Date:	**11 January 2019**
Golder Project No.:	**1893614/3000**
Information Request No.:	**EMAB-14**
Revision No.:	**Rev. 0**
Reviewer:	
Topic:	**Model Calibration**
Responded By:	

Comment:

The User Manual (Cole and Scott 2015) states “Results will be suspect at best and will not withstand scrutiny at worst if the model is applied with insufficient and/or inadequate calibration data.” As noted by Golder in the modelling report, “because the pit lake is not yet constructed, model calibration is not possible”. In lieu of calibration data for the pit lake, Golder used data from other regional modelling studies. The most recent of the studies referred to was Vandenberg et al. 2015. It is noteworthy that the authors of this study note that “the calibration was considered to be approximate because the true values of a large proportion of the measured data were not known. All of these inputs and assumptions carry inherent variability and uncertainty, which impose and propagate uncertainty on model predictions.” Although we have a useful tool, it is clear that calibration is essential for reliability of the predictions. Given the caution expressed by both the Users Manual and Vandenberg et al. 2015 regarding model calibration, one needs to treat the model results with a bit of skepticism and adopt a cautious approach.

Recommendation:

Diavik should complete sensitivity analyses for a range of potential inputs to the model (e.g. meteorological conditions, lake temperature, porewater quality, dissolved oxygen content, etc.).

Response:

A sensitivity analysis was completed to assess the sensitivity of the hydrodynamic model results to several variables, as suggested in this IR and others. The sensitivity scenarios were performed for the A418-Development Case. A single model scenario upon which to base all others is a necessary limitation to the sensitivity analysis because the number of simulations rises exponentially when multiple pits, development cases and other multi-variable factors are added to the analysis.

A sensitivity analysis was completed by changing one variable per simulation, which could be a coefficient or time series of input data, keeping all other model inputs fixed, and re-running the Development Scenario. The difference in results indicate the effect or ‘sensitivity’ of model results to that single input. This approach can provide valuable information when specific input data are unavailable, certain aspects of the model or calibration are uncertain, or some future condition cannot be defensibly chosen, versus another value, to apply to future conditions. The sensitivity analysis can answer the question of *what if some other input turns out to be real*? The limitation of this approach is that it oversimplifies the problem because few, if any, variables are truly independent of all other variables (Vandenberg 2017). A further limitation to the approach is that unrealistic values and scenarios can be selected to test model responses or where the true range of inputs is not known. Therefore, results of sensitivity analyses should be interpreted within the scope of understanding model response, and not as realistic outcomes that could have implications to the environment or humans.

The details of each scenario are outlined below and summarized in Table 1 (In attachment). The results of each scenario are presented as Table 2 in the attachment and as time series plots and time-concentration-depth contours in the attachment. The Development Case figures are provided for comparison against results.

A418 – Development Case Sensitivities

Sensitivity 1

Two runs were completed to test the sensitivity of the model to the temperature of PK. For these models, the original temperature of PK of 5°C was changed to 7°C and 3°C for Sensitivities 1-a and 1-b, respectively.

Scenario 2

This run was completed to test the sensitivity of the model to the inflow of local runoff. Since the original model accounted for local runoff to the pit, this inflow was removed.

Scenario 3

Two runs were completed to test the sensitivity of the model to the Wind Sheltering Coefficient (WSC) model input parameter. For these models, the original WSC of 0.8 was changed to 0.7 and 0.9 for Sensitivities 3-a and 3-b, respectively.

Scenario 4

Four model runs were completed to test the sensitivity of the model to extreme wind events. The original model makes use of a 19-year time series (1999-2017) of wind speed that repeats throughout the simulation. To account for extreme wind events, constant wind speeds were applied beginning July 1, 2048 (20 years after closure) for the remainder of simulation period. Constant wind speeds corresponding to 25%, 50%, 75%, and 100% of the maximum observed windspeed in the original 19-year time series were applied for scenario 4-a, -b, -c, and -d, respectively. Table 2 lists the values used for each scenario. Note that this scenario is not plausible, but provides information about the amount of wind energy that would be required to fully overturn the water column for the Development Case.

