Before the Waikato Regional
and Hauraki District Councils

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| Under | the Resource Management Act 1991 (**RMA**) |
| In the matter of | An application for resource consents to extend the Waihi Gold Mine via underground and open pit mining methods known as Project Martha |
| By | **Oceana Gold (New Zealand) Limited** |
| | Applicant |

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# Statement of evidence of Ian Jenkins for Oceana Gold (New Zealand) Limited

29 October 2018

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**Counsel:**
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## Qualifications and experience

1 My name is Ian Robert Jenkins.

2 I am a consulting Geologist and Environmental Scientist, Technical Director and New Zealand Operations Director of AECOM New Zealand Limited (AECOM). I have worked at AECOM and its predecessor companies since 1992, which includes URS New Zealand Limited, Woodward-Clyde NZ limited, and Murray-North Limited.

3 I hold a Bachelor of Science in Geology and a Master of Science (Honours) in Geology and Environmental Science from the University of Auckland. For the seven years from 2000 to 2006 I was a lecturer for a post-graduate course in groundwater chemistry and contaminant hydrogeology at the University of Auckland.

4 My Master's thesis was on the assessment and management of mine wastes from mine sites in the Coromandel region.

5 I have over 25 years' experience undertaking design, geochemistry and groundwater assessments for mine sites. This experience includes geology, hydrogeology, geochemistry, water quality, mine waste containment and design for mine sites throughout New Zealand.

6 I have provided geochemical advice on the major hard rock gold mines throughout New Zealand over the past two and a half decades. I have also provided specialist geochemical modelling input to a number of mining projects in Australia.

7 I have acted as an independent commissioner specialising in soil and groundwater contamination, remediation and landfill design for the then Auckland Regional Council (now Auckland Council) on a number of occasions.

8 I am the AECOM Project Director for the assessment of geochemistry for Project Martha.

9 I carried out the technical work on the geochemical assessment of mined materials at the Martha, Favona, Correnso and Trio Mines and the pit lake chemistry at the site since 1996 and have continued to provide technical support to the mine on geochemistry related issues since that time.

10 In preparing this evidence I have reviewed:

(a) The reports and statements of evidence of other experts giving evidence relevant to my area of expertise, including:

    - (i) GHD 2018. Project Martha – Water Management, May 2018
    - (ii) HydroNumerics, 2018. Project Martha - Martha Phase 4 Pit Extension – Pit Lake Limnology. Scoping Study of Water Quality - Nutrients and Primary Production. Final Report, 22 May 2018.
    - (iii) HydroNumerics, 2018. Project Martha - Martha Phase 4 Pit Extension – Pit Lake Limnology. Final Report, 22 May 2018.
    - (iv) The evidence of Ian Boothroyd, Chris Simpson and Sioban Hartwell
  - (b) The aspects of the Waikato Regional Council section 42A report relevant to my area of expertise, and in particular Appendix D of that report comprising a review of geochemistry for Project Martha prepared by Dr Webster-Brown.

11 I have read the Code of Conduct for Expert Witnesses in the Environment Court Practice Note 2014. This evidence has been prepared in accordance with it and I agree to comply with it. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

**Scope of evidence**

12 I have been asked by Oceana Gold (New Zealand) Limited (**OGNZL**) to prepare evidence in relation to the geochemistry effects and pit lake management of Project Martha. This includes:

- (a) A description of the geochemical character of the various materials under consideration including underground and pit slip overburden, and ore/tailings
- (b) Recommended mitigation measures to manage water quality effects associated with overburden and ore handling and disposal
- (c) Pit lake physical and geochemical modelling, expected water quality conditions, and recommended pit lake management measures.

13 I confirm that my evidence relates to the proposal known as Project Martha as described in Chapter 3 of the Assessment of Environmental Effects dated 25 May 2018 (**AEE**).

14 I confirm that I am the co-author, reviewer and technical lead for the two reports dated May 2018 entitled Project Martha Geochemical Assessment (AECOM, 2018a) and Martha Pit Lake Management Strategy (AECOM, 2018b) attached as Appendices S and U to the AEE.

## Executive summary

15 The following paragraphs summarise key findings from two technical reports prepared by AECOM relating to the geochemistry and management of material expected to be encountered during Project Martha (AECOM, 2018a) and a strategy for the management of the Martha Pit Lake (AECOM, 2018b).

16 The primary materials likely to be encountered during Project Martha are hydrothermally altered andesites, consistent with materials encountered in the Martha Mine area over the past 30 years. Overburden, slip material and ore/tailings from Project Martha are therefore expected to exhibit geochemical characteristics consistent with material already mined from the Martha Pit.

17 The mitigation measures and management practices currently adopted on site for overburden have proven effective for the management of acid rock drainage, and are considered appropriate to manage water quality associated with overburden and slip material from the proposed Project Martha operations.

18 Existing management practices for tailings material currently in place are considered suitable to manage water quality associated with the addition of tailings to existing facilities TSF1A and TSF2. Once completed, tailings from Project Martha are expected to comprise approximately 5% of the material balance stored in each of these facilities.

19 To ensure current management practices remain appropriate, regular static testing of Project Martha overburden, slip material and ore should be continued to identify any significant variation from expected chemistry, and inform alkalinity dosing requirements for overburden material.

20 The primary source of acid rock drainage to the pit lake is likely to be runoff from the pit walls. Limiting pit wall runoff is considered an important strategy to manage the acidity load contributing to the lake. Additional strategies include the modification of lake inflows to increase alkalinity and the introduction of alkalinity to the lake once filling is complete.

21 Geochemical modelling results suggest the strategies currently proposed for mitigating the pit lake water quality are effective at meeting management objectives and water quality criteria for discharge to the Mangatoetoe Stream.

22 The requirement to introduce a source of alkalinity to the pit lake in the long term will depend on the actual acidity load from the pit walls. However, the inclusion of an alkalinity dosing system is considered necessary to provide contingency, in the event that measures implemented to reduce the acidity load from the pit wall and/or the reduction in acidity load due to weathering, do not achieve acceptable water quality in the pit lake.

## GEOCHEMICAL CHARACTER OF MATERIALS UNDER CONSIDERATION

23 The materials under consideration include overburden and ore/tailings from the following Project Martha components:

(a) Martha Underground Mine (including the Rex orebody)

(b) Phase 4 Cutback (including the debris associated with the north wall rockfall)

24 Results of targeted geochemical testing of materials under consideration were not available at the time technical reports (AECOM 2018a and 2018b) were prepared. This information has since been made available and is presented here for completeness alongside the existing comparable dataset (Table 1). The geochemical character of materials under consideration is within the range of materials encountered in the wider operations at the Martha Mine. These rock and ore materials are considered to be well characterised based on observations and geochemical testing spanning over 30 years of mining from the Martha Pit and associated operations.

