	<0.1	<0.005	<0.005	<0.01	<0.01
WD 3	0.001	0.12	<0.005	<0.01	<0.5	2.8	0.6	<0.1	0.002	<0.1	<0.005	<0.005	<0.01	<0.01
POR 1	0.004	2.4	<0.005	<0.01	<0.5	9.2	<0.5	<0.1	0.002	<0.1	<0.005	0.11	<0.01	<0.01
DCB 2	0.001	0.28	<0.005	<0.01	<0.5	4.8	<0.5	<0.1	0.002	<0.1	<0.005	<0.005	<0.01	<0.01
DCB 4	0.002	0.29	<0.005	<0.01	<0.5	6.9	<0.5	<0.1	0.002	<0.1	<0.005	<0.005	<0.01	<0.01
KS 1	1.9	<0.05	<0.005	0.17	11	0.02	3.1	<0.1	0.002	<0.1	<0.005	0.19	<0.01	28.7
KS 2	0.004	1.3	<0.005	<0.01	<0.5	12	1.7	<0.1	0.002	<0.1	<0.005	0.01	<0.01	<0.01
HLS 3	0.004	0.49	<0.005	<0.01	<0.5	3.6	0.5	<0.1	0.003	<0.1	<0.005	<0.005	<0.01	<0.01
GMD 3	0.008	2.6	<0.005	<0.01	<0.5	0.64	<0.5	<0.1	0.003	<0.1	<0.005	<0.005	<0.01	<0.01
Livestock (ANZECC 2000)	**N/G**	**150**	**N/G**	**1**	**100**	**N/G**	**20**	**N/G**	**N/G**	**N/G**	**N/G**	**200**	**N/G**	**20**

Table A1-7: Dilute Acid (1:20 Acetic) Leachate, Major Ions, Metals and Metalloids

Sample	pH	Ag	Al	As	B	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	Hg	K	Li
	pH units	µg/L	mg/L	µg/L	mg/L	µg/L	µg/L	mg/L	µg/L	µg/L	mg/L	mg/L	mg/L	µg/L	mg/L	µg/L
WD 1	4.4	<0.01	2.8	1.7	0.02	112	1.1	372	3.5	32	0.07	<0.01	144	<0.1	0.20	8.7
WD 3	4.3	0.28	0.79	11	0.03	1528	4.0	284	1.2	17	0.14	0.02	49	<0.1	1.1	4.2
POR 1	4.1	0.03	2.0	2.3	0.02	210	1.3	234	0.42	9.3	0.01	0.01	90	<0.1	2.3	3.6
DCB 2	4.3	0.05	1.1	2.2	0.02	847	2.4	280	0.58	25	0.11	<0.01	48	<0.1	1.5	3.2
DCB 4	4.5	0.12	2.0	2.1	0.01	383	3.0	412	1.0	62	0.03	<0.01	136	<0.1	3.8	8.0
KS 2	4.2	0.04	0.29	7.5	0.02	18	1.8	239	1.0	2.4	0.05	0.06	108	<0.1	0.20	3.3
HLS 3	4.5	0.31	2.7	1.0	0.03	37	0.7	401	0.68	37	0.04	<0.01	157	<0.1	2.2	10
GMD 3	5.2	0.03	0.73	0.3	0.02	15	1.1	1,441	1.7	8.1	<0.01	<0.01	58	<0.1	0.20	3.4

Table A1-7: Dilute Acid (1:20 Acetic) Leachate, Major Ions, Metals and Metalloids, continued

Sample	Mg	Mn	Mo	Na	Nb	Ni	Pb	S	Sb	Se	Sn	Ta	Te	Th	U	V	Zn
	mg/L	mg/L	µg/L	mg/L	µg/L	mg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L
WD 1	141	16	<0.05	1.6	<0.005	0.04	87	0.55	0.73	<0.5	<0.1	<0.001	<0.1	0.098	0.19	<0.01	0.37
WD 3	180	6.0	0.12	0.7	<0.005	0.11	13	1.8	1.3	0.7	<0.1	0.001	2.6	0.182	0.11	<0.01	0.04
POR 1	96	3.6	0.58	2.3	<0.005	0.01	49	1.0	2.3	0.7	<0.1	<0.001	0.3	0.33	0.55	0.02	0.32
DCB 2	182	4.2	0.14	5.4	<0.005	0.11	11	1.5	1.4	<0.5	<0.1	<0.001	0.8	0.104	0.12	<0.01	0.14
DCB 4	185	8.8	<0.05	1.2	<0.005	0.15	19	0.75	1.2	0.6	<0.1	<0.001	<0.1	0.06	0.05	<0.01	0.30
KS 2	98	2.4	0.6	0.8	<0.005	<0.01	148	2.2	14	0.7	<0.1	<0.001	0.8	0.18	0.06	<0.01	0.60
HLS 3	159	12	<0.05	3.8	<0.005	0.04	3.4	0.62	0.53	0.8	<0.1	<0.001	<0.1	0.072	0.08	<0.01	0.23
GMD 3	19	24	<0.05	1.9	<0.005	<0.01	1.9	0.36	0.19	3.8	<0.1	<0.001	<0.1	<0.005	0.01	<0.01	0.03

APPENDIX 2: LABORATORY REPORTS

15 Davison Street, Maddington
Western Australia 6109
Telephone: +61 8 9251 8100
Facsimile: +61 8 9251 8110
intertek.com
ABN: 32 008 787 237

QUANTITATIVE X-RAY DIFFRACTION ANALYSIS

REPORT PREPARED FOR	MARTINICK BOSCH SELL PTY LTD M. NORTH
CLIENT CODE	
JOB CODE	1710818
No. of SAMPLES	6
CLIENT O/N	M. NORTH
SAMPLE SUBMISSION No.	N/A
PROJECT	KCGM MT CHARLOTTE KCGMMCG
STATE	PULPS
DATE RECEIVED	21/08/2017
DATE COMPLETED	13/09/2017
DATE WRITTEN	13/09/2017
WRITTEN BY	Dr Sharon Ness
ANALYSING LABORATORY	Perth

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SAMPLE DETAILS

DISCLAIMER

This report relates specifically to the sample(s) that were drawn and/or provided by the client or their nominated third party. The reported results(s) provide no warranty or verification on the sample(s) representing any specific goods and/or shipment and only relate to the sample(s) as received and tested. This report is prepared solely for the use of the client named in this report. Intertek accepts no responsibility for any loss, damage or laibility suffered by a third party as a result of any reliance upon or use of this report.

The results provided are not intended for commercial settlement purposes.

SIGNIFICANT FIGURES

The method detection limit is approximately 1 wt% for most phases.

Uncertainty in the analysis should reflect errors (absolute) of no greater than: +/- 10% for phases 50-95%, +/- 5% for phases 10-50% and +/- 2% for phases 3-10%. Phases of < 3% are approaching detection limit and normally no refinements are made on these.

Please note that results are rounded off to integer values

LEGEND

ND	Not Detected

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JOB INFORMATION

PREPARATION

XRD16 (dry 50C, mill < 60um, micronised)

ANALYTICAL METHOD

XRDQUANT02 - Quantitative analysis, crystalline and amorphous content, double scan

SAMPLING

Sample(s) coned and quartered, then grab(s) taken

AMORPHOUS CONTENT DETERMINATION

Internal standard double scan

ADDITIONS

Internal standard ZnO (zincite)

SAMPLE PRESENTATION

Sample(s) packed and presented as unoriented powder mount(s) of the total sample

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JOB INFORMATION

INSTRUMENTATION AND PARAMETERS

INSTRUMENT:

PANalytical Cubix^3 XRD
Copper radiation (operating at 45 kV and 40 mA)
Graphite monochromator (diffracted beam)

PARAMETERS:

Parameter	Setting
Start angle (deg 2θ)	4
End angle (deg 2θ)	65
Step size (deg 2θ)	0.02
Time/active length (secs)	150
Active length (deg 2θ)	4.01

SOFTWARE:

Qualitative analysis: Bruker Diffrac.EVA 4.2 Search/Match
ICDD PDF-2 (2015) database

Quantitative analysis: SIROQUANT Version 4

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RESULTS

The quantitative analysis of the crystalline and amorphous content of each sample is given in the file, **282.00_1710818 XRD RESULTS.xlsx**, attached to the report email.

Calculation of the phase abundances has been based on the Brindley contrast corrections using a particle diameter of 4 µm.

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NOTES

NONE

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QUALITY CONTROL

NIST STANDARD REFERENCE MATERIAL (SRM) 656

This standard is used for quality control on the instrument and software.

The standard reference material is a powder which consists of sub-micrometer, equi-axial, non-aggregated grains that do not display the effects of absorption contrast, extinction or preferred orientation.

An aliquot of this SRM, spiked with 10% Al2O3 (SRM 676a) for the amorphous content determination, was prepared as un-oriented powder mount of the total sample and the pattern analysed with SIROQUANT™.

Sample ID **α 656 (High α Phase Powder)**

		1710818	method std dev	SRM certified	SRM uncert
Phase	Formula	wt%	wt%	wt%	wt%
Amorphous content		10.0	0.6	9.5	0.61
Si3N4, alpha	Si3N4	87.0	0.6	87.5	0.59
Si3N4, beta	Si3N4	3.0	0.1	3.0	0.05

Each interval defined by the certified value and its uncertainty is a 95% confidence interval for the true value of the mean in the absence of systematic error.

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15 Davison Street, Maddington
Western Australia 6109
Telephone: +61 8 9251 8100
Facsimile: +61 8 9251 8110
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METHOD DESCRIPTION

Quantification is determined from the chosen software package: this uses the full-profile Rietveld method of refining the profile of the calculated XRD pattern against the profile of the measured XRD pattern. The total calculated pattern is the sum of the calculated patterns of the individual phases.

Results are given as weight % of the total crystalline phases and amorphous content.

The amorphous content quantifies the amorphous material and unknown minerals or known minerals for which there is not a suitable crystal structure.

Corrections are incorporated into the process that allows for a more accurate description of the mineral's contribution to the measured pattern and to allow for variation due to atomic substitution, layer disordering, preferred orientation, and other factors that affect the acquisition of the XRD scan.

The limitations of qualitative XRD analysis are as follows:

There is a limit of detection of approximately 1 wt% on the crystalline phases.
The detection of a phase may be dependent on its crystallinity.
Where there exist multiple phases, overlap of diffracted reflections can occur, thus rendering some ambiguity into the interpretation.
Overlapping reflections of a major phase can mask the presence of minor or trace phases.

Some phases cannot be unambiguously identified as they are present in minor or trace amounts.

The limitations of quantitative XRD analysis by a full-profile Rietveld method are as follows:

The limitations for qualitative XRD analysis apply.
The method as described is standardless: it relies solely on the published crystallographic data available for each phase. Some data may not exactly describe the phases present.

Particle size is important with respect to the absorption of the X-rays by the sample. Micronising reduces the particle size to that more suitable for quantitative analysis.

The accuracy of the analysis is dependent on sampling and sample preparation in addition to the calculated profiles being exactly representative of the chemistry of the component phases and their crystallinity. Some preferred orientation effects and reflection overlaps may occur which cannot be adequately resolved.

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AMORPHOUS CONTENT

INTERNAL STANDARD METHOD

Single scan (SIROQUANT™ and TOPAS)

The amorphous content is determined from the addition of a known spike of a well-crystalline internal standard to each sample.

When amorphous material is present, the weight percentage of the spike found is larger than actually weighed out. The amount of amorphous material that causes the difference in the spike weight percentages is then calculated and all weight percentages are normalised to include the amorphous content.

Double scan (SIROQUANT only)

SIROQUANT™ also allows the choice of using the spiked pattern completely, or combining the run with a previous unspiked pattern result. This choice is given because the weight percentages from an unspiked pattern are more accurate since the intensities are not diluted by the spike addition. The percentages from the unspiked sample are normalised to the amorphous content calculated from the spiked sample pattern.

EXTERNAL STANDARD METHOD

The amorphous content is determined from the external standard method[1].

The normalisation constant is determined from the external standard which allows the calculated weight fractions to be placed on an absolute scale.

Reference:

1. O'Connor, B.H., and Raven, M.D., "Application of the Rietveld refinement procedure in assaying powdered mixtures", Powder Diffraction 3(1), (1988), 2-6.

Modelling

A pattern representing a poorly crystalline form of silica is used in the SIROQUANT program.[2]

Reference:

2. Ward, C.R. and French, D., "Determination of glass content and estimation of glass composition in fly ash using quantitative X-ray diffractometry." Fuel 85 (2006), 2268-2277.

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MINERALS
TEST REPORT

CLIENT

MARTINICK BOSCH SELL PTY LTD
4 Cook Street
WEST PERTH, W.A. 6005
AUSTRALIA

JOB INFORMATION

JOB CODE	: 282.0/1709783
NO. SAMPLES	: 27
NO. ELEMENTS	: 49
CLIENT ORDER NO.	: M. NORTH (Job 1 of 0)
SAMPLE SUBMISSION NO.	:
PROJECT	: KCGM MT CHARLOTTE KCGMMCG
DATE RECEIVED	: 13/07/2017
DATE REPORTED	: 27/09/2017
DATE PRINTED	: 27/09/2017

REPORT NOTES

TESTED BY

Intertek
15 Davison Street, Maddington 6109, Western Australia
PO Box 144, Gosnells 6990, Western Australia
Tel: +61 8 9251 8100
Email: min.aus.per@intertek.com

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It is common practice to report data derived from analytical instrumentation to a maximum of two or three significant figures. Some data reported herein may show more figures than this. The reporting of more than two or three figures in no way implies that figures beyond the least significant digit have significance.

For more information on the uncertainty on individual reported values, please contact the laboratory.

SAMPLE STORAGE

All solid samples (assay pulps, bulk pulps and residues will be stored for 60 days without charge. Following this samples will be stored at a daily rate until clients written advice regarding return, collection or disposal is received. If storage information is not supplied on the submission, or arranged with the laboratory in writing the default will be to store the samples with the applicable charges. Storage is charged at $4.00 per m3 per day, expenses related to the return or disposal of samples will be charged at cost. Current disposal cost is charged at $150.00 per m3.

Samples received as liquids, waters or solutions will be held for 60 days free of charge then disposed of, unless written advice fo return or collection is received.

LEGEND	X	= Less than Detection Limit		NA	= Not Analysed
	SNR	= Sample Not Received		UA	= Unable to Assay
	*	= Result Checked		>	= Value beyond Limit of Method
	DTF	= Result still to come		+	= Extra Sample Received Not Listed
	IS	= Insufficient Sample for Analysis			

ELEMENTS	Ag	Ag	Al	Al	ANC	As
UNITS	ppm	ug/l	ppm	mg/l	kgH2SO4/t	ppm
DETECTION LIMIT	0.05	0.01	50	0.01	1	0.5
DIGEST	4A/	Ws/	4A/	Ws/	ANCx/	4A/
ANALYTICAL FINISH	MS	MS	OE	OE	VOL	MS
SAMPLE NUMBERS						
0001 WD1 UGHS144 28-30m	0.36	0.03	6.91%	0.27	209	7.2
0002 WD2 UGHS012 280-282m	0.27		4.04%		204	1.7
0003 WD3 UGHS154 87-89m	5.44	0.06	2.41%	0.06	422	23.2
0004 WD4 UGHS007 325-327m	0.28		7.02%		318	5.1
0005 WD5- UGHS012 371-373m					343	
0006 POR1 - UGHS012 330-333m	1.20	X	7.62%	0.36	86	21.8
0007 POR2 UGHS140 55-57m	0.15		8.13%		74	4.1
0008 POR3 UGHS132 56-58m	X		7.44%		179	4.0
0009 POR4 UGHS010 395-398m	1.37		7.83%		78	5.5
0010 DCB1 UGHS012 313-316m	6.90		7.10%		216	70.6
0011 DCB2 UNGD010 329-330m	2.05	0.02	2.55%	0.13	419	3.5
0012 DCB3 UGHS140 31-33m	0.24		6.37%		289	1.8
0013 DCB4 UGHS140 66-69m	0.47	0.01	6.50%	0.36	276	9.4
0014 DCB5 UGHS132 92-94m					350	
0015 KS1 UGHS012 356-358m	1.43	X	3.90%	0.41	10	487.0
0016 KS2 UGHS092 151-154m	1.37	0.10	2299	X	128	38.3
0017 KS3 UGHS010 90-92m					145	
0018 KS4 UGHS010 500-502m	2.64		5.67%		53	166.0
0019 KS5 UGHS144 70.5-72m	1.92		4.33%		86	179.2
0020 HLS1 UGHS038A 432-434m	0.13		3.26%		480	66.7
0021 HLS2 UGHS039 52-54m	X		7.41%		243	7.7
0022 HLS3 UGHS039 74-77m	0.13	X	7.18%	0.43	246	36.0
0023 HLS4 CKD13 474-481m	0.06		3.65%		431	36.3
0024 NOB REG MC044273 12-13m	X		9.43%		21	20.0
0025 NOB GMD1 MC04272 40-45m	0.13		7.50%		228	23.8
0026 NOB GMD2 MC04273 201-206m	0.60		7.16%		100	4.7
0027 NOB GMD3 MC04273 225-230m	0.08	0.07	6.00%	0.47	180	3.8
STANDARDS						
0001 DS-1						
0002 OREAS 502b						
0003 OREAS 905	0.55		7.68%			34.9
0004 NAG Std 3						
BLANKS						
0001 Control Blank	X	X	X	X	0	X

ELEMENTS	As	B	Ba	Ba	Be	Be
UNITS	ug/l	mg/l	ppm	ug/l	ppm	ug/l
DETECTION LIMIT	0.1	0.01	0.1	0.05	0.05	0.1
DIGEST	Ws/	Ws/	4A/	Ws/	4A/	Ws/
ANALYTICAL FINISH	MS	OE	MS	MS	MS	MS
SAMPLE NUMBERS						
0001 WD1 UGHS144 28-30m	0.3	0.12	277.5	7.93	0.31	X
0002 WD2 UGHS012 280-282m			199.4		0.50	
0003 WD3 UGHS154 87-89m	8.7	0.11	572.4	175.18	1.31	X
0004 WD4 UGHS007 325-327m			206.7		0.66	
0005 WD5- UGHS012 371-373m						
0006 POR1 - UGHS012 330-333m	3.0	0.12	1272.2	9.47	1.57	X
0007 POR2 UGHS140 55-57m			1183.0		1.51	
0008 POR3 UGHS132 56-58m			1120.8		1.49	
0009 POR4 UGHS010 395-398m			1238.0		2.20	
0010 DCB1 UGHS012 313-316m			227.3		0.72	
0011 DCB2 UNGD010 329-330m	1.2	0.11	136.9	182.61	1.15	X
0012 DCB3 UGHS140 31-33m			123.2		0.62	
0013 DCB4 UGHS140 66-69m	2.9	0.12	380.1	23.84	0.87	X
0014 DCB5 UGHS132 92-94m						
0015 KS1 UGHS012 356-358m	7.8	0.14	121.2	6.15	0.42	0.2
0016 KS2 UGHS092 151-154m	0.2	0.12	10.3	0.90	0.25	X
0017 KS3 UGHS010 90-92m						
0018 KS4 UGHS010 500-502m			233.6		0.65	
0019 KS5 UGHS144 70.5-72m			409.0		0.97	
0020 HLS1 UGHS038A 432-434m			48.2		0.15	
0021 HLS2 UGHS039 52-54m			147.9		0.46	
0022 HLS3 UGHS039 74-77m	1.7	0.14	188.6	0.93	0.31	X
0023 HLS4 CKD13 474-481m			21.6		0.16	
0024 NOB REG MC044273 12-13m			9.3		0.27	
0025 NOB GMD1 MC04272 40-45m			11.5		0.31	
0026 NOB GMD2 MC04273 201-206m			41.7		0.53	
0027 NOB GMD3 MC04273 225-230m	0.4	0.11	12.0	0.68	0.52	X
STANDARDS						
0001 DS-1						
0002 OREAS 502b						
0003 OREAS 905			2841.6		3.12	
0004 NAG Std 3						
BLANKS						
0001 Control Blank	X	0.06	X	X	X	X

ELEMENTS	C	CO3	Ca	Ca	Cd	Cd
UNITS	%	mgCaCO3/L	ppm	mg/l	ppm	ug/l
DETECTION LIMIT	0.01	1	50	0.01	0.02	0.02
DIGEST		Ws/	4A/	Ws/	4A/	Ws/
ANALYTICAL FINISH	/CSA	VOL	OE	OE	MS	MS
SAMPLE NUMBERS						
0001 WD1 UGHS144 28-30m	2.61	26	4.48%	11.27	1.32	X
0002 WD2 UGHS012 280-282m	1.86		3.18%		0.06	
0003 WD3 UGHS154 87-89m	5.70	23	3.02%	5.74	0.16	X
0004 WD4 UGHS007 325-327m	4.60		8.35%		0.13	
0005 WD5- UGHS012 371-373m	4.46					
0006 POR1 - UGHS012 330-333m	1.18	26	2.10%	12.57	0.16	X
0007 POR2 UGHS140 55-57m	1.15		2.01%		0.07	
0008 POR3 UGHS132 56-58m	2.33		4.21%		0.06	
0009 POR4 UGHS010 395-398m	1.10		1.95%		0.23	
0010 DCB1 UGHS012 313-316m	3.36		4.01%		0.65	
0011 DCB2 UNGD010 329-330m	6.06	26	3.07%	6.85	0.06	X
0012 DCB3 UGHS140 31-33m	4.11		6.96%		0.06	
0013 DCB4 UGHS140 66-69m	4.40	26	6.24%	11.83	0.29	X
0014 DCB5 UGHS132 92-94m	4.88					
0015 KS1 UGHS012 356-358m	0.36	X	1500	49.59	15.83	23.61
0016 KS2 UGHS092 151-154m	2.24	X	3.17%	17.46	0.56	X
0017 KS3 UGHS010 90-92m	2.49					
0018 KS4 UGHS010 500-502m	1.54		1.37%		9.57	
0019 KS5 UGHS144 70.5-72m	1.62		2.04%		2.16	
0020 HLS1 UGHS038A 432-434m	6.09		7.23%		0.22	
0021 HLS2 UGHS039 52-54m	3.92		6.81%		0.09	
0022 HLS3 UGHS039 74-77m	3.53	28	6.08%	12.12	0.13	X
0023 HLS4 CKD13 474-481m	5.42		6.03%		0.05	
0024 NOB REG MC044273 12-13m	0.05		2.85%		0.08	
0025 NOB GMD1 MC04272 40-45m	2.91		6.33%		0.12	
0026 NOB GMD2 MC04273 201-206m	1.02		3.51%		0.06	
0027 NOB GMD3 MC04273 225-230m	2.12	15	6.08%	10.38	0.07	X
STANDARDS						
0001 DS-1	3.21					
0002 OREAS 502b						
0003 OREAS 905			6018		0.37	
0004 NAG Std 3						
BLANKS						
0001 Control Blank	X	X	X	X	X	X

ELEMENTS	Cl	Co	Co	olourChange	Cr	Cr
UNITS	mg/l	ppm	ug/l	NONE	ppm	mg/l
DETECTION LIMIT	2	0.1	0.1	0	5	0.01
DIGEST	Ws/	4A/	Ws/	ANCx/	4A/	Ws/
ANALYTICAL FINISH	COL	MS	MS	QUAL	OE	OE
SAMPLE NUMBERS						
0001 WD1 UGHS144 28-30m	4	58.6	X	Yes	379	X
0002 WD2 UGHS012 280-282m		61.8		Yes	1270	
0003 WD3 UGHS154 87-89m	2	57.4	X	Yes	906	X
0004 WD4 UGHS007 325-327m		34.9		Yes	348	
0005 WD5- UGHS012 371-373m				Yes		
0006 POR1 - UGHS012 330-333m	8	7.3	X	Yes	23	X
0007 POR2 UGHS140 55-57m		7.6		Yes	22	
0008 POR3 UGHS132 56-58m		28.4		Yes	61	
0009 POR4 UGHS010 395-398m		10.3		Yes	37	
0010 DCB1 UGHS012 313-316m		52.1		Yes	428	
0011 DCB2 UNGD010 329-330m	8	55.1	X	Yes	1098	X
0012 DCB3 UGHS140 31-33m		47.6		Yes	367	
0013 DCB4 UGHS140 66-69m	5	44.9	X	Yes	324	X
0014 DCB5 UGHS132 92-94m				Yes		
0015 KS1 UGHS012 356-358m	32	150.0	34.6	Yes	119	X
0016 KS2 UGHS092 151-154m	10	11.1	X	No	83	X
0017 KS3 UGHS010 90-92m				Yes		
0018 KS4 UGHS010 500-502m		153.2		Yes	205	
0019 KS5 UGHS144 70.5-72m		75.6		No	184	
0020 HLS1 UGHS038A 432-434m		58.5		Yes	1143	
0021 HLS2 UGHS039 52-54m		25.1		Yes	157	
0022 HLS3 UGHS039 74-77m	8	53.2	X	Yes	308	X
0023 HLS4 CKD13 474-481m		75.1		Yes	1889	
0024 NOB REG MC044273 12-13m		50.0		No	46	
0025 NOB GMD1 MC04272 40-45m		42.0		Yes	28	
0026 NOB GMD2 MC04273 201-206m		38.5		Yes	29	
0027 NOB GMD3 MC04273 225-230m	X	39.2	X	Yes	15	X
STANDARDS						
0001 DS-1						
0002 OREAS 502b						
0003 OREAS 905		15.2			26	
0004 NAG Std 3						
BLANKS						
0001 Control Blank	X	X	X		X	X

ELEMENTS	Cu	Cu	EC	Fe	Fe	Final-pH
UNITS	ppm	mg/l	uS/cm	%	mg/l	NONE
DETECTION LIMIT	1	0.01	10	0.01	0.01	0.1
DIGEST	4A/	Ws/	Ws/	4A/	Ws/	ANCx/
ANALYTICAL FINISH	OE	OE	MTR	OE	OE	MTR
SAMPLE NUMBERS						
0001 WD1 UGHS144 28-30m	95	X	82	8.71	X	1.6
0002 WD2 UGHS012 280-282m	99		129	7.25		1.2
0003 WD3 UGHS154 87-89m	117	X	87	6.79	X	0.3
0004 WD4 UGHS007 325-327m	48		159	5.03		1.4
0005 WD5- UGHS012 371-373m			143			1.7
0006 POR1 - UGHS012 330-333m	88	X	115	2.51	X	1.3
0007 POR2 UGHS140 55-57m	4		134	2.42		1.3
0008 POR3 UGHS132 56-58m	11		800	4.93		1.1
0009 POR4 UGHS010 395-398m	28		146	2.34		1.3
0010 DCB1 UGHS012 313-316m	61		187	5.55		1.2
0011 DCB2 UNGD010 329-330m	44	X	117	6.46	X	0.3
0012 DCB3 UGHS140 31-33m	37		146	6.97		1.5
0013 DCB4 UGHS140 66-69m	85	X	139	6.39	X	1.4
0014 DCB5 UGHS132 92-94m			181			0.3
0015 KS1 UGHS012 356-358m	2062	0.17	578	23.18	28.70	1.4
0016 KS2 UGHS092 151-154m	407	X	114	9.19	X	0.9
0017 KS3 UGHS010 90-92m			291			1.3
0018 KS4 UGHS010 500-502m	2524		562	19.15		1.1
0019 KS5 UGHS144 70.5-72m	458		292	14.94		1.4
0020 HLS1 UGHS038A 432-434m	47		206	6.34		0.3
0021 HLS2 UGHS039 52-54m	68		196	5.15		1.3
0022 HLS3 UGHS039 74-77m	100	X	172	7.66	X	1.4
0023 HLS4 CKD13 474-481m	32		151	6.79		0.3
0024 NOB REG MC044273 12-13m	104		434	7.94		1.7
0025 NOB GMD1 MC04272 40-45m	89		198	8.75		1.3
0026 NOB GMD2 MC04273 201-206m	27		159	10.42		1.6
0027 NOB GMD3 MC04273 225-230m	36	X	86	11.87	X	1.2
STANDARDS						
0001 DS-1						
0002 OREAS 502b						
0003 OREAS 905	1510			4.30		
0004 NAG Std 3						
BLANKS						
0001 Control Blank	X	X	X	X	X	

ELEMENTS	Fizz-Rate	HCO3	Hg	Hg	K	K
UNITS	NONE	mgCaCO3/L	ppm	ug/l	ppm	mg/l
DETECTION LIMIT	1	2	0.1	0.1	20	0.1
DIGEST	ANCx/	Ws/	AR1/	Ws/	4A/	Ws/
ANALYTICAL FINISH	QUAL	VOL	MS	MS	OE	OE
SAMPLE NUMBERS						
0001 WD1 UGHS144 28-30m	2	8	0.1	X	695	0.3
0002 WD2 UGHS012 280-282m	2		X		1.49%	
0003 WD3 UGHS154 87-89m	2	5	0.1	X	2457	1.2
0004 WD4 UGHS007 325-327m	2		X		3.75%	
0005 WD5- UGHS012 371-373m	3					
0006 POR1 - UGHS012 330-333m	3	39	0.3	X	1.95%	4.9
0007 POR2 UGHS140 55-57m	2		X		2.22%	
0008 POR3 UGHS132 56-58m	2		X		1.63%	
0009 POR4 UGHS010 395-398m	2		X		2.41%	
0010 DCB1 UGHS012 313-316m	2		0.1		1.88%	
0011 DCB2 UNGD010 329-330m	3	102	X	X	7234	2.8
0012 DCB3 UGHS140 31-33m	3		X		1.86%	
0013 DCB4 UGHS140 66-69m	2	88	X	X	2.93%	8.0
0014 DCB5 UGHS132 92-94m	3					
0015 KS1 UGHS012 356-358m	1	3	1.1	X	1.02%	2.8
0016 KS2 UGHS092 151-154m	3	30	0.6	X	328	0.4
0017 KS3 UGHS010 90-92m	3					
0018 KS4 UGHS010 500-502m	3		1.0		2.19%	
0019 KS5 UGHS144 70.5-72m	3		0.5		2.13%	
0020 HLS1 UGHS038A 432-434m	3		X		6088	
0021 HLS2 UGHS039 52-54m	3		X		1.16%	
0022 HLS3 UGHS039 74-77m	3	34	X	X	1.28%	5.4
0023 HLS4 CKD13 474-481m	3		X		2006	
0024 NOB REG MC044273 12-13m	X		X		234	
0025 NOB GMD1 MC04272 40-45m	3		X		2569	
0026 NOB GMD2 MC04273 201-206m	3		X		871	
0027 NOB GMD3 MC04273 225-230m	3	25	X	X	275	0.4
STANDARDS						
0001 DS-1						
0002 OREAS 502b			X			
0003 OREAS 905					3.05%	
0004 NAG Std 3						
BLANKS						
0001 Control Blank		4	X	X	X	X

ELEMENTS	Li	Mg	Mg	Mn	Mn	Mo
UNITS	ug/l	ppm	mg/l	ppm	mg/l	ppm
DETECTION LIMIT	0.05	20	0.01	1	0.001	0.1
DIGEST	Ws/	4A/	Ws/	4A/	Ws/	4A/
ANALYTICAL FINISH	MS	OE	OE	OE	OE	MS
SAMPLE NUMBERS						
0001 WD1 UGHS144 28-30m	1.05	4.30%	4.41	2139	0.009	0.5
0002 WD2 UGHS012 280-282m		10.82%		1338		0.3
0003 WD3 UGHS154 87-89m	1.13	10.22%	7.52	1207	0.001	0.2
0004 WD4 UGHS007 325-327m		3.55%		1151		0.4
0005 WD5- UGHS012 371-373m						
0006 POR1 - UGHS012 330-333m	1.94	9593	4.89	316	0.004	1.6
0007 POR2 UGHS140 55-57m		8294		337		0.3
0008 POR3 UGHS132 56-58m		2.66%		559		0.1
0009 POR4 UGHS010 395-398m		8552		343		1.2
0010 DCB1 UGHS012 313-316m		4.02%		2067		0.5
0011 DCB2 UNGD010 329-330m	1.70	10.00%	8.14	1251	0.001	0.2
0012 DCB3 UGHS140 31-33m		4.28%		1125		0.2
0013 DCB4 UGHS140 66-69m	2.01	4.05%	6.14	1599	0.002	0.6
0014 DCB5 UGHS132 92-94m						
0015 KS1 UGHS012 356-358m	5.75	9611	20.75	511	1.938	6.7
0016 KS2 UGHS092 151-154m	0.96	1.50%	6.95	441	0.004	1.9
0017 KS3 UGHS010 90-92m						
0018 KS4 UGHS010 500-502m		1.06%		708		5.0
0019 KS5 UGHS144 70.5-72m		1.23%		452		4.3
0020 HLS1 UGHS038A 432-434m		9.81%		1159		0.2
0021 HLS2 UGHS039 52-54m		2.29%		1227		0.5
0022 HLS3 UGHS039 74-77m	2.73	3.92%	5.54	2083	0.004	0.4
0023 HLS4 CKD13 474-481m		10.99%		1129		X
0024 NOB REG MC044273 12-13m		2.96%		1557		0.1
0025 NOB GMD1 MC04272 40-45m		3.32%		1431		0.3
0026 NOB GMD2 MC04273 201-206m		3.25%		1468		0.6
0027 NOB GMD3 MC04273 225-230m	0.55	2.47%	2.73	1819	0.008	0.7
STANDARDS						
0001 DS-1						
0002 OREAS 502b						
0003 OREAS 905		2878		392		3.3
0004 NAG Std 3						
BLANKS						
0001 Control Blank	0.08	X	X	X	X	X

ELEMENTS	Mo	Na	Na	NAG	NAGpH	NAG(4.5)
UNITS	ug/l	ppm	mg/l	kgH2SO4/t	NONE	kgH2SO4/t
DETECTION LIMIT	0.05	20	0.1	1	0.1	1
DIGEST	Ws/	4A/	Ws/	NAGx/	NAGx/	NAGx/
ANALYTICAL FINISH	MS	OE	OE	VOL	MTR	VOL
SAMPLE NUMBERS						
0001 WD1 UGHS144 28-30m	0.21	2.75%	3.2	0	8.1	0
0002 WD2 UGHS012 280-282m		1579				
0003 WD3 UGHS154 87-89m	0.12	9969	1.7	0	8.0	0
0004 WD4 UGHS007 325-327m		943		0	9.9	0
0005 WD5- UGHS012 371-373m				0	8.7	0
0006 POR1 - UGHS012 330-333m	2.37	3.10%	7.6	0	8.5	0
0007 POR2 UGHS140 55-57m		3.12%		0	9.2	0
0008 POR3 UGHS132 56-58m		2.81%				
0009 POR4 UGHS010 395-398m		2.67%		0	9.1	0
0010 DCB1 UGHS012 313-316m		2.11%		0	8.3	0
0011 DCB2 UNGD010 329-330m	0.28	9213	5.0	0	8.4	0
0012 DCB3 UGHS140 31-33m		8464		0	9.5	0
0013 DCB4 UGHS140 66-69m	0.29	6705	3.7	0	8.3	0
0014 DCB5 UGHS132 92-94m				0	8.5	0
0015 KS1 UGHS012 356-358m	X	1591	7.9	412	2.0	337
0016 KS2 UGHS092 151-154m	1.26	1277	1.6	0	7.4	0
0017 KS3 UGHS010 90-92m				102	2.7	72
0018 KS4 UGHS010 500-502m		1979		232	2.3	185
0019 KS5 UGHS144 70.5-72m		875		242	2.2	218
0020 HLS1 UGHS038A 432-434m		931		0	7.1	0
0021 HLS2 UGHS039 52-54m		1.34%		0	8.5	0
0022 HLS3 UGHS039 74-77m	0.49	6325	15.4	0	8.4	0
0023 HLS4 CKD13 474-481m		357		0	8.1	0
0024 NOB REG MC044273 12-13m		2.57%				
0025 NOB GMD1 MC04272 40-45m		2.28%		0	9.2	0
0026 NOB GMD2 MC04273 201-206m		2.36%				
0027 NOB GMD3 MC04273 225-230m	2.63	1.69%	5.6	0	9.2	0
STANDARDS						
0001 DS-1						
0002 OREAS 502b						
0003 OREAS 905		2.44%				
0004 NAG Std 3				22	2.5	19
BLANKS						
0001 Control Blank	X	X	X	6	4.4	0

ELEMENTS	Nb	Ni	Ni	OH	Pb	Pb
UNITS	ug/l	ppm	mg/l	mgCaCO3/L	ppm	ug/l
DETECTION LIMIT	0.005	1	0.01	0	0.5	0.5
DIGEST	Ws/	4A/	Ws/	Ws/	4A/	Ws/
ANALYTICAL FINISH	MS	OE	OE	VOL	MS	MS
SAMPLE NUMBERS						
0001 WD1 UGHS144 28-30m	X	150	X	0.0000000	12.2	X
0002 WD2 UGHS012 280-282m		291			2.1	
0003 WD3 UGHS154 87-89m	X	279	X	0.0000000	3.0	X
0004 WD4 UGHS007 325-327m		105			3.3	
0005 WD5- UGHS012 371-373m						
0006 POR1 - UGHS012 330-333m	X	10	X	0.0000000	13.3	X
0007 POR2 UGHS140 55-57m		8			6.5	
0008 POR3 UGHS132 56-58m		69			4.6	
0009 POR4 UGHS010 395-398m		7			20.9	
0010 DCB1 UGHS012 313-316m		220			33.0	
0011 DCB2 UNGD010 329-330m	X	257	X	0.0000000	2.4	X
0012 DCB3 UGHS140 31-33m		159			4.2	
0013 DCB4 UGHS140 66-69m	X	170	X	0.0000000	7.6	X
0014 DCB5 UGHS132 92-94m						
0015 KS1 UGHS012 356-358m	X	210	0.17	0.0000000	98.8	10.6
0016 KS2 UGHS092 151-154m	X	11	X	0.0000000	18.7	X
0017 KS3 UGHS010 90-92m						
0018 KS4 UGHS010 500-502m		182			45.3	
0019 KS5 UGHS144 70.5-72m		140			32.5	
0020 HLS1 UGHS038A 432-434m		702			3.3	
0021 HLS2 UGHS039 52-54m		55			3.8	
0022 HLS3 UGHS039 74-77m	X	126	X	0.0000000	5.3	X
0023 HLS4 CKD13 474-481m		1030			0.8	
0024 NOB REG MC044273 12-13m		55			X	
0025 NOB GMD1 MC04272 40-45m		50			3.0	
0026 NOB GMD2 MC04273 201-206m		36			1.1	
0027 NOB GMD3 MC04273 225-230m	X	24	X	0.0000000	1.1	X
STANDARDS						
0001 DS-1						
0002 OREAS 502b						
0003 OREAS 905		10			30.7	
0004 NAG Std 3						
BLANKS						
0001 Control Blank	X	1	X	0.0000000	X	X

ELEMENTS	pH	pH Drop	S	S	S	S
UNITS	NONE	NONE	%	mg/l	%	%
DETECTION LIMIT	0.1	0.1	0.01	0.05	0.01	0.02
DIGEST	Ws/	ANCx/		Ws/	SHCl/	SCR/
ANALYTICAL FINISH	MTR	MTR	/CSA	OE	OE	VOL
SAMPLE NUMBERS						
0001 WD1 UGHS144 28-30m	9.4	3.1	0.75	3.27	X	
0002 WD2 UGHS012 280-282m	9.4	3.3	0.13			
0003 WD3 UGHS154 87-89m	9.2	3.0	2.57	7.38	0.01	
0004 WD4 UGHS007 325-327m	9.1	3.1	0.77		X	
0005 WD5- UGHS012 371-373m	9.1	3.2	1.29		X	
0006 POR1 - UGHS012 330-333m	9.3	3.4	1.43	7.44	X	
0007 POR2 UGHS140 55-57m	9.2	3.4	0.45		X	
0008 POR3 UGHS132 56-58m	8.6	3.1	0.12			
0009 POR4 UGHS010 395-398m	9.0	3.5	1.13		X	
0010 DCB1 UGHS012 313-316m	9.0	3.0	1.44		X	
0011 DCB2 UNGD010 329-330m	9.2	2.9	1.44	6.51	X	
0012 DCB3 UGHS140 31-33m	9.2	3.1	0.55		X	
0013 DCB4 UGHS140 66-69m	9.1	3.0	1.11	4.77	X	
0014 DCB5 UGHS132 92-94m	9.1	3.0	0.91		X	
0015 KS1 UGHS012 356-358m	4.9	2.8	21.59	88.20	0.15	17.50
0016 KS2 UGHS092 151-154m	8.3	2.9	6.19	11.47	0.03	5.32
0017 KS3 UGHS010 90-92m	8.3	3.0	10.08		0.03	7.71
0018 KS4 UGHS010 500-502m	7.6	2.8	11.87		0.11	8.44
0019 KS5 UGHS144 70.5-72m	8.1	3.1	13.39		0.04	10.80
0020 HLS1 UGHS038A 432-434m	9.0	3.0	0.32		X	
0021 HLS2 UGHS039 52-54m	9.2	3.1	0.24		X	
0022 HLS3 UGHS039 74-77m	9.1	3.1	1.10	6.33	X	
0023 HLS4 CKD13 474-481m	9.2	3.0	0.27		X	
0024 NOB REG MC044273 12-13m	9.6	2.9	0.02			
0025 NOB GMD1 MC04272 40-45m	9.0	3.1	1.09		X	
0026 NOB GMD2 MC04273 201-206m	9.3	3.4	0.06			
0027 NOB GMD3 MC04273 225-230m	8.9	3.1	0.30	1.67	X	
STANDARDS						
0001 DS-1			2.53			
0002 OREAS 502b						
0003 OREAS 905						
0004 NAG Std 3						
BLANKS						
0001 Control Blank	7.1		X	X	X	

ELEMENTS	SO4	Sb	Sb	Se	Se	Sn
UNITS	%	ppm	ug/l	ppm	ug/l	ppm
DETECTION LIMIT	0.03	0.05	0.01	0.5	0.5	0.1
DIGEST		4A/	Ws/	4A/	Ws/	4A/
ANALYTICAL FINISH	/CALC	MS	MS	MS	MS	MS
SAMPLE NUMBERS						
0001 WD1 UGHS144 28-30m	2.25	1.78	2.61	0.6	X	0.1
0002 WD2 UGHS012 280-282m	0.40	0.80		X		0.3
0003 WD3 UGHS154 87-89m	7.71	1.00	2.79	0.9	0.6	X
0004 WD4 UGHS007 325-327m	2.31	1.15		X		0.3
0005 WD5- UGHS012 371-373m	3.86					
0006 POR1 - UGHS012 330-333m	4.27	5.67	9.17	X	X	0.8
0007 POR2 UGHS140 55-57m	1.36	2.19		X		0.7
0008 POR3 UGHS132 56-58m	0.35	2.73		X		0.7
0009 POR4 UGHS010 395-398m	3.40	2.90		X		0.8
0010 DCB1 UGHS012 313-316m	4.31	4.17		X		1.8
0011 DCB2 UNGD010 329-330m	4.33	1.36	4.78	0.5	X	0.1
0012 DCB3 UGHS140 31-33m	1.65	3.00		X		0.3
0013 DCB4 UGHS140 66-69m	3.33	3.52	6.94	X	X	0.3
0014 DCB5 UGHS132 92-94m	2.73					
0015 KS1 UGHS012 356-358m	64.67	13.88	0.02	17.0	3.1	12.4
0016 KS2 UGHS092 151-154m	18.54	14.22	12.40	4.5	1.7	0.3
0017 KS3 UGHS010 90-92m	30.19					
0018 KS4 UGHS010 500-502m	35.56	12.06		15.1		17.1
0019 KS5 UGHS144 70.5-72m	40.12	16.60		7.2		2.2
0020 HLS1 UGHS038A 432-434m	0.97	0.76		X		X
0021 HLS2 UGHS039 52-54m	0.73	3.39		X		0.7
0022 HLS3 UGHS039 74-77m	3.29	1.65	3.62	0.7	0.5	0.3
0023 HLS4 CKD13 474-481m	0.82	0.44		X		X
0024 NOB REG MC044273 12-13m	0.05	3.52		X		0.2
0025 NOB GMD1 MC04272 40-45m	3.25	4.32		X		0.2
0026 NOB GMD2 MC04273 201-206m	0.17	0.61		X		0.2
0027 NOB GMD3 MC04273 225-230m	0.89	0.76	0.64	X	X	1.4
STANDARDS						
0001 DS-1	7.58					
0002 OREAS 502b						
0003 OREAS 905		2.10		2.9		4.0
0004 NAG Std 3						
BLANKS						
0001 Control Blank	X	X	X	X	X	X

ELEMENTS	Sn	Ta	Te	Te	Th	Th
UNITS	ug/l	ug/l	ppm	ug/l	ppm	ug/l
DETECTION LIMIT	0.1	0.001	0.2	0.1	0.01	0.005
DIGEST	Ws/	Ws/	4A/	Ws/	4A/	Ws/
ANALYTICAL FINISH	MS	MS	MS	MS	MS	MS
SAMPLE NUMBERS						
0001 WD1 UGHS144 28-30m	X	0.002	X	X	0.60	X
0002 WD2 UGHS012 280-282m			0.3		0.99	
0003 WD3 UGHS154 87-89m	X	0.002	5.9	X	0.78	X
0004 WD4 UGHS007 325-327m			1.1		1.17	
0005 WD5- UGHS012 371-373m						
0006 POR1 - UGHS012 330-333m	X	0.002	0.7	X	8.91	X
0007 POR2 UGHS140 55-57m			X		9.29	
0008 POR3 UGHS132 56-58m			X		6.69	
0009 POR4 UGHS010 395-398m			0.4		9.74	
0010 DCB1 UGHS012 313-316m			5.6		0.62	
0011 DCB2 UNGD010 329-330m	X	0.002	2.9	X	0.81	X
0012 DCB3 UGHS140 31-33m			X		0.49	
0013 DCB4 UGHS140 66-69m	X	0.002	X	X	0.48	X
0014 DCB5 UGHS132 92-94m						
0015 KS1 UGHS012 356-358m	X	0.002	3.1	X	4.80	X
0016 KS2 UGHS092 151-154m	X	0.002	1.5	X	0.23	X
0017 KS3 UGHS010 90-92m						
0018 KS4 UGHS010 500-502m			4.5		4.60	
0019 KS5 UGHS144 70.5-72m			4.4		4.15	
0020 HLS1 UGHS038A 432-434m			X		0.15	
0021 HLS2 UGHS039 52-54m			X		0.63	
0022 HLS3 UGHS039 74-77m	X	0.003	0.3	X	0.53	X
0023 HLS4 CKD13 474-481m			X		0.14	
0024 NOB REG MC044273 12-13m			X		0.26	
0025 NOB GMD1 MC04272 40-45m			X		0.20	
0026 NOB GMD2 MC04273 201-206m			X		0.56	
0027 NOB GMD3 MC04273 225-230m	X	0.003	X	X	0.57	X
STANDARDS						
0001 DS-1						
0002 OREAS 502b						
0003 OREAS 905			X		15.07	
0004 NAG Std 3						
BLANKS						
0001 Control Blank	X	0.002	X	X	X	X

ELEMENTS	TotAlk	U	U	V	V	Zn
UNITS	mgCaCO3/L	ppm	ug/l	ppm	mg/l	ppm
DETECTION LIMIT	2	0.01	0.005	1	0.01	1
DIGEST		4A/	Ws/	4A/	Ws/	4A/
ANALYTICAL FINISH	/CALC	MS	MS	OE	OE	OE
SAMPLE NUMBERS						
0001 WD1 UGHS144 28-30m	34	0.15	X	175	X	671
0002 WD2 UGHS012 280-282m		0.23		118		60
0003 WD3 UGHS154 87-89m	28	0.18	X	126	X	54
0004 WD4 UGHS007 325-327m		0.27		127		50
0005 WD5- UGHS012 371-373m						
0006 POR1 - UGHS012 330-333m	65	2.16	0.109	60	X	77
0007 POR2 UGHS140 55-57m		2.12		53		64
0008 POR3 UGHS132 56-58m		1.40		133		47
0009 POR4 UGHS010 395-398m		2.27		52		75
0010 DCB1 UGHS012 313-316m		0.16		193		304
0011 DCB2 UNGD010 329-330m	128	0.19	X	106	X	50
0012 DCB3 UGHS140 31-33m		0.11		159		55
0013 DCB4 UGHS140 66-69m	114	0.13	X	171	X	208
0014 DCB5 UGHS132 92-94m						
0015 KS1 UGHS012 356-358m	3	1.25	0.189	53	X	7256
0016 KS2 UGHS092 151-154m	30	0.07	0.006	6	X	221
0017 KS3 UGHS010 90-92m						
0018 KS4 UGHS010 500-502m		1.33		100		4789
0019 KS5 UGHS144 70.5-72m		1.17		69		994
0020 HLS1 UGHS038A 432-434m		0.05		107		141
0021 HLS2 UGHS039 52-54m		0.18		201		67
0022 HLS3 UGHS039 74-77m	62	0.15	X	189	X	90
0023 HLS4 CKD13 474-481m		0.03		117		68
0024 NOB REG MC044273 12-13m		0.04		247		63
0025 NOB GMD1 MC04272 40-45m		0.05		281		71
0026 NOB GMD2 MC04273 201-206m		0.11		326		95
0027 NOB GMD3 MC04273 225-230m	40	0.14	X	358	X	90
STANDARDS						
0001 DS-1						
0002 OREAS 502b						
0003 OREAS 905		5.14		10		139
0004 NAG Std 3						
BLANKS						
0001 Control Blank	4	X	X	X	X	X

ELEMENTS	Zn
UNITS	mg/l
DETECTION LIMIT	0.01
DIGEST	Ws/
ANALYTICAL FINISH	OE
SAMPLE NUMBERS	
0001 WD1 UGHS144 28-30m	X
0002 WD2 UGHS012 280-282m	
0003 WD3 UGHS154 87-89m	X
0004 WD4 UGHS007 325-327m	
0005 WD5- UGHS012 371-373m	
0006 POR1 - UGHS012 330-333m	X
0007 POR2 UGHS140 55-57m	
0008 POR3 UGHS132 56-58m	
0009 POR4 UGHS010 395-398m	
0010 DCB1 UGHS012 313-316m	
0011 DCB2 UNGD010 329-330m	X
0012 DCB3 UGHS140 31-33m	
0013 DCB4 UGHS140 66-69m	X
0014 DCB5 UGHS132 92-94m	
0015 KS1 UGHS012 356-358m	28.74
0016 KS2 UGHS092 151-154m	X
0017 KS3 UGHS010 90-92m	
0018 KS4 UGHS010 500-502m	
0019 KS5 UGHS144 70.5-72m	
0020 HLS1 UGHS038A 432-434m	
0021 HLS2 UGHS039 52-54m	
0022 HLS3 UGHS039 74-77m	X
0023 HLS4 CKD13 474-481m	
0024 NOB REG MC044273 12-13m	
0025 NOB GMD1 MC04272 40-45m	
0026 NOB GMD2 MC04273 201-206m	
0027 NOB GMD3 MC04273 225-230m	X

STANDARDS
0001 DS-1
0002 OREAS 502b
0003 OREAS 905
0004 NAG Std 3

BLANKS	
0001 Control Blank	X

METHOD CODE DESCRIPTION

Method Code	Analysing Laboratory NATA Laboratory Accreditation	NATA Scope of Accreditation
/CALC	Intertek Genalysis Perth **3244 3237** No digestion or other pre-treatment undertaken. Results Determined by calculation from other reported data.	
/CSA	Intertek Genalysis Perth **3244 3237** Induction Furnace Analysed by Infrared Spectrometry	**MPL_W043, CSA : MPL_W043**
4A/MS	Intertek Genalysis Perth **3244 3237** Multi-acid digest including Hydrofluoric, Nitric, Perchloric and Hydrochloric acids in Teflon Tubes. Analysed by Inductively Coupled Plasma Mass Spectrometry.	**4A/ : MPL_W002, MS : ICP_W003**
4A/OE	Intertek Genalysis Perth **3244 3237** Multi-acid digest including Hydrofluoric, Nitric, Perchloric and Hydrochloric acids in Teflon Tubes. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.	**4A/ : MPL_W002, OE : ICP_W004**
ANCx/MTR	Intertek Genalysis Perth **3244 3237** Acid Neutralizing Capacity Digestion Procedure. Analysed with Electronic Meter Measurement	
ANCx/QUAL	Intertek Genalysis Perth **3244 3237** Acid Neutralizing Capacity Digestion Procedure. Analysed by Qualitative Inspection	
ANCx/VOL	Intertek Genalysis Perth **3244 3237** Acid Neutralizing Capacity Digestion Procedure. Analysed by Volumetric Technique.	
AR1/MS	Intertek Genalysis Perth **3244 3237** 1g Aqua-Regia digest. Analysed by Inductively Coupled Plasma Mass Spectrometry.	

METHOD CODE DESCRIPTION

Method Code	Analysing Laboratory NATA Laboratory Accreditation	NATA Scope of Accreditation
NAGx/MTR	Intertek Genalysis Perth **3244 3237**	Net Acid Generation Extraction of samples with H2O2 Analysed with Electronic Meter Measurement
NAGx/VOL	Intertek Genalysis Perth **3244 3237**	Net Acid Generation Extraction of samples with H2O2 Analysed by Volumetric Technique.
SCR/VOL	Intertek Genalysis Perth **3244 3237**	Chromium Reducible Suplhur Analysed by Volumetric Technique.
SHCl/OE	Intertek Genalysis Perth **3244 3237**	Acid Soluble soil. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.
Ws/COL	Intertek Genalysis Perth **3244 3237**	Water Extraction using a sample:water ratio of 1:5 or to client request. Analysed by UV-Visible Spectrometry.
Ws/MS	Intertek Genalysis Perth **3244 3237**	Water Extraction using a sample:water ratio of 1:5 or to client request. Analysed by Inductively Coupled Plasma Mass Spectrometry.
Ws/MTR	Intertek Genalysis Perth **3244 3237**	Water Extraction using a sample:water ratio of 1:5 or to client request. Analysed with Electronic Meter Measurement
Ws/OE	Intertek Genalysis Perth **3244 3237**	Water Extraction using a sample:water ratio of 1:5 or to client request. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.

METHOD CODE DESCRIPTION

Method Code	Analysing Laboratory NATA Laboratory Accreditation	NATA Scope of Accreditation
Ws/VOL	Intertek Genalysis Perth **3244 3237**	Water Extraction using a sample:water ratio of 1:5 or to client request. Analysed by Volumetric Technique.

MINERALS
TEST REPORT

CLIENT

MARTINICK BOSCH SELL PTY LTD
4 Cook Street
WEST PERTH, W.A. 6005
AUSTRALIA

JOB INFORMATION

JOB CODE	: 282.0/1710554
NO. SAMPLES	: 8
NO. ELEMENTS	: 33
CLIENT ORDER NO.	: M. NORTH (Job 1 of 1)
SAMPLE SUBMISSION NO.	:
PROJECT	: KCGM MT CHARLOTTE KCGMMCG
DATE RECEIVED	: 13/07/2017
DATE REPORTED	: 27/09/2017
DATE PRINTED	: 27/09/2017

REPORT NOTES

1. Amended Report - This report replaces the previously issued results

TESTED BY

Intertek
15 Davison Street, Maddington 6109, Western Australia
PO Box 144, Gosnells 6990, Western Australia
Tel: +61 8 9251 8100
Email: min.aus.per@intertek.com

This report relates specifically to the sample(s) tested that were drawn and/or provided by the client or their nominated third party to Intertek. The reported result(s) provide no warranty or verification on the sample(s) representing any specific goods and/or shipment. This report was prepared solely for the use of the client named in this report. Intertek accepts no responsibility for any loss, damage or liability suffered by a third party as a result of any reliance upon or use of this report. The results provided are not intended for commercial settlement purposes.
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SIGNIFICANT FIGURES

It is common practice to report data derived from analytical instrumentation to a maximum of two or three significant figures. Some data reported herein may show more figures than this. The reporting of more than two or three figures in no way implies that figures beyond the least significant digit have significance.

For more information on the uncertainty on individual reported values, please contact the laboratory.

SAMPLE STORAGE

All solid samples (assay pulps, bulk pulps and residues will be stored for 60 days without charge. Following this samples will be stored at a daily rate until clients written advice regarding return, collection or disposal is received. If storage information is not supplied on the submission, or arranged with the laboratory in writing the default will be to store the samples with the applicable charges. Storage is charged at $4.00 per m3 per day, expenses related to the return or disposal of samples will be charged at cost. Current disposal cost is charged at $150.00 per m3.

Samples received as liquids, waters or solutions will be held for 60 days free of charge then disposed of, unless written advice fo return or collection is received.

LEGEND	X	= Less than Detection Limit		NA	= Not Analysed
	SNR	= Sample Not Received		UA	= Unable to Assay
	*	= Result Checked		>	= Value beyond Limit of Method
	DTF	= Result still to come		+	= Extra Sample Received Not Listed
	IS	= Insufficient Sample for Analysis			

ELEMENTS	Ag	Al	As	B	Ba	Be
UNITS	ug/l	mg/l	ug/l	mg/l	ug/l	ug/l
DETECTION LIMIT	0.01	0.01	0.1	0.01	0.05	0.1
DIGEST	ASLP/	ASLP/	ASLP/	ASLP/	ASLP/	ASLP/
ANALYTICAL FINISH	MS	OE	MS	OE	MS	MS
SAMPLE NUMBERS						
0001 WD1 UGHS144 28-30m	X	2.78	1.7	0.02	112.14	1.1
0002 WD3 UGHS154 87-89m	0.28	0.79	10.6	0.03	1528.30	4.0
0003 POR1 - UGHS012 330-333m	0.03	1.95	2.3	0.02	209.89	1.3
0004 DCB2 UNGD010 329-330m	0.05	1.05	2.2	0.02	847.16	2.4
0005 DCB4 UGHS140 66-69m	0.12	1.95	2.1	0.01	383.31	3.0
0006 KS2 UGHS092 151-154m	0.04	0.29	7.5	0.02	17.99	1.8
0007 HLS3 UGHS039 74-77m	0.31	2.72	1.0	0.03	37.01	0.7
0008 NOB GMD3 MC04273 225-230m	0.03	0.73	0.3	0.02	14.90	1.1
CHECKS						
0001 WD1 UGHS144 28-30m	0.02	2.85	2.1	X	125.16	1.0
STANDARDS						
0001 TMDW	1.94		79.8		52.18	20.5
BLANKS						
0001 Control Blank	X	X	X	0.01	X	X

ELEMENTS	Ca	Cd	Co	Cr	Cu	Fe
UNITS	mg/l	ug/l	ug/l	mg/l	mg/l	mg/l
DETECTION LIMIT	0.01	0.02	0.1	0.01	0.01	0.01
DIGEST	ASLP/	ASLP/	ASLP/	ASLP/	ASLP/	ASLP/
ANALYTICAL FINISH	OE	MS	MS	OE	OE	OE
SAMPLE NUMBERS						
0001 WD1 UGHS144 28-30m	372.41	3.49	31.5	0.07	X	144.11
0002 WD3 UGHS154 87-89m	283.99	1.23	16.8	0.14	0.02	48.59
0003 POR1 - UGHS012 330-333m	234.19	0.42	9.3	0.01	0.01	89.92
0004 DCB2 UNGD010 329-330m	279.94	0.58	24.6	0.11	X	47.97
0005 DCB4 UGHS140 66-69m	411.68	1.04	61.8	0.03	X	136.34
0006 KS2 UGHS092 151-154m	238.75	1.02	2.4	0.05	0.06	107.87
0007 HLS3 UGHS039 74-77m	401.19	0.68	36.6	0.04	X	157.13
0008 NOB GMD3 MC04273 225-230m	1440.61	1.66	8.1	X	X	57.67
CHECKS						
0001 WD1 UGHS144 28-30m	370.62	3.48	34.4	0.07	X	145.31
STANDARDS						
0001 TMDW		10.17	25.4			
BLANKS						
0001 Control Blank	X	X	X	X	X	X

ELEMENTS	Hg	K	Li	Mg	Mn	Mo
UNITS	ug/l	mg/l	ug/l	mg/l	mg/l	ug/l
DETECTION LIMIT	0.1	0.1	0.05	0.01	0.001	0.05
DIGEST	ASLP/	ASLP/	ASLP/	ASLP/	ASLP/	ASLP/
ANALYTICAL FINISH	MS	OE	MS	OE	OE	MS
SAMPLE NUMBERS						
0001 WD1 UGHS144 28-30m	X	0.2	8.74	140.87	15.670	X
0002 WD3 UGHS154 87-89m	X	1.1	4.24	179.59	5.993	0.12
0003 POR1 - UGHS012 330-333m	X	2.3	3.62	96.35	3.601	0.58
0004 DCB2 UNGD010 329-330m	X	1.5	3.17	182.19	4.215	0.14
0005 DCB4 UGHS140 66-69m	X	3.8	8.00	185.05	8.781	X
0006 KS2 UGHS092 151-154m	X	0.2	3.33	98.41	2.393	0.60
0007 HLS3 UGHS039 74-77m	X	2.2	10.11	158.54	12.355	X
0008 NOB GMD3 MC04273 225-230m	X	0.2	3.40	18.52	23.639	X
CHECKS						
0001 WD1 UGHS144 28-30m	X	0.3	9.14	144.90	16.578	X
STANDARDS						
0001 TMDW	X		20.08			101.08
BLANKS						
0001 Control Blank	X	X	X	X	0.002	X

ELEMENTS	Na	Nb	Ni	Pb	pH	S
UNITS	mg/l	ug/l	mg/l	ug/l	NONE	mg/l
DETECTION LIMIT	0.1	0.005	0.01	0.5	0.1	0.05
DIGEST	ASLP/	ASLP/	ASLP/	ASLP/	ASLP/	ASLP/
ANALYTICAL FINISH	OE	MS	OE	MS	MTR	OE
SAMPLE NUMBERS						
0001 WD1 UGHS144 28-30m	1.6	X	0.04	86.9	4.4	0.55
0002 WD3 UGHS154 87-89m	0.7	X	0.11	12.5	4.3	1.80
0003 POR1 - UGHS012 330-333m	2.3	X	0.01	49.1	4.1	0.99
0004 DCB2 UNGD010 329-330m	5.4	X	0.11	10.9	4.3	1.47
0005 DCB4 UGHS140 66-69m	1.2	X	0.15	19.0	4.5	0.75
0006 KS2 UGHS092 151-154m	0.8	X	X	147.5	4.2	2.22
0007 HLS3 UGHS039 74-77m	3.8	X	0.04	3.4	4.5	0.62
0008 NOB GMD3 MC04273 225-230m	1.9	X	X	1.9	5.2	0.36
CHECKS						
0001 WD1 UGHS144 28-30m	1.7	X	0.04	89.6	4.4	0.60
STANDARDS						
0001 TMDW		0.013		38.9		
BLANKS						
0001 Control Blank	X	X	X	X	2.9	X

ELEMENTS	Sb	Se	Sn	Ta	Te	Th
UNITS	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l
DETECTION LIMIT	0.01	0.5	0.1	0.001	0.1	0.005
DIGEST	ASLP/	ASLP/	ASLP/	ASLP/	ASLP/	ASLP/
ANALYTICAL FINISH	MS	MS	MS	MS	MS	MS
SAMPLE NUMBERS						
0001 WD1 UGHS144 28-30m	0.73	X	X	X	X	0.098
0002 WD3 UGHS154 87-89m	1.34	0.7	X	0.001	2.6	0.182
0003 POR1 - UGHS012 330-333m	2.28	0.7	X	X	0.3	0.330
0004 DCB2 UNGD010 329-330m	1.44	X	X	X	0.8	0.104
0005 DCB4 UGHS140 66-69m	1.17	0.6	X	X	X	0.060
0006 KS2 UGHS092 151-154m	13.89	0.7	X	X	0.8	0.180
0007 HLS3 UGHS039 74-77m	0.53	0.8	X	X	X	0.072
0008 NOB GMD3 MC04273 225-230m	0.19	3.8	X	X	X	X
CHECKS						
0001 WD1 UGHS144 28-30m	0.90	0.5	X	X	X	0.089
STANDARDS						
0001 TMDW	9.99	9.9	X	0.041	3.3	0.015
BLANKS						
0001 Control Blank	X	X	X	X	X	X

ELEMENTS	U	V	Zn
UNITS	ug/l	mg/l	mg/l
DETECTION LIMIT	0.005	0.01	0.01
DIGEST	ASLP/	ASLP/	ASLP/
ANALYTICAL FINISH	MS	OE	OE
SAMPLE NUMBERS			
0001 WD1 UGHS144 28-30m	0.187	X	0.37
0002 WD3 UGHS154 87-89m	0.113	X	0.04
0003 POR1 - UGHS012 330-333m	0.549	0.02	0.32
0004 DCB2 UNGD010 329-330m	0.115	X	0.14
0005 DCB4 UGHS140 66-69m	0.048	X	0.30
0006 KS2 UGHS092 151-154m	0.057	X	0.60
0007 HLS3 UGHS039 74-77m	0.077	X	0.23
0008 NOB GMD3 MC04273 225-230m	0.014	X	0.03
CHECKS			
0001 WD1 UGHS144 28-30m	0.195	X	0.39
STANDARDS			
0001 TMDW	9.958		
BLANKS			
0001 Control Blank	X	X	X

METHOD CODE DESCRIPTION

Method Code	Analysing Laboratory NATA Laboratory Accreditation	NATA Scope of Accreditation
ASLP/MS	Intertek Genalysis Perth **3244 3237** AS4439.3-1997: Australian Standard Leachates Protocol for Wastes, Sediments & Contaminated Soils. Analysed by Inductively Coupled Plasma Mass Spectrometry.	**ASLP/ : ENV_W037, MS : ICP_W003**
ASLP/MTR	Intertek Genalysis Perth **3244 3237** AS4439.3-1997: Australian Standard Leachates Protocol for Wastes, Sediments & Contaminated Soils. Analysed with Electronic Meter Measurement	
ASLP/OE	Intertek Genalysis Perth **3244 3237** AS4439.3-1997: Australian Standard Leachates Protocol for Wastes, Sediments & Contaminated Soils. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.	**ASLP/ : ENV_W037, OE : ICP_W004**

5.12 Appendix 5.12: GIDJI Gidji I Tailings Geochemistry

4 Cook Street
West Perth WA 6005
Australia

Telephone +61 8 9226 3166
Email: info@mbsenvironmental.com.au

MEMORANDUM

Attention:	Janine Cameron	From:	Dr Thomas Robson
Company:	Kalgoorlie Consolidated Gold Mines	Date:	5 February 2021
Subject:	Gidji 1 Tailings Geochemistry	Project:	Gidji 3 TSF

1. BACKGROUND

Kalgoorlie Consolidated Gold Mine (KCGM) are currently looking to extend the Gidji Tailings Storage Facility (TSF), located around 20 km north of Kalgoorlie, Western Australia. The intention is to construct a third tailings cell, referred to as Gidji 3, and KCGM have submitted an application for the development under Section 45c of the *Environmental Protection Act*.

The s45c application includes provision to use tailings from the first cell of the Gidji TSF (Gidji 1) to construct embankments for Gidji 3. The tailings contained in Gidji 1 were produced using a calcine (roaster) process to enhance recovery of refractory (sulfidic) gold concentrates prior to 2001, after which an ultra-fine grind (UFG) process was adopted to eventually replace the Gidji roaster. Deposition into Gidji 1 ceased in April 2012 with deposition between early 2002 and April 2012 comprising a mixture of calcine and UFG tailings. The embankments of the second, lined, TSF cell (Gidji 2) and subsequent raises were constructed using Gidji 1 tailings. Tailings deposited within Gidji 2 (and proposed Gidji 3) are and will be produced entirely from the UFG process.

The UFG and calcine tailings have some contrasting geochemical properties; most significantly, the UFG tailings contain a high proportion of sulfide (20-25% as total S) whereas the calcine tailings contain very little sulfide and moderate amounts of sulfur (2 to 2.5%) present as gypsum (calcium sulfate). Consequently, the UFG tailings are potentially acid forming (PAF), whilst the calcine tailings forming the majority of Gidji 1 are non-acid forming (NAF).

The Department of Water and Environmental Regulation (DWER) presented KCGM with a request for further information (RFI) in response to the s45c application. The RFI indicates that no information has been provided in relation to the suitability of the Gidji 1 tailings for embankment construction. The department has specifically asked for information around the potential for cyanide and other contaminants of potential concern (CoPCs) to be leached from the material and potential for acidification. The department has also requested information on the geotechnical suitability and stability of the material from Golder Associates (KCGM's Engineers of Record), which is provided in a separate memo.

KCGM has asked MBS Environmental (MBS) to review and collate all relevant information for Gidji 1 calcine tailings and to provide an assessment to address some of the knowledge gaps highlighted by DWER.

The scope of work for the Gidji 1 tailings review is as follows:

- Review technical reports and data provided by KCGM relating to Gidji tailings and construction of the Gidji TSF.
- Collate all relevant geochemical data.

- Assess the data in relation to the suitability of the Gidji 1 tailings for construction of the Gidji 3 embankments.
- Prepare a concise technical memorandum to address the geochemical aspects of the DWER RFI, noting that KCGM has separately commissioned a certified tailings engineer to address geotechnical knowledge gaps identified in the RFI.

2. INFORMATION SOURCES

All available technical reports of relevance to the Gidji TSF or Gidji tailings were reviewed by MBS. Geochemical information and testing results were drawn from two reports, as summarised in Table 1. The details of the analytical test work are provided in the body of the technical reports.

Table 1: Summary of Information Sources and Data

Document	Data Extracted
Gidji Roaster Geochemical Characterisation of Profile-Samples from Tailings-Bed (GCA 2003)	• Acid base accounting (ABA) • Electrical conductivity (EC) and pH • Acid-Base Characteristic Curves (ABCC)
Assessment of Geochemical Behaviour of Mercury in Mine Tailings for the Kalgoorlie Gold Mine (Earth Systems 2014)	• Bottle leach aqueous geochemistry • Elemental composition

The data drawn from the studies (Table 1) are considered to be relevant to this assessment on the basis that:

- The laboratory test procedures and interpretation used in each study are consistent with current good practice and the analytical determinations were undertaken by laboratories accredited by the National Association of Testing Authorities (NATA), except for ABCC testing undertaken using in-house laboratory facilities (GCA 2003).
- The sample assessed by Graeme Campbell and Associates (sample GCA4668) reflected 100% calcine tailings, and therefore the acid base accounting results from GCA (2003) represent the residual (remaining) tailings from the Gidji 1 TSF cell. Whilst ABA testing has been undertaken as part of subsequent studies (Earth Systems 2014, MBS 2018), these reflected the influence of UFG tailings, which have a much higher acid formation risk than the calcine tailings.
- Whilst the tailings assessed by Earth Systems (2014) as part of an investigation into mercury geochemistry (referred to as 'GID' in the report) reflect a mixture of 80% calcine tailings and 20% UFG tailings, the results are considered conservatively representative of calcine tailings. Some key aspects considered were:
  - Solubility of CoPCs would typically be greater in UFG tailings compared with calcine tailings due to the higher potential for sulfide oxidation and associated oxidative-dissolution in the UFG tailings.
  - Both tailings were produced using cyanide extraction and both contain residual cyanide species, which can form variably stable soluble complexes with some metals and metalloids (e.g. cobalt, copper, mercury). The basic (alkaline) pH of unoxidised UFG tailings (pH 8), as well as the water leachate salinity and chloride content were consistent with results for calcine tailings - reflective of process water. As such, the geochemical parameters exerting most control on CoPC solubility are similar in both materials.
  - Mercury present in mercury telluride minerals like coloradoite (HgTe) is preserved in the UFG tailings, whereas much of the mercury was volatilised by the Gidji roaster process and lost from the calcine tailings. By extrapolation between the mercury concentration of mixed tailings (20% UFG, 80% calcine) and pure UFG tailings (Earth Systems 2014), it is estimated that the pure calcine tailings contain approximately 0.2 mg/kg mercury.

– Excepting volatile elements like mercury, both calcine and UFG tailings were produced from ore of the same provenance. Therefore the concentrations of most elements are expected to be relatively consistent between materials.

3. DATA ASSESSMENT APPROACH

3.1 ACID FORMATION RISK

MBS uses a combined acid generation risk classification scheme (Table 2) based on NAPP (net acid production potential) and NAG pH (net acid generation test pH) determinations to classify waste rock materials for acid generation risk, which is consistent with guidance set out in AMIRA (2002) and the equivalent Federal guidelines (DIIS 2016).

Table 2: Acid Formation Risk Classification Criteria

Primary Geochemical Waste Type Class	NAPP Value kg H_2SO_4/t	NAG pH
Potentially Acid Forming (PAF)	≥10	< 4.5
Potentially Acid Forming – Low Capacity (PAF-LC)	0 to 10	< 4.5
Uncertain (UC)	Positive	> 4.5
	Negative	< 4.5
Non-Acid Forming (NAF)	Negative	> 4.5 or sulfur <0.2%*
Acid Consuming (AC)	< -100	>4.5
Barren	≤2 and sulfur < 0.05%	-

** Application of 0.2% sulfur cut-off as a screening tool for the need for determination of NAG pH for classification may be applied on a site specific basis in conjunction with assessment of ANC and NPR). This uses a ratio analysis approach for low risk samples based on Western Australian conditions where extensive experience has indicated no potential for samples with less than 0.2% sulfur to generate net acidity in arid conditions for waste rock from hard rock mines. A negative NAPP and NPR of more than 4 (DIIS 2016) indicates no considered risk of acid generation in such instances.*

3.2 ELEMENTAL ENRICHMENT

MBS uses the global abundance index (GAI) approach to compare elemental concentrations in waste rock materials with the average earth crustal abundance (AusIMM 2001, Smith and Huyck 1999). Where concentrations of any given element fall below the laboratory limit of reporting (LOR), an indicative value equal to the respective LOR is used to calculate GAI or the GAI is assigned as zero. The main purpose of the GAI is to provide an indication of any elemental enrichment that could be of environmental significance. The GAI (based on a log-2 scale) is expressed in integer increments from 0 to 6 (INAP 2009). A GAI of 0 indicates that the content of the element is less than or up to three times the average crustal abundance; a GAI of 1 corresponds to a three-to-six-fold enrichment; a GAI of 2 corresponds to a six-to-12-fold enrichment and so forth, up to a GAI of 6, which corresponds to a 96-fold, or greater, enrichment above average crustal abundances. A GAI of 3 or more is generally considered 'significant' and may warrant further investigation.

3.3 SALINE AND METALLIFEROUS SEEPAGE

The potential for tailings to generate potentially harmful seepage/runoff was assessed by comparison of leachate (water bottle roll extraction, Earth Systems (2014)) concentrations against relevant water quality guideline values, typically those set out in the *Australian and New Zealand Guidelines for Fresh & Marine Water Quality* (ANZG 2018). These guideline values included:

- ANZG Livestock drinking water default guideline values (DGVs).
- Non-potable groundwater use (NPUG, DER 2014) trigger values.

- USEPA Maximum Contaminant Level (MCL) for thallium. Note that the current freshwater ecosystem ANZG DGV for thallium is considered unreliable, hence the application of the USEPA value.

4. SUMMARY OF GEOCHEMICAL CHARACTERISTICS

The laboratory testwork results relied upon for this review are collated in Attachment 1. The key geochemical characteristics of the Gidji 1 tailings are as follows:

- Gidji 1 tailings are non-acid forming (NAF):
  - Sulfur speciation indicated that of the total sulfur (2.3%) in the sample, almost all (2%) was present as sulfate, which has no potential to generate additional acidity. This is consistent with the calcination of the material, which would have oxidised or volatilised the majority of the sulfur in the original ore, leaving a minor proportion of oxidised sulfur (sulfates) compounds (e.g. gypsum) and possibly traces of oxidisable sulfur (pyrite).
  - The acid neutralising capacity (ANC) of the sample (26 H_2SO_4/t) is greater than the acid production potential (AP, 9.2 H_2SO_4/t), yielding a negative NAPP value (-17 kg H_2SO_4/t). This assumes all insoluble sulfur is present as oxidisable pyrite. In reality, it should also be noted that oxidised sulfate minerals such as jarosite (from pyrite oxidation) are poorly soluble and may lead to sulfate results being less than total sulfur and hence overestimation of the AP.
  - The effective NAPP, which is based on the carbonate content of the sample (0.25%) is also negative (-11 H_2SO_4/t). Effective NAPP is a more conservative predictor of the potential of mine wastes to generate net acidic seepage because only ANC representing readily reactive carbonates is considered in the calculation, as opposed to less reactive ANC provided by silicate dissolution.
  - Acid consumption curves (ABCC) suggest, very conservatively, a carbonate buffering capacity in the order of 12 H_2SO_4/t (to pH 4.5), consistent with ANC provided by ankerite (Ca-Mg-Fe carbonates). Cautiously calculating an Effective NAPP from this value also yields a negative result (-3 H_2SO_4/t) despite a potentially elevated predicted AP. This indicates that the risk of the tailings producing net acidic seepage is very low even using the most conservative assessment assumptions.
- Based on screening by GAI, the Gidji 1 tailings are significantly enriched in several environmentally significant metals and metalloids:
  - Silver (Ag) based on a total concentration of 1.8 mg/kg versus a crustal average of 0.07 mg/kg.
  - Arsenic (As), given the tailings sample contained 1,740 mg/kg arsenic relative to 25 mg/kg typically found in crustal rocks and soils. Antimony, commonly associated with arsenic, was also present at 39 mg/kg compared with a typical value of 0.2 mg/kg.
  - Chloride (Cl) based on the tailings containing 0.73% chlorine compared with 0.013% in typical crustal rocks. This is a result of the saline process water.
  - Cobalt (Co), which was present at 295 mg/kg in the tailings versus a crustal average of 25 mg/kg.
  - Copper (Cu) based on the tailings containing 826 mg/kg relative to a typical abundance of 60 mg/kg.
  - Mercury (Hg) as the tailings concentration (1 mg/kg) was over ten times the average crustal abundance (0.08 mg/kg).
  - Molybdenum (Mo) due to the tailings containing 26 mg/kg compared with the average of 2 mg/kg.
  - Lead (Pb) given the tailings contained 238 mg/kg versus 16 mg/kg in average crustal rocks.
  - Selenium (Se) due to the sample containing 2 mg/kg compared with the average crustal abundance of 0.2 mg/kg.
  - Tellurium (Te) based on a total concentration of 31 mg/kg versus a crustal average of 0.001 mg/kg.
- Water leach extraction (1 kg dry weight tailings extracted with 1 L deionised water, rolled for at least 8 hours) indicated that runoff or seepage from the Gidji 1 tailings is likely to be neutral to basic (pH 8.5), of

brackish salinity (4,480 mg/L total dissolved solids, TDS) and to contain sulfate concentrations at around the livestock drinking water DGV (1,000 mg/L). Given the environmental context and low acid formation risk and low potential for further oxidation of the material, the tailings are unlikely to generate harmfully saline or acidic seepage.

- Detectable concentrations of cyanide were present in the 1:1 extract of Gidji 1 tailings (porewater ratio). This included 3.3 mg/L total cyanide, including weak-acid dissociable (WAD, 1.4 mg/L) and free cyanide (1.1 mg/L). Whilst these concentrations are not considered to be particularly high (given high porewater type extraction ratio), the presence of these species is likely associated with the formation of soluble cyanide-metal complexes, which may increase the environmental mobility of some CoPCs. It should also be noted that cyanide breaks down once exposed to ultraviolet light and the atmosphere; hence the presence of cyanide and metal complexes would be expected to further diminish over time if Gidji 1 tailings were used to construct embankments. Furthermore, assessment results are from 2014 and further aging of the tailings on site since this time suggest that the material proposed for embankment construction would contain less cyanide than the freshly produced tailings characterised by Earth Systems (2014).
- Water leach extraction also indicated that some but not all of the enriched chemical species (see above) are likely to be soluble to the extent where consideration of potential environmental risk is warranted:
  - Whilst the tailings are enriched in silver, lead, selenium and antimony, water leachable concentrations of these species were below the analytical limit of reporting (LOR). Water leachable molybdenum (0.08 mg/L) was below the livestock drinking water DGV (0.15 mg/L). The solubility of these species in terms of rainfall runoff and percolation/seepage is unlikely to be environmentally significant.
  - Whilst arsenic was leached at around the NPUG trigger level (0.12 mg/L versus 0.1 mg/L), the concentration was below the corresponding livestock DGV (5 mg/L) and, at this concentration, arsenic oxyanions (e.g. arsenate) are expected to be effectively adsorbed or co-precipitated with iron oxyhydroxides present in the soils and regolith of the surrounding environment. The overall risk from arsenic leachability is considered to be low. The extraction ratio (1:1, porewater) is also noted to be substantially higher than typical used for assessments against these trigger values - a more typical extraction ratio for such comparison (1:10 or 1:20 ratio extract) would be expected to produce concentrations in the order of 0.01 mg/L (1/10th) and hence below the NPUG value.
  - Cobalt, copper and mercury were leached from the tailings at concentrations exceeding broadly applicable water quality screening values. Cobalt (3.2 mg/L) and copper (1.5 mg/L) marginally exceeded the livestock drinking water DGVs of 1 mg/L, whilst mercury (0.02 mg/L) exceeded the corresponding DGV of 0.002 mg/L by one order of magnitude. These findings are consistent with the formation of soluble cyanide-metal complexes. These complexes will likely decrease in solubility over time with cyanide decomposition (aging), and again noting the high extraction ratio used for these tests.

5. RISK ASSESSMENT

A qualitative risk assessment was undertaken to examine the potential environmental risks resulting from replicating the embankment design used for Gidji 2 (i.e. using Gidji 1 tailings to construct raises) for the proposed Gidji 3 cell(s). The assessment approach is discussed in the following subsections and the outcomes of the assessment are summarised in Table 6.

5.1 RISK PATHWAYS CONSIDERED

The potential impacts assessed in relation to use of Gidji 1 tailings to construct embankment raises of the proposed Gidji 3 tailings cell(s) were:

- Acidification of Gidji 1 tailings embankment materials due to *in situ* sulfide oxidation.
- Acidification of Gidji 1 tailings embankment materials due to interaction with acidic seepage from UFG tailings to be contained in lined Gidji 3 cell(s).

- Degradation of groundwater quality due to contributions of seepage or runoff from Gidji 1 tailings, produced by percolating rainwater.
- Degradation of surface water quality due to contributions of seepage or runoff from Gidji 1 tailings, produced by percolating rainwater.
- Degradation of surface water quality due to erosion and dispersal of Gidji 1 tailings from Gidji 3 embankment.
- Degradation of soil quality due to release of rainfall runoff including salts from Gidji 1 tailings.
- Degradation of soil quality due to erosion and dispersal of Gidji 1 tailings from the Gidji 3 embankments.

5.2 METHODOLOGY

The assessment was completed with consideration of the International Standard ISO 31000:2018 - 'Risk Management – Guidelines' (ISO 2018). Risk was determined based on an assessment of the consequence and likelihood of a potential impact using procedures summarised below:

- Identify key CoPCs, environmental values (e.g. beneficial uses of groundwater, ability of soils to support native vegetation) and release scenarios to identify those combinations critical to avoiding unacceptable environmental outcomes.
- Establish 'base case' setting for each risk pathway assessed. These conditions typically relate to design specifications of infrastructure, aspects of the Mine Closure Plan and existing environmental conditions.
- Undertake assessment of inherent risks, based on base case conditions, for each scenario.
- Identify appropriate mitigation measures for control of unacceptable inherent risks and assess residual risk.
- Recommend alternative potential mitigation measures and identify requirements for further investigation to address any unacceptable residual risks if necessary.

Contributors to the risk assessment were Thomas Robson (Senior Environmental Geochemist, MBS Environmental), Michael North (Principal Environmental Geochemist, MBS Environmental) and Janine Cameron (Closure Specialist, KCGM).

5.2.1 Consequence Scale

Several aspects were considered in determining the consequence of each potential impact, including:

- Type of impact (direct or indirect).
- Geographic extent, size, and scale.
- Duration, frequency, and reversibility of the potential impact.
- Whether the potential impacts are from planned or unplanned events.
- Sensitivity of the receptor/resource and the value of the receptor/resource.

The consequence ratings for impacts varied from Insignificant, through to Catastrophic as defined in Table 3.

Table 3: Risk Assessment Consequence Scale

Descriptor	Explanation
Insignificant	Negligible changes to water and/or soil quality. Minimal contamination within immediate vicinity of operation, easily treatable in short term and does not result in additional adverse impacts on associated environmental values (e.g. ability of soils to support native vegetation).
Minor	Contained, low impact to soil and water quality of project area. Minimal contamination, which is localised and treatable in medium term, with no subsequent additional impact on environmental values (e.g. ability of soils to support native vegetation).
Moderate	Uncontained impact to soil and water quality, amenable to remediation in the short term. Localised, low level land contamination that results in additional adverse impacts on associated environmental values (e.g. ability of soils to support native vegetation) in the short to medium term.
Major	Extensive hazardous impact to soil and water quality that will require long-term remedial works. Includes low level contamination on a regional scale resulting in additional adverse impacts on associated environmental values requiring medium to long term management.
Catastrophic	Uncontained hazardous impact to soil and water quality with long term residual effects. Moderate to severe contamination on a regional scale resulting in permanent damage with severe environmental and socioeconomic disruption.

5.2.2 Likelihood Scale

Likelihood reflects the probability of exposure to CoPCs resulting in potential harm (i.e. consequence) to environmental values. Where practicable, likelihood was determined using quantitative information or data. Definitions for likelihood are presented in Table 4.

Table 4: Risk Assessment Likelihood Scale

Descriptor	Explanation
Rare	Highly unlikely, but it may occur in exceptional circumstances
Unlikely	Not expected, but there is a slight possibility it may occur at some time
Possible	The event might occur at some time as there is a history of occurrence at similar projects.
Likely	There is a strong possibility the event will occur as there is a history of frequent occurrence at similar projects.
Almost Certain	Very likely. The event is expected to occur in most circumstances as there is a history of regular occurrence at similar projects.

5.2.3 Risk Rating

Inherent and residual risk ratings were determined by assessing the likelihood and consequence of an impact before and after the application of mitigation or management measures. The level of risk was determined using the matrix shown in Table 5.

Table 5: Risk Level Matrix

Likelihood	Consequences				
	Insignificant	Minor	Moderate	Major	Catastrophic
Rare	Low	Low	Medium	Medium	High
Unlikely	Low	Low	Medium	High	High
Possible	Low	Low	Medium	High	Extreme
Likely	Low	Medium	High	Extreme	Extreme
Almost Certain	Medium	Medium	High	Extreme	Extreme

Table 6: Qualitative Risk Assessment Outcomes

Receptors	Potential Impacts	Risk Assessment (Inherent)			Comments	Risk Management Measures	Risk Assessment (Residual)		
		Likelihood	Consequence	Risk Rating			Likelihood	Consequence	Risk Rating
Surface water, soils and groundwater	Acidification of Gidji 1 tailings embankment due to *in situ* sulfide oxidation (with secondary impacts as below).	Rare	Minor	Low	Acid base accounting indicates a low risk of Gidji 1 tailings generating net acidic seepage. Majority of sulfur present in oxidised forms such as gypsum, which will not generate additional acidity. A toe drain will	Not required	Rare	Minor	Low
Surface water, soils and groundwater	Acidification of Gidji 1 tailings embankment due to interaction with PAF UFG tailings contained within the Gidji 3 cell(s) (with secondary impacts as below).	Possible	Minor	Low	The tailings to be deposited within the Gidji 3 cell are potentially acid forming (PAF) and surface tailings may produce acidic leachate when exposed to the atmosphere. The interaction of acidic seepage from the UFG tailings with embankments constructed using Gidji 1 tailings could hypothetically result in the generation of acidic, metalliferous drainage (AMD) due to the geochemical characteristics of the UFG tailings to be placed in Gidji 3.	As with Gidji 2, the Gidji 3 tailings impoundment will be fitted with a composite liner (compacted Gidji 1 tailings walls, overlain with welded HDPE) overlain with a seepage interception drainage system. The HDPE liner will extend to the crest of the embankment surface to effectively minimise porewater migration into the embankment as well as pipe erosion of the embankment. Gidji 3 is a downstream TSF, meaning that the embankment thickness increases with each raise, further minimising the potential for interaction with seepage from the impounded UFG tailings. During operations, embankment runoff will be managed with a toe bund reporting to a lined dam. In the unlikely event there is seepage, an existing network of seepage recovery bores will identify and manage seepage. During operations, the risk of overtopping will be controlled through effective decant management. At closure, the toe drain and recovery bores will continue to operate for as long as necessary for water controls, until final closure designs including capping are implemented.	Rare	Minor	Low
Surface Water	Degraded surface water quality due to inputs of rainfall-driven seepage/runoff from the Gidji 3 embankment (i.e. interaction between rainwater and Gidji 1 calcine tailings).	Possible	Minor	Low	Seepage and runoff interacting with Gidji 1 calcine tailings may contain environmentally significant concentrations of metals/metalloids (Co, Cu, Hg) and their cyanide/chloro complexes. Gidji 1 tailings are enriched in certain metals, metalloids and salts, which may be deleterious to aquatic flora and fauna. There are no permanent surface water bodies within 2 km of the Gidji TSF. A creek line lies approximately 3 km to the east of the TSF but drains a separate sub-catchment. The Gidji Lake playa is located approximately 3 km to the west of the TSF. No groundwater dependent ecosystems are identified in the area.	During operations, seepage and runoff from the outer embankment will be managed through toe bunding and a network of seepage recovery bores located downgradient of the TSF. Construction of downstream raises will result in the outer embankment being periodically covered with a fresh layer of Gidji 1 calcine tailings, which will help to maintain the integrity of the outer surface and minimise erosion. Closure concepts involve sheeting the embankments with competent waste rock, which will minimise interaction of rainfall runoff with the tailings and control embankment erosion. An inward-draining design for the tailings will also limit runoff over embankments.	Rare	Minor	Low
Surface Water	Degraded surface water quality due to erosion and dispersal of Gidji 1 tailings from Gidji 3 embankment.	Unlikely	Minor	Low			Unlikely	Minor	Low

Receptors	Potential Impacts	Risk Assessment (Inherent)			Comments	Risk Management Measures	Risk Assessment (Residual)		
		Likelihood	Consequence	Risk Rating			Likelihood	Consequence	Risk Rating
Soils	Degraded soil quality due to inputs of rainfall runoff from Gidji 3 embankment (interaction with Gidji 1 calcine tailings).	Unlikely	Minor	Low	Seepage and runoff interacting with Gidji 1 calcine tailings may contain environmentally significant concentrations of metals/metalloids (Co, Cu, Hg) and their cyanide/chloro complexes. Gidji 1 tailings are enriched in certain metals, metalloids and salts, which may be deleterious to soil quality and native vegetation. Given the semi-arid climate and topography of the area, widespread transport of embankment runoff or eroded tailings particles is unlikely to significantly affect soils away from the immediate vicinity of the TSF (i.e. toe bunds).	Relatively minimal embankment erosion is anticipated during operations. Construction of downstream raises will result in the outer embankment being periodically covered with a fresh layer of Gidji 1 calcine tailings, which will help to maintain the integrity of the outer surface and minimise erosion. During operations, the embankment runoff will be captured by a toe drain reporting to a lined dam. At closure the embankment will be protected from erosion by a capping layer, which will minimise erosion. A crest bund will prevent rainwater from reaching the outer embankment. Current closure design is for an inward-draining store and release design for the cell.	Unlikely	Minor	Low
Soils	Degraded soil quality due to erosion and dispersal of Gidji 1 tailings from Gidji 3 embankment.	Unlikely	Minor	Low			Unlikely	Minor	Low
Groundwater	Degraded groundwater quality due to inputs of rainfall runoff from Gidji 3 embankment (interaction with Gidji 1 calcine tailings)	Unlikely	Minor	Low	Seepage and runoff may contain environmentally significant concentrations of metals/metalloids (Co, Cu, Hg) and their cyanide/chloro complexes. Given the semi-arid climate of the operation area, significant and uncontained inputs of seepage/runoff from the tailings embankments to groundwater is unlikely, and would be a very small contribution in relation to the Gidji 1 TSF. An existing network of seepage recovery bores will identify and manage seepage. Natural groundwater has low environmental value (naturally acidic and saline), with Mining Operations identifed as the only beneficial user.	An existing network of seepage recovery bores will identify and manage seepage, in the unlikely event that it should occur. During operations, the embankment runoff will be captured by a toe drain reporting to a lined dam and the exisitng bores will remain be in operation. At closure the embankment will be protected by a capping layer, which will minimise erosion. A crest bund will prevent rainwater from reaching the outer embankment. Current closure design is for an inward-draining store and release design for the cell. The replication of the Gidji 2 embankment construction for Gidji 3 is not expected to result in any additional impacts to groundwater, which has minimal environmental value (naturally acidic) but is monitored and managed as an ongoing concern.	Unlikely	Minor	Low

6. SUMMARY AND CONCLUSION

A review of existing geochemical testwork results was undertaken for the Gidji 1 calcine tailings. The key geochemical characteristics pertaining to potential environmental hazards were used to facilitate a qualitative risk assessment to determine the suitability of the Gidji 1 calcine tailings to construct embankment raises as part of the proposed Gidji 3 tailings storage cell(s) design. As appropriate for the knowledge gaps identified by DWER, the assessment focused on potential for cyanide and other contaminants of potential concern to be leached from the material and potential for acidification of the Gidji 1 tailings themselves.

The outcomes of this review and risk assessment indicate that the use of Gidji 1 tailings to construct lined embankment raises as part of the proposed Gidji 3 tailings storage cell(s) is unlikely to result in unacceptable environmental outcomes. This conclusion was based on the geochemical testing results presented, existing environmental conditions, the existing use of Gidji 1 tailings for embankment construction of Gidji 2, existing management infrastructure and understanding of closure planning for the Gidji TSF.

I trust that this assessment will assist in your planning and approval process for Gidji 3. Please contact me to discuss any aspect of this assessment or for additional advice.

Yours sincerely
MBS Environmental



Dr Thomas Robson
Senior Environmental Geochemist

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Attachment 1: Collated Analytical Results

7. REFERENCES

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Attachment 1: Collated Analytical Results

Table A1-1: Sample Descriptions

Sample ID	Study	Sample Depth (mbgl)	Material	Description
GID	Earth Systems (2014)	N/A	Tailings	80% caline tailings / 20% UFG tailings
TSF-2	Landloch (2020)	1	Tailings	Gidji TSF embankment sample at depth
TSF-3	Landloch (2020)	2.5	Tailings	Gidji TSF embankment sample at depth
CGA4668	GCA (2003)	N/A	Tailings	100% calcine tailings

Table A1-2: Acid Base Accounting (ABA) Summary

Paramater	Units	Result
Sample ID	CGA4668	
Study	GCA (2003)	
Description	100% calcine tailings	
pH	pH Units	8.7
EC	uS/cm	34
TDS	mg/L	22
Total S	%	2.3
SO4_S	%	2
Total C	%	0.25
Acid Insoluble C	%	<0.01
ANC	kg H_2SO_4/tonne	26
NAPP		-17
NAG pH	pH Units	N.D
NAG (pH 4.5)	kg H_2SO_4/tonne	N.D
NAG (pH 7)		N.D
MPA		70.4
AP		9.2
CC-ANC		20
Eff. NAPP (CC-ANC)		-11
NPR	Ratio	2.8
Classification		NAF

Table A1-3: Global Abundance Indices (GAIs)

Paramater	Units	Tailings Concentration	GAI	Average Crustal Abundance
Sample ID	GID			
Study	Earth Systems (2014)			
Description	80% caline tailings / 20% UFG tailings			
Ag	mg/kg	1.8	4	0.07
Al	%	1.93	0	8
As	mg/kg	1,740	6	25
Ba	mg/kg	13	0	430
Be	mg/kg	0.2	0	3
Bi	mg/kg	0.4	0	0.2
Ca	%	2.94	0	3
Cd	mg/kg	1.3	2	0.18
Ce	mg/kg	2.2	0	45
Cl	%	0.73	5	0.013
Co	mg/kg	295	3	25
Cr	mg/kg	49	0	200
Cs	mg/kg	0.4	0	3
Cu	mg/kg	826	3	60
Fe	%	38	2	5
Ga	mg/kg	0.9	0	17
Ge	mg/kg	0.2	0	15
Hf	mg/kg	<1	0	3
Hg	mg/kg	1	3	0.08
In	mg/kg	<0.1	0	0.1
K	%	0.31	0	2.6
La	mg/kg	1	0	30
Li	mg/kg	5.3	0	30
Mg	%	0.81	0	2.1
Mn	mg/kg	480	0	900
Mo	mg/kg	26	3	2
Na	%	0.59	0	2.4
Nb	mg/kg	0.2	0	20
Ni	mg/kg	158	0	80
Pb	mg/kg	238	3	16
Rb	mg/kg	3.1	0	120
Sb	mg/kg	39	6	0.2
Se	mg/kg	2	3	0.2
Sn	mg/kg	0.3	0	2.5
Sr	mg/kg	158	0	350
Te	mg/kg	31	6	0.001
Th	mg/kg	0.2	0	10
Ti	%	1.2	1	0.5
Tl	mg/kg	0.6	0	1
U	mg/kg	0.1	0	3
V	mg/kg	26	0	150
W	mg/kg	2.8	1	1
Y	mg/kg	3.3	0	30
Zn	mg/kg	381	2	70
Zr	mg/kg	10	0	160

Values of three of higher are highlighted.

Where elemental concentrations were below laboratory limit of reporting (<LOR), a GAI of zero was assigned.

Table A1-4: Water Bottle Leach Extraction
- Major Parameters and Ions

Parameter	Units	Result	Livestock Drinking Water DGV (ANZECC 2000/ANZG 2018)	NPUG (DER 2014)
Sample ID	GID			
Study	Earth Systems (2014)			
Description	80% caline tailings / 20% UFG tailings			
pH	pH Units	8.5	6.5-8.5	N/G
EC	µS/cm	7,000	6,250	N/G
TDS	mg/L	4,480	4,000	N/G
Ca	mg/L	346	1,000	N/G
K	mg/L	20	N/G	N/G
Mg	mg/L	43	No limit	N/G
Na	mg/L	1,270	N/G	N/G
Sulfate	mg/L	1,080	1,000	1,000
Chloride	mg/L	1,700	N/G	250
Alkalinity	mg $CaCO_3$/L	24	N/G	N/G
Acidity	mg $CaCO_3$/L	<1	N/G	N/G
Free Cyanide	mg/L	1.1	N/G	0.8
WAD Cyanide	mg/L	1.4	N/G	N/G
Total Cyanide	mg/L	3.3	N/G	N/G
Thiocyante	mg/L	120	N/G	N/G

N/G : No applicable guideline value.

Table A1-5: Water Bottle Leach Results
- Metals and Metalloids

Parameter	Units	Result	Livestock Drinking Water DGV (ANZECC 2000/ANZG 2018)	NPUG (DER 2014)	Other Guideline
Sample ID	GID				
Study	Earth Systems (2014)				
Description	80% caline tailings / 20% UFG tailings				
Ag	mg/L	<0.01	N/G	1	
Al	mg/L	<0.01	5	0.2	
As	mg/L	0.12	0.5	0.1	
B	mg/L	<0.05	5	40	
Bi	mg/L	<0.001	N/G	N/G	
Cd	mg/L	<0.0001	0.01	0.02	
Co	mg/L	3.2	1	N/G	
Cr	mg/L	0.001	1	0.5	
Cu	mg/L	1.5	1	20	
Fe	mg/L	<0.05	No limit	0.3	
Hg	mg/L	0.021	0.002	0.01	
Mn	mg/L	0.01	N/G	5	
Mo	mg/L	0.08	0.15	0.5	
Ni	mg/L	0.18	1	0.2	
Pb	mg/L	<0.001	0.1	0.1	
Sb	mg/L	0.02	N/G	0.03	
Se	mg/L	<0.01	0.02	0.1	
Sn	mg/L	<0.001	N/G	N/G	
Te	mg/L	<0.005	N/G	N/G	
Tl	mg/L	<0.001	N/G	N/G	0.002 (USEPA MCL)
U	mg/L	<0.001	0.2	0.17	
V	mg/L	0.02	N/G	N/G	
Zn	mg/L	<0.005	20	3	

N/G : No applicable guideline value.

Table A1-6: Acid Base Characteristic Curve (ABCC) Results

Replicate 1			Replicate 2		
Cumulative Acid Added (mL)	Cumulative Acid Consumption (kg H_2SO_4/t)	pH	Cumulative Acid Added (mL)	Cumulative Acid Consumption (kg H2SO4/t)	pH
0	0	9.3	0	0	9.6
0.4	0.2	8.8	0.4	0.2	9.1
0.8	0.4	8.6	0.8	0.4	8.8
1.2	0.6	8.4	1.2	0.6	8.6
1.6	0.8	8.3	1.6	0.8	8.4
2	1	8.2	2	1	8.4
2.8	1.4	8.2	2.8	1.4	8.2
3.2	1.6	8	3.2	1.6	8.2
3.6	1.8	8	3.6	1.8	8.1
4	2	7.8	4	2	8
4.4	2.2	7.8	4.4	2.2	8
4.8	2.4	7.7	4.8	2.4	7.9
5.2	2.6	7.6	5.2	2.6	7.9
5.6	2.8	7.6	5.6	2.8	7.8
6	3	7.5	6	3	7.7
6.4	3.2	7.5	6.4	3.2	7.7
6.8	3.4	7.4	6.8	3.4	7.6
7.2	3.6	7.3	7.2	3.6	7.6
7.6	3.8	7.4	7.6	3.8	7.5
8	4	7.3	8	4	7.5
8.4	4.2	7.3	8.4	4.2	7.4
8.8	4.4	7.2	8.8	4.4	7.4
9.2	4.6	7.2	9.2	4.6	7.3
9.6	4.8	7.2	9.6	4.8	7.3
10	5	7.1	10	5	7.2
10.4	5.2	7.1	10.4	5.2	7.2
10.8	5.4	7	10.8	5.4	7.2
11.2	5.6	7	11.2	5.6	7.1
11.6	5.8	6.9	11.6	5.8	7.1
12	6	6.9	12	6	7
12.4	6.2	6.8	12.4	6.2	7
12.8	6.4	6.7	12.8	6.4	6.9
13.2	6.6	6.6	13.2	6.6	6.9
13.6	6.8	6.5	13.6	6.8	6.8
14	7	6.4	14	7	6.8
14.4	7.2	6.4	14.4	7.2	6.7
14.8	7.4	6.2	14.8	7.4	6.7
15.2	7.6	6.1	15.2	7.6	6.6
15.6	7.8	6.1	15.6	7.8	6.5
16	8	6	16	8	6.4
16.4	8.2	5.9	16.4	8.2	6.2
16.8	8.4	5.8	16.8	8.4	6.1
17.2	8.6	5.6	17.2	8.6	6
17.6	8.8	5.5	17.6	8.8	5.9
18	9	5.4	18	9	5.7
18.4	9.2	5.3	18.4	9.2	5.6
18.8	9.4	5.2	18.8	9.4	5.5
19.2	9.6	5.1	19.2	9.6	5.4
19.6	9.8	5.1	19.6	9.8	5.2
20	10	5	20	10	5.1
20.4	10.2	5	20.4	10.2	5.1
20.8	10.4	4.9	20.8	10.4	5
21.2	10.6	4.8	21.2	10.6	4.9
21.6	10.8	4.8	21.6	10.8	4.9
22	11	4.8	22	11	4.8
22.4	11.2	4.7	22.4	11.2	4.7
22.8	11.4	4.7	22.8	11.4	4.7
23.2	11.6	4.6	23.2	11.6	4.6
23.6	11.8	4.6	23.6	11.8	4.6
24	12	4.5	24	12	4.5
24.4	12.2	4.5	24.4	12.2	4.5
24.8	12.4	4.7	24.8	12.4	4.4
25.2	12.6	4.7	25.2	12.6	4.4
25.6	12.8	4.6	25.6	12.8	4.3
26	13	4.6	26	13	4.3
26.4	13.2	4.5	26.4	13.2	4.2
26.8	13.4	4.4	26.8	13.4	4.2
27.2	13.6	4.4	27.2	13.6	4.1
27.6	13.8	4.3	27.6	13.8	4.1
28	14	4.2	28	14	4
28.4	14.2	4.2	28.4	14.2	4
28.8	14.4	4.1	28.8	14.4	3.9
29.2	14.6	4.1	29.2	14.6	3.9
29.6	14.8	4.1	29.6	14.8	3.8
30	15	4	30	15	3.8
30.4	15.2	4	30.4	15.2	3.7
30.8	15.4	3.9	30.8	15.4	3.7
31.2	15.6	3.9	31.2	15.6	3.6
31.6	15.8	3.8	31.6	15.8	3.6
32	16	3.8	32	16	3.5
32.4	16.2	3.8	32.4	16.2	3.5
32.8	16.4	3.7	32.8	16.4	3.5
33.2	16.6	3.7	33.2	16.6	3.4
33.6	16.8	3.7	33.6	16.8	3.4
34	17	3.6	34	17	3.3
34.4	17.2	3.6	34.4	17.2	3.3
34.8	17.4	3.6	34.8	17.4	3.3
35.2	17.6	3.5	35.2	17.6	3.3
35.6	17.8	3.5	35.6	17.8	3.2
36	18	3.4	36	18	3.2
36.4	18.2	3.4	36.4	18.2	3.2
36.8	18.4	3.4	36.8	18.4	3.2
37.2	18.6	3.4	37.2	18.6	3.1
37.6	18.8	3.3	37.6	18.8	3.1
38	19	3.3	38	19	3
38.4	19.2	3.3			
38.8	19.4	3.2			
39.2	19.6	3.2			
39.6	19.8	3.2			
40	20	3.1			
40.4	20.2	3.1			
40.8	20.4	3.1			
41.2	20.6	3			
41.6	20.8	3			

5.13 Appendix 5.13: GIDJI TSF Hydrological Review

Big Dog Hydrogeology Pty Ltd
135 Burgoyne Road Albany WA 6330
simon@bigdoghydrogeology.com.au
+61408230235

KCGM
Hydrogeological Review of The Gidji TSFs



Report Status

Revision	Date	Signature
Rev A (draft)	*January 2019*	
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EXECUTIVE SUMMARY

Kalgoorlie Consolidated Gold Mines Pty Ltd (KCGM) manages the mining and ore processing operations at the Fimiston Gold Mine Operations, located adjacent to the City of Kalgoorlie-Boulder in the Eastern Goldfields Region of Western Australia. KCGM is the management company for the mining operations and is owned by Newmont Australia Pty Ltd and Barrick (Australia Pacific) Pty Limited. KCGM was formed in 1989 by the amalgamation of multiple individual mining leases hosting several small open pit and underground mining operations along Kalgoorlie's Mt Percy, Mt Charlotte and Golden Mile orebodies.

Gold ore from KCGM's mining operations is processed at the Fimiston Processing Plant which is located on the eastern side of the Fimiston Open Pit (Figure 1). High sulphide concentrate is processed at the Gidji Processing Plant, located around 20 km north of Kalgoorlie Boulder (Figure 1). Tailings from the Gidji Processing Plant have been deposited in the unlined Gidji I TSF, and the lined Gidji II TSF. A third facility, the Gidji III TSF is currently being designed and permitted and will include lined cells.

Monitoring and recovery of seepage from the formations below the Gidji TSFs have been undertaken since 1995. KCGM has requested that Big Dog Hydrogeology Pty Ltd (BDH) review the current performance of seepage recovery and monitoring at the Gidji TSFs and provide updated recommendations for ongoing management of the tailings storage facilities during both operations and closure. The results of the hydrogeological review and resulting recommendations for ongoing groundwater management are provided in this report.

Seepage from the unlined Gidji I TSF has been managed during the operating period by operating the Gidji Trench and up to 28 production bores to remove seepage and groundwater and to control groundwater depths around the TSF. Operation of the trench and bores at average rates up to 6 L/s has successfully managed groundwater depths outside the operational footprint of the facilities, and for the 16 monitoring bores currently defined as compliance locations, groundwater depth has been greater than the current compliance limit of 4 m from 1999 to 2018.

From 2012 to 2018 average annual total pumping has reduced from 4.2 L/s to around 0.7 L/s. This response was predicted and is due to groundwater elevations approaching the base of the transmissive portion of the ferricrete and alluvial sediment groundwater system, which significantly reduces the flow rate available from each production bore. Rising groundwater elevations around the Gidji TSFs in 2017 and 2018 are attributed to precipitation driven recharge from surface, and in particular to precipitation events occurring in February 2017, February 2018 and October 2018. The existing pumping system has been demonstrated to be capable of managing groundwater depths during ongoing draindown of the Gidji I TSF and during any future precipitation driven recharge events, which would cause the total pumping rate from the bores to be increased.

Hydrochemical monitoring data are consistent with background groundwater being present prior to TSF operation, having a naturally low pH of around 3 in most locations, having TDS concentrations around 50,000 mg/L and having negligible CN concentrations. Operation of the unlined cells in the Gidji I TSF since 1989 has resulted in seepage of decant water entering the groundwater system, with seepage influences reducing after the cells were permanently decommissioned in 2015. TDS concentrations in groundwater are most diagnostic of seepage influences as they are not expected to be affected by attenuation during flow through the groundwater system. The influence of seepage can also be discerned in groundwater pH, groundwater EC, in concentrations of total CN, WAD CN, free CN, and in filterable concentrations of Cu and Co.

As the groundwater mound beneath the Gidji I TSF continues to decline, groundwater hydraulic gradients outside the area of the production bores will act away from the TSF, and some further changes in hydrochemistry can be expected due to the migration of residual seepage emplaced during the operating period. The recent increase in TDS concentrations at MB R25, and the recent increases in CN concentrations at MB R07, MB R14 and MB R25 are attributed to this influence.

Based on the current review of monitoring data it is concluded that:

1. The groundwater monitoring regime required for compliance with licence L5946/1988/13 provides sufficient data to identify groundwater flow directions and the influences of TSF seepage on groundwater hydrochemistry and should be continued.
2. The interpretation monitoring undertaken by KCGM provides a detailed understanding of recharge processes and controls on groundwater hydrochemistry and should be continued.
3. No additions to the compliance or interpretation monitoring are required.
4. The existing pumping system is sufficient to manage groundwater depths as the groundwater mound below the Gidji I TSF continues to decay.
5. No changes to the existing monitoring regime are required to manage ongoing deposition in the Gidji II TSF.

It is recommended that during construction of the Gidji III TSF, three additional monitoring bores be installed to the northeast of the facility, for the combined purposes of 1) investigating whether a groundwater system is present in this area; 2) providing monitoring data to confirm that the lined cells in the Gidji III TSF perform as designed, and do not result in significant rates of seepage to groundwater; and 3) monitoring any potential influences of residual seepage from the Gidji I TSF if they are found to extend this far from the facility.

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Appendix B Long term hydrographs

Appendix C Time series groundwater hydrochemistry

1. Introduction

1.1 Background

Kalgoorlie Consolidated Gold Mines Pty Ltd (KCGM) manages the mining and ore processing operations at the Fimiston Gold Mine Operations, located adjacent to the City of Kalgoorlie-Boulder in the Eastern Goldfields Region of Western Australia. KCGM is the management company for the mining operations and is owned by Newmont Australia Pty Ltd and Barrick (Australia Pacific) Pty Limited. KCGM was formed in 1989 by the amalgamation of multiple individual mining leases hosting several small open pit and underground mining operations along Kalgoorlie's Mt Percy, Mt Charlotte and Golden Mile orebodies.

Gold ore from KCGM's mining operations is processed at the Fimiston Processing Plant which is located on the eastern side of the Fimiston Open Pit (Figure 1). Tailings from the Fimiston Processing Plant are currently deposited in the Fimiston I, Fimiston II and Kaltails Tailings Storage Facilities (TSFs) as marked in Figure 1. High sulphide concentrate is processed at the Gidji Processing Plant, located around 20 km north of Kalgoorlie Boulder (Figure 1). When commissioned in 1989, the process in the Gidji Processing Plant included a roasting component, before extracting the gold and depositing the tailings in the Gidji I TSF (see Figure 2 for detail of the Gidji TSFs). Subsequently, as a result of the KCGM Emissions Reduction Project, roasting was discontinued and replaced with an ultrafine grinding circuit, with the resulting tailings placed in the Gidji II TSF. The proposed Gidji III TSF indicated in Figure 2 is currently being designed and permitted and will receive tailings from the ultrafine grinding circuit.

Monitoring and recovery of seepage from the formations below the Gidji TSFs have been undertaken since 1995. The performance of the seepage recovery system is regularly summarised and reported by KCGM, and an independent review of the monitoring and management of seepage was most recently undertaken in 2015 (PCA, 2015). KCGM has requested that Big Dog Hydrogeology Pty Ltd (BDH) review the current performance of seepage recovery and monitoring at the Gidji TSFs and provide updated recommendations for ongoing management of the tailings storage facilities during both operations and closure. The results of the hydrogeological review and resulting recommendations for ongoing groundwater management are provided in this report.

1.2 Licensing

The operation of the Gidji Processing Plant and associated TSFs is governed by Prescribed Premises Licence L5946/1988/13 which was most recently issued by the Department of Water and Environmental Regulation (DWER) in October 2016, and is reproduced in Appendix A. Conditions for the management and monitoring of seepage from the Gidji TSFs included in the licence are summarised as:

1. Samples must be collected annually from the Gidji Trench and the Gidji Return Dam (decant pond) and analysed for pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), and cyanide (CN) in the forms of total, free, and Weak Acid Dissociable (WAD).
2. Depth to groundwater must be measured in compliance monitoring bores and operational area monitoring bores quarterly.
3. Depth to groundwater must be maintained greater than 4 m at compliance monitoring bores.
4. Operational area and compliance monitoring bores must be monitored six monthly for pH and EC, and annually for TDS, total CN, free CN and WAD CN.
5. Summaries of groundwater monitoring results must be provided to DWER quarterly.
6. Monitoring results must be summarised in the Annual Environmental Report (AER) submitted to DWER.

The objective of applying a compliance limit of 4 m for groundwater depth at compliance monitoring bores in licence L5946/1988/13 is to ensure that hypersaline groundwater does not rise into the potential root zone for vegetation downgradient of the TSFs.

1.3 Objectives of review

Specific objectives for the hydrogeological review of the Gidji TSFs over the remaining Life Of Mine (LOM) by BDH were agreed with KCGM to be:

1. Confirm whether groundwater elevation and groundwater chemistry monitoring data continue to support the interpretation of hydrogeological conditions compiled in 2015 (PCA, 2015).
2. Investigate whether the installed seepage pumping system remains appropriate for the management of seepage from the TSFs.
3. Identify whether the current groundwater monitoring regime remains appropriate for the definition and management of groundwater conditions around the TSFs.
4. Determine whether any changes to the monitoring regime are required for the management of the proposed Gidji III TSF.
5. Determine whether the current understanding and modelling of groundwater conditions in closure remains valid.

1.4 Relevant preceding study

The study most relevant to the understanding of the hydrogeological regime at the Gidji TSFs comprises a review undertaken in 2015 (PCA, 2015). Components of this review and key conclusions were:

1. Geological, hydrogeological, hydrochemical and operational data for the TSFs were compiled and reviewed.
2. The KCGM approach to managing seepage from the TSFs (operation of production bores) was concluded to be effective and to have sufficient capacity to continue to be effective in managing groundwater depths to ensure they remained below the compliance limit set in licence L5946/1988/13.
3. The groundwater monitoring regime was concluded to be providing appropriate data for the management of the TSFs and no changes were recommended.
4. A numerical model of groundwater responses to TSF seepage was constructed and calibrated. The model predicted a rapid decay in total pumping rates within two years of terminating deposition at Gidji I, and a continuing gradual decline in the groundwater mound to the north, east and south of the Gidji I TSF, with minor reduction in groundwater levels to the west.

The description of the Gidji TSF hydrogeology provided in the 2015 review has been used as the basis for the current study, and the available groundwater monitoring data have been reviewed to confirm that the conceptual and numerical models developed and described in the 2015 study remain valid.

2. Gidji operations and hydrogeological setting

2.1 Gidji TSF operational history

The Gidji I TSF comprises two unlined tailings storage cells (Figure 2) and was commissioned in 1989 to store tailings generated from the processing of concentrate in the Gidji Processing Plant. Tailings have been discharged to the TSF as a slurry containing around 50% by weight of finely ground rock particles. The liquid portion of the slurry comprises hypersaline water derived from remote water supply borefields and includes residual chemicals from ore processing, including lime and cyanide. Excess water within the tailings cells (decant water) has been removed from the TSF via the Gidji Return Dam and returned to the mine water management circuit.

Two new tailings storage cells, referred to as the Gidji II TSF, were constructed to the northwest of the Gidji I TSF in 2011 and 2013 (Figure 2). The Gidji II TSF was constructed with a composite HDPE and compacted clay liner below the cells, in order to minimise seepage from the saturated tailings cells into the underlying geological formations.

A further two cells are planned for construction to the northeast of the Gidji I TSF (referred to as the Gidji III TSF as indicated in Figure 2). The Gidji III TSF is planned to be constructed with a composite HDPE and compacted clay liner below the tailings storage cells, in order to minimise seepage from the saturated tailings cells into the underlying geological formations.

Since commissioning of the Gidji I TSF in 1989, tailings have been deposited to the two cells (referred to as Gidji I west and Gidji I east) on a rotational schedule, with each cell being used for several months at a time, before being left for the tailings to consolidate and dry out. Deposition into the Gidji I west cell stopped in May 2012, and deposition to the Gidji I east cell stopped in August 2013, with deposition to the Gidji II TSF commencing in 2012.

During 2015, tailings deposition was temporarily restarted in the Gidji I TSF, with deposition in that facility subsequently being permanently terminated by August 2015. Since August 2015, all tailings deposition has been to the lined Gidji II TSF.

2.2 Gidji TSF seepage recovery

Operation of the unlined cells in the Gidji I TSF has allowed some tailings water to seep into the shallow formations underlying the facility. Prior to 1999, seepage was recovered by the operation of a production bore (PB R01) and the Gidji Trench, both of which were commissioned in 1994. Subsequently the volume of seepage recovery was increased by the addition of five production bores in 1999, the addition of 13 production bores in 2000 and the addition of nine production bores in 2003. All of the production bores are equipped with low flow air displacement pumps which operate continuously to extract the maximum possible volume from each bore. A total of 28 production bores have been installed, located as marked in Figure 3, with four of those production bores subsequently decommissioned (PB R13, PB R14, PB R15 and PB R16) during the construction of the Gidji II TSF.

Groundwater depths and groundwater chemistry have been monitored in a total of 35 monitoring bores surrounding the Gidji TSFs, located as marked in Figure 3. Six of those monitoring bores (MB R04, MB R05, MB R11, MB R17, MB R18 and MB R31) have been subsequently decommissioned during the operating period.

Total annual seepage recovery volumes from 1995 to 2018 are plotted in Figure 4. These annual totals do not include flow from the Gidji Trench which is not metered. However seepage rates to the trench are low and have been estimated to be less than 0.1 L/s (PCA, 2015). Annual recovery volumes peaked at 156,000 m^3 in 2006, equivalent to an average pumping rate for the year of 4.9 L/s. Recovery volumes were relatively low (equivalent to around 0.5 L/s) from 1994 to 1999 when PB R01 and the seepage trench were being operated and increased significantly in 1999 with the addition of new production bores. Annual seepage production declined from 135,000 m^3 in 2012 (equivalent to 4.2 L/s) to 21,000 m^3 in 2018 (equivalent to 0.7 L/s), due to lowered groundwater levels reducing the available yield from each production bore.

Figure 4 includes the estimated annual tailings deposition to the Gidji I TSF where records are available, along with annual precipitation totals measured at the Kalgoorlie Boulder airport. There appears to be no correlation between annual precipitation and seepage pumping volumes, whereas seepage pumping volumes clearly reduced rapidly in 2014 and 2016, which were the periods following tailings deposition terminating in the Gidji I TSF.

2.3 Rainfall and evaporation

Climate data recorded at the Kalgoorlie Boulder Airport Station collected by the Australian Bureau of Meteorology (BoM) provide the primary source to characterise the local climate for the Gidji facilities. The station is located around 20 km south of the Gidji operations and daily climate records are available from 1939 up to the current date. Annual rainfall at Kalgoorlie over the period of recording has ranged from 109 mm in 1940 to 531 mm in 1992, with a long term average of 268 mm. Annual evaporation greatly exceeds precipitation and averages around 2,600 mm.

Table 1 provides annual precipitation totals recorded during the period of operation of the Gidji TSFs from 1989 to 2018 and compares the annual totals against the long term average. Annual precipitation was highest in 1992 (531 mm), and lowest in 1991 (164 mm). Since the Gidji I TSF was permanently decommissioned in 2015, annual precipitation has been close to average.

Table 1: Annual precipitation totals

Year	Annual Precipitation (mm)	Compared to Long Term Average
1989	180.6	67%
1990	299.6	112%
1991	163.8	61%
1992	530.8	198%
1993	326.2	122%
1994	245	91%
1995	480	179%
1996	235.2	88%
1997	245.4	92%
1998	313.4	117%
1999	384.8	144%
2000	446	167%
2001	226	84%
2002	188.2	70%
2003	318.6	119%
2004	279.6	104%
2005	170.2	64%
2006	190.2	71%
2007	196.6	73%
2008	266.6	100%
2009	254	95%
2010	165.4	62%
2011	389.4	145%
2012	240.6	90%
2013	367.8	137%
2014	359.2	134%
2015	233.6	87%
2016	313.2	117%
2017	256.8	96%
2018	233.6	87%

2.4 Topography and surface water hydrology

Ground surface at the Gidji facilities slopes downwards to the west, towards a chain of salt lakes as indicated in Figure 1, which includes Gidji Lake. The drainage divide lies around 2 km east of the Gidji facilities. There are no defined drainage channels near the Gidji facilities, and runoff occurs as overland sheet flow following relatively rare large precipitation events.

2.5 Hydrogeology

Regional geological conditions around the Gidji site are well understood from public domain mapping and resource investigation undertaken by KCGM. Bedrock underlying the Gidji facilities is broadly mapped as sedimentary, felsic volcanic and volcaniclastic rocks. The shallow geological conditions immediately underlying the Gidji facilities are well defined from geotechnical and hydrogeological investigation drilling undertaken during the construction and management of the facilities and comprise Cainozoic sedimentary deposits overlying weathered bedrock.

There are three major groundwater transmitting systems recognised in the Eastern Goldfields region of Western Australia, which are potentially relevant to the hydrogeology of the Gidji facilities, and these comprise:

1. Palaeochannel systems; a localised but extensive network of alluvial sands of Tertiary age occurring at up to 60 m depth (referred to as the Wollubar Sandstone). As mapped in Figure 1, the Kunanalling tributary of the Yindarlgooda North palaeochannel is known to be present around 1 km to the west of the Gidji facilities. The sand unit within this channel is exploited by KCGM as a process water supply, via the Northern Borefield which is located as illustrated in Figure 1. Monitoring of the Northern Borefield has confirmed that groundwater is supplied as leakage from the formations underlying and overlying the Wollubar Sandstone as well as from storage within the sands. The Wollubar Sandstone is overlain by a stiff, plastic clay referred to as the Perkolilli Shale, which has a very low hydraulic conductivity, and results in the sands being confined prior to borefield operation. A review of the performance of the Northern Borefield using data to the end of 2017 identified that the Kunanalling tributary remains confined, (the groundwater elevation as measured in the Wollubar Sandstone is above the top of the Wollubar Sandstone) despite the operation of the Northern Borefield at total rates between 20 and 110 L/s over the period 1985 to 2017 (BDH, 2018). The extent and properties of the paleochannel groundwater system are well understood from regional groundwater exploration programs and investigations undertaken by government agencies (e.g. Commander et al, 1992).
2. The ferricrete and alluvial sediment groundwater system; comprising sand, gravel and fractured ferricrete within clay deposits, typically occurring between 5 and 40 metres below ground level in well-developed surface drainages in the Eastern Goldfields and overlying the bedrock. A thin layer of this unit is present below the Gidji TSFs and this the unit targeted by the production bores for seepage recovery.
3. The bedrock groundwater system; where groundwater flow potentially occurs in fractured and weathered zones within the basement rocks at depth. This groundwater system occurs in discrete locations in the Eastern Goldfields, usually associated with structural dislocation which occurs at the orebodies and is not expected to be present below the Gidji TSFs.

Locally the sedimentary sequence below the Gidji TSFs comprises, from surface downwards:

- A surficial layer of alluvium and colluvium up to 2 m thick, comprising red-brown clayey silt and sand, potentially including calcrete developed in some locations.
- Dense, red-brown clay and sandy clay, with a thickness of 2 to 3 m.

- A layer of clay, sand and gravel, up to 5 m thick. This unit often contains very hard bands or nodules of indurated ferricrete. This geological unit equates to the ferricrete and alluvial groundwater system as described above. Groundwater transmission typically occurs with fractures and solution cavities formed within the indurated ferricrete. This unit has been reported to be best developed along the southwest of the Gidji I TSF and is also present along the northwest of the Gidji I TSF. It is reported to be thin or absent to the east of the Gidji I TSF.
- Laminated, multicoloured clays which may contain small amounts of clay or gravel.

The hydraulic conductivity of most of the sedimentary units below the Gidji TSFs is low, however the ferricrete and alluvial sediment groundwater system has sufficient hydraulic conductivity to allow the transmission of seepage and groundwater at low rates. This unit has been identified as the only significant groundwater transmitting and producing unit near the Gidji TSFs.

The locations of the Northern Borefield production bores and monitoring bores which are closest to the Gidji TSFs are illustrated in Figure 5. Figure 6 reproduces a hydrogeological cross section constructed along the location indicated in Figure 5. Figure 6 illustrates that the shallow ferricrete and alluvial groundwater system below the Gidji TSFs is a completely separate groundwater system to the deep Wollubar Sandstone in the Northern Borefield, being offset to the east, and being vertically separated by the Perkolilli Shale which has a low hydraulic conductivity.

Production and monitoring bores in the Northern Borefield are typically screened in the Wollubar Sandstone below 35 m Below Ground Level (mBGL) (production bore G1 in Figure 5 is screened from 43 to 49 mBGL, and production bore MP1 in Figure 5 is screened from 40.3 to 49.6 mBGL). Depth to groundwater in monitoring bore GL3 in Figure 5 is currently around 20 mBGL. In contrast, production bores to the west of the Gidji I TSF are screened typically to around 20 mBGL, and monitoring bores to the west of the Gidji I TSF currently have groundwater depths around 7 mBGL.

As there are no groundwater monitoring bores that were installed at the Gidji TSFs prior to tailings deposition, it is unclear whether shallow groundwater was present prior to the operation of the Gidji I TSF, or whether the current saturation of the ferricrete and alluvial sediments has been driven primarily by seepage.

3. Review of groundwater depths and elevations

3.1 Data collection, quality control and compliance limits

The measurement of groundwater depth has been undertaken generally on a monthly basis in all monitoring bores around the Gidji TSFs, which exceeds the minimum monitoring frequency of quarterly required in licence L5946/1988/13 and provides an extensive dataset defining groundwater depth trends. The collar elevation has been accurately surveyed for all monitoring bores allowing groundwater depths to be converted to groundwater elevations. Groundwater depth is not recorded in the production bores as it is strongly influenced by the cycling of the installed pumps.

Quality control of monitoring bore groundwater depths has been achieved by comparing reported depths against the casing depth, and by plotting data against time to identify anomalous points. In general, the groundwater depth data are indicated to be suitably reliable for interpretation. A few suspect measurements have been disregarded during interpretation, and these include:

- A number of measurements made in 2005 which are anomalously shallow.
- A number of measurements made in MB R06s, where the groundwater depth was equivalent to the base of the casing. This bore is screened to 8 mBGL and is affected by the operation of adjacent production bores causing it to sometimes go dry. In some periods, groundwater depth measurements reflect a small amount of water perched in the base of the casing, and do not reflect the groundwater level in the surrounding groundwater system.
- An anomalously shallow groundwater depth in MB R24 in 2013.
- An anomalously shallow groundwater depth in MB R10 in 2006.
- Groundwater depth measurements in MB R02 and MB R03 in October 2015, which appear to have been switched between the bores.

Licence L5946/1988/13 defines a compliance limit for groundwater depth below surface of 4 m. This limit applies only to 16 monitoring bores defined as compliance bores, which are currently MB R07, MB R08, MB R13 to MB R15, MB R19 to MB R28, and MB R34.

3.2 Groundwater depth trends

Appendix B provides long term groundwater depth hydrographs for all monitoring bores over the entire monitoring period (starting in 1999), while Figures 7 to 11 provide more detail of the recent trends (from 2008 to 2018). In each case:

1. The bores have been grouped into western monitoring bores, trench monitoring bores, decant monitoring bores, and eastern monitoring bores. This grouping is included in Figure 3 and is based on previous observations that the bores in each of these areas exhibit common responses (PCA, 2015). For example the eastern monitoring bores, which are located in areas where no ferricrete is present, demonstrate larger changes in groundwater depths (90^{th} percentile range of 4.7 m), compared to the western monitoring bores intersecting ferricrete (which have a 90^{th} percentile range of 1.8 m). The grouping of monitoring bores in each plot allows common trends across each area to be recognised and allows discrete localised variations in groundwater depth to be discounted.
2. Monitoring data are plotted as depth below surface. As the objective of the seepage management system is to ensure that the hypersaline groundwater does not approach the potential root zone of downgradient variation, this provides a direct indication of the success of the groundwater management program.

3. For plots which include monitoring bores currently defined in licence L5946/1988/13 as compliance bores, the compliance bores are plotted using symbols for each monitoring point, while the remaining bores (defined as operational area bores) are plotted as continuous lines.
4. For plots which include compliance monitoring bores, the licence compliance limit of 4 m is plotted for comparison with depths measured in these bores.
5. Total monthly average pumping rates are included in each plot, to investigate the relationship between groundwater depths and borefield operation.
6. Monthly precipitation totals measured at the Kalgoorlie Boulder airport are included to investigate any relationship between recharge events and groundwater depths.
7. Key milestones for changes in tailings deposition at the Gidji I TSF are annotated in the plots for reference and comparison.

Observations from the groundwater depth hydrographs in Appendix B and Figures 7 to 11 are:

- For all of the compliance monitoring bores, groundwater depth has been below the current licence compliance limit of 4 mBGL throughout the monitoring period from 1991 to present. In November 2018, the shallowest groundwater depth in any compliance bore was 6.53 m at MB R26.
- The trends discussed in the 2015 review (PCA, 2015) remain apparent, and include:
  - Shallow groundwater depths when monitoring commenced in 1999.
  - Increasing groundwater depths from 1999 to 2003 associated with total pumping being increased from 0.5 L/s to around 5 L/s.
  - Gradually increasing groundwater depths from 2003 to 2008, and slightly decreasing groundwater depths from 2008 to 2013, in response to the overall balance between tailings deposition, seepage and total pumping.
  - Short term cycling of groundwater depth related to deposition cycles in the Gidji I TSF cells or to the operation of nearby production bores.
  - No strong correlation between short term changes in groundwater depths and precipitation patterns prior to 2017.
  - Much larger changes in groundwater depths in the eastern monitoring bores compared to the western monitoring bores.
- Trends in groundwater depths and pumping rates since 2013 which are evident from the data to 2018 (Figures 7 to 11) are:
  - Monthly total pumping reduced by around 50% during the 12 months following stopping tailings deposition in the Gidji I TSF in 2013, remained stable for the 12 months following restarting deposition in 2014, and reduced by a further 50% in the 12 months following final decommissioning of the Gidji I TSF in 2015. These trends confirm a direct link between total pumping and deposition in the Gidji I TSF. In the period of tailings deposition in the Gidji II TSF from 2016 to 2018, total pumping has averaged 0.8 L/s, due to the increasing groundwater depths around the production bores.
  - For the trench monitoring bores and decant monitoring bores, strongly increasing groundwater depths are observed from 2013 to 2018, with the largest increases in groundwater depths being 6 m at MB R09 and 8 m at MB R10.
  - For the western monitoring bores, groundwater depths increased from 2013 to January 2017, decreased in early 2017, and then increased again to 2018.
  - For the eastern monitoring bores, groundwater depths increased to January 2017, and then decreased on average from 2017 to 2018.

- Nearly all of the monitoring bores appear to show changes in groundwater depths due to recharge associated with precipitation events in February 2017, February 2018 and October 2018. This response is unusual compared to the responses prior to 2017. However the responses are consistent with observations from other KCGM borefields, which confirm that the magnitude and spacing of individual precipitation events in the Kalgoorlie region in those periods was conducive to unusually high rates of recharge. In February 2017, this resulted from several close spaced daily precipitation totals of around 30 mm, which resulted in 158 mm of precipitation occurring over two weeks. In February 2018, this resulted from multiple small daily events which resulted in around 95 mm of precipitation occurring over a six week period. In October 2018, this resulted from multiple small daily events which resulted in 133 mm of precipitation occurring over a six week period.
- As a result of the combined influences of tailings deposition in the Gidji I TSF to 2013, terminating deposition in 2013 and 2015, and the three significant recharge events, in most of the monitoring bores it is noted that:
  - Groundwater depths were close to their lowest (ie groundwater elevations were close to highest) in August 2013.
  - Groundwater depths were close to their greatest (ie groundwater elevations were close to their lowest) in January 2017.
  - Groundwater depths had recovered slightly (ie groundwater elevations had risen slightly) in November 2018.

3.3 Groundwater depth in 2018

Figure 12 provides a colour shaded contour map of depth to groundwater from surface in November 2018, using data available from the monitoring bores. Interpolation of groundwater depth has been achieved by:

1. Converting the groundwater depth at each bore to a groundwater elevation.
2. Contouring a smoothly varying groundwater elevation surface between the bores (Figure 13).
3. Subtracting the groundwater elevation surface from the current topographic surface defined from survey data provided by KCGM.
4. Contouring the differences between the two surfaces.

This approach provides the most reliable interpretation of groundwater depth, as it takes account of any depressions or hills in the natural surface that occur between the monitoring bores. Figure 12 illustrates that groundwater is generally around 6 to 8 m below surface to the west and southwest of the Gidji TSFs, increasing to more than 15 m below surface to the east and north. The shallowest groundwater occurs within the operational area for the TSFs, in the eastern corner of the Gidji I TSF. Locally slightly shallower groundwater is indicated near MB R32 to the northwest of the Gidji II TSF, and near the production bores to the south of the Gidji I TSF. In each case these local variations result from natural depressions in the ground surface defined from the ground survey data. In all locations outside the operational footprint, groundwater remained safely below the compliance limit of 4 mBGL in November 2018.

3.4 Groundwater elevations

Groundwater depths measured in the monitoring bores in November 2018 have been converted to groundwater elevation using the surveyed bore collar and have been contoured in Figure 13. Groundwater elevations range from 342 mAHD close to the Gidji I TSF in the east, to 337 mAHD in the west, and to 330 mAHD in the south, east and north. Residual mounding associated with TSF seepage is clearly evident in the contours which illustrate a radial pattern around the Gidji I TSF. Relatively steep hydraulic gradients are indicated by the close spaced contours to the north, east and south of the Gidji TSFs, while low hydraulic gradients are contoured to the west, consistent with higher hydraulic conductivity conditions in the west. These trends are consistent with groundwater elevations contoured throughout the operating periods for the Gidji TSFs, and the low hydraulic gradients to the west correlate with the presence of higher hydraulic conductivity ferricrete within the ferricrete and alluvial sediment groundwater system.

Figures 14 and 15 provide groundwater elevation contours for August 2013 (highest groundwater elevations in recent years) and for January 2017 (lowest groundwater elevations in recent years). In each case the shape of the contours is very similar to those for November 2018, demonstrating the influence of groundwater mounding near the Gidji I TSF, and confirming that low hydraulic gradients consistently are observed to the west. However the actual groundwater elevations are generally higher in 2013 compared to 2018, and slightly lower in 2017 compared to 2018.

3.5 Recent changes in groundwater elevations

Groundwater elevations were at their highest in recent years in August 2013 and at their lowest in January 2017. The change in groundwater elevations between these dates has been interpolated by subtracting the contours in Figure 15 from those in Figure 14. The resulting change in groundwater elevations is presented in Figure 16. Blue and green shaded areas reflect a lowering of groundwater elevations, while yellow and red shading reflects a rise in groundwater elevations. In all locations where monitoring bores are available to control the interpretation, groundwater elevations reduced from 2013 to 2017. The magnitude of the change was around 0.5 to 1 m in the west, and around 2 to 5 m in the north, east and south. These significant changes in groundwater elevations, despite a reduction in total pumping, reflect the rapid response of the groundwater system to terminating tailings deposition in the Gidji I TSF.

Figure 17 provides colour shaded contours for the changes in groundwater elevations from 2013 to 2018. In the areas where monitoring bores are available to control the interpretation, groundwater elevations also reduced between 2013 and 2018. In the west, the magnitude of the reduction was comparable with that in 2017. In the north, east and south, the reduction in groundwater elevations was smaller compared to those in 2017.

Figure 18 investigates the changes in groundwater elevations between January 2017 and November 2018. In locations close to the Gidji TSFs, and near the production bores, groundwater elevations mostly reduced from 2017 to 2018 (green shading). More distant from the Gidji TSFs, groundwater elevations rose by around 0.2 m in the west, and by between 1 and 3 m in the north, east and south (yellow and orange shading). This distribution of responses, with large changes distant from the Gidji TSFs, and slight reductions near the Gidji TSFs, confirms that the changes from 2017 to 2018 are related to precipitation recharge, and not to the occurrence of TSF seepage.

3.6 Conclusions regarding groundwater depth management

Seepage from the unlined Gidji I TSF has been managed during the operating period by operating the Gidji Trench and up to 28 production bores to remove seepage and groundwater and to control groundwater depths around the TSF. Operation of the trench and bores at monthly average total rates up to 6 L/s has successfully managed groundwater depths outside the operational footprint of the facilities, and for the 16 monitoring bores currently defined as compliance locations, groundwater depth has been greater than the current compliance limit of 4 m from 1999 to 2018.

From 2014 to 2018 total annual average pumping has reduced from around 4 L/s to around 0.5 L/s. This response was expected and predicted (PCA, 2015), and is due to groundwater elevations approaching the base of the transmissive portion of the ferricrete and alluvial sediment groundwater system, which significantly reduces the flow rate available from each production bore. The lowering of groundwater elevations is a direct response to the termination of tailings deposition in the Gidji I TSF, with all deposition now occurring in the lined Gidji II TSF. Contouring of groundwater elevations confirms that groundwater mounding remains present around the Gidji I TSF, and this mound will continue to be removed by ongoing pumping at low rates.

Rising groundwater elevations around the Gidji TSFs in 2017 and 2018 are attributed to precipitation driven recharge from surface, and in particular to precipitation events occurring in February 2017, February 2018 and October 2018. This inferred source is confirmed by the distribution of the observed changes in groundwater elevations, which are larger distant from the TSFs and smaller close to the TSFs.

The existing pumping system has been demonstrated to be capable of managing groundwater depths during ongoing draindown of the Gidji I TSF and during any future precipitation driven recharge events, which would cause the total pumping rate from the bores to be increased.

4. Review of groundwater chemistry

4.1 Data collection and quality control

As described in Section 1.2, the minimum requirements for hydrochemical data collection are defined in licence L5946/1988/13 and include the collection of samples from the Gidji Trench, the Gidji Return Dam, the operational area bores and the compliance monitoring bores, with samples analysed for pH, EC, TDS, WAD CN, total CN and free CN.

In addition, KCGM have undertaken in the past and in some cases continue to undertake interpretation hydrochemical monitoring, including:

- Field measurement of pH and EC in production bores and monitoring bores.
- Periodically sampling production bores and analysing for a range of major ions and metals.
- Periodically sampling all monitoring bores for a variable range of parameters.
- Annual sampling of compliance monitoring bores for a comprehensive suite of major ions, CN species, and filterable metals concentrations. These annual samples have been collected since the 1990s and continue to be collected.

Detailed investigations into hydrochemical data quality have not been undertaken, however time series plots of all parameters have been reviewed, and anomalous points have been investigated. These investigations have identified that the hydrochemical data are of suitable quality for interpretation, although the following data anomalies should be considered during interpretation:

- Laboratory determined TDS concentrations in some periods appear to bias very high, in particular for production bore samples in April 2008, and also on some other sampling occasions in 2006 and 2008 at both production bores and monitoring bores. These samples did not have unusually high EC or chloride concentrations, and the elevated TDS concentrations reported by the laboratory are considered suspect. These observations are consistent with monitoring data from other KCGM facilities which have identified that laboratory TDS may occasionally significantly over-report concentrations for hypersaline groundwater.
- Laboratory EC values for a number of sampling locations vary by three orders of magnitude, and it is apparent that EC units have been incorrectly converted for some samples.

4.2 Time series hydrochemical trends

4.2.1 Background

As a screening approach to investigating all available hydrochemical data, Appendix C provides time series plots for all hydrochemical analytes available from the KCGM database. Details of the plots are:

- All production bores, operational area and compliance monitoring bores have been included in the plots.
- All production bores have been combined in the same plot to allow consistent trends to be correlated. Composite plots for monitoring bores have been compiled using the same bore grouping as was identified from groundwater depth trends (western, trench, decant and eastern bores).
- The date when tailings deposition was first stopped in the Gidji TSF is marked on each graph, as this was the event which caused the greatest changes in groundwater elevations and may potentially have an influence on groundwater chemistry.
- Total monthly average pumping rates are included in each plot to investigate any correlation with hydrochemistry.

- Monthly precipitation data are included on each plot to investigate whether the influence of inferred recharge events can be discerned in groundwater chemistry.
- Laboratory results below detection have been plotted as the detection limit. Due to the long history of monitoring, and the changes in detection limits which have occurs, this may introduce some artificial variation to some plots.
- Where necessary, concentrations have been plotted at log scale to provide more detail on the changes in low concentrations.

4.2.2 Gidji I TSF decant

The Gidji Return Dam receives decant water recovered from the tailings cells in the Gidji I and Gidj II TSFs. This dam therefore provides the best indication of the hydrochemistry of seepage from the unlined Gidji I TSF cells. Under licence L5946/1988/13 the Gidji Return Dam is required to be monitored annually for TDS, pH, EC, WAD CN, total CN and free CN. Average values for these analytes calculated from data collected prior to 2014 (in the period when deposition was occurring to the Gidji I TSF) are summarised in Table 2. A spot sample was collected from the Gidji II decant water in November 2015 and was analysed for a range of filterable metals (MBS, 2016). These results are also included in Table 2 for reference. The 2015 sample from the Gidji II TSF has similar hydrochemistry to the averages for the Return Water Dam and confirms recent decant water hydrochemistry is consistent with the remainder of the operating period

Decant water at the Gidji TSFs which potentially contributes to seepage from the unlined cells in the Gidji I TSF is characterised as having:

- High TDS concentrations, greater than 100,000 mg/L, and dominated by Na and Cl, with a significant contribution from sulphate.
- An alkaline pH averaging 9.
- Elevated EC due to the high TDS concentrations, averaging 105,000 uS/cm.
- High cyanide concentrations, averaging for 1,140 mg/L total CN, 704 mg/L for WAD CN, and 272 mg/L for free CN.
- Elevated concentrations of Co, Cu, and Fe.

Table 2: Gidji Return Dam hydrochemistry

Sample type	Unit	Average	Spot Sample
Location		Gidji Return Dam	Gidji II TSF Decant
Date		1995 to 2013	Nov-15
pH		9	8.4
EC	uS/cm	106000	114000
TDS	mg/L	107000	NA
Ca	mg/L	1325	1095
Mg	mg/L	459	1515
Na	mg/L	32557	32280
K	mg/L	848	486
Cl	mg/L	48813	37400
Sulphate	mg/L	10273	18851
Bicarbonate	mg/L	940	1210
Nitrate	mg/L	30	NA
Total CN	mg/L	1140	1082
WAD CN	mg/L	704	555
Free CN	mg/L	272	78
Filterable Al	mg/L	0.56	<1
Filterable As	mg/L	0.90	0.08
Filterable Cd	mg/L	0.05	<0.002
Filterable Co	mg/L	171	129.28
Filterable Cu	mg/L	426	523.8
Filterable Fe	mg/L	16	184.1
Filterable Hg	mg/L	0.10	<0.01
Filterable Mn	mg/L	0.11	<0.1
Filterable Ni	mg/L	10	18.1
Filterable Pb	mg/L	0.03	<0.05
Filterable Sb	mg/L	0.32	0.07
Filterable Se	mg/L	0.36	0.26
Filterable Zn	mg/L	0.28	<0.1

Note: NA Not analysed

4.2.3 pH

Laboratory and field measurements of pH in production bores and monitoring bores are plotted in Figures C1 to C10 in Appendix C. Comparing the equivalent plots for these parameters indicates that trends are consistent between field pH and laboratory pH, and on average laboratory pH is 0.2 to 0.5 units higher than field pH, which is consistent with changes in the level of dissolved CO_2 in the samples during transport and handling.

pH is variable with both location and time, over a large range of 3 to 8. There appears to be a trend of higher pH close to the Gidji I TSF (pH 4 to 6 at MB R06d, MB R04, MB R01), and lower pH distant from the TSF (pH 3 to 4 in most other monitoring bores), which would be consistent with the influence of high pH seepage from the TSF, however an exception is noted at MB R23 which is distant from the TSF and mostly has a neutral (high) pH.

Low groundwater pH in the range 3 to 4 is not unusual in the ferricrete and alluvial sediment groundwater system and is consistently observed at the Fimiston I and II TSFs, at the Kaltails TSF and in the Morrisons Flats area near the KCGM facilities. The low pH has been interpreted to be a natural background effect, and to result from long term ferrolysis reactions between the groundwater and the host geology.

4.2.4 TDS and EC

Figures C11 to C25 provide all the available data on field measured EC, laboratory measured EC, and laboratory determined TDS by evaporation concentrations. TDS concentrations appear to potentially be diagnostic of seepage influences and the TDS data are therefore reproduced as Figures 19 to 23 for reference. The errors in converting laboratory EC units described in Section 4.1 are evident in Figures C16 to C20, and the inferred errors in determining TDS concentrations are evident from the spikes in 2006 and 2008 in Figures 19 to 23, with these spikes not being replicated in the EC plots. Since around 2007, field EC and laboratory EC have been consistent, while prior to 2007 a larger scatter is evident between the field and laboratory datasets.

TDS concentrations at production bores have been in the range 80,000 to 140,000 mg/L, and have varied significantly during the monitoring period, potentially reflecting changes in decant water quality within the Gidji I TSF (TDS concentrations at the Gidji Return Dam have varied from 50,000 mg/L to 190,000 mg/L from 1995 to 2018). The decant and trench bores illustrate a clear trend of increasing TDS concentrations from 1995 to 2008 (Figures 21 and 22) with concentrations rising from 50,000 mg/L to around 130,000, and subsequently stabilising or declining slightly. These responses are consistent with the influence of seepage of high TDS decant water from the Gidji I TSF. TDS would be expected to be the analyte which is most diagnostic of TSF seepage influences, as TDS is significantly elevated in decant water, and is expected to be conserved during flow through the groundwater system, whereas metals and CN concentrations are expected to be affected by pH, and by hydrochemical and geochemical influences along the travel paths.

Some western monitoring bores display rising trends in TDS from 1995 to 2003, similar to the decant and trench bores, but most more distant monitoring bores have relatively consistent TDS concentrations, which range from around 50,000 mg/L in bores distant from the TSF (such as MB R28 located distant from the Gidji I TSF to the west plotted in Figure 20) to around 100,000 mg/L in bores near the TSF, such as MB R07, MB R12 and MB R14 plotted in Figure 20. No decline in TDS concentrations associated with either terminating deposition in the Gidji I TSF or the inferred recharge events in 2017 and 2018 can be discerned from the annual monitoring data.

4.2.5 Major ions

Figures C26 to C70 in Appendix C present all of the available data for concentrations of Ca, Mg, Na, K, Cl, nitrate, Si, bicarbonate and sulphate. For most analytes, there are insufficient data to define long term trends, however major ion concentrations appear relatively stable in most locations. Bicarbonate is an exception, varying over wide ranges and directly linked to changes in groundwater pH. Sulphate may have increased at production bores between 2001 and 2010, which would be consistent with the influence of the elevated sulphate in decant water, however this trend is only defined by one set of samples. There may be a trend of increasing Ca and Cl concentrations in some western and eastern monitoring bores since deposition in the Gidji I TSF terminated, but these changes are identified in only a few bores and are within the historical range of observed concentrations.

4.2.6 Cyanide

A large dataset is available for concentrations of WAD CN, free CN and total CN in production bores and monitoring bores, and all available data are plotted in Figures C71 to C85 in Appendix C. CN concentrations are highly variable with location and time, and the concentrations have therefore been plotted at a logarithmic scale in the figures. WAD CN concentrations appear to be potentially diagnostic of seepage influences and the WAD CN data are therefore reproduced in Figures 24 to 28 for reference. The trends in WAD CN and free CN are very similar in the plots, with the actual concentrations for WAD CN being slightly higher than free CN, when viewed at log scale. Total CN follows broadly the same trends as are identified in free CN and WAD CN but with some differences in trends, and with total CN being higher than WAD CN, as expected.

CN concentrations in production bores illustrate large changes associated with both short term and long term trends which may relate to varying contributions of seepage to the pumped flows. The trench and decant monitoring bores display similar CN trends to those identified for TDS. Relatively low concentrations were evident in 1995, and CN concentrations increased by a factor of 10 to 100 from 1995 to 2008 consistent with seepage influences, and then stabilised (Figures 26 and 27). Unlike TDS concentrations, the trench and decant bores demonstrate a consistent decline in CN concentrations following decommissioning of the Gidji I TSF, consistent with a declining influence from seepage.

CN concentrations have been mostly close to or below detection in the eastern monitoring bores since 2001, although occasional isolated spikes in total CN concentration occur. The western monitoring bores generally demonstrate significant but variable CN concentrations. At monitoring bores MB R07, MB R14 and MB R25 the log scale plots for the western monitoring bores in Figures 25, C77 and C82 indicate increasing CN concentrations from around 2015. These bores are all located in a similar area to the west of the Gidji I TSF. CN trends at these bores have been examined in more detail in Figure 29 and TDS trends are examined in more detail in Figure 30. In combination the time series plots identify that:

- While total CN has been variable in all three monitoring bores, a consistent increasing trend in concentrations is evident from 2015 at MB R07, from 2013 at MB R14 and from 2016 at MB R25.
- WAD CN and free CN concentrations have exhibited a broadly similar relationship to total CN over the monitoring period, and the recent trends appear to be related to an increase in the total CN, rather than to a change in the proportion of total CN which is present in WAD and free forms.
- At MB R25, distant from the Gidji I TSF, TDS concentrations have increased from 90,000 mg/L in 2014 to 115,000 mg/L in 2018, and the corresponding but delayed changes in total CN concentrations (from 0 mg/L in 2016 to 15 mg/L in 2017) would be consistent with the expansion of the seepage zone from the Gidji I TSF, driven by seepage which occurred prior to decommissioning the facility. pH has remained consistent at around 3.2 through this period at MB R25.
- At MB R07 and MB R14, TDS concentrations have been relatively consistent since 2015, while total CN concentrations have increased since 2015. At each of these bores, the rising trend in total CN concentrations coincides with and correlates with an increase in groundwater pH of around 0.5 units.
- The TDS and CN concentrations at MB R07, MB R14 and MB R25 remain within the range observed over the entire monitoring period in bores near the Gidji I TSF. The recent increases in CN concentrations at MB R25 potentially reflect a small expansion in the zone of seepage influence around the Gidji I TSF, driven by hydraulic gradients associated with the residual mounding around the TSF. The recent increases in CN concentrations at MB R07 and MB R14 potentially reflect rises in groundwater pH, as the stability and solubility of CN is strongly controlled by pH. The rises in groundwater pH may reflect a small increase in the influence of high pH seepage.

- Overall, the changes in TDS and CN concentrations at MB R07, MB R14 and MB R25 are consistent with small changes in the extent and pH of seepage to the west of the Gidji I TSF. That seepage is inferred to have been emplaced during the operating period and based on the locations of the bores and the timing of the trends, the hydrochemical trends are not consistent with any recent change in the seepage behaviour of the TSFs.

4.2.7 Filterable metals

Filterable concentrations of metals measured at production and monitoring bores around the Gidji I TSF are plotted in Figures C86 to C150 in Appendix A. In all cases the concentrations have been plotted at logarithmic scale to provide additional detail of the trends at low concentrations. Observations of metals distributions from the time series plots are:

- Filterable concentrations of Sb and Pb are generally low and close to the detection limit.
- Filterable Ni and Hg follow similar trends, being present at the production bores, western, trench and decant monitoring bores, but being absent in the eastern monitoring bores. Concentrations are generally low, and for Ni much lower than sampled in the decant water. No consistent trends with time or location are evident in the available data and the metals can not be correlated with seepage influences.
- A correlation is identified between filterable concentrations of Al and Zn and groundwater pH. MB R23 and MB R06d which mostly have a neutral pH have low concentrations of Al and Zn, while the monitoring bores with a pH around 3 have concentrations of filterable Al up to 200 mg/L and filterable Zn up to 1 mg/L. These concentrations are much higher than observed in decant water and reflect the interactions between low pH groundwater and the geology hosting the groundwater system.
- Filterable Cu concentrations demonstrate a correlation with CN concentrations which is consistent with Cu being present complexed with CN. Cu concentrations are highest at PB R01, MB R06d and MB R01, all of which have very high CN concentrations. The distribution of Cu in groundwater can be linked to seepage influences. However the recent Cu concentrations (mostly less than 1 mg/L) are significantly lower than in decant water and suggest significant attenuation occurs in flow through the groundwater system.
- Concentrations of filterable Co have been up to 100 mg/L in production bores and in monitoring bores close to the TSF, consistent with the influence of TSF seepage as the decant water also has high Co concentrations. Co would be expected to be complexed with CN, however the correlation between Co and CN is not as strong as observed for Cu.
- Disregarding a few points which potentially have been entered to the KCGM database with the wrong units, the time series plots for filterable As, Cd, Cr and Se indicate these metals are present at low but detectable concentrations, and the distribution of these metals in groundwater can not be correlated with seepage influences.
- Filterable Fe has been present in production bores and monitoring bores at up to 100 mg/L and filterable Mn has been present at up to 10 mg/L. No correlation is evident with distance from the TSF or CN concentrations, and these metals appear to be largely controlled by pH, redox conditions and interactions with the host geology, rather than seepage influences.

4.3 pH, TDS and CN distributions in 2018

Analytes which have been identified from the time series plots as having patterns consistent with seepage influences which are greatest close to the Gidji I TSF are pH, TDS and CN. Measurements for these parameters from both production bores and monitoring bores in October 2018 have been contoured in Figures 31 to 34. As some bores were not sampled in October 2018, in a few bores the value from the October 2017 sampling have been used in the contours.

With the exception of MB R23, which is distant from the Gidji I TSF and has a variable but mostly neutral pH, groundwater pH displays consistent regional trends in Figure 31, including 1) a background pH of around 3.1; and 2) a higher pH in the range 4 to 7 near the TSF driven by the influence of alkaline seepage (Gidji Return Dam water has an average pH of 9). The pH contours indicate a preferential seepage flowpath to the west of the Gidji I TSF through the locations of MB R07 and MB R14.

The groundwater TDS concentrations contoured in Figure 32 demonstrate patterns consistent with those identified for pH, but provide more detail on the seepage pathways, as TDS is not expected to be attenuated in flow through the groundwater system (compared to pH which is affected by buffering within the groundwater and CN which is affected by pH). The TDS concentrations are broadly consistent with background groundwater concentrations around 50,000 mg/L, and the influence of seepage from the Gidji I TSF occurring at greater than 100,000 mg/L. The inferred preferential pathway through the locations of MB R07 and MB R14 is clearly defined in the contours, and the residual influence of seepage is evident in TDS concentrations at MB R26, further to the west. The TDS concentrations also identify a preferential seepage flowpath to the northwest towards MB R29. The contoured TDS concentrations indicate a seepage influence on groundwater chemistry extending from the Gidji I TSF around 600 m to the west, around 400 m to the northwest, and around 300 m to the south, east and north.

The distributions of WAD CN and total CN in groundwater contoured in Figures 33 and 34 illustrate a similar seepage influence to pH and TDS, with preferential flowpaths to the west and northwest evident. The highest concentrations in groundwater are significantly lower than in decant water (total CN in groundwater up to 200 mg/L compared to an average of 1,140 mg/L in the Gidji Return Dam, WAD CN concentrations in groundwater up to 100 mg/L compared to an average of 700 mg/L in decant water), consistent with attenuation of CN in the low pH groundwater system. Total CN appears to provide a more reliable indication of seepage extent compared to WAD CN.

4.4 Conclusions regarding groundwater chemistry management

Although it is unknown whether groundwater was present in the ferricrete and alluvial sediments below the Gidji I TSF prior to TSF operation, the long term trends in TDS concentrations in Figures 19 to 23, and the contoured hydrochemical data in Figures 31 to 34 are consistent with background groundwater being present, having a naturally low pH of around 3 in most locations, having TDS concentrations around 50,000 mg/L and having negligible CN concentrations. These inferred conditions are consistent with observations of the natural background hydrochemistry of the ferricrete and alluvial sediment groundwater system in other locations near KCGM facilities.

Operation of the unlined cells in the Gidji I TSF since 1989 has resulted in seepage of decant water entering the groundwater system, with seepage influences reducing after the cells were permanently decommissioned in 2015. As indicated by samples from the Gidji Return Dam, seepage is expected to have a high pH, TDS above 100,000 mg/L, and elevated concentrations of CN, Co, Cu and Fe.

TDS concentrations in groundwater are most diagnostic of seepage influences as they are not expected to be affected by attenuation during flow through the groundwater system. The influence of seepage can also be discerned in groundwater pH, groundwater EC, in concentrations of total CN, WAD CN, free CN, and in filterable concentrations of Cu and Co. The groundwater hydrochemistry identifies preferential seepage flowpaths to the west and northwest, consistent with the presence of ferricrete in these areas which increases the hydraulic conductivity of the groundwater system. The production bores installed to recover seepage are predominantly located to the west and northwest of the Gidji I TSF and are therefore suitably designed to intercept these flowpaths.

As the groundwater mound beneath the Gidji I TSF continues to decline, groundwater hydraulic gradients outside the area of the production bores will act away from the TSF, and some further changes in hydrochemistry can be expected due to the migration of residual seepage emplaced during the operating period. The recent increase in TDS concentrations at MB R25, and the recent increases in CN concentrations at MB R07, MB R14 and MB R25 are attributed to this influence.

5. Conclusions and recommendations for ongoing seepage management

5.1 Suitability of current monitoring regime

Groundwater monitoring at the Gidji TSFs which is undertaken to comply with the conditions of licence L5946/1988/13 comprises:

1. Annual samples from the Gidji Trench and the Gidji Return Dam (decant pond) analysed for pH, EC, TDS, free CN, WAD CN and total CN.
2. Operational area and compliance monitoring bores monitored six monthly for pH and EC, and annually for TDS, total CN, free CN and WAD CN.
3. Depth to groundwater measured in compliance monitoring bores and operational area monitoring bores quarterly.

Additional groundwater monitoring which is undertaken by KCGM for interpretation purposes comprises:

1. Monthly records of total seepage and groundwater abstraction from production bores.
2. Monthly measurement of depth to groundwater in operational area and compliance monitoring bores.
3. Annual sampling of all production bores and compliance monitoring bores for a comprehensive suite including major ions and filterable metals.

The reviews of groundwater depth and groundwater hydrochemical data in Sections 3 and 4 have identified that:

- Since 2017 the groundwater system has been subject to recharge in response to precipitation events occurring over periods of a week to a month.
- TDS concentrations are the most diagnostic hydrochemical parameter for seepage influences, and EC provides a useful means of confirming the reliability of TDS concentrations.
- Groundwater pH is a control on metals concentrations and is inferred to have a role in the attenuation of CN.
- Total CN concentrations are useful in identifying the attenuated extent of seepage influences.
- Free CN and WAD CN concentrations are of some use in interpreting seepage influences.
- Comprehensive suite hydrochemical analyses have some value in understanding the controls on metals concentrations in groundwater.

It is therefore concluded that:

1. The groundwater monitoring regime required for compliance with licence L5946/1988/13 provides sufficient data to identify groundwater flow directions and the influences of TSF seepage on groundwater hydrochemistry and should be continued.
2. The interpretation monitoring undertaken by KCGM provides a more detailed understanding of recharge processes and controls on groundwater hydrochemistry and should be continued.
3. No additions to the compliance or interpretation monitoring are required.

5.2 Effectiveness of current seepage recovery around the Gidji I TSF

Operation of the Gidji Trench and the production bores has been demonstrated to successfully manage groundwater depths to ensure they have remained below the current compliance limit throughput the operating period for the Gidji I TSF. Currently the system operates at low total pumping rates, due to groundwater levels approaching the base of the ferricrete and alluvial groundwater system, which reduces the flow rate available from each production bore. However, the pumping systems in the bores are configured so that if groundwater levels rise in response to seepage or natural recharge, flow rates from the existing bores will increase. The existing system is therefore concluded to be sufficient to manage groundwater depths as the groundwater mound below the Gidji I TSF continues to decay.

5.3 Management of the Gidji II TSF

The lined cells in the Gidji II TSF have been utilised for tailings deposition since 2012. The reviews of groundwater depth and groundwater hydrochemistry data in Sections 3 and 4 have not identified any seepage influences from the Gidji II TSF. Based on the known geology, the interpreted hydrogeology, and the measured groundwater elevations and groundwater flow directions, the existing monitoring bores are suitably located to identify any seepage influences from the Gidji II TSF if they should occur in future. No changes to the existing monitoring regime are required to manage ongoing deposition in the Gidji II TSF.

5.4 Management of the planned Gidji III TSF

Figure 35 illustrates the planned footprint of the Gidji III TSF, which is planned to be constructed with double lined cells, comprising a compacted clay layer overlain by an HDPE membrane. The performance of the Gidji III TSF for seepage management would therefore be expected to be similar to that of the Gidji II TSF. Monitoring bores which are anticipated to be decommissioned during construction of the Gidji III TSF are highlighted in Figure 35, and comprise MB R03, MB R10, MB R21 and MB R34. This would result in the removal of all of the monitoring bores to the northeast of the Gidji I TSF which are currently being used to monitor the influence of residual seepage emplaced during the operating period.

Figure 6 illustrates that the ferricrete and alluvial sediment groundwater system is expected to pinch out to the northeast of the Gidji I TSF, and it is likely that low hydraulic conductivity conditions occur in the area of the Gidji III TSF. In order to confirm this interpretation, it is recommended that during construction of the Gidji III TSF, three additional monitoring bores be installed to the northeast of the facility, for the combined purposes of 1) investigating whether a groundwater system is present in this area; 2) providing monitoring data to confirm that the lined cells in the Gidji III TSF perform as designed, and do not result in significant rates of seepage to groundwater; and 3) monitoring any potential influences of residual seepage from the Gidji I TSF if they are found to extend this far from the facility.

Proposed locations for the monitoring bores are indicated in Figure 35, and these locations would require adjustment based on actual field conditions and the final designs for the Gidji III TSF and associated infrastructure, including access roads and powerlines. As groundwater is expected to be relatively deep in these locations, the bores would need to be drilled to a minimum of 30 m depth and may potentially extend into weathered bedrock and unweathered bedrock. Completion details would need to be determined from an assessment of any hydrogeological units encountered during drilling. Currently it is anticipated that the most suitable bore completion in each location would be single bore, fully screened from around 5 m depth to the base of the casing. This would ensure that the bore monitors any deep groundwater which is currently present and is suitably designed to identify any saturation of the shallow units which would potentially occur in the unlikely event of seepage from the lined Gidji III TSF.

5.5 Management for closure

Potential future groundwater responses during closure of the Gidji TSFs have been investigated by numerical modelling (PCA, 2015). Conclusions and predictions from the numerical model were that:

- A seepage rate of 500 kL/day (5.8 L/s) from the Gidji I TSF during the operating period was applied in the model to provide a match with the observed mounding below the TSF.
- 120,000 m^3 of pore water was predicted to be released from the Gidji I TSF in the draindown period following closure.
- Total pumping was expected to decline from around 4.5 L/s prior to closure to around 1.2 L/s within two years.
- Within three years of closure, groundwater levels were predicted to decline by up to 5 m close to the eastern boundary of the Gidji I TSF, with smaller changes to the east, north and south, and much smaller changes to the west.

The observed responses of the groundwater system since decommissioning the Gidji I TSF have been generally consistent with the predictions of the model, and it is noted that:

- Total pumping has declined in a similar manner to that predicted, with average annual pumping reducing from 4.2 L/s in 2012 to 0.7 L/s in 2018.
- Changes in groundwater elevation following closure are best illustrated in Figure 16, which contours the changes prior to the recharge events in 2017 and 2018. The reduction in groundwater elevations was around 5 m to the east of the Gidji I TSF, and around 1 m to the west of the Gidji I TSF.

The primary difference between the modelled groundwater responses and the observed groundwater responses is the occurrence of the inferred recharge events in 2017 and 2018. The numerical model did not simulate natural recharge to the groundwater system, as the monitoring data available at that time indicated that seepage from the Gidji I TSF was a much larger input to the groundwater system than natural recharge.

Overall, the model predictions of groundwater responses following closure of the Gidji I TSF remain valid for use in closure planning at the Gidji facilities. However it should be considered when using the model predictions, that if further natural recharge events occur, the decay of the groundwater mound may occur over a longer period than predicted by the model.

References

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MBS 2016, *Geochemical Tailings Characterisation*, *Memorandum from David Allen of MBS to Janine Cameron of KCGM dated 24 March 2016*, MBS Environmental Pty Ltd.

PCA 2015, *Gidji Tailings Storage Facility, Review of Hydrogeological Data and Groundwater Management.*, Peter Clifton & Associates.

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34. Total CN distribution in 2018
35. Recommended monitoring for Gidji III TSF

Figures

Legend

Groundwater production bores

- Northern Borefield
- Southern Borefield
- Kaltails Supply Borefield
- Eastern Borefield
- Kaltails TSF Borefield
- Trafalgar Borefield
- Palaeochannel

Mine facilities

- Pit
- Tailings storage facility
- Mt Charlotte underground mining operation
- Trans Australian Railway
- Roads
- Airport facility
- Drainage
- Salt lakes

0 5 10 km

N

Map projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 51

This map contains data which are (C) Copyright Commonwealth of Australia (Geoscience Australia) 2006 and data which are reproduced by permission of the Western Australian Land Information Authority, CL39/2009.

