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APPENDIX E

Water Quality Letter

24 March 2020

Debbie Clarke
Oceana Gold (New Zealand)

Our ref: 12502848

Your ref:

Dear Debbie Clarke,

Deepdell North Stage III Project - Receiving Water Quality Analysis
Response to Otago Regional Council RFI

1 Introduction

This letter responds to the Section 92 Request for Information (RFI) issued to Oceana Gold (New Zealand) Limited (OGLNZ) on Surface Water aspects of the proposed Deepdell North Stage III Project. GHD Limited (GHD) prepared a report on water management that was submitted in support of resource consent applications. The following sections respond to RFI's 16, 17 and part of 20.

Note that the question initiating each response is included in the italic blue text below.

2 RFI 16 – Model hydrological calibration

16. Model hydrological calibration:

(a) Provide a presentation of the 6.5 year hydrological calibration period (graphically)

The full model calibration is graphically presented in Figure 2-1 following. The blank sections in the gauge data indicate where the gauge was not in service.

Note that the calibration of the model was done over the full period, Figure A-4 presented in the report was shown as an example. The period for graphical representation shown was selected based on it being the most recent and including a more continuous period of gauge data.

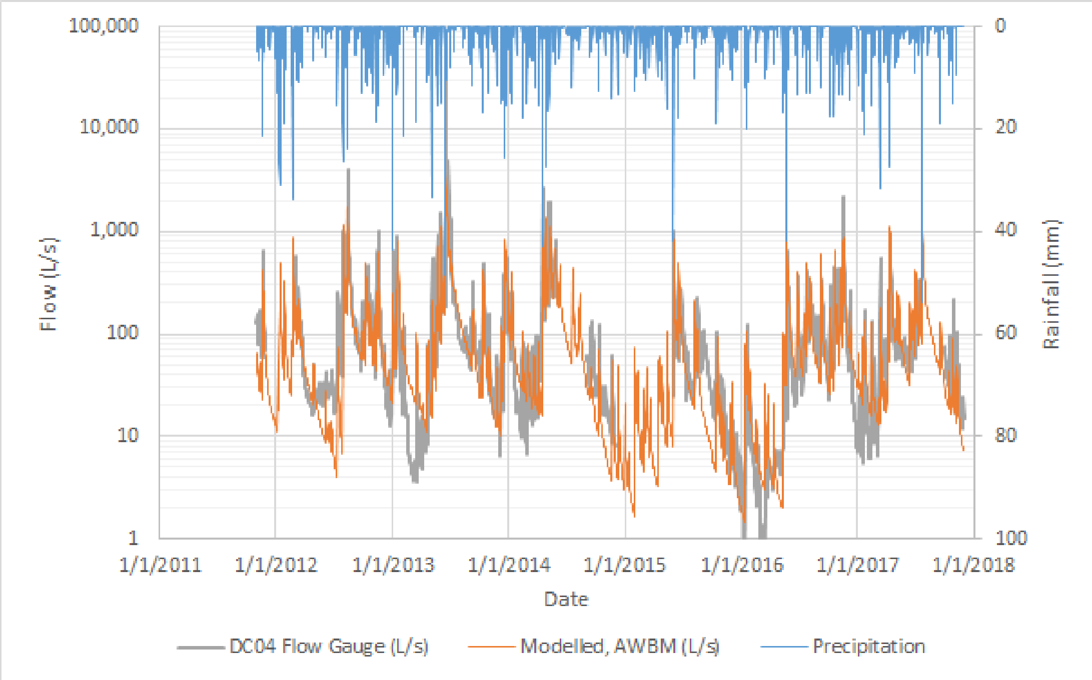

Figure 2-1 AWBM calibration

(b) Provide analysis and tabulation of model performance by comparing simulated flows to observed based on Moriasi et al. 2007, using hydrological parameters NSE and PBIAS.

Based on Moriasi et al. 2007 the following hydrological parameters are calculated for the streamflow model calibration.

Flow Regimes[1]	NSE (-)	PBIAS (%)	Modelled Annual Volume (Mm^3/y)	Observed Annual Volume (Mm^3/y)	Count (days)
Full Record	0.23	31.8	84.0	123.1	1833
Flow < 1000 L/s	0.70	8.5	67.4	73.6	1806
Flow < 100 L/s	0.95	12.2	14.4	16.4	1341

[1] Flow regime determined from mean of observed and calculated flow to balance low flow periods

The classification of the overall model performance would be 'not satisfactory' based on Moriasi et al. 2007. However, calibration of the model was not concerned with the high flow events where there is significant dilution available from un-affected catchments.

When calculating the hydrological parameters ignoring flood flow events (~2% of high flows), the Nash-Sutcliffe efficiency (NSE) is 0.7 with a percent bias (PBIAS) of 8.5%. This suggests that the model performance can be evaluated as 'good'. Moreover the positive PBIAS indicates that the model under predicts the runoff and this is conservative given the models purpose. For flows less than 100 L/s the NSE evaluation suggests that the model is 'very good' and PBIAS evaluation suggests it is 'satisfactory', though this is tending more conservative.

It is noted that the model over predicts flows for the lowest 1.7% of flows, however this was considered acceptable as in these dry periods the stream intermittently flows above and below ground, so there is potential that dilution of the total load discharging from the mine site is conservatively under represented.

Further, during these dry periods the modelled high concentration seepage discharge rates are not reduced and the potential for contaminant mass to be lost to the ground is not included in the model.

(c) Provide a presentation of any calibration data for runoff or water levels within the existing mine site, to assess suitability of the water balance model for simulating disturbed site flows (and subsequently, predicting water quality loads).

