



TECHNICAL MEMORANDUM

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TO Sandra Pouliot
Mine Canadian Malartic

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**RESPONSE TO COMMENTS RELATED TO SULPHATE INFLUENCE ON METHYLMERCURY
GENERATION AND WILD RICE HARVESTING – HAMMOND REEF GOLD PROJECT**

1.0 INTRODUCTION

Concern has been expressed by the Government Review Team (GRT) in meetings with Canadian Malartic Corporation (CMC) regarding the discharge of sulphate to Marmion Reservoir and the potential impact that increased sulphate concentrations may have on generation of methylmercury in the reservoir and on the harvest of wild rice in areas downstream of the Raft Lake Dam. The concern was initially raised by the Canadian Environmental Assessment Agency (CEAA) and subsequently re-iterated by the Ministry of Natural Resources and Forestry (MNR) and the Ontario Ministry of Environment and Climate Change (MOECC).

Baseline fish tissue data collected by CMC (Golder 2016) indicates that some fish have elevated levels of mercury relative to consumption guidelines (Ontario 2015) and compared to the sampled reference lake (Sapawe Lake). Concern was raised by the GRT that discharge of sulphate by the project may result in an increase in sulphide concentration in the sediment of Marmion Reservoir and, as a result, may increase the generation of methylmercury. Concern was also raised that increased sulphate concentrations may have a negative impact on the existing wild rice harvesting areas downstream of the Raft Lake Dam.

In response to the concerns raised by the GRT, CMC prepared a *Methylmercury and the Hammond Reef Project* fact sheet which was submitted on December 9, 2016. Following this submission, additional verbal comments were received from the GRT, including identification of recent research work completed in the field. A follow-up letter was also received by CMC from the MOECC on March 16, 2017 regarding the fish tissue study (Golder 2016) submitted at the same time as the fact sheet. This letter also requested additional information relating to sulphate distribution.

This memorandum provides an updated response which includes a summary of recent available literature from this active area of academic research. In addition, responses to the specific information requests of the MOECC letter related to sulphate/sulphides have been provided in Section 4.

2.0 BACKGROUND SUMMARY

Mercury is an element that naturally occurs in rocks and sediments. It can be released to the atmosphere through human activity such as burning of coal for heating and cooking, industrial processes and waste incineration. Mercury is deposited from the atmosphere as dust or in rainfall and is taken up in surface vegetation or deposited in lakes and rivers. Mercury is currently found in the waters of Marmion Reservoir and surrounding lakes and rivers due to atmospheric deposition. Mercury will not be used for mineral processing and the activities of the

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Hammond Reef Project (the Project) are not expected to add mercury to the reservoir or waters throughout the Project's life cycle.

When an area is flooded to create a reservoir (e.g. Marmion Reservoir), the existing mercury present in the submerged vegetation or that settles to the bottom sediments can be transformed by bacteria through a process called methylation. In methylation, mercury joins with carbon and hydrogen to form methylmercury. The presence of bacteria, sulphate and sulphide, iron, lakebed sediment composition and availability of sunlight all influence mercury and methylmercury concentrations in surface waters. Bacteria and sulphate have a tendency to increase concentrations of methylmercury under certain conditions, whereas the presence of sulphide and iron can decrease methylmercury concentrations. Additional processes including photo-demethylation act to reduce the amount of methylmercury in surface waters (as indicated in Chapter 6 of Canadian Mercury Science Assessment, (CMSA), 2016).

Methylmercury can be absorbed by a fish either from water passing over its gills or by ingestion with its diet. Fish eliminate mercury at a very slow rate and concentrations of mercury can gradually accumulate. The mercury in fish is passed on to those that consume the fish, such as humans, which also eliminate mercury at a very slow rate, and in turn may also build up concentrations of mercury over time.

The MOECC provides guidance on fish consumption to limit mercury exposure in humans, including recommended limits on the number of fish that should be eaten (Ontario 2015). The recommended limits depend on where the fish are caught because different lakes have different mercury levels in the fish. Data on the pre-mining, existing conditions for fish in Marmion Reservoir has indicated that some fish have elevated levels of mercury. In response to concerns and requests from local stakeholder groups, CMC has collected additional pre-mining information on mercury levels in fish in Marmion Reservoir, Lizard Lake and Turtle Bay (Golder 2016). The results of this additional investigation were provided as an attachment to the fact-sheet provided to the GRT on December 9, 2016.

2.1 Sulphate/Sulphide and Mercury at the Hammond Reef Project

There are significant differences between the geology of the Hammond Reef Project and other projects in the vicinity of Atikokan, most notably the Steep Rock Mine. The Steep Rock Mine geology contains significant amounts of sulphide minerals which have oxidized to produce Acid Rock Drainage (ARD), releasing high sulphate concentrations (greater than 1500 mg/L) to the environment. In contrast, the Hammond Reef Project contains very little sulphide minerals and, based on standard methodology (INAP, 2012; MEND, 2009), is considered non-acid generating (see Geology, Geochemistry and Soils TSD). Sulphate release from the geology of the Hammond Reef Project is expected to be substantially lower (150 – 250 mg/L) than that of the Steep Rock Mine, and is governed not by geology and oxidation, but rather is released as a function of processing and treatment for cyanide, a chemical used to extract gold from the mined ore.