340000 350000 360000 370000

6630000 6620000 6610000 6600000 6590000 6580000

Northern Borefield
Yindarlgooda North Palaeochannel
Gidji Processing Plant and TSFs
Kanowna Belle mine
Mt Percy mine
Central Drainage
Eastern Borefield
Fimiston I TSF
Fimiston II TSF
Kalgoorlie - Boulder
Mt Charlotte underground mining operation
Fimiston Pit (Golden Mile)
Trafalgar Borefield
Kaltails TSF Borefield
Kaltails TSF
Yindarlgooda South Palaeochannel
Kaltails Supply Borefield
Southern Borefield

KANOWNA-MULGARRIE RD
KING OF THE WEST LAKE
CARMELIA RD
KURNALPI-PINJIN RD
LAKE GWYNNE
LAKE PERKOLILLI
GIDJI RD
YARRI RD
GOLDFIELDS HWY
BULONG RD
ANZAC DR
GREAT EASTERN HWY
BALLAST RD
Trans Australian Railway
MOUNT MONGER RD
HANNAN'S LAKE
HOME RULE SWAMP
RED LAKE

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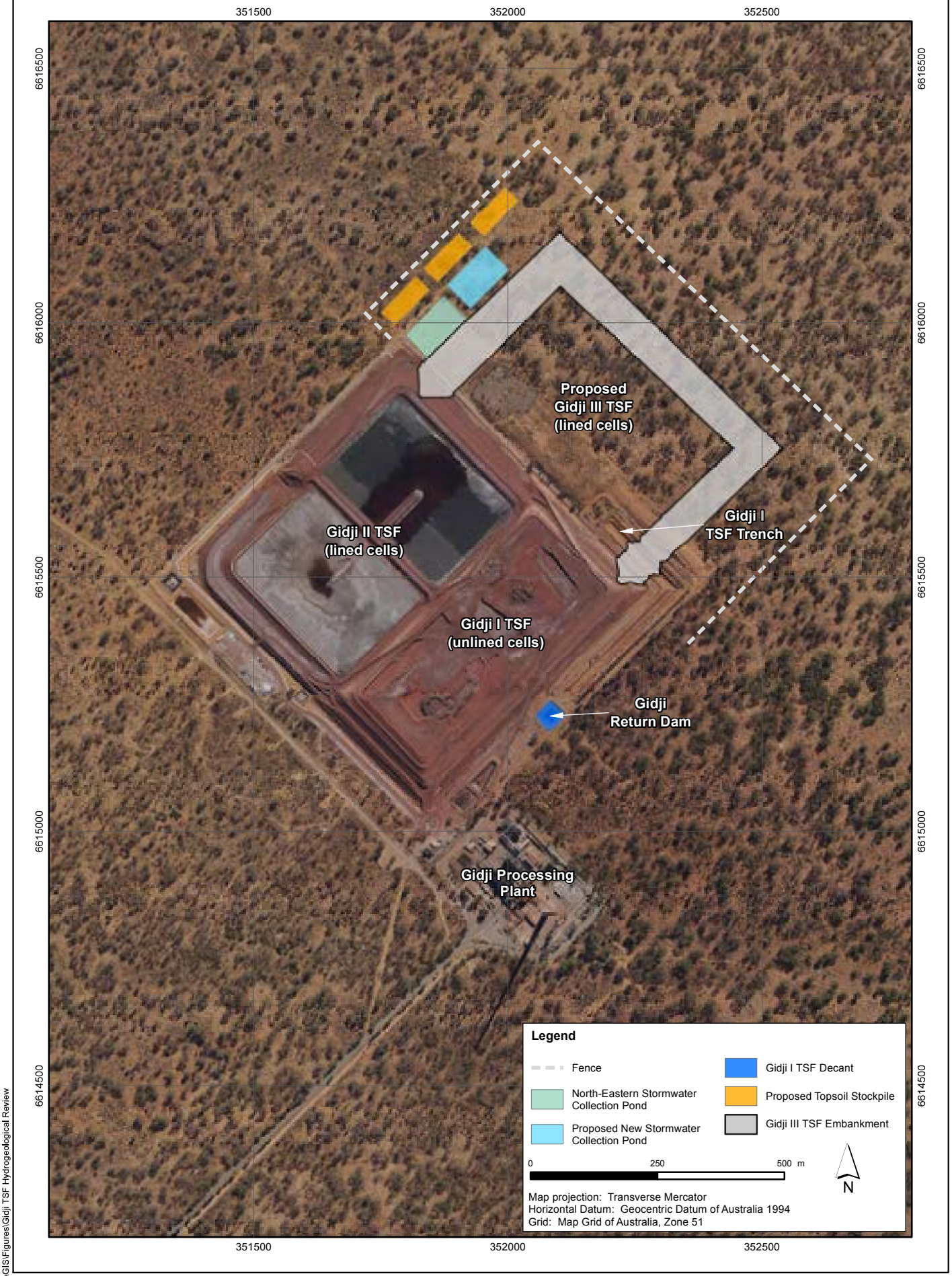
BIG DOG HYDROGEOLOGY

Regional setting

Figure 1

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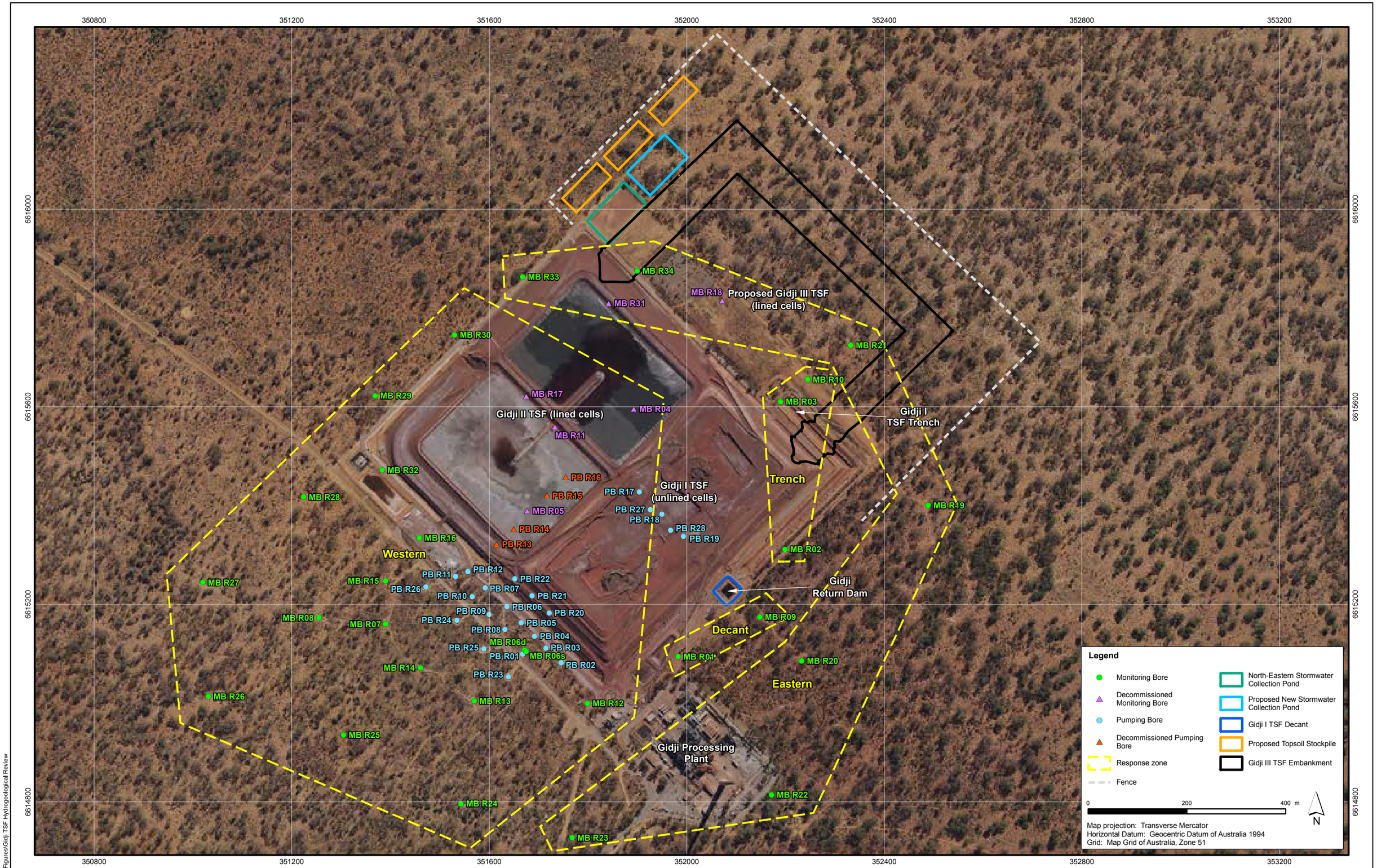
BIG DOG HYDROGEOLOGY

Gidji facilities

Figure 2

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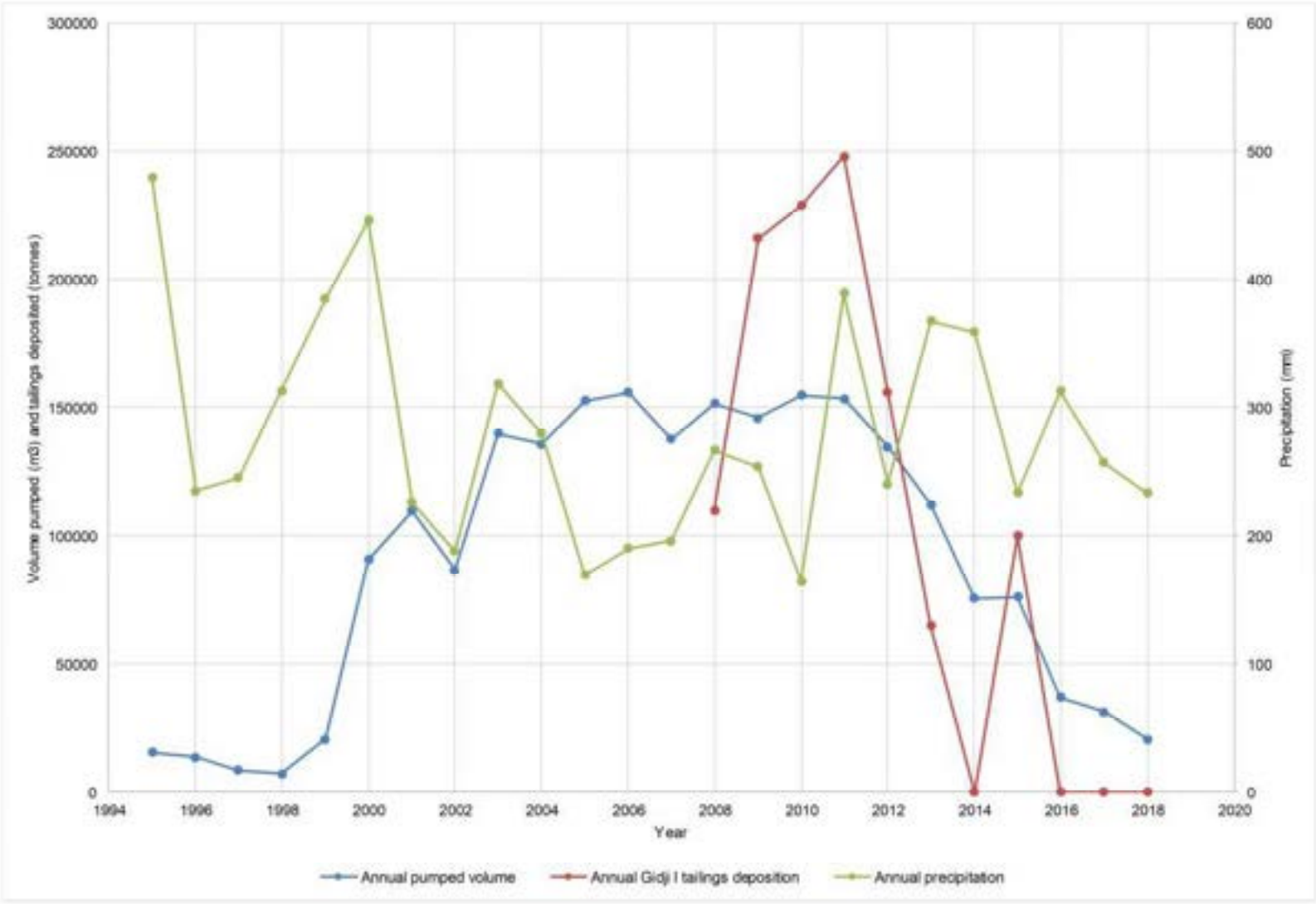
BIG DOG HYDROGEOLOGY

Monitoring and pumping locations

Figure 3

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Report: Gidji TSF Hydrogeological Review



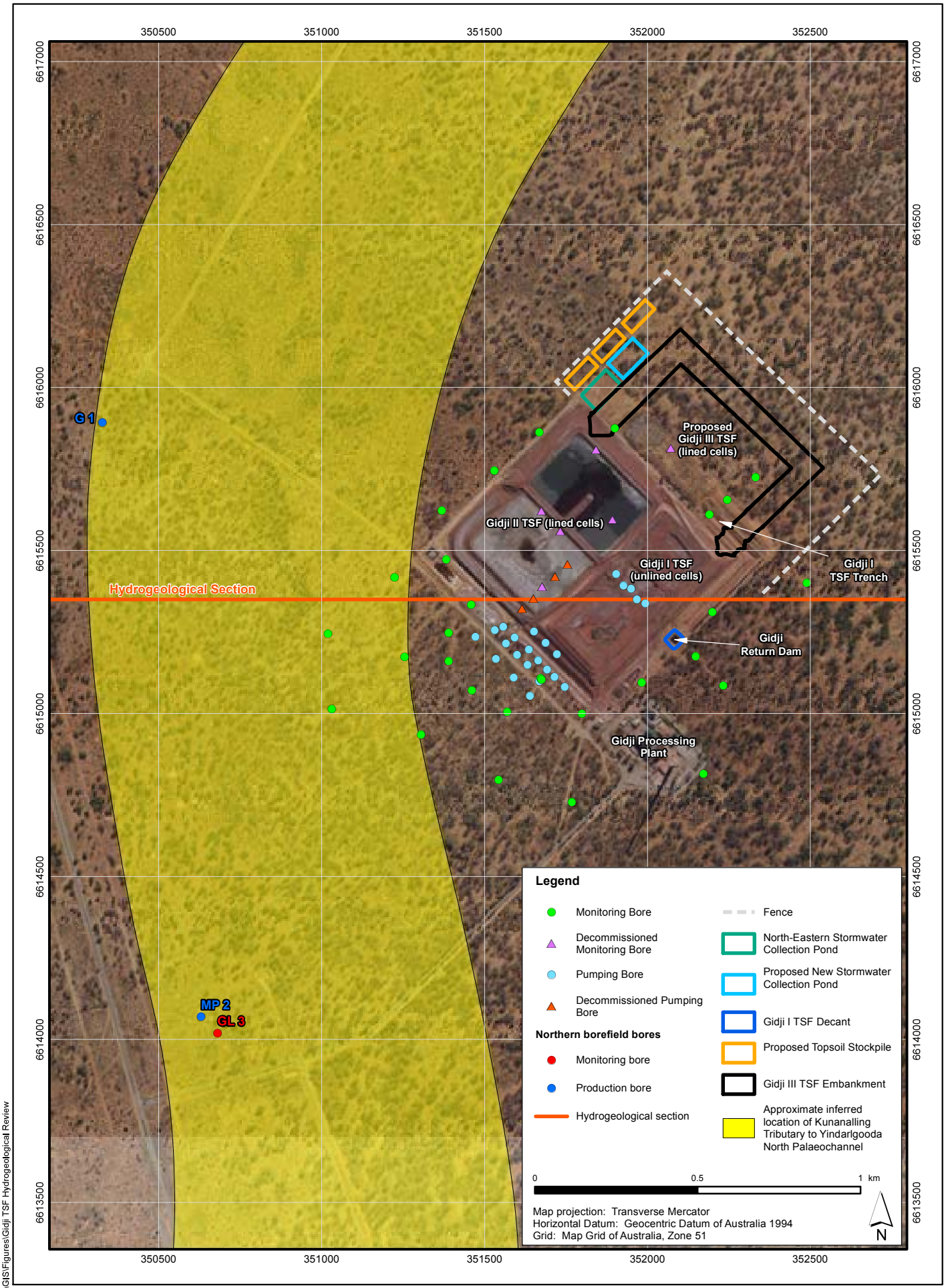
Annual pumping and deposition volumes

Figure 4

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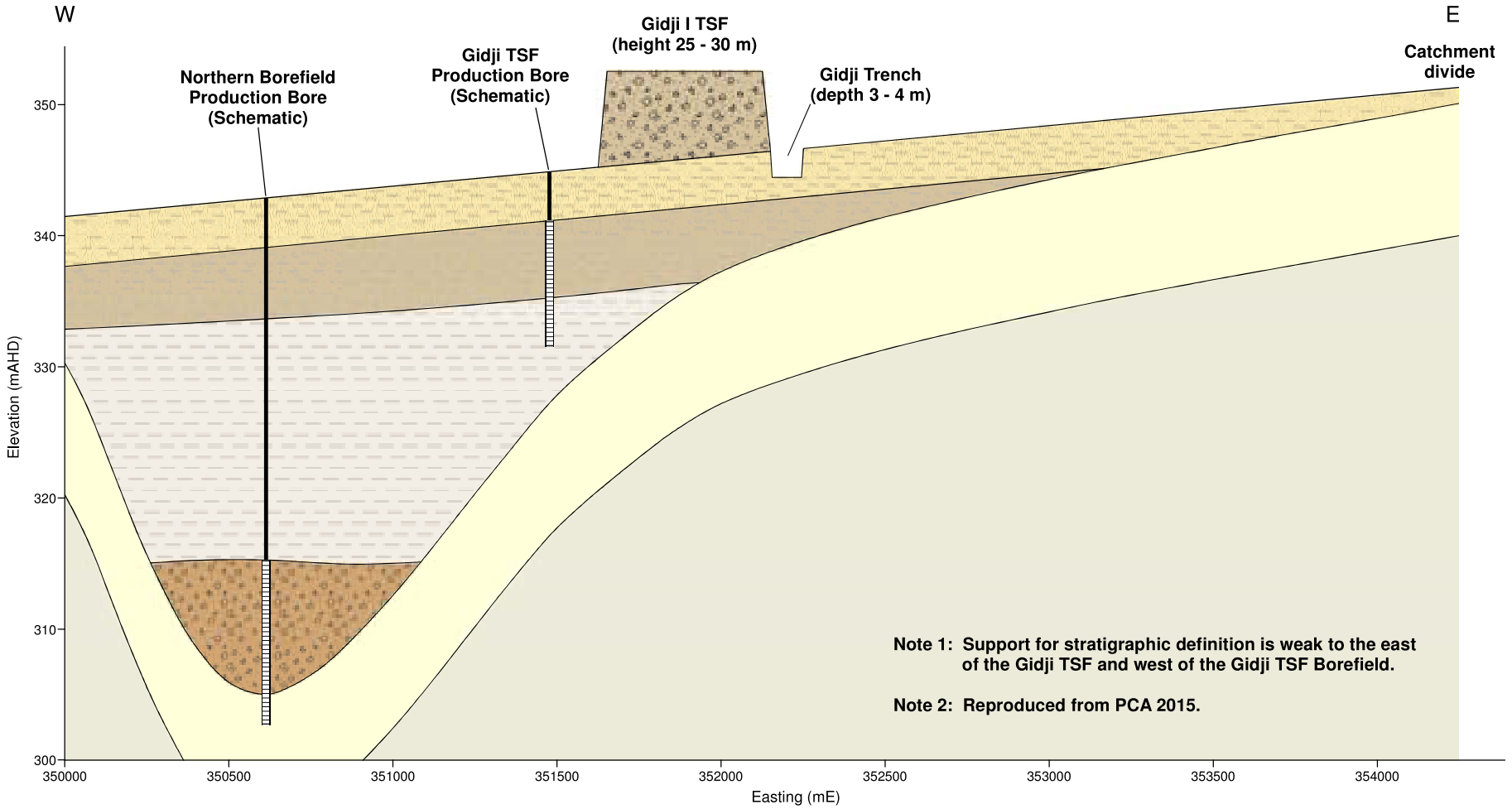
BIG DOG HYDROGEOLOGY

Gidji facilities and Northern Borefield

Figure 5

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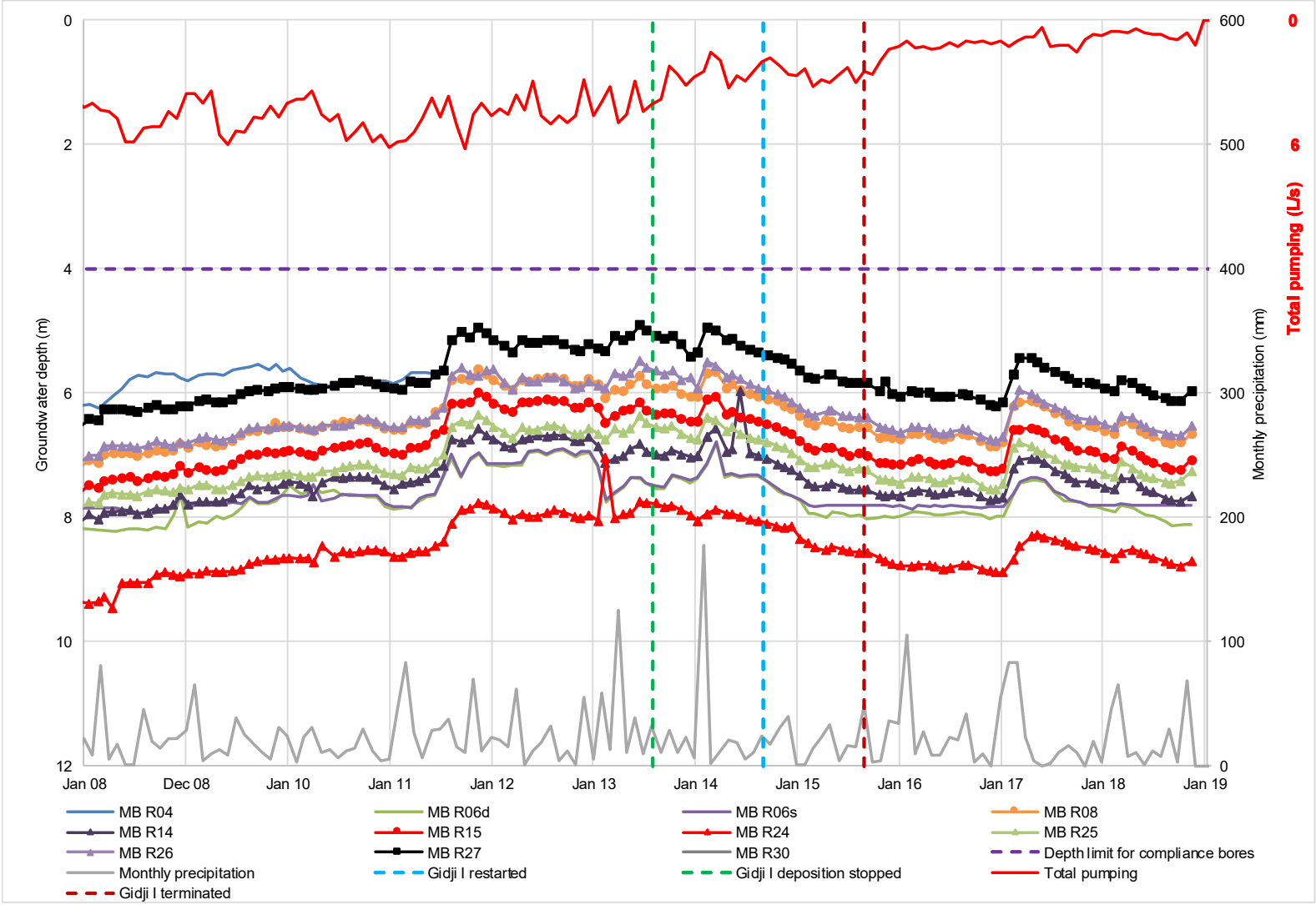
BIG DOG HYDROGEOLOGY

Hydrogeological section

Figure 6

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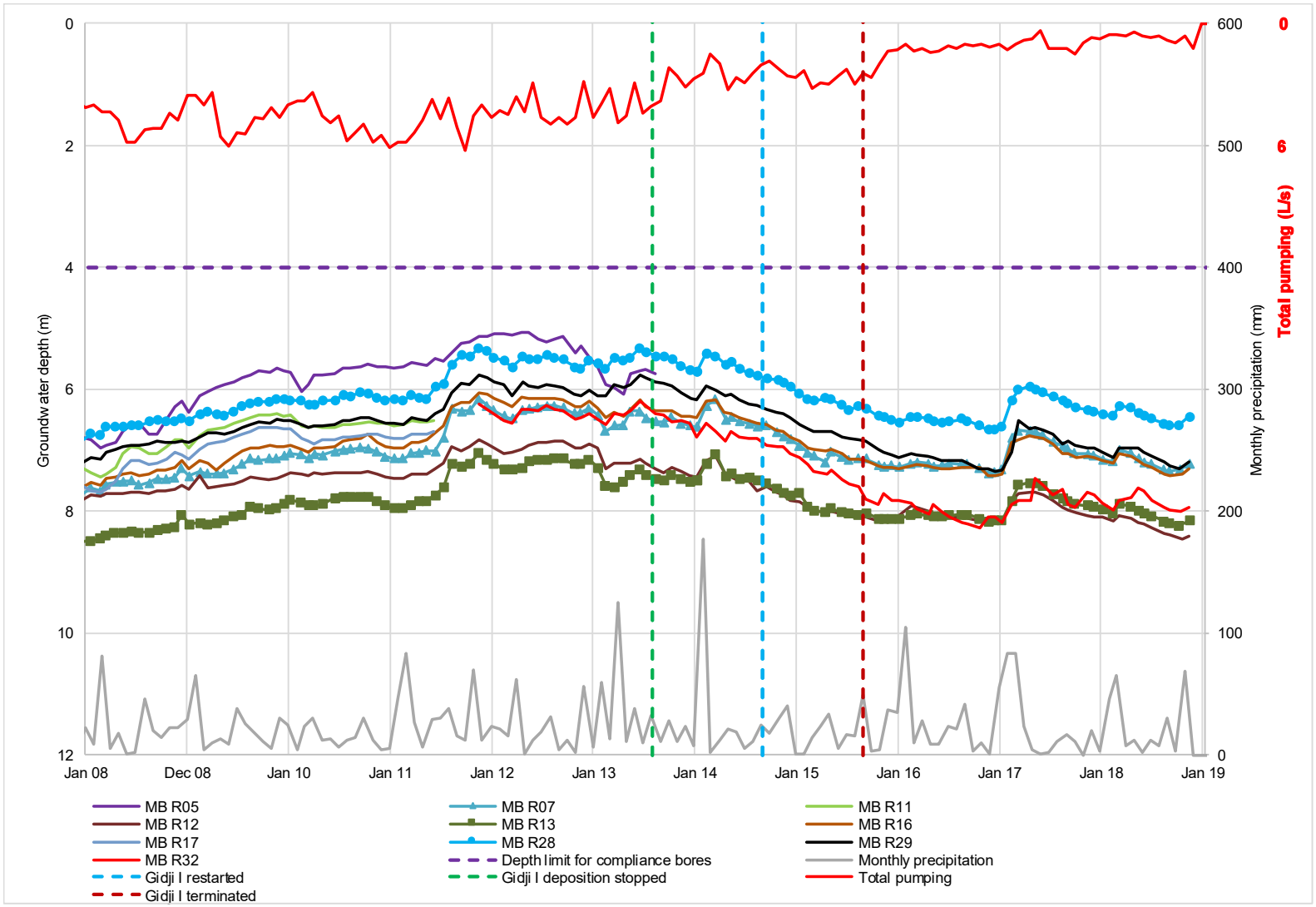
BIG DOG HYDROGEOLOGY

Recent hydrographs - western bores part 1

Figure 7

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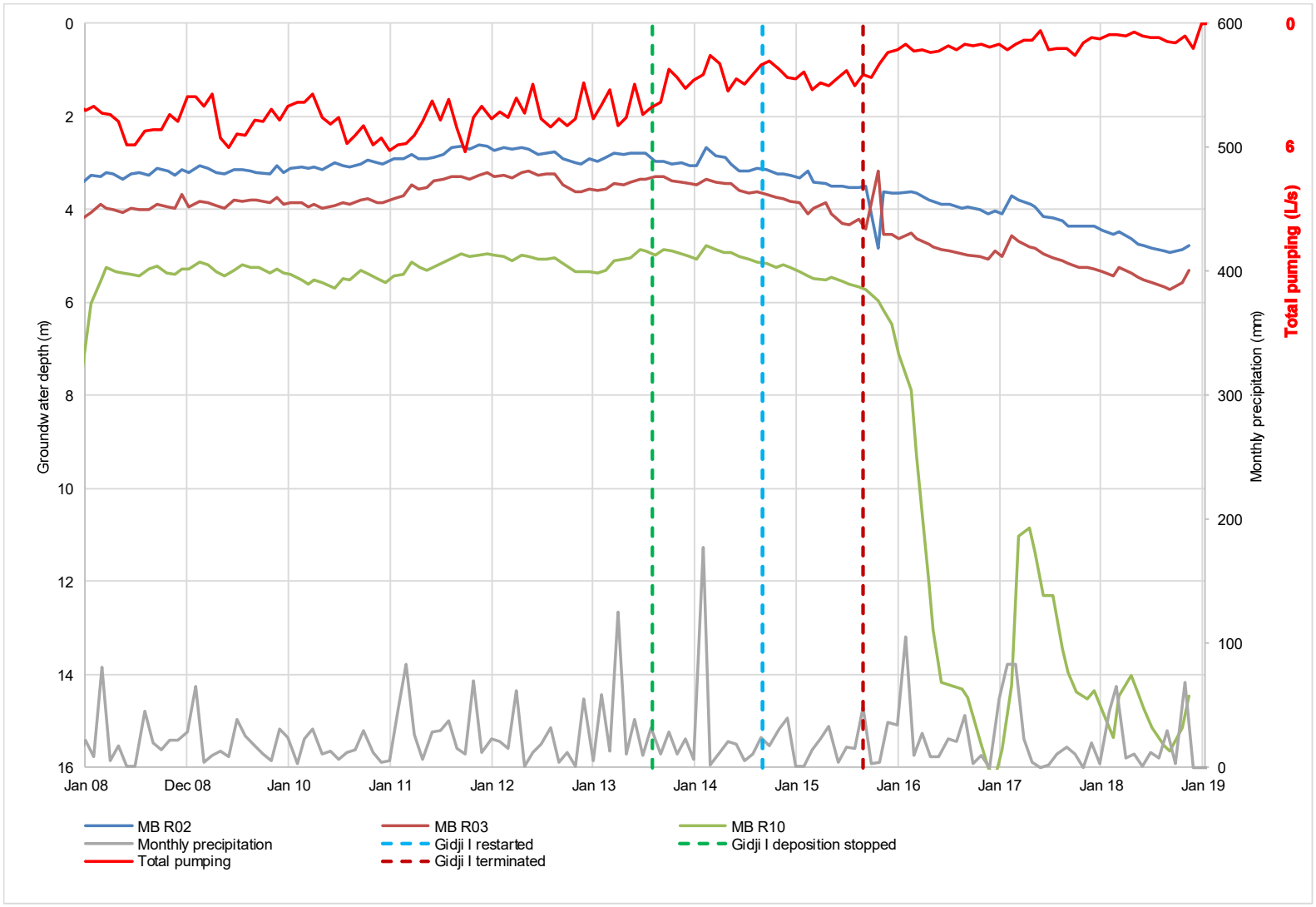
BIG DOG HYDROGEOLOGY

Recent hydrographs - western bores part 2

Figure 8

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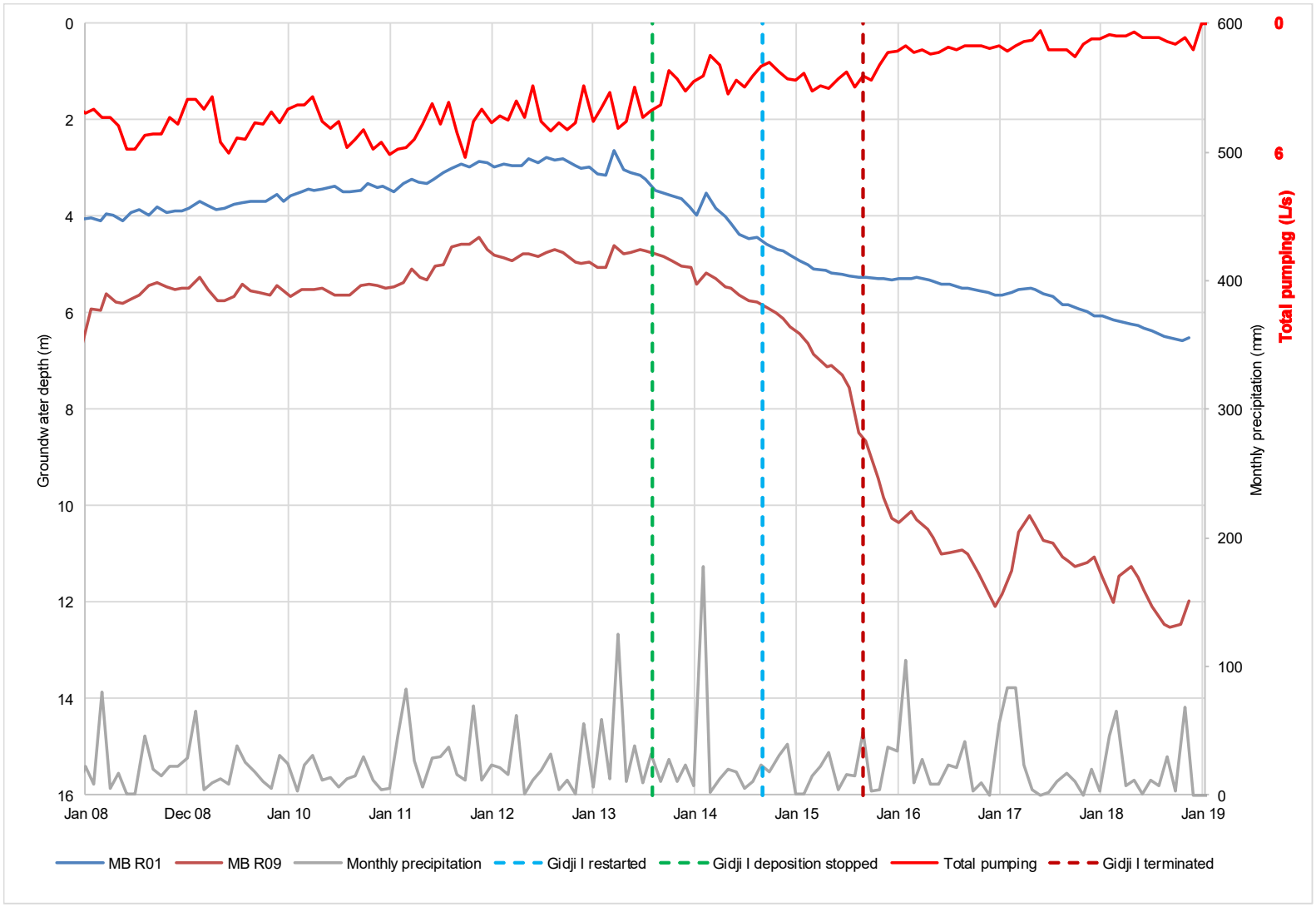
BIG DOG HYDROGEOLOGY

Recent hydrographs - trench bores

Figure 9

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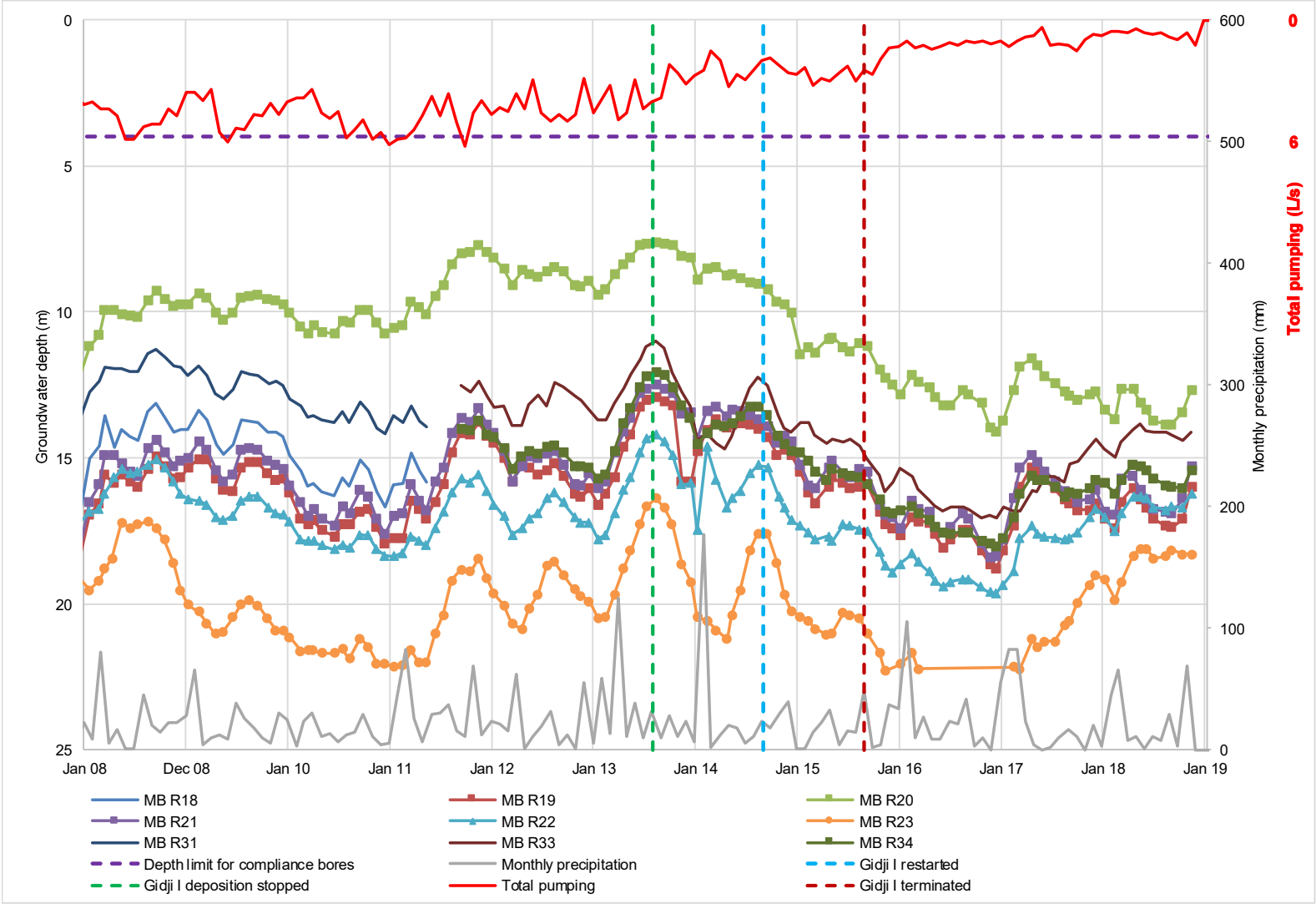
Recent hydrographs - decant bores

Figure 10

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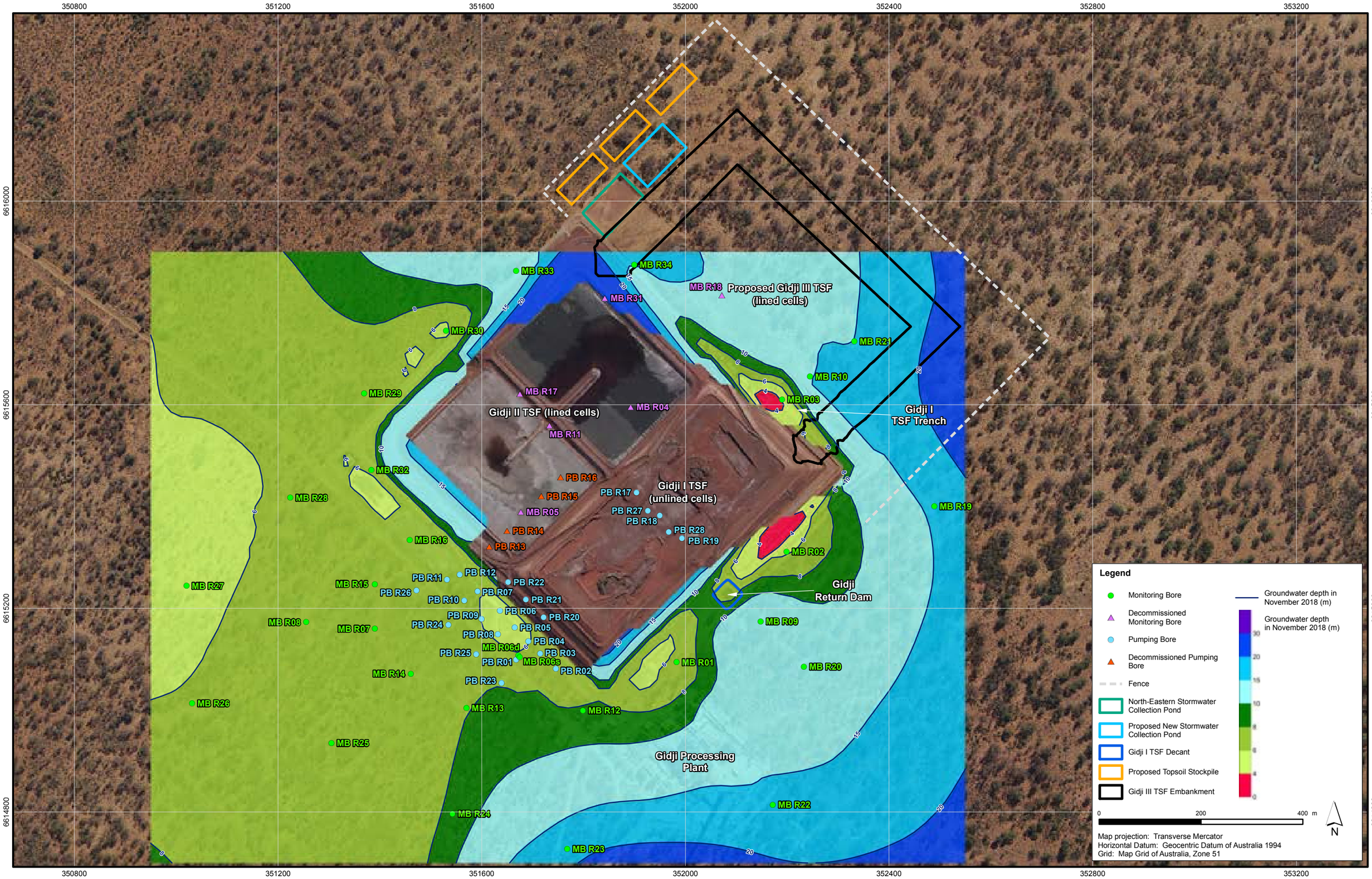
BIG DOG HYDROGEOLOGY

Recent hydrographs - eastern bores

Figure 11

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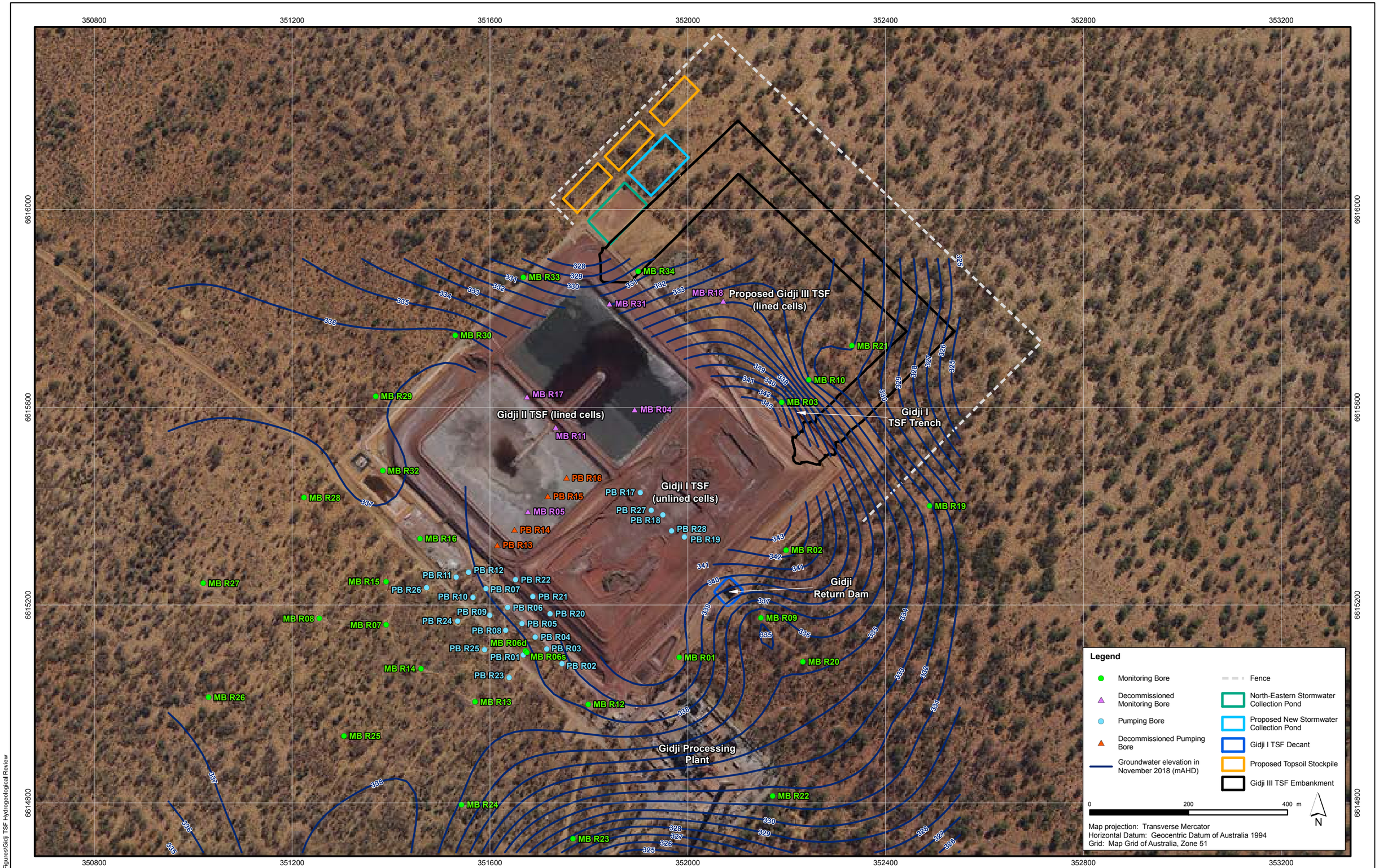
BIG DOG HYDROGEOLOGY

Groundwater depth in November 2018

Figure 12

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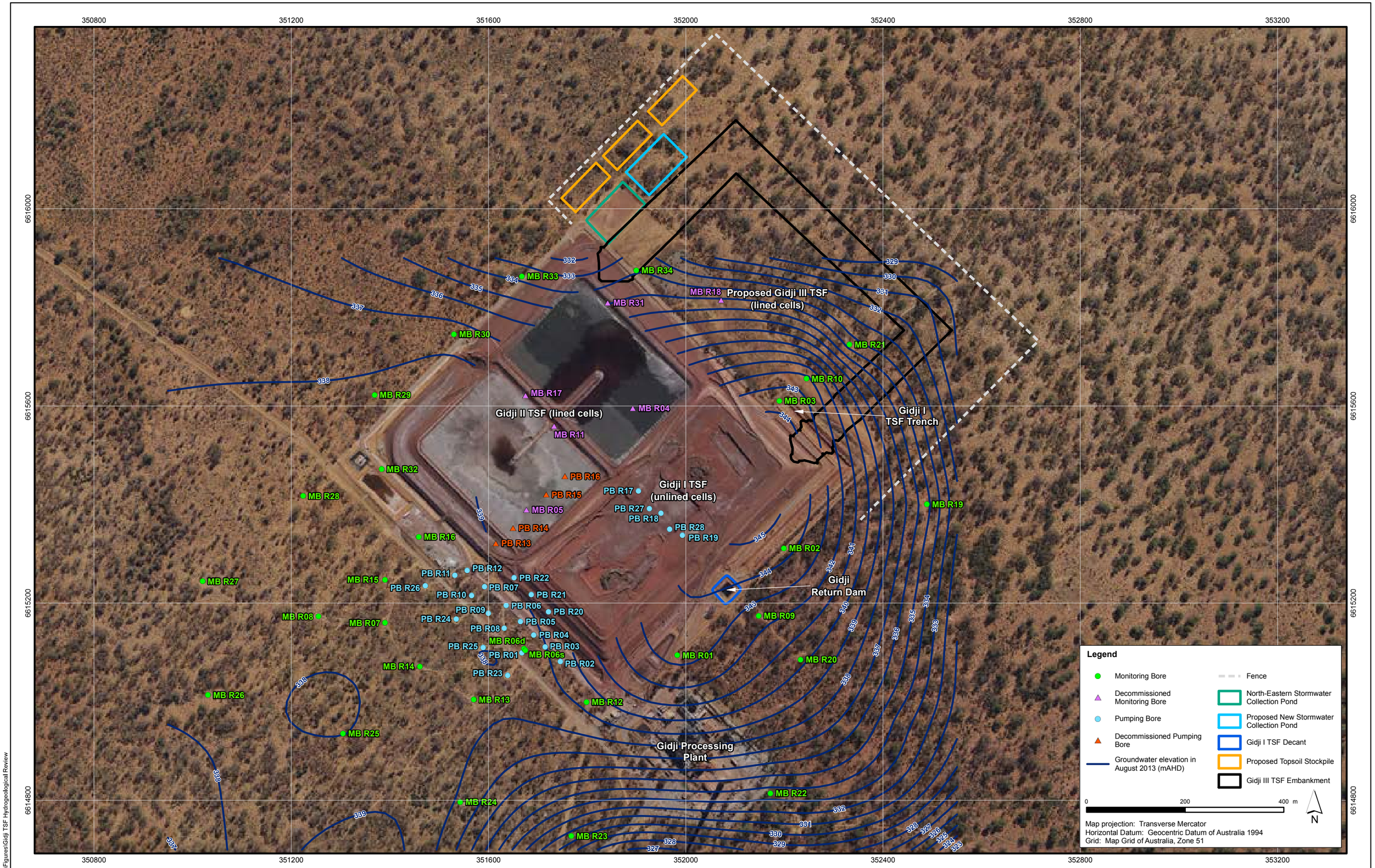
BIG DOG HYDROGEOLOGY

Groundwater elevations in November 2018

Figure 13

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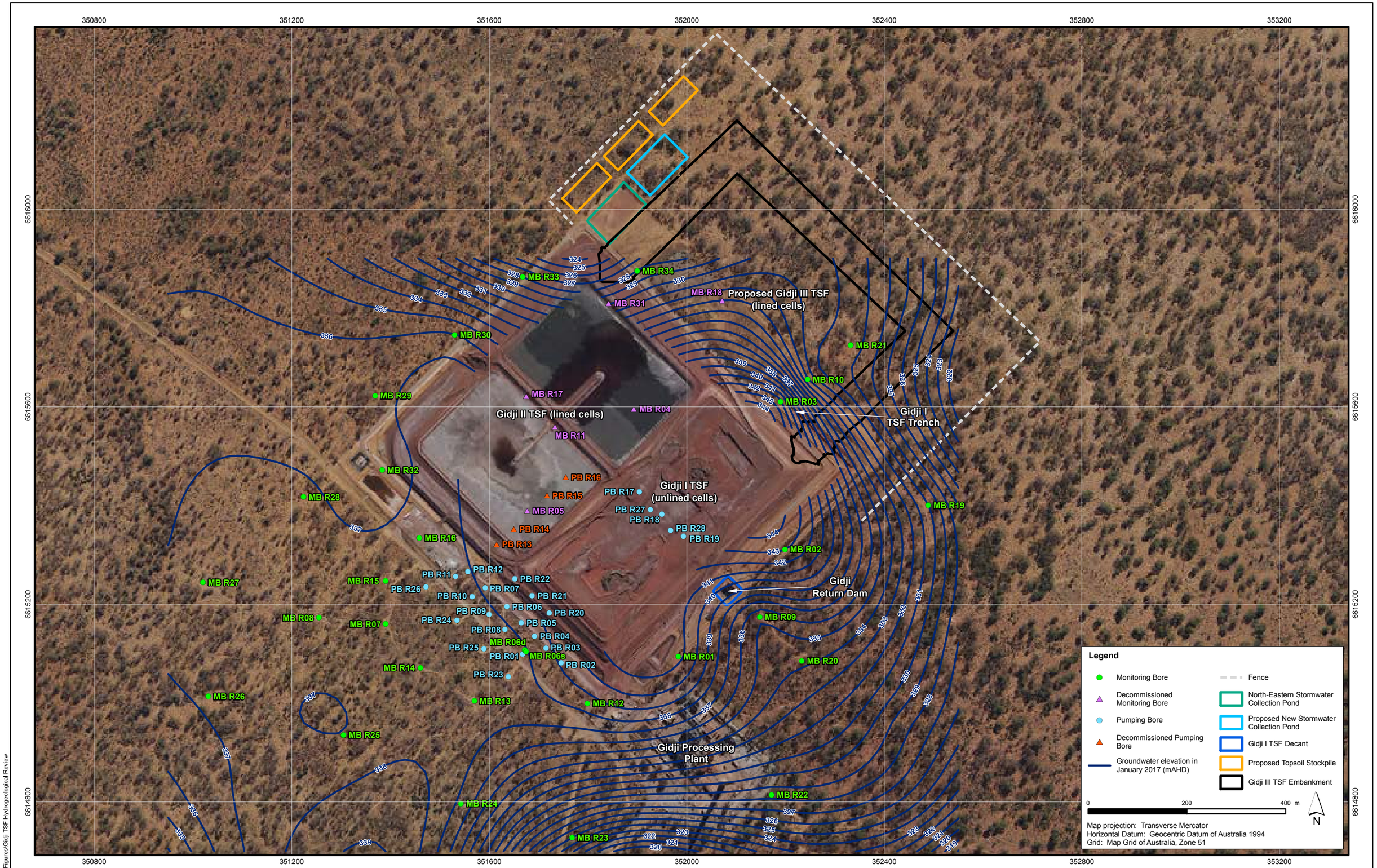
BIG DOG HYDROGEOLOGY

Groundwater elevations in August 2013

Figure 14

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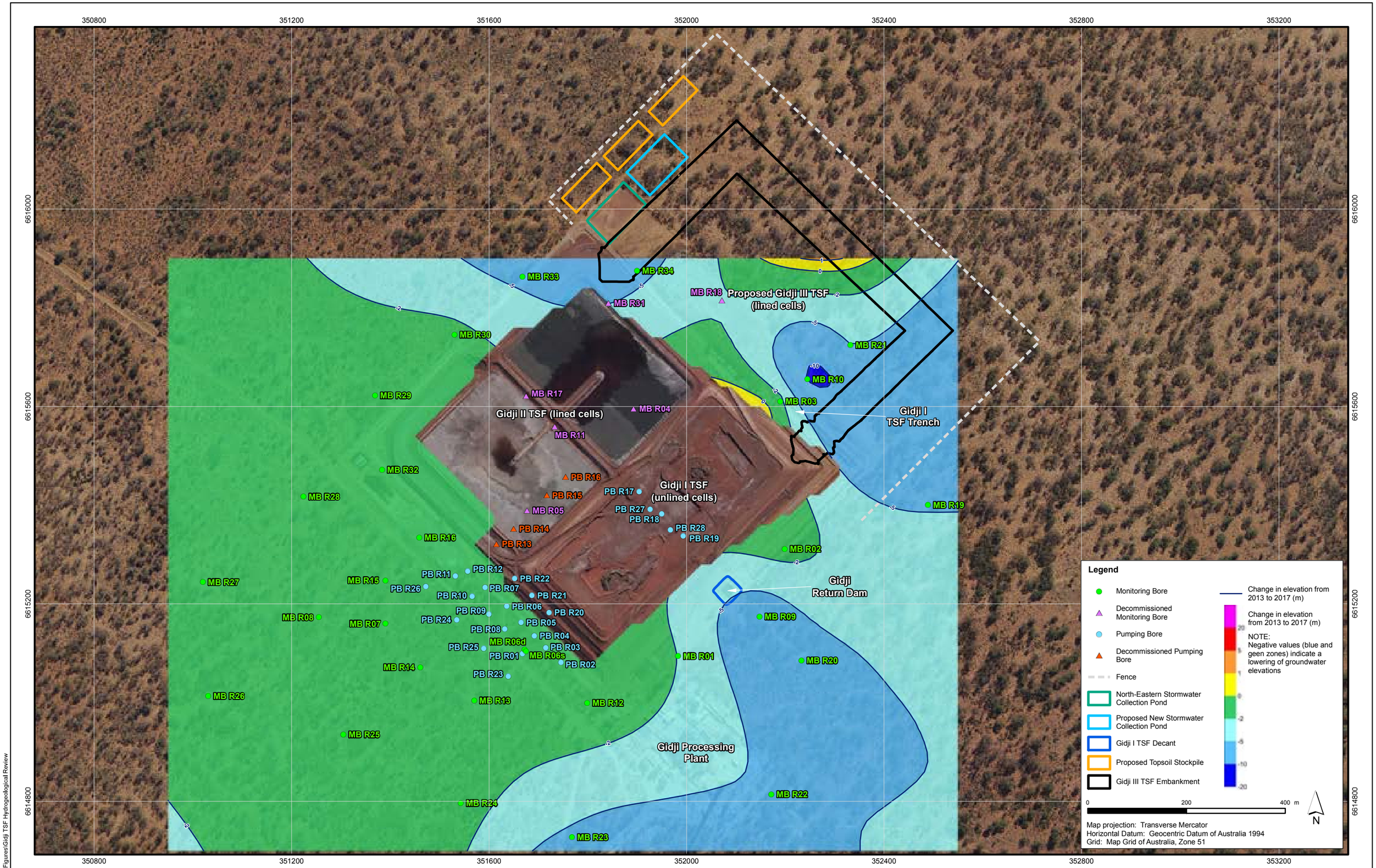
BIG DOG HYDROGEOLOGY

Groundwater elevations in January 2017

Figure 15

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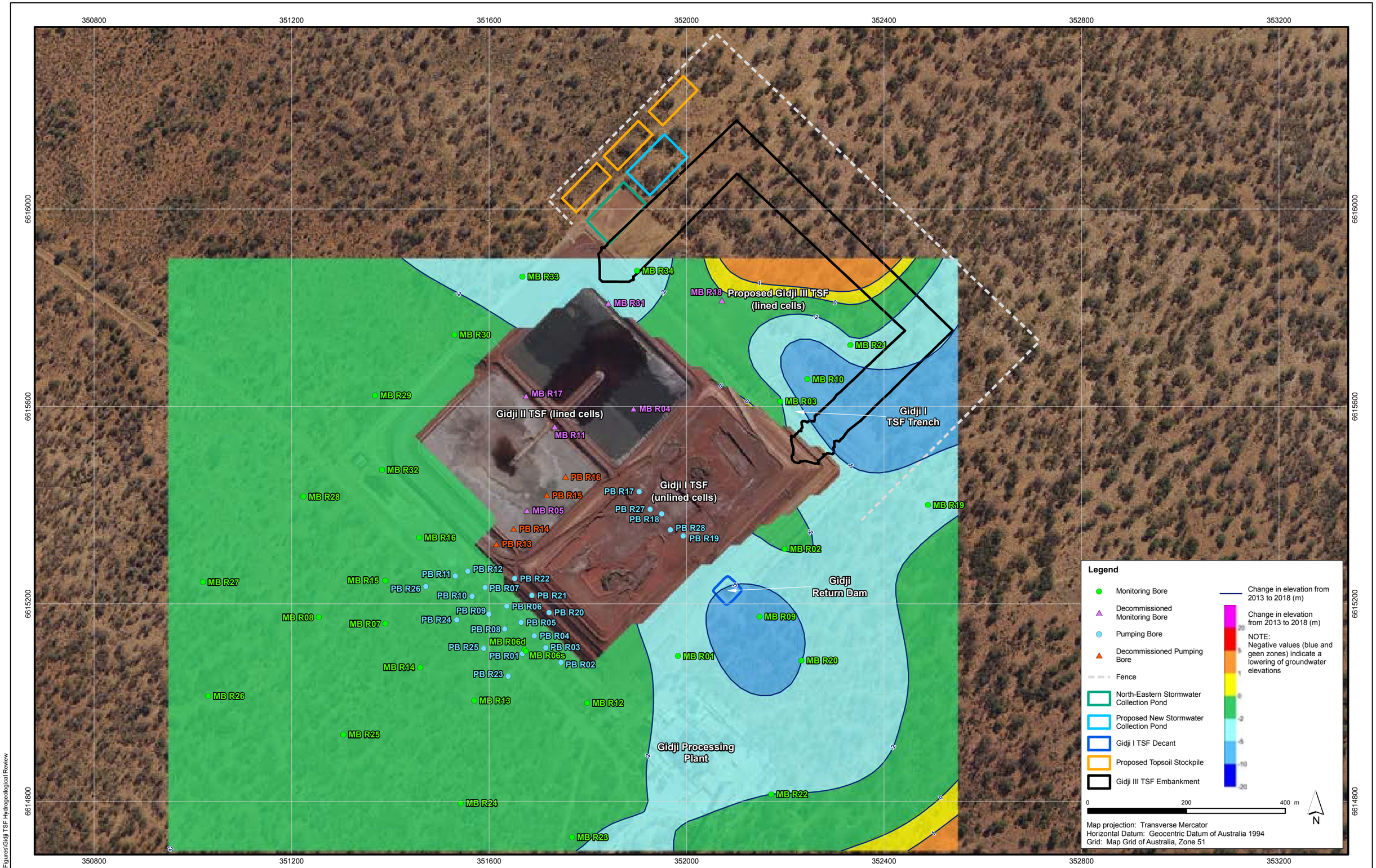
BIG DOG HYDROGEOLOGY

Change in elevations from 2013 to 2017

Figure 16

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BIG DOG HYDROGEOLOGY

Change in elevations from 2013 to 2018

Figure 17

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Report: Gidji TSF Hydrogeological Review

350800 351200 351600 352000 352400 352800 353200

6616000 6615600 6615200 6614800

MB R33 MB R34 MB R18 Proposed Gidji III TSF (lined cells) MB R31 MB R30 MB R21 MB R10 MB R29 MB R17 MB R03 MB R04 Gidji I TSF Trench Gidji II TSF (lined cells) MB R11 MB R32 PB R16 PB R15 PB R17 Gidji I TSF (unlined cells) MB R28 MB R05 PB R27 PB R18 MB R19 PB R14 PB R28 PB R19 MB R16 PB R13 MB R02 PB R12 PB R11 MB R27 MB R15 PB R22 PB R26 PB R07 PB R10 PB R21 Gidji Return Dam PB R09 PB R06 PB R20 MB R08 MB R09 MB R07 PB R24 PB R05 PB R08 PB R04 MB R06d PB R25 PB R03 PB R01 MB R06s MB R01 MB R20 PB R02 MB R14 PB R23 MB R26 MB R13 MB R12 MB R25 Gidji Processing Plant MB R22 MB R24 MB R23

Legend

- Monitoring Bore
- Decommissioned Monitoring Bore
- Pumping Bore
- Decommissioned Pumping Bore
- Fence
- North-Eastern Stormwater Collection Pond
- Proposed New Stormwater Collection Pond
- Gidji I TSF Decant
- Proposed Topsoil Stockpile
- Gidji III TSF Embankment
- Change in elevation from 2013 to 2018 (m)
- Change in elevation from 2017 to 2018 (m)

NOTE: Negative values (blue and geen zones) indicate a lowering of groundwater elevations

20 5 1 0 -2 -5 -10 -20

0 200 400 m

N

Map projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 51

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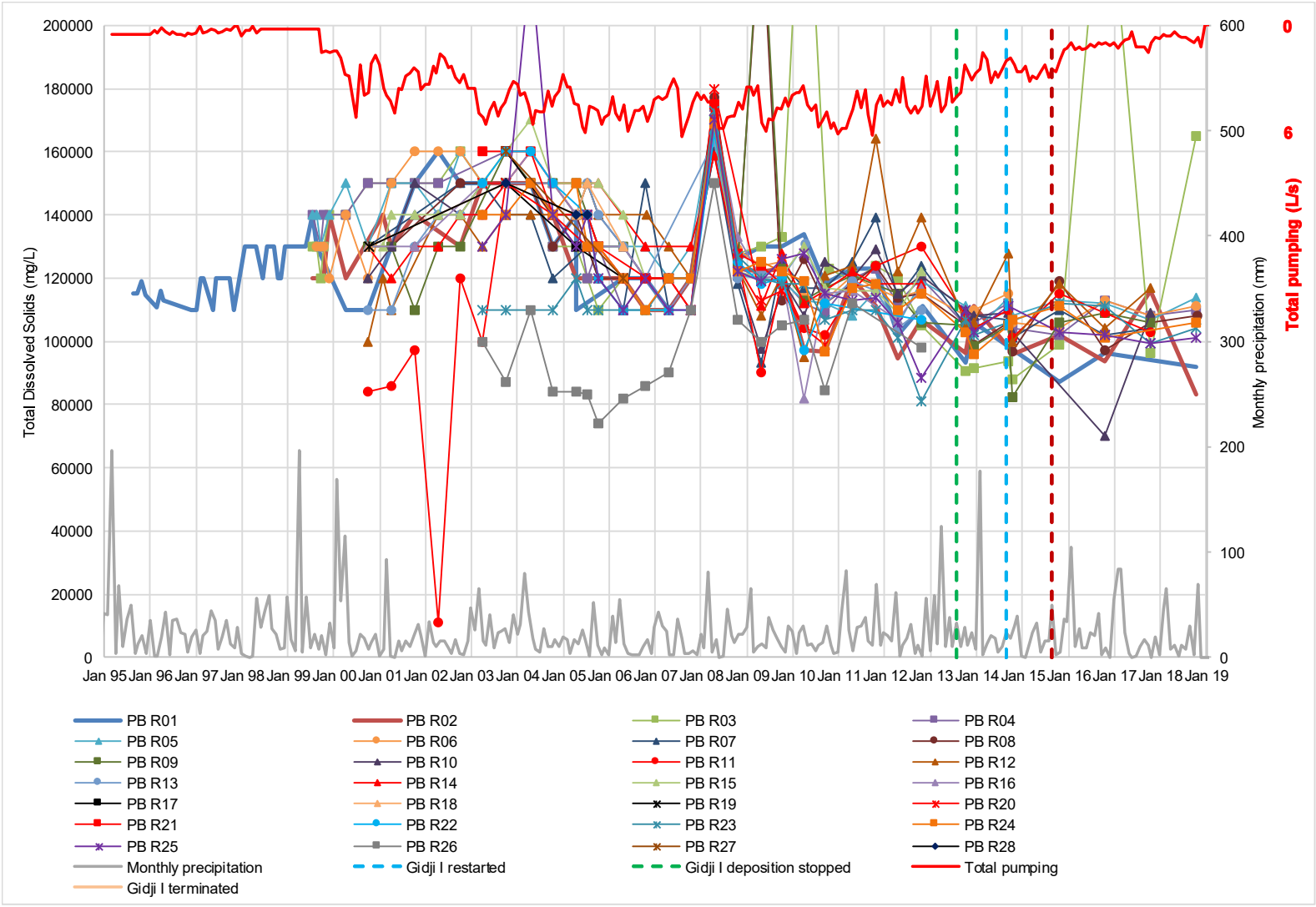
BIG DOG HYDROGEOLOGY

Change in elevations from 2017 to 2018

Figure 18

Date: January 2019

Report: Gidji TSF Hydrogeological Review



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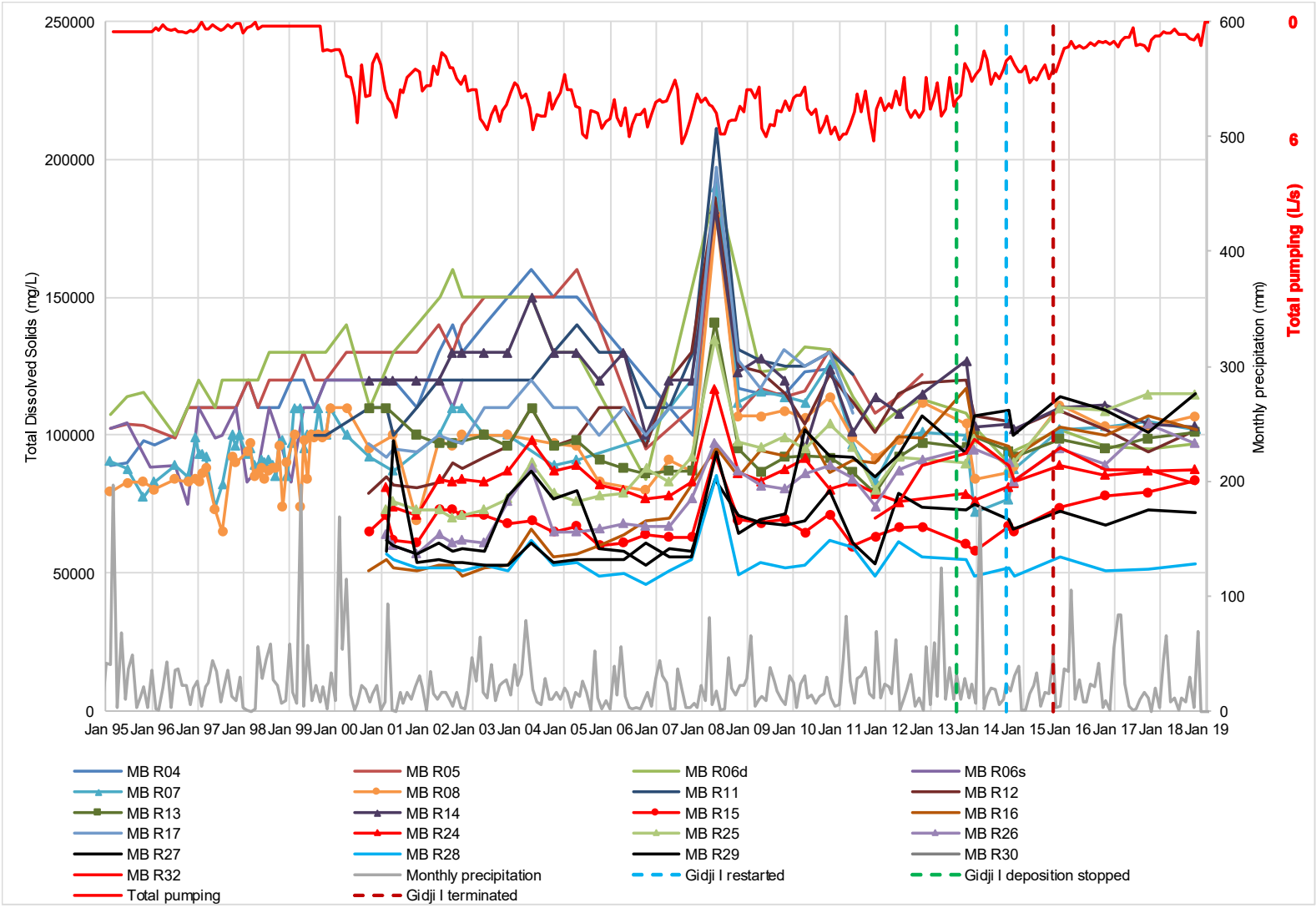
BIG DOG HYDROGEOLOGY

TDS - production bores

Figure 19

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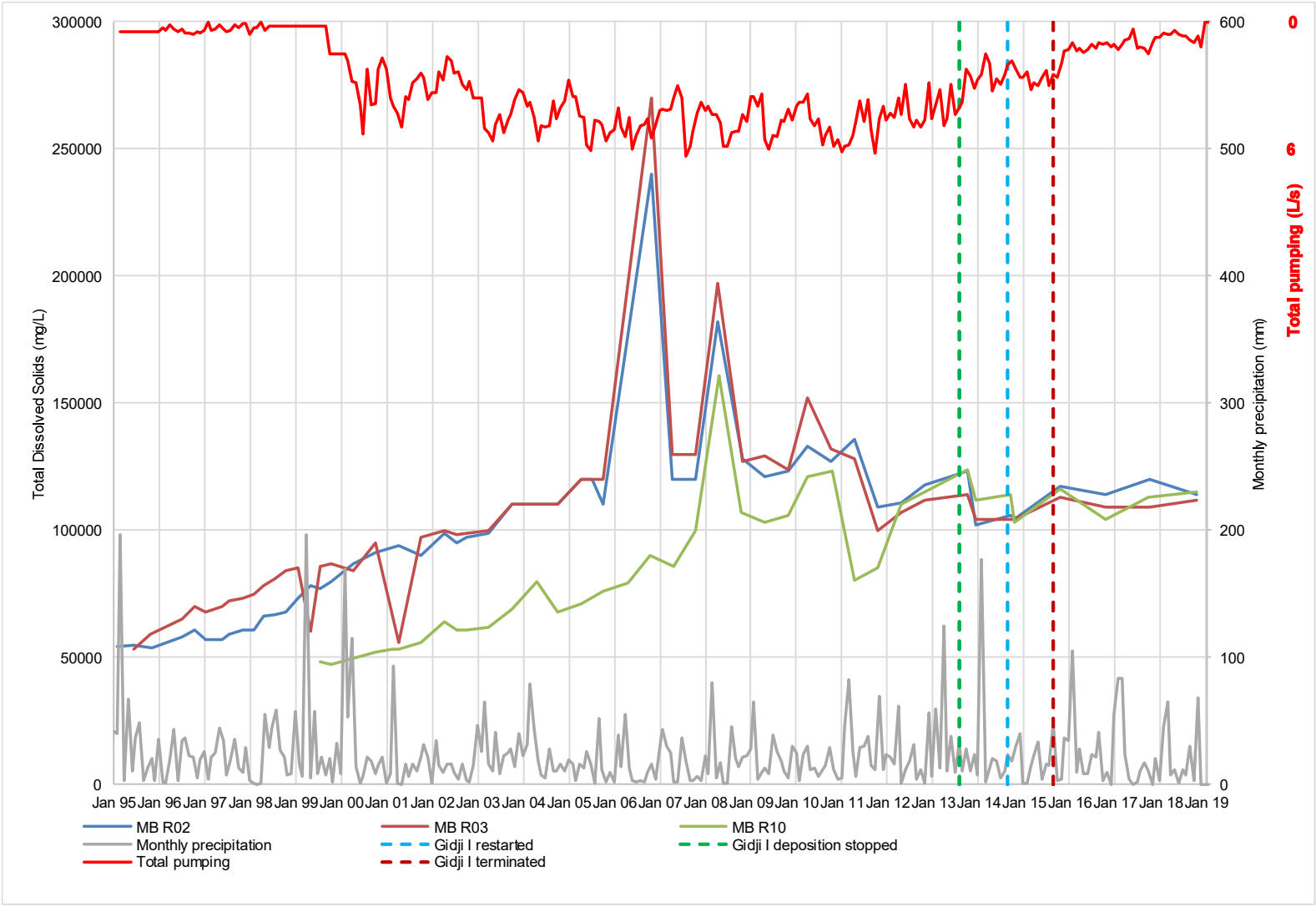
BIG DOG HYDROGEOLOGY

TDS - western bores

Figure 20

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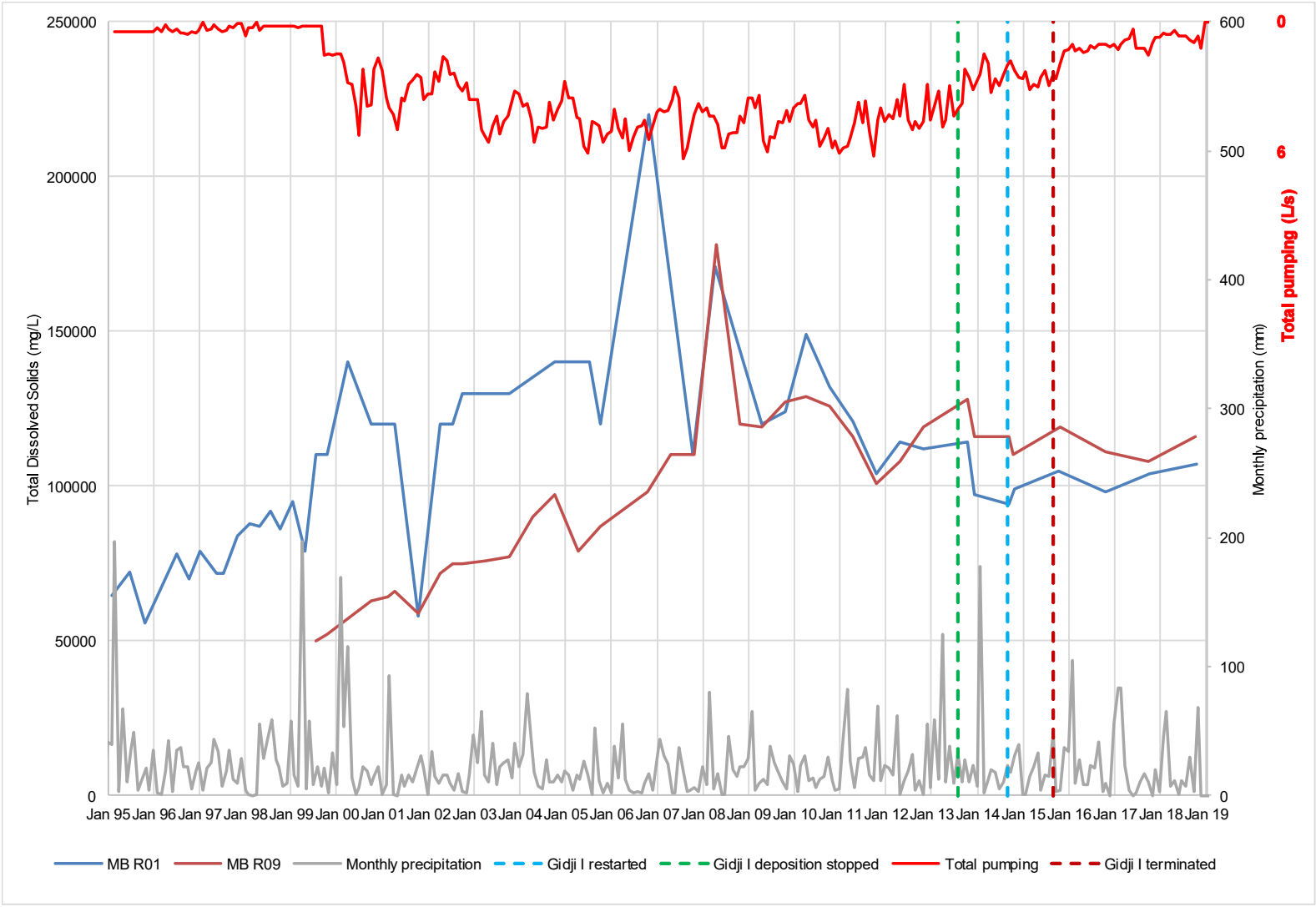
BIG DOG HYDROGEOLOGY

TDS - trench bores

Figure 21

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Report: KCGM Gidji TSF Hydrogeological Review



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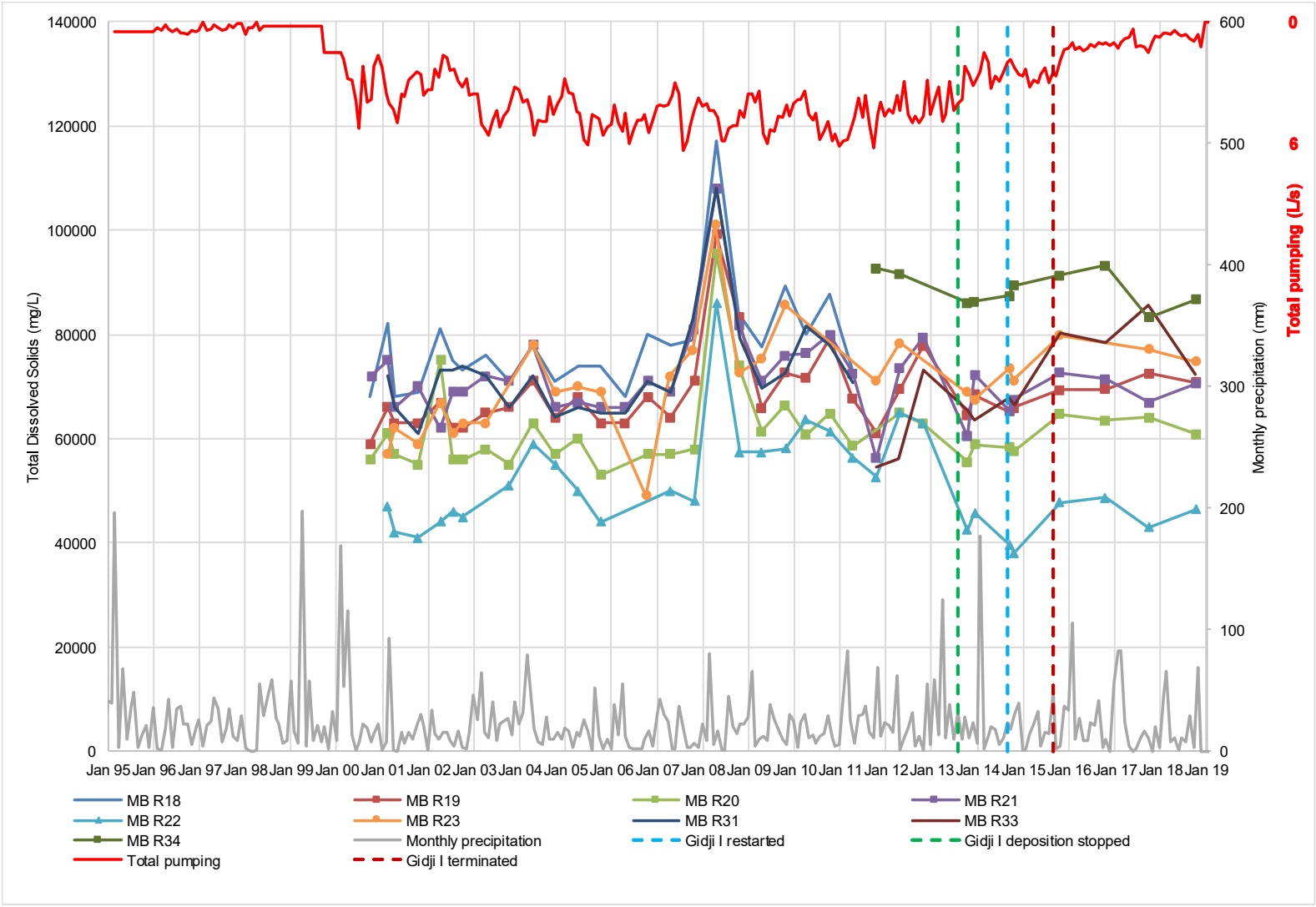
BIG DOG HYDROGEOLOGY

TDS - decant bores

Figure 22

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Report: KCGM Gidji TSF Hydrogeological Review



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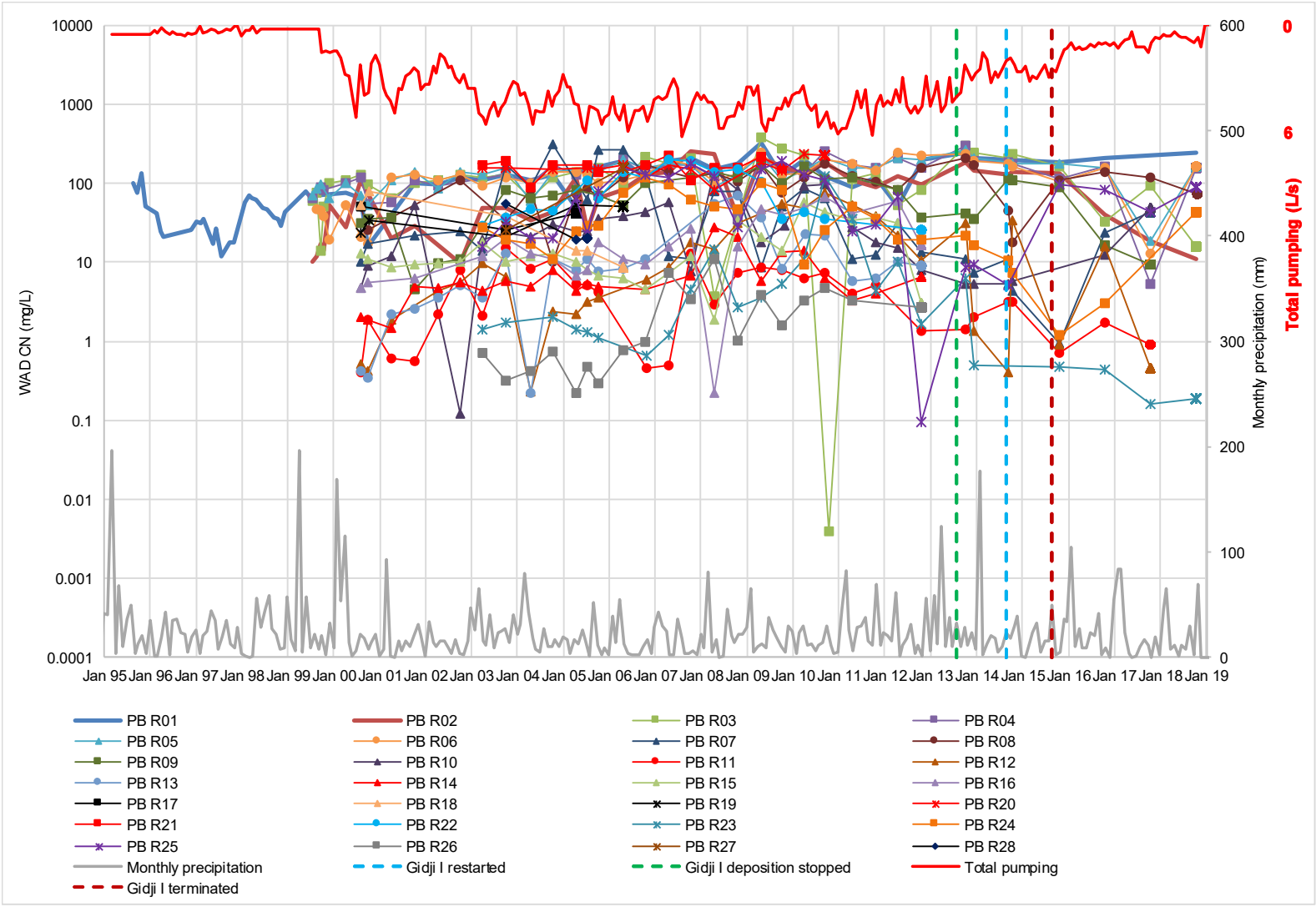
BIG DOG HYDROGEOLOGY

TDS - eastern bores

Figure 23

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Report: KCGM Gidji TSF Hydrogeological Review



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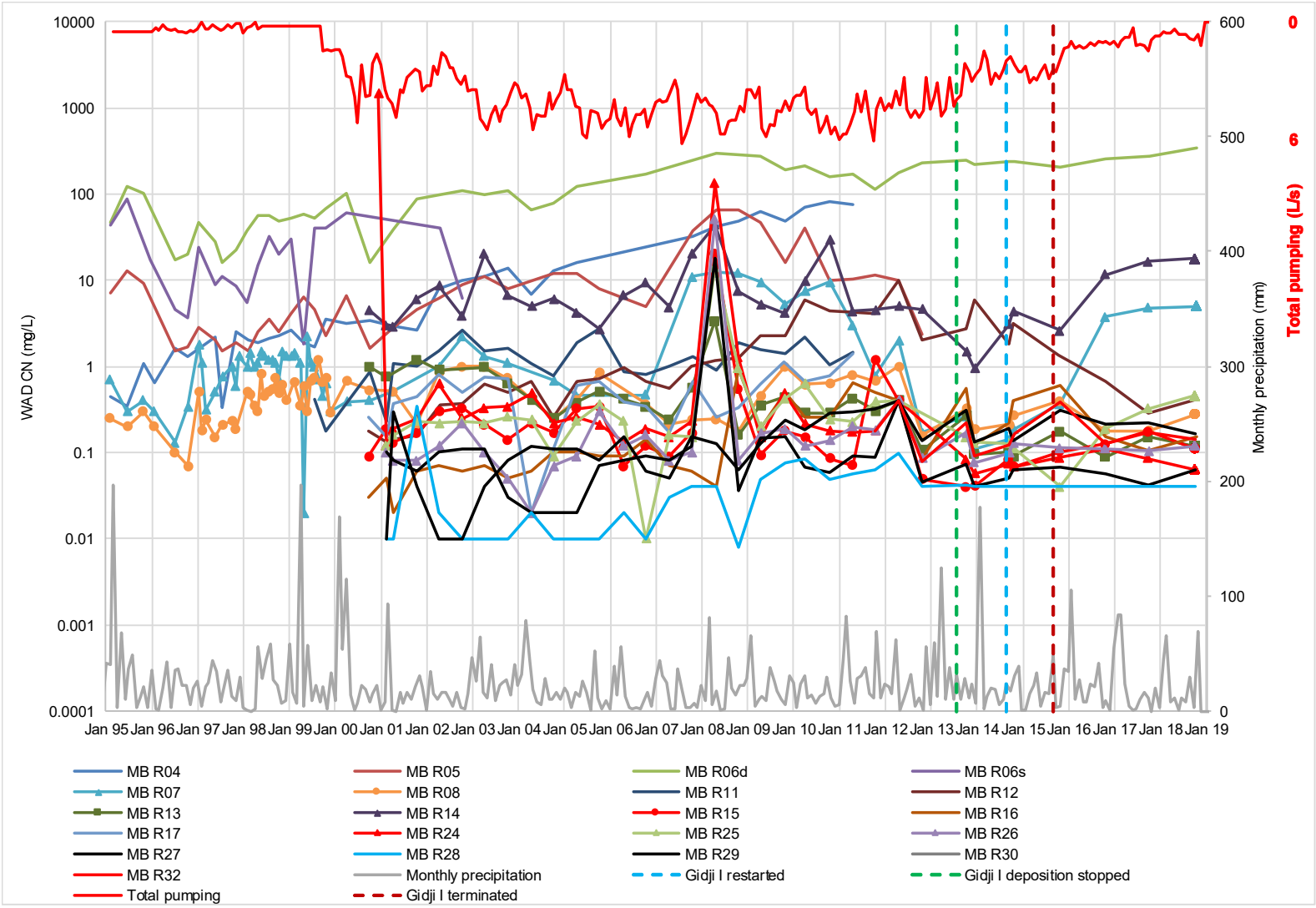
BIG DOG HYDROGEOLOGY

WAD CN - production bores

Figure 24

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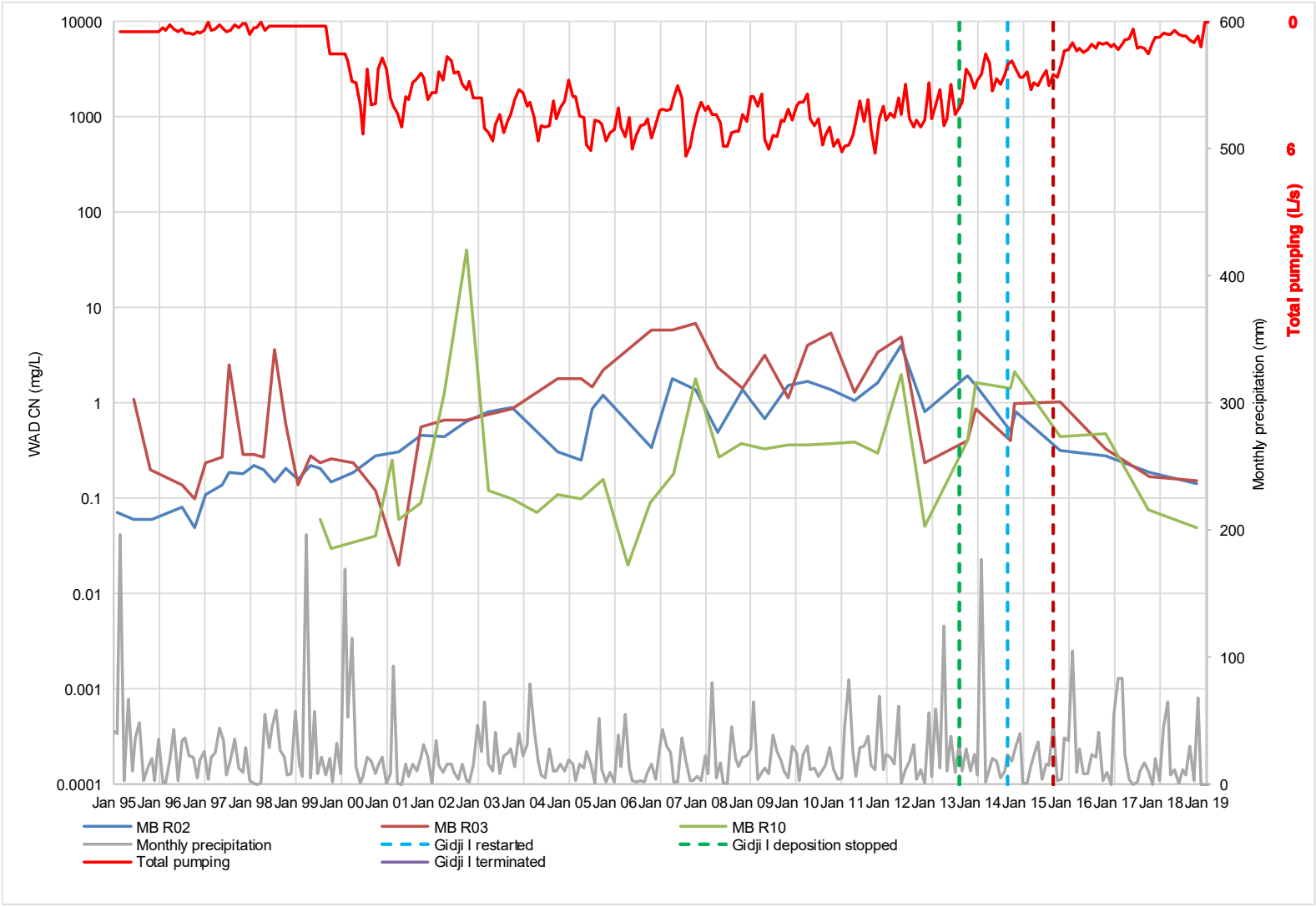
BIG DOG HYDROGEOLOGY

WAD CN - western bores

Figure 25

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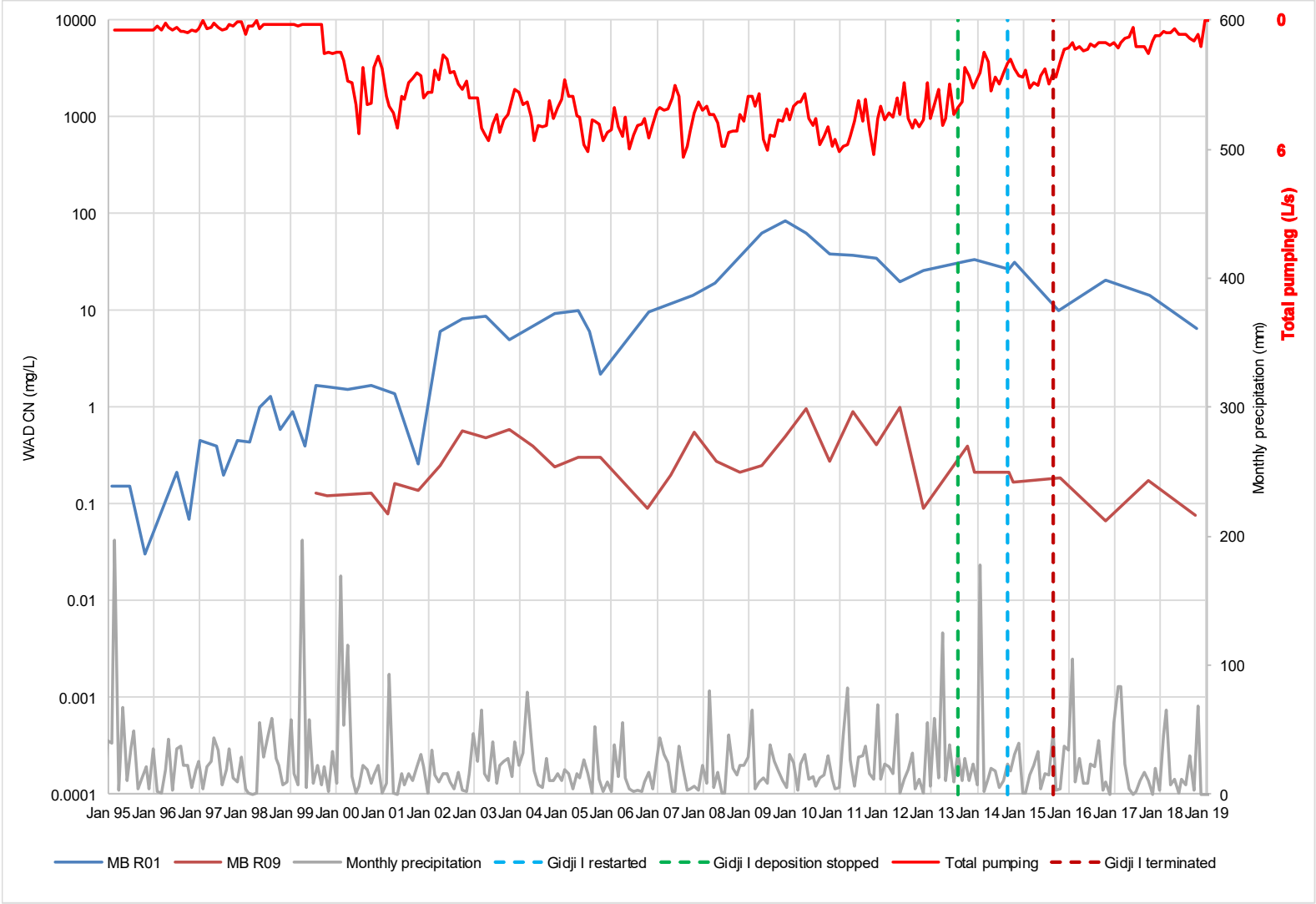
BIG DOG HYDROGEOLOGY

WAD CN - trench bores

Figure 26

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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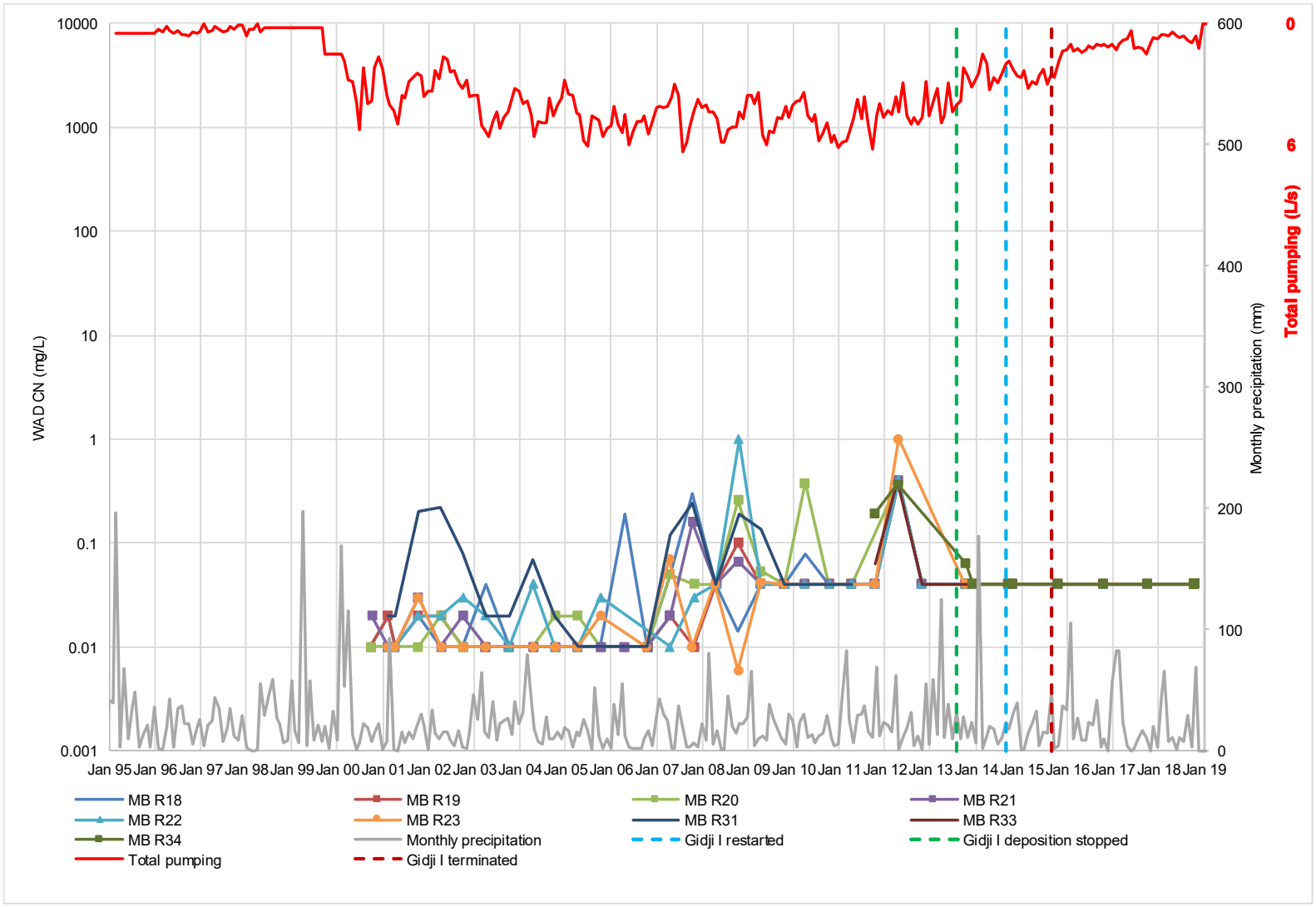
BIG DOG HYDROGEOLOGY

WAD CN - decant bores

Figure 27

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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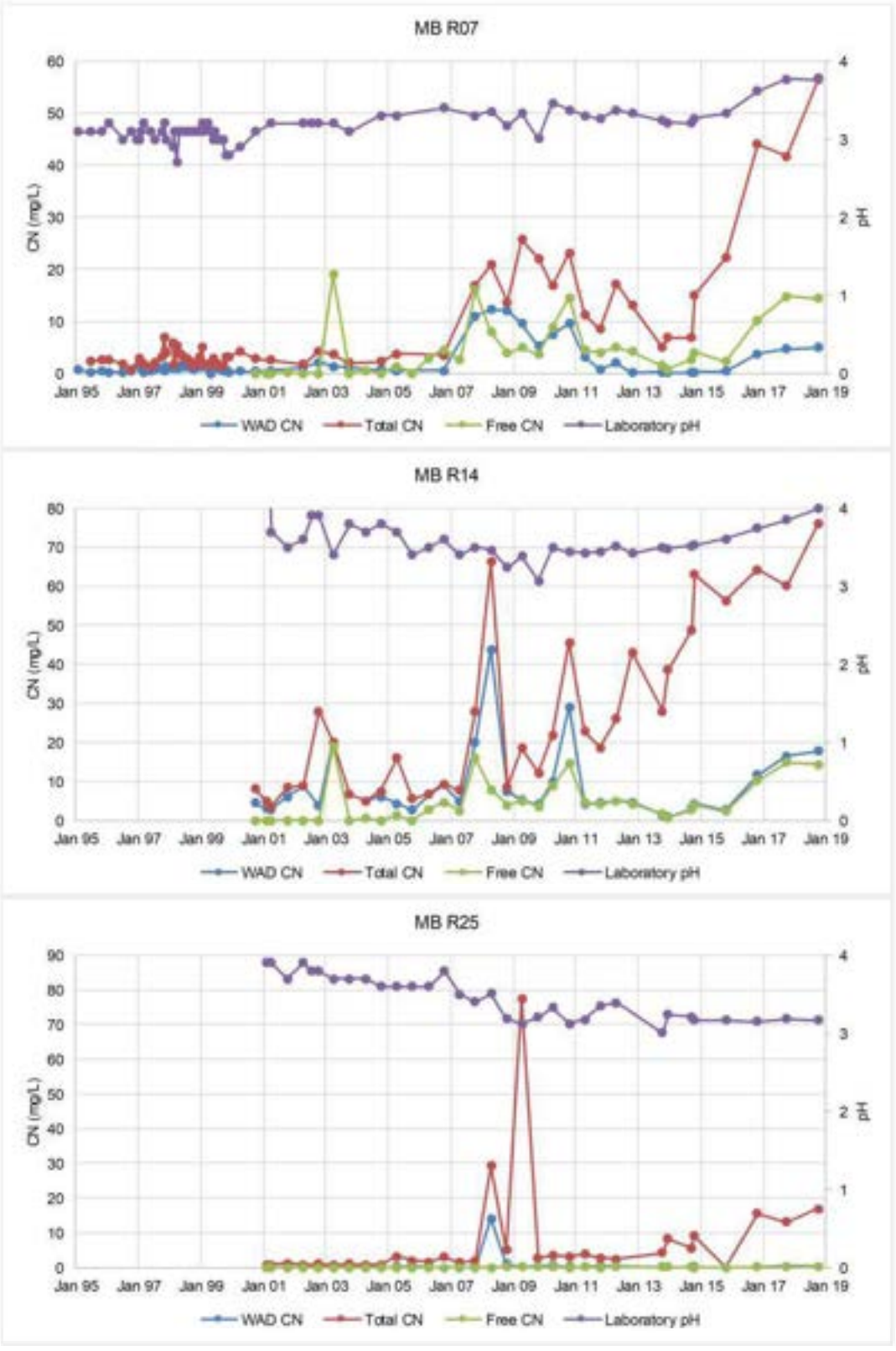
BIG DOG HYDROGEOLOGY

WAD CN - eastern bores

Figure 28

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



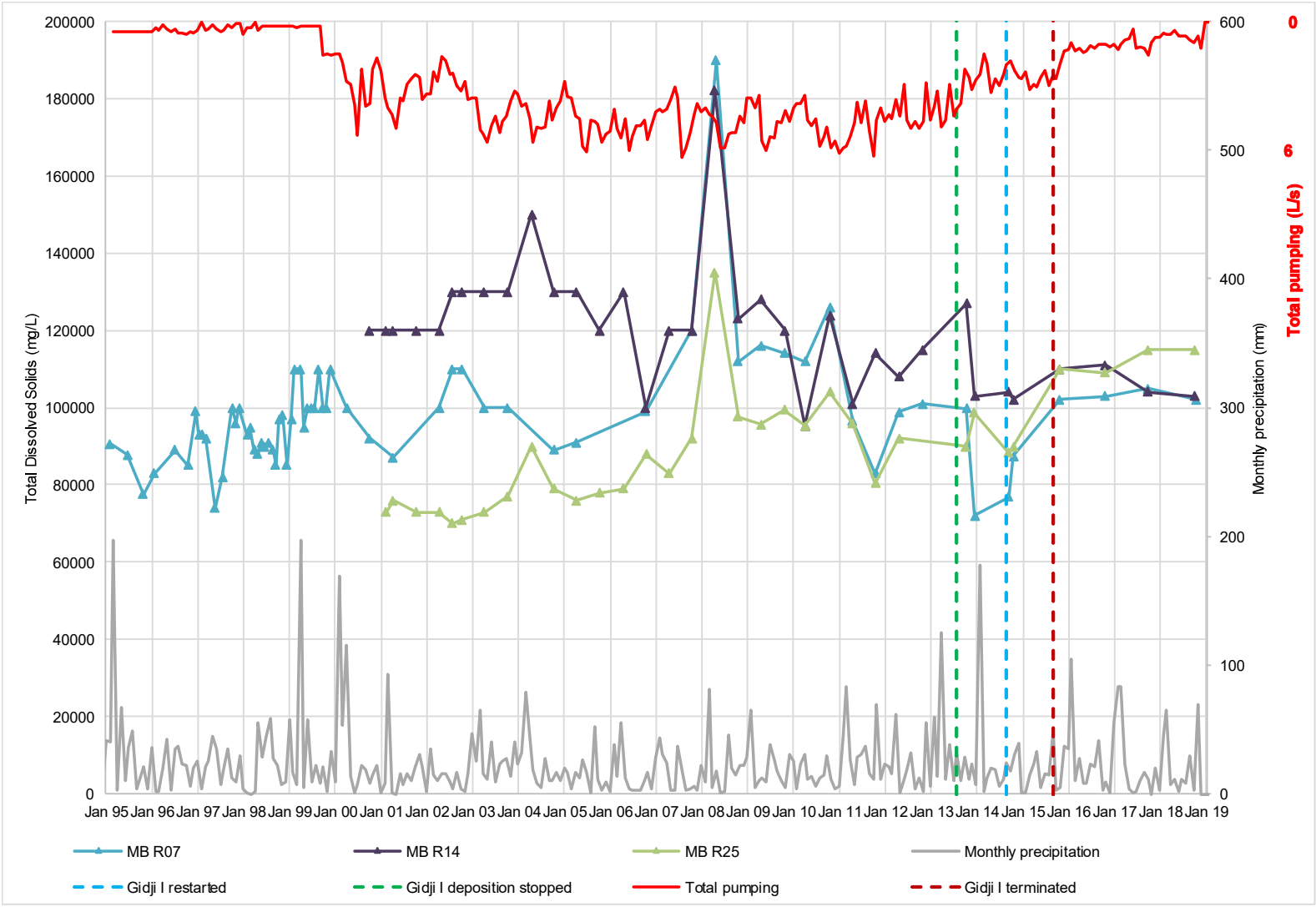
CN trends in MB R07, MB R14 and MB R25

Figure 29

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review

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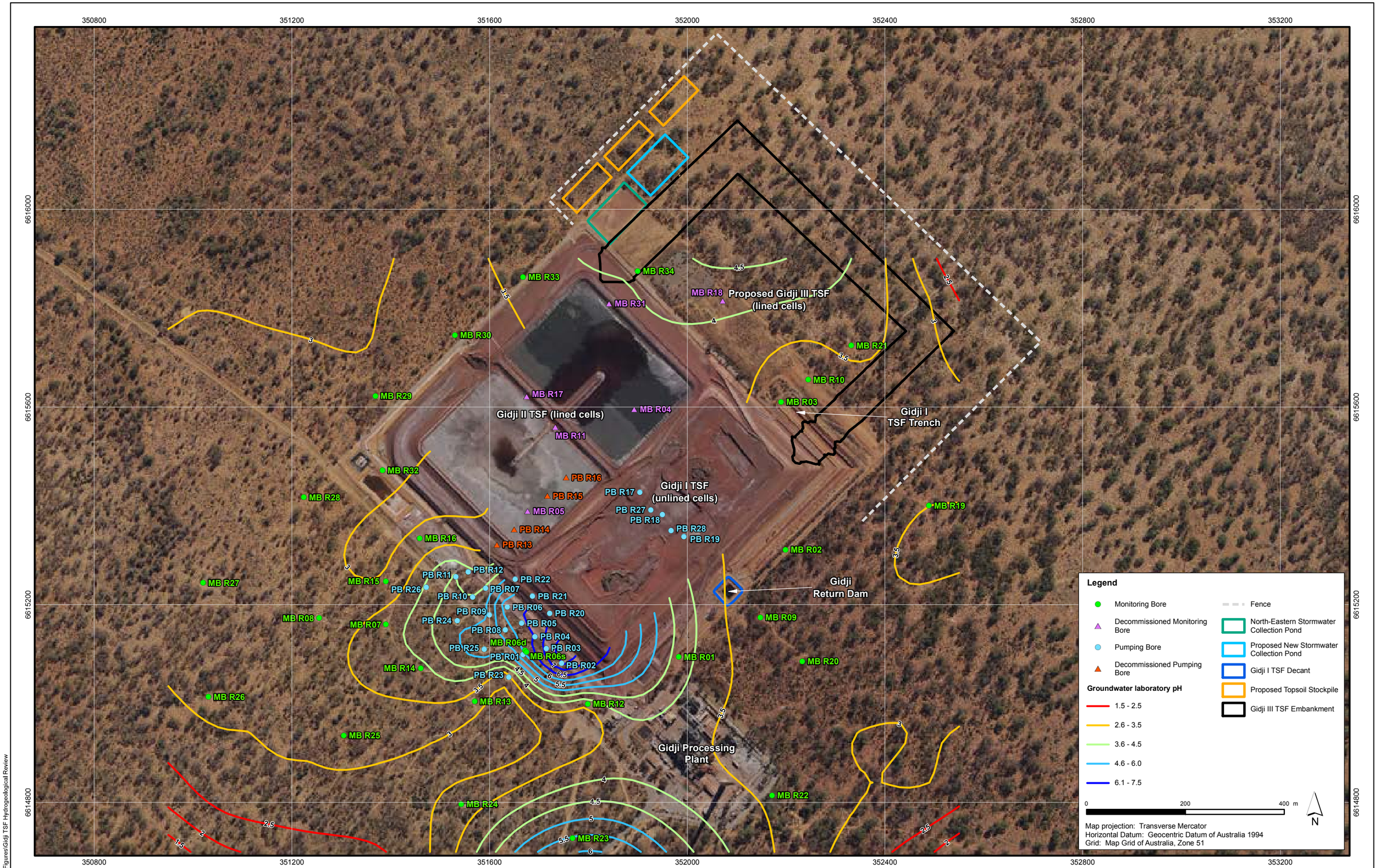
BIG DOG HYDROGEOLOGY

TDS trends in MB R07, MB R14 and MB R25

Figure 30

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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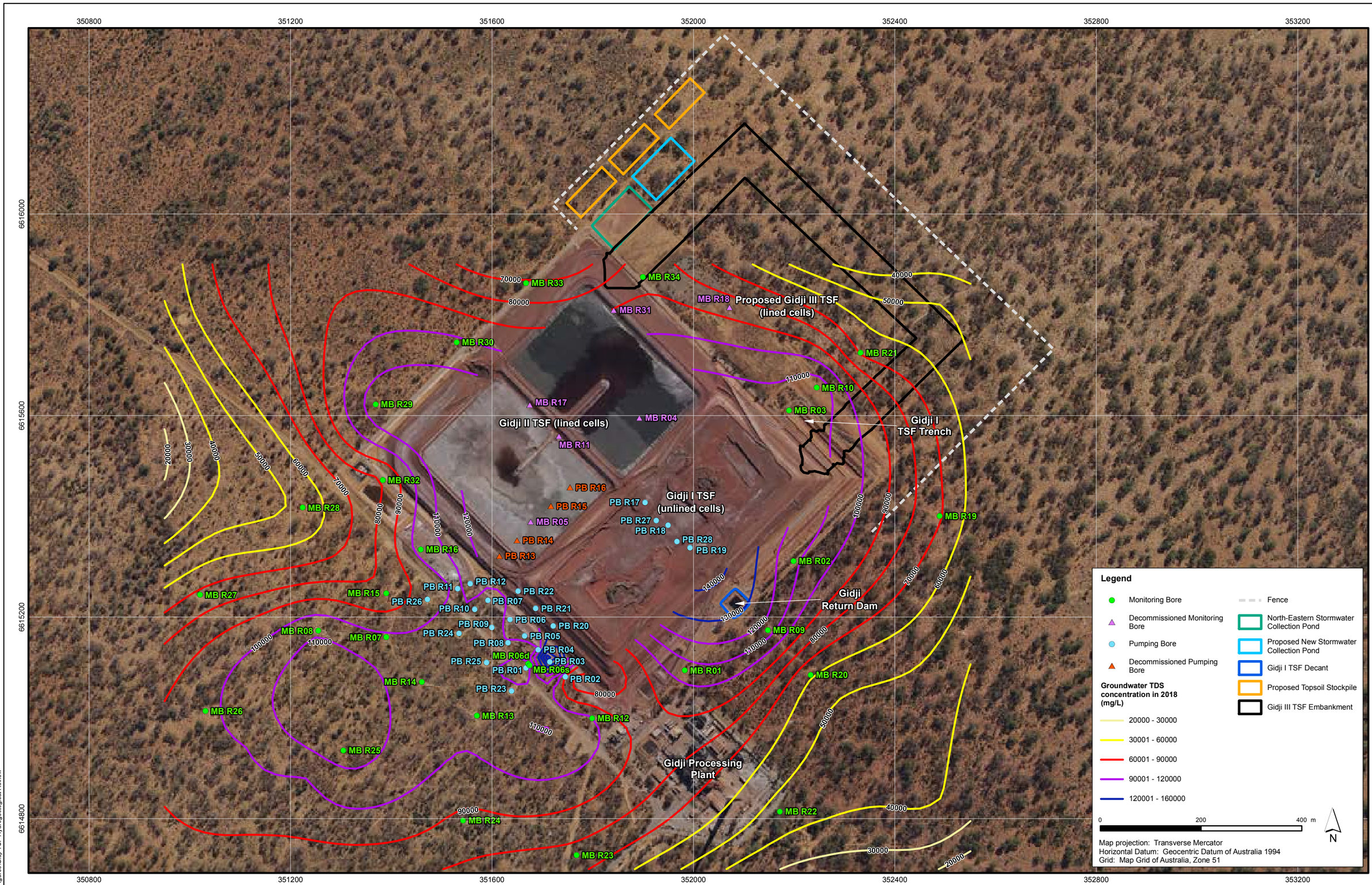
BIG DOG HYDROGEOLOGY

Laboratory pH distribution in 2018

Figure 31

Date: January 2019

Report: Gidji TSF Hydrogeological Review



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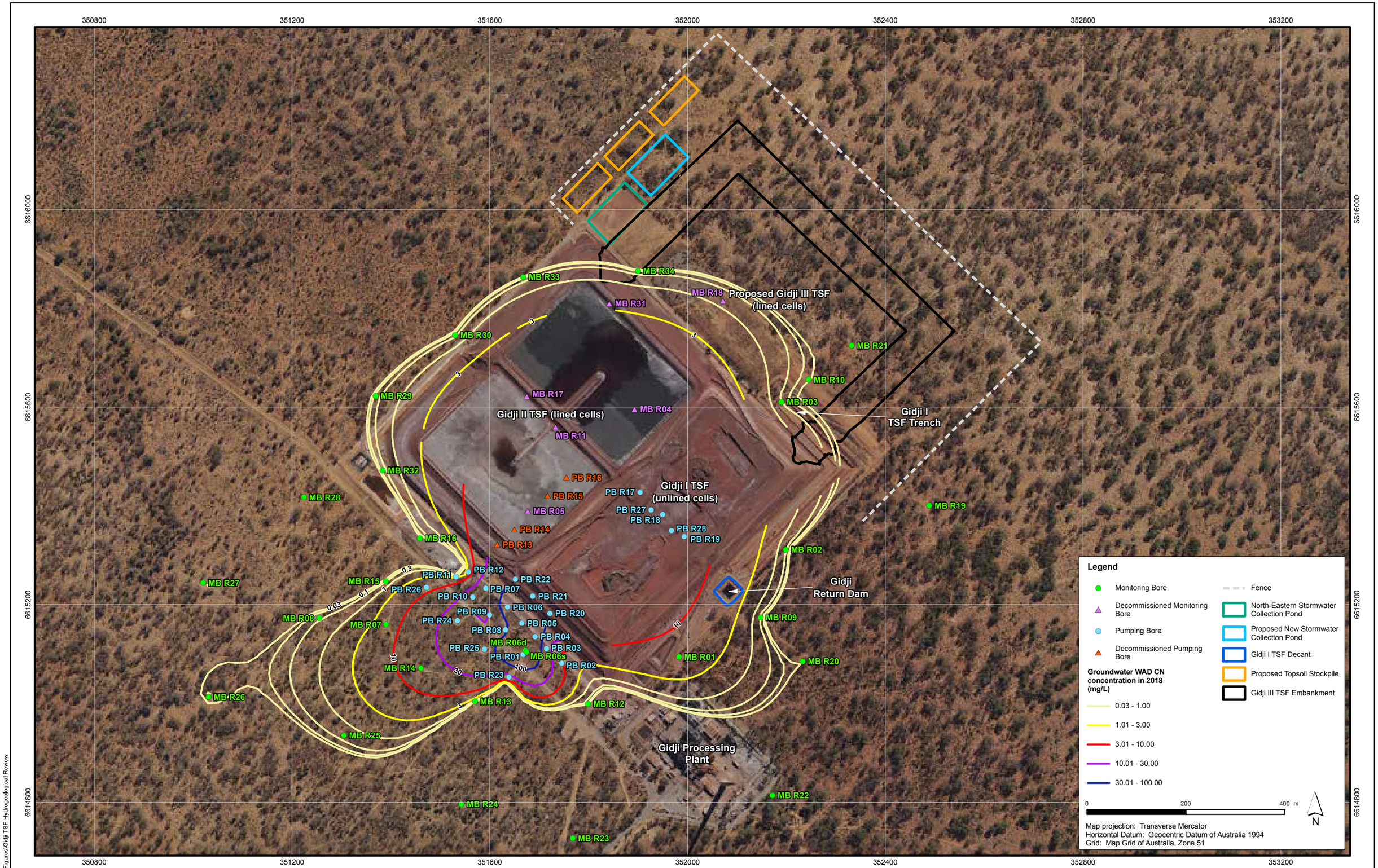
BIG DOG HYDROGEOLOGY

TDS distribution in 2018

Figure 32

Date: January 2019

Report: Gidji TSF Hydrogeological Review



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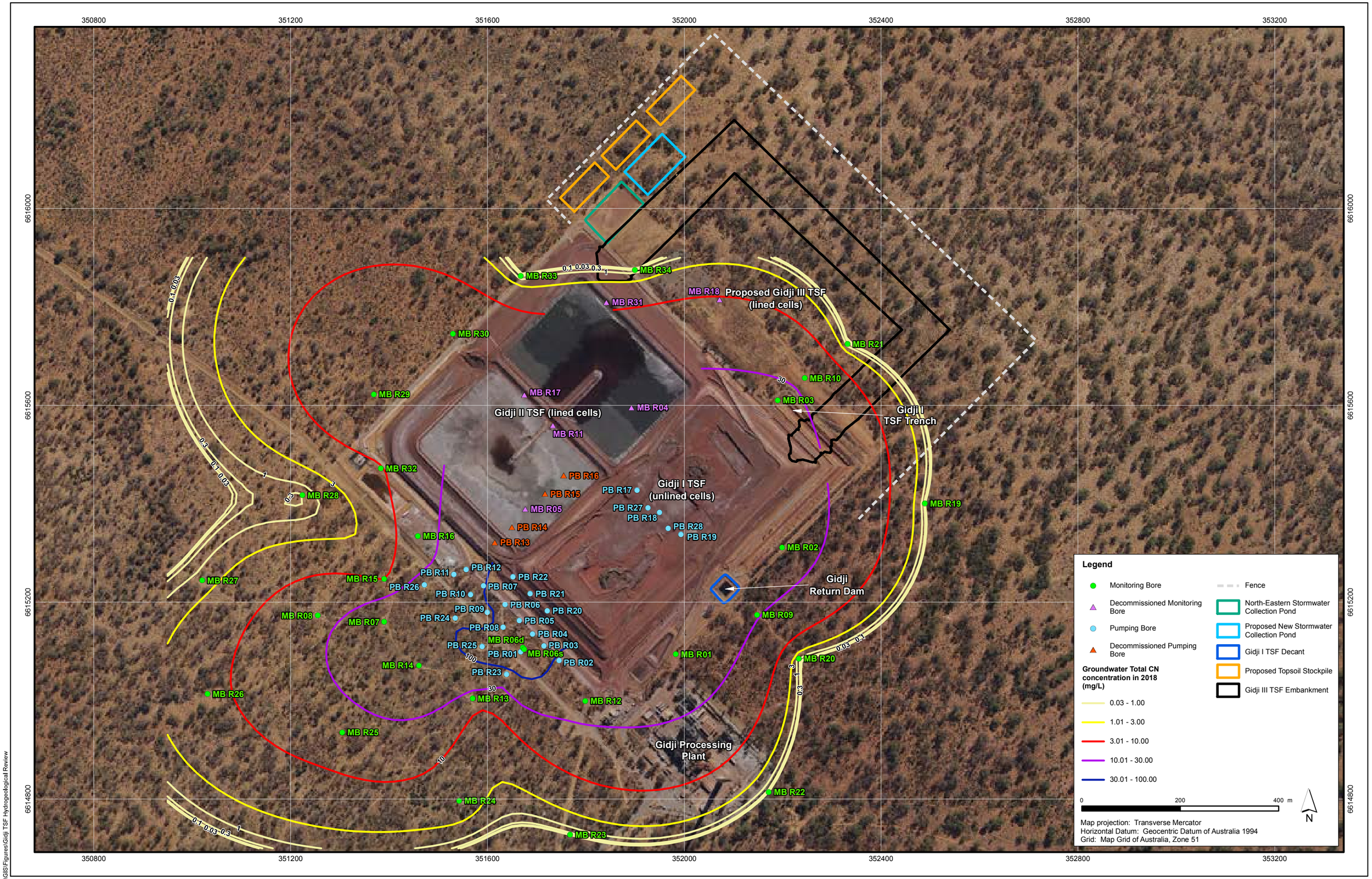
BIG DOG HYDROGEOLOGY

WAD CN distribution in 2018

Figure 33

Date: January 2019

Report: Gidji TSF Hydrogeological Review



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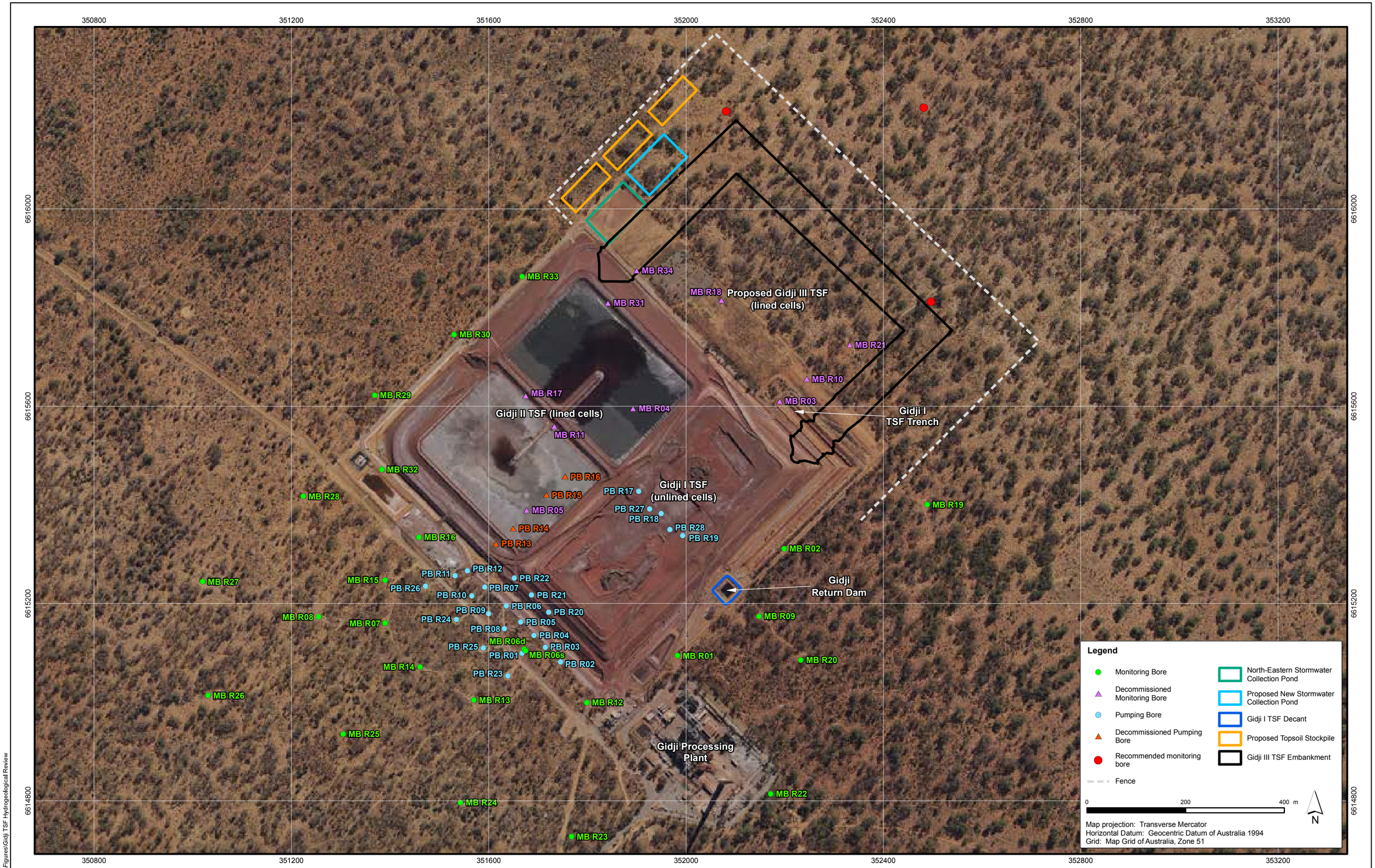
BIG DOG HYDROGEOLOGY

Total CN distribution in 2018

Figure 34

Date: January 2019

Report: Gidji TSF Hydrogeological Review



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BIG DOG HYDROGEOLOGY

Recommended monitoring for Gidji III TSF

Figure 35

Date: January 2019

Report: Gidji TSF Hydrogeological Review

Appendix A
DWER licence L5946/1988/13

Government of Western Australia
Department of Environment Regulation

Amendment Notice 1

LIC1866

Licence Number	L5946/1988/13
Licence Holder	Kalgoorlie Consolidated Gold Mines Pty Ltd
ACN	009 377 619
Registered business address	Black Street KALGOORLIE WA 6430
Date of amendment	5 October 2016
Prescribed Premises	Category 5: Processing or beneficiation of metallic or non-metallic ore
Premises	Gidji Processing Plant Tenements G24/24-33 KALGOORLIE WA 6430

Amendment

The Chief Executive Officer (CEO) of the Department of Environment Regulation (DER) has amended the above licence in accordance with section 59 of the *Environmental Protection Act 1986* as set out in this Amendment Notice.

Jonathan Bailes

Manager Licensing (Process Industries)

an officer delegated under section 20 of the Environmental Protection Act 1986 (WA)

Amendment Notice

This notice is issued under section 59 of the *Environmental Protection Act* 1986 (EP Act) to amend the licence issued under the EP Act for a prescribed premises as set out below. This notice of amendment is given under section 59B(9) of the EP Act.

Amendment Description

Licence L5946/1988/13 was granted by DER on 26 September 2015. The licence was last amended on 21 April 2016 to remove metal smelting activities (ore roasting) which are no longer carried out. Ore roasting has been replaced by the use of Ultra-Fine Grinding (UFG) Mills commissioned in 2001 (10tph mill) and 2015 (30tph mill).

The Licence Holder has submitted an application to amend the licence in accordance with Ministerial Statement No. 1032 (MS1032) issued by the Environmental Protection Authority (EPA) on 30 June 2016. The Ministerial Statement approves an increase in production throughput from 351,000tpa to 438,000tpa.

The use of the UFG Mills has resulted in efficiency gains which enable the premises to process approximately 25% more ore using the existing infrastructure.

The amendment application also included a request to remove vegetation monitoring requirements near the premises Tailings Storage Facility as specified in condition 2.2.1. Other minor administrative amendments have also been made.

Decision

Increase in throughput capacity

The increased throughput authorised by MS1032 will result in an increased rate of discharge of tailings to the Gidji II Tailings Storage Facility (TSF). The main environmental risks associated with an increased discharge of tailings to the Gidji II TSF relate to potential increased seepage from the base and walls of the TSF and overtopping of the TSF.

These risks are mitigated by the design of the TSF which is regulated by the Department of Mines and Petroleum, and who also require an annual audit and assessment of the structural stability of the TSF. The TSF is designed using the downstream method of construction meaning that there is no requirement to allow the tailings to dry and consolidate prior to raise construction.

The Gidji II TSF has a containment capacity of 2.2Mt at a dry density of 1.6t/m^3 (Golder Associates, August 2015). A revised water balance for the increase production shows that there will be an increase in supernatant return that will require treatment in the cyanide destruction plant.

The TSF will be managed according to the *Kalgoorlie Consolidated Gold Mines Gidji Tailings Storage Facilities Operating manual- October 2015 Update* (Golder Associates, November 2015).

Condition 1.2.2 of the licence requires the Licence Holder to maintain an operating freeboard of 300mm in the TSF cells and the supernatant return water dam. Condition 1.2.3 requires six-hourly visual inspections of the tailings and supernatant return water lines, ponding on the surface of the TSF, maintenance of the freeboard, and integrity of the external walls of the TSF. Where an issue is identified, corrective action is

required to be undertaken to mitigate environmental impacts.

The Gidji II TSF was constructed with a composite clay and HDPE liner with a permeability of less than $1x10^{-9}$ m/s. The TSF also has an over-liner drainage system to maximise the recovery of seepage within the TSF. Seepage from the TSF is also managed by the use of groundwater production bores and compliance monitoring bores that limit the extent to which ambient groundwater levels rise within the vicinity of the TSF in accordance with licence condition 1.2.4.

The Delegated Officer considers these control measures to be adequate to manage the risks associated with an increase in tailings generated as a consequence of the increased production throughput capacity.

Vegetation Monitoring

Vegetation monitoring has been conducted at the site since 1999 to determine if groundwater mounding resulting from seepage from the Gidji I TSF is causing impacts on vegetation growth. The Gidji I TSF was lined with a clay base, and a series of groundwater production bores and seepage trenches were used to manage and recover seepage from this TSF. A series of targets and limits for water quality and standing water levels were incorporated into the licence requiring management action to prevent ambient groundwater levels from reaching the root zone of vegetation. The Licence Holder has requested that vegetation monitoring is removed from the licence as current groundwater abstraction and monitoring controls have demonstrated that the impact to vegetation from seepage can be adequately managed by controlling the groundwater levels in the vicinity of the Gidji I TSF.

The Delegated Officer accepts that the use of groundwater production bores and seepage trenches has been an effective measure in mitigating environmental impacts and that the continuation of vegetation monitoring is no longer required. Furthermore, tailings deposition is no longer occurring in the Gidji I TSF, and the newly commissioned Gidji II TSF is appropriately lined and contains an over drainage layer which will significantly reduce groundwater mounding beneath the TSFs. Quarterly groundwater monitoring results since the closure of the Gidji I TSF indicate a decrease in groundwater mounding beneath the TSFs which is expected to decrease further over time.

The Delegated Officer has removed the vegetation monitoring requirements on the basis of the above and that the vegetation monitoring carried out to date has not demonstrated any impacts such as declining vegetation health over the groundwater mounding risk areas.

Administrative Amendments

The Delegated Officer has made minor administrative amendments to correct typographical errors and remove improvement condition 3.1.1 as the Dust Management Plan was submitted to DER on the 4 July 2016 and assessed as meeting the requirements of the condition.

Amendment History

Instrument	Issued	Amendment
L5946/1988/13	26/09/2014	Licence re-issue
L5946/1988/13	4/12/ 2014	Licence amendment to increase plant throughput capacity from 225,000 tonnes to 351,000 tonnes per annum and to allow for the use of Gidji I TSF.
L5946/1988/13	21/04/ 2016	Licence amendment to remove metal smelting or refining and the Gidji I TSF for deposition of tailings. The vehicle wash down bay is also removed. The licence has also been amended to extend the duration of the licence in accordance with DER's *Guidance Statement on Licence Duration.*
L5946/1988/13	5/10/2016	Amendment Notice 1 Amended to increase the approved throughput capacity, and remove the requirements for vegetation monitoring and the improvement condition requiring the submission of a dust management plan.

Amendment

1. The approved licence production or design capacity is amended from *351,000 tonnes per annual period* to *438,000 tonnes per annual period*.

2. Condition 2.1.2 of the licence is amended by the insertion of the red text shown in underline below:

   2.1.2 The Licensee shall ensure that:
   (a) quarterly monitoring is undertaken at least 45 days apart;
   (b) six monthly monitoring is undertaken at least 5 months apart; and
   (c) annual monitoring is undertaken at least 9 months apart.

3. Condition 2.2.1 of the licence is amended by the by the deletion of the text shown in strikethrough below and the insertion of the red text shown in underline below:

   2.2.1 The Licensee shall undertake monitoring in ~~Tables 2.2.1 and 2.2.2~~ Table 2.2.2 according to the specifications in ~~these tables~~ that table.

4. The licence is amended by the deletion of the following Table 2.2.1:

Table 2.2.1: Monitoring of vegetation			
Purpose	*Monitoring Reference*	*Parameter*	*Frequency*
Monitor the vegetation in the vicinity of the Gidji roaster to identify if there is any detrimental impacts on vegetation caused by seepage from the TSFs	*1, 2, 6, 7, 8, 9, 12, 13, 14, 15 as shown on the map of TSF photographic monitoring locations in Schedule 1*	*Photographs of vegetation at monitoring points associated with monitoring bores or identifiable field markers. Photographs are to be taken at a fixed focal length and away from the TSFs to standardise information gained.*	*Annually (between 1 September and 30 November)*

5. The licence is amended by the deletion of the following condition 3.1.1:

3.1.1 The Licensee shall complete the improvement in Table 3.1.1 by the date of completion in Table 3.1.1.

Table 3.1.1: Improvement program		
Improvement reference	*Improvement*	*Date of completion*
IR1	*The Licensee shall submit to the CEO a Dust Management Plan (DMP) covering the management of dust onsite that may potentially cause a risk to the environment. As a minimum the DMP shall include:* • *A review of the adequacy of current dust management practices and provide recommendations for changes to operating procedures or monitoring if required.* • *Standard operational procedures (SOPs) for the identification, assessment and management actions for fugitive dust emissions; and* • *Identification of roles and responsibilities under the DMP.* *The Licensee shall implement the DMP.*	*31 July 2016*

6. Table 4.2.1 of the licence is amended by the deletion of the text shown in strikethrough below and the insertion of the red text shown in underline below:

Table 4.2.1: Annual Environmental Report		
Condition or table (if relevant)	Parameter	Format or form[1]
-	Summary of any failure or malfunction of any pollution control equipment that has resulted in any reportable environmental incidents that have occurred during the annual period and any action taken	None specified
~~Table 2.2.1~~	~~TSF Photographic Vegetation Monitoring Programme including an assessment of the vegetation by a person with tertiary or post-secondary qualifications in plant ecology, botanical or environmental studies.~~	
4.1.3	Compliance	Annual Audit Compliance Report (AACR)
4.1.4	Complaints summary	None specified
Table ~~5.2.2~~ 4.2.2	Reference non annual reporting data and provide a summary of the key findings and recommendations	
Table ~~5.3.1~~4.3.1	Summary of any saline, alkaline or cyanide constituent spills greater than 5000L that escaped from pipeline bunding	

Note 1: Forms are in Schedule 2

7. Table 4.2.2 of the licence is amended by the by the deletion of the text shown in strikethrough below and the insertion of the red text shown in underline below:

Table 4.2.2: Non-annual reporting requirements				
Condition or table (if relevant)	Parameter	Reporting period	Reporting date (after end of the reporting period)	Format or form
2.1.3	Calibration	Available on request	14 calendar days	None specified
-	Copies of original monitoring reports submitted to the Licensee by third parties	Not Applicable	Within 14 days of the CEO's request	As received by the Licensee from third parties
Table 2.2.2	Groundwater monitoring including summary of any limit ~~target~~ exceedances	Quarterly	46 calendar days	None specified

Government of Western Australia
Department of Environment Regulation

Licence

Environmental Protection Act 1986, Part V

Licensee: Kalgoorlie Consolidated Gold Mines Pty Ltd

Licence: L5946/1988/13

Registered office:	Kalgoorlie Consolidated Gold Mines Pty Ltd Black Street KALGOORLIE WA 6430
ACN:	009 377 619
Premises address:	Gidji Processing Plant Tenements G24/24-33 KALGOORLIE WA 6430
Issue date:	Friday, 26 September 2014
Commencement date:	Monday, 29 September 2014
Expiry date:	Saturday, 28 September 2029

Prescribed premises category
Schedule 1 of the *Environmental Protection Regulations 1987*

Category number	Category description	Category production or design capacity	Approved Premises production or design capacity
5	Processing or beneficiation of metallic or non-metallic ore	50 000 tonnes or more per year	351,000 tonnes per annual period

438,000

Conditions
This Licence is subject to the conditions set out in the attached pages.

.....
Jonathan Bailes
Manager Licensing (Process Industries)
Officer delegated under section 20
of the *Environmental Protection Act 1986*

Contents

Introduction 2
Licence conditions 5
1 General 5
2 Monitoring 8
3 Improvements 9
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Schedule 1: Maps 12
Schedule 2: Reporting & notification forms 17

Introduction

This Introduction is not part of the Licence conditions.

DER's industry licensing role
The Department of Environment Regulation (DER) is a government department for the state of Western Australia in the portfolio of the Minister for Environment. DER's purpose is to advise on and implement strategies for a healthy environment for the benefit of all current and future Western Australians.

DER has responsibilities under Part V of the *Environmental Protection Act 1986* (the Act) for the licensing of prescribed premises. Through this process DER regulates to prevent, control and abate pollution and environmental harm to conserve and protect the environment. DER also monitors and audits compliance with works approvals and licence conditions, takes enforcement action as appropriate and develops and implements licensing and industry regulation policy.

Licence requirements
This Licence is issued under Part V of the Act. Conditions contained within the Licence relate to the prevention, reduction or control of emissions and discharges to the environment and to the monitoring and reporting of them.

Where other statutory instruments impose obligations on the Premises/Licensee the intention is not to replicate them in the licence conditions. You should therefore ensure that you are aware of all your statutory obligations under the Act and any other statutory instrument. Legislation can be accessed through the State Law Publisher website using the following link:
http://www.slp.wa.gov.au/legislation/statutes.nsf/default.html

For your Premises relevant statutory instruments include but are not limited to obligations under the:

- *Environmental Protection (Unauthorised Discharges) Regulations 2004* – these regulations make it an offence to discharge certain materials such as contaminated stormwater into the environment other than in the circumstances set out in the regulations.
- *Environmental Protection (Controlled Waste) Regulations 2004* - these regulations place obligations on you if you produce, accept, transport or dispose of controlled waste.
- *Environmental Protection (Noise) Regulations 1997* – these regulations require noise emissions from the Premises to comply with the assigned noise levels set out in the regulations.

You must comply with your licence. Non-compliance with your licence is an offence and strict penalties exist for those who do not comply.

Licence holders are also reminded of the requirements of section 53 of the Act which places restrictions on making certain changes to prescribed premises unless the changes are in accordance with a works approval, licence, closure notice or environmental protection notice.

Licence fees
If you have a licence that is issued for more than one year, you are required to pay an annual licence fee prior to the anniversary date of issue of your licence. Non payment of annual licence fees will result in your licence ceasing to have effect meaning that it will no longer be valid and you will need to apply for a new licence for your Premises.

Ministerial conditions
If your Premises has been assessed under Part IV of the Act you may have had conditions imposed by the Minister for Environment. You are required to comply with any conditions imposed by the Minister.

Premises description and Licence summary
Kalgoorlie Consolidated Gold Mines Ltd (KCGM) operates the Fimiston open pit, Mt Charlotte underground mine, Fimiston mill, and Gidji Processing Plant on behalf of joint venture owners Barrick Ltd (Australia Pacific) and Newmont Asia Pacific Ltd (Newmont).

The Gidji Processing Plant, located 17 kilometres north of Kalgoorlie-Boulder, treats refractory gold sulphide concentrate produced by the Fimiston mill. The purpose of this amendment is to remove metal smelting or refining from the licence. The Licensee also applied to increase the throughput of 351,000 to 438,000 tonnes per annual period however this was not assessed on the basis that this increase needs to be approved under Part IV of *The Environmental Protection Act 1986* and any approved increase reflected in Ministerial Statement Nos. 77 and 28. This Part IV amendment is delayed, and the Licensee has requested that the parts of the application which do not require amendment of the Ministerial Statement to be processed. A separate application will be made for the increased to throughput following the finalisation of the Part IV process.

Historically, the sulphide ore was initially roasted to oxidate the sulphide which in turn allowed the fine gold particles to be dissolved once the ore was placed into cyanide solution. In order to reduce gaseous emissions to air, the site undertook an Emissions Reduction Project under Works Approval W5659/2014/1. This involved the replacement of the two 20 tonne per hour roasters with one 30 tonne per hour Ultrafine Grinding Mill (UFG) to process refractory ore from Fimiston. This is in addition to the existing 10 tonne per hour UFG mill, maintaining the sites 40 tonne per hour processing of refractory ore. The two roasters ceased operating on 26 January 2015 and 5 April 2015 respectively. This Licence amendment removes reference to all point source air emissions and associated monitoring requirements. Additionally ambient monitoring requirements in accordance with the *Environmental Protection (Goldfields Residential Areas) (Sulfur Dioxide) Policy 2003* are also no longer relevant to this licence.

The tailings from the cyanide leach and carbon-in-pulp adsorption process is sent to the Gidji Tailings Storage Facilities (TSFs). Currently, two cells are in operation, Gidji II (east) and Gidji II (west). These cells were commissioned in 2012 and 2014 respectively. Associated infrastructure supporting the process plant includes access tracks, borefields (production and monitoring bores), water storage ponds, transfer ponds and seepage interception trench. This amendment includes the removal of the Gidji I TSF as an approved tailing deposition area. Under a previous licence amendment (4 December 2014), DER agreed to allow the use of the use of the Gidji I TSF as an interim measure until the TSF reached its maximum capacity or until the new UFG mill was commissioned (whichever came first).

This amendment also removes reference to the vehicle wash down bays from the licence as no vehicles are washed down at the Gidji facility. This was confirmed through DER's Inspection of the premises on 25 March 2015.

Other changes have also been made to reflect administrative changes implemented within DER.

The licences and works approvals issued for the Premises since 1/10/2007 are:

Instrument log		
Instrument	Issued	Description
L5946/1988/10	1 October 2007	Licence re-issue
L5946/1988/11	29 September 2009	Licence re-issue
W4862/2011/1	4 April 2011	Works Approval for Gidji TSF extension
L5946/1988/12	1 December 2011	Licence re-issue and amendment to some condition wording
L5946/1988/12	19 April 2012	Licence amendment due to commissioning of TSF II East Cell
L5946/1988/12	12 June 2014	Licence amendment due to commissioning of TSF II West Cell
W5659/2014/1	26 June 2014	Works Approval for Emissions Reduction Program (install Ultra Fine Grinding (UFG) mill)
L5946/1988/13	26 September 2014	Licence re-issue, conversion to REFIRE format and TSF seepage and groundwater monitoring amendments
L5946/1988/13	4 December 2014	Licence amendment to increase plant throughput capacity from 225,000 tonnes to 351,000 tonnes per annum and to allow for the use of Gidji I TSF.
L5946/1988/13	21 April 2016	Licence amendment to remove metal smelting or refining and the Gidji I TSF for deposition of tailings. The vehicle wash down bay is also removed. The licence has also been amended to extend the duration of the licence in accordance with DER's *Guidance Statement on Licence Duration.*

Severance

It is the intent of these Licence conditions that they shall operate so that, if a condition or a part of a condition is beyond the power of this Licence to impose, or is otherwise *ultra vires* or invalid, that condition or part of a condition shall be severed and the remainder of these conditions shall nevertheless be valid to the extent that they are within the power of this Licence to impose and are not otherwise *ultra vires* or invalid.

END OF INTRODUCTION

Licence conditions

1 General

1.1 Interpretation

1.1.1 In the Licence, definitions from the *Environmental Protection Act 1986* apply unless the contrary intention appears.

1.1.2 For the purposes of this Licence, unless the contrary intention appears:

'Act' means the *Environmental Protection Act 1986;*

'annual' means the inclusive period from 1 January until 31 December in that year;

'AS/NZS 5667.1' means the Australian Standard AS/NZS 5667.1 *Water Quality – Sampling – Guidance of the Design of sampling programs, sampling techniques and the preservation and handling of samples;*

'AS/NZS 5667.11' means the Australian Standard AS/NZS 5667.11 *Water Quality – Sampling – Guidance on sampling of groundwaters;*

'averaging period' means the time over which a limit is measured or a monitoring result is obtained;

'CEO' means Chief Executive Officer of the Department of Environment Regulation;

'CEO' for the purpose of correspondence means:

Chief Executive Officer
Department Administering the *Environmental Protection Act 1986*
Locked Bag 33
CLOISTERS SQUARE WA 6850
Email: info@der.wa.gov.au

'CN-free' means free cyanide;

'CN-total' means total cyanide;

'CN-WAD' means weak acid dissociable cyanide;

'compliance bores' means those compliance monitoring bores listed in Table 2.2.2 and at the locations depicted in Schedule 1: Maps-Gidji operations monitoring bore location:

'environmentally hazardous material' means material (either solid or liquid raw materials, materials in the process of manufacture, manufactured products, products used in the manufacturing process, by-products and waste) which if discharged into the environment from or within the premises may cause pollution or environmental harm. Note: Environmentally hazardous materials include dangerous goods where they are stored in quantities below placard quantities. The storage of dangerous goods above placard quantities is regulated by the Department of Mines and Petroleum;

'freeboard' means the distance between the maximum water surface elevations and the top of retaining banks or structures at their lowest point;

'Licence' means this Licence numbered L5946/1998/13 and issued under the Act;

'Licensee' means the person or organisation named as Licensee on page 1 of the Licence;

'mm' means millimetre;

'mg/L' means milligrams per litre;

'NATA' means the National Association of Testing Authorities, Australia;

'NATA accredited' means in relation to the analysis of a sample that the laboratory is NATA accredited for the specified analysis at the time of the analysis;

'Premises' means the area defined in the Premises Map in Schedule 1 and listed as the Premises address on page 1 of the Licence;

'quarterly' means the 4 inclusive periods from 1 January to 31 March, 1 April to 30 June, 1 July to 30 September and 1 October to 31 December in that year;

'Schedule 1' means Schedule 1 of this Licence unless otherwise stated;

'Schedule 2' means Schedule 2 of this Licence unless otherwise stated;

'six monthly' means the 2 inclusive periods from 1 January to 30 June and 1 July to 31 December in that year;

'spot sample' means a discrete sample representative at the time and place at which the sample is taken;

'SWL' means standing water level;

'TSF' means an engineered containment pond or dam used to store tailings, i.e. a tailings storage facility;

'TDS' means total dissolved solids

'usual working day' means 0800 – 1700 hours, Monday to Friday excluding public holidays in Western Australia; and

'µS/cm' means microsiemens per centimetre.

1.1.3 Any reference to an Australian or other standard in the Licence means the relevant parts of the standard in force from time to time during the term of this Licence.

1.1.4 Any reference to a guideline or code of practice in the Licence means the version of that guideline or code of practice in force from time to time and shall include any amendments or replacements to that guideline or code of practice made during the term of this Licence.

1.2 Premises operation

1.2.1 The Licensee shall ensure that all pipelines containing environmentally hazardous materials are either:
(a) equipped with automatic cut-outs in the event of a pipe failure; or
(b) provided with secondary containment sufficient to contain any spill for a period equal to the time between routine inspections.

1.2.2 The Licensee shall ensure that waste material is only stored and/or treated within vessels or compounds provided with the infrastructure detailed in Table 1.2.2.

Table 1.2.2: Containment infrastructure		
Storage vessel or compound and location in map of storage locations in Schedule 1	Material	Requirements
Gidji II TSF East Cell	Tailings	HDPE lined with under drainage layer, netted during tailings deposition Minimum freeboard of 300mm
Gidji II TSF West Cell		HDPE lined with under drainage layer, netted during tailings deposition Minimum freeboard of 300mm
Production water dam Return water dam	Any substance containing saline, alkaline or cyanide constituents resulting from activities on the Premises	HDPE lined, netted Minimum freeboard of 300mm

1.2.3 The Licensee shall:

(a) undertake inspections as detailed in Table 1.2.3;

(b) take corrective action to mitigate adverse environmental consequences as soon as practicable, where any inspection identifies that an appropriate level of environmental protection is not being maintained; and

(c) maintain a record of all inspections undertaken.

Table 1.2.3: Inspection of infrastructure		
Scope of inspection	Type of inspection	Frequency of inspection[1]
Tailings pipelines	Visual integrity	Every 6 hours during operations
Return water lines		
Tailings deposition	Visual	
Ponding on the surface of the TSF	Visual to confirm location of the pond	
Freeboard	Visual to confirm required freeboard capacity is available	
External wall of the TSF	Visual integrity	

Note 1: If circumstances at the scheduled time of inspection are identified as immediately hazardous to personnel the inspection should be undertaken as soon as practicable and the reason(s) recorded.

1.2.4 The Licensee shall install and maintain groundwater production bores to control the impact of seepage on groundwater levels such that the ambient groundwater water level limit measured in compliance monitoring bores are met.

2 Monitoring

2.1 General monitoring

2.1.1 The licensee shall ensure that:
(a) all water samples are collected and preserved in accordance with AS/NZS 5667.1;
(b) all groundwater sampling is conducted in accordance with AS/NZS 5667.11; and
(c) all laboratory samples are submitted to and tested by a laboratory with current NATA accreditation for the parameters being measured.

2.1.2 The Licensee shall ensure that:
(a) quarterly monitoring is undertaken at least 45 days apart;
(b) six monthly monitoring is undertaken at least 5 months apart; and
(c) annual monitoring is undertaken at least 9 months apart.

2.1.3 The Licensee shall ensure that all monitoring equipment used on the Premises to comply with the conditions of this Licence is calibrated in accordance with the manufacturer's specifications or any relevant and effective internal management system.

2.1.4 The Licensee shall, where the requirements for calibration cannot be practicably met, or a discrepancy exists in the interpretation of the requirements, bring these issues to the attention of the CEO accompanied with a report comprising details of any modifications to the methods.

2.2 Ambient environmental quality monitoring

2.2.1 The Licensee shall undertake monitoring in Tables 2.2.1 and 2.2.2 according to the specifications in those tables.

Table 2.2.1: Monitoring of vegetation

Purpose	Monitoring Reference	Parameter	Frequency
Monitor the vegetation in the vicinity of the Gidji roaster to identify if there is any detrimental impacts on vegetation caused by seepage from the TSFs	1, 2, 6, 7, 8, 9, 12, 13, 14, 15 as shown on the map of TSF photographic monitoring locations in Schedule 1	Photographs of vegetation at monitoring points associated with monitoring bores or identifiable field markers. Photographs are to be taken at a fixed focal length and away from the TSFs to standardise information gained.	Annually (between 1 September and 30 November)

Table 2.2.2: Monitoring of ambient groundwater quality					
Monitoring point reference and location on map of groundwater monitoring locations in Schedule 1	Parameter	Limit	Units	Averaging period	Frequency
Gidji Trench, Gidji Return Dam	pH[1]	-	-	Spot sample	Annually
	Electrical conductivity[1]		µS/cm		
	TDS	-	mg/L		Annually
	CN-free				
	CN-WAD				
	CN- total				
Compliance Monitoring bores MBR7,MBR8, MBR13-MBR15, MBR19-MBR28, MBR34	Standing water level (SWL)[1]	4	mbgl	Spot sample	Quarterly
	pH[1]	-	-		Six monthly
	Electrical conductivity[1]		µS/cm		
	TDS	-	mg/L		Annually
	CN-free				
	CN-WAD				
	CN- total				
Operational area monitoring bores MBR1–MBR3, MBR6d,MBR6s, MBR9,MBR10, MBR12, MBR16, MBR29,MBR30, MBR32,MBR33	Standing water level (SWL)[1]	-	mbgl	Spot sample	Quarterly
	pH[1]		-		Six monthly
	Electrical conductivity[1]		µS/cm		
	TDS		mg/L		Annually
	CN-free				
	CN-WAD				
	CN- total				

Note 1: In-field non-NATA accredited sampling permitted

3 Improvements

3.1.1 The Licensee shall complete the improvement in Table 3.1.1 by the date of completion in Table 3.1.1.

Table 3.1.1: Improvement program		
Improvement reference	Improvement	Date of completion
IR1	The Licensee shall submit to the CEO a Dust Management Plan (DMP) covering the management of dust onsite that may potentially cause a risk to the environment. As a minimum the DMP shall include: • A review of the adequacy of current dust management practices and provide recommendations for changes to operating procedures or monitoring if required. • Standard operational procedures (SOPs) for the identification, assessment and management actions for fugitive dust emissions; and • Identification of roles and responsibilities under the DMP. The Licensee shall implement the DMP.	31 July 2016

4 Information

4.1 Records

4.1.1 All information and records required by the Licence shall:
- (a) be legible;
- (b) if amended, be amended in such a way that the original and subsequent amendments remain legible or are capable of retrieval;
- (c) except for records listed in 4.1.1(d) be retained for at least 6 years from the date the records were made or until the expiry of the Licence or any subsequent licence; and
- (d) for those following records, be retained until the expiry of the Licence and any subsequent licence:
  - (i) off-site environmental effects; or
  - (ii) matters which affect the condition of the land or waters.

4.1.2 The Licensee shall complete an Annual Audit Compliance Report indicating the extent to which the Licensee has complied with the conditions of the Licence, and any previous licence issued under Part V of the Act for the Premises for the previous annual period.

4.1.3 The Licensee shall implement a complaints management system that as a minimum records the number and details of complaints received concerning the environmental impact of the activities undertaken at the Premises and any action taken in response to the complaint.

4.2 Reporting

4.2.1 The Licensee shall submit to the CEO an Annual Environmental Report by 31 March after the end of the annual period. The report shall contain the information listed in Table 4.2.1 in the format or form specified in that table.

Table 4.2.1: Annual Environmental Report

Condition or table (if relevant)	Parameter	Format or form[1]
-	Summary of any failure or malfunction of any pollution control equipment that has resulted in any reportable environmental incidents that have occurred during the annual period and any action taken	None specified
Table 2.2.1	TSF Photographic Vegetation Monitoring Programme including an assessment of the vegetation by a person with tertiary or post-secondary qualifications in plant ecology, botanical or environmental studies.	
4.1.3	Compliance	Annual Audit Compliance Report (AACR)
4.1.4	Complaints summary	None specified
Table 5.2.2	Reference non annual reporting data and provide a summary of the key findings and recommendations	
Table 5.3.1	Summary of any saline, alkaline or cyanide constituent spills greater than 5000L that escaped from pipeline bunding	

Note 1: Forms are in Schedule 2

4.2.2 The Licensee shall ensure that the Annual Environmental Report also contains an assessment of the information contained within the report against previous monitoring results.

4.2.3 The Licensee shall submit the information in Table 4.2.2 to the CEO according to the specifications in that table.

Table 4.2.2: Non-annual reporting requirements

Condition or table (if relevant)	Parameter	Reporting period	Reporting date (after end of the reporting period)	Format or form
2.1.3	Calibration	Available on request	14 calendar days	None specified
-	Copies of original monitoring reports submitted to the Licensee by third parties	Not Applicable	Within 14 days of the CEO's request	As received by the Licensee from third parties
Table 2.2.2	Groundwater monitoring including summary of any target exceedances	Quarterly	46 calendar days	None specified

4.3 Notification

4.3.1 The Licensee shall ensure that the parameters listed in Table 4.3.1 are notified to the CEO in accordance with the notification requirements of the table.

Table 4.3.1: Notification requirements

Condition or table (if relevant)	Parameter	Notification requirement[1]	Format or form[2]
-	Any spills of environmentally hazardous materials greater than 250L occurring in locations that may adversely impact on the environment	As soon as practicable but no later than 5pm of the next usual working day	None specified
-	Any liquid spills greater than 5000L containing saline, alkaline or cyanide constituents that escape from overland pipeline bunding		
2.1.1	Breach of any limit specified in the Licence	Part A: As soon as practicable but no later than 5pm of the next usual working day. Part B: As soon as practicable	N1
2.1.4	Calibration report	As soon as practicable.	None specified

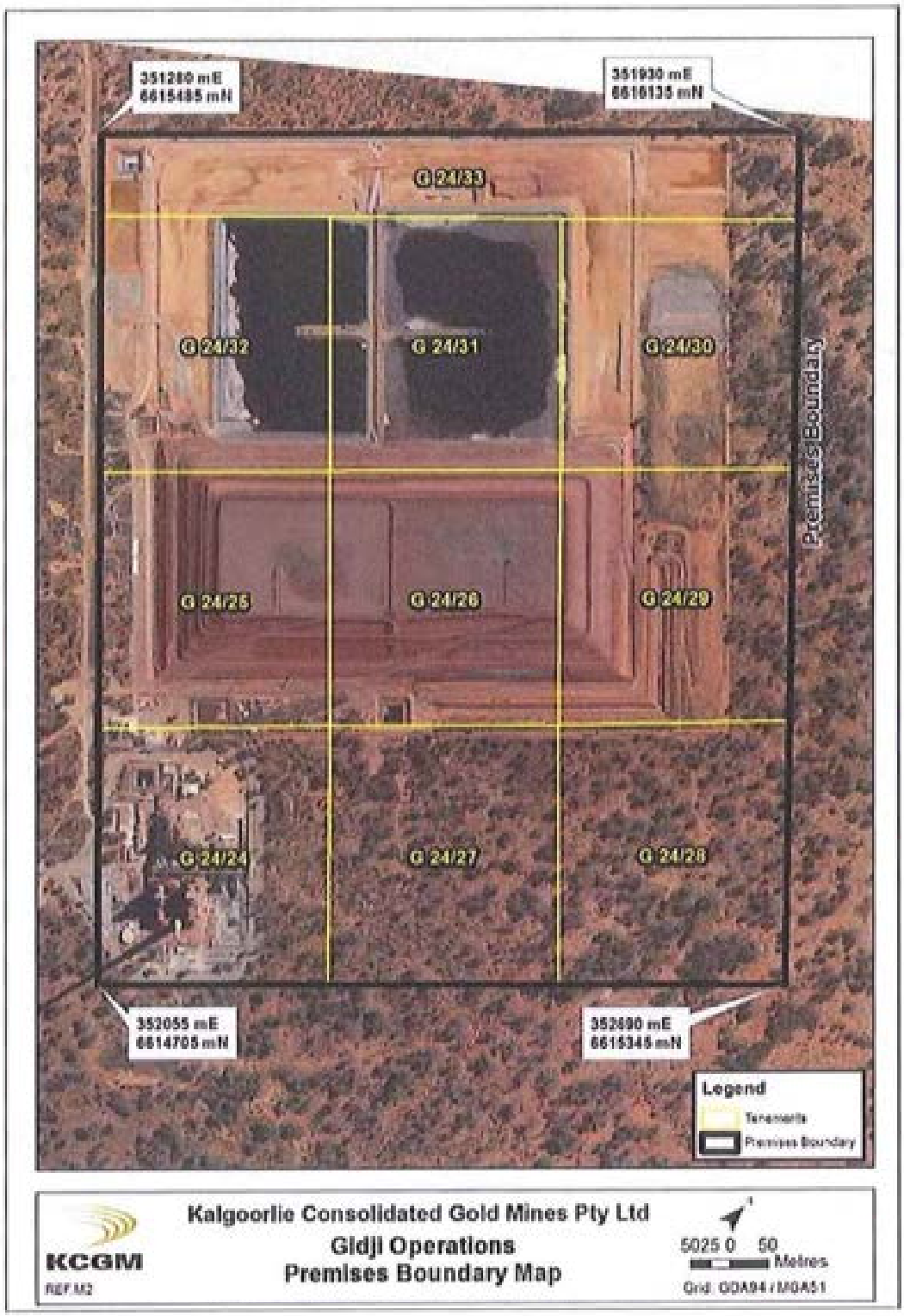
Note 1: Notification requirements in the Licence shall not negate the requirement to comply with s72 of the Act

Note 2: Form N1 is located in Schedule 2

Schedule 1: Maps

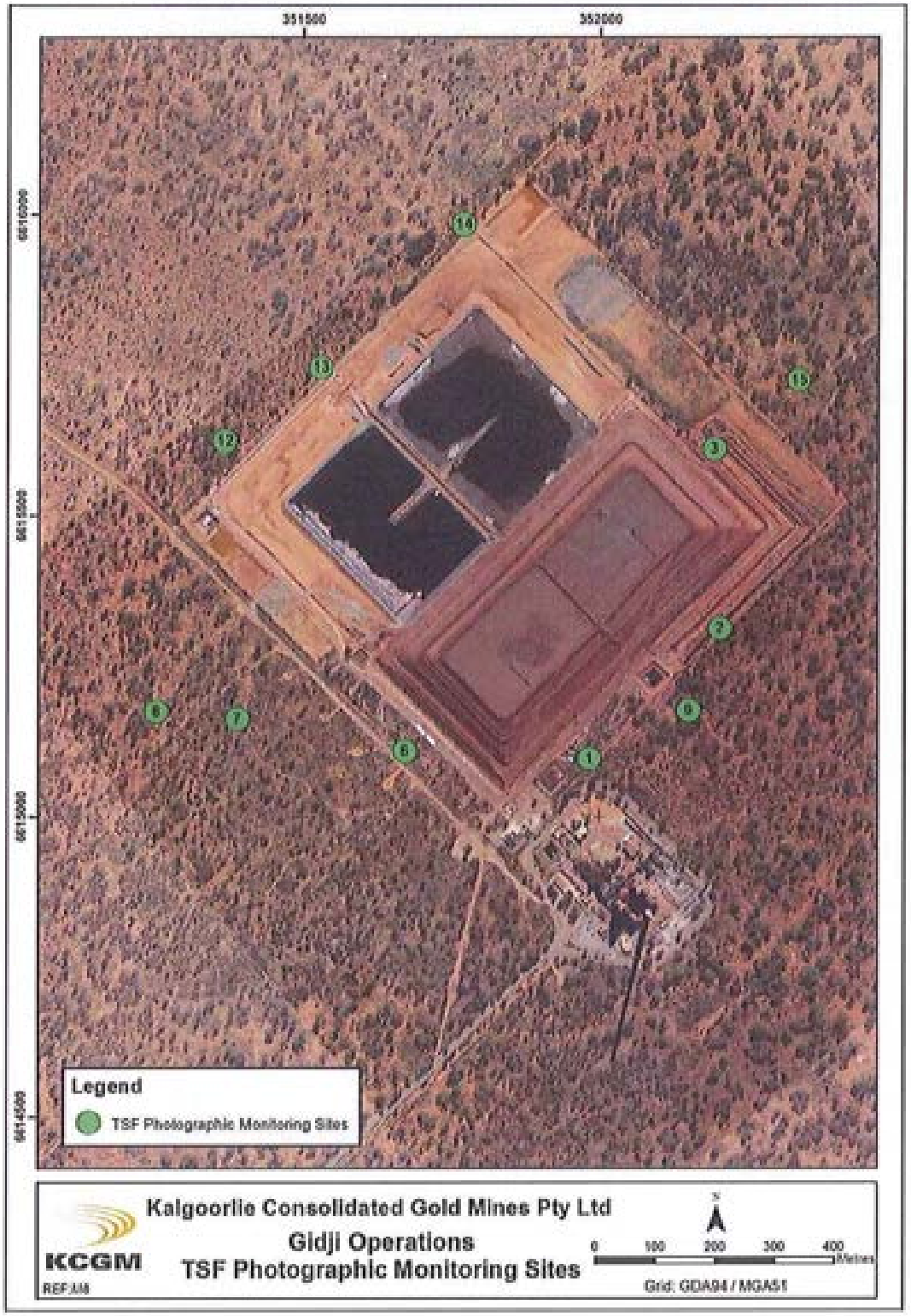
Premises map

The Premises is shown in the map below. The black line depicts the Premises boundary.



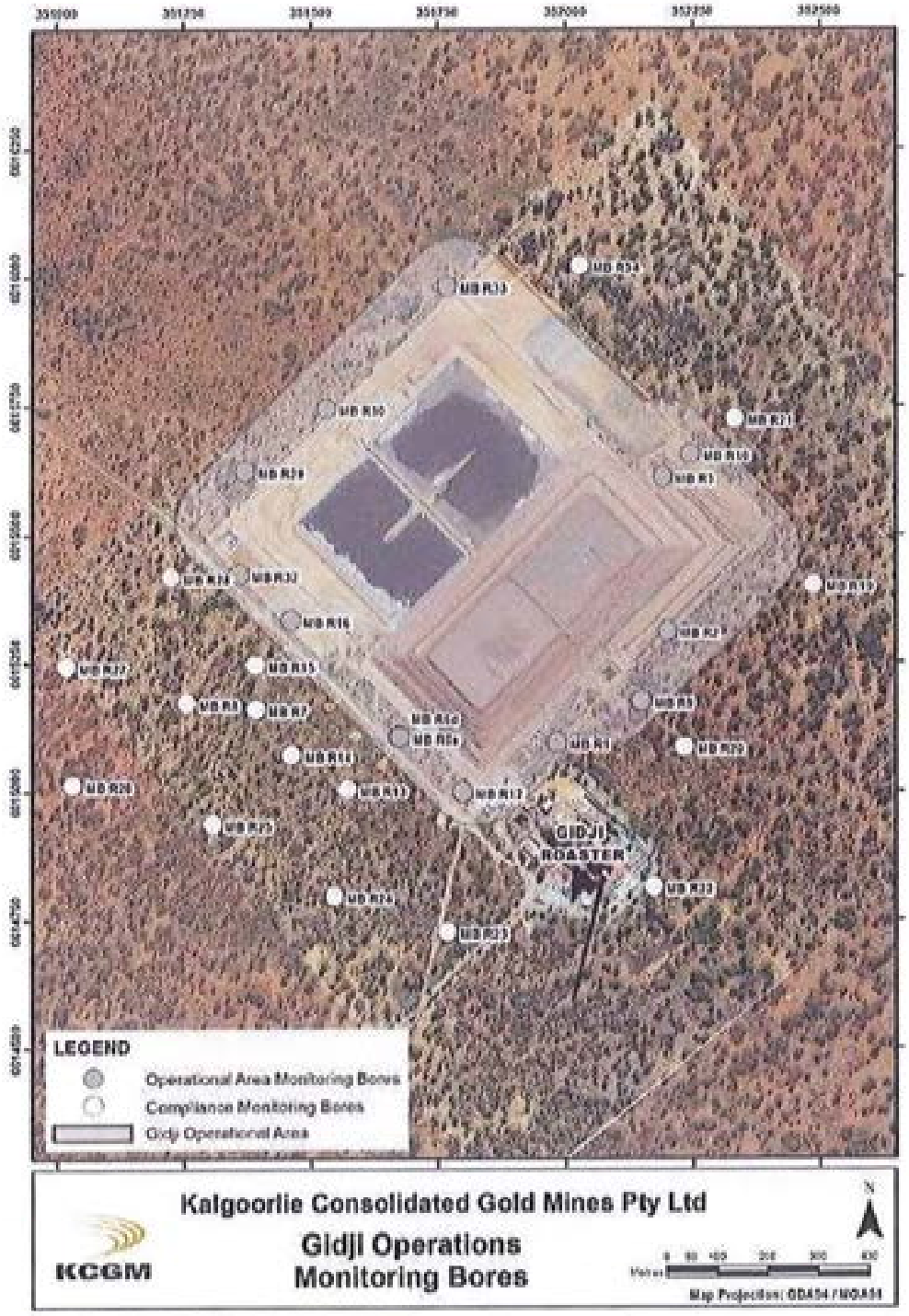
Map of TSF photographic monitoring locations

The locations of the monitoring points defined in Tables 2.2.1 are shown below.
Note: monitoring location 3 is no longer used.