25 It is understood from consultation with OGNZL on the geology and nature of the ore body to be mined that it is expected to comprise primarily Andesite and Quartz Andesite, consistent with material excavated from the Martha Pit over the last 30 years. Ignimbrite, volcanic ash and alluvial sediments have been observed overlying these primary lithologies at shallower levels. The Andesites and Quartz Andesites have experienced hydrothermal alteration associated with the formation of the mineralisation. The alteration varies in intensity but exhibits characteristics of predominantly argillic clay alteration and propylitic alteration, although other alteration types are also present.

26 With respect to mine waste management, argillic alteration type is of interest as these materials generally have greater acid generating potential and propylitic alteration is of interest as these materials typically have greater acid neutralising potential.

27 Review of borehole logs for drill cores intercepting materials in the vicinity of the Martha Underground Mine (UW485, 920SP2MN1141, 800SP2MN1106, 800SP2MN1130); the Rex orebody (UW520, UW498, UW522), and the Martha Phase 4 Cutback (GT022, UW467) confirm this interpretation.

28 In addition, the Phase 4 Pit is a cutback of areas of the existing pit wall and current pit wall rock exposures provide further information on typical materials that will be encountered from this proposal.

29 While alteration types give a reliable indication of acid producing potential, analytical methods are used to quantify the acid producing potential of samples and derived limestone amendment rates where required.

30 Static testing is used to calculate the theoretical balance (Net Acid Producing Potential (NAPP)) or ratio (Net Potential Ratio (NPR)) between acid-producing and acid neutralising components of a material and is therefore referred to as acid-base accounting (ABA). ABA typically produces conservative estimates of the acid generating/neutralising potential of the material, as it assumes all sulphur occurs as sulphide, and that pyrite is completely oxidised to sulphate and ferric iron. Net Acid Generation (NAG) testing is another static test, that is useful for determining limestone dosing rates for introducing lag to waste materials awaiting final disposal. Static testing does not consider reaction rates or the relative availability of acid producing and acid neutralising components.

31 Kinetic tests assess natural or accelerated weathering by providing uncontrolled or optimal conditions respectively, in terms of oxygen and water to determine reaction kinetics. Kinetic testing can be completed in the field (e.g. column leach testing) or in the laboratory (e.g. humidity cell testing). The acid generation rates derived using these methods can provide an indication of the inherent lag within materials and provide a more robust basis for assessing limestone amendment rates.

32 The characterisation of mine materials considers the following:

(a) Overburden, which is the rock excavated from the proposed operations and placed either within the Rock and Tailings Storage Area or used directly as backfill in the underground mine.

(b) Slip material, which is the material within the slip on the north wall of the open pit. This material has been exposed to weathering and as a result may require additional treatment to overburden to mitigate acid generating potential.

(c) Ore from the proposed operations that will be processed by the mill operation with the residual tailings being placed in the existing tailings storage facilities.

**Overburden**

33 The geochemical character of overburden material from Project Martha was originally interpreted from two existing datasets. Dataset one comprises static geochemical results from 46 samples of Martha Mine overburden (EGI, 1994). Dataset two comprises static geochemical results for 15 samples from the north wall of the Martha Pit (OGNZL data). Summary statistics for historical overburden

geochemistry are presented in Table 1. Grey columns reflect the geochemical character of the data considered representative of Project Martha overburden.

34 The datasets referred to in paragraph 33 provide a conservative indication of the Project Martha overburden and suggest this material would, on average, have higher acid-producing capacity than the material from the wider site. The data is used for overburden management, as outlined in paragraphs 45 to 58, and has been proven to be effective for these materials for the existing operation. Adopting a conservative approach in the initial characterisation for overburden management is considered a precautionary approach, noting there is the ability to further optimise this for ongoing operations as monitoring data for the mined materials becomes available.

35 Targeted sampling and geochemical testing of three additional datasets (representing the three main components of the project - Martha Underground, Rex Vein and Martha Phase 4), was also undertaken. Sample numbers were selected based on the existing known Martha dataset to ensure the minimal sample size required to categorise the mean concentration (of sulphur, Sb, Se and As) was achieved. This information has become available after the technical reports (AECOM 2018a and 2018b) were prepared. These datasets are presented in Table 1 alongside the existing datasets and comprise 40, 35 and 30 samples respectively.

36 Utilising the datasets referred to in paragraph 35, the data confirms that the Martha Underground and Rex Vein overburden material has, on average, a lower acid-producing capacity than the adopted approach in the initial characterisation. The dataset utilised for the Martha Phase 4 overburden material is in line with the initial assessment.

37 I note Dr Webster's overall comments and comments around geochemical assessment (Section 3) and in particular trace element concentrations and consider the additional trace element data comprising 49 samples from Martha Underground, 41 samples from Rex Vein and 39 samples from Martha Phase 4 provide robust characterisation of the project components and confirm the appropriateness of the assessment in the technical reports (AECOM 2018a and 2018b).

### Slip Material

38 The geochemical characterisation of slip material from the north wall of the Martha Pit is based on historic geochemical data representing samples collected by OGNZL from the benches of the north wall of Martha Pit during cutback of the north wall over the past 10 years.

39 This data is used for management of these materials as outlined in paragraphs 65 to 73, and has been proven to be effective for these materials for the existing operation.

**Ore/Tailings**

40 Current tailings storage facilities TSF1A and TSF2 are dominated by tailings generated following processing of ore material sourced from Martha Pit and surrounds.

41 The ore and tailings from the Martha Underground Mine are expected to exhibit similar geochemical characteristics to that of material previously mined from the Martha Pit.

42 Seepage water from the tailings storage facility receiving tailings from the Project Martha is also expected to exhibit similar geochemical characteristics to the seepage that has been measured previously from TSF1A and TSF2 (Table 2).

43 Dr Webster-Brown queries why selenium is not included in the current TSF seepage chemistry data and whether it is monitored. Selenium is monitored and has been added to Table 2. It is typically below the detection limit at TSF2 and close to the detection limit at TSF1A.

## RECOMMENDED MITIGATION MEASURES TO MANAGE WATER QUALITY

44 Overburden, slip material and ore/tailings from Project Martha are expected to exhibit geochemical characteristics consistent with material already mined from the Martha Pit. The same mitigation measures and management practices to those currently adopted are therefore recommended to manage water quality for the proposed operations. The philosophy behind the current management practices is summarised as follows:-

(a) Addition of limestone to Potentially Acid Forming (PAF) material is required to create a lag in acid generation until overburden is encapsulated within its permanent repository;

(b) The refinements to the management practices over the past decades are based on maintaining a slurry pH of above 5.5 until final capping is complete to control the rate of sulphate release;

(c) Testing of the material prior to conveying allows limestone addition via the lime silo on the conveyor belt to be adjusted as necessary;

(d) Regular (monthly) PAF slurry testing and, where shown to be necessary, regular surface limestone application after placement have proven to be effective at managing the material prior to placement of a permanent cover; and

(e) The current overburden management practices are effective at controlling the mine overburden materials and preventing acid rock drainage.