Mixing of the Project's treated effluent will be enhanced through the operation of an effluent diffuser. Mixing analysis (Golder 2013) has shown that, at the edge of the initial mixing zone, within 100 m of the Project's treated effluent discharge location, concentrations of sulphate in Marmion Reservoir will approach background concentrations, resulting in a 0.3 mg/L increase compared to background concentrations as predicted in the Lake Water Quality TSD and as presented in Figures 1 and 2, attached. Further downstream at Raft Lake Dam, under normal operating conditions it is expected that sulphate values will be about 1.8 mg/L which is very close to the baseline condition of (1.6 mg/L), thus wild rice areas, which are located downstream of Marmion Reservoir, are not expected to be influenced by the project. Further assessment of potential influence on wild rice harvest areas is provided in Section 3 of this memorandum.

The mercury present in the Marmion Reservoir is likely due to atmospheric deposition over time. There is no additional direct source of mercury resulting from the Hammond Reef Project. Mercury concentrations as measured in samples of rock from the Hammond Reef Project ore body were below laboratory detection limits as documented in the Geochemistry Geology and Soils TSD.

Changing conditions within the Marmion Reservoir, such as fluctuating water levels due to operation of the Raft Lake Dam, influence the uptake and release of mercury to/from the reservoir sediments. The competing roles of sulphate, sulphide, photo-degradation on mercury uptake, release or reduction are discussed below.

2.2 Marmion Reservoir Information

For a basin such as the Marmion Reservoir, which has many natural inputs of mercury (e.g. upstream wetlands), a large surface area which influences photo-demethylation, and fluctuating water elevations due to operation of the Raft Lake Dam, it is not possible to isolate the overall influence of one process over another to accurately predict potential changes over time that may result from minor changes in sulphate concentrations such as those predicted for the Hammond Reef Project. However, information related to Marmion Reservoir that may be useful in understanding the influence of sulphate on the overall system is provided below:

- Baseline information from nearby lakes, bays and upstream tributaries indicate that existing sulphate concentrations range from <0.3 mg/L to about 6 mg/L. These values are within the range of expected concentrations in the reservoir.
- Active use of the reservoir for power production results in water level fluctuations on the order of meters and operation of the mine is not expected to change this water level fluctuation.
- Sulphate concentrations in the mine discharge are expected to remain relatively consistent over time, and will have only minor influence on mixed concentrations in the reservoir.
- Within 100 meters of the treated effluent discharge location, sulphate concentrations are predicted to reduce to approximately 1.9 mg/L under expected average conditions (an increase of 0.3 mg/L above baseline). This discharge will occur in open water, away from the shoreline sediments influenced by changing water level as shown on Figures 1 and 2.

3.0 SULPHATE/SULPHIDE INFLUENCE ON WILD RICE

Cycling of sulphate/sulphide in lakebed sediments and its influence on wild rice production is another area of active research, provided below is an excerpt from the Minnesota Pollution Control Agency (MPCA) website (MPCA, 2017):

“The MPCA studied how sulfate affects wild rice and concluded sulfate levels should be calculated for each wild rice water, based on location-specific factors. The study, which began in 2012, found that:

- In the sediment in which wild rice is rooted, sulfate from the water above is converted to sulfide by bacteria.
- Higher levels of sulfide in the sediment create an environment that is less hospitable to wild rice.

However, certain factors change the rate at which sulfate is converted to sulfide. Most significantly, higher levels of iron can lead to less sulfide, and higher levels of organic carbon can lead to more sulfide.

To take these variables into account, the MPCA developed an equation that can determine a sulfate level that will protect wild rice for a specific water body...”

The MPCA (2015) established a relationship between sulphide porewater concentration, sulphate concentration in surface water, and sediment iron concentration and organic carbon content. This relationship is defined by the following equation:

$$\text{Sulphide (mg/L)} = 7.7873 [\text{Sulphate (mg/L)}]^{0.345} [\text{Organic Carbon (\%)}]^{0.486} [\text{Sediment Iron (\mu g/g)}]^{-0.675} \quad (1)$$

Substituting the threshold sulphide concentration of 0.165 mg/L and solving for sulphate concentration yields the following relationship, which has been proposed by the MPCA as a means to establish a site-specific sulphate standard for the protection of wild rice:

$$\text{Sulphate (mg/L)} = 0.0000136 [\text{Organic Carbon (\%)}]^{-1.410} [\text{Sediment Iron (\mu g/g)}]^{1.956} \quad (2)$$

Based on analysis of 134 lakebed sediment samples collected from waterbodies in the Hammond Reef Project area, the average and median iron concentrations were 23,000 $\mu\text{g/g}$ and 12,700 $\mu\text{g/g}$, respectively (Water and Sediment Quality TSD, Appendix 2.IV). Using equation 2 above and assuming the lower median iron concentration and a reasonable organic carbon content of 30%, a sulphate standard of 12.0 mg/L for the protection of wild rice can be calculated.