Table 2. Wind speed changes applied in Scenario 4.

Scenario	Percent of Maximum Observed Value	Wind speed (m/s)
4a	25%	5.68
4b	50%	11.36
4c	75%	17.04
4d	100%	22.72

Scenario 5

This model run was completed to test the sensitivity of the model to a warming air temperature trend as a result of climate change. The original air temperature time series was developed using Diavik on-site meteorological data. Using data provided in Tetra Tech (2017), a new time series was developed whereby the annual temperature increase rate was applied. Table 3 details the annual warming rate by month, and Figure 1 shows the comparison between the original time series and the time series used in this scenario.

Table 3. Annual increase in temperature (°C) by month.

Month	Annual Warming Rate (°C/yr)
January	0.086
February	0.086
March	0.052
April	0.052
May	0.052
June	0.023
July	0.023
August	0.023
September	0.054
October	0.054
November	0.054
December	0.086

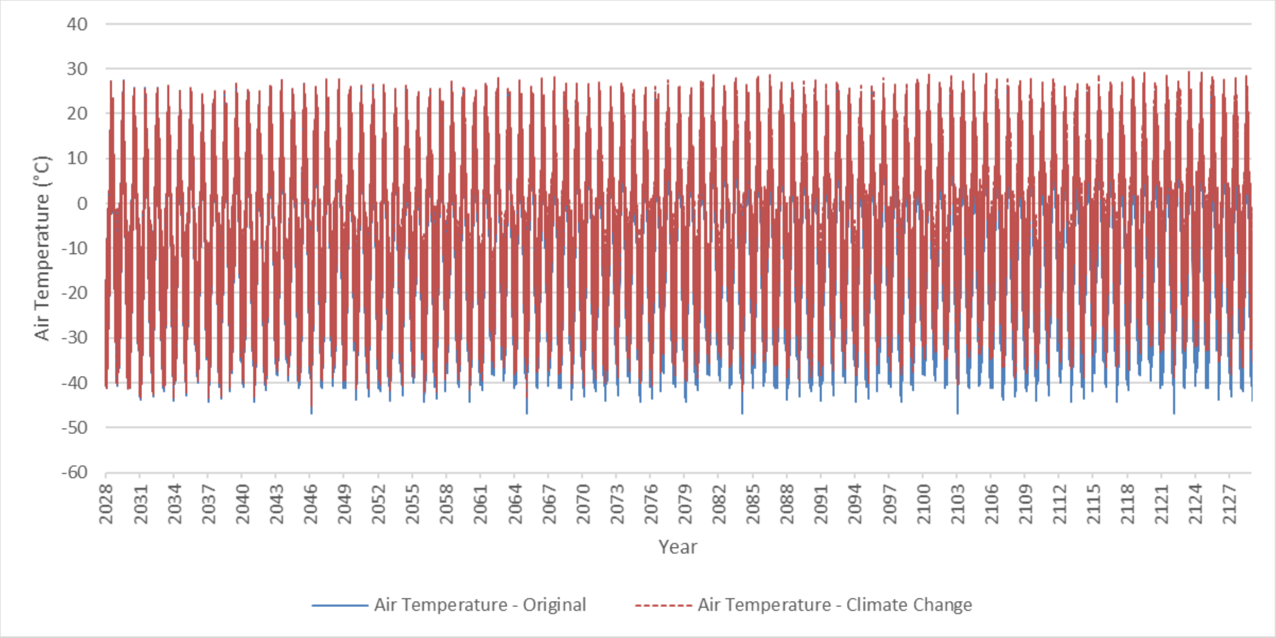

Figure 1. Original model air temperature time series vs. air temperature time series used in the Scenario 5 as a result of climate change.

Scenario 6

Two model runs were completed to test the sensitivity of the model to the PK consolidation rate. The original model makes use of a time series of water volume released through consolidation. The present rate applied in the model is thought to be an over-estimate, which was conservative from the perspective of mass loading. To account for a different rate of consolidation, the time series were calculated to release this water at a quarter of, and half of, the original rate for sensitivities 6-a and 6-b, respectively.