**Overburden Management**

45 Where possible it is recommended overburden is placed directly into its final repository. It is acknowledged, however that this is not always possible and material may need to be stored temporarily prior to final placement.

46 Temporary stockpiling is currently proposed to occur at the Rock and Tailings Storage Area (RTSA).

47 Final repositories for overburden are proposed to include the Central Stockpile, Eastern Stockpile, embankments of the Tailings Storage Facility (TSF), and as backfill in the underground workings.

48 Recommendations for overburden management have been divided into two categories to account for material requiring temporary stockpiling prior to final placement, and material placed directly underground as backfill. A flowchart summarising the recommendations which follow is presented in Figure 1.

***Recommendations for management of material temporarily stockpiled at the RTSA***

49 Daily testing of overburden should be undertaken to classify the material as either PAF or Non Acid Forming (NAF). This should comprise (at minimum) analyses for NAG, pH and NAPP, consistent with current operational procedures at the site.

50 Limestone amendment rates for PAF are to be calculated based on the NAPP value and the length of time the overburden is expected to be exposed to oxidising conditions (lag period). Limestone amendment requirements for a nominal 200 day temporary-storage scenario based on a sulphate generation rate derived from kinetic tests, and a NAPP value of 103 kg $H_2SO_4$/t are provided in Table 3. The NAPP value adopted represents the 95 % Upper Confidence Limit (UCL) from results of historic static testing of Martha Mine overburden. The 95 % UCL is considered to represent a conservative upper bound.

51 Ongoing monitoring of overburden placed in the RTSA is recommended to confirm limestone dosing rates are appropriate, and to inform any refinements to the dosing rates.

52 Dr Webster-Brown seeks clarification of the kinetic experiments used to derive dosing requirements. The kinetic testing data set is based on column leaching tests undertaken as part of previous phases of the Martha Pit development by

EGi between 1994 and 1996. Given the acid base and trace element data confirm that the current project overburden will have the same geochemical characteristics this data is considered representative. We also note management practices based on this data have proven effective as outlined in paragraph 44.

### *Recommendations for management of material placed directly underground*

53 To date, active mitigation measures have not been required for overburden placed directly as backfill in underground workings at the site, as the potential for ongoing oxidation is considered limited. Thirty percent (30%) of the total Martha Underground backfill is proposed to comprise Cement Aggregate Fill (CAF). This CAF is expected to introduce a source of alkalinity/neutralising capacity to mitigate the effect of acid production.

54 As with material to be temporarily stockpiled, daily testing of overburden to be placed directly underground should be undertaken to classify the material as either PAF or NAF, and establish a NAPP value.

55 Overburden placed directly as backfill in underground workings to date is assessed as having a 95th percentile upper confidence limit NAPP value of 103 kg $H_2SO_4$/t. As a result NAPP values below 103 kg $H_2SO_4$/t are not expected to require limestone amendment prior to backfilling. This value does not allow for alkalinity associated with CAF adding a level of conservatism to this threshold for limestone amendment.

56 Based on the results of the targeted overburden sampling and geochemical testing outlined in 35 and 36, it is considered unlikely that overburden material will exhibit a NAPP value of greater than 103 kg $H_2SO_4$/t.

57 For material returning a NAPP value greater than 103 kg $H_2SO_4$/t, limestone amendment is considered appropriate. Amendment rates are to be calculated based on results of the geochemical testing, following procedures currently employed at the site.

58 Providing the recommended procedures are followed, and overburden material returns NAPP values of 103 kg $H_2SO_4$/t or below, the potential for backfilled overburden to leach significant oxidation products and trace elements into the groundwater once the repositories are flooded is considered low.

59 This conclusion is supported by geochemical equilibrium modelling (using PHREEQC version 3.3.12), whereby previously characterised groundwater chemistry in the vicinity of the site was mixed with leachate chemistry from column leach testing of existing Martha Mine overburden to simulate the potential ratios of groundwater and leachate (9:1, 8:2 and 7:3). Results of this modelling suggest that mixing of acidified leachate, in this case inferred to represent the

chemistry of fluid within pore spaces of the overburden, with existing groundwater would have minimal impacts on groundwater chemistry as a whole. Table 4 presents the results of geochemical modelling in conjunction with actual groundwater quality in the vicinity of Project Martha.

60 There are several phases in the evolution of groundwater quality within the backfilled underground mine flooding. There is an initial phase where iron precipitates will be present and trace element sorption onto oxides and hydroxides will control the concentrations present. Over time conditions will become more reducing. Trace elements will desorb from hydroxides with sulphate reducing conditions that will form sulphides leading to low trace element concentrations. Table 4 has been amended to show the effect of these interim conditions and the longer term.

61 Dr Webster-Brown raises some concerns in relation to the modelling undertaken relating to the effect of cement aggregate fill, the initial leachate, the redox conditions, the amount of iron oxide, the ionic strength and the modelled pH. These factors are all considered in the range of scenarios modelled. Based on the simple conceptual model of groundwater evolution outlined in paragraph 60, the key steps that influence the modelled result are as follows, and the model results based on only these model steps are shown in the revised Table 4:-

(a) for the interim conditions – is a mix of groundwater and column leachate at the range of ratios (9:1, 8:2 and 7:3) and allowing for adsorption of trace elements to simulate transient conditions post flooding.

(b) for the longer-term situation – is a mix of groundwater and column leachate at the range of ratios (9:1, 8:2 and 7:3) and allowing for precipitation of over saturated sulphides to simulate anaerobic conditions.

62 The scenarios modelled conservatively assume an acid leachate as this introduces the highest load of trace elements into the modelled scenarios, as would be the case if partially oxidised slip material was used as backfill. Regardless this acid leachate is neutralised by the buffering capacity of groundwater, so the scenario represents a worst case in terms of the initial mass load of trace elements. If we were to model neutral conditions then there would have been minimal oxidation of sulphides and thereby trace elements mobilised. Similarly cement aggregate fill would result in near neutral pH that would limit trace element mobility.

63 The scenarios modelled show a range of pHs and Table 4 has been revised from the version issued in AECOM 2018a to reflect this. Table 4 has also been updated to show the correct calcium concentrations which contained typographical errors in AECOM 2018a.

64 Based on the hydrogeology outlined in the evidence of Mr Simpson, the receiving environment for any groundwater sourced from the backfill is likely be the pit lake. The range of values presented in the modelling results would not impact the overall water quality of the pit lake.

**Slip Material Management**

65 The material comprising the slip surface area (to a likely maximum depth of 5 m) has been exposed to oxidation for a period exceeding three years. During this time the material's intrinsic neutralising capacity has diminished, and the generation of acidic leachate products has already contributed some acid rock drainage which has been visible at times around the slip toe are in the pit floor (refer Aerial photo from April 2016).

66 Slip material is proposed to be used as underground backfill, or be placed in one of the permanent above ground storage structures, but could be stored temporarily awaiting final placement.

