

Memo

To:	John Roberts, PEng	Client:	TMAC
From:	Sarah Portelance, PEng Kelly Sexsmith, PGeo	Project No:	1CT022.002
Reviewed By:	Maritz Rykaart, PhD, PEng	Date:	January 28, 2016
Subject:	Document P6-10b, Water and Load Balance Model – Results of Sensitivity Analysis for TIA and Doris Creek		

1 Context

A series of Technical Review comments requested additional scenarios to be evaluated through the water and load balance model. These include:

- ECCC 4, KIA 11A and KIA 11C: Requested inclusion of free cyanide, mercury and selenium from process water be included in water quality predictions.
- KIA 11A: Requested a description of the site specific variable hydrology and requested that it be included into the load balance of the water quality predictions.
- KIA 5, KIA 11B and AANDC TC4: Requested that the water and load balance evaluate the 75th percentile input values for background water quality, pollution control and sediment control pond concentrations, ore and waste rock source terms and the tailings beach source term.

TMAC reviewed available data from geochemical testing and identified alternative test results for cyanide, selenium and mercury. The maximum concentrations from the process water aging tests as listed in Table 1 was subsequently used for the Base Case and the Sensitivity Analysis. The Base Case is as presented in Document P6-10 of the Application. The Sensitivity Analysis results and input values are presented in this memo and addresses the additions proposed by interveners as described above.

Table 1: Maximum process water concentration for free cyanide, mercury and selenium from process water ageing tests

Parameter	Concentrations (mg/L)
WAD Cyanide	0.27
Mercury	0.000079
Selenium	0.0075

This memo includes the results of the water and load balance Sensitivity Analysis which includes free cyanide, mercury and selenium process water concentrations as described in Table 1, variable hydrology implemented as a Monte Carlo simulation based on historical precipitation and temperature data, and 75th percentile input values for background water quality, Sedimentation Control and Pollution Control Pond concentrations, ore and waste rock source terms and the tailings beach source term. The memo supercedes an earlier memo presenting sensitivity analysis for the TIA issued on Jan 27, 2016.

In the original water and load balance report (Document P6-10 of the application), results were only shown for the TIA. In this memo, results are also provided for Doris Creek, at TL-3¹. This second set of results does not include cyanide, ammonia, nitrate or nitrite because those are all short lived in the TIA, and discharges will not occur until concentrations of those parameters reach levels that are acceptable for direct discharge.

2 Results

2.1 TIA

Table 2 summarizes the results of the Base Case and Sensitivity analysis within the TIA post closure after the North Dam has been breached. Results are presented in each case for two conditions; the open water period when discharge from the TIA to Doris Lake would occur (Open Water Mean), and the period when the ice cover is at its maximum and no discharge occurs (Max. Cryoconcentration). This 100% cryoconcentration assumption is unrealistically conservative but is added to bracket the results recognizing that some degree of cryoconcentration does occur.

Highlighted cells in Table 2 indicate values that exceed CCME guideline values for freshwater aquatic life in the TIA.

- For the Base Case four elements exceed these guideline values during the open water season within the TIA; aluminum, chromium, copper and iron. These metals exceed the guideline value by 1.7, 1.3, 1.7 and 1.1 times respectively, which are likely well below the factors of safety built into these guideline values.
- For the Sensitivity Analysis five elements exceed CCME guideline values for freshwater aquatic life during the open water season in the TIA; aluminium, arsenic, chromium, copper, and iron. These metals exceed the guideline values by 2.3, 2.0, 2.0, 2.6, and 1.6 respectively. Once again, these exceedances are likely well below the factors of safety built into these guideline values.
- None of the base case or sensitivity analysis results exceeded the CCME guidelines for livestock watering, which are indicative of potential effects on terrestrial wildlife.

¹ TL-3 is a point of compliance in the current water licence, located ~80m downstream of the base of the waterfall in Doris Creek. At closure, when flows from the TIA are returned to the natural channel between the TIA and Doris Lake, water quality at TL-3 is effectively the same as the water quality in the outlet of Doris Creek and the upper reach of Doris Creek.

It is important to note that the 75th percentile background concentrations for aluminum, chromium, and iron were higher than the CCME guideline values for freshwater aquatic life, and the WAD cyanide levels in the background were at a detection limit equivalent to the CCME guideline.

A series of graphs illustrating the results of the modeling for both the Base Case and Sensitivity results for all the parameters listed in Table 2 is provided in Attachment A.