Scenario 7

Two model runs were completed to test the sensitivity of the model to the pore water chemistry. The original model uses a constant pore water TDS concentration of 3504.88 mg/L (mean value of observed data). TDS concentrations were calculated as per APHA (2005) and using the 25th and 75th percentile constituent concentrations to obtain the 75th and 25th percentile TDS concentrations. The calculations yielded 6150 mg/L (75th percentile) and, 346 mg/L (25th percentile) for scenarios 7-a and 7-b, respectively.

Scenario 8

Two model runs were completed to test the sensitivity of the model to initial conditions (TDS concentration) of the water column. Scenario 8-a was updated to include 5 m of PK pore water prior to filling the pit. The mass of TDS in 5 m of PK pore water directly overlying the deposited PK was calculated using the following assumptions:

1. The volume in the bottom 5 m was calculated as 345,530 m^3.
2. The concentration of TDS in the PK pore water is 3504 mg/L.
3. The remaining volume in the freshwater cap is 27,686,047 m^3.
4. The concentration of TDS in the remaining volume of freshwater cap is 16.69 mg/L.

Based on these assumptions, the initial TDS concentration of the pit lake was calculated as being 60 mg/L. The model was run using this TDS as the initial concentration of the pit lake.

The initial condition for TDS concentration in Scenario 8-b was updated to include rock wall runoff loadings during filling of the pit. The mass of TDS in the rock wall runoff was calculated using the following assumptions:

1. Based on the water quality results at locations PW8 to PW11, the calculated TDS load (using APHA 2005 methodology) associated with the rock wall runoff yields a total of 2.3026 tonnes.
2. The pit lake volume with the 150 m fresh water cap is 29,249,000 m^3.

Based on these assumptions, the load associated with the rock wall runoff would represent an additional 0.079 mg/L on the initial TDS concentration. As the original initial TDS concentration in the pit lake was 16.69 mg/L, this was updated to 16.77 mg/L for this scenario.

Scenario 9

This run was completed to test the sensitivity of the model to groundwater inflows during the filling period. For this Scenario, the initial TDS concentration in the pit lake was updated to account for groundwater inflows. The mass of TDS in the groundwater inflows was calculated using the following assumptions:

1. The total groundwater volume to the pit was calculated during filling, based on predicted groundwater inflows by water elevation in the pit. The total volume was calculated as being 177,647 m^3.
2. A calculated TDS concentration (APHA 2005) of 211 mg/L was applied to this volume of groundwater. TDS concentrations were derived from monitoring data at station 1645-75B.
3. A mixed initial TDS concentration in the flooded pit lake was calculated assuming that the remaining volume has TDS concentration of 16.69 mg/L.

This calculation yields an initial TDS concentration in the pit lake of 17.95 mg/L.

Scenario 10

Three runs were completed to test the sensitivity of the model to the maximum vertical eddy viscosity. For these models, the original value of 0.001 m^2/s was changed to 0.01, 0.1, and 1.0 m^2/s for scenarios 10-a, 10-b, and 10-c, respectively.

Results

The figures provided in the attachment show the results of each scenario described above. Under all plausible scenarios, there are small changes to the transport of constituents and long-term mixing, but the pit lake remains stratified over the long-term. This sensitivity analysis provides additional confidence in the original predictions, recognizing that they are preliminary and subject to additional vertical mixing imposed by the model's structure. By extension, the water quality results presented based on this hydrodynamic model are thought to be reasonably accurate, and likely conservative.

References

APHA 2005 (Standard Methods for the Examination of Water and Wastewater, 21st Ed.)

Tetra Tech 2017. Thermal Evaluation of Type III Rock Closure Cover at North Country Rock Pile, Daivik Diamond Mine, NT, Canada. Submitted to Diavik Diamond Mines Inc. on September 27, 2017.

Vandenberg, J.A., K. Salzsauler and S. Donald. 2016. Best Practices Checklist for Modelling Mine Waters. International Mine Water Association, July 2016. Leipzig, Germany.