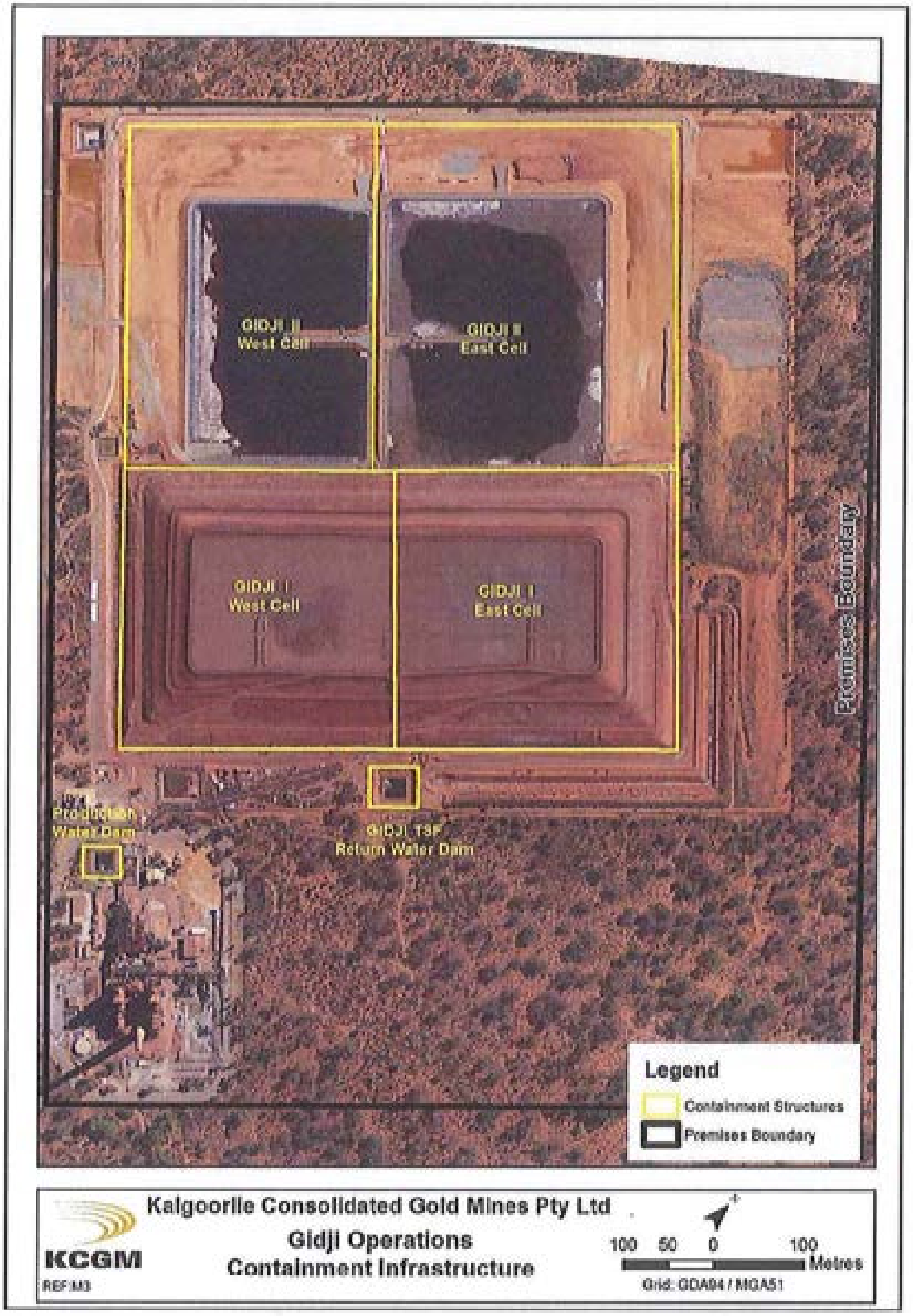
Map of groundwater monitoring locations

The locations of the monitoring points defined in Table 2.2.2 are shown below.



Map of storage locations

Storage locations as defined in Tables 1.3.2 are shown below.



Map of groundwater production bores



Schedule 2: Reporting & notification forms

These forms are provided for the proponent to report monitoring and other data required by the Licence. They can be requested in an electronic format.

ANNUAL AUDIT COMPLIANCE REPORT PROFORMA

SECTION A

LICENCE DETAILS

Licence Number:	Licence File Number:
Company Name: Trading as:	ABN:
Reporting period: _____ to _____	

STATEMENT OF COMPLIANCE WITH LICENCE CONDITIONS

1. Were all conditions of the Licence complied with within the reporting period? (please tick the appropriate box)

Yes ☐ Please proceed to Section C

No ☐ Please proceed to Section B

Each page must be initialled by the person(s) who signs Section C of this Annual Audit Compliance Report (AACR).

Initial:

SECTION B
DETAILS OF NON-COMPLIANCE WITH LICENCE CONDITION.

Please use a separate page for each Licence condition that was not complied with.

a) Licence condition not complied with:	
b) Date(s) when the non-compliance occurred, if applicable:	
c) Was this non-compliance reported to DER?:	
☐ Yes ☐ Reported to DER verbally Date _____ ☐ Reported to DER in writing Date _____	☐ No
d) Has DER taken, or finalised any action in relation to the non-compliance?:	
e) Summary of particulars of the non-compliance, and what was the environmental impact:	
f) If relevant, the precise location where the non-compliance occurred (attach map or diagram):	
g) Cause of non-compliance:	
h) Action taken, or that will be taken to mitigate any adverse effects of the non-compliance:	
i) Action taken or that will be taken to prevent recurrence of the non-compliance:	

Each page must be initialled by the person(s) who signs Section C of this AACR

Initial:

SECTION C

SIGNATURE AND CERTIFICATION

This Annual Audit Compliance Report (AACR) may only be signed by a person(s) with legal authority to sign it. The ways in which the AACR must be signed and certified, and the people who may sign the statement, are set out below.

Please tick the box next to the category that describes how this AACR is being signed. If you are uncertain about who is entitled to sign or which category to tick, please contact the licensing officer for your premises.

If the licence holder is		The Annual Audit Compliance Report must be signed and certified:
An individual	☐	by the individual licence holder, or
	☐	by a person approved in writing by the Chief Executive Officer of the Department of Environment Regulation to sign on the licensee's behalf.
A firm or other unincorporated company	☐	by the principal executive officer of the licensee; or
	☐	by a person with authority to sign on the licensee's behalf who is approved in writing by the Chief Executive Officer of the Department of Environment Regulation.
A corporation	☐	by affixing the common seal of the licensee in accordance with the *Corporations Act 2001*; or
	☐	by two directors of the licensee; or
	☐	by a director and a company secretary of the licensee, or
	☐	if the licensee is a proprietary company that has a sole director who is also the sole company secretary – by that director, or
	☐	by the principal executive officer of the licensee; or
	☐	by a person with authority to sign on the licensee's behalf who is approved in writing by the Chief Executive Officer of the Department of Environment Regulation.
A public authority (other than a local government)	☐	by the principal executive officer of the licensee; or
	☐	by a person with authority to sign on the licensee's behalf who is approved in writing by the Chief Executive Officer of the Department of Environment Regulation.
a local government	☐	by the chief executive officer of the licensee; or
	☐	by affixing the seal of the local government.

It is an offence under section 112 of the *Environmental Protection Act 1986* for a person to give information on this form that to their knowledge is false or misleading in a material particular. There is a maximum penalty of $50,000 for an individual or body corporate.

I/We declare that the information in this annual audit compliance report is correct and not false or misleading in a material particular.

SIGNATURE: _____

NAME:
(printed) _____

POSITION: _____

DATE: _____/_____/_____

SIGNATURE: _____

NAME:
(printed) _____

POSITION: _____

DATE: _____/_____/_____

SEAL (if signing under seal)

Licence: L5946/1988/13 Licensee: Kalgoorlie Consolidated Gold Mines Pty Ltd
Form: N1 Date of breach:

Notification of detection of the breach of a limit

These pages outline the information that the operator must provide. Units of measurement used in information supplied under Part A and B requirements shall be appropriate to the circumstances of the emission. Where appropriate, a comparison should be made of actual emissions and authorised emission limits.

Part A

Licence Number	
Name of operator	
Location of Premises	
Time and date of the detection	

Notification requirements for the breach of a limit	
Emission point reference/ source	
Parameter(s)	
Limit	
Measured value	
Date and time of monitoring	
Measures taken, or intended to be taken, to stop the emission	

Part B

Any more accurate information on the matters for notification under Part A.	
Measures taken, or intended to be taken, to prevent a recurrence of the incident.	
Measures taken, or intended to be taken, to rectify, limit or prevent any pollution of the environment which has been or may be caused by the emission.	
The dates of any previous N1 notifications for the Premises in the preceding 24 months.	

Name	
Post	
Signature on behalf of Kalgoorlie Consolidated Gold Mines Pty Ltd	
Date	

Government of Western Australia
Department of Environment Regulation

Decision Document

Environmental Protection Act 1986, Part V

Proponent: Kalgoorlie Consolidated Gold Mine Pty Ltd

Licence: L5946/1988/13

Registered office:	Kalgoorlie Consolidated Gold Mines Pty Ltd Black Street KALGOORLIE WA 6430
ACN:	099 377 619
Premises address:	Gidji Processing Plant Tenements G24/24-33 KALGOORLIE WA 6430
Issue date:	Friday, 26 September 2014
Commencement date:	Monday, 29 September 2014
Expiry date:	Saturday, 28 September 2029

Decision

Based on the assessment detailed in this document the Department of Environment Regulation (DER) has decided to issue an amended licence. DER considers that in reaching this decision, it has taken into account all relevant considerations and legal requirements and that the Licence and its conditions will ensure that an appropriate level of environmental protection is provided.

Decision Document prepared by: Cristina Angel
Senior Licensing Officer

Decision Document authorised by: Jonathan Bailes
Delegated Officer

Contents

1	Purpose of this document	2
2	Administrative summary	3
3	Executive summary of proposal and assessment	4
4	Decision table	5
5	Advertisement and consultation table	12
6	Risk Assessment	13

1 Purpose of this document

This Decision Document explains how DER has assessed and determined the application and provides a record of DER's decision-making process and how relevant factors have been taken into account. Stakeholders should note that this document is limited to DER's assessment and decision making under Part V of the *Environmental Protection Act 1986*. Other approvals may be required for the proposal, and it is the proponent's responsibility to ensure they have all relevant approvals for their Premises.

2 Administrative summary

Administrative details		
Application type	Works Approval ☐ New Licence ☐ Licence amendment ☒ Works Approval amendment ☐	
Activities that cause the premises to become prescribed premises	**Category number(s)** 5	**Assessed design capacity** 438,000 tonnes per annual period
Application verified	Date: 20 August 2015	
Application fee paid	NA	
Works Approval has been complied with	Yes☐ No☐ N/A☐	
Compliance Certificate received	Yes☐ No☐ N/A☐	
Commercial-in-confidence claim	Yes☐ No☒	
Commercial-in-confidence claim outcome		
Is the proposal a Major Resource Project?	Yes☒ No☐	
Was the proposal referred to the Environmental Protection Authority (EPA) under Part IV of the *Environmental Protection Act 1986*?	Yes☐ No☒	Referral decision No: Managed under Part V ☐ Assessed under Part IV ☐
Is the proposal subject to Ministerial Conditions?	Yes☒ No☐	Ministerial statement Nos: 28 & 77 EPA Report No:
Does the proposal involve a discharge of waste into a designated area (as defined in section 57 of the *Environmental Protection Act 1986*)?	Yes☐ No☒ Department of Water consulted Yes ☐ No ☒	
Is the Premises within an Environmental Protection Policy (EPP) Area Yes☐ No☒		
Is the Premises subject to any EPP requirements? Yes☐ No☒		

3 Executive summary of proposal and assessment

Kalgoorlie Consolidated Gold Mines Ltd (KCGM) operates the Fimiston open pit, Mt Charlotte underground mine, Fimiston mill and Gidji Processing Plant on behalf of joint venture owners Barrick Ltd (Australia Pacific) and Newmont Asia Pacific Ltd (Newmont).

The Gidji Processing Plant, located 17 kilometres north of Kalgoorlie-Boulder, treats refractory gold sulphide concentrate produced by the Fimiston mill. The purpose of this amendment is to remove metal smelting or refining from the licence. The Licensee also applied to increase the throughput of 351,000 to 438,000 tonnes per annual period however this was not assessed on the basis that this increase needs to be approved under Part IV of *The Environmental Protection Act 1986* and any approved increase reflected in Ministerial Statement Nos. 77 and 28. This Part IV amendment is delayed and the Licensee has requested that the parts of the application which do not require amendment of the Ministerial Statement to be processed. A separate application will be made for the increased to throughput following the finalisation of the Part IV amendment.

Historically, the sulphide ore was initially roasted to oxidate the sulphide which in turn allowed the fine gold particles to be dissolved once the ore was placed into cyanide solution. In order to reduce its gaseous emissions to air, the site undertook an Emissions Reduction Project under Works Approval W5659/2014/1. This involved the replacement of the two 20 tonne per hour roasters with one 30 tonne per hour Ultrafine Grinding Mill (UFG) to process refractory ore from Fimiston. This is in addition to the existing 10 tonne per hour UFG mill, maintaining the sites 40 tonne per hour processing of refractory ore. The two roasters ceased operating on 26 January 2015 and 5 April 2015 respectively. This Licence amendment removes reference to all point source air emissions and associated monitoring requirements. Additionally, ambient monitoring requirements in accordance with the *Environmental Protection (Goldfields Residential Areas) (Sulfur Dioxide) Policy 2003* are also no longer relevant to this licence.

The tailings from the cyanide leach and carbon-in-pulp adsorption process are sent to the Gidji Tailings Storage Facilities (TSFs). Currently, two cells are in operation, Gidji II (east) and Gidji II (west). These cells were commissioned in 2012 and 2014 respectively. Associated infrastructure supporting the process plant includes access tracks, borefields (production and monitoring bores), water storage ponds, transfer ponds and seepage interception trench. This amendment includes the removal of the Gidji I TSF as an approved tailing deposition area. Under a previous licence amendment (4 December 2014), DER agreed to allow the use of the use of the Gidji I TSF as an interim measure until the TSF reached its maximum capacity or until the new UFG mill was commissioned (whichever came first).

This amendment also removes reference to the vehicle wash down bays from the licence as no vehicles are washed down at the Gidji facility. This was confirmed through DER's Inspection of the premises on 25 March 2015. This expiry date of this Licence has also been amended to extend in accordance with DER's *Guidance Statement on Licence Duration (November 2014)*.

Other changes have also been made to reflect administrative changes implemented within DER.

4 Decision table

All applications are assessed in line with the *Environmental Protection Act 1986*, the *Environmental Protection Regulations 1987* and DER's Operational Procedure on Assessing Emissions and Discharges from Prescribed Premises. Where other references have been used in making the decision, they are detailed in the decision document.

DECISION TABLE			
Works Approval / Licence section	**Condition number W = Works Approval L= Licence**	**Justification (including risk description & decision methodology where relevant)**	**Reference documents**
Definitions	NA	Definitions have been amended to remove reference to any terminology associated with removed conditions. Other definitions have been removed in accordance with administrative changes implemented within DER.	NA
General conditions	NA	These conditions have been removed from the previous licence in accordance with administrative changes implemented within DER: • Condition 1.2.1 has been removed as it contains explanatory text only; • Condition 1.2.2 has been removed as it is not sufficiently clear or certain; Condition 1.2.3 and 1.2.4 have been removed as it is the occupier's responsibility to ensure that they comply with relevant legislative requirements for secondary activities such as the storage and handling of environmentally hazardous materials. Unauthorised discharges of environmentally hazardous materials are subject to the provisions of the *Environmental Protection (Unauthorised Discharges) Regulations 2004*. • Condition 1.2.5 has been removed as it is not sufficiently clear or certain. The condition does not specify what stormwater infrastructure is required to be constructed and maintained or what if any specific management actions are required. Contaminated stormwater has previously been assessed as posing a moderate risk. DER has considered whether the risk profile of the premises has significantly changed since the previous licence was granted. Significant changes have occurred at the site and although greater quantities cyanide will be used per tonne of concentrate processed, there will be no increase in on-site storage of reagents. Deliveries will increase in frequency to maintain stock levels to meet	DER public website at: www.der.wa.gov.au *Environmental Protection Act 1986.* *Environmental Protection (Unauthorised Discharge) Regulations 2004*

DECISION TABLE			
Works Approval / Licence section	**Condition number W = Works Approval L= Licence**	**Justification (including risk description & decision methodology where relevant)**	**Reference documents**
		increased throughput. On this basis, and in accordance with administrative changes, this condition has been removed as the risk can be managed through established site procedures. The substantive offences of the EP Act provide enforceable prohibitions for discharges of contaminated stormwater that result in pollution or environmental harm.	
Premises operation	L1.2.1- 1.2.4	Premises operation has been reassessed as part of this amendment. Reference to vehicle wash down bays is removed from Table 1.2.1 as no vehicles are washed down at the Gidji processing plant. References to the clay lined Gidji I TSF West Cell and the Gidji I TSF East cell are also removed from Table 1.2.1. The construction of these cells is not considered adequate to contain supernatant from tailings deposited within these cells.	*Environmental Protection Act 1986.* *Environmental Protection (Unauthorised Discharge) Regulations 2004* Amendment supporting documentation (30 June 2015; 20 August 2015)
Emissions General	NA	Condition 2.1 in the previous version of the licence. Removal of nil condition sections of licence in accordance with administrative changes implemented by DER.	DER public website at: www.der.wa.gov.au
Point source emissions to air, surface water, groundwater and land	NA	Conditions 2.2-2.5 in the previous version of the licence. Point source air emission conditions have been removed from this licence as the site is no longer authorised to undertake metal roasting activities. Both roasters ceased to be operational on 26 January 2015 and 5 April 2015 respectively. A decommissioning plan is being developed to remove the infrastructure. Removal of nil condition sections of licence in accordance with administrative changes implemented by DER.	Amendment supporting documentation (30 June 2015; 20 August 2015) DER public website at: www.der.wa.gov.au

DECISION TABLE			
Works Approval / Licence section	**Condition number W = Works Approval L= Licence**	**Justification (including risk description & decision methodology where relevant)**	**Reference documents**
Fugitive emissions	NA	Conditions 2.6.1- 2.6.2 in the previous version of the licence. Refer to improvements section below. Removal of nil condition sections of licence in accordance with administrative changes implemented by DER.	*Environmental Protection Act 1986.* DER public website at: www.der.wa.gov.au
Odour and Noise	NA	Conditions 2.7-2.8 in previous version of licence. Removal of nil condition sections of licence in accordance with administrative changes implemented by DER.	DER public website at: www.der.wa.gov.au
Monitoring general	NA	Condition 3.1.3 from the previous licence is removed as it is not enforceable and does not clearly state the outcome that must be achieved.	DER public website at: www.der.wa.gov.au
Monitoring of point source emissions to air	NA	Conditions 3.2.1-3.2.3 in the previous version of the licence. There are no point source emissions to air authorised under this amended licence. This section and all conditions relating to point source emissions to air have been removed.	
Monitoring of point source emissions to surface water, groundwater, land; and monitoring of inputs and outputs	NA	Conditions 3.3- L3.7 from the previous licence. Removal of nil condition sections of licence in accordance with administrative changes implemented by DER.	DER public website at: www.der.wa.gov.au

DECISION TABLE			
Works Approval / Licence section	**Condition number W = Works Approval L= Licence**	**Justification (including risk description & decision methodology where relevant)**	**Reference documents**
Ambient environmental quality monitoring	NA	Conditions 3.8.1, 3.8.2, 3.8.3 and 3.9.1 from the previous licence. There are no point source emissions to air authorised under this amended licence. All conditions relating to ambient air quality and meteorological monitoring have been removed from this licence. The requirements to undertake ambient groundwater monitoring and vegetation monitoring are retained in this licence. Removal of nil condition sections of licence in accordance with administrative changes implemented by DER.	*Environmental Protection Act 1986.* Gidji Tailings Storage Facilities Operating Manual- October 2015 Update DER public website at: www.der.wa.gov.au
	L2.1.4	Reference to vegetation monitoring location 3 has been removed from Table 2.1.4 as it is located in a disturbed area containing mining infrastructure with restricted access.	Kalgoorlie Consolidated Gold Mines Annual Environment Report 2015 Email correspondence from Catherine Wharton, 8 April 2016
Improvement Condition	L3.1.1	The condition requiring the submission of a report on hydrogeological data, seepage recovery procedures, and the current groundwater monitoring programme is removed. This condition was completed and the report was received by DER on 31 March 2015. Fugitive dust emission have previously been assessed as moderate. DER has considered whether the risk profile of fugitive dust from the premises has significantly changed since the previous licence was issued. No significant changes have occurred, and therefore in accordance with administrative changes implemented within DER, generic fugitive conditions have been removed. Fugitive dust will be managed through the development of a site-specific Dust Management Plan.	Gidji Tailings Storage Facility Review of Hydrogeological Data and Groundwater Management (March 2015). *Environmental Protection Act 1986.* DER public website at: www.der.wa.gov.au

DECISION TABLE			
Works Approval / Licence section	**Condition number W = Works Approval L= Licence**	**Justification (including risk description & decision methodology where relevant)**	Reference documents
		Standard operation *Emission:* Fugitive dust emissions from vehicle and plant movements, cleared areas, and the TSFs. Dust from TSFs will contain cyanide and other toxic metals. Gidji I TSF is not currently in use and the dust suppressing the effect of the wet tailings is not available to reduce fugitive dust emissions. Dry and high wind conditions promote dust lift off from TSFs and other surfaces. *Impact:* Dust and cyanide emissions can be harmful to human health and the environment. Elevated total suspended particulates (TSP) impact on vegetation by smothering and through abrasion to leaves. Particulate matter less than 10 (PM_{10}) or 2.5 ($PM_{2.5}$) microns in diameter can be inhaled deep into the lungs creating health impacts. The acute toxicity of cyanide is extremely harmful when inhaled by fauna or human receptors. *Controls:* Use of water carts and ongoing supervision by site personnel with the early identification of any potential dust issues. Cyanide is broken down by UV light. The proposed deposition of tailings on an irregular basis will assist in reducing dust generation. Risk Assessment *Consequence:* Moderate *Likelihood:* Possible *Risk rating:* Moderate Regulatory Controls Improvement condition IR1 has been added requiring the occupier to develop a Dust Management Plan to detail how the Licensee will manage the risk associated with fugitive dust emissions. Residual Risk *Likelihood:* Moderate *Consequence:* Unlikely *Risk rating:* Moderate	
Information	NA	Condition 5.1.2 from the previous licence version is removed as the condition is not enforceable as the conditions for compliance are unclear.	DER public website at: www.der.wa.gov.au

DECISION TABLE			
Works Approval / Licence section	**Condition number W = Works Approval L= Licence**	**Justification (including risk description & decision methodology where relevant)**	**Reference documents**
Reporting	L4.2.1	Condition 1.2.2 from the previous licence version has been removed. However, DER still requires an annual summary of reportable environmental incidents and actions taken to be provided in the Annual Environmental Report. Reporting conditions 5.2.1, 5.2.2 and 5.2.3 from the previous licence version have been changed to reflect changes to premises operations and administrative changes implemented in DER: • Condition 5.2.1 - the removal of reference to SO_2 Vegetation Monitoring Program from Table 5.2.1 as the premises no longer has point source air emissions; • Condition 5.2.2 –part (a) removal. Condition part was not enforceable and did not clearly state the outcome that must be achieved by the Licensee. • Condition 5.2.2 – part (b) removal of reference to target reporting in the Annual Environmental Report. • Condition 5.2.3- removal of reference to point source air emissions monitoring, roaster plant process monitoring, ambient SO_2 and meteorological monitoring requirements in Table 5.2.2.	Amendment supporting documentation (30 June 2015; 20 August 2015 DER public website at: www.der.wa.gov.au
Notification	L4.3.1	Updates have been made to this condition to remove reference to 'any failure or malfunction of pollution control equipment of any incident which has caused, is causing of may cause pollution' as this requirement exists in section 72 of the *Environmental Protection Act 1986*. Further information on reporting pollution obligations under s72 of the EP Act can be found at www.der.wa.gov.au/your-environment/reporting-pollution. Form N1 has been amended to reflect these changes.	Section 72 of *Environmental Protection Act 1986*. DER public website at: www.der.wa.gov.au
EPP related Requirements	NA	Conditions 6.1.1- 6.5.1 from the previous licence version have been removed. There are no point source air emissions authorised under this licence and all conditions relating to the *Environmental Protection (Goldfields Residential Areas) (Sulfur Dioxide) Policy 2003* and ambient air quality have been removed from the licence.	Amendment supporting documentation (30 June 2015; 20 August 2015

DECISION TABLE			
Works Approval / Licence section	**Condition number W = Works Approval L= Licence**	**Justification (including risk description & decision methodology where relevant)**	**Reference documents**
Schedules	N/A	As there is no point source air emissions authorised under this licence, maps and attachments referencing air emissions discharge locations, ambient air monitoring and meteorological locations, and data formatting requirements, have been removed. Form N1 has been updated.	Amendment supporting documentation (30 June 2015; 20 August 2015 DER public website at: www.der.wa.gov.auN/A
Licence Duration	N/A	The licence duration has been amended in accordance with DER's Guidance Statement on Licence Duration. An expiry date of 28 September 2029 was determined as it is the latest date that aligns with the annual licence period and the Licensee's legal access to all the tenements included within the prescribed premises boundary.	DER's Guidance Statement on Licence Duration (November 2014).

5 Advertisement and consultation table

Date	Event	Comments received/Notes	How comments were taken into consideration
18 March 2016	Proponent sent a copy of draft amended instrument	-	-
8 April 2016	Proponents comments received via email from Catherine Wharton	Licensee requested that vegetation monitoring location 3 be removed from the licence condition Minor typographical and administrative changes recommended.	DER confirmed with aerial photography and the 2015 Annual Environmental Report that this location is within an infrastructure area and removed reference to it within vegetation monitoring condition 2.1.4. Minor typographical and administrative changes made.

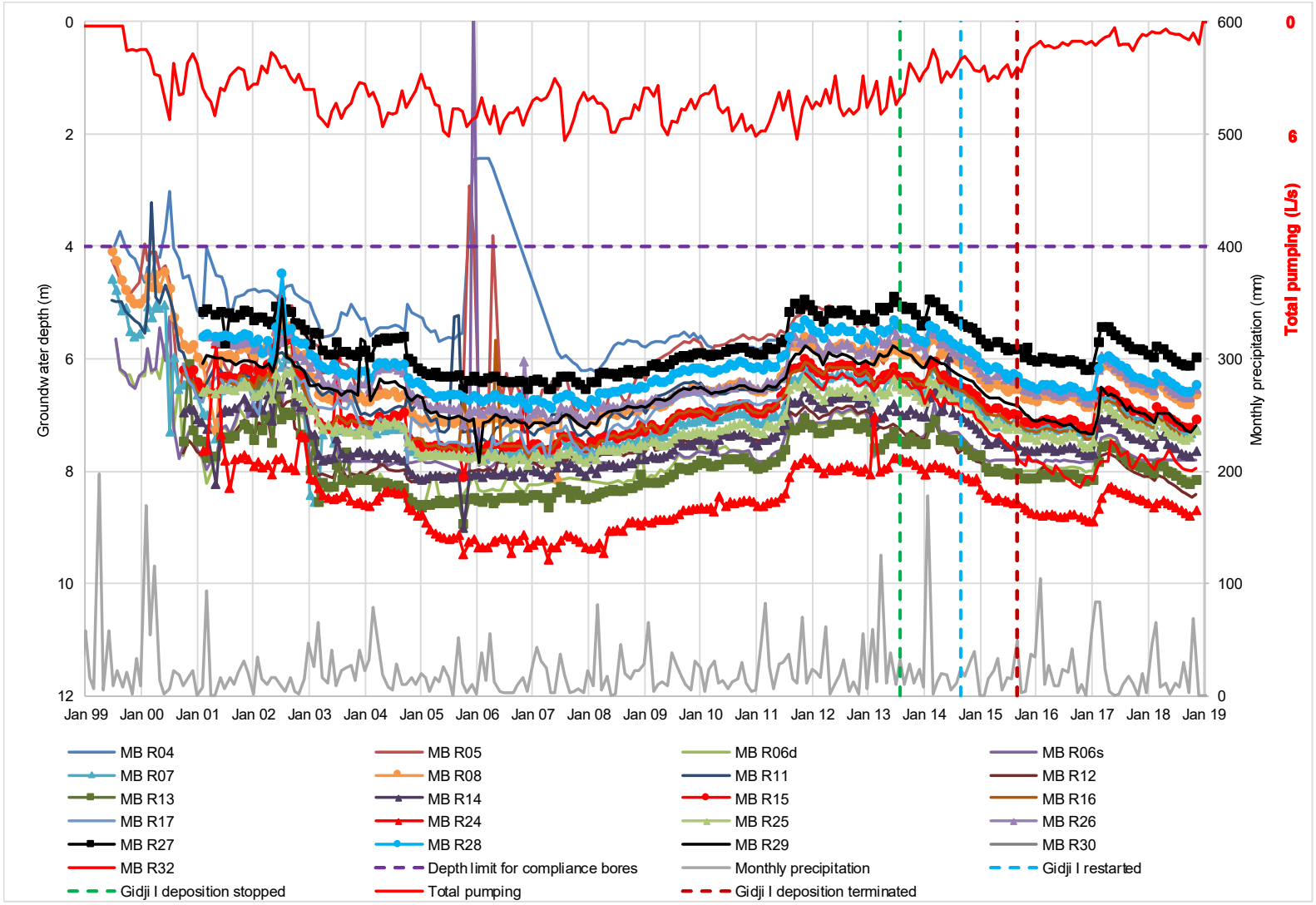
6 Risk Assessment

Note: This matrix is taken from the DER Corporate Policy Statement No. 07 - Operational Risk Management

Table 1: Emissions Risk Matrix

Likelihood	Consequence				
	Insignificant	Minor	Moderate	Major	Severe
Almost Certain	Moderate	High	High	Extreme	Extreme
Likely	Moderate	Moderate	High	High	Extreme
Possible	Low	Moderate	Moderate	High	Extreme
Unlikely	Low	Moderate	Moderate	Moderate	High
Rare	Low	Low	Moderate	Moderate	High

Appendix B
Long term hydrographs



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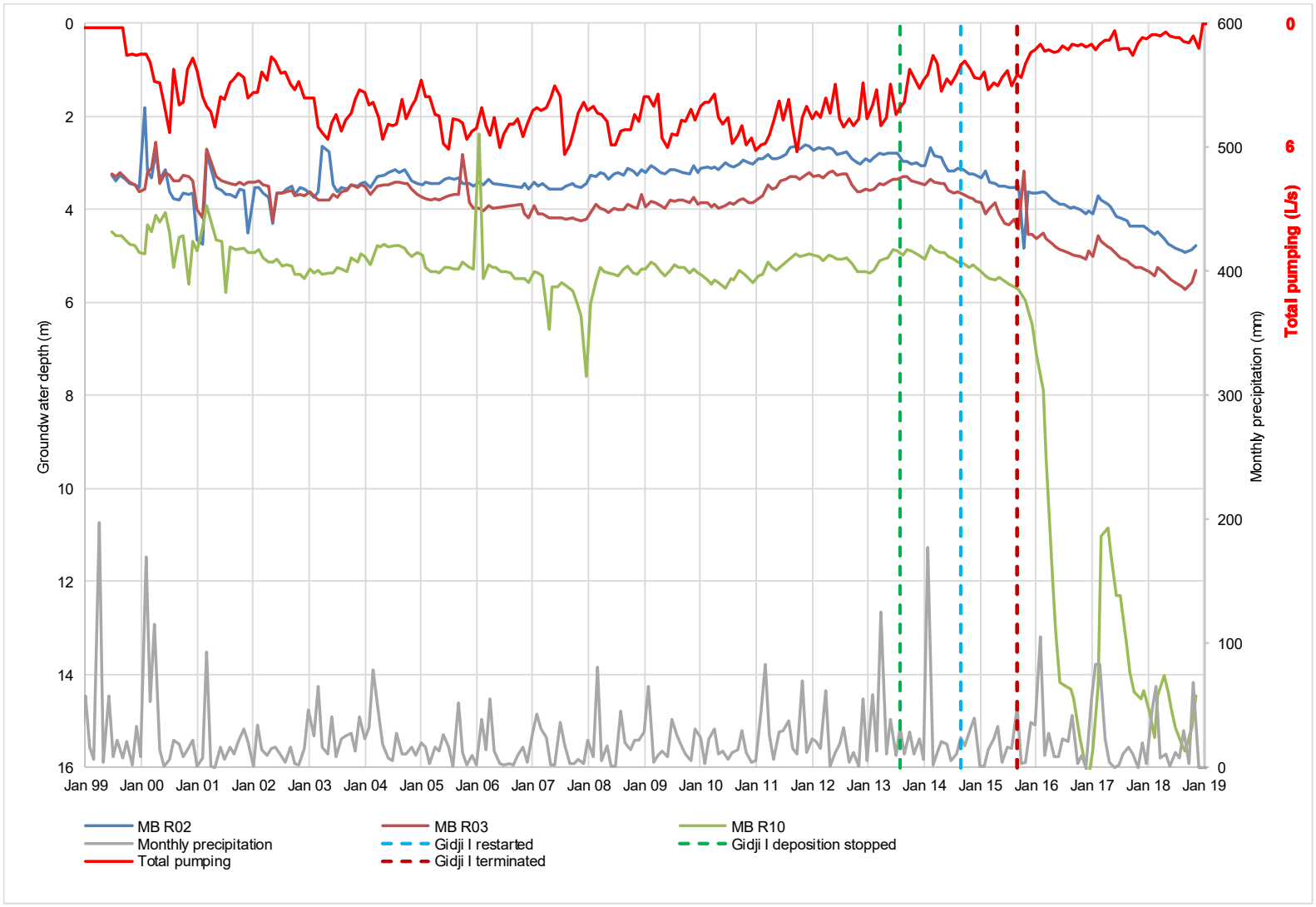
BIG DOG HYDROGEOLOGY

Long term hydrographs - western bores

Figure B1

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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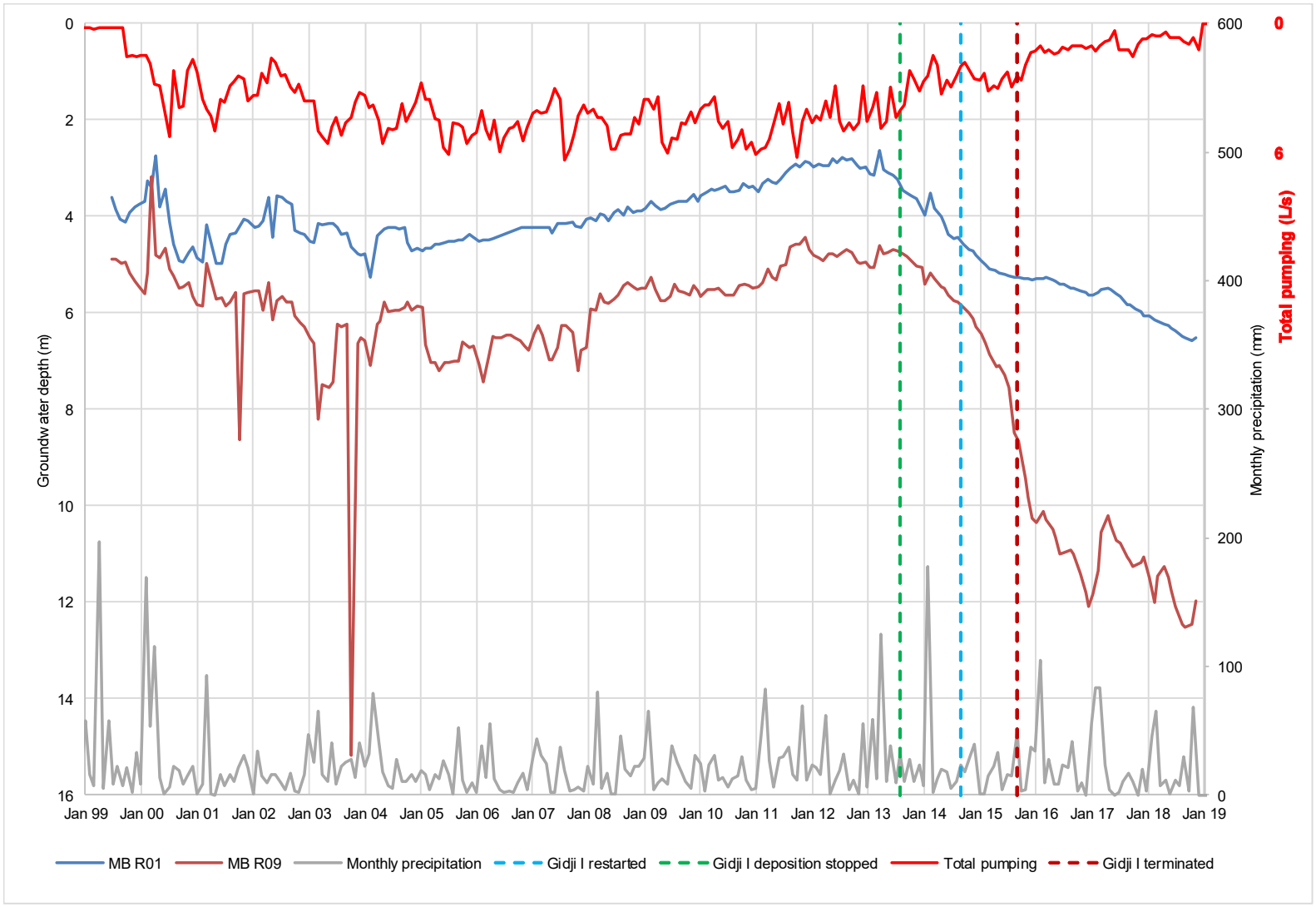
BIG DOG HYDROGEOLOGY

Long term hydrographs - trench bores

Figure B2

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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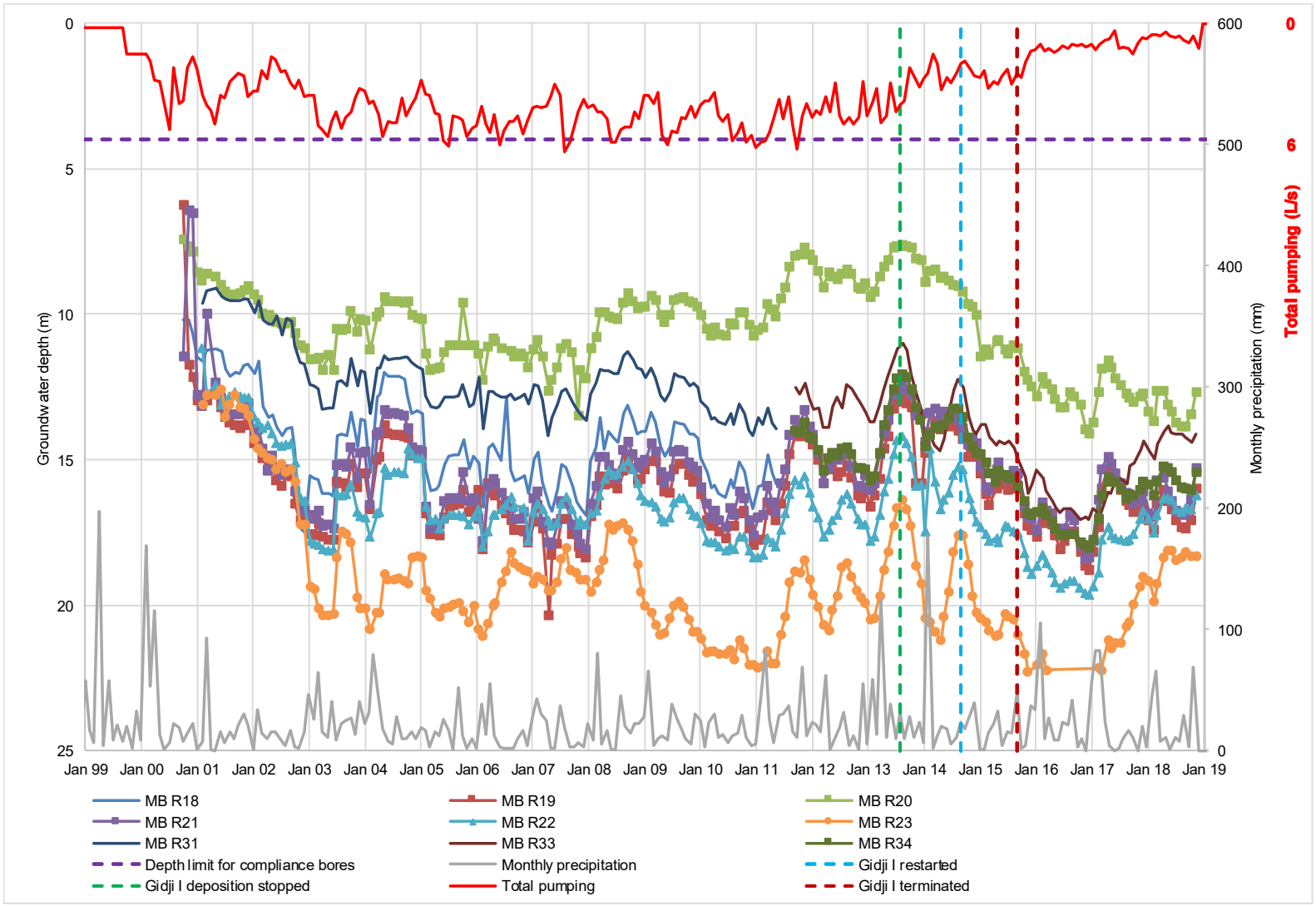
BIG DOG HYDROGEOLOGY

Long term hydrographs - decant bores

Figure B3

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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BIG DOG HYDROGEOLOGY

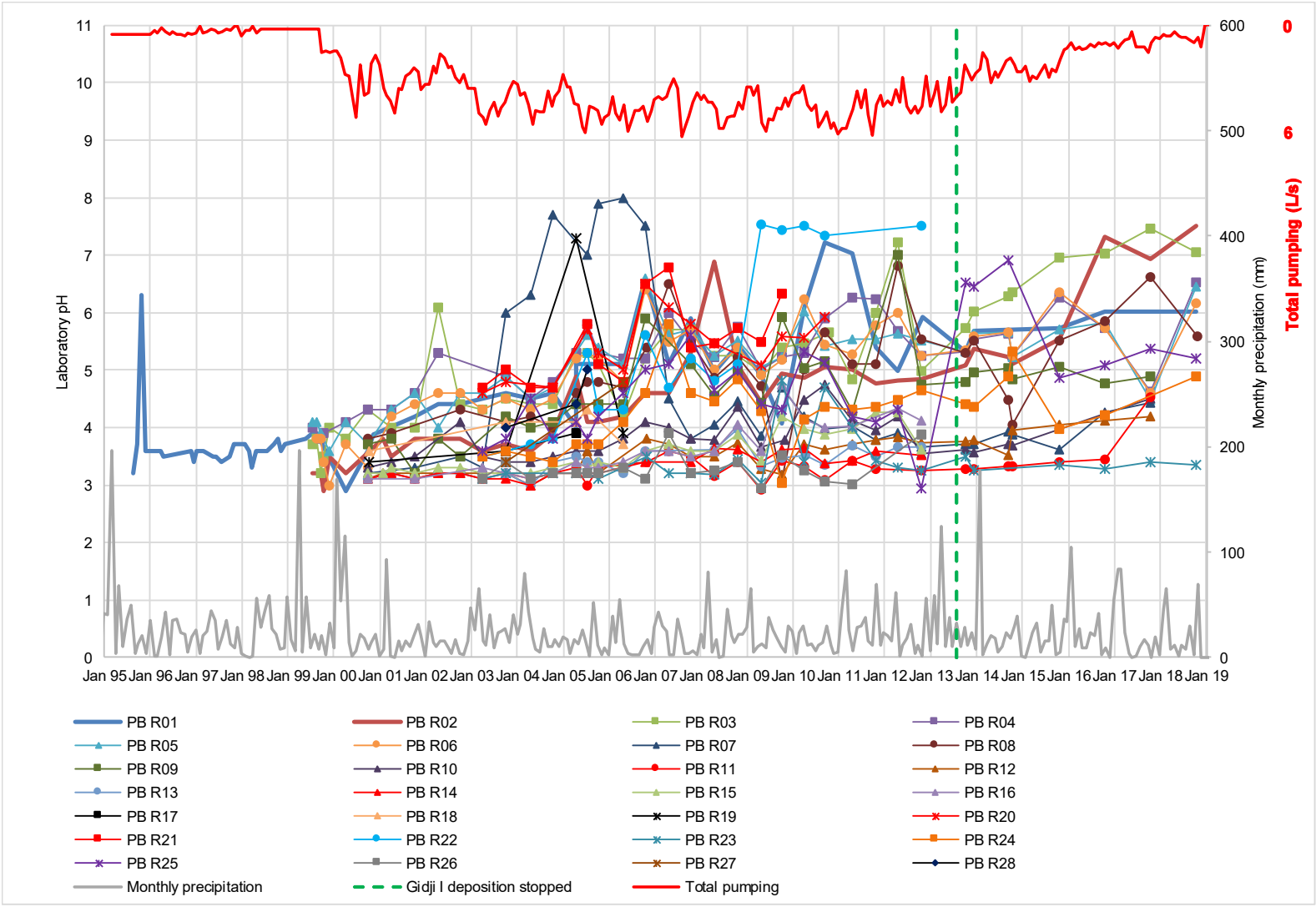
Long term hydrographs - eastern bores

Figure B4

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review

Appendix C
Time series groundwater hydrochemistry



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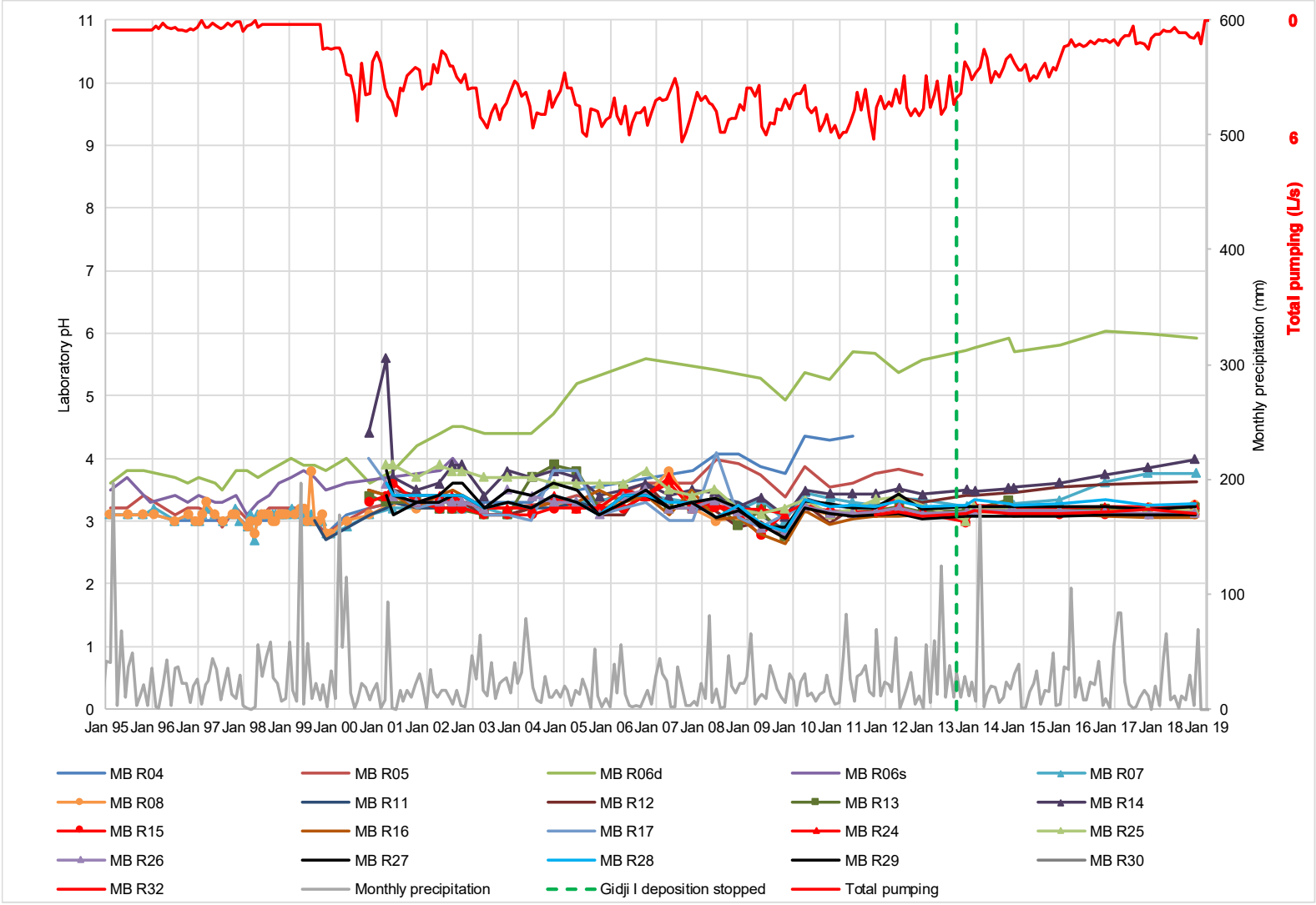
BIG DOG HYDROGEOLOGY

Groundwater Laboratory pH - production bores

Figure C1

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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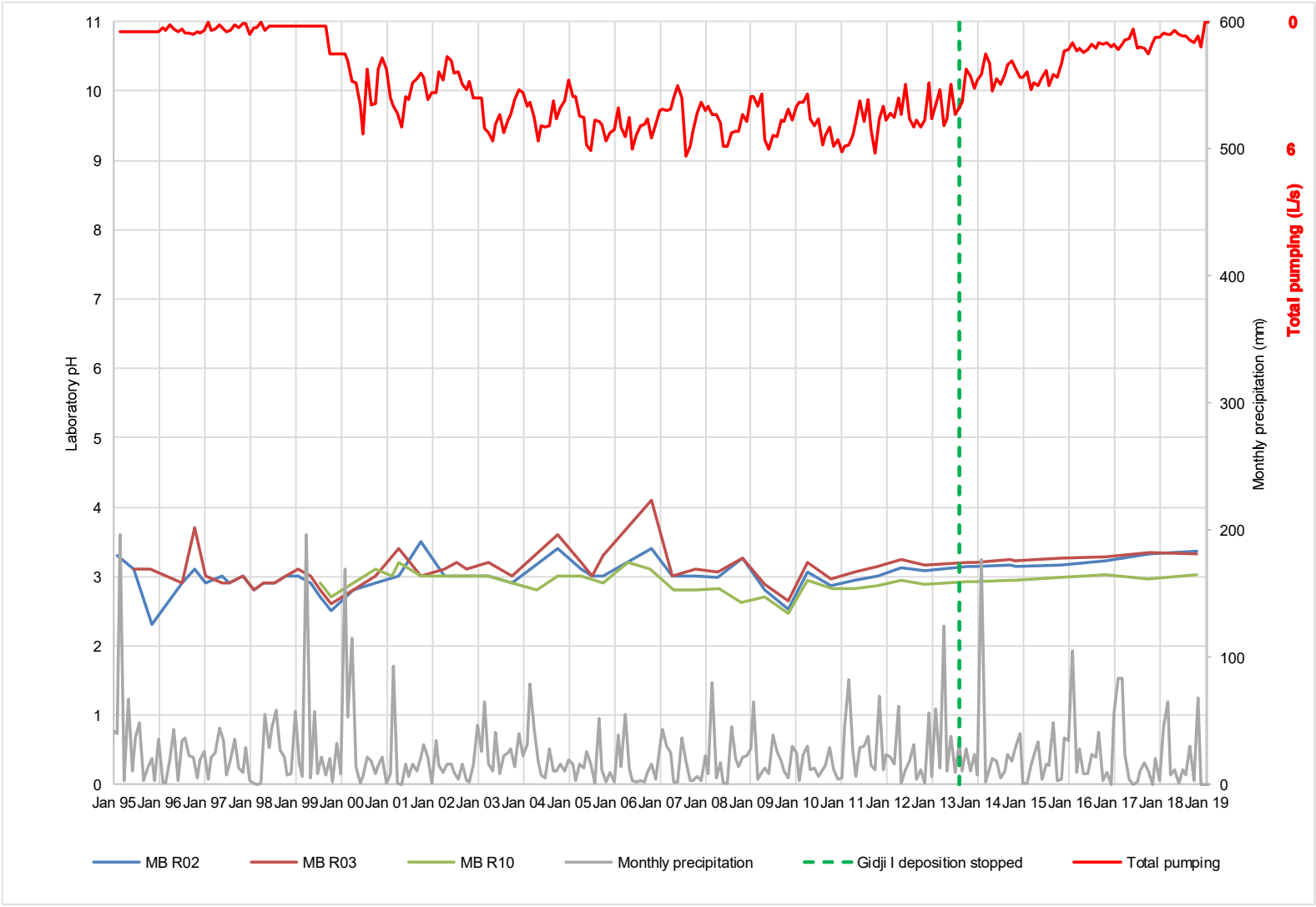
BIG DOG HYDROGEOLOGY

Groundwater Laboratory pH - western bores

Figure C2

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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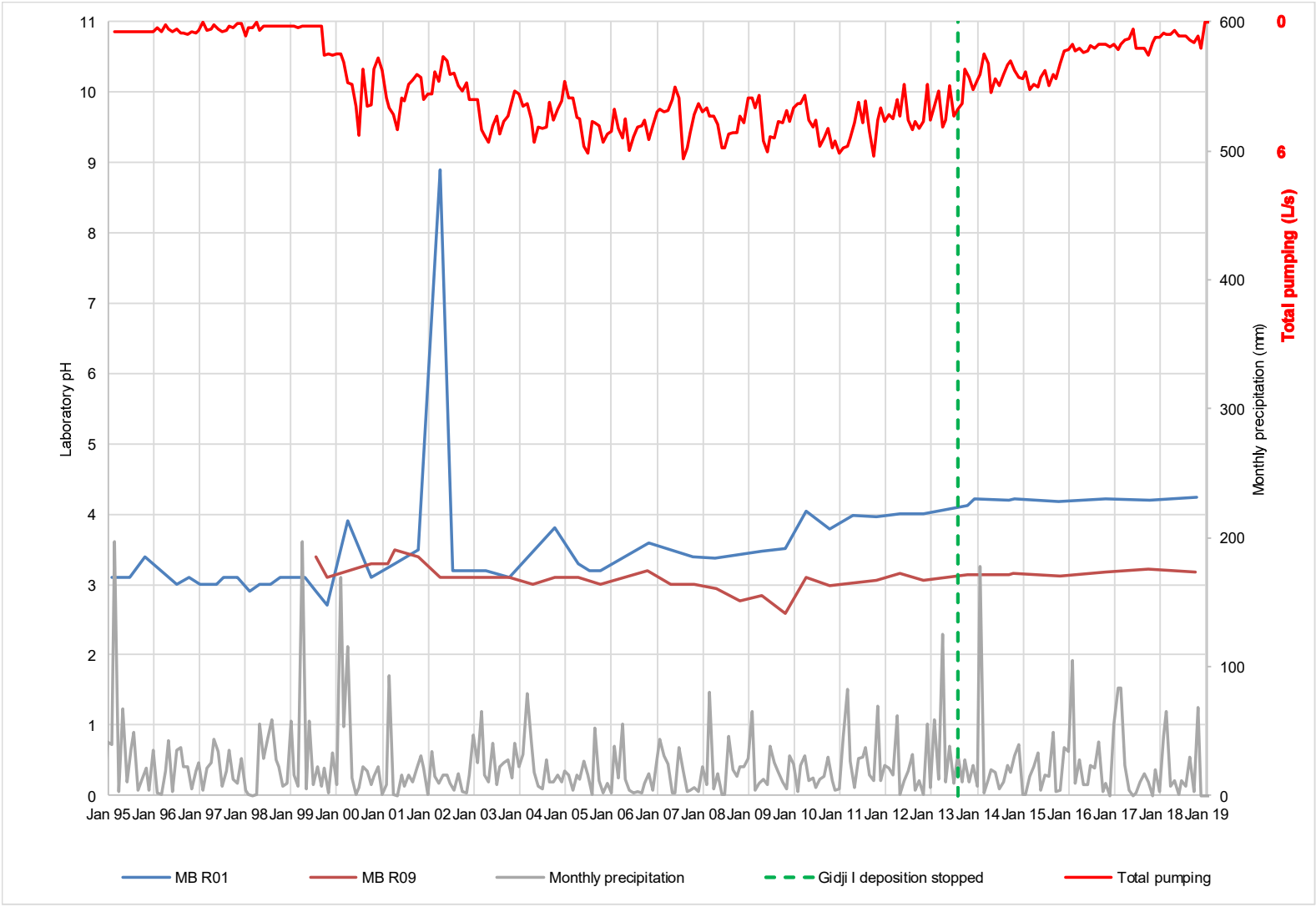
BIG DOG HYDROGEOLOGY

Groundwater Laboratory pH - trench bores

Figure C3

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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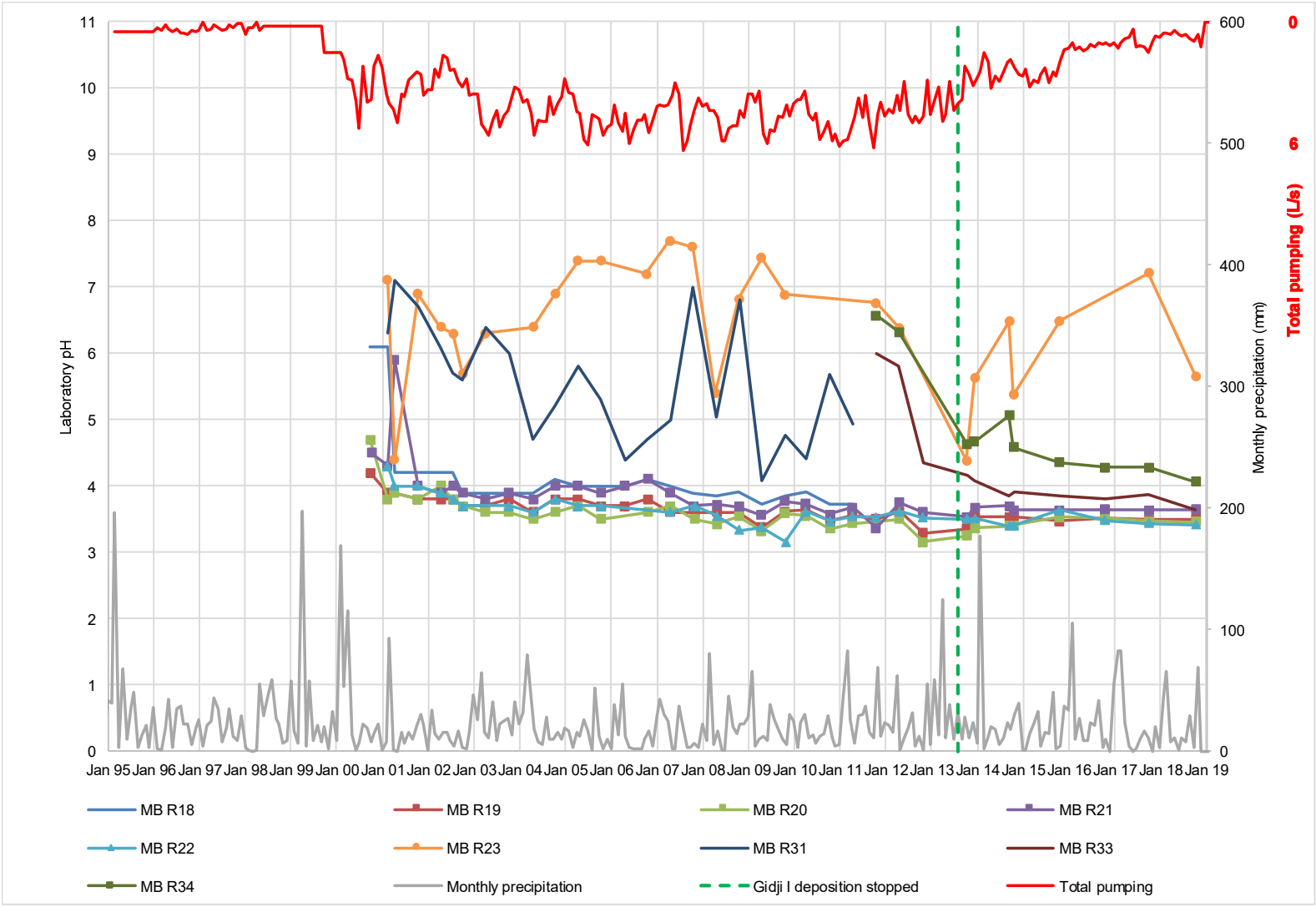
BIG DOG HYDROGEOLOGY

Groundwater Laboratory pH - decant bores

Figure C4

Date: January 2019

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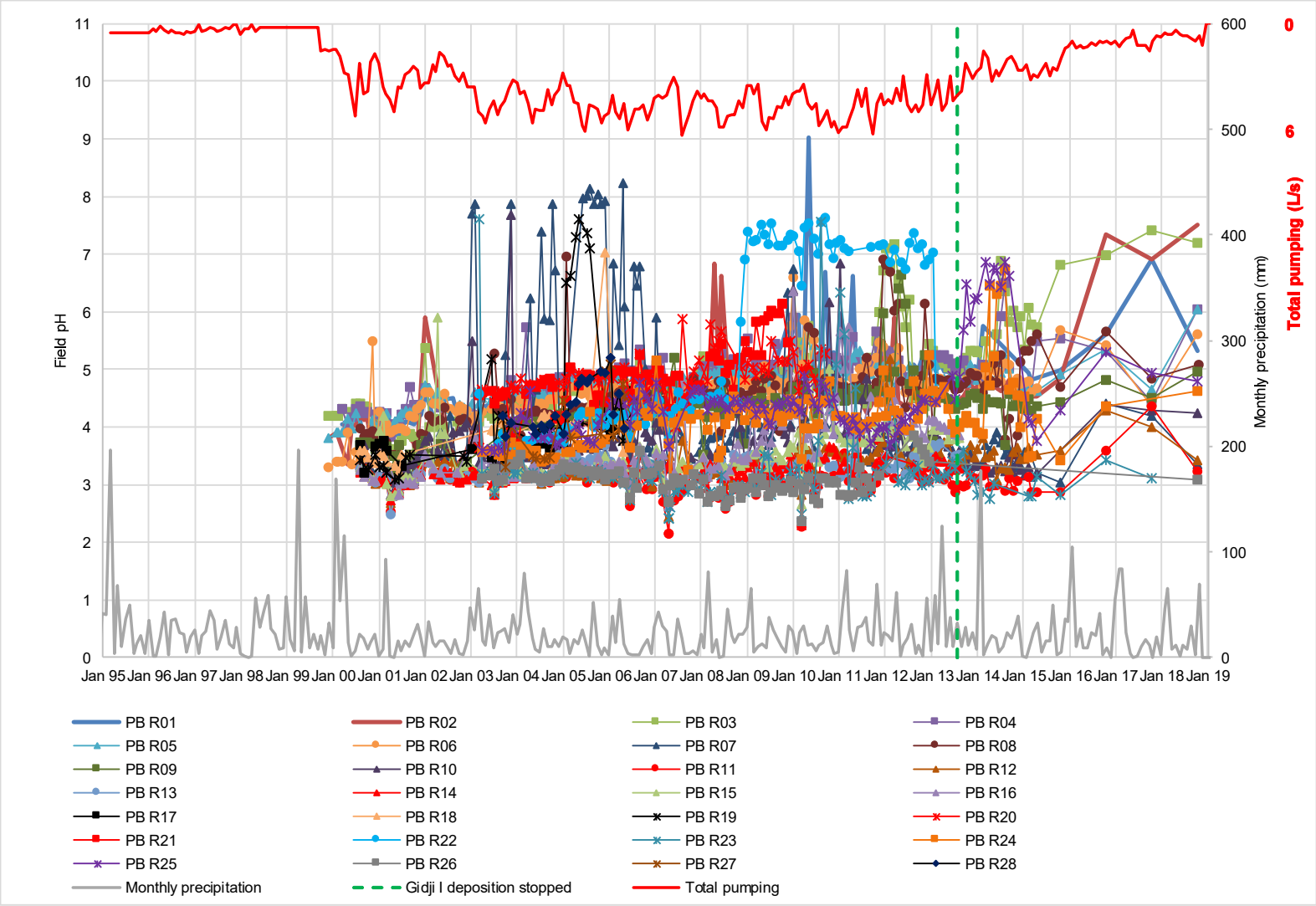
BIG DOG HYDROGEOLOGY

Groundwater Laboratory pH - eastern bores

Figure C5

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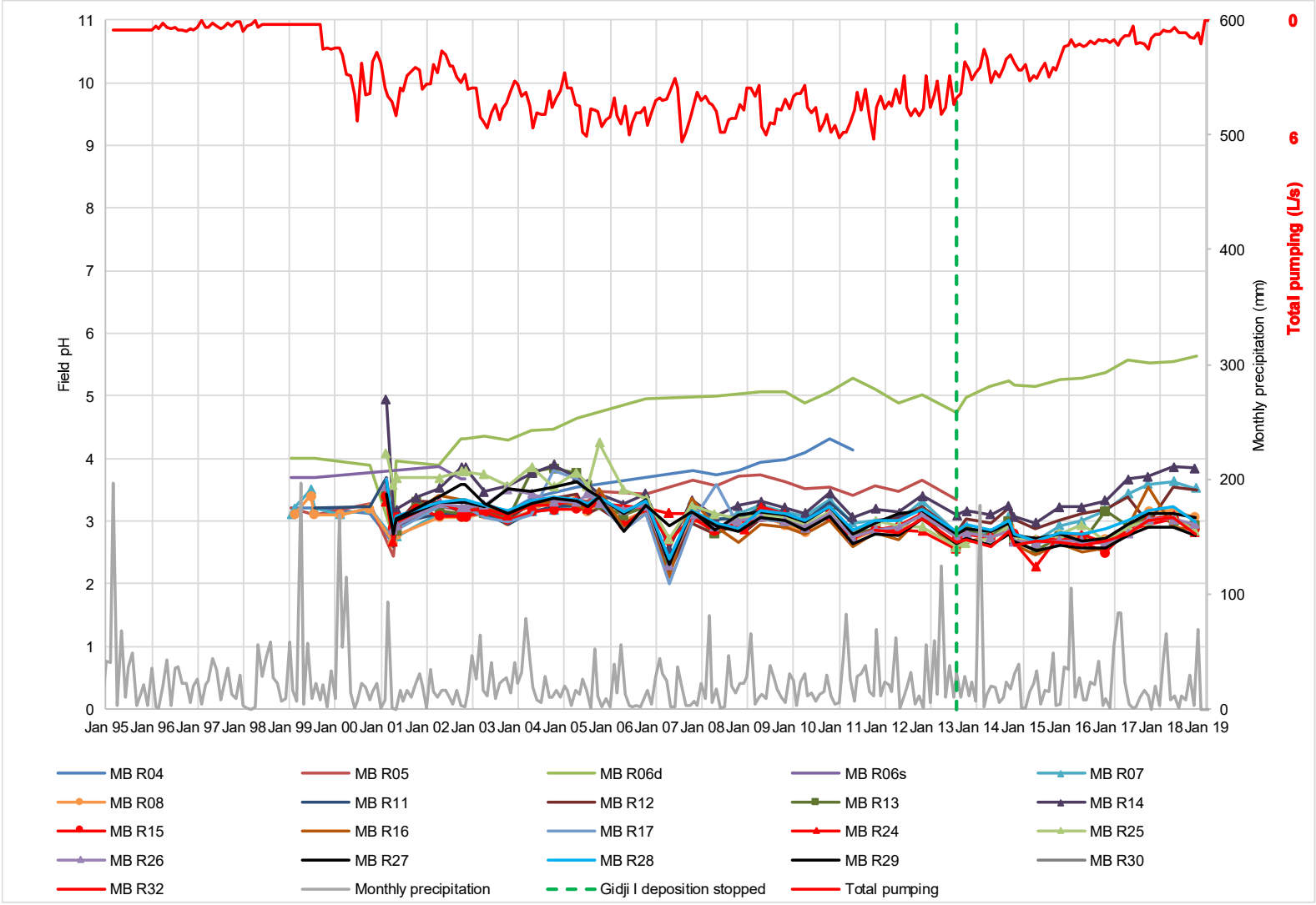
BIG DOG HYDROGEOLOGY

Groundwater Field pH - production bores

Figure C6

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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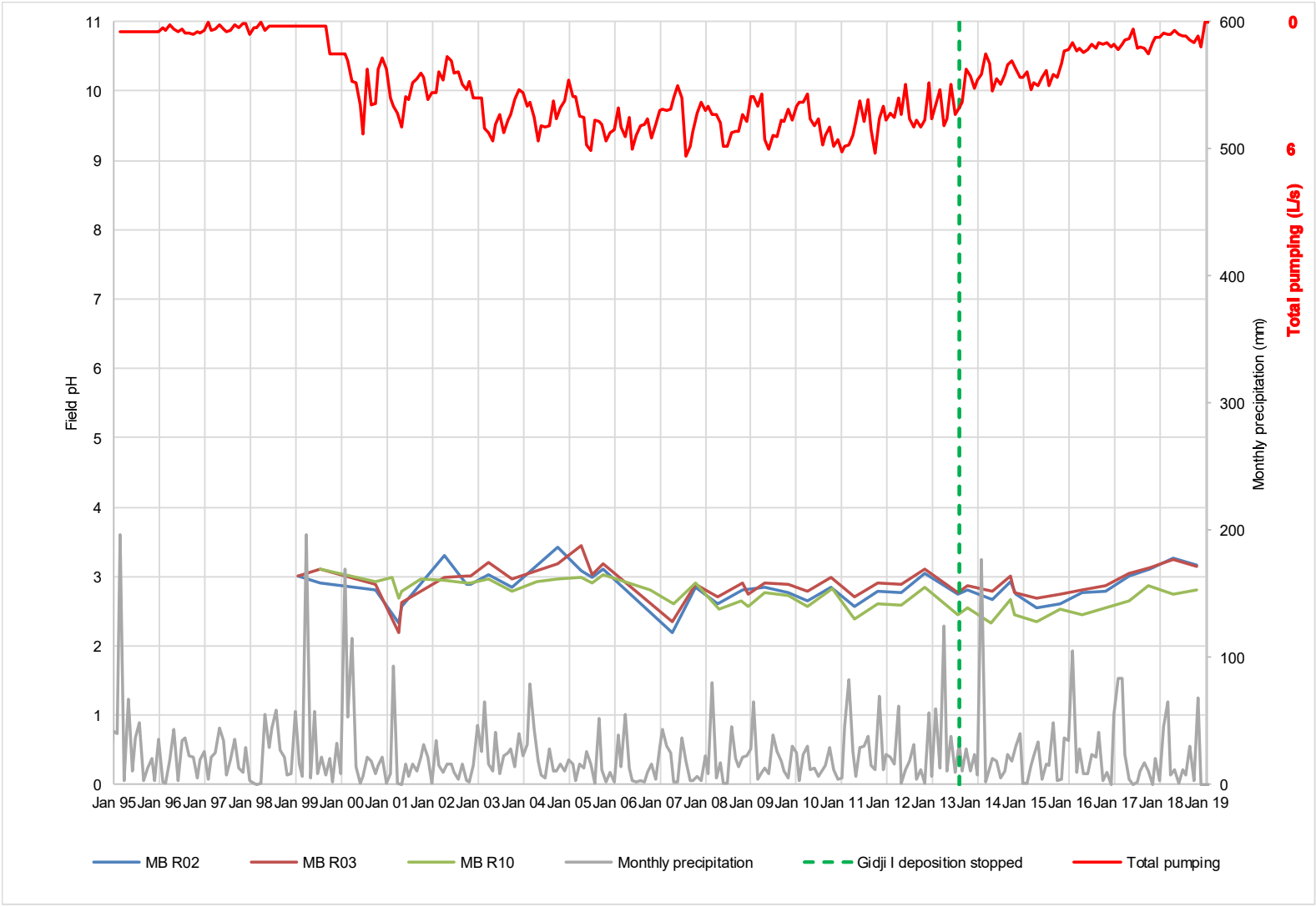
BIG DOG HYDROGEOLOGY

Groundwater Field pH - western bores

Figure C7

Date: January 2019

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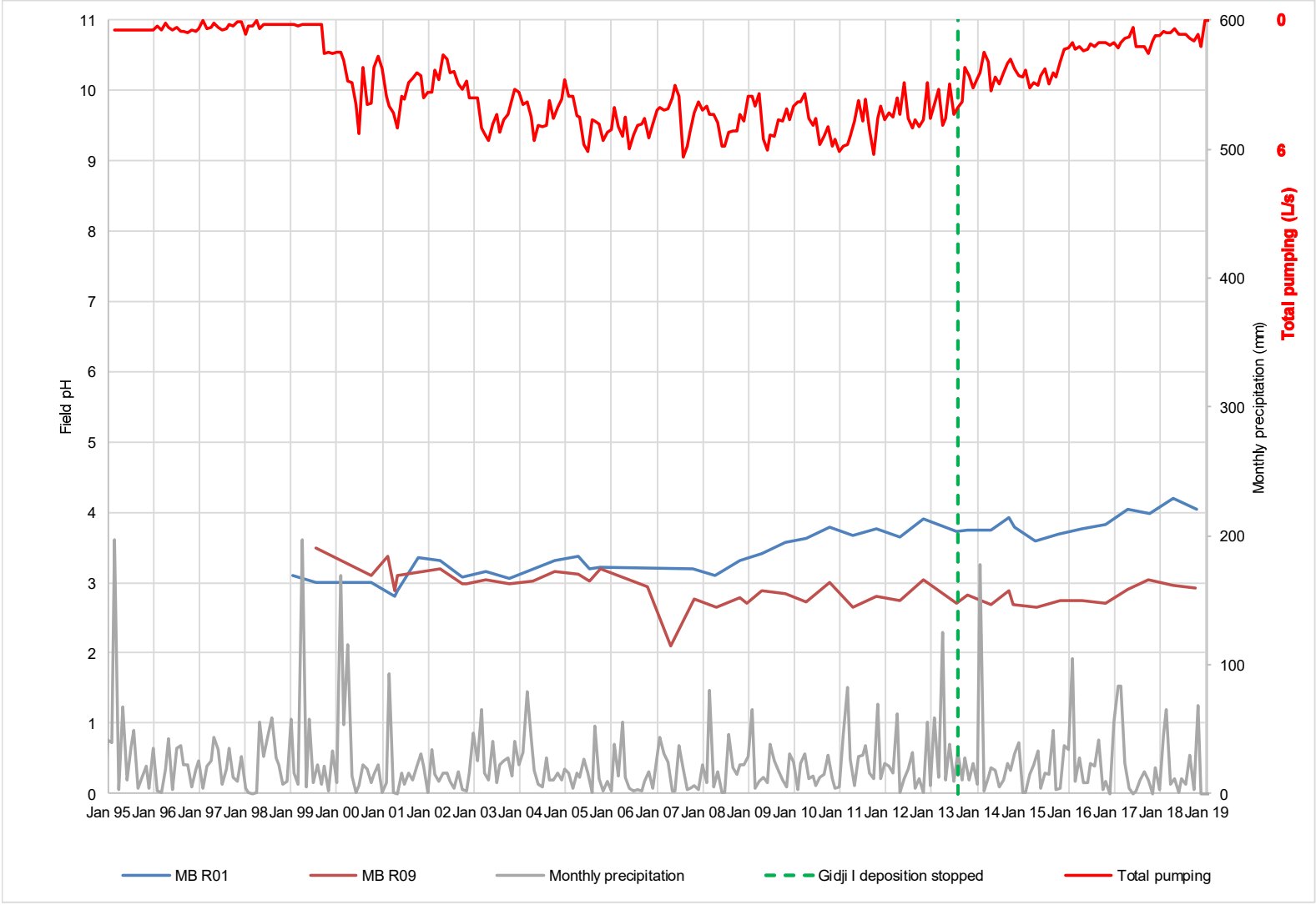
BIG DOG HYDROGEOLOGY

Groundwater Field pH - trench bores

Figure C8

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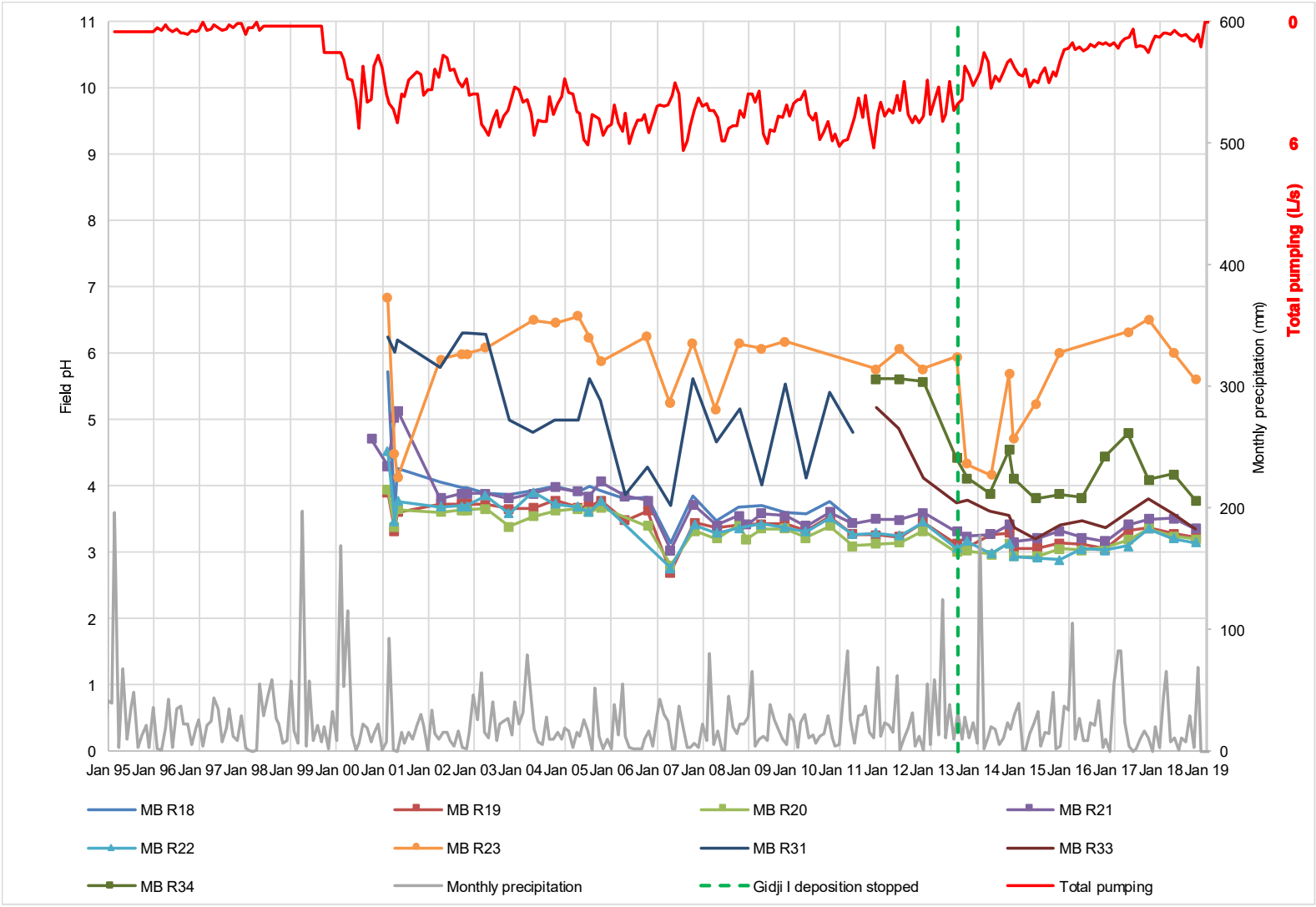
BIG DOG HYDROGEOLOGY

Groundwater Field pH - decant bores

Figure C9

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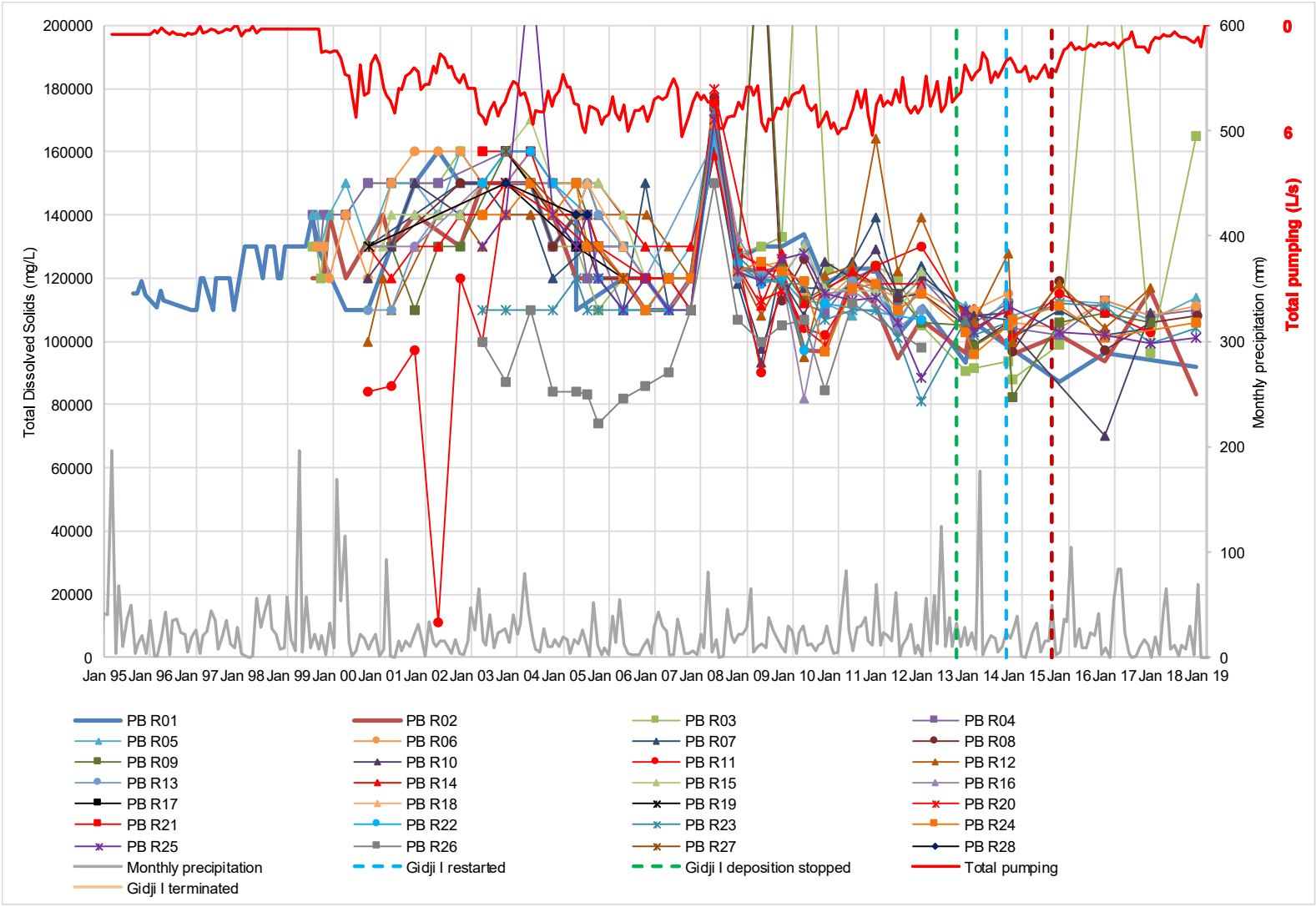
BIG DOG HYDROGEOLOGY

Groundwater Field pH - eastern bores

Figure C10

Date: January 2019

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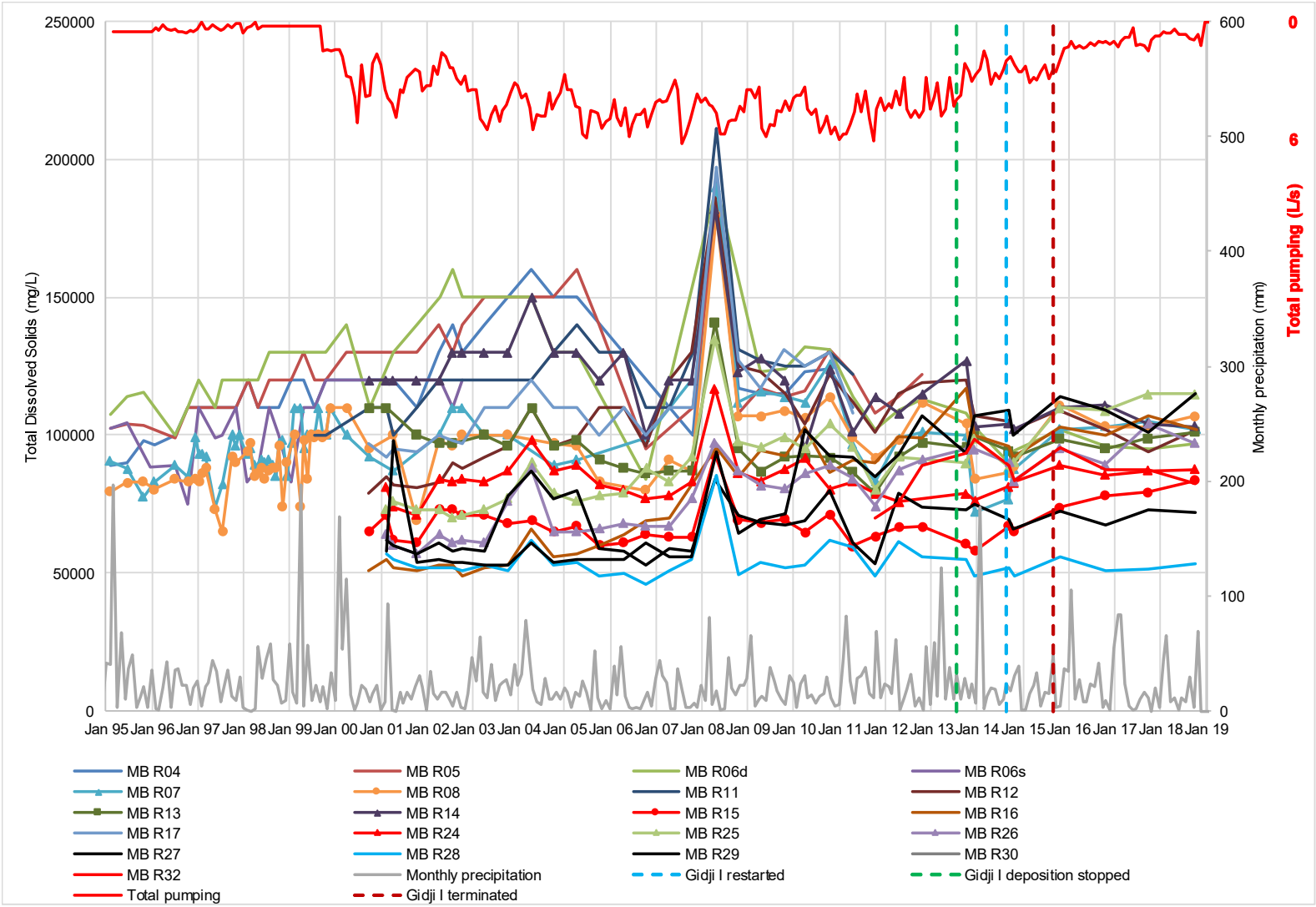
BIG DOG HYDROGEOLOGY

Groundwater TDS - production bores

Figure C11

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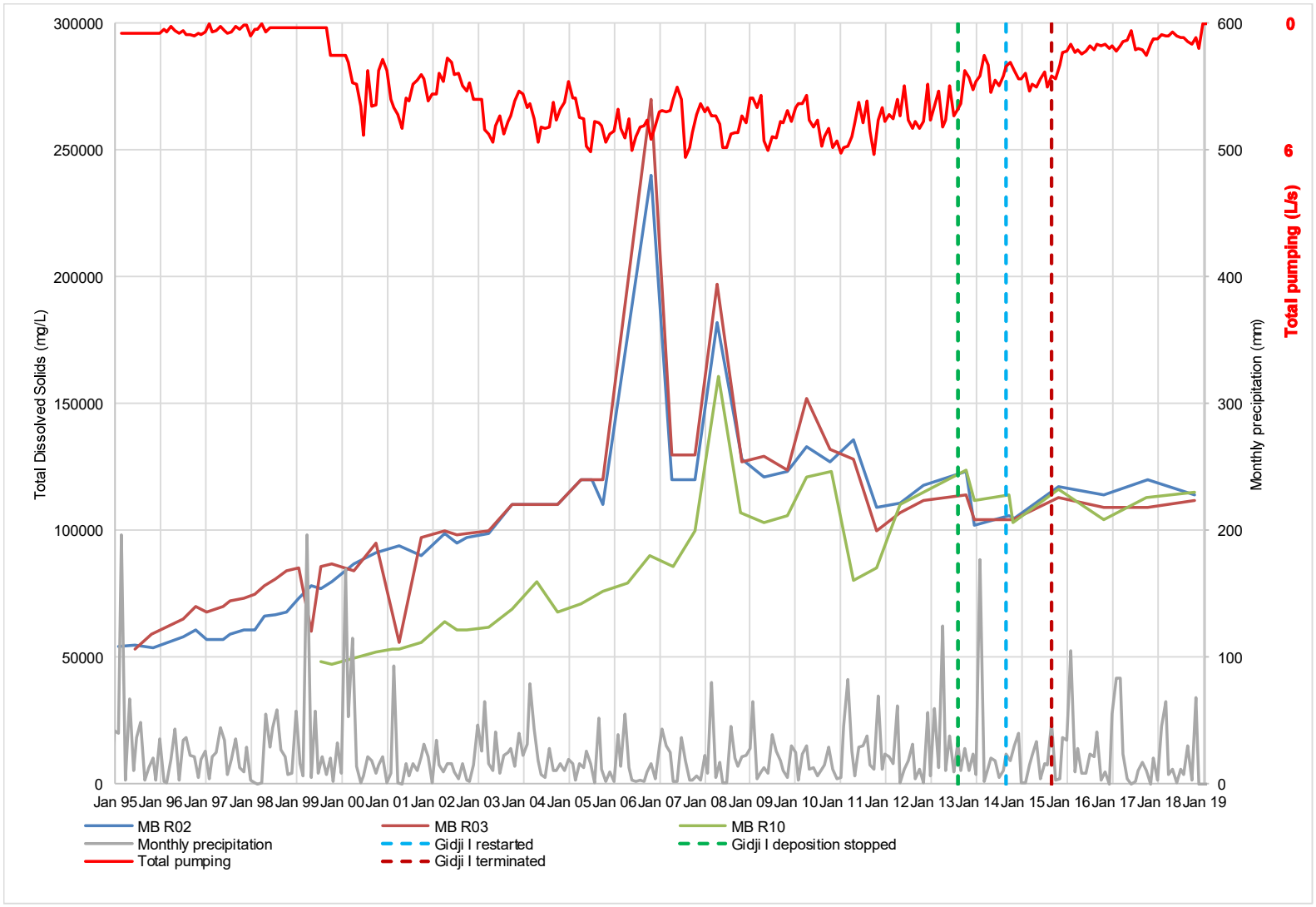
BIG DOG HYDROGEOLOGY

Groundwater TDS - western bores

Figure C12

Date: January 2019

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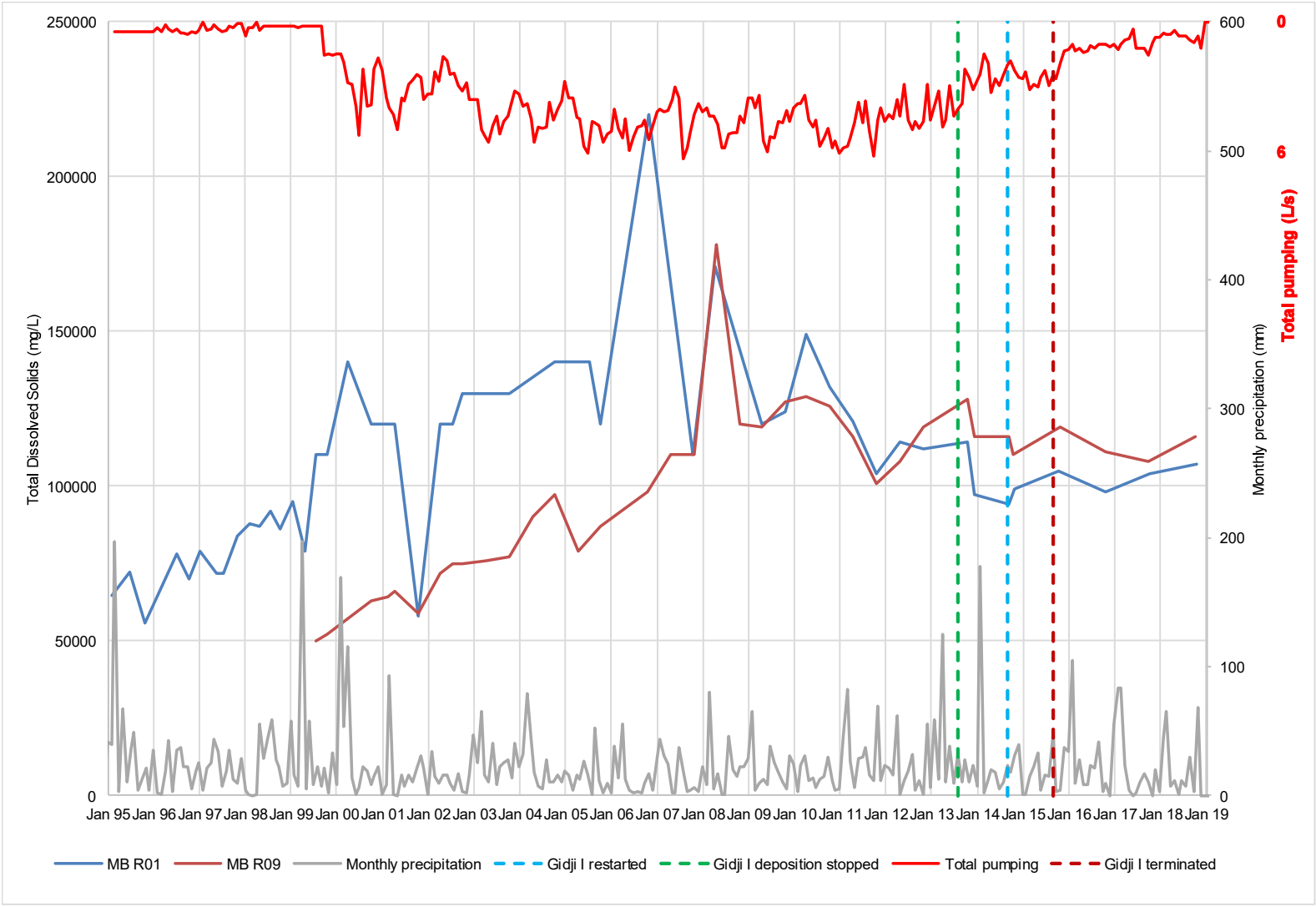
BIG DOG HYDROGEOLOGY

Groundwater TDS - trench bores

Figure C13

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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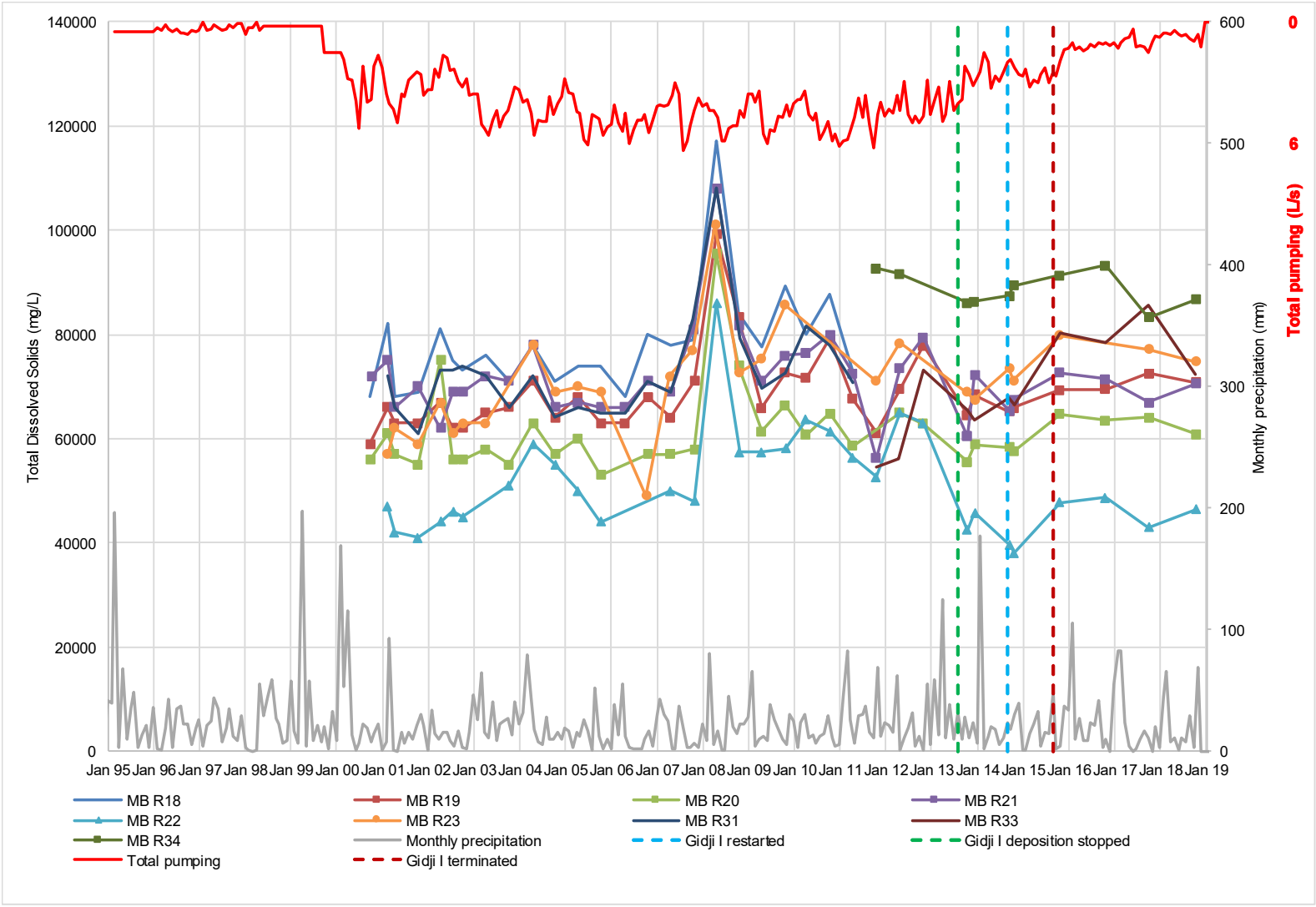
BIG DOG HYDROGEOLOGY

Groundwater TDS - decant bores

Figure C14

Date: January 2019

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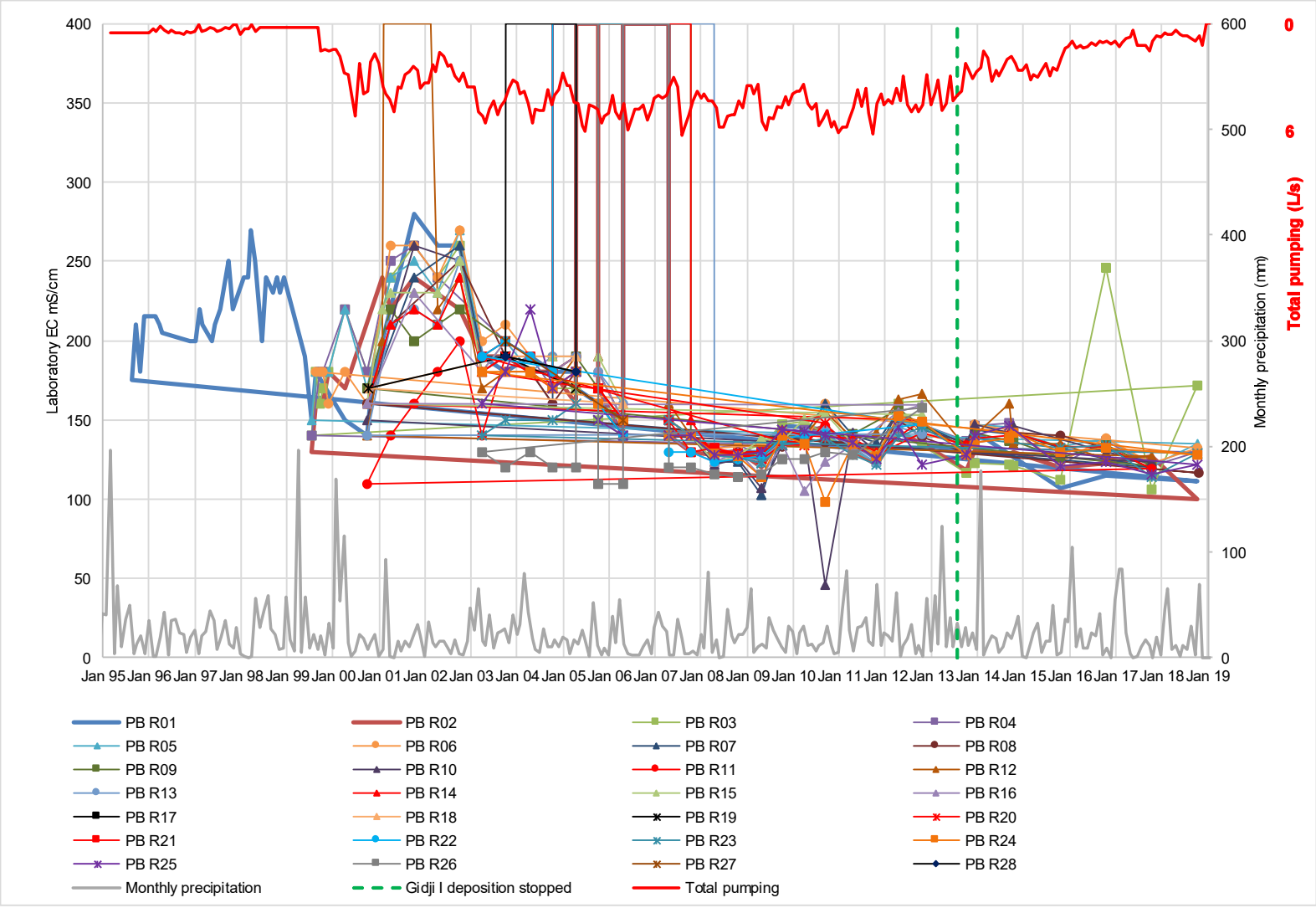
BIG DOG HYDROGEOLOGY

Groundwater TDS - eastern bores

Figure C15

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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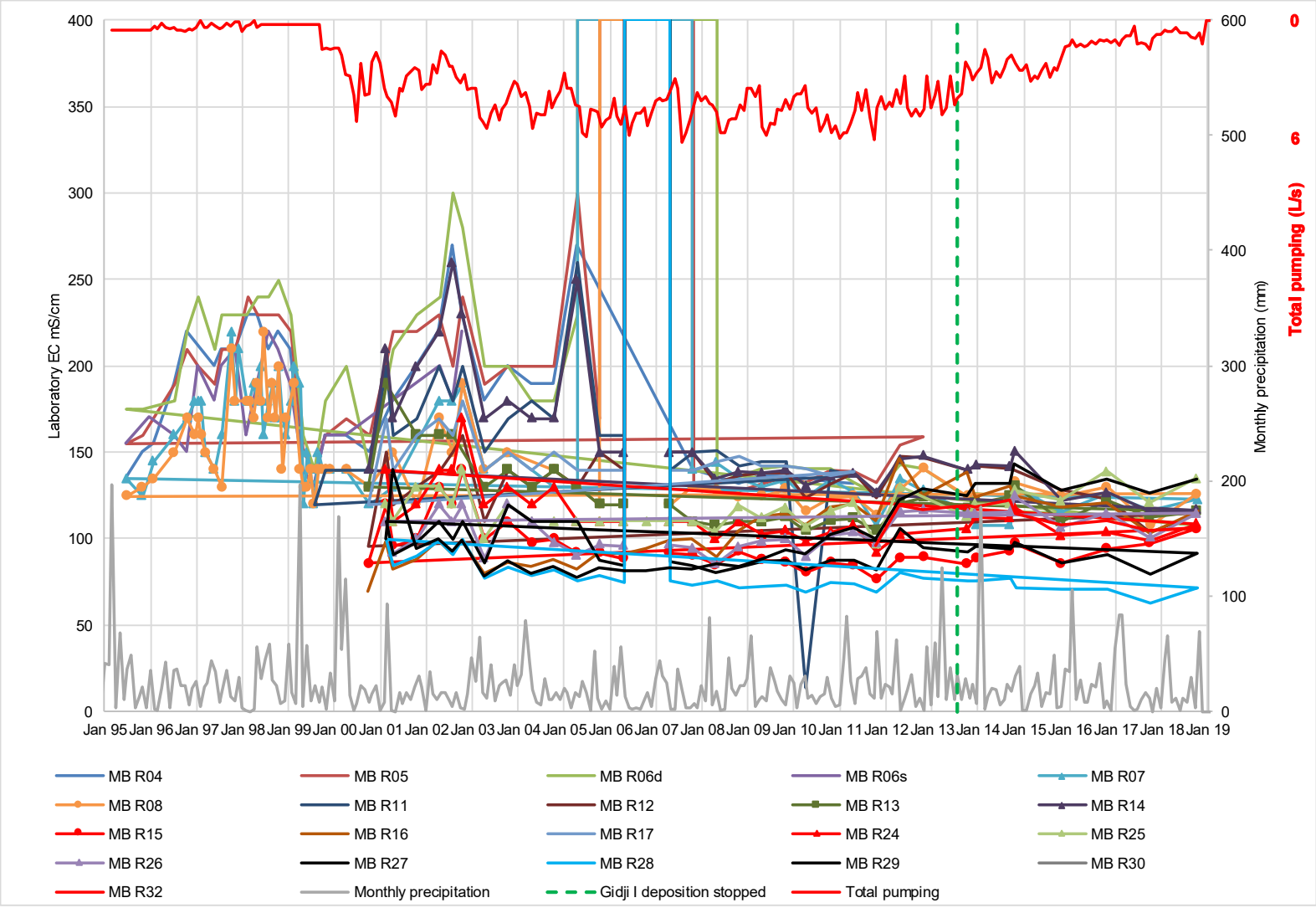
BIG DOG HYDROGEOLOGY

Groundwater Laboratory EC - production bores

Figure C16

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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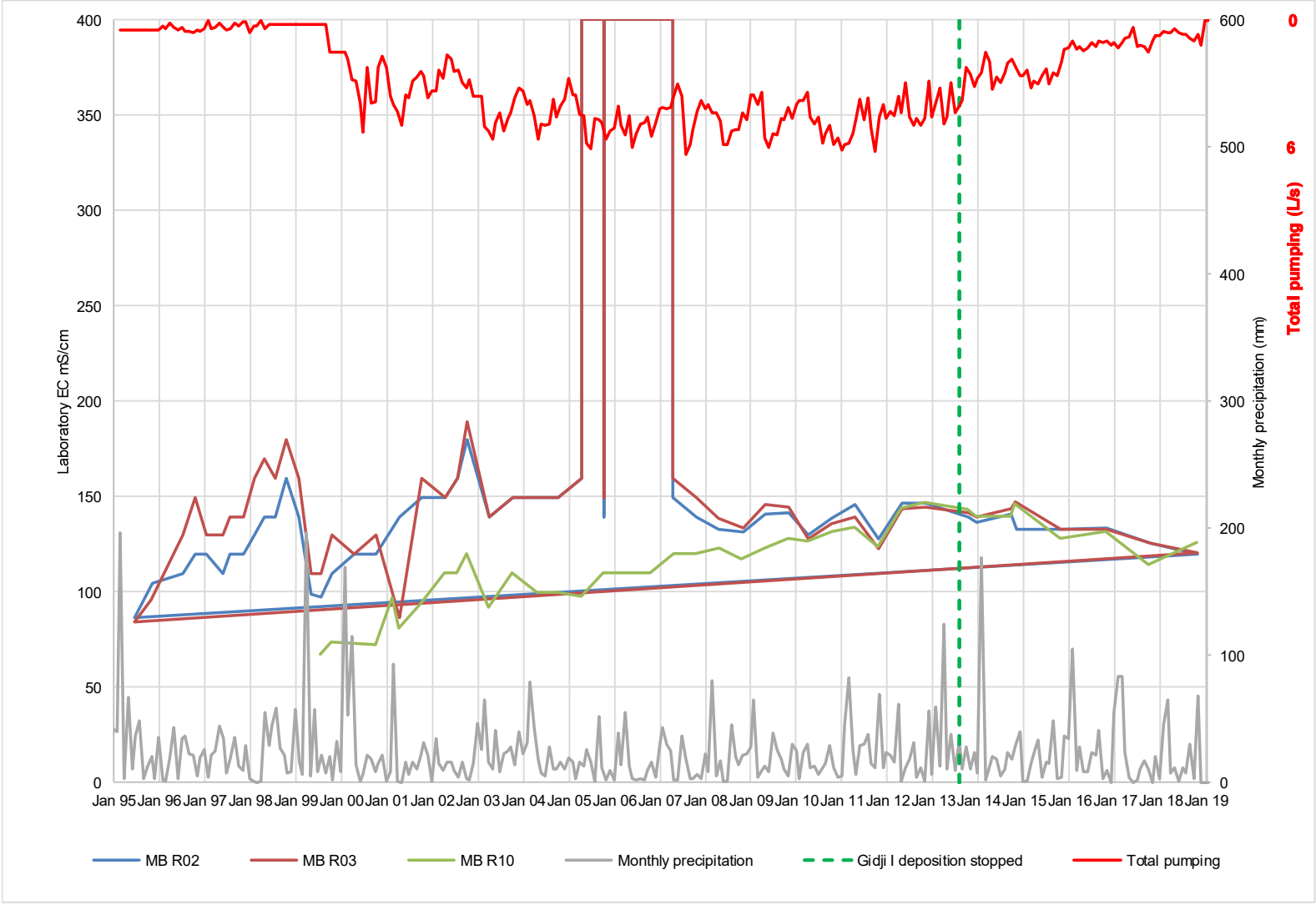
BIG DOG HYDROGEOLOGY

Groundwater Laboratory EC - western bores

Figure C17

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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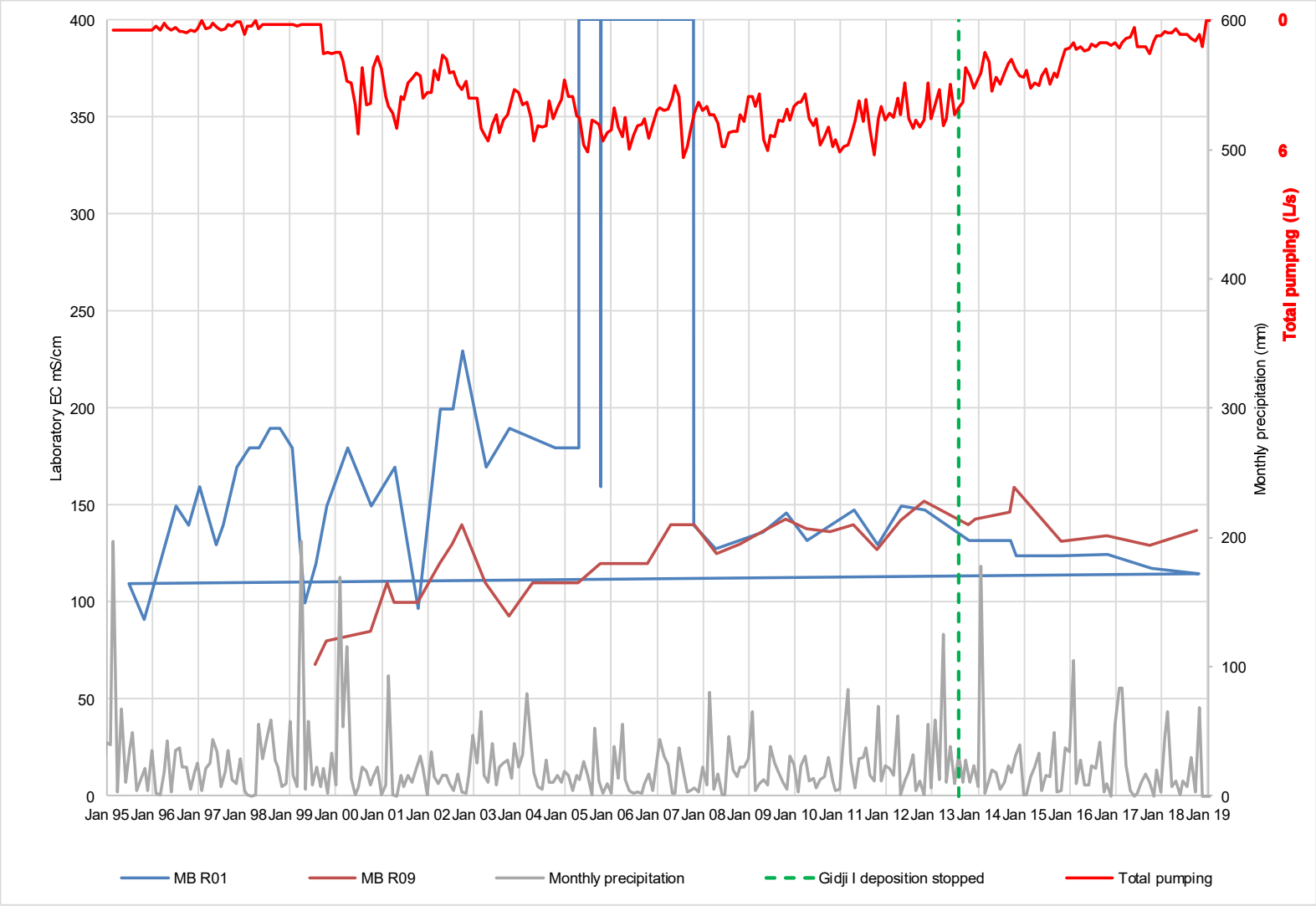
BIG DOG HYDROGEOLOGY

Groundwater Laboratory EC - trench bores

Figure C18

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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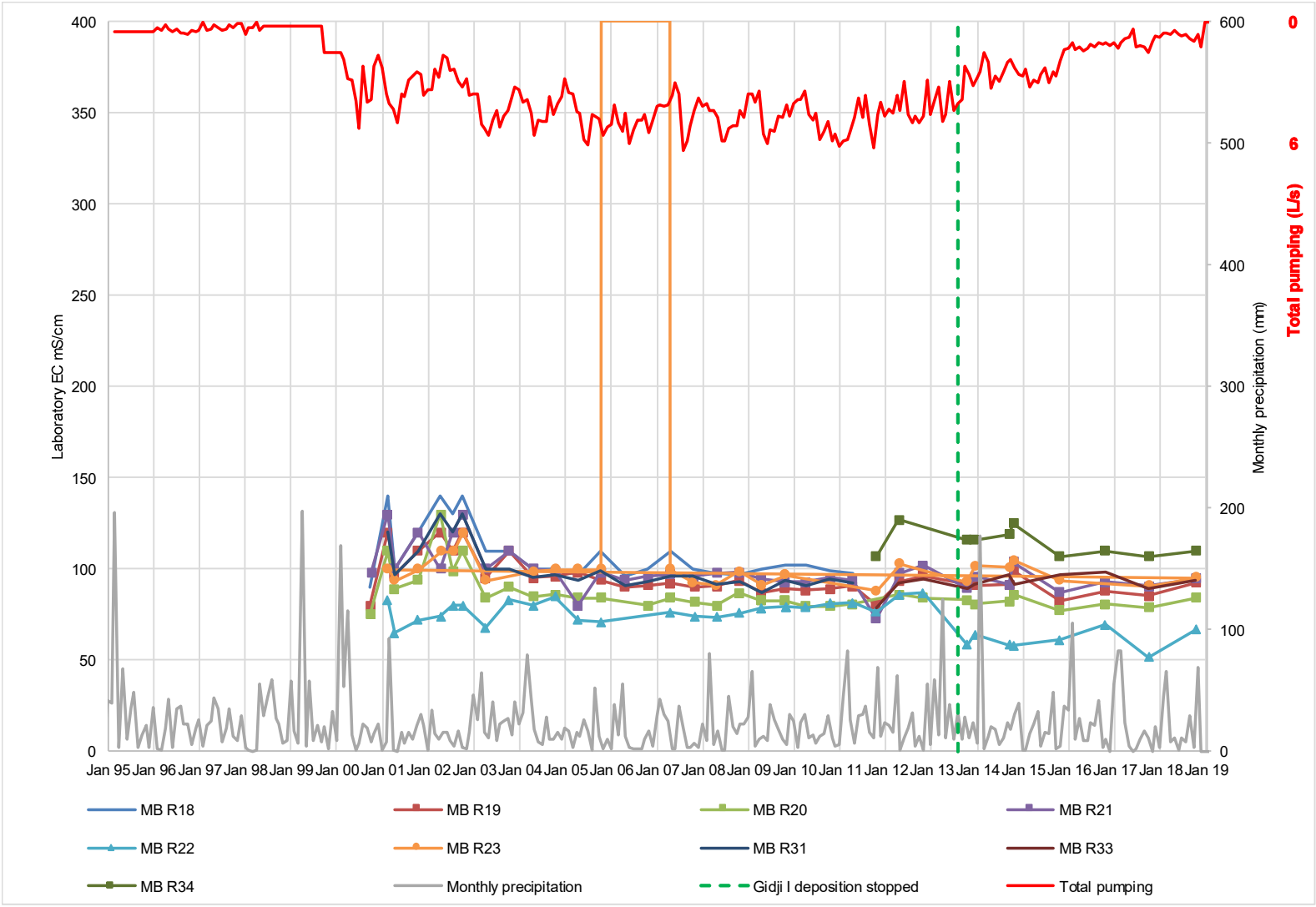
BIG DOG HYDROGEOLOGY

Groundwater Laboratory EC - decant bores

Figure C19

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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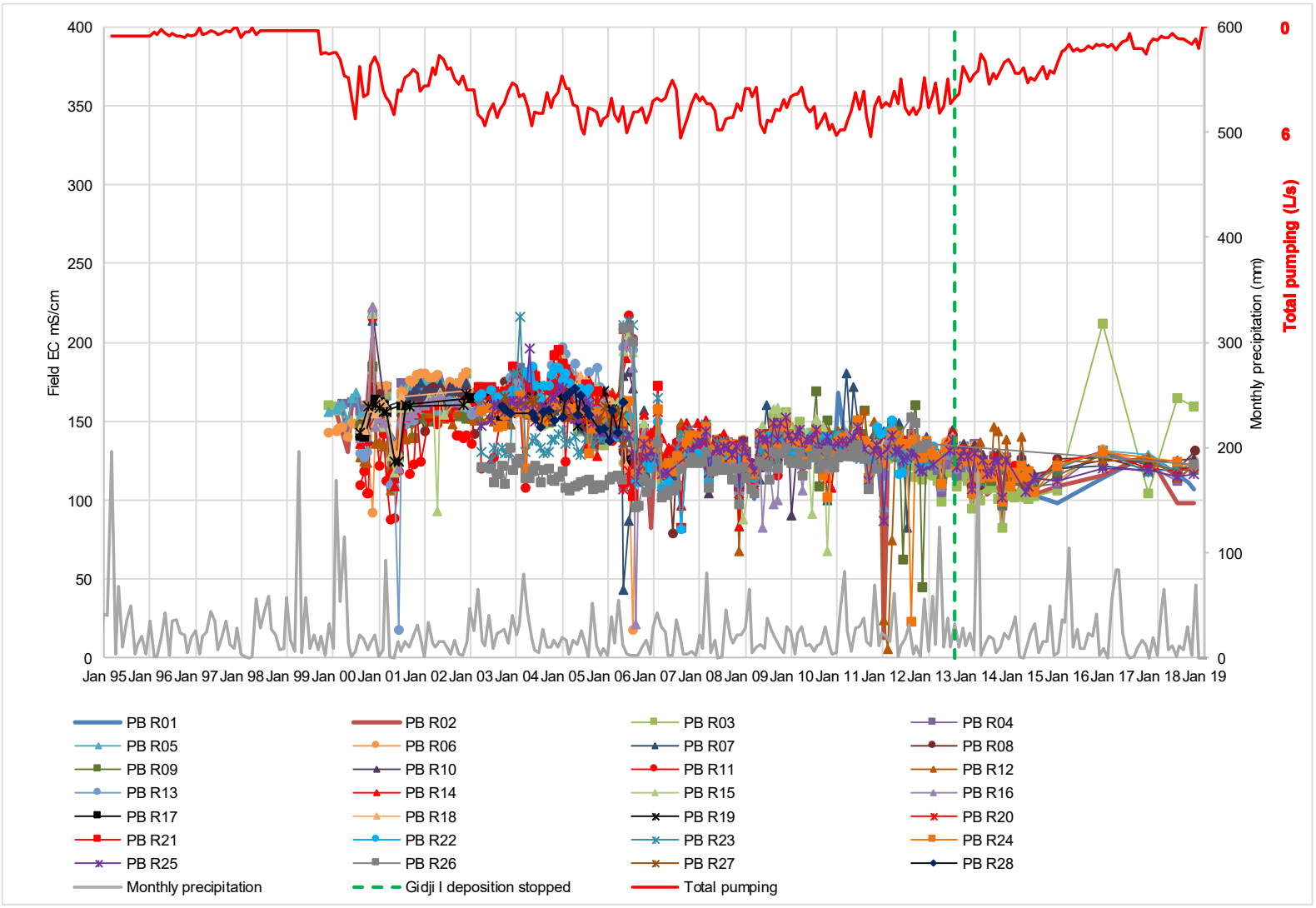
BIG DOG HYDROGEOLOGY

Groundwater Laboratory EC - eastern bores

Figure C20

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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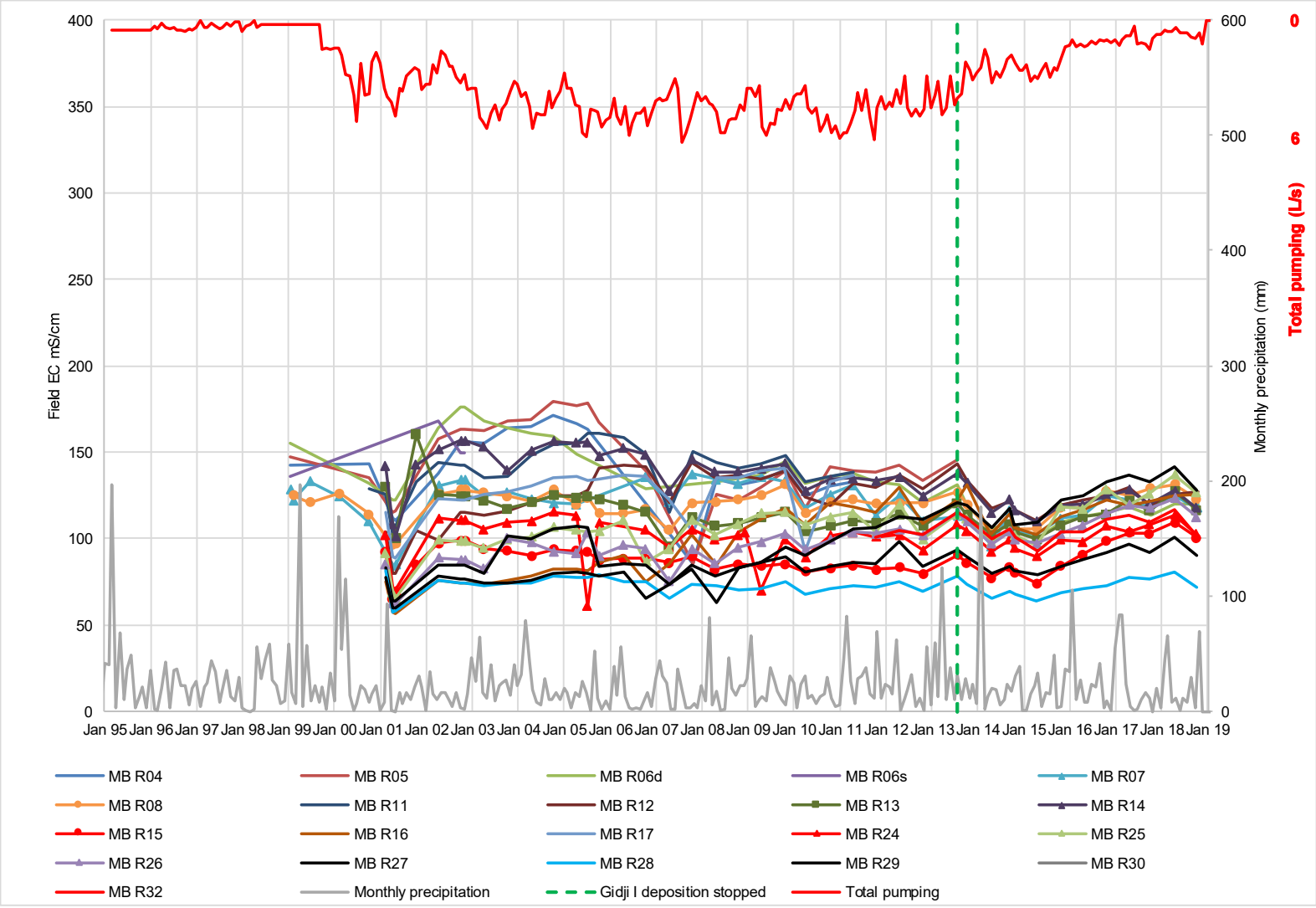
BIG DOG HYDROGEOLOGY

Groundwater Field EC - production bores

Figure C21

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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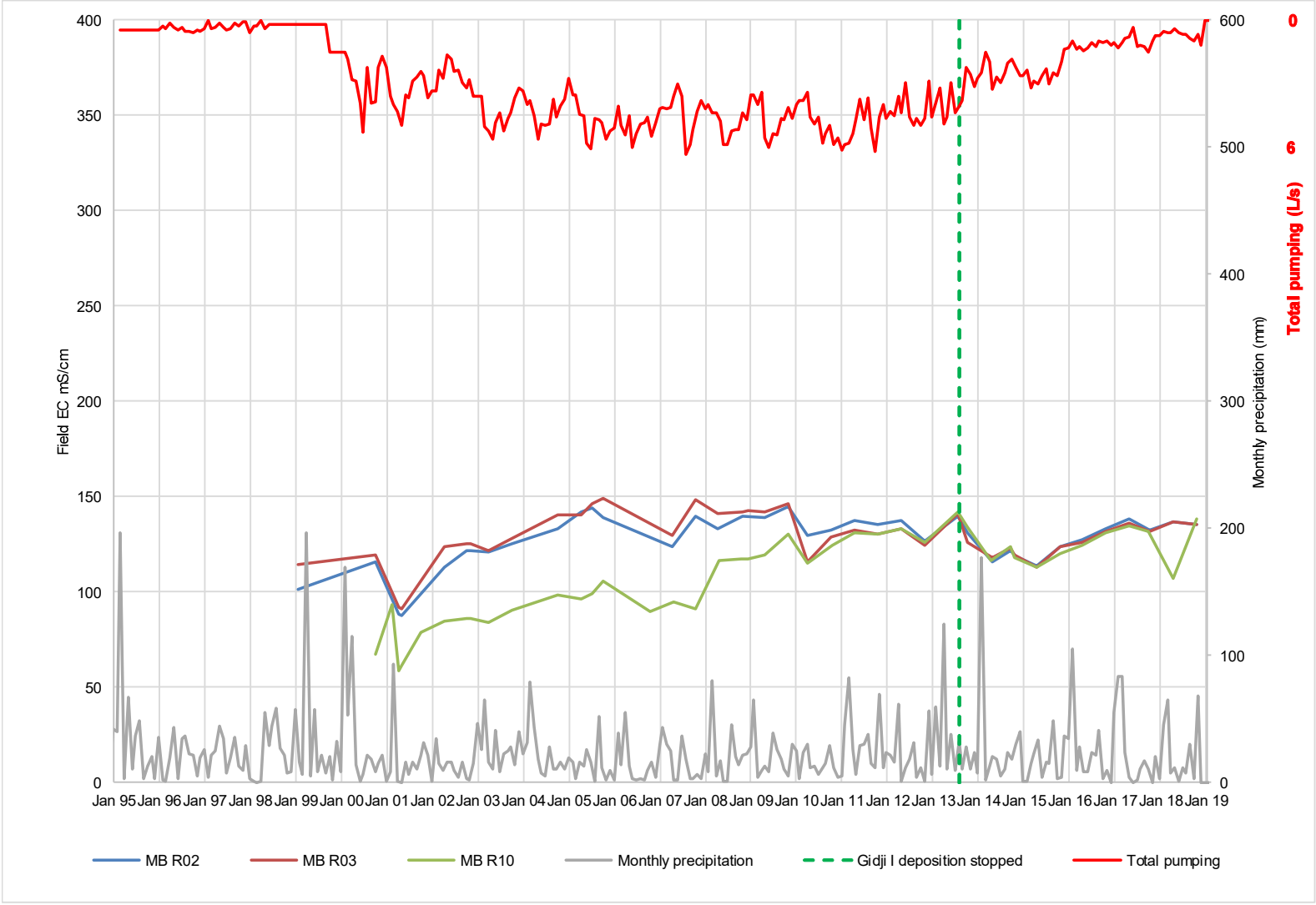
BIG DOG HYDROGEOLOGY

Groundwater Field EC - western bores

Figure C22

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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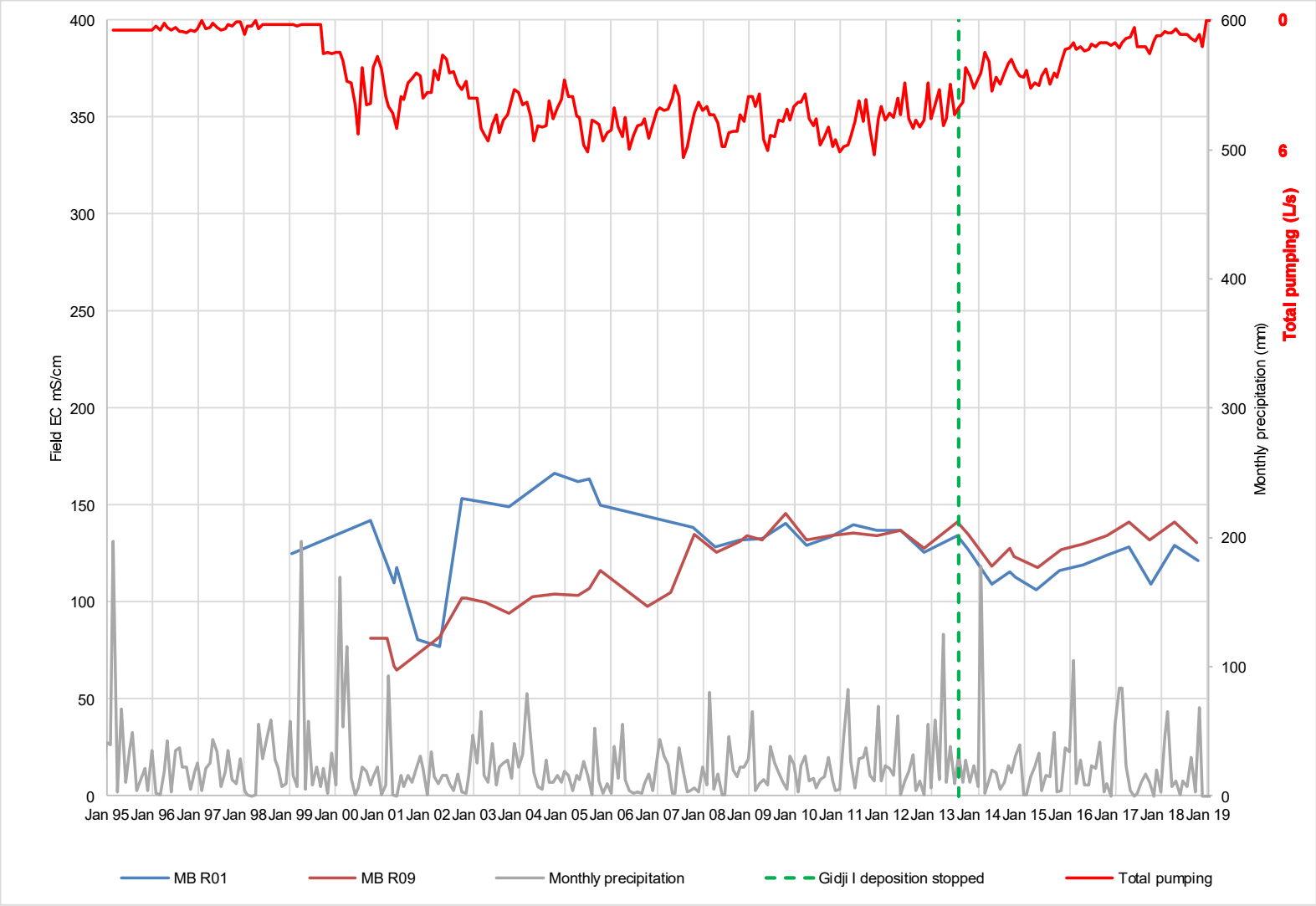
BIG DOG HYDROGEOLOGY

Groundwater Field EC - trench bores

Figure C23

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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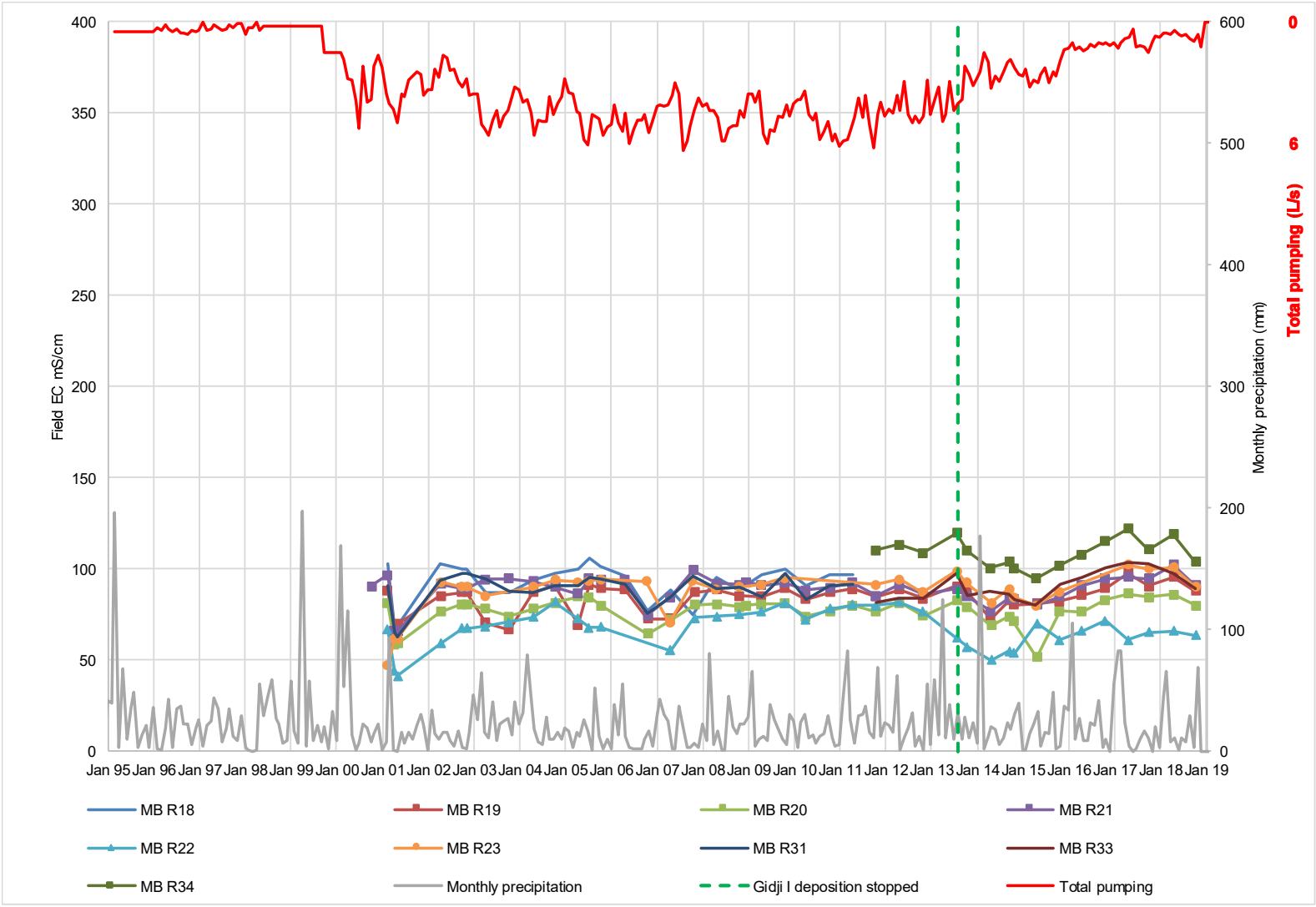
BIG DOG HYDROGEOLOGY

Groundwater Field EC - decant bores

Figure C24

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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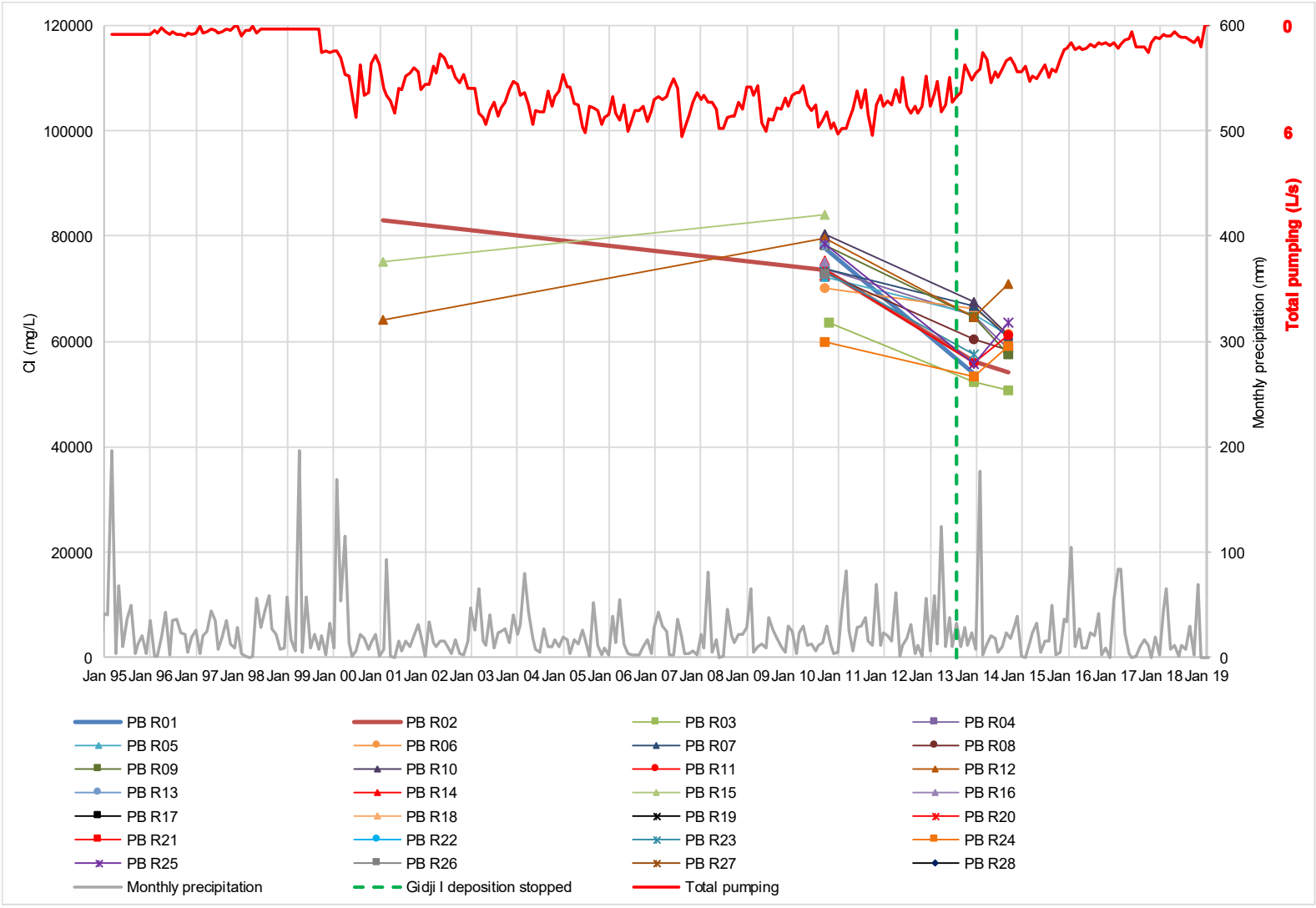
BIG DOG HYDROGEOLOGY

Groundwater Field EC - eastern bores

Figure C25

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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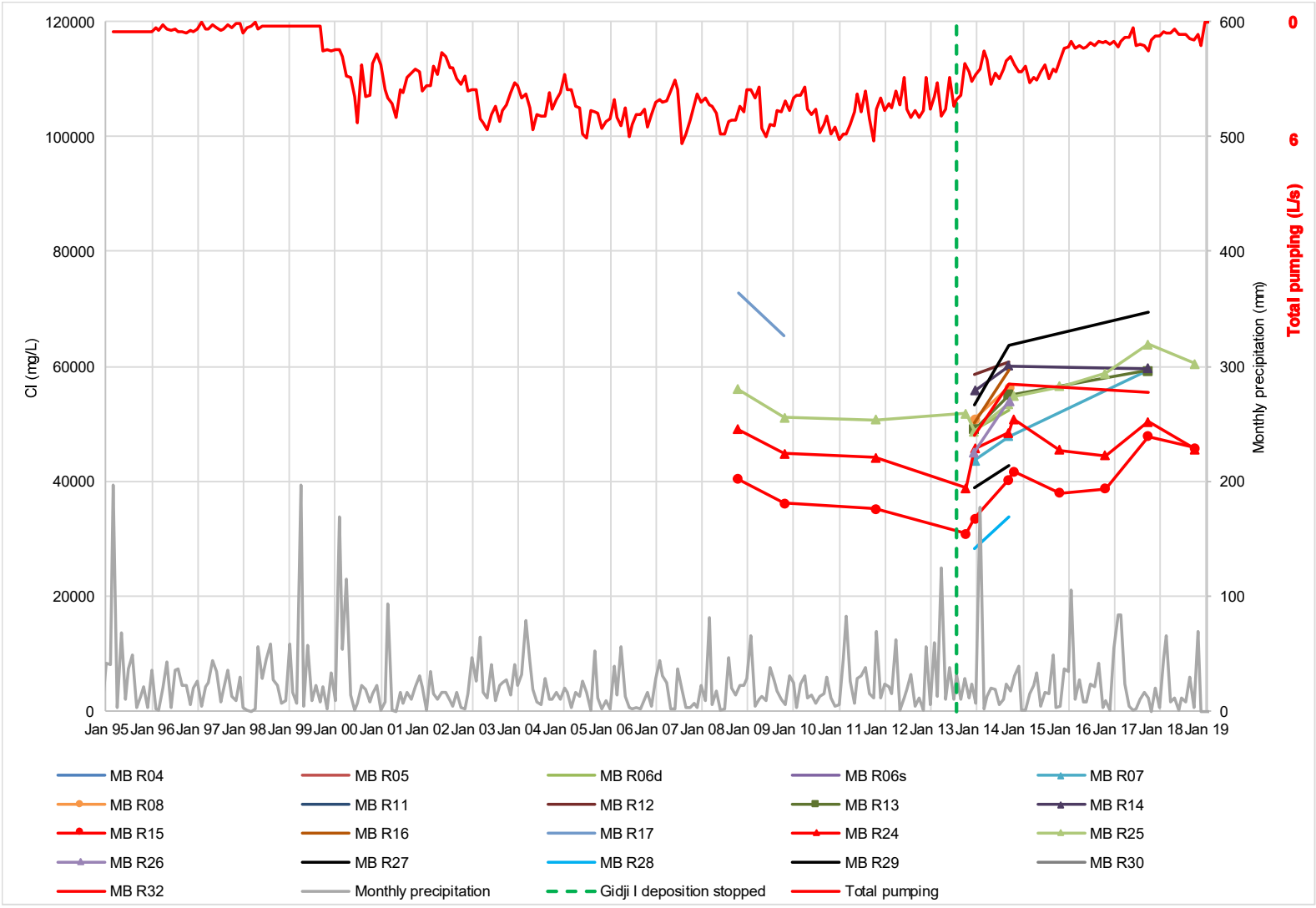
BIG DOG HYDROGEOLOGY

Groundwater Cl - production bores

Figure C26

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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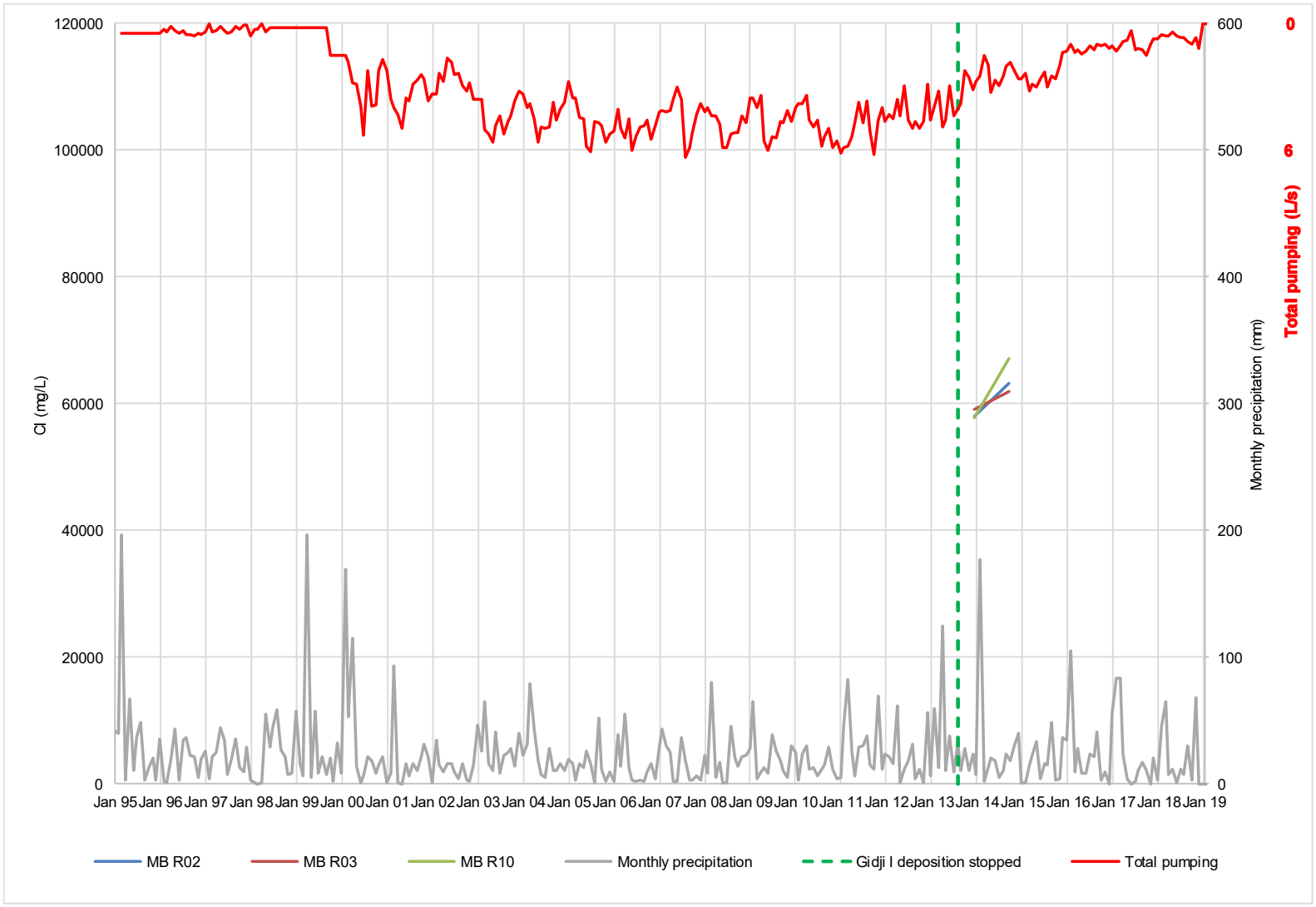
BIG DOG HYDROGEOLOGY

Groundwater Cl - western bores

Figure C27

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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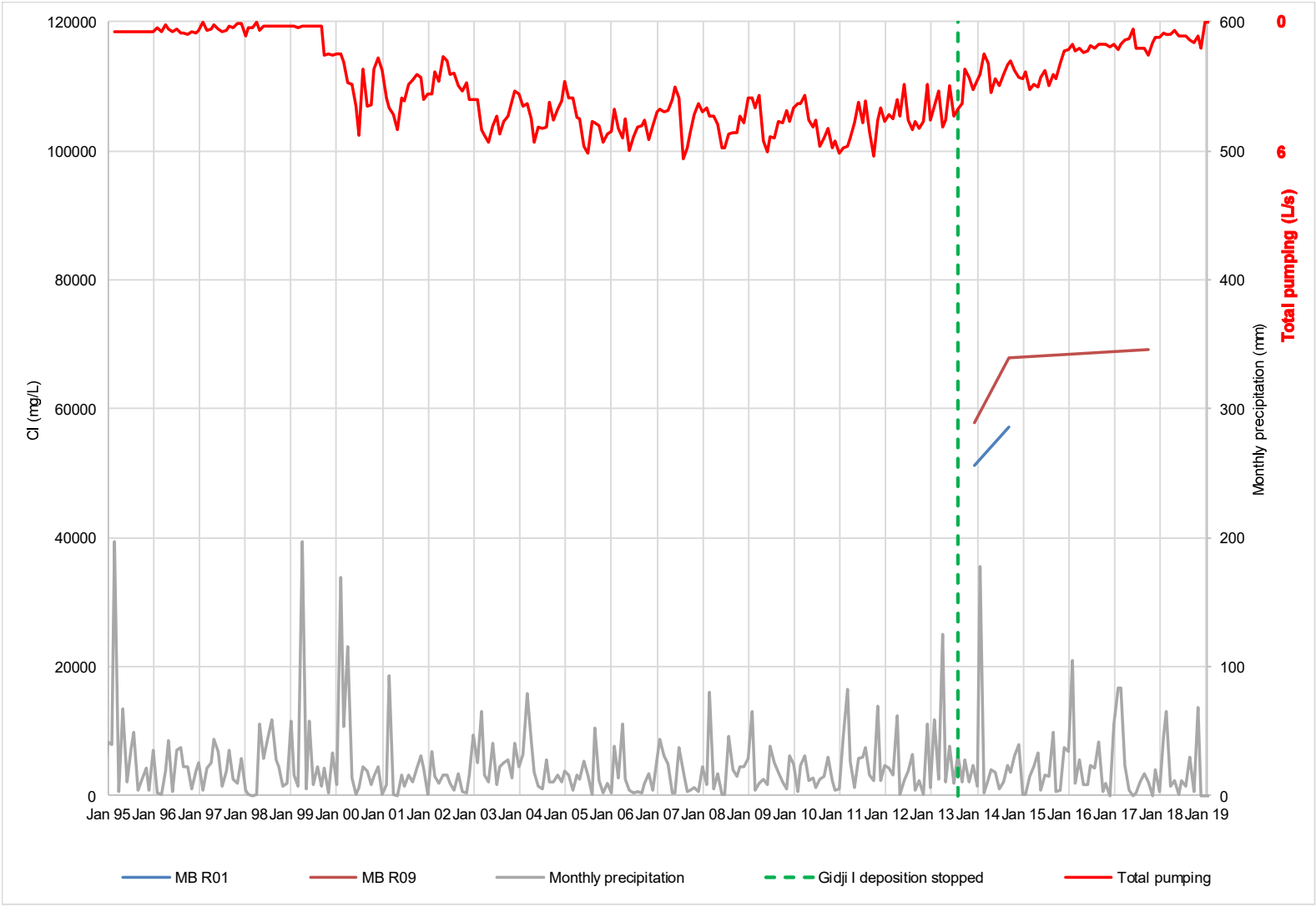
BIG DOG HYDROGEOLOGY

Groundwater Cl - trench bores

Figure C28

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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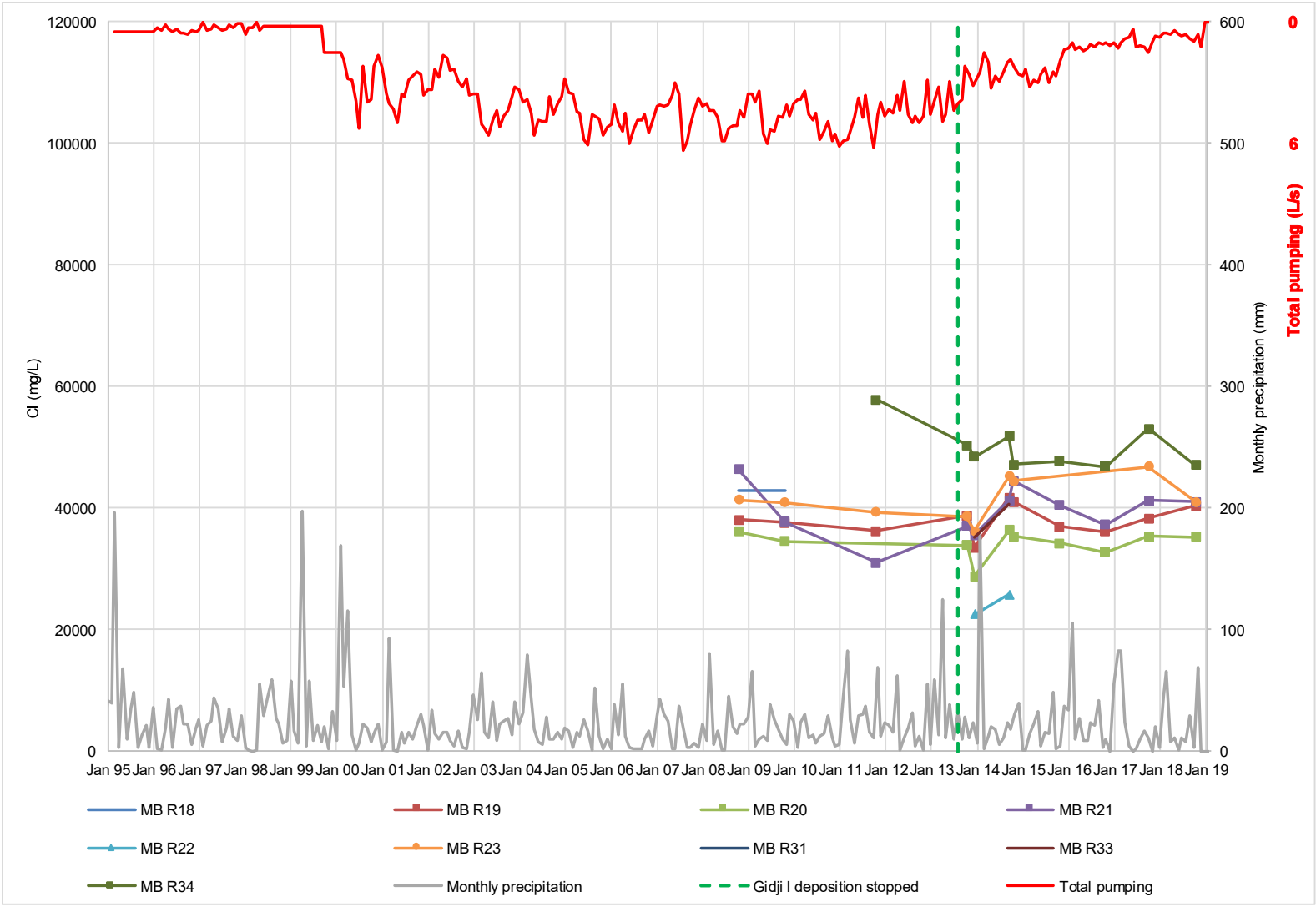
BIG DOG HYDROGEOLOGY

Groundwater Cl - decant bores

Figure C29

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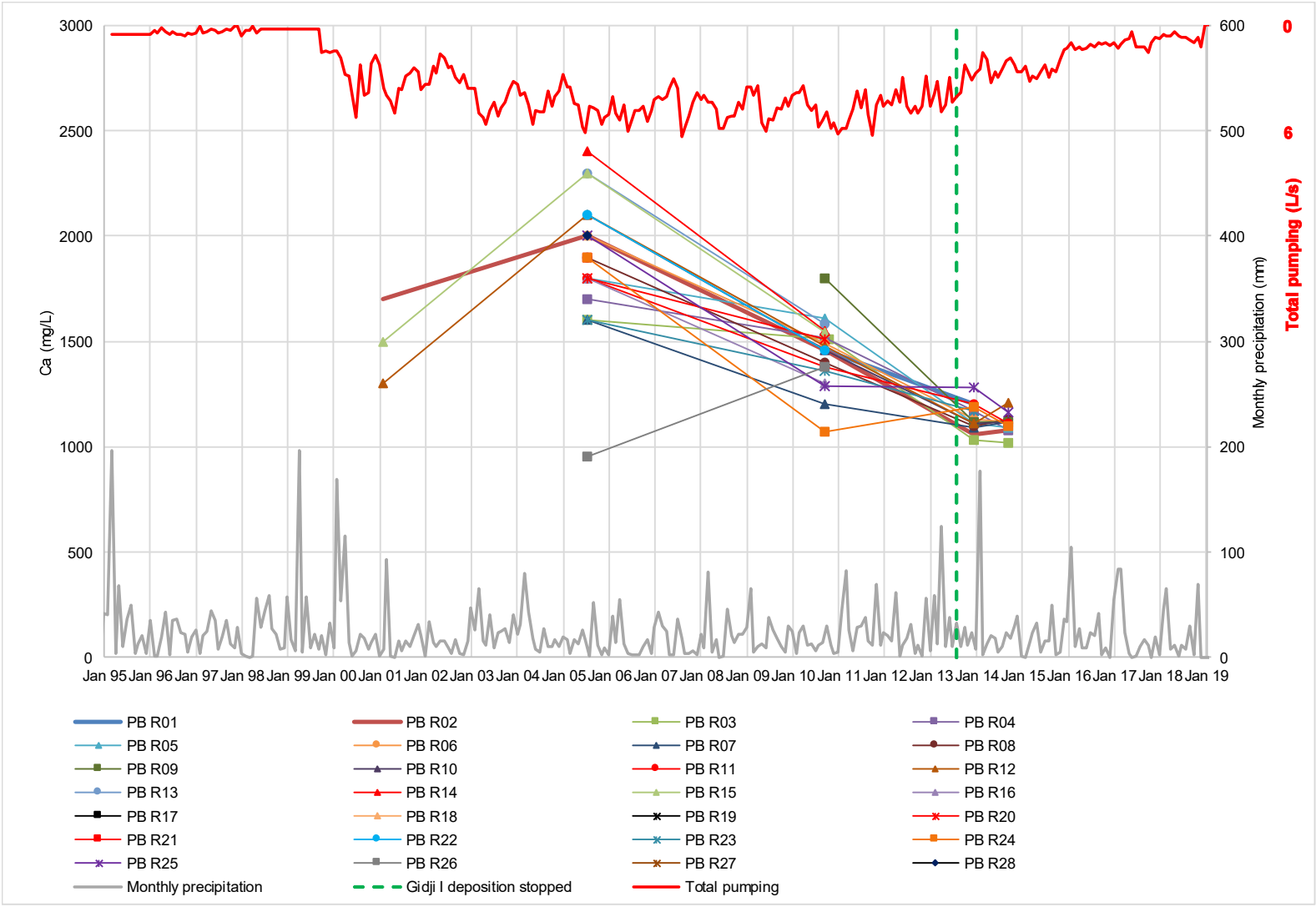
BIG DOG HYDROGEOLOGY

Groundwater Cl - eastern bores

Figure C30

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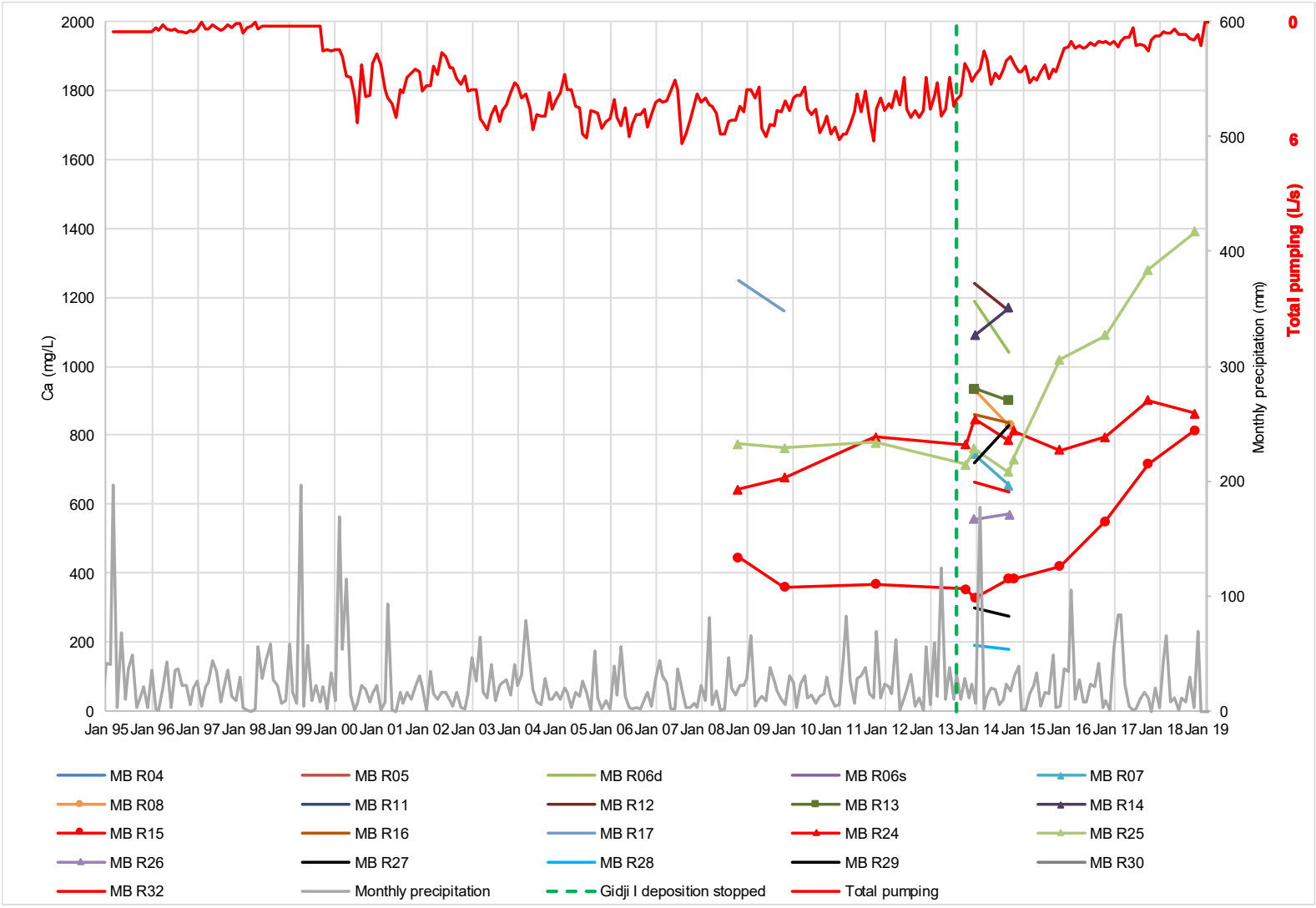
BIG DOG HYDROGEOLOGY

Groundwater Ca - production bores

Figure C31

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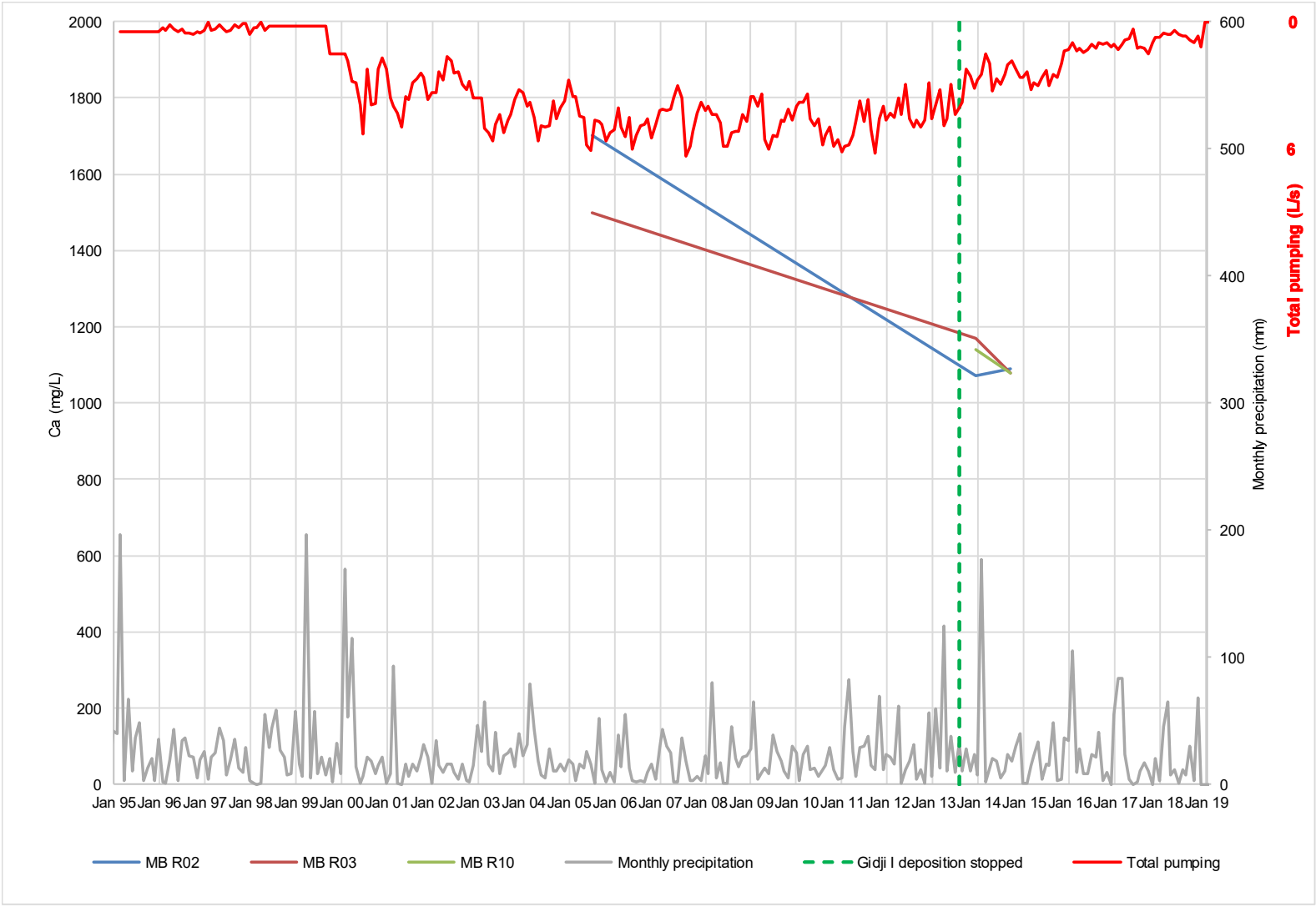
BIG DOG HYDROGEOLOGY