The nearest wild rice areas are downstream of the Raft Lake Dam. Under typical lakebed sediment conditions, the sulphate concentrations discharging at the Raft Lake Dam (1.8 mg/L) are well below protective thresholds proposed by the MPCA.

4.0 LITERATURE REVIEW (PROCESSES INFLUENCING METHYLMERCURY CONCENTRATIONS)

Substantial amounts of active research is ongoing regarding mercury and methylmercury as recently summarized in the Canadian Mercury Science Assessment Report (CMSA 2016). As described more fully in CMSA (2016) the production and release of methylmercury is a balance between production rates as driven by sulphate addition to the sediment substrate, and inhibition of methylation as driven by the presence of sulphide and iron within the substrate. In freshwater systems such as the Marmion Reservoir additional photo-demethylation decreases the concentration of methylmercury.

4.1 Methylmercury Generation

Methylmercury generation is a well-known phenomenon in flooded reservoirs, although the precise biochemical mechanisms are not yet fully elucidated (Paranjape and Hall 2017). Sulfate-reducing bacteria were the first organisms identified as the primary bacteria responsible for mercury methylation (Compeau and Bartha 1985). Sulphate-reducing bacteria are obligated anaerobes that obtain energy for growth by oxidation of organic substrates. They use sulphate as the terminal electron acceptor and convert sulphate to sulphide. During this process, some strains of sulfate-reducing bacteria methylate bioavailable inorganic oxidized mercury (Hg^{2+}) to methylmercury (Shao et al. 2012). Other microorganisms including iron reducing bacteria and methanogens have also been identified as being able to methylate mercury (Hogarth et al. 2015). Several factors affect the methylation of mercury, including: the activity and abundance of methylating bacteria, bioavailability of inorganic mercury, quality and quantity of labile dissolved organic carbon, concentrations of sulphur species, redox conditions, pH, and temperature (Paranjape and Hall 2017).

Because sulphate-reducing bacteria are the primary bacteria responsible for mercury methylation, both sulphate and sulphide concentrations play a role in methylmercury production. The presence of sulfur has been found to have strong correlations to methylmercury concentrations in several types of aquatic environments. The presence

of sulfate stimulates the methylation process (Shao et al., 2012; Coleman Wasik et al. 2012; Mitchell et al. 2008; Branfireun et al. 1999), while the presence of high concentrations of sulphide may inhibit it (Bailey 2015; Shao et al. 2012; Benoit et al. 2001; Benoit et al. 1999; Gilmour et al. 1998). Low sulphide concentrations allow for the formation of neutral mercury sulphide complexes capable of diffusing through cell membranes, thereby promoting methylation. Higher concentrations of sulphide can result in charged mercury sulphide complexes that decrease mercury bioavailability (Paranjape and Hall 2017).

4.2 Sulphate Influence

Although not directly related to water column concentrations, controlled experiments have demonstrated that addition of sulphate to lakebed sediments or peat bogs stimulates methylmercury production. Shao et al. (2012) cultured two sulphate-reducing bacteria species, *Desulfobulbus propionicus* and *Desulfovibrio vulgaris*, in freshwater fish pond sediment conditions under various sulphate concentrations and inorganic mercury amendments. The results of the study demonstrated that the addition of sulfate stimulated the growth of sulphate-reducing bacteria in sediments and that methylmercury concentrations were sensitive to sulfate concentrations. A medium sulfate concentration (0.11 mg/g) produced higher concentrations of methylmercury than treatments lacking sulphate addition (0.06 mg/g) or treatments amended with higher sulphate concentrations (0.55 mg/g).

Coleman Wasik et al. (2012) experimentally manipulated atmospheric sulfate loading to a small boreal peatland and monitored the resulting short and long-term changes in methylmercury production. An increase in porewater methylmercury concentration in response to sulfate addition was clearly evident following spring sulfate application to the central-bog. In each year, porewater sulfate concentrations in the experimental treatment peaked one day following the additions (2.9 ± 2.1 mg/L in 2006 and 3.8 ± 2.2 mg/L in 2008). As sulfate concentrations declined, the porewater methylmercury pool increased (4.3 ± 2.1 ng/L in 2006 and 3.6 ± 1.0 ng/L in 2008). In contrast, mean sulfate and methylmercury concentrations in the control area were consistently low each spring (<0.5 mg/L and <0.6 ng/L, respectively). Coleman Wasik et al. (2012) concluded that the added sulfate stimulated the activity of sulphate-reducing bacteria resulting in a net increase in methylmercury production. In a related study, Mitchell et al. (2008) explored the effects that different amounts of sulphate and labile organic carbon had on the production of methylmercury in peatlands, using two different loads of sulphate (4 times and 10 times the average annual atmospheric deposition) and loads of glucose, acetate, and lactate. The pre-addition concentrations of sulphate were 0.13 ± 0.14 mg/L and 0.02 ± 0.03 mg/L for the 4 times and 10 times sulphate loads, respectively. The post-addition concentrations of sulphate were 6.7 ± 1.7 mg/L and 26.0 ± 10.8 mg/L for the 4 times and 10 times sulphate loads, respectively. Mitchell et al. (2008) concluded that the addition of sulphate resulted in both significantly greater net production of methylmercury and a significantly greater increase in %-methylmercury when compared to controls. Branfireun et al. (1999) showed that adding sulphate to experimental peatland plots (control plot sulphate concentrations varied from 0.04 mg/L to 0.71 mg/L; experimental plot sulphate concentrations varied from 9 mg/L to 31.5 mg/L) resulted in measurable increases in pore water methylmercury concentrations. In the control plots, methylmercury concentrations ranged from 0.20 ng/L to 2.6 ng/L. In the experimental plots, methylmercury concentrations ranged from 3.46 ng/L to 5.13 ng/L.