Flows from disturbed areas have not been historically gauged. In absence of this data the rational method was applied for determining runoff and this is to represent the response to rainfall being more immediate in the smaller disturbed catchments.

Runoff coefficients from Golder Associates 2011 report (Golder Associates 2011. Macraes Phase III Project - Site wide surface water model. April 2011.) were applied for this purpose, and checked against our understanding of similar catchments.

Daily Rainfall (mm)	Run-off Coefficients	
	Impacted Areas	WRS Areas
0	0.05	0
10	0.2	0.05
50	0.4	0.15
90+	0.7	0.4

3 RFI 17 – Water quality modelling

17. Water quality modelling:

(a) Provide context on why the normal distribution was utilised versus a DWC/EMC approach, and how the 20% standard deviation applied to these distributions captures the range of observed concentrations from monitoring data.

DWC and EMC values could not be confidently defined for all water sources with the available data, hence the normal distribution approach was preferred.

At the key sampling locations, correlation between flow and concentration can be observed, with a typical trend of decreasing concentration with increase in flow. For example, DC07 and DC08 sulfate concentration compared with DC04 flow rates as shown in Figure 3-1. These sampling locations are fed by multiple affected and non-affected catchments so are not suitable for defining source concentrations, however, it does indicate that the lower flow regimes are critical for compliance and model development considered this.

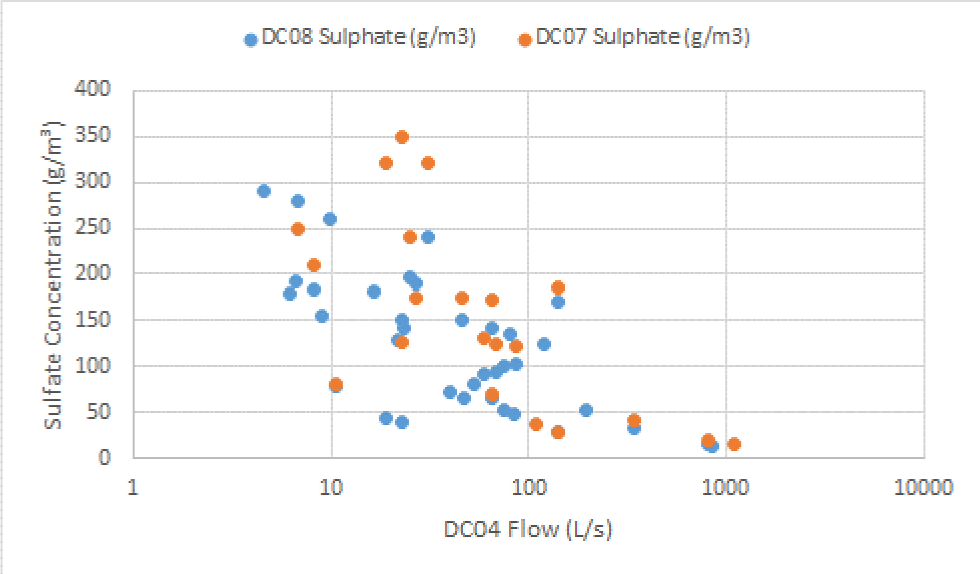

Figure 3-1 Sulfate concentrations with flow in Deepdell Creek

Water quality inputs are based on a normal distribution about a mean determined from available monitoring data. The distribution was defined with a standard deviation equivalent to 20% of the mean, a lower cutoff value of 0.7×mean and an upper of 1.3×mean (the authors note that these cutoff parameters were not shown in the technical report) as shown in Figure 3-2.

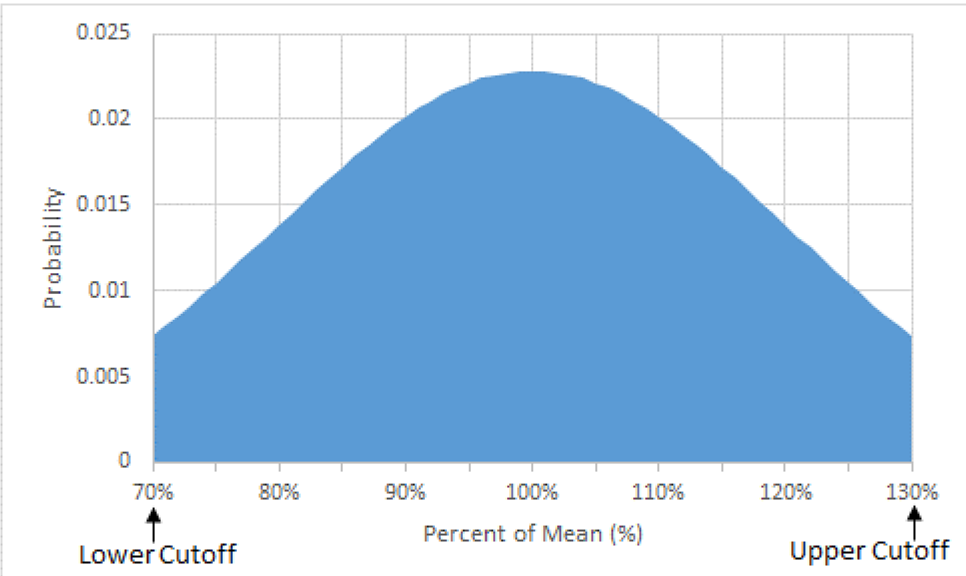

Figure 3-2 Applied water quality distribution at sources

Figure 3-3 to Figure 3-8 show a comparison between the modelled water quality range and recent water quality measurements for a number of water sources. The modelled range generally captures the measured data conservatively.