Groundwater Ca - western bores

Figure C32

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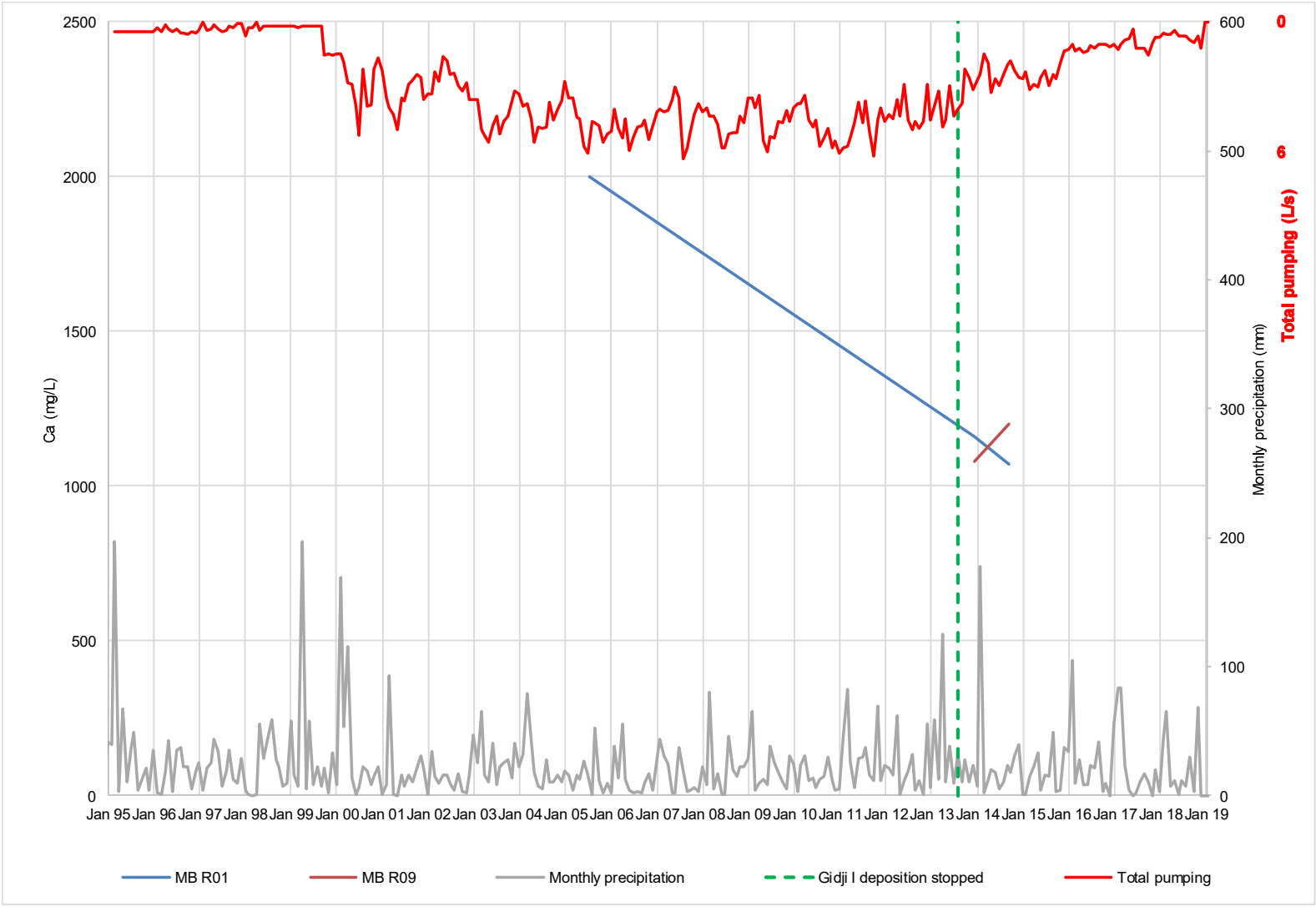
BIG DOG HYDROGEOLOGY

Groundwater Ca - trench bores

Figure C33

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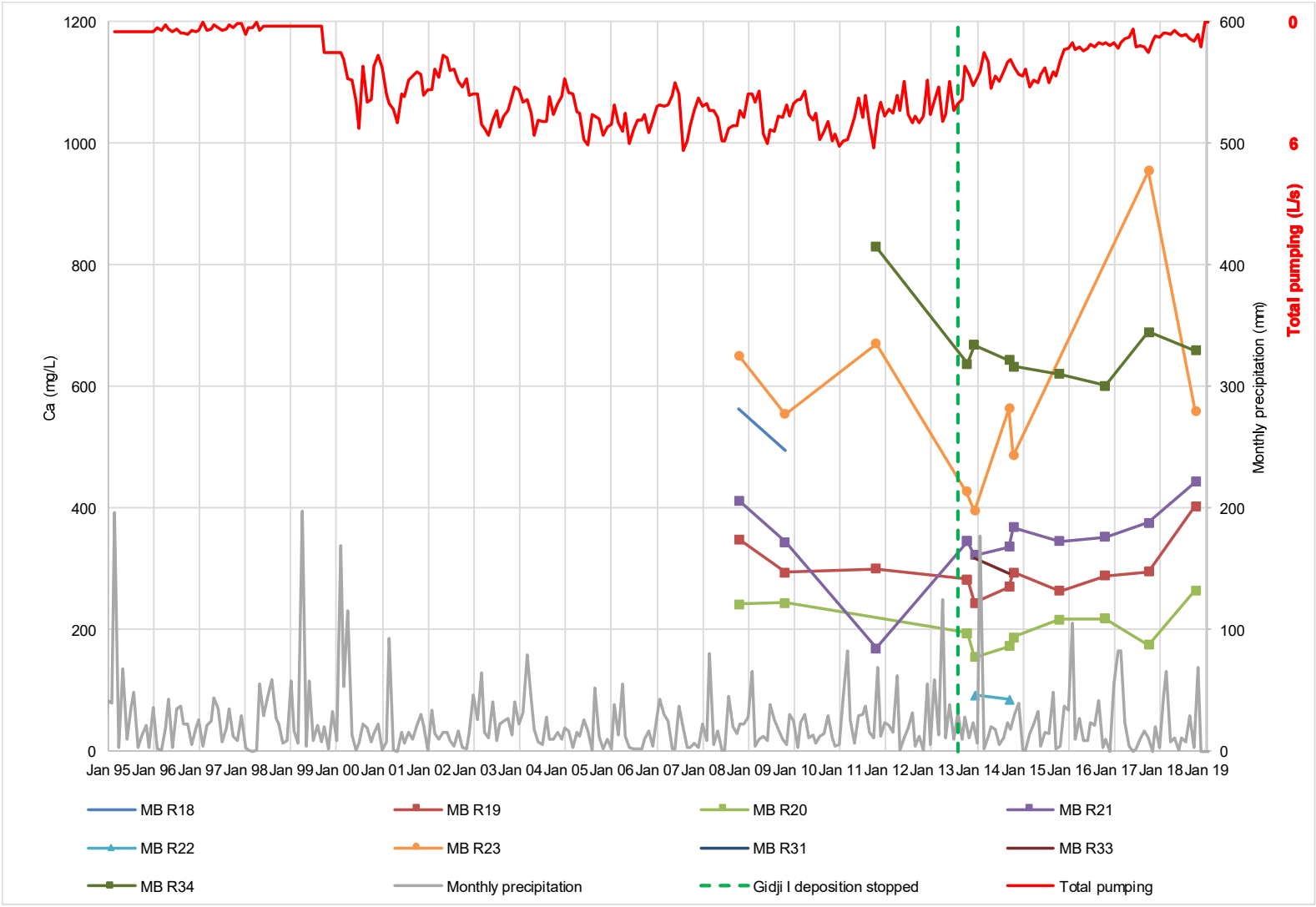
BIG DOG HYDROGEOLOGY

Groundwater Ca - decant bores

Figure C34

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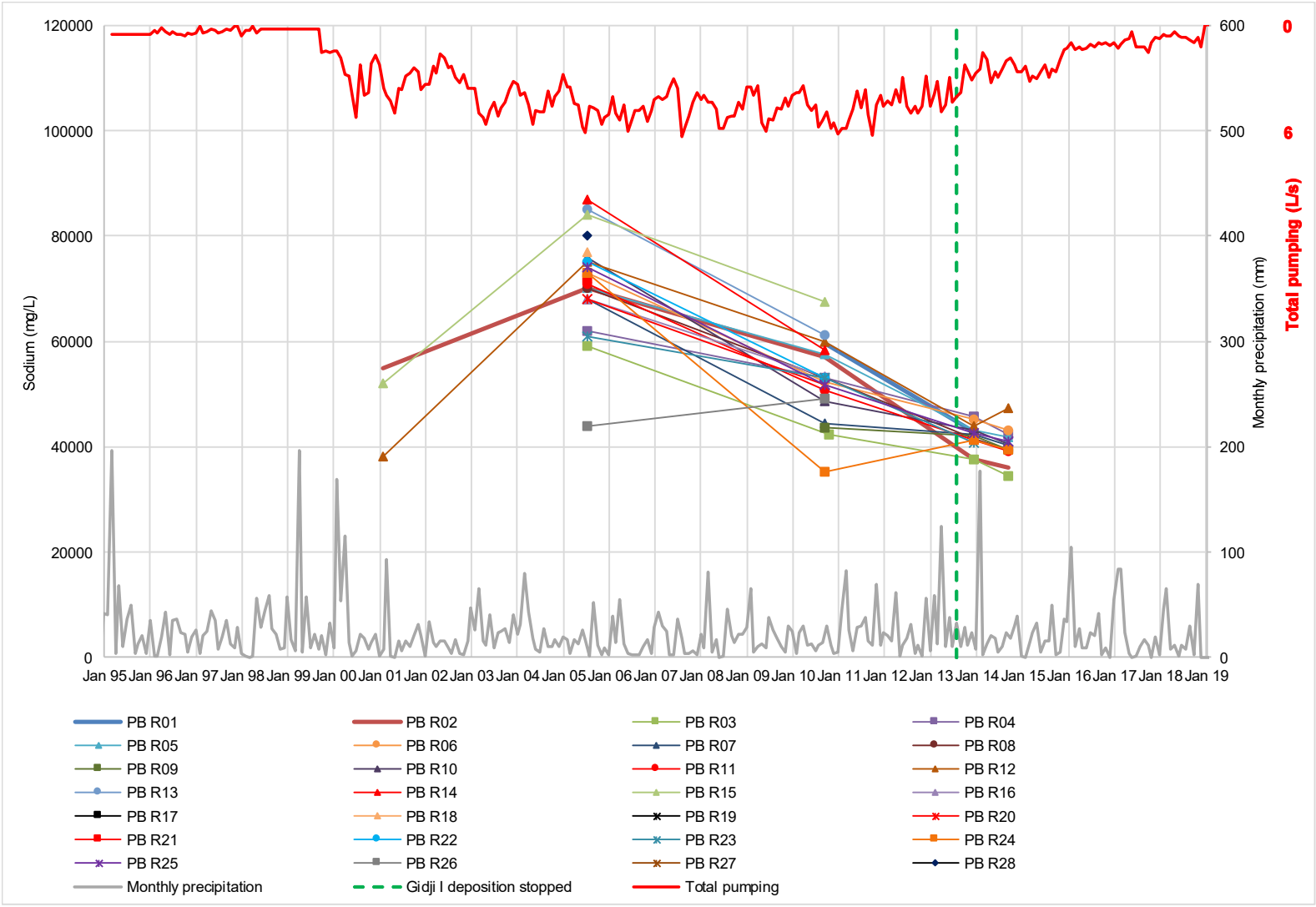
BIG DOG HYDROGEOLOGY

Groundwater Ca - eastern bores

Figure C35

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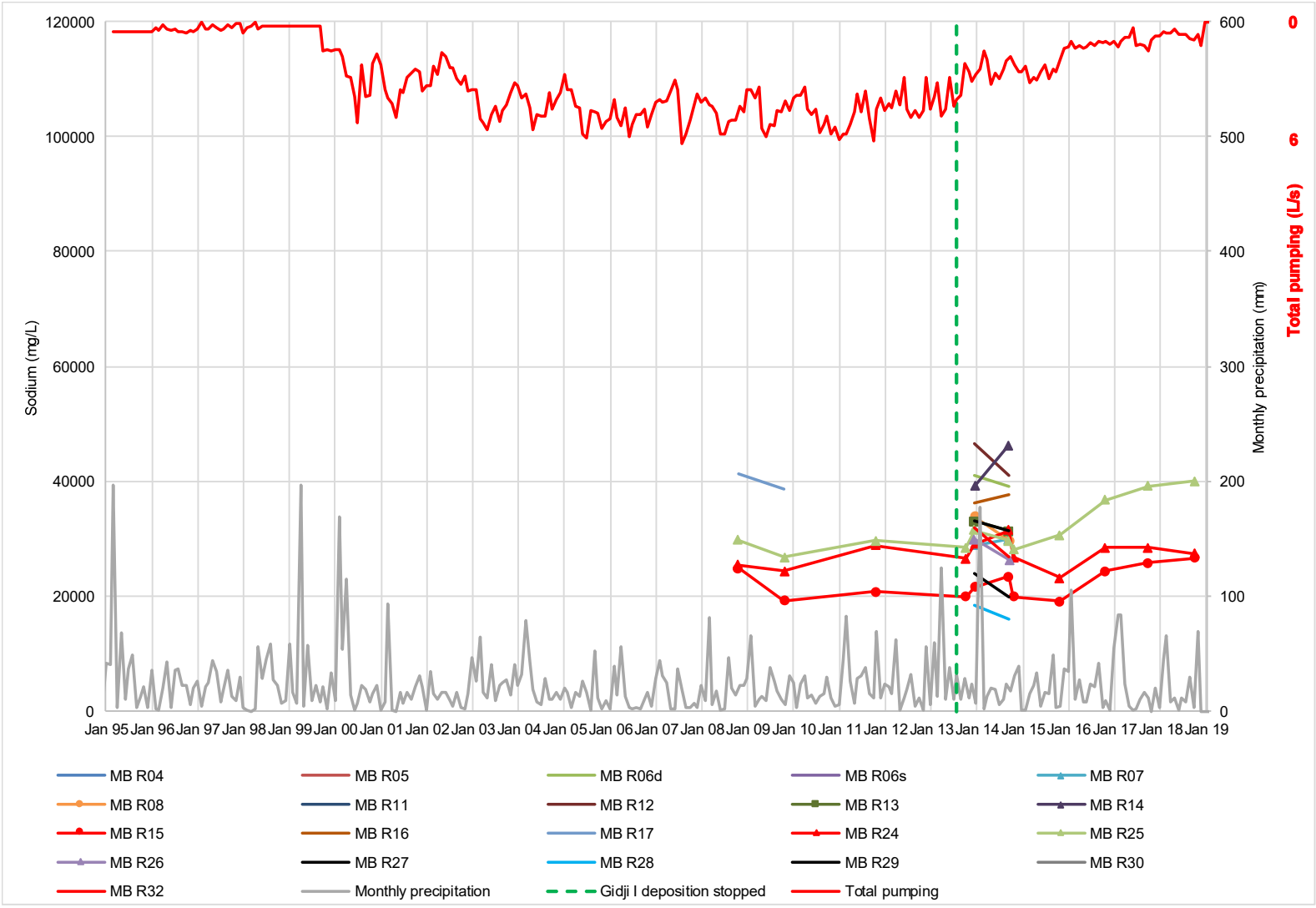
BIG DOG HYDROGEOLOGY

Groundwater Na - production bores

Figure C36

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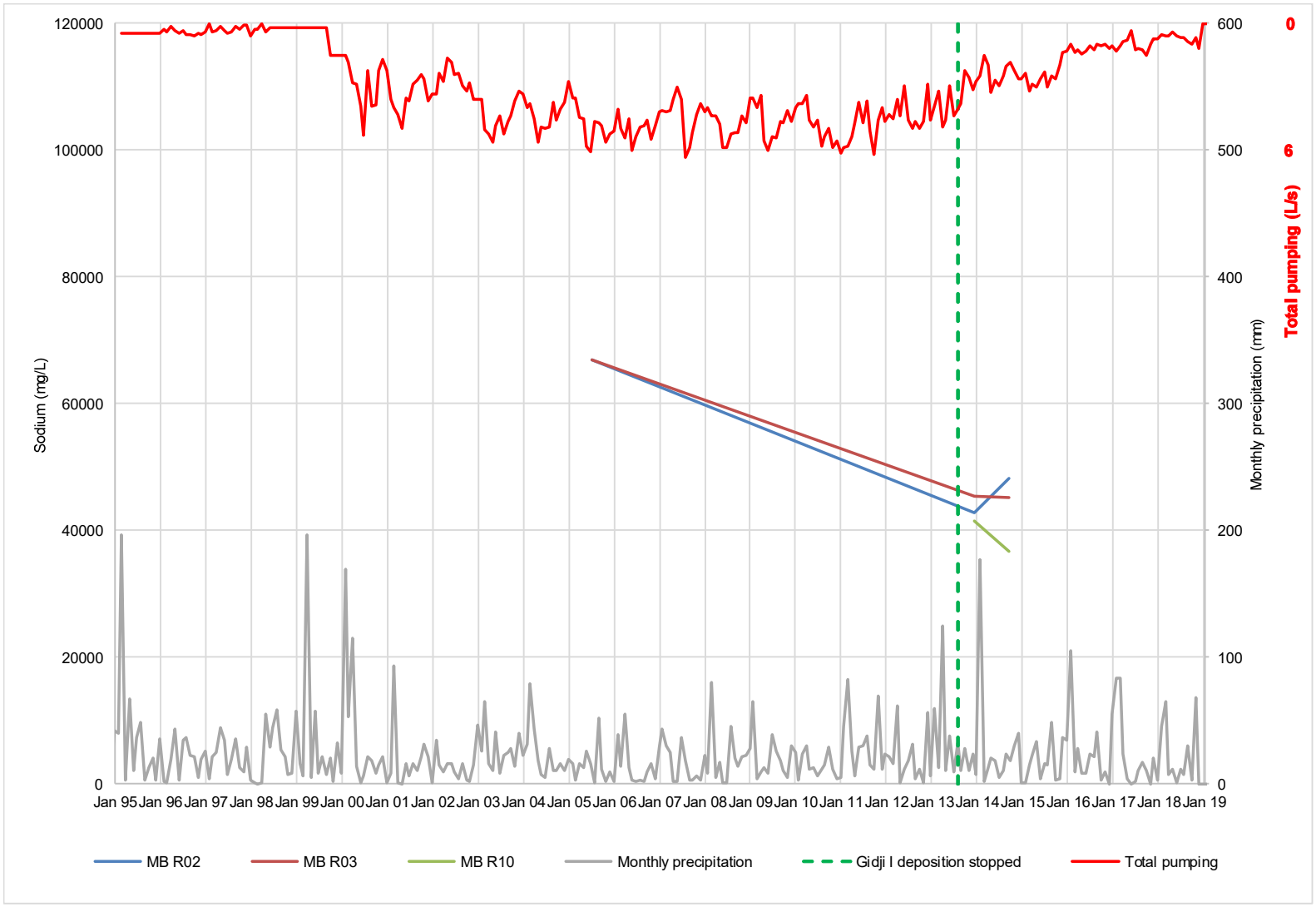
BIG DOG HYDROGEOLOGY

Groundwater Na - western bores

Figure C37

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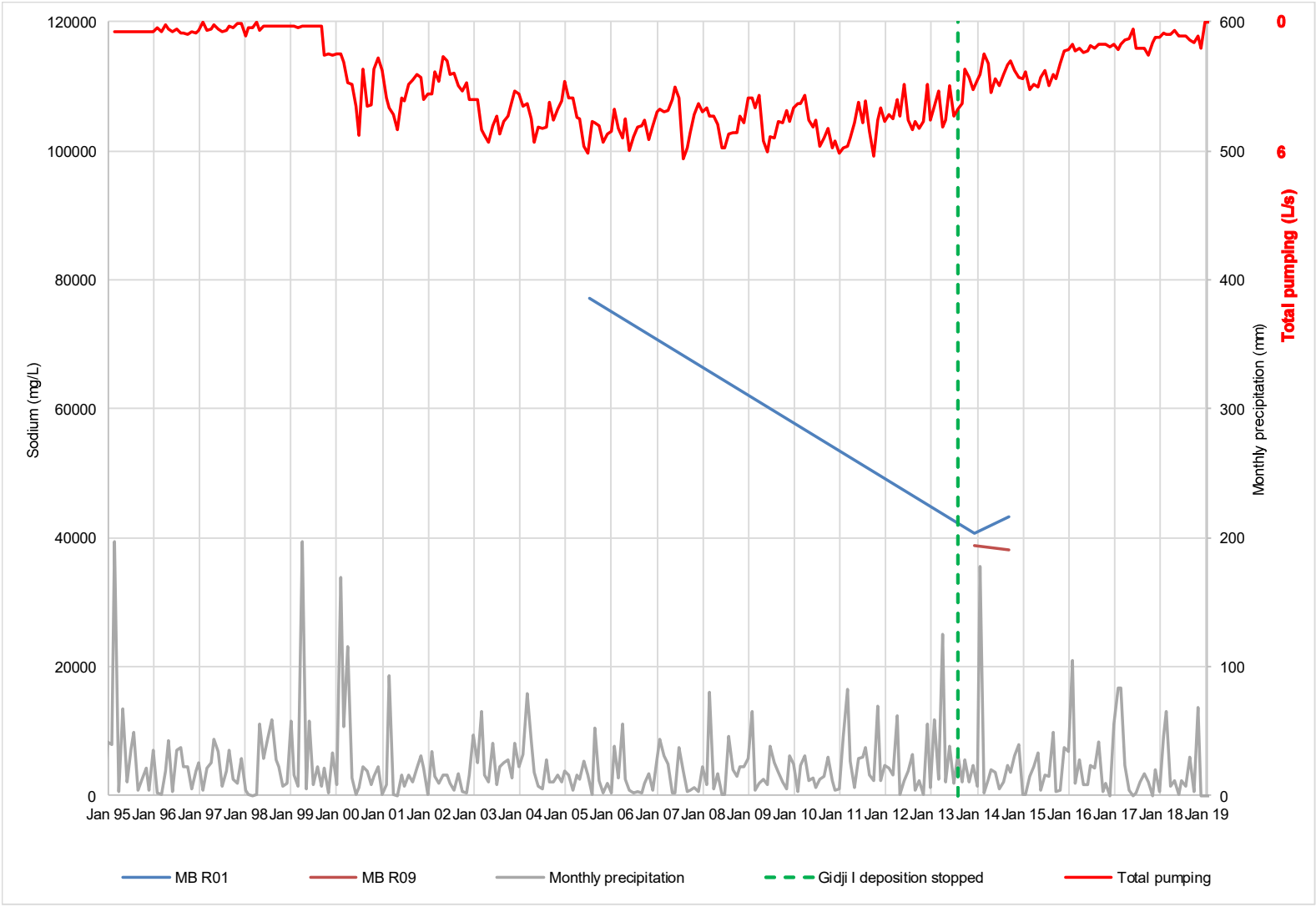
BIG DOG HYDROGEOLOGY

Groundwater Na - trench bores

Figure C38

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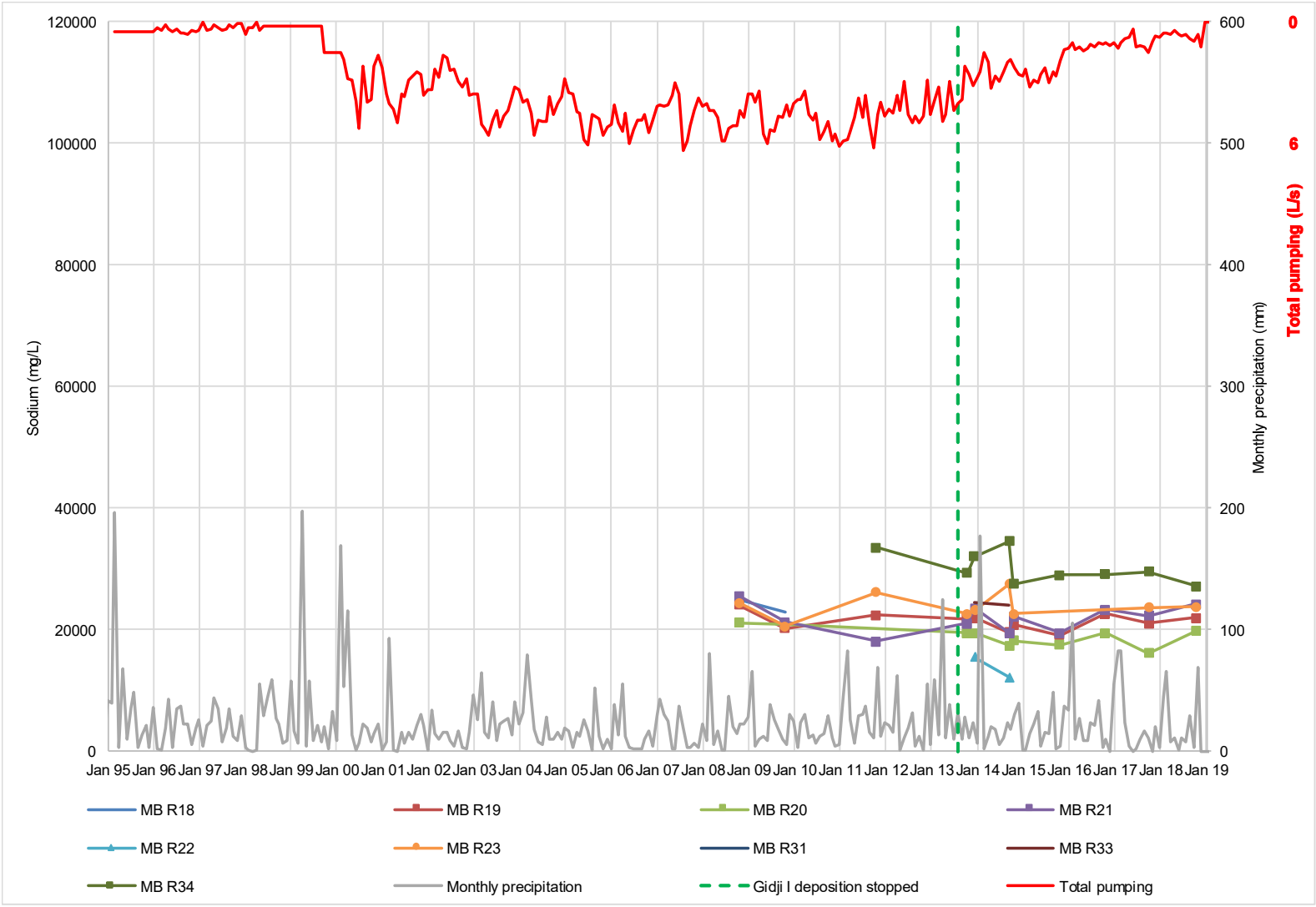
BIG DOG HYDROGEOLOGY

Groundwater Na - decant bores

Figure C39

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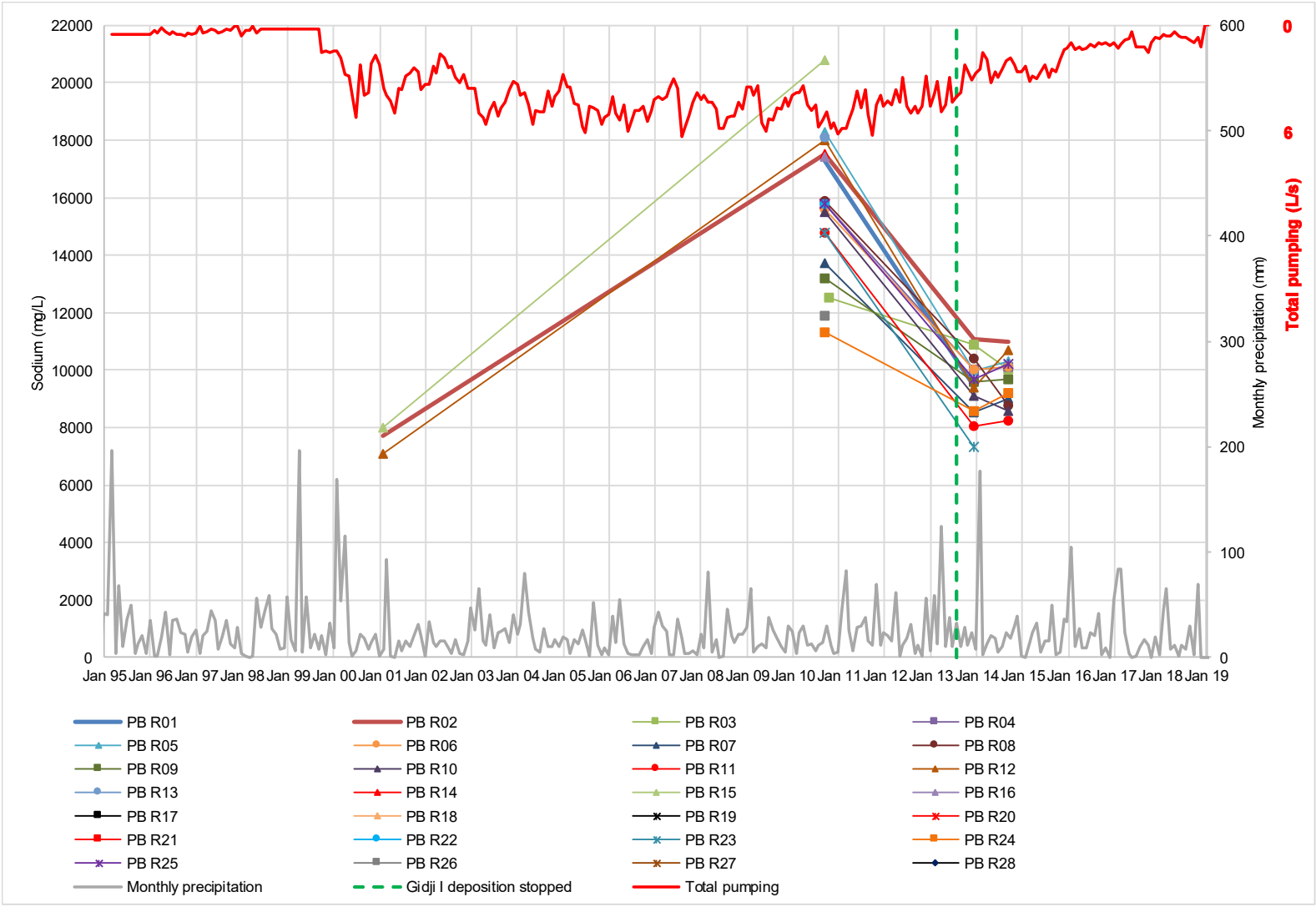
BIG DOG HYDROGEOLOGY

Groundwater Na - eastern bores

Figure C40

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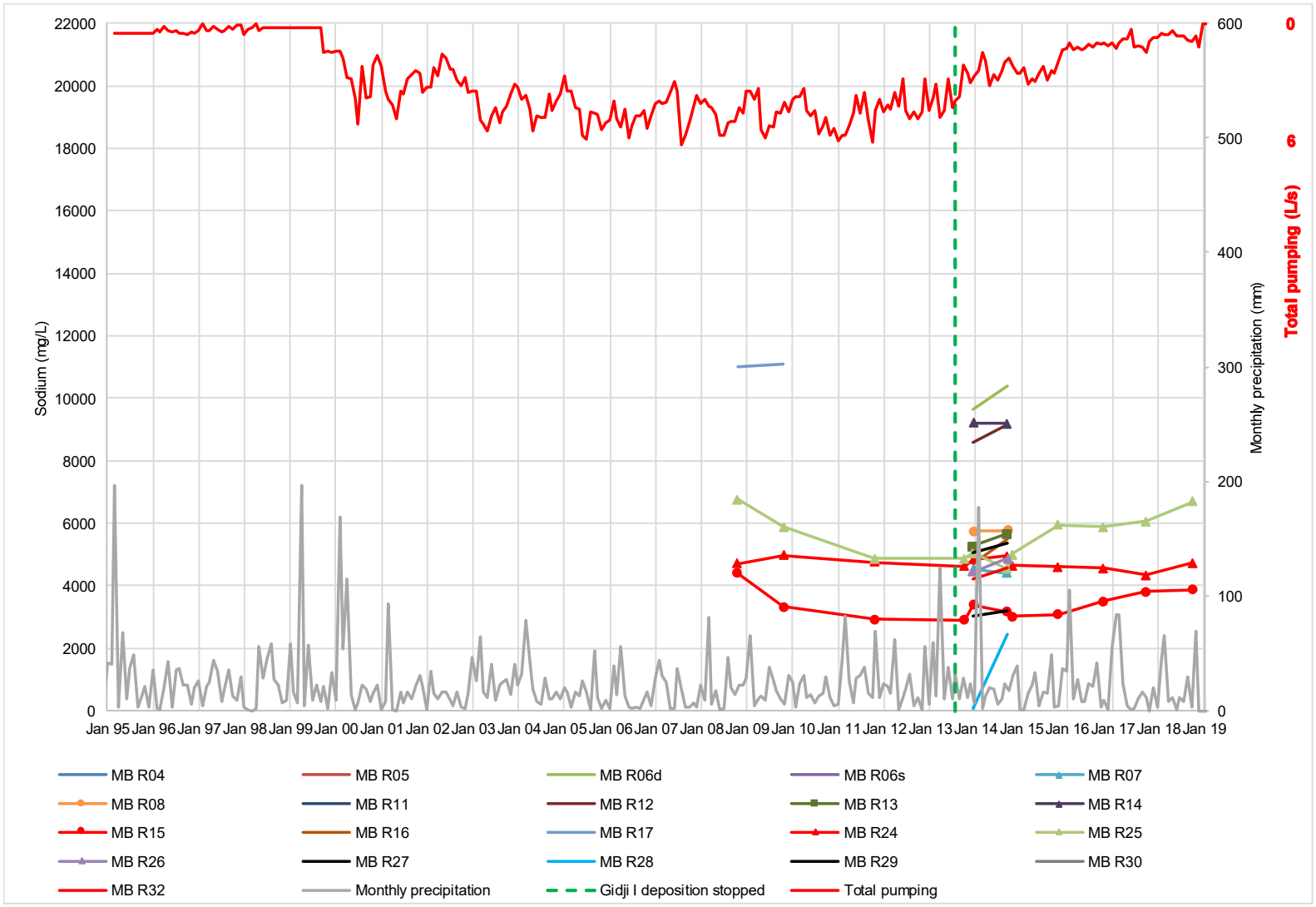
BIG DOG HYDROGEOLOGY

Groundwater sulphate - production bores

Figure C41

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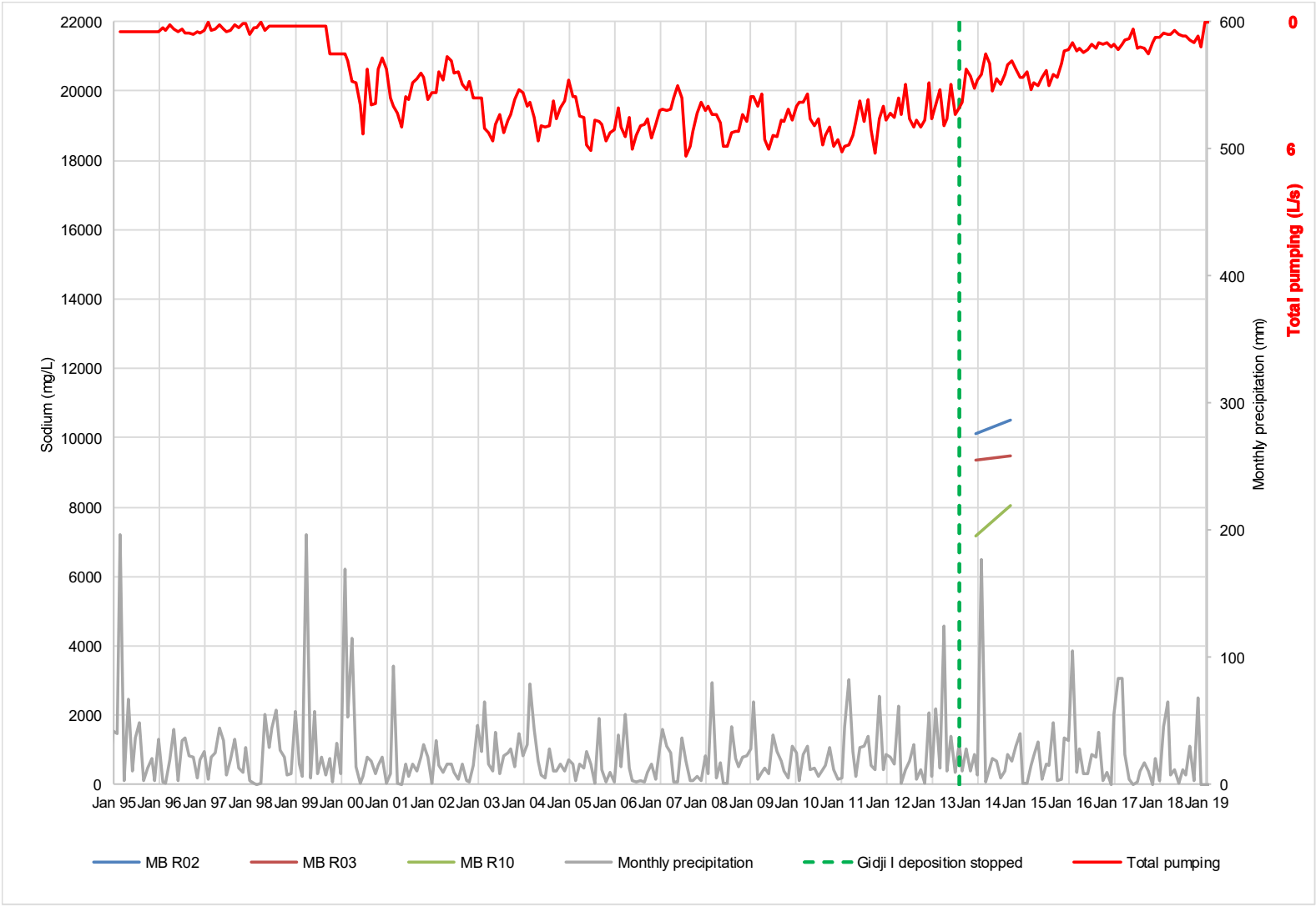
BIG DOG HYDROGEOLOGY

Groundwater sulphate - western bores

Figure C42

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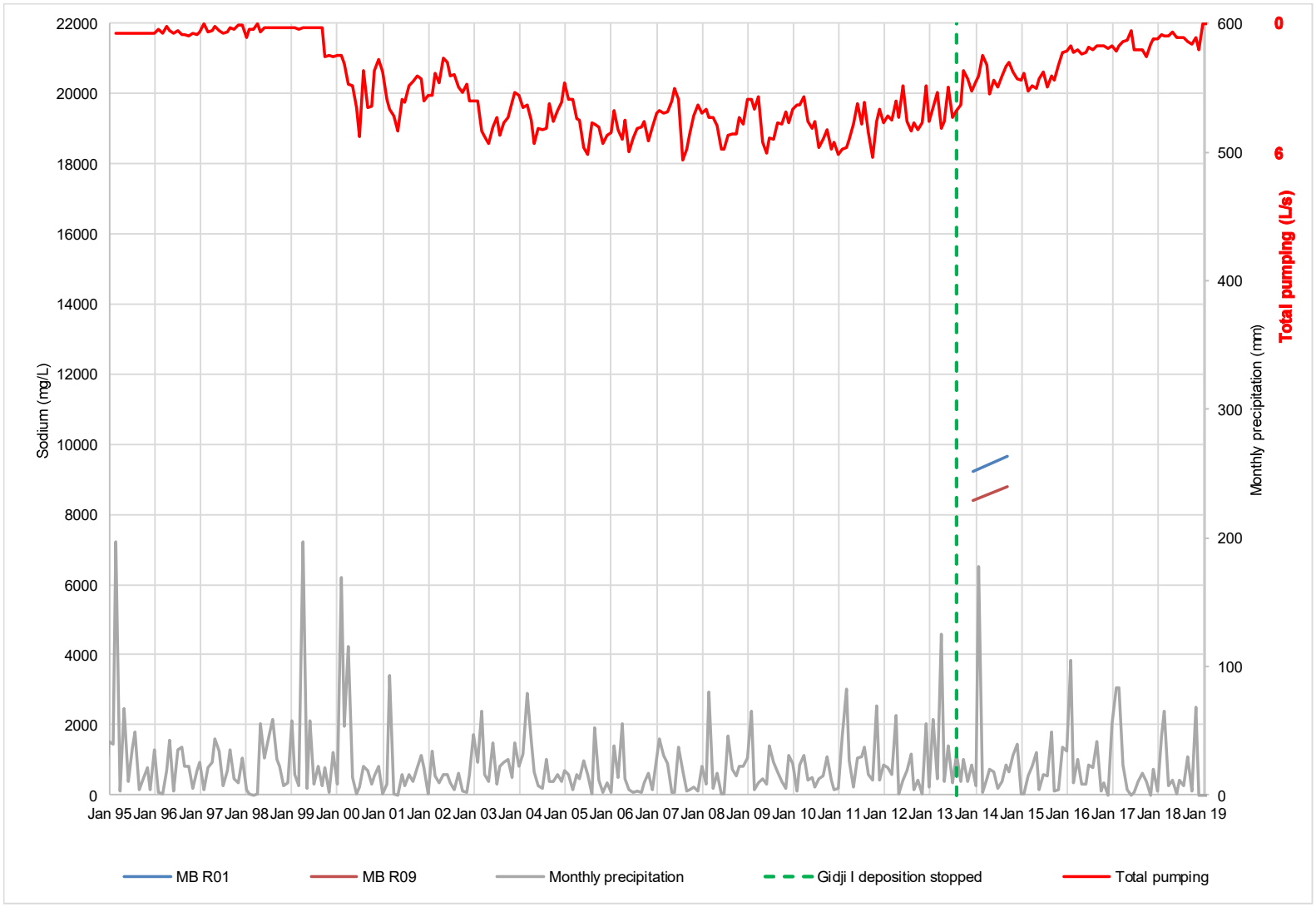
BIG DOG HYDROGEOLOGY

Groundwater sulphate - trench bores

Figure C43

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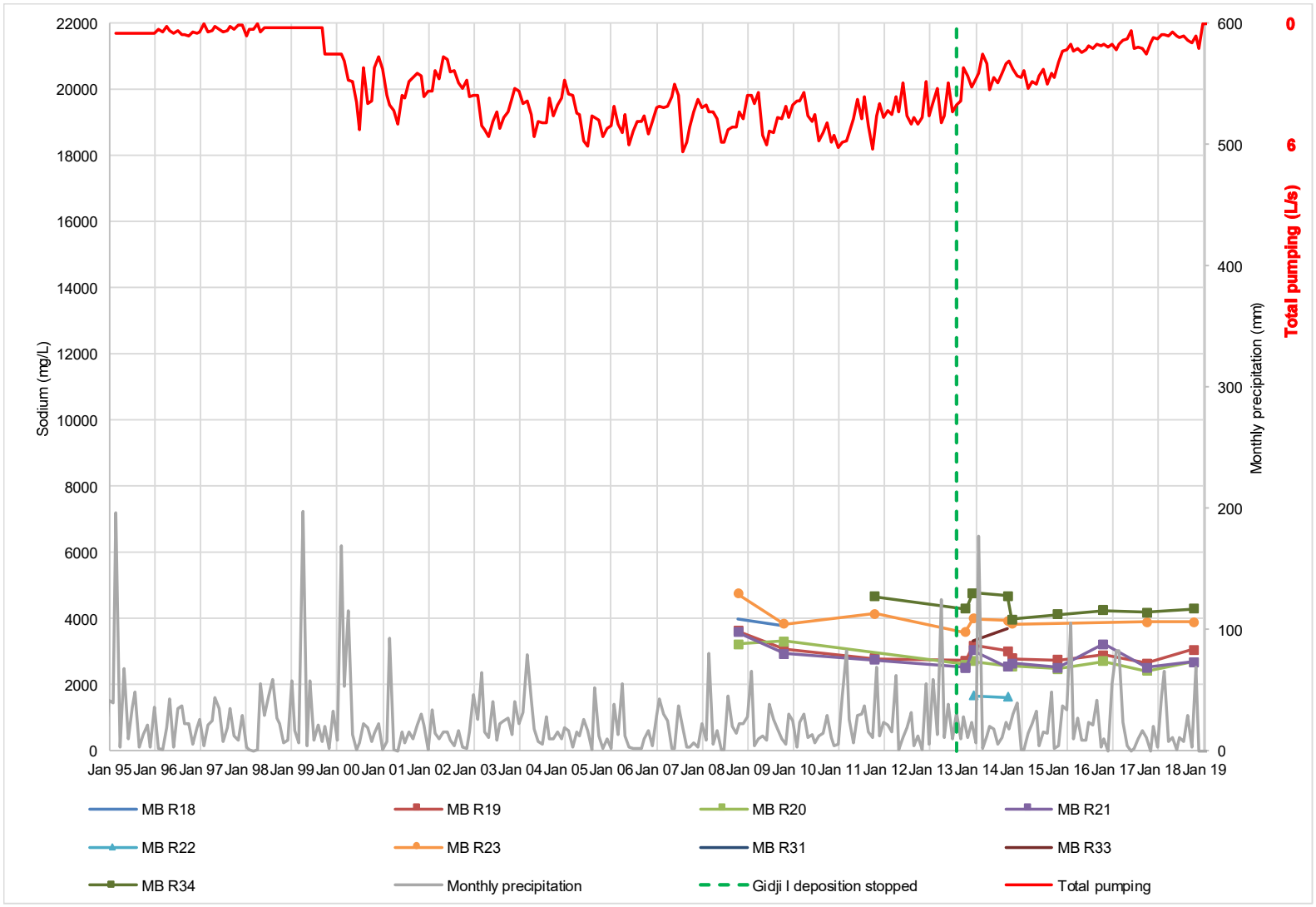
BIG DOG HYDROGEOLOGY

Groundwater sulphate - decant bores

Figure C44

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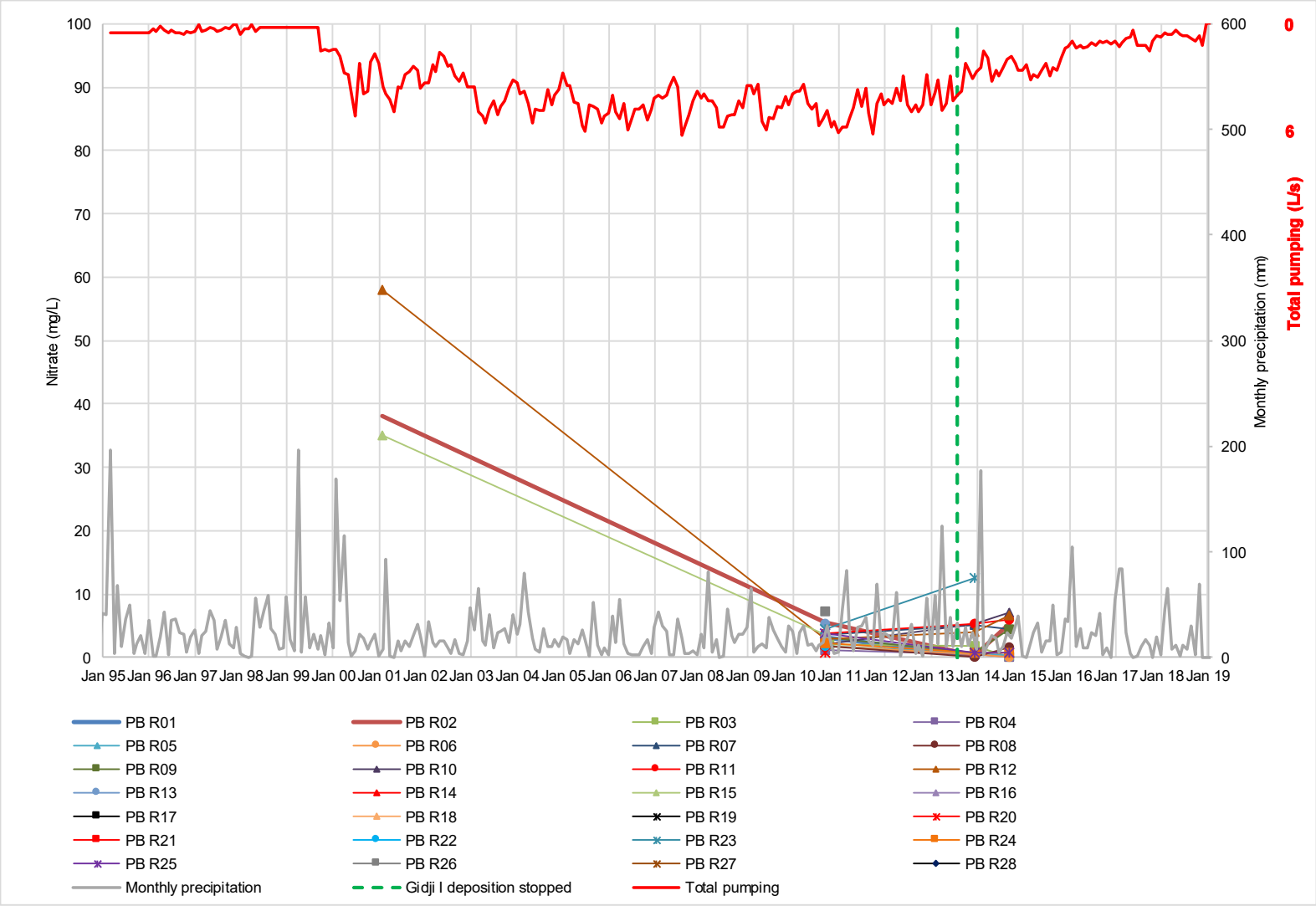
BIG DOG HYDROGEOLOGY

Groundwater sulphate - eastern bores

Figure C45

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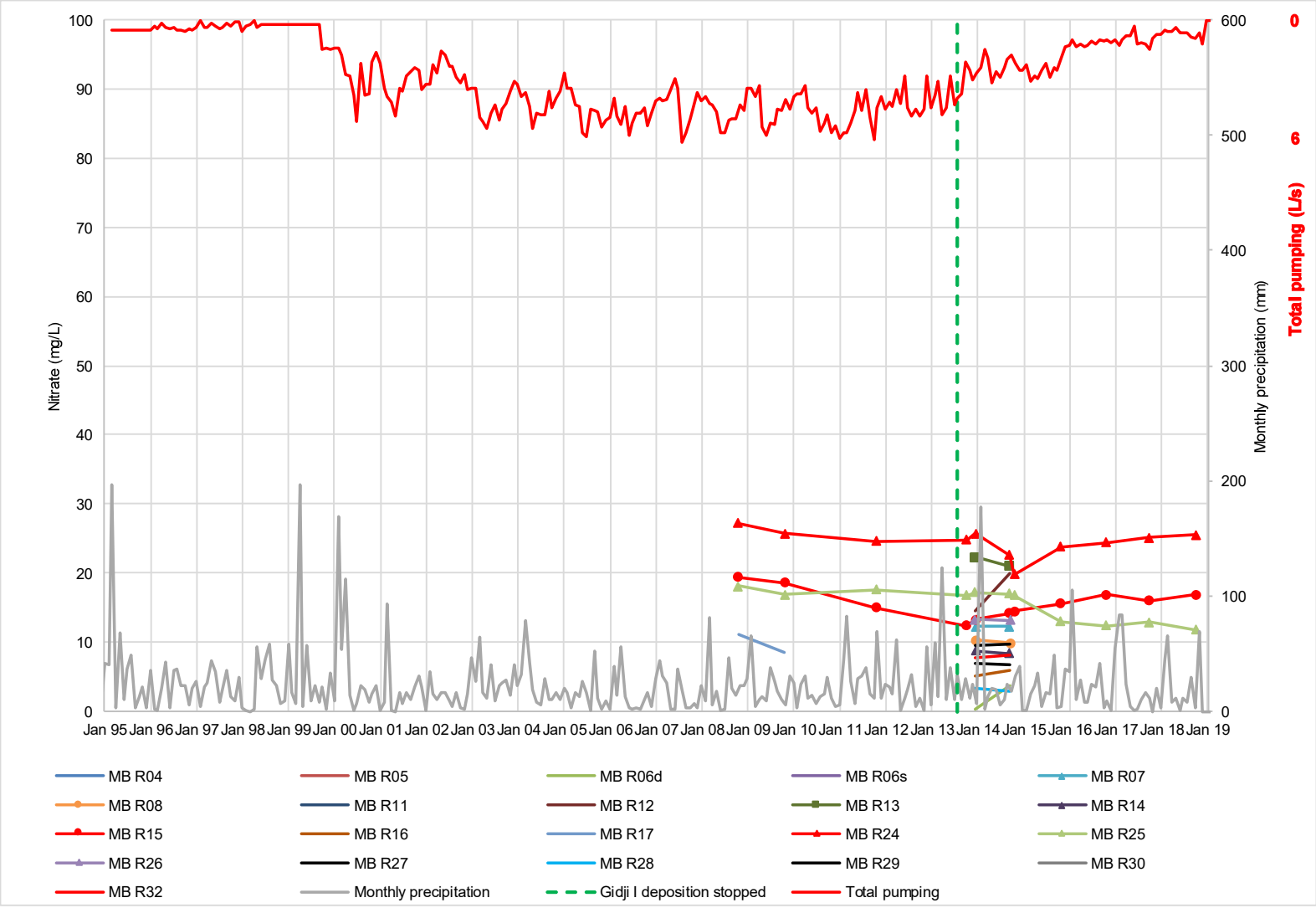
BIG DOG HYDROGEOLOGY

Groundwater nitrate - production bores

Figure C46

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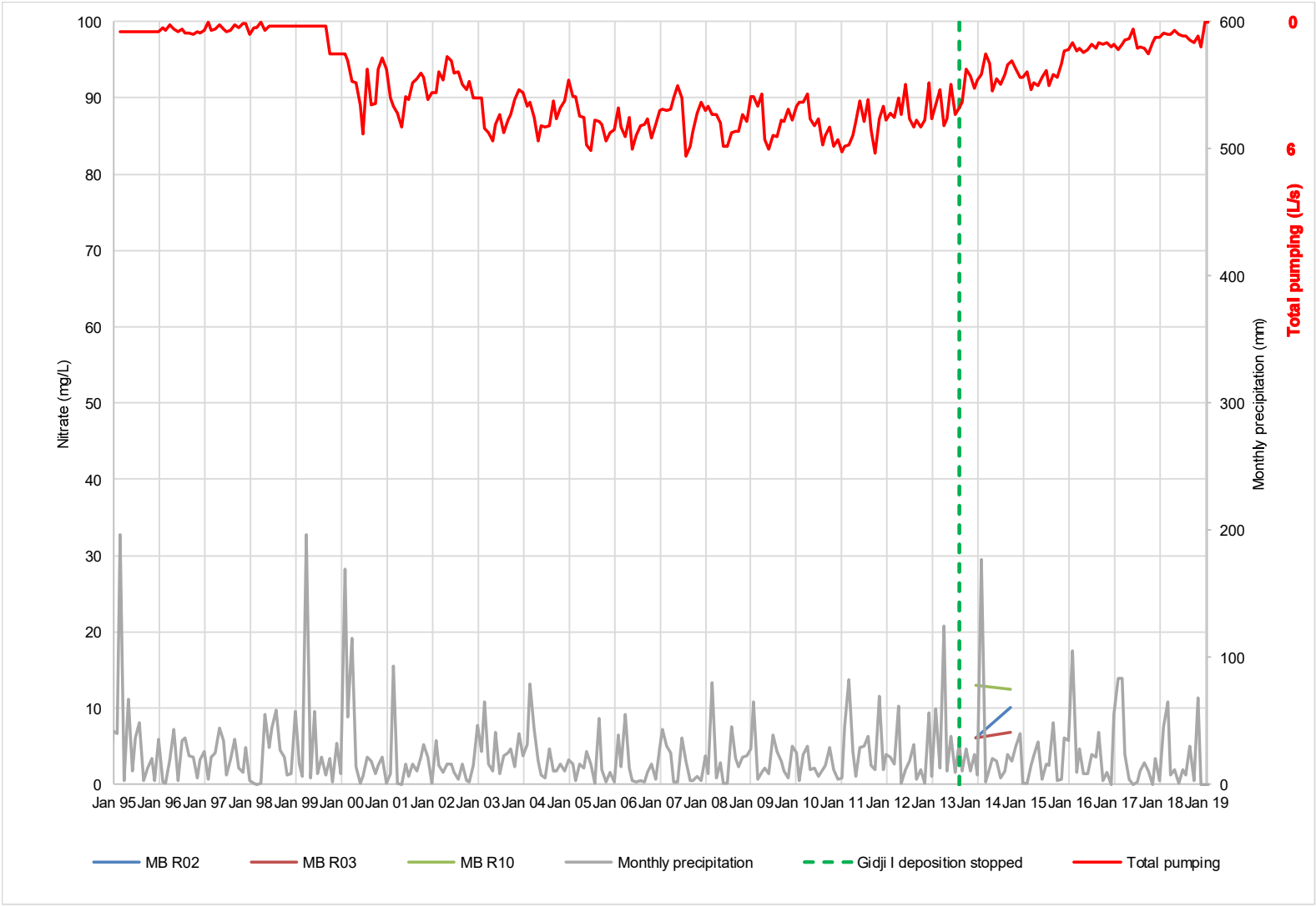
BIG DOG HYDROGEOLOGY

Groundwater nitrate - western bores

Figure C47

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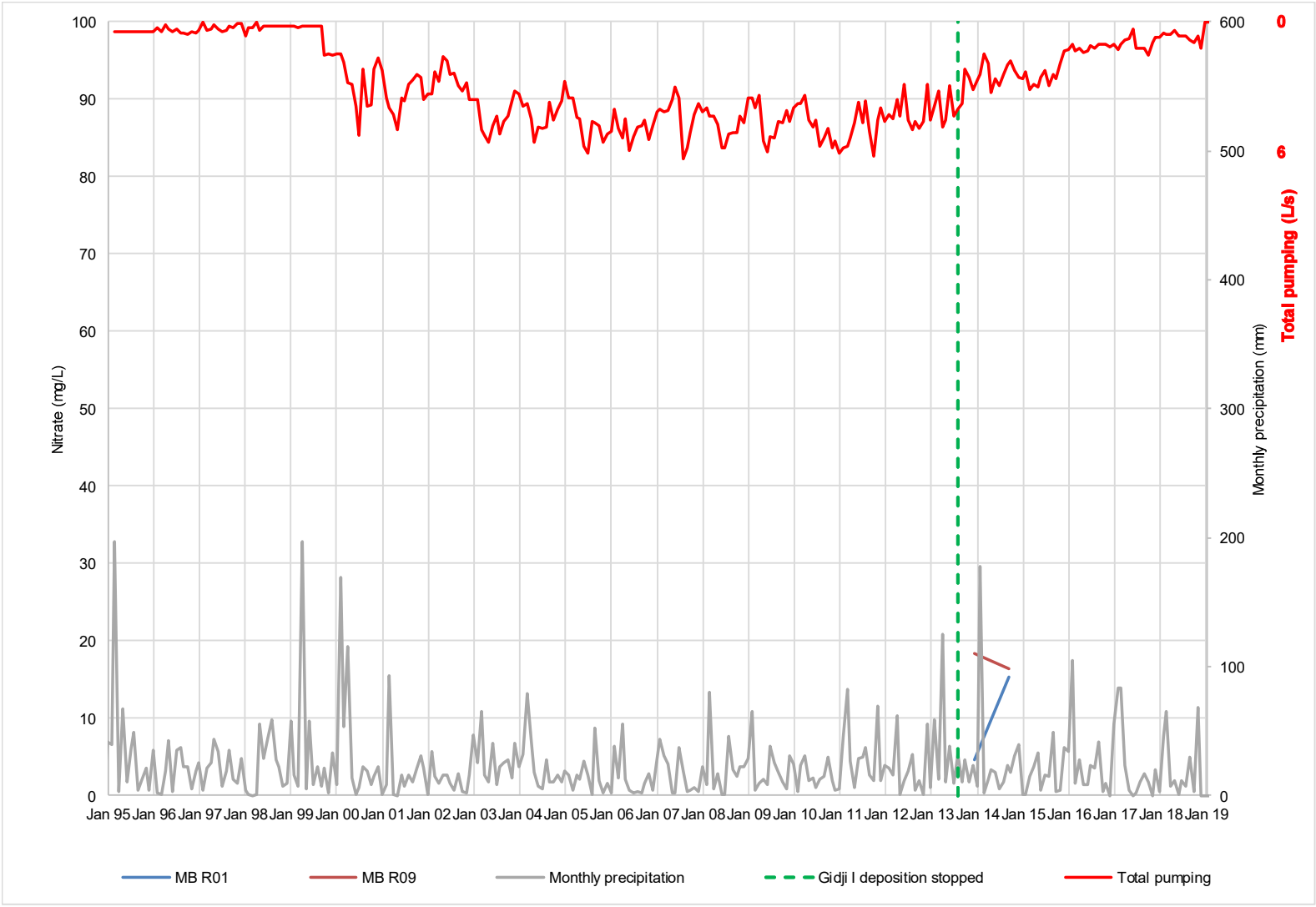
BIG DOG HYDROGEOLOGY

Groundwater nitrate - trench bores

Figure C48

Date: January 2019

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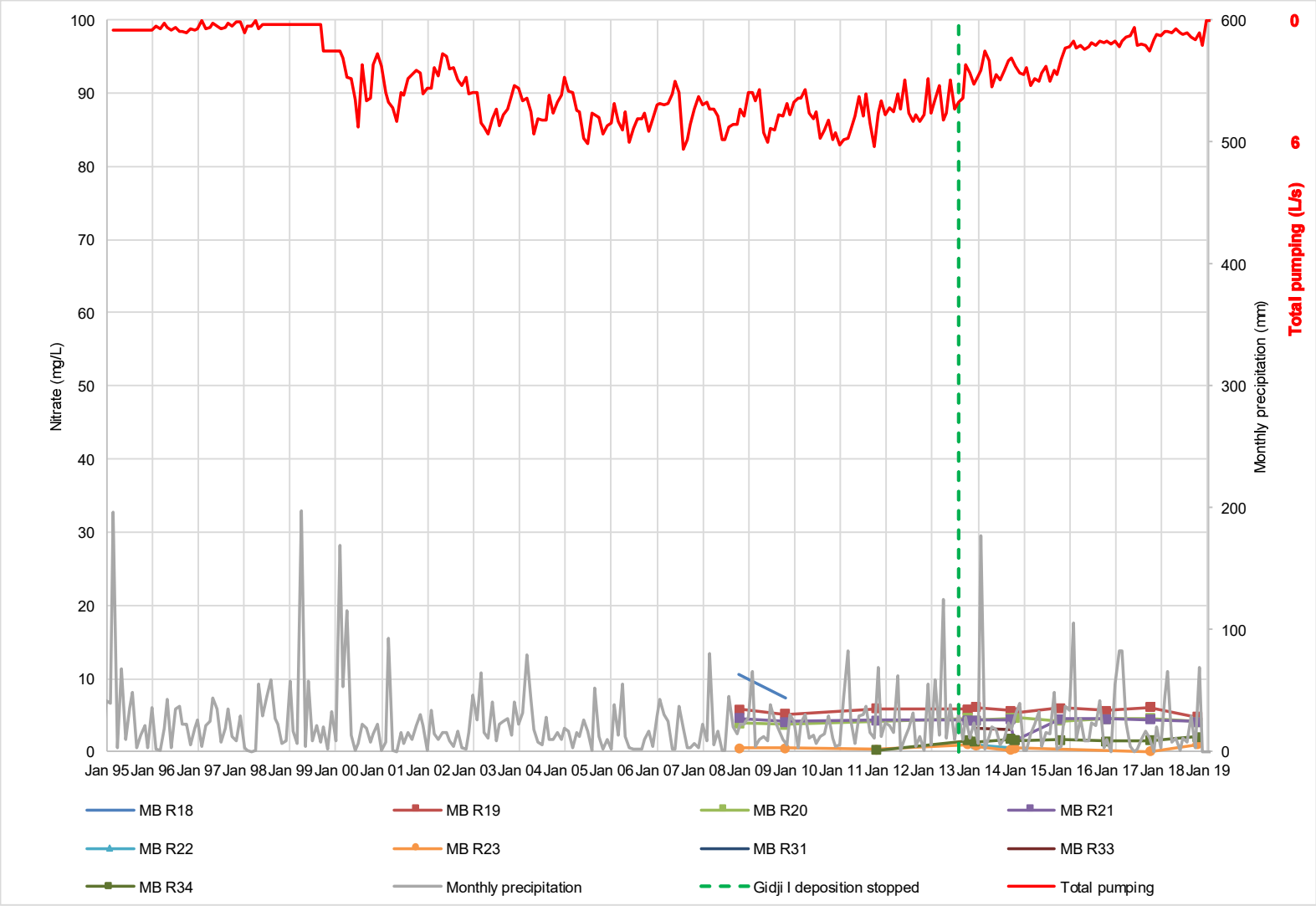
Groundwater nitrate - decant bores

Figure C49

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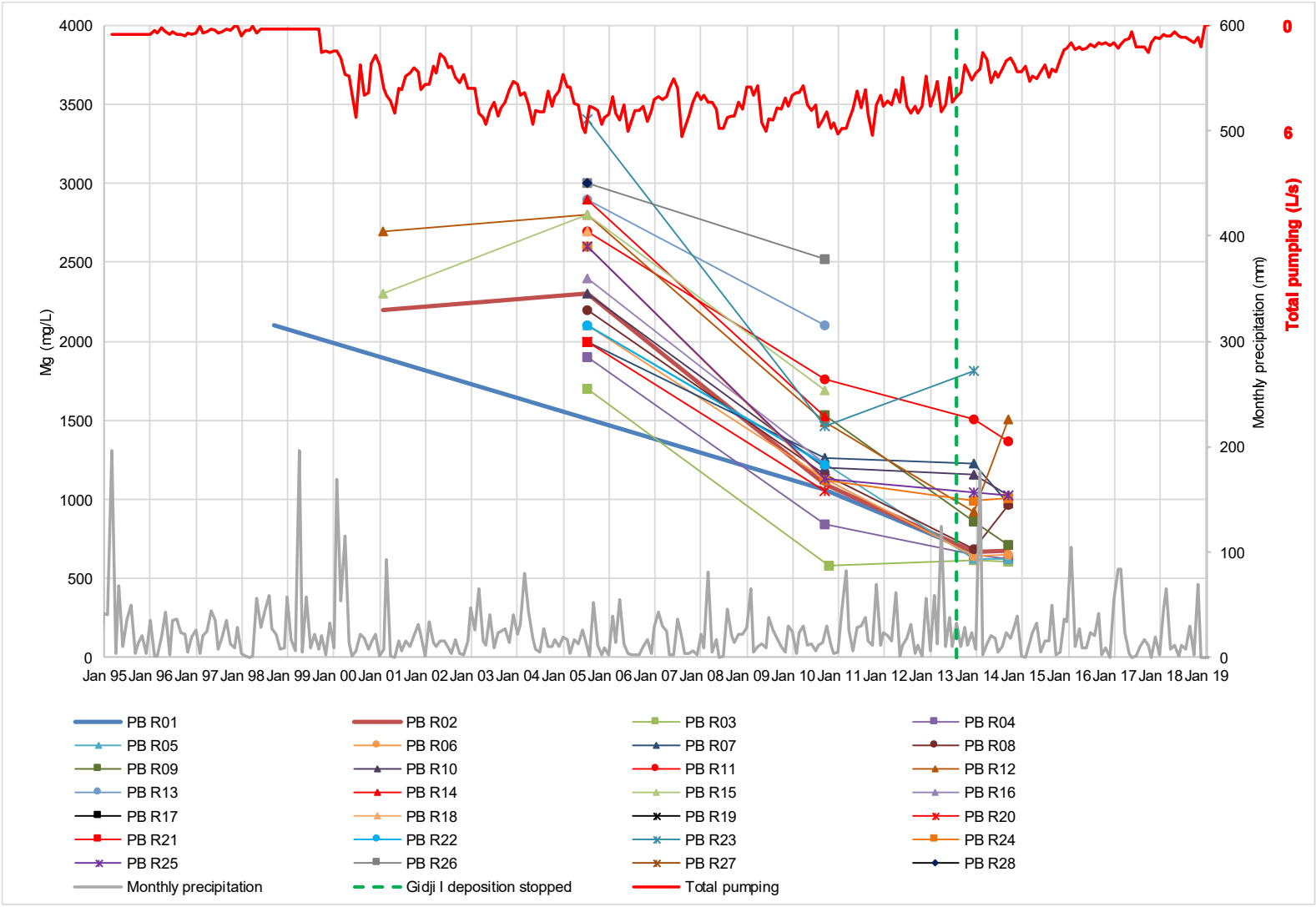
BIG DOG HYDROGEOLOGY

Groundwater nitrate - eastern bores

Figure C50

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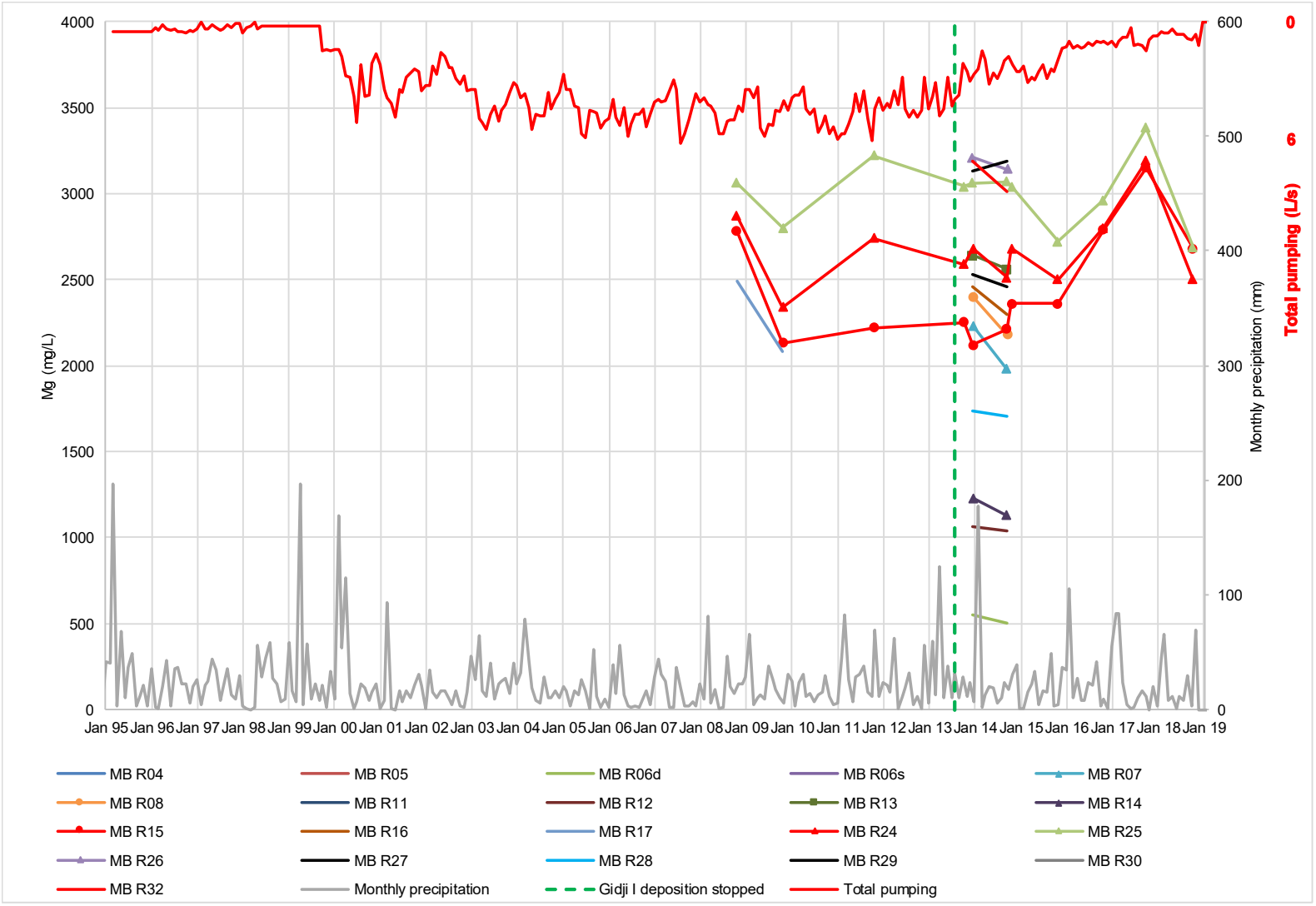
Groundwater Mg - production bores

Figure C51

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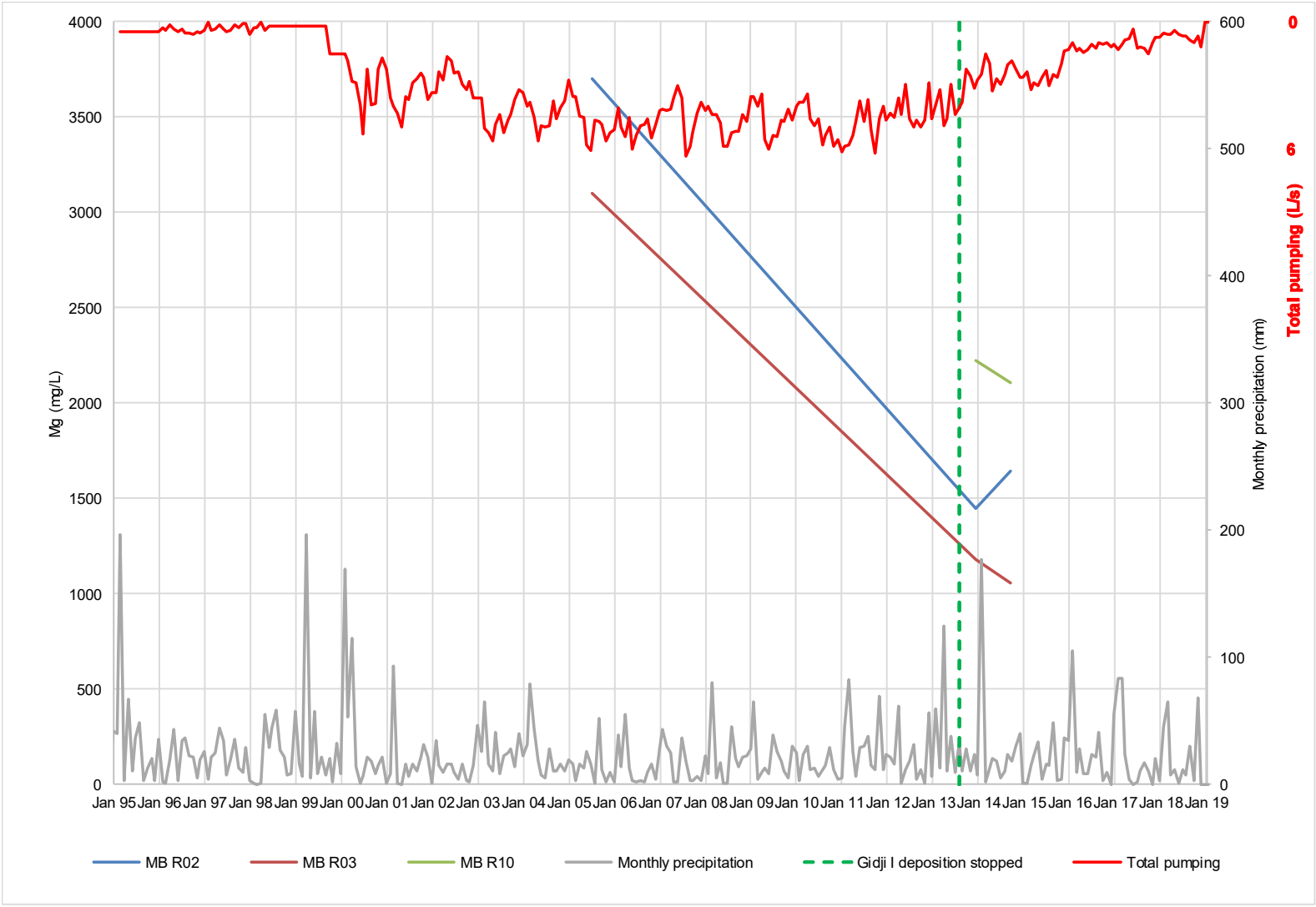
BIG DOG HYDROGEOLOGY

Groundwater Mg - western bores

Figure C52

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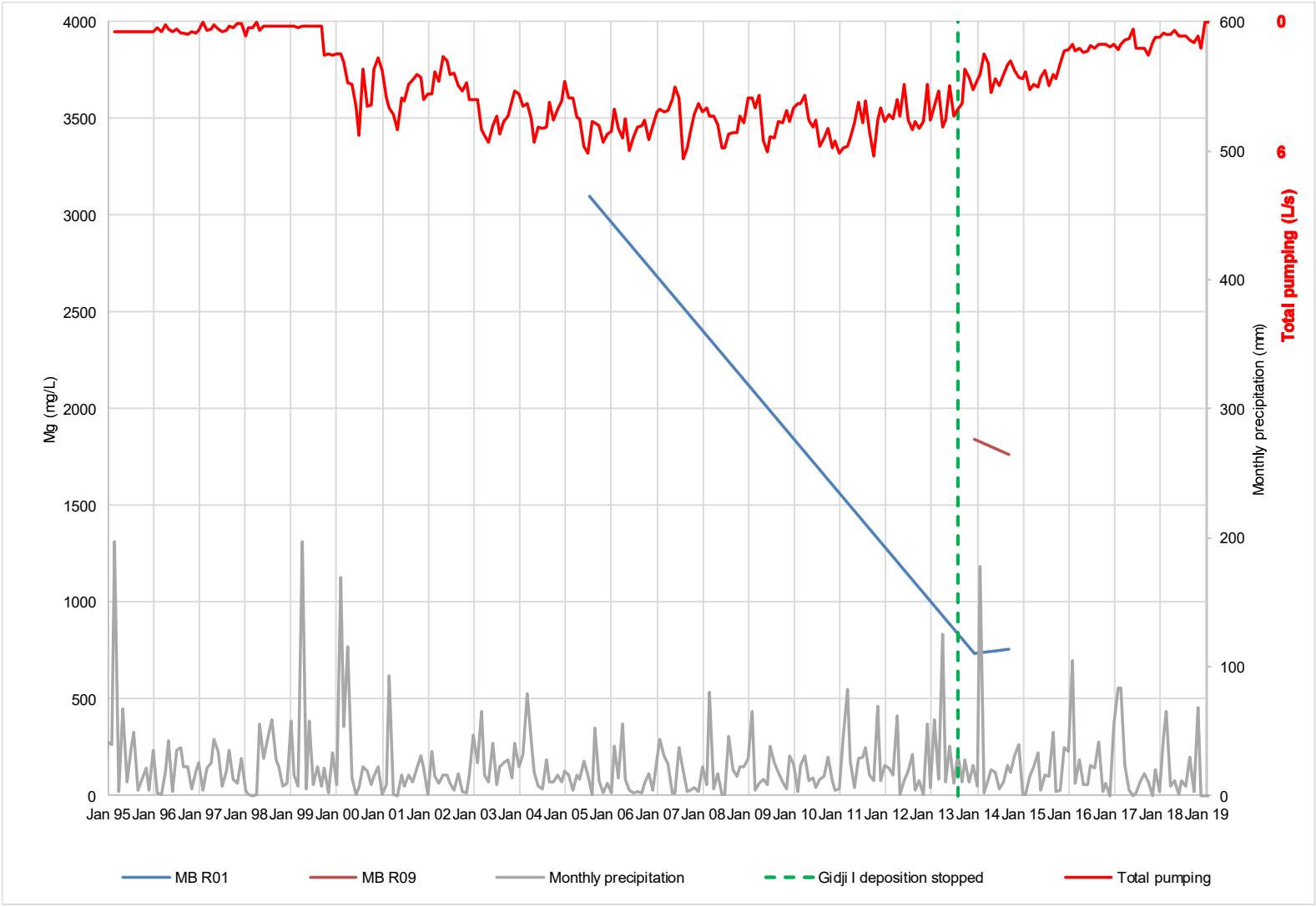
BIG DOG HYDROGEOLOGY

Groundwater Mg - trench bores

Figure C53

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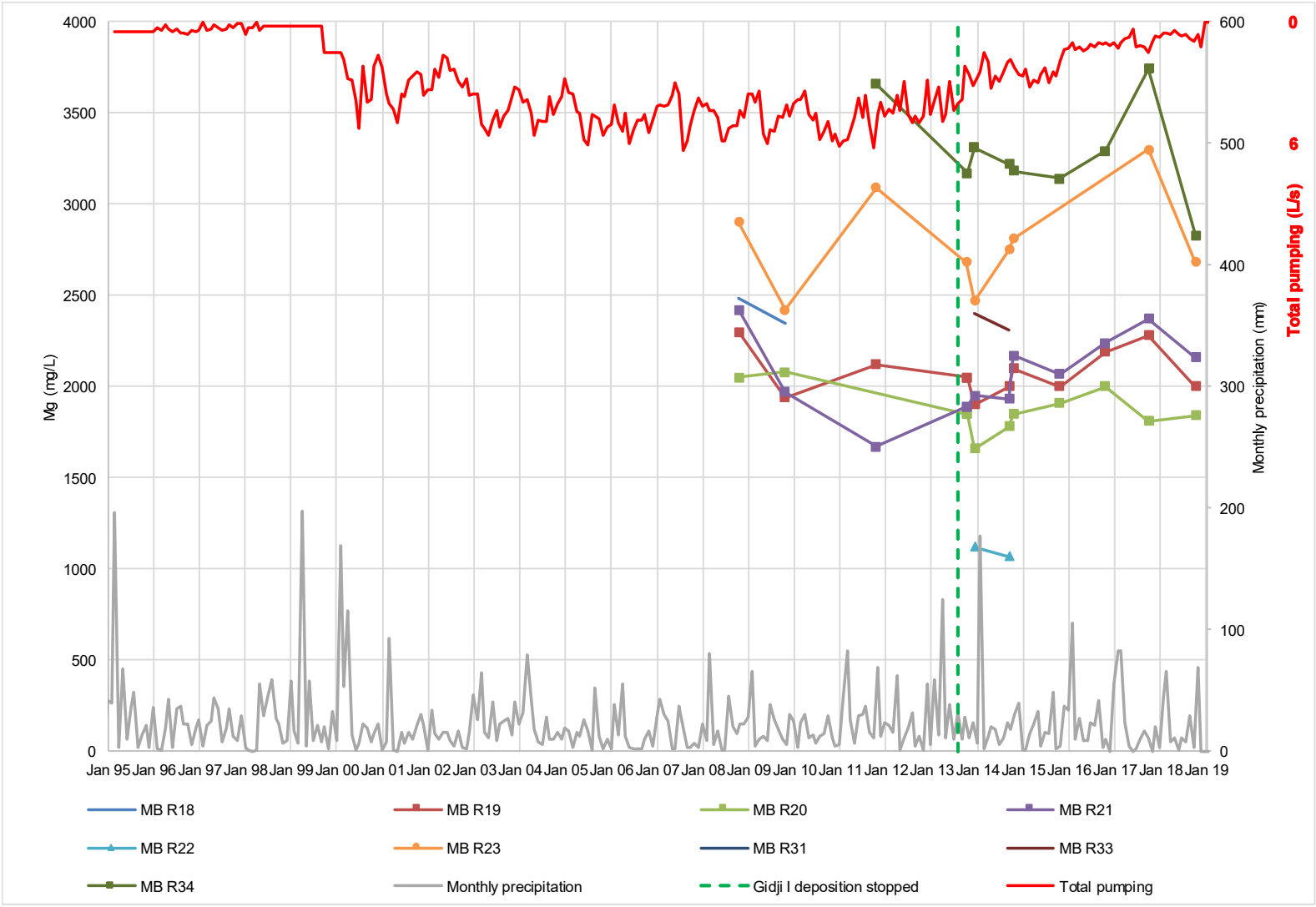
BIG DOG HYDROGEOLOGY

Groundwater Mg - decant bores

Figure C54

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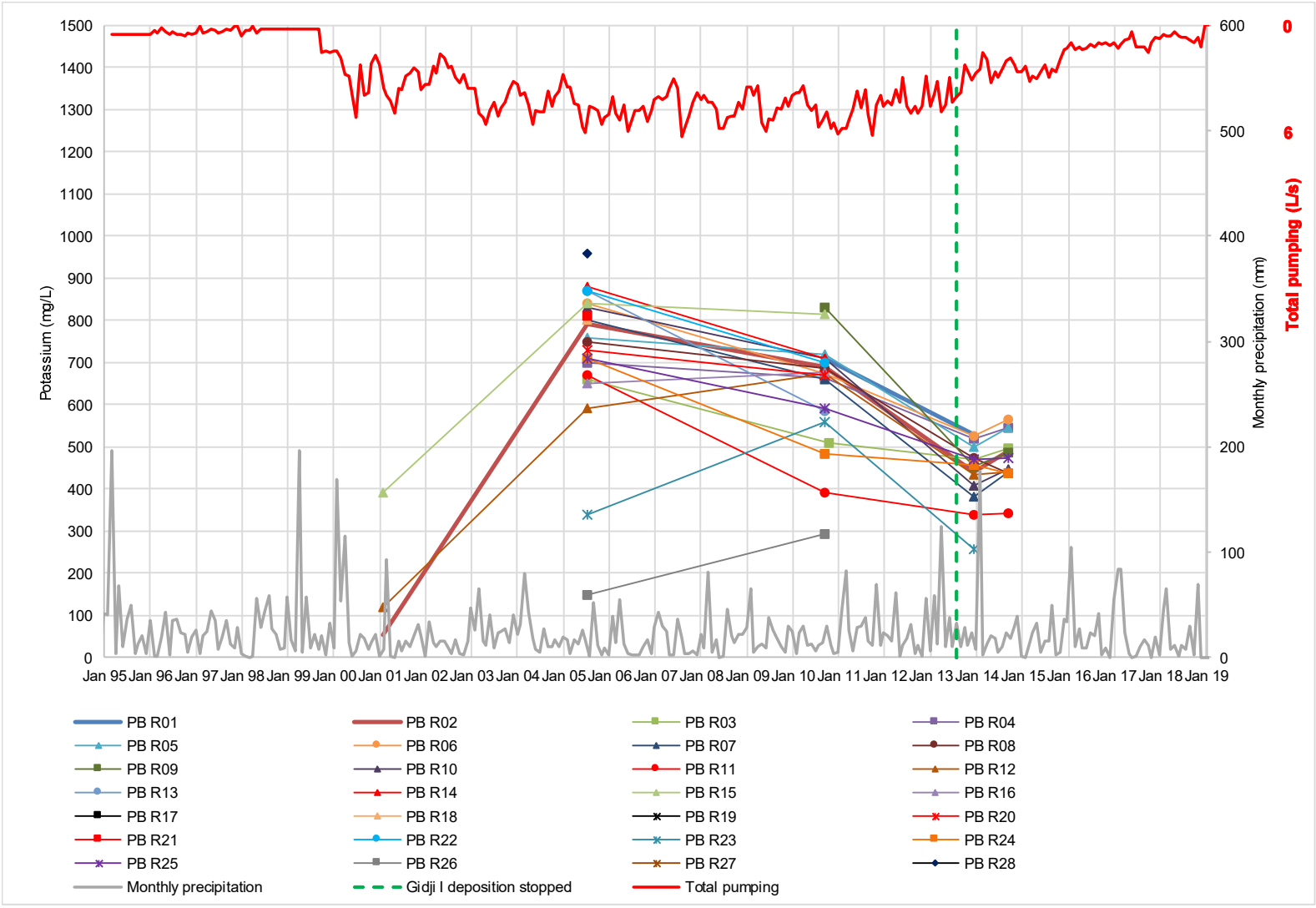
BIG DOG HYDROGEOLOGY

Groundwater Mg - eastern bores

Figure C55

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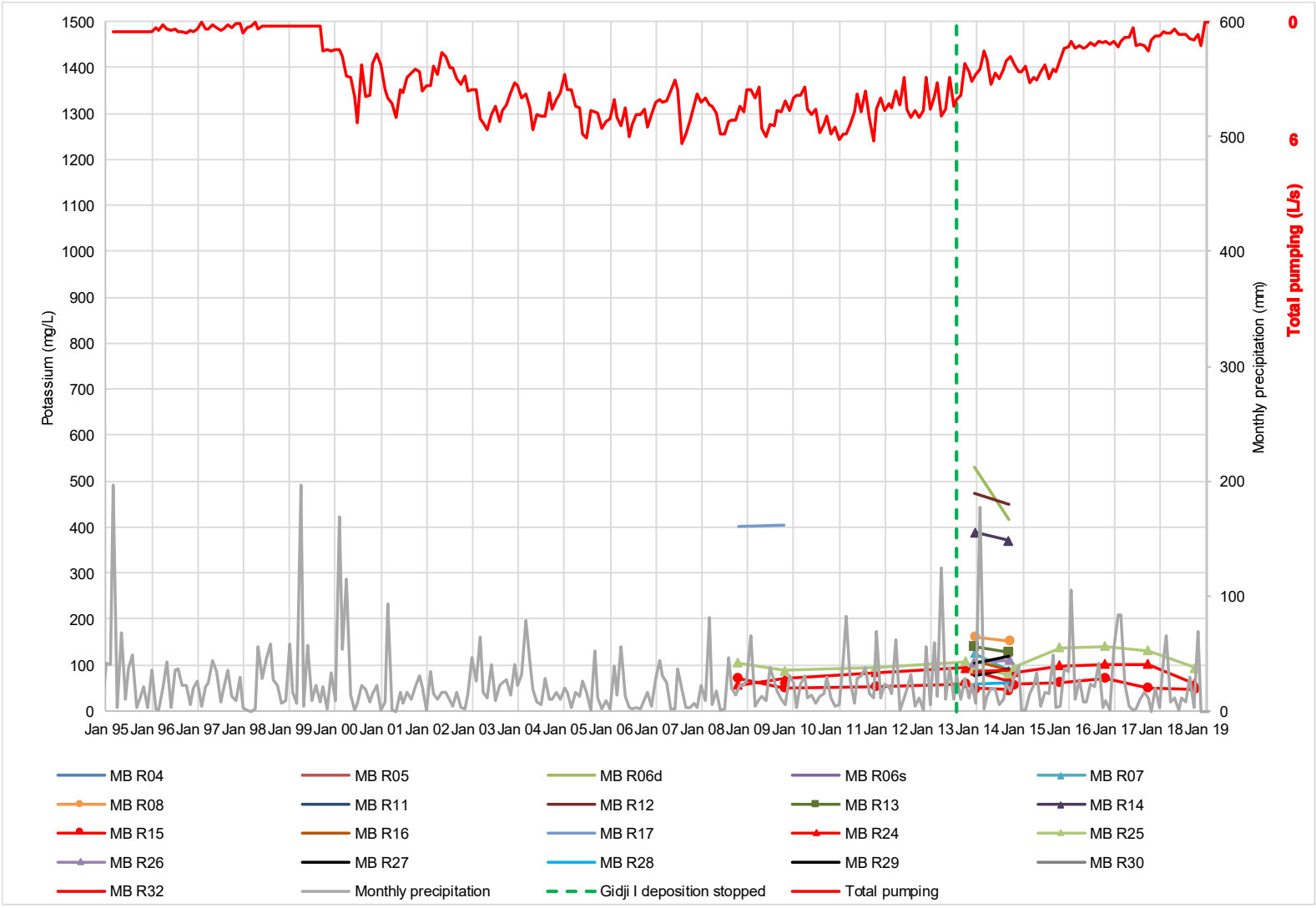
BIG DOG HYDROGEOLOGY

Groundwater K - production bores

Figure C56

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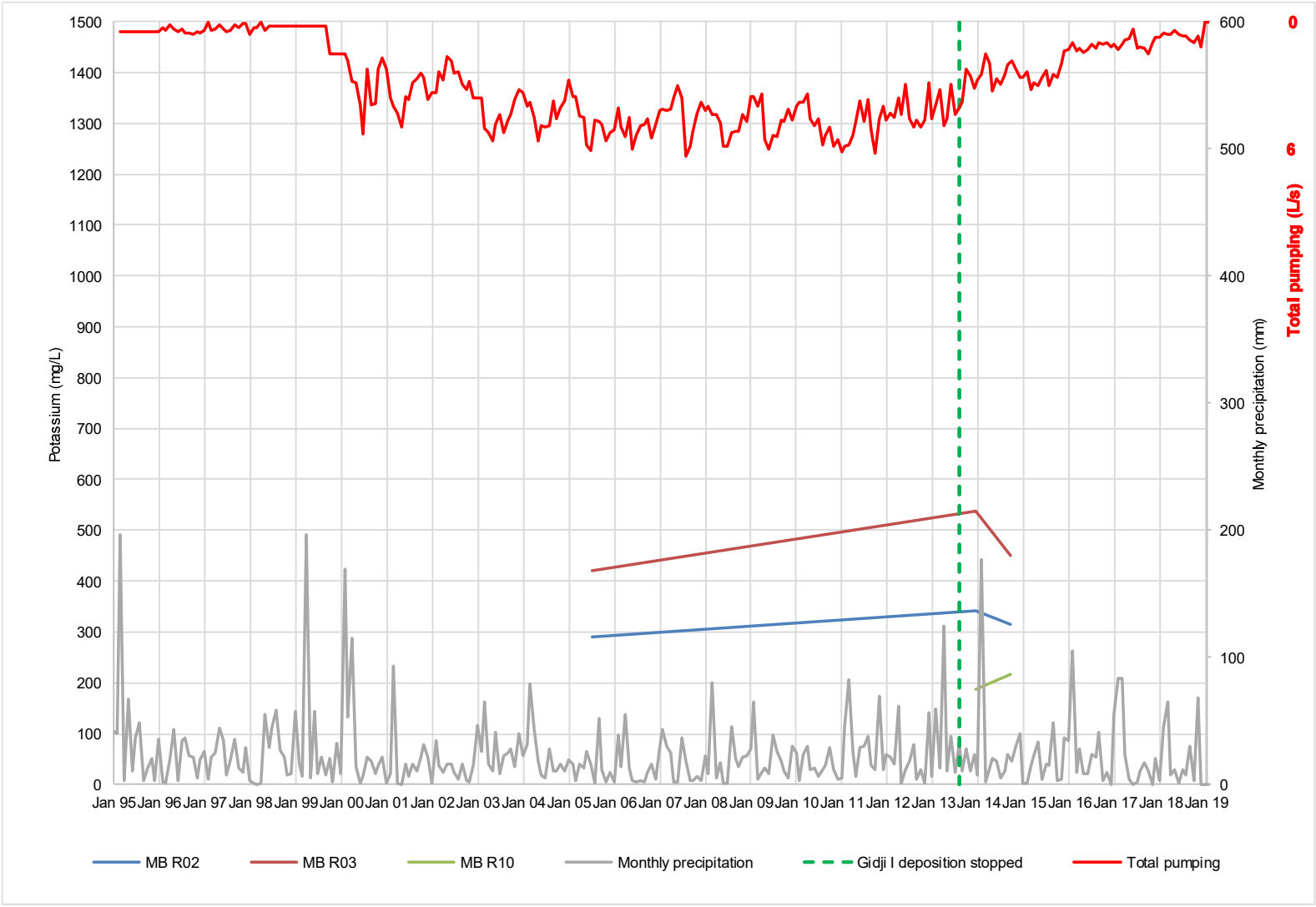
Groundwater K - western bores

Figure C57

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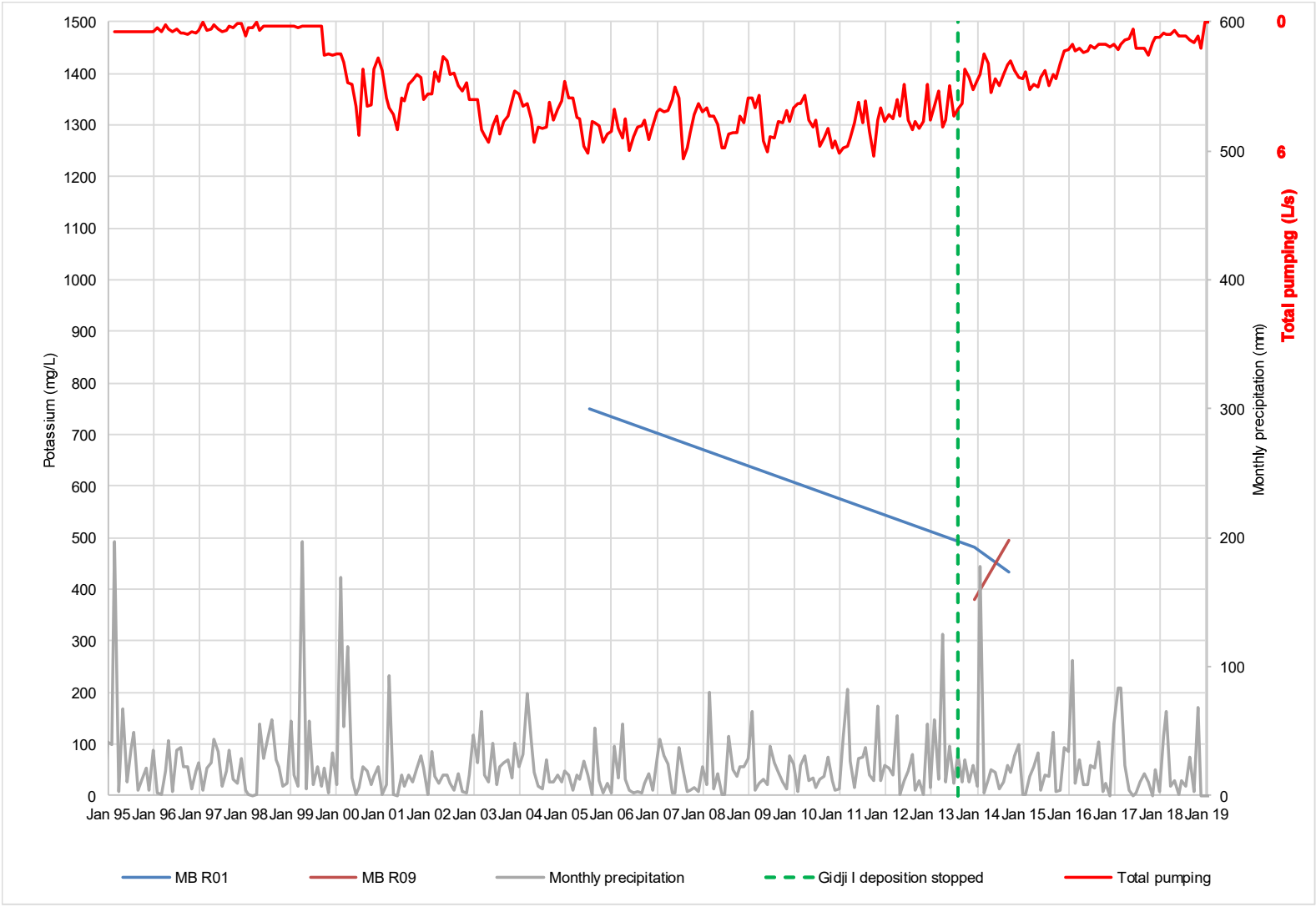
BIG DOG HYDROGEOLOGY

Groundwater K - trench bores

Figure C58

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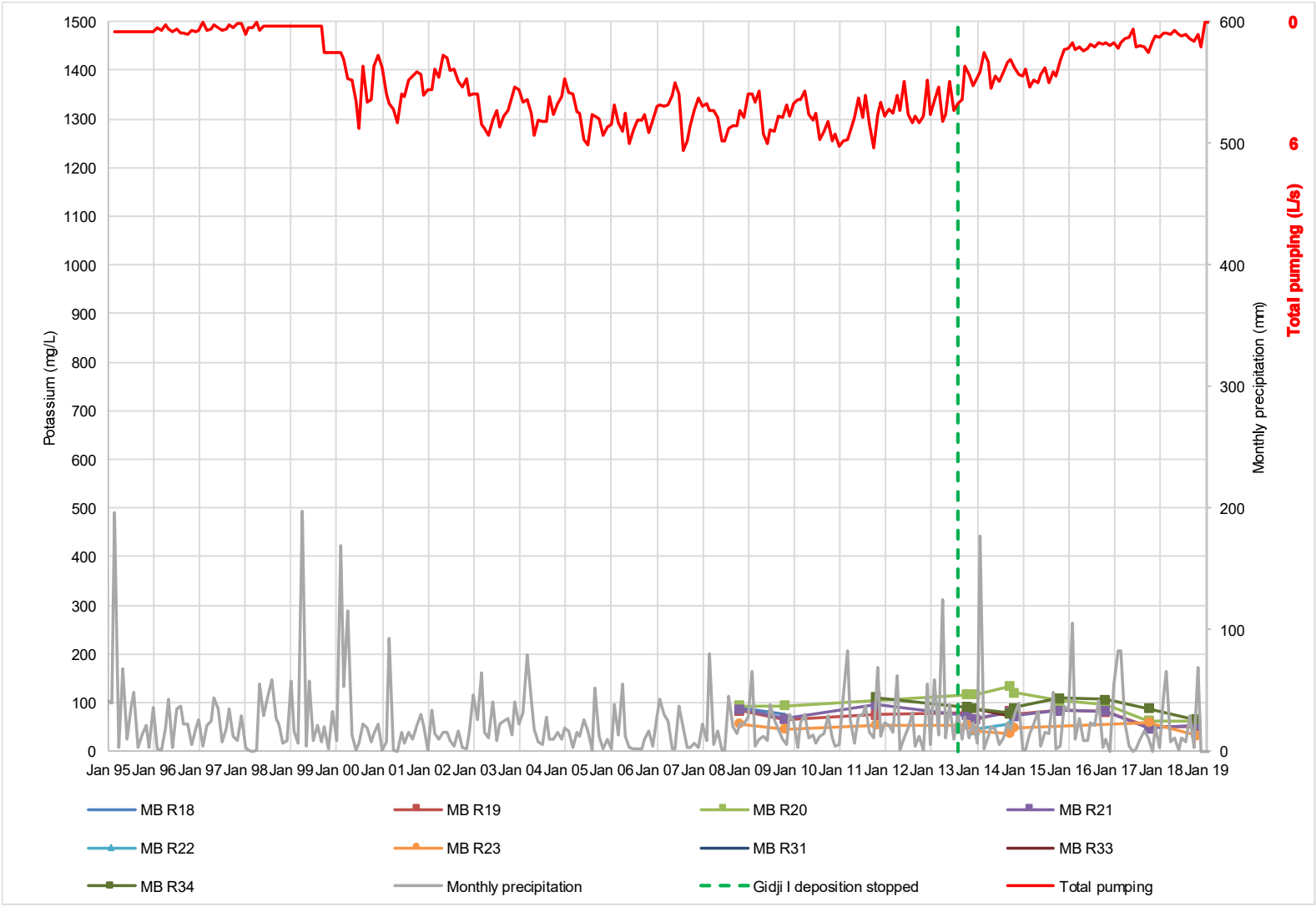
BIG DOG HYDROGEOLOGY

Groundwater K - decant bores

Figure C59

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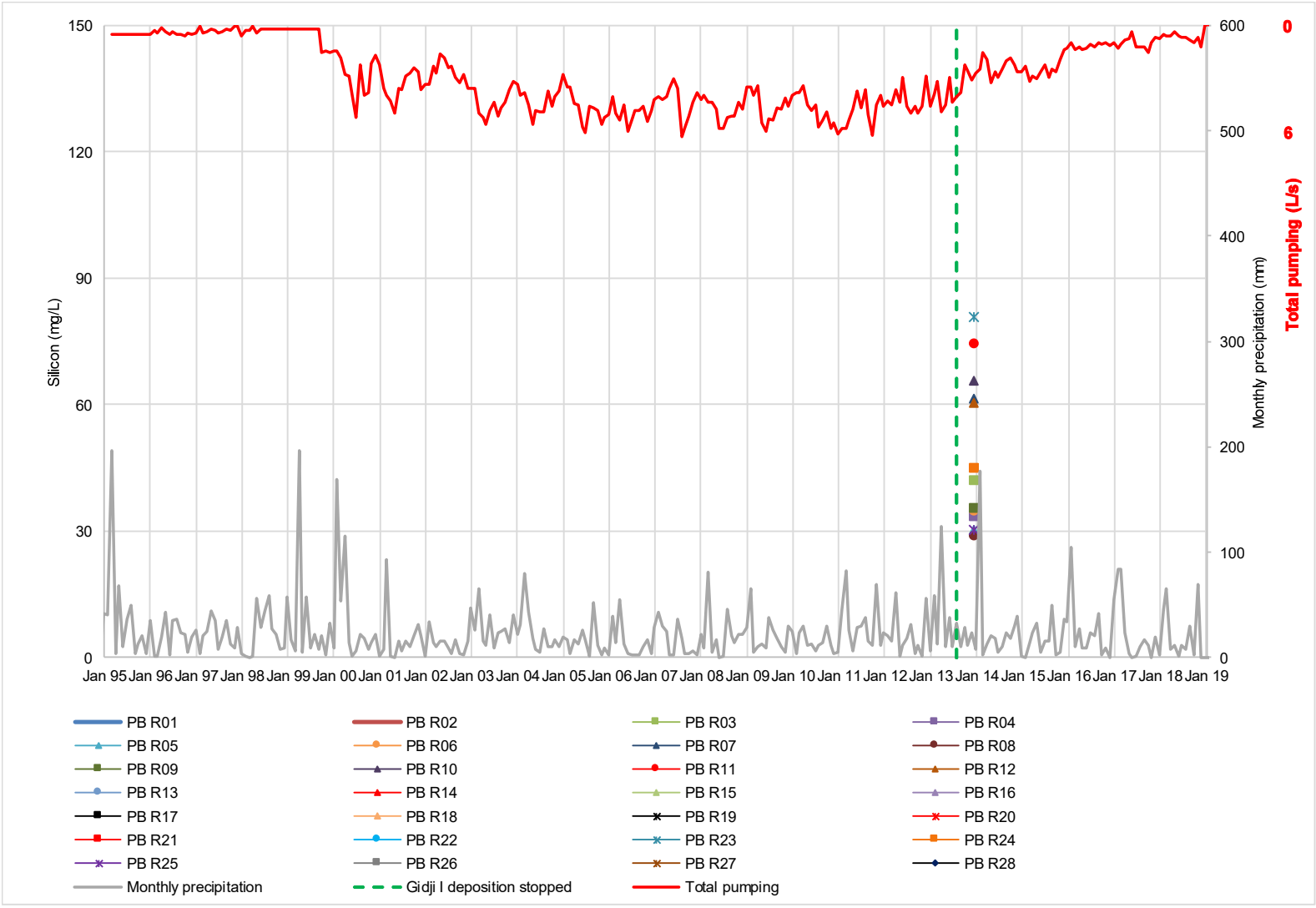
BIG DOG HYDROGEOLOGY

Groundwater K - eastern bores

Figure C60

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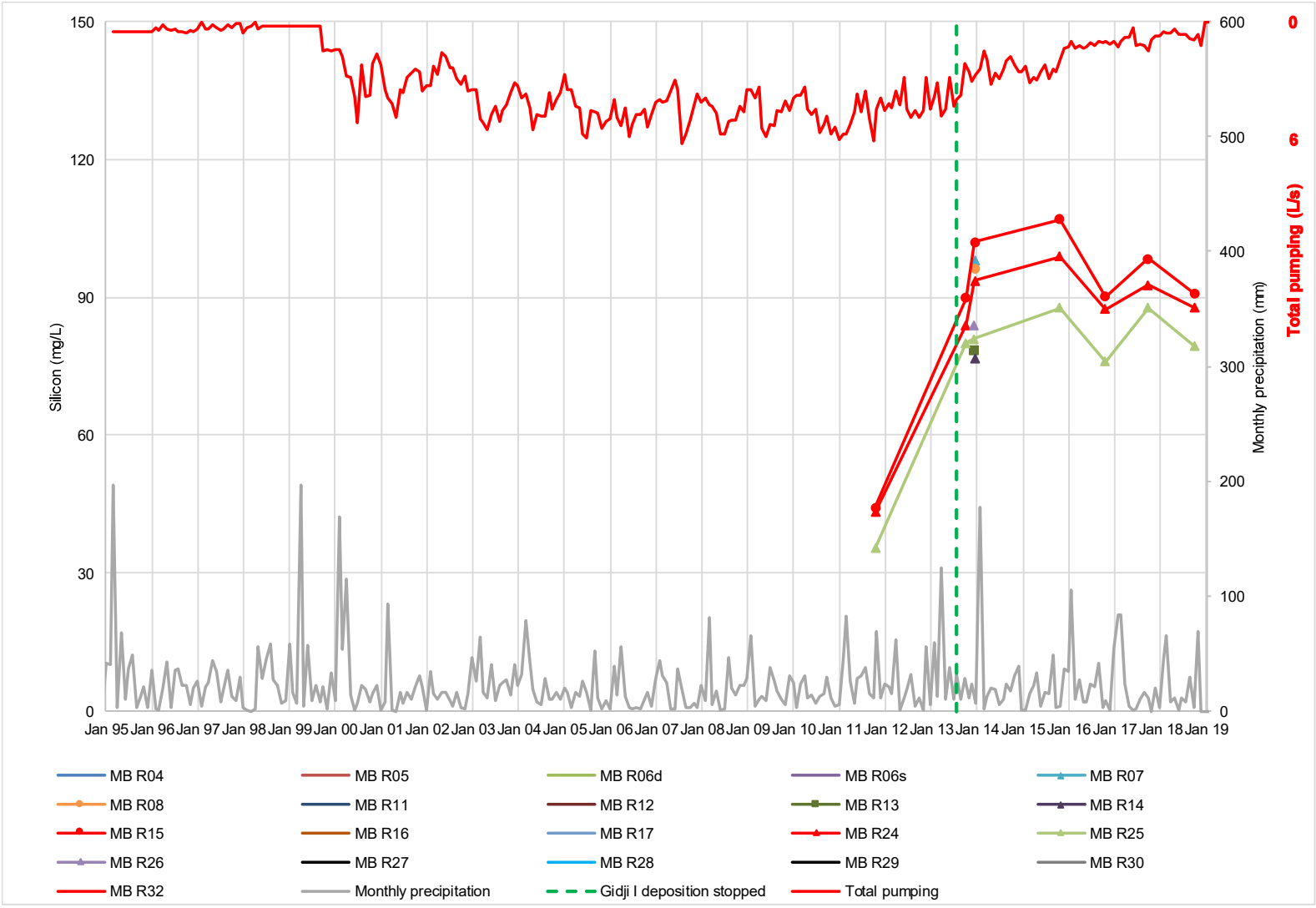
BIG DOG HYDROGEOLOGY

Groundwater silicon - production bores

Figure C61

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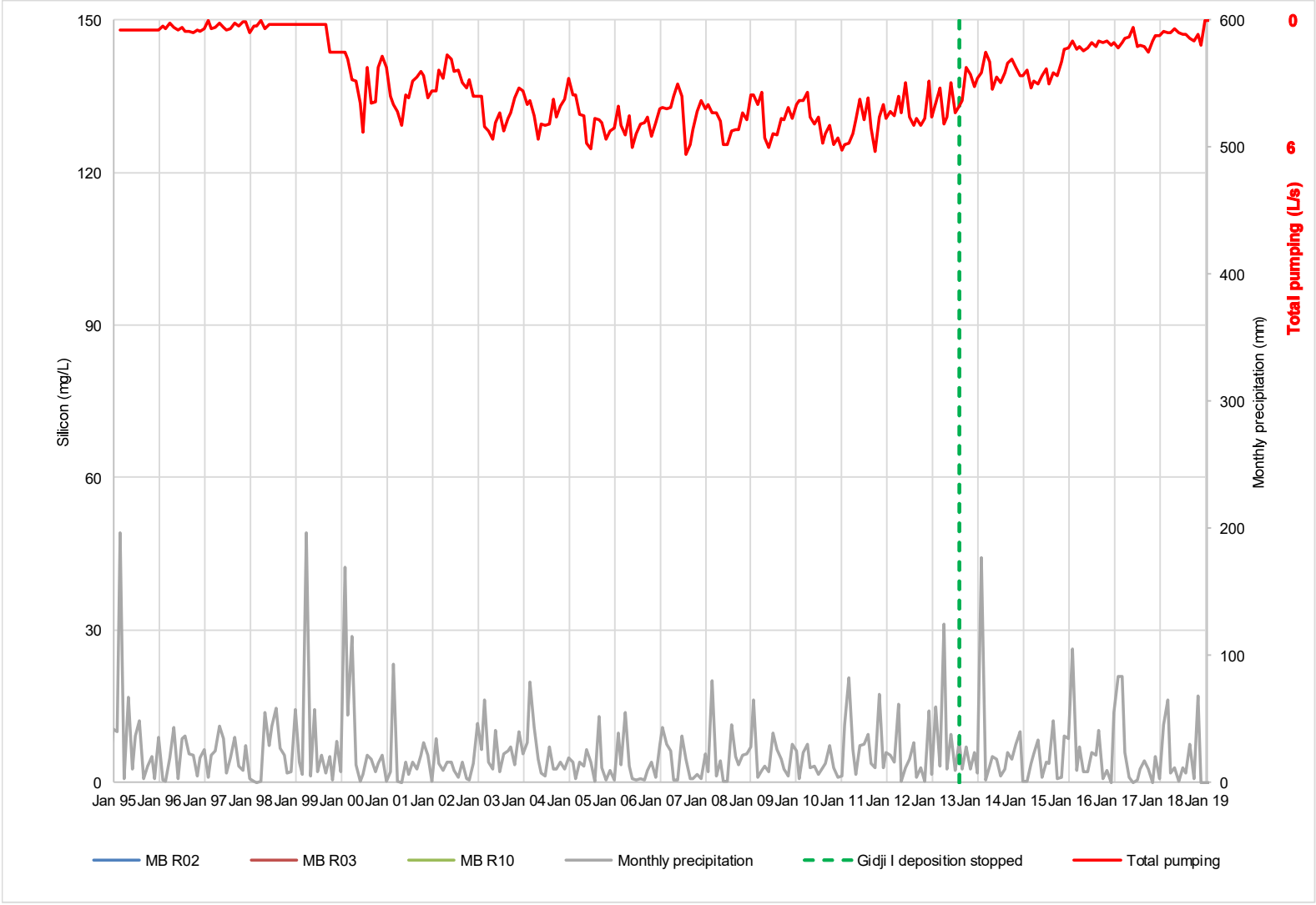
BIG DOG HYDROGEOLOGY

Groundwater silicon - western bores

Figure C62

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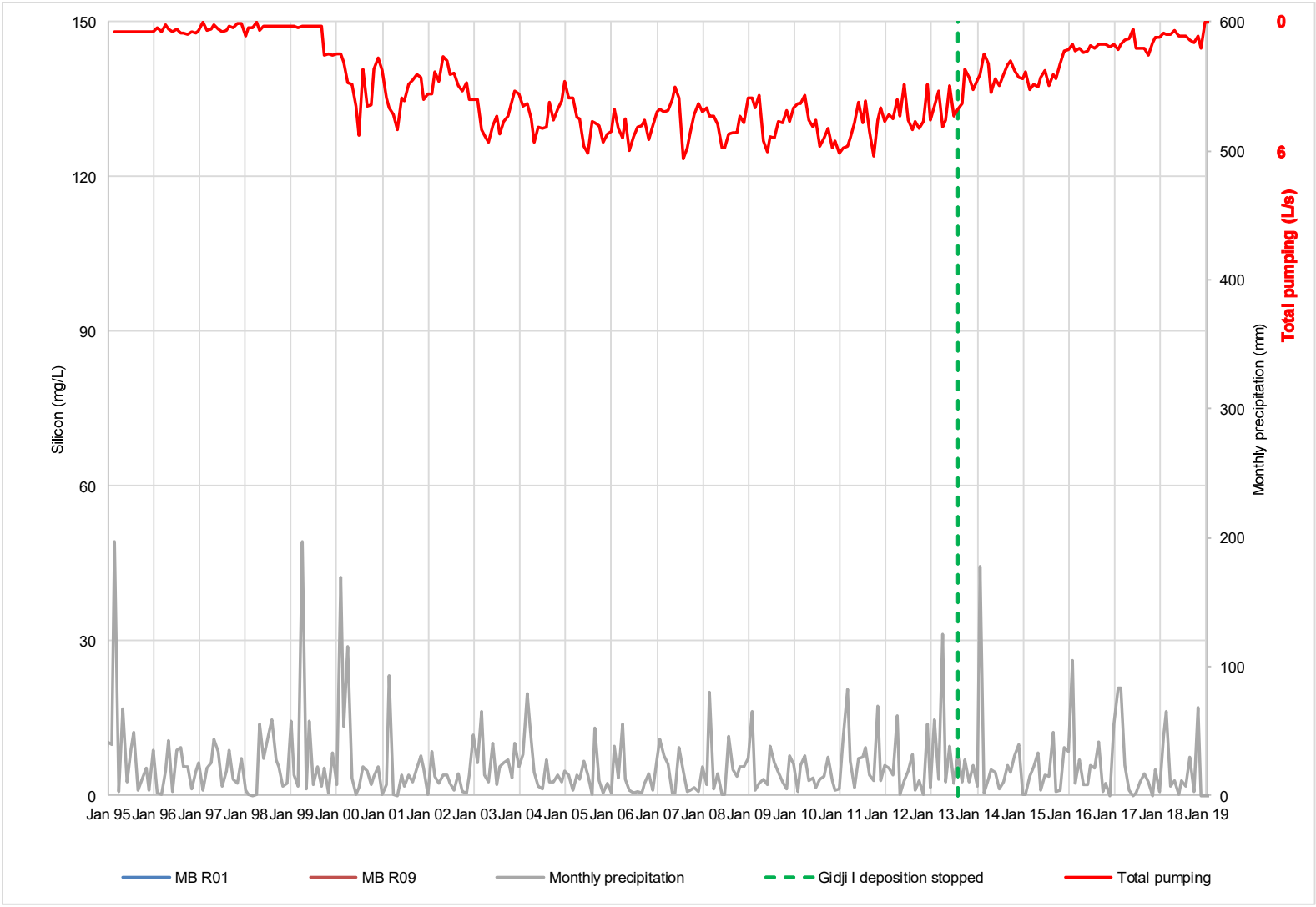
BIG DOG HYDROGEOLOGY

Groundwater silicon - trench bores

Figure C63

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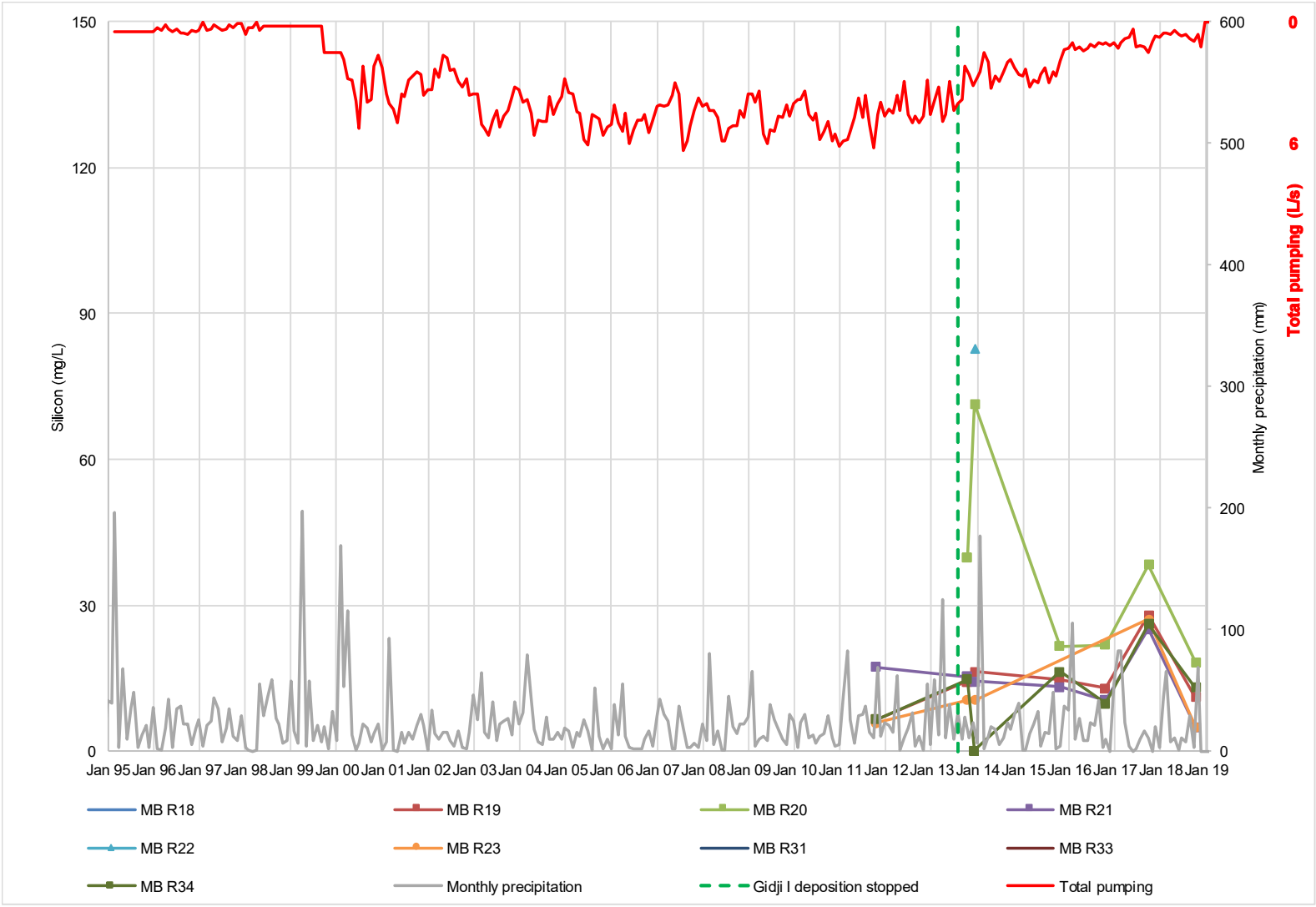
BIG DOG HYDROGEOLOGY

Groundwater silicon - decant bores

Figure C64

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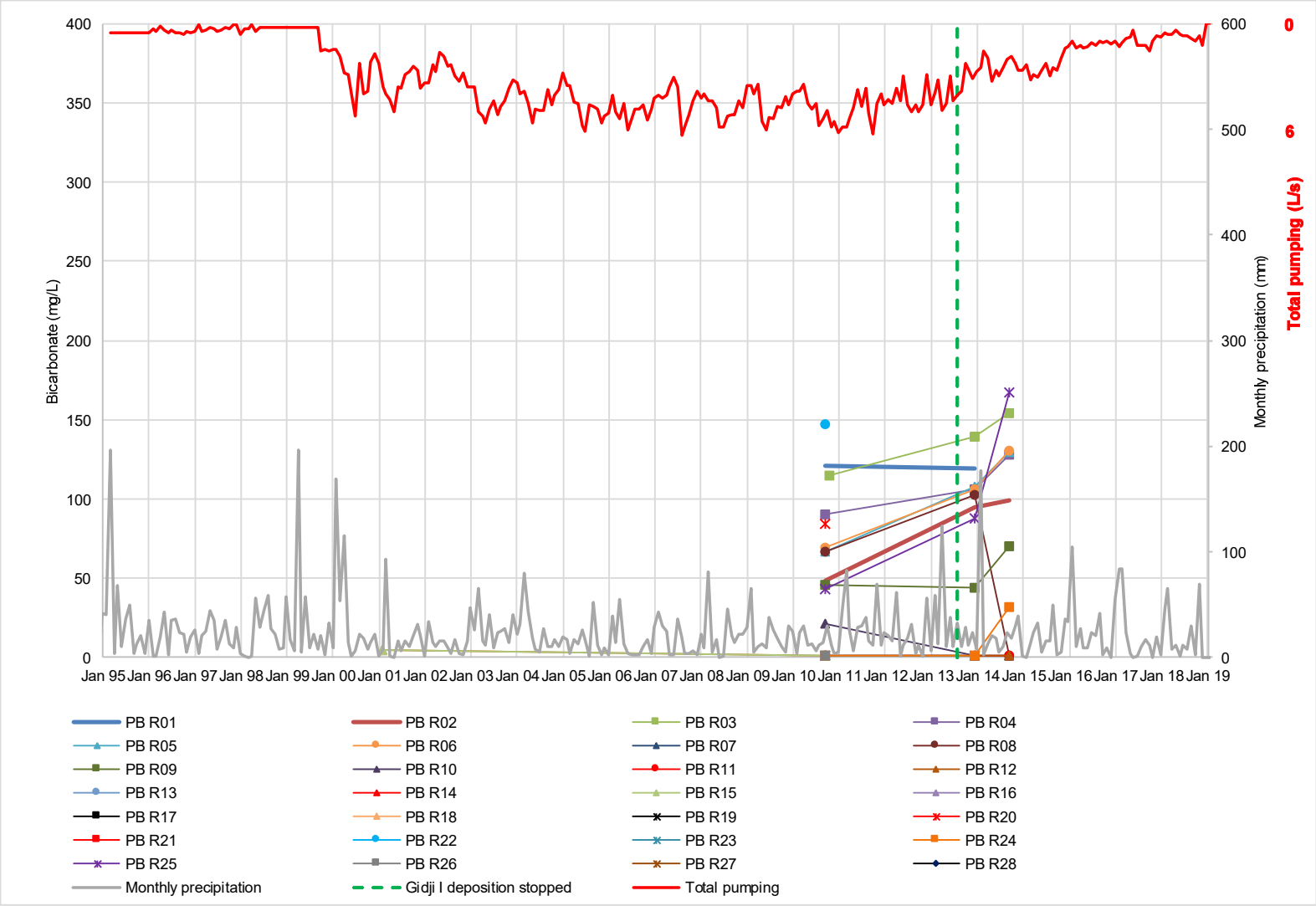
BIG DOG HYDROGEOLOGY

Groundwater silicon - eastern bores

Figure C65

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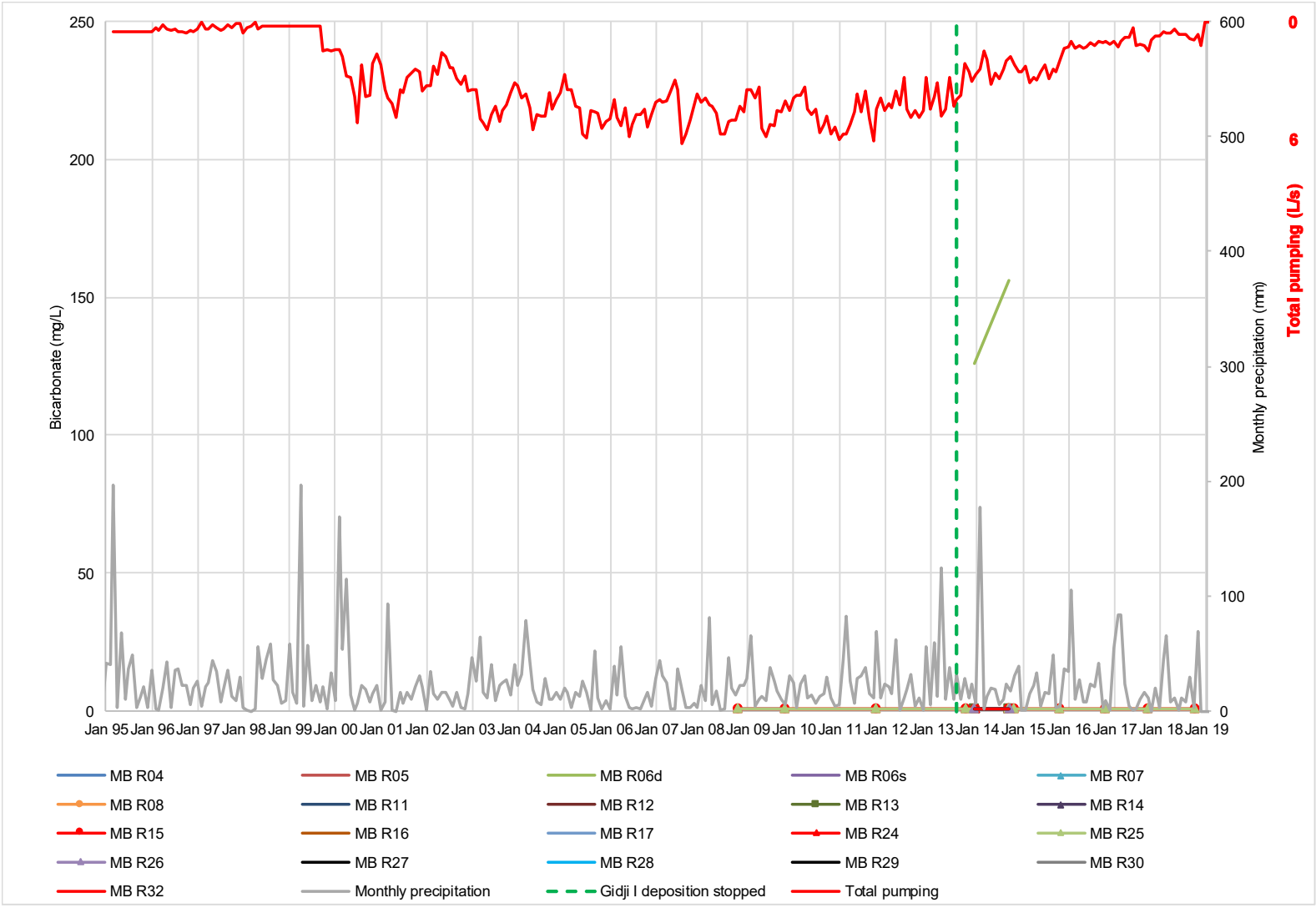
BIG DOG HYDROGEOLOGY

Groundwater bicarbonate - production bores

Figure C66

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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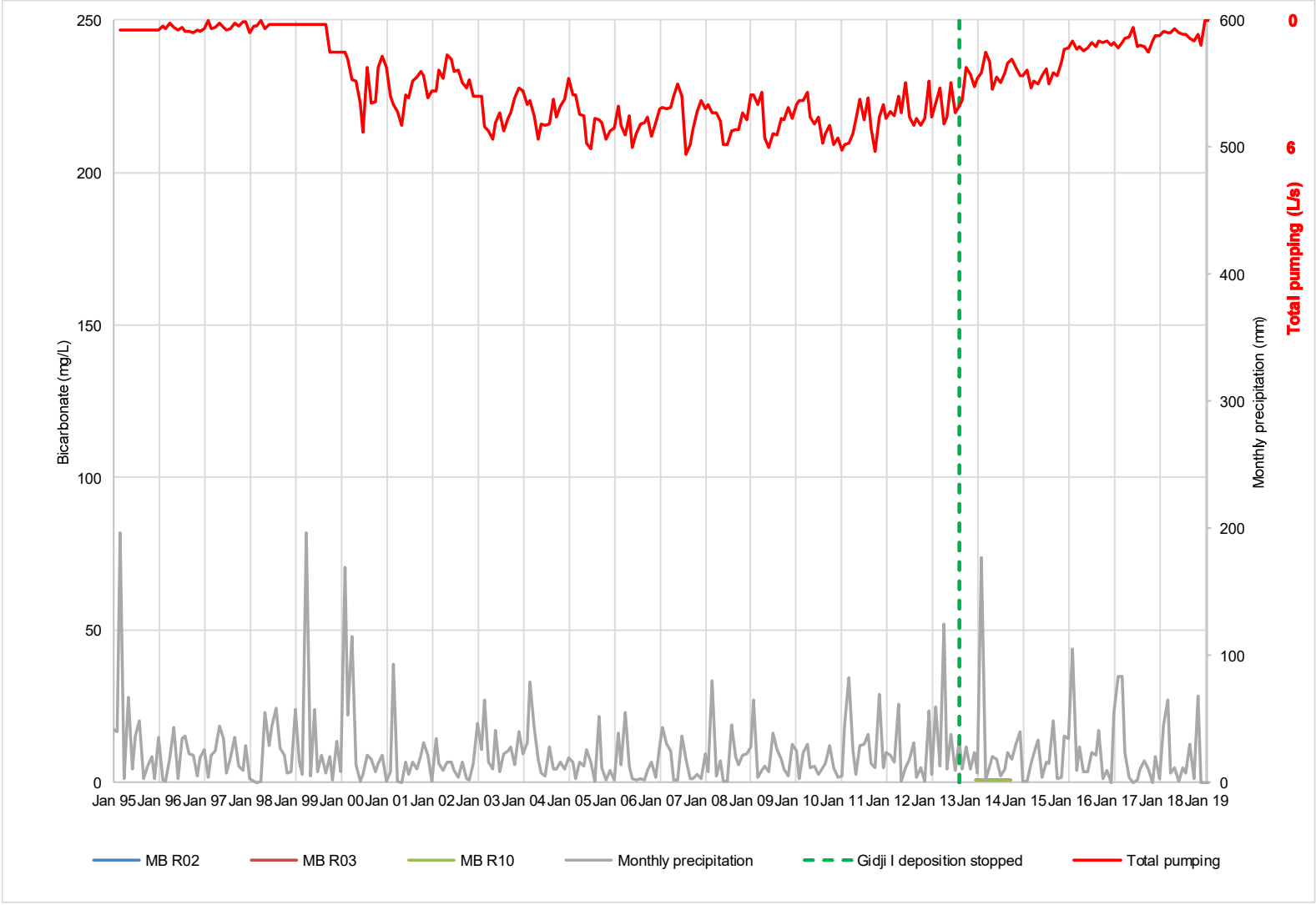
BIG DOG HYDROGEOLOGY

Groundwater bicarbonate - western bores

Figure C67

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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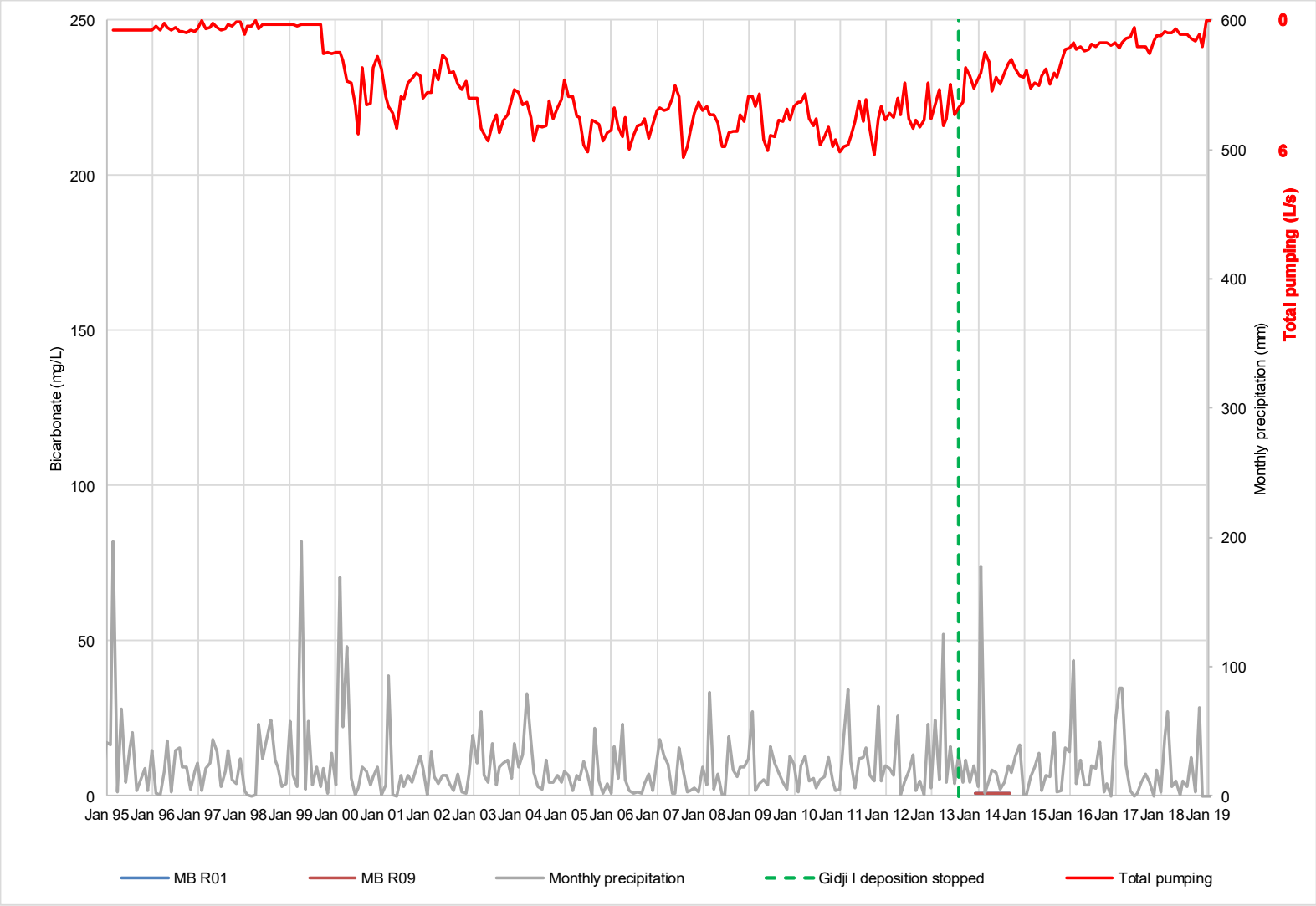
BIG DOG HYDROGEOLOGY

Groundwater bicarbonate - trench bores

Figure C68

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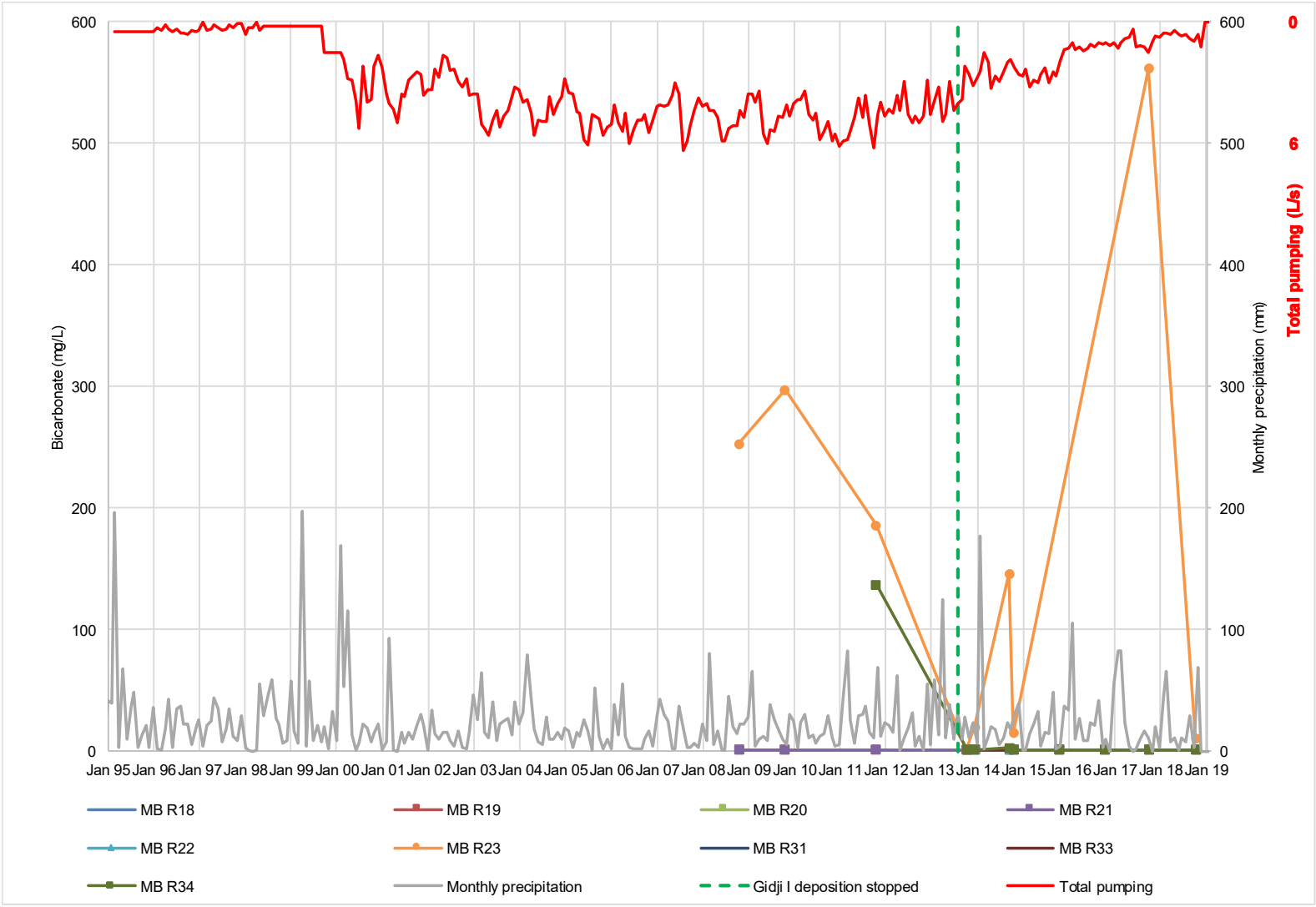
BIG DOG HYDROGEOLOGY

Groundwater bicarbonate - decant bores

Figure C69

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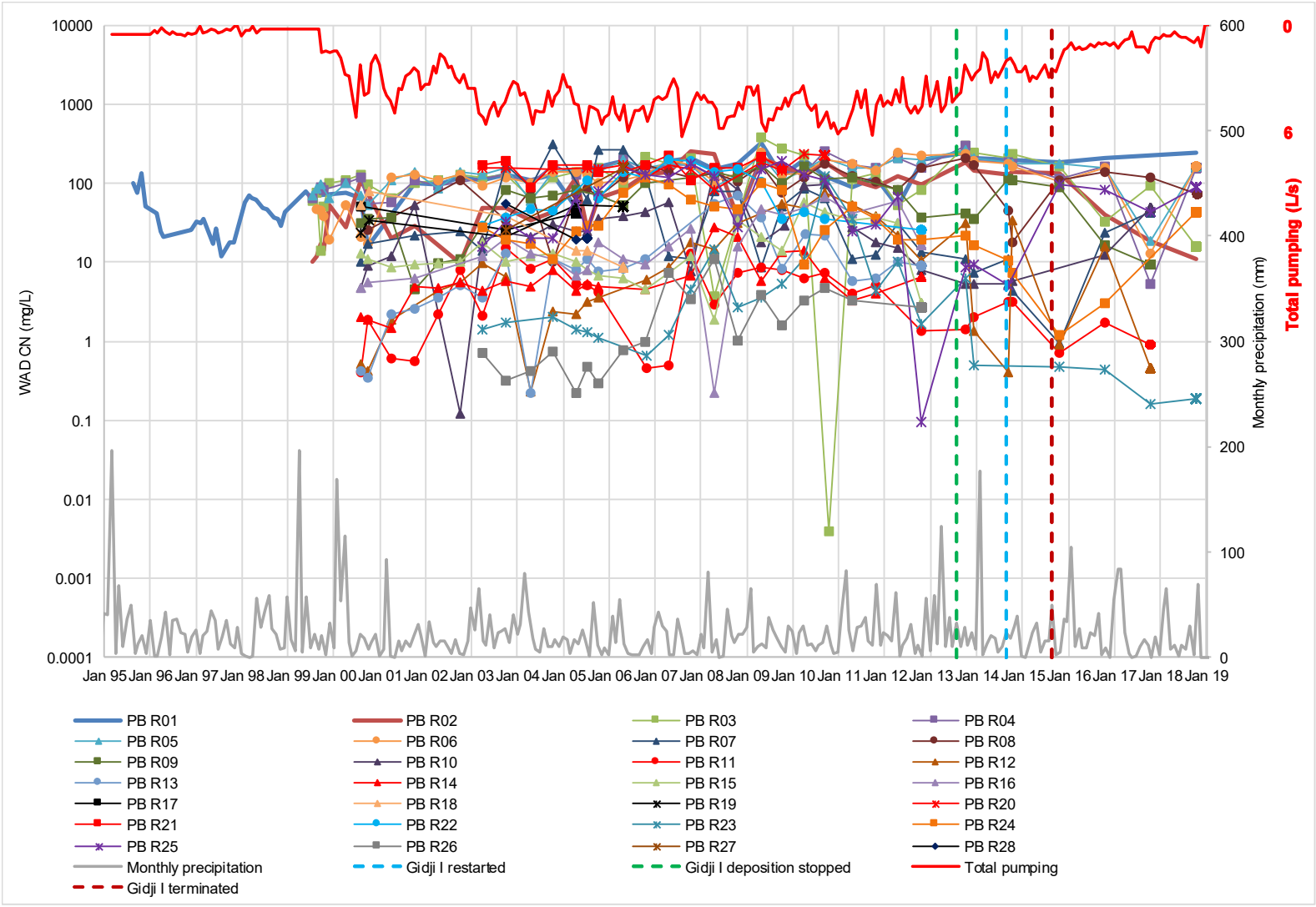
BIG DOG HYDROGEOLOGY

Groundwater bicarbonate - eastern bores

Figure C70

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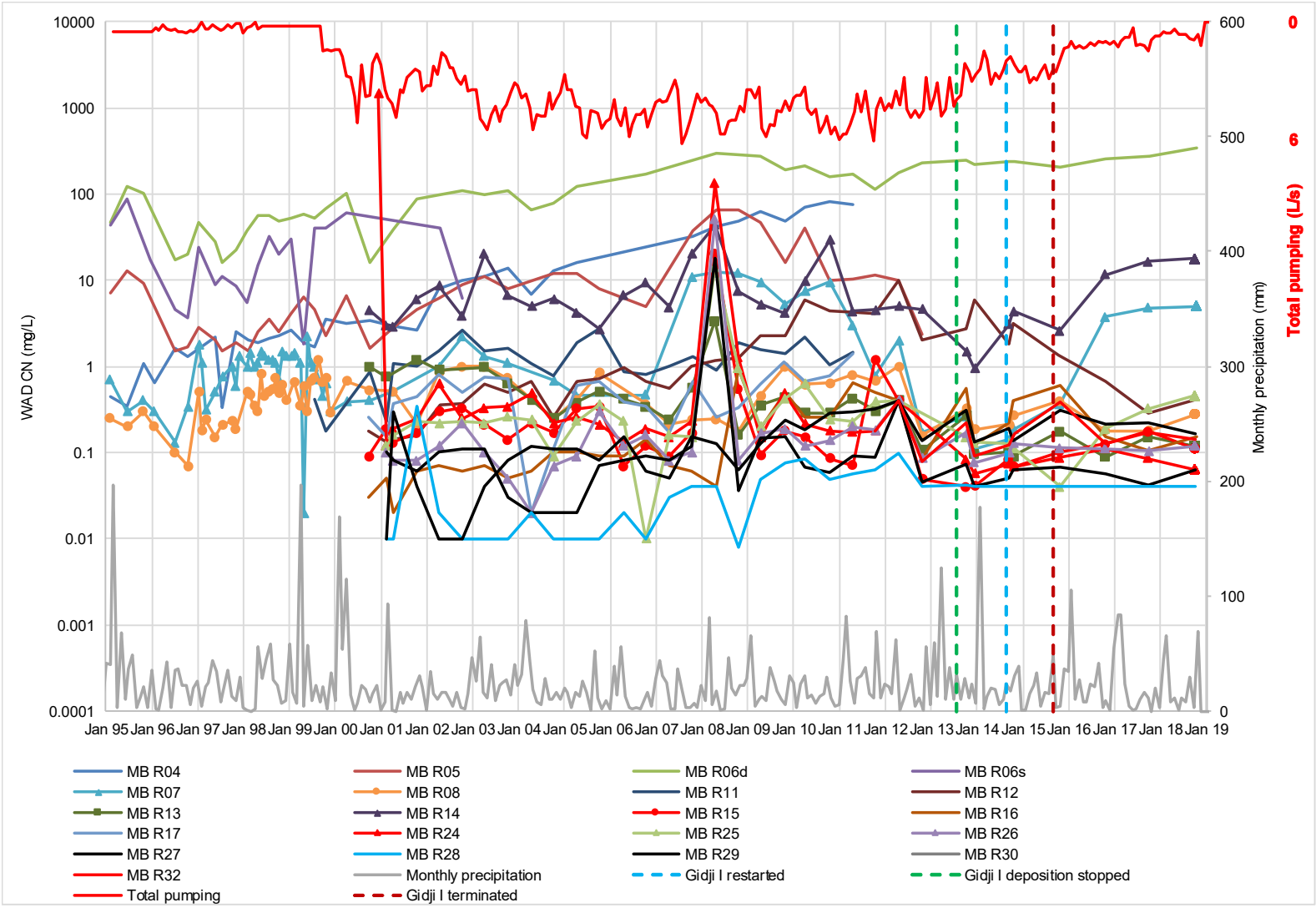
BIG DOG HYDROGEOLOGY

Groundwater WAD CN - production bores

Figure C71

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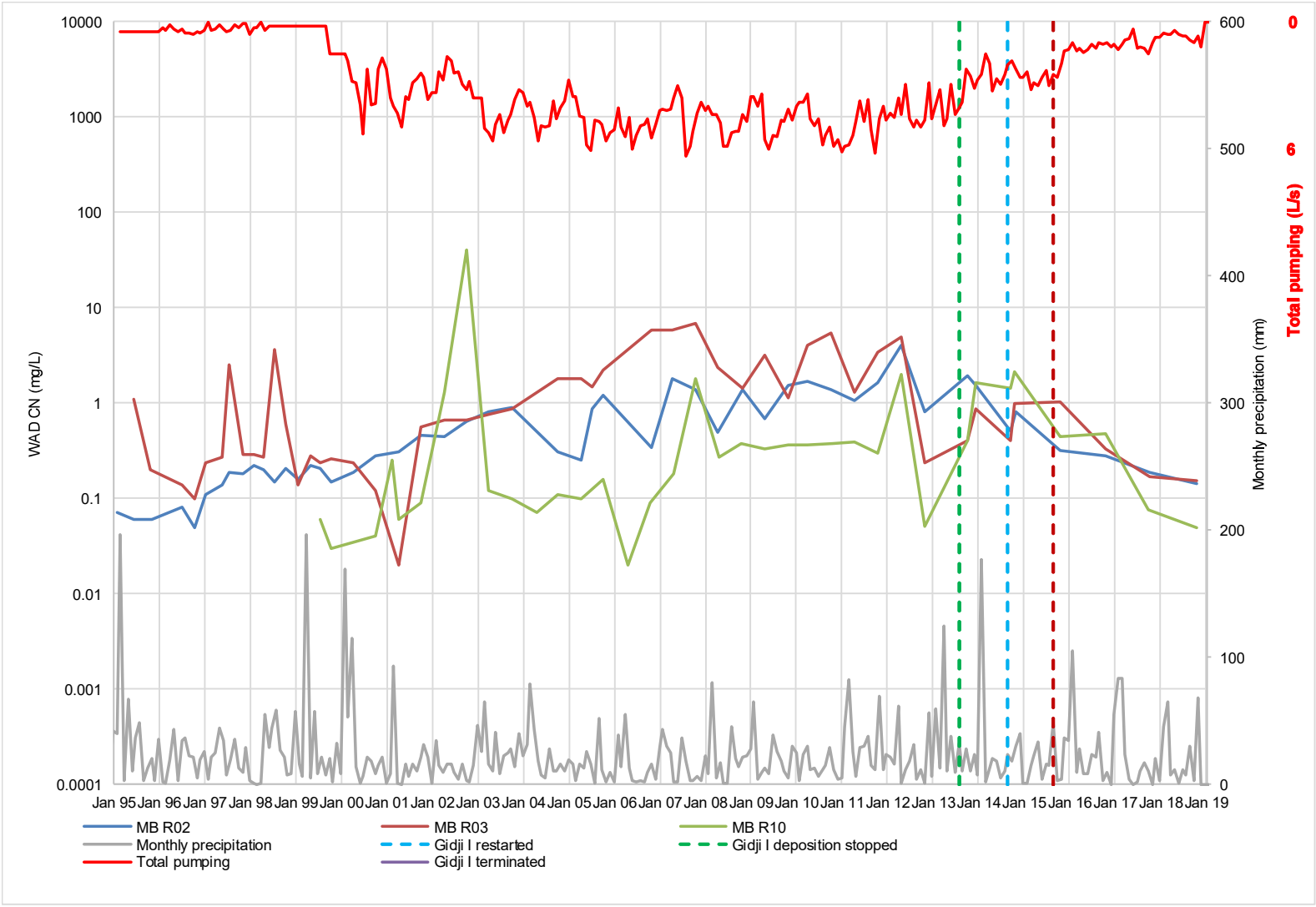
BIG DOG HYDROGEOLOGY

Groundwater WAD CN - western bores

Figure C72

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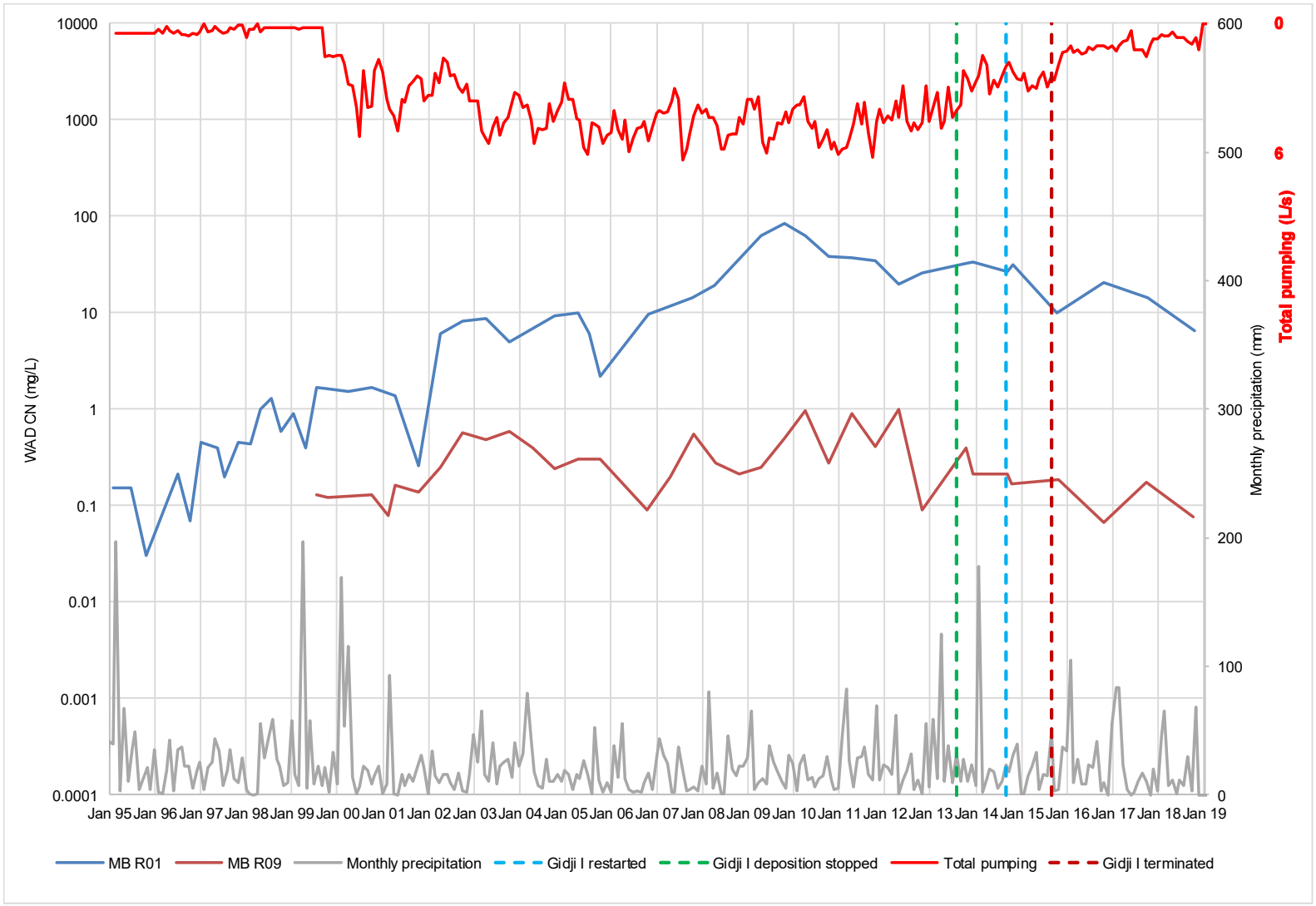
BIG DOG HYDROGEOLOGY

Groundwater WAD CN - trench bores

Figure C73

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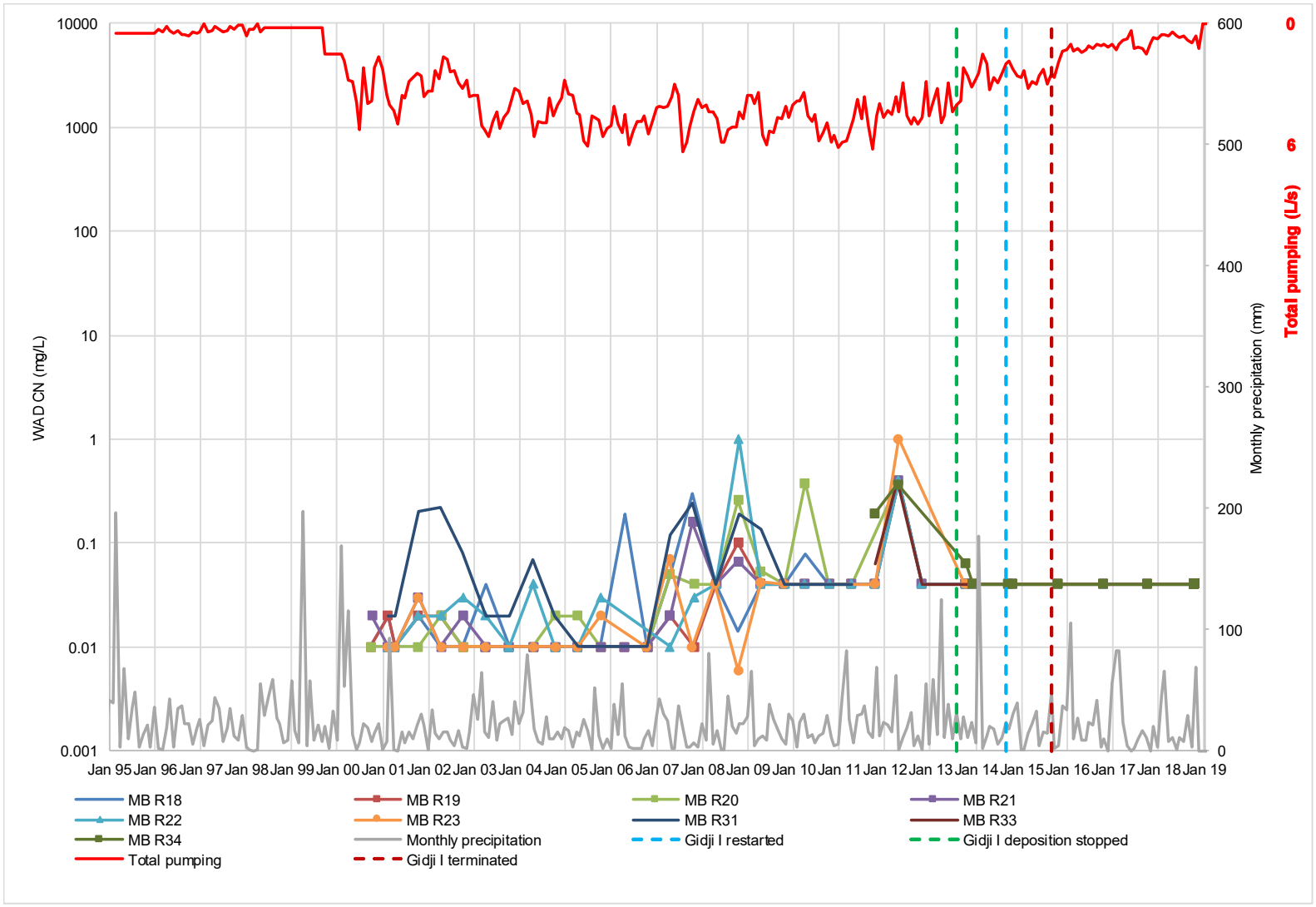
BIG DOG HYDROGEOLOGY

Groundwater WAD CN - decant bores

Figure C74

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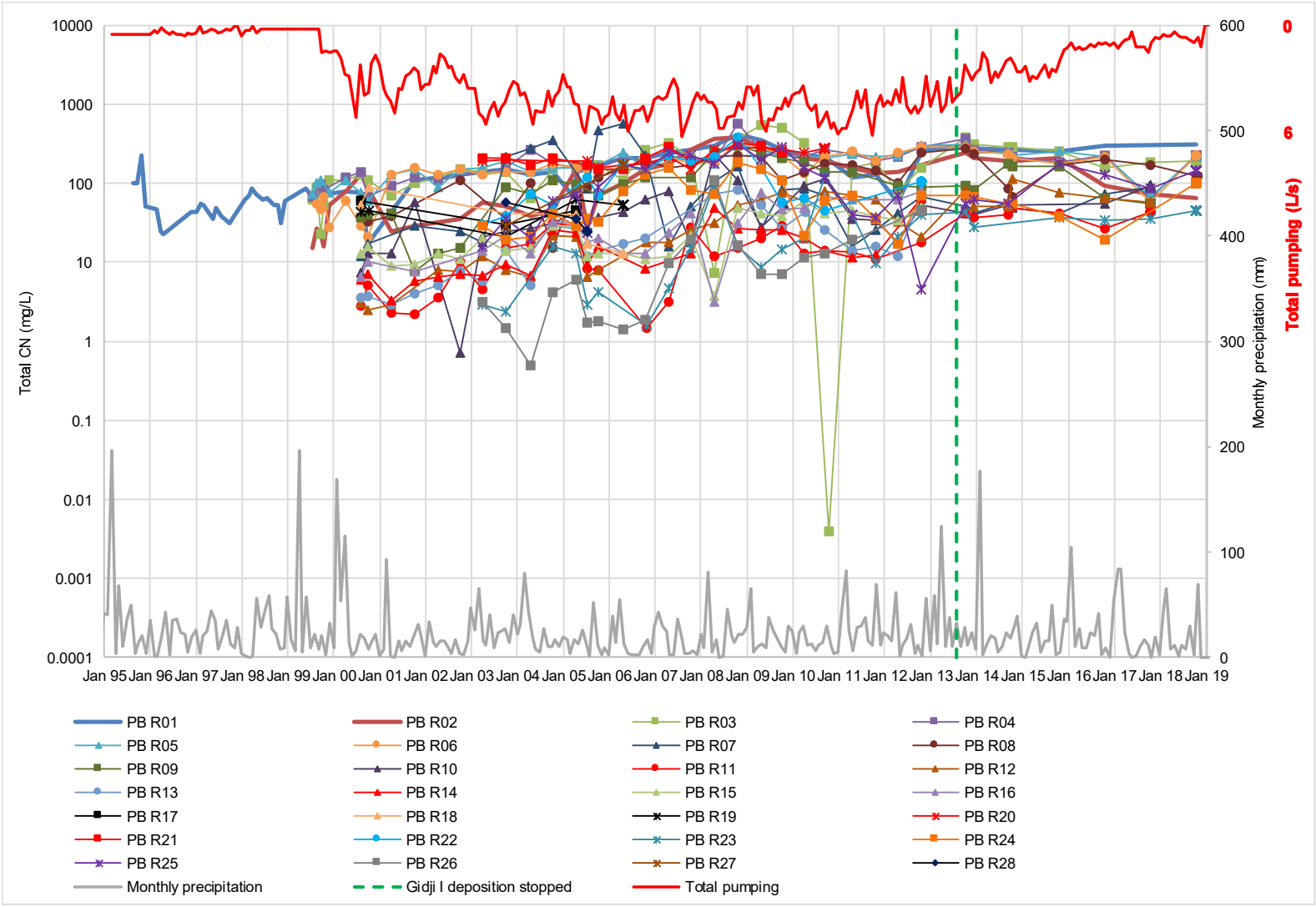
BIG DOG HYDROGEOLOGY

Groundwater WAD CN - eastern bores

Figure C75

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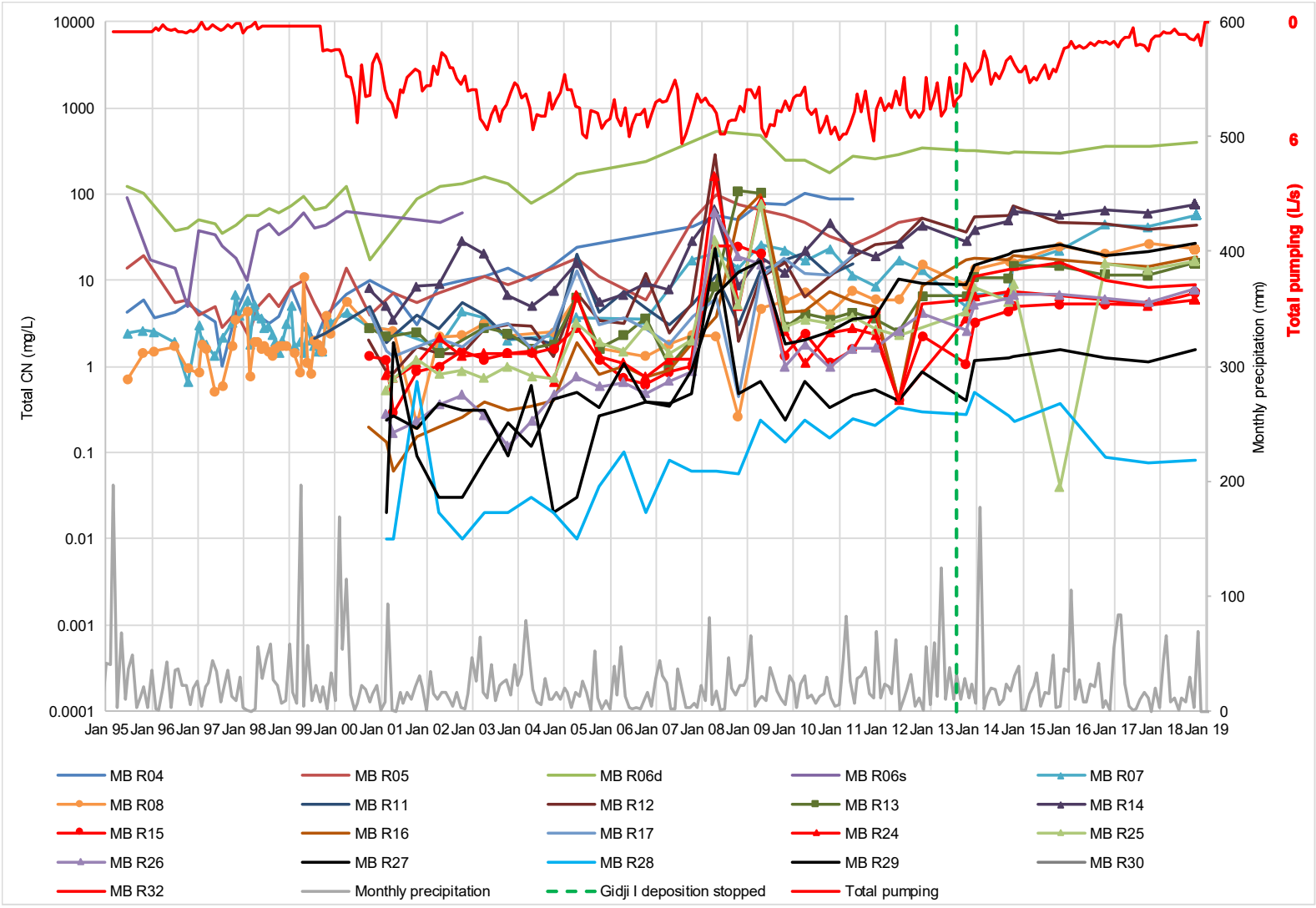
BIG DOG HYDROGEOLOGY