During the process of methylation, compounds such as sulphide and ferrous iron accumulate in the sediment as the bi-products of sulfate and ferric iron reduction. When reservoir water levels drop, sediments are exposed to the air, which may result in the reduced compounds being re-oxidized to sulfate and ferrous iron. This could provide a fresh source of electron accepting compounds for microbial communities when the water levels are raised again and result in higher methylmercury production. Eckley et al. (2015) concluded that the role of sulphide oxidation to sulfate during sediment exposure to the air may be important in replenishing sediment sulfate levels, which could enhance the activity of sulphate-reducing bacteria and increase methylmercury concentrations in reservoirs.

Gabriel et al. (2014) derived relationships between total mercury in fish trophic levels and surface water sulphate concentrations from 1998 to 2009 from multiple stations across the Everglades Protection Area. The data in the study showed consistent and identifiable areas of high- and low-fish total mercury concentrations across the range of surface water sulphate concentrations. Health-concerning fish total mercury levels were present at all surface water sulphate concentrations; however, most of these mercury levels occurred in the 1-20 mg/L sulphate concentration range.

4.3 Sulphide Influence

With respect to presence of sulphide (typically formed under reducing conditions) there are numerous examples in peer-reviewed literature that show that sulphide inhibits methylmercury production. Results of a study by Bailey (2015) suggest that the net production and partitioning of methylmercury in sulfate-impacted freshwater sediments are governed by processes related to the concentration of dissolved sulphide in sediment porewater and showed that sulphide can inhibit methylmercury production at concentrations $>10\text{-}100\ \mu\text{M}$ (0.032 - 3.2 mg/L). Bailey (2015) noted that the presence of ferrous iron can act to limit sulphide concentrations in sediments. At sites where free iron has not been depleted, porewater sulphide may not be present in high enough concentrations to inhibit mercury methylation because the sulphide binds with iron.

Benoit et al. (2001) conducted laboratory experiments using pure cultures of *Desulfobulbus propionicus* to test the hypothesis that sulphide inhibits mercury methylation by decreasing its bioavailability to sulfate-reducing bacteria. At low sulphide concentrations of 10^{-6} to 10^{-5} M (0.032 to 0.32 mg/L), methylmercury production was linearly related to the concentration of filtered inorganic mercury. The methylation of filtered inorganic mercury decreased about fourfold as sulphide concentrations were increased from 10^{-6} to 10^{-3} M (0.032 to 32 mg/L). Benoit et al. (2001) concluded that the decline was consistent with a decrease in the bioavailability of inorganic mercury. Benoit et al. (1999) examined sediment pore waters from the Patuxent River and the Florida Everglades. Both sites showed a decrease in bulk sediment methylmercury concentrations with an increase in sulphide concentrations. In the Patuxent River, bulk sediment methylmercury concentrations decreased from approximately 1 ng/g dw to less than 0.5 ng/g dw as porewater sulphide concentrations increased from 10^{-7} to 10^{-4} M (0.0032 to 3.2 mg/L). In the Florida Everglades, bulk sediment methylmercury concentrations decreased from approximately 3 ng/g dw to less than 0.5 ng/g dw as porewater sulfide concentrations increased from 10^{-7} to 10^{-4} M (0.0032 to 3.2 mg/L). To examine the biogeochemical controls of mercury methylation, Gilmour et al. (1998) conducted amendment experiments using potential stimulants and inhibitors of methylation with intact sediment cores from the Everglades. The addition of $50\ \mu\text{M}$ (1.6 mg/L) sulphide to sediments with ambient pore water sulphide concentration of about $200\ \mu\text{M}$ (6.4 mg/L) significantly inhibited methylmercury production.