67 As per recommendations for overburden, it is recommended that slip material that is to be disposed of underground is tested periodically to classify the material as either PAF or NAF, and determine a NAPP value to inform whether limestone amendment is appropriate.

68 It is recommended that slip material destined for temporary storage (prior to permanent disposal) be blended with limestone at a rate sufficient to fully neutralise residual oxidation products.

69 It is estimated that the top five metres of the slip material has been exposed to oxidation. Limestone blending rates have been calculated for this material based on an inferred mass of PAF rock present, the exposure period, and sulphate generation rates from kinetic tests.

70 Limestone amendment rates outlined in the technical report (AECOM 2018a), suggest up to 21 kg/$CaCO_3$ per tonne of oxidised slip material may be required to achieve a NPR of 1.2, or a 20% surplus of acid neutralising capacity relative to the acid producing potential.

71 It is anticipated that these amendment rates will be refined as management of the slip material progresses. Ongoing site management practices, based on the philosophy outlined in paragraph 44, have shown actual rates required for adequate mitigation of acid rock drainage have been as low as 25 % of the calculated values in paragraph 70. Periodic testing of the slip material is recommended to refine the actual amendment rates required.

72 These calculations account for neutralisation of the oxidation and acid production that has occurred prior to excavation. Additional limestone amendment would be determined based on the recommendations for management of material temporarily stockpiled before final placement underground or in the permanent above ground repositories as outlined in paragraphs 45 to 58.

73 I note Dr Webster-Brown's concern in relation to assumptions about the slip material and the fact that this is now partially oxidised. The samples collected from the north wall of the pit (presented in Table 1) were collected prior to the slip occurring. They therefore represent material within the slip and were also partially oxidised material as a result of being exposed in the pit wall for several years. Given further sampling of the material within the slip has not been possible for safety reasons a conservative approach has been taken as outlined in paragraphs 65 to 70. Further the suitability of the approach in terms of overburden management will be verified as outlined in paragraph 67 and 68.

### Ore and Tailings Management

74 Approximately 70% of the existing tailings in TSF1A and 100% of the existing tailings in TSF2 have been sourced from ore in the Martha open pit area. These facilities are also the proposed destination for processed ore (tailings) from Project Martha.

75 Once completed, tailings from Project Martha are expected to comprise approximately 5% of the material balance stored in each of these facilities.

76 Based on recent seepage water quality data from TSF1A and TSF2 (refer to Table 2), the relative volume Project Martha tailings are expected to contribute to these facilities, and the likelihood that Project Martha tailings will be geochemically similar to existing tailings, current operational practices with regard to tailings are considered suitable to manage water quality.

77 To ensure that current management practices remain suitable, geochemical data for ore material will be collected for Project Martha. It is recommended this is compared with the composition of the ore processed to generate the existing tailings. Should this analysis reveal any notable differences, then appropriate ore and tailings management can be implemented.

## MARTHA PIT LAKE

### *Pit lake physical and geochemical modelling*

78 The pit lake water quality has been assessed using the following approach:

(a) A conceptual model has been developed to define each component providing inflows to the pit lake. In summary this includes rainfall, groundwater, pit wall runoff and river water during filling. The primary source of acid rock drainage is pit wall runoff.

(b) These inflows to the pit lake are characterised in terms of volumes and chemistry. The volumes are taken from the pit lake water balance completed by GHD (2018). The chemistry of the inflows is defined by monitoring data collected at the site. In the case of pit wall runoff, sampling has taken place over more than 20 years.

(c) Physical pit lake modelling, undertaken by Hydronumerics (2018a and 2018b), uses the flows and chemistry to determine the stratification that will develop within the lake taking account of the pit shape (bathymetry), density of inflows and the meteorological conditions. This modelling defines the lake limnology including the proportions of each inflow component within each layer of the final lake.

(d) The geochemical model then focusses on the components within the upper lake (epiliminion) and the chemistry of the inflows to derive predictions of discharge quality after mixing and equilibration for a range of scenarios, for example during filling and over the long term once the lake is discharging to the receiving environment. For the 15 year post-filling scenario the effects of adsorption onto ferric hydroxide are also assessed.

79 Geochemical modelling of the pit lake was undertaken using PHREEQC modelling software, version 3.4.0. PHREEQC is utilised to assess geochemical reactions of the combined water qualities of the pit lake in order to account for and assess overall pit lake water quality. It is a widely utilised software in regards to assessing water quality as a result of mining operations. Water within the upper layer of the lake, the epilimnion, is the focus of modelling as it represents the water which will discharge from the lake, and also the water with which human contact is most likely.

80 Modelling was undertaken for both short term pit lake water quality (during the filling stage) and long term pit water quality (following the filling stage). Both modelling stages included the provision of active manipulation of water quality via alkalinity addition.

81 During the filling stage, to be dominated via diversion of flow from the Ohinemuri River, river water entering the pit was assumed to have a limestone-amended alkalinity equivalent to 60 mg/L bicarbonate.

82 For the post filling stage, it was assumed the lake water is actively treated with limestone.

83 It is envisaged that a reduction in acidity source from the pit walls – either through active measures such as pit wall amendment, runoff diversion and amendment or natural weathering, will reduce the reliance on active limestone treatment of the lake water in the long term.

### *Expected water quality conditions during filling (short term lake water quality)*

84 Scenarios to represent both summer and winter during year four of lake filling were simulated. Year four was selected following results of the physical assessment, which indicated the proportion of high PAF pit wall runoff present in the epilimnion would be greatest during this phase of filling (although not discharging). Results of this geochemical modelling are presented in Table 5.

85 Modelling results indicate epiliminion water quality will typically improve in winter months relative to summer months due to effects of increased dilution.

86 Modelling results indicate epilimnion water quality would meet receiving water quality standards for most elements, based on an assumed hardness of 100 mg/L. Notable exceptions include the pH during the summer epilimnion minimum and copper for both summer and winter scenarios (Table 5).

87 Dr Philips raised some concern regarding knowledge gaps around the effects of filling of the lake in terms of metal concentrations, and the subsequent effects of the discharge to Mangatoetoe Stream. There is a considerable timeframe between mine closure and discharge to Mangatoetoe Stream and the existing and proposed consent conditions require ongoing monitoring to confirm the current predictions. It is also envisaged that during this time (as well as between now and mine closure), measures to reduce pit wall acidity and associated trace elements will be investigated further in order to reduce reliance on active treatment and further verify the conceptual understanding of the pit lake chemistry.

### *Expected water quality conditions following filling (long term lake water quality)*

88 Scenarios were considered to represent long term pit lake water quality across a range of conditions and timeframes (5, 10 and 15 years post filling). Key changes to conditions included the acidity load received from the pit walls, the formation of hydrous ferric oxides, and whether the pit lake is amended with limestone.