Groundwater Total CN - production bores

Figure C76

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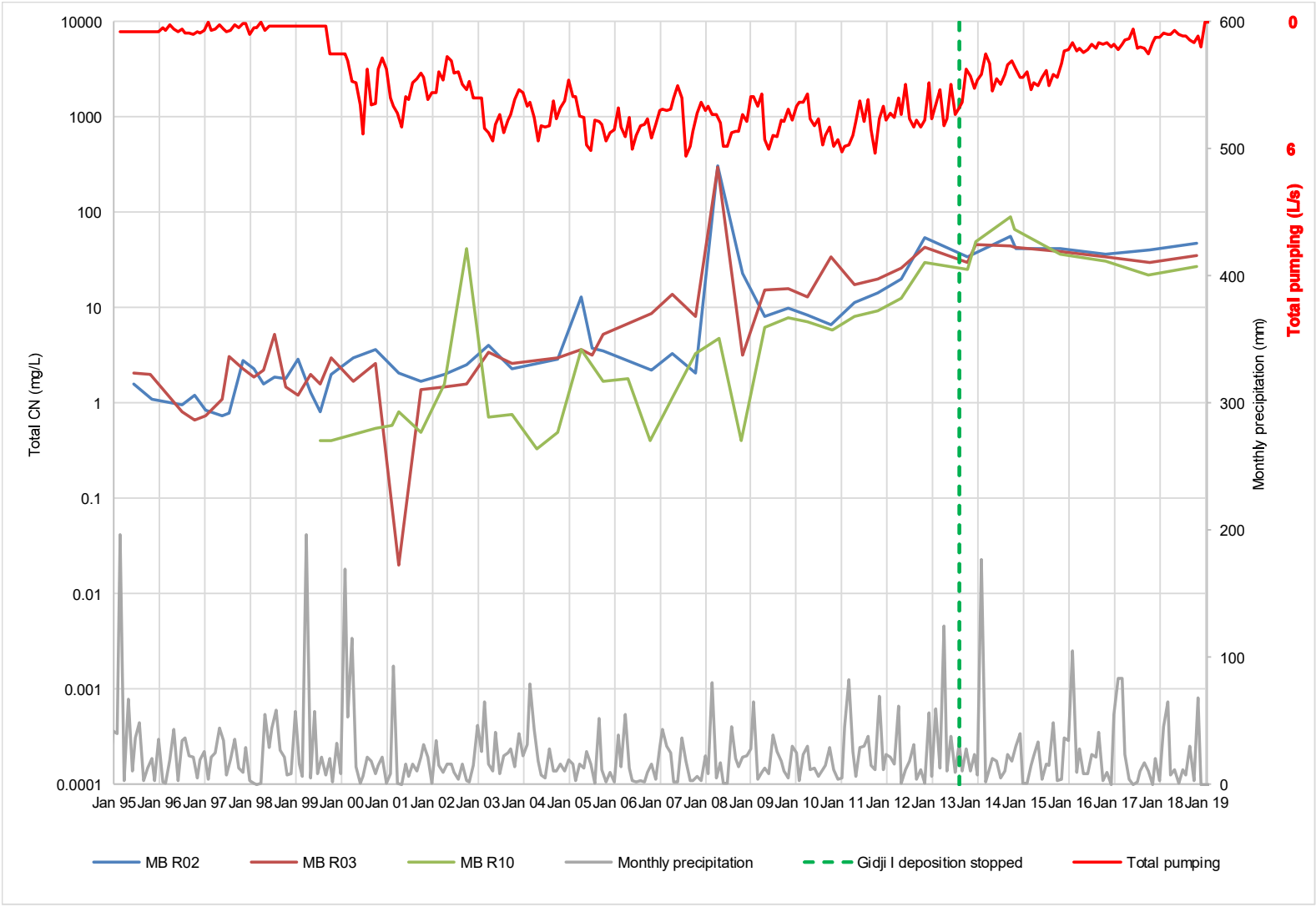
BIG DOG HYDROGEOLOGY

Groundwater Total CN - western bores

Figure C77

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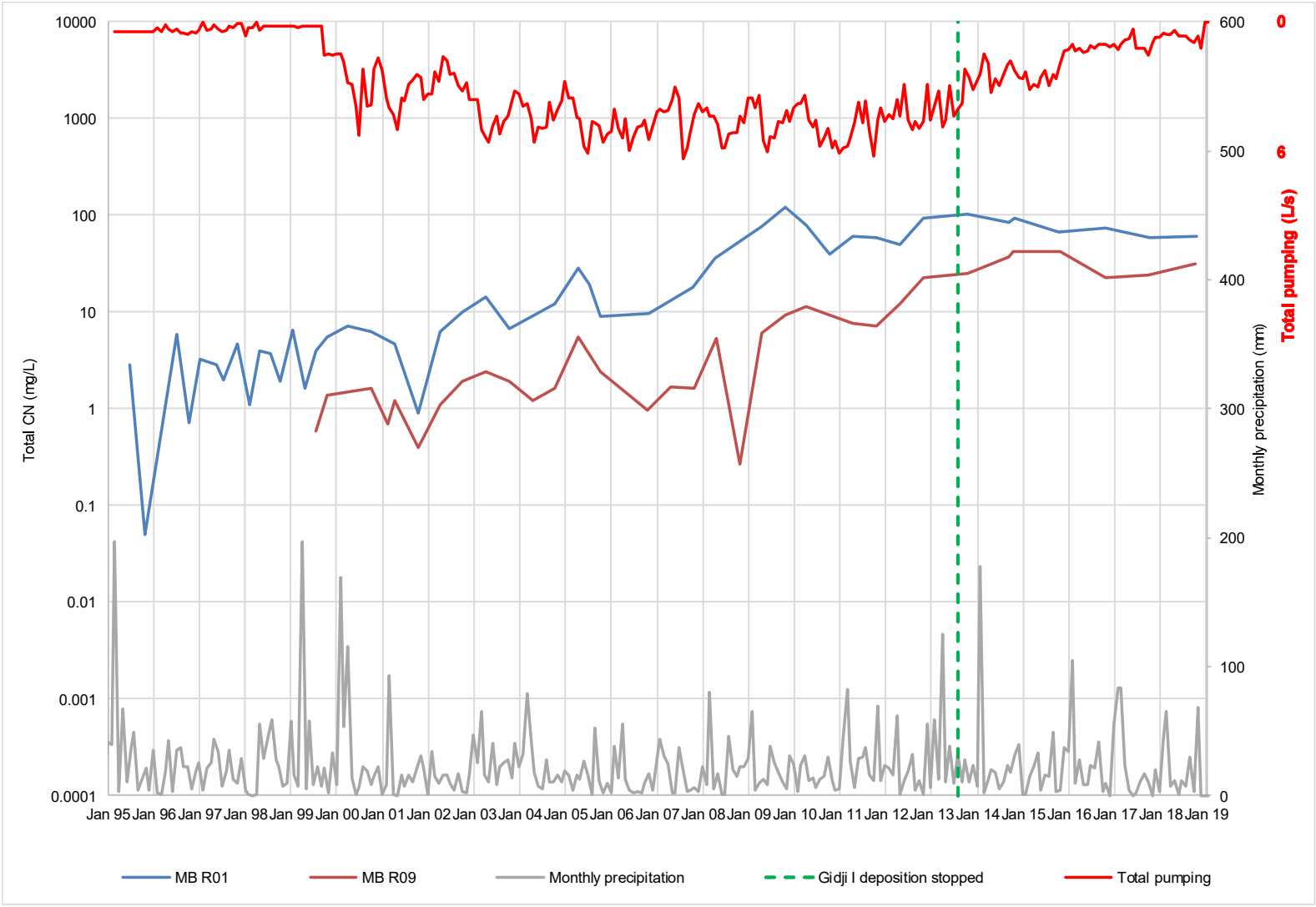
BIG DOG HYDROGEOLOGY

Groundwater Total CN - trench bores

Figure C78

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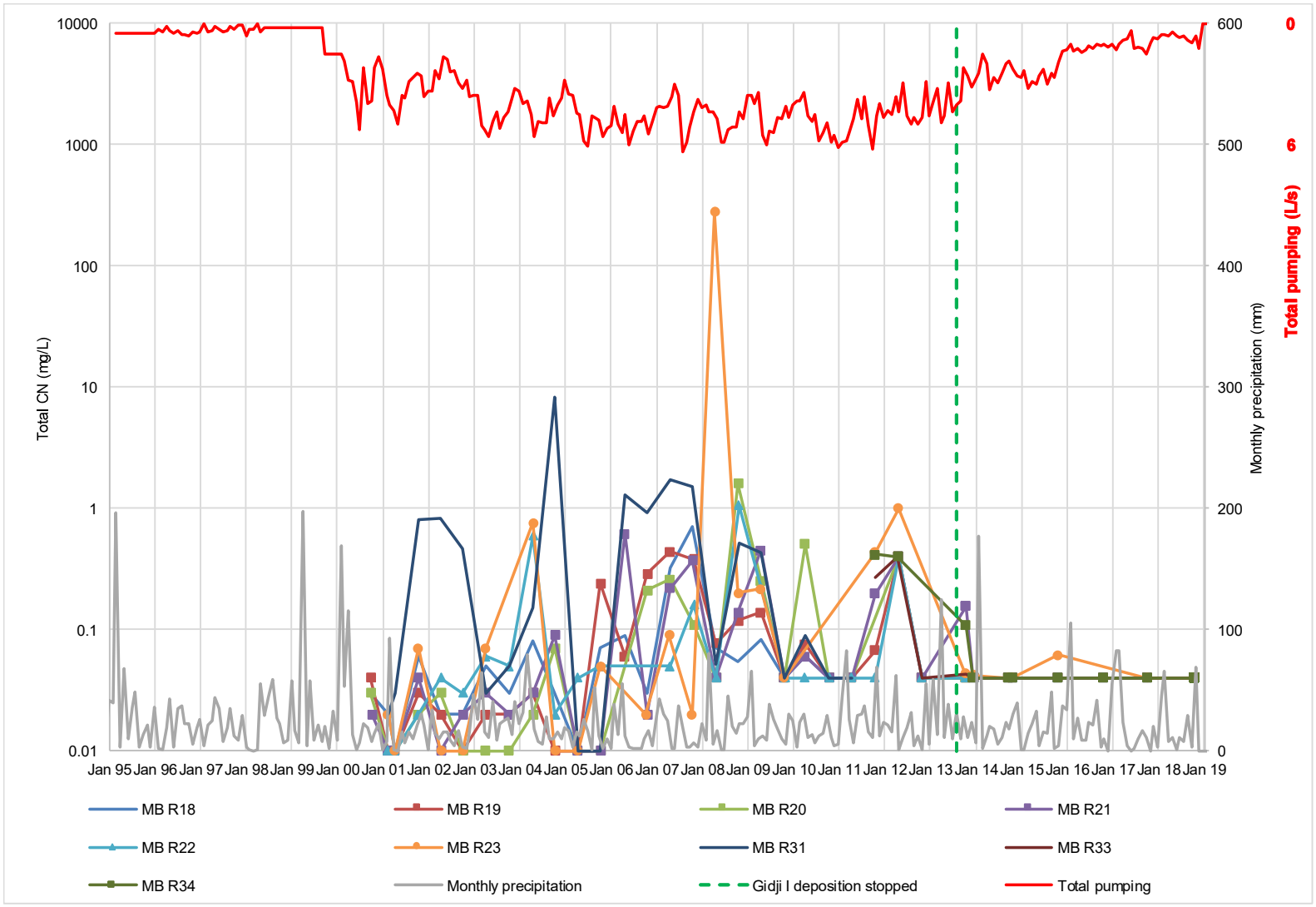
BIG DOG HYDROGEOLOGY

Groundwater Total CN - decant bores

Figure C79

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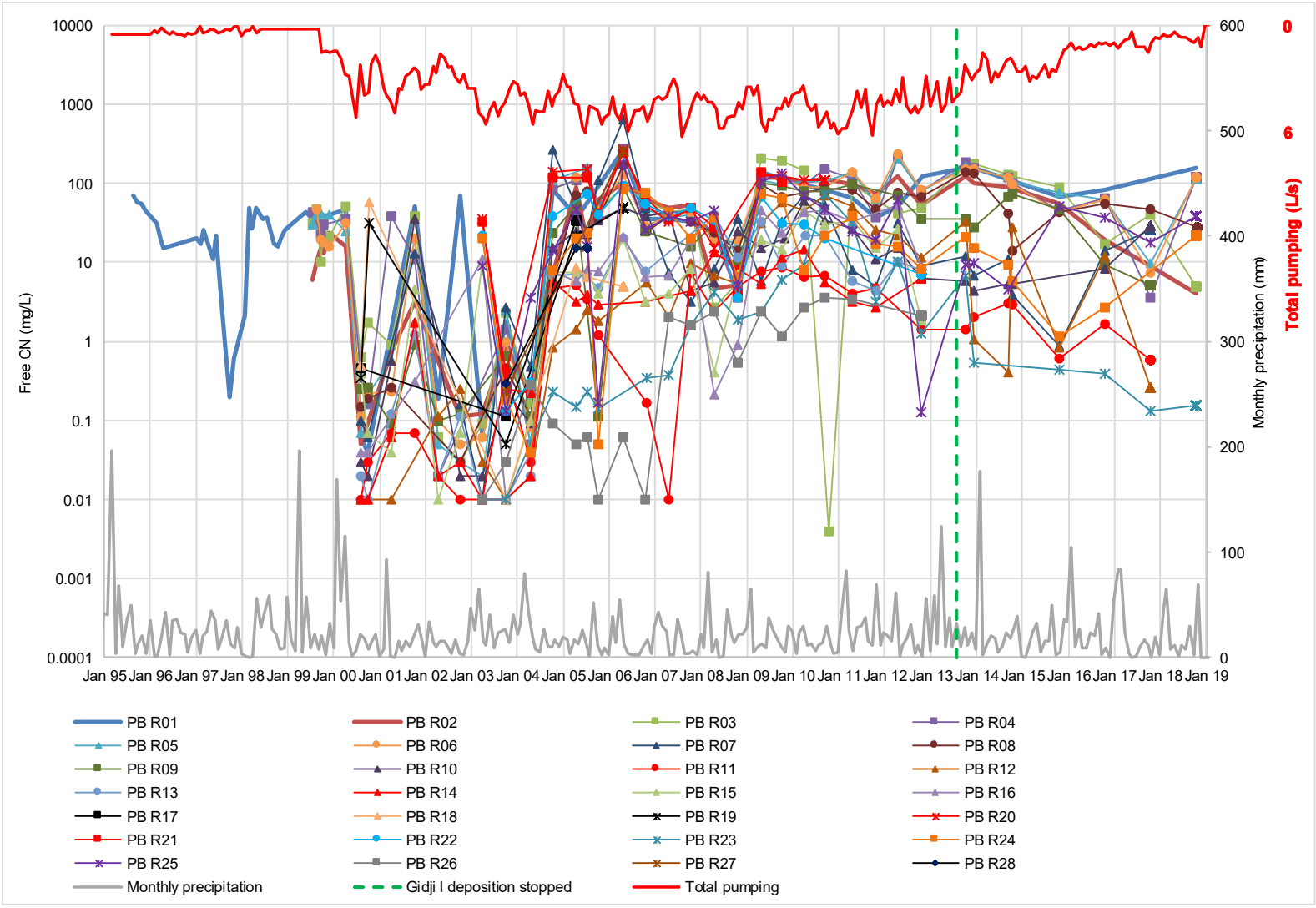
BIG DOG HYDROGEOLOGY

Groundwater Total CN - eastern bores

Figure C80

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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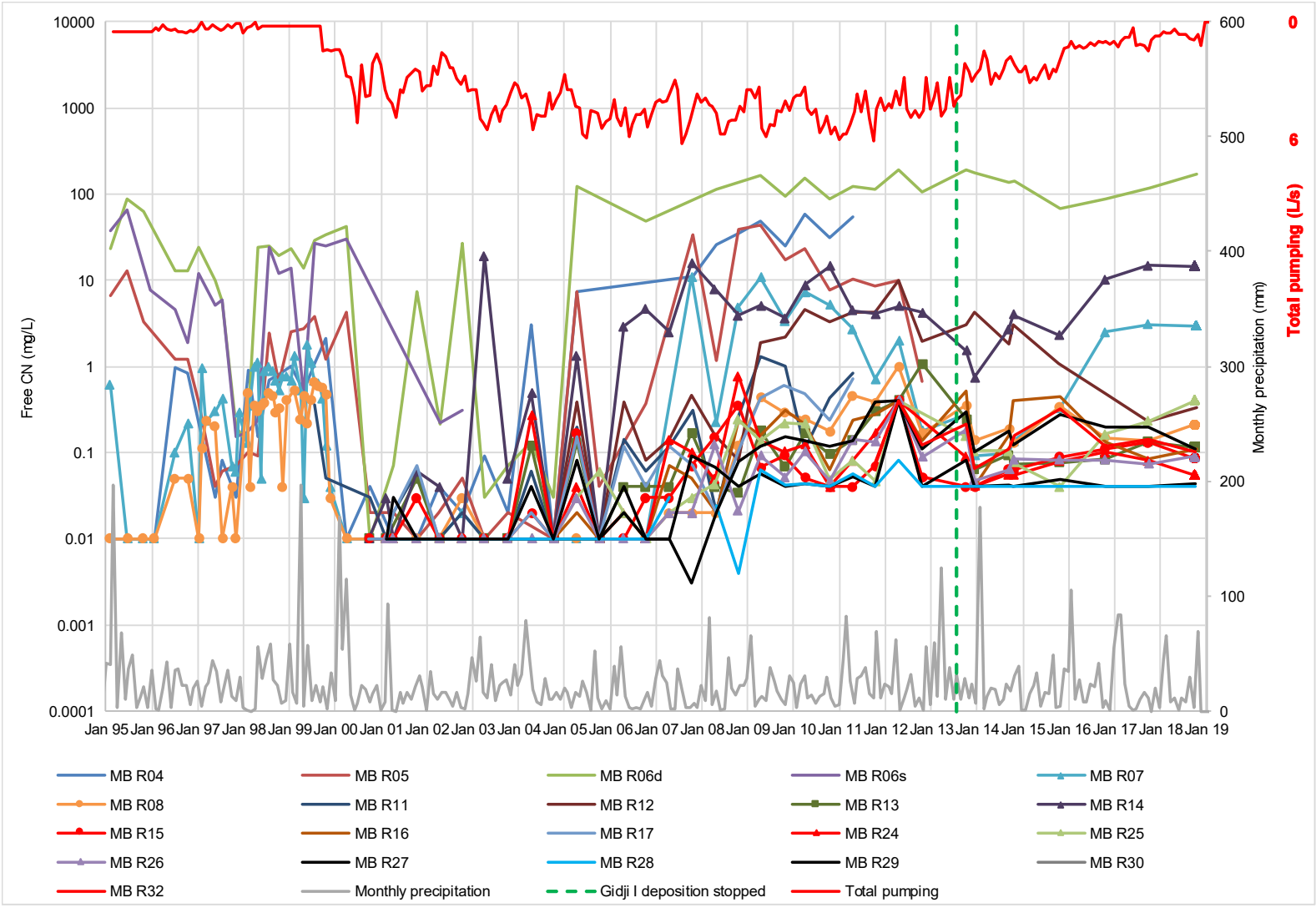
BIG DOG HYDROGEOLOGY

Groundwater Free CN - production bores

Figure C81

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



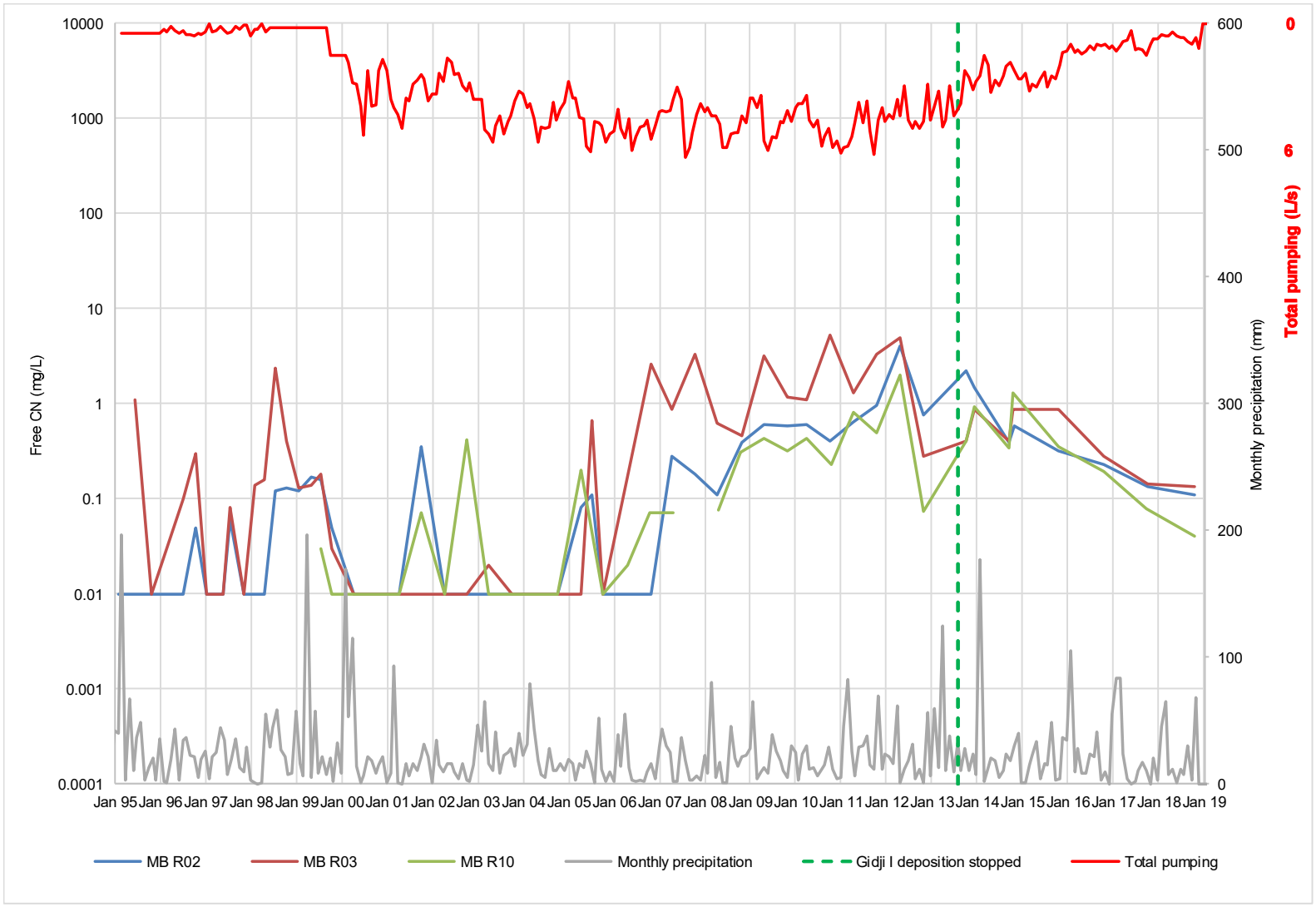
Groundwater Free CN - western bores

Figure C82

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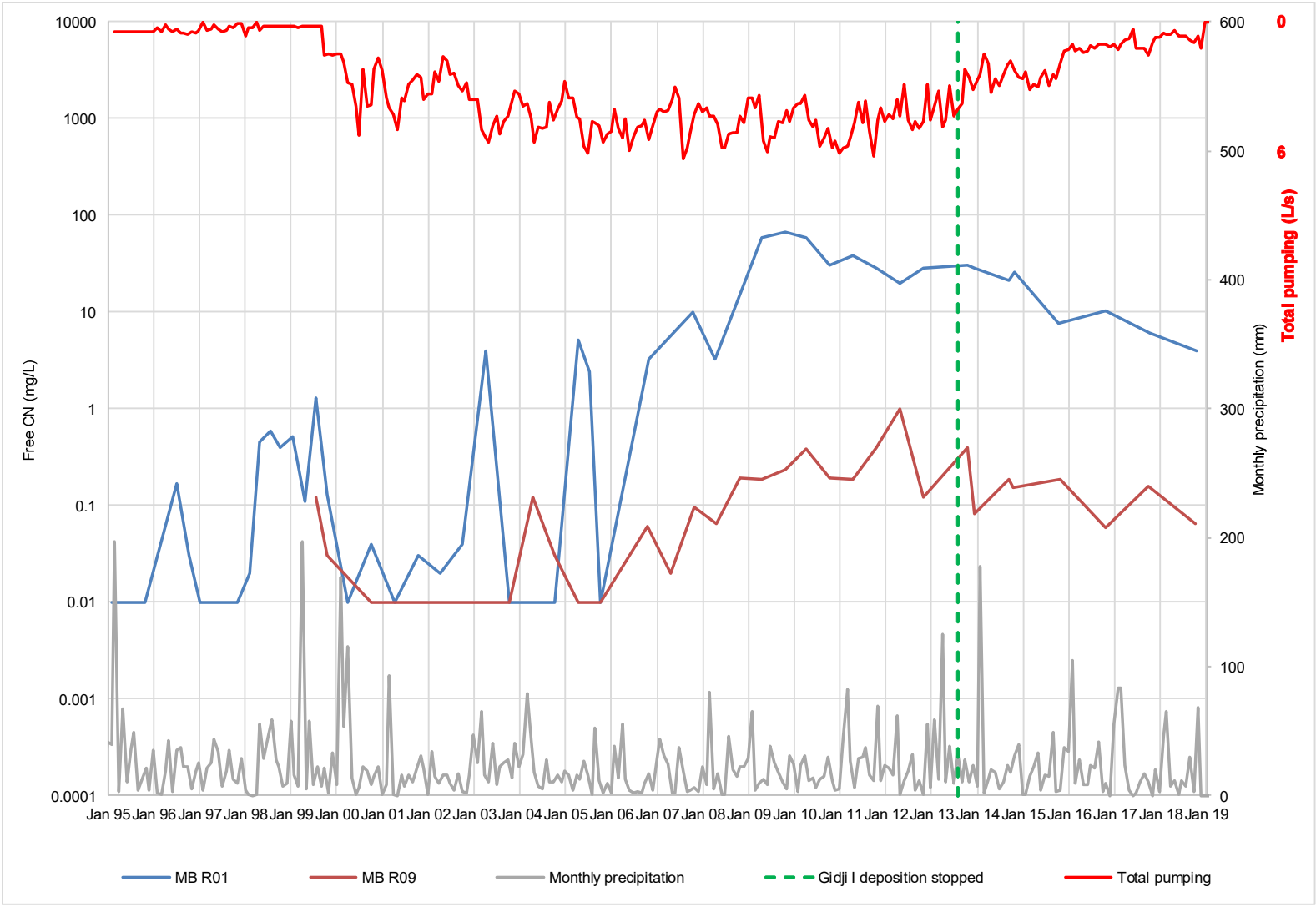
BIG DOG HYDROGEOLOGY

Groundwater Free CN - trench bores

Figure C83

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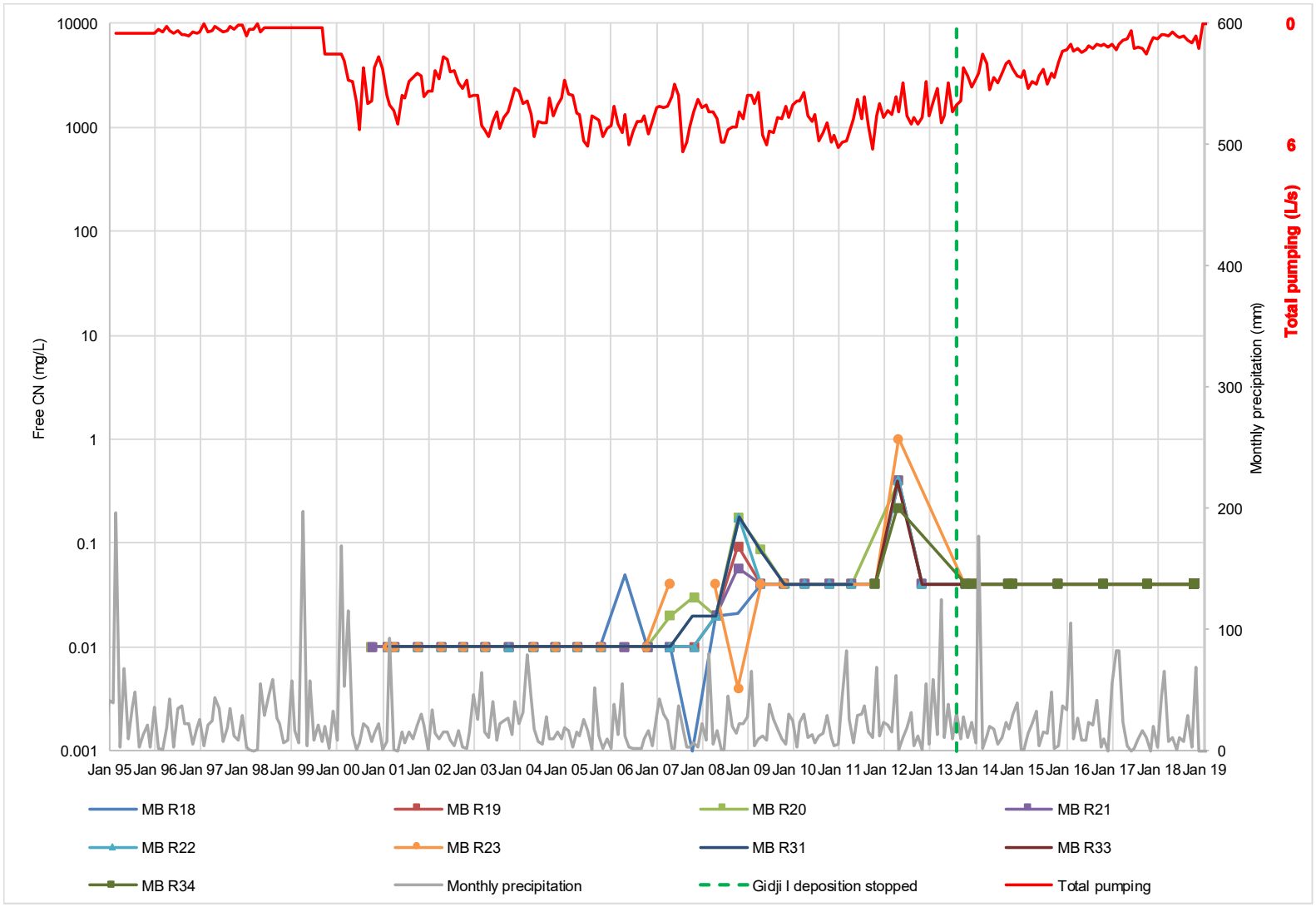
BIG DOG HYDROGEOLOGY

Groundwater Free CN - decant bores

Figure C84

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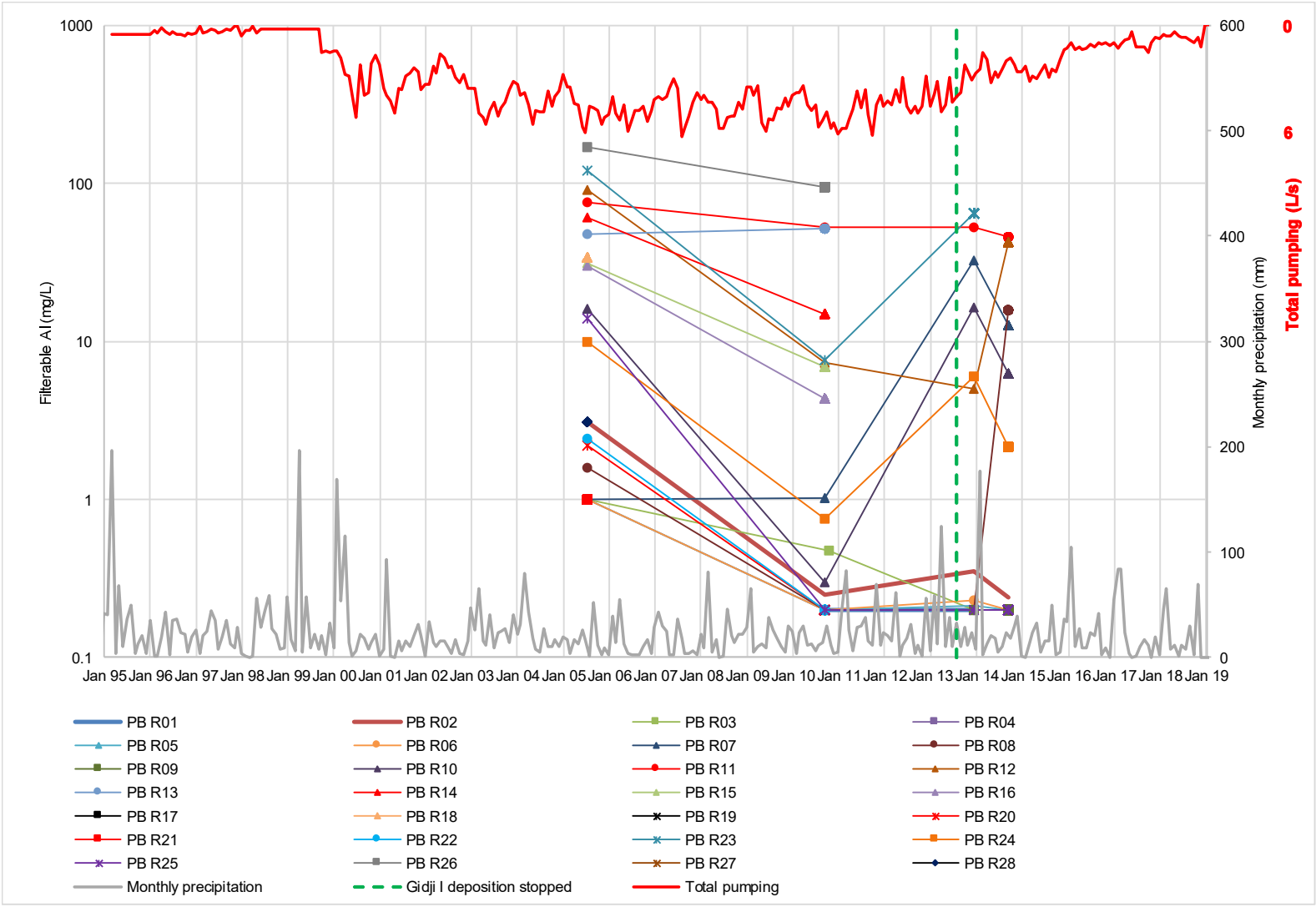
BIG DOG HYDROGEOLOGY

Groundwater Free CN - eastern bores

Figure C85

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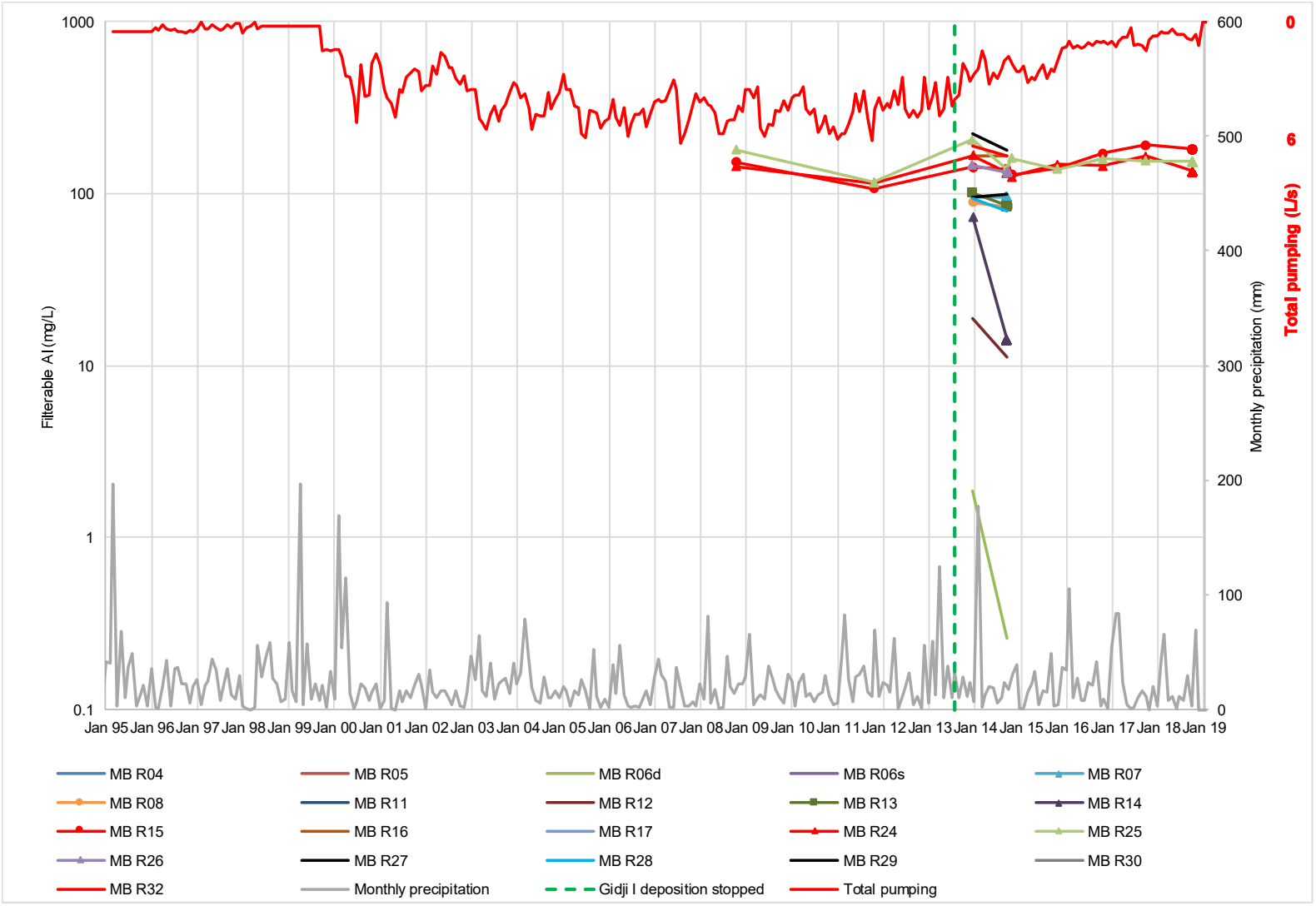
BIG DOG HYDROGEOLOGY

Groundwater Filterable Al - production bores

Figure C86

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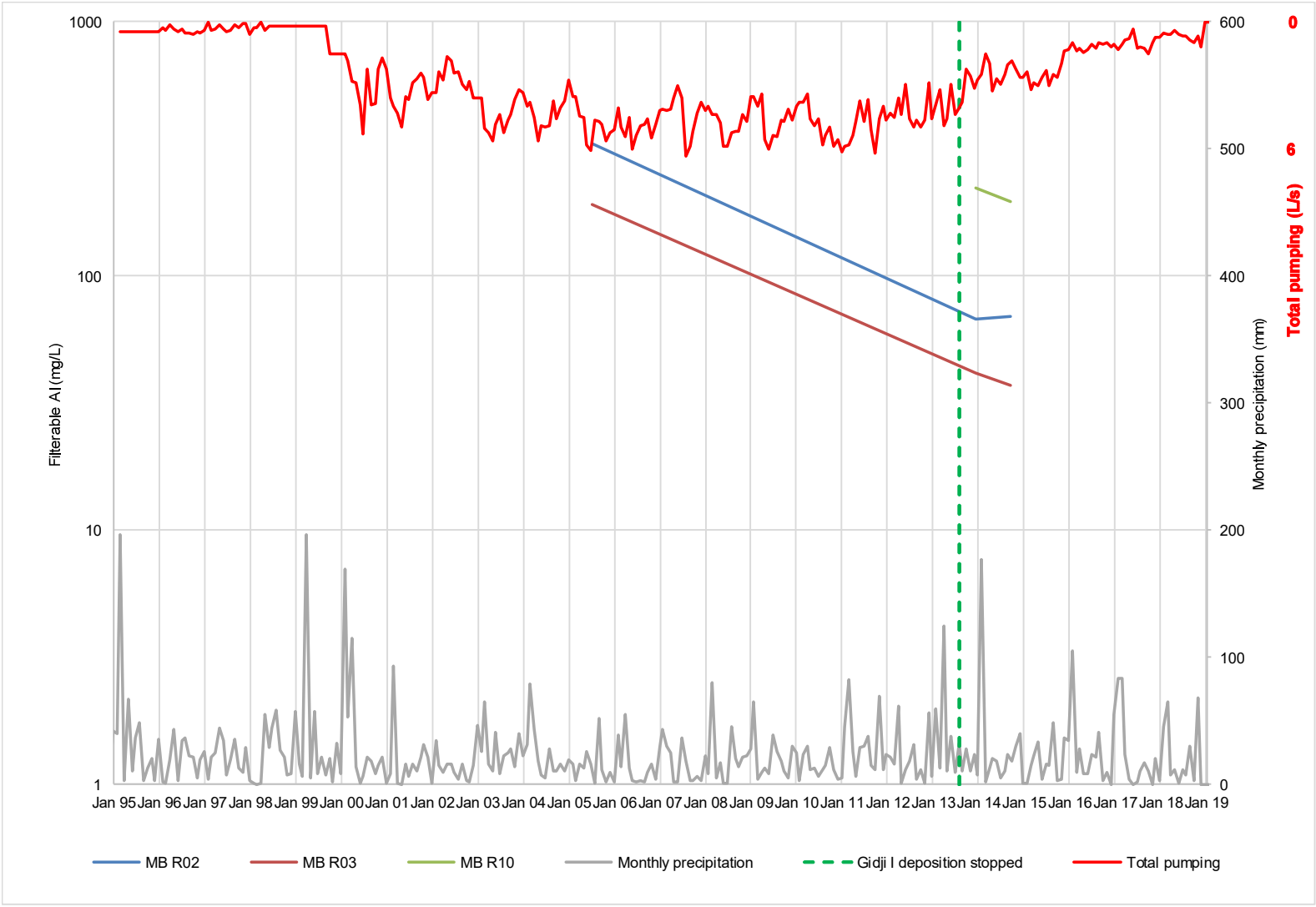
BIG DOG HYDROGEOLOGY

Groundwater Filterable Al - western bores

Figure C87

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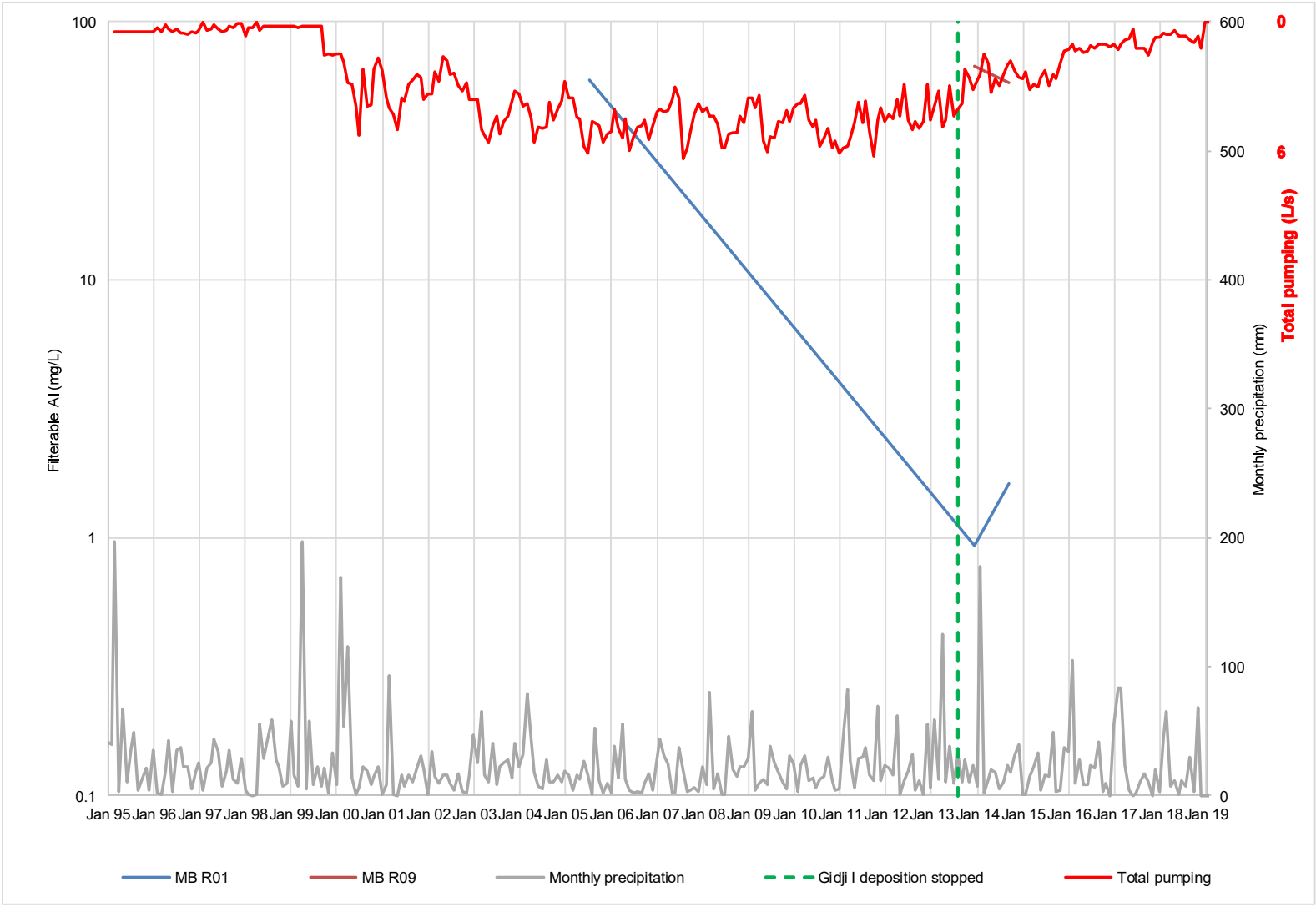
BIG DOG HYDROGEOLOGY

Groundwater Filterable Al - trench bores

Figure C88

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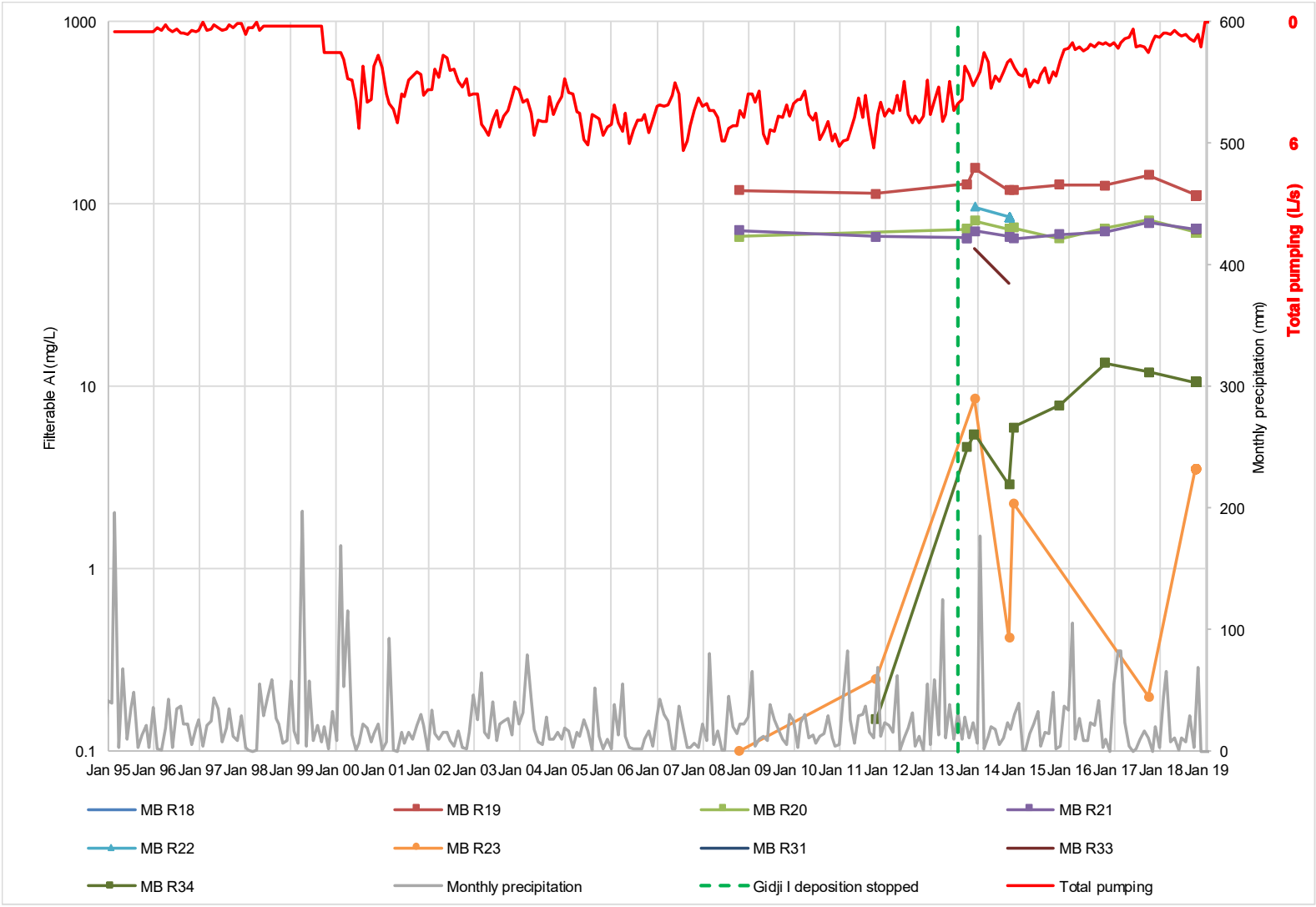
BIG DOG HYDROGEOLOGY

Groundwater Filterable Al - decant bores

Figure C89

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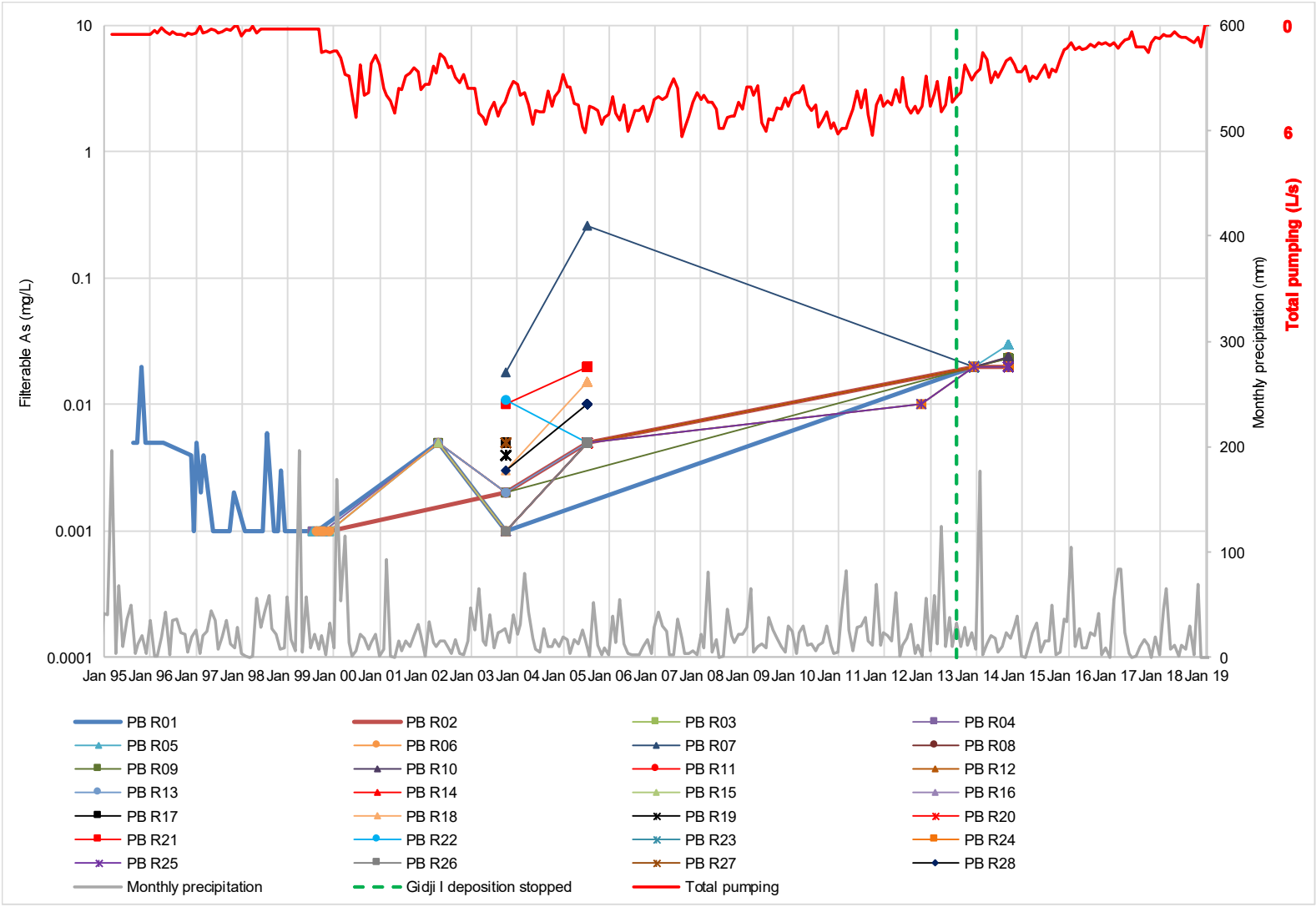
BIG DOG HYDROGEOLOGY

Groundwater Filterable Al - eastern bores

Figure C90

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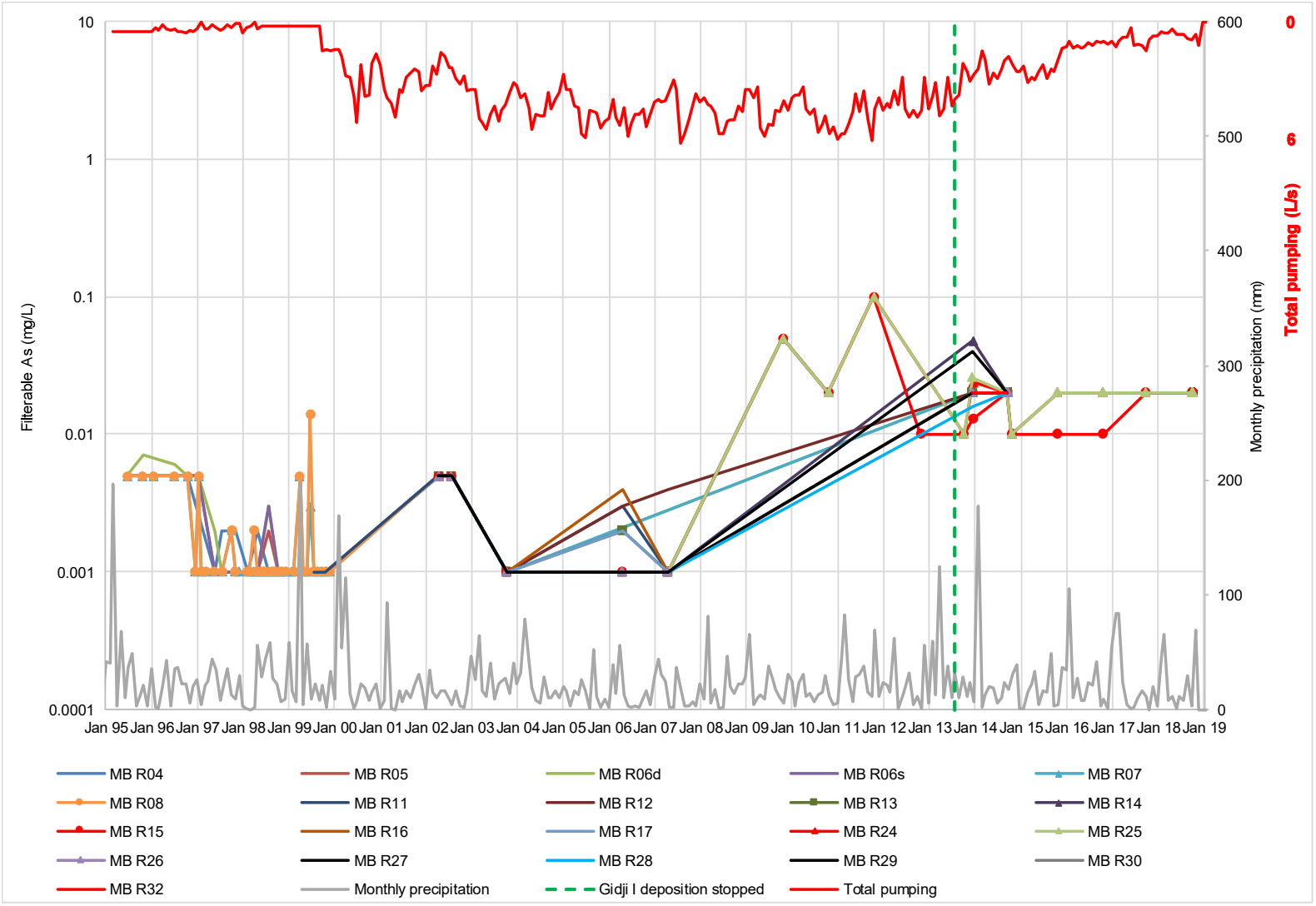
BIG DOG HYDROGEOLOGY

Groundwater Filterable As - production bores

Figure C91

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



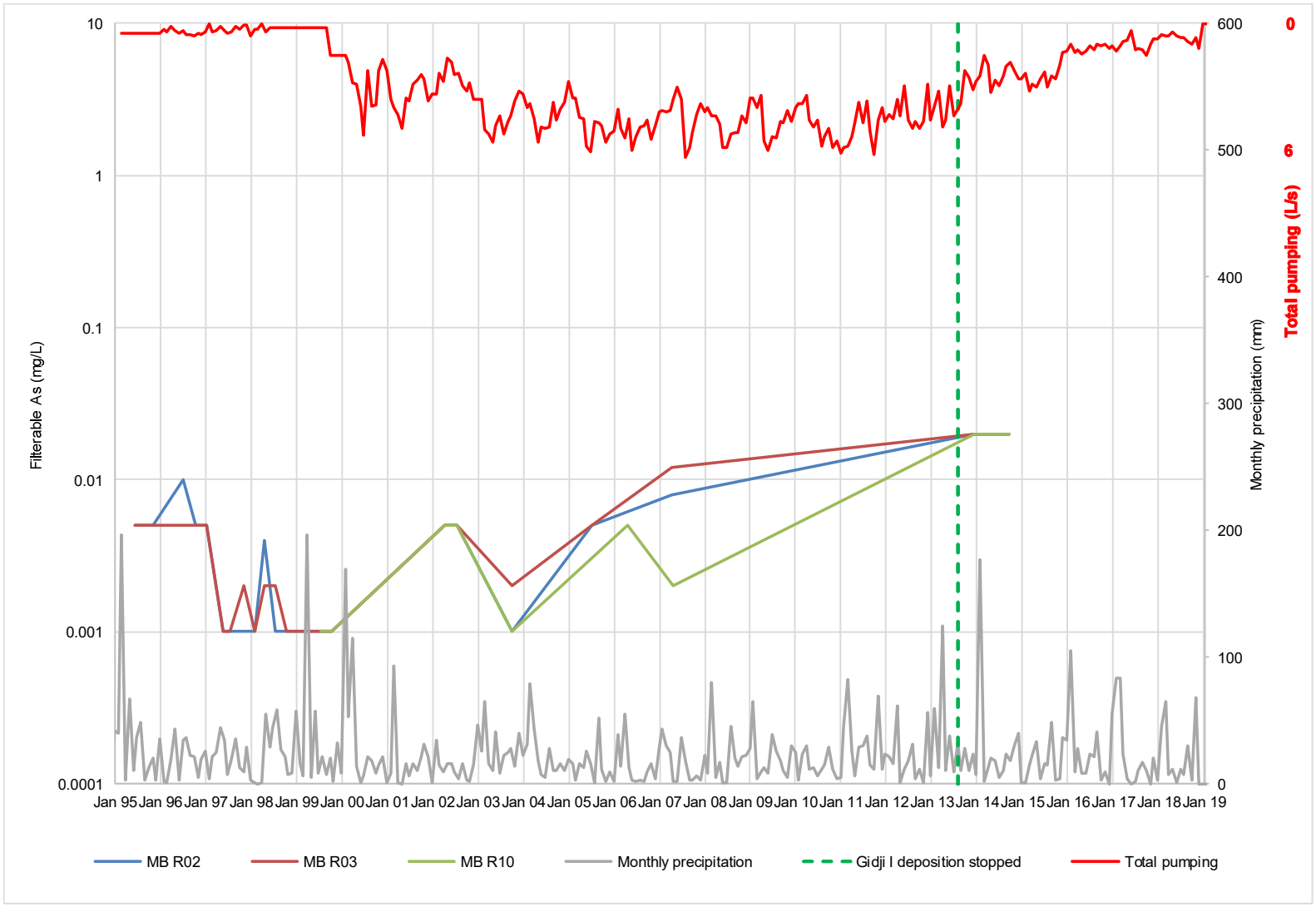
Groundwater Filterable As - western bores

Figure C92

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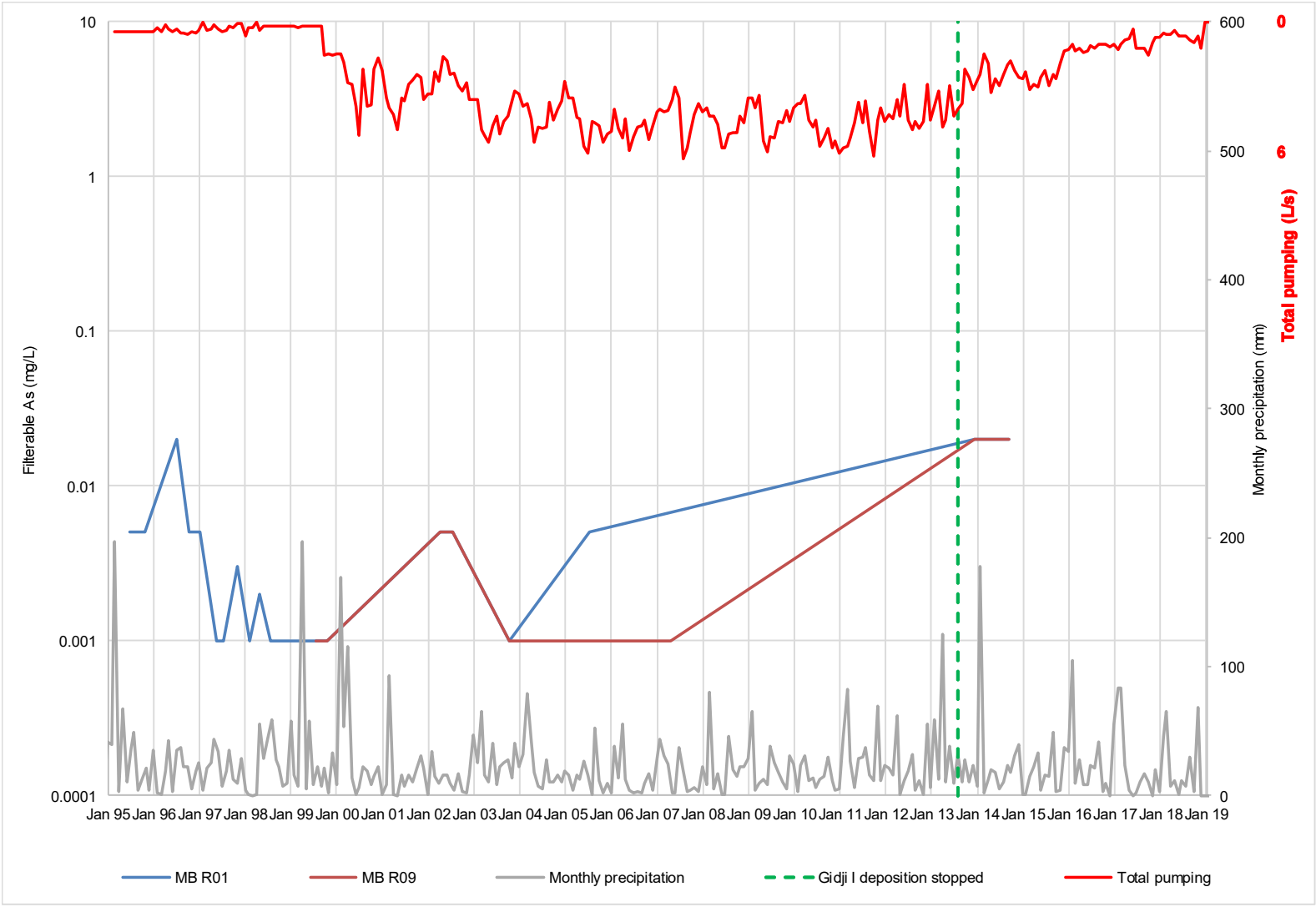
BIG DOG HYDROGEOLOGY

Groundwater Filterable As - trench bores

Figure C93

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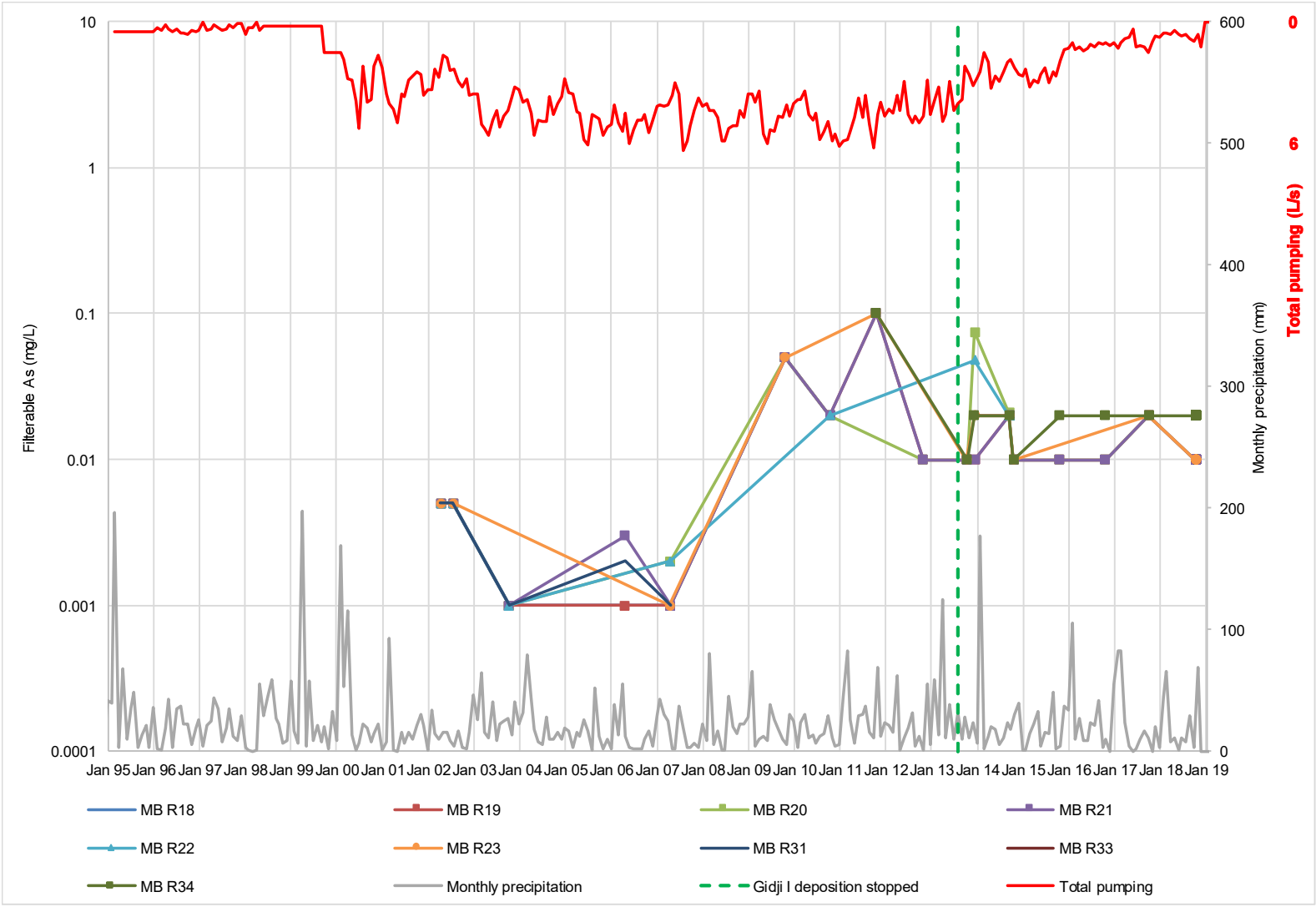
BIG DOG HYDROGEOLOGY

Groundwater Filterable As - decant bores

Figure C94

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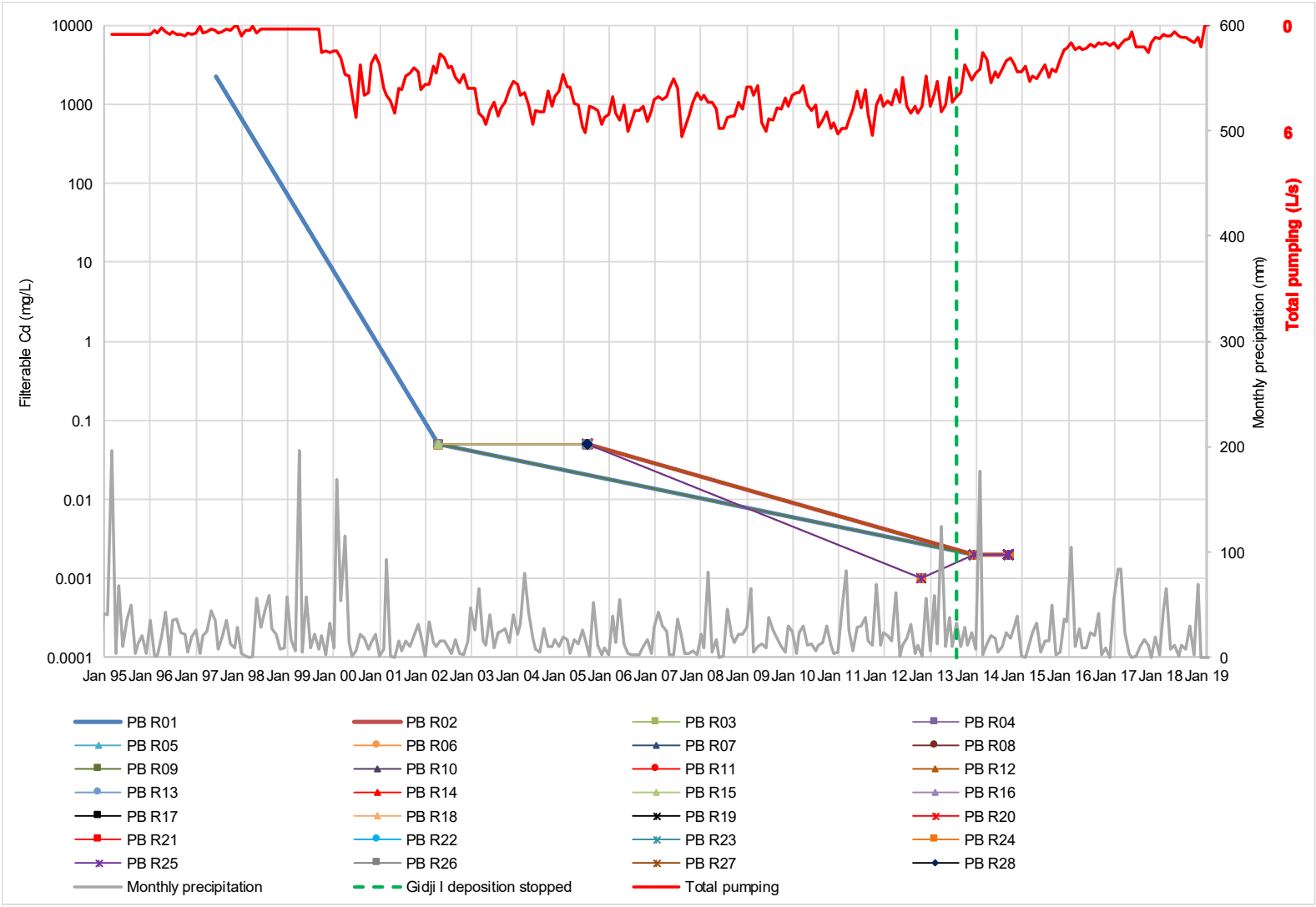
BIG DOG HYDROGEOLOGY

Groundwater Filterable As - eastern bores

Figure C95

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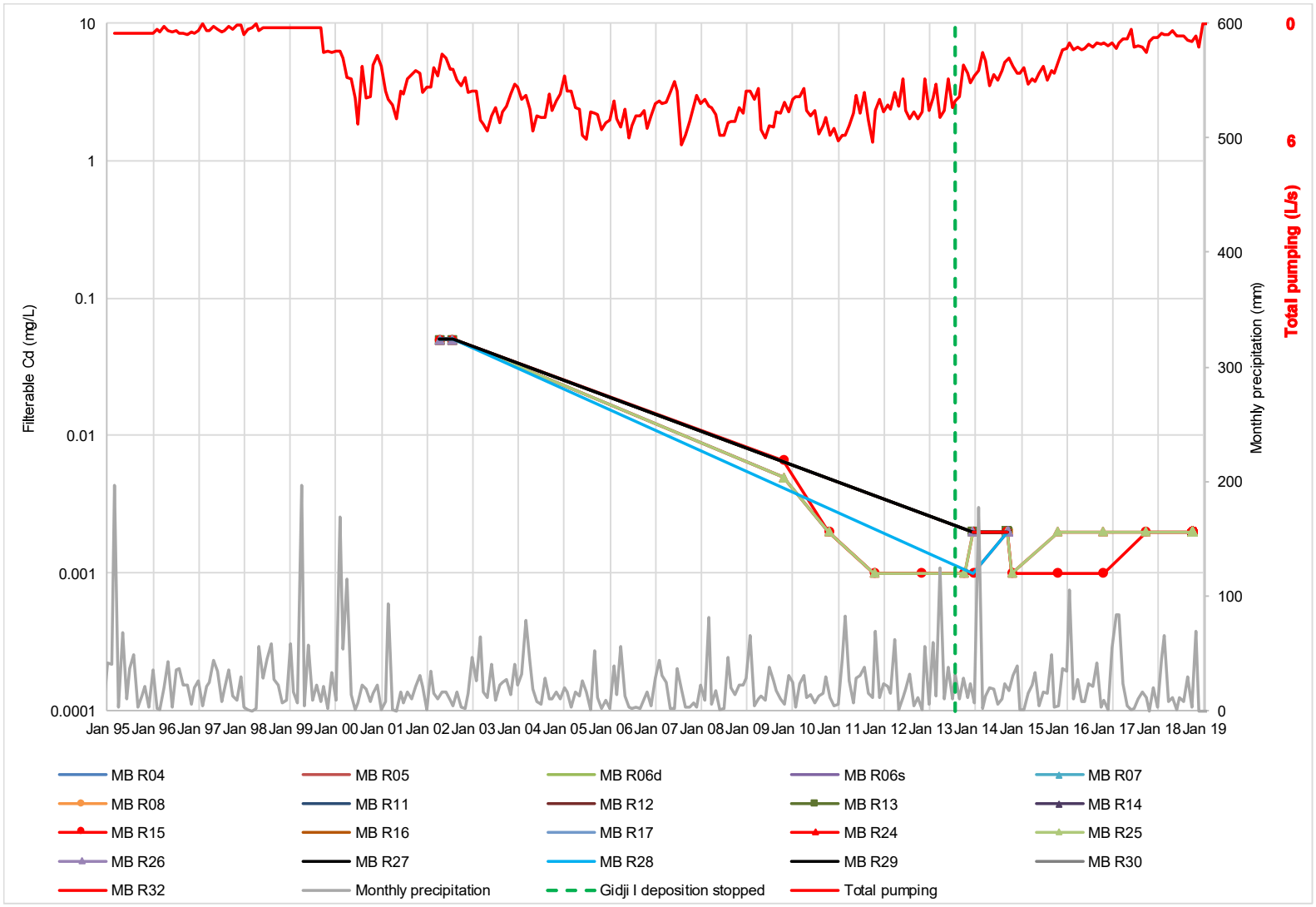
BIG DOG HYDROGEOLOGY

Groundwater Filterable Cd - production bores

Figure C96

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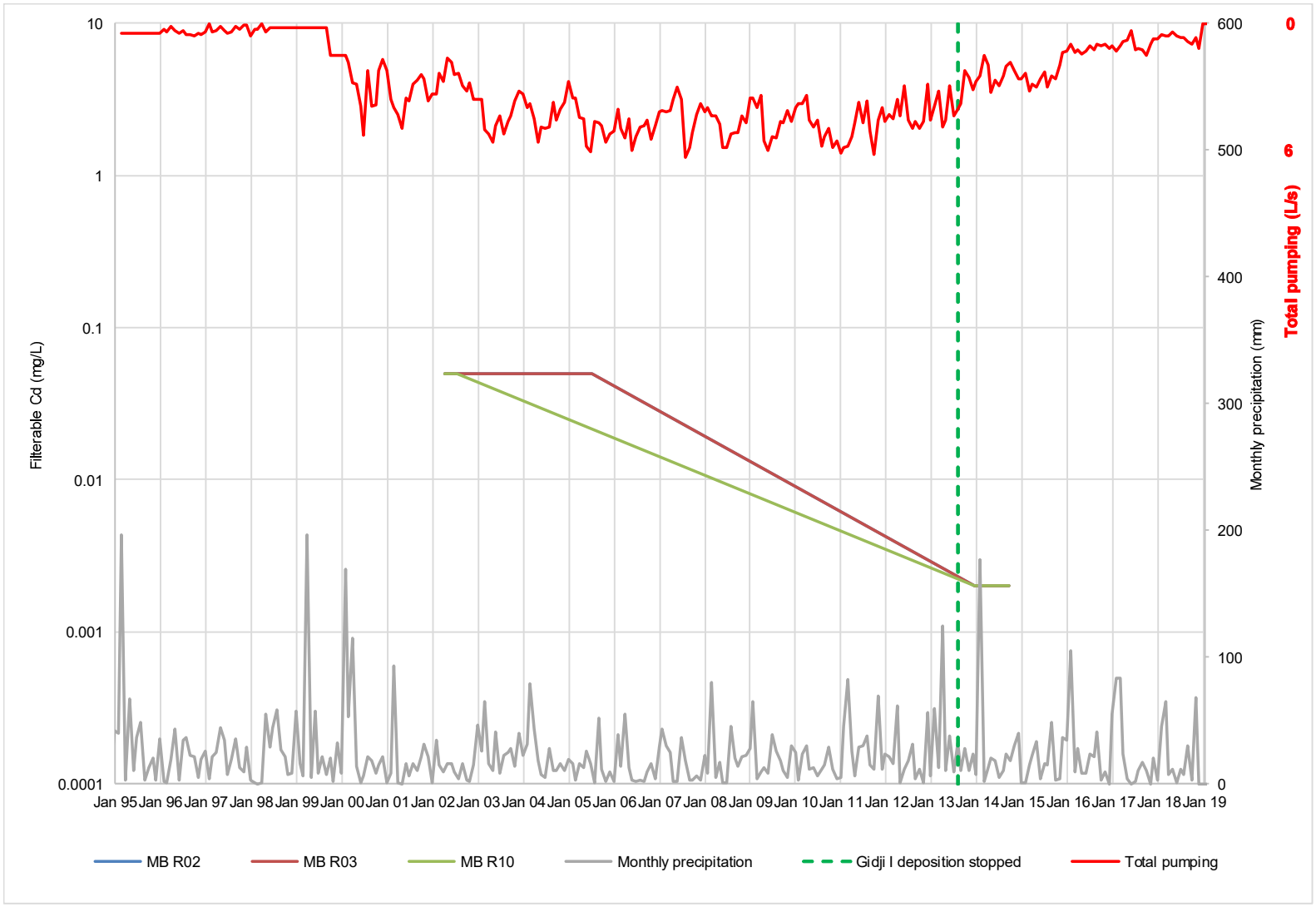
BIG DOG HYDROGEOLOGY

Groundwater Filterable Cd - western bores

Figure C97

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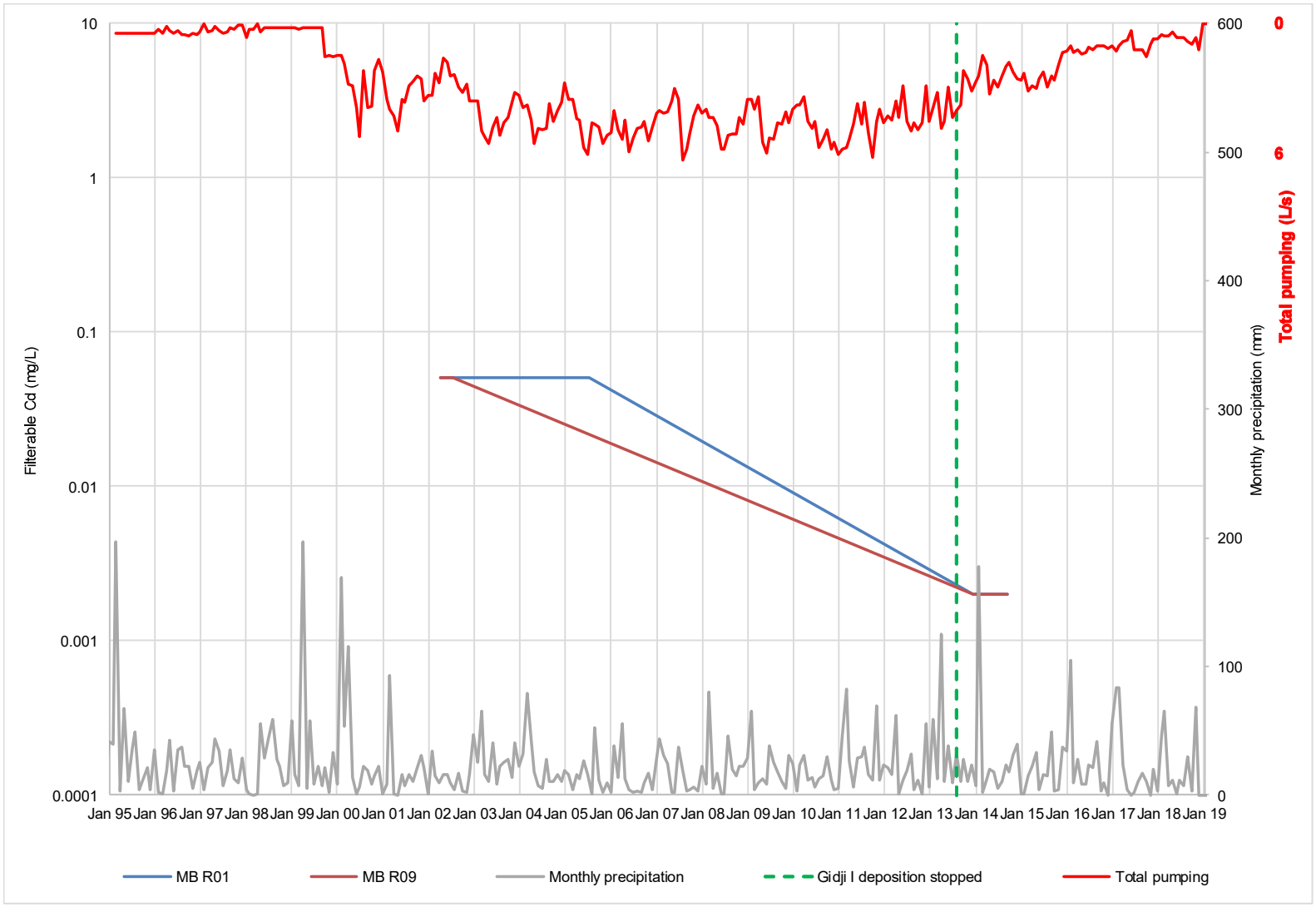
BIG DOG HYDROGEOLOGY

Groundwater Filterable Cd - trench bores

Figure C98

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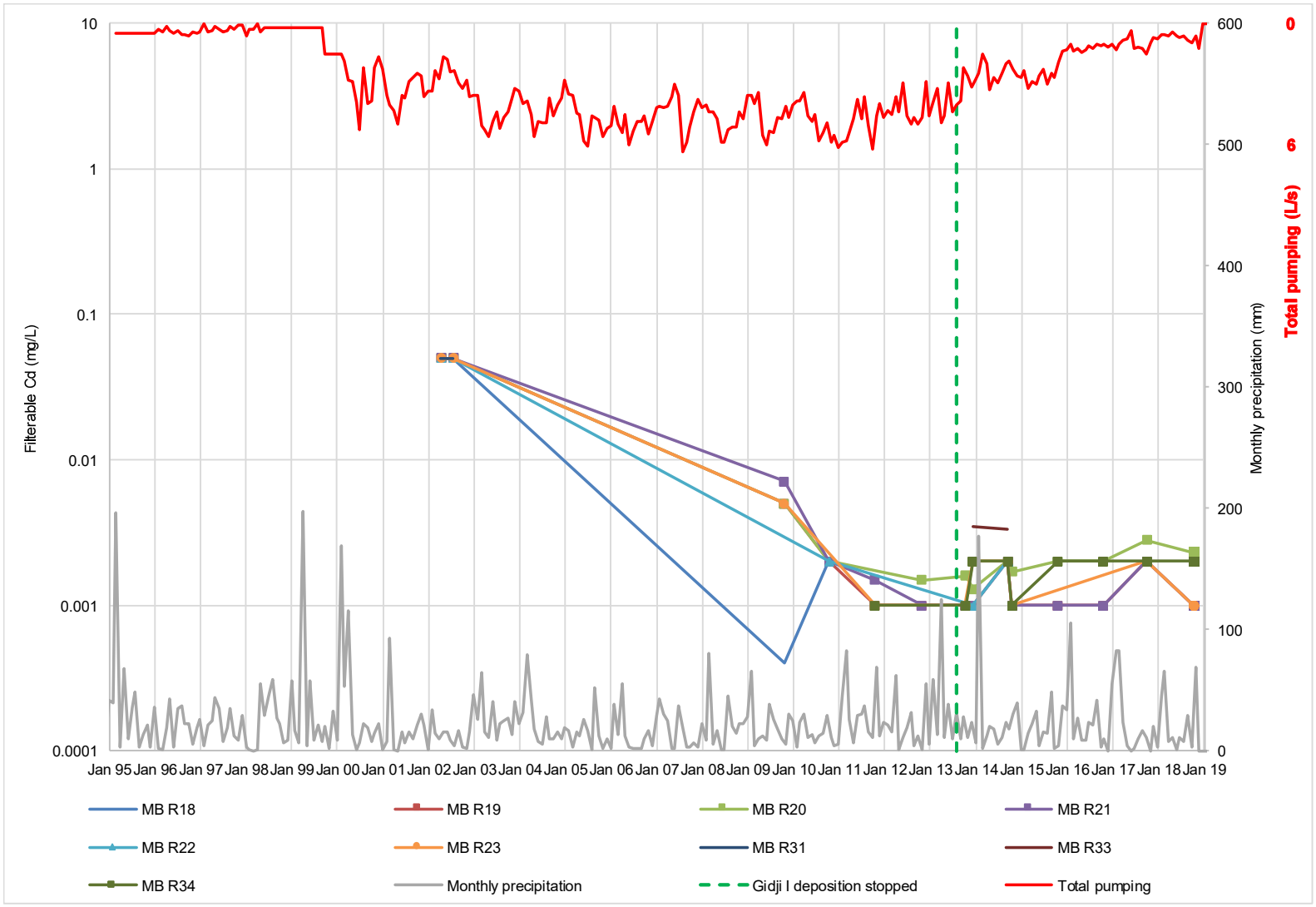
BIG DOG HYDROGEOLOGY

Groundwater Filterable Cd - decant bores

Figure C99

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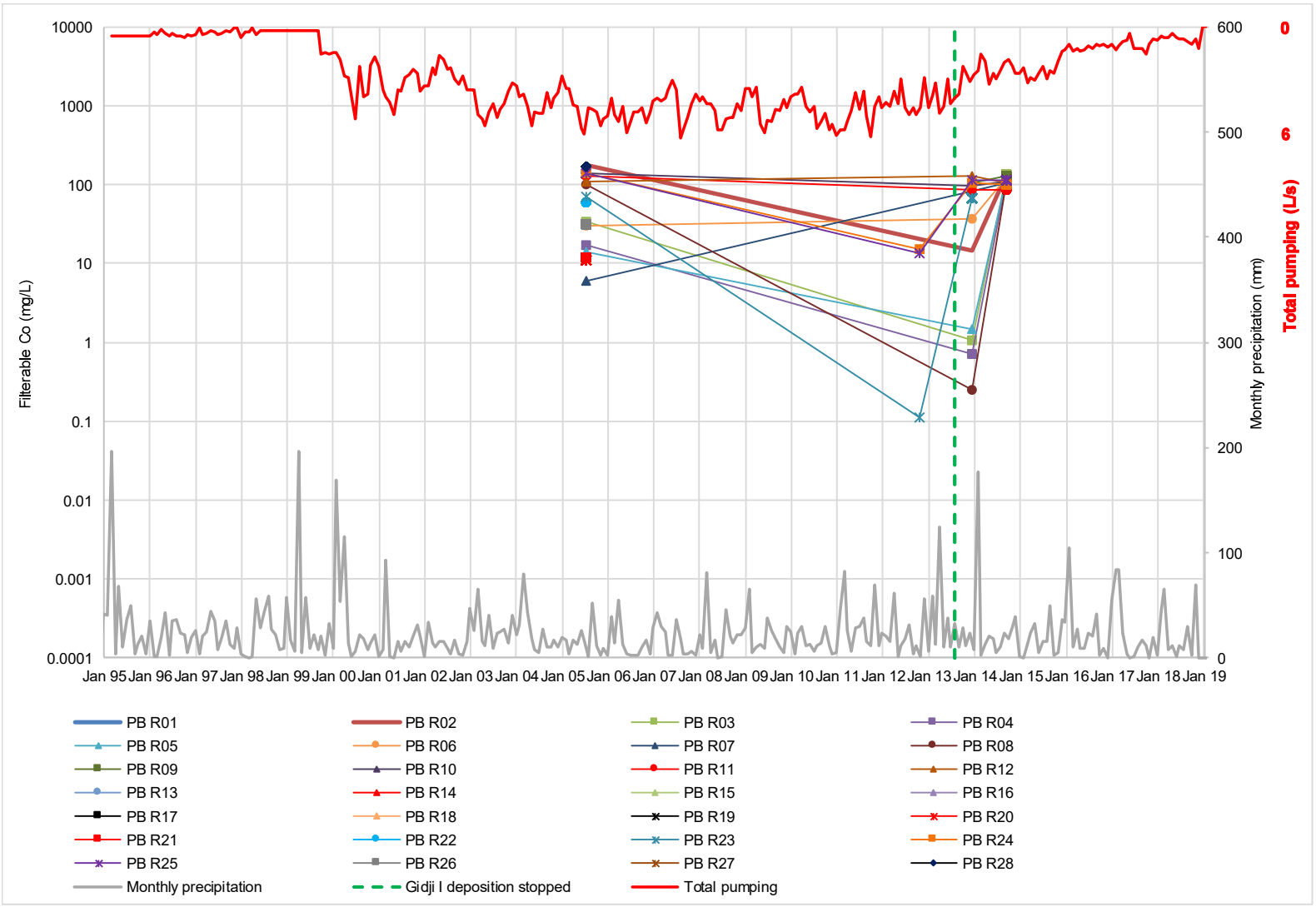
BIG DOG HYDROGEOLOGY

Groundwater Filterable Cd - eastern bores

Figure C100

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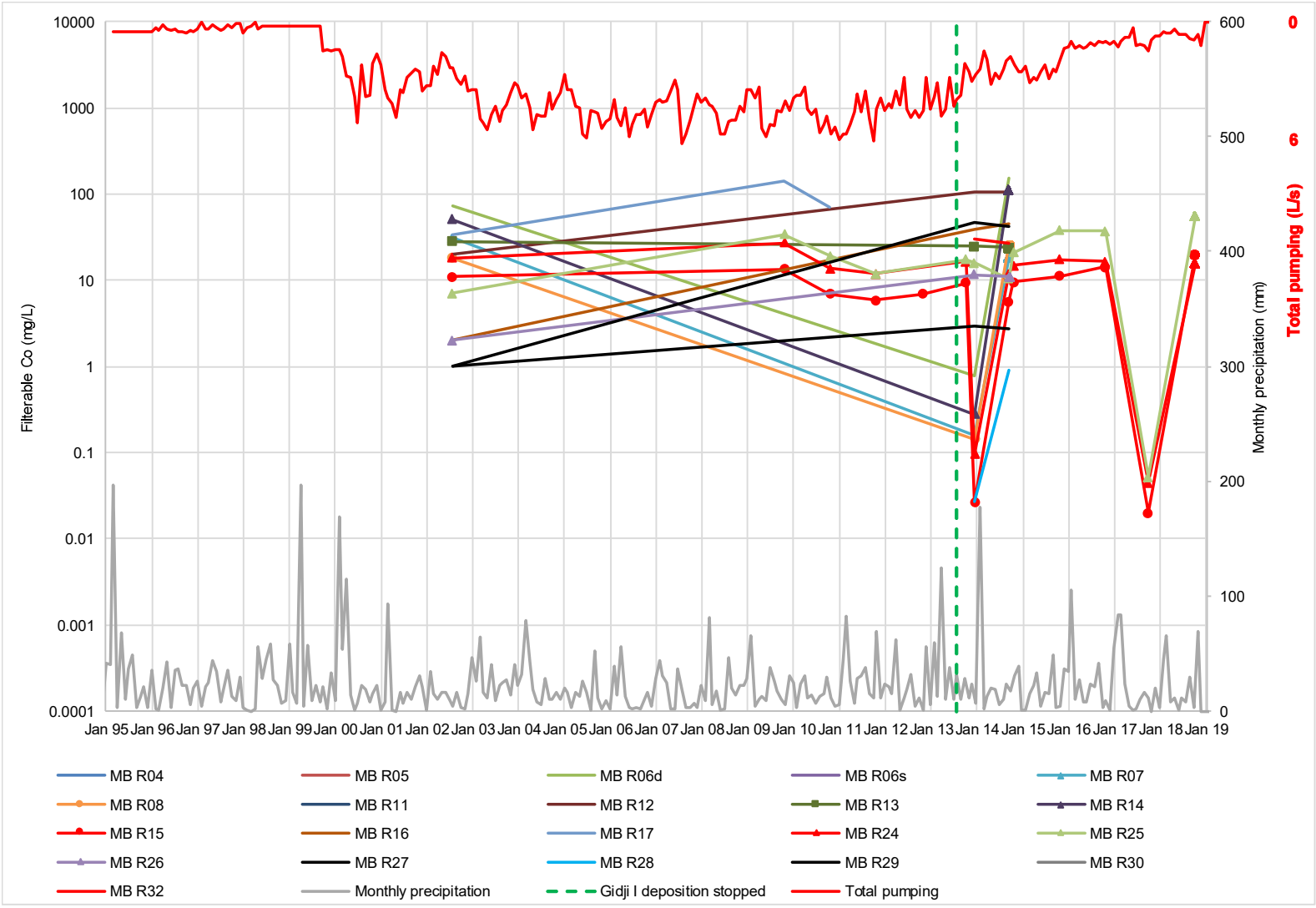
BIG DOG HYDROGEOLOGY

Groundwater Filterable Co - production bores

Figure C101

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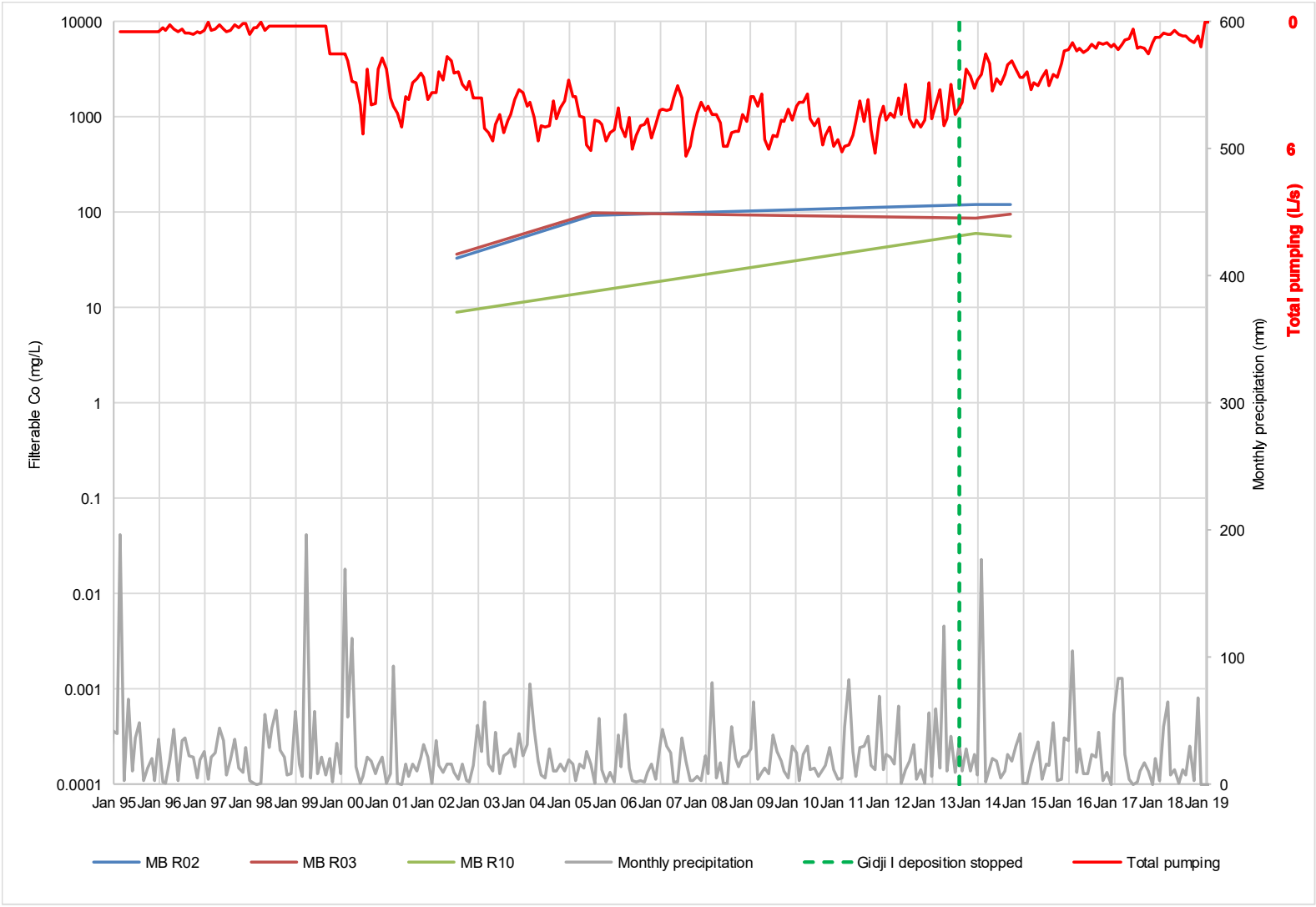
BIG DOG HYDROGEOLOGY

Groundwater Filterable Co - western bores

Figure C102

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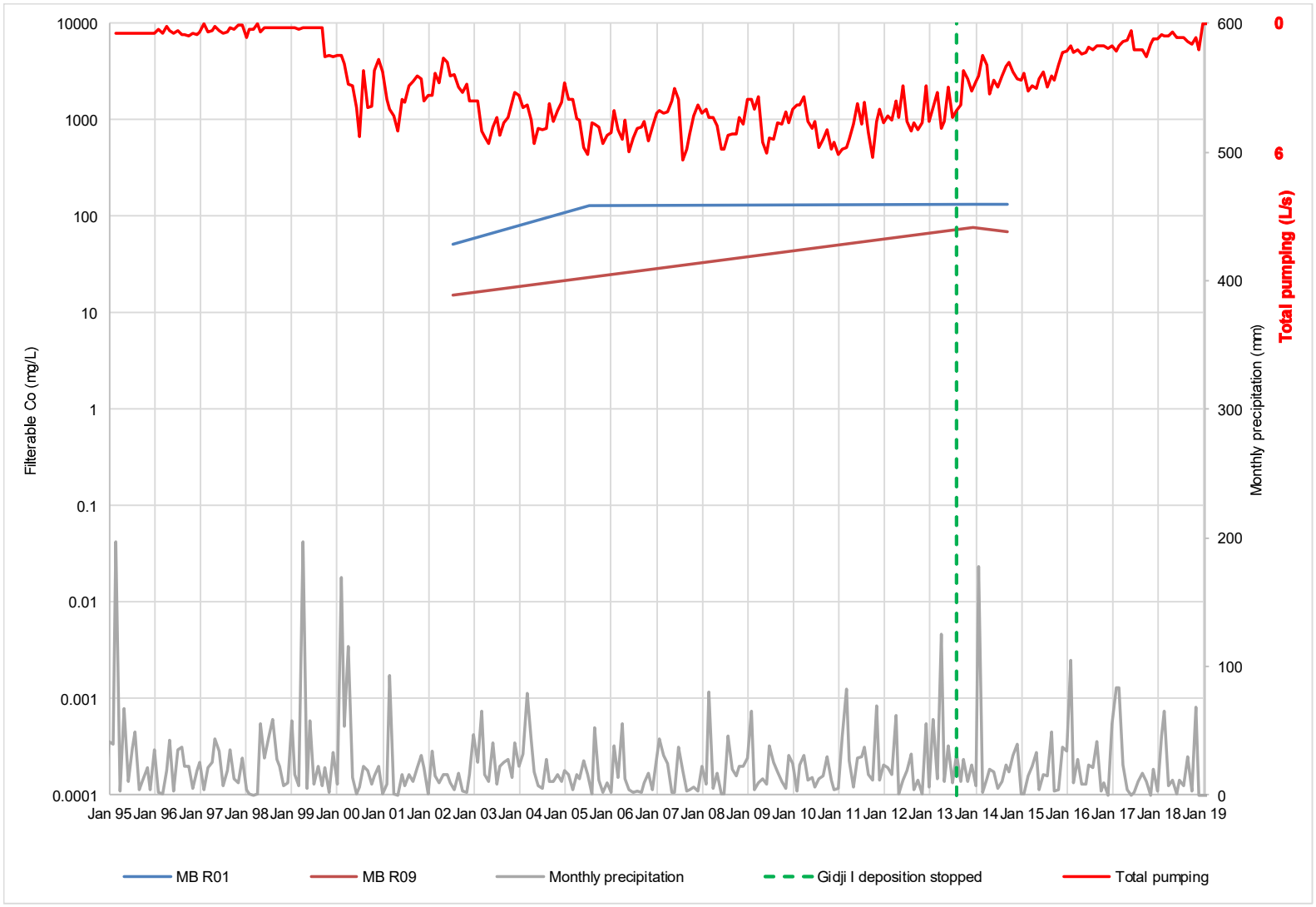
BIG DOG HYDROGEOLOGY

Groundwater Filterable Co - trench bores

Figure C103

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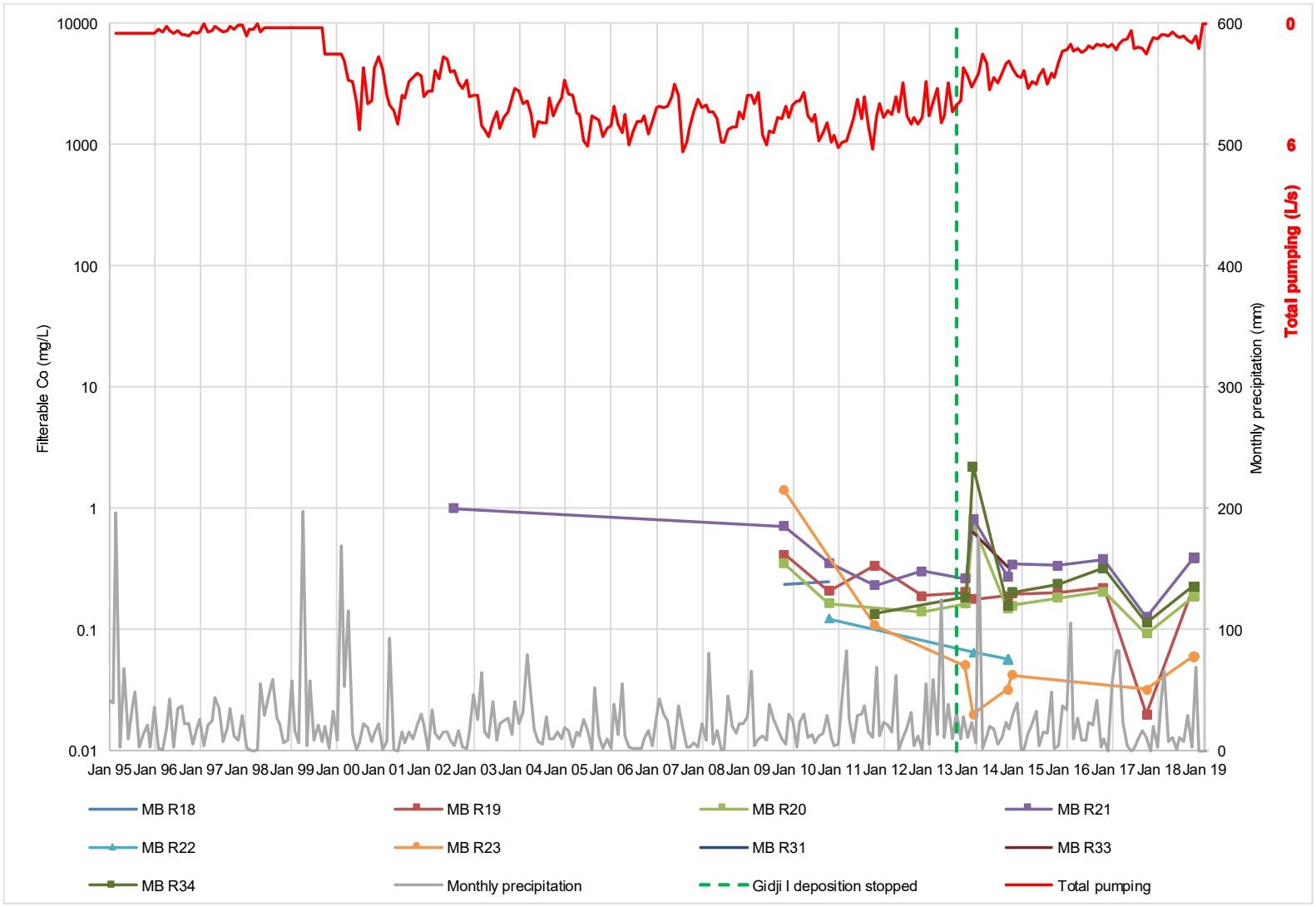
BIG DOG HYDROGEOLOGY

Groundwater Filterable Co - decant bores

Figure C104

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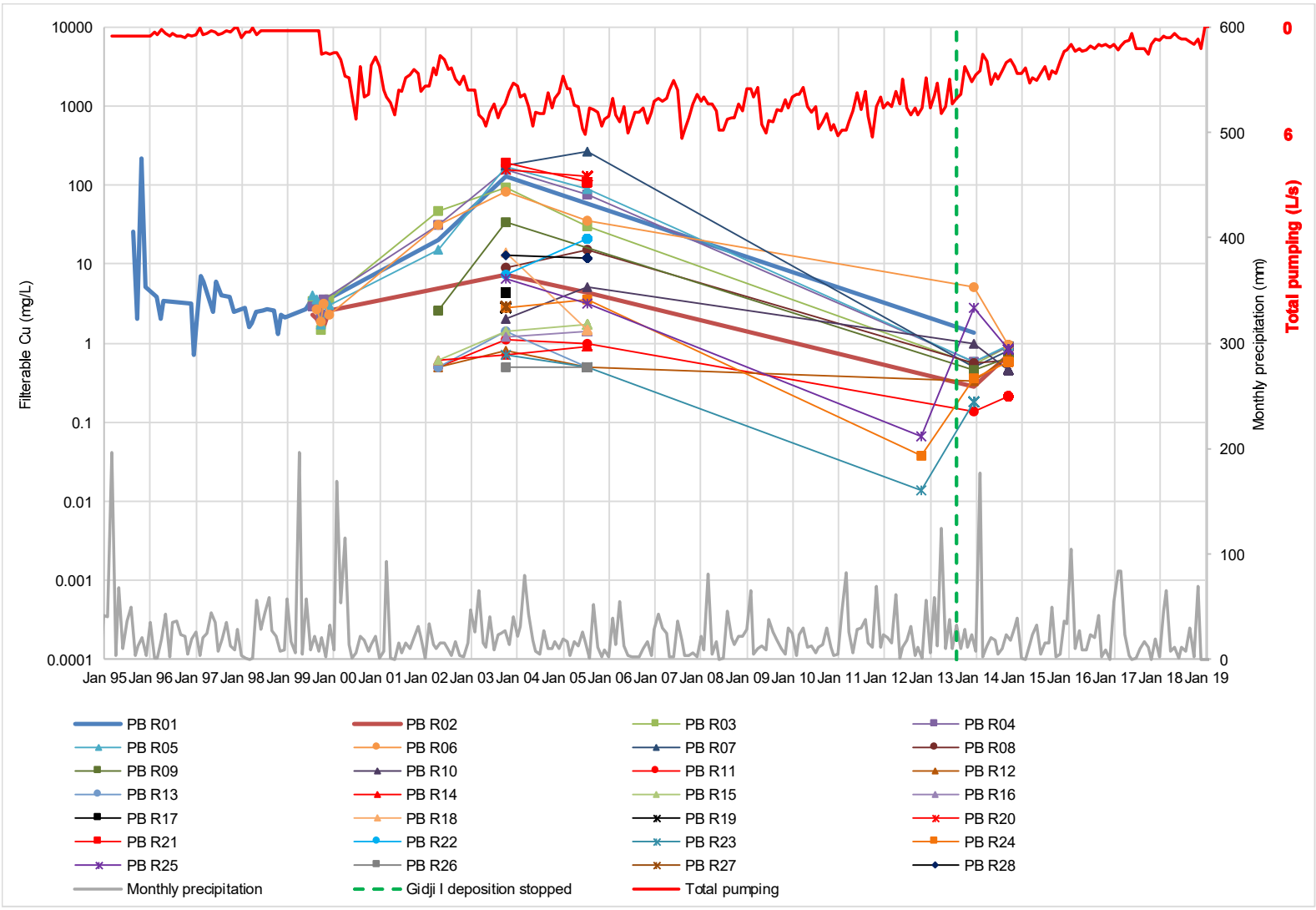
BIG DOG HYDROGEOLOGY

Groundwater Filterable Co - eastern bores

Figure C105

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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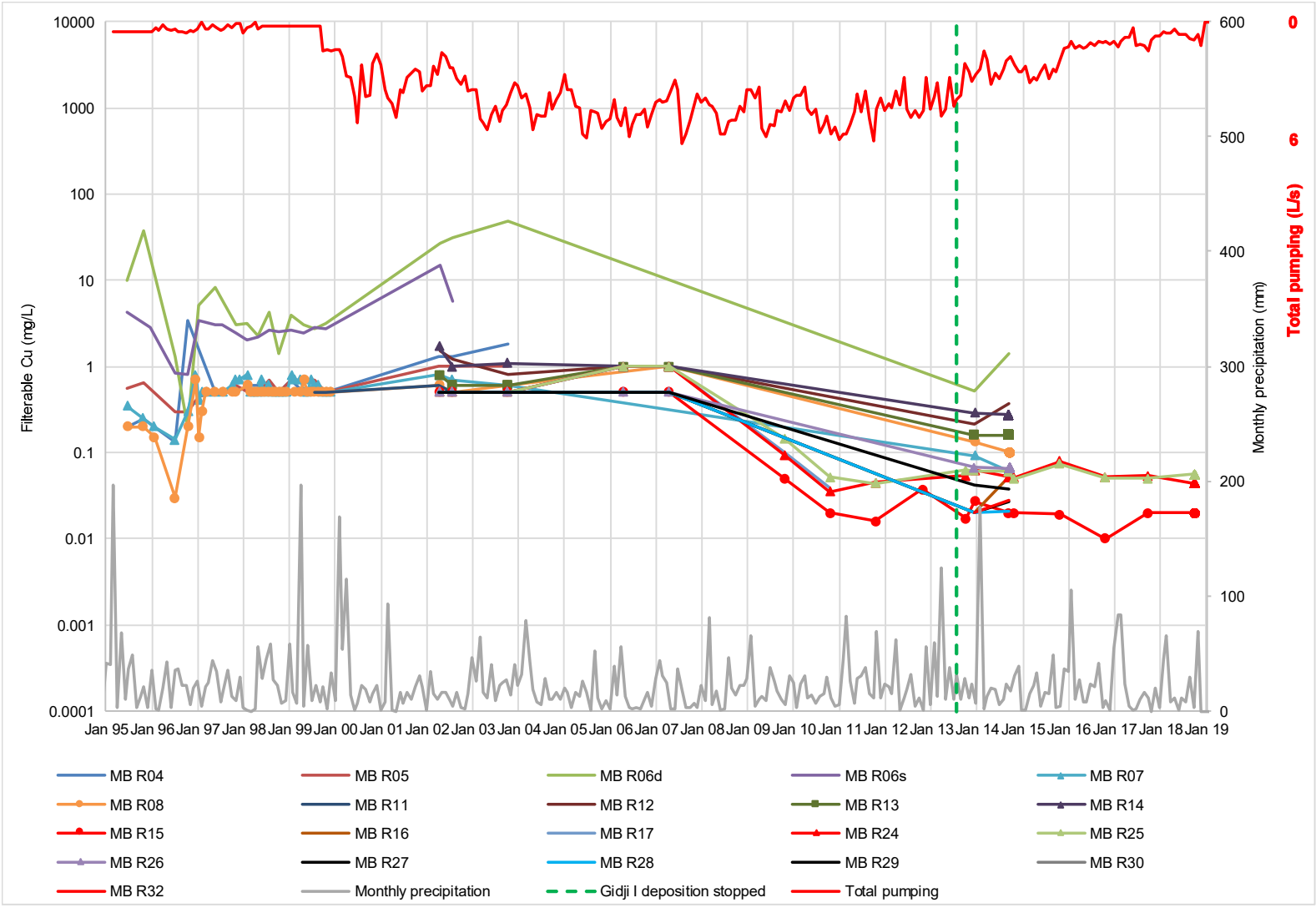
BIG DOG HYDROGEOLOGY

Groundwater Filterable Cu - production bores

Figure C106

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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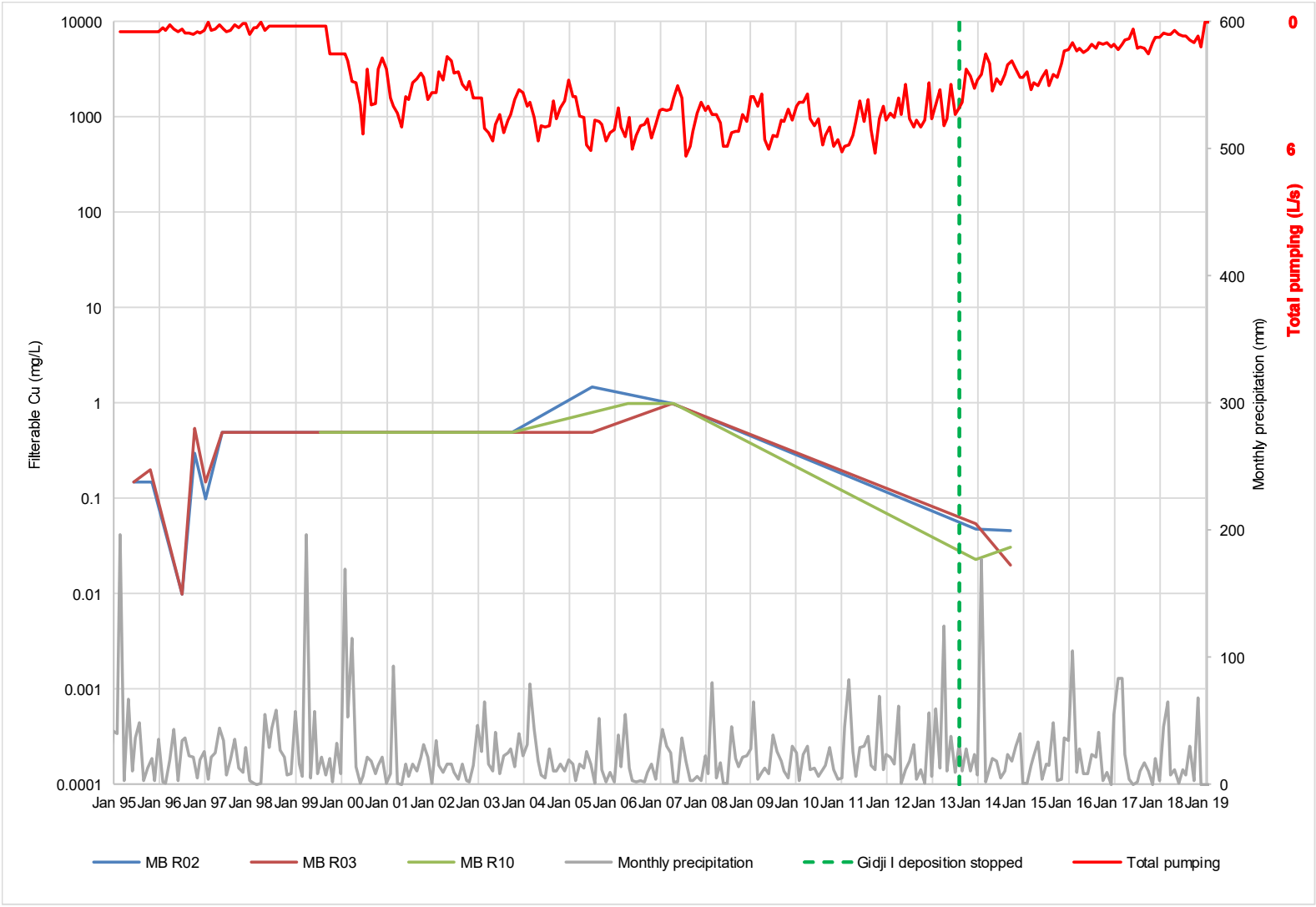
BIG DOG HYDROGEOLOGY

Groundwater Filterable Cu - western bores

Figure C107

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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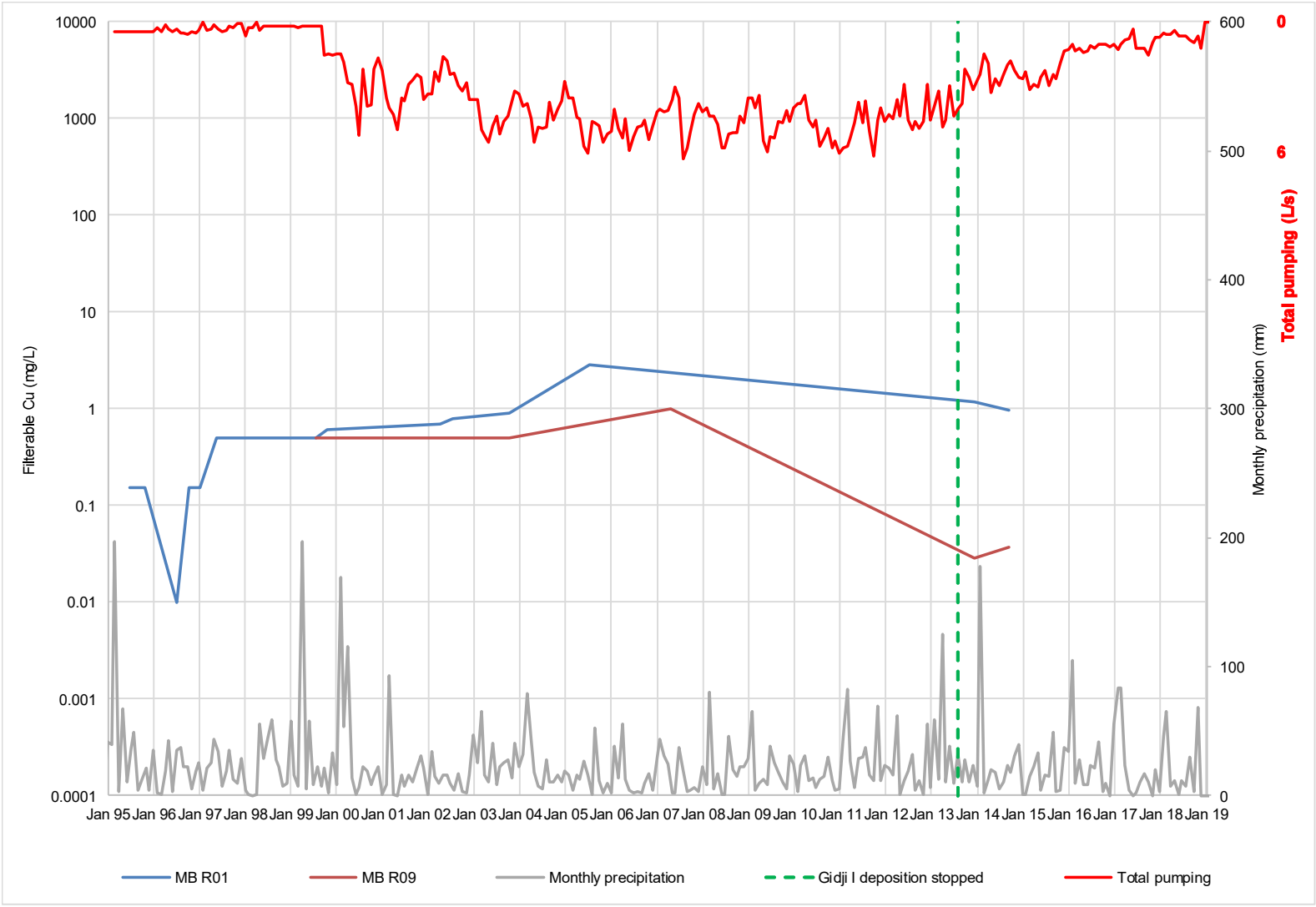
BIG DOG HYDROGEOLOGY

Groundwater Filterable Cu - trench bores

Figure C108

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Report: KCGM Gidji TSF Hydrogeological Review



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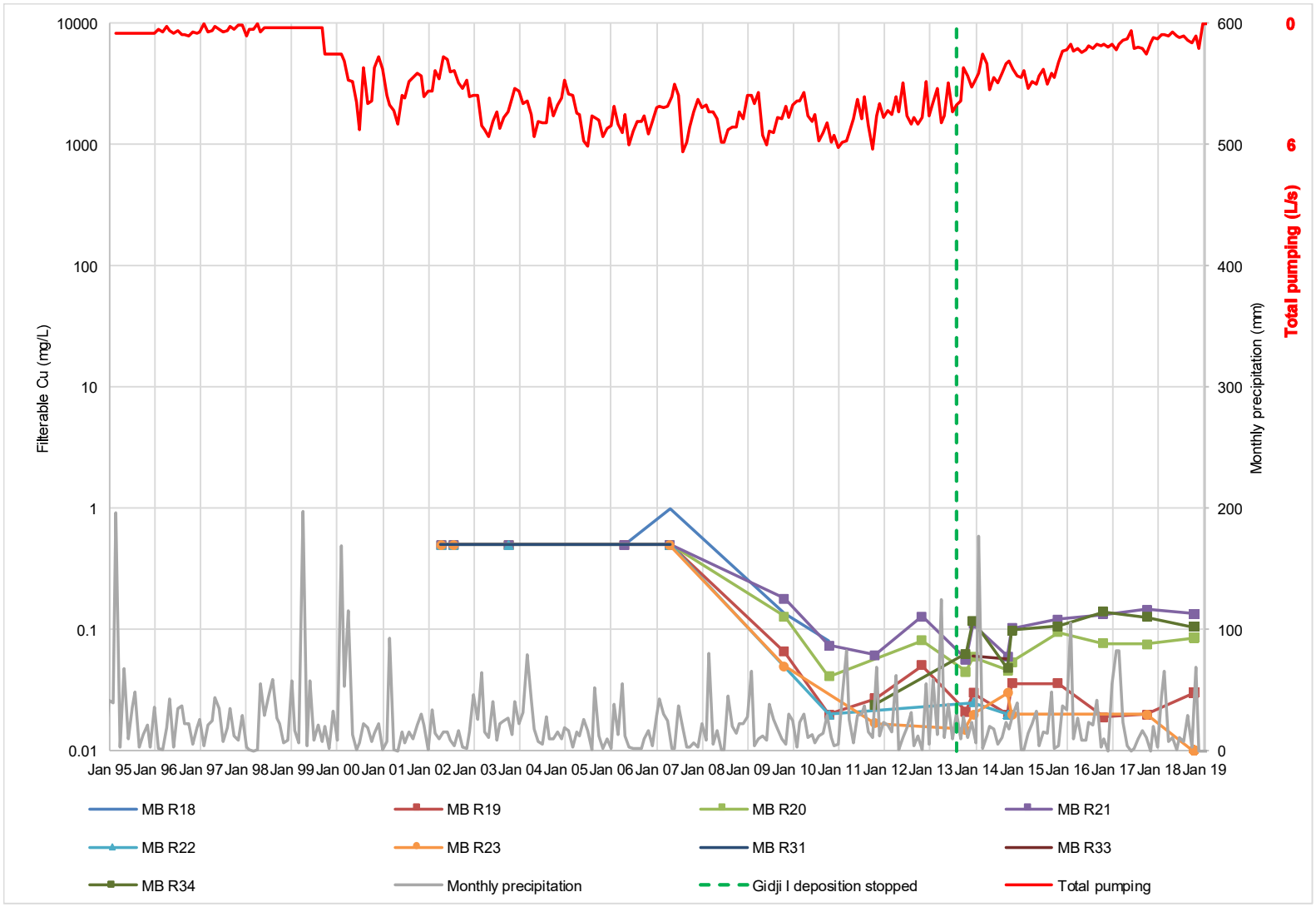
BIG DOG HYDROGEOLOGY

Groundwater Filterable Cu - decant bores

Figure C109

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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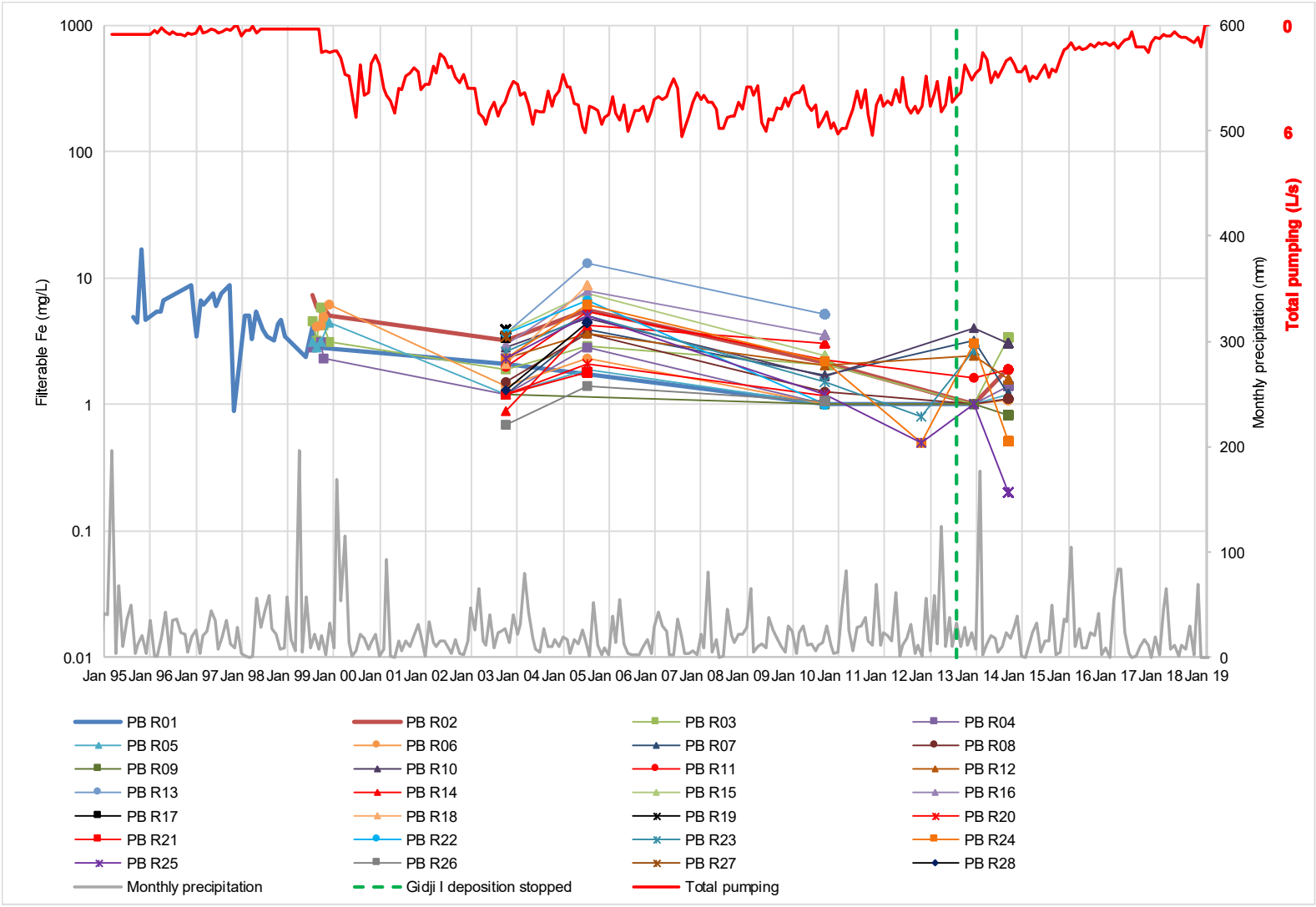
BIG DOG HYDROGEOLOGY

Groundwater Filterable Cu - eastern bores

Figure C110

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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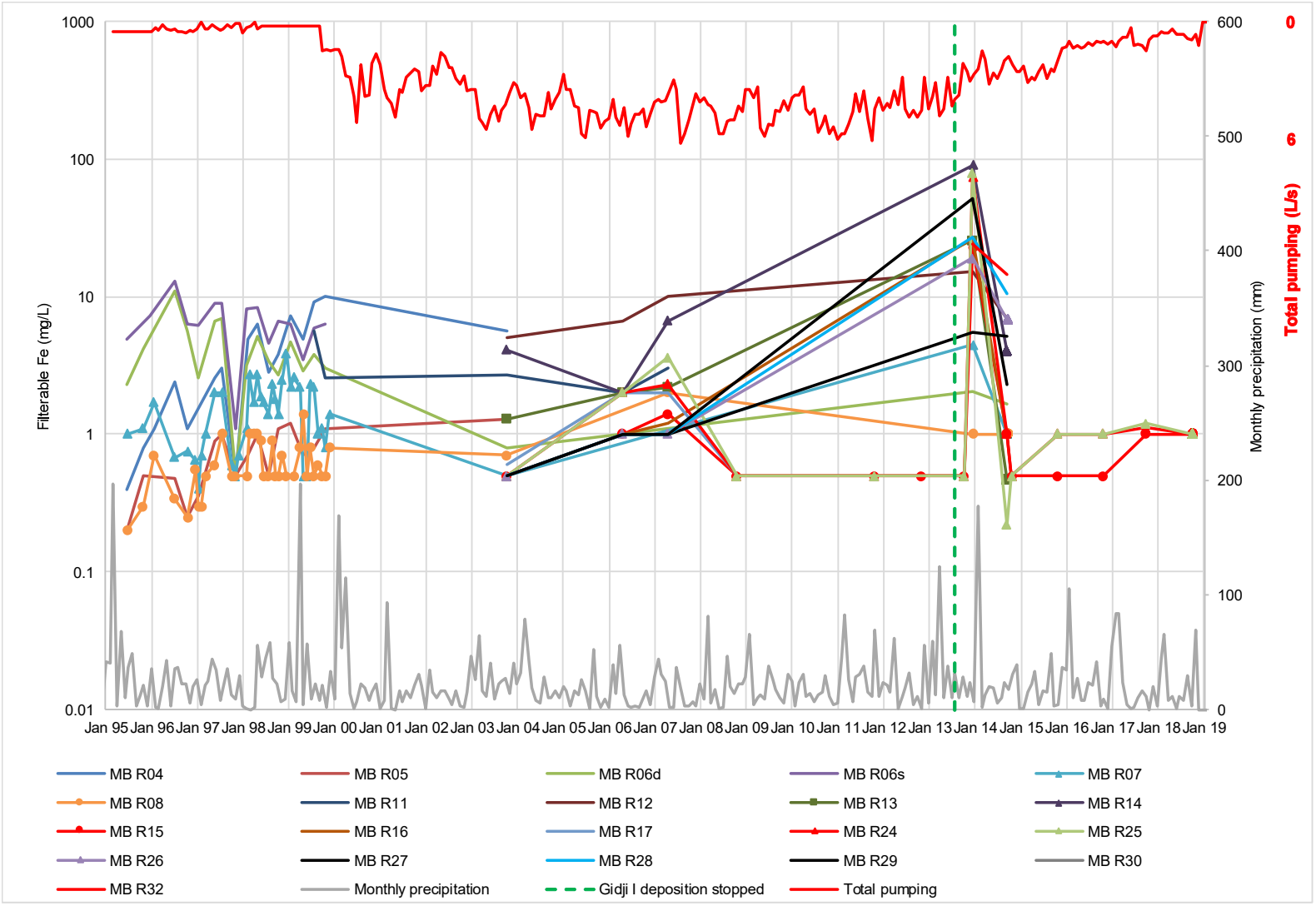
BIG DOG HYDROGEOLOGY

Groundwater Filterable Fe - production bores

Figure C111

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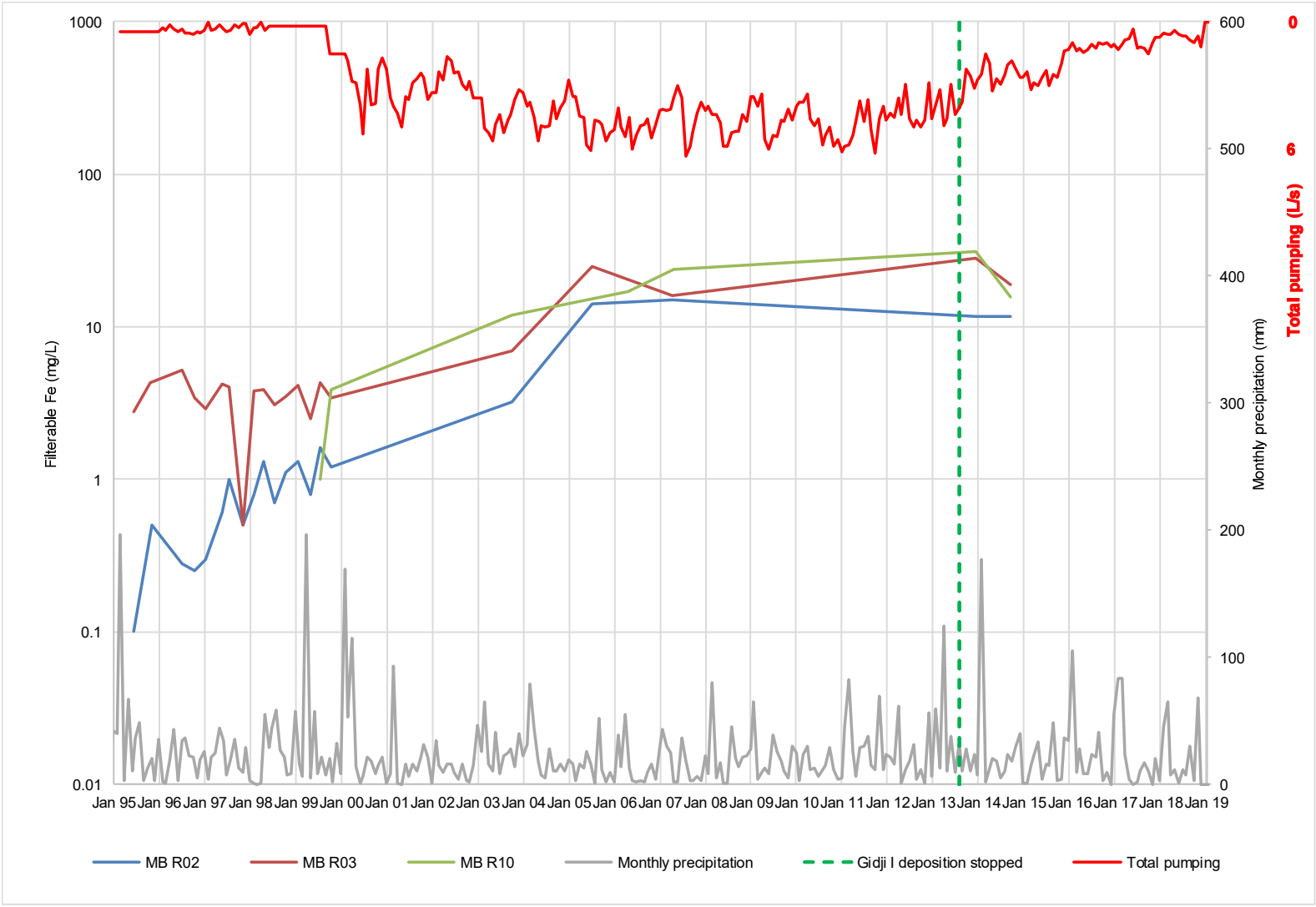
BIG DOG HYDROGEOLOGY

Groundwater Filterable Fe - western bores

Figure C112

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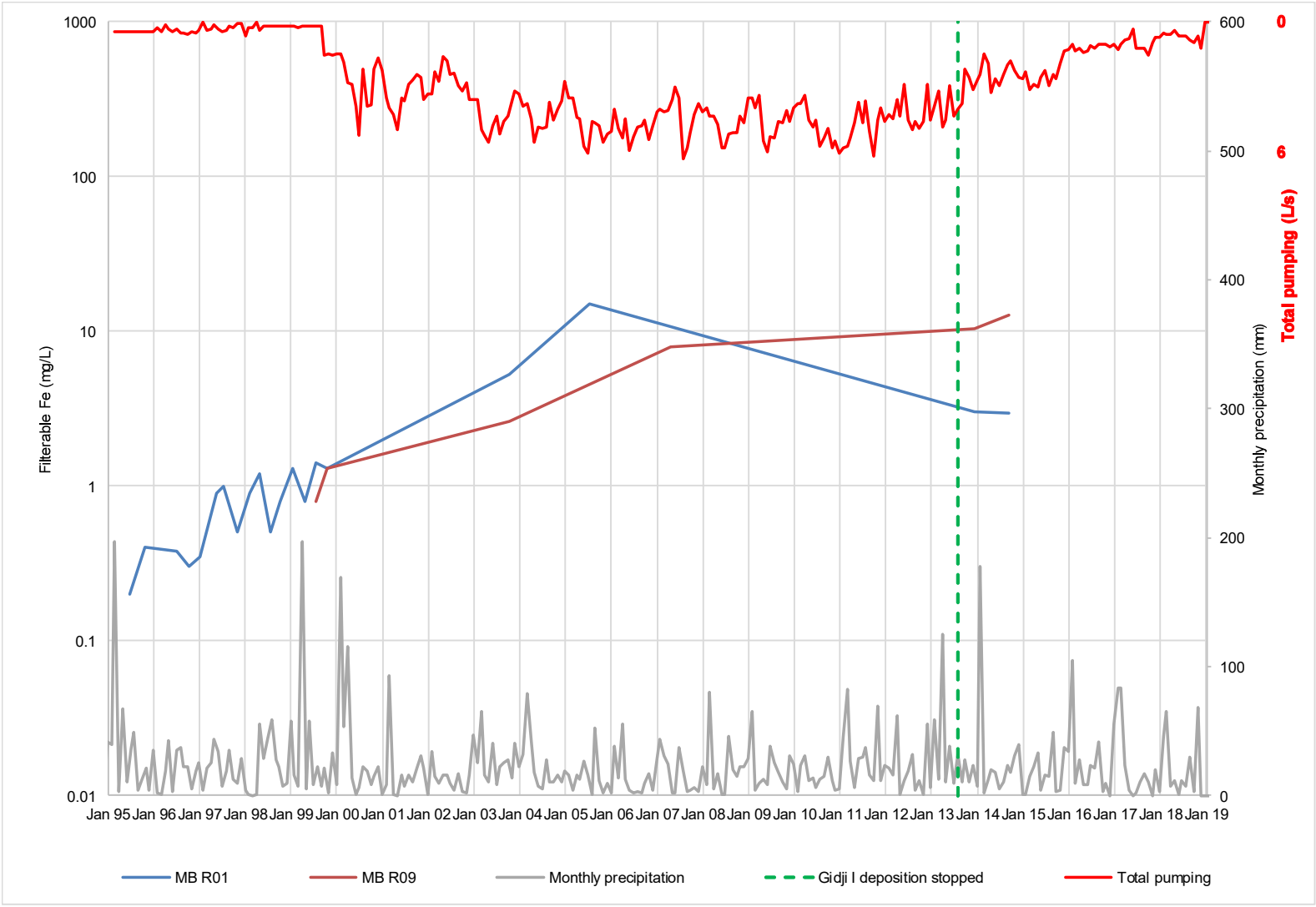
BIG DOG HYDROGEOLOGY

Groundwater Filterable Fe - trench bores

Figure C113

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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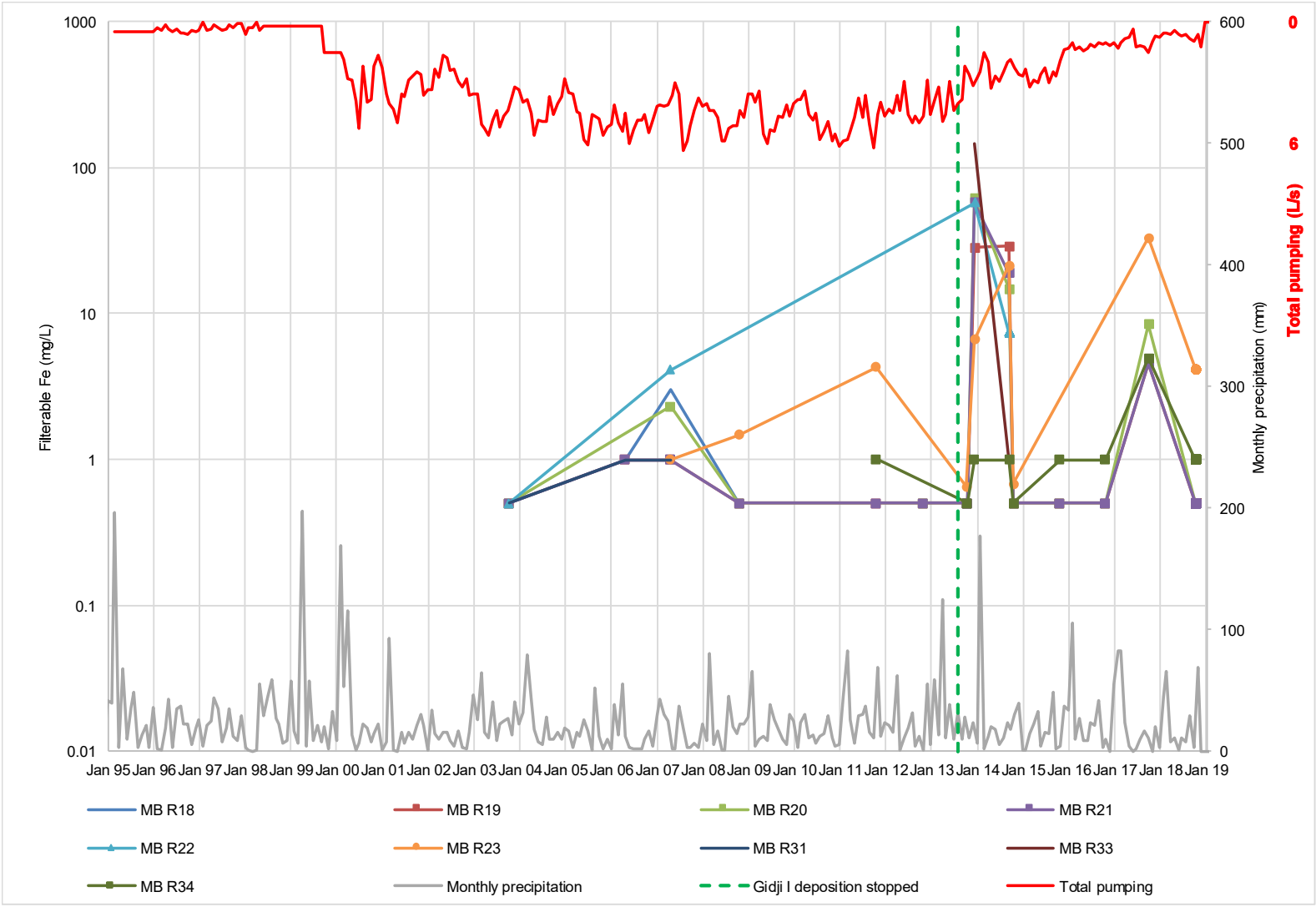
BIG DOG HYDROGEOLOGY

Groundwater Filterable Fe - decant bores

Figure C114

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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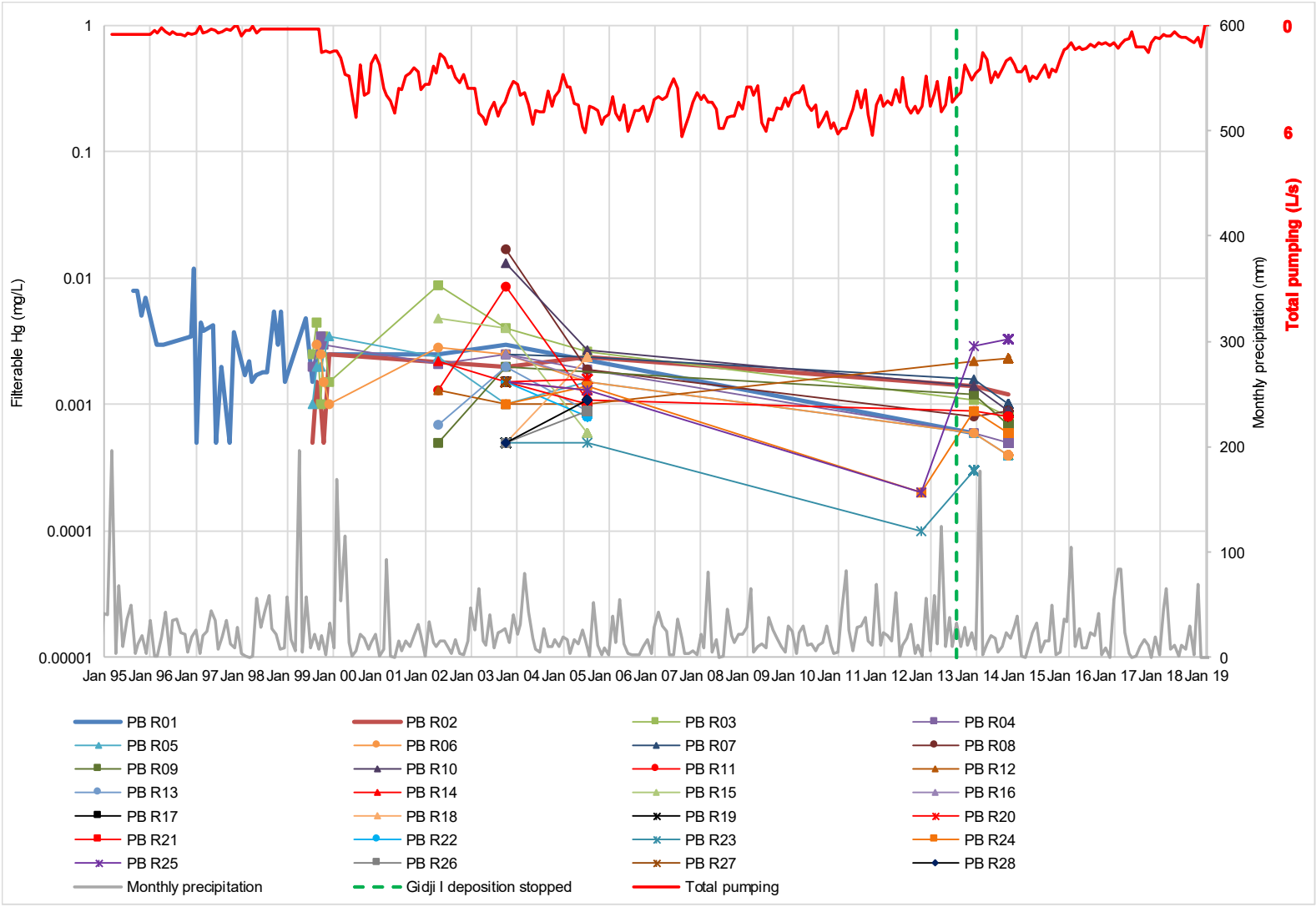
BIG DOG HYDROGEOLOGY

Groundwater Filterable Fe - eastern bores

Figure C115

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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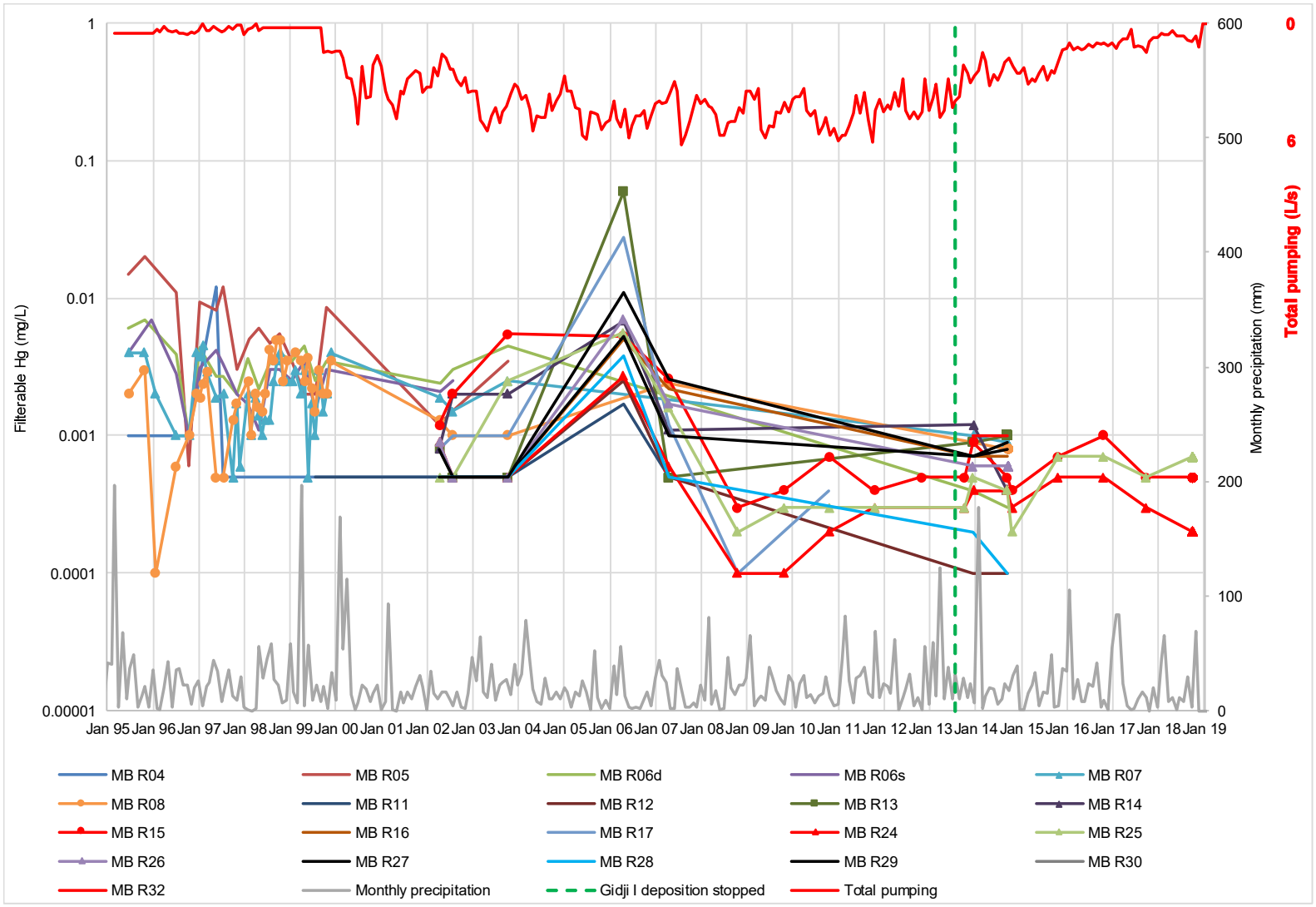
BIG DOG HYDROGEOLOGY

Groundwater Filterable Hg - production bores

Figure C116

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Report: KCGM Gidji TSF Hydrogeological Review



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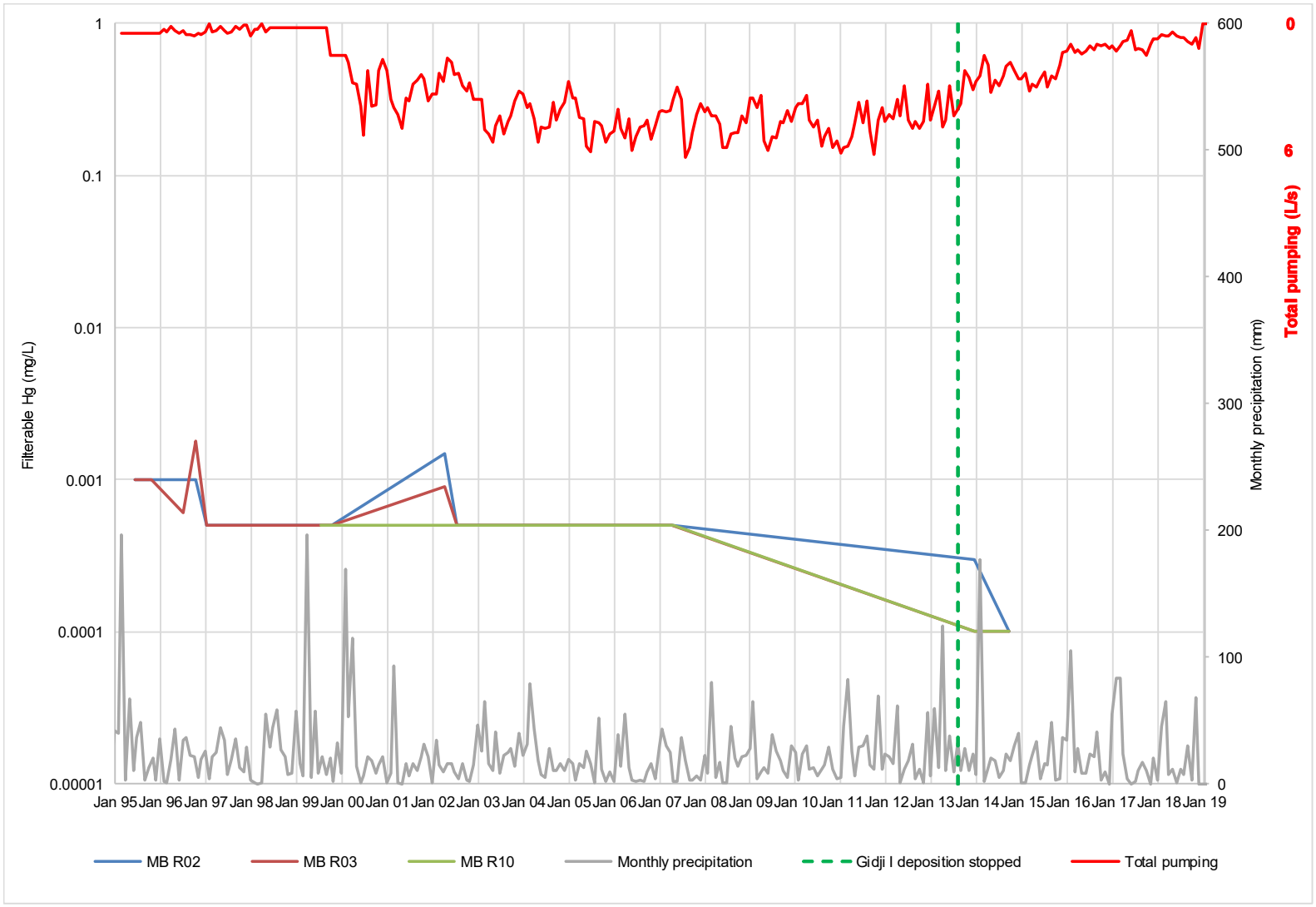
BIG DOG HYDROGEOLOGY

Groundwater Filterable Hg - western bores

Figure C117

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Report: KCGM Gidji TSF Hydrogeological Review



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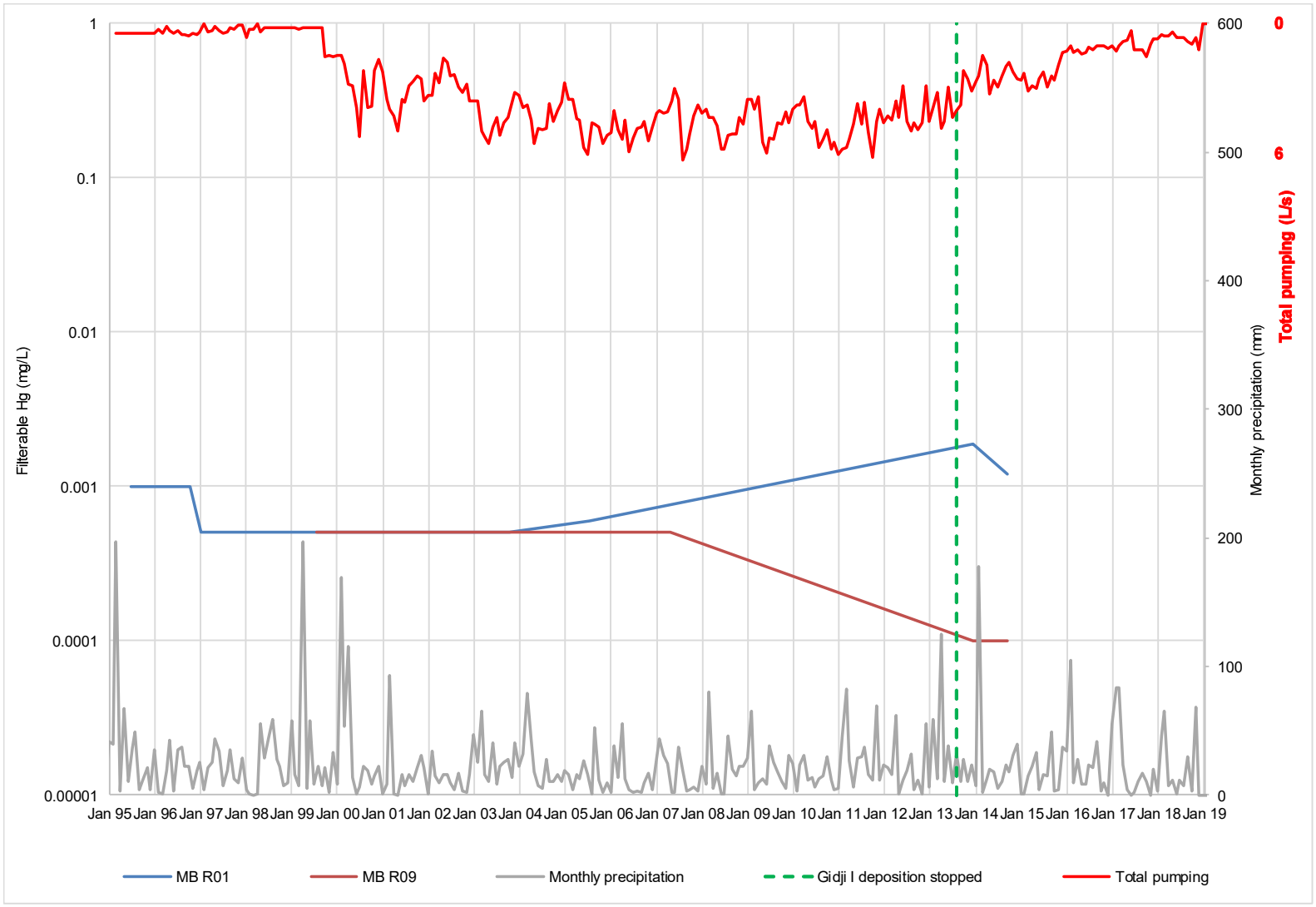
BIG DOG HYDROGEOLOGY

Groundwater Filterable Hg - trench bores

Figure C118

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Report: KCGM Gidji TSF Hydrogeological Review



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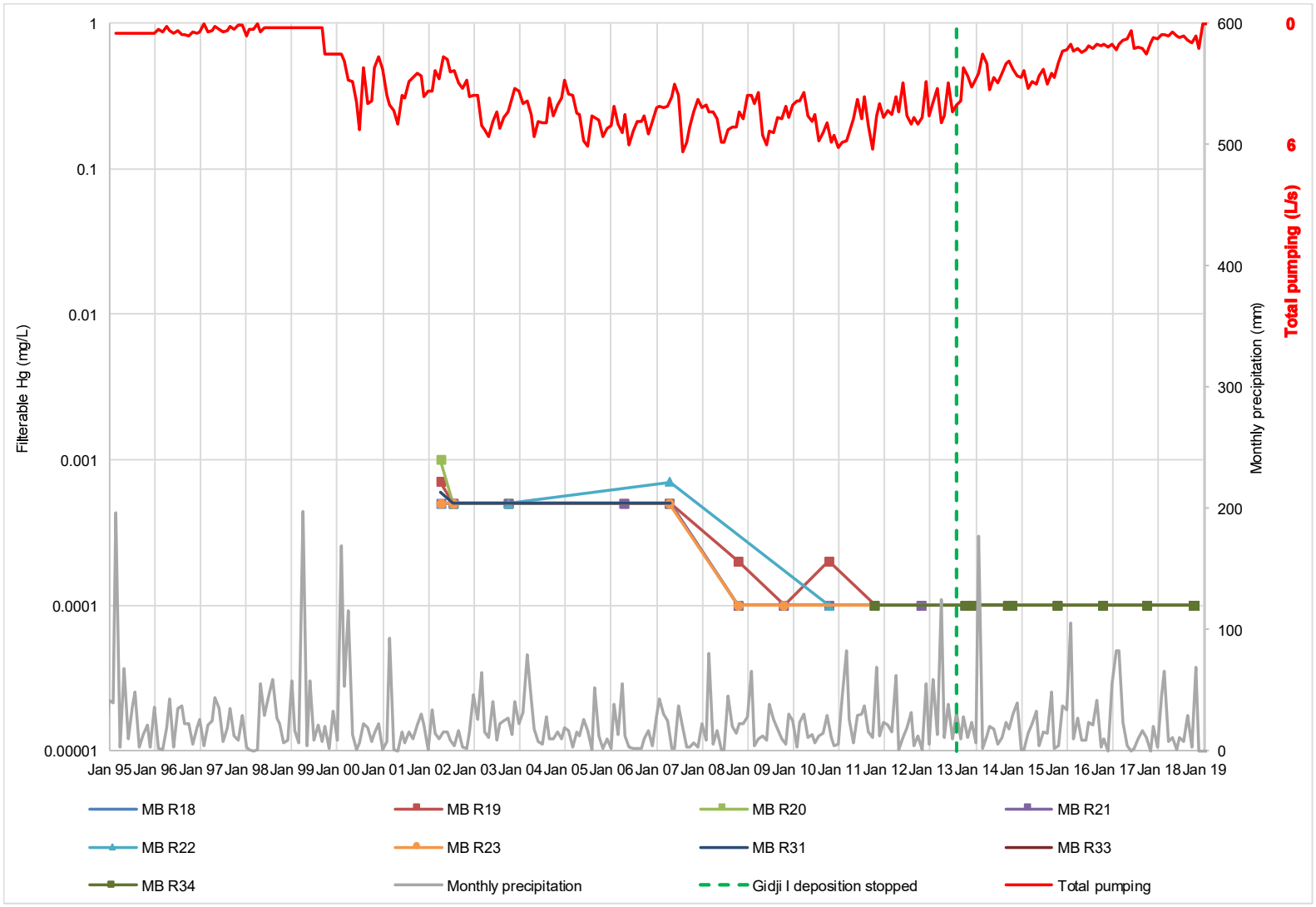
BIG DOG HYDROGEOLOGY

Groundwater Filterable Hg - decant bores

Figure C119

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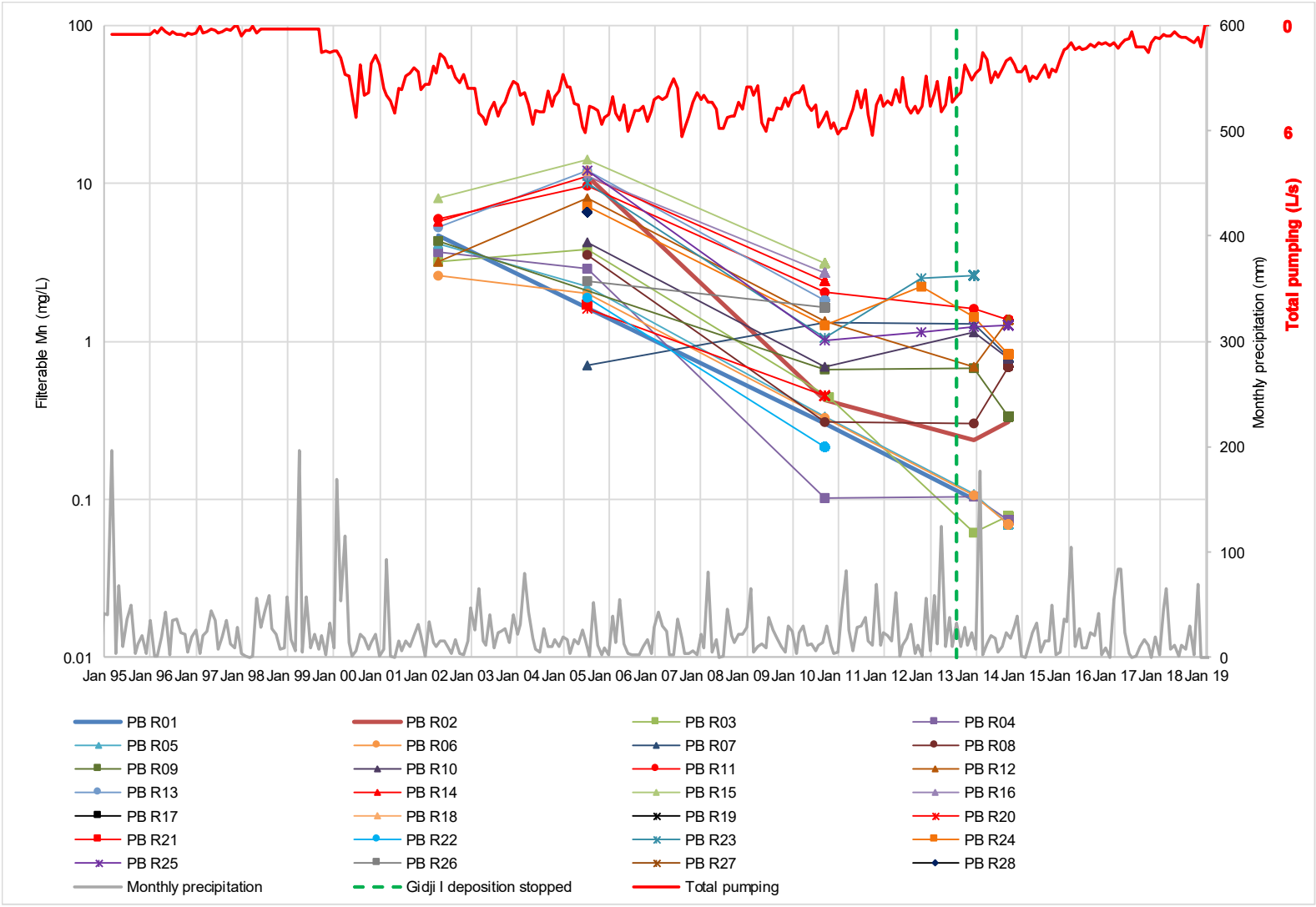
BIG DOG HYDROGEOLOGY