4.4 Methylmercury Photo-degradation and Other Processes in Surface Water

Several other processes serve to influence the concentration of methylmercury in freshwater systems. Chapter 6 in CMSA (2016) provides a good overview of these, sometimes conflicting, processes. Chemical and biological oxidation-reduction reaction convert mercury between the gaseous Hg^0 which is volatile and can escape to the atmosphere and aqueous Hg^{2+} . The loss of H^0 (photochemical reduction) generally decreases the amount of H_2^+ available for methylation, and can limit the formation of MeHg. Other factors influencing production or reduction of methylmercury in natural systems include:

Photodemethylation – the process by which MeHg is degraded photolytically by solar radiation resulting in its conversion to gaseous Hg^0 and Hg^{2+} . This is influenced by:

- Light intensity, attenuation and quality (depth of water) – influences the rate of photodemethylation;

- Dissolved organic matter (DOM) (quantity and quality) – higher DOM content reduces light;
- Ions such as Cl^- and Fe^{3+} - influence rates of methylation and demethylation with Cl^- resulting in lower rates and Fe^{3+} increasing the rate; and
- Activity of microbes – the influence of microbial activity is often inferred as it is indistinguishable from bioavailability of Hg^{2+} .

Physical factors which vary significantly in the natural environment that influence the degree of methylation and demethylation include: temperature, oxidation/reduction due to multiple processes including sulphate/sulphide interactions and pH.

Biological processes – can result in reduction of MeHg through reductive demethylation and oxidative demethylation which are, in part moderated by sulphate and sulphide, but which can also be moderated by other redox pairs.

4.5 Implications of Competing Processes on Methylmercury in Marmion Reservoir

The balance between all of the processes described above determines the net methylmercury concentrations. To date, predictive evaluations have primarily been completed in laboratory settings or in well controlled study areas, in small systems, testing single variables while holding other variables constant. There are several recommendations for continued study to better understand how these processes may influence freshwater systems as described in section 6.5 of CMSA 2016.

Given the variety of processes all working together in competing ways, it is not possible to accurately determine how small changes to large complex systems (i.e. Marmion basin), such as increasing sulphate values by 0.2 to 0.3 mg/L within portions of Marmion basin over a baseline which varies substantially between <0.3 to 6 mg/L will influence the overall methylmercury concentration in the overall basin.

It is expected that the small incremental and reversible change with respect to sulphate concentrations due to operation of the mine will have minimal, if any influence, on the overall methylmercury concentrations in the reservoir. Rather, it is expected that the more influential processes will include the continued fluctuation of water levels due to operation of the Raft Lake Dam, inputs from the natural environment, and photodemethylation. Given the concern, however CMC is willing to work with the GRT, public and first nations on this issue, as indicated in Section 6.

5.0 RESPONSES TO MOECC LETTER OF MARCH 16, 2017

A letter from MOECC (March 16, 2017), requested additional information on a number of aspects related to implications of sulphate discharge on mercury levels in Marmion Reservoir as follows:

MOECC Request

- Provide the predicted sulphate levels in the effluent at discharge through modelling (including consideration of mixing zones and adjacent areas which may have potential for increased methylation).

Response: Model results for sulphate by lake zone, including overall basin mixing and mixing within the vicinity of the diffuser are provided in Figures 1 and 2 (attached) which are based on the near-field mixing modelling (Golder 2013) and the basin-wide mixing modelling completed and described in the Lake Water Quality TSD and

presented in the Lake Water Quality TSD, Version 2, Appendix 2.III. We have provided results for an assumed final effluent discharge concentration of 250 mg/L, under worst case condition.

As can be observed in these figures, within less than 100 m of the diffuser concentrations decrease to 1.9 mg/L, within 0.3 mg/L of the Marmion Reservoir concentration average concentration 1.6 mg/L. Areas near the diffuser are in open water and will not be near areas where rising and falling water levels will influence exposed shoreline.

Further from the near-field mixing zone concentrations are within the typical range (1.0 to 2.9 mg/L) of concentrations observed in Marmion Reservoir.

Concentrations of upstream locations and within the basin are variable and often greater than the projected mixed water quality (e.g. HGRWQ-28 upstream of the site ranges from ranges from 1.8 mg/L to 3.1 mg/L sulphate). A summary of the range of sulphate values observed under baseline condition by sub-basin (see Water and Sediment Quality TSD, Appendix 2.III) is as follows:

Marmion Reservoir (overall) 1.0 mg/L – 2.9 mg/L

Premier Lake – 2.1 mg/L – 2.5 mg/L

Lynxhead bay – 1.3 mg/L – 1.7 mg/L

Turtle bay – 1.4 mg/L – 1.8 mg/L

Hawk bay – 1.3 mg/L – 1.7 mg/L

Light Bay 1.9 mg/L – 2.9 mg/L

Sawbill Bay 1.4 mg/L – 1.8 mg/L.

MOECC Requests

- Examine the potential for mercury uptake by large bodied fish (walleye, northern pike, and smallmouth).
- Assess how mercury levels in fish may be impacted as a result of the discharge.

Response: Given the minor changes in sulphate concentration within the overall basin, the multiple competing processes of mercury release / depletion, and the current body of academic knowledge it is not scientifically possible for CMC, or any other academic researcher to reasonably or definitively determine the potential change in mercury uptake by large bodied fish as influenced by the slight changes in sulphate within a basin the size and complexity of the Marmion Reservoir.