89 Results of modelling indicate that long term pit lake water quality meets receiving water quality standards based on assumed hardness of 100 mg/L, aside from marginal exceedances for chromium and copper in the 15 year post filling scenario (Scenario F (2)) without adsorption onto ferric hydroxides (Table 6). Scenario F (2) gives modelled discharge concentrations for total chromium (III and IV) and copper of 0.012 mg/L and 0.013 mg/L respectively. When modelling

considers the effects of ferric hydroxides the predictions for these scenarios meet receiving water criteria.

90 Post filling, the active treatment of lake water via dosing with limestone is considered likely to be a necessary contingency measure in order to ensure discharge water is within the receiving water quality standards. However, depending on the rate of pit wall weathering and/or the success of pit wall acidity reduction, the reliance and/or requirement for active treatment in the long term could be minimised.

### *Recommended pit lake management measures*

91 The following three key management measures are recommended to meet the desired water quality and pit lake management objectives.

(a) Reduction of the acid rock drainage contribution from pit walls to the lake. Where this is modelled, results indicate the potential efficacy a reduction of acidic inflow could have on pit lake water quality. Approximately 90% of the total acidity load entering the lake is estimated to be sourced from pit wall runoff, and as such it is recommended this mitigation measure is explored further.

(b) Modifying lake inflows during filling to increase alkalinity. It is proposed that the Ohinemuri River diversion is channeled into the pit by a method in which a source of alkalinity can be added easily. This could involve routing via the crusher slot or limestone rip rap on the haul road. A target alkalinity value equivalent to 60 mg/L bicarbonate is considered achievable and has been adopted for modelling this scenario.

(c) Increasing the alkalinity within the lake once filling is complete. It is likely this mitigation measure will be required until long term water quality approximates steady state conditions meeting water quality criteria and it should be adopted as a contingency measure until other measures (such as a reduction in acidity contribution from the pit walls) are deemed to be sufficient. It is proposed that powdered limestone is introduced via a dosing system where lake water is extracted, treated to form slurry, and then pumped back into the lake.

## Conclusion

92 Overburden, ore and slip materials likely to be encountered during Project Martha are considered to be geochemically similar to material previously encountered in the wider Martha Mine area.

93 The currently adopted management practices for these materials in conjunction with the ongoing monitoring recommended in this statement is considered appropriate to manage water quality for the proposed operations.

94 The results of the geochemical modelling suggest that the adopted strategies for mitigating the pit lake water quality will be effective at meeting the management objectives and the water quality criteria for any discharge to the Mangatoetoe Stream.

95 The long term need for active alkalinity introduction to the pit lake will depend on actual acidity load from the pit walls (which has been shown to diminish with time). However, the inclusion of an alkalinity dosing system is considered necessary to provide contingency, in the event that measures implemented to reduce the acidity load from the pit wall, and/or the reduction in acidity load due to weathering, do not achieve acceptable water quality in the pit lake.

**Ian Jenkins**
29 October 2018

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AECOM **Table 1. Summary of Geochemical Results for Overburden**