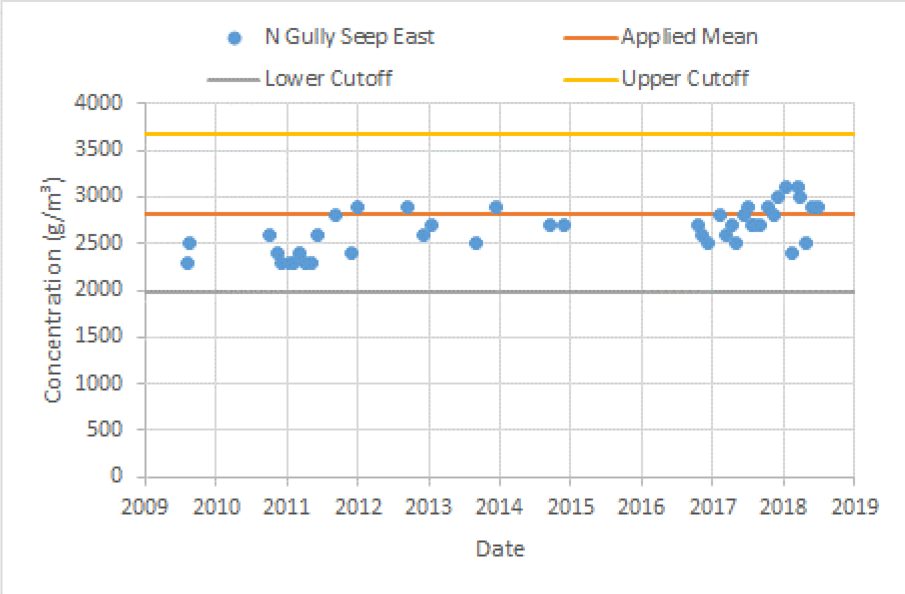

Figure 3-3 Northern Gully seepage Sulfate concentrations

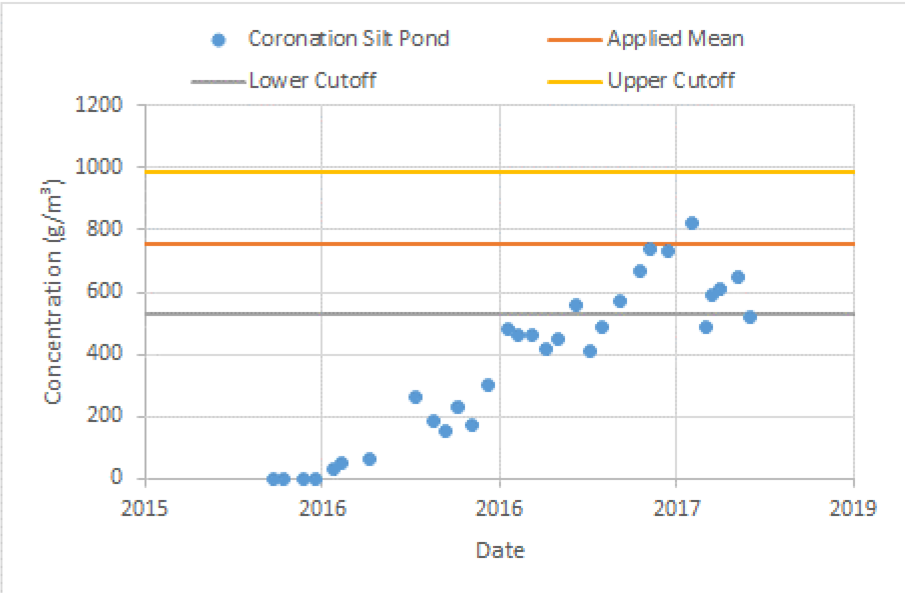

Figure 3-4 Coronation Silt Pond Sulfate concentrations

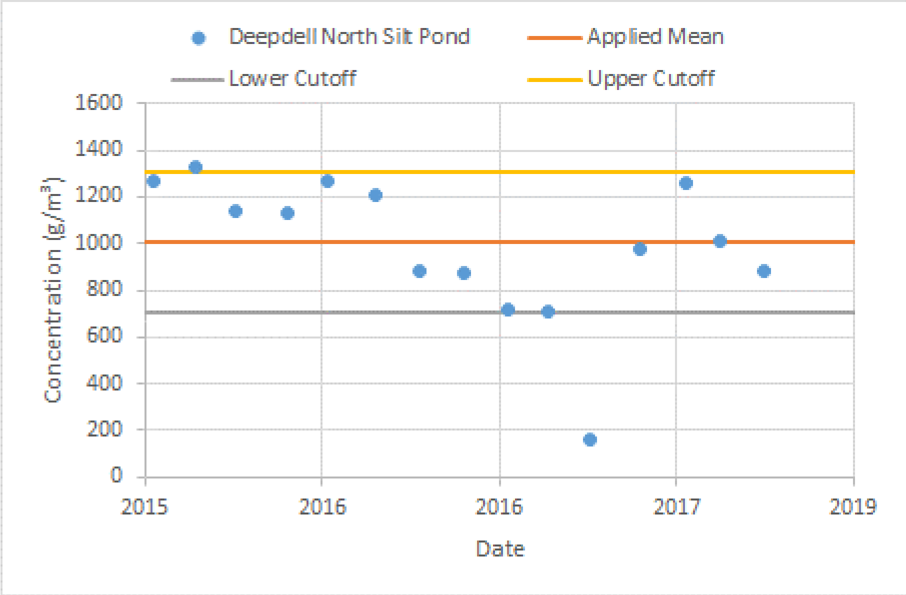

Figure 3-5 Deepdell North Silt Pond Sulfate concentrations

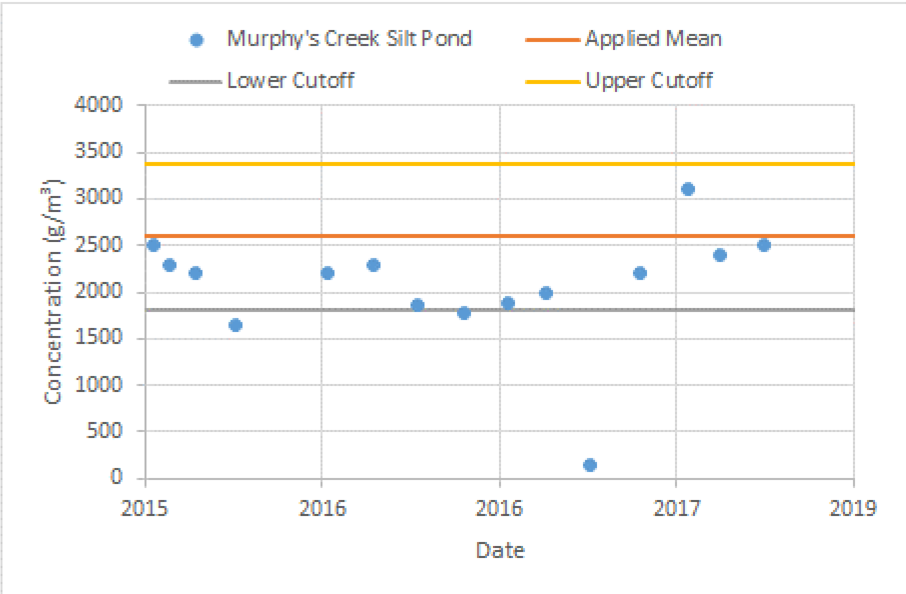

Figure 3-6 Murphys Creek Silt Pond sulfate concentrations

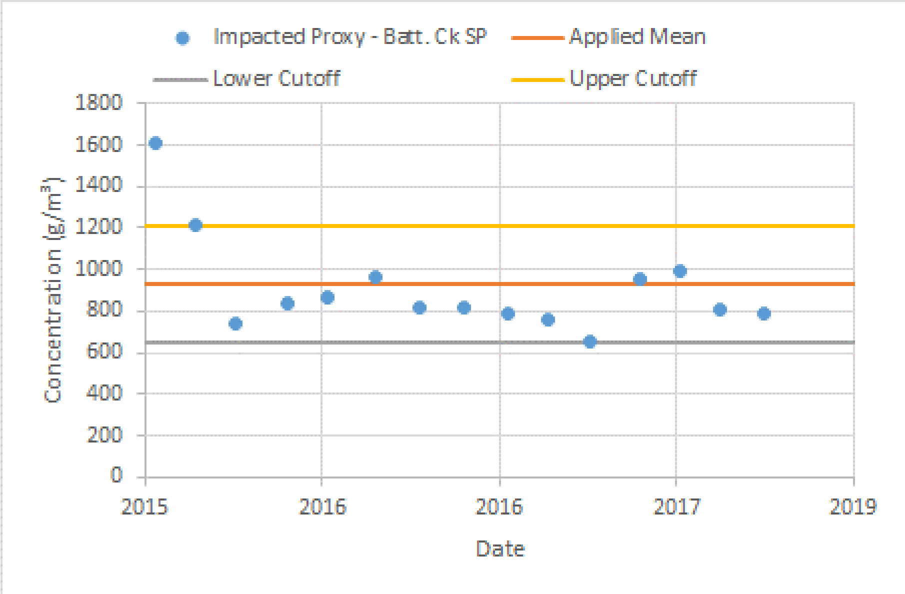