Groundwater Filterable Hg - eastern bores

Figure C120

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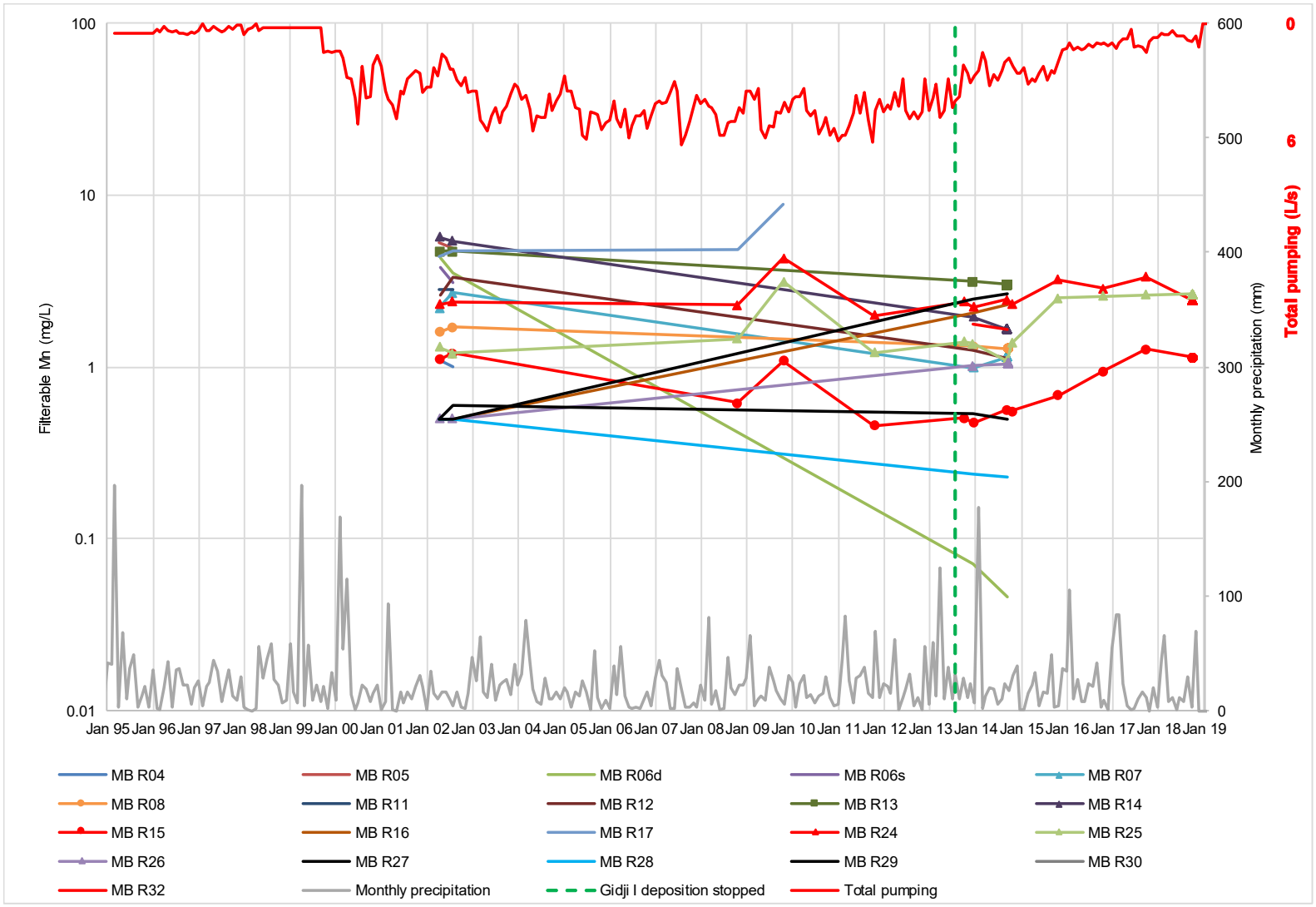
BIG DOG HYDROGEOLOGY

Groundwater Filterable Mn - production bores

Figure C121

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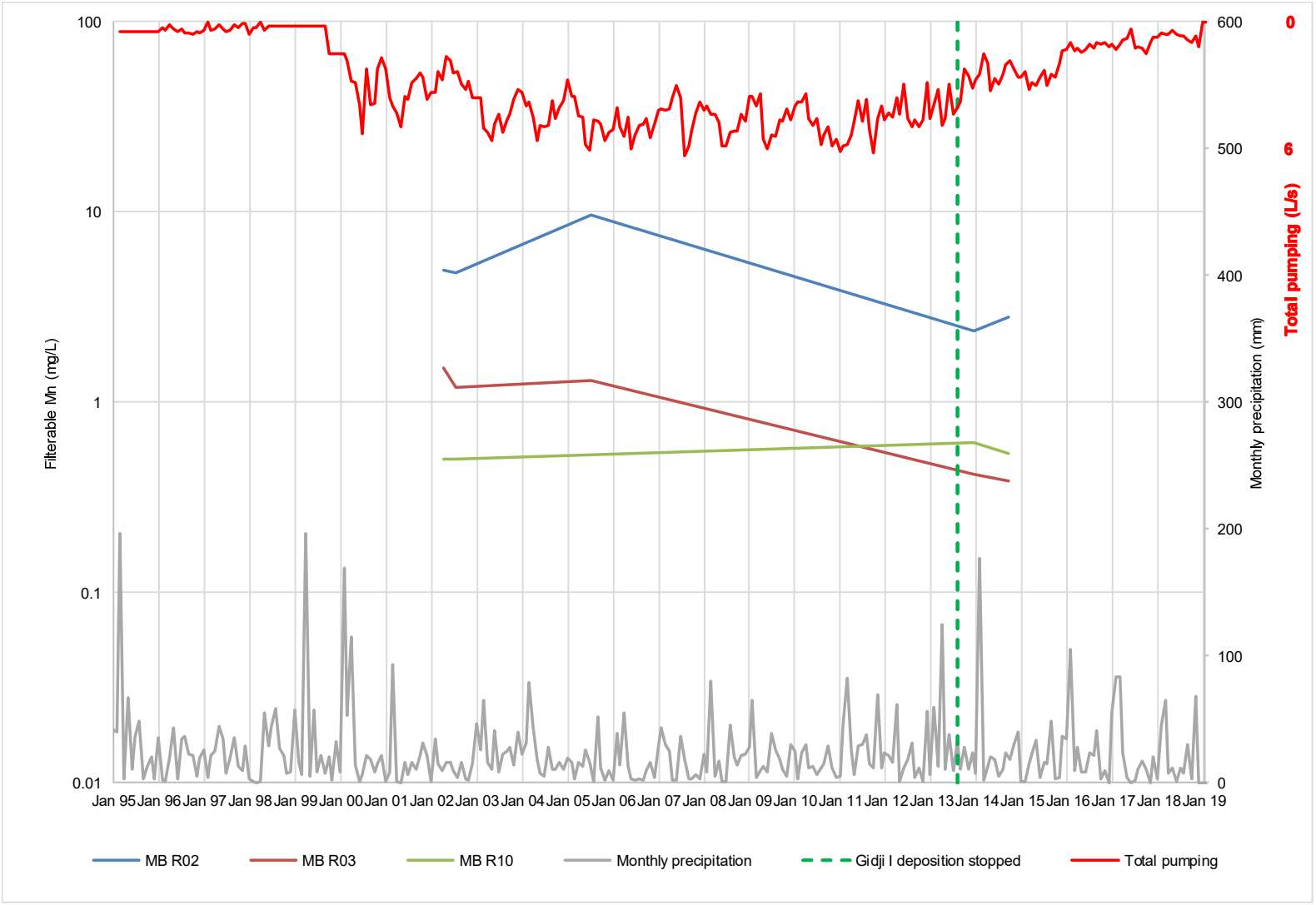
BIG DOG HYDROGEOLOGY

Groundwater Filterable Mn - western bores

Figure C122

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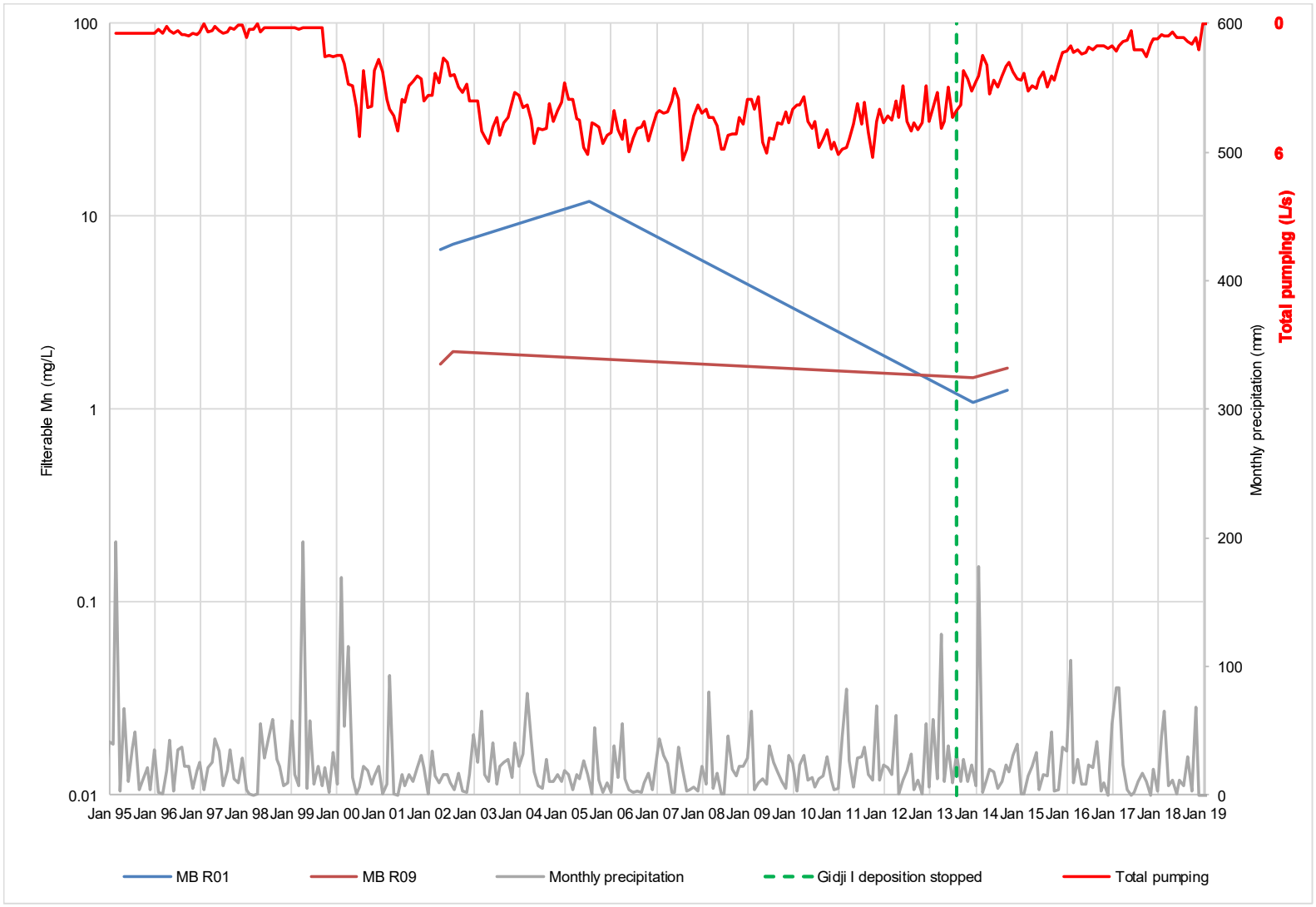
BIG DOG HYDROGEOLOGY

Groundwater Filterable Mn - trench bores

Figure C123

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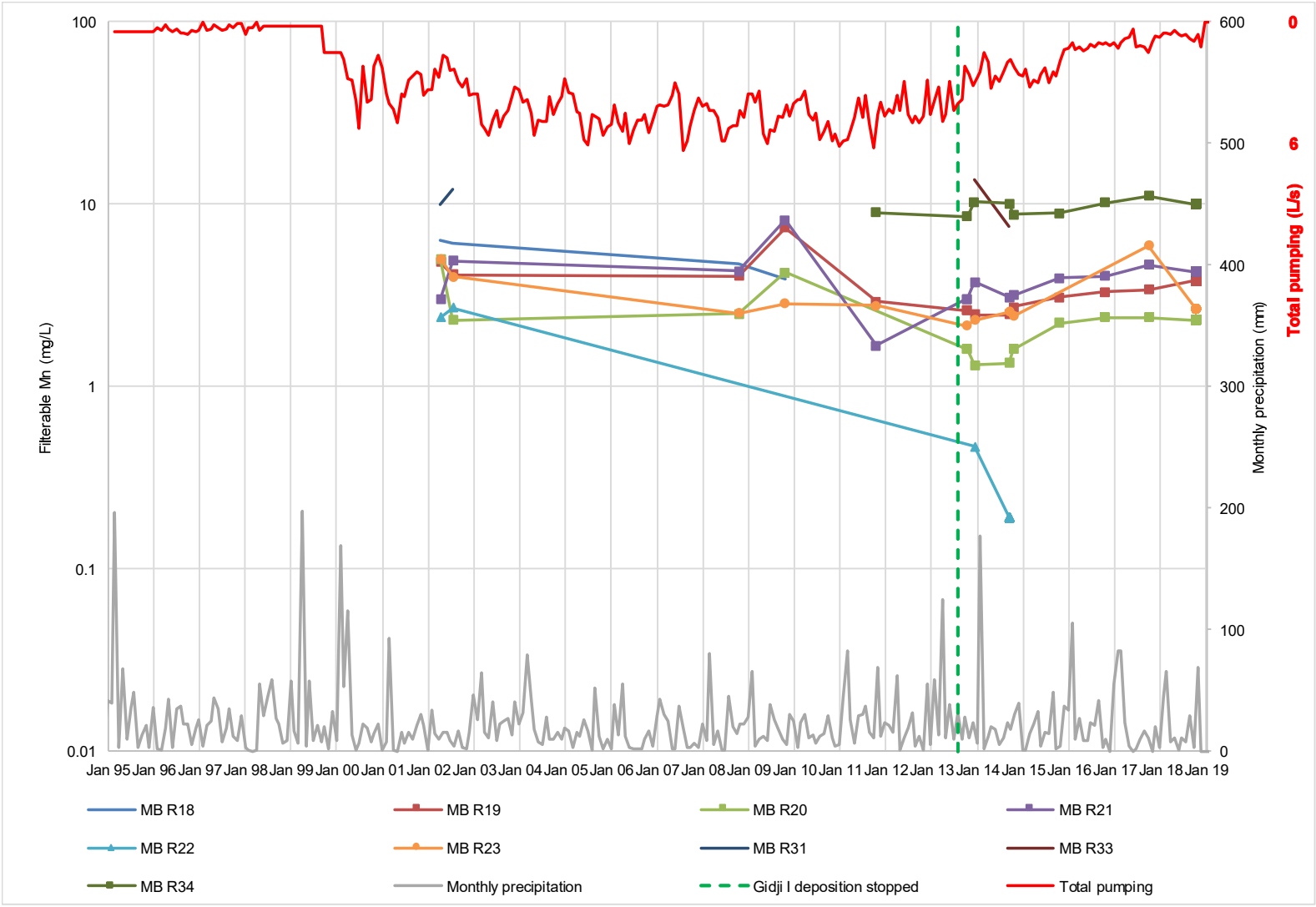
BIG DOG HYDROGEOLOGY

Groundwater Filterable Mn - decant bores

Figure C124

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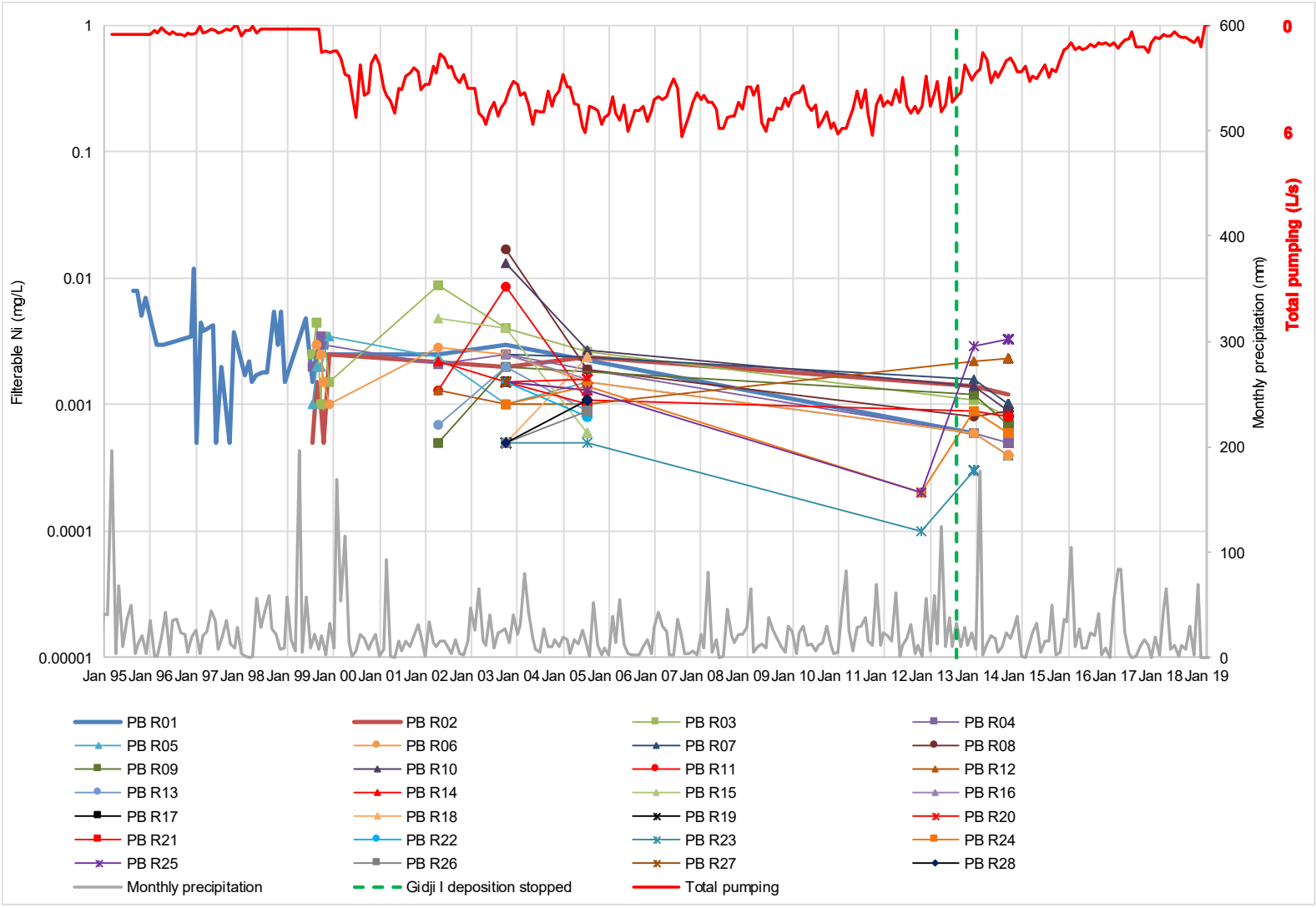
BIG DOG HYDROGEOLOGY

Groundwater Filterable Mn - eastern bores

Figure C125

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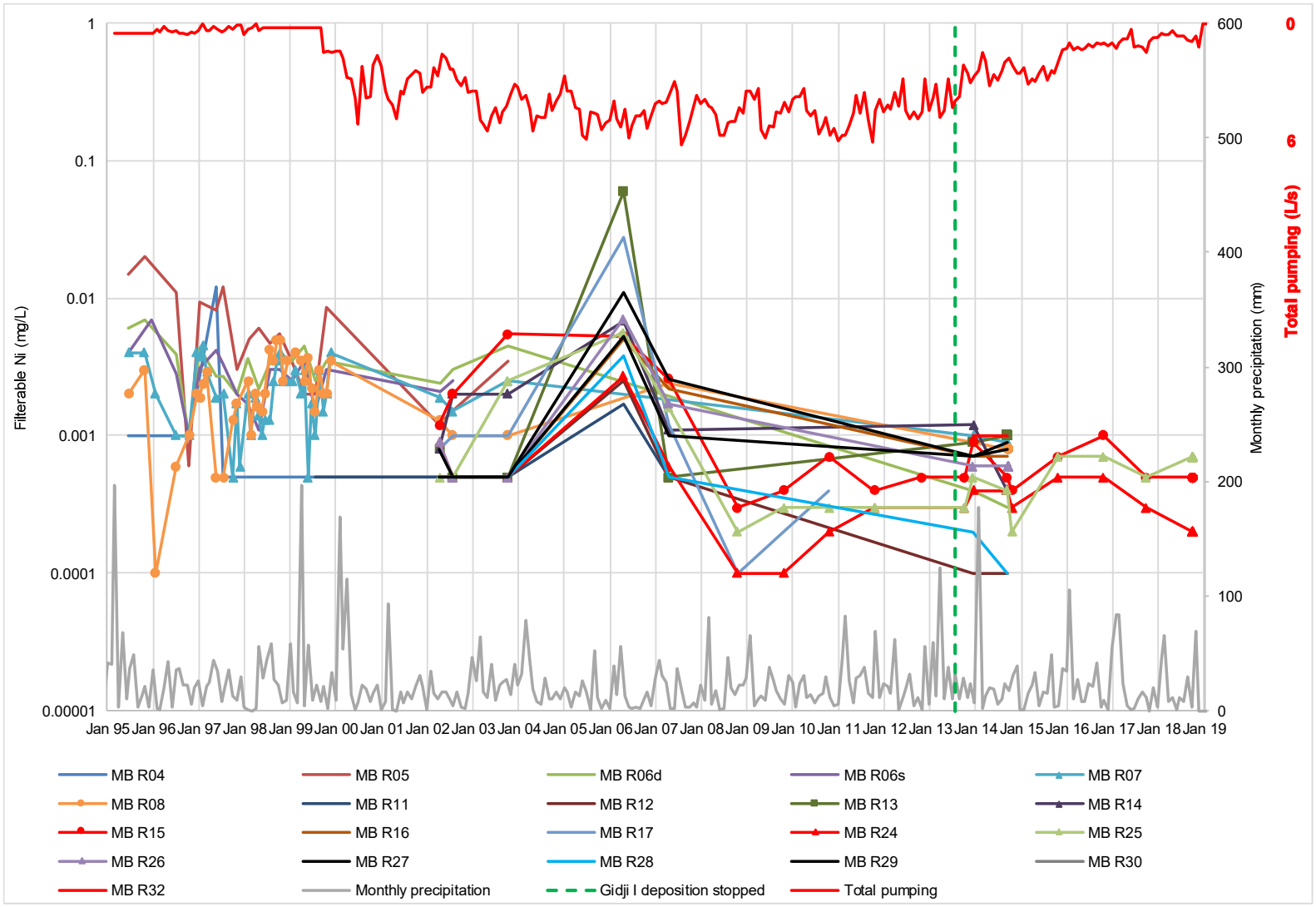
BIG DOG HYDROGEOLOGY

Groundwater Filterable Ni - production bores

Figure C126

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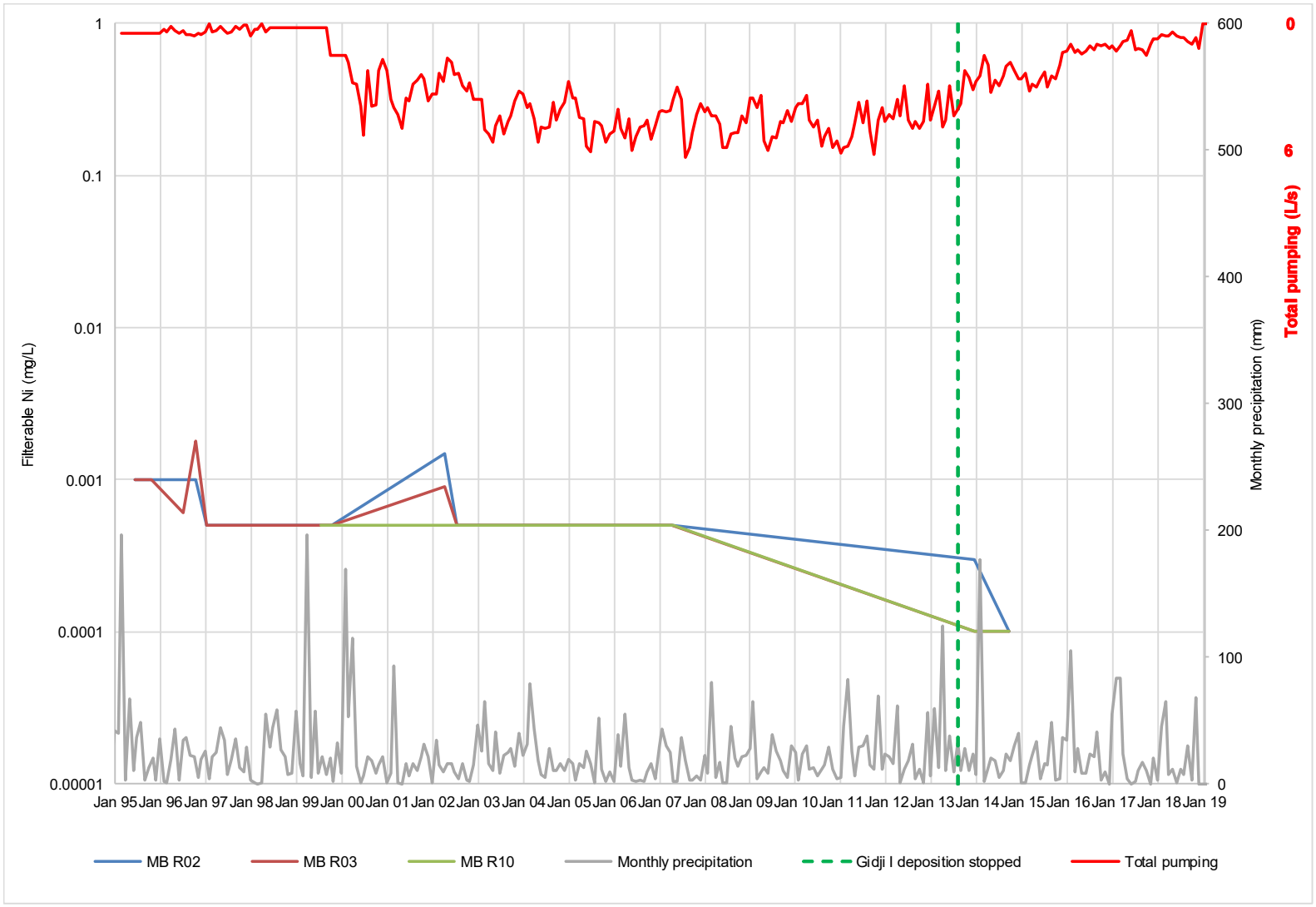
BIG DOG HYDROGEOLOGY

Groundwater Filterable Ni - western bores

Figure C127

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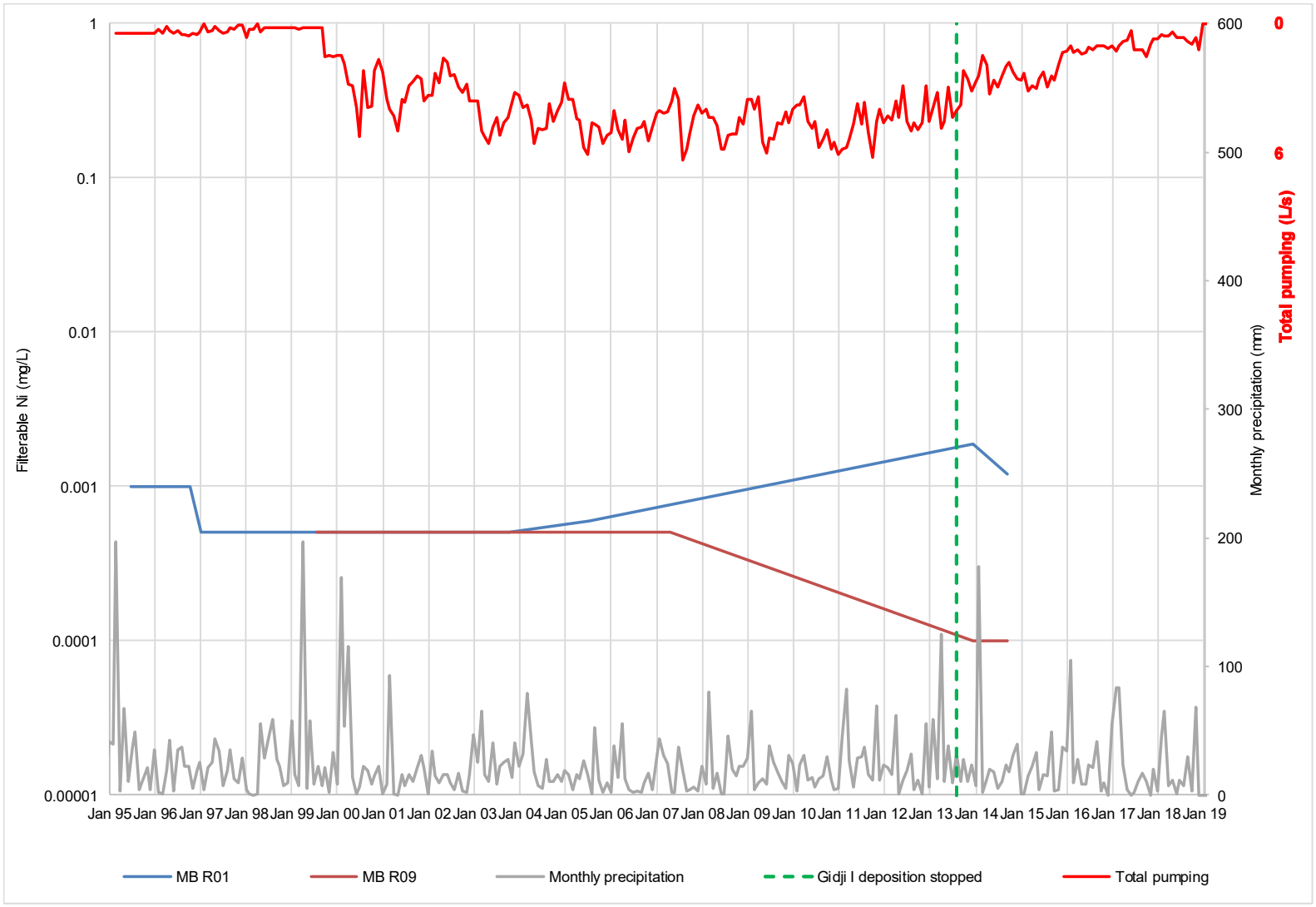
BIG DOG HYDROGEOLOGY

Groundwater Filterable Ni - trench bores

Figure C128

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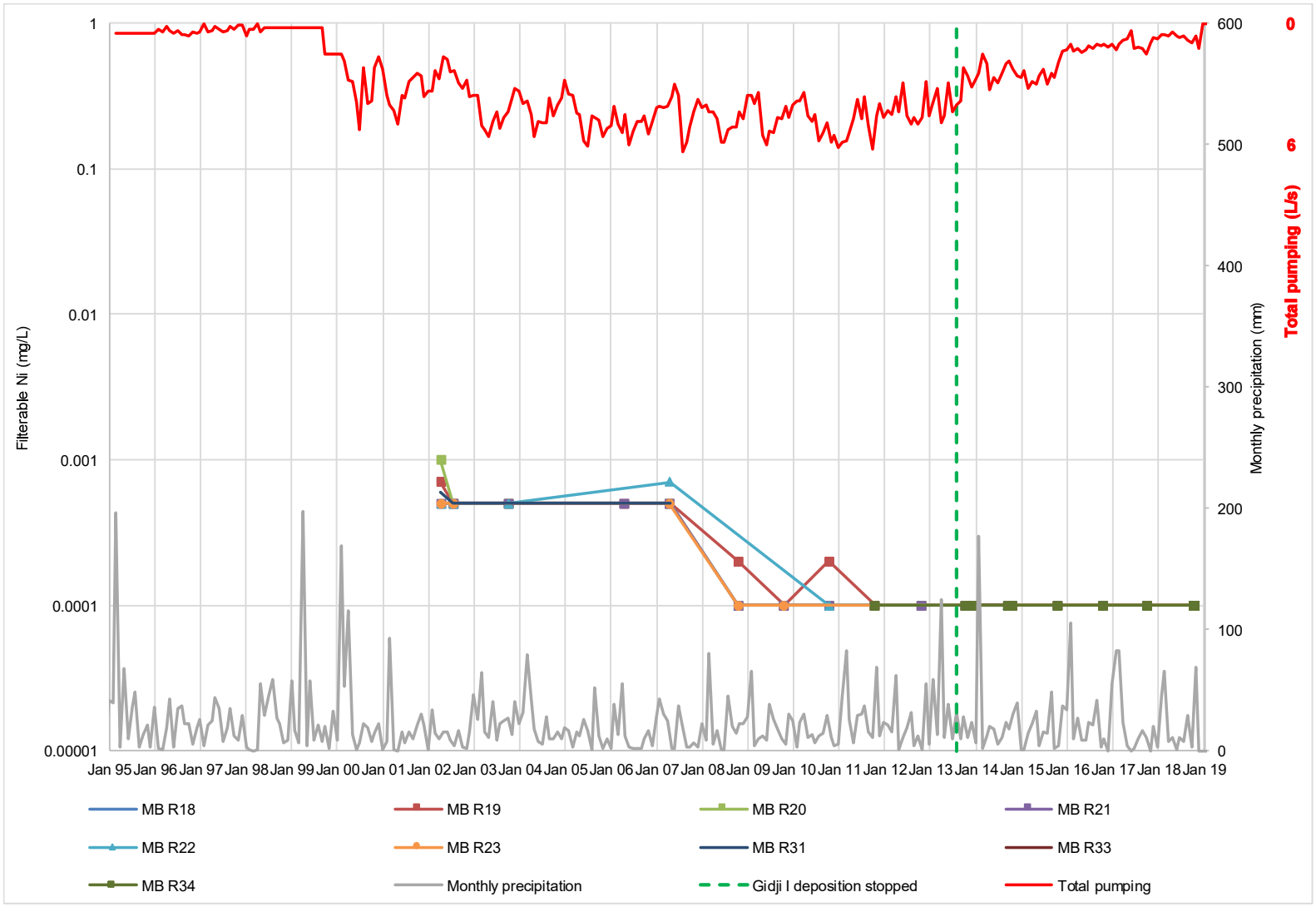
BIG DOG HYDROGEOLOGY

Groundwater Filterable Ni - decant bores

Figure C129

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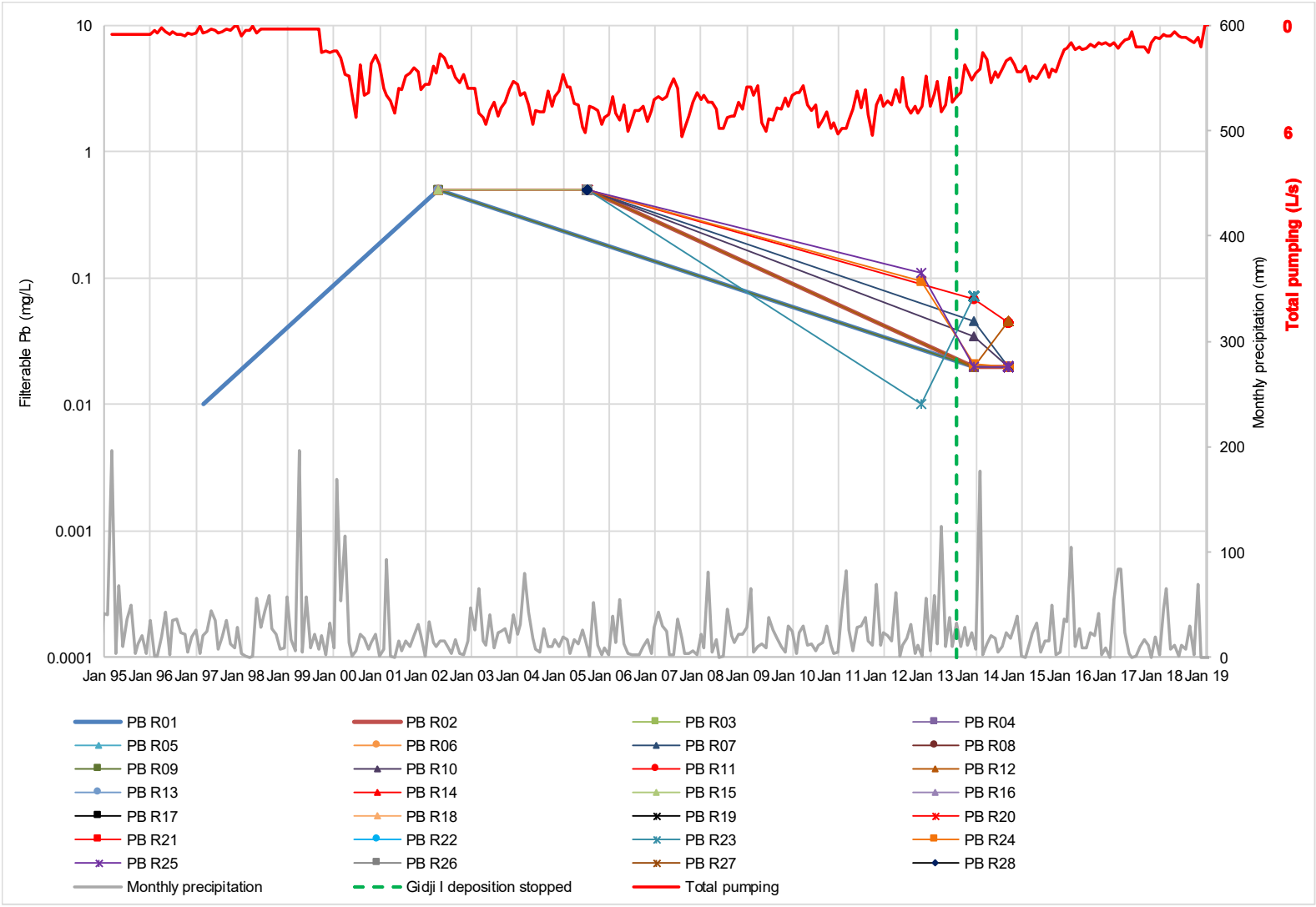
BIG DOG HYDROGEOLOGY

Groundwater Filterable Ni - eastern bores

Figure C130

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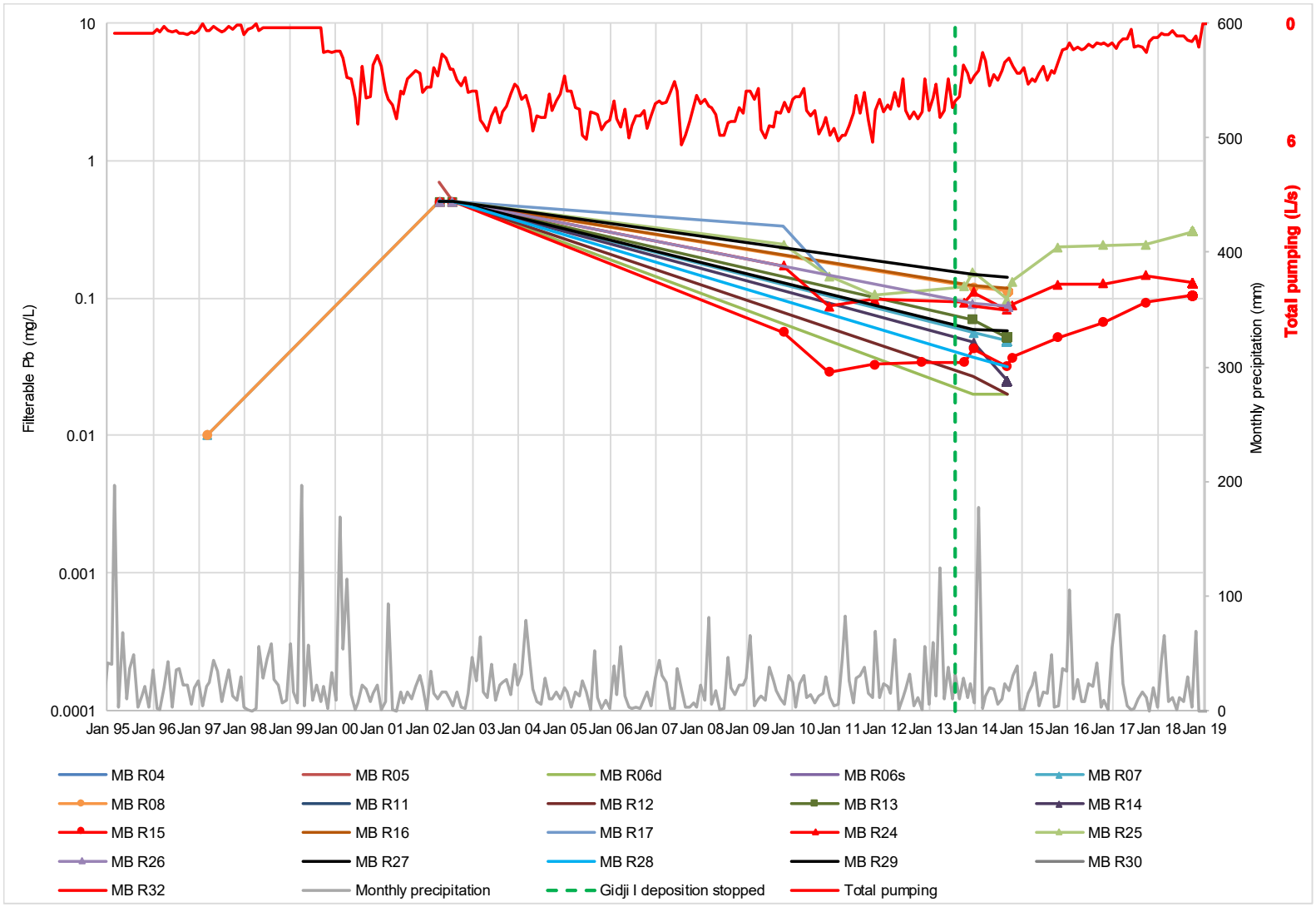
BIG DOG HYDROGEOLOGY

Groundwater Filterable Pb - production bores

Figure C131

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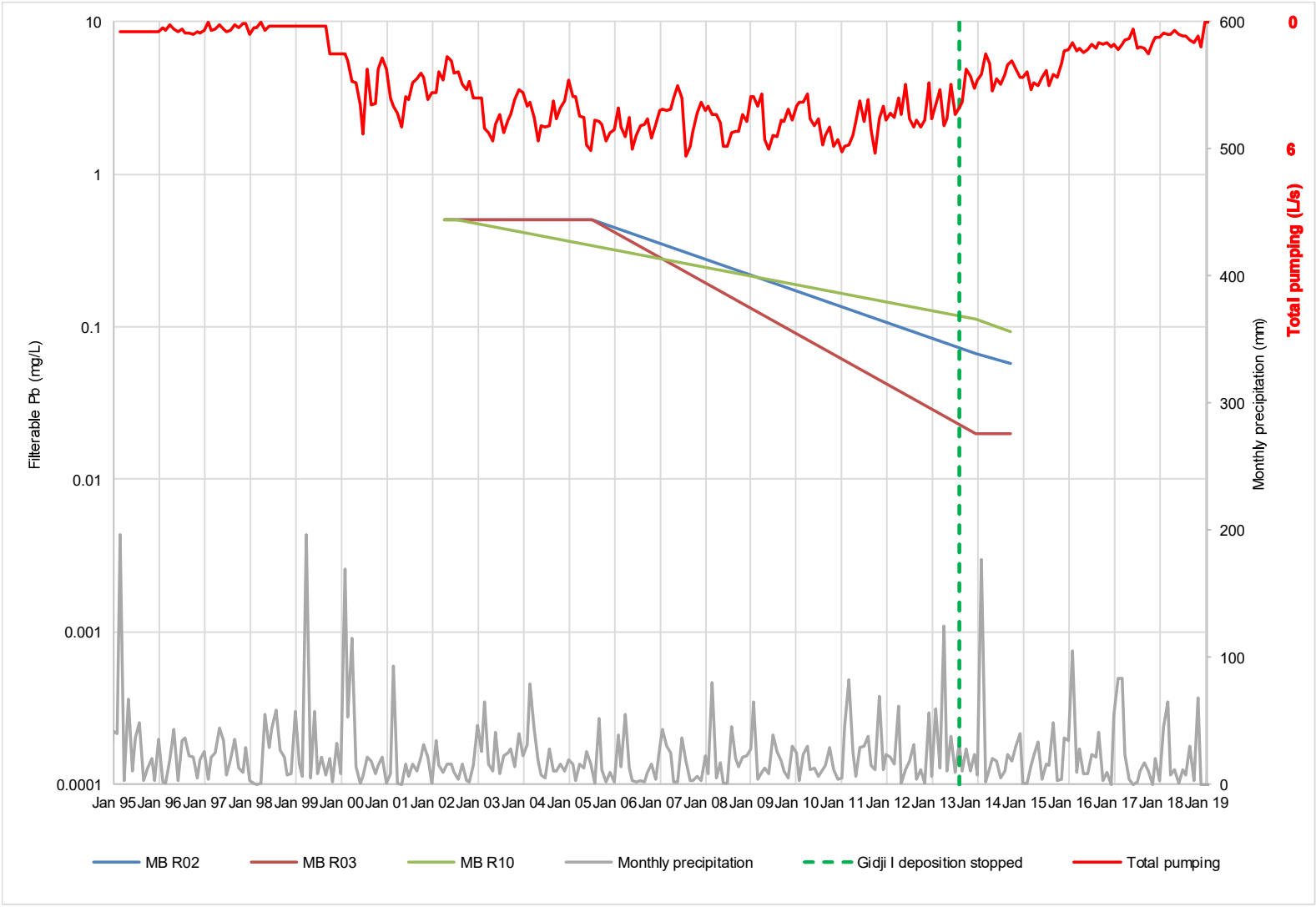
BIG DOG HYDROGEOLOGY

Groundwater Filterable Pb - western bores

Figure C132

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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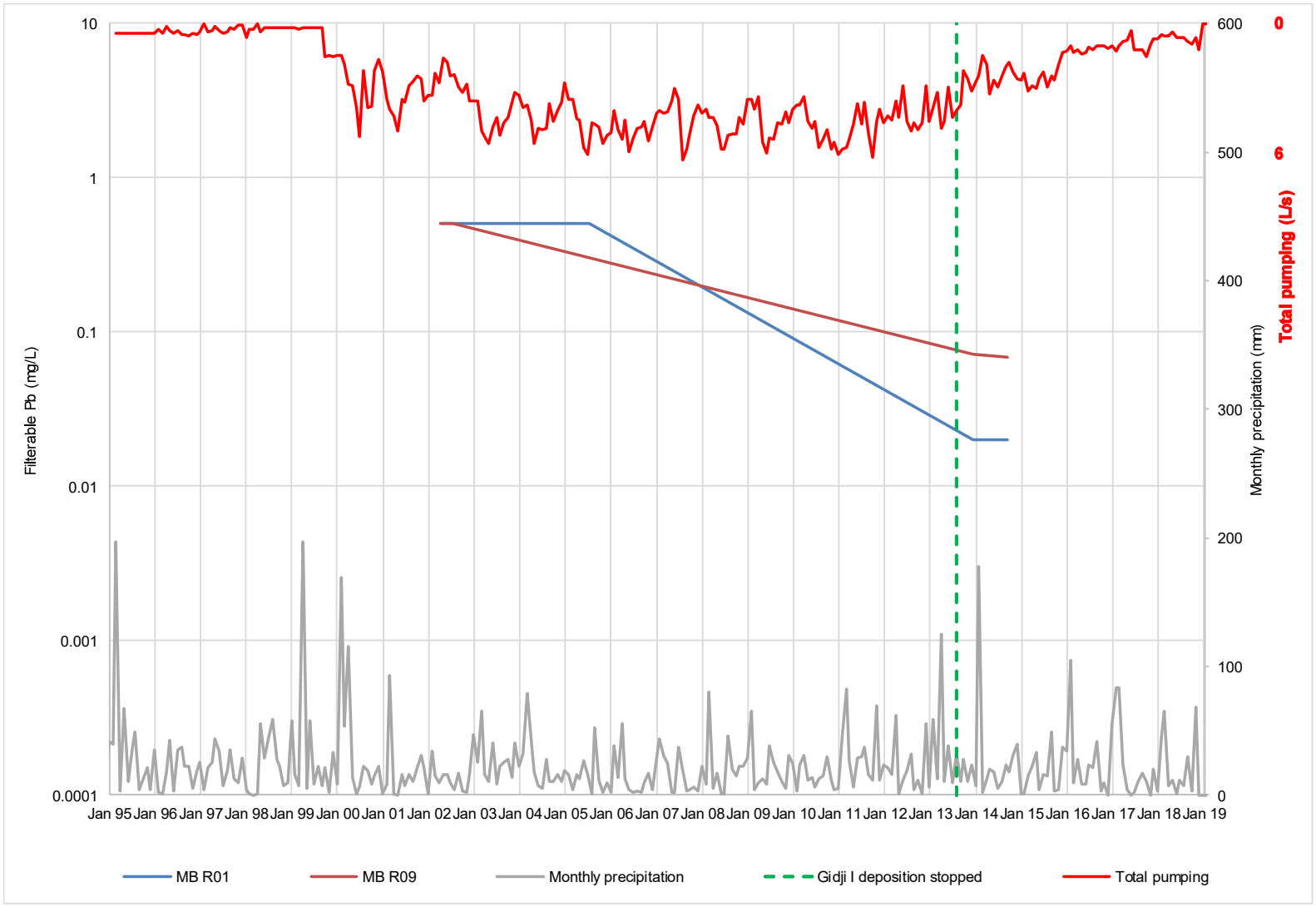
BIG DOG HYDROGEOLOGY

Groundwater Filterable Pb - trench bores

Figure C133

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Report: KCGM Gidji TSF Hydrogeological Review



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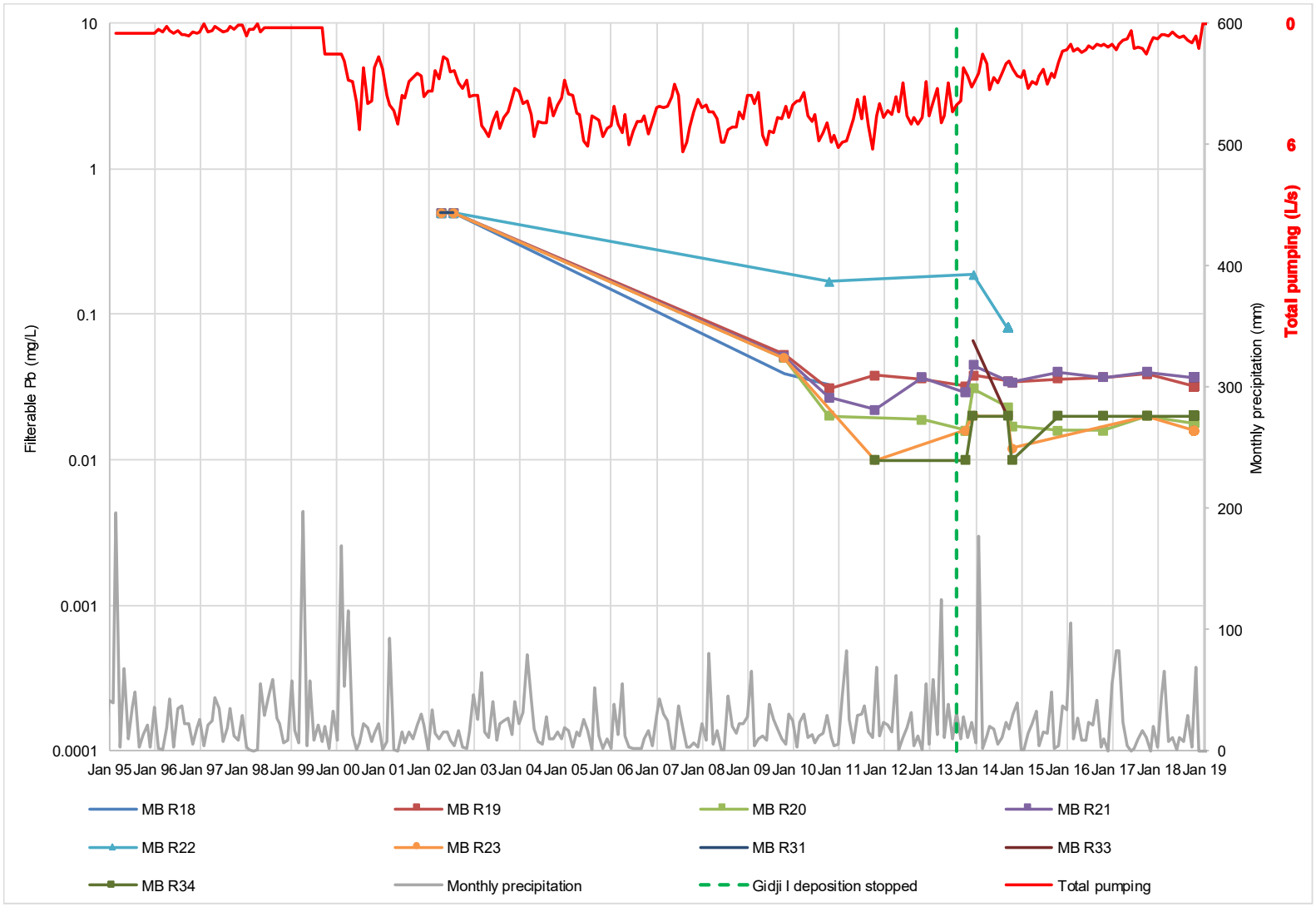
BIG DOG HYDROGEOLOGY

Groundwater Filterable Pb - decant bores

Figure C134

Date: January 2019

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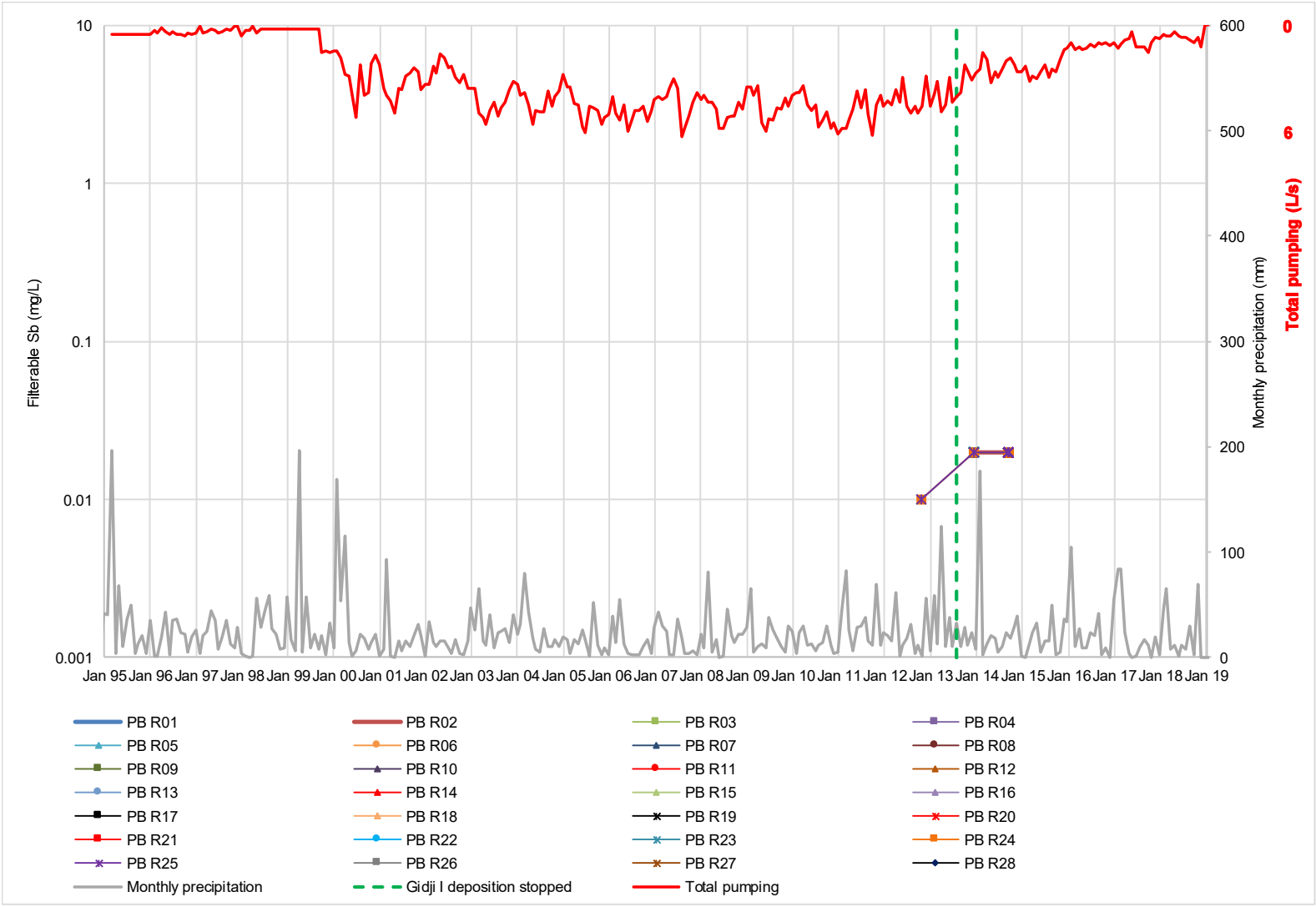
BIG DOG HYDROGEOLOGY

Groundwater Filterable Pb - eastern bores

Figure C135

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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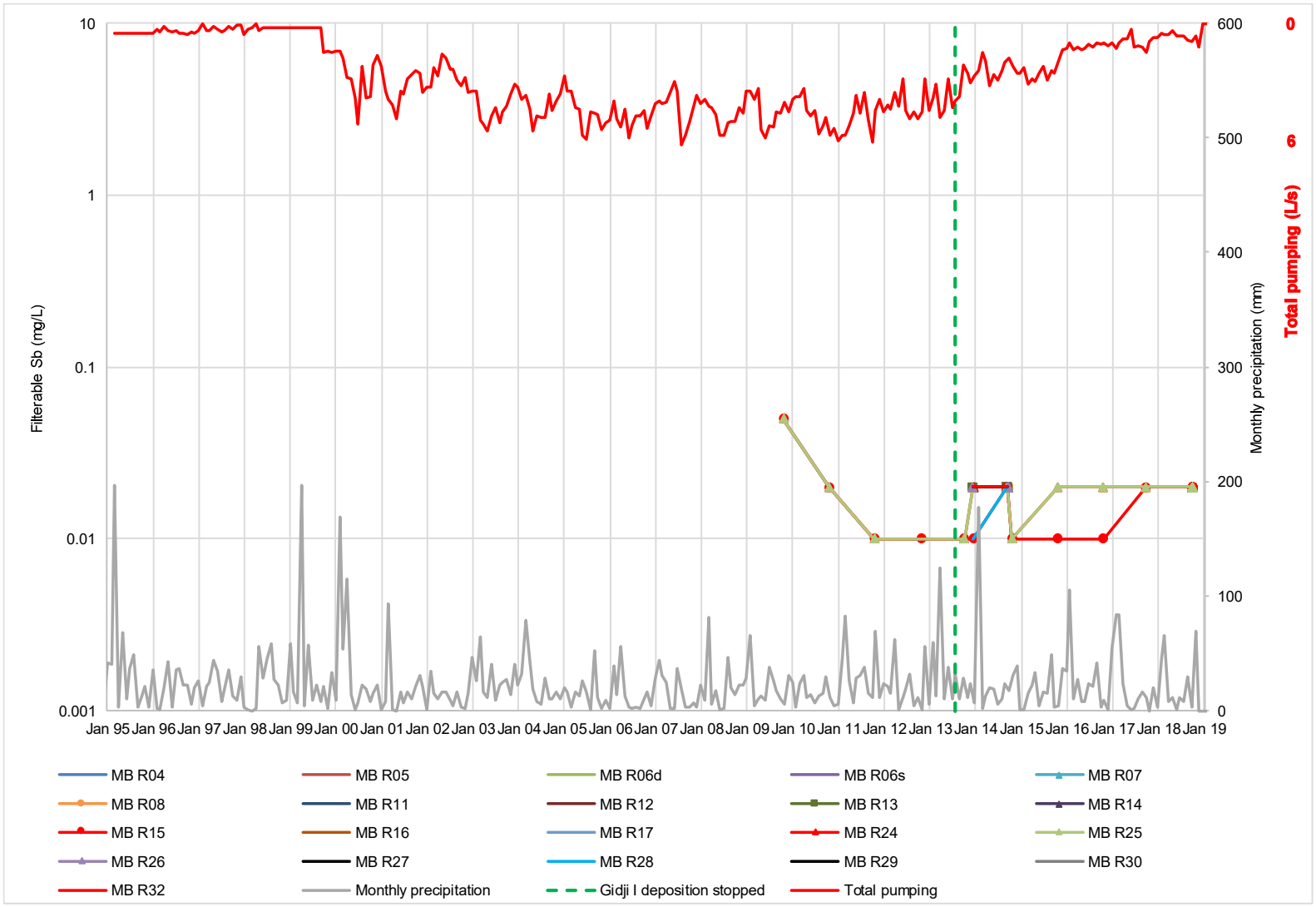
BIG DOG HYDROGEOLOGY

Groundwater Filterable Sb - production bores

Figure C136

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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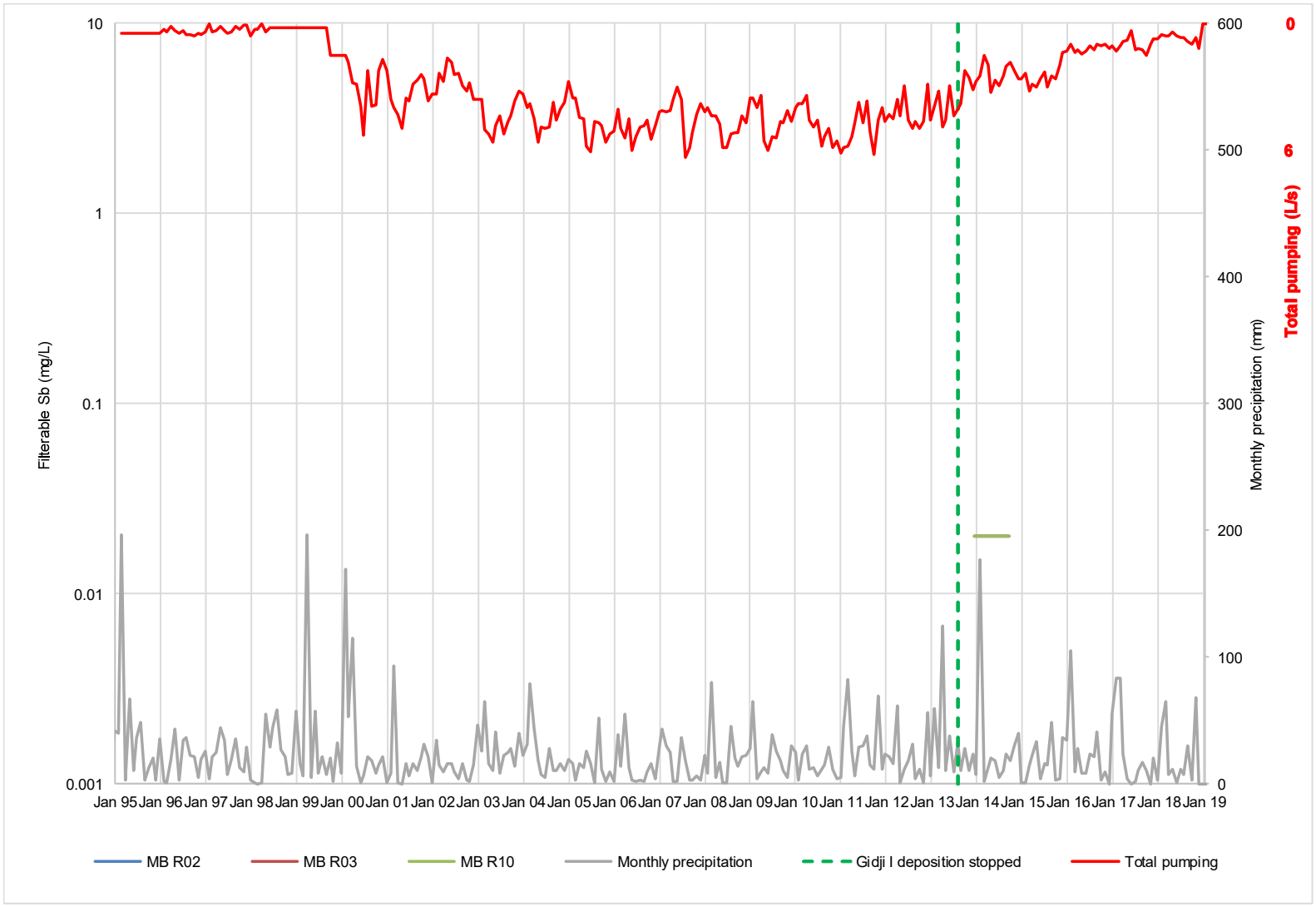
BIG DOG HYDROGEOLOGY

Groundwater Filterable Sb - western bores

Figure C137

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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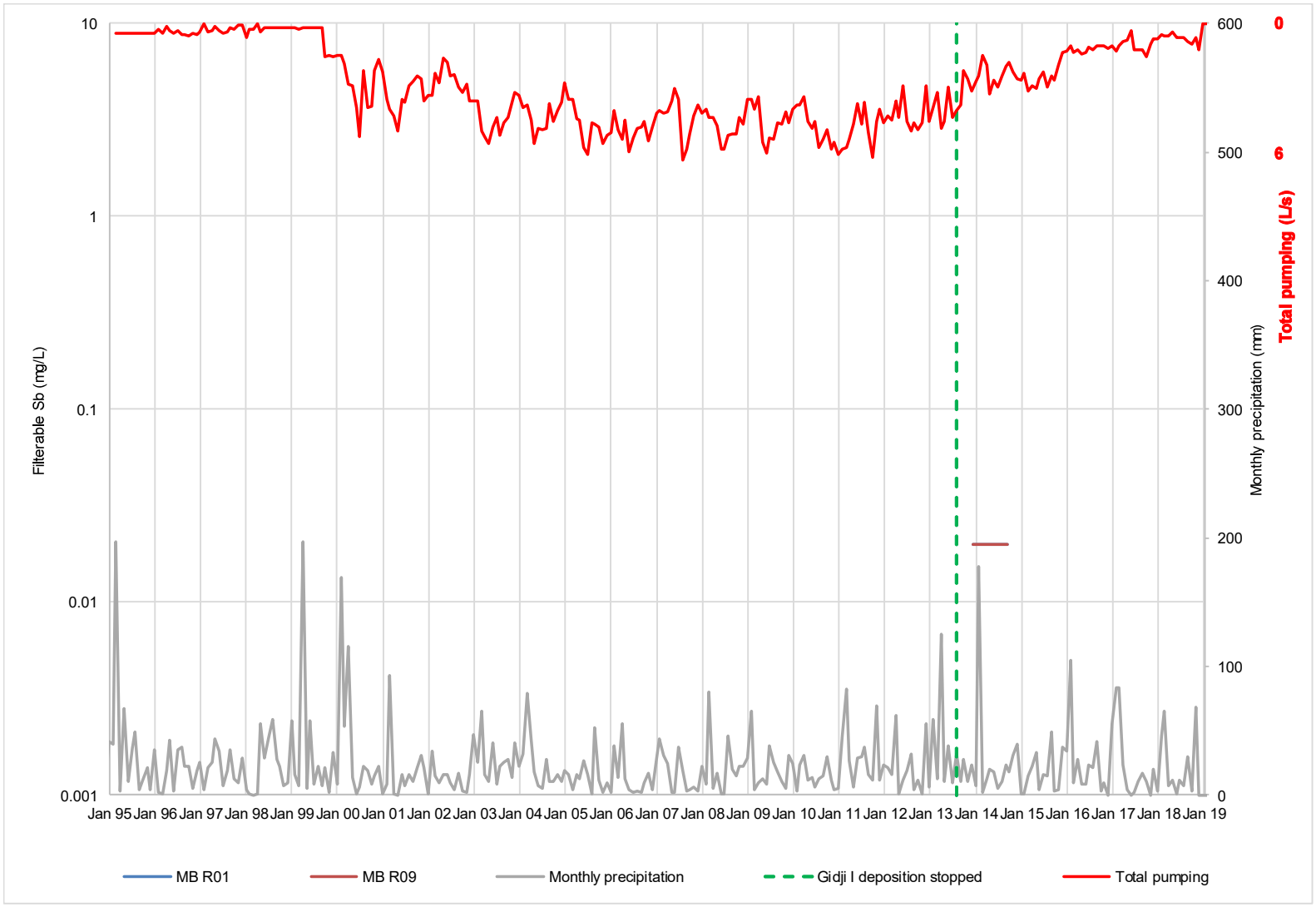
BIG DOG HYDROGEOLOGY

Groundwater Filterable Sb - trench bores

Figure C138

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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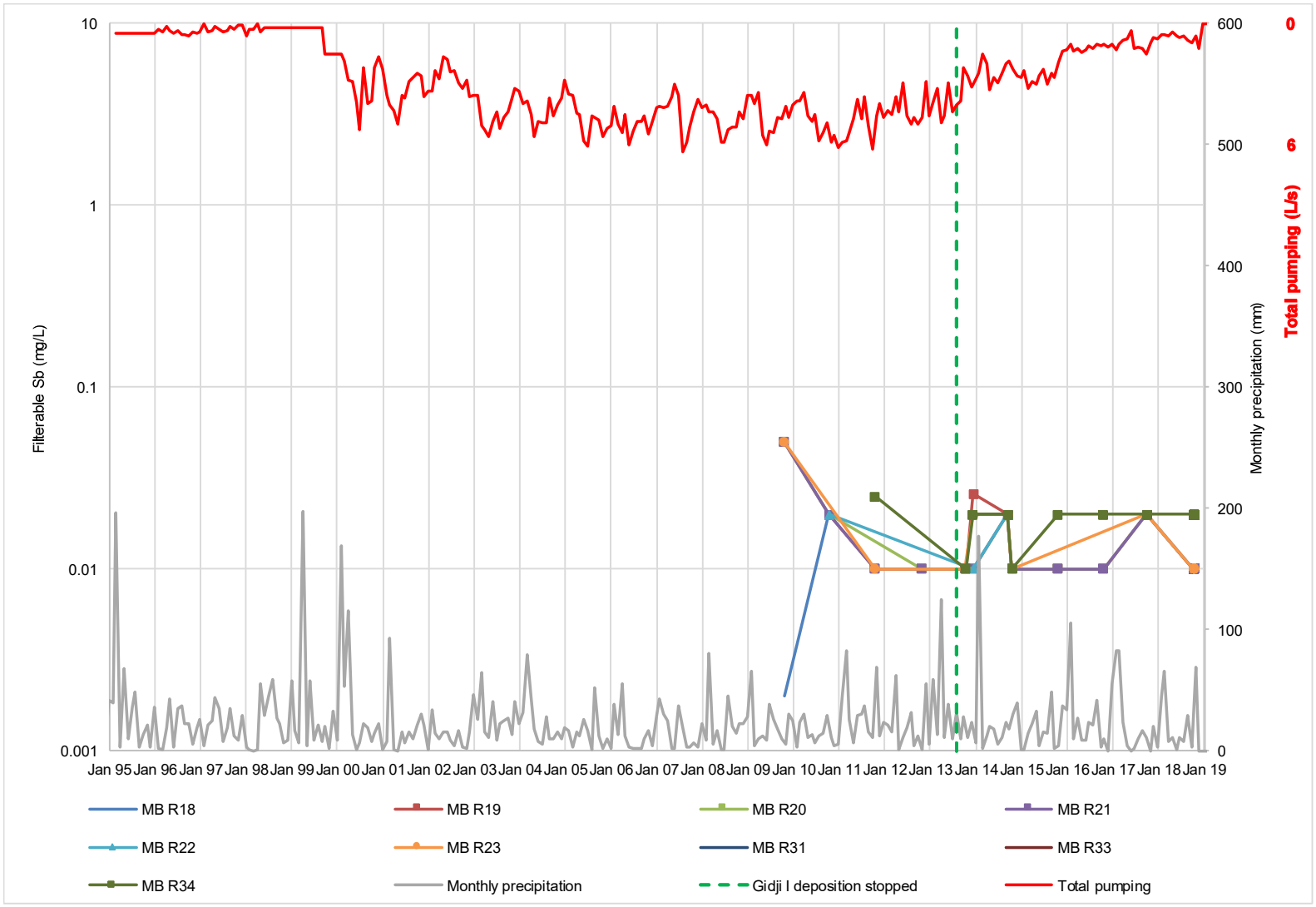
BIG DOG HYDROGEOLOGY

Groundwater Filterable Sb - decant bores

Figure C139

Date: January 2019

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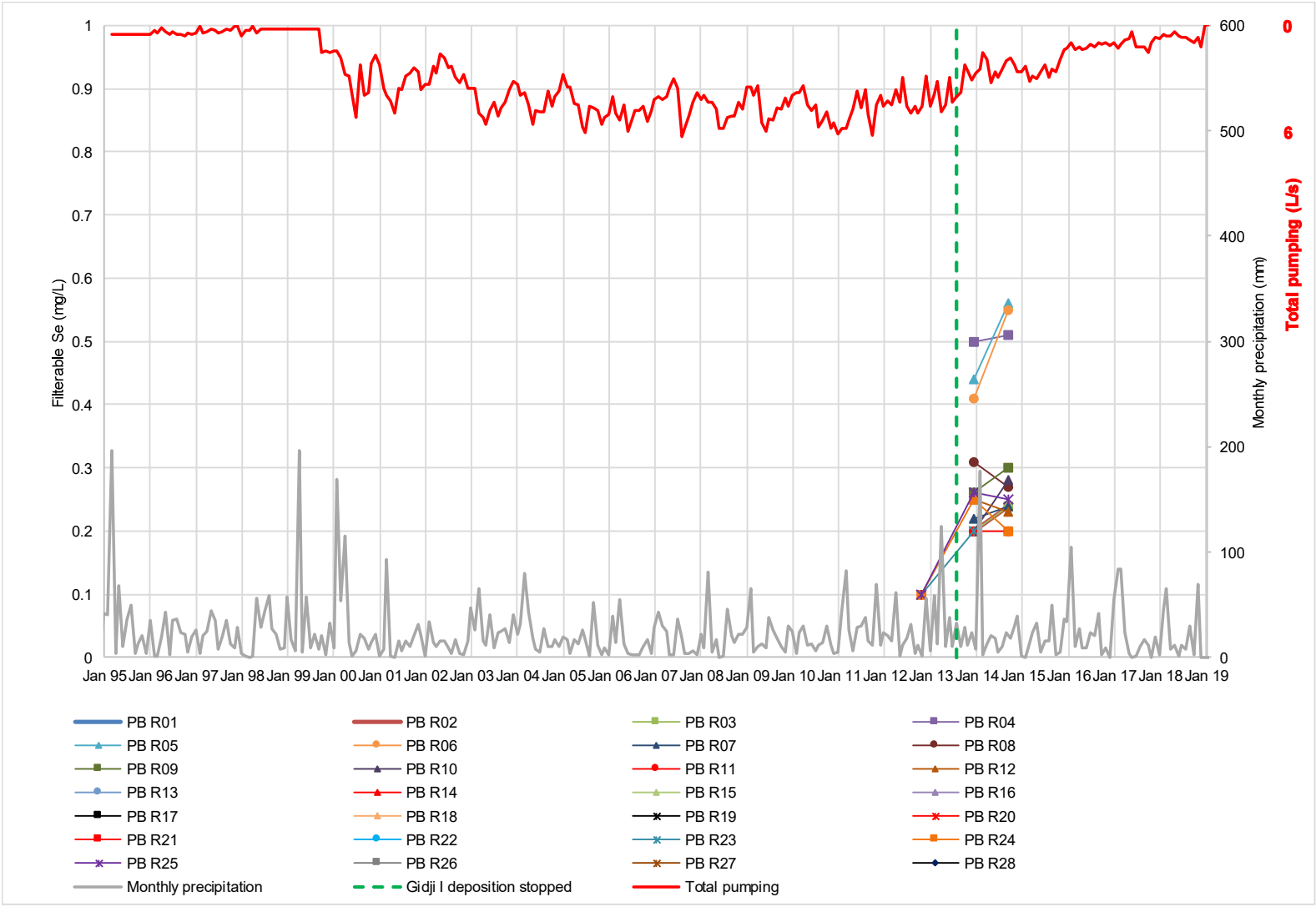
BIG DOG HYDROGEOLOGY

Groundwater Filterable Sb - eastern bores

Figure C140

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Report: KCGM Gidji TSF Hydrogeological Review



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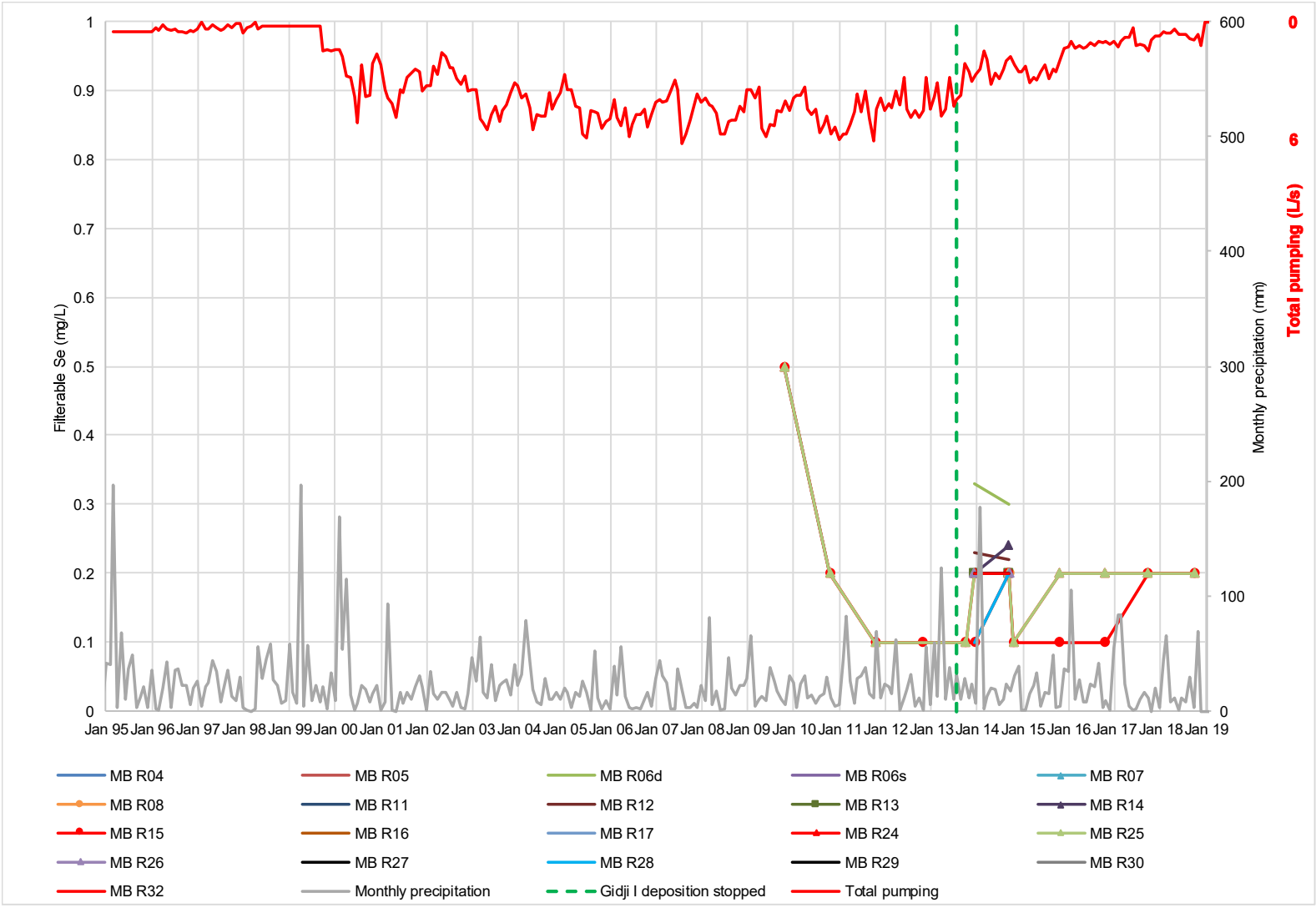
BIG DOG HYDROGEOLOGY

Groundwater Filterable Se - production bores

Figure C141

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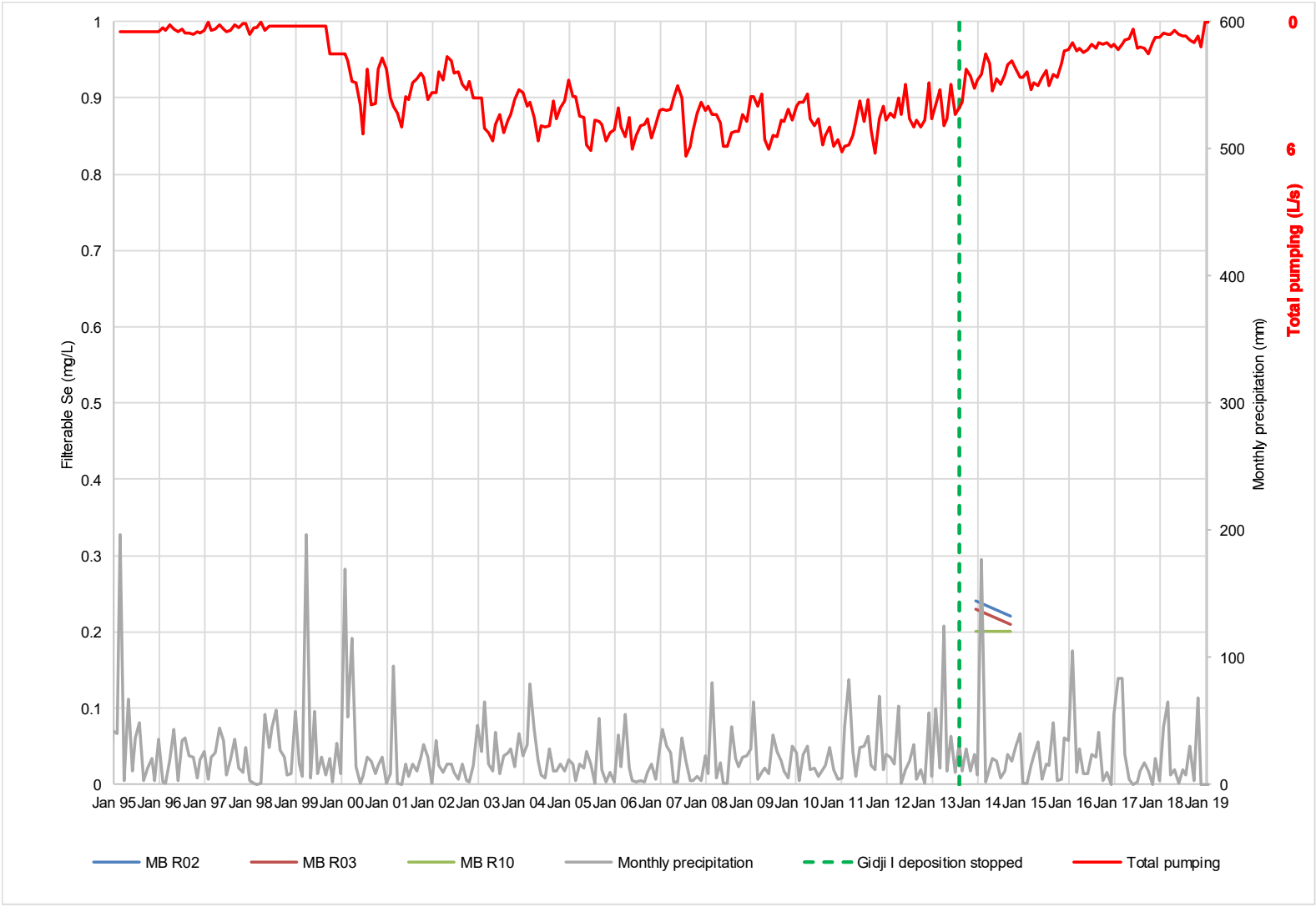
BIG DOG HYDROGEOLOGY

Groundwater Filterable Se - western bores

Figure C142

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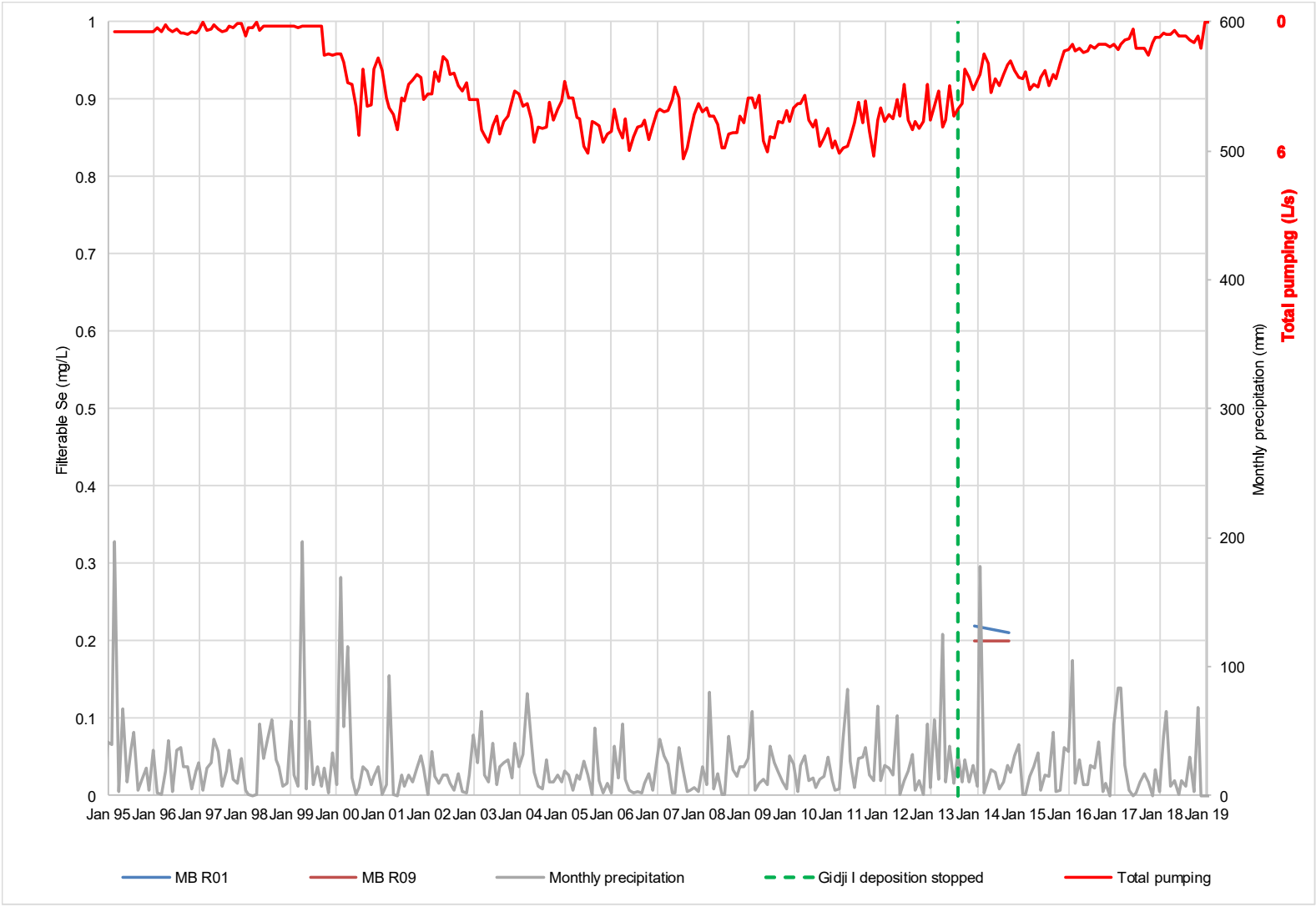
BIG DOG HYDROGEOLOGY

Groundwater Filterable Se - trench bores

Figure C143

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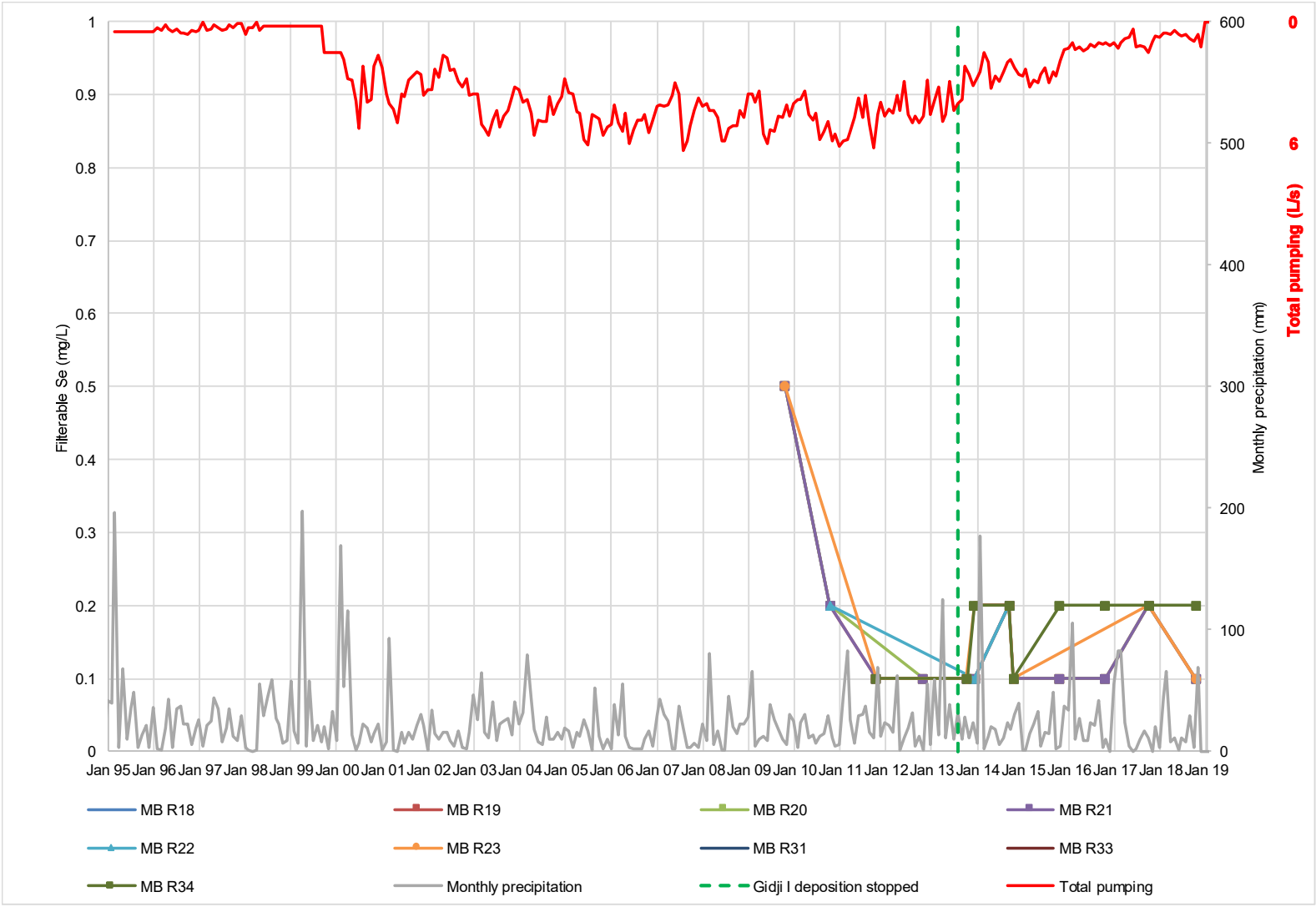
BIG DOG HYDROGEOLOGY

Groundwater Filterable Se - decant bores

Figure C144

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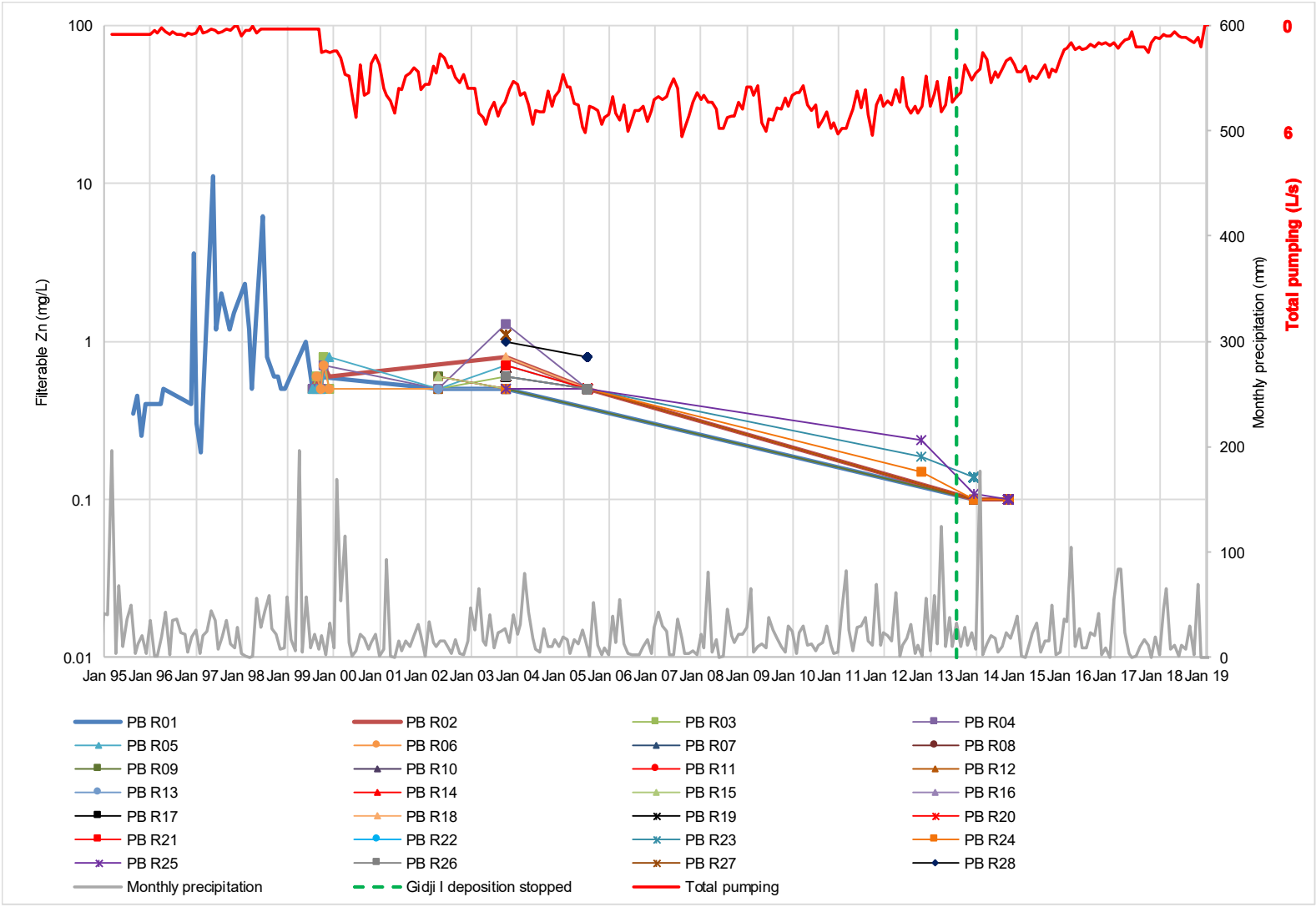
BIG DOG HYDROGEOLOGY

Groundwater Filterable Se - eastern bores

Figure C145

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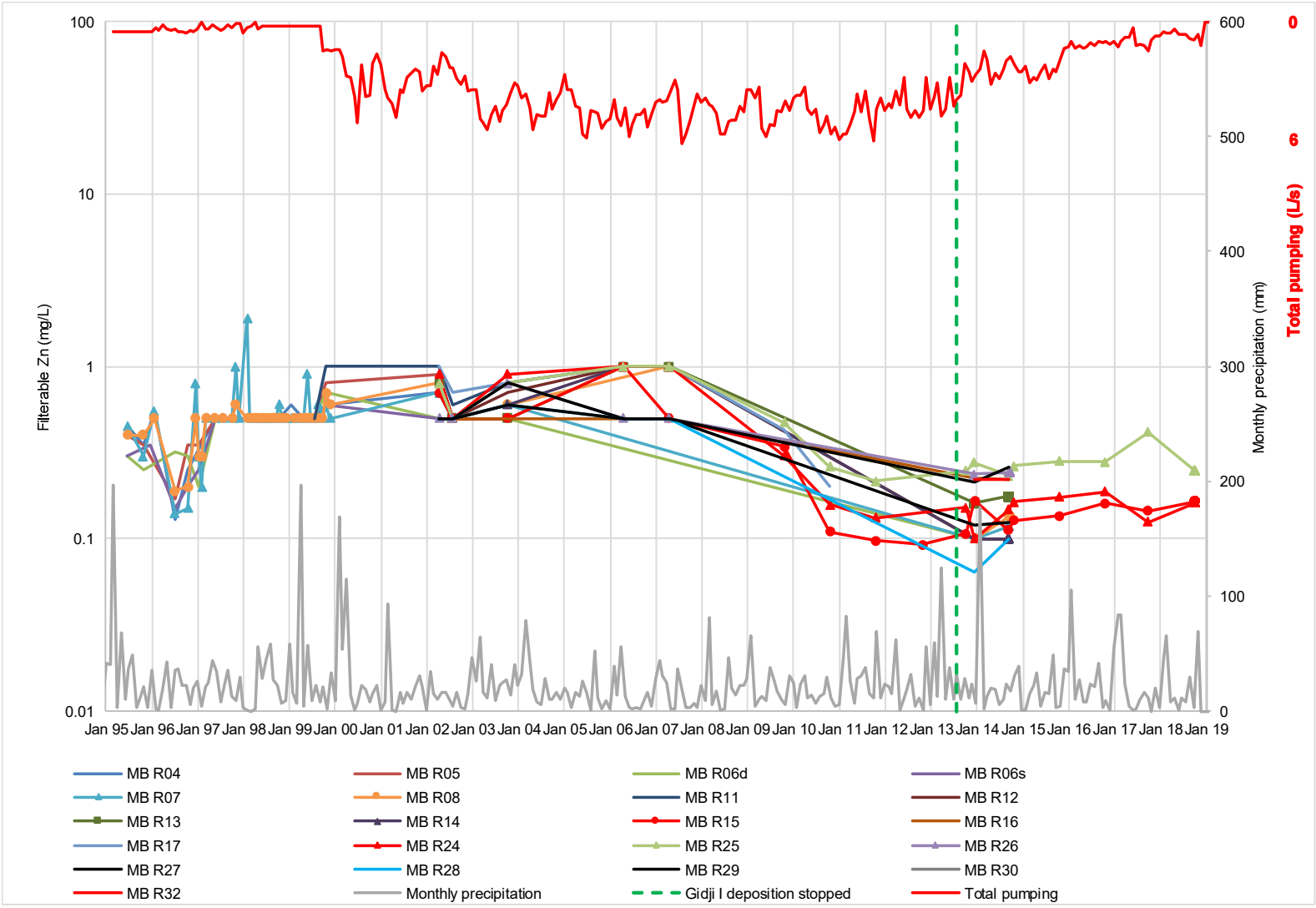
BIG DOG HYDROGEOLOGY

Groundwater Filterable Zn - production bores

Figure C146

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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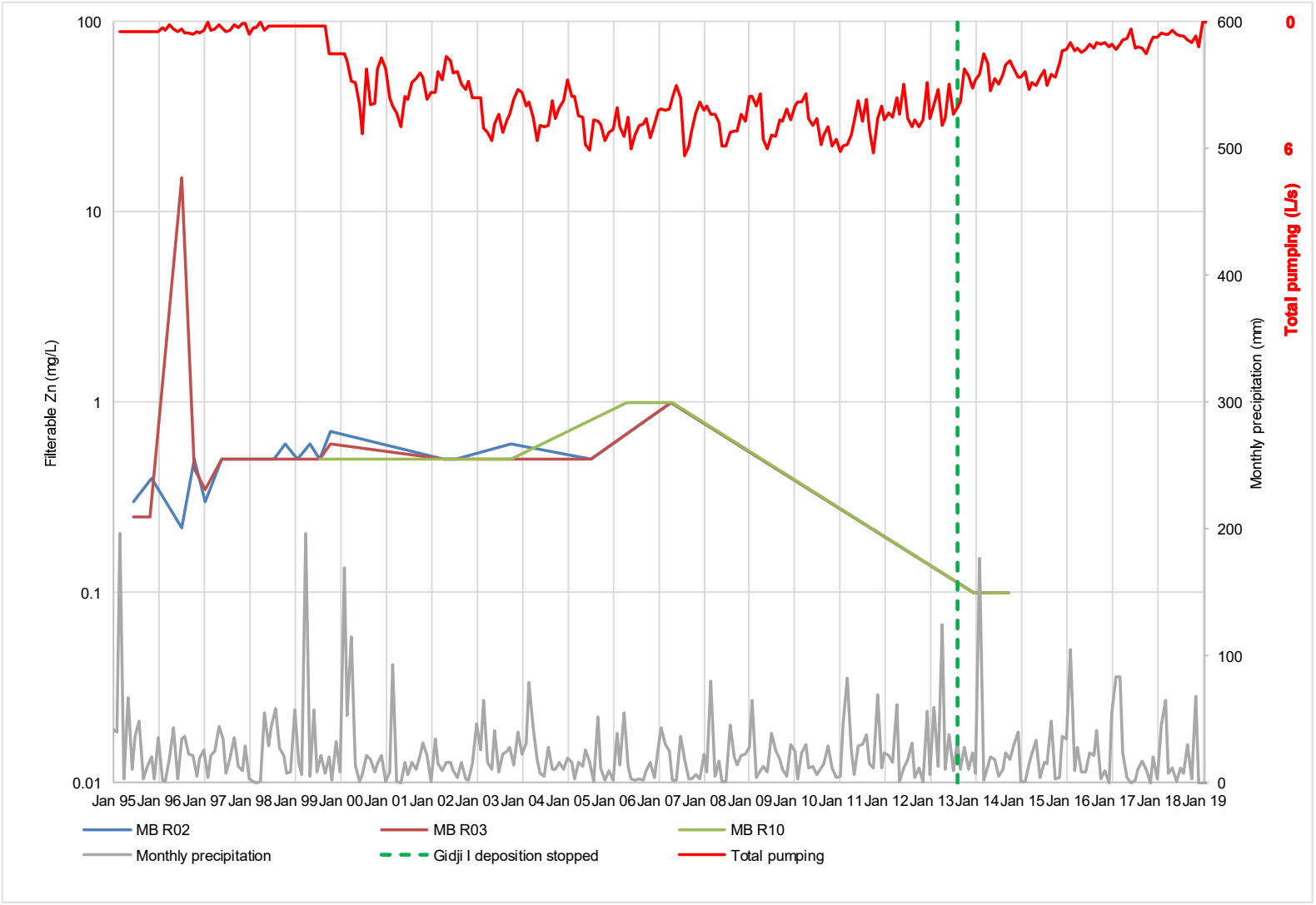
BIG DOG HYDROGEOLOGY

Groundwater Filterable Zn - western bores

Figure C147

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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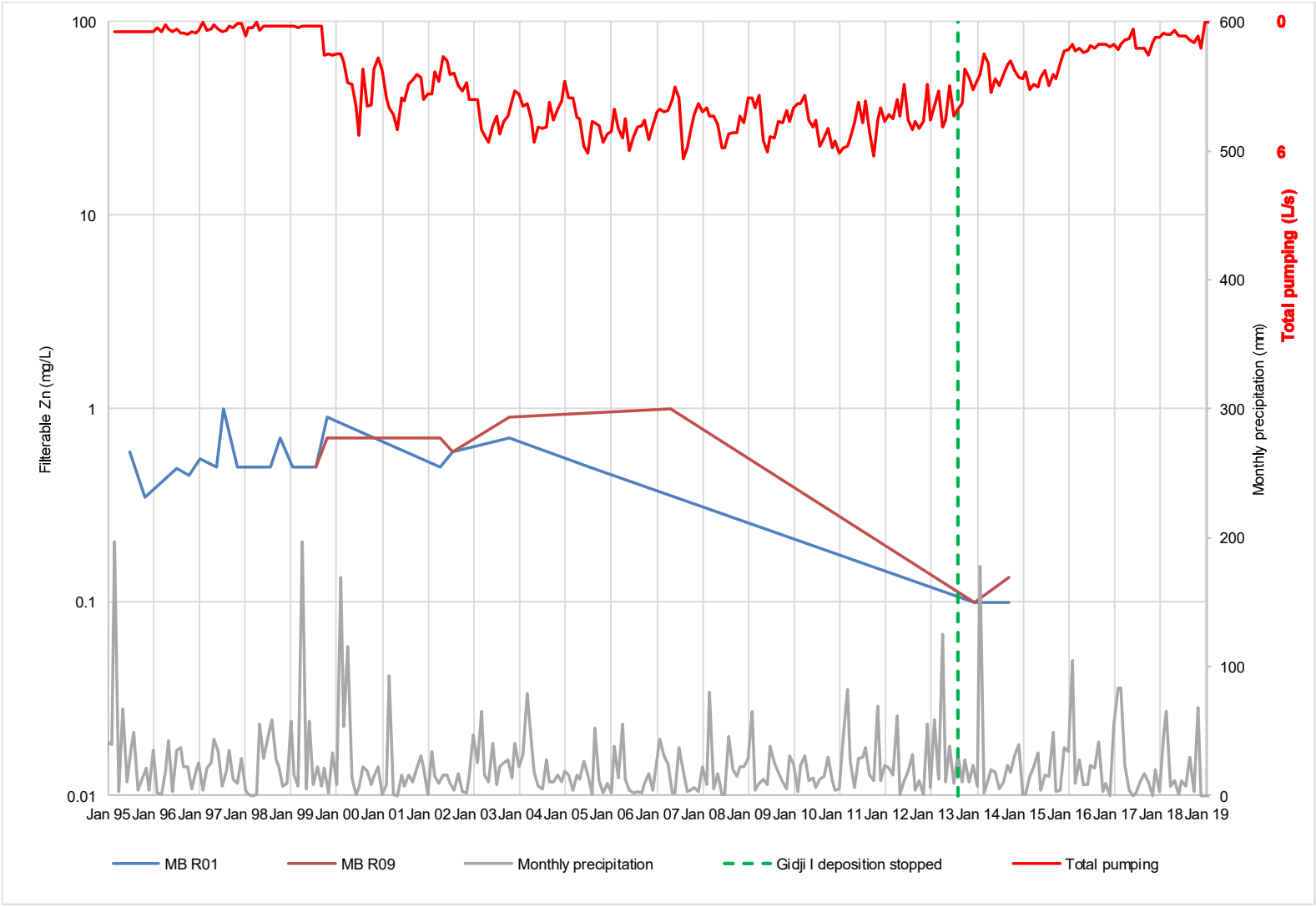
BIG DOG HYDROGEOLOGY

Groundwater Filterable Zn - trench bores

Figure C148

Date: January 2019

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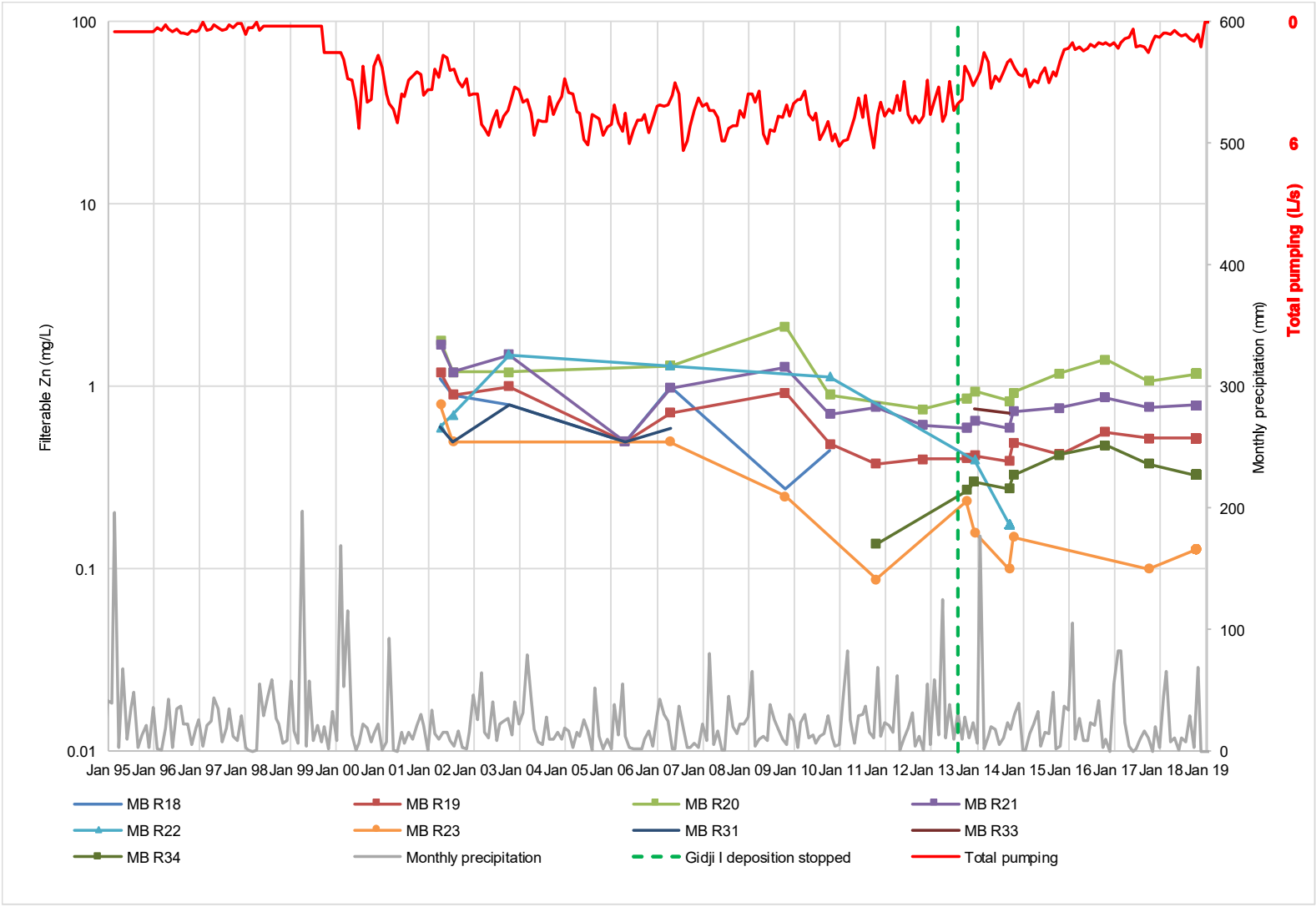
BIG DOG HYDROGEOLOGY

Groundwater Filterable Zn - decant bores

Figure C149

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review



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BIG DOG HYDROGEOLOGY

Groundwater Filterable Zn - eastern bores

Figure C150

Date: January 2019

Report: KCGM Gidji TSF Hydrogeological Review

5.14 Appendix 5.14: GIDJI TSF Erosion Studies

Landloch

LONG-TERM EROSION OF THE GIDJI I AND II TSF EMBANKMENT:

EXPANDED ERODIBILITY TESTING AND EROSION MODELLING RESULTS



Kalgoorlie Consolidated Gold Mines Operations

Northern Star Resources Limited

November 2024

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TOOWOOMBA
PO Box 57
HARLAXTON QLD 4350
Phone (07) 4613 1825

PERTH
PO Box 5175
SOUTH LAKE WA 6164
Phone (08) 9494 2835

NEWCASTLE
PO Box 7017
Redhead NSW 2290
Phone (02) 4965 7717

Landloch Pty Ltd
A.C.N. 011 032 803
A.B.N. 29011032803

Web site: www.landloch.com.au
Email: admin@landloch.com.au

Project Number: 2088.21b

Report Title: Long-term erosion of the Gidji I and II TSF embankment: expanded erodibility testing and erosion modelling results

Client: Kalgoorlie Consolidated Gold Mines Pty Ltd

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1 INTRODUCTION

This report summarises the results of erodibility testing and long-term erosion modelling of surface cover materials undertaken by Landloch Pty Ltd (Landloch) for Kalgoorlie Consolidated Gold Mines Operations (KCGM Operations) as part of closure planning for the Gidji Tailings Storage Facility (TSF).

The report provides results from an expanded erodibility testing regime and erosion modelling program. It builds upon work previously completed by Landloch between 2018 and 2020 and reported previously by Landloch (2021). The previous work focussed on the erosion potential of soils at the Gidji Operational Area. The expanded study includes consideration of the erosion potential of these same soils with the inclusion of rock armour to increase their erosion resistance.

1.1 Project aims

This project seeks to consider the long-term erosion potential of available surface cover materials for the Gidji TSF. The key erosion-related consideration for the closure design is the development of an embankment surface that is erosionally stable in the long-term. Implicit in this aim is the creation of an embankment with a low tendency for rill and gully erosion. The current TSF embankment profile geometry can be used to guide the erosion assessment. Maximum embankment heights of 16m and embankment gradients of 16, 18, and 20° were considered.

This report does not consider aspects related to the:

- TSF capping design in terms of the thickness of layers required in order to manage risks posed by the underlying tailings.
- Design of surface water control features such as engineered rock drains. However, comments will be made as to the risks these structures pose to successful closure.
- Design of the upper surface of the TSF. However, the risks of uncontrolled discharge of runoff from the top to the embankment will be discussed.
- Regional surface water drainage issues.
- Seepage and groundwater issues.
- Management of the geochemical and physical properties of the tailings.

2 BACKGROUND

2.1 The Gidji TSF

The Gidji TSF forms part of the Gidji Operational Area, located 17 km north of Kalgoorlie-Boulder. The Gidji Operational Area also includes tailings processing and water management infrastructure, and a soil stockpile.

The name Gidji TSF is used to describe the combined Gidji I and Gidji II TSFs. Gidji I was constructed in 1988/1989 and Gidji II was constructed in 2011/2012. Gidji I covers an area of 18ha, and is comprised of two cells. The Gidji I starter embankment is constructed from subsoil sourced from within the Gidji I footprint. Subsequent

embankment raises used tailings previously deposited within Gidji I. Gidji II covers an area of 23ha, and is also comprised of two cells. The Gidji II TSF embankment is constructed entirely of previously deposited tailings from Gidji I.

Gidji I is positioned directly to the south-east of Gidji II. The base of Gidji II is lined with clay and a high density polyethylene composite liner. Gidji I is not lined. The soil stockpile lies to the north-east of the Gidji TSF. The layout of the Gidji TSF and the location of the soil stockpile is shown in Figure 1.



Figure 1: Gidji TSF, comprised of Gidji I and Gidji II, and the soil stockpile (Image source: Google Earth).

2.2 Gidji TSF post mining land use

At closure, the Gidji Operational Area will be decommissioned and rehabilitated to a modified landscape, with requirements of the Western Australian *Contaminated Site Act*

(2003) being met. The Gidji TSF has the potential to be an area of restricted access due to the nature of the TSF. Retention of existing fencing to restrict access, particularly in the short-term when vegetation growth is becoming established, and for exclusion of pastoral activities is likely, again to meet the requirements of the *Contaminated Sites Act* (2003) (KCGM 2018).

Consistent with these closure requirements, this assessment on long-term erosion potential has been based on the need to develop erosionally stable surfaces with low risk of rill and gully erosion and with little reliance on vegetation to form a surface cover that positively contributes to erosion resistance. Vegetation may establish (and be required to meet other closure requirements), but is not crucial to the establishment of an erosionally stable embankment surface.

3 BASELINE MATERIAL CHARACTERISATION

3.1 Data sources

Baseline soils and tailings characterisation data were reviewed from three sources:

1. *Gidji I and II TSF: Embankment Erosion Study* (Landloch 2021)
2. *Memorandum: Material Characterisation of topsoil stockpiles at Gidji Tailing Storage Facility* (Howard 2020)
3. *Memorandum: Material Characterisation – Gidji Tailings Storage Facility Extension* (O'Riley 2020)

3.2 Sample details

3.2.1 Landloch (2021) samples

Twelve samples (~5kg each) were collected by H. Jebaliya of KCGM in December 2018. Three of these samples were originally described as tailings sourced from one location (multiple depths) at the toe of the eastern Gidji TSF embankment and 9 samples were soils sourced from 3 locations within the soil stockpile to the north-east of the Gidji TSF. Samples were collected from the surface (0 m) and 1 m and 2.5 m below ground level. Details for the 12 samples as supplied by KCGM are given in Table 1. No sample coordinates were supplied. However it is known that one of the soil sites was located in the northern zone of the stockpile, one was located in the central zone of the stockpile, and one was located in the southern zone of the stockpile.

On inspection of the sample supplied, the surface tailings sample (Tailings - T1) appears to be tailings based on its dark brown/black colour and fine texture. In contrast, the two deeper samples (Tailings - T2 & Tailings - T3) appear to be more like a soil in colour and texture. This is likely due to the deeper materials being taken from the area of the starter embankment that was constructed from soils from within the TSF footprint. Therefore Tailings - T2 and Tailings - T3 are included in this assessment, and Tailings - T1 is excluded.

Table 1: Grab sample details as supplied by KCGM.

Sample ID	Material	Description
Topsoil - N1	Soil	North end, surface sample
Topsoil - N2	Soil	North end, 1m depth
Topsoil - N3	Soil	North end, 2.5m depth
Topsoil - M1	Soil	Middle, surface sample
Topsoil - M2	Soil	Middle, 1m depth
Topsoil - M3	Soil	Middle, 2.5m depth
Topsoil - S1	Soil	South end, surface sample
Topsoil - S2	Soil	South end, 1m depth
Topsoil - S3	Soil	South end, 2.5m depth
Tailings - T1	Tailings	East toe of TSF, surface sample
Tailings - T2	Soil	East toe of TSF, 1m depth
Tailings - T3	Soil	East toe of TSF, 2.5m depth

The 11 soil samples were tested for the following properties:

- $pH_{1:5}$ (water);
- Electrical conductivity ($EC_{1:5}$);
- Exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, and Al^{3+});
- Exchangeable Sodium Percentage (ESP);
- Coarse fragments (>2mm);
- Particle size distribution (coarse sand, fine sand, silt, and clay);
- Emerson dispersion index;
- Saturated hydraulic conductivity, and
- Four point moisture retention curve.
- Total N;
- Total P;
- Organic C;
- Plant available (Colwell) P;
- Plant available (Colwell) K;
- Plant available (KCl) S; and
- Plant available (DTPA extractable) trace elements (Cu, Mn, Zn, Fe).

3.2.2 Howard (2020) samples

Howard (2020) collated historical data reported in Landloch (2021) (outlined above) as well as data reported by Outback Ecology Services (OES) in 2011 (OES 2011). OES analysed 2 samples of stockpiled soils (G01 and G05 in Figure 2) and 5 samples of undisturbed soils (G02, G03, G04, G06, and G07) from land that is now covered by the Gidji II TSF. The soils from this area were stripped and stockpiled within the current soil stockpile on site.

The locations of the sampling are shown in Figure 2. Coordinates are provided in Table 2. Samples were taken from a depth of 0.2-0.4 m below the surface of the stockpile for the undisturbed soils and 0.05-1.0 m below ground level for the stockpiled soils.

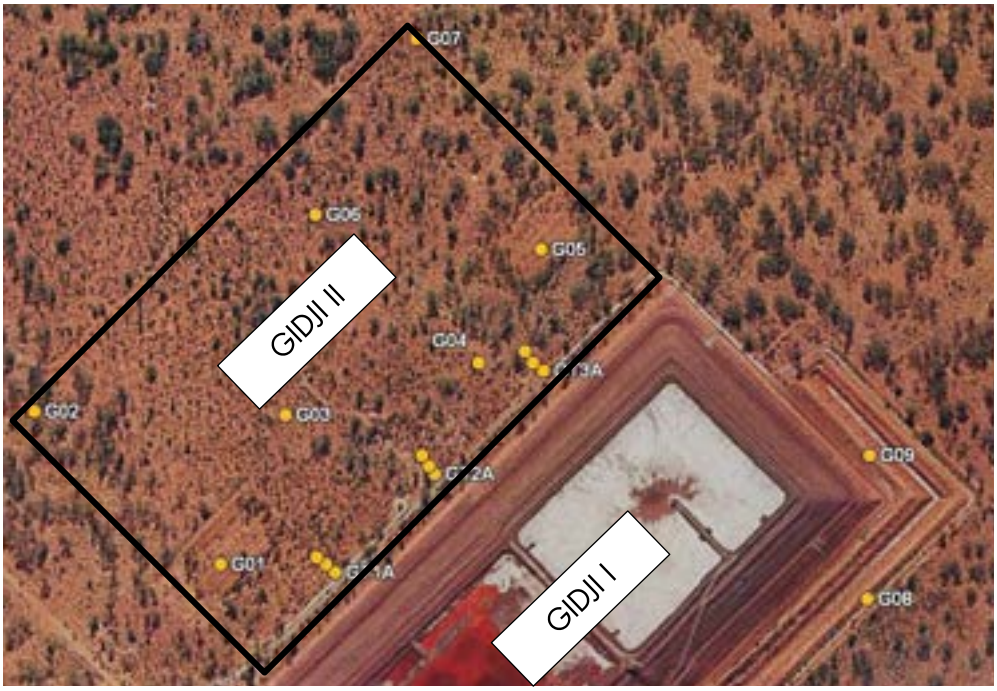


Figure 2: Locations of previous sampling by Outback Ecology Services, with the approximate location of the Gidji II TSF cell superimposed (Image source: Outback Ecology Services (2011)).

Table 2: Details of the OES samples (GDA94, zone 51).

Sample ID	Easting (m)	Northing (m)	Description
G01	351,577	6,615,407	Soil stockpile, with species of *Maireana, Acacia, Atriplex* and *Eremophila*
G02	351,382	6,615,566	Undisturbed soil. Eucalypt woodland with *Maireana sedifolia*, and species of *Eremophila* and *Acacia*
G03	351,645	6,615,563	Undisturbed soil. Open Eucalypt woodland with *Maireana, Atriplex, Acacia*, and *Allocasuarina* spp.
G04	351,847	6,615,617	Undisturbed soil. Eucalypt woodland with *Maireana sedifolia*, and species of *Eremophila* and *Acacia*
G05	351,912	6,615,736	Soil stockpile, with sparse *Maireana, Atriplex* and some annuals
G06	351,676	6,615,772	Undisturbed soil. Eucalypt woodland with *Maireana sedifolia*, and species of *Eremophila* and *Acacia*
G07	351,781	6,615,956	Undisturbed soil. Eucalypt woodland with *Maireana sedifolia*, and species of *Eremophila* and *Acacia*

OES (2011) reported the following properties:

- $pH_{1:5}$ (water);
- Electrical conductivity ($EC_{1:5}$);
- Exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+});
- Exchangeable Sodium Percentage (ESP);
- Coarse fragments (>2mm);
- Emerson dispersion index;
- Texture;
- Organic C; and
- Plant available (Colwell) P & K and plant available (KCl) S.

Howard (2020) also reported data for the stockpiled soils sourced from another 20 locations and 4 depths (except for Site 6 that had only 3 depths due to a smaller stockpile thickness) across the stockpile. Samples were collected in November 2019. The sample coordinates are given in Table 3 and the locations are shown in Figure 3. Samples were collected at each location from depths of 0-0.5m, 0.5-1.0m, 1.0-1.5m, and 1.5-2.0m. Samples at sites TP35 and TP30 were given these codes to align the codes of another sampling program (organised by Golder Associates) that was underway at the same time as Landloch's sampling.

Table 3: Coordinates of 2019 samples (GDA94, zone 51).

Sample ID	Easting (m)	Northing (m)	Sample ID	Easting (m)	Northing (m)
1	352,370	6,615,526	TP35	352,067	6,615,830
2	352,325	6,615,562	11	352,027	6,615,789
3	352,284	6,615,602	12	352,032	6,615,860
4	352,244	6,615,642	13	351,983	6,615,834
5	352,202	6,615,689	14	351,991	6,615,893
6	352,158	6,615,658	15	351,959	6,615,928
7	352,160	6,615,727	16	351,945	6,615,873
8	352,119	6,615,697	TP30	351,900	6,615,900
9	352,116	6,615,773	17	351,920	6,615,974
10	352,078	6,615,742	18	351,884	6,615,929

Seventy-nine (79) samples were collected and assessed for:

- $pH_{1:5}$ (water);
- Electrical Conductivity ($EC_{1:5}$);
- Emerson dispersion index; and
- Texture.

A subset of 20 of these 79 samples were further tested for

- $pH_{1:5}$ (water) (as a check of Landloch's rapid pH measure);
- $EC_{1:5}$ (as a check of Landloch's rapid EC measure);
- Exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, and Al^{3+});

- Effective Cation Exchange Capacity (ECEC);
- Exchangeable Sodium Percent (ESP); and
- Particle size distribution (coarse sand, fine sand, silt, clay).

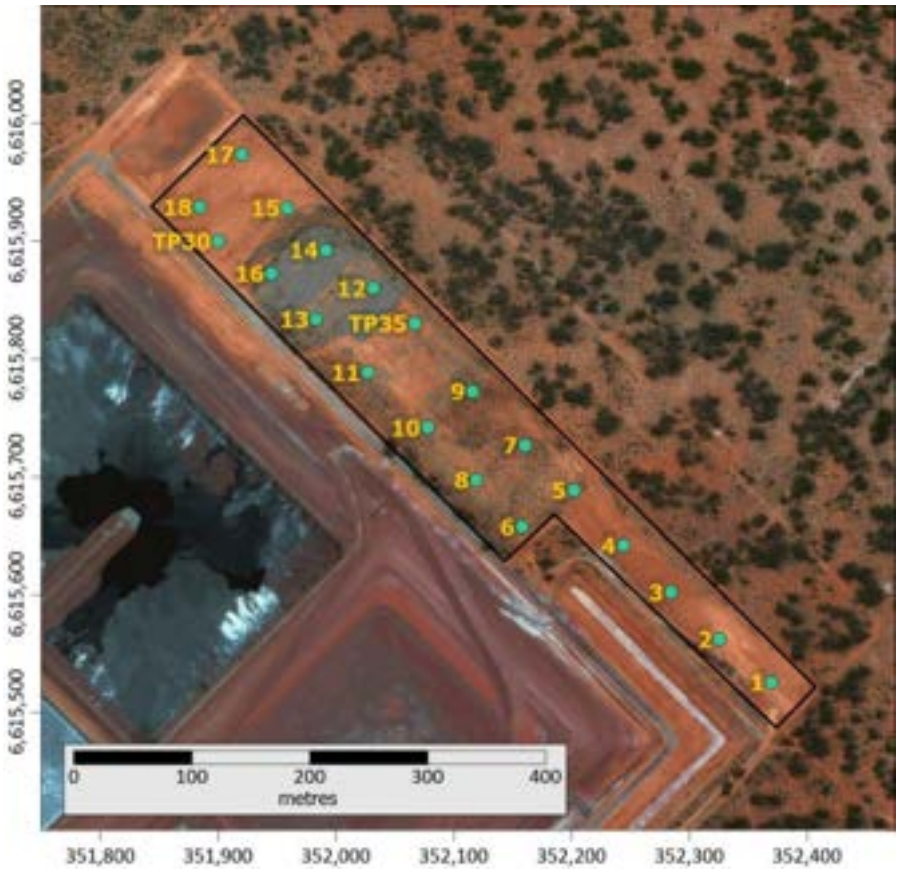


Figure 3: Locations of sampling from the Gidji topsoil stockpile.

3.2.3 O'Riley (2020) samples

O'Riley (2020) collected soil samples from16 undisturbed locations to the north of the existing stockpile as part of planning for an extension of the Gidji TSF. These locations are shown in Figure 4 and detailed in Table 4.

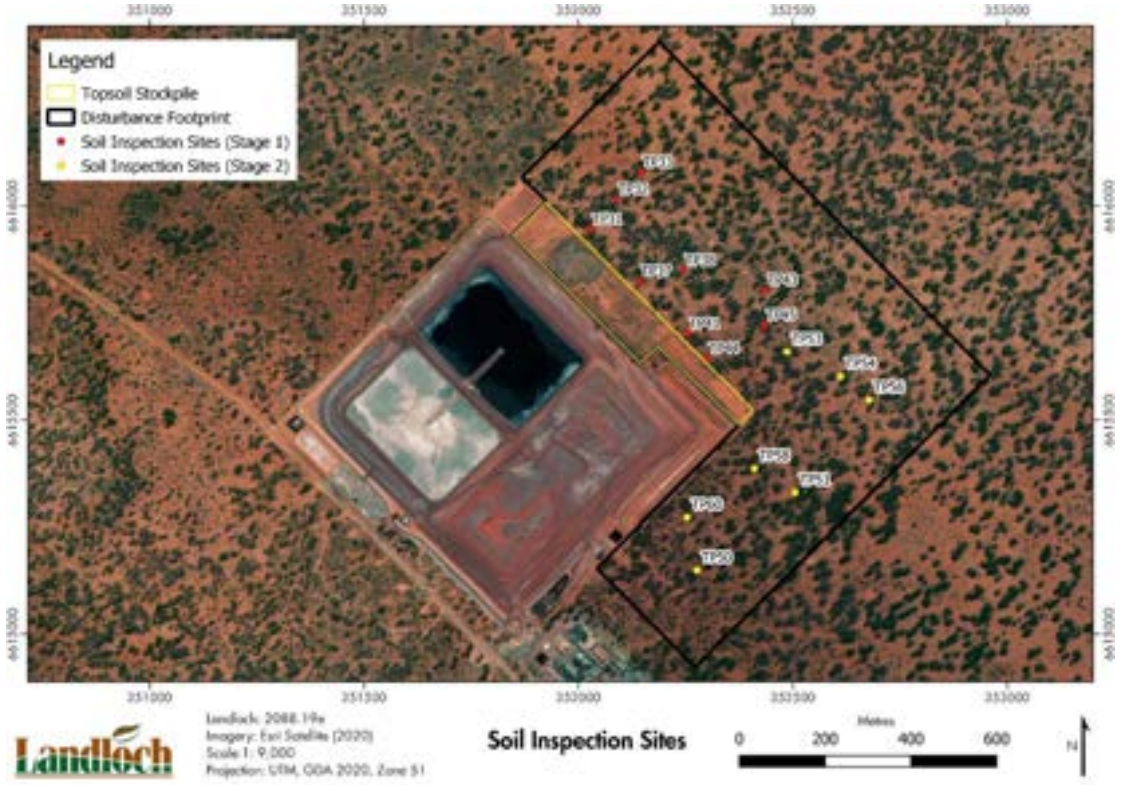


Figure 4: Soil sampling locations for undisturbed soils in a proposed TSF extension area.

Table 4: Soil inspection site coordinates (GDA20, Zone 51).

Soil inspection site	Easting (m)	Northing (m)
TP31	352,026	6,615,944
TP32	352,087	6,616,014
TP33	352,144	6,616,078
TP37	352,140	6,615,823
TP38	352,243	6,615,849
TP41	352,253	6,615,701
TP43	352,435	6,615,802
TP44	352,298	6,615,643
TP45	352,432	6,615,720
TP50	352,276	6,615,149
TP51	352,505	6,615,331
TP53	352,486	6,615,659
TP54	352,611	6,615,602
TP56	352,678	6,615,547
TP58	352,410	6,615,387
TP60	352,253	6,615,273

Samples were collected in two campaigns, 27 samples in campaign 1 (TP31-TP45) and 13 samples in campaign 2 (TP50-TP60). A total of 40 samples were collected. At each site, one sample of the soil (A) horizon, and one or two samples of subsoil from the diagnostic (B) horizon were collected. A summary of the testing conducted on each sample is given in Table 5.

Table 5: Soil laboratory analysis reported in O'Riley (2020)

Parameter	Campaign 1	Campaign 2
$pH_{1:5}$ (water)	✓	✓
$EC_{1:5}$	✓	✓
Total Cl	✓	✓
Exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} & Al^{3+})	✓	✓
Effective cation exchange capacity (ECEC)	✓	✓
Exchangeable sodium percentage (ESP)	✓	✓
Coarse fragments	×	✓
Particle size distribution	✓	✓
Emerson dispersion index*	✓	✓
Colour (Munsell)	×	✓
Organic Carbon	✓	×
Total N & Total P	✓	×
Available P and K (Colwell)	✓	×
Available Sulphur (KCl)	✓	×
Available (DTPA extractable) trace elements (Cu, Zn, Mn & Fe)	✓	×

*A modified Emerson test was also completed for samples with $EC_{1:5}$ >1dS/m. In this test, the sample was pre-leached with deionised water to remove dissolved salts prior to assessment of aggregate stability.

3.3 Results

Across the various sampling campaigns detailed above, a total of 129 soil samples have been assessed. Ninety four (94) were from stockpiled soils and 35 were from undisturbed soil profile. A collation of all the characterisation results is given in Appendix A. The results are summarised in Tables 6 and 7 for the stockpiled and undisturbed soils, respectively. Discussion of the results can be found in the following sections.

3.3.1 Soil pH

The soils are generally moderately alkaline with the median pH of the stockpiled and undisturbed soils being 8.4. Of the 129 samples, 88% are moderately alkaline (8.0-9.0), 5% are slightly alkaline (7-8), and 6% are strongly alkaline (9.0-10.0). Only one sample had an acid pH (6.0). Alkaline soil pH values are common for soils in the vicinity of Kalgoorlie.

3.3.2 Salinity ($EC_{1:5}$) and chloride

The soils are generally saline, with median $EC_{1:5}$values for the stockpiled and undisturbed soils being 0.8dS/m and 1.0dS/m, respectively. Saline soils are common for the Kalgoorlie area. Recent statistical analysis of soils from KCGM indicated that $EC_{1:5}$ values or as much as 2dS/m having little impact on vegetation cover and diversity values. Of the soils assessed, 83% of the soils had $EC_{1:5}$ values <2dS/m. Therefore, the soils can, as a whole, support vegetation growth, with more salt tolerant species likely to perform better than salt sensitive species.

Table 6: Summary of the results of the characterisation of 94 soil stockpile samples

Analyses	Unit	n	Min	Max	Median
pH, EC, Exchangeable Cations, Emerson					
$pH_{1:5}$ (water)	pH units	94	7.9	9.8	8.4
$EC_{1:5}$	dS/m	94	0.1	5.7	0.8
Chloride	mg/kg	31	18	6,226	902
ECEC	meq/100g	33	4.9	56.5	8.4
Ca^{2+}	meq/100g	33	1.6	34.9	3.8
Mg^{2+}	meq/100g	33	1.1	32.5	2.5
K^{+}	meq/100g	33	0.3	1.0	0.5
Na^{+}	meq/100g	32	0.1	21.6	1.4
Al^{3+}	meq/100g	31	0.01	0.02	0.01
ESP	%	32	0.4	42	16
Ca:Mg	-	33	0.6	8.8	2.0
ESI	-	32	0.1	0.78	0.07
Emerson Index	-	94	2	4	4
Water Holding Properties					
K_{sat}	mm/hr	3	12	79	21
PAWC	%	3	7	9	8
Plant Nutrients					
Total N	mg/kg	9	317	522	382
Total P	mg/kg	9	67	101	88
Organic C	%	13	0.2	1.5	0.6
Available P	mg/kg	13	4.5	20	14
Available K	mg/kg	13	213	420	313
Available S	mg/kg	13	8.9	211	42
Available Cu	mg/kg	9	0.7	3.4	1.4
Available Fe	mg/kg	9	7.9	51	17
Available Mn	mg/kg	9	0.2	78	5.2
Available Zn	mg/kg	9	0.3	0.9	0.6
Particle Size Distribution					
Gravel	%	15	0	11	4
Coarse sand	%	31	30.6	53.4	41.9
Fine Sand	%	31	21.3	37.7	30.0
Silt	%	31	1.5	15	5.1
Clay	%	31	13.4	31.4	23.6
Texture	-	92	Sandy Loam	Clay	Sandy Clay

Table 7: Summary of the results of the characterisation of 35 undisturbed soil samples

Analyses	Unit	n	Min	Max	Median
pH, EC, Exchangeable Cations, Emerson					
$pH_{1:5}$ (water)	pH units	30	6.0	9.5	8.4
$EC_{1:5}$	dS/m	30	0.1	7.1	1.0
Chloride	mg/kg	31	36	13,268	1,615
ECEC	meq/100g	27	5.4	22.6	9.3
Ca^{2+}	meq/100g	27	1.5	15.9	5.1
Mg^{2+}	meq/100g	27	1.4	5.9	3.2
K^{+}	meq/100g	27	0.2	0.9	0.5
Na^{+}	meq/100g	27	0.0	0.9	0.5
Al^{3+}	meq/100g	25	0.01	0.03	0.01
ESP	%	27	0.0	41	10
Ca:Mg	-	26	0.5	5.8	1.6
ESI	-	26	0.01	0.77	0.09
Emerson Index	-	27	2	4	3
Water Holding Properties					
K_{sat}	mm/hr	0	-	-	-
PAWC	%	0	-	-	-
Plant Nutrients					
Total N	mg/kg	15	187	912	414
Total P	mg/kg	15	45	223	99
Organic C	%	25	0.04	1.0	0.2
Available P	mg/kg	24	1.5	20	5.8
Available K	mg/kg	25	68	443	249
Available S	mg/kg	25	6.9	484	101
Available Cu	mg/kg	15	0.2	1.8	1.0
Available Fe	mg/kg	15	0.5	16	1.2
Available Mn	mg/kg	14	1.0	47	4.2
Available Zn	mg/kg	6	0.3	1.3	0.5
Particle Size Distribution					
Gravel	%	23	0	15	1.4
Coarse sand	%	25	27.7	47.5	35.8
Fine Sand	%	25	27.8	42.5	33.7
Silt	%	25	4.0	20.8	7.5
Clay	%	25	13.6	29.0	20.6
Texture	-	35	Sandy Loam	Clay	Sandy Clay Loam

The relationship between chloride and $EC_{1:5}$ is shown in Figure 5. The two are strongly correlated, indicating that the salts are largely chloride-based. Chloride-based salts are highly mobile and move with the wetting front during infiltration and percolation of water through soils.

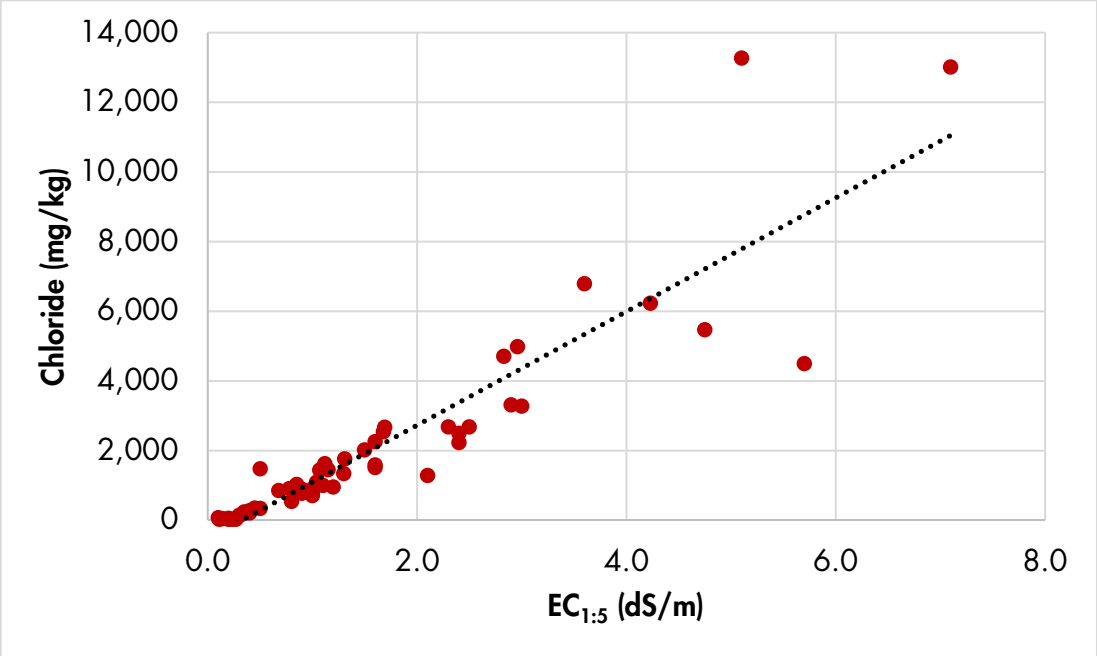


Figure 5: Relationship between chloride and $EC_{1:5}$.

3.3.3 Structural decline of the fine fraction

Landloch considered structural decline of the fine fraction of a material from a range of perspectives.

First, the Exchangeable Sodium Percentage (ESP) is an indicator of structural decline caused by clay dispersion. Typically, ESP values >6% indicate an increased risk of clay dispersion, though clay dispersion is actually influenced by complex interactions between exchangeable cation types, salt concentrations, and clay content.

Second, magnesic soils (those with elevated exchangeable magnesium concentrations relative to the other exchangeable cations) can be dispersive even when the ESP is <6%.

Third, very low salinity can also increase the tendency for soil structural decline, even in soils that, by definition, are not otherwise dispersive. The Electrochemical Stability Index (ESI) has recently been developed as a means of considering the relationship between sodicity and salinity. The ESI is defined as the ratio of EC1:5 and ESP. A tentative critical ESI value for soils is 0.05[1]. Materials with ESI <0.05 can be considered potentially prone to structural decline caused by clay dispersion.

Finally, materials with very high fine sand, silt, and clay fractions (fine sand + silt + clay >70%) are increasingly prone to mobilisation of these fine particles within the macropores of the soil matrix.

To capture these complexities, Landloch defines a material's tendency for structural decline based on four sets of conditions. If any of these sets of conditions are true, the material is classified as being prone to structural decline:

Condition 1) ESP-based criteria:

- ESP > 6%,
- clay content >10%,
- ECEC >3meq/100g, and
- exchangeable sodium concentration >0.3meq/100g.

Condition 2) Exchangeable Mg-based criteria:

- clay content >10%,
- ECEC >3meq/100g, and
- Ratio of exchangeable Ca to exchangeable Mg <0.5.

Condition 3) ESI-based criteria:

- clay content >10%, and
- ESI <0.05.

Condition 4) PSD-based criteria:

- Fine sand + silt + clay >70%

These criteria are summarised in Table 8. The soils are generally classed as prone to structural decline due to high ESP, and sufficient clay content and ECEC. It is noted that clay dispersion may be initially masked in materials with high salinity (>0.5dS/m). High salinity acts to flocculate clay particles and counteracts the dispersion potential present due to the high ESP. However, as soil salinity reduces over time via rainfall infiltration, the tendency for the clay fraction to disperse will increase. Therefore, it is prudent that these materials be managed as being prone to structural decline.

The result of structural decline of these soils can include:

- Increased bulk densities of the surface leading to:
  - poor seed germination and plant growth;
  - reduced infiltration capacity and lower amounts of water being available for plants;
  - increased runoff leading to increased surface erosion potential; and
- Tunnel erosion and potential breaching of the surface cover layer leading to exposure of underlying layers.

Table 8: Assessment of the risk of structural decline

Analysis	Unit	Median Values	
		Stockpile Soils	Undisturbed Soils
ECEC	meq/100g	8.4	9.3
Exchangeable Sodium	meq/100g	1.4	1.2
Ca:Mg	-	2.0	1.6
ESP	%	16	10
ESI	%	0.07	0.08
Clay <0.002mm	%	23.6	20.6
Fine Sand + Silt + Clay	%	58.0	64.1
Condition 1 Result		✓	✓
Condition 2 Result		×	×
Condition 3 Result		×	×
Condition 4 Result		×	×
Prone to structural decline		Yes	Yes

3.3.4 Fertility

The fertility of the soils appears to be suitable for plant growth. The differences between the stockpiled and undisturbed soils are not likely sufficient to cause large differences in plant growth. This is supported by the presence of vegetation on the topsoil stockpile. Amendment with fertiliser is not recommended.

3.3.5 Water holding characteristics

The 3 soils tested for water holding properties all have similar plant available water capacity values (7-9%). Considering a rare rainfall event (AEP of 1% or ARI of 100 years) with a 12 hour duration delivering a rainfall total of 120mm[1], the soils would typically wet to a depth of approximately 1.0 m. This indicates that there are likely to be infrequent storm events that can wet a typical mine landform cover system and allow that water to interact with the underlying tailings.

The materials are slow to moderately permeable, and K_{sat} values ranging from 12-79mm/hr and having a median value of 21mm/hr.

3.4 Selection of bulk samples

A representative bulk sample of the topsoil was sampled from the soil stockpile. The selection was based primarily on the soil's hand texture, $EC_{1:5}$, $pH_{1:5}$ (water), and Emerson class. It was recommended that soil be taken from the southern area of the stockpile, with the sample being limited to the surface 1.5m of the profile. The properties of the bulk soil sample supplied was compared against the median values for the soils. The bulk sample has similar properties to the median soil values except that it has higher salinity (Table 9). The elevated salinity is not expected to significantly change the hydraulic properties of the soil, given that the median soil values are also saline. The bulk soil sample is considered to be a representative sample of the soils sampled across the stockpile.

The bulk sample of waste rock was sourced from run of mine waste. The baseline properties of the waste rock are also given in Table 9.

Additional particle size and rock data were generated for the bulk samples. Figure 6 give the particle size distribution (PSD) curve for the bulk sample of soil and rock. Predicted curves are also provided for a 1:1 soil: rock mixture and a 1:2 soil: rock mixture. These two mixtures were assessed as part of the expanded erodibility study.

The Gidji soil is considerably finer than the waste rock, and the mixtures of soil and rock (as expected) have PSDs that lie between the soil and waste rock.

[1] Based on Intensity-Frequency-Duration (IFD) design storm data supplied by the Bureau of Meteorology for Kalgoorlie-Boulder.

Table 9: Median values for the properties of the stockpiled soils, and properties of the bulk samples of soil and waste rock supplied for testing.

Analyses	Unit	Stockpiled Soils (Median)	Stockpiled Soils (Bulk)	Waste Rock (Bulk)
$pH_{1:5}$ (water)	pH units	8.4	8.7	8.6
$EC_{1:5}$	dS/m	0.8	1.7	0.9
Chloride	mg/kg	902	1,643	499
ECEC	meq/100g	8.4	18.6	3.1
ESP	%	16	15	6.6
Ex. Ca	meq/100g	3.8	9.9	2.3
Ex. Mg	meq/100g	2.5	4.7	0.5
Ex. K	meq/100g	0.5	1.1	0.1
Ex. Na	meq/100g	1.4	2.8	0.2
Ex. Al	meq/100g	0.01	0.01	0.01
Ca:Mg	-	2.0	2.1	4.9
Emerson Class	-	4	4	6
Gravel	%	3.5	12.0	90.0
Coarse Sand	%	41.9	40.4	69.2
Fine Sand	%	30.0	33.0	15.7
Silt	%	5.1	8.8	8.7
Clay	%	23.6	17.8	6.4

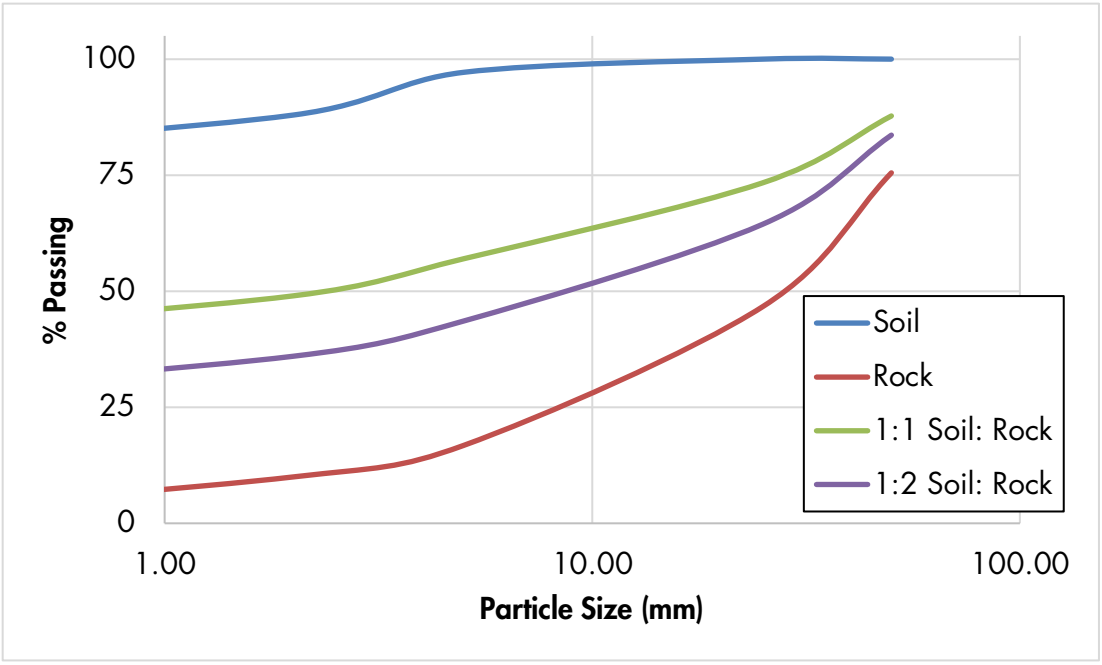


Figure 6: PSD curves for the bulk soil and waste rock samples, and predicted curves for the two soil: rock mixtures assessed as part of this study.

4 LANDFORM DESIGN METHODOLOGY

4.1 Definition of 'acceptable' erosion

Some degree of erosion will always occur from any land surface. The concept of 'acceptable' erosion is widely mentioned, but common definitions appear to have little relevance to minesite rehabilitation. For example, Wischmeier and Smith (1978) defined tolerable soil loss for cropland as "*the maximum rate of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely.*" A value of 4.5t/ha/y was developed for erosion of rangeland soils and shallow cultivated soils by USA soil conservation agencies (Wight and Siddoway 1982) using similar criteria to those applied for crop land (i.e., maintenance of land productivity). In contrast to only considering land productivity, Landloch's approach to landform design aims to create rehabilitated slopes on which rilling will be minimised. In the mining context, rilling:

- Is most likely to lead to further flow concentration and possibly drive the formation of gullies that is turn will greatly accelerate erosion rate over time.
- Generates significantly more sediment by weight than interrill erosion;
- Is more likely to increase the risk that the integrity of a sheeting layer is compromised, possibly exposing problematic wastes below the sheeting layer;
- Increases the removal of materials from the land surface which in turn negatively impacts on vegetation establishment and growth in areas affected by rills; and
- Is a more visible form of erosion than interrill erosion, and is often the focus of erosion assessments by regulators.

In Landloch's experience, erosion rates that produce batters with a low tendency to rill are :

- Mean average annual erosion – 5t/ha/y
- Mean peak annual erosion – 10t/ha/y

These are consistent with the findings of the *Acceptable erosion rates for mine waste landform rehabilitation modelling in the Pilbara, Western Australia* (Howard and Loch 2019). Although this study used Pilbara data, much of the results are relevant for erosion in arid lands. As part of the project, a review of information relating to erosion rates on natural and man-made landforms was conducted. This review showed that a wide range of approaches have been used to define acceptable erosion rates, including linking them to rates of soil formation; maintenance of soil quality, which may include considerations of plant/crop productivity, effective soil depth, and soil organic matter and nutrient stores; rates of natural erosion in adjoining areas; potential for gully formation; and water quality impacts. Based on this review, a guideline was developed to define acceptable erosion rates for use in the design of stable mine waste landforms. The rates listed above are consistent with those rates associated with landforms with a moderate risk of erosion occurring. They are also consistent with the threshold values used for other landforms across KCGM.

4.2 Computer simulation of runoff and erosion

4.2.1 The WEPP model

The WEPP model was developed by the United States Department of Agriculture to predict runoff, erosion, and deposition for hillslopes.

WEPP is a simulation model with a daily input time step, although internal calculations on days when rainfall occurs uses shorter time steps. Plant and soil characteristics important to erosion processes are updated every day. When rainfall occurs, those plant and soil characteristics are considered in determining the likelihood of runoff. If runoff is predicted to occur, the model computes sediment detachment, transport, and deposition at points along the slope profile.

The erosion component of the WEPP model uses a steady-state sediment continuity equation as the basis for the erosion computations. Soil detachment in interrill areas is calculated as a function of the effective rainfall intensity and runoff rate. Soil detachment in rills is predicted to occur if the flow hydraulic shear stress is greater than the soil's critical shear stress, and when the sediment load of the flow is below its transport capacity. Deposition in rills is computed when the sediment load is greater than the capacity of the flow to transport it.

All WEPP model simulations completed by Landloch uses a 100-year stochastic climate sequence for the site developed from observed daily and sub-daily data from nearby weather stations.

4.2.2 Climate file

Climate sequences are needed to simulate runoff and soil loss with the WEPP model. For each day of simulation, WEPP requires ten daily weather variables:

- Precipitation (mm),
- Precipitation duration (hr),
- Peak storm intensity,
- Time to storm peak,
- Average minimum temperature,
- Average maximum temperature,
- Dew point temperature,
- Solar radiation,
- Wind speed, and
- Wind direction.

Of these, the four rainfall-related variables (underlined in list above) are of particular importance because previous studies have shown that predicted runoff and erosion are most sensitive to these rainfall variables (Nearing *et al.* 1990; Chaves and Nearing 1991). For most sites around the world, complete historical weather data on these variables are not available. To use WEPP for runoff and erosion prediction, synthetic weather sequences that statistically preserve the mean and variations in the historical observations are required.

CLIGEN is a stochastic weather generator that can be used to provide WEPP climate input files. CLIGEN has been extensively assessed for a wide range of climates in Australia, and it was found that CLIGEN was most suitable to provide the required climate input for WEPP to predict runoff and erosion in Australia (Yu 2003).

Daily climate data for KCGM were sourced from the Australian Bureau of Meteorology (BoM) through the SILO Patched Point data facility. Patched Point data provides a continuous daily data set of observed rainfall, temperature, and solar radiation data, with any missing data points being 'patched' with data from nearby stations. Where no other stations are nearby data is patched with the average of the observed data for the same day and month from other years. The Kalgoorlie-Boulder climate site was used. Rainfall intensity (6-minute pluviograph) data were also sourced from the Bureau of Meteorology for Kalgoorlie-Boulder. Using the two data sets, the following parameter values were computed and used to develop the synthetic climate sequence for the site:

- Mean daily rainfall on wet days for each month,
- Standard deviation and skewness coefficient of daily rainfall for each month,
- Probability of a wet day following a dry day for each month,
- Probability of a wet day following a wet day for each month,
- Mean daily max. temperature for each month,
- Standard deviation of daily max. temperature for each month,
- Mean daily min. temperature for each month,
- Standard deviation of daily min. temperature for each month,
- Mean maximum 30-min rainfall intensity for each month, and
- Probability distribution of the dimensionless time to peak storm intensity.

These parameter values were assembled to create a CLIGEN parameter file for the site. Wind data (used to calculate soil evaporation) were not synthesised by CLIGEN because Priestley-Taylor's method for estimating the potential evaporation will automatically be used by WEPP. A 100-year climate sequence was generated using CLIGEN version 5.1 (Yu 2002).

4.2.3 Determination of WEPP erodibility parameters

Interrill erodibility (K_i) describes the detachment and movement of particles by the combined action of raindrops and shallow overland flows. Rill erodibility (K_R) describes the detachment of particles by shear stresses caused by concentrated flows. Critical shear for rill initiation (τ_c) is the shear stress applied by concentrated flows to the surface above which particle detachment and transport by flow rapidly increases and rills form. Within WEPP, effective hydraulic conductivity (K_e) defines the rate of water movement through a defined soil profile in response to wetting by rainfall, and is derived through analysis of a material's steady infiltration and runoff rates. Effective hydraulic conductivity that required within the van Genuchten water retention model, and is different to saturated hydraulic conductivity.

The calibrated WEPP erodibility parameters for the topsoil were derived from data collected using laboratory-based experimental methods involving the application of:

- Simulated rain and measurement of runoff rate and sediment loads in runoff to obtain estimates of K_i and K_e;
- Concentrated surface water flows, and measurement of flow characteristics and sediment loads to obtain estimates of K_R and τ_c; and
- Settling columns to obtain estimates of settling velocity that in turn was used in the model to describe sediment particle size and density distributions.

Interrill erosion was measured by applying simulated rain with known rainfall intensity to simulation plots 0.75m wide and 0.75m long. Rill erosion was measured by applying overland flow to simulation flumes 0.4m wide and 2.0m long.

Estimates of erosion rates are sensitive to the particle size and density distributions of the eroded sediment. The version of the WEPP model available for general use has been coded to estimate sediment properties solely on the basis of input soil particle size distribution data. However, Landloch has access to a version of WEPP not otherwise available that specifically allows input of detailed sediment particle size and density distributions. This modified version of the WEPP has been applied in this study because it can more accurately predict erosion. Settling columns were used to develop equivalent sand size distributions for the sediment (Loch 2001). This approach is particularly useful as it integrates both particle size and density distributions into a data set that can be readily entered into the WEPP model. Consequently, several samples of the rain-impacted surface of all samples were taken using sampling and handling methods described by Loch (1994). Images from the simulations undertaken are provided in Appendix B.

4.2.4 WEPP model input conditions considered within simulations

WEPP simulations were conducted using the topsoil tested in this project without addition of rock armour and with addition of rock armour. Two mixing ratios were considered: 1:1 soil:rock and 1:2 soil:rock.

When topsoil without addition of rock armour was considered, rill spacing was set at 5 m, consistent with a soil surface that contains considerable fines and that is prone to rill erosion. When topsoil with addition of rock armour was considered, rill spacing was set at 1 m, consistent with a surface with a lower tendency to extensively rill.

Surface roughness was set at 3 cm for both the topsoil without rock addition and the topsoil with rock addition. This setting is consistent with the value used when calibrating the model runoff predictions using the rainfall simulator infiltration data.

WEPP model runs were performed without runoff from upslope areas discharging onto the embankment surface being simulated. If discharge does occur, erosion rates are likely to be considerably higher than those predicted in this modelling.

4.2.5 Vegetation impacts on long-term erosion

The impacts of vegetation on reducing erosion were discounted because of the low surface contact cover levels that are typically achieved in the WA Goldfields region. Vegetation within the Kalgoorlie area has projected foliar cover levels of 5-15% (DPIRD

2019). This means that basal cover levels (grasses in direct contact with the surface) would be in the order of <5%.

The Revised Universal Soil Loss Equation's (RUSLE) (Renard *et al.* 1997) cover factor provides a useful benchmark when the effects of vegetation on erosion are being considered. Figure 7 is a typical curve relating erosion by water (soil loss) and surface contact cover for an arid zone soil with few trees and large shrubs. For a 0-5% surface contact cover level (shaded in green in Figure 7), erosion could be expected to be ~90-100% of the erosion that would occur from an unvegetated surface. Therefore, although vegetation has some impact on soil erosion, it is unlikely to be able to manage erosion risk in the long-term at KCGM. This means that the surface created during rehabilitation must be suitably stable against erosion without the assistance of vegetation. This approach will ensure stability is reached quickly, and that periodic events such as fire or drought, and other pressures such as grazing will not adversely impact erosion potential. Further, surfaces that are erosionally stable are also more likely to support the germination and growth of vegetation than surfaces that are mobile and erosion prone.

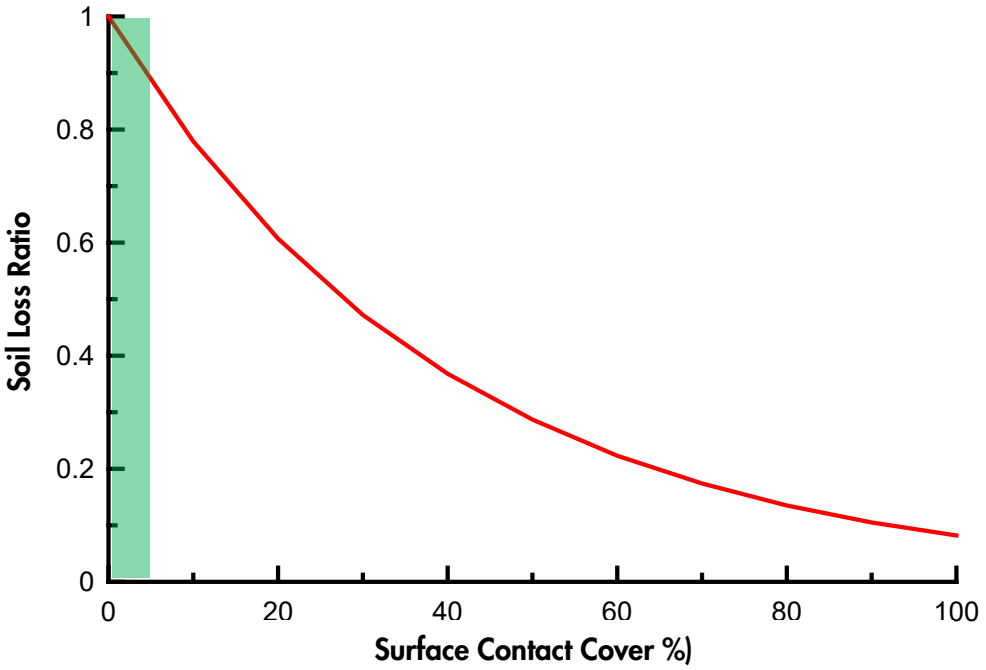


Figure 7: Soil loss ratio for a range of contact cover levels. A soil loss ratio of 1 is the erosion rate of a bare, unvegetated soil. A soil loss ratio of 0 is a soil with 100% surface contact cover.

5 RESULTS

5.1 WEPP parameters

The WEPP model erodibility parameters derived by laboratory testing are provided in Table 10.

Table 10: WEPP parameters derived from laboratory testing.

Material	Effective hydraulic conductivity, K_e	Interrill erodibility, K_i	Rill erodibility, K_R	Critical shear, τ_c
	mm/h	kg.s/m^4	s/m	Pa
Soil	7	2,161,120	0.0181	6
1:1 Soil:Rock	10	770,839	0.0008	27
1:2 Soil:Rock	7	551,340	0.0010	57

All three materials have low effective hydraulic conductivity (K_e), consistent with a material with a surface prone to some structural decline. The addition of rock has not caused an increase in K_e as can occur in some instances. This suggests that the waste is flowing predominantly through the soil matrix and not through pore spaces created by the rock. Interrill erodibility (K_i) values are quite high for the topsoil, and decrease as rock content increases. This is due to a decrease in the surface area open to detachment by raindrop impact (rock particles do not detach under rain). Critical shear (τ_c) is low for the soil, and significantly increases when rock is added. This means that the topsoil will be prone to rill erosion over short slope lengths, whereas the rock will be less prone to rilling and can likely be used on longer slope lengths. The rill erodibility (K_R) result is also high for the soil, and decreases when rock is added. This means that rill development is more likely for the soil than for either of the surfaces to which rock has been added.

The sediment properties of the three surfaces tested are given in Figure 8. All materials produce relatively small amounts of sediment that is highly transportable (~20%). The sediment produced by the soil is finer than that produce from either of the soil:rock mixtures. The two soil:rock mixtures produce sediments with similar particle size distributions.

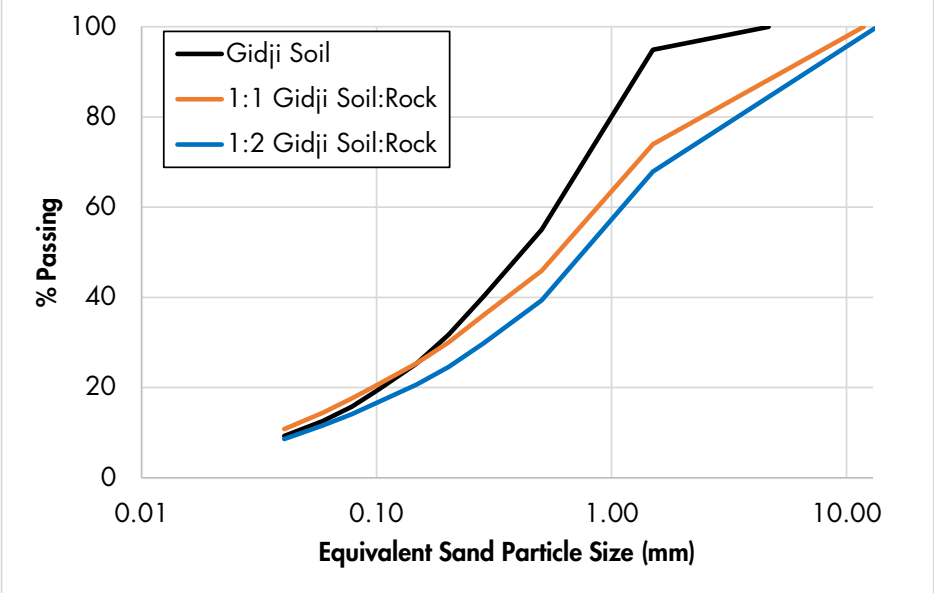


Figure 8: Sediment properties.

5.2 WEPP modelling results

5.2.1 16m high, 16-20° uniform slope

WEPP was used to model erosion for a 16m high uniform (linear) slope without any water discharging from the TSF top to the embankments. Gradients of 16, 18, and 20° were considered. Results for the uniform slope are shown in Table 11. Cells shaded orange indicate embankment geometries that are predicted to erode at unacceptable rates. Cells shaded green indicate embankment geometries that are predicted to erode at acceptable rates.

The uniform gradient profile sheeted with topsoil is predicted to erode at very high rates. It is likely that the soil without addition of any rock armour will rill heavily, with rills cutting through the soil layer until the underlying layers are exposed. At this point, the erosion rates of the batter are likely to change to match the erodibility of the underlying materials. Based on this finding, placement of a topsoil layer on a uniform embankment at the Gidji TSF is not recommended without addition of rock armour to the soil.

The 1:1 soil: rock mixture reduces mean average annual erosion rates to 0.4-0.5t/ha/y, well below the acceptable level or 5t/ha/y. The rockier 1:2 soil rock mixture achieves even lower erosion rates (0.2t/ha/y), though this further reduction is not necessary given that acceptable rates are achieved using the 1:1 soil: rock mixture.

Table 11: WEPP erosion results for 16m high, uniform gradient batter profile without run-on from the TSF top.

Sample	Batter Height (m)	Uniform Gradient (°)	WEPP-Predicted Long-term Average Annual Erosion (t/ha/y)	
			Mean	Peak
Soil	16	16	120	138
	16	18	133	154
	16	20	146	171
1:1 Soil: Rock	16	16	0.4	1.5
	16	18	0.4	1.7
	16	20	0.5	1.8
1:2 Soil: Rock	16	16	0.2	0.2
	16	18	0.2	0.2
	16	20	0.2	0.2

Though not modelled as part of this project, these results indicate that if a rock armour is applied, erosionally stable slope heights greater than 16 m could be achieved.

6 DISCUSSION

Erosion modelling results of the rock-armoured soil slopes indicate that acceptable erosion rates can be achieved with the addition of rock armour to the Gidji soil. Use of the Gidji soil by itself (without rock addition) would result is high erosion rates on the embankments and extensive rill erosion.

Adoption of a suitable soil/rock mixing ratio is important. The 1:1 soil: rock mixture is predicted to erode at acceptable erosion rates for the 16 m high lift without run-on from the TSF top discharging to the embankment. Use of the rockier 1:2 soil:rock mixture is not required as acceptable erosion rates are achieved for the 1:1 soil:rock mixture. This will mean that less rock is rock to be sourced and transported to Gidji; this will have implications for cost as transport costs will be reduced.