| Parameter | Trio Andesite Waste Rock | | Favona Andesite Waste Rock | | Martha Mine Waste Rock | | Correnso Andesite Waste Rock | | North Wall Data | | Martha Underground (MUG) | | Rex Vein (Rex) | | Martha Phase 4 (Mp4) | | Mean Concentration in Earths Crust[1] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 25 Samples | | 85 Samples | | 46 Samples | | 27 Samples | | 15 Samples | | 40 ABA / 49 Trace Elements Samples | | 35 ABA / 41 Trace Elements Samples | | 30 ABA / 39 Trace Elements Samples | | |
| | Arithmetic Mean | Range | Arithmetic Mean | Range | Arithmetic Mean | Range | Arithmetic Mean | Range | Arithmetic Mean | Range | Arithmetic Mean | Range | Arithmetic Mean | Range | Arithmetic Mean | Range | |
| ***Acid Generating Potential*** | | | | | | | | | | | | | | | | | |
| Total Sulphur (%) | 2.1 | 0.5 - 5.1 | 2.3 | 0.01 – 6.0 | 3.0 | 0.01 – 9.3 | 2.15 | 0.47 - 3.39 | 3.3 | 0.58 - 4.5 | 0.8692 | 0.103-3.03 | 1.6 | 0.007-3.91 | 3.1 | 1.37-4.7 | **0.03** |
| Total Carbon (%) | 0.3 | 0.02 - 0.7 | - | - | - | - | 0.70 | 0.21 - 1.53 | - | - | - | - | - | - | - | - | - |
| MPA (%CaCO3) | 6.5 | 1.5 – 15.9 | 7.0 | 0.03 – 19 | 9.5 | 0.03 – 29 | 6.7 | 1.5 - 10.6 | 10.0 | 1.8 - 14.1 | 2.7 | 0.3-9.5 | 5.0 | 0.02-12.2 | 9.8 | 4.3-14.6 | - |
| ANC (%CaCO3) | 7.8 | <2 – 15.0 | 1.5 | 0.03 – 13 | 3.1 | <2 – 16 | 7.3 | 2.0 - 15 | 4.7 | 0 - 32 | 6.3 | 2.3-8.9 | 7.1 | 2.3-12.8 | 7.2 | 1.5-11.8 | - |
| ANC/MPA | 1.6 | 0.13 - 8.12 | 1 | 0.004 – 32 | 0.9 | 0 – 18 | 1.36 | 0.2 - 4.6 | 0.45 | 0 - 2.7 | 2.3 | 0.9-7.1 | 1.40 | 1.0 - 105 | 0.7 | 0.4-0.8 | - |
| AP (kg CaCO$_3$/tonne) | 65 | 15 - 159 | 70 | 0.3 - 190 | 112 | 0.3 - 291 | 67 | 14.7 - 106 | 102 | 18 - 140 | 27.2 | 3.2-94.7 | 50 | 0.2-122 | 98 | 43-146 | - |
| NP (kg CaCO$_3$/tonne) | 53 (26)$^2$ | 20 - 150 (1.7 - 58.7)$^2$ | 15 | 0.3 - 130 | 31 | <2 - 155 | 58 | 17.5 - 127 | - | - | - | - | - | - | - | - | - |
| NNP (kg CaCO$_3$/tonne) | -41 | -152 - 43 | -54 | -181 - 114 | -73 | -252 – 63 | -15 | -87.8 - 72.5 | - | - | - | - | - | - | - | - | - |
| NAG pH | - | - | - | - | 3.4 | 2.1 - 7.5 | 8.7 | 2.3 - 11.2 | 4.1 | 2.3 - 8.5 | 8.3 | 3.3-11.2 | 6.6 | 2.7-11.2 | 6.2 | 2.5-10.9 | - |
| ***Major Elements*** | | | | | | | | | | | | | | | | | |
| Aluminium (%) | 7.1 | 6.02 - 8.06 | 4.6 | 0.5 – 10 | 7.4 | 0.7 – 12 | 7.3 | 6.2 - 8.2 | - | - | 1.1 | 0 - 13.4 | 1.0 | 0 - 13.1 | 1.0 | 0 - 12.8 | **8.2** |
| Iron (%) | 3.7 | 2.79 - 4.72 | 3.0 | 0.9 – 6 | 3.4 | 0.2 – 6 | 3.5 | 3.1 - 4.3 | - | - | 3.9 | 3.1 - 6.6 | 3.9 | 3.1 - 6.9 | 3.9 | 2.8 - 6.7 | **4.1** |
| Calcium (%) | 1.4 | 0.17 - 3.54 | 0.4 | 0.01 – 4 | 1.1 | 0.03 – 6 | 2.3 | 1.2 - 4.2 | - | - | 2.1 | 0.2 - 5.6 | 2.7 | 0.2 - 5.6 | 3.1 | 0.3 - 5.7 | **4.1** |
| Magnesium (%) | 1.8 | 0.44 - 2.71 | 0.7 | 0.01 – 2 | 1.6 | 0.01 – 4.5 | 1.7 | 1.3 - 2.2 | - | - | 1.8 | 1.2 - 3.2 | 2.0 | 1 - 2.9 | 1.7 | 1 - 2.9 | **2.3** |
| Sodium (%) | 0.8 | 0.08 - 1.57 | 0.1 | < 0.01 – 1.6 | 0.4 | <0.01 – 2.1 | 1.0 | 0.5 - 1.7 | - | - | 1.4 | 0.1 - 2.4 | 1.4 | 0.4 - 2.4 | 0.5 | 0 - 2.4 | **2.3** |
| Potassium (%) | **3.4** | 1.48 - 5.51 | 1.7 | 0.1 – 3.5 | **2.7** | 0.3 – 5.6 | 4.9 | 2.1 - 6.2 | - | - | 3.6 | 0.8 - 6.2 | 2.9 | 0.7 - 6.4 | 2.3 | 0.4 - 7.1 | **2.1** |
| ***Trace Elements*** | | | | | | | | | | | | | | | | | |
| Antimony | **2.4** | 1 - 7.07 | **24** | 1.0 – 118 | **6** | 0.02 – 50 | **12.8** | 0.7 - 51 | - | - | **1.5** | 0.1 - 7.3 | **2.5** | 0.1 - 6.8 | **2.1** | 0.1 - 10.6 | **0.2** |
| Arsenic | **30.1** | 6 - 99.6 | **94** | 15 – 540 | **26** | 1.2 – 78 | **58.4** | 19 - 164 | - | - | **19.6** | 2.8 - 68.6 | **11.8** | 1.6 - 63.9 | **24.7** | 2.7 - 68.3 | **1.5** |
| Barium | **546** | 90 - 710 | 209 | 20 - 720 | 347 | 34 – 980 | **796** | 520 - 981 | - | - | **586** | 290 - 1650 | **485** | 270 - 1580 | 402 | 40 - 1840 | **500** |
| Cadmium | **0.16** | 0.04 - 0.4 | **0.25** | 0.03 – 4 | 0.1 | <0.02 – 0.6 | **0.69** | 0.1 - 3 | - | - | 0.1 | 0 - 0.4 | 0.1 | 0 - 0.5 | 0.1 | <0.02 - 0.7 | **0.1** |
| Cobalt | 16.5 | 12.3 - 24 | 15 | 2 – 32 | 21 | 0.8 – 57 | 19.1 | 12.1 - 29 | - | - | 19 | 12.2 - 89.6 | 20 | 12 - 91.3 | 18 | 11.1 - 86.7 | **20** |
| Chromium | **150** | 50 - 281 | **163** | 44 – 392 | **146** | 81 – 277 | 75.1 | 51 - 125 | - | - | 75.8 | 13 - 249 | **128.2** | 49 - 235 | 78.0 | 18 - 146 | **100** |
| Copper[3] | 24.9 | 12.6 - 61.8 | 39 | 11 – 380 | 29 | 8 – 150 | 24.7 | 2 - 88 | - | - | **392** | 8.6 - 7820 | **244** | 13.2 - 7430 | **428** | 5.4 - 7400 | **50** |
| Lead | **23.2** | 8.2 - 132 | **41** | 4 – 1070 | 10 | 1 – 28 | **23.3** | 8 - 103 | - | - | 14 | 4.8 - 56.2 | 11 | 5.9 - 51.8 | 14 | 5.7 - 50.6 | **14** |
| Mercury | **0.15** | 0.01 - 0.9 | **0.75** | 0.06 – 4.5 | **0.4** | 0.04 – 2 | 0.05 | 0.025 - 0.099 | - | - | **0.1** | <0.005 - 0.5 | **0.3** | <0.005 - 1.1 | **0.2** | <0.005 - 3.3 | **0.05** |
| Manganese | 915 | 94 - 1450 | 294 | 26 – 1540 | **985** | 90 – 3400 | **1070** | 638 - 2731 | - | - | **1030** | 595 - 2370 | 947 | 421 - 1840 | 742 | 161 - 1700 | **950** |
| Molybdenum | **1.6** | 0.6 - 4.6 | **4** | 1 – 12 | **1.8** | 0.3 – 6 | **1.9** | 0.6 - 6 | - | - | **3.1** | 0.2 - 36.8 | **2.1** | 0.2 - 35.6 | **3.1** | 0.5 - 37.6 | **1.5** |
| Nickel | 31.8 | 13.4 - 66 | 14 | 6 – 27 | 57 | 7 – 159 | 25.9 | 14 - 39 | - | - | 34.3 | 6.4 - 122.5 | 48.7 | 18.6 - 100 | 33.2 | 5.9 - 87.5 | **80** |
| Selenium | **2.0** | 1 - 6 | **2.5** | < 1 – 15 | **1.1** | 0.1 – 4 | **6.37** | 2 - 36 | - | - | **2.0** | 1 - 6 | **1.5** | <1 - 7 | **1.4** | <1 - 6 | **0.05** |
| Vanadium | 113 | 84 - 146 | 86 | 5 – 180 | 104 | 3 – 206 | **194** | 181 - 205 | - | - | 111 | 90 - 179 | 126 | 78 - 191 | 102 | 59 - 183 | **160** |
| Zinc | **92.6** | 44 - 227 | **96** | 7 – 1670 | 63 | <2 – 152 | **82.6** | 31 - 201 | - | - | **75.2** | 52 - 199 | 72.2 | 48 - 239 | 70.6 | 16 - 221 | **75** |

Notes:
Units are in mg/kg unless stated otherwise
* Number of data points insufficient to generate meaningful value.
Arithmitic mean (and lower bound of Range) assumes values reported at analytical detection limit are equal to analytical detection limit.
1. Bowen, HJM, 1979,Environmental Geochemistry of the Elements.
2. Geochemical Abundance Indices - The Gardguide version 0.7 - National Institute of Acid Prevention
3. Elevated mean Cu with respect to previous overburden is driven by outliers
**Bold** Concentrations exceed the mean value for the earths crust.