Figure 3-7 Battery Creek Silt Pond Sulfate concentrations (applied as proxy data for impacted catchments)

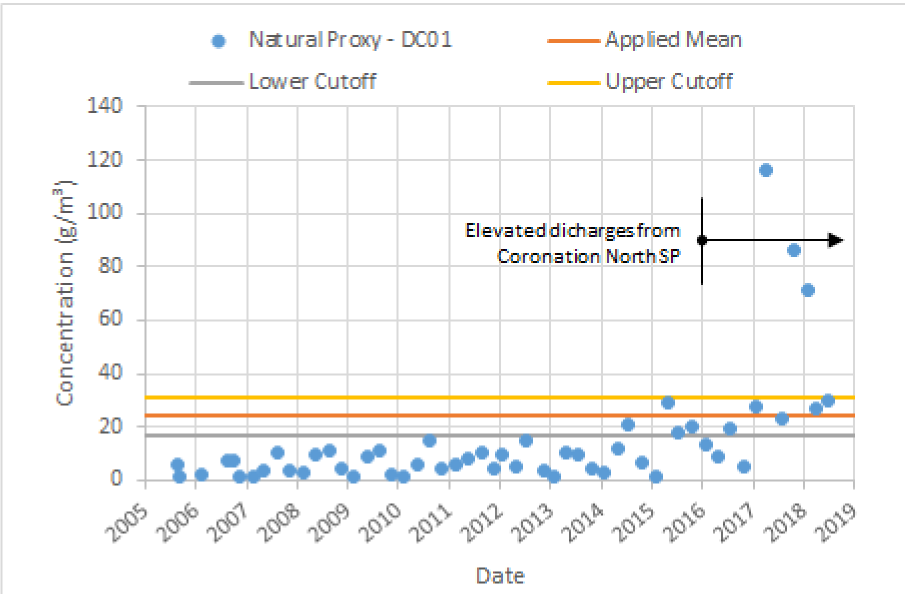

Figure 3-8 DC01 Sulfate concentrations (applied as proxy data for natural catchments)

(b) Describe how the Deepdell Creek and wider Shag River catchments outside of the mining domain were simulated for water quality. This may include describing any landuse mapping that was undertaken, or if 'natural' water quality modelling parameters were applied to any landuse outside of the mining footprint.