The Metal Mining Effluent Regulations (MMER) under the Fisheries Act requires metal mines to conduct Environment Effects Monitoring (EEM) as a condition governing the authority to deposit effluent. The Hammond Reef Project will design an appropriate EEM program in consultation with the associated regulators. EEM studies are designed to detect and measure changes in aquatic ecosystems (i.e., receiving environments). The metal mining EEM program is an iterative system of monitoring and interpretation phases that is used to assess the effectiveness of environmental management measures, by evaluating the effects of effluents on fish, fish habitat and the use of fisheries resources by humans. Long-term effects are assessed using regular cyclical monitoring and interpretation phases designed to investigate the impacts on the same parameters and locations. In this way, both a spatial and temporal characterization of potential effects to assess changes in receiving environments are obtained. Study elements include fish population and fish habitat assessments, benthic invertebrate surveys, fish

tissue analyses, effluent characterization, sub-lethal toxicity and water quality monitoring. In addition, should the project proceed, CMC will work with government and academic institutions and researchers to evaluate the merits of other potential studies within this rapidly developing field.

MOECC Request

- Identify mitigation measures planned for potential impacts:

Response: It is difficult at this time to identify mitigation measures given that:

- fish are currently impacted as a result of the operation of the reservoir (flooding and changing of water levels leading to mercury release);
- ii) the degree of impairment or impact attributable to the existing operations of power producers is ill-defined;
- iii) sulphate is generated through cyanide treatment, and that sulphate itself is very difficult or impossible to effectively treat;
- iv) expected changes in sulphate concentrations in the basin are minor (within the natural range of the basin), and
- v) due to the competing processes at play, it is not scientifically possible to accurately define the impact attributable to the Project or to sulphate concentration increase.

Should the project proceed, it is proposed that mitigation be a multi-stakeholder concern with all parties undertaking activities that influence the water quality in Marmion Reservoir and be based on ongoing monitoring results of mercury in fish tissue. We recommend that mitigation be focused on the human receiver such that intake of mercury through consumption be managed through continued monitoring and updating of the Ontario fish consumption guidelines to appropriately recommended intake of fish caught from the Marion Reservoir, similar to the current mitigation in place for all Ontario lakes. CMC would be willing to work with regulators and academic institutions to study this issue and provide data and resources, along with other stakeholders, to develop the appropriate guideline values.

MOECC Request

- Identify monitoring plans for both.

Response:

CMC proposes the following monitoring be completed.

- Ongoing monitoring of discharge water quality and basin water quality as determined through the Environmental Compliance Approval (ECA) permitting process;
- Periodic re-evaluation of fish tissue mercury levels as part of a formal Environmental Effects Monitoring (EEM) program. Should the project proceed and water quality monitoring indicate sulphate concentrations are higher than predicted, a more frequent fish tissue monitoring program would be developed in consultation with the relevant regulatory agencies and First Nations communities.

6.0 CLOSING STATEMENT

CMC recognizes and appreciates concerns with respect to sulphate release and its potential influence on methylmercury generation. However, for a basin such as the Marmion Reservoir, which has many natural inputs of mercury (e.g. upstream wetlands), a large surface area which influences photo-demethylation, and fluctuating water elevations due to operation of the Raft Lake Dam, it is not possible to isolate the overall influence of one process over another to accurately predict potential changes over time that may result from minor changes in sulphate concentrations.

Should the project proceed, CMC is committed to work with the regulating authorities and First Nations on this important issue. Other parties with activities on the Marmion Reservoir should also be included in this process. Should fish tissue mercury levels rise relative to the already impacted fish tissue concentrations CMC is committed to working with the regulators to provide data with which to update the safe consumption guidelines for fish in Ontario such that the public and First Nations communities can continue to safely enjoy this resource.