## Table 2: Existing TSF Seepage Water Quality

| | TSF1A (Actual) [2] | TSF2 (Actual) [1] |
|---|---:|---:|
| pH | 6.3 | 6.4 |
| $SO_4$ | 492 | 97 |
| Al | 0.005 | 0.01 |
| Fe | 21 | 5 |
| Ca | 51 | 21 |
| Mg | 27 | 9.1 |
| Na | 154 | 73 |
| K | 16 | 8 |
| Sb | 0.0002 | 0.0002 |
| As | 0.002 | 0.001 |
| Ba | 0.05 | 0.14 |
| Cd | 0.0001 | 0.00005 |
| Co | 0.17 | 0.11 |
| Cr | 0.001 | 0.001 |
| Cu | 0.002 | 0.002 |
| Pb | 0.0001 | 0.0001 |
| Hg | 0.0001 | 0.0001 |
| Mn | 8.7 | 3.8 |
| Ni | 0.014 | 0.005 |
| Se | 0.004 | < 0.001 |
| Zn | 0.03 | 0.004 |

All concentrations reported in mg/L (where actual data was below the method detection limit, the detected limit has been taken as the recorded concentration).

[1] Mean Underdrainage Data (U1-U4), 2014 to July 2017

[2] Mean Underdrainage Data (TU), 2014 to August 2017

**Table 3: Limestone Amendment Requirements – Short Term Exposure**

| Item | Value |
|---|---|
| NAPP (95th percent UCL) | 103 kg $H_2SO_4$/tonne |
| Adopted Sulphate Generation Rate | 0.06 kg $SO_4$/tonne/day |
| Limestone Dosing Requirement (for 200 day lag) | 12 kg $CaCO_3$/tonne overburden |
| Limestone Amendment Rate | 1.2 % |

**Table 4: Existing and Modelled Groundwater Chemistry**

| Input | Existing Groundwater | Porewater of backfilled material | Predicted Groundwater Quality | Predicted Groundwater Quality |
|---|---|---|---|---|
| | | | Long Term - Anaerobic | Interim - With and without adsorption on Secondary Oxide Hydroxides |
| Source | Shaft No.7[#] | Raw Column Data[#] | 70 - 90 % Groundwater | 70 - 90 % Groundwater |
| pH | 6.5 | 2.5 | 5.2 - 7.5 | 5.2 - 7.3 |
| $SO_4$ | 128 | 1453 | < 1230 | < 1210 |
| Ca | 370 | 314 | 380 - 390 | 240 - 390 |
| Mg | 140 | 45 | < 90 | < 80 |
| Na | 46 | 5 | < 42 | < 42 |
| K | 14 | 6 | 8 - 9 | 8 - 9 |
| Fe | 0.4 | 1416 | 20 - 40 | 20 - 60 |
| As | 0.01 | 0.006 | < 0.013 | < 0.013 |
| Cd | 0.0002 | 0.02 | < 0.003 | < 0.013 |
| Cr | 0.0002 | 0.01 | < 0.003 | < 0.005 |
| Cu | 0.001 | 1.4 | < 0.3 | < 0.4 |
| Pb | 0.0002 | 0.01 | < 0.002 | < 0.003 |
| Ni | 0.03 | 1.4 | < 0.3 | < 0.42 |
| Zn | 0.1 | 1.7 | < 0.4 | < 0.6 |
| Mn | 14 | 2 | < 10 | 8 - 10 |
| Hg | 0.00008 | < 0.00008 | < 0.00008 | < 0.00008 |
| Sb | 0.001 | 0.001 | < 0.0001 | < 0.0002 |
| Se | 0.001 | 0.02 | < 0.005 | < 0.008 |
| Co | 0.01 | 2 | < 0.4 | < 0.6 |

* All concentrations mg/L, pH = pH Units

# Based on mean recorded concentrations

**Table 5: Short term lake water quality modelling results**

| | Filling - Summer | Filling - Winter | Receiving Water Quality Standards** |
|---|---|---|---|
| | Scenario A | Scenario B | Hardness |
| | + Alkalinity in River Water | | 100 mg/L $CaCO_3$ |
| pH | 6.1 | 7.3 | 6.5 - 9.0 |
| Al | 0.036 | 0.001 | |
| As | 0.004 | 0.004 | 0.19 |
| Ca | 55 | 57 | |
| Cd | 0.0002 | 0.0002 | 0.001 |
| Co | 0.021 | 0.017 | |
| Cr[##] | 0.010 | 0.009 | 0.01 |
| Cu | 0.016 | 0.013 | 0.011 |
| Fe | 0.006 | 0.0003 | 1 |
| Hg[#] | <0.0001 | <0.0001 | 0.000012 |
| K | 0.4 | 0.8 | |
| Mg | 5.9 | 5.4 | |
| Mn | 0.50 | 0.45 | 2 |
| N | 0.454 | 0.464 | |
| Na | 48 | 41 | |
| Ni | 0.044 | 0.036 | 0.16 |
| P | 0.077 | 0.067 | |
| Pb | 0.0001 | 0.0001 | 0.0025 |
| S | 154 | 131 | |
| Sb | <0.001 | <0.001 | |
| Se | 0.001 | 0.001 | 0.02 |
| Si | 8.8 | 9.0 | |
| Zn | 0.038 | 0.032 | 0.1 |
| TDS (Calculated) | 266 | 238 | |
| Hardness (mg/L CaCO3) | 162 | 164 | |

*All results reported in mg/L except pH (pH units)

**The receiving water quality standards are hardness dependent and allow for an appropriate dilution following discharge. For purposes of comparison (as the pit lake will not discharge during the filling period), the standards given assume a hardness of 100 mg/L and are provided here as reference only.

[#] Detection limit of raw data is higher than receiving water quality standard

[##] Modelled concentrations are based on Cr(III) and Cr(VI). Receiving water standard is based on toxic form only (Cr(VI).