Land use mapping outside of the mine domain was not carried out and water quality was applied across these areas based on the assumed 'natural' water quality. Based on aerial imagery, both the Deepdell Creek and Shag River catchments are dominated by sheep and beef farming and alpine tussock area.

The natural water quality inputs are based on measurements taken at DC01, where there were minimal impacts from mining activities prior to works at Coronation WRS (Figure 3-8). Consideration was also given to observations at DC07 prior to 1995 where DC01 data was sparse for a given parameter (Figure 3-9). Further sense checks considered measured values within the Shag River to check the potential that mass loads from the upper Shag catchment is influencing the concentrations above what would be expected from the natural proxy data applied. Considering the sulfate example, natural proxy data applied a conservative mean value of 24 g/m³, such that the upper range of observed sulfate concentrations is captured within the normal distribution (Figure 3-8). Note that the high levels measured at DC01 since 2015 were disregarded in this analysis as these are shown to be caused by works at the Coronation WRS.

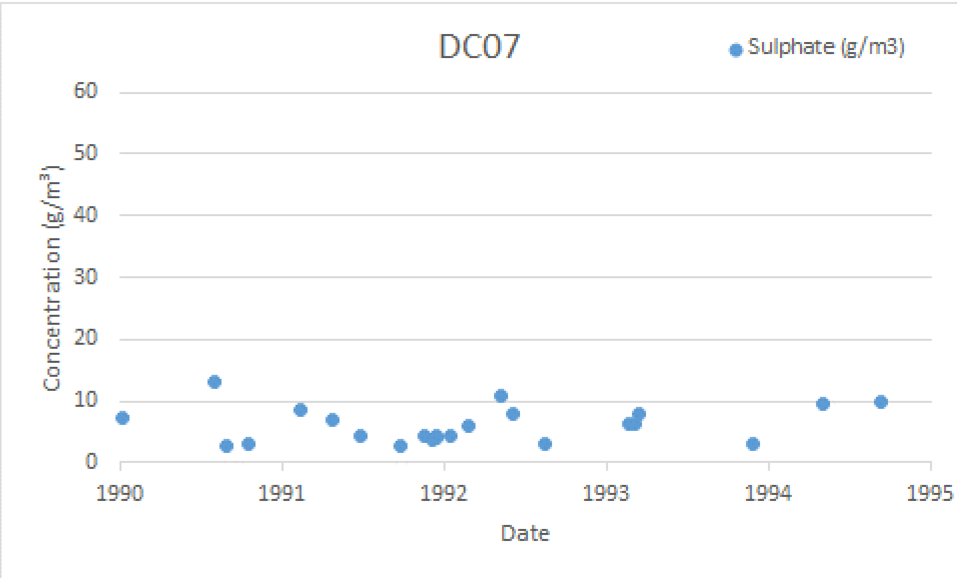

Figure 3-9 DC07 Sulfate concentrations (checked against proxy data for natural catchments)

Only four data points for Nitrate were available at DC01 prior to 2015, thus early measurements at DC07 (Figure 3-10) were applied as the baseline natural catchment inputs. The calculated mean of 0.034 g/m³ was elevated to 0.05 g/m³ such that the 95th percentile was appropriately captured within the modelled normal distribution.

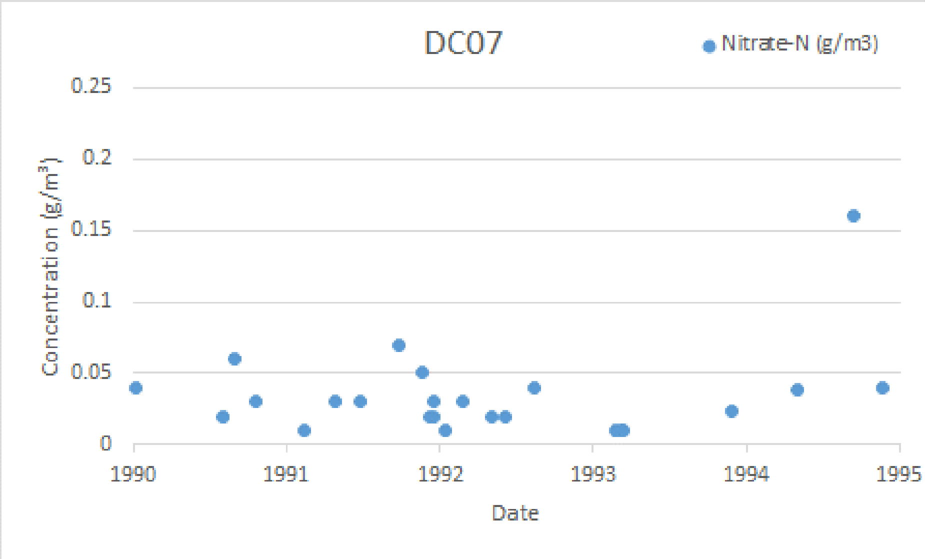

Figure 3-10 DC07 Nitrate concentrations (checked against proxy data for natural catchments)

(c) Describe (and present) how the baseline water quality model was calibrated for Deepdell Creek and Shag River based on the current state (including current mining operations) in order for scenarios of the Deepdell North Stage III project to be assessed.