7 CONCLUDING REMARKS

Erosion potential for the Gidji soil has been assessed. The assessment is based on:

- Consideration of the prevailing climate and its erosivity.
- Known factors critical for stability of natural and disturbed surfaces.
- Assessment of the variability of materials found on site.
- Characterisation of the erodibility of the soil at Gidji and mixtures of that soil with run of mine waste from KCGM.
- Computer simulations of runoff and erosion on the range of typical slopes.

Consequently, the results are based on site data and its interpretation using well-validated procedures.

7.1 Conclusions from the erosion study

The following points summarise the findings of the erosion study:

1. The Gidji soil was characterised and the bulk sample tested was shown to be representative of the soil resource available for rehabilitation of the Gidji TSF.
2. The bulk sample of the Gidji soil was characterised by experimental methods to derive the key erodibility parameters to calibrate the WEPP model. Rock was also added to the soil at 1:1 soil:rock and 1:2 soil:rock mixture ratios and these mixtures were also assessed for erodibility.
3. WEPP simulations show that for a slope 16m high and with a gradient of 16-20°, the Gidji soil will not be capable of providing a safe, stable, and sustainable surface for closure in terms of its erosional performance. It is likely to erode at high rates, be prone to extensive rill erosion, and expose the underlying materials.
4. If uncontrolled runoff from the top of the TSF is allowed to discharge to a soil-covered embankment, erosion rates will increase to rates that are even higher than those reported for the scenario where runoff is controlled on the TSF top.
5. Mixing fresh waste rock into the soil at the surface to create a soil-rock layer is predicted to significantly reduce long-term erosion rates.
6. A mixing ratio of 1:1 soil: rock is sufficient to produce an erosionally stable surface. Rockier slopes are not required, unless slope heights greater than 16 m are considered as part of closure of the Gidji TSF.
7. Adoption of the less rocky (1:1) mixture will mean that less rock will be needed to be sourced for rehabilitation, compared to adoption of the rockier (1:2) mixture.

8. Linear designs only were considered for the embankment because:
    a. the very high erosion rates of the soil meant that concave designs would provide insufficient additional erosion protection and would not lead to acceptable long-term erosion rates.
    b. The 1:1 soil:rock mixture was very stable and did not require use of a concave profile. A concave profile could be adopted for reasons other than stability if desired (e.g. aesthetics)
9. More complex shapes were also not considered for the same reasons as above. These would include:
    a. shapes with batters that are non-uniform in plan view (i.e. contain ridges and swales).
    b. Shapes that allow discharge from the TSF top onto the batters. Given the predicted erosion resistance of the rock-armoured batters, it could be possible to consider a water discharging landform for rehabilitation.
10. Closure plans often contemplate the use of rock drains as a means of conveying runoff from the top of the TSF to the base of the embankment. Rock drains are an observed point of failure in closure designs because:
    a. They often contain insufficient capacity to convey overland flow (while maintaining free board);
    b. They are poorly placed and constructed;
    c. Their inlet can become blocked with sediment over time, causing water and sediment to then discharge in an uncontrolled manner next to the drain;
    d. Settlement of the freshly constructed rehabilitation surface via consolidation can cause the inlet to sit higher than the surrounding surface and water to not flow into the drain, which in turn can lead to ponding and potentially overtopping of the embankment next to the drain; and/or
    e. The substrate used is prone to tunnel erosion.
11. The need for engineered structures should be considered, and reliance on their use reduced wherever possible. If they are used, they should be designed having adequately considered the risks detailed above. They should be able to be shown to the stable for a period of several hundred years.
12. Long-term erosion should be further considered using a landform evolution model such as SIBERIA. This assessment would consider erosion of the final rehabilitated three-dimensional (3D) TSF shape. The 3D shape would need to include any runoff control structures such as rock drains or crest bunds. The erodibility testing of the different mixing ratios done in this study could be incorporated into this next stage of landform design, and would provide material-specific input parameters for the landform evolution model. Use of material-specific input parameters will increase the robustness of the landform evolution model output.

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APPENDIX A – COLLATION OF SOILS DATA

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Sample ID	Depth	$pH_{1:5}$ (water)	$EC_{1:5}$	Chloride	Extraction Method	ECEC	ESP	Ex. Ca	Ex. Mg	Ex. K	Ex. Na	Ex. Al	Ca:Mg	ESI	Emerson Class	Gravel	Coarse Sand	Fine Sand	Silt	Clay	Hand texture	K_{sat}	33kPa Moisture Content	100kPa Moisture Content	300kPa Moisture Content	1,500kPa Moisture Content	PAWC	Total N	Total P	Avail. P	Avail. K	Avail. S	Organic C	Extract. Cu	Extract. Fe	Extract. Mn	Extract. Zn	Extract. B
	m	pH units	dS/m	mg/kg	-	meq/100g	%	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	-	-	-	%	%	%	%	%	-	mm/h	%	%	%	%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
n		94	94	31	-	33	32	33	33	33	32	31	33	32	94	15	31	31	31	31	92	3	3	3	3	3	3	9	9	13	13	13	13	9	9	9	9	9
Topsoil - N1	0	9.77	0.27	20.1	15C1	30.8	10.64	22.07	4.98	0.48	3.28	0.01	4.4	0.03	4	10.7	40.3	31.8	5.1	22.8	LMC	-	-	-	-	-	-	317	67.1	13.5	213	14	0.79	1.42	23.1	9.2	0.87	0.6
Topsoil - N2	1	8.66	0.5	1,473	15C1	32.6	11.68	23.26	4.99	0.52	3.8	0.01	4.7	0.04	4	3.5	38.4	31.9	7.3	22.4	LMC	12	22	15	14	13	9	504	92.9	20.1	276	133	0.43	0.88	7.9	0.5	0.36	1.29
Topsoil - N3	2.5	8.71	1.07	1,432	15C1	29.8	14.77	19.99	4.99	0.38	4.4	0.01	4	0.07	4	4.7	43.4	27	7.2	22.4	ZCL	-	-	-	-	-	-	522	92.9	10.2	286	120	0.35	1.36	50.6	77.9	0.86	0.27
Topsoil - M1	0	8.54	0.11	17.8	15C1	11.1	2.71	7.78	2.5	0.48	0.3	0.01	3.1	0.04	4	3.2	53.4	25.9	7.2	13.4	SL	-	-	-	-	-	-	367	87.2	16.9	313	13.3	0.43	1.98	23	5.15	0.65	1.02
Topsoil - M2	1	9.09	0.23	25.2	15C1	27.8	5.34	20.74	4.99	0.55	1.48	0.01	4.2	0.04	4	7.4	43.8	34	3.5	18.7	LC	79	19	14	13	12	7	440	87.5	15.4	282	35.9	1.53	2.68	26.8	8.09	0.63	1.26
Topsoil - M3	2.5	9.12	0.32	160	15C1	29.3	9.74	20.05	5.78	0.62	2.86	0.01	3.5	0.03	4	10.2	48.3	33.8	2.3	15.6	LC	-	-	-	-	-	-	348	91.2	11.9	308	29.2	0.24	3.38	16.7	14.9	0.55	1.03
Topsoil - S1	0	8.94	1.04	1083	15C1	31.7	17.23	20.49	5.18	0.59	5.47	0.01	4	0.06	4	7.9	40.8	31.9	4	23.3	LC	-	-	-	-	-	-	382	75.1	18.7	285	211	0.46	0.98	7.91	0.23	0.44	4.35
Topsoil - S2	1	8.65	0.78	902	15C1	56.2	4.84	20.48	32.47	0.51	2.72	0.01	0.6	0.16	4	5.4	42.4	28.9	3.9	24.8	ZCL	21	18	12	11	10	8	442	83.7	14.8	334	101	0.39	0.89	7.9	0.9	0.33	1.15
Topsoil - S3	2.5	8.53	0.45	346	15C1	28.6	4.09	23.49	3.33	0.59	1.17	0.01	7.1	0.11	4	3.1	43.8	30	3.8	22.4	CL	-	-	-	-	-	-	328	101	17.9	323	42.1	0.57	0.66	8.11	0.61	0.4	0.6
Tailings - T2	1	8.36	4.23	6,226	15C1	51.8	41.67	22.22	7.45	0.54	21.59	0.01	3	0.10	4	6.1	35.6	27.2	10.5	26.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tailings - T3	2.5	7.85	4.75	5,468	15C1	56.5	24.31	34.94	7.29	0.5	13.73	0.01	4.8	0.20	4	1.2	35.3	29.5	10.5	24.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G01	0.05	8.5	0.11	-	-	19.7	-	16.8	1.9	1	-	-	8.8	-	4	1.9	-	-	-	-	SCL	-	-	-	-	-	-	-	-	12	420	8.9	0.64	-	-	-	-	-
G01	1	8.55	0.31	-	-	20.7	0.4	17.1	2.7	0.8	0.1	-	6.3	0.78	4	3	-	-	-	-	CL	-	-	-	-	-	-	-	-	4.5	371	96	0.69	-	-	-	-	-
G05	0.05	8.5	0.11	-	-	-	-	-	-	-	-	-	-	-	4	0	-	-	-	-	SCL	-	-	-	-	-	-	-	-	12	420	8.9	0.64	-	-	-	-	-
G05	1	8.55	0.31	-	-	-	-	-	-	-	-	-	-	-	4	0	-	-	-	-	CL	-	-	-	-	-	-	-	-	4.5	371	96	0.69	-	-	-	-	-
1	0.5	8.7	3	3,274	-	8.4	38.5	2.27	2.48	0.43	3.25	0.01	0.9	0.08	3	-	32.5	21.3	14.8	31.4	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	1	8.9	2.4	2,494	-	7.6	35.9	1.99	2.48	0.42	2.74	0.01	0.8	0.07	2	-	33.1	21.7	15	30	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	1.5	8.9	2.1	1,279	-	6.1	35	1.61	1.96	0.37	2.13	0.01	0.8	0.06	2	-	30.6	23.7	14.7	31	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	2	8.5	2.4	2,223	-	10	21.2	4.04	3.3	0.53	2.12	0.02	1.2	0.11	4	-	33.8	25.8	11.1	29.5	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	0.5	9.4	3.4	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	1	9.4	1.8	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	1.5	8.9	1.2	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	2	8.4	2.3	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	SCL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	0.5	8.5	1	760	-	7.5	12.5	4.12	2.01	0.44	0.94	0.01	2.0	0.08	3	-	48.4	32.2	1.5	17.8	SCL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	1	8.4	1.6	1,583	-	9	18.9	4.15	2.71	0.44	1.7	0.01	1.5	0.08	3	-	46.2	31.2	7	15.6	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	1.5	8.4	2.3	2,679	-	9	22.7	3.77	2.67	0.53	2.04	0.01	1.4	0.10	3	-	43.7	29.2	5.3	21.7	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	2	8.3	5.7	4,490	-	7.5	17	3.49	2.36	0.33	1.27	0.01	1.5	0.34	4	-	36.6	37.7	5.4	20.3	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	0.5	8.4	2.5	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	1	8.9	2.7	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	1.5	8.9	3.3	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	2	8.9	2.8	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	0.5	8.4	0.5	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	1	8.4	0.8	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	1.5	8.4	0.7	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	2	8.4	0.7	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	0.5	8.4	0.7	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	1	8.4	1.1	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	1.5	8.4	0.9	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	0.5	8.4	0.5	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	1	8.4	1.3	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	1.5	8.4	0.8	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	2	8.4	0.7	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	0.5	8.4	0.7	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	1	8.4	0.9	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	1.5	8.4	0.4	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	2	8.4	1.3	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Sample ID	Depth	$pH_{1:5}$ (water)	$EC_{1:5}$	Chloride	Extraction Method	ECEC	ESP	Ex. Ca	Ex. Mg	Ex. K	Ex. Na	Ex. Al	Ca:Mg	ESI	Emerson Class	Gravel	Coarse Sand	Fine Sand	Silt	Clay	Hand texture	K_{sat}	33kPa Moisture Content	100kPa Moisture Content	300kPa Moisture Content	1,500kPa Moisture Content	PAWC	Total N	Total P	Avail. P	Avail. K	Avail. S	Organic C	Extract. Cu	Extract. Fe	Extract. Mn	Extract. Zn	Extract. B
	m	pH units	dS/m	mg/kg	-	meq/100g	%	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	-	-	-	%	%	%	%	%	-	mm/h	%	%	%	%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
n		94	94	31	-	33	32	33	33	33	32	31	33	32	94	15	31	31	31	31	92	3	3	3	3	3	3	9	9	13	13	13	13	9	9	9	9	9
9	0.5	8.4	1.3	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	1	8.4	1.1	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	1.5	8.4	1	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	2	8.4	0.8	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	0.5	9	0.2	26.7	-	5.3	12.1	3.08	1.16	0.43	0.64	0.01	2.7	0.02	3	-	42.9	30.1	1.6	25.4	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	1	9.1	0.2	52.5	-	5.3	15	2.86	1.16	0.47	0.79	0.01	2.5	0.01	3	-	42	32.6	1.6	23.8	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	1.5	8.9	0.3	129	-	5.2	11.7	2.98	1.12	0.51	0.61	0.01	2.7	0.03	4	-	47.9	29.2	1.5	21.3	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	2	8.7	0.4	272	-	5.3	9.8	3.03	1.27	0.46	0.52	0.01	2.4	0.04	4	-	47	27.9	1.6	23.5	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TP35	0.5	8.4	1.2	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TP35	1	8.4	1	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TP35	1.5	8.4	0.9	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TP35	2	8.4	0.7	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	0.5	8.4	0.8	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	1	8.4	0.7	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	1.5	8.4	0.7	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	2	8.4	0.7	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	0.5	8.4	0.4	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	1	8.4	0.4	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	1.5	8.4	0.7	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	2	8.4	0.8	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	0.5	8.4	0.5	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	1	8.4	0.7	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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13	2	8.4	0.6	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	0.5	8.4	0.2	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	1	8.4	0.4	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	1.5	8.4	0.6	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	2	8.4	0.6	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	0.5	8.7	1	840	-	6.6	15.8	3.07	2.02	0.44	1.04	0.01	1.5	0.06	4	-	37.1	28.3	5.3	29.3	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	1	8.5	1.3	1,334	-	6.5	16.4	2.92	2.12	0.4	1.07	0.01	1.4	0.08	3	-	42.6	34	3.5	19.9	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	1.5	8.6	1.1	992	-	6.3	16	2.84	1.98	0.43	1	0.01	1.4	0.07	3	-	40.5	30.4	5.4	23.7	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	2	8.5	0.9	888	-	4.9	13.5	2.51	1.34	0.35	0.66	0.01	1.9	0.07	4	-	39.7	31.3	5.3	23.7	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	0.5	8.4	0.2	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	1	8.4	0.4	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	CL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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16	2	8.4	0.6	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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TP30	1	8.4	1.1	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TP30	1.5	8.4	1	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TP30	2	8.4	0.9	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	0.5	8.4	0.7	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	1	8.4	1.1	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	1.5	8.4	0.9	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	2	8.4	0.7	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	0.5	8.6	0.8	538	-	7.3	17.7	3.72	1.83	0.42	1.28	0.01	2.0	0.05	4	-	42.2	28.9	3.4	25.4	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	1	8.6	1.2	945	-	7.8	16.9	3.53	2.5	0.43	1.32	0.01	1.4	0.07	3	-	39	33.9	3.4	23.6	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	1.5	8.6	1	895	-	7.7	16.8	3.8	2.12	0.48	1.3	0.01	1.8	0.06	3	-	41.9	28.4	3.5	26.1	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	2	9	0.9	775	-	6.1	22.5	2.4	1.96	0.39	1.38	0.01	1.2	0.04	4	-	37.7	32.8	3.5	25.9	SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

APPENDIX B – LABORATORY IMAGES

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Figure B1: 10% rainfall simulation plot after rain



Figure B2: 20% rainfall simulation plot after rain



Figure B3: 30% rainfall simulation plot after rain

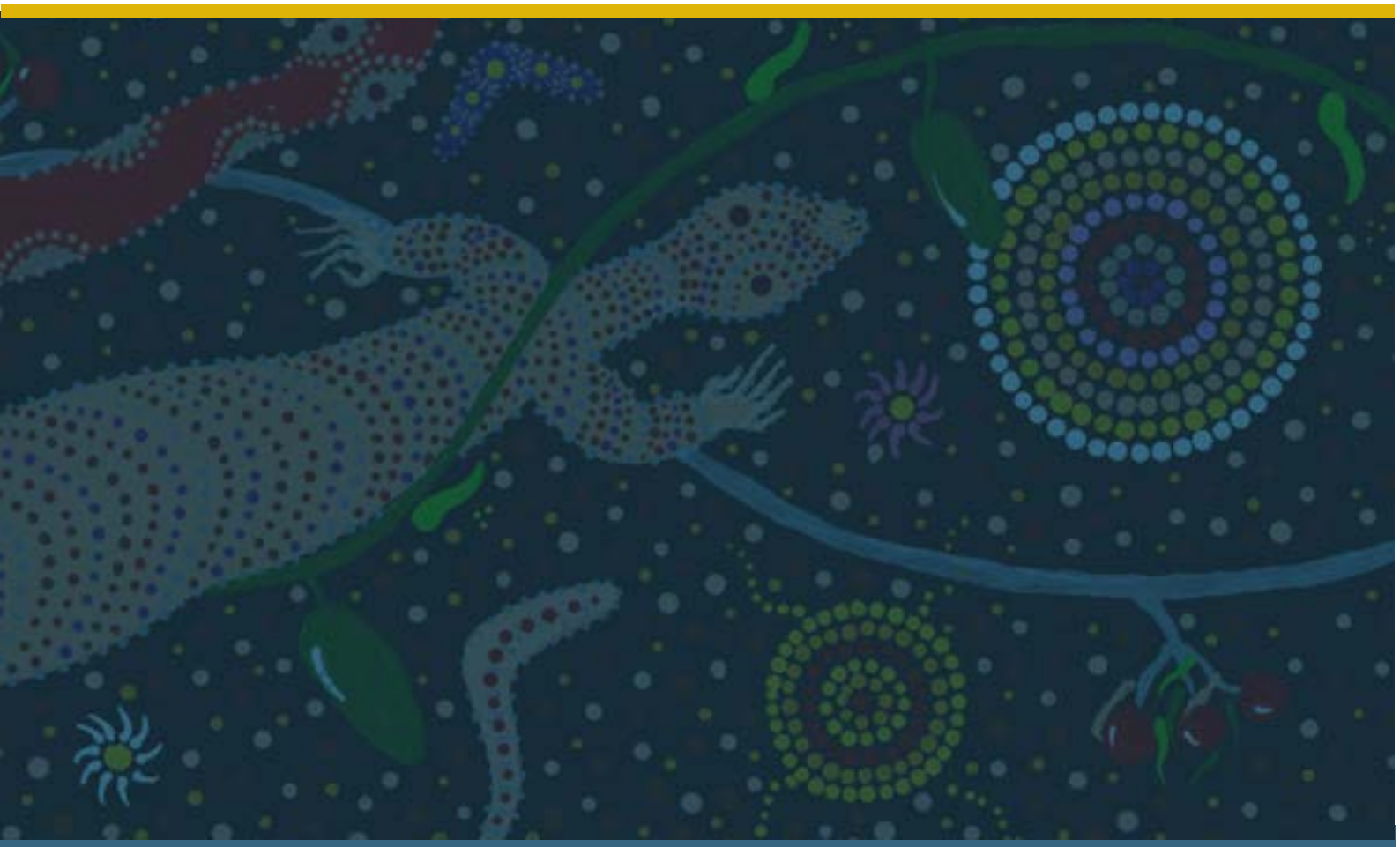


Figure B4: Flumes after application of overland flows.

6. APPENDIX 6: CONTAMINATED SITES SUMMARY

DEPARTMENT NAME / SITE / AREA

KCGM Contaminated Sites Summary



KALGOORLIE CONSOLIDATED GOLD MINES PTY LTD

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APPENDICES

Appendix 1: AOC Historial Aerial Photographs

1. Purpose, Scope, and Background

This document provides a summary of the contaminated sites reported by KCGM since 2007.

One hundred and twenty five potentially contaminated sites have been identified within KCGM leases on the basis of activity currently or historically undertaken. Whilst normally a whole land parcel (either tenement, lot or other legally defined parcel) would normally be reported, in 2007, KCGM reported its contaminated sites by discreet 'Areas of concern' (AOC). Of these, 113 AOC had an individual Form 1 submitted to the DWER (formally DEC) as required under the Contaminated Sites Act 2003. The remaining AOCs were reported either by Normandy Kaltails (Newmont) in 2007 or subsequently by KCGM in later years. Tenements were used to locate each site and the boundaries of each area of concern were provided as coordinates.

When feedback was provided from 2010 onwards, DWER grouped these sites into two large 'Potentially Contaminated' zones. Some AOC were partially or completely excluded from these areas, leaving KCGM uncertain of their current classification (e.g., Gidji sites). Additionally, KCGM is yet to review correspondence from DWER in relation to the sites reported by Newmont in 2007. In order to resolve this uncertainty, KCGM intends to liaise with the DWER to confirm the status of all reported sites. Additionally, several legacy/historic sites were reported to the DWER for which KCGM may not be liable for investigation and remediation and KCGM intends to obtain legal advice in order to clarify liability surrounding these sites before any further works are completed.

During 2017, KCGM conducted a review of the reported contaminated sites as outlined above, applying a risk based methodology where sites where ranked (based on current knowledge) on their ability to potentially pose a risk to human health, the environment or environmental values, through application of current understanding of sources, pathways and receptors including acknowledgement of data gaps that may exist within the understanding of the conceptual site model. The intention is to prioritise higher risk sites for assessment, remediation and/or management. The risk methodology and rationale are presented in Section 2.1, along with the strategy that KCGM intends to implement moving forward around contaminated sites and resolving any outstanding governance issues.

Based on the risk assessment completed in 2017, from 2018 to 2021, Preliminary Site Investigations and data gathering was undertaken at several AOC/Zones of Influence (ZOI). The outcomes from these investigations have been incorporated into Section 3, which details the available information on each ZOI and its associated AOCs, including maps and photographs where relevant. Appendix 1 contains historical aerial photography of each ZOI and the AOC contained within each to illustrate potential activities and rehabilitation that has occurred over time.



Figure 1: Fimiston Mt Charlotte and Mt Percy Zones of Influence

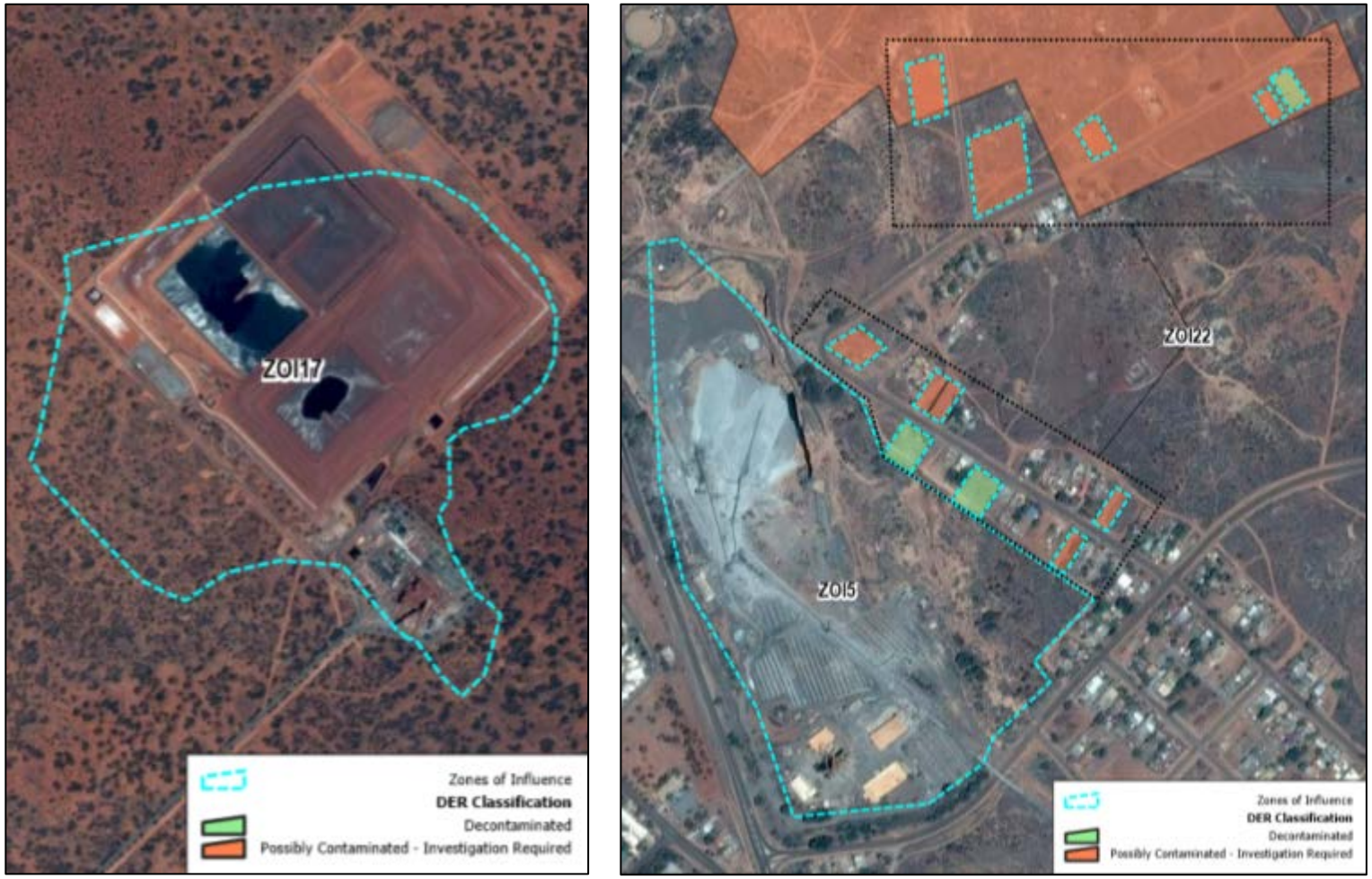


Figure 2: Gidji (ZOI7) and Mt Charlotte (ZOI5) and Williamstown (ZOI22) Zones of Influence

2. CONTAMINATED SITES FRAMEWORK

The *Contaminated Sites Act* 2003 (CS Act) was established to identify record, manage, and clean up contamination. It is important to note that whilst the *Mining Act* 1978 is generally the key legislative instrument for mine sites, whenever a provision of the CS Act is inconsistent with a provision of the *Mining Act* 1978 or a mining tenement, the provision of the CS Act prevails.

In line with the CS Act, contaminated sites (either known or suspected) are required to be reported to the Department of Water and Environmental Regulation (DWER) [formerly Department of Environment Regulation (DER)]. DWER administers and enforces the CS Act which includes classifying sites (in consultation with the Department of Health) and making information on contaminated sites available to the public. 'Contaminated' land, water or sites are defined by DWER guidelines as:

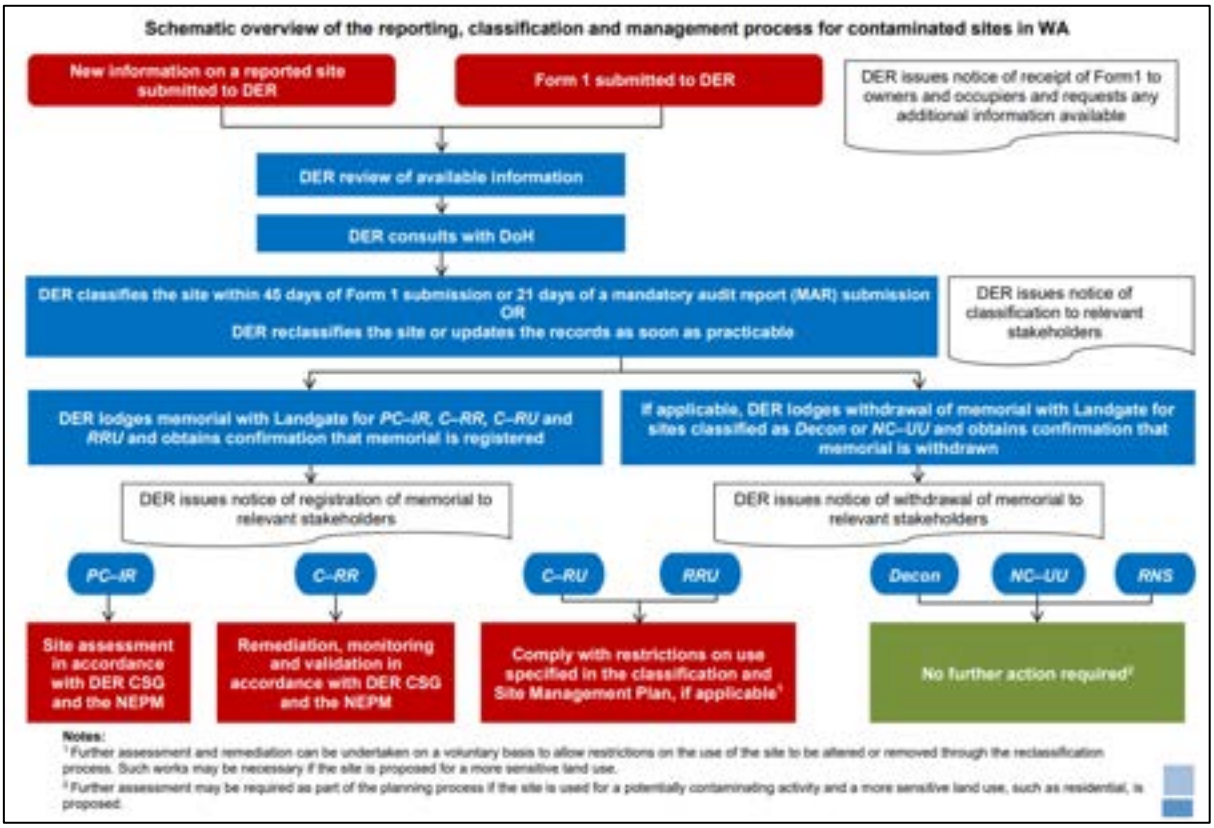
> "…having a substance present in or on that land, water or site at above background concentrations that presents, or has the potential to present, a risk of harm to human health, the environment or any environmental value".

Investigating and cleaning up contaminated sites is, in most cases, the responsibility of the polluter or current site owner. Part 3 of the CS Act deals with remediation of contaminated sites and includes the hierarchy of responsibility for remediation as follows:

- The person who has caused, or contributed to, the contamination of the site.
- The owner or occupier of the site who has changed, or proposes to change, the use of the site.
- The owner of the site.
- The State.

Note that a person who caused, or contributed to, the contamination of a site before the commencement of the CS Act is responsible for remediation of the site only to the extent that the person caused, or contributed to, that contamination by an act that was done without lawful authority. The person most likely to be

A schematic overview of the reporting, classification, and management process for contaminated sites in WA (DWER (2017) – *Identification, reporting and classification of contaminated sites in Western Australia*) is shown below in Figure 3. As per this process, once a site is reported, it is classified by DWER and a memorial on title (or the tenement) is lodged. In cases where the classification is potentially contaminated – investigation required (PC-IR), contaminated – remediation required (C-RR), contaminated – restricted use (C-RU) or remediated restricted use (RRU), then assessment, remediation and/or management is required.



KEY: PC-IR Potentially Contaminated – Investigation required; C-RR Contaminated – Remediation required; C-RU Contaminated – Restricted use; RRU Remediated – restricted use

Figure 3: Process for Classifying Contaminated Sites (DER 2017)

The DWER guidance document *Assessment and Management of Contaminated Sites* (DER, 2014) provides further information in relation to the following:

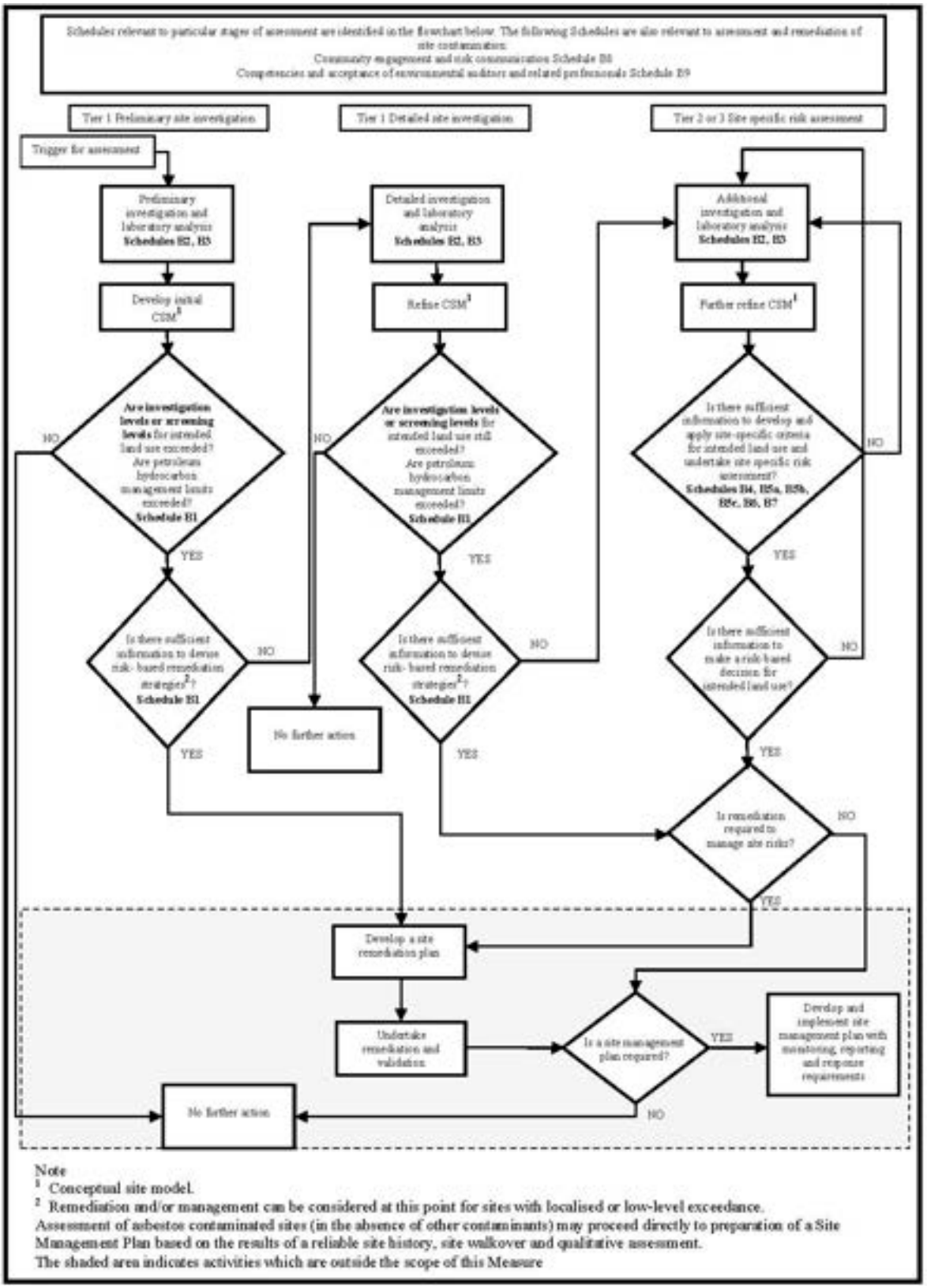
- Assessing and managing contaminated sites.
- Assessing risks to human health, the environment, and environmental values.
- Generic (tier 1) assessment levels and their application.
- Applying NEPM assessment levels in Western Australia.
- Reporting requirements.
- Community engagement.

DWER encourages a five-tiered staged and iterative approach to contaminated sites investigations, as outlined below (and illustrated in Figure 4):

- Stage 1 – Preliminary Site Investigation (PSI)
- Stage 2 – Detailed Site Investigation (DSI)
- Stage 3 – Remedial Action Plan (RAP)

- Stage 4 – Site Remediation and Validation (SRV)
- Stage 5 – Site Management Plan (SMP)

The overall objective is to reach end point classifications for each site, confirming that sites do not pose a risk to human health, the environment or environmental values or alternatively these risks can be effectively managed through restrictions and further actions are not required.



Note
[1] Conceptual site model.
[2] Remediation and/or management can be considered at this point for sites with localised or low-level exceedance.
Assessment of asbestos contaminated sites (in the absence of other contaminants) may proceed directly to preparation of a Site Management Plan based on the results of a reliable site history, site walkover and qualitative assessment.
The shaded area indicates activities which are outside the scope of this Measure

Figure 4: Five Tier Approach to Assessment of Contaminated Sites

2.1 KCGM Contaminated Sites Risk Assessment and Strategy

KCGM's Contaminated Sites Strategy aims to address its obligations under the CS Act (including protecting human health, the environment, and environmental values) while managing corporate risk and liability for rehabilitation. The objective is to achieve final end point classifications (ideally "decontaminated", "not contaminated – unrestricted use" or "remediated restricted use")under the Act which align with the potential and likely beneficial uses of sites and take into consideration expectations of key stakeholders through an open and transparent engagement process. Where areas are still operational, assessments and interim management measures will be undertaken to ensure that risks to human health are minimised with final remediation and validation undertaken as part of the approved Mine Closure Plan.

Mining and extractive industries are listed as potentially contaminating activities by the DWER. As noted in Section 1, initially 113 sites were reported to DER in 2007 by KCGM, mostly related to mining or ancillary processes (e.g., water transfer). DWER grouped these sites into two large 'Potentially Contaminated' zones when feedback was provided from 2010 onwards. Some AOC were partially or completely excluded from this area, leaving KCGM uncertain of their current classification (e.g., Gidji sites). KCGM intends to liaise with the DWER to confirm the status of all reported sites as investigations progress and more information becomes available. Additionally, several legacy/historic sites were reported to the DWER for which KCGM may not be liable for investigation and remediation. KCGM intends to obtain legal advice in order to clarify liability surrounding these sites before any further works are completed.

Notwithstanding, in 2017 KCGM undertook a review of all reported and classified contaminated sites and grouped them into zones of influence (ZOI). A risk-based methodology where those sites which are deemed (based on current knowledge) to potentially pose a risk to human health, the environment or environmental values are prioritised for assessment, remediation and/or management. This assessment examined sources, pathways and receptors including identification of data gaps that may exist within the understanding of the conceptual site model. Factors considered included (but are not limited) to:

- Current and future use of the area/sources (e.g., including beneficial use of groundwater)
- Contaminants of concern, including existing soil and groundwater data.
- Toxicology and fate and transport characteristics.
- Details of any existing engineering/management controls in place.
- Depth to groundwater and ambient groundwater conditions.
- Distance to sensitive receptors (including surface water discharge point, residential areas).
- Community expectations.

The intention is to prioritise higher risk sites for assessment, remediation and/or management.

3. DETAIL ON REPORTED CONTAMINATED SITES

3.1 ZOI1 – Fimiston I & II TSFs

This Zone of Influence contains the following AOCs:

- AOC16 Fimiston I TSF
- AOC107 Fimiston I TSF Groundwater Plume
- AOC14 Fimiston II TSF
- AOC15 Fimiston II TSF Groundwater Plume
- AOC38 Herliette TSF
- AOC75 Croesus TSF
- AOC62 Historic Shire Tip

These sites have been grouped due to the overriding influence of the Fimiston TSFs on adjacent sites, ensuring that source differentiation within this area would be difficult.

These sites are partially covered by the DWER Potentially Contaminated Zone.

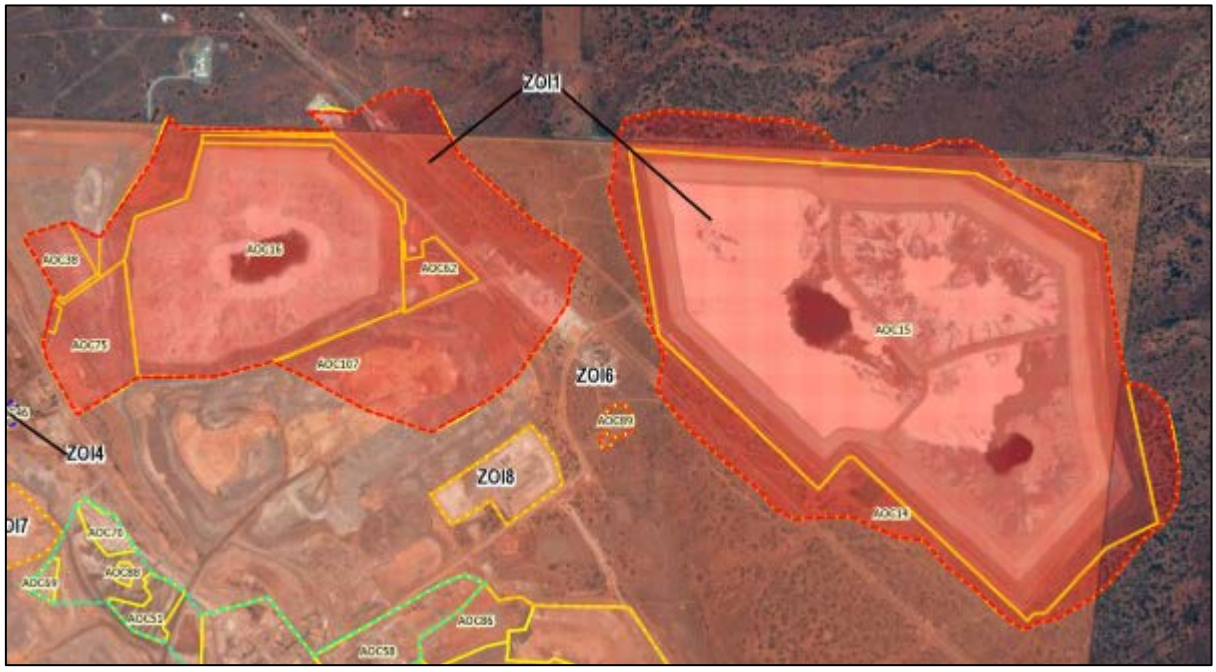


Figure 5: Zone of Influence 1 and associated Areas of Concern

3.1.1 AOC16 Fimiston I TSF & ACO 15 Fimiston II TSF

Tailings from the Fimiston Mill have been deposited into Fimiston I since the conception of KCGM and within Fimiston II since the mid-1990s. Tailings are managed during operations under the Fimiston Licence to Operate, issued under Part V of the *Environmental Protection Act* 1986 (EP Act) and also via tenement conditions issued under the *Mining Act* 1978 via Mining Proposals. Closure of the facilities will be in accordance with the approved Mine Closure Plan, which will outline the capping design required in order for the facility to be 'safe, stable and non-polluting'. Closure planning for the Fimiston TSFs included rock armouring the outer slopes and a rock or oxide cap on the upper surfaces to encapsulate the tails. In 2019-2021 implementation of capping and rehabilitation, i.e., encapsulation of a portion of the northern slope and SW slope was completed. This work will continue over the next few years.

Geochemical characterisation studies of Fimiston tailings have been conducted on five occasions. A summary of geochemical testing to date (MBS Environmental, 2018b) and further work by MBS on mercury characterisation (MBS Environmental, 2020) indicates that, post-closure, the tailings generated by the Fimiston Processing Plant (Fimiston tailings) will:

- remain NAF (non-acid forming) with alkaline pore water
- Remain hypersaline with the predicted formation of a surface gypsum crust, which is predicted to reduce infiltration rates into underlying tailings.
- During operation the solubility of trace metals and metalloids and any potential for infiltration to groundwater will reflect cyanide based chemistry of the Fimiston process water. Metals noted in low to moderate concentrations in Fimiston supernatant solution include copper, mercury, antimony, lead, nickel, and cobalt.
- Post closure the potential for leaching of trace metals and metalloids is considered very low as gradual cyanide degradation, surface adsorption (including arsenic as insoluble iron bound species) and the alkaline nature of the tailings will reduce the mobility of most metals and metalloids to very low levels. Simulation of oxidised tailings conditions by analysis of tailings solutions after accelerated laboratory oxidation with peroxide indicate extremely low levels of all environmentally significant metals and metalloids.
    - Mercury concentrations in Fimiston and Kaltails tailings solids and leachates are low.
    - Very low concentrations of tellurium in water and acetic acid leachates indicate that most of the tellurium is present as stable, insoluble minerals (namely coloradoite). Given the only beneficial use of groundwater is for industrial uses (including mining), and there are no ecological users of groundwater, the very low concentrations found in tailings leachate are unlikely to have an adverse impact.
    - KCGM tailings are not enriched with chromium. Seepage from the Fimiston TSFs is predicted to be circum-neutral to alkaline after mine closure, under which conditions trivalent chromium (III) concentrations are predicted to be very low and of limited environmental significance. Chromium (VI) is unstable in all but highly oxidising conditions and is not expected to be persistent in tailings seepage.

- Fimiston and Kaltails tailings are not enriched with nickel. Water leachates and tailings fluids of Fimiston and Kaltails tailings contain very low concentrations of dissolved nickel and predicted concentrations are unlikely to increase after mine closure.

- The risk of leachate from the stored Fimiston tailings once rehabilitated adversely impacting groundwater is considered low, especially considering the hypersaline groundwater receiving environment.

Surface runoff is intermittent and the adjacent Eastern floodway is ephemeral in nature. During active deposition and wetting of the facility, dust generation is minimised. Further, no receptor for any COPCs currently exists as groundwater within the area is suitable only for mineral processing due to naturally hypersaline conditions.

No pathway exists to enable any COPC to be made available to potential receptors.

SOURCE	RECEPTOR	PATHWAY	IMMEDIATE RISK
Tailings	• Local environment • Human (workers)	• Nil	Nil

3.1.2 AOC107 Fimiston I TSF Seepage Plume & AOC14 Fimiston II TSF Seepage Plume

Seepage from the Fimiston TSFs is regulated under the *EP Act* including Ministerial Statements, and a Part V Licence to Operate, with licence conditions imposed relating to maintenance of groundwater levels below the root zone of natural vegetation, the key environmental value. Closure of the facilities will be in accordance with an approved Mine Closure Plan, which will outline the closure design required in order for the facility to be 'safe, stable and non-polluting', including management of the seepage plume post closure to ensure no adverse impacts on native vegetation.

COPC within seepage from the Fimiston TSFs are considered to be low, as demonstrated by frequent monitoring in accordance with the current Licence to Operate. Leachate not considered to present a risk to the environment – see geochemical characterisation for Fimiston tailings in Section 3.1.1. Further, no receptor for any COPCs currently exists as groundwater within the area is suitable only for mineral processing due to naturally hypersaline conditions.

Further, no receptor for any COPCs currently exists as groundwater within the area is suitable only for mineral processing due to naturally hypersaline conditions.

No pathway exists to enable any COPC to be made available to potential receptors.

Source	Receptor	Pathway	Immediate Risk
Seepage	• Nil	• Seepage	Low

3.1.3 AOC38 – Herliette TSF

The Herliette TSF is an inactive, which operated from 1983/84 to 1990s, depositing tails from nearby mining operations. It is less than 15 m high, not lined and the base is constructed of insitu clays/silty

clays. It is likely that some nickel tails may be present. Following decommissioning of the facility, the site was rehabilitated in the late 1990s by placing approximately 1 m rock capping (to act as a capillary break) and approximately 0.2 m of local topsoil. In 2012, this topsoil was harvested for further use in rehabilitation prior to the facility being covered by construction of the Northern Waste Rock Dump (WRD). The TSF is now fully encapsulated by a minimum of 100m of fresh competent waste rock dumped to construct the Northern WRD.

Material characterisation sampling and analysis was conducted of the tailings prior to encapsulation, with results indicating that leaching of COPC would be unlikely (and will be further reduced by encapsulation), therefore there is a limited pathway for groundwater contamination (SoilWater, 2012). The waste rock cover has eliminated the pathway for dust generation.

KCGM consider that this site to be remediated and no further risk, as it has been completed encapsulated.

Source	Receptor	Pathway	Immediate Risk
Seepage	• Nil	• Unlikely	Nil

3.1.4 AOC75 – Old Croesus TSF

Old Croesus TSF abuts the Fimiston I TSF to the east. It was operational from the 1960s to 1988, initially as a fresh water tailings but then later changed to hypersaline tailings. The western external face was rehabilitated in 1999/2000 as a dust control measure by covering the batters with 1 m of competent waste rock and 0.5 m of oxide. Poor water control has caused tunnel erosion in this area. From 2012 onwards, the majority of the remaining exposed tailings were encapsulated during construction of the Northern WRD, although a very small area on the upper surface remains exposed.

In 2020 the western side of the TSF was rehabilitated, with the wall reshaped, water control measures put in place on the upper surface and capping of the slope with at least 0.5 m of waste rock, with a store and release cover of growth media. The TSF is now completely encapsulated.

A desktop review in 2007 (KCGM, 2007) of two studies conducted in 1997 (Normandy Kaltails, 1998) and 2006 (KCGM, 2006) on the potential re-treatment of the tailings determined that it was not economical to reprocess the TSF. In both instances, three tailings layers were assayed; the top was devoid of gold, the middle contained nickel residue and the bottom contained the highest gold grade. Historic sampling has provided indications that there are levels of nickel and copper above ecological levels within the middle layers of the TSF.

Material characterisation sampling in 2016 (MBS Environmental, 2016) indicates that:

- Tailings are classified as NAF with low to moderate theoretical acid production potential and correspondingly moderate to high levels of ANC; a significant portion of sulfur in most samples being in the already oxidised form (sulfate). Old Croesus was further classified as acid consuming.
- Leachate and hence any potential for seepage (depending on closure design) from these tailings is predicted to be brackish to moderately saline in perpetuity.

- The tailings are geochemically enriched in gold, silver, antimony and tellurium as a result of the nature of the particular gold mineralisation, but none of these elements were found to be soluble in water extracts or dilute acetic acid extracts to any extent considered to be of environmental concern post-closure when covered.
- The tailings are geochemically benign, with only moderate levels of salinity in leachates and/or potential seepage, which will remain alkaline.

The above geochemical assessment indicates that a suitably designed waste rock cover to prevent wind and water erosion will be sufficient post-closure to prevent negative impacts on the surrounding environment.

KCGM consider that rehabilitation of this TSF is now complete and no further risk, as it has been completely encapsulated by waste rock.

Source	Receptor	Pathway	Immediate Risk
Seepage	• Nil	• Unlikely	Nil

3.1.5 AOC62 – Historic shire tip

This small facility was operated as a municipal shire landfill until the mid 1980s. It has since been encapsulted by the North Eastern WRD during early 2000s and rehabilitated during works on Fimiston I. It is unknown what materials were deposited.

A pool of surface water occurs intermittent at the south eastern toe of the dump after rainfall events, although surface water flow is thought to be constrained by the adjacent topsoil stockpile and WRD.

KCGM considers that this site is of low risk due to source – receptor – pathways being limited by waste rock encapsulation, and the hypersaline nature of groundwaters. The area is limited in access by mining activities, however, care should be undertaken during any works which will disturb the toe of the exisiting WRD rehabilitation during movement of the topsoil stockpile.

Source	Receptor	Pathway	Immediate Risk
Seepage from landfill	• Local Environment	• GW unlikely • Surface water flows unlikely	Low

3.2 ZOI2 – Kaltails TSF

This Zone of Influence contains the following Areas of Concern:

- AOC115 Kaltails Seepage Plume
- AOC116 Kaltails TSF
- AOC117 Former Kaltails Processing Plant

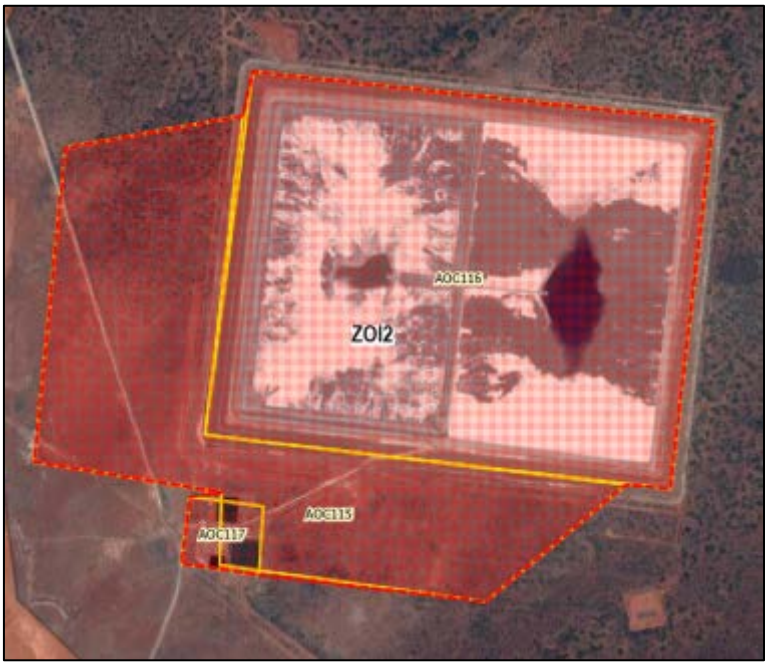


Figure 6: Zone of Influence 2 and associated Areas of Concern

3.2.1 ACO 117 Former Kaltails Processing Plant

This area contained the processing plant for the retreatment of hydraulically mined tailings during the Kaltails Project, which was decommissioned and rehabilitated when the Kaltails project ceased in the early 2000s. KCGM constructed water ponds and pipelines over some of this area as part of recommissioning of the TSF in 2011.

Residual COPCs within soils from the Kaltails Retreatment Project may be present, however limited soils testing has been completed as per Contaminated Sites Requirements. Given that much of the area is covered with operating infrastructure, and managed as per the EP Act and Regulations, KCGM considers that the immediate risk from this area to the environment and human health is low. Groundwater in this area is shallow, but is hypersaline and there is no other beneficial use other than industrial use (including mining).

Source	Receptor	Pathway	Immediate Risk
Contaminated soil	• Local Environment (mining area)	• Dust • Vegetation uptake	Low

3.2.2 AOC 116 Kaltails TSF

The Kaltails TSF covers an area of approximately 216 ha and is located to the south east of the Fimiston WRDs. The Kaltails TSF was first operated between 1988 and 1999 as part of a major regional tailings retreatment project of tailings dams deposited in the footprint of the southern Fimiston WRDs. The facility was recommissioned by KCGM in 2011 for storage of tailings from the Fimiston Mill and is currently operated in accordance with the Part V Licence to Operate for the Fimiston Operations.

Closure planning for TSFs includes rock armouring the outer slopes and a rock or oxide cap on the upper surfaces to encapsulate the TSFs. In 2020 implementation of capping and rehabilitation, i.e., encapsulation of the northern slope of Kaltails East cell. This work will continue over the next few years.

Geochemical characterisation of Fimiston tailings as described in Section 3.1.1 is applicable to Kaltails TSF from 2011 onwards. Characterisation of Kaltails tailings deposited during initial operation from 1988 to 1999 indicated that the tailings were NAF (Golder Associates, 2008).

Dust generation from the TSF is adequately supressed by the wet upper surface during operations, such that dust generation does not appear to be a significant issue. Surface water is managed from the TSF during operations within toe drains and dams surrounding the facility. As such, KCGM considers that the risk from the Kaltails TSF is low considering the benign nature of the tailings and current operational management programs. In 2020/2021 capping of the northern flank of the east cell was completed, with more than 0.5m of waste rock capping placed over the outer slope surface.

Closure of the facilities will be in accordance with an approved Mine Closure Plan, which will outline the closure design required in order for the facility to be 'safe, stable and non-polluting'. Current closure design is for a rock cap to be applied which will adequately mitigate the risk of wind erosion and dusting.

Source	Receptor	Pathway	Immediate Risk
Tailings	• Local Environment	• Nil	Nil

3.2.3 AOC 115 Kaltails TSF Seepage Plume

Due to the Kaltails TSF being unlined, seepage from active deposition on the dam occurs. KCGM currently undergoes seepage management during operations through a network of recovery bores in accordance with a Seepage and Groundwater Management Plan required by the Fimiston Operations Part V EP Act licence. As such, vegetation monitoring conducted since 2011 has not indicated that seepage from the Kaltails TSF has had any adverse effects on the surrounding vegetation.

Closure of the facilities will be in accordance with an approved Mine Closure Plan, which will outline the closure design required in order for the facility to be 'safe, stable and non-polluting', including management of the seepage plume post closure to ensure no adverse impacts on native vegetation.

KCGM does not consider the Kaltails Seepage Plume to be an immediate risk in terms of contaminated sites as levels are adequately managed in accordance with licence conditions. COPC within seepage from the Fimiston TSFs are considered to be low. Further, no receptor for any COPCs currently exists as the only beneficial use for groundwater within the area is mining and mineral processing due to naturally hypersaline conditions.

Source	Receptor	Pathway	Immediate Risk
Seepage	• Local Environment	• Seepage	Low

3.3 ZOI3 – Mining Operations

This Zone of Influence contains the following AOCs:

- AOC51 Open Pits Fuel Farm
- AOC57 Fimiston Mill
- AOC58 Contractor Workshops
- AOC69 Sam Pearce Underground Support Facilities
- AOC70 Crushing Facilities
- AOC79 Chaffers Workshop Area
- AOC88 Saline Water Transfer Pond



Figure 7: Zone of Influence 3 and associated Areas of Concern

These areas are all currently part of active mining operations and are managed in accordance with the *EP Act* and *Mining Act*. KCGM considers that immediate risk from these sites is adequately managed through operational management procedures. Long term risk from these sites will be managed through investigation and remediation (if required) during closure.

Some sites have had opportunistic sampling undertaken during operations.

Source	Receptor	Pathway	Immediate Risk
Leaks, spills of chemicals; Seepage from ponds	• Local Environment	• GW unlikely • Surface water flows	Low

3.3.1 AOC57 Fimiston Mill

The Fimiston Mill was constructed as the Processing Plant for ore from the Fimiston Open Pit in 1989. It covers approximately 20 ha and is located to the east of the Fimiston Pit. Two parallel circuits process refractory sulphide ore from the Fimiston Open Pit and Mt Charlotte Underground Mine. The key components of the processing circuit are:

- primary crushing plant;
- a semi-autogenous grinding mill with pebble crushing circuit;
- two ball mills; and
- flotation and two CIL circuits.

The Fimiston Mill and associated tailings deposition is managed in accordance with a Part V Licence and the International Cyanide Management Code, which has strict requirements on the protection of human health and the environment from releases of cyanide.

The infrastructure at the Fimiston Mill is underlain by a bitumen or concrete hardstand and all process water ponds are lined with concrete or poly liner (Figure 8). Surface water flows from drains surrounding the facility are monitored for exceedances of water quality parameters in accordance with *Environmental Protection* (*Unauthorised Discharge) Regulations*.

Preliminary drill composite sampling of the Fimiston Mill during 2013 (samples taken during geotechnical drilling for footings) indicated elevated concentrations of COPC confined to surface soils, below current concrete hardstands.



Figure 8: Fimiston Mill 2017 (facing west)

3.3.2 AOC58 Contractors Workshops

The Open Pits Contractor Workshops are operational areas used for the maintenance of the open pit mining fleet, washdown and laydown (Figure 9). Surface water flows from the drains surrounding the facility are monitored for exceedances of water quality parameters in accordance with *EP* (*Unauthorised Discharge) Regulations*. It is unlikely that there is a pathway to groundwater due to significant depth to groundwater. Due to dewatering of the adjacent Fimiston Open Pit, groundwater contours are towards the pit. At closure the pit will be a groundwater sink. There is no receptor due to the hypersaline nature of the groundwater (no other beneficial uses).



Figure 9: Contractor Workshops 2017 (facing east)

3.3.3 AOC69 Sam Pearce Underground Support Facilities

The Sam Pearce facilities are used for similar activities as the Open Pits workshops, but they are smaller in scale and are located on the edge of the Fimiston Open Pit. Surface water flow from this area reports to the Open Pit. It is unlikely that there is a pathway to groundwater due to significant depth to groundwater. Due to dewatering of the adjacent Fimiston Open Pit, groundwater contours are towards the pit.

3.3.4 AOC70 Crushing Facilities

These facilities are used for crushing of ore mined from the Fimiston Pit. Most likely COPC would be associated with hydrocarbon use. Surface water from this area reports to drainage adjacent to Fimiston Mill, which is monitored for exceedances of water quality parameters in accordance with *EP (Unauthorised Discharge) Regulations*. It is unlikely that there is a pathway to groundwater due to significant depth to groundwater. Due to dewatering of the adjacent Fimiston Open Pit, groundwater contours are towards the pit.

3.3.5 AOC79 Chaffers Workshop Area

This area was used as a mineral processing and workshop area until decommissioning in late 1990s and equipment removal in the early 2000s. This area has been mined through as part of the Morrison Cutback and no longer exists.

3.3.6 AOC88 Saline Water Transfer Pond

This area has been used for transfer of saline water for dust suppression. Further investigation will be conducted as part of closure planning for this feature. The COC are salts.

3.4 ZOI4 – AOC46 Mines Rescue Fire Training Ground

This site has been used for firefighting training of the KCGM Emergency Responses Team, where active burning and extinguishing of materials has been conducted since the early 1990s. The current firefighting foams are unlikely to contain per- and polyfluoroalkyl substances (PFAS) although other PFAS-containing foams may have been used in the past. This area is currently part of active mining operations and is managed in accordance with the *EP Act* and *Mining Act*. KCGM considers that immediate risk from this site is adequately managed through operational management procedures.

In 2019/2020 further investigation was conducted at this AOC. The draft PSI has been completed, with some further actions required to complete the study. Early findings are as follows:

No soil samples exceeded the human health criteria for a commercial/industrial setting, indicating that the site does not pose a risk to site workers/visitors in the site's current setting. However, bonded asbestos containing materials (ACM) was identified during the site inspection in the bushland area north of the fire training ground, likely sourced from dumped waste material.

Elevated concentrations of hydrocarbons (TRH) were noted, consistent with the use of fire ignition (e.g., kerosene) and remnant burnt materials. Perfluorooctanesulfonic acid (PFOS) impacts exceeded

indirect ecological investigation levels at several locations including at a sample location in cleared bushland approximately 10 m north of the fire training ground.

Groundwater pathways for transfer of COPCs are not considered highly likely due to depth to groundwater and the only beneficial use being mining/mineral processing. The AOC is within the drawdown cone of the Fimiston Pit / Mt Charlotte underground mine. In the extremely unlikely event that any groundwater exists, it would report to mine pumping systems that are creating the drawdown and the water would become part of the mine water system. At closure water at the bottom of Mt Charlotte underground mine is expected to decant to the Fimiston Open Pit after approximately 100 years. Fimiston Open Pit is a groundwater sink at closure, and will eventually have a pit lake. Modelling has proved that the pit lake will fill to approximately halfway up the pit wall, and will never overtop. The pit lake water will be hypersaline, and unfavourable for development of any form of eco system.



Figure 10: Zone of Influence 4 and associated Area of Concern

Monitoring of long-term risk will continue. Additional containment controls are currently being considered for viability, as an outcome of the PSI. If remediation is required, expected to be actioned closer to closure, when the facility is no longer used.

Source	Receptor	Pathway	Immediate Risk
Leaks, spills of chemicals; Use of Fire Suppressants	• Local Environment	• Surface water flows • Soils	Low

3.5 ZOI5 – Mt Charlotte

This Zone of Influence contains the following:

- AOC29 Cassidy Headframe Workshops and Hydrocarbon Area

- AOC30 Mt Charlotte Vent Rise North
- AOC36 Mt Charlotte Southern Vent Rise
- AOC37 Mt Charlotte Compressor House
- AOC72 Historical TSF (Mt Charlotte)
- AOC87 Mt Charlotte Hydrocarbon Storage Area

These areas have been grouped together as they are located in the same geographical area, or are associated with the Mt Charlotte Underground. KCGM considers that the operational sites (29, 30, 36, 37, 72, and 87) are of a low immediate risk from a contaminated sites perspective as they are managed in accordance with the Mining and EP Acts.

These areas will be actioned for contaminated sites investigation closer to closure.

Source	Receptor	Pathway	Immediate Risk
Contaminated Soil	• Local Environment	• Soil • Air	Low

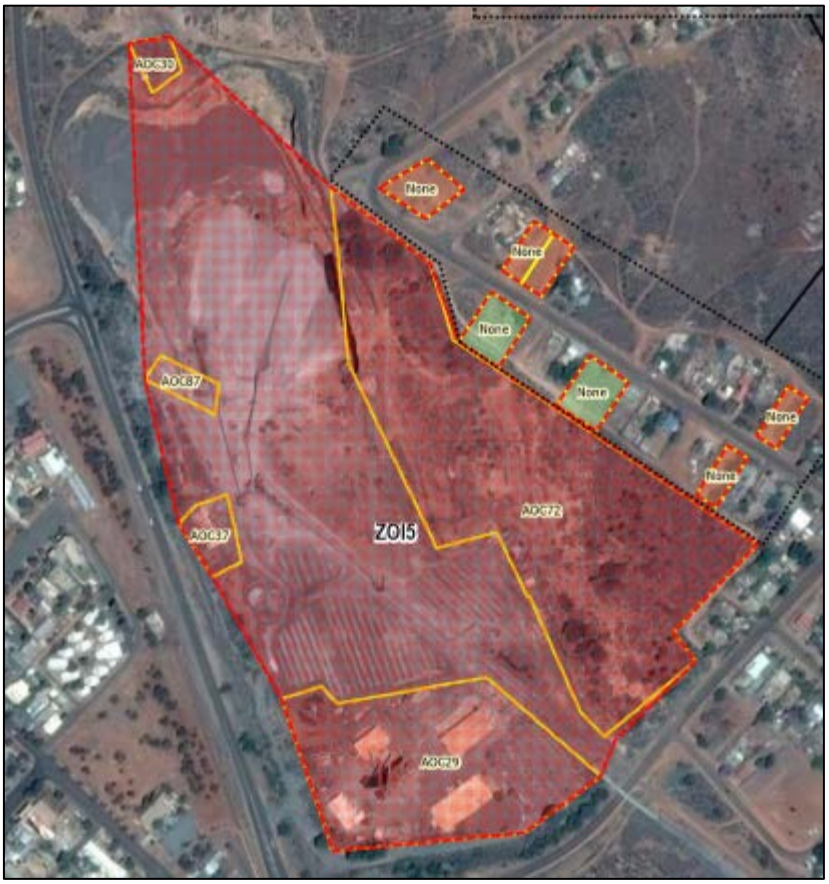


Figure 11: Zone of Influence 5 and associated Areas of Concern

3.5.1 AOC29, 37 & 87 Cassidy Workshops and Hydrocarbon Areas

Cassidy headframe and winder are still operational to service the Mt Charlotte mine. The remainder of the area is used as a core yard and has either been covered with road base, concrete hardstand or sheeted with gravels. Likely COPCs in this area would be associated with hydrocarbon use.

3.5.2 AOC30 & 36 Mt Charlotte Northern and Southern Vent Rises

These areas are operational ventilation shafts that have the potential for COPCs associated with hydrocarbons.

3.5.3 AOC72 Historical TSF

This area appears to have been used as a mineral processing facility, with small tailings and heap leach/ponds present in historical photos. Tailings material looks to have been partially removed in the early 1990s (final disposal destination unclear). The area was then ripped and seeded with a range of native plants. There is limited vegetation regrowth.

Testing of the soil in 2012 prior to earthworks around the Southern Ore body vent fan indicate that where present, the tailings material occurs at a depth of 60 cm, is extremely saline and had elevated levels of arsenic and mercury (Outback Ecology, 2012). Further sampling is required to suitably classify the soils throughout the entire area, concentrating on likely areas of contamination in association with remnant tailings. However, sampling and remediation of northern part of area is unlikely due to geotechnical safe working condition limitations around the Mt Charlotte Glory Hole. Due to constraints imposed by the Mining Act, this area is not easily accessible at present.

Given the current general success of revegetation in the area, the pathway for COPC transfer via dust is considered to be reduced. Groundwater is hypersaline, and the area is within the Mt Charlotte dewatering zone, and therefore not considered a viable pathway. The area is not accessible by the public due to security fencing.

3.6 ZOI6 – Saline Water Transfer Station

This Zone of Influence includes:

- AOC 89 Saline Water Storage
- AOC 114 Saline Water Storage

These sites have been grouped as they are the same type of infrastructure, although geographically separated. KCGM considers the immediate risk from these sites to be low due to operational mitigation measures reducing the likelihood and consequence of any spills/leaks from infrastructure. The COC are salts.

Source	Receptor	Pathway	Immediate Risk
Bore/Process Water	• Local Environment	• Soil	Low



Figure 12: Zone of Influence 6 and associated Areas of Concern

3.6.1 AOC 89 & 114 Saline Water Transfer Tanks

This AOC contains a decommissioned saline water transfer tank and saline water catchpit. The catchpit has been partially backfilled and rehabilitated. Remaining area is operational and will not be treated or rehabilitated until end of mine life. The COC are salts.

3.6.2 AOC 114 Kaltails Borefield Transfer Tank

This AOC has been incorrectly reported to the DWER and an amendment will need to be submitted to correct its positioning. It was reported on the basis that spills of saline water abstracted from the borefields have occurred in this area, but potential COPCs within this water are limited. Secondary containment (earthen bunds) is present to prevent spills from reaching the wider environment. The COC are salts.

3.7 ZOI7 – Pit Adjacent Legacy TSFs

This Zone of Influence contains the following Areas of Concern:

- AOC110 Croesus TSF
- AOC66 Morrisons TSF (also known as Calcine & Historic TSF)

These AOCs have been grouped as they share similar geochemistry and are within the immediate proximity of the Fimiston Pit.



Figure 13: Zone of Influence 7 and associated Areas of Concern

3.7.1 AOC110 Croesus TSF

The inactive Croesus TSF, located at the northern end of the Fimiston Pit, is currently rehabilitated or capped with waste rock. A very small section of the eastern wall is exposed, and has allowed for geochemical sampling. Approximately half of the TSF was reclaimed by Normandy Kaltails between 1998 and 1999 with recovery of further economic grade not considered viable. After mining of the northern portion of the tailings, the remaining area was ripped and seeded in conjunction with the Croesus Mill site in 2001.

Geochemical sampling conducted in 2016 (MBS Environmental, 2016) indicates:

- Tailings are NAF with low to moderate theoretical acid production potential and correspondingly moderate to high levels of ANC, with a significant portion of sulfur in most samples being in the already oxidised form (sulfate).
- Leachate and hence any potential for seepage (depending on closure design) is predicted to be alkaline and moderately saline in perpetuity.
- Tailings is geochemically enriched in gold, silver, antimony, and tellurium as a result of the nature of the particular gold mineralisation, but none of these elements were found to be soluble in water extracts or dilute acetic acid extracts to any extent considered to be of environmental concern when covered post-closure.
- Tailings are geochemically enriched in arsenic, cobalt, copper, molybdenum, selenium, and lead. Selenium, lead and copper were not found to be soluble under the alkaline conditions expected to prevail post-closure and these elements, despite enrichment, are not considered to pose a risk to the environment.
- Concentrations of cobalt (2.25 mg/L on a 1:20 basis) and molybdenum (0.202 mg/L on a 1:20 basis) in water leachate were found to marginally exceed the livestock drinking water guidelines of 1 mg/L and 0.15 mg/L, respectively.

The TSF is located within the cone of depression for dewatering of the Fimiston Open Pit and Mt Charlotte underground mine. Any operational seepage will report to mine pumping systems that are creating the drawdown and the water would become part of the mine water system. At closure water at

the bottom of Mt Charlotte underground mine is expected to decant to the Fimiston Open Pit after approximately 100 years. Fimiston Open Pit is a groundwater sink at closure, and will eventually have a pit lake. Modelling has proved that the pit lake will fill to approximately halfway up the pit wall, and will never overtop. The pit lake water will be hypersaline, and unfavourable for development of any form of eco system.

KCGM does not consider this TSF to be of immediate or future risk to the environment or human health as the pathways for transport of COPC are limited due to existing rehabilitation or capping, supressing dust generation, depth to hypersaline groundwater and surface water drainage from this landform reporting to operational mining areas. Long term closure of this facility will consider the geochemical characterisation of materials in order to adequately minimise any potential seepage of COPC.

Source	Receptor	Pathway	Immediate Risk
Tailings	• Nil	• Nil	Nil

3.7.2 AOC66 – Historic TSF (Morrisons TSF)

This facility is a legacy of prior mining operations and has been partially reclaimed by Pericles Resources around 2005.

The has been relocated and is now dumped within the Trafalgar WRD. The calcine tailings have been capped with a domed (water shedding), traffic compacted oxide layer, with waste rock on top of the capping layer. Once the waste rock dump reaches final high, the upper surface will be rehabilitated with a store and release growth medium layer.

Geochemical characterisation of the material in 2016 (MBS Environmental, 2016) indicates that:

- Tailings are geochemically enriched in arsenic, cobalt, copper, molybdenum, and selenium.
- Selenium and copper were not found to be soluble under the alkaline conditions expected to prevail post-closure and these elements, despite enrichment, are not considered to pose a risk to the environment.
- Concentrations of arsenic (0.63 mg/L on a 1:20 basis) and molybdenum (0.175 mg/L on a 1:20 basis) in water leachate marginally exceeded the livestock drinking water guidelines of 0.5 mg/L and 0.15 mg/L, respectively.

The TSF is located within the cone of depression for dewatering of the Fimiston Open Pit. Any operational seepage will report to mine pumping systems that are creating the drawdown and the water would become part of the mine water system. The Fimiston Open Pit is a groundwater sink at closure, and will eventually have a pit lake. Modelling has proved that the pit lake will fill to approximately halfway up the pit wall, and will never overtop. The pit lake water will be hypersaline, and unfavourable for development of any form of ecosystem.

KCGM does not consider this TSF to be of immediate or future risk to the environment or human health as the pathways for transport of COPC are limited due to existing encapsulation, suppressing dust

generation, depth to hypersaline groundwater and surface water drainage from this landform reporting to operational mining areas.

Source	Receptor	Pathway	Immediate Risk
Tailings	• Nil	• Nil	Nil

3.8 ZOI8 – AOC20 Paringa TSF

This Zone of Influence contains a single Area of Concern; AOC 20 – Paringa TSF (Figure 14). This TSF has been kept separate to other AOCs due to its use for operational activities other than tailings deposition after it was decommissioned.



Figure 14: Zone of Influence 8

The TSF ceased active deposition in 1987 after four years of operations. The TSF is not lined, the base is constructed of insitu clays/silty clays and it is less than 15 m high. The since the 2000s the TSF upper surface has been used for disposal/irrigation of Treated Waste Water and as a bioremediation facility. The western cell has also been used to dispose of carbon pulp (historical underground timbers pulped in the mill). For these activities, the TSF is managed in accordance with a licence issued under Part V of the *EP Act*.

Geochemical characterisation was conducted on a surface sample of Paringa tailings in 2016 (MBS Environmental, 2016). The results indicated that the tailings has low to moderate theoretical acid production potential and correspondingly moderate to high levels of ANC, with a significant portion of sulfur in most samples being in the already oxidised form (sulfate). As a result, all samples were classified as NAF, with Paringa TSF classified as acid consuming. Leachate and hence any potential for seepage from this tailings is predicted to be alkaline and moderately saline in perpetuity. The tailings were found to be geochemically enriched in gold, silver, antimony, and tellurium due to particular gold mineralisation, but none of these elements were found to be soluble in water extracts or dilute acetic acid extracts to any extent considered to be of environmental concern post-closure when covered. The Paringa TSF is therefore considered to contain geochemically benign tailings, with only moderate levels of salinity in leachates and/or potential seepage, which will remain alkaline.

Drilling and sampling of this TSF was undertaken in 2019, with assessment of results still underway. The drilling depth penetrated through the tailings pile, into the underlying ground surface. Piezometers were installed in some of the drill holes. The piezometers have been sampled, and have been dry, i.e., there is no water table in the TSF.

The TSF has not been observed to actively dust to any major degree. The current final closure design is encapsulation through expansion of the adjacent waste dump, which will eliminate the possibility of dust generation and greatly reduce the potential for seepage through reduction in water infiltration. Therefore, the source of COPC is considered negligible in the long term. KCGM considers that this site is of low immediate risk due to source – receptor pathways being limited by active management of offsite environmental impacts, the benign nature of tailings, the hypersaline nature of the groundwater.

Drilling through the tailings dam was undertaken in 2019, with samples taken for analysis. Interpretation has not commenced. Piezometers were installed in some of the drill holes, but no phreatic surface was identified.

Source	Receptor	Pathway	Immediate Risk
Leaks, spills of chemicals Tailings	• Local Environment	• GW unlikely • Dust	Low

3.9 ZOI9 – Legacy TSF Footprints (Encapsulated)

This Zone of Influence contains the following:

- AOC64 Historic TSF
- AOC65 Historic TSF
- AOC 85 Historic Tailings Wash Area

These Areas have been grouped together as they are located adjacent to one another and have all been covered to some degree by the Fimiston WRDs.



Figure 15: Zone of Influence 9 and associated Areas of Concern

These areas contain the remnant footprints of tailings facilities that were reprocessed during the Kaltails project in the 1990s. They were covered under at least 40 m of waste rock within the Trafalgar Waste Dump during 2000s, eliminating the pathway for exposure via dust. Water infiltration through the WRD does occur, but is reduced by the waste rock capping, minimising the potential for transfer of COPC into surface and groundwaters.

Given testing conducted on similar tails within the area (MBS Environmental, 2016), it is likely that the remnant tailings contains elevated levels of COPCs, however if present, they are likely to be in insoluble forms. Further investigation of area not possible due to waste dump placement.

KCGM considers this AOC to be low risk considering the placement of waste rock limiting the pathways for COPC transfer to the wider environment.

Source	Receptor	Pathway	Immediate Risk
Tailings and Soil	• Local Environment	• Surface water movement (low)	Low

3.10 ZOI10 – Oroya, Balgold, and Galconda TSFs

This Zone of Influence includes:

- AOC52 Oroya TSF
- AOC53 Balgold Heap leach Footprints
- AOC74 Galconda TSF Footprint

- AOC86 Balgold-Galconda Tails Wash Area
- AOC105 Former Balgold Heap Leach Pads

These sites have been grouped together as they are located adjacent to one another and source differentiation between distinct sites within this area would be difficult, especially considering that they are almost completely covered by waste rock and/or subgrade stockpiles. All sites, other than ACO105 will be discussed together in the below sections.



Figure 16: Zone of Influence 10 and associated Areas of Concern

3.10.1 Oroya, Balgold, and Galconda TSFs

The Oroya TSF received tailings from the Oroya Processing Plant until it was decommissioned in the late 1990s. After a period of consolidation and drying, the TSF was progressively encapsulated by waste rock from 1998 to 2002. Rehabilitation of the overlying waste rock dump was completed from 1998 to 2003. A geotechnical study of the TSF confirmed that it was stable under waste rock loading (Golder Associates, 2011). No sampling of the TSF was conducted to Contaminated Sites standards when the tailings was exposed and it is now no longer possible due to waste rock placement.

The Balgold and Galconda TSFs were operational between 1984 and 1992 and were progressively encapsulated by waste rock from the mid-1990s to 2002. The majority of the tailings is covered by waste rock, with only small area of the Balgold TSF wall remaining exposed. Geochemical sampling was conducted on this exposed tailings in 2016 (MBS Environmental, 2016):

- Tailings are NAF with low to moderate theoretical acid production potential and correspondingly moderate to high levels of ANC, with a significant portion of sulfur in most samples being in the already oxidised form (sulfate).

- Leachate and hence any potential for seepage (depending on closure design) is predicted to be alkaline and brackish in perpetuity.
- Geochemically enriched in gold, silver, antimony, and tellurium as a result of the nature of the particular gold mineralisation, but none of these elements were found to be soluble in water extracts or dilute acetic acid extracts to any extent considered to be of environmental concern post-closure when covered.
- Marginally enriched in mercury (1.1 mg/kg) along with a higher concentration of tellurium (13.9 mg/kg), but were not found to be soluble in water extracts and are not considered to pose a risk to the environment when covered with waste rock to prevent water and wind erosion.
- Tailings is geochemically benign but other materials within the Balgold, Oroya, and Galconda operations area are expected to be variable in nature.

It was concluded that a suitably designed waste rock cover to prevent wind and water erosion will be sufficient post-closure to prevent negative impacts on the surrounding environment. Given that the majority of these tailings are already covered, KCGM considers that there is low immediate risk from this facility on any potential receptors.

The Balgold-Galconda Tailings Wash Area (AOC 86) was reported as a tailings wash area, but recent review of historic photographs of the area suggest that it was more likely used as an infrastructure/laydown area. It is currently used as an operational laydown and storage area. Monitoring of surface water runoff has occurred during operations for unauthorised discharge, which could be used for preliminary investigations for effects on surface water. This site is unlikely to have groundwater impacts due to depth of the groundwater to surface and also the hypersaline nature of the groundwater (no other beneficial uses).

KCGM considers that risk from a Contaminated Sites perspective is adequately managed through encapsulation and the groundwater production borefields.

Source	Receptor	Pathway	Immediate Risk
Tailings Seepage	• Local Environment (soil)	• Surface water movement (low) • Seepage expression	Low

3.10.2 AOC105 Former Balgold Heap Leach Pads

Little information is known about this small area to the south of the large TSFs. Limited documentation states that they were heap leach pads/ponds and they appear to have been used up until the mid-1990s, when they were capped and rehabilitated. The area has been capped and rehabilitated. Rehabilitation has performed well, with less success on the upper surfaces of the ponds, suggesting high soil salinity.

KCGM considers that the risk from this AOC is low considering effective rehabilitation has limited pathways for COPC transfer via dust and surface water movement. There is no ecological or human

receptor for groundwater as the only beneficial use for groundwater is mining. Further sampling of this area may be undertaken to better understand any potential sources of COPCs.

Source	Receptor	Pathway	Immediate Risk
Mineral Processing Residues	• Local Environment (soil)	• Surface water movement (low) • Seepage expression • Vegetation uptake	Low

3.11 ZOI11 – Croesus Mill

This Zone of Influence includes:

- AOC42 Former Croesus Mill
- AOC111 Historic Concentrate Storage Area
- AOC112 Historic Tailings Wash Area

These sites have been grouped together as they are located adjacent to one another and source differentiation between distinct sites within this area would be difficult, especially considering these sites have been partially buried under the Environmental Noise Bund and/or mined through.



Figure 17: Zone of Influence 11 and associated Areas of Concern

3.11.1 AOC111 – Historic Concentrate Storage Area

No information is available on this AOC, therefore it is unclear why it was originally reported. Review of aerial photographs from the 1980s and 1990s shows that the area has been heavily impacted by mining and mineral processing activities, including being mined through during development of the Croesus Pit and then backfilled during development of the Fimiston Pit. KCGM does not consider this area to be a source of COPC and will apply for this area to have a revised classification of 'Report unsubstantiated'.

3.11.2 AOC112 Northern Croesus Mill and Tailings Wash (a.k.a. Historic Tailings wash area)

This site consists of the rehabilitated footprints of ponds, pipeline corridors, laydowns and residue/tails stockpiles that were used during operation of the Croesus Processing Plant (Mill) in the late 1980s and early 1990s. The site was decommissioned and rehabilitated during 'Greening the Golden Mile' in 1999. Success of vegetation growth in the area has been variable, likely due to residual salinity.

The majority of this area is either covered by a waste rock dump (Croesus Noise Bund) or has adequate vegetation coverage to mitigate dust generation. Depth to hypersaline groundwater in this area is considerable, and the area is within the cone of depression for Fimiston Open Pit and Mt Charlotte, and as such KCGM does not believe seepage to groundwater is a viable COPC pathway. Soil contamination and uptake by vegetation may be a credible pathway; however, adequate soil sampling has not been undertaken. Preliminary sampling has indicated that metals contamination above Ecological Investigation Limits is confined to first 5-40 cm of soil profile, but original results were not conducted to

Contaminated Sites data standards. Further soil sampling should be conducted to further define potential sources of COPCs and the risk to the local environment. The entire area is currently fenced off and not accessible by the general public – likely to remain so indefinitely. Access by mine workers is limited to periodic rehabilitation monitoring.

KCGM considers that this area has low immediate risk from a contaminated sites perspective.

Source	Receptor	Pathway	Immediate Risk
Soils	• Local Environment	• Uptake by vegetation	Low

3.11.3 AOC42 – Former Croesus Mill

This site contains the rehabilitated footprint of the Croesus processing plant, which contained a roaster and associated infrastructure including carparks, tailings, and process water dams. The plant was decommissioned and rehabilitated (including hand planting with local native seedlings) in 1997-1999 and partially encapsulated by Croesus Noise Bund in 2001-2003. There are areas of limited vegetation success at within the northern section – salinity suspected to be a limiting factor. The entire area is currently fenced off and not accessible by the general public – likely to remain so indefinitely. Access by mine workers is limited to periodic rehabilitation monitoring.

Further sampling of soils is required in this area to define any potential sources of COPC. However, pathways and receptors for transfer of COPC are considered limited due to depth to groundwater and the hypersaline nature of groundwaters. Dust generation is not considered an issue from these rehabilitated areas and surface water flows are generally confined to within rehabilitated areas.

KCGM considers that this area has low immediate risk from a contaminated sites perspective.

Source	Receptor	Pathway	Immediate Risk
Soils	• Local Environment	• Uptake by vegetation	Low

3.12 ZOI12 – Boorara Rd Rehabilitated Areas

This Zone of Influence contains the following AOCs:

- AOC40 Former Gold Processing Plant
- AOC41 Former Force Workshop
- AOC42 Former Croesus Mill
- AOC43 Former Gold Processing Plant
- AOC44 Historic TSF
- AOC45 Former Gold Processing Plant

It should be noted that further clarity on the liability for remediation of these sites is required. KCGM is unsure if they liable for investigation and remediation of these sites, despite initially reporting them.

No soil sampling has been completed in these areas, although poor vegetation growth from rehabilitation in some areas tends to indicate salinity may be present. Should KCGM be determined to be liable for remediation of this site, further testing of soils in the area is recommended to define any sources of COPC and the immediate risk from this area.

Source	Receptor	Pathway	Immediate Risk
Contaminated soil	• Local Environment • Humans	• GW unlikely • Dust • Surface water	LOW



Figure 18: Zone of Influence 12 and associated Areas of Concern

3.12.1 AOC40 Former Gold Processing Plant

This area was operated prior to the 1980s as a Processing Plant, with tailings/residue appearing to have been deposited in legacy TSF on site (see Appendix 1, Figure A30). The site was rehabilitated in 1993/94 with the processing plant removed and area ripped, seeded and hand planted with local provenance species.

The site is bordered by Borarra Rd to the south an active infrastructure corridor to the east. It is currently accessible by members of the public.

A draft PSI has been prepared as an outcome over work done over the period 2019 – 2021. The likely outcome is, after removal of asbestos fragments, end classification to Contaminated, Restricted Use.

3.12.2 AOC41 Former Force Workshop (reported as Former workshop)

This site was used as a mining fleet maintenance workshop. It is bordered by Borarra Rd to the south and Goldfields Hwy to the West. It is currently accessible by members of the public and is used as public open space. No permanent structures are present.

Cleanup and rehabilitation of the site (approx. 10,804 m^2) occurred in 2003 and documentation states that it was planned to include the removal of all equipment, waste and infrastructure, and hydrocarbon and saline contaminated soil. Soil was to be removed to a nominal 0.5 m depth or less where contamination was not visually evident.

A draft PSI has been prepared as an outcome over work done over the period 2019-2021. Additional sampling is required to make a determination on end point classification.

3.12.3 AOC43 Former Gold Processing Plant

This site encompasses part of the former "WAMPRI" processing plant and waste dump. The plant was decommissioned and rehabilitated in 1997-1999. Growth media and rehabilitation materials were trucked to site in order to construct a 2-3 m bund on the eastern and southern edges of the area. The area was hand planted and seeded, with vegetation growth being very successful.

The tailings may have been produced using potable, rather than saline water. The tailings storage appears to have been removed, with only the footprint of the tailings remaining. Internal KCGM documentation suggests that the tails were stockpiled on Croesus TSF and rehabilitated.

A draft PSI has been prepared as an outcome over work done over the period 2019-2021. The likely outcome is end point classification to Contaminated – Restricted Use.

3.12.4 AOC44 & AOC45 Historic TSF and Former gold processing plant

This site, also known as Mt Ferrum, operated in the mid-1980s and consisted of an open pit, mineral processing plant, heap leach and tailings facilities. Operations were backfilled, mineral processing plant decommissioned, and tailings/heap leach rehabilitated in 1997. There is currently good vegetation growth present.

The area is accessible to the general public, although visitations are infrequent. A dust monitor is present on the upper surfaces of the facility, although it only measures size fractions, not speciation of COPC.

A draft PSI has been prepared for work completed over the period 2019 – 2021. The likely outcome is end point classification to Not Contaminated – Unrestricted Use for both AOC44 and AOC 45.

3.13 ZOI13 – Morrison's Flats Tailings Wash Area

This site is known as AOC63.

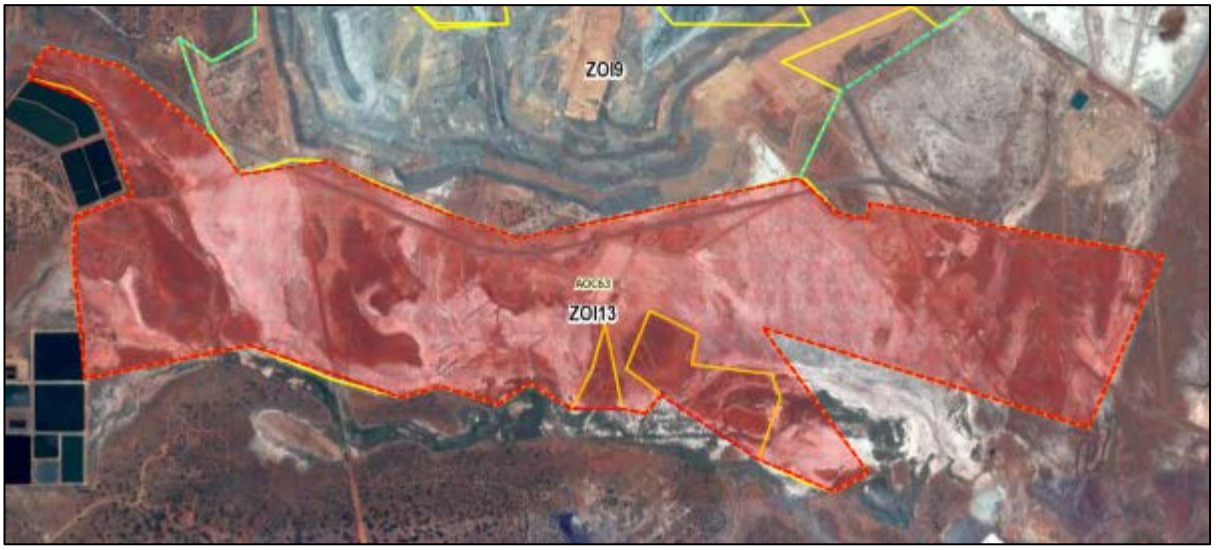


Figure 19: Zone of Influence 13 and associated Area of Concern

Tailings have been deposited in this area since before the turn of the 20th century, processing ore from the Golden Mile. Due to mineral processing methods used at the time, much of these tailings were enriched in heavy metals, including gold. Some of the tailings were reclaimed as part of the Kaltails Retreatment Project from 1988 to 1999 and the resulting tailings were deposited within the Kaltails TSF. Some of the remaining footprints of the TSFs have been progressively covered by the expansion of the Fimiston WRD to the south. Other historical TSFs in the area have been subjected to sheet wash flows which have spread tailings material over surrounding areas of soil. Further expansion of the WRD is planned which will gradually cover the remaining footprints.

Initial sampling and analysis of the tailings (including the Joshtails TSF) and tailings wash areas indicated that tailings material was fully oxidised (not PAF) but contained variably enriched levels of mercury, arsenic, silver, antimony, and tellurium. Concentrations were highest areas where tailings piles were evident. Analysis of underlying soils in wash areas indicated the species were not migrating through into the soil. Concentrations of tailings (but generally not the underlying soils) exceeded Ecological Investigation Limits but were below levels of concern for human health.

Further geochemical assessment and results indicated the species were largely insoluble – particularly for some samples where porewaters have gradually developed higher concentrations of soluble forms of mercury. Speciation indicated mercury was present as either coloradoite (insoluble) or mercury salts but not volatile elemental mercury. The properties of the tailings indicate no increased risk of mobilisation of metals if wash area tailings are relocated for remediation/closure purposes.

Further work is being completed to characterise the groundwater environment surrounding this ZOI to determine any potential impacts from tailings seepage.

Source	Receptor	Pathway	Immediate Risk
Tailings	• Local Environment	• Groundwater	Not Yet Determined

3.14 ZOI14 – Mt Percy Open Pit Lakes

This Zone of Influence includes:

- AOC101 Union Club Pit
- AOC102 Sir John
- AOC103 Mystery Pit



Figure 20: Zone of Influence 14 and associated Areas of Concern

Mining occurred at the Mt Percy site between 1985 and 1992 when the Mystery and Union Club Open Pits were mined to a maximum depth of 90 m.

The groundwater phreatic surface coincides with the Mystery Pit floor. As a result, this wall section appears to be fully drained and the mine void contains no permanently ponded water. The Union Club Pit floor however extends deeper to 300 m AHD resulting in the lower part of the pit intersecting the groundwater table. The intersection of the phreatic surface within the moderately to slightly weathered zone implies the uppermost Union Club slope, i.e., the weathered zone, is fully drained. The current pit lakes have remained relatively stable for a number of years reflecting the balance between groundwater and rainfall inflow and evaporation from the lake.

Routine analysis of pit lake waters as part of ongoing operational water monitoring indicates that COPCs are below investigation levels. There is also no beneficial use of groundwater other than mining – therefore there is no receptor. KCGM does not consider these areas to be a source of COPC and will apply for to have a revised classification of 'Report unsubstantiated'.

Source	Receptor	Pathway	Immediate Risk
Nil	• Nil	• Groundwater	Nil

3.15 ZOI15 – Mt Percy Rehab Features

This Zone of Influence includes the following Areas of Concern:

- AOC8 Mt Percy TSF
- AOC10 Former Mt Percy Plant
- AOC25 Mt Percy Workshop and Wash Area
- AOC31 Sir John Open Pit
- AOC90 Mt Percy Former ROM Pad

These sites have been grouped together due to geographical location and their closed and rehabilitated status. All Mt Percy sites are fenced and public access is excluded.



Figure 21: Zone of Influence 15 and associated Areas of Concern

3.15.1 AOC8 Mt Percy TSF

The Mt Percy TSF consists of two paddocks (TSF 1 and TSF 2) and is approximately 39 ha, with embankments (maximum height of 24m) constructed both of mine waste (oxide) and tailings. It received tailings from the Mt Percy processing plant (AOC10) from 1985 to 1997, and was rehabilitated in 2001. The final geotechnical stability assessment (conducted in 1997) indicated satisfactory stability.

Rehabilitation involved capping with a considerable amount of oxide (1-2 m in places) and slope angles were either constructed, or reshaped with oxide waste to 20°. At the time, the main purpose of rehabilitation was for prevention of dust and increased amenity to the City of Kalgoorlie Boulder.

Limited characterisation of tailings from the Mt Percy TSF was undertaken by Australian Groundwater Consultants as a part of the Mt Percy TSF extension works approval in 1988 (selected metals, cyanide, salinity, and pH). In addition, one tailings sample was assessed in 1991 by KCGM and was found to have a pH of 7.6, electrical conductivity 120 dS/m, labile N 21 ppm, phosphorus 6 ppm, potassium 90 ppm, sodium 27,000 ppm, and phosphorus retention index (PRI) 148.

Further geochemical characterisation in 2016 (MBS Environmental, 2016) indicates:

- Tailings are classified as NAF with low to moderate theoretical acid production potential and correspondingly moderate to high levels of ANC; a significant portion of sulfur in most samples being in the already oxidised form (sulfate). Mt Percy TSF was further classified as acid consuming.
- Leachate and hence any potential for seepage from these tailings is predicted to be brackish in perpetuity.
- Geochemically enriched in gold, silver, antimony and tellurium as a result of the nature of the particular gold mineralisation, but none of these elements were found to be soluble in water extracts or dilute acetic acid extracts to any extent considered to be of environmental concern post-closure when covered.
- That the tailings are considered to geochemically benign, with only moderate levels of salinity in leachates and/or potential seepage, which will remain alkaline.
- Geochemical assessment indicates that a suitably designed cover to prevent wind and water erosion will be sufficient post-closure to prevent negative impacts on the surrounding environment.

During operational monitoring of groundwater around the TSF, shallow groundwater was intersected in four boreholes on the south eastern side, where groundwater occurs as a result of a perched water table in shallow alluvium (the only location near the Mt Percy TSF where this unit occurs). As of 2000, only the four monitor bores on the south eastern side of the Mt Percy TSF contained groundwater (Peter Clifton & Associates, 2001). It was expected that as the TSF drained, groundwater levels would subside. The remaining five monitor bores on other sides of the TSF were dry, indicating that groundwater at these sites was below the bottom of the monitor bore casings.

Hydrochemical data from monitor bores south eastern side of the TSF indicate that seepage from this TSF influenced the chemistry of shallow groundwater, but this shallow alluvium aquifer is not significant aquifer and does not contain significant amounts of groundwater. The pH of groundwater appears to

decrease in a south easterly direction moving away from the TSF, an expected trend as the geochemical environment in the shallow alluvial and colluvial soils in this area would promote acidic conditions. The background groundwater quality in this alluvial unit is unknown, but data collected by KCGM in the same catchment and down-gradient of the Mt Percy TSF suggest any natural groundwater in this unit would be moderately saline and acidic (TDS ~40,000 mg/L and pH ~3-4). Some of this seepage was recovered by the Mt Percy Trench until mid-1999 when the trench became dry.

There are no records of cyanide concentrations in the slurry that was discharged to the Mt Percy TSF, however based on other TSFs operated by KCGM these concentrations were expected to be around 100 mg/L. The shallow groundwater on the south eastern side of the TSF is therefore expected to contain much less cyanide than the water that was discharged to the TSF. Cyanide is not expected to persist in the shallow groundwater around the Mt Percy TSF because the prevailing acidic environment would promote cyanide degradation.

KCGM considers that the risk to the environment and human health from the Mt Percy TSF to be low due to the geochemically benign nature of the tailings material and material used in rehabilitation, naturally saline and acidic groundwater and rehabilitation mitigating dust generation from the TSF.

Any further long term risk from the TSF will be adequately managed through implementation of KCGM's Mine Closure Plan.

Source	Receptor	Pathway	Immediate Risk
Tailings Seepage	• Local Environment	• Groundwater	Nil
Tailings	• Local Environment	• Nil	Nil

3.15.2 AOC10 Former Mt Percy Plant & AOC90 Mt Percy Former ROM Pad

The Mt Percy Plant was commissioned in 1986 and decommissioned in mid-1997. The mill had the capacity to process approximately 1 Mtpa of ore, and consisted of a two stage crushing circuit, grinding circuit, leach tanks, CIP adsorption tanks and carbon stripping circuit.

Rehabilitation of the plant area consisted of picking up surface material to a depth of 1 m and was likely deposited into the open pits. The ROM pad was battered down to less than 15° and ripped to 0.75 cm deep with 1.5 m spacing. No additional rehabilitation materials were applied. Visual inspections of the plant site in 2014 indicate that the site has good recruitment of understorey species, and scattered growth of overstorey species such as *Eucalyptus.* The ROM has variable re-vegetation, with some areas preforming poorly.

Further sampling of soils is required in this area to define any remaining potential sources of COPC. However, pathways and receptors for transfer of COPC are considered limited due to depth to groundwater and the hypersaline nature of groundwaters. Dust generation is not considered an issue due to rehabilitation and surface water flows are generally confined to within rehabilitated areas.

KCGM considers that this area has low immediate risk from a contaminated sites perspective.

Source	Receptor	Pathway	Immediate Risk
Soil	• Local Environment	• Vegetation Uptake	Low

3.15.3 AOC25 Mt Percy Workshop and Wash Area

This area appears to have been used as a material stockpile, and also as a workshop area. It was rehabilitated in the late 1990s, with varying success, likely due latent salinity in the soil. Surface water tends to pool in the centre of this area due to operational pipeline bunding (Fimiston water transfer) blocking flow of water offsite.

Materials are generally sandy clay loam in texture, had very high soil strength and had varying levels of structural stability (Emerson Class 2 to 4) (Outback Ecology, 2010). The materials were moderately alkaline, generally had extreme salinities and had low organic matter and nutrient status. No additional soil analysis has been undertaken.

Further sampling of soils is required in this area to define any potential sources of COPC. However, pathways and receptors for transfer of COPC are considered limited due to depth to groundwater and the hypersaline nature of groundwaters. Dust generation is not considered an issue from these rehabilitated areas and surface water flows are generally confined to within rehabilitated areas.

Source	Receptor	Pathway	Immediate Risk
Soil	• Local Environment	• Vegetation Uptake	Low

3.15.4 AOC31 Sir John Open Pit

Mining occurred at the Mt Percy site between 1985 and 1992. In 1999, the Sir John Open Pit was used for the disposal of tailings material removed from the Hannans North Tourist Mine (formerly the Australian Prospectors and Miners Hall of Fame site (AOC26)). Potentially acid forming Black Flag Bed shale that was stockpiled on the Mt Percy ROM pad was also deposited into this open pit and encapsulated within the tailings material. The pit has not been completely backfilled, with general waste also dumped in the pit, such as conveyors, PVC piping, and tyres. Settlement cracks and subsidence exist within the already backfilled portion.

Surface sampling of the material used to backfill the pit was conducted in 2010 (Outback Ecology, 2010). The materials range from silty loam to sandy clay loam in texture, have very high soil strength values and are structurally unstable (Emerson Class 2) although non-sodic (Table ES1 and ES2). The materials were moderately alkaline, extremely saline and, as would be expected, had low organic matter and nutrient status. In addition, the in-fill material commonly reported concentrations of arsenic, chromium, copper, and nickel which were above their respective Ecological Investigation Levels (EILs), however higher EIL values may be acceptable for some metal concentrations in areas where soils naturally have high background concentrations of these elements.

Further sampling of soils is required in this area to define any potential sources of COPC. However, pathways and receptors for transfer of COPC are considered limited due to depth to groundwater and

the hypersaline nature of groundwaters. Dust generation is not considered an issue from this area and surface water flows are generally confined to within rehabilitated areas.

Source	Receptor	Pathway	Immediate Risk
Soil	• Local Environment	• Vegetation Uptake	Low

3.16 ZOI16 – Hannans North Tourist Mine

This Zone of Influence contains the following Areas of Concern:

- AOC12 Mullingar TSF
- AOC26 Former TSF at Hannans North Tourist Mine
- AOC27 Mullingar Tailings Wash Area

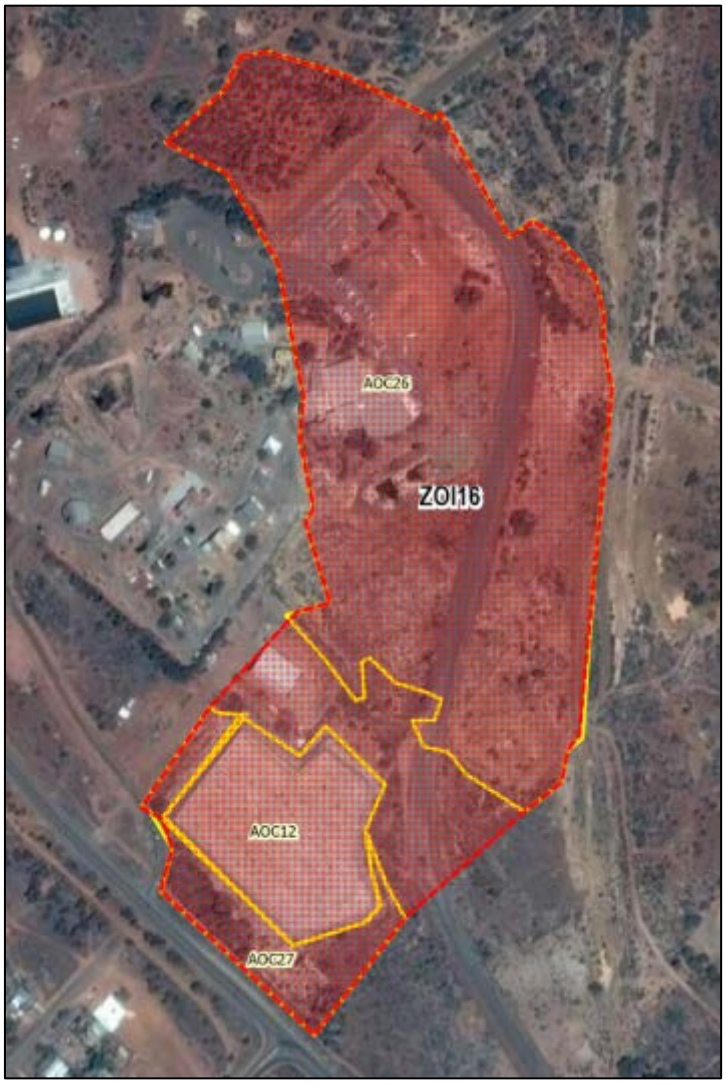


Figure 22: Zone of Influence 16 and associated Areas of Concern

3.16.1 AOC12 & 27 Mullingar TSF & TSF Wash Area at Hannans North Tourist Mine

This TSF is the last historical 'hand built' TSF on the Golden Mile and as such may be considered to have heritage value. There are currently some concerns over geotechnical stability of this TSF.

Geochemical testing of the tails in 2017 have indicated that the tailings are:

- NAF and Acid Consuming;
- Marginally enriched in lead and mercury;
- Substantially enriched in Molybdenum, Tellurium (insoluble forms), Antimony;
- Water leachates were brackish to saline and circum-neutral to moderately alkaline;
- Slightly elevated (>0.01 mg/L, above non-potable groundwater re-use guidelines) concentrations of mercury were recorded in three water leachate Mullingar samples (maximum 0.025 mg/L). No samples exceeded the non-potable groundwater use guideline of 0.01 mg/L if adjusted for a 1:20 ratio extraction. Three samples also reported molybdenum (maximum 0.40 mg/L) concentrations above the livestock drinking water guideline;
- All Mullingar samples contained detectable concentrations of soluble mercury, ranging from 0.002 mg/L to 0.007 mg/L, although the concentrations of soluble mercury are still relatively low and total mercury also low as evidenced by only marginal enrichment (maximum concentration 1.1 mg/kg; and
- Concentrations of soluble aluminium, boron, barium, bismuth, iron, chromium, manganese, nickel, uranium, vanadium, and zinc were very low and therefore considered to be of no environmental consequence.

The tailings is therefore considered to contain geochemically benign tailings, with only moderate levels of salinity in leachates and/or potential seepage, which will remain alkaline.

Drilling through the tailings dam was undertaken in 2019, with samples taken for analysis. Interpretation has not commenced. Piezometers were installed in some of the drill holes, but no phreatic surface was identified.

Source	Receptor	Pathway	Immediate Risk
Tailings	• Local Environment	• Dust • Sediment Transport	Low

3.16.2 AOC26 – Former TSF at Hannans North Tourist Mine

This facility was a legacy of prior mining and mineral processing in the area, with tailings appearing to have been deposited directly into the environment, i.e., no modern tailings management practises were used. In the late 1990s, tailings were removed and placed in Sir John Pit at Mt Percy and the area was rehabilitated. Part of the area was then used for the Mining Hall of Fame (MHoF) building and grounds

in the early 2000s. These buildings and the surrounding area are publicly accessible and now part of a tourist attraction. Approximately 40-50% off the site is sealed below buildings or roads/carparks.

Further sampling of soils is required in this area to define any potential sources of COPC. However, pathways and receptors for transfer of COPC are considered limited due to depth to groundwater and the hypersaline nature of groundwaters. Dust generation is not considered an issue from sealed and rehabilitated areas and surface water flows are generally confined.

Source	Receptor	Pathway	Immediate Risk
Soil	• Local Environment	• Vegetation	Low

3.17 ZOI17 – Gidji Sites

This Zone of Influence contains the following Areas of Concern:

- AOC1 Gidji Processing Plant
- AOC2 Gidji TSF Plume
- AOC3 Gidji TSF
- AOC4 Chemix Pond
- AOC6 Chemix Plant
- AOC7 Former Gidji Landfill Site
- AOC9 Temporary Gidji Concentrate Storage Sites

These sites have been grouped as they are located in the same area, separated from the other KCGM sites by approximately 17 km.

It should be noted that these sites were reported in 2007 in accordance with requirements, but KCGM has not received formal classification from the DWER. Re-reporting of these sites to ensure they are included in the regulatory database may be required based on advice received. Opportunity to consolidate and redefine site boundaries may be possible at this time.

Management of these sites is completed in accordance with an *EP Act* Part V Licence and is also managed in accordance with approvals received under Part IV of the *EP Act* and Mining Proposals submitted in accordance with the *Mining Act*. Therefore, KCGM considers that the immediate risk to the environment and human health from a contaminated sites perspective is adequately mitigated by operational management.



Figure 23: Zone of Influence 17 and associated Areas of Concern

3.17.1 AOC1 Gidji Processing Plant

The Gidji Processing Plant was commissioned in 1989 to treat concentrate from the Fimiston Plant. This provided the opportunity for a phased reduction of in-town roasting through the decommissioning of the remaining three in-town roasters and the establishment of a central roasting facility, Gidji, located 18 km north of the City. In 2015, the roasters were decommissioned and Ultra Fine Grind (UFG) became the primary methods for treating concentrate at Gidji. The Processing Plant is predominantly covered by a concrete or bitumen hardstand, with drains surrounding the facility to re-direct runoff into catch dams for use within the plant.

Preliminary sampling during geotechnical testing for new infrastructure footings has indicated low levels COPCs confined to surface soils. Further investigation will be conducted opportunistically during operations and prior to decommissioning to aid management of any contaminated soil material.

The site investigation boundary should be expanded to consider the Cyanide Destruct Plant to the north, process water ponds and laydowns.

Source	Receptor	Pathway	Immediate Risk
Soil	• Local Environment	• Vegetation	Low

3.17.2 AOC2 &3 – Gidji Groundwater Plume and TSF

The Gidji I facility comprises two cells and was constructed in 1988/1989, with deposition commencing in 1989. The starter embankments were constructed from clay, silt and clayey sand sourced from within the storage footprint. Subsequent upstream raise construction has utilised deposited tailings sourced from within the impoundment. Both cells reached approved height in 2013 and all tailings produced from Gidji Plant are now deposited only within Gidji II. No rehabilitation has been undertaken at the Gidji I TSF as the tailings material is being used to construct the downstream lifts of Gidji II TSF. The TSF has been observed to dust during high winds.

Tailings deposited within the Gidji I TSF are a mix of a calcine tailings stream produced by the roaster and a minor stream of tailings produced from Ultrafine Grinding (UFG), reflecting a change in processing methods over time. A review of the available geochemical data was completed in 2021 (MBS Environmental 2021) which identified that the Gidji I tailings are:

- NAF with a greater ANC than acid production potential.
- Significantly enriched in several environmentally significant metals and metalloids based on screening by GAI; silver, arsenic, chloride, cobalt, copper, mercury, Molybdenum, lead, selenium and tellurium.
- Water leach extraction indicated that some but not all of the enriched chemical species (see above) are likely to be soluble to the extent where consideration of potential environmental risk is warranted.
    - Whilst the tailings are enriched in silver, lead, selenium and antimony, water leachable concentrations of these species were below the analytical limit of reporting (LOR). Water leachable molybdenum was below the livestock drinking water default guidance values (DGV). The solubility of these species in terms of rainfall runoff and percolation/seepage is unlikely to be environmentally significant.
    - Whilst arsenic was leached at around the non-potable use guidelines (NPUG) trigger level, the concentration was below the corresponding livestock DGV and, at this concentration, arsenic oxyanions (e.g. arsenate) are expected to be effectively adsorbed or co-precipitated with iron oxyhydroxides present in the soils and regolith of the surrounding environment. The overall risk from arsenic leachability is considered to be low. The extraction ratio (1:1, porewater) is also noted to be substantially higher than typical used for assessments against these trigger values - a more typical extraction ratio for such comparison (1:10 or 1:20 ratio extract) would be expected to produce concentrations in the order of 0.01 mg/L (1/10th) and hence below the NPUG value.
    - Cobalt, copper and mercury were leached from the tailings at concentrations exceeding broadly applicable water quality screening values. Cobalt and copper marginally exceeded the livestock drinking water DGVs of 1 mg/L, whilst mercury (0.02 mg/L) exceeded the corresponding DGV of 0.002 mg/L by one order of magnitude. These findings are consistent with the formation of soluble cyanide-metal complexes. These complexes will likely decrease in solubility over time with cyanide decomposition (aging), and again noting the high extraction ratio used for these tests.

- Water leach extraction also indicated that runoff or seepage from the Gidji 1 tailings is likely to be neutral to basic (pH 8.5), of brackish salinity (4,480 mg/L total dissolved solids, TDS) and to contain sulfate concentrations at around the livestock drinking water DGV (1,000 mg/L).
- Given the environmental context and low acid formation risk and low potential for further oxidation of the material, the tailings are unlikely to generate harmfully saline or acidic seepage.

A ferricrete and alluvial sediment groundwater system is present below the Gidji TSFs, and seepage has caused localised groundwater levels to rise which contains elevated concentrations of both TDS and WADCN. During operations, a seepage and groundwater recovery borefield (a seepage interception trench and low yielding production bores) has been operated to control groundwater levels, and prevent the naturally saline groundwater from rising into the root zone of vegetation. The borefield also acts to minimise the migration of the elevated TDS and WADCN concentrations in groundwater observed near the TSF.

A seepage model was developed in 2015 for the Gidji I TSF (PCA,2015). This work indicated that:

- Most seepage from Gidji I TSF will report to the shallow groundwater system and migrate westwards towards Gidji Lake or more likely become isolated pockets of perched groundwater, due to active abstraction bores.
- Seepage will not adversely affect the current beneficial users of the groundwater resource (mineral processing and mining).
- While a rapid decline in the phreatic surface within the Gidji I TSF is expected post-deposition, dissipation of the groundwater mound would be slow.
- Large rainfall events are unlikely to have a material effect on groundwater levels around the TSFs.

Groundwater levels at Gidji are declining, as the seepage source, Gidji I TSF, is no longer operational. However post-deposition, dissipation of the groundwater mound is expected to be slow, due to the nature of sediments that form the aquifer.

During operations, the health condition of the Eucalyptus woodland in the vicinity of the TSF has been classified as being in very good and good condition, with no impact from the TSFs.

KCGM considers that the immediate risk to the local environmental and human health from Gidji I TSF seepage is low, despite elevated COPC considering that there is no ecological or human receptor – groundwater's only beneficial use is for mining. As the Gidji II TSF is lined, KCGM does not believe that is poses a risk as a Contaminated Site.

Source	Receptor	Pathway	Immediate Risk
Tailings	• Local Environment	• Dust	LOW
Tailings Seepage	• Local Environment	• Soil • Groundwater	Low

3.17.3 AOC 4 & 6 – Chemix Pond & Plant

The Chemix plant was located on a Miscellaneous Licence overlying KCGM tenements near the Gidji roaster, used to convert manganese oxide to manganese sulphate using the sulphur dioxide emitted by the roasting process at Gidji. Production at the Chemix site ceased in April 1995 and the site remained on the KCGM managed lease without ongoing care and maintenance by the owners who went into administration.

The Chemix site was decommissioned and rehabilitated by KCGM in 2000. Sampling of materials from locations around the Chemix site was undertaken by KCGM in 1998 (original results unable to be located). Analysis identified all samples collected as either manganese oxide or manganese sulphate. No significant quantities of heavy metals were identified in any of the samples. Further sampling is required to adequately assess any sources of COPC from this site, however, receptors for any COPCs are limited due to the depth and saline nature of groundwater underlying the site.

Source	Receptor	Pathway	Immediate Risk
Soil	• Limited	• Vegetation uptake	Low

3.17.4 AOC7 – Former Gidji Landfill Site

Little is known about this site other than it was used as a landfill. The site appears to be relatively small and has been covered and rehabilitated.

Further sampling is required to adequately assess any sources of COPC from this site, but receptors for any COPCs are limited due to the depth and saline nature of groundwater underlying the site.

Source	Receptor	Pathway	Immediate Risk
Soil	• Limited	• Vegetation uptake	Low

3.17.5 AOC9 – Temporary Gidji concentrate storage site

Little known about operation of this area, other than it was used as a temporary concentrate storage area. The site has been rehabilitated and appears to have god vegetation growth.

Further sampling is required to adequately assess any sources of COPC from this site, however, receptors for any COPCs are limited due to the depth and saline nature of groundwater underlying the site.

Source	Receptor	Pathway	Immediate Risk
Soil	• Limited	• Vegetation uptake	Low

3.18 ZOI 18 – Johnson St East

This Zone of Investigation contains the following Areas of Concern:

- AOC104 19 Johnson St Boulder

- AOC98 24 Johnson St Boulder
- AOC99 28 Johnson St Boulder

These sites have been grouped together as they are located close to each other and have been used for light commercial premises.

19 Johnson St currently has permanent structures on it and is used for storage of infrastructure and core from the Fimiston Mining area. Activities of tenants of the property (whilst managed by KCGM) may have resulted in concentrations of COPC within the permanent structures. Since this site was reported as a contaminated site, no tenants have occupied it.

24 and 28 Johnson St are currently vacant land, with 28 Johnson St almost completely covered by the Environmental Noise Bund, limiting any pathways for COPC due to prevention of dust and reduction of water infiltration. 24 Johnson St has had a history of rubbish being dumped on the vacant land, and also has issues with safe access due to historical mining voids. Further investigation of this site is required to adequately assess the risk to the environment and human health, although KCGM considers that this site has a low risk from a contaminated sites perspective considering it is well vegetated (reduce dust), has no permanent structures and has deep connection with groundwater.

In 2020 a PSI was undertaken, with the report currently in draft format. The following outcomes are expected:

- 19E Johnston Street (AOC104) – end point classification as C-RU, suitable for commercial/industrial use no further actions required.
- 24E Johnston Street (AOC 98) – end point classification as NC-UU, no actions required
- 28E Johnston Street – end point classification as NC-UU, no further actions required.



Figure 24: Zone of Influence 18 and associated Areas of Concern

Source	Receptor	Pathway	Immediate Risk
Soils	• Local Environment • Humans	• Dust • Vapours	Low

3.19 ZOI 19 – Dwyer St – Light Commercial

This Zone of Influence includes the following Areas of Concern:

- AOC93 3 Dwyer St Boulder
- AOC92 6 Dwyer St Boulder

These sites are grouped together as they are in the same geographical area and have both been used for similar light commercial premises. Both properties are currently leased by KCGM.

3 Dwyer St was reported due to suspected hydrocarbon contamination due to leaks from above ground hydrocarbon storage tanks.

6 Dwyer St was reported due to past activities completed on the property (Hydrocarbon storage, metal treatment/finishing and sand blasting) potentially being the source of COPCs such as hydrocarbons and metals. Due to the managed light commercial nature of surrounding properties, they are not considered to be an immediate risk to human health or the environment.

In 2020 a PSI was undertaken, with the report currently in draft format. The following outcomes are expected:

- 3 Dwyer Street (AOC 93) – end point classification as PC-IR, suitable for commercial/industrial use, additional sampling required before being able to close out the assessment process.
- 6 Dwyer Street (AOC 92) – end point classification as PC-IR, suitable for commercial/industrial use, additional sampling required before being able to close out the assessment process.



Figure 25: Zone of Influence 19 and associated Areas of Concern

Source	Receptor	Pathway	Immediate Risk
Soils	• Local Environment • Humans	• Dust • Vapours	Low

3.20 ZOI 20 – Holmes St – Technical College

This Zone of Influence includes the following Areas of Concern:

- AOC108 31 Holmes St Boulder
- AOC109 29 Holmes St Boulder

These sites were grouped as they are adjacent to each other and buildings overlap each block. The valuation description for the blocks adjacent to and including these two AOC in 2004 was “35 year old brick office and 2 sheds on 5 freehold lots” and “Secondary office and industrial accommodation”.

31 Holmes St was reported as it was a former site of a metallurgical laboratory, which is no longer used for this purpose. Buildings used for laboratory work still remain and no further testing of the buildings or grounds has been completed.

29 Holmes St was reported as Light Commercial, but shares a building with 31 Holmes St, so most likely has the same usage history.

A PSI investigation has been undertaken on these blocks, with a draft report completed.

31 Holmes Street – end point classification as C-RU, suitable for commercial/industrial use, no further actions required.

29 Holmes Street – end point classification as NC-UU, suitable for multiple uses, no further actions required.



Figure 26: Zone of Influence 20 and associated Areas of Concern

Source	Receptor	Pathway	Immediate Risk
Soils	• Local Environment • Humans	• Dust • Vapours	Low

3.21 ZOI 21 – Oroya & Chaffers St – Vacant Land

This Zone of Influence includes the following Areas of Concern:

- AOC94 13 Chaffers St Boulder
- AOC95 11 Chaffers St Boulder
- AOC96 3 Chaffers St Boulder
- AOC97 15 Oroya St Boulder

These sites were grouped as they are in close proximity to each other and were all reported as asbestos contamination was suspected due to presence of asbestos housing. Since reporting of these sites, demolition of the permanent structures has been completed and all four lots are now vacant.

In 2016, KCGM was informed by the City of Kalgoorlie Boulder of 'extractive materials' (rock and soils) that had been illegally dumped on 3, 11 and 13 Chaffer St. The source of the materials could not be determined (unknown disposer) and KCGM removed the materials to its nearby waste dump.

In 2020 a PSI was undertaken, with the report currently in draft format. The outcomes likely to be an end point classification 'suitable for commercial/industrial use'. Further actions likely to be required are asbestos fragments remediation and final walk over before being able to close out the assessment process.



Figure 27: Zone of Influence 21 and associated Areas of Concern

Source	Receptor	Pathway	Immediate Risk
Asbestos materials	• Local Environment	• Dust • Fragmentation	Low

3.22 ZOI 22 – Williamstown Suspected Asbestos

This ZOI contains the following properties:

- VCL PIN 687197 (2 Austral Street)
- VCL PIN 687234 (7 Kanowna Old)
- VCL PIN 692786 (5 Kanowna Old)
- VCL PIN 692786 (19 Austral St)
- 36 Austral St (Lot 3547 on Deposited Plan 175259)
- Lot 3548, 38 Austral St
- 77 Brownhill Rd
- Lot 3956 on Deposited Plan 215926

- 11 Brownhill Rd
- 12 Brownhill Rd

These properties were all reported due to the suspected presence of asbestos. In 2015, it was identified that remnant asbestos material remained within vacant blocks in the suburb of Williamstown, adjacent to the Mt Charlotte surface operations, after KCGM had demolished houses on these parcels. Investigations and decontamination of several of these properties were undertaken in accordance with Contaminated Sites requirements, which resulted in three of these sites being classified as 'Decontaminated' by DWER. The other eight sites remain as 'Potentially Contaminated – Investigation Required'.



Figure 28: Zone of Influence 21 Areas of Concern

Source	Receptor	Pathway	Immediate Risk
Soils	• Local Environment • Humans	• Dust • Inhalation • Ingestion	Low

3.23 Returned Form 1s

3.23.1 AOC 5 & 11 – Borefields and Pipelines

The submitted Form 1s for these two AOCs were returned/rejected by the DWER after initial submission in 2007 as insufficient information to adequately assess them was provided. Correspondence states that:

"None of the reports provide any details of actual leaks or spills… or any other evidence to support a suspicion that contamination is present or likely to be present… DEC considers that the information currently contained in these Form 1 submissions does not provide reasonable grounds to believe or suspect that the sites are contaminated. The Form 1 submissions have therefore not been accepted as valid reports… and are returned to you for further consideration… Where KCGM is aware of additional evidence to support a suspicion that contamination may be present at a site (e.g., records of leaks or spills, observations or soil staining or groundwater monitoring results), the relevant Form 1 report should be resubmitted to DEC accompanied by this additional evidence. "

KCGM is in agreement with DWER's judgement that reporting of the borefields as a whole is not likely to represent actual potentially contaminated areas.

3.24 Not KCGM Liability

3.24.1 AOC50 – Former State Battery

Mineral processing operations have likely occurred on this reserve since the 1940s. Liability for this site lies with the State (Perth Mint), and it lies outside of the DWER Contaminated Zone for KCGM sites.

The State Battery reserve was reported by KCGM due to known elevated levels of mercury present during drilling prior to the construction of the re-alignment of the Kalgoorlie Bypass road (to allow expansion of the Fimiston Pit). During construction of the Bypass Rd, the area that was suspected of containing elevated levels of mercury was capped with 700 mm of clean fill. A second round of validation drilling was conducted following construction, and elevated levels of mercury were not detected.

The remaining areas of the site which were rehabilitated are currently accessible to the public and are utilised for a harness horse racing training track. Approximately 75% of the area is covered by the KCGM Environmental Noise Bund. Drilling at the time of road realignment did not intersect groundwater, indicating it is >50 m bgl.

KCGM considers that liability for this site lies with the State Mine and it is not required to perform any further work for this AOC.

4. REFERENCES

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APPENDIX 1: AOC HISTORIAL AERIAL PHOTOGRAPHS

ZOI1 FIMISTON I & II TSF



Figure A1: Fimiston TSF Plume and TSF 1999 (left) and 2014 (right)



Figure A2: Fimiston I 1997 (left) Fimiston I 2014 (right)

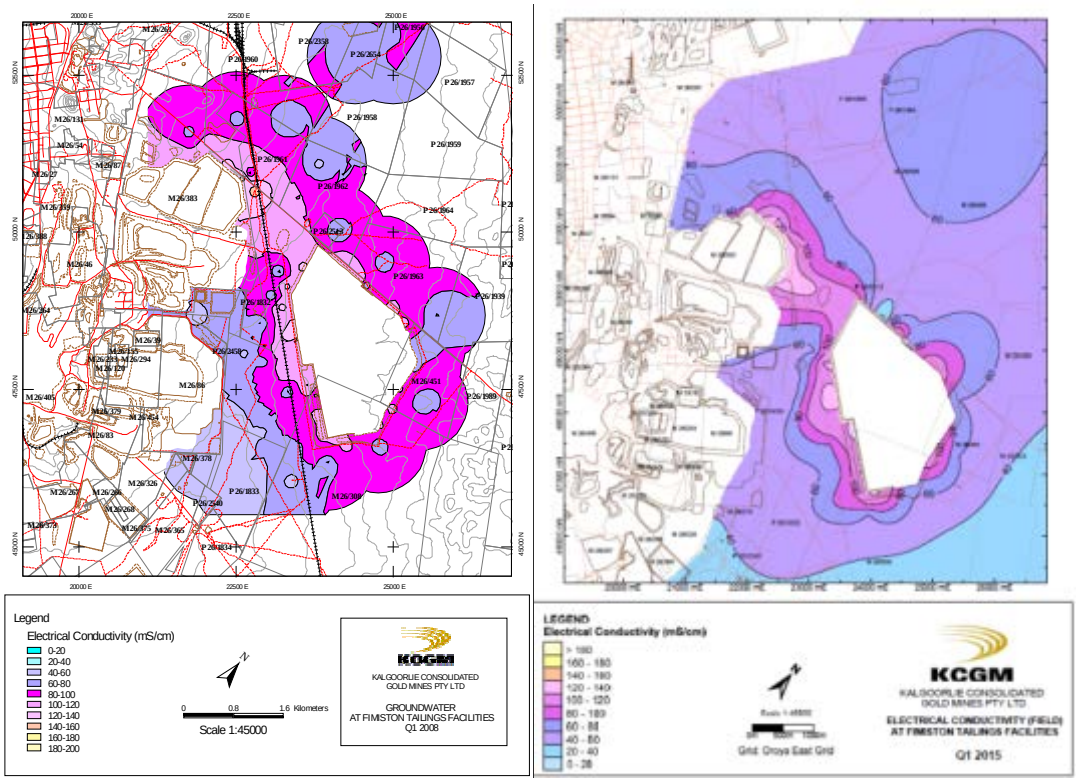




Figure A3: Herliette TSF 1989 (left) and 2014 (right)



Figure A4: Croesus TSF 1983 (left) and 2014 (right)

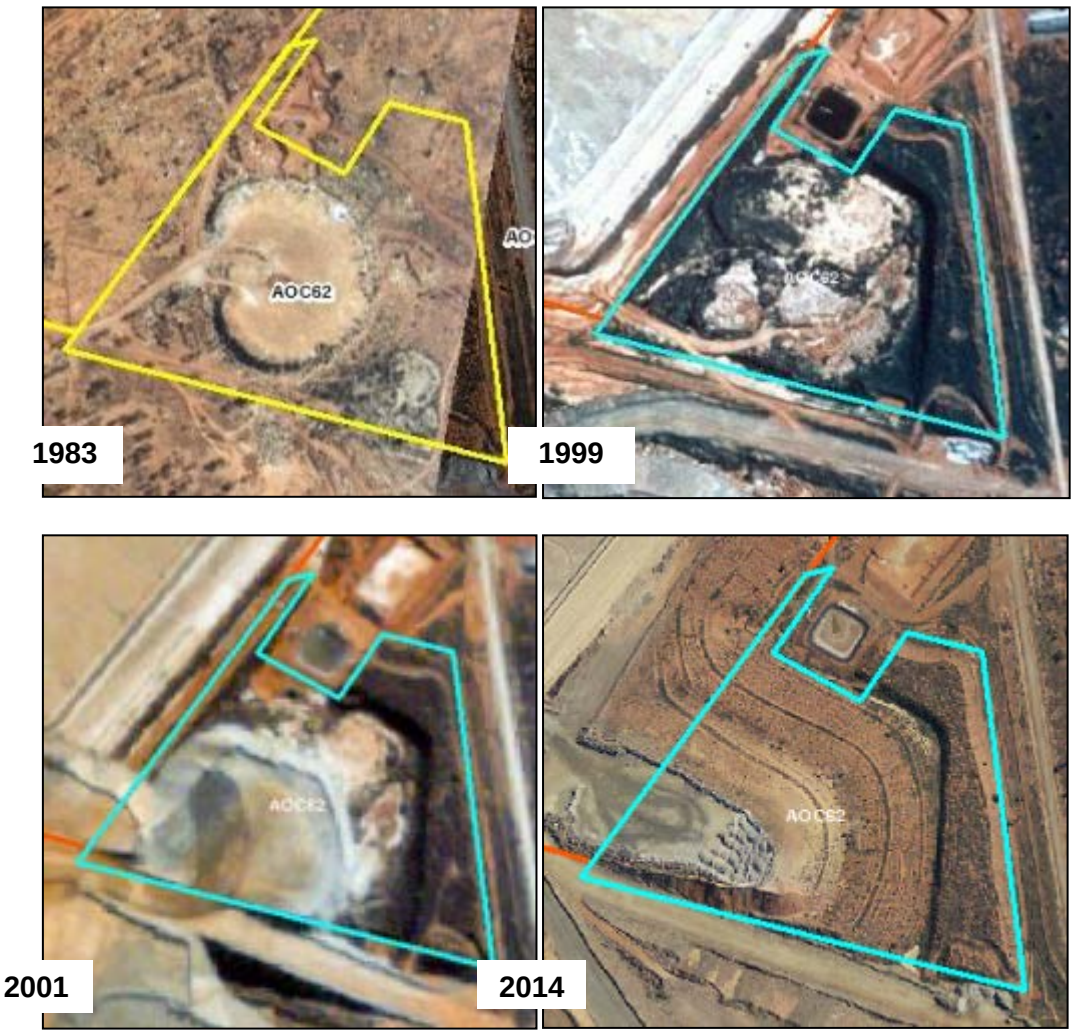


Figure A5: Historical Shire Tip 1983-2014

ZOI 2 KALTAILS TSF



Figure A6: Kaltails Reported Contaminated Sites 1999 (top) and 2013 (bottom)

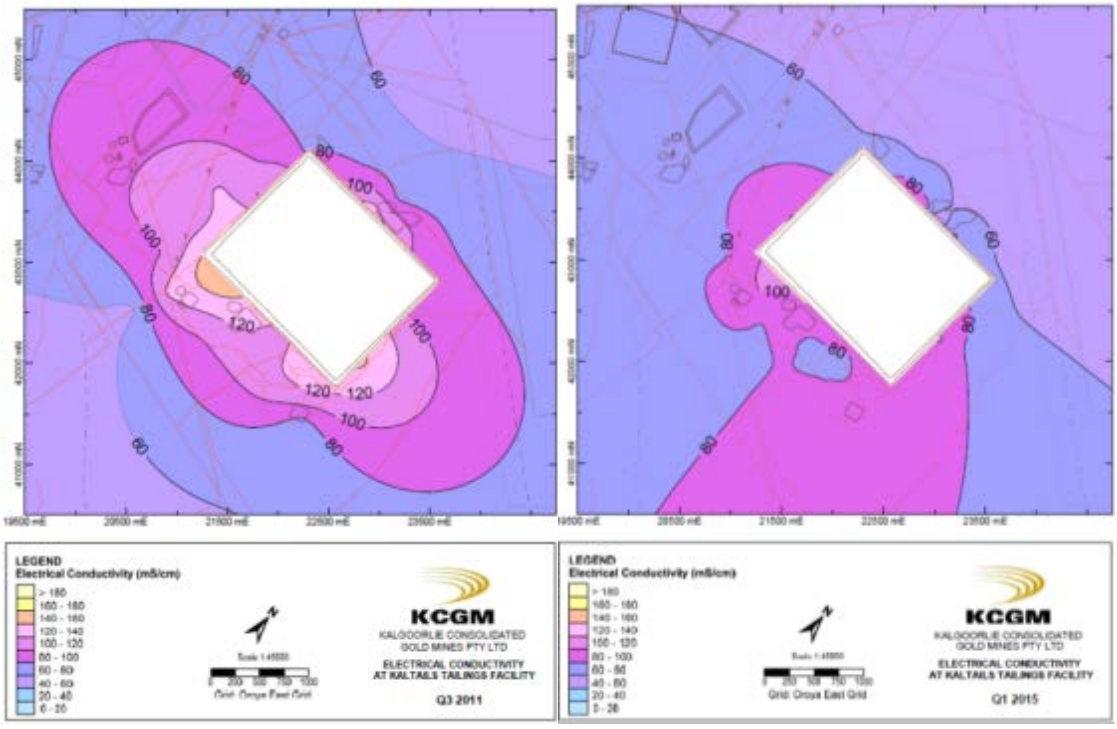


Figure A7: Kaltails TSF Seepage Plume EC Contour Graphs

ZOI3 MINING OPERATIONS



Figure A8: Fimiston Mill 1989 during construction (left) and 2014 (right)



Figure A9: Crushing Facilities 1989 (left) and 2014 (right)

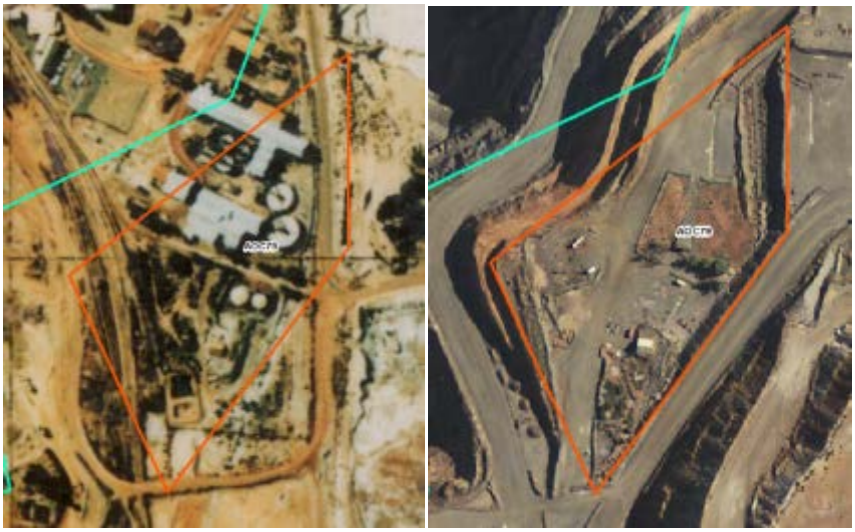


Figure A10: Chaffers Workshop Area 1987 (left) and 2014 (right)

ZOI 5 – MT CHARLOTTE

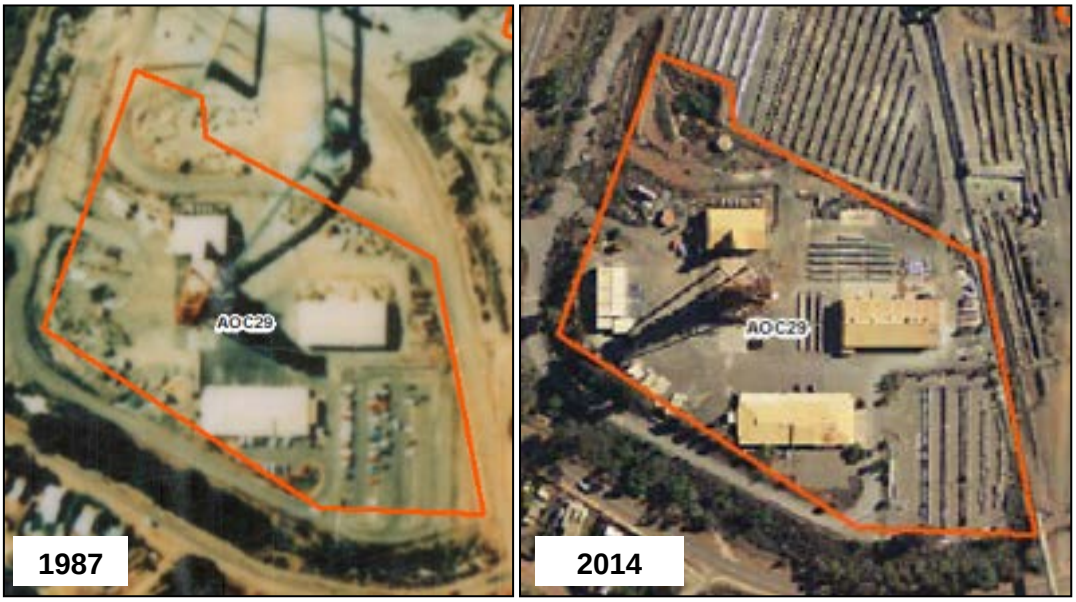


Figure A11: AOC 29 – Workshops and hydrocarbon storage area at the Cassidy headframe



Figure A12: Mt Charlotte Northern Vent Rise (left) and Southern Vent Rise (right)



Figure A13: Mt Charlotte compressor house 2014

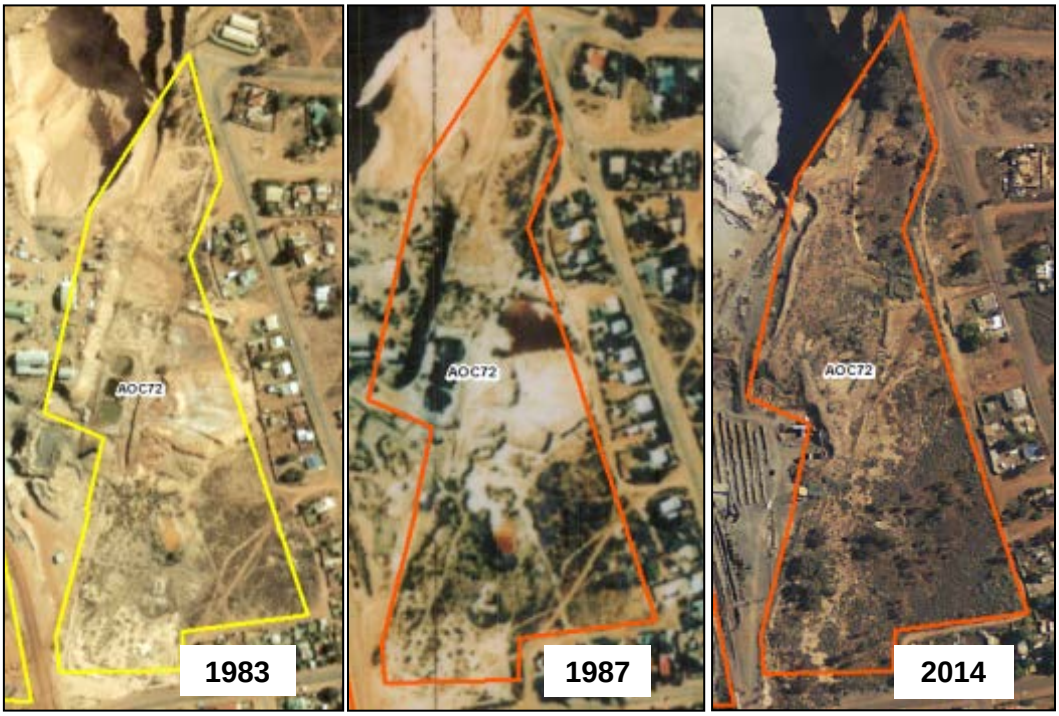


Figure A14: Mt Charlotte Historical TSF



Figure A15: View from Cassidy Head Frame circa. early 1980s



Figure A16: AOC87 Mt Charlotte hydrocarbon storage area

ZOI 6 – SALINE WATER TRANSFER



Figure A17: Saline Transfer Tank AOC88 Area 1980s (left) and 2014 (right)



Figure A18: AOC89 Saline water transfer station

ZOI 7 – PIT ADJACENT TSFS



Figure A19: Croesus TSF 1988 (left) and 2014 (right)

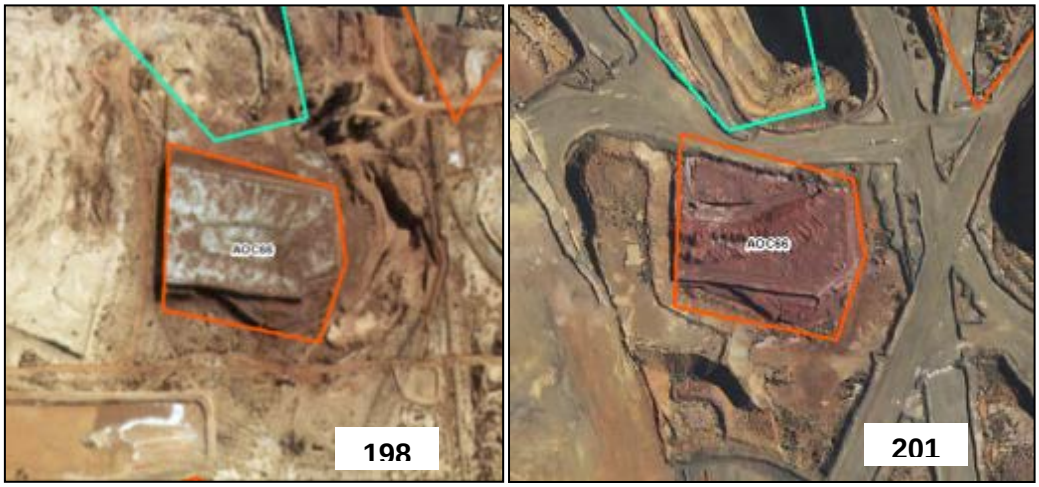


Figure A20: Historic Calcine TSF

ZOI 8 – PARINGA TSF



Figure A21: Paringa TSF ZOI 9 – Legacy TSFs (Encapsulated)

ZOI 9 – LEGACY TSF FOOTPRINTS (ENCAPSULATED)



Figure A22: AOC64 – Historic TSF

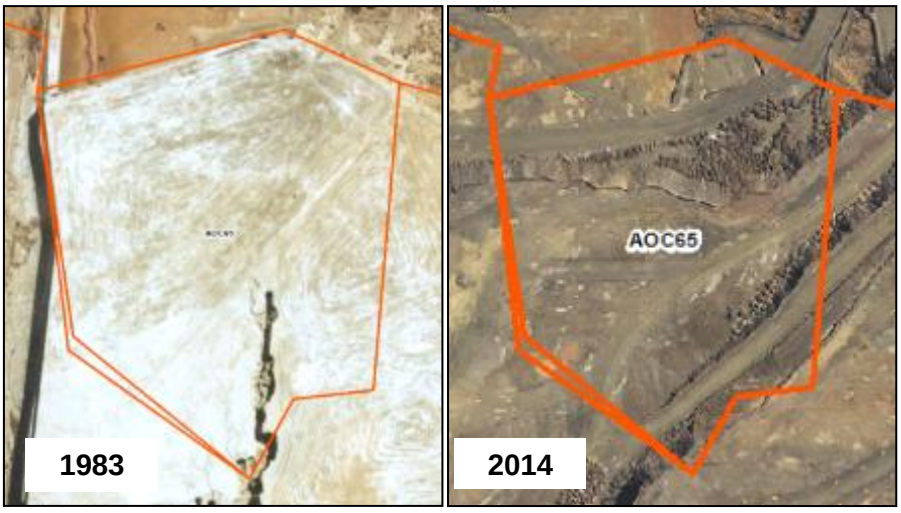


Figure A23: Historic TSF AOC 65

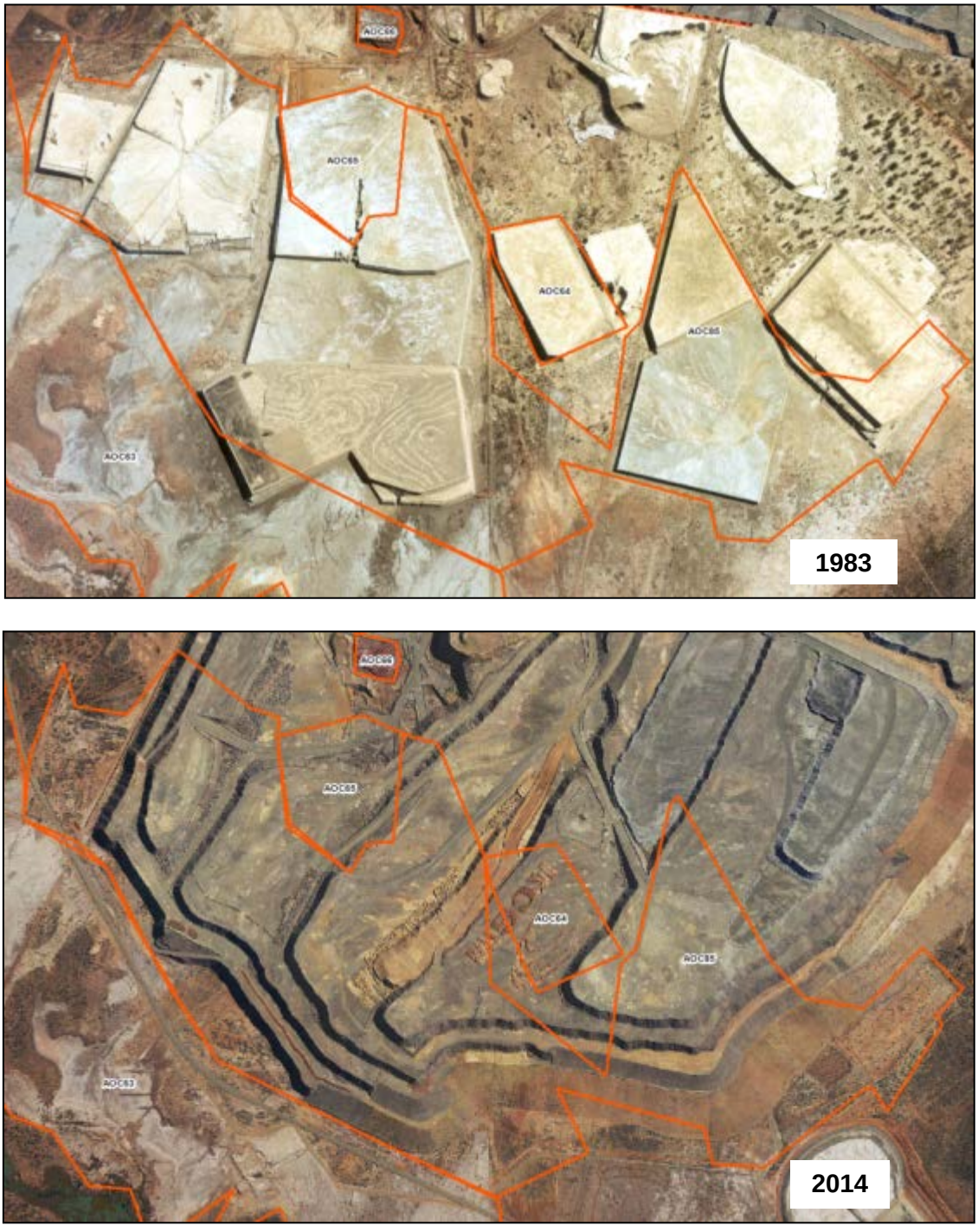


Figure A24: AOC85 Historic tailings wash area

ZOI10 – OROYA, GALCONDA, AND BALGOLD TSFS

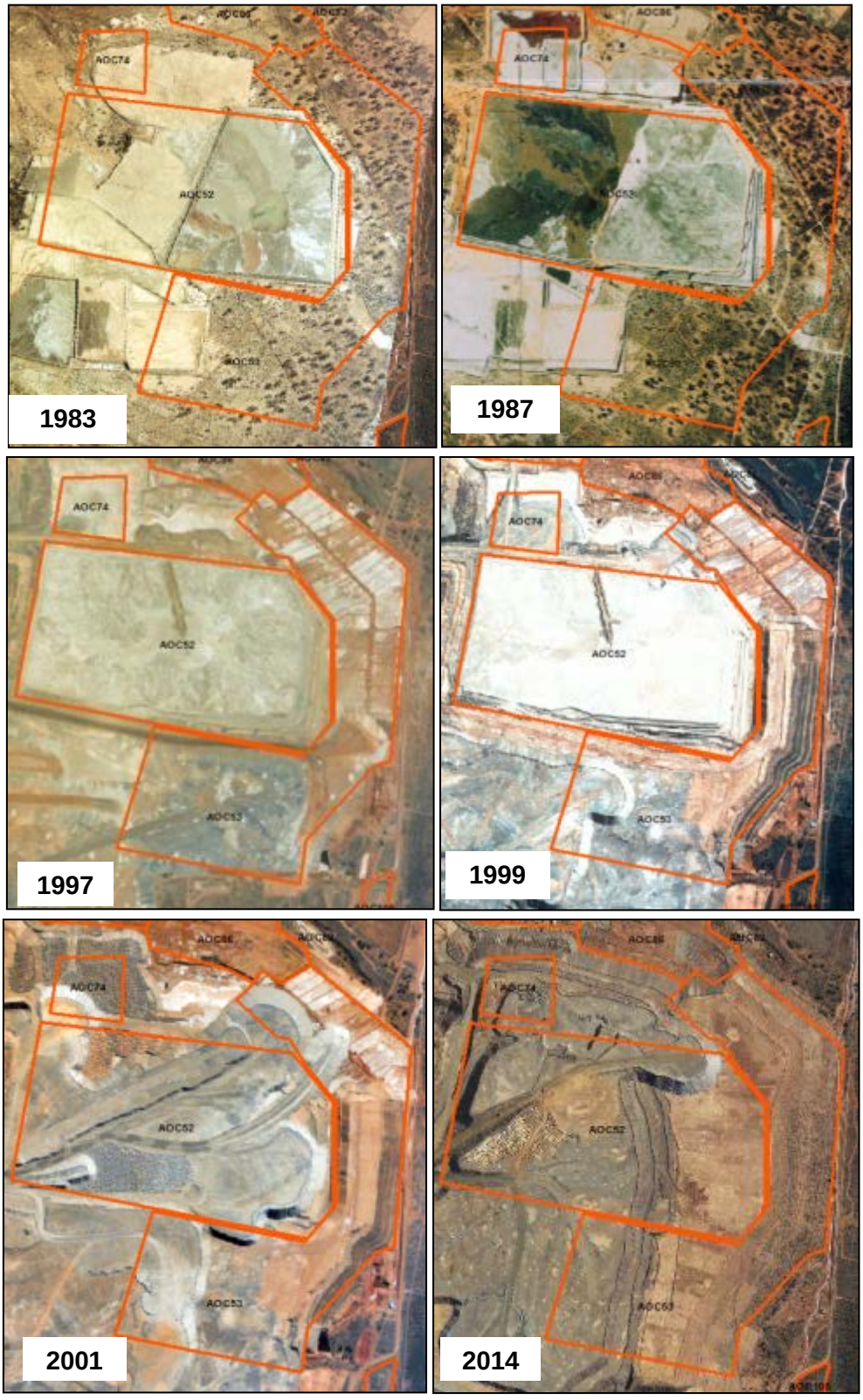


Figure A25: Oroya, Balgold and Galconda TSFs





Figure A26: Contractors Workshops and Balgold-Galconda tailings wash area 2014

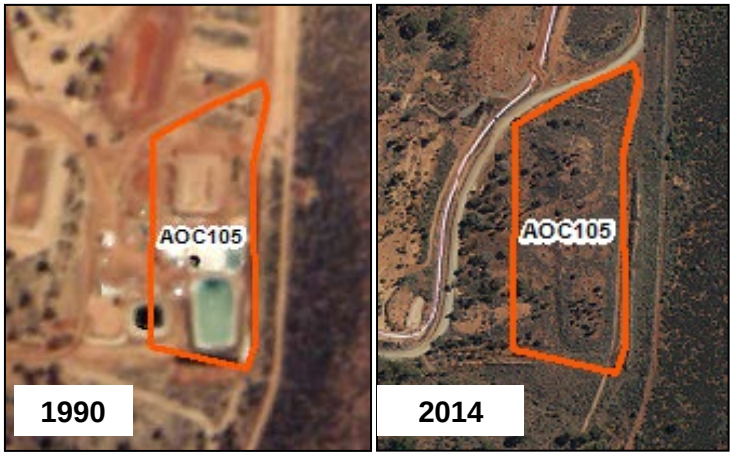


Figure A27: Former Balgold heap leach pads 1990 (left) and 2014 (right)

ZOI11 – CROESUS PLANT



Figure A28: AOC111 Historic concentrate storage area







Figure A29: AOC112 Historic tailings Wash Area

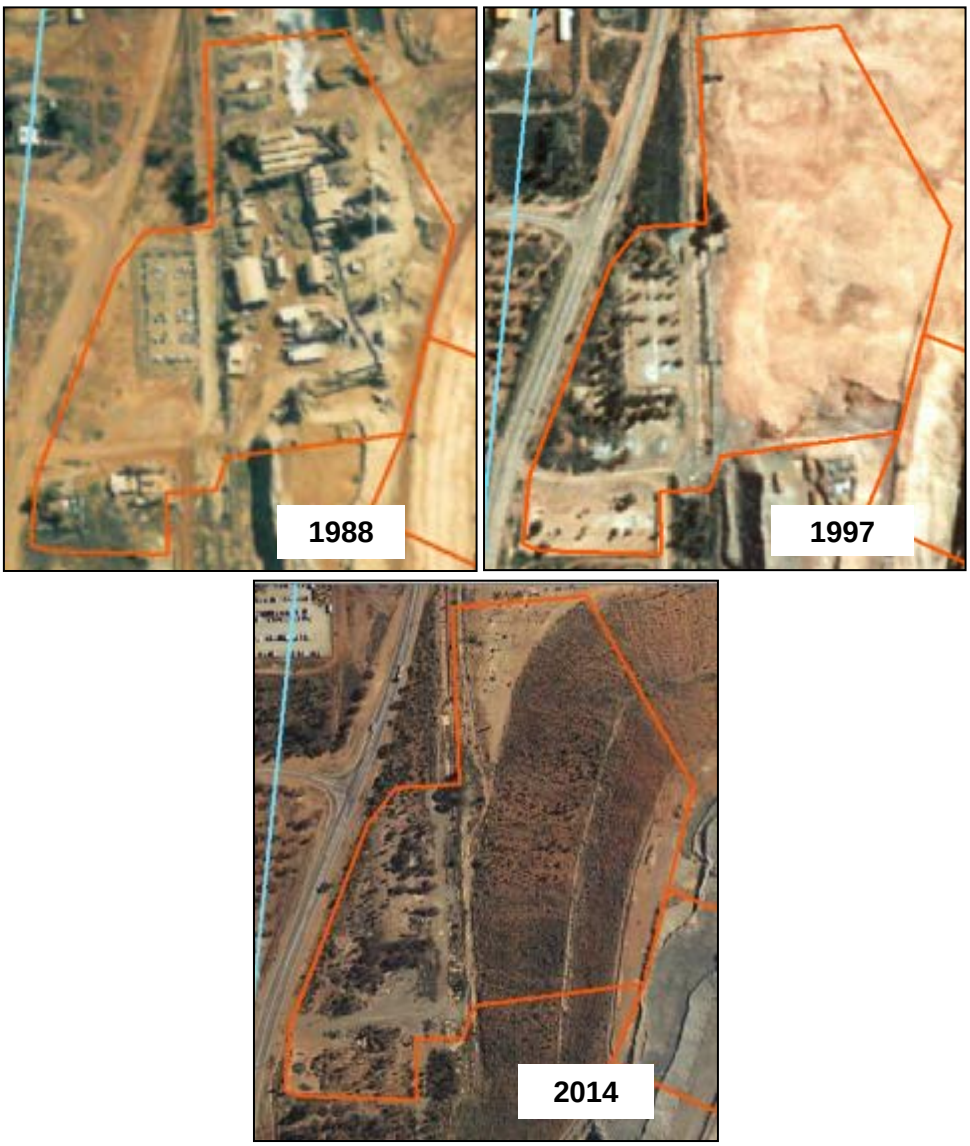


Figure A30: Croesus Mill 1988 (top left), 1997 (top right) and 2014 (bottom)

ZOI12 – BORRARA RD REHAB AREAS

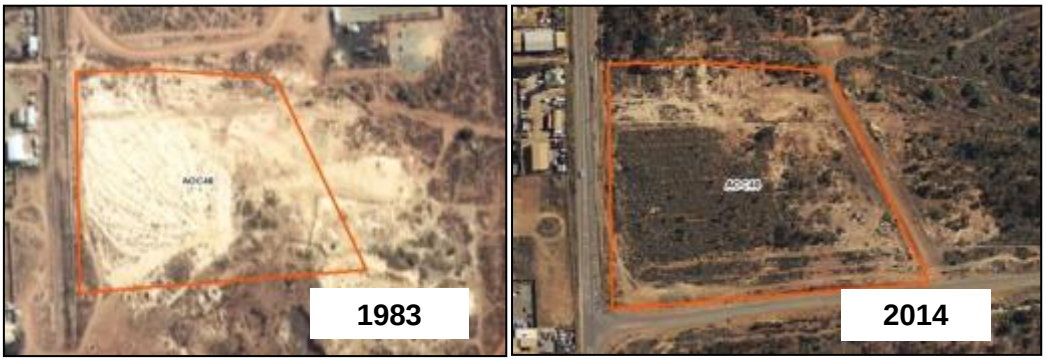


Figure A31: Former Processing Plant

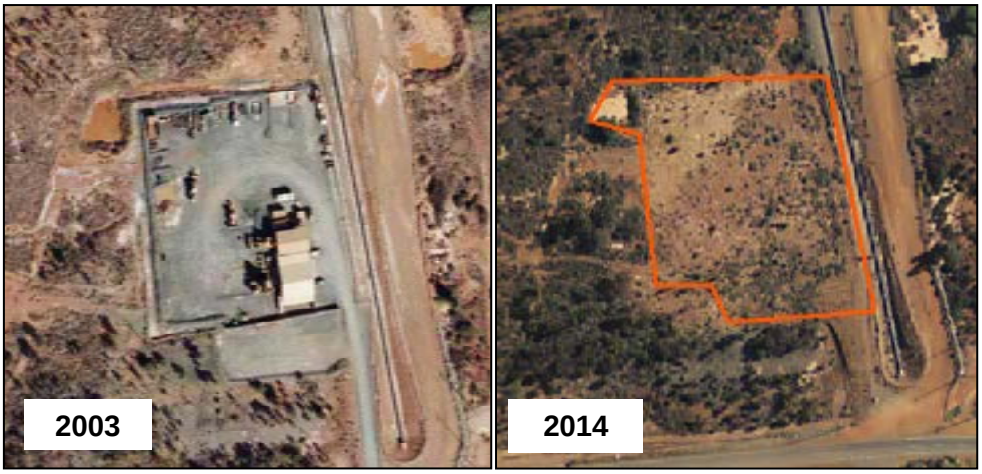


Figure A32: Force Workshop

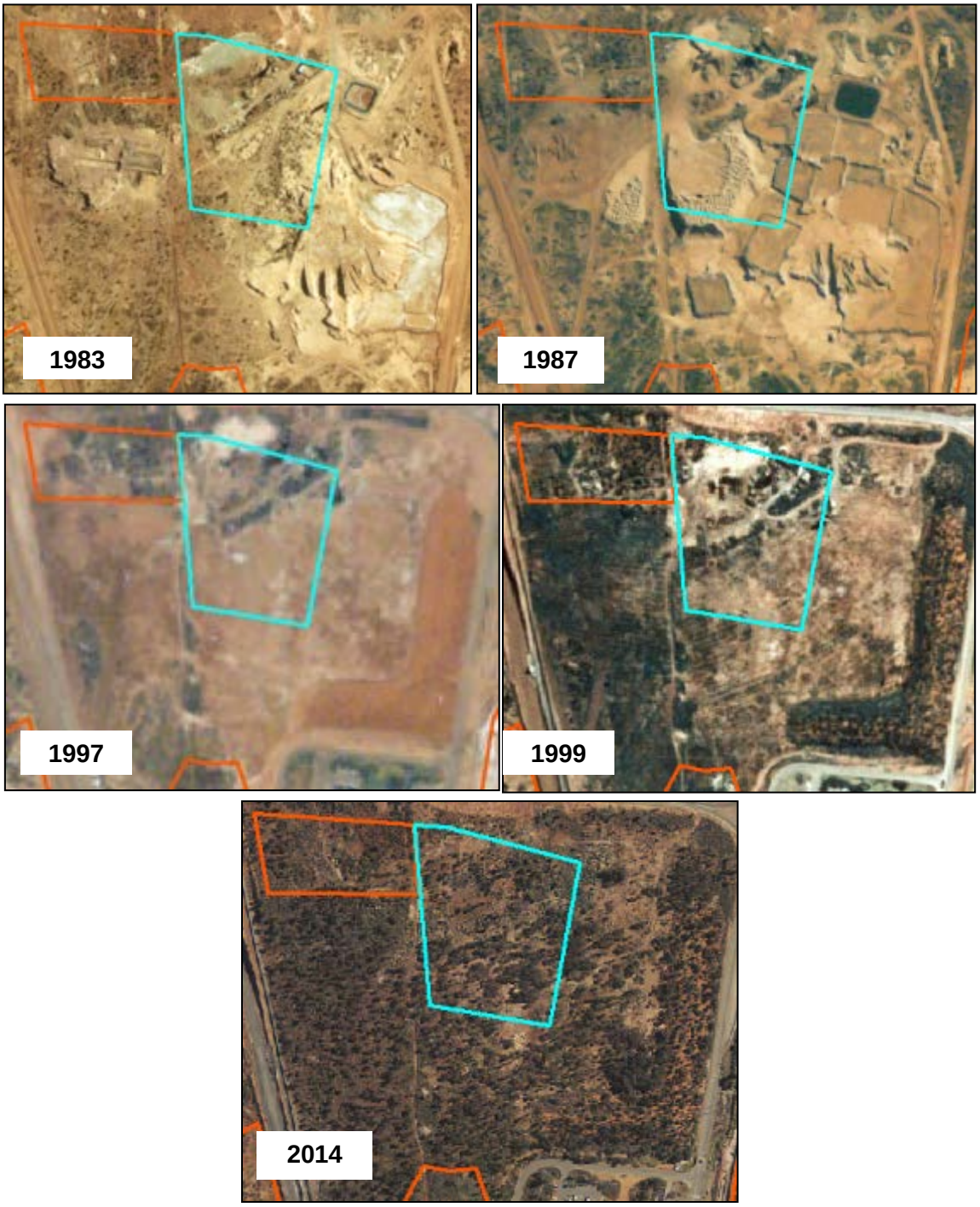


Figure A33: Former gold processing plant

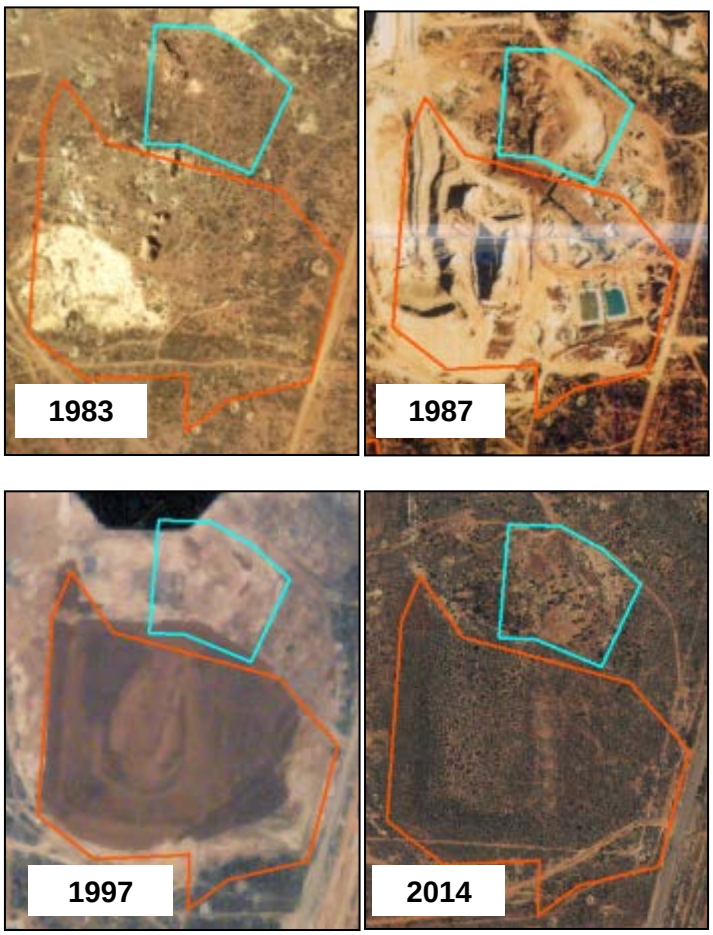


Figure A34: Mt Ferrum TSF (orange) and Mineral Processing Plant (blue)

ZOI 13 – MORRISONS FLATS

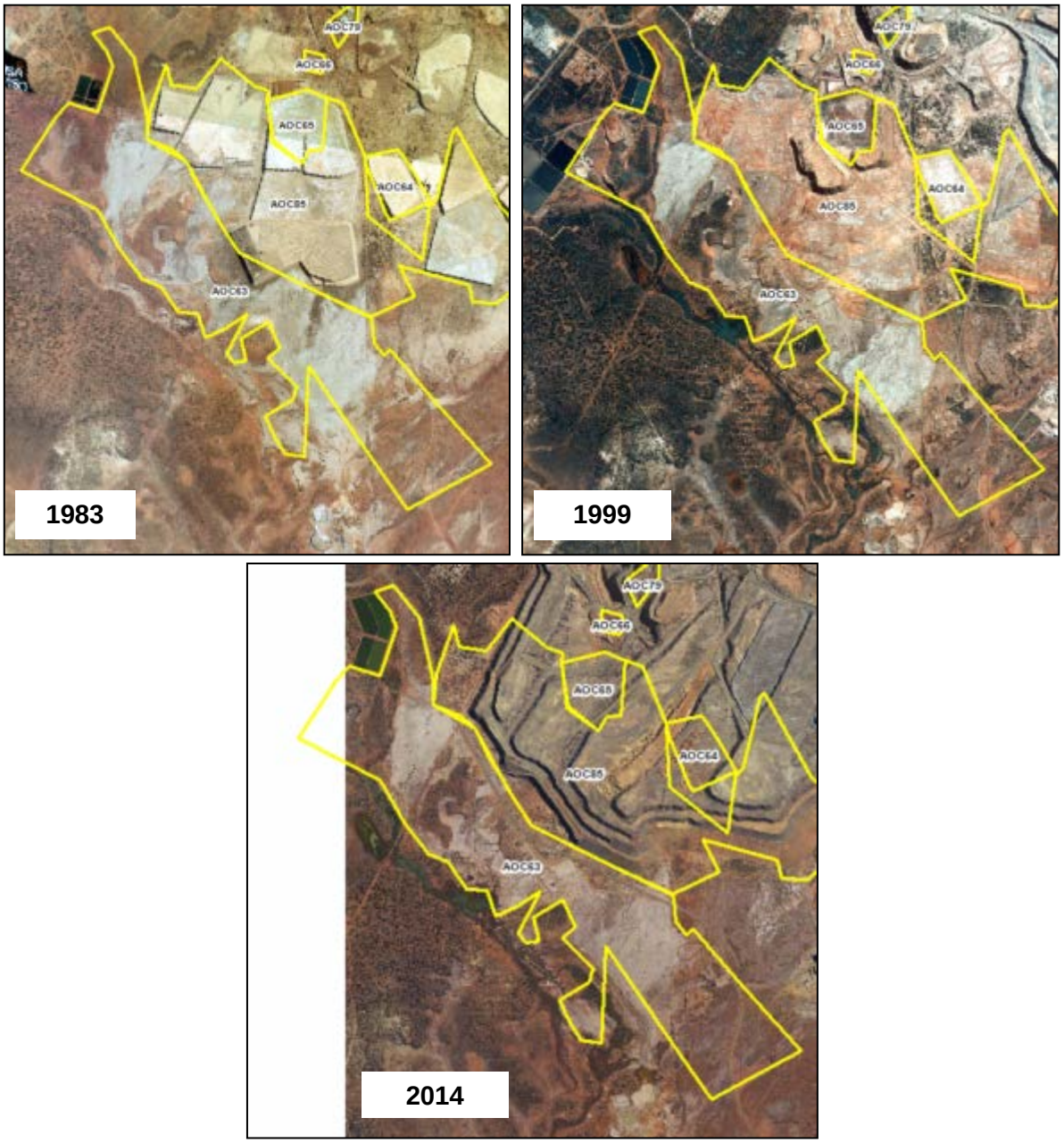


Figure A35: Morrisons Flats

ZOI 14 – MT PERCY PIT LAKES

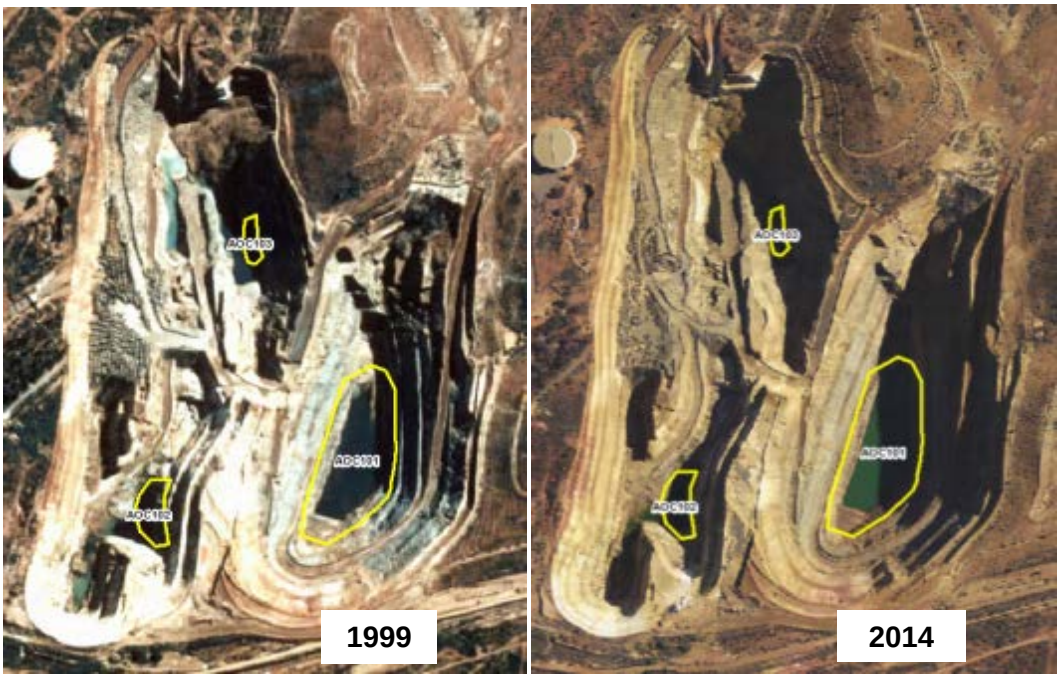


Figure A36: Mt Percy Pit Lakes

ZOI15 – MT PERCY REHABBED AREAS



Figure A37: Mt Percy TSF

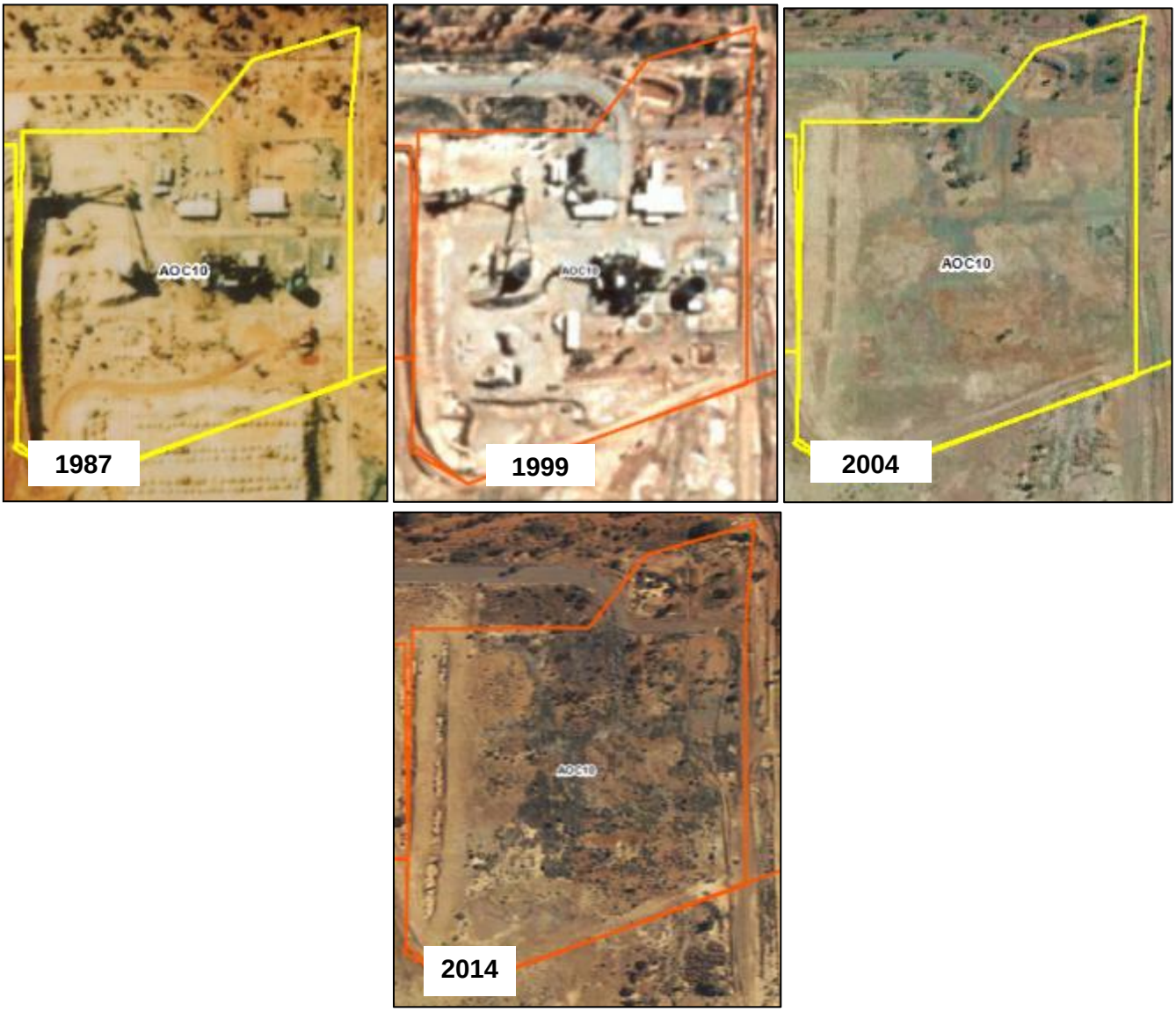


Figure A38: Mt Percy Former mill 1999 (left) and 2014 (right)

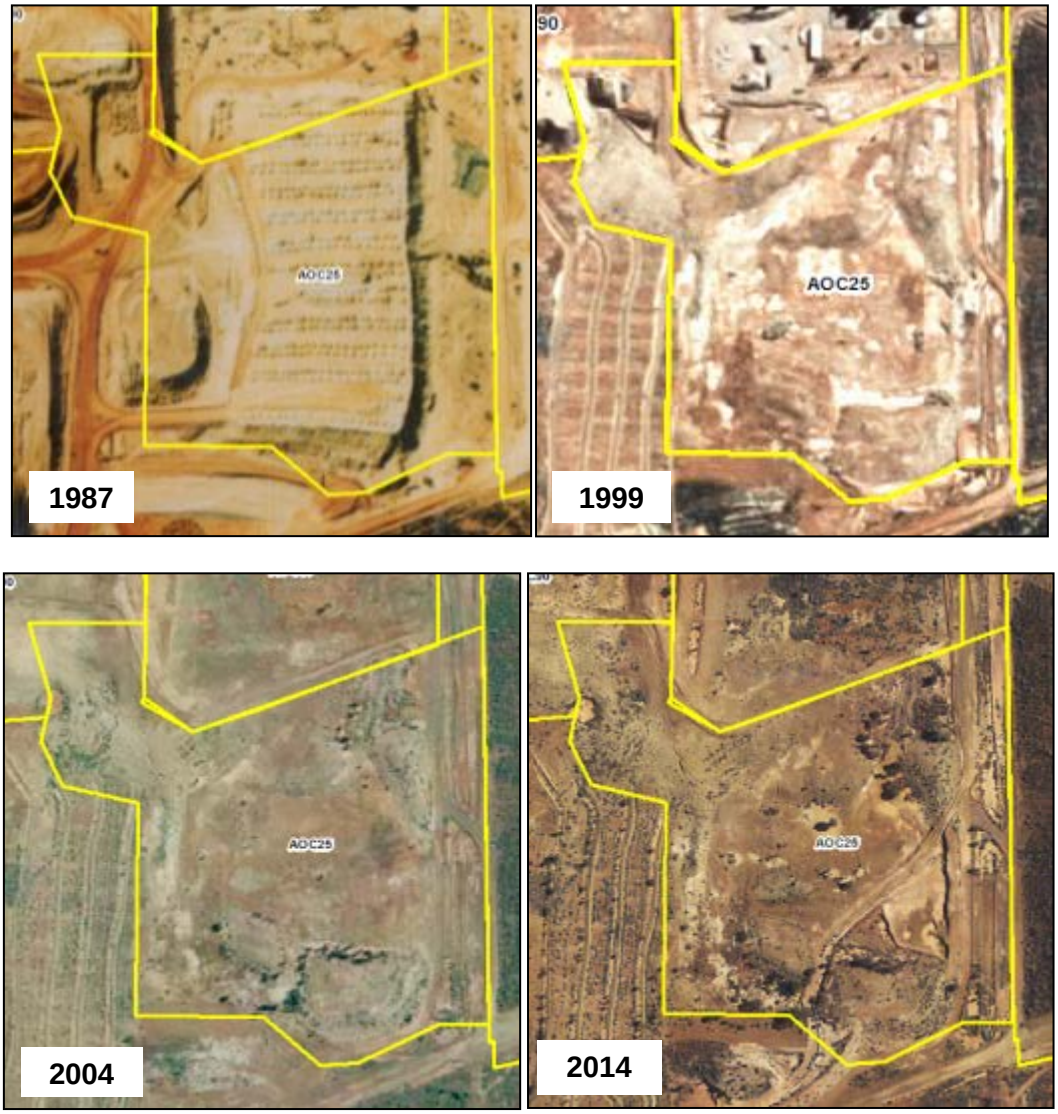


Figure A39: Mt Percy Workshop

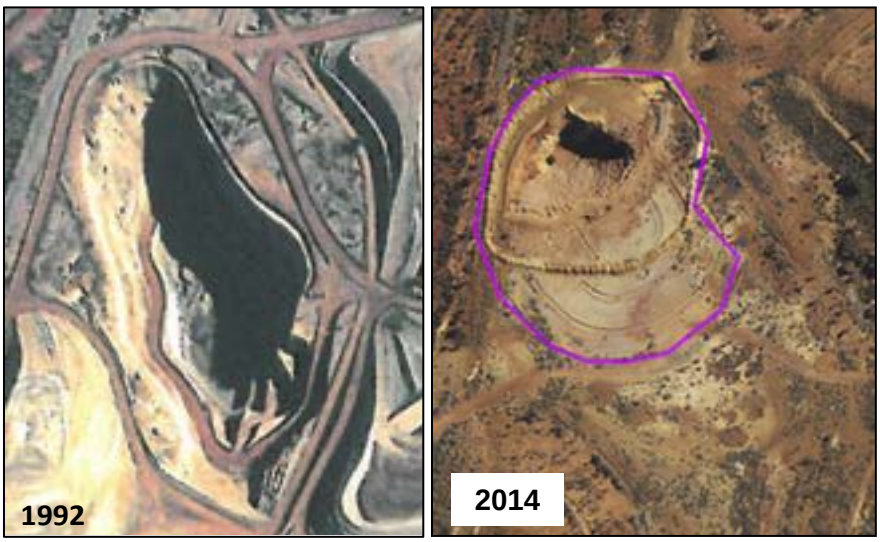


Figure A40: Sir John Open Pit Feature (showing extent of backfill)



Figure A41: Mt Percy Sir John Pit 2009

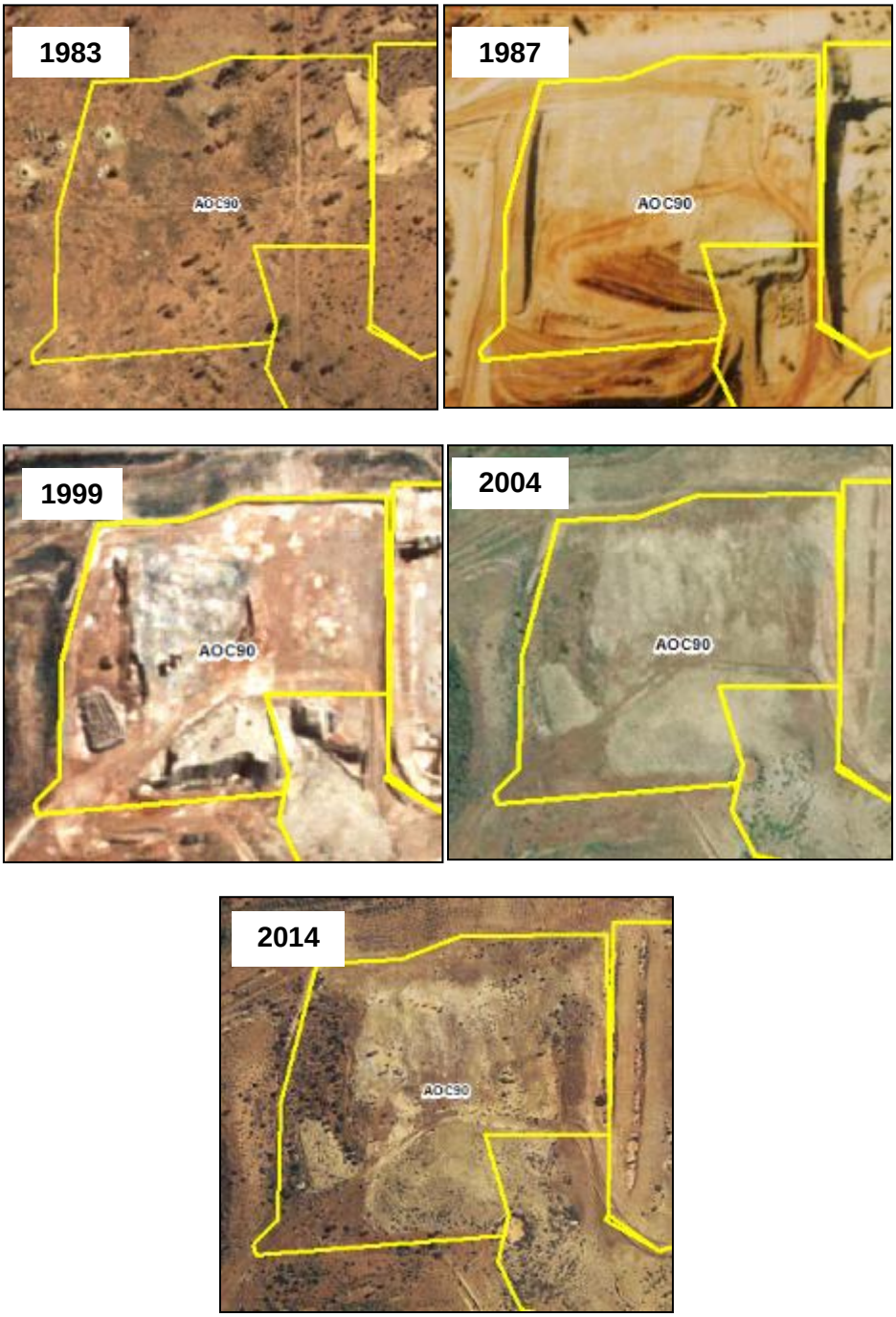


Figure A42: Mt Percy ROM Pad

ZOI 16 – HANNANS NORTH

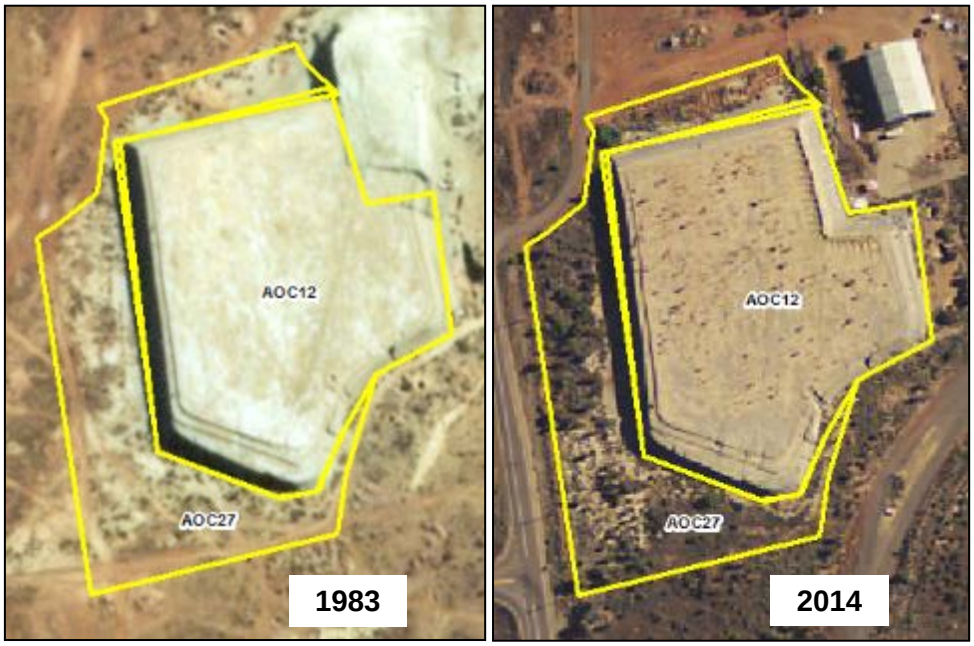


Figure A43: Mullingar TSF

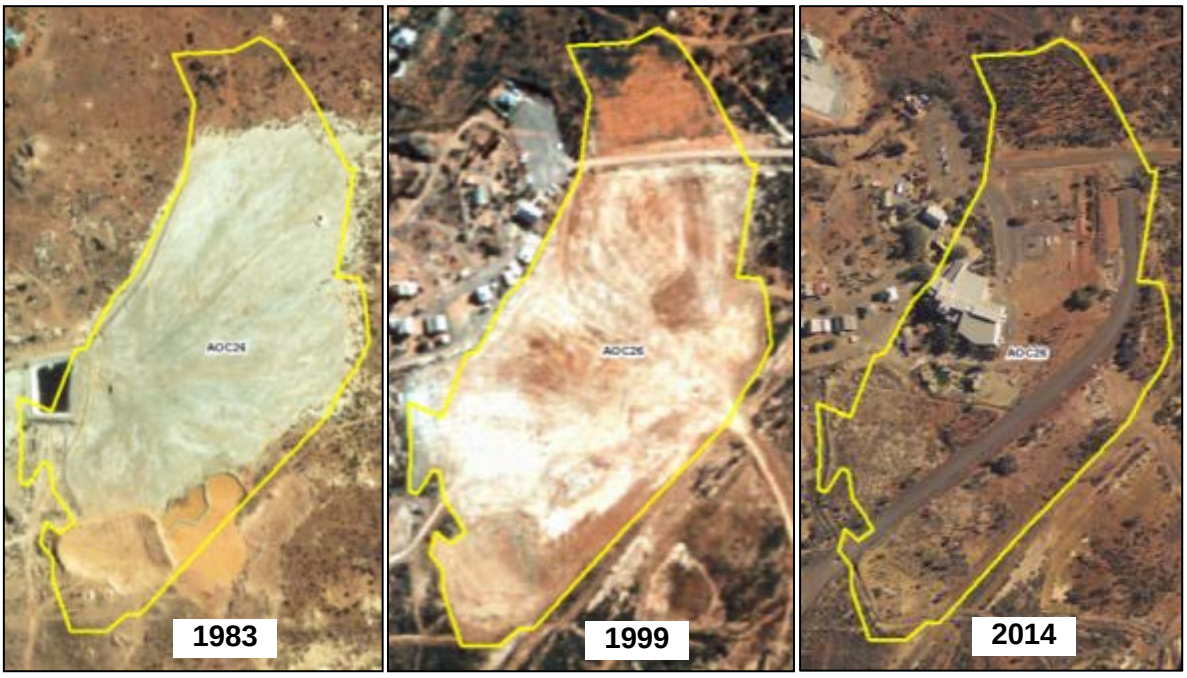


Figure A44: Hannans North Former TSF

7. CYANIDE CODE CLOSURE DOCUMENTATION

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Fimiston Processing Plant and Gidji Processing Plant Decommissioning Plan

Kalgoorlie Consolidated Gold Mines

June 2024

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Fimiston Processing Plant and Gidji Processing Plant Decommissioning Plan
Kalgoorlie Consolidated Gold Mines

KCGM

WSP
Level 3, 51-55 Bolton St
Newcastle NSW 2300
PO Box 1162
Newcastle NSW 2300

Tel: +61 2 4929 8300
Fax: +61 2 4929 8382
wsp.com

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	Name	Date	Signature
Prepared by:	Chris Roberts	26/06/2024	
Reviewed by:	Stawm Malan	26/06/2024	
Approved by:	Raina Hattingh	26/06/2024	

WSP acknowledges that every project we work on takes place on First Peoples lands.
We recognise Aboriginal and Torres Strait Islander Peoples as the first scientists and engineers and pay our respects to Elders past and present.