2.2 Doris Creek

Table 3 summarizes the results of the Base Case and Sensitivity Analysis in Doris Creek for the post closure period after the North Dam has been breached. Results are presented in each case for two conditions; the open water period when discharge from the TIA to Doris Lake would occur (Open Water Mean), and the period when the ice cover is at its maximum, no discharge from the TIA occurs, and essentially negligible discharge from Doris Lake occurs. During this latter period, it is conservatively assumed that cryoconcentration occurs within Doris Lake. As discussed previously, cyanide and nitrogen species are not included in the modelling because these are short-lived in the TIA, and discharges from the TIA and other source areas will not occur until these have reached acceptable levels for discharge.

Highlighted cells in Table 3 indicate values that exceed CCME guideline values for freshwater aquatic life in Doris Creek.

- In the Base Case none of the elements exceed the guidelines during the open water season. However, chromium concentrations are the same as the guideline, and chromium, copper and mercury exceed the guidelines by a small margin during the winter months when cryoconcentration is expected to occur. Comparison of the background concentrations to the open water concentrations for these parameters indicates that the TIA and other sources have a negligible effect on water quality during periods of discharge. Therefore, the increase during the winter months is attributed primarily to cryoconcentration of the background water quality.
- The Sensitivity Analysis yielded similar results for chromium, copper and mercury to that of the Base Case results. Additionally, concentrations of aluminum and iron exceeded the CCME guidelines for freshwater aquatic life by a small margin during the winter months. This is attributed to a combination of elevated background concentrations (which exceeded CCME levels in some instances), and the cryoconcentration assumptions used in the model. It is further noted that modelled results for these two parameters are strongly affected by the assumptions used to incorporate suspended sediments in the source terms for waste rock and tailings, which assumed TSS levels of 15 mg/L. At closure, TSS levels are expected to be much lower than the values assumed in the model, and as a result, total aluminum and iron concentrations are expected to be less than indicated by the model.

None of the Base Case or Sensitivity Analysis results for open water or under ice conditions exceeded the CCME guidelines for livestock watering, which are indicative of potential effects on terrestrial wildlife.

Table 2: Summary of Base Case and Sensitivity analysis results for TIA water quality

Parameter	Post Closure				Background				CCME Guideline (Freshwater Aquatic Life)	CCME Guideline (Livestock Watering)
	Base Case		Sensitivity Analysis*		Median Background		75th Background			
	Open Water Mean	Max Cryo- concentration	Open Water Mean	Max Cryo- concentration	Min	Max	Min	Max		
Chloride	58	127	64	140	41	64	61	65	120	
Total CN	0.00029	0.00057	0.00064	0.0012	0.0050	0.0050	0.0050	0.0050		
WAD CN	0.000000010	0.000000036	0.00064	0.0012	0.0050	0.0050	0.0050	0.0050	0.0050	
Ammonia N	0.0013	0.0019	0.0028	0.0068	0.050	0.16	0.050	0.16	1.54	
Nitrate	0.20	0.44	0.25	0.54	0.050	0.050	0.050	0.050	13.00	
Nitrite	0.015	0.032	0.015	0.033	0.0013	0.0016	0.0013	0.0016	0.060	
Aluminum	0.17	0.27	0.23	0.39	0.040	0.055	0.050	0.16	0.10	5
Arsenic	0.0031	0.0066	0.010	0.022	0.00040	0.00050	0.00040	0.00050	0.0050	
Barium	0.0048	0.0094	0.011	0.024	0.0030	0.020	0.0033	0.020		
Beryllium	0.000046	0.000093	0.00094	0.0021	0.0010	0.0010	0.0010	0.0010		
Boron	0.027	0.058	0.069	0.15	0.050	0.10	0.050	0.10	1.50	
Cadmium	0.000015	0.000031	0.000026	0.000055	0.000010	0.000011	0.000010	0.000010	0.000070	
Chromium	0.0013	0.0018	0.0020	0.0033	0.0010	0.0010	0.0010	0.0010	0.0010	0.05
Cobalt	0.00019	0.00033	0.0022	0.0048	0.00050	0.0020	0.00050	0.0020		1
Copper	0.0035	0.0073	0.0051	0.011	0.0014	0.0015	0.0015	0.0016	0.0020	0.5
Iron	0.34	0.48	0.49	0.78	0.083	0.17	0.14	0.31	0.30	
Lead	0.00013	0.00024	0.00055	0.0011	0.00010	0.00011	0.00010	0.00050	0.0010	0.1
Manganese	0.037	0.069	0.055	0.11	0.018	0.058	0.025	0.058		
Mercury	0.0000052	0.0000088	0.000020	0.000027	0.000010	0.000020	0.000020	0.000020	0.000026	0.003
Molybdenum	0.00083	0.0018	0.0063	0.014	0.0010	0.0050	0.0010	0.0050	0.070	0.5
Nickel	0.0010	0.0020	0.0024	0.0050	0.0018	0.0020	0.0018	0.0020	0.025	1
Selenium	0.00050	0.0011	0.00059	0.0013	0.00010	0.00040	0.00010	0.00040	0.0010	0.05
Silver	0.000019	0.000038	0.000035	0.000074	0.000020	0.000020	0.000020	0.000020	0.00010	
Strontium	0.047	0.096	0.046	0.10	0.036	0.041	0.036	0.041		
Thallium	0.000042	0.000089	0.00013	0.00027	0.00010	0.00020	0.00010	0.00020	0.00080	
Uranium	0.000080	0.00017	0.00017	0.00038	0.00010	0.00020	0.00010	0.00020	0.015	0.2
Vanadium	0.00081	0.0014	0.0014	0.0027	0.0010	0.0016	0.0010	0.0016		0.1
Zinc	0.0041	0.0084	0.0057	0.012	0.0040	0.0052	0.0040	0.0052	0.030	50