The water quality model was validated by running the model based on existing mine state over the previous 3.5 years (2015-2018) and comparing model outputs with measured data. Where the comparison was found to be inadequate water quality inputs were adjusted to suit. The validation was run with actual measured rainfall and statistical water quality inputs

Figure 3-11 and Figure 3-12 present the comparison of measured and modelled sulfate levels at DC08 and Shag River at Loop Road sites respectively. Figure 3-13 and Figure 3-14 present the comparison of measured and modelled Nitrate levels at DC08 and Shag River at Loop Road sites respectively. In each case the model is shown to conservatively represent concentrations at the higher percentiles where exceedance of consent conditions could potentially occur.

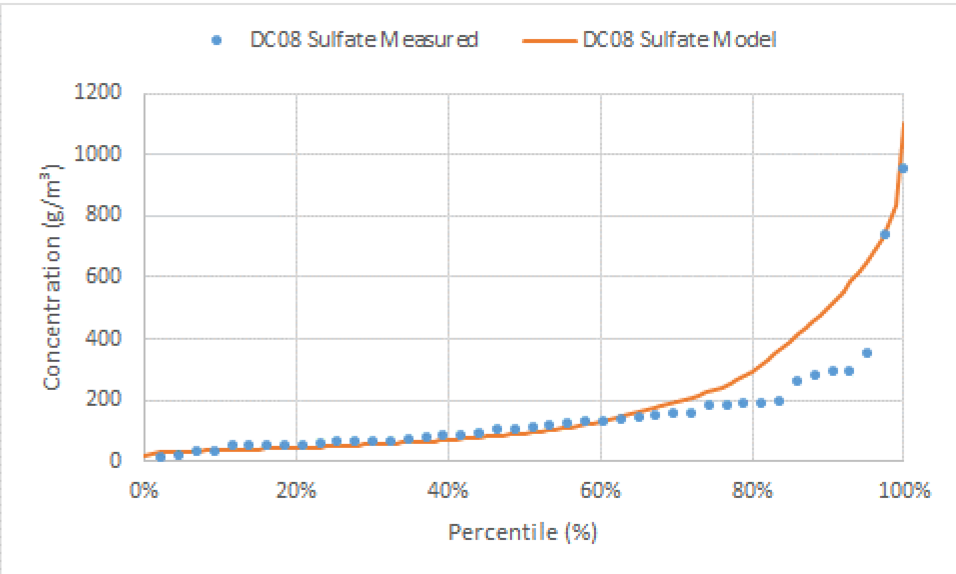

Figure 3-11 Comparison of measured and modelled Sulfate concentrations at DC08 for 2015-2018

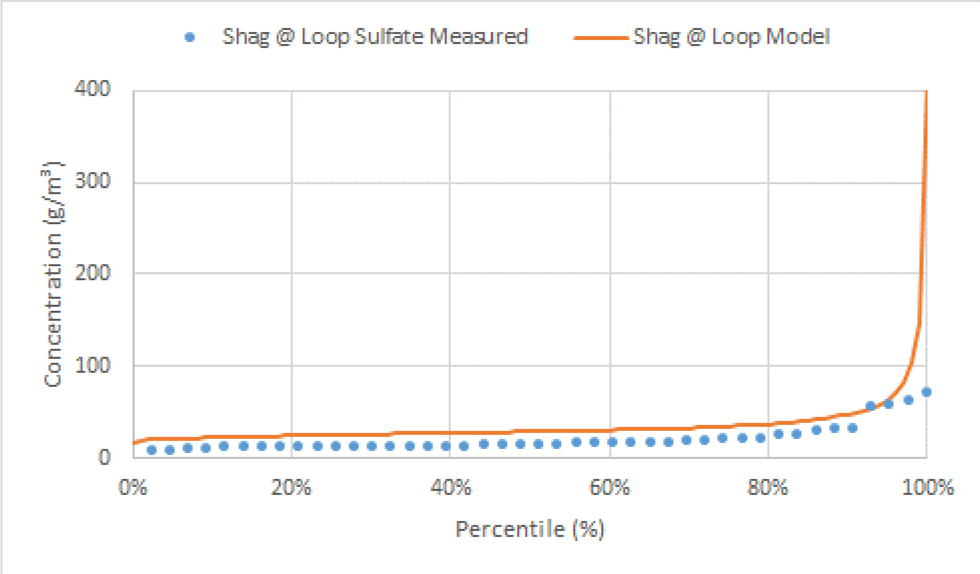

Figure 3-12 Comparison of measured and modelled Sulfate concentrations at Shag River at Loop Road for 2015-2018

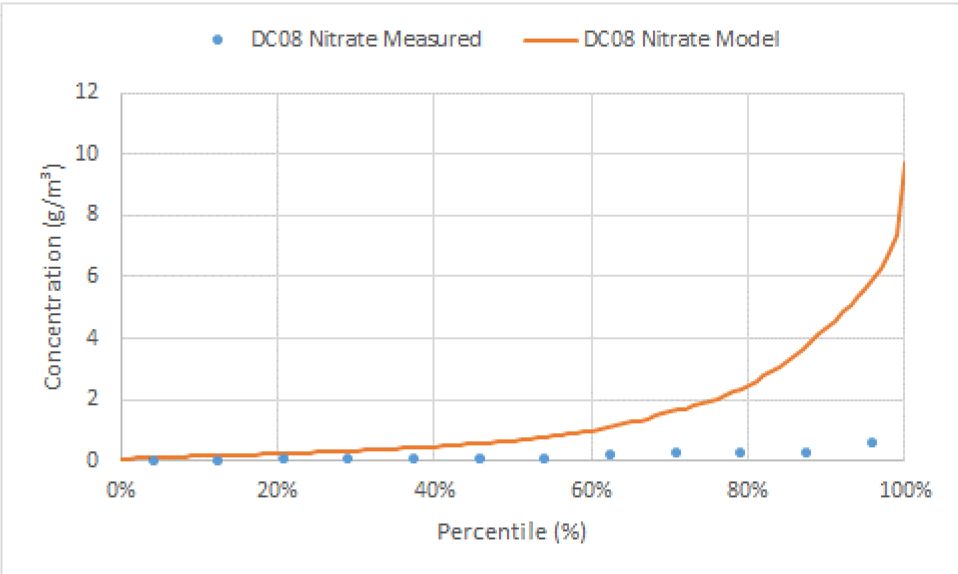

Figure 3-13 Comparison of measured and modelled Nitrate concentrations at DC08 for 2015-2018