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Executive summary

Kalgoorlie Consolidated Gold Mines Pty Ltd (KCGM), owned by Northern Star Resources (Northern Star), operates the Fimiston Processing Plant (Fimiston) and the Gidji Processing Plant (Gidji) in the West Australian Eastern Goldfields. Both sites use cyanide in their ore processing operations.

KCGM is a signatory of the International Cyanide Management Code for the Manufacture, Transport, and Use of Cyanide in the Production of Gold or Silver (the Code). As part of being compliant with the Code, some of the conditions KCGM must comply with at decommissioning include:

- Implementing procedures for decommissioning of cyanide facilities that protect human health, wildlife, and livestock.
- Being capable of fully funding cyanide-related decommissioning activities.

WSP was engaged by KCGM to review the previous Decommissioning Plan and revise as necessary to include changes to the cyanide facilities since 2021 (previous Plan update), as well as to fulfil the above-related decommissioning requirements of the Code.

KCGM has various cyanide facilities at Fimiston and Gidji, including tanks, vessels, pipes, and pumps. Cyanide facilities are separated high risk (>1000 mg/L CN), medium risk (0.5 to 1000 mg/L CN) and low risk (<0.5 mg/L CN) facilities. For classification purposes, risk relates to adverse cyanide exposure to humans strength depending on the cyanide concentrations of these facilities. Following plant closure at Fimiston and Gidji, the cyanide facilities will be cleaned and dismantled. There are also several sites at the Fimiston and Gidji that are potentially contaminated with cyanide and would need to be investigated and potentially remediated.

In accordance with the requirements in Standard of Practice 5.2.1 of the Code, all decommissioning costs assume work to be undertaken by an external, third party. The estimated cost of decommissioning the cyanide facilities at Fimiston and Gidji, as at 2024, is approximately $2,970,000.

1 Introduction

Kalgoorlie Consolidated Gold Mines (KCGM) - owned by Northern Star Resources (Northern Star), operates the Fimiston Processing Plant (Fimiston) and the Gidji Processing Plant (Gidji). The facilities are located in the Eastern Goldfields of West Australia (WA)(Figure 1). Both sites utilise sodium cyanide as a key reagent in the gold recovery process.

This report represents the Decommissioning Plan for Fimiston and Gidji, both of which are currently projected to close in 2038 as per KCGM Mine Closure Plan 2022 (MCP 2022).

1.1 Scope of report

In November 2021, KCGM engaged WSP to review and revise their 2014 Decommissioning Plan. That revision included updates to the cyanide facilities between 2014 and 2021 and aligned the Plan to the requirements of the International Cyanide Management Code (the Code) Standards of Practice (SOP) 5.1 and 5.2.

In 2024, WSP was again requested to update this Decommissioning Plan, considering updates to the facilities since 2021, if applicable. It also addresses nominal changes to Section 6.1 (Tailings storage facilities – strategies) and Section 11 (Document review) as required by 2023 audit findings and includes updated unit rates for the decommissioning costs (Section 9).

This report represents the Decommissioning Plan for Fimiston and Gidji, as at 2024.

Note: The Decommissioning Plan was developed to satisfy the Code requirements for SOP 5.1 and 5.2, and hence does not include information or costs associated with the closure of the tailings storage facilities (TSF) at KCGM.

1.2 International cyanide management code

The Code is a voluntary industry programme which focuses exclusively on the safe management of cyanide. Principle 5 of the Code addresses decommissioning. KCGM is a signatory to the Code. The following is an extract from Principle 5 of the Code (ICMI, 2021a):

"Principle 5 – Decommissioning: Protect communities and the environment from cyanide through development and implementation of decommissioning plans for cyanide facilities.

Standard of Practice 5.1: Plan and implement procedures for effective decommissioning of cyanide facilities to protect human health, wildlife and livestock.

Standard of Practice 5.2: Establish an assurance mechanism capable of fully funding cyanide-related decommissioning activities."

2 Definitions

Term	Definition
CIL	Carbon in leach
CIP	Carbon in pulp
CN	Cyanide
CNWAD	WAD cyanide (Weak Acid Dissociable cyanide)
Cyanide	Refers to any form of cyanide (solid, liquid or gas phase). This may include cyanide reagents
Decommissioning	Decommissioning is defined by the International Cyanide Management Institute (ICMI) as a process which involves treating, neutralising or managing cyanide in preparation for closure so that it does not then present a risk to people or the environment. This includes decontamination of equipment, removal of residual cyanide, rinsing of heap leach pads and controlling or managing contaminated surface or groundwater. Decommissioning does not include activities such as stabilisation of tailings storage facilities (TSF) or heaps, revegetation of disturbed land, long-term management of seepage or environmental monitoring
HAZOP	Hazard Operability: a technique that identifies the potential hazards and operating issues
High Cyanide	A solution or slurry containing greater than 1000 mg/L sodium cyanide. Tanks, vessels, and piping, which have contained cyanide at high concentrations, will require cleaning with high pressure water and detoxification using sodium hypochlorite
Low Cyanide	A solution or slurry containing less than 0.5 mg/L sodium cyanide
Medium Cyanide	A solution or slurry containing 0.5 to 1000 mg/L sodium cyanide. Tanks and piping carrying such solutions or pulps require only water washing to render safe for subsequent activity
SDS	Safety Data Sheet
NaCN	Sodium cyanide
Plume	A body of contaminated groundwater that moves away from the source of the contamination
PPE	Personal Protective Equipment
Tph	Tonnes per hour
TSF	Tailings Storage Facility

3 Description of cyanide facilities

3.1 Processing overview

There are currently two active processing plants operated by KCGM - Fimiston and the Gidji.

Fimiston comprises two parallel circuits for processing refractory sulphide ore from the Fimiston open pit and ore from the Mt Charlotte underground mine. Ore produced by KCGM is treated through the following processing circuit at Fimiston:

- Two primary crushing plants
- Two semi-autogenous grinding mills with pebble crushing circuit
- Three ball mills
- Flotation and three carbon-in-leach circuits.

In the flotation circuit, the gold bearing refractory sulphide is separated and referred to as concentrate. The concentrate is deslimed and slimes are leached at Fimiston and the coarse fraction separated into two streams:

- One stream is washed, filtered, and transferred to the Gidji Facility. At Gidji, the concentrate is re-pulped and processed by one of two Ultrafine Grinding Mills. These processes are followed by a conventional carbon-in-pulp (CIP) circuit, where gold is adsorbed onto activated carbon. The loaded carbon is then transported to the Fimiston elution circuit for stripping, electrowinning, and smelting.
- The other stream is transferred to the ultra-fine grinding mill at Fimiston. This mill reduces the particle size of the concentrate to expose enough gold surfaces to facilitate cyanide leach recoveries. After grinding, it joins the slimes to be leached at the Fimiston in the carbon-in-leach adsorption circuits where the gold is extracted.

Fimiston also comprises elution, electrowinning circuits and facilities for smelting, pouring and the production of gold bullion.

A cyanide destruction plant is used at Gidji to treat TSF return and tailings seepage water. Refer to Section 3.33.3 for a description of the cyanide destruction plant.

Process flowsheets for Fimiston, Gidji, and the cyanide destruction plant are included in Appendix A, and major cyanide facilities are listed in Appendix B.

3.2 Tailings storage facilities

Tailings produced at Fimiston are discharged into the Fimiston and Kaltails TSFs. The Fimiston TSFs are described as follows:

- Fimiston I comprises an amalgamated single operational cell, made up of the combined Fimiston I East and Fimiston I West (that incorporated the former Croesus TSF in 2003), with deposition to Fimiston I ceasing in July 2013.
- Fimiston II comprises AB Paddock (a combination of two previously separate cells – A Paddock and B Paddock), C Paddock, and D Paddock (i.e., three operational cells in total). Construction of upstream raises were design to accommodate additional storage capacity in 2020.
- Fimiston I Extension, E and F Paddock were recently commissioned in 2024. They are upstream TSFs and will take approximately 2 years to reach full operations capacity.

The Kaltails TSF is described as follows:

- The Kaltails TSF comprises two operational cells, Kaltails East and Kaltails West, which are located atop the original six cells that ceased operation in 1999.

Tailings produced from the Gidji Facility are discharged into the nearby Gidji TSFs. These TSFs are described as follows:

- Gidji I comprises of two cells (East and West). The maximum storage capacity of Gidji I has been achieved, with deposition ceasing on the Gidji I East TSF cell in August 2013.
- The Gidji II TSF has been constructed to provide tailings storage capacity for the Gidji Facility now that the existing Gidji I TSF has reached its maximum storage capacity. The Gidji II East Cell was commissioned in May 2012. Construction of the Gidji II West TSF commenced in late August 2013 and was commissioned January 2014. Downstream raises are under construction to increase storage capacity and commenced in 2020. Both Gidji II cells are lined to prevent seepage and bird exclusion netting has been erected to protect wildlife from cyanide bearing tailings and supernatant.

In addition to the netting of the Gidji II cells, the decant pond/containment pond/toe drain have also been netted to exclude wildlife access. The removal of these nets is considered to be part of closure and consequently has not received further consideration in this plan. As mentioned in Section 1.1, this Decommissioning Plan is only concerned with the decommissioning, reduction and removal of cyanide bearing facilities and equipment. It does not include information or costs associated with the closure of the TSFs (with the exception of pipes and pumps at each TSF). Refer to the MCP 2022 and associated TSF operating manuals for further descriptions regarding their closure.

3.3 Changes to infrastructure facilities from 2021 Decommissioning Plan

There are no significant changes to the cyanide facilities at Fimiston and Gidji since 2021.

4 Cyanide facility closure – general safety considerations

Cyanide is delivered to both Fimiston and Gidji in a liquid form by road in a tank called an ISO tanker. These containers are approved by the Department of Energy, Mines, Industry Regulation and Safety (DEMIRS) for the transport of 30% sodium cyanide solution. Upon delivery at the Fimiston, the liquid cyanide is transferred to the cyanide storage tank. Upon delivery at the Gidji Facility, cyanide is unloaded into cyanide storage bullets.

Cyanide is acutely toxic, with a human lethal dose of 250 mg of an inorganic cyanide salt (oral ingestion) and approximately 50 mL (at 1.85 mmol/L) of hydrogen cyanide gas (inhalation) (WHO, 1993). Therefore, the hazard posed by sodium cyanide to human health is one of the primary concerns during cyanide facility decommissioning.

General human health risks associated with decommissioning of cyanide facilities may be summarised as follows:

- Residual cyanide and/or other caustic solutions in pipelines and structures impacting deconstruction workers
- Hydrogen cyanide (HCN) gas present in confined spaces
- Transport of perceived or actual cyanide residue within decommissioned infrastructure to future uses
- Leakage of cyanide from storage facilities
- Improper application of procedures and work permits
- Exposure to diluted cyanide solutions within process streams.

Safety issues relating to cyanide handling and exposure will be included in the overall safety management plan developed for the reclamation and closure plan for Fimiston and Gidji.

Other safety matters that may apply to these sites are:

- Uncontrolled access to site – safety and security
- Safety of people during removal of plant, equipment, and structures:
  - Isolation of plant and equipment
  - Lifting operations
  - Working at heights
  - Large mobile equipment interaction
  - Exposure to other hazardous materials and contaminants.
  - Damage to equipment owned and operated by others, including operational interruption.
- Potential environmental impacts:
  - Dust generation
  - Exposure to contaminants
  - Noise
  - Inappropriate waste tracking and disposal
  - Transport/traffic management.

4.1 Emergency response plan

The current KCGM Emergency Response Plan (ERP) will be revised and reissued in the final six months of operation to accommodate the non-routine aspects of closure of the cyanide facility. The revision will commence three months prior to shutdown of processing facility.

4.2 Safety induction

Cyanide-specific site safety inductions are required for all employees and contractors involved in the decommissioning of the cyanide facility prior to commencing tank cleanout, equipment modification or dismantling activities. The cyanide supplier (Australian Gold Reagents Pty Ltd (AGR)) will be contracted to conduct site-based cyanide safety training two months prior to shut down and will also induct the selected tank detoxification contractor prior to their commencement on site.

4.3 Health and safety procedures

Existing health and safety procedures will be revised to meet cyanide plant decommissioning and removal requirements no less than two months prior to plant shutdown. Team-based risk assessments commences the health and safety procedures for the facilities' closure.

4.4 Supervisory training

Supervisory training will be carried out on a progressive basis from the shutdown date forward for incoming personnel and earlier for designated KCGM decommissioning team members. An additional consultant resource will be utilised if necessary to conduct training relating to removal of plant, contract coordination. And safety tagging.

4.5 Safety contract exhibit

Tender documents received for contract removal of cyanide plant require the health and safety budget to be specified in the documentation. The tender documents will detail plans for inspection of the workplace, safety meetings and their topics, toolbox meetings, and audits against the safety and health procedures. Each contractor group will present a safety management plan to ensure it meets the requirements of the KCGM safety management plan. The same requirement applies to the purchase of any cyanide facility asset.

4.6 Audits and inspections

Health and safety inspections of the workplace and auditing will be carried out throughout decommissioning. Inspection sheets will be used to capture the information which will be entered into a site database. Auditing and inspections will be completed on a monthly basis by the relevant KCGM Operations Superintendent and by the dismantling contract supervisor.

4.7 Risk assessment and hazard identification

Prior to decommissioning and removal of cyanide facility assets, hazard, and operability (HAZOP) and workplace risk assessments will be completed to identify the hazards associated with decommissioning and the control measures required.

The risk assessments will be carried out by a team comprising supervisory, contractors, purchasing, engineering, safety, and environmental representatives. They will incorporate environmental and community relation impacts and be documented and accessible on the KCGM intranet.

Hazard identification will be reported through the existing hazard identification and risk assessment procedure.

5 General environmental considerations

As per the ICMI Auditor Guidance (ICMI, 2021b), decommissioning addresses cyanide remaining on-site upon cessation of production activities. The ICMI definition of decommissioning refers to "treating, neutralising or otherwise managing cyanide and cyanide containing process solutions remaining in storage and production facilities in preparation for closure so that they do not present a risk to people, wildlife or the environment due to their cyanide content."

A key objective for the decommissioning of Fimiston and Gidji (including pumps and pipelines associated with the TSFs) is to ensure that there is no environmental harm during, or after closure.

Currently, extensive monitoring for cyanide concentrations in TSF ponds and groundwater is undertaken. WSP has assumed that no new groundwater bores will be required at KCGM for monitoring at closure. Standard of Practice 5.1 in the ICMI Auditor Guidance provides that decommissioning does not include activities such as environmental monitoring. As such, the cost of groundwater monitoring is not included in the decommissioning cost; however, it is included as part of the closure and reclamation plan.

Strategies ensuring the safe and secure closure of facilities will predominantly be implemented prior to the cessation of operations, as outlined in the MCP 2022. Ministerial Statement 782, which pertains to mine closure planning requirements prescribed by the WA Minister for Environment as part of the operation's project approvals and site tenement conditions, requires that KCGM submit revised mine closure plans every three years.

This Decommissioning Plan defines the critical elements that are required for closure of the cyanide facilities. These elements form a part of the wider scoped MCP 2022. Key elements of the plan are discussed in Section 6 and will be revised as closure becomes imminent.

5.1 Water management

Both Fimiston and Gidji are located within the semi-arid goldfields environment where evaporation exceeds rainfall. These environmental conditions are conducive to full containment and evaporation of the water containing cyanide. Environmental impact of the TSFs can also be managed by preventing wildlife access to ponded water where the Weak Acid Dissociable cyanide (CNWAD) concentrations are elevated (concentrations of 50 mg/L CNWAD are typically "non-lethal to wildlife" as outlined in the ICMI Auditor Guidance). Promotion of evaporation and restriction of access following facility closure are therefore key strategies.

Planning for closure of the KCGM TSFs envisages:

- Intent to use the TSF as a disposal method for rinse waters from the plant.
  - Reagent is drained down and sold where applicable
  - Tanks are rinsed and rinse waters are blended to <50 mg/L WAD CN with this diluted water sent to the TSFs
  - TSF water volumes are monitored to enable capacity of tank rinse waters
- Minimum CN contaminated volumes of water are contained in both residue and water dams at the end of the processing plant clean-up period. This action allows for minimal probability of discharge of contaminated water from the site.
- Pumping and piping infrastructure are retained following cessation of production to facilitate movement of residual water over dry beaches to promote evaporation if necessary.
- Post closure groundwater quality monitoring programmes are well defined in the closure provision and MCP 2022, in conjunction with statutory requirements and approvals.
- Groundwater quality and quantity control infrastructure remains in place for as long as necessary.

These strategies are covered in greater detail in Section 6.

5.2 Contaminated sites

Guidelines for environmental investigations of potentially contaminated sites are set out in the Department of Water and Environmental Regulation (DWER) Contaminated Sites Management Series (2003) and in particular, the Contaminated Site Assessment General Guideline for Reporting and Contaminated Site Assessment Criteria.

The DWER recommends a staged approach to environmental site investigations, which generally comprises four main stages:

- Stage 1 – Preliminary Site Investigation (PSI). An investigation consisting of a desktop study, conducting interviews, a site walkover and, where appropriate, limited sampling. The PSI will be of such scope as to indicate whether contamination is present, or likely to be present, and to guide whether a Detailed Site Investigation (DSI) is needed.
- Stage 2 – Detailed Site Investigation. Confirms potential or actual contamination, identified during the PSI, through a comprehensive sampling programme. This investigation aims to delineate the vertical and lateral extent of contamination both on-site and off-site to enable an assessment of the risk to the environment and/or human health to be made. Prior to the implementation of the DSI, a Sampling and Analysis Programme (SAP) is required to set out the objectives of the DSI. This is usually endorsed by an Auditor (if required for the site) prior to the commencement of any intrusive on-site assessments. If gross contamination is encountered during the DSI, further delineation may be required as additional stages of work.
- Stage 3 – Preparation of a Site Management Plan. This documents the type and extent of remediation required to ensure that the site is suitable for its current or intended future use, and to protect the surrounding environment and land uses.
- Stage 4 – Remediation, Validation and Ongoing Management. This is the process of demonstrating that a contaminated site has been successfully remediated and that the objectives of the site management plan have been achieved.

In 2007, a register of suspected contaminated sites in KCGM operational areas was reported to the DWER. This register included several suspected contaminated sites at Fimiston and Gidji (see Figures 1 and 2 respectively and Appendix D). The majority of the classifications are classified as Potentially Contaminated – Investigation required, with select classifications remaining pending.

KCGM has indicated that a PSI was undertaken for the operational areas in 2008. This included soil and water testing where required. The KCGM Register of Contaminated Sites has been updated to include this additional information. Completed contaminated sites investigations are included in report format within the Mine Closure Plan appendices. No further investigations have been undertaken for these specific areas at this stage.

KCGM has a groundwater monitoring programme (including associated infrastructure) established in accordance with the DWER license conditions and approved Seepage and Groundwater Management Plans. Monitoring bores are regularly sampled for DWER licence and Seepage and Groundwater Management Plan compliance; in addition, time series closure data is collected. As the groundwater quality is hypersaline, with mineral processing the only beneficial user, for closure the most critical parameter is maintaining water levels below the root zone for trees (generally below 4m). Production bores, with automatic pumps, are currently installed at both facilities to control groundwater levels and will remain in operation until water levels are below the target level post closure. Production bore water is currently used by the processing plant. At closure, the water will be directed into the unused Fimiston pit. Maintenance of groundwater levels is the key post closure requirement as well as maintaining the <50mg/L CNWAD. Water quality changes are not material to the current beneficial user (mineral processing). Remediation is not considered in the context of this decommissioning plan. It is also assumed that no further monitoring infrastructure will need installation for the decommissioning phase. Therefore, this decommissioning plan is solely concerned with the identification and remediation of cyanide contamination in soil.

6 Plant area closure strategies

6.1 Detailed task development and scheduling

To promote a safe and cost-effective decommissioning, planning for the shutdown of Fimiston, Gidji and associated cyanide facilities will include detailed task lists and schedules. The compilation of task lists will be the responsibility of a dedicated person(s) who is familiar with the plant hardware. Task list preparation will commence no less than three months prior to plant shutdown. The task lists will include a detailed description of activities and resources.

These lists are a valuable tool to identify special safety precautions (e.g., barricading, confined space entry or safety harness requirement) and maintenance project requirements (e.g., installation of temporary pipeline or additional local hose point). They also enable an accurate estimate of the time required to complete the facility decommissioning. A Gantt chart will be compiled, which serves as a master reference document for all personnel involved in the decommissioning of the facility and enables daily tracking of progress against the plan.

6.2 Cyanide stock reduction

The quantity of 30% sodium cyanide solution in stock at both Fimiston and Gidji will be reduced to meet minimum operating requirements prior to plant closure. Stocks will be reduced to approximately one week's supply in the last two weeks of operation.

For effective cyanide stock reduction, close liaison is required between processing staff, the supply department, and the cyanide suppliers. A formal fortnightly meeting between the Mill Superintendent and the Supply Coordinator will be started two months prior to plant closure. Reagent stocks and supply issues will be discussed in these meetings.

At closure, some cyanide will still be required for gold recovery from tank carbon. An estimate of the elution requirement can be made based on the known carbon inventory and cyanide requirement per strip. In the event of overestimation, cyanide concentration can be raised for the final gold recovery activities to facilitate disposal without adverse process impact. In the event of an underestimation, excess cyanide would be sold back to suppliers.

6.3 Pre-closure storage tank cleanout

The timing of clean-up for tanks will depend on several factors including cyanide concentration during operations. As there is only one cyanide storage tank located at Fimiston (F71TK01), it is not possible to empty and clean out the tank during plant operation without the use of a temporary storage facility on site. A sample from F71TK01 will be collected from close to the base of the tank no less than 12 months prior to closure. This will estimate the amount of accumulated solid precipitate in F71TK01 and, therefore, inform the requirement for construction of a temporary storage facility if required.

At Gidji the four cyanide storage bullets will be targeted for progressive isolation and cleanout in the final two months of plant operation as a safety precaution. Any sludge present in the cyanide storage tanks becomes a potential dust hazard once dry. The pre-closure bullet cleanout at the Gidji Facility can concentrate specifically on sludge removal as each tank will undergo a final cleanout and detoxification after plant closure.

6.4 Cyanide disposal

If there is an excess supply of 30% sodium cyanide solution, various cyanide disposal options will be considered. If the excess supply is large (more than 20 kL) the cyanide supplier may be asked to recover the cyanide for use at another mine site. However, if the excess supply is small (less than 20 kL) then the cyanide solution can be diluted with raw

water to <50 mg/L CNWAD and disposed of into the TSFs. In this case, this relative contribution on the volume and concentration of stored cyanide solution in the TSF will be calculated. This would minimise the impact on CNWAD concentrations in open water, thus preventing harm to wildlife.

Alternative methods for on-site disposal would be:

- Increase cyanide loading to carbon inventory strips prior to closure.
- Use excess cyanide to leach lower grade tank sediments in the Acacia reactor.

6.5 Plant clean-up

Immediately following cessation of production at Fimiston and Gidji, the plants will be washed down with water and cleaned of mud/dust/salt encrustation. It is highly likely that this material will have relatively high cyanide content in the cyanide storage and reticulation facilities. Clean-up must be of sufficient standard that no residual safety hazard is presented to personnel dismantling the plant.

Wash water should be pumped to the TSFs should be <50 mg/L CN WAD CN in line with the Code and other sections within the report.

6.5.1 Tanks and vessels

The following Sections divide the tanks/vessels in higher risk (>1000 mg/L CN), medium risk (0.5 to 1000 mg/L CN) and low risk (<0.5 mg/L CN) facilities. For classification purposes, risk relates to adverse cyanide exposure to humans.

A full list of high and medium strength tanks and vessels is included in Appendix B.

6.5.1.1 "High strength" cyanide tanks

All facilities that have contained greater than 1000 mg/L sodium cyanide solution in the operating life will be considered "high strength" cyanide vessels. "High strength" facilities at Fimiston and Gidji include the following:

- Fimiston Cyanide Storage Tank (1)
- Fimiston Acacia Reactor Area Reaction Vessel (1)
- Fimiston Acacia Reactor Area Pregnant Eluate Storage Tank (1)
- Fimiston Acacia Reactor Area Solution Tank (1)
- Fimiston, Flotation Concentrate Carbon In Leach Tanks (8)
- Gidji Cyanide Storage Bullet Tanks (4)
- Gidji Calcine Leach Tanks (9)
- Gidji Calcine Adsorption Tanks (9).

High Strength facilities will be decontaminated by a specialist contractor using sodium hypochlorite in accordance with CSBP procedures (Appendix C). The process can be summarised as follows:

- Rundown stocks of cyanide and remove residual cyanide to the TSF.
- Undertake a series of water washes of the tank, pipework, and equipment. Dispose of wash water in the TSF.
- Wash tank and its equipment with a 1.5% sodium hypochlorite solution. Pump washings to a waste disposal area that is approved by KCGM's Environmental personnel and that does not contain cyanide. The solution (or washings) will not contain cyanide as it has been consumed by the hypochlorite. As such, this solution will naturally breakdown and is not a contaminant. Therefore, it can be allowed to soak into soil in a designated area.

- Wash the tank with water to remove hypochlorite solution residue, which may be corrosive to steel surfaces. Pump washings to a waste disposal area that is approved by KCGM's Environmental personnel and that does not contain cyanide.
- Tanks are to remain open until deconstruction or demolition occurs.

For both the Fimiston and Gidji "high strength" cyanide tanks, it is proposed to engage a specialist contractor with the equipment needed to scour internal tank surfaces with up to 145 PSI pressure spray water in a sequential wash and sodium hypochlorite rinse process described above. Such contractors can generally detoxify a single tank in a period of several hours. An estimate of approximately 1400 hours has been received for cleaning the "high cyanide" facilities at the Fimiston and Gidji listed above.

Cyanide header tanks at each CIL train at the Fimiston will be flushed internally as part of the ring main. With the coverplate removed, these tanks can be rinsed with sodium hypochlorite using a broom dipped into 1.5% sodium hypochlorite solution. External hose down and washing is also undertaken to remove traces of cyanide containing encrustation.

6.5.1.2 "Medium strength" cyanide tanks

"Medium strength" facilities are those which have contained solution or slurry of between 0.5 mg/L and 1000 mg/L sodium cyanide. "Medium Strength" facilities at Fimiston and Gidji include the following:

- Fimiston, Decant Transfer Tank
- Fimiston, Decant Return Lines
- Fimiston, Decant Dams (3)
- Fimiston, Process Water Tank
- Fimiston, Flotation Tailings Carbon In Leach Tanks (12)
- Fimiston, Plant Spillage Transfer Tank
- Fimiston, Tailings Delivery Piping
- Fimiston, Elution Columns (2)
- Fimiston, Lean Eluate Tanks (2)
- Fimiston, Elution Water Tank
- Fimiston, Eluate Circulation Tank (2)
- Fimiston, Barren Eluate Tank
- Fimiston, Eluate Storage Tank (2)
- Fimiston, Cathode Wash Trough
- Fimiston, Circuit Water Tank
- Fimiston, CIL Cyanide Water Tank
- Fimiston, Saline/Decant Water Mixing Tank
- Gidji, Cyanide Destruction Surge Tank
- Gidji, Clarifier Feed Tank
- Gidji, Tails Hopper
- Gidji, Decant Dam (Dam Return Water)

- Gidji, Toe Dam
- Gidji, Saline Dam
- Gidji, Dam Return Tank
- Gidji, Cyanide Destruction Clarifier
- Gidji, Cyanide Destruction Tanks (2).

Once emptied, “medium strength” tanks and piping will be hosed down with water only. As a general principle, the structure will be cleaned from the top down to prevent re-contamination with removed built up and caked slurry. If scale on tanks resists normal hose pressure, it may be necessary to spot clean areas with high pressure hoses (up to 6000 PSI).

After the sides of tanks have been cleaned, sediment at the base of the leach tanks will be manually removed through manholes and pumped to either the TSF or to the Acacia Reactor (depending on gold assays).

Leach and adsorption tanks will be emptied individually in a sequence calculated to recover carbon to elution in the most cost-effective manner. The tank emptying sequence will involve displacing higher -slurry from the leach tanks into the first adsorption stage by pumping initially from the back of the adsorption circuits to the front of the circuits at Fimiston and Gidji. A pump installed at the tank base will be required. Slurry underflow from the loaded carbon screen will be allowed to drain by gravity into the carbon safety screen underflow launder on the relevant tank train via a temporary HDPE line. The final tank to be emptied must be the first adsorption stage to take advantage of the installed carbon recovery pump.

6.5.1.3 “Low strength” cyanide tanks

“Low strength” facilities are those that have contained solution or slurry with minimal sodium cyanide content (<0.5 mg/L). These facilities are very low risk to human health and will generally only require flushing with raw water prior to decommissioning. “Low Strength” facilities at Fimiston and Gidji include the following:

- Fimiston, Chilled Water Tank Semi-Autogenous (SAG) Mill Heat Exchanger
- Fimiston, Flotation Area Gland Seal Water Storage Tank
- Fimiston, Final Tailings Collection Tank
- Fimiston, Sludge Hopper
- Fimiston, Cathode Spray Water Tank
- Fimiston, Cyanide Water Tank
- Fimiston, Silt Trap Tank.

6.5.2 Piping

All steel and polyethylene piping that has contained cyanide solution will be flushed after closure in accordance with the KCGM Isolation and Tagging (Permit to Work) procedure for the cyanide ring main.

At Fimiston, the clean-up process will involve adding a minimum of 30 m^3 of potable water to the cyanide storage tank (and circulating through the ring main for at least 30 minutes. The storage tank would then be drained by opening the cyanide addition valves on each tank feed point.

Following the water flush, the cyanide supplier (AGR) would be consulted regarding a hypochlorite solution rinse. The procedure for this would likely involve an addition of an appropriate volume of 1.5% hypochlorite to the cyanide storage tank. This would be circulated through the ring main for 30 minutes, and then the cyanide lines would be drained by breaking flanges at low points. AGR does not recommend disposal of hypochlorite wash liquors into tailings dams where they can come into contact with cyanide and form highly toxic cyanogen chloride gas. Hypochlorite wash liquors are

generally safe to discharge on the ground in the plant area provided it cannot run off into environmentally sensitive areas. Any such discharge should be under the direction of KCGM Environmental personnel.

6.5.3 Steel structures

All steel structures in the cyanide facility will be hosed down as far as practicable using plant raw water as described in Section 6.5. No further specialised cleaning or protective coating is necessary.

6.5.4 Bins, chutes, and hoppers

Bins, chutes, and hoppers will be hosed out to remove carbon build-up. The carbon bins and hoppers in the elution area require no further treatment.

6.5.5 Pumps

Pumps and other mechanical rotating equipment in the cyanide, elution and carbon regeneration areas will be washed down externally with raw water to remove traces of cyanide. After washing, old grease will be purged (as far as practicable) and removed to the TSFs. New grease will then be applied to moving parts. Vapour phase inhibitor may be added to oil sumps on relevant equipment while it is still warm. Specific requirements for these actions will be outlined in the detailed task listing and would be carried out by maintenance personnel in conjunction with the KCGM operations clean-up phase.

6.5.6 Instrumentation

Following cleaning (see Section 6.8– Laboratory), selected instruments (i.e. pH meters, oxygen meters, cyanide monitors and analysers) will be repackaged to prevent corrosion and removed to storage.

6.5.7 Concrete

Concrete surfaces in the cyanide bunds will be thoroughly washed down with raw water to remove potential residual material. Specific areas of concrete (in elution and leaching areas) will be subjected to sample coring to evaluate if gold content is high enough to consider treatment.

6.6 Goldroom

The elution and electrowinning circuit will be in use for several weeks after the plant ceases production to allow for the recovery of gold from the plant carbon inventory. Once drained, the elution tanks will be thoroughly washed with potable water (approximately 20 m^3) from the eluate circulation tanks (F66TK61 and F66TK 62) through the electrowinning cells for one hour. Following the recirculation flush, the cells, tanks, and pumps will then be washed down with potable water and drained. The goldroom sump will also be emptied and dug out as part of a gravity trap recovery programme.

6.7 Acacia reactor

The gravity area Acacia Reactor will be used after plant closure to recover gold from high-grade plant clean-up residues. Therefore, it is likely that decommissioning and clean-up of the reactor vessel and associated reagent mixing, feed and holding tanks will not occur until at least two months after plant closure. This will involve a thorough washdown of the area with potable water, and two tanks will require hypochlorite detoxification. Surface cleaning of pumps using brooms dipped in hypochlorite will also be required.

6.8 Laboratory

Decommissioning of the laboratory will occur towards the end of the processing plant decommissioning period. The laboratory will be decommissioned as follows:

- Any equipment in the laboratory that has been contaminated with cyanide will be considered as “high strength” cyanide concentration and will be soaked in appropriate cyanide detoxifying reagent and triple rinsed with clean water.
- All rinse water and detoxifying reagents will be collected for disposal within the TSFs.
- All leftover chemicals will be sent back to the supplier, to another mine site or destroyed/disposed in the approved manner.
- Once the infrastructure has been removed, the area will be tested for contamination, and decontaminated as necessary.

6.9 Plant removal, dismantling and demolition

Removal and dismantling of the plant facilities at both Fimiston and Gidji are planned to occur in accordance with typical current gold industry practice. This involves a valuation of plant and equipment, followed by auction of significant items at site and dismantling and demolition of remaining plant to concrete level under contract to realise scrap metal value. Market conditions at the time of closure will influence the value of the cyanide circuit facilities (i.e., the prevailing value of scrap metal and the possible presence of a new mine in the Goldfields area). If components of the facility are unable to be sold, they would be cut down for scrap. Disposal costs have not been considered as part of the final costing, as it is assumed that this equipment will be sold at closure.

6.10 Earth-mounted cyanide tanks

The medium and high-grade cyanide tanks at Fimiston and Gidji are mounted on a concrete annular ring of compacted soil/clay in accordance with standard tank construction practice. Due to the magnitude of cyanide concentration in the high-grade tanks, there is potential for contamination of the underlying soil and groundwater to have occurred through leaks over time. The removal of these high-grade tanks will be followed by soil testing through the base plate.

6.11 Tailings storage facilities – strategies

As mentioned in Section 3.2, this Decommissioning Plan only considers the decommissioning, reduction and removal of cyanide bearing facilities and equipment. It does not include information or costs associated with the closure of the TSFs (with the exception of pipes and pumps at each TSF).

As the TSFs will be rehabilitated to ensure internal drainage, and given that evaporation rates significantly exceed rainfall, seepage from the TSFs is only expected during the drain-down period. Cover modelling indicates that minimal seepage will occur once the TSF surfaces have been rehabilitated (Big Dog Hydrogeology, 2022).

Hydrochemical source terms were developed to represent the chemical characteristics of each pit lake inflow (e.g., groundwater inflow, TSF seepage) using a combination of water quality monitoring data and results from materials characterisation studies, as summarised in the MCP 2022. This includes the chemical compositions of the resulting source terms.

Water quality monitoring data from process plant (mill) inputs, specifically from bore fields collecting seepage-affected groundwater at Kaltails and Fimiston I/II/IIE TSFs between February 2013 and April 2020, indicates that the recovered TSF seepage levels of cyanide concentrations are 1.1 mg/L at Kaltails and 0.7 mg/L at Fimiston I/II/IIE (MCP 2022).

However, the geochemical model does not simulate oxidative degradation of cyanide (i.e. cyanide is treated as a conservative ion); therefore, predicted concentrations are overestimated. Cyanide (e.g. from tailings water inflows) will break down when exposed to circum-neutral water, oxidants and ultraviolet light. Given these limitations, predicted cyanide concentrations should be interpreted as maximum potential concentrations rather than likely concentrations.

While the predicted cyanide concentrations may be overestimated due to the conservative nature of the geochemical model, the rehabilitation measures and natural degradation processes are expected to minimize actual seepage and cyanide levels post-closure.

6.12 Piping and pumping

All steel and polyethylene piping that have contained cyanide solution will be flushed after closure. Pipelines to the TSFs will be flushed with raw water for 20 to 30 minutes as part of standard shutdown procedures to minimise bogging the line. Given that these lines would have contained “medium” strength cyanide, flushing with raw water should suffice to remove cyanide from the lines.

Once the pipelines are no longer being used, they will be cut into shorter lengths and removed from site for salvage.

7 Post-closure wash management

The Fimiston and Gidji areas will be cleaned following closure and the residue, process water and reagents will be removed from the system as described in Section 6.5. The process water pond will be retained and used as both a wash down water source as well as a sump to monitor the quality of water washings from the plant area.

Following plant clean-up, cyanide containing water will be transferred to the operating TSFs for evaporation. TSFs containing cyanide will be managed to provide sufficient freeboard to handle both the wash water volume and a 1 in 100 year, 72-hour storm event.

Wash water likely to contain sodium hypochlorite will not be transferred to the TSFs as the reaction between this water and the supernatant in the TSF is likely to result in the evolution of cyanogen chloride gas that is toxic and could result in worker exposure if the appropriate PPE is not being worn. The wash water will not contain cyanide as it has been consumed by the hypochlorite. As such, this solution will naturally breakdown and is not a contaminant. Therefore, it can be allowed to soak into soil in a designated area, as determined by KCGM's Environmental personnel (e.g., a raw water dam or surface water structure).

8 Groundwater monitoring

The impact of mining activities on local groundwater resources may pose a risk to end users. However, a letter from the DER to KCGM dated 23 August 2006 states “the beneficial use of saline and hyper-saline water in the region is defined as for Mineral Ore Processing”. Impacts to groundwater may include:

- Changes in groundwater quality
- Changes (increase or decrease) in groundwater levels.

At Fimiston, the primary impact to groundwater in the vicinity of the TSFs is rising groundwater levels, whereas at the Gidji, the primary impact is on groundwater quality (elevated cyanide concentrations in groundwater).

KCGM has a groundwater management system. The system is operated in accordance with the DWER licence conditions and approved Seepage and Groundwater Management Plans. Production bores at Fimiston and Gidji, are used to manage groundwater around the TSFs. Bore pumps currently installed at both facilities to control groundwater levels and are costed to remain in operation as long as required with water being directed back into the relevant TSFs or disused pit.

Groundwater monitoring will continue post closure to track progress towards closure criteria. The MCP 2022 states that there will be a reduction over time, expected to be an exponential decay curve for the number of production bores required to maintain water levels to achieve closure criteria. The cost for groundwater management is not included in this decommissioning plan as it is covered in the closure provision costs.

9 Decommissioning costs

In accordance with the requirements in Standard of Practice 5.2.1 of the Code, all decommissioning costs assume third party engagement. The estimated cost of a third party being engaged for the decommissioning of the cyanide facilities at Fimiston and Gidji is approximately $2,970,000. This cost is outlined in Appendix E.

The following assumptions regarding decommissioning costs were made in the preparation of this estimate:

- These costs have been developed to satisfy the ICMI requirements
- The costs presented in this 2024 update purely include an update of unit rates. No amendments have been made to approach and/or specific line items.
- The ultimate fate of the equipment and structures will strongly influence the method and cost of removal.
- All costs are in Australian dollars as of June 2024.
- An average hourly rate for a third-party contractor has been assumed to be $149.33 as supplied via quote received from Cleanaway 9 February 2024.
- A specialist detoxification contractor will be used to undertake the detoxification of all “high cyanide” tanks as outlined previously (refer to Section 6.5.1.1). A quote received from Veolia (Rob Reynor, 4 March 2024) was based on 720 hours for Fimiston and 1404 hours for Gidji Facility using two operators, one leading hand, one supervisor, high-pressure water unit, vacuum truck and pump, sodium hypochlorite liquor (27.5%), and associated PPE to complete the task of cleaning the ‘high strength’ tanks. This quote is provided in Appendix F.
- The cleaning of “medium strength” cyanide tanks (35 at Fimiston and 10 at Gidji Facility) is based on an average of 60 man-hours per tank at Fimiston and the Gidji. Likewise, the cleaning of ‘low strength’ tanks at Fimiston (7) is based on an average of 40 man-hours per tank. These estimates are based upon experience of similar internal and external tank cleaning exercises at Boddington Gold Mine. They are reflective of a heavy sediment content being present in the base of several tanks at that site and a similar phenomenon is expected at KCGM.
- Other than the materials and reagents cost for the cleaning of the ‘high strength’ tanks (which has been estimated by the detoxification contractor), it has been assumed that the materials/reagents required for decommissioning is 10% of the total cost for each of the estimated cyanide facility direct cost and safety cost.
- The largest safety cost is incurred in carrying out cyanide specific inductions for all site personnel prior to closure and all specific cyanide area contractors entering site during and after plant closure.
- Reports from previous environmental studies will be made available to the third party conducting any contaminated sites investigation.
- There was limited information on previous cyanide-related environmental investigations available at the time of update of this plan. As such, a full contaminated sites investigation as per the Western Australian Contaminated Sites Act 2003 has not been costed. Instead, the cost has been estimated by limiting the areas for investigation to those classified as “high cyanide” as per Section 6.5.1.1. The area of impact from these “high cyanide” areas is assumed to be limited to the underlying soil to a maximum depth of 5 m below ground level.
- In addition to the “high cyanide” areas in Section 6.5.1.1, an area of 50 m^2 has been included for the loading bay where liquid cyanide is delivered at Fimiston and Gidji, as there is potential for cyanide spillage onto the soil.
- KCGM has a groundwater monitoring programme (including associated infrastructure) developed in accordance with their DWER licence conditions and approved Seepage and Groundwater Monitoring Plans. The cost for this monitoring and groundwater remediation (if required) is not included within this decommissioning plan. The Cyanide Code Auditor Guidance Notes for Standard Operating Procedure 5.1.1 notes that decommissioning does not include activities such as environmental monitoring. As such, it is understood that groundwater monitoring provisions and remediation are covered in the general mine closure and reclamation plan.

- Decontamination and rehabilitation of the TSFs have be addressed in the Closure provision.
- 0.5 m^3 of soil will weigh 1 t.
- Land surface remediation will consist of removing contaminated soil to an appropriate landfill. We have assumed that 80% of the cyanide contaminated soil will be sufficiently diluted in the TSF to warrant on-site disposal within this storage structure. The remaining 20% of contaminated soil is assumed to "high" cyanide concentration and will require removal to a suitable landfill facility.
- The contaminated soil to be disposed of meets the landfill contaminant threshold for a Class III landfill and can thus be accepted by Yarri Road Waste Facility, Kalgoorlie.
- The landfill disposal charge for contaminated soil at the Yarri Road Waste Facility is $98.00/t (City of Kalgoorlie-Boulder Schedule of Fees and Charges 2023/2024)
- Contaminated soil cartage costs (including loading) have been developed from first principles as $28 using updated 2024 load and haul rates for 20 km haul from KCGM facilities to the refuse facility.
- Separate workforces are provided for each facility.
- The Cyanide Safety Training cost is based on the preparation, delivery, attendance, and administration of a training course of up to 2.5 h duration for up to 50 contractors.
- The Supervisory training-KCGM + contractors' cost is based on a contractor workforce of 50 people with nominal work crew size of five including the supervisor. Accordingly training hours are based on the preparation, delivery, attendance, and administration of a training course of up to 8 h duration for up to 12 supervisors.
- The Workplace risk assessment and HAZOP cost is based on two HAZOP workshops of one day duration with attendance of up to 10 stakeholders including preparation, facilitation, attendance, and reporting for each facility. And two Hazard and Risk Assessment workshops of one day duration with attendance of up to 10 stakeholders including preparation, facilitation, attendance, and reporting.
- Travel time is based excl. Perth with four-hour allowance for return travel for attendance at sessions.

10 Decommissioning schedule

Refer to Appendix G for the estimated decommissioning schedule.

11 Document review

This Decommissioning Plan will be reviewed as per KCGM standard document control procedures, or at least every three years. In addition, the plan will be reviewed in the event of major changes to the cyanide facilities and/or changes in the decommissioning techniques.

12 Limitation statement

Your attention is drawn to the document titled – “Limitation statement”, which is included in Appendix H of this report. The statements presented in that document are intended to inform a reader of the report and its proper use. There are important limitations as to who can use the report and how it can be used. It is important that a reader of the report understands and has realistic expectations about those matters. The Limitation Statement document does not alter the obligations WSP has under the contract between it and its client.

13 References

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ICMI (2021b). Auditor Guidance for Use of the Gold Mining Operations Verification Protocol, International Cyanide Management Institution, June 2021.

KCGM (2022). KCGM Mine Closure Plan 2022

Murdoch University Parker Centre (2008). Cyanide Facility Decommissioning Plan (ICMI Code Principle 5) for Kalgoorlie Consolidated Gold Mines, Revision 2, March 2008.

WHO (1993). IPCS/CEC Evaluation of Antidotes Series, Volume 2, Antidotes For Poisoning By Cyanide, World Health Organization, Geneva, 1993.

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Figures



LEGEND

★ SITE LOCATIONS

0 2.5 5

1:125,000 KILOMETRES

NOTE:

1. COORDINATE SYSTEM: GDA 1994 MGA ZONE 51

REFERENCES:

1. BING MAPS TOPOGRAPHIC MAP FROM © 2021 MICROSOFT CORPORATION © 2021 TOMTOM

CLIENT
KALGOORLIE CONSOLIDATED GOLD MINES

PROJECT
FIMISTON MILL AND GIDJI ROASTER DECOMMISSIONING PLAN

TITLE
LOCATION PLAN

CONSULTANT
wsp

YYYY-MM-DD	2024-05-22
DESIGNED	CR
PREPARED	CR
REVIEWED	SM
APPROVED	RH

PROJECT NO.	CONTROL	REV.	FIGURE
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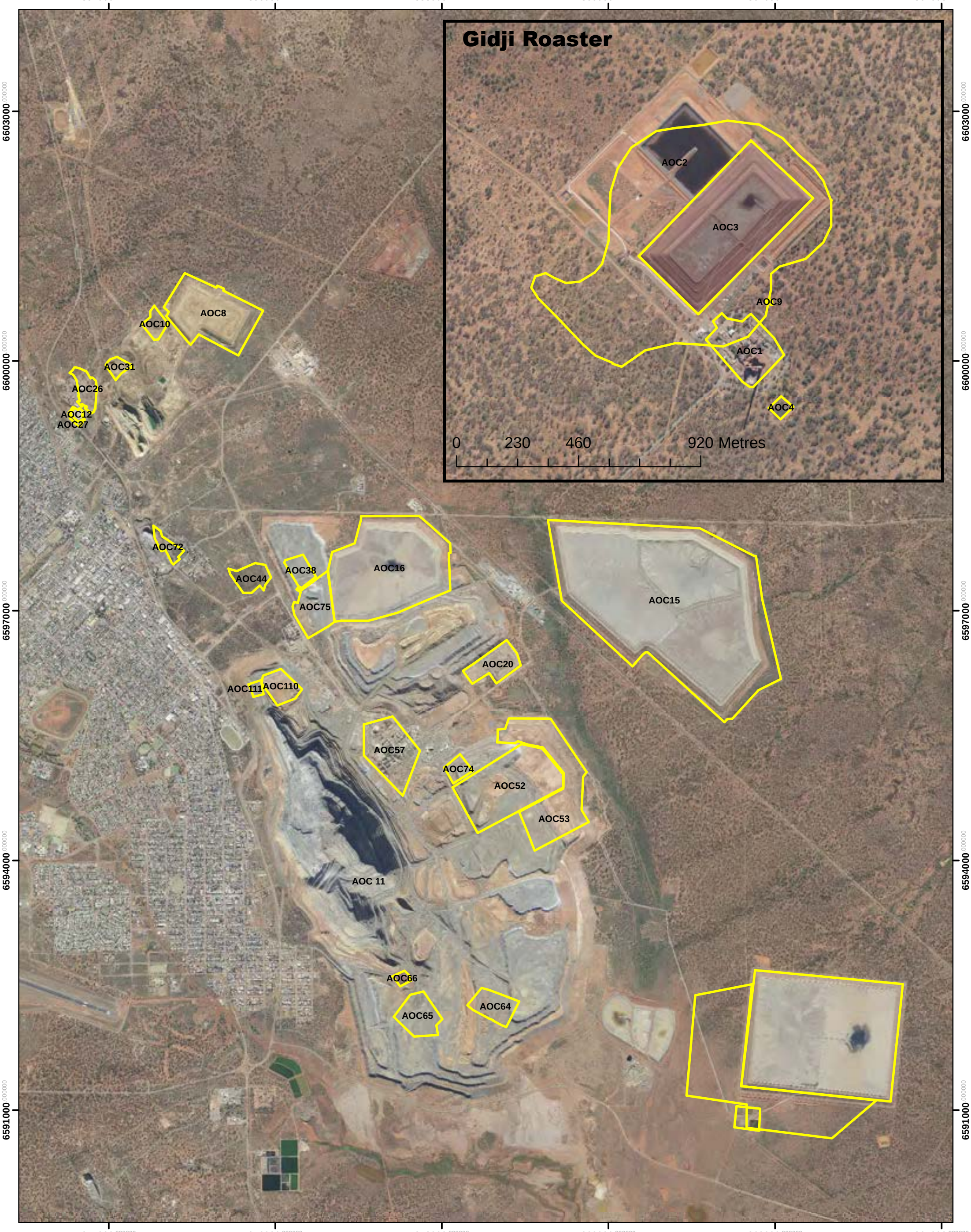


Figure 2
KCGM Suspected Cyanide Contaminated Sites

N

0 700 1,400 2,800 Metres

KCGM Suspected Contaminated Areas

Appendix A

Process flow sheets

FROM PIT
STOCKPILE RG850
FROM RR
PRIMARY CRUSHER
FEEDERS
CV01
CV02
ORE STOCKPILE
RECYCLE CRUSHING
RECYCLE ORE BINS
CV26
CV27
FIMISTON SAG MILL RECYCLE CRUSHING SCREEN
CV22
CV23
CV24
CV25
FIMISTON SAG MILL
SCATS BUNKER
CV21
CV20
FIACRE CRUSHING PLANT
CV31 (RADIAL)
COARSE ORE STOCKPILE
HOPPER
CV32
CV33
CV34
CV35
MT.CHARLOTTE SAG MILL
CV36
CV37
SCATS BUNKER
MT.CHARLOTTE FEEDERS
TRASH DEWATERING SCREEN
TRASH BUNKER
CYCLONE CLUSTER
MT.CHARLOTTE BALL MILL
MT.CHARLOTTE LEACH FEED THICKENER
CYCLONE CLUSTER
BALL MILL No.1
BALL MILL No.2
CROSS-STREAM SAMPLERS
SAMPLER CONDITIONING TANK
CONDITIONING TANK
ROUGHER COLUMN No.19
ROUGHER COLUMN No.20
ROUGHER COLUMN No.21
EAST SCAVENGER FLOTATION CELLS
WEST SCAVENGER FLOTATION CELLS
CYCLONE CLUSTER
REGRIND MILL
CLEANER SCAVENGER FLOTATION CELLS
CLEANER FLOTATION CELLS
RECLEANER FLOTATION CELLS
FLOTATION TAILINGS THICKENER No.2
FLOTATION TAILINGS THICKENER No.3
UFG MILL CLASSIFICATION CYCLONES
SLIMES FLOTATION
UFG FEED STORAGE TANK
ULTRA FINE GRINDING MILL
UFG FEED PREPARATION CYCLONES
DEWATERING SCREENS
FILTER FEED TANK
CONCENTRATE FILTERS No.1 & 2
CONCENTRATE STOCKPILE
CONCENTRATE STORAGE YARD
TO GOLD ROASTER
FLOTATION CONCENTRATES THICKENER
CONCENTRATE THICKENER OVERFLOW WATER TANK
MT.CHARLOTTE ROUGHER FLOTATION CELL
MT.CHARLOTTE SCAVENGER FLOTATION CELLS
FROM GOLD ROASTER
LOADED CARBON
LOADED CARBON RECOVERY SCREEN
CARBON TRANSFER VESSEL
BARREN CARBON STORAGE BIN
FEEDER
CARBON IN LEACH TRAIN No. 1
CARBON IN LEACH TRAIN No. 2
CARBON IN LEACH TRAIN No. 3
BARREN CARBON CATCH SCREEN
BARREN CARBON STORAGE HOPPER
ACID WASH COLUMNS
ELUTION COLUMNS
HEAT EXCHANGERS
CARBON REGENERATION KILNS
LEAN ELUATE STORAGE TANK
CARBON SAFETY CATCH SCREENS
CARBON COLLECTION
CARBON DEWATERING SCREENS
TAILINGS DAM
ELUATE STORAGE TANK No. 1
ELUATE CIRCULATION TANK No. 1
ELECTROWINNING CELL No. 1A
ELECTROWINNING CELL No. 1B
BARREN ELUATE TANK
ELUATE STORAGE TANK No. 2
ELUATE CIRCULATION TANK No. 2
ELECTROWINNING CELL No. 2A
ELECTROWINNING CELL No. 2B
SLUDGE HOPPER
SLUDGE FILTER PRESS
SLUDGE SMELTING FURNACE
SLUDGE DRYING OVEN
BULLION
GRAVITY CIRCUIT FEED HOPPER
MT.CHARLOTTE GRAVITY CIRCUIT FEED SCREEN
GRAVITY CONCENTRATOR
CONCENTRATE THICKENER HOPPER
MT. CHARLOTTE GRAVITY CIRCUIT
BALL MILL 1 GRAVITY CIRCUIT FEED SCREEN
BALL MILL No. 1 GRAVITY CIRCUIT
BALL MILL 2 GRAVITY CIRCUIT FEED SCREEN
BALL MILL No. 2 GRAVITY CIRCUIT
CONCENTRATE SETTLING CONE
LEACHEAD SCREW FEEDER
ACACIA MIXING TANK
ACACIA REACTOR
PREGRAVITY ELUATE STORAGE TANK

MK	DATE	REVISION	BY	CKD	APP
3	22/2/05	GRAVITY CIRCUIT ADDED	JB		
2	11/1/02	UFG ADDED	JB		
1	10/9/01	UFG ADDED	JB		
0	24/8/01	BACKDRAFTED & ISSUED	JB		
A	3/7/01	PRELIMINARY ISSUE FOR COMMENT	JB		

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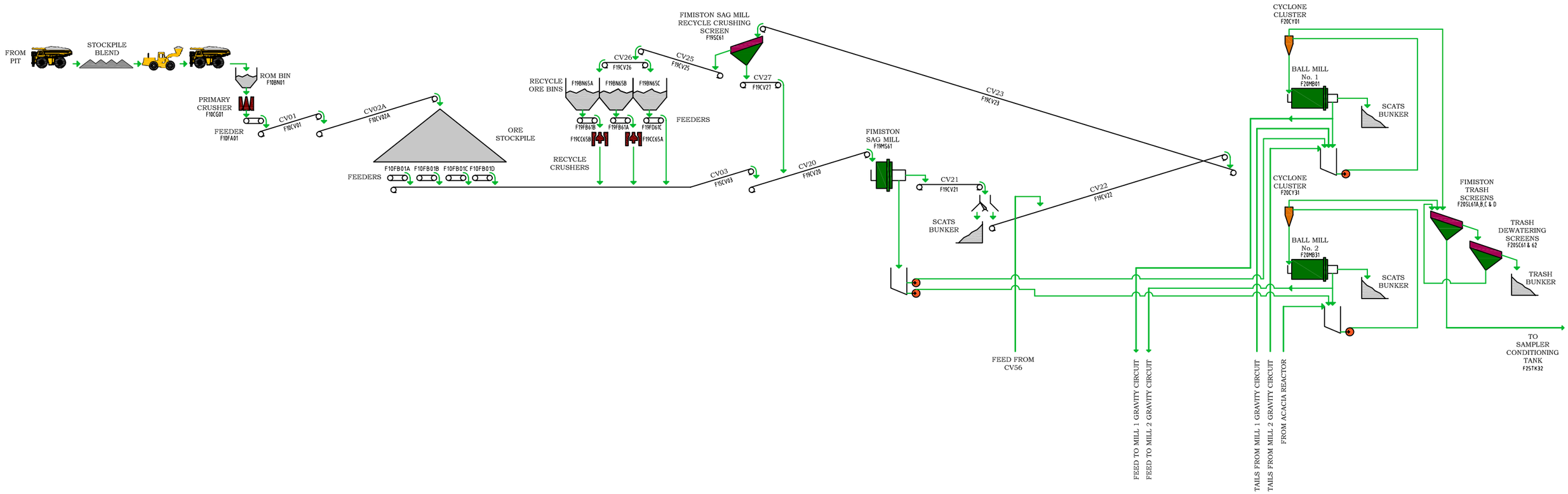
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DRAWN	JB 3/7/01
DESIGNED	
CHECKED	
APPROVED	
PROJ APP	

FIMISTON PLANT
PROCESS FLOWSHEET (SIMPLIFIED)
AS AT JANUARY 2005
OVERALL PLANT

SIZE	DRAWING NUMBER	REV
A0	00-F-1007	3

KALGOORLIE CONSOLIDATED GOLD MINES PTY. LTD. ABN 009 377 619 003



MK	DATE	REVISION	BY	CKD	APP
3	22/2/05	GRAVITY CIRCUIT ADDED	JB		
2	11/1/02	UFG ADDED	JB		
1	10/9/01	UFG ADDED	JB		
0	28/8/01	BACKDRAFTED & ISSUED	JB		
A	3/7/01	PRELIMINARY ISSUE FOR COMMENT	JB		

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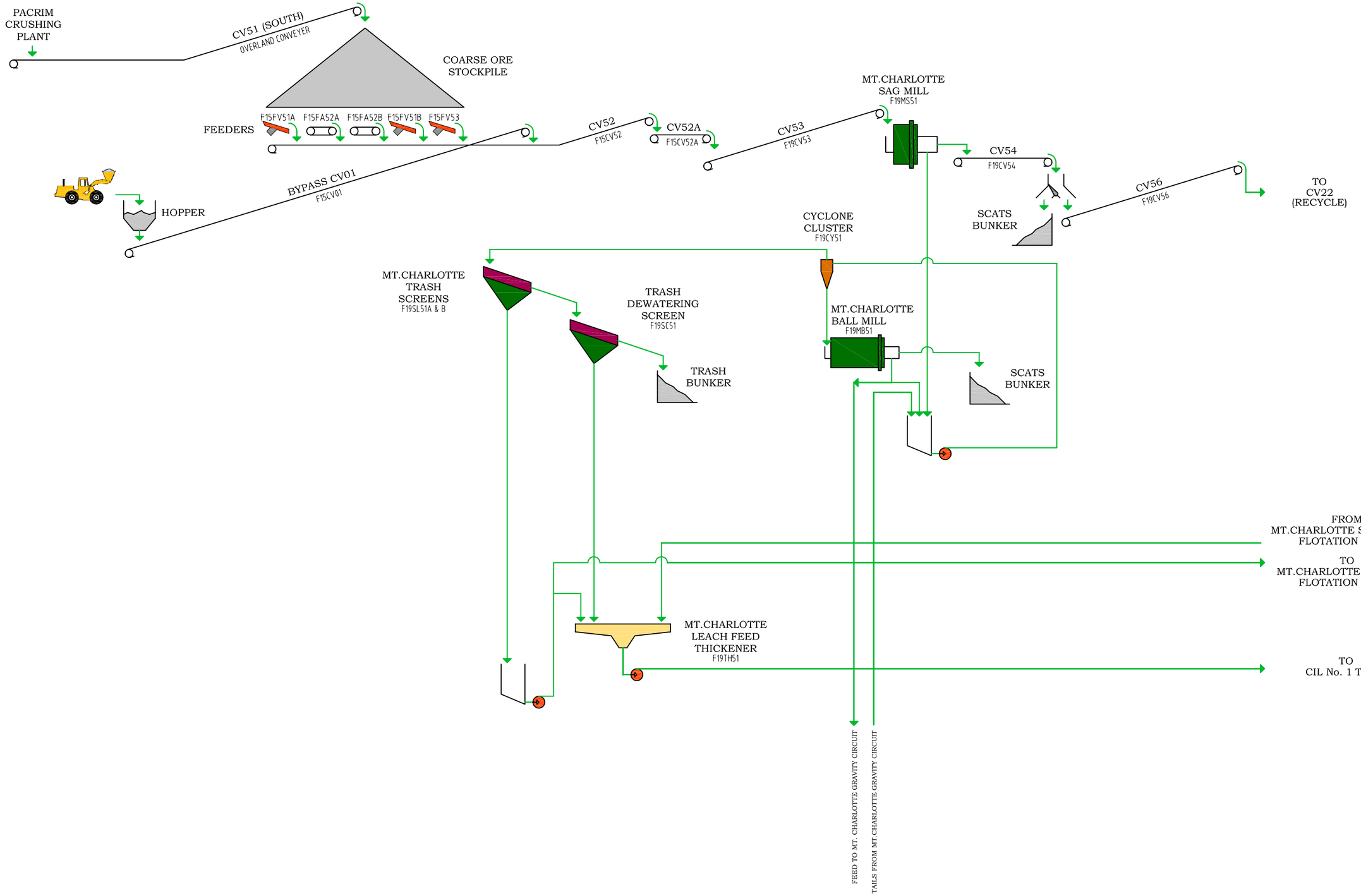
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DRAWN	JB	3/7/01
DESIGNED		
CHECKED		
APPROVED		
PROJ.APP		
PROJ. FILE #.		

FIMISTON PLANT
PROCESS FLOWSHEET (SIMPLIFIED)
AS AT JANUARY 2005
FIMISTON CRUSHING CIRCUIT

SIZE	DRAWING NUMBER	REV
A1	00-F-1008	3

KALGOORLIE CONSOLIDATED GOLD MINES PTY. LTD. ABN 009 377 619 003



MK	DATE	REVISION	BY	CKD	APP
3	22/2/05	GRAVITY CIRCUIT ADDED	JB		
2	11/1/02	UFG ADDED	JB		
1	10/9/01	UFG ADDED	JB		
0	28/8/01	BACKDRAFTED & ISSUED	JB		
A	3/7/01	PRELIMINARY ISSUE FOR COMMENT	JB		

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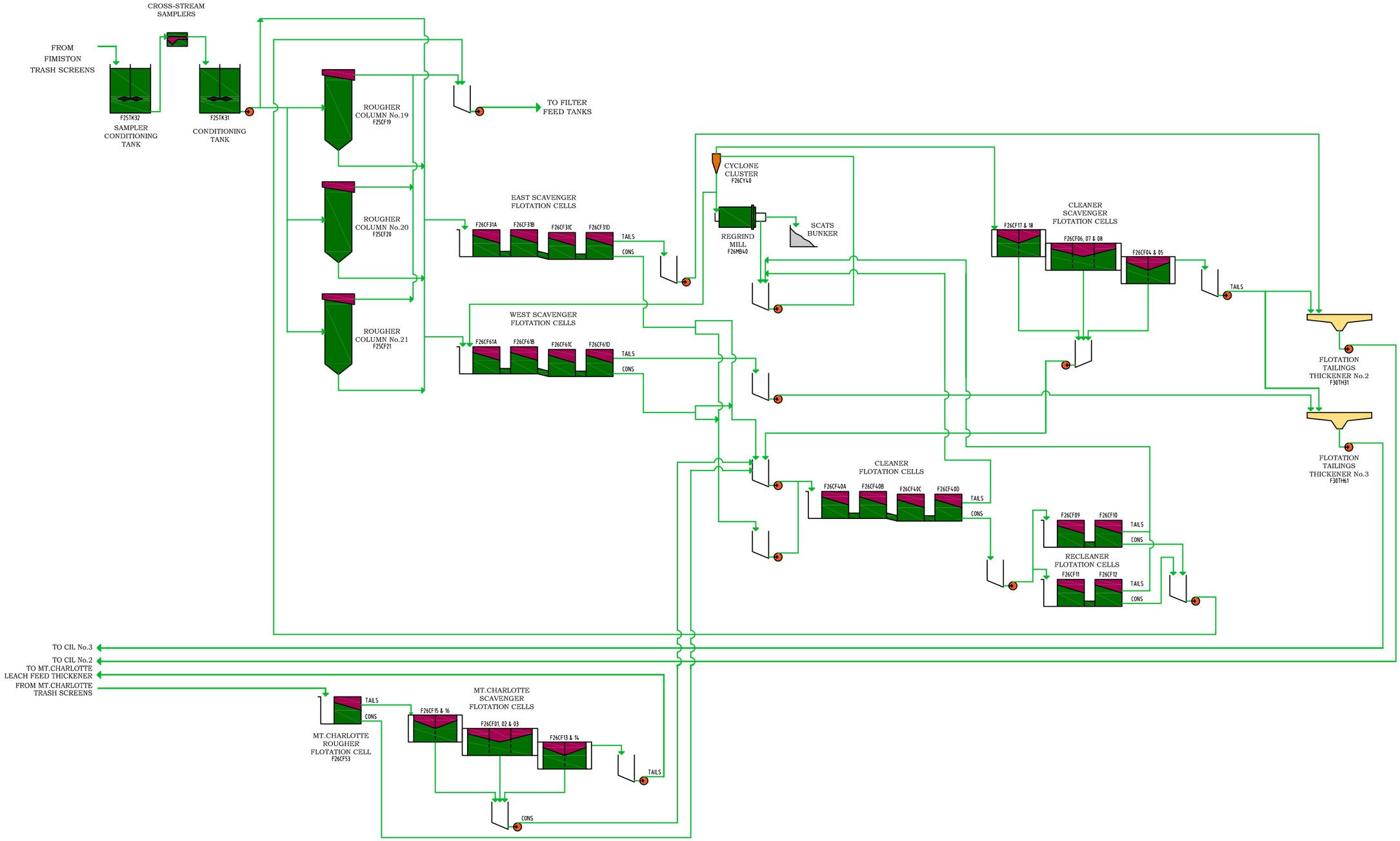
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DRAWN	JB	3/7/01
DESIGNED		
CHECKED		
APPROVED		
PROJ.APP		
PROJ. FILE #.		

FIMISTON PLANT
PROCESS FLOWSHEET (SIMPLIFIED)
AS AT JANUARY 2005
MT.CHARLOTTE CRUSHING CIRCUIT

SIZE	DRAWING NUMBER	REV
A1	00-F-1009	3

KALGOORLIE CONSOLIDATED GOLD MINES PTY. LTD. ABN 009 377 619 003



MK	DATE	REVISION	BY	CKD	APP
3	22/2/05	GRAVITY CIRCUIT ADDED	JB		
2	11/1/02	UFG ADDED	JB		
1	10/9/01	UFG ADDED	JB		
0	28/8/01	BACKDRAFTED & ISSUED	JB		
A	3/7/01	PRELIMINARY ISSUE FOR COMMENT	JB		

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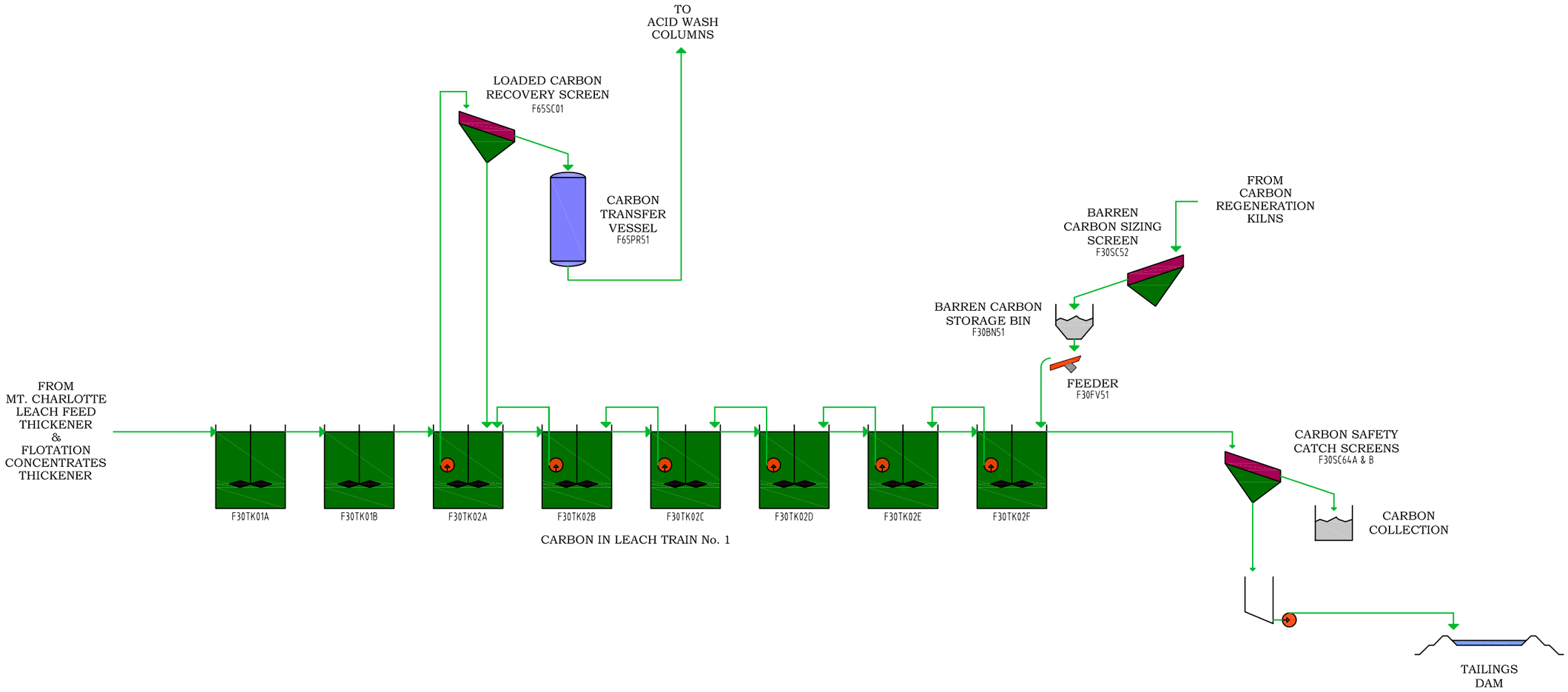
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APPROVED		
PROJ.APP		
PROJ. FILE #.		

FIMISTON PLANT
PROCESS FLOWSHEET (SIMPLIFIED)
AS AT JANUARY 2005
FLOTATION

SIZE	DRAWING NUMBER	REV
A1	00-F-1010	3

KALGOORLIE CONSOLIDATED GOLD MINES PTY. LTD. ABN 009 377 619 003



MK	DATE	REVISION	BY	CKD	APP
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2	11/1/02	UFG ADDED	JB		
1	10/9/01	UFG ADDED	JB		
0	28/8/01	BACKDRAFTED & ISSUED	JB		
A	3/7/01	PRELIMINARY ISSUE FOR COMMENT	JB		

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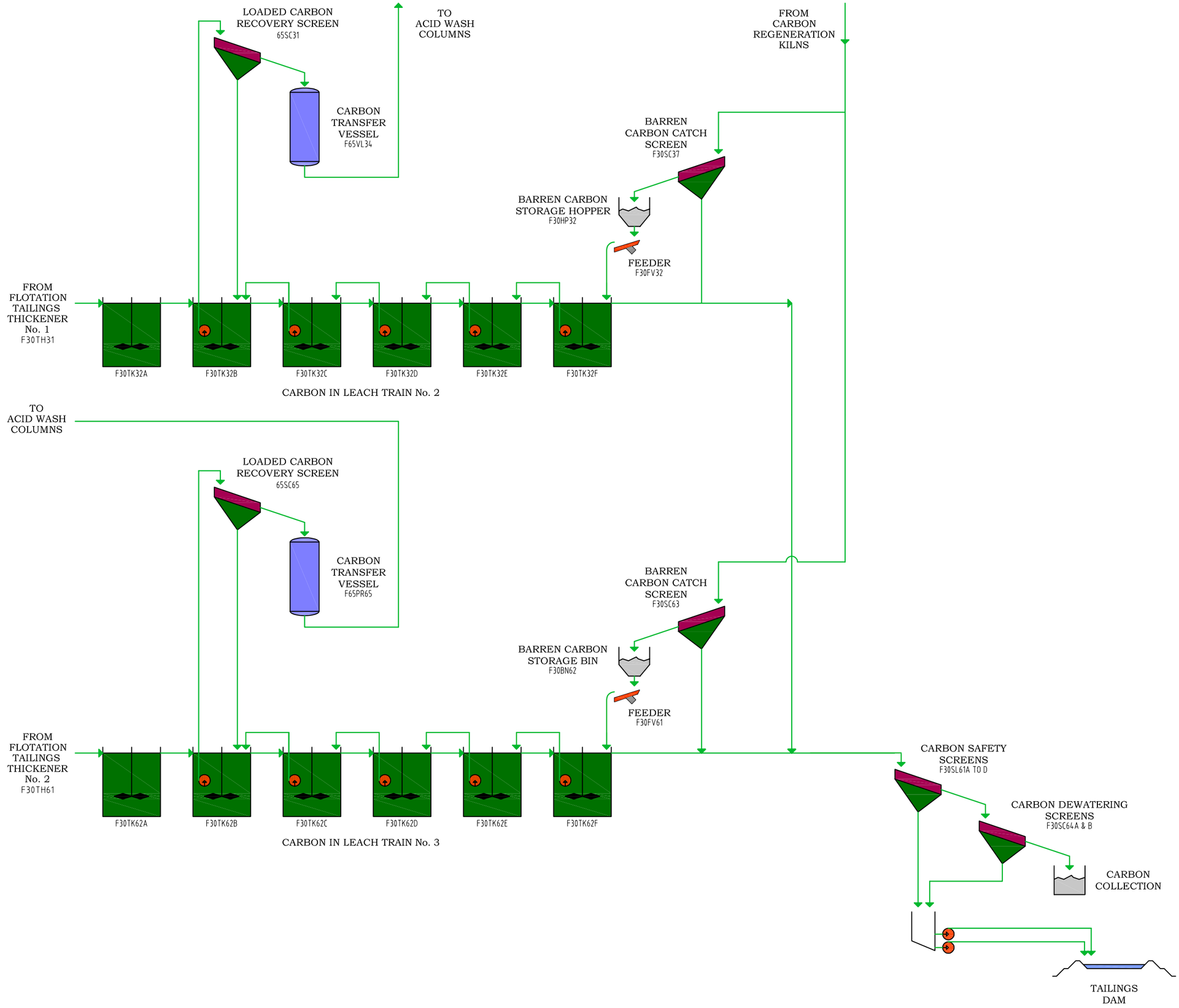
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APPROVED		
PROJ.APP		
PROJ. FILE #.		

FIMISTON PLANT
PROCESS FLOWSHEET (SIMPLIFIED)
AS AT JANUARY 2005
CIL - MT.CHARLOTTE CIRCUIT

SIZE	DRAWING NUMBER	REV
A1	00-F-1011	3

KALGOORLIE CONSOLIDATED GOLD MINES PTY. LTD. ABN 009 377 619 003



MK	DATE	REVISION	BY	CKD	APP
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0	28/9/01	BACKDRAFTED & ISSUED	JB		
A	3/7/01	PRELIMINARY ISSUE FOR COMMENT	JB		

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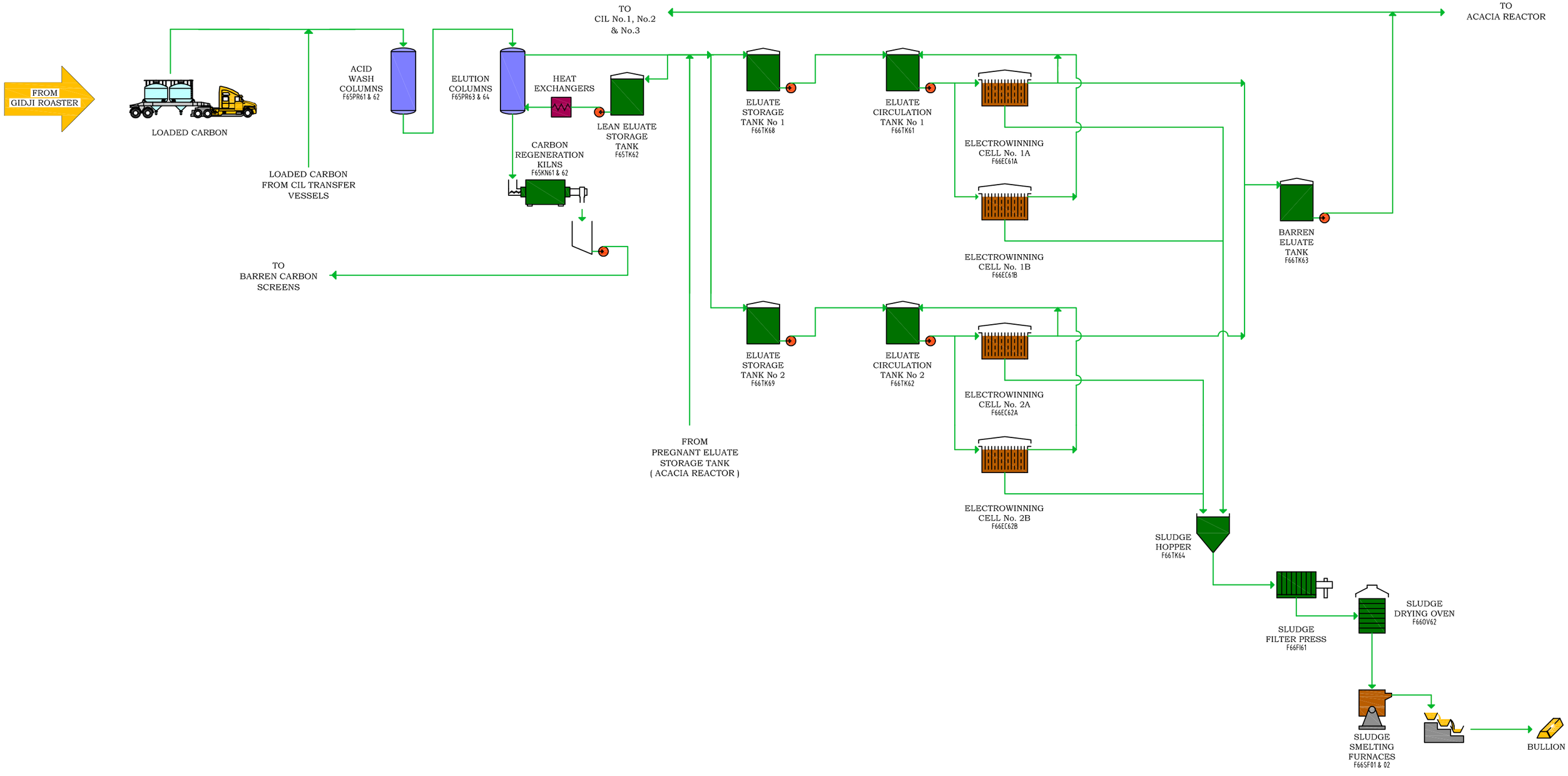
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DESIGNED		
CHECKED		
APPROVED		
PROJ.APP		

FIMISTON PLANT
PROCESS FLOWSHEET (SIMPLIFIED)
AS AT JANUARY 2005
CIL - FIMISTON CIRCUIT

SIZE	DRAWING NUMBER	REV
A1	00-F-1012	3

KALGOORLIE CONSOLIDATED GOLD MINES PTY. LTD. ABN 009 377 619 003



MK	DATE	REVISION	BY	CKD	APP
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2	11/1/02	UFG ADDED	JB		
1	10/9/01	UFG ADDED	JB		
0	28/8/01	BACKDRAFTED & ISSUED	JB		
A	3/7/01	PRELIMINARY ISSUE FOR COMMENT	JB		

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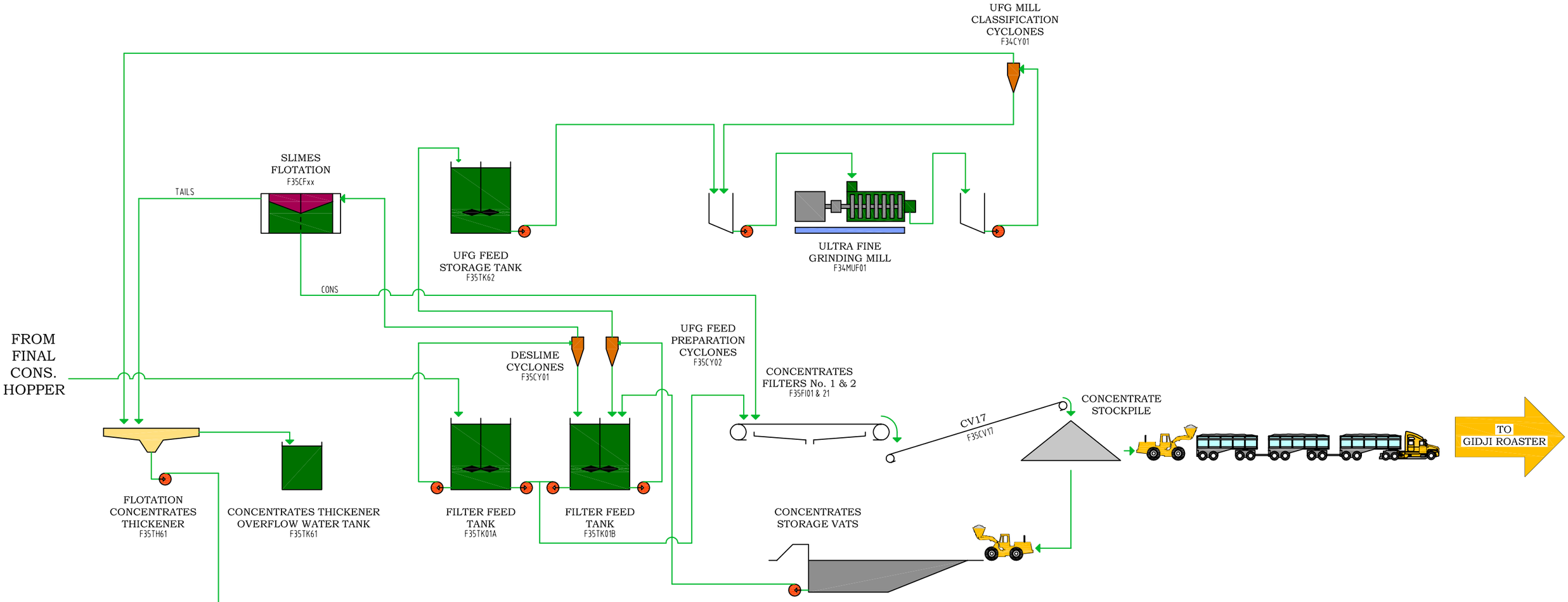
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DRAWN	JB	3/7/01
DESIGNED		
CHECKED		
APPROVED		
PROJ.APP		

FIMISTON PLANT
PROCESS FLOWSHEET (SIMPLIFIED)
AS AT JANUARY 2005
CIL - ELUTION / GOLD CIRCUIT

SIZE	DRAWING NUMBER	REV
A1	00-F-1013	3

KALGOORLIE CONSOLIDATED GOLD MINES PTY. LTD. ABN 009 377 619 003



MK	DATE	REVISION	BY	CKD	APP
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2	11/2/01	UFG ADDED	JB		
1	10/9/01	UFG ADDED	JB		
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A	3/7/01	PRELIMINARY ISSUE FOR COMMENT	JB		

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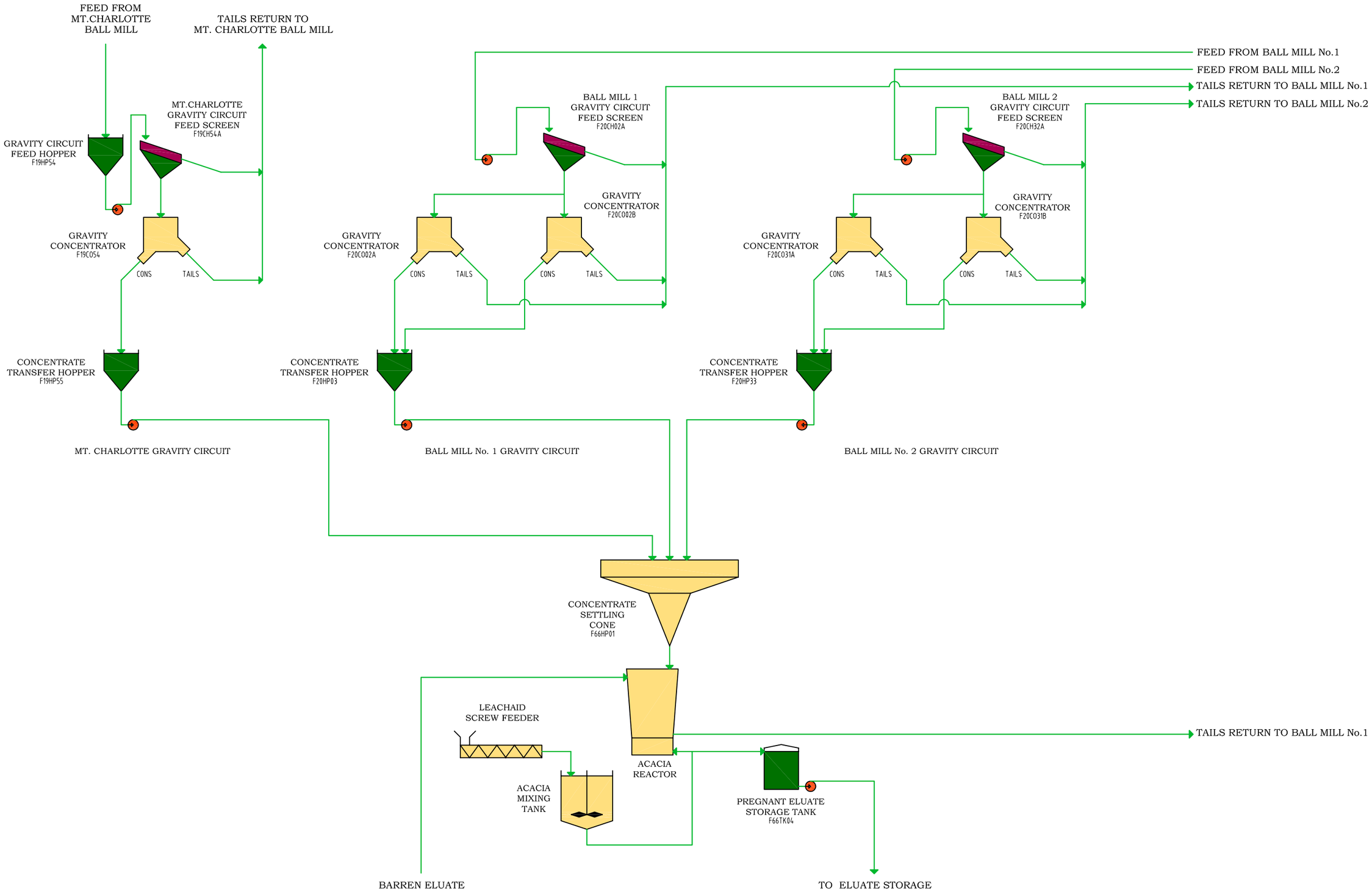
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DESIGNED		
CHECKED		
APPROVED		
PROJ.APP		

FIMISTON PLANT
PROCESS FLOWSHEET (SIMPLIFIED)
AS AT JANUARY 2005
CONCENTRATES

SIZE	DRAWING NUMBER	REV
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KALGOORLIE CONSOLIDATED GOLD MINES PTY. LTD. ABN 009 377 619 003



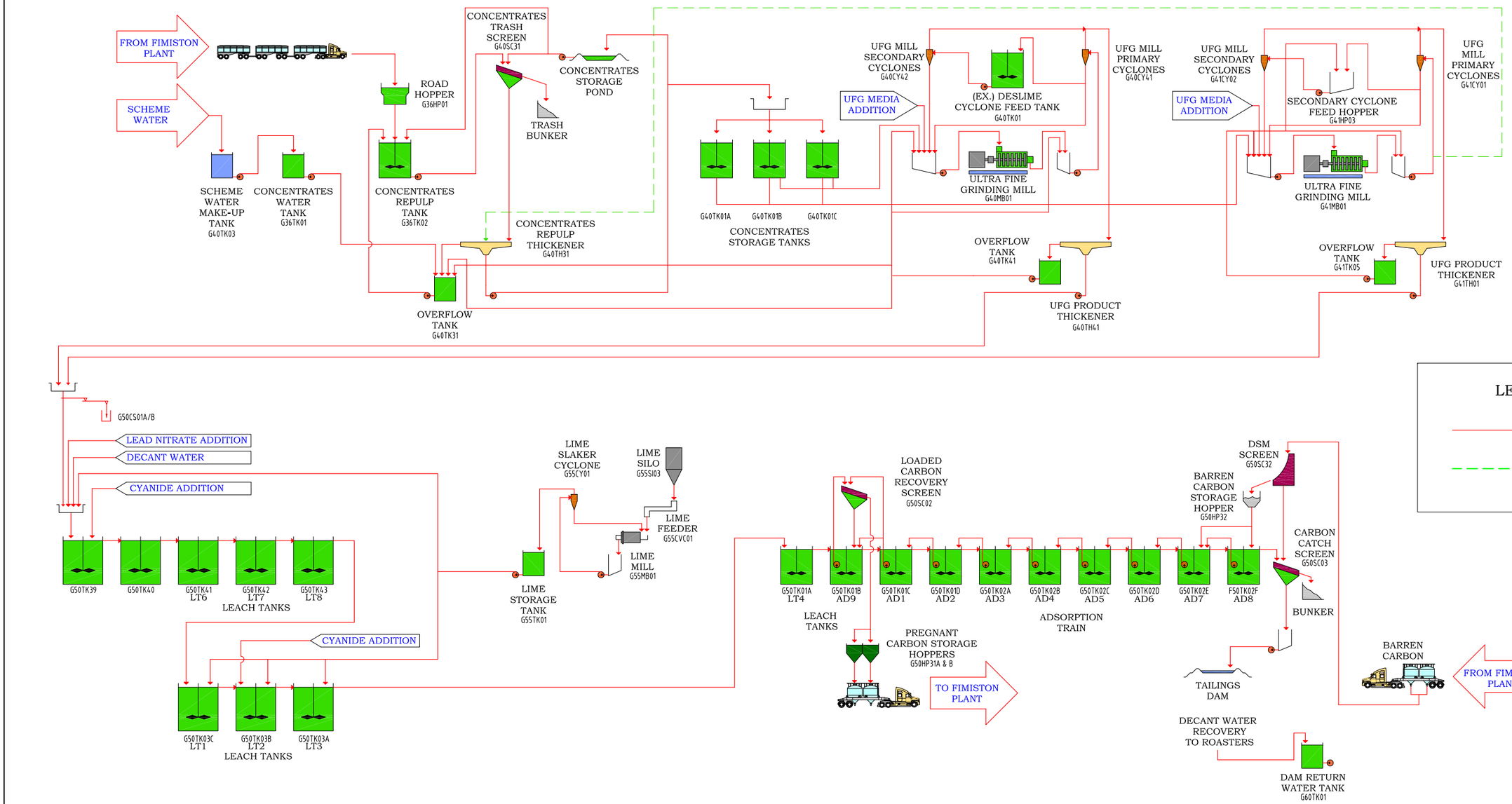
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DRAWN	JB 3/7/01
DESIGNED	
CHECKED	
APPROVED	
PROJ.APP	
PROJ. FILE #.	
DWG NO.	
REFERENCE DRAWINGS	

FIMISTON PLANT
PROCESS FLOWSHEET (SIMPLIFIED)
AS AT JANUARY 2005
GRAVITY CIRCUIT

SIZE	DRAWING NUMBER	REV
A1	00-F-1014__002	3

KALGOORLIE CONSOLIDATED GOLD MINES PTY. LTD. ABN 009 377 619 003



MK	DATE	REVISION	BY	CKD	APP
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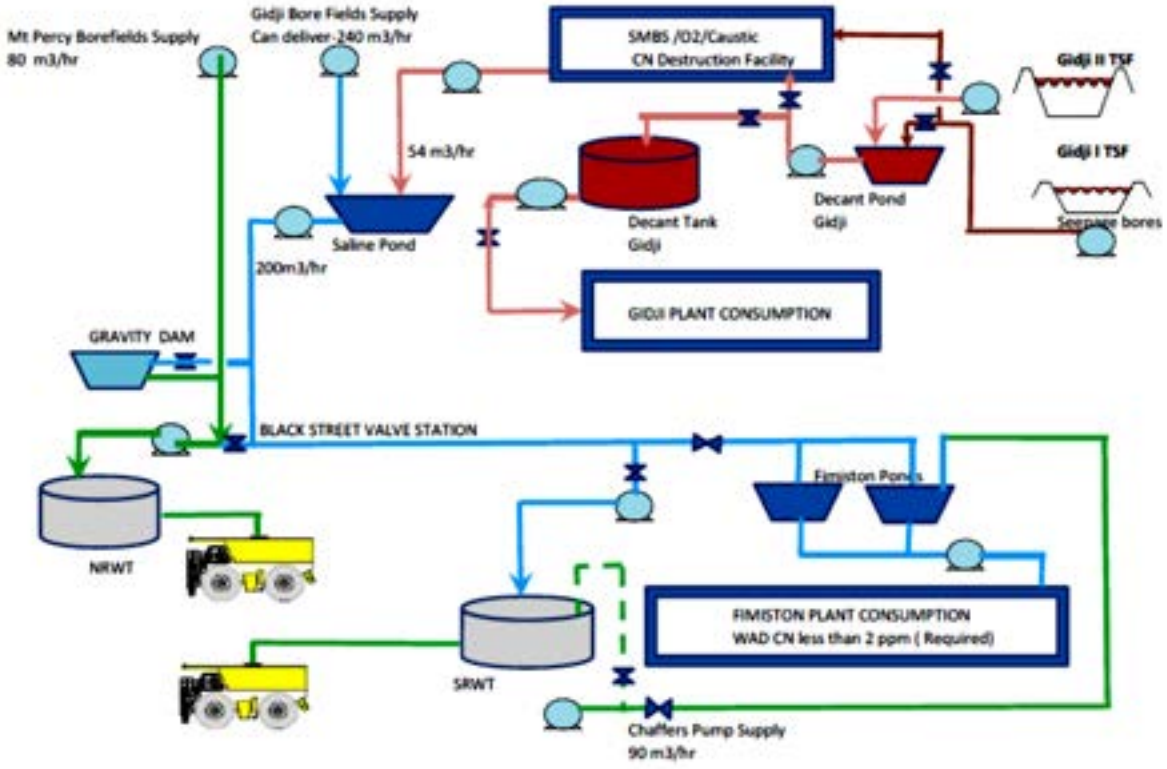
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DRAWN	JB	17/6/16	
DESIGNED			
CHECKED			
APPROVED			
PROJ.APP			
PROJ. FILE #.			

GIDJI TREATMENT PLANT
GENERAL - GIDJI SITE
GIDJI UFG OVERVIEW
PROCESS FLOW DIAGRAM

SIZE	DRAWING NUMBER	REV
A1	01\F\1009	0

KALGOORLIE CONSOLIDATED GOLD MINES PTY. LTD.

ABN 009 377 619 003



KCGM Cyanide Destruction Plant – Water Flow

Appendix B

Cyanide facilities

Equipment Number	Description	Location	Assumed Cyanide Level
F66TK01	Acacia Reactor Area Solution Tank	Fimiston	High
F66TK04	Acacia Reactor Area Pregnant Eluate Storage Tank	Fimiston	High
F66VL01	Acacia Reactor Vessel	Fimiston	High
F71TK01	Cyanide Storage Tank	Fimiston	High
G50TK01C	Calcine CIL 1	Gidji	High
G50TK01D	Calcine CIL 2	Gidji	High
G50TK02A	Calcine CIL 3	Gidji	High
G50TK02B	Calcine CIL 4	Gidji	High
G50TK02C	Calcine CIL 5	Gidji	High
G50TK02D	Calcine CIL 6	Gidji	High
G50TK02E	Calcine CIL 7	Gidji	High
G50TK02F	Calcine CIL 8	Gidji	High
G50TK03A	Calcine Adsorption Tank 1	Gidji	High
G50TK03B	Calcine Adsorption Tank 2	Gidji	High
G50TK03C	Calcine Adsorption Tank 3	Gidji	High
G50TK01A	Calcine Adsorption Tank 4	Gidji	High
G50TK01B	Calcine Adsorption Tank 5	Gidji	High
G50TK41	Calcine Adsorption Tank 6	Gidji	High
G50TK42	Calcine Adsorption Tank 7	Gidji	High
G50TK43	Calcine Adsorption Tank 8	Gidji	High
G55TK17A	Cyanide Bullet Tank 1	Gidji	High
G55TK17B	Cyanide Bullet Tank 2	Gidji	High
G55TK17C	Cyanide Bullet Tank 3	Gidji	High
G55TK17D	Cyanide Bullet Tank 4	Gidji	High
DDT	Decant Transfer Tank	Fimiston	Medium
DDT01PE	Decant Return Lines	Fimiston	Medium
DF1T	Decant Dam 1	Fimiston	Medium
DF2T	Decant Dam 2	Fimiston	Medium
DF3T	Decant Dam 3 (Including Storm Water Pond)	Fimiston	Medium
F19TK51	Process Water Tank	Fimiston	Medium
F30TK01A	Flotation Concentrate Leach Tank "A"	Fimiston	Medium
F30TK01B	Flotation Concentrate Leach Tank "B"	Fimiston	Medium
F30TK02A	Flotation Concentrate Carbon In Leach Tank "A"	Fimiston	Medium
F30TK02B	Flotation Concentrate Carbon In Leach Tank "B"	Fimiston	Medium
F30TK02C	Flotation Concentrate Carbon In Leach Tank "C"	Fimiston	Medium
F30TK02D	Flotation Concentrate Carbon In Leach Tank "D"	Fimiston	Medium
F30TK02E	Flotation Concentrate Carbon In Leach Tank "E"	Fimiston	Medium
F30TK02F	Flotation Concentrate Carbon In Leach Tank "F"	Fimiston	Medium
F30TK32A	Flotation Tailings Carbon In Leach Tank "A"	Fimiston	Medium
F30TK32B	Flotation Tailings Carbon In Leach Tank "B"	Fimiston	Medium
F30TK32C	Flotation Tailings Carbon In Leach Tank "C"	Fimiston	Medium
F30TK32D	Flotation Tailings Carbon In Leach Tank "D"	Fimiston	Medium
F30TK32E	Flotation Tailings Carbon In Leach Tank "E"	Fimiston	Medium
F30TK32F	Flotation Tailings Carbon In Leach Tank "F"	Fimiston	Medium
F30TK32FINS	Instrumentation - CIL 2 Tank F	Fimiston	Medium
F30TK62A	CIL Tank "A”	Fimiston	Medium
F30TK62B	CIL Tank "B"	Fimiston	Medium

Equipment Number	Description	Location	Assumed Cyanide Level
F30TK62C	CIL Tank "C"	Fimiston	Medium
F30TK62D	CIL Tank "D"	Fimiston	Medium
F30TK62E	CIL Tank "E"	Fimiston	Medium
F30TK62F	CIL Tank "F"	Fimiston	Medium
F30TK64	Plant Spillage Transfer Tank	Fimiston	Medium
F30TL01/31/61	Tailings Delivery Piping	Fimiston	Medium
F65PR63	Elution Column	Fimiston	Medium
F65PR64	Elution Column	Fimiston	Medium
F65TK61	Lean Eluate Tank 1	Fimiston	Medium
F65TK62	Lean Eluate Tank 2	Fimiston	Medium
F65TK63	Elution Water Tank	Fimiston	Medium
F66TK61	Eluate Circulation Tank 1	Fimiston	Medium
F66TK62	Eluate Circulation Tank 2	Fimiston	Medium
F66TK63	Barren Eluate Tank	Fimiston	Medium
F66TK68	Eluate Storage Tank 1	Fimiston	Medium
F66TK69	Eluate Storage Tank 2	Fimiston	Medium
F66TK72	Cathode Wash Trough	Fimiston	Medium
F75TK61	Circuit Water Tank	Fimiston	Medium
F75TK62	CIL Cyanide Water Tank	Fimiston	Medium
F75TK64	Saline/Decant Water Mixing Tank	Fimiston	Medium
-	Cyanide Destruction Surge Tank	Gidji	Medium
-	Clarifier Feed Tank	Gidji	Medium
G50HP01	Tails Hopper	Gidji	Medium
G60PN01	Decant Dam (Dam Return Water)	Gidji	Medium
G60PN04	Toe Dam	Gidji	Medium
G60PN05	Saline Dam	Gidji	Medium
G60TK01	Dam Return Tank	Gidji	Medium
G61TH66	Cyanide Destruction Clarifier	Gidji	Medium
G61TK64	Cyanide Destruction Tank 1	Gidji	Medium
G61TK65	Cyanide Destruction Tank 2	Gidji	Medium
F19TK62	Chilled Water Tank- Fimiston SAG Mill Heat Exchanger	Fimiston	Low
F26TK40	Flotation Area Gland Seal Water Storage Tank	Fimiston	Low
F30TK63	Final Tailings Collection Tank	Fimiston	Low
F66TK64	Sludge Hopper	Fimiston	Low
F66TK65	Cathode Spray Water Tank	Fimiston	Low
F75TK01	Cyanide Water Tank	Fimiston	Low
F75TK65	Silt Trap Tank	Fimiston	Low

Appendix C

CSBP Procedure

Sodium Cyanide Solution Storage Facility Decontamination

A printed or saved copy is an UNCONTROLLED copy. Check that it is the latest available version before use.	
Title:	**SODIUM CYANIDE SOLUTION STORAGE FACILITY DECONTAMINATION**
Number:	**CSBP-OP-09-040-09**
Version Number:	**11.0.0**
Date Revised:	**05 July 2021**
Owner:	**Darren Gould**
Authoriser:	**Lee Barker**
Reasons for Creating or Amending Document	**Full Review of Document**
Actual Change Details:	**Minor edits and spelling.**

This procedure has been developed / revised following a Risk Assessment of the tasks associated with this procedure as follows.

Risk Assessment Number:		**Version No:**	7.2
Version number of Procedure developed / revised resulting from above Risk Assessment:	7.0	**Date:**	January 2013
REVIEW PERIOD RANKING:	**H**	**Date of Ranking:**	
Extreme: Review period 12 months **High:** Review period 2 years **Moderate:** Review period 3 years **Low**: Review period 5 years		**Procedure Review due on:**	

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1. INTRODUCTION

The document describes the procedures required to decontaminate an Australian Gold Reagents Pty Ltd (AGR) owned sodium cyanide solution storage facility so that the residual cyanide (CN-) concentration in the storage facility, including storage tank, associated pipework and equipment, is at, or below, 1 part per million (ppm), expressed as mg of CN- per Litre of solution (mg/L). The storage facility will thus be rendered safe to handle prior to dismantling and removal from site.

⚠ WARNING

This procedure has been written for a standard AGR facility. There are many other designs of storage facility, which will require this procedure to be adapted before being applied. This must only be done with the approval of this document's Owner and Authoriser.

2. OVERVIEW

AGR owns sodium cyanide solution storage facilities at various mine sites. These are operated by the mine itself, usually for the purpose of purifying gold. When the mine is decommissioned, it is sometimes necessary to decommission and decontaminate the cyanide storage tank and ancillary equipment, prior to its dismantling and removal from site.

Prior to decommissioning, arrangements are made with the operator of the AGR facility to use, as much as practicable, the sodium cyanide solution inventory, in order to minimise any residual cyanide solution in storage.

Once sodium cyanide solution in storage is minimised, the residual stock in the storage tank is pumped away to a Mine mixing tank, or other safe holding area (usually a tailings dam) until suction is lost at the storage tank discharge pump.

A series of water washes of the storage tank, pipework and equipment is commenced, with all washings being pumped away to a Mine mixing tank, or other safe holding area (possibly tailings dam), until testing of wash water samples discharged reveals that cyanide content, as CN^-, is 1 ppm, or less.

A wash with sodium hypochlorite (hypo) solution of the storage tank and its equipment follows to ensure that any residual cyanide is removed. The hypochlorite washings are pumped to waste (not to the Mine mixing tank, nor tailings dam, nor any area where cyanide may be found). This is followed by a water wash of the tank and equipment (not to the Mine mixing tank, nor tailings dam, nor any area where cyanide may be found) to remove any hypochlorite which may be corrosive to steel surfaces.

The AGR storage facility is then ready for safe dismantling and removal from site.

It is envisaged that the decommissioning and decontamination process will need a work crew and supervisor. AGR may be able to provide an observer and technical advisor. The mine site needs to provide an observer to liaise with the work crew. All personnel involved in this type of work must be fully trained in the properties and safe handling of sodium cyanide solution. In addition, all personnel must be fully trained and conversant with the usage and performance of all personal protection equipment being used.

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3. EQUIPMENT AND PERSONNEL REQUIREMENTS

3.1 GENERAL REQUIREMENTS

The following general requirements must be observed when conducting a decontamination activity:



Sodium Cyanide solution and Hydrogen Cyanide are EXTREMELY TOXIC.



Sodium Cyanide solution is corrosive in contact with skin and eyes.



Hydrogen Cyanide is flammable when present in large concentrations.



Read Sodium Cyanide solution material safety data sheet (IF0871) BEFORE starting this procedure.



Undertake training and become familiar with the properties and safe handling of sodium cyanide solution, and in the use and limitations of personal protection equipment (GM-11-031-01) -used in this procedure.

3.1.1 Procedural and Hygiene

a. Read and become familiar with this procedure.

b. Become familiar with the properties and safe handling of sodium cyanide solution.

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c. Become familiar with the use and limitations of personal protection equipment (PPE) to be used for this job.

d. Always wash all protective equipment before each work day and at the end of the day.

e. Do not smoke or drink during the decontamination process without giving due regard to personal hygiene and cross contamination.

f. Thoroughly wash hands and face before smoking, drinking or eating breaks and always wash before each work break.

g. Always shower at the end of the day.

h. Any splashes of sodium cyanide solution or its washings, contacting the skin, must be washed off with clean running water immediately.

i. In an emergency or if symptoms of cyanide poisoning develop activate the site's emergency response system.

j. Ensure clear communication of the scope of the job is made known to the Mine Management so that requirements can be arranged.

3.1.2 Personnel

All personnel working on this job must physically and mentally capable of working on a mine site, as well as undergo the following training and inductions:

a. AGR Cyanide Awareness Training, and

b. Specific Minesite Induction

3.1.3 Management

Prior to the commencement of a decontamination exercise Mine Management must assign a responsible Mine representative with whom the requirements of the job, including health, safety and emergency response, can be communicated.

3.1.4 Waste Management

Concentrated sodium cyanide solution and washings containing diluted cyanide will need to be disposed off as part of this process.

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It is important that Mine Management assign a mixing tank or other or other safe holding area (usually a tailings dam) to dispose of large volumes of cyanide contaminated liquor.

A volume of washings containing hypochorite will need to be disposed of. These liquors will not contain cyanide. These liquors are incompatible with cyanides, and cannot be disposed of in a mixing tank or tailings dam where they may come into contact with cyanide. The resultant reaction may lead to evolution of highly toxic cyanogen chloride gas.

Ensure that Mine Management designate a safe holding area to dispose of these liquors. These liquors are generally safe to dump on the nearby ground, provided there will be no run-off into ecologically sensitive areas. Check with the site's environmental officers.



Concentrated sodium hypochlorite solution and concentrated sodium cyanide solution react to produce extremely toxic cyanogen chloride gas.

3.1.5 Water

Large volumes of clean water, at satisfactory pressure, will be required for washing and cleaning all facility items. Consider supply via a road tanker as an alternative.

3.1.6 Clean Area

Set aside a clean area near the facility to set down decontaminated and clean items, so that these will not be re-contaminated with cyanide.

3.1.7 Personal Protective Equipment

Ensure that the following PPE is available to each person involved in the decontamination of the sodium cyanide solution storage area:

a. Ensure familiarity with the requirments of CSBP Class 1, 2 and 3 PPE.

b. Hard hat;

c. Chemical safety glasses;

d. Goggles;

e. Full face shield;

f. AUER 3SE full face mask with an AUER 89 ABEK CON-ST canister (or equivalent equipment) for protection against HCN gas;

g. Supplied air;

h. Safety harness for working on top of tank and pipeline rack (needed only for person working at heights);

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i. Full PVC wet weather gear overalls;

j. PVC gauntlet-type gloves;

k. Rubber safety boots (wellingtons).

l. Become familiar with the required monitoring and testing equipment.

3.1.8 Monitoring

The following monitoring equipment will be necessary for checking the tank atmosphere and cyanide (CN^-) content of washings during the decontamination of the cyanide facility.

a. HCN gas detector suitable for pre-vessel entry testing;

b. Suitable oxygen meter;

c. Suitable explosive gas meter;

d. Merck cyanide test kits suitable for CN^- levels down to 1 ppm;

e. Personal air monitors, (equivalent to Dräger PAC III personal air monitors) for detection of HCN concentration up to 50 ppm.

⚠ WARNING

Ensure that all monitoring and testing equipment is correctly calibrated by a competent laboratory before use

3.1.9 General Equipment

The following items are the minimum required in the course of decontamination of the cyanide facility:

a. Portable vacuum pump, Sandpiper diaphragm-type, using compressed air;

b. Two 20 litre drums of sodium hypochlorite solution 12·5% wt/vol (10 kg granular calcium hypochlorite pail is a suitable alternative);

c. Intrinsically safe torch;

d. Two yard brooms;

e. Hand tools (wrenches, spanners, screwdrivers, etc.);

f. Spray manifold for washing tank walls and inside of tank roof;

g. Two 200 L polyethylene drums (for preparing hypo solution);

h. Two 20 L plastic buckets;

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i. Two rubber hoses 20 m long x 25 mm diameter;

j. Two shovels;

k. Vacuum hose 10 m long x 50 mm diameter;

l. Clean water, at sufficient pressure, for washing and cleaning. Supply via road tanker may be an alternative;

m. Mobile crane, 18 tonne;

n. Large blower fan (about 600 mm diameter);

o. Small suction fan (about 200 mm diameter);

p. Cherry picker.

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4. PROCEDURE

4.1 DISMANTLING AND WATER WASHING OF RECEIVAL PIPEWORK

Consult AGR facility drawing before commencing.



All pipework and equipment must be labelled and marked before dismantling.



CLASS 2 PPE must be worn when performing the next steps as some disconnections may release cyanide.



Ensure all existing pipework and equipment is labelled and marked on a corresponding AGR facility drawing to enable easy reconstruction of the facility.



Always assume dangerous levels of cyanide when dismantling equipment.

4.1.1 Receival Pipework

After obtaining required Mine clearances and **doning appropriate PPE**, enter AGR storage facility and label and mark all pipework in the **entire** storage facility that is to be decontaminated and dismantled.

a. Dismantle ring main return to tank, if fitted.

b. Identify battery limits and ring-main return nozzle on tank

c. Blank above flanges.

d. If above pipework belongs to AGR, use crane to remove and lower to floor inside bund.

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e. Commence dismantling and washing.

f. Open drain valve connecting truck unloading pad and bund

Dismantle receival pipework and, together with above ringmain, wash with large amounts of water (fill and empty each pipe with water) into bund sump area. Receival pipework includes the following:

a. Flexible cyanide discharge hose;

b. Flexible air line hose;

c. Isotainer unloading pipe;

d. Unloading vent pipe;

e. Tank vent pipe; and

f. All flanges, bolts and nuts used in the above equipment

4.1.2 Cleanup

Use brooms dipped in water to ensure that the truck unloading pad and unloading tower surfaces are thoroughly covered with water, then using water hose pressure to rinse these off.

Ensure that all water used is collected into the facility bund sump.

After washing all pipework thoroughly, sample last washings and test for CN^- concentration. If CN^- concentration is less than 30 ppm remove items to a high dry area within the bund ready for a hypo wash later in step **4.4.**

If CN^- concentration is equal to, or greater than 30 ppm, repeat the washing of items, sample washings and test again.

4.1.3 Washings

Pump out washing from bund sump. All water washings now collected in the bund sump must be pumped away to safe holding area designated by the Mine (tailings dam) using the facility sump pump.

4.2 EMPTYING THE STORAGE TANK

Note level in sodium cyanide solution storage tank by dipping storage tank.

⚠ WARNING

All pipework and equipment must be labelled and marked before dismantling.

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Class 2 PPE must be worn when performing the next steps as some disconnections may release cyanide.



Ensure all existing pipework and equipment is labelled and marked on a corresponding AGR facility drawing to enable easy reconstruction of the facility

Don appropriate PPE, enter the AGR storage facility, climb to the roof of the storage tank, then insert a dip stick (or plumb line) through vent hole to check the tank level. Ensure a cherry picker or elevated work platform is used.

If the liquid level in the storage tank is at the same, or higher, level than the transfer pump suction pipe (tank discharge pipe), continue with step 4.2.1.1 below. Otherwise proceed to step 4.2.1.2**.**



Check facility drawing to ensure pump suction line inside tank dips below tank liquid level before starting discharge pump. This will avoid dry-starting and running the pump, thus preventing pump damage.

4.2.1 Empty storage tank of concentrated Sodium Cyanide Solution.

Start the transfer pump, pumping cyanide out of the storage tank into the Mine's mixing tank, until the transfer pump loses suction.

Continue running the transfer pump, after suction is lost, **for no more than 2 minutes.** This will ensure that all sodium cyanide solution that can be pumped out of the storage tank is removed via the transfer pump.



Do not run transfer pump dry for more than 2 MINUTES to prevent damaging the pump.

4.2.2 Remove storage tank manhole cover.

Taking extreme care, unbolt and remove the storage tank, side manhole cover

Using gas testing equipment sample atmosphere inside storage tank for hydrogen cyanide concentration oxygen content and explosive gas level.

Double check HCN measurement using the personal air monitor.

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Always assume dangerous levels of hydrogen cyanide when dismantling the manhole cover.



Only enter the tank if necessary for pumping out. Refer to safe working in confined spaces (GM-11-031-52).

4.2.3 Vacuum tank floor

Connect the following to the *Sandpiper* portable vacuum pump:

a. Vacuum hose length at the pump suction end.

b. Place the other end of this hose through the storage tank manhole into the sodium cyanide solution remaining in the tank.

c. Discharge hose length at the pump discharge end.

d. Place the other end of this hose inside the bund sump of the storage facility.



Ensure that the hose is secured and does not whip loose once the pump is started.

Start the Sandpiper portable vacuum pump, pumping cyanide out of the storage tank into the bund sump, until the vacuum pump loses suction.

Start the bund sump pump, pumping cyanide out of the bund sump into the Mine's mixing tank.

Using the facility's water supply maintain a constant flow of water to dilute the cyanide product.

Continue vacuuming out of the storage tank, and in turn, pumping out of the bund sump, until all cyanide solution is removed from the storage tank.

If necessary, these bund sump contents can be pumped away to the safe holding area designated by the Mine (tailings dam).

Maintain water flow until all cyanide is vacuumed out of storage tank.

Stop the bund sump bund immediately suction is lost.

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Do not run bund sump pump dry to prevent damaging the pump.



Class 2 PPE must be worn when performing the next steps as some disconnections may release cyanide.

4.2.4 Open storage tank drain valve.

Taking extreme care, unbolt and remove the blank from the 50 mm drain valve at the bottom of the storage tank.

Crack open the storage tank drain valve and allow tank's contents to drain out of tank and into the bund sump of the storage facility.

Start the bund sump pump, pumping cyanide out of the bund sump into the Mine's mixing tank.

Using the facility's water supply maintain a constant flow of water to dilute the cyanide product.

Continue draining the storage tank, and in turn, pumping out of the bund sump, until all cyanide solution is removed from the storage tank.

If necessary washings can be pumped away to the safe holding area designated by the Mine (tailings dam).

Maintain water flow until all cyanide is drained out of storage tank.

Stop the bund sump bund immediately suction is lost.



Do not run bund sump pump dry to prevent damaging the pump.

4.2.5 Wash storage tank floor

Holding the end of a water hose, peer through the storage tank manhole, and vigorously spray water into the storage tank, flushing the tank floor.

Allow tank's contents to drain out of tank and into the bund sump of the storage facility.

Start the bund sump pump, pumping cyanide out of the bund sump into the Mine's mixing tank.

If necessary wahsings can be pumped away to the safe holding area designated by the Mine (tailings dam).

Continue to flush out remaining cyanide from the tank floor until the washings run clear.

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Continue draining the storage tank, and in turn, pumping out of the bund sump, until all cyanide solution is removed from the storage tank and the tank floor washings are clear. Ensure to stop the bund sump bund immediately suction is lost.

If there is residual sludge on the tank floor and this cannot be removed at this stage, tank entry will be required to remove this sludge. Tank entry will be performed in step **4.3.2.**



Do not run bund sump pump dry to prevent damaging the pump.

4.2.6 Ventilate storage tank atmosphere.

Place the large blower fan at the manhole and start fan to blow atmosphere out of the tank's vent flange (vent pipe previously removed in step **4.1.1**).

Place the small suction fan at the tank's vent flange and start fan to ventilate the interior of the tank.



Do not attempt to enter the storage tank at this stage until the tank's atmosphere has been aired.



Allow the tank to ventilate at least 8 hours (preferably overnight).

4.3 WATER WASHING OF STORAGE TANK

4.3.1 Test storage tank atmosphere.

Don appropriate PPE, enter the AGR storage facility, and decommission the large blower fan at the storage tank manhole.

Continue operating the small suction fan at the tank's vent flange to ventilate the interior of the tank.

At the storage tank manhole, using gas testing equipment, sample the atmosphere inside storage tank for hydrogen cyanide concentration, oxygen content and explosive gas level.

Double check HCN measurement using the personal air monitor.

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Always assume dangerous levels of hydrogen cyanide when sampling inside the storage tank.



Under no circumstances should any person attempt to enter the storage tank if the hydrogen cyanide concentration inside exceeds 50 PPM.

If the hydrogen cyanide concentration inside the storage tank is less than 50 ppm, personnel may enter the storage tank under the guidelines of SAFE WORKING IN CONFINED SPACES (GM-11-031-52), wearing appropriate PPE, as required, and continue onto step **4.3.2** below.

Otherwise repeat from step **4.2.6** onwards.

4.3.2 Clean Sludge and Scale.



Continue operating the small suction fan at the tank's vent flange to ventilate interior of tank.



If the personal hydrogen cyanide monitor indicates that the HCN level exceeds 50 PPM at any stage, all personnel must exit the interior of the tank.



Scale may have accumulated on the internal tank walls. The scale should be removed at this stage of the operation.

Wearing appropriate PPE enter storage tank via manhole, and using brooms and running water clean the tank floor by pushing any residual cyanide sludge towards the tank drain valve.

Allow tank's contents to drain out of tank and into the bund sump of the storage facility.

Start the bund sump pump, pumping the tank's contents out of the bund sump into the Mine's mixing tank.

Continue to flush out remaining sludge from the tank floor until the washings run clear.

Continue draining the storage tank, and in turn, pumping out of the bund sump, until all sludge is removed from the storage tank.

If necessary, washings can be pumped away to the safe holding area designated by the Mine (tailings dam).

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⚠ WARNING

Do not run bund sump pump dry to prevent damaging the pump.

4.3.3 Replace manhole door

Once all sludge has been removed from the storage tank floor, exit the tank.

Replace manhole cover onto tank, together with gasket and re-bolt.

Decommission and remove the small suction fan at the tank vent flange.

Shut storage tank drain valve.

4.3.4 Assemble spray manifold

Assemble the spray manifold and water supply hose for washing interior storage tank roof and wall.

Test the sprays with water outside the storage tank, at tank height, before inserting into tank, to ensure that water spray produced will reach and impact with cleansing force against interior tank roof and wall.

4.3.5 Wash interior storage tank roof and wall.

Introduce the spray manifold and water supply hose through the opened storage tank vent flange, so that the sprays of water will impact the tank's interior roof.

Open water supply to spray manifold.

Ensure that the roof and walls of the tank are being washed.

Continue washing, whilst monitoring storage tank level.

When storage tank liquid level is 100 mm above the level of the transfer pump suction pipe (tank discharge pipe), stop the water supply and pull spray manifold out of storage tank.

Dip tank occasionally to ascertain liquid level. Empty storage tank of water washings.

Start the transfer pump, if fitted, pumping cyanide out of the storage tank into the Mine's mixing tank.

RESPONSE

If a centrifugal transfer pump is not fitted, use the Sandpiper diaphragm portable vacuum pump to drain the tank's contents.

When storage tank liquid level is just above the level of the transfer pump suction pipe (tank discharge pipe), stop the transfer pump.

Remove blank from transfer pump drain line and carefully crack open drain valve.

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Open drain line fully, and after allowing 20 litres of liquid out, take a sample of the liquid for testing of cyanide concentration.

Using the Merck cyanide test kit, test the sample of liquid taken for CN^- concentration. If CN^- concentration is less than 30 ppm, the tank is now ready for a hypo wash, described in step **4.4**.

If CN^- concentration is equal to, or greater than 30 ppm, repeat the washing of items, sample washings and test again.

Re-start the transfer pump.

As soon as suction is lost stop the transfer pump.



Do not run transfer pump dry for more than 2 minutes to prevent damaging the pump.

4.3.6 Remove storage tank manhole cover

Taking extreme care, unbolt and remove the storage tank, side manhole cover.

Using gas testing equipment sample atmosphere inside storage tank for hydrogen cyanide concentration oxygen content and explosive gas level.

Double check HCN measurement using personal air monitor.



Always assume dangerous levels of hydrogen cyanide when dismantling the manhole cover.



Under no circumstances should any person attempt to enter the storage tank if the hydrogen cyanide concentration inside exceeds 50 PPM.

Following step **4.2.3** vacuum contents of storage tank to the Mine's mixing tank.

Replace manhole door, gasket and re-bolt it to storage tank.

Open the storage tank drain valve and allow any residue left inside storage tank to drain out of tank and into the bund sump.

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4.3.7 Dismantle transfer pump and pipework.



Class 2 PPE must be worn when performing the next steps as some dilute cyanide residue may be present, especially when draining cyanide pumps.

Shut the storage tank discharge valve (nearest to the tank).

Open all drain valves upstream and downstream of transfer pump and carefully bleed out any contents present in the line into the bund sump. Pump this material, either into Mine mixing tank, or tailings dam.

Carefully unbolt and remove transfer pump, suction and discharge pipes, valves and drains up to the battery limits. Lay these in the bund, adjacent to the sump.



Always assume cyanide residues may be present when dismantling pipework.

Blank the open lines at the battery limits.

4.3.8 Dismantle sump pump and remaining equipment.



Class 2 PPE must be worn when performing the next steps as some dilute cyanide residue may be present, especially when draining cyanide pumps.

Dismantle any flange or spool up to the battery limits of the cyanide storage facility.

Thoroughly inspect all tie lines used to connect AGR facility sump pump line to Mine holding area to ensure they are empty. If lines are full, determine in conjunction with Mine representative an action plan for removing washings that may contain cyanide contamination from the lines, and cleaning the lines.

Blank off tie lines at battery limits to prevent contamination entering the facility.

Dismantle sump pump and all flanges, valves, gaskets, nuts and bolts. Lay these in the bund, adjacent to the sump pump.

Remove drain valve and pipe from concrete truck unloading pad and place inside the bund.

After draining the lines above from cyanide contaminated washings, flush them thoroughly with water.

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RESPONSE

Mines usually use black polypropylene pipe.

4.4 SODIUM HYPOCHLORITE WASHING AND PART DISMANTLING OF STORAGE FACILITY

⚠ WARNING

All pipework and equipment must be labelled and marked before dismantling.

DANGER

Class 2 PPE must be worn with a full faced respirator when performing the next steps as sodium hypochlorite is corrosive to the skin, and may generate toxic cyanogen chloride gas on contact with cyanide.

DANGER

Ensure that mine management has allocated a safe holding area to dump the next hypo washings. These cannot be pumped into the mine's mixing tank nor tailings dam nor anywhere where there is a possibility of hypo washings coming into contact with cyanide.

⚠ WARNING

Ensure all existing pipework and equipment is labelled and marked on a corresponding AGR facility drawing to enable easy reconstruction of the facility.

4.4.1 Prepare sodium hypochlorite (hypo) 1·5% wt/vol wash solution.

Don appropriate PPE, enter the AGR storage facility, and commence preparation of sodium hypochlorite (hypo) wash solution. (style Step 2)

An aqueous chlorine (Cl2) strength of approximately 1·5 % wt/vol as Cl2 is sufficient to neutralise any remaining cyanide in the storage facility. Make this solution as follows:

To 180 litres of clean water in the poly drum add one full 20 litre container of neat sodium hypochlorite 12·5% wt/vol solution.

Alternatively, if a smaller volume of neutralising hypo solution is required, proceed as follows:

To a clean plastic bucket, dilute neat sodium hypochlorite solution 12·5% wt/vol in water in the following ratio:

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1 volume hypo: 9 volumes water.

This will give a Cl2 strength of approximately 1·5 % wt/vol as chlorine (Cl2).

Stir thoroughly for complete mix.

RESPONSE

To make an aqueous chlorine (Cl2) strength of approximately 1·5 % wt/vol as Cl2 using granular calcium hypochlorite with 650g/kg available chlorine (Cl2), dissolve the granular hypo in water according to this ratio:

1 kg granular hypo: 50 L water

Therefore, to make 200 litres of hypo solution using granular hypo, proceed as follows;

To 200 litres of clean water in the poly drum add 4 kg of granular calcium hypochlorite with 650g/kg available chlorine (Cl2).

This will give a Cl2 strength of approximately 1·5 % wt/vol as chlorine (Cl2).

Stir thoroughly for complete mix.

4.4.2 Assemble spray manifold

Test the sprays with water, outside the storage tank, at tank height, before inserting into tank.

Connect the following to the Sandpiper portable vacuum pump:

a. Vacuum hose length at the pump suction end;

b. Place the other end of this hose into the hypo solution drum

c. Discharge hose length at the pump discharge end; and

d. Connect the other end of this hose to the spray manifold wash feed.

Ensure that hypo solution spray produced will reach and impact with cleansing force against interior tank roof and wall.

⚠ WARNING

Ensure that the hose is secured and does not whip loose once the pump is started.

Wash interior storage tank roof and wall with 1·5 % wt/vol hypo solution.

Wash interior of storage tank roof and wall by following step **4.3**, using approximately 200 L of hypo solution.

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Ensure sufficient hypo solution is available to decontaminate:

a. All the receival pipework and hoses from step **4.1.1**.

b. Storage tank vent pipe, overflow pipe and gaskets;

c. Transfer pump, bund sump pump, pipework and gaskets;

d. Bund floor and walls; and

e. All bolts and nuts used in the above equipment.



A fresh batch of 1·5 % wt/vol hypo solution can be made up if necessary.

4.4.3 Remove storage tank manhole cover

Taking extreme care, unbolt and remove the storage tank manhole cover.

Place manhole cover, gasket, bolts and nuts near the bund sump so that these items are soaked with hypo solution.

Using gas testing equipment sample atmosphere inside storage tank for hydrogen cyanide concentration, oxygen contenty and explosive gas level.

Double check HCN measurement using the personal air monitor.



Always assume dangerous levels of hydrogen cyanide when dismantling the manhole cover.



Under no circumstances should any person attempt to enter the storage tank if the hydrogen cyanide concentration inside exceeds 50 PPM.

Following step **4.2.3** vacuum contents of storage tank into the bund sump.

Open the storage tank drain valve and allow tank's contents to drain out of tank and into the bund sump of the storage facility.

When the tank has finished draining unbolt the tank drain valve and place it in the bund.

The bund sump may overflow with continuing addition of hypo washings. This may be desirable in order to decontaminate all the remaining equipment listed in step **4.4.2**.

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4.4.4 Dismantle storage tank overflow pipe.

Using safety harness and lifting aid (and crane) carefully unbolt and remove the overflow pipe from the storage tank and place it on the bund floor, or in such a position that it drains into the bund.

Use water to wash inside of overflow pipe and gasket.

Allow washings to run into bund sump.

4.4.5 Hypo wash dismantled equipment

Wash thoroughly each individual piece of equipment so far dismantled (listed in step **4.4.2** above), manhole cover, drain valve blank, overflow pipe, gasket, bolts and nuts, with hypo solution.

Use brooms dipped in the hypo solution to ensure that the truck unloading pad, unloading tower surfaces, bund walls, bund floor and any other surface is thoroughly sluiced with hypo solution.

For the smaller pieces it may be easier to dip these into the bund sump where the hypo solution has accumulated.

Take a sample of water washings from any item that has not been fully immersed in the bund contents.

4.4.6 Take a sample of the bund contents.

Using the Merck cyanide test kit, test the samples of liquid taken.

If the test results indicate that the hypo washing liquor in the facility has a cyanide concentration of more than 1 ppm:

a. Continue soaking all the dismantled equipment with fresh hypo solution (fresh from the hypo 200 L drum) and then repeat from step **4.4.2** above.

b. If the test results indicate that the washing liquor in the storage tank has a cyanide concentration of less than 1 ppm continue onwards.

4.4.7 Segregate dismantled equipment

Using lifting aids (and crane) remove all items so far washed with hypo out of the bund and place on the truck unloading pad.

Water rinse all dismantled equipment

Using water hose, thoroughly rinse all items on the truck unloading pad, including unloading pad itself and unloading tower.

Tag all washed equipment on truck unloading pad and labeled as Decontaminated.

Washings are not contaminated with cyanide and are quite safe to allow soaking into surrounding soil.

Clean up all equipment used.

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Thoroughly wash, inside the bund, all equipment used: shovels, brooms, wheelbarrows, etc., firstly with water, then with fresh hypo solution from the hypo 200 L drum.

Sample washings and test for cyanide. If more than 1 ppm, repeat above step **4.4.1** with more fresh hypo solution. If less than 1 ppm continue onwards

Finally, thoroughly wash the equipment used above with clean water, tag and label Decontaminated. Place this equipment on the truck unloading pad next to the decontaminated parts.

4.4.8 Neutralise bund liquid

Use the Sandpiper portable vacuum pump, to pump all remaining hypo solution in the poly drum onto the facility bund, including inside the seal pot.

Sample the bund liquid, and inside the seal pot, and test for cyanide. If more than 1 ppm, repeat above, spraying fresh hypo solution to the entire bund area, and inside the seal pot. If less than 1 ppm continue onwards.



Ensure that mine management has allocated a safe holding area to dump the hypo washings. These cannot be pumped into the mine's mixing tank nor tailings dam nor anywhere where there is a possibility of hypo washings coming into contact with cyanide.



Hypo solution and concentrated sodium cyanide solution react to produce extremely toxic cyanogen chloride gas.

Use the Sandpiper portable vacuum pump to pump all liquid out of the bund, and seal pot, to a safe area designated by Mine Management.

Do not pump to the Mine mixing tank, nor the tailings dam, nor any area where cyanide may be present.

Washings are not contaminated with cyanide and are quite safe to allow soaking into surrounding soil.

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4.5 FINAL WATER WASHING OF STORAGE TANK AND BUND

4.5.1 Assemble spray manifold



Under no circumstances should any person attempt to enter the storage tank if the hydrogen cyanide concentration inside exceeds 50 PPM.

Assemble the spray manifold and water supply hose for washing interior storage tank roof and wall.

Test the sprays with water outside the storage tank, at tank height, before inserting into tank, to ensure that water spray produced will reach and impact with cleansing force against interior tank roof and wall.

4.5.2 Wash interior storage tank roof and wall

Follow step **4.3** to wash the interior roof and walls of the storage tank

Remember that this may be a two operator job and will require slow downwards and rotational motion for thorough cleaning.

Continue washing until a pool of water forms on the floor of the storage tank (Peer through the manhole without entering storage tank).

Sample the liquid on the storage tank floor, and test for cyanide. If more than 1 ppm, repeat washing step. If less than 1 ppm continue onwards.

4.5.3 Wash PPE used

Wash all protective equipment used with clean water.

Sample the liquid from the PPE washings, and test for cyanide. If more than 1 ppm, repeat washing step. If less than 1 ppm continue onwards.

Thoroughly dry face mask, PVC wet weather gear, gloves and boots after use.

Canister filter must be disposed off.

4.5.4 Empty and tag facility

Use the Sandpiper portable vacuum pump to pump all liquid out of the bund to a safe area designated by the Mine Management.

Washings are not contaminated with cyanide and are quite safe to allow soaking into surrounding soil.

When the bund is completely empty tag and label *Decontaminated*.

4.5.5 Sample storage tank atmosphere.

At the storage tank manhole, without going inside the tank, sample atmosphere inside storage tank for:

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Hydrogen cyanide concentration;

Double check HCN with personal air monitor.

If the HCN level is above 1ppm, place large blower fan at manhole entrance and keep fan running at least 8 hours (preferably overnight) to purge and ventilate storage tank atmosphere.

Re-test storage tank atmosphere for HCN level in the morning.

Once HCN concentration is below 1 ppm tag and label the storage tank *Decontaminated.*

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Appendix D

Contaminated sites register

KCGM ID	Location	Contamination Type Suspected	Potential Contamination Area	DER Assessment
AOC1	Gidji	Hydrocarbons, alkali, salinity, metals, cyanide	Soil	Pending
AOC2	Gidji	Cyanide, metals, salinity	Soil, groundwater	Pending
AOC3	Gidji	Cyanide, metals, salinity	Soil	Pending
AOC8	Gidji	Metals, salinity, cyanide	Soil	Potentially Contaminated – Investigation Required
AOC9	Gidji	Metals, salinity, cyanide	Soil	Pending
AOC10	Gidji	Metals, salinity, cyanide	Soil	Potentially Contaminated – Investigation Required
AOC12	Gidji	Metals, salinity, cyanide	Soil	Potentially Contaminated – Investigation Required
AOC15	Fimiston North	Metals, salinity, cyanide	Soil	Potentially Contaminated – Investigation Required
AOC16	Fimiston North	Metals, salinity, cyanide	Soil	Potentially Contaminated – Investigation Required
AOC20	Fimiston North	Metals, salinity, cyanide, hydrocarbons	Soil	Potentially Contaminated – Investigation Required
AOC26	Fimiston North	Metals, salinity, cyanide	Soil	Potentially Contaminated – Investigation Required
AOC27	Fimiston North	Metals, salinity, cyanide	Soil	Potentially Contaminated – Investigation Required
AOC31	Fimiston North	Metals, salinity, cyanide	Soil	Potentially Contaminated – Investigation Required
AOC38	Fimiston North	Metals, salinity, cyanide	Soil	Potentially Contaminated – Investigation Required
AOC44	Fimiston North	Metals, salinity, cyanide	Soil	Potentially Contaminated – Investigation Required
AOC52	Fimiston North	Metals, salinity, cyanide	Soil	Potentially Contaminated – Investigation Required
AOC53	Fimiston North	Metals, salinity, cyanide	Soil	Potentially Contaminated – Investigation Required
AOC57	Fimiston North	Hydrocarbons, salinity, metals, cyanide, alkali	Soil	Potentially Contaminated – Investigation Required
AOC64	Fimiston South	Metals, salinity, cyanide	Soil	Potentially Contaminated – Investigation Required
AOC65	Fimiston South	Metals, salinity, cyanide	Soil	Potentially Contaminated – Investigation Required
AOC66	Fimiston South	Metals, salinity, cyanide	Soil	Potentially Contaminated – Investigation Required
AOC72	Fimiston North	Metals, salinity, cyanide	Soil	Pending
AOC74	Fimiston North	Metals, salinity, cyanide	Soil	Potentially Contaminated – Investigation Required
AOC75	Fimiston North	Metals, salinity, cyanide	Soil	Potentially Contaminated – Investigation Required
AOC90	Fimiston South	Metals, salinity, cyanide	Soil	Potentially Contaminated – Investigation Required
AOC105	Fimiston North	Cyanide, metals	Soil	Potentially Contaminated – Investigation Required
AOC110	Fimiston North	Metals, salinity, cyanide	Soil	Potentially Contaminated – Investigation Required
AOC115	Fimiston North	Metals, salinity, cyanide	Soil	Pending
AOC116	Fimiston North	Metals, salinity, cyanide	Soil	Pending
AOC117	Fimiston North	Metals, salinity, cyanide	Soil	Pending

Appendix E

Decommissioning costs

Areas/Action	Fimiston			Gidji		
	Labour Hours	Labour Unit Cost	Cost	Labour Hours	Labour Unit Cost	Cost
Cyanide Facility Direct Cost						
Detailed task development (plant only)	60	$149.33	$8,960	60	$149.33	$8,960
Cyanide stock reduction	16	$149.33	$2,389	16	$149.33	$2,389
Weekly meeting re: stock reduction	16	$149.33	$2,389	-		-
Pre-closure cyanide tank(s) clean out or assessment	216	$149.33	$32,254	128	$149.33	$19,114
Residual cyanide disposal	24	$149.33	$3,584	10	$149.33	$1,493
Plant clean up - High strength tanks	-		$650,534	-		$1,258,859
Plant clean up - Medium strength tanks	2100	$149.33	$313,583	600	$149.33	$89,595
Plant clean up - Low strength tanks	280	$149.33	$41,811	-		-
Plant clean up - Pipework	50	$149.33	$7,466	30	$149.33	$4,480
Plant clean up - Steel structures	120	$149.33	$17,919	80	$149.33	$11,946
Plant clean up - bins chutes and hoppers	20	$149.33	$2,987	10	$149.33	$1,493
Plant clean up - pumps and instrumentation	25	$149.33	$3,733	15	$149.33	$2,240
Plant clean up - concrete	100	$149.33	$14,933	30	$149.33	$4,480
Acacia Reactor (external area)	16	$149.33	$2,389	-		-
Goldroom (including elution area)	60	$149.33	$8,960	-		-
Laboratory	20	$149.33	$2,987	-		-
Materials/reagents (excluding high strength tanks)	-			-		$146,189
Contaminated sites PSI	-			-		$50,000
Contaminated sites detailed investigation and remediation	-			-		$400,965
Sub Total			***$1,129,934***			***$1,409,142***
Safety Costs						
Revise emergency response plan	35	$149.33	$5,226	35	$149.33	$5,226
Cyanide safety training	300	$149.33	$44,798	300	$149.33	$44,798
Revise permit to work system	35	$149.33	$5,226	35	$149.33	$5,226
Supervisory training-KCGM + contractors	160	$149.33	$23,892	160	$149.33	$23,892
Revise health and safety procedures	80	$149.33	$11,946	80	$149.33	$11,946
Develop safety contract exhibit-closure contracts	35	$149.33	$5,226	35	$149.33	$5,226
Workplace risk assessment and HAZOP	400	$149.33	$59,730	400	$149.33	$59,730
Travel Time Associated with Safety & Training	360	$149.33	$53,757	360	$149.33	$53,757
Materials	35	$149.33	$5,226	35	$149.33	$5,226
Sub Total			***$215,028***			***$215,028***
Total Estimated Closure Costs			**$1,344,962**			**$1,624,170**

Appendix F

Specialist detoxification contractor quote

09/02/2024 Cleanaway Industrial Services

Cleanaway Waste Management Limited
ABN: 57 099 813 546

27 Beach Street
Kwinana Beach WA 6167

Australia
M 0499363431

Golder Associates

Re: 2024 Schedule of Rates

Thank you for providing Cleanaway with the opportunity to submit our Industrial Services Schedule of Rates for your consideration.

Cleanaway has decades of experience helping our partners achieve their objectives. Our expertise in this field is peerless and is the reason why we are so well respected in our industry and can offer an unrivalled capacity. As the leader in industrial services and waste management in the Southwest region we have the size, scale, experience and vision required for a more flexible approach and the capacity to evolve as required. Our large support network, combined with some of Australia's most advanced technologies, enables management of a broad range of general, industrial, commercial, construction, hazardous and problematic wastes, as well as specialised industrial cleaning, technical and maintenance solutions.

Our people are what sets us apart to create true value – we have a large team of in-house specialists to deliver on all required services including technical and specialised work.

Our services include but are not limited to:

- High Pressure Water Internal Vessel Cleaning and De-scaling
- Ultra-high Pressure External & Internal Cleaning
- UHP surface preparation for Fabric Maintenance
- Non-Destructive Digging
- Concrete Demolition using HPW for remedial works
- Vacuum Loading of Heavy or Light Products
- Vacuum Loading and transport of Waste Liquids
- Decontamination services

In line with your specification, we are pleased to provide the following Schedule of Rates.

Service Fee Details		
Service Description	Unit	Rate (Ex. GST) ($)
Industrial Labour (Provided with Equipment)		
Operator Normal Time (Mon-Fri 0600-1600)	Per Hour	$88.00
Operator Overtime (All hours outside of 0600-1600 Mon-Fri)	Per Hour	$103.00
Operator Public Holidays – All Hours	Per Hour	$126.00
Team Leader Normal Time (Mon-Fri 0600-1600)	Per Hour	$98.00
Team Leader Overtime (All hours outside of 0600-1600 Mon-Fri)	Per Hour	$113.00
Team Leader Public Holidays – All Hours	Per Hour	$136.00
Supervisor Normal Time (Mon-Fri 0600-1600)	Per Hour	$108.00
Supervisor Overtime	Per Hour	$118.00
Supervisor Public Holiday	Per Hour	$150.00
Project Management/Admin Fee	Per Day	$350.00
Working Rates (All hours)		
Vacuum Truck (Heavy Vac)	Per Hour	$188.00
High Velocity Vacuum with HPW Jetting Capabilities (6kl cap)	Per Hour	$192.00
Vacuum Tanker (10kl capacity)	Per Hour	$162.00
Semi-Vacuum Tanker (24kL Capacity)	Per Hour	$182.00
Flat bed (Controlled Waste Licensed)	Per Hour	$72.00
Diaphragm Pump	Per Hour	$85.00
3000 PSI Pressure Washer	Per Hour	$75.00
Ultra High Pressure Pump - 3,000 bar@24 lpm	Per Hour	$130.00
650 HP Pump (256L @ 1000bar)	Per Hour	$400.00
Tank Head (Hammelmann Tank Cleaning Head)	Per Hour	$42.00
Utility (4x4 Mine spec)	Per Hour	$30.00
Road Sweeper	Per Hour	$105.00
Mower – Floor Cleaning Nozzle	Per Hour	$40.00

Please note:

- Industrial Labour rates effective when supplied with Cleanaway Equipment.
- Travel time will be charged at the respective hourly rate from point of mobilization
- Operators will be charged out from yard to site and back to yard once completed job. This may vary depending on job scope.

- All adhoc equipment, materials and Subcontractor costs will be charged at cost +10%.

I am available at your convenience to discuss further any of the skills that can be provided, the schedule of rates or specific requirements in relation to this proposal, please do not hesitate to contact me on 0499363431.

Thank you again for allowing us the opportunity to forward our Schedule of Rates. We sincerely look forward to any opportunity to work with Golder in the future. Yours sincerely

Regards

Mathew Sprott

Industrial & Waste Services
Operations Supervisor

Mob: +61 499 363 431
E: mathew.sprott@cleanaway.com.au | www.cleanaway.com.au



Quote from Rob Reynor: Veolia 04/03/2024

Site	High CN Tank	Activity Hours	Cost 2024
Fimiston			
	Cyanide storage tank	72	$64,548.46
	Acacia reactor area vessel	24	$21,754.15
	Acacia reactor area pregnant eluate tank	18	$21,754.15
	Acacia reactor area solution tank	18	$16,476.26
	Flotation concentrate CIL	72	$64,905.46
	Flotation concentrate CIL	72	$64,905.46
	Flotation concentrate CIL	72	$64,905.46
	Flotation concentrate CIL	72	$64,905.46
	Flotation concentrate CIL	72	$64,905.46
	Flotation concentrate CIL	72	$64,905.46
	Flotation concentrate CIL	72	$64,905.46
	Mob/demob	12	$6,757.30
SubTotal		**720**	**$650,534**
Gidji			
	Cyanide storage bullet tank	24	$21,754.15
	Cyanide storage bullet tank	24	$21,754.15
	Cyanide storage bullet tank	24	$21,754.15
	Cyanide storage bullet tank	24	$21,754.15
	leach tank 1	72	$64,905.46
	leach tank 2	72	$64,905.46
	leach tank 3	72	$64,905.46
	Leach tank 4	72	$64,905.46
	Leach tank 6	72	$64,905.46
	Leach tank 7	72	$64,905.46
	Leach tank 8	72	$64,905.46
	UFG leach tank	72	$64,905.46
	UFG leach tank	72	$64,905.46
	adsorption tank 1	72	$64,548.46
	adsorption tank 2	72	$64,548.46
	adsorption tank 3	72	$64,548.46
	adsorption tank 4	72	$64,548.46
	adsorption tank 5	72	$64,548.46
	adsorption tank 6	72	$64,548.46
	adsorption tank 7	72	$64,548.46
	adsorption tank 8	72	$64,548.46
	adsorption tank 9	72	$64,548.46
	Mob/demob	12	$6,757.30
SubTotal		**1404**	**$1,258,859**
Fimiston and Gidji Total		**2124**	**$1,909,393**

Appendix G

Decommissioning schedule

ID	Task	Man Hours	Months From Closure																									
			-24	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	24
Safety																													
1	Revise emergency response plan	70																											
2	Cyanide safety training	2000																											
3	Revise permit to work system	70																											
4	Supervisory training-KCGM + contractors	1600																											
5	Revise health and safety procedures	160																											
6	Develop safety contract exhibit-closure contracts	70																											
7	Workplace risk assessment and HAZOP	4000																											
Cyanide Facility																													
8	Detailed task development (plant only)	120																											
9	Cyanide stock reduction	32																											
10	Weekly meeting re: stock reduction	16																											
11	Pre-closure cyanide tank(s) clean out or assessment	344																											
12	Residual cyanide disposal	34																											
13	Plant clean-up – High strength tanks	1968																											
14	Plant clean-up – Medium strength tanks	2760																											

ID	Task	Man Hours	Months From Closure																								
			-24	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	24
15	Plant clean-up – Low strength tanks	280																											
16	Plant clean-up – Pipework	80																											
17	Plant clean-up – Steel structures	200																											
18	Plant clean-up – bins chutes and hoppers	30																											
19	Plant clean-up – pumps and instrumentation	40																											
20	Plant clean-up – concrete	130																											
21	Acacia Reactor (external area)	16																											
22	Goldroom (including elution area)	60																											
23	Laboratory	20																											
24	Contaminated sites PSI	-																											
25	Contaminated sites detailed investigation and remediation	-																											

Appendix H

Limitation statement

Limitation Statement

PERMITTED PURPOSE

This Report is provided by WSP for the purpose described in the Agreement and no responsibility is accepted by WSP for the use of the Report in whole or in part, for any other purpose (*Permitted Purpose*).

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