Note: Highlighted cells with red text indicate parameters that exceed CCME guideline values for freshwater aquatic life.

There were no exceedances of CCME guidelines for livestock watering.

* Results are for the 95th percentile hydrology assumptions, which are conservative with regard to water quality predictions

Table 3: Summary of Base Case and Sensitivity analysis results for Doris Creek at TL-3

Parameter	Post Closure				Background				CCME Guideline (Freshwater Aquatic Life)	CCME Guideline (Livestock Watering)
	Base Case		Sensitivity Analysis*		Median Background		75th Background			
	Open Water Mean	Max Cryo-concentration	Open Water Mean	Max Cryo-concentration	Min	Max	Min	Max		
Chloride	64	85	64	87	63	64	61	65	120	
Aluminum	0.045	0.065	0.13	0.18	0.040	0.055	0.050	0.16	0.10	5
Arsenic	0.00046	0.00070	0.00062	0.0011	0.00040	0.00050	0.00040	0.00050	0.0050	
Barium	0.0051	0.016	0.012	0.027	0.0030	0.020	0.0033	0.020		
Beryllium	0.0010	0.0013	0.0010	0.0014	0.0010	0.0010	0.0010	0.0010		
Boron	0.052	0.073	0.073	0.13	0.050	0.10	0.050	0.10	1.5	
Cadmium	0.000010	0.000014	0.000010	0.000014	0.000010	0.000011	0.000010	0.000010	0.000070	
Chromium	0.0010	0.0014	0.0010	0.0014	0.0010	0.0010	0.0010	0.0010	0.0010	0.05
Cobalt	0.0020	0.0027	0.0020	0.0027	0.00050	0.0020	0.00050	0.0020		1
Copper	0.0015	0.0022	0.0017	0.0024	0.0014	0.0015	0.0015	0.0016	0.0020	0.5
Iron	0.11	0.20	0.26	0.36	0.083	0.17	0.14	0.31	0.30	
Lead	0.00010	0.00015	0.00029	0.00067	0.00010	0.00011	0.00010	0.00050	0.0010	0.1
Manganese	0.020	0.031	0.033	0.047	0.018	0.058	0.025	0.058		
Mercury	0.000020	0.000027	0.000020	0.000027	0.000010	0.000020	0.000020	0.000020	0.000026	0.003
Molybdenum	0.0049	0.0067	0.0049	0.0067	0.0010	0.0050	0.0010	0.0050	0.070	0.5
Nickel	0.0020	0.0027	0.0020	0.0027	0.0018	0.0020	0.0018	0.0020	0.025	1
Selenium	0.00040	0.00055	0.00040	0.00055	0.00010	0.00040	0.00010	0.00040	0.0010	0.05
Silver	0.000020	0.000027	0.000021	0.000028	0.000020	0.000020	0.000020	0.000020	0.00010	
Strontium	0.038	0.055	0.038	0.055	0.036	0.041	0.036	0.041		
Thallium	0.00010	0.00014	0.00014	0.00027	0.00010	0.00020	0.00010	0.00020	0.00080	
Uranium	0.00010	0.00015	0.00015	0.00027	0.00010	0.00020	0.00010	0.00020	0.015	0.2
Vanadium	0.0010	0.0014	0.0011	0.0015	0.0010	0.0016	0.0010	0.0016		0.1
Zinc	0.0042	0.0067	0.0049	0.0067	0.0040	0.0052	0.0040	0.0052	0.030	50

Note: Highlighted cells with red text indicate parameters that exceed CCME guideline values for freshwater aquatic life.

There were no exceedances of CCME guidelines for livestock watering.

* Results are for the 95th percentile hydrology assumptions, which are conservative with regard to water quality predictions

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Attachment A

Plots of Trace Element Concentrations over Time in the TIA



