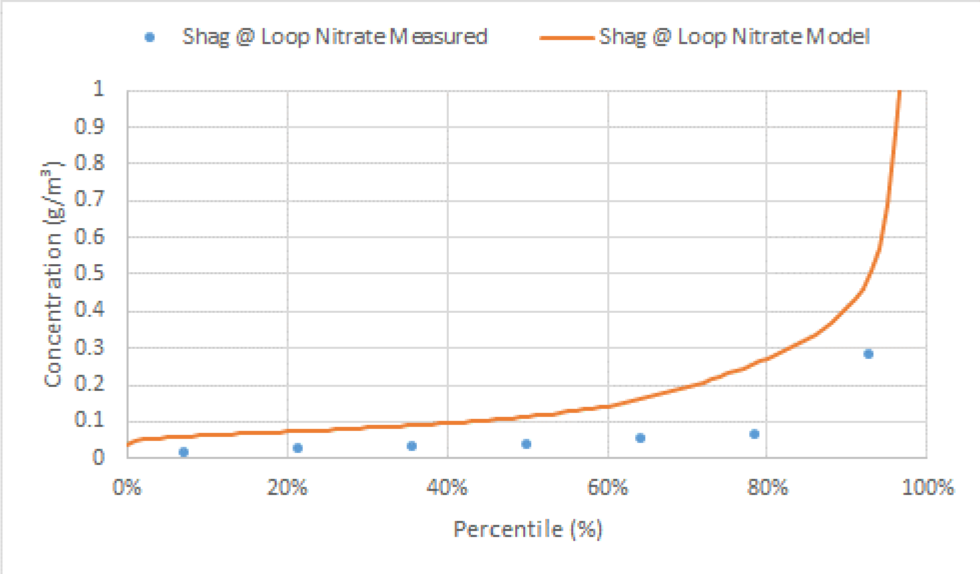

Figure 3-14 Comparison of measured and modelled Nitrate concentrations at Shag River at Loop Road for 2015-2018

4 RFI 20 – Highlay Creek water quality

Provide the likely contaminant concentrations in both Highlay Creek and its Western Tributary (location shown in appendix 1) and proposed water quality standards for these creeks that can be applied in consent conditions. For nutrients, these standards should be set to control plant growth rather than toxicity.

Contaminant concentrations within Highlay Creek and its Western Tributary were not modelled as a discrete point within the modelling completed for the initial water management report. A predictive analysis has been conducted to assess the water quality at three locations including, the Western Tributary and the existing monitoring points of HC01 and HC02, as shown in the following figure.