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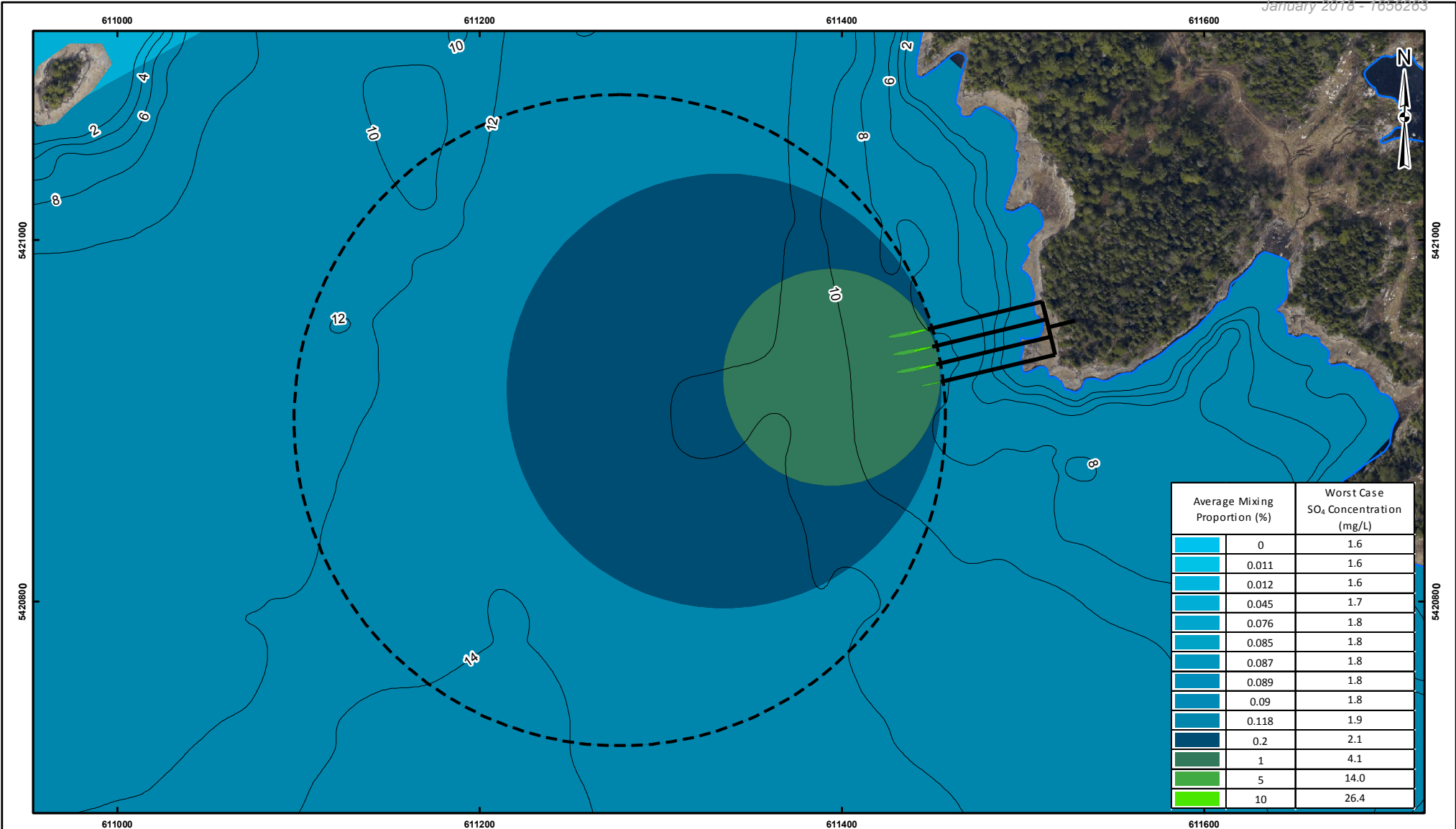
ATTACHMENTS:

Figure 1: Maximum Extent of Plume Dilution Near Outfall

Figure 2: Predicted Long Term Average Effluent Concentrations

AA/KDV/sk

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Average Mixing Proportion (%)	Worst Case SO ₄ Concentration (mg/L)
0	1.6
0.011	1.6
0.012	1.6
0.045	1.7
0.076	1.8
0.085	1.8
0.087	1.8
0.089	1.8
0.09	1.8
0.118	1.9
0.2	2.1
1	4.1
5	14.0
10	26.4

LEGEND

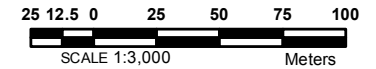
- Conceptual Effluent Pipeline
- Bathymetry Contour
- Shoreline