**Table 6: Long term pit lake water quality modelling results (discharge)**

| | Discharge – Year 0 | Discharge – Year 5 | Discharge – Year 10 | Discharge – Year 15 | Discharge – Year 5 | Discharge – Year 10 | Discharge – Year 15 | Discharge – Year 15 | Mangatoetoe Receiving Water Quality Standards** |
|---|---|---|---|---|---|---|---|---|---|
| | Scenario C | Scenario D (1) | Scenario E(1) | Scenario F(1) | Scenario D (2) | Scenario E(2) | Scenario F(2) | Scenario F(3) | Hardness |
| | Alkalinity in River Water | Alkalinity in River Water + Acidity Reduction in Fresh PAF | | | Alkalinity in River Water + Pit Lake Amendment | | | Alkalinity in River Water Pit + Lake Amendment + HFO Formation | 100 mg/L $CaCO_3$ |
| pH | 7.6 | 7.8 | 7.7 | 7.5 | 8.4 | 8.3 | 8.2 | 7.0 | 6.5 - 9.0 |
| Al | 0.0002 | 0.003 | 0.003 | 0.002 | 0.011 | 0.010 | 0.008 | 0.075 | |
| As | 0.003 | 0.001 | 0.001 | 0.001 | 0.004 | 0.005 | 0.005 | <0.001 | 0.19 |
| Ca | 53 | 48 | 43 | 39 | 87 | 82 | 77 | 37 | |
| Cd | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 0.001 |
| Cl | 80 | 69 | 60 | 52 | 69 | 60 | 52 | 52 | |
| Co | 0.007 | 0.012 | 0.014 | 0.016 | 0.011 | 0.012 | 0.014 | <0.001 | |
| Cr$^{\#\#}$ | 0.006 | 0.003 | 0.004 | 0.004 | 0.009 | 0.010 | 0.012 | <0.001 | 0.01 |
| Cu | 0.007 | 0.009 | 0.010 | 0.011 | 0.010 | 0.011 | 0.013 | <0.001 | 0.011 |
| Fe | 0.0002 | 0.0001 | 0.0002 | 0.0002 | <0.0001 | <0.0001 | <0.0001 | 0.057 | 1 |
| Hg | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.000001 | 0.000012 |
| K | 1.5 | 1.8 | 1.7 | 1.5 | 1.8 | 1.7 | 1.6 | 1.6 | |
| Mg | 3.1 | 4.3 | 4.6 | 5.0 | 3.8 | 3.9 | 4.2 | 4.2 | |

|  | **Discharge – Year 0** | **Discharge – Year 5** | **Discharge – Year 10** | **Discharge – Year 15** | **Discharge – Year 5** | **Discharge – Year 10** | **Discharge – Year 15** | **Discharge – Year 15** | **Mangatoetoe Receiving Water Quality Standards**** |
|---|---|---|---|---|---|---|---|---|---|
|  | **Scenario C** | **Scenario D (1)** | **Scenario E(1)** | **Scenario F(1)** | **Scenario D (2)** | **Scenario E(2)** | **Scenario F(2)** | **Scenario F(3)** | **Hardness** |
| Mn | 0.13 | 0.42 | 0.48 | 0.56 | 0.20 | 0.21 | 0.23 | 0.23 | 2 |
| N | 0.48 | 0.41 | 0.36 | 0.32 | 0.42 | 0.37 | 0.33 | 0.33 |  |
| Na | 18 | 38 | 42 | 45 | 21 | 21 | 20 | 20 |  |
| Ni | 0.015 | 0.027 | 0.031 | 0.034 | 0.022 | 0.025 | 0.028 | <0.001 | 0.16 |
| P | 0.061 | 0.027 | 0.028 | 0.029 | 0.085 | 0.102 | 0.118 | <0.001 |  |
| Pb | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 0.0025 |
| S | 56 | 98 | 112 | 127 | 88 | 99 | 112 | 86 |  |
| Sb | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |  |
| Se | <0.001 | .<0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.02 |
| Si | 8.9 | 7.8 | 7.0 | 6.1 | 7.8 | 6.9 | 6.1 | 6.1 |  |
| Zn | 0.018 | 0.017 | 0.020 | 0.022 | 0.028 | 0.033 | 0.038 | <0.001 | 0.1 |
| TDS (Calculated) | 135 | 195 | 207 | 220 | 216 | 219 | 225 | 153 |  |
| Hardness (mg/L CaCO3) | 145 | 138 | 126 | 117 | 233 | 220 | 210 | 119 |  |

*All results reported in mg/L except pH (pH units)

**The receiving water quality standards are hardness dependant and allow for an appropriate dilution following discharge. The standards given assume a hardness of 100 mg/L and are provided here as reference only.

[#]Detection limit of raw data is higher than receiving water quality standard

[##]Modelled concentrations are based on Cr(III) and Cr(VI). Receiving water standard is based on toxic form only (Cr(V

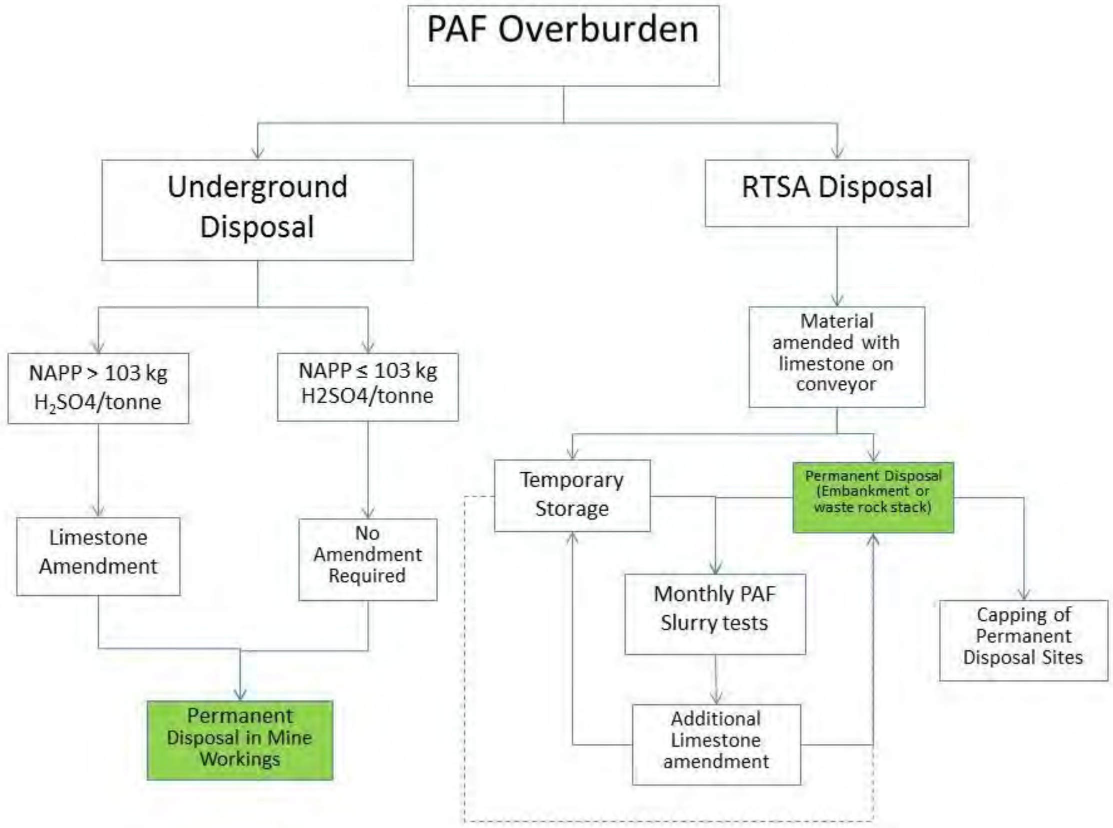

**Figure 1: Conceptualised Overburden Management**