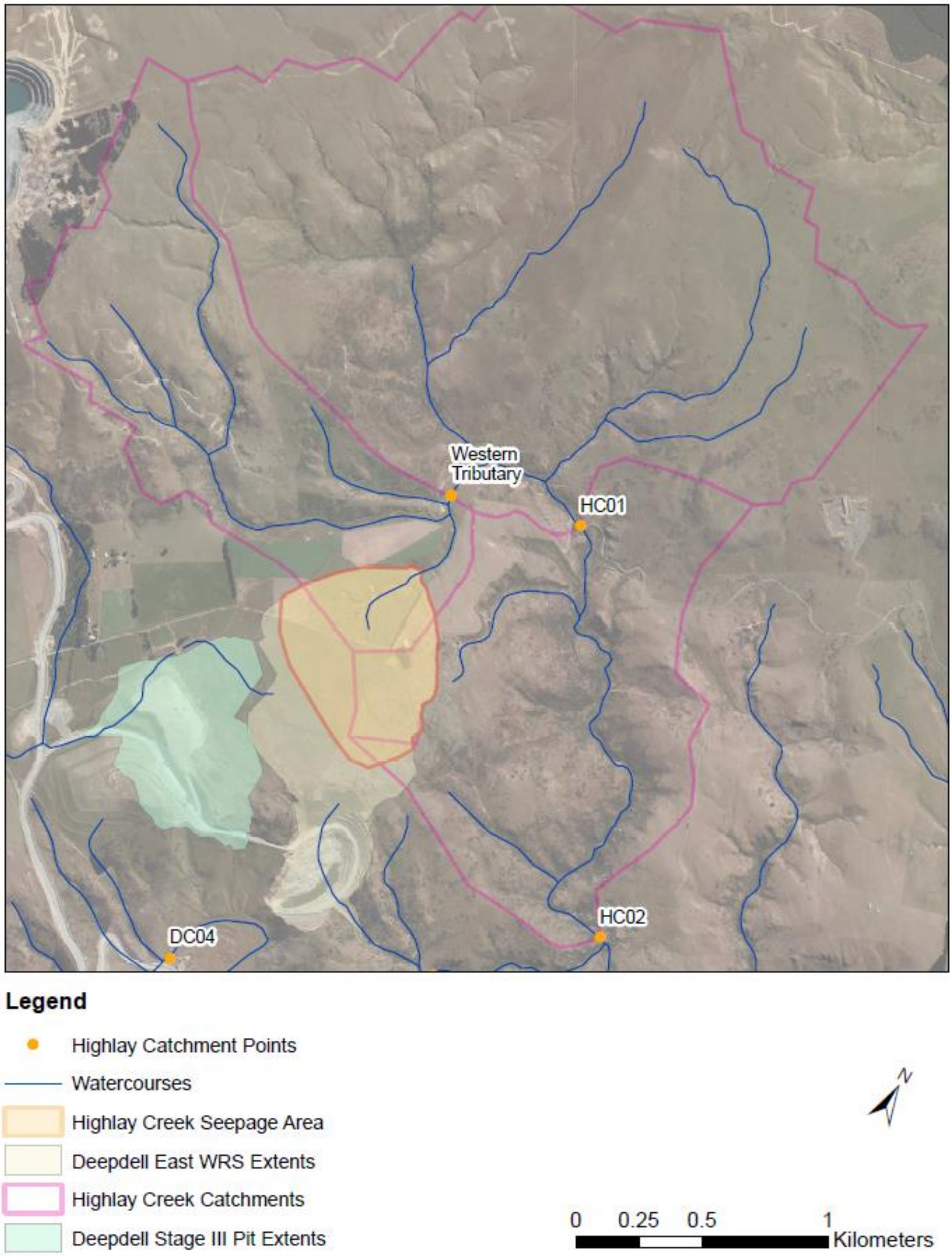

Figure 4-1 Highlay Creek catchment

A summary of the catchment areas is given in the following table

Catchment Description	Area (ha)
Highlay Creek (to below HC01)	631
Highlay Creek (to HC01)	559
Western Tributary	156
WRS seepage reporting to Highlay Creek	37.7
WRS runoff reporting to Highlay Creek	24.4

Analysis was carried out to assess the likely 50th Percentile and 95th percentile water quality values.

Water quality was assessed based on evidence showing concentrations within the receiving environment are generally the highest during low flow periods. Further, the limited data available suggests that the natural catchment flow rates respond quicker to periods of low rainfall than the WRS seepage flow rates.

Based on this, the 95th percentile water quality assessment applies the mean mass loading rate from seepage and low dilution flow from the natural catchment with the following inputs:

- 5th percentile (low) flows for the natural catchment,
- 95th percentile (high) water quality measurements for the natural catchment,
- Mean seepage rates from the Deepdell East WRS, and
- Mean seepage water quality from the Deepdell East WRS.

A further assessment of median water quality is based upon:

- 50th percentile flows for the natural catchment,
- 50th percentile water quality measurements for the natural catchment,
- Mean seepage rates from the Deepdell East WRS, and
- Mean seepage water quality from the Deepdell East WRS.

Analysis of the existing ground topography indicates that the majority of seepage reporting to Highlay Creek will flow through the proposed northern silt pond and this is represented in the modelling. It is noted that Highlay Creek can drop to very low flows and the Western Tributary is ephemeral in nature such that visible base flow can be minimal in dry periods. As a result model estimates and ongoing monitoring information will be more reliable for locations HC01 and HC02 than the Western Tributary.

Based on water balance and mass load analysis, the following table summarises the median and 95th percentile water quality estimates for three locations (Western Tributary, HC01, HC02) in the Highlay Creek catchment. The water quality estimates assume that the WRS has been developed to the full extent proposed in the project description.

Parameter	HC01 Water Quality Monitoring (May 2018 - Sept 2019)[1]		Deepdell East WRS Seepage	Point 1, Western Tributary		Point 2, HC01		Point 3, HC02	
	Median	95th %	Mean	Median	95th %	Median	95th %	Median	95th %
Ammonia	0.01	0.01	0.02	0.012	0.016	0.011	0.013	0.010	0.012
Arsenic	0.001	0.002	0.01	0.003	0.007	0.001	0.004	0.001	0.003
Copper	0.0008	0.0013	0.0013	0.001	0.001	0.001	0.001	0.001	0.001
Hardness	33	67	1030	206	634	88	327	76	279
Iron	0.12	0.26	0.1	0.12	0.17	0.12	0.22	0.12	0.23
Lead	0.0001	0.0001	0.0003	0.0001	0.0002	0.0001	0.0002	0.0001	0.0001
Nitrate	0.09	0.41	14	2.5	8.4	0.9	4.1	0.7	3.4
Sulphate	7	22	522	96	316	35	157	29	132
Zinc	0.001	0.0025	0.001	0.001	0.002	0.001	0.002	0.001	0.002

Note: Values for some parameters may be elevated over actuals where lower detection limits are recorded.

[1.] Water quality from the natural catchments is based on recent measurements taken at HC01 between May 2018 and September 2019.

Predictive modelling of dissolved reactive phosphorous has not been incorporated into the water balance and mass load modelling as there is insufficient historical monitoring of this parameter to model statistically. It is recognised that the availability of dissolved reactive phosphorous has an effect on plant growth in the streams.

The existing monitoring location of HC02 could appropriately serve as a monitoring point for the Highlay Creek catchment to provide water quality data for Highlay before mixing with the Deepdell catchment downstream. This captures all discharges reporting to the Highlay Creek from the proposed developments. The HC01 point which has a more developed monitoring record captures the majority of the seepage and partial WRS surface runoff, however excludes discharge through the silt pond on the Eastern side of the proposed WRS reporting to the lower Highlay catchment.

Sincerely
GHD Limited

Jeff Tuck
Water Engineer

Nick Eldred
Project Director