REFERENCE

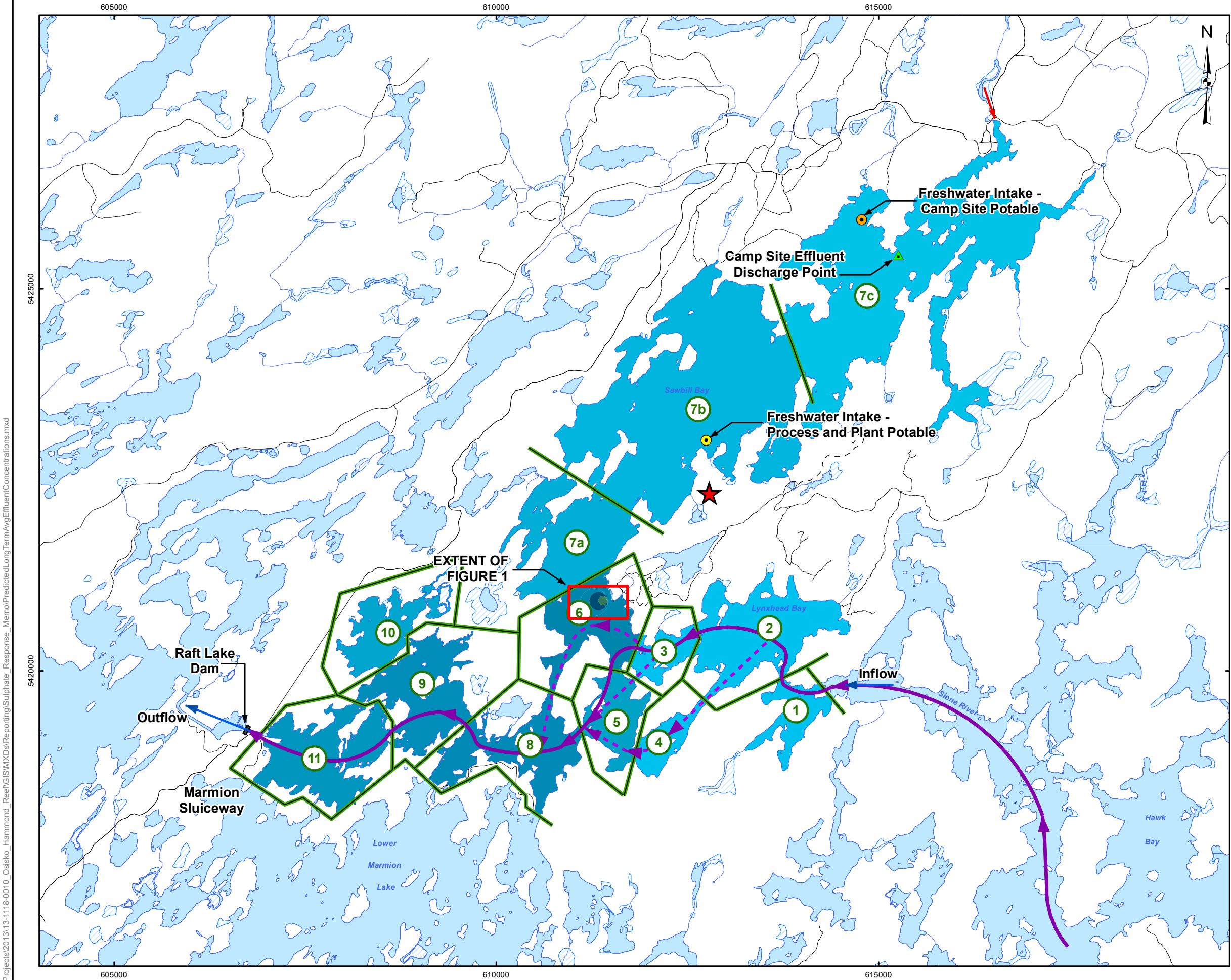
Base Data - Provided by OSISKO Hammond Reef Gold Project Ltd
 Base Data - MNR NRVIS, obtained 2004
 Produced by Golder Associates Ltd under licence from
 Ontario Ministry of Natural Resources, © Queens Printer 2008
 Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15N

NOTE:

Plume dilution shown for maximum design discharge (Q = 0.12m³/s)



PROJECT		HAMMOND REEF GOLD PROJECT ATIKOKAN, ONTARIO, CANADA	
TITLE		MAXIMUM EXTENT OF PLUME DILUTION NEAR OUTFALL	
 Golder Associates Mississauga, Ontario	PROJECT NO. 13-1118-0010	SCALE AS SHOWN	VERSION 2
	DESIGN CGE 16 Mar. 2012	<p style="text-align: center; font-size: 24pt; font-weight: bold;">FIGURE: 1</p>	
	GIS JO/PR 18 May. 2017		
	CHECK AA 18 May. 2017		
REVIEW AA 18 May. 2017			



LEGEND

- ★ Proposed Location of Mine Processing Plant
- ▲ Effluent Discharge Point
- Freshwater Intake - Camp Site Potable
- Freshwater Intake - Process and Plant Potable
- Main River Flow
- Secondary Flow Path
- Major Tributaries
- Road
- River/Stream
- Lake
- ▨ Wetland
- ① Model Compartment

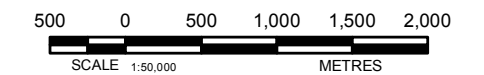
Average Mixing Proportion (%)	Worst Case SO ₄ Concentration (mg/L)
0	1.6
0.011	1.6
0.012	1.6
0.045	1.7
0.076	1.8
0.085	1.8
0.087	1.8
0.089	1.8
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1	4.1
5	14.0
10	26.4

NOTE:

Plume dilution shown for maximum design discharge (Q = 0.12m³/s)

REFERENCE

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 Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15N



PROJECT		HAMMOND REEF GOLD PROJECT ATIKOKAN, ONTARIO, CANADA	
TITLE		PREDICTED LONG TERM AVERAGE EFFLUENT CONCENTRATIONS	
Golder Associates Mississauga, Ontario	PROJECT NO.	13-1118-0010	SCALE AS SHOWN
	DESIGN	OGE 14 Nov. 2008	VERSION 2
	GIS	JO/PR 18 May. 2017	FIGURE: 2
	CHECK	AA 18 May. 2017	
REVIEW	AA 18 May. 2017		

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