ARCADIS Design & Consultancy for natural and built assets

Environmental Monitoring Advisory Board

AIR QUALITY MONITORING REPORT REVIEW

Review of DDMI 2014-2015 Consolidated Environmental Air Quality Monitoring Report

July 2016

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Consolidated Environmental Air Quality

Monitoring Report

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1 INTRODUCTION

As requested by the Environmental Monitoring Advisory Board (EMAB), Arcadis Canada Inc. (Arcadis) undertook a review of the 2014-2015 Consolidated Environmental Air Quality Monitoring Report (AQMR) [ERM 2016a] prepared for Diavik Diamond Mines (2012) Inc. (DDMI). The report summarizes the air quality monitoring activities conducted at the Diavik diamond mine during 2014 and 2015. This includes the following:

- The total suspended particulate (TSP) continuous monitoring program;
- The dustfall monitoring and snow core sampling program; and,
- The National Pollutant Release Inventory (NPRI) and greenhouse gas (GHG) emissions inventories.

The aspects of the AQMR included within Arcadis' review include the following:

- Applicability of study design and methodology to achieve objectives;
- Quality of data and analyses;
- Defensibility of conclusions; and,
- Issues raised by the report.

Arcadis completed a review of each of the above components of the air quality monitoring program in place at the Diavik diamond mine, as described in the ERM [2016a] report. The following sections outline the findings of the review. The report concludes with a summary of key findings and recommendations for future monitoring activities.

2 DISCUSSION

The review of the AQMR is discussed in terms of monitoring design, data quality, representation of data in relation to station locations, effectiveness of monitoring dust suppression, comparison to modelling results, and integration of operational information.

2.1 Continuous TSP Monitoring

Continuous air monitoring (CAM) was commissioned in April 2013 at two sampling locations: 1) the communications building adjacent to the accommodations complex; and 2) the A154 dike along the southeast corner of the A154 pit. The locations were based on the results of an updated air dispersion modelling analysis and the proximity to the Project footprint. A beta attenuation monitor (BAM) is used to measure TSP at the CAM stations.

Our comments with respect to continuous TSP monitoring are presented in Table 1.

Table 1. Review of Continuous TSP Monitoring

No.	Comment
1.	**AQMR, Page 2-2:** *"The location of the A154 Dike monitor and the site near the CB was selected based on the proximity to the boundary of the Project footprint and the results of the updated air dispersion modelling assessment and power requirements."* The appropriateness of station location cannot be confirmed based on modelling predictions since modelling predictions were not submitted as part of the AQMR. Based on the prevailing winds in the windrose from 2015 meteorology and facility layout shown in Figure 2.1-1, the station locations may not be appropriate to capture the maximum TSP concentrations. The current set up of stations is based on predominantly westerly winds. An analysis of meteorology of several years should be conducted to determine if the 2015 meteorology is typical. If the meteorology of 2015 is the norm, then an examination into moving the stations should be considered and whether it is feasible.
2.	**AQMR, Page 2-4:** *"Where applicable, observations were adjusted by ERM, as required, using the methodology in the Alberta Air Monitoring Directive Chapter 6: Ambient Data Quality (Alberta Environment and Sustainable Resource Development 2014). This included below zero adjustments for TSP concentrations; however, no baseline adjustments were performed because zero and span calibration reports were not completed in 2014 or 2015."* Calibration certificates and/or records for 2014 and 2015 should be provided with the AQMR to demonstrate that calibrations have been completed as appropriate, in accordance with the equipment manufacturers' recommendations for instrument maintenance and calibration.
3.	**AQMR, Page 2-10:** *"There were 162 and 202 days in 2014 with sufficient hourly TSP data to calculate daily mean TSP values for the CB and A154 Dike Stations, respectively. Insufficient data were available to make robust seasonal comparisons as the majority of missing data occurred during the summer at both stations."* No details were provided as to the reason for the missing data. Details on annual averages cannot be made with confidence as 56% and 45% of the data were missing for the stations. Typically, if more than 25% of data is incomplete then trends should not be estimated for these data.
4.	**AQMR, Page 2-11:** *"Values on these days were not included in the annual arithmetic mean calculation. The CB Station did not experience long periods of no results recorded like the A154 Dike Station did in 2015."* It states that missing data were not included in the annual average calculations. However, in Figures 2.3-3 and 2.3-4, missing data are displayed on the graphs as zero. This suggests that the data for these days are tabulated as zero and may be included in averaging period calculations. Missing data should be absent from the figures as in Figures 2.3-1 and 2.3-2.
5.	**AQMR, Page 2-10:** *"In 2015 at the CB Station, TSP was greater (124 µg/m3) than the 24 hr mean standard (120 µg/m3) on one (1) occasion (February 5, 2015); however, the overall annual mean (13.6 µg/m3) was lower than the annual mean standard (60 µg/m3) in 2015. These results are consistent with the prediction from the 2012 dispersion model which predicted two (2) 24 hr exceedances per year."*

	It is stated that there is one exceedance at the CB station in 2015 without any description of potential causes. In discussions on June 23 2016, it was mentioned that ice fog could be the potential cause of the spike in TSP. Further details should be provided to show that ice fog is the cause of the high measurement. The frequency of ice fog events should be analyzed and compared to TSP values to determine if higher values occur during periods of ice fog. Are there systems in place to prevent artificial spikes due to weather conditions such as ice fog? If so, why did they not function in this instance? Overall, a detailed explanation of the TSP spike should be included. Furthermore, there is not enough information provided in the report to compare monitored values to modelled values. The statement that monitored data are in agreement with the 2012 model predictions cannot be verified by the reader. It is recommended that the dispersion modelling report be attached as an Appendix, such that the reader can view it when it is referenced in the AQMR.

2.2 Dustfall and Snow Core Sampling

The dustfall monitoring and snow core sampling programs were implemented in 2001 under the Aquatic Effects Monitoring Program (AEMP) as a means of collecting information on dust deposition with distance from mining activities. A summary of the 2014-2015 results is provided in the AQMR, while details are provided in Appendix A, *Diavik Diamond Mine 2015 Dust Deposition Report* (DDMDDR) prepared by ERM [2016b]. With no guidance in the NWT for dustfall, the AQMR compares Diavik dustfall levels to objectives used by the Province of British Columbia (B.C.) for the mining industry (1.7 to 2.9 mg/dm^2/day, based on a 30-day average) [B.C. MOE, 2016]. This is the same procedure used in the 2013 Air Quality Monitoring Report [Rio Tinto 2014].

Our comments with respect to dustfall and snow core sampling are presented in Table 2.

Table 2. Review of Dustfall and Snow Core Sampling

No.	Comment
6.	**AQMR, Page 3-10:** *"The predominant winds in 2014 were from the east, south, and southeast, with sporadic strong winds from the north. The 2015 predominant wind directions were largely omnidirectional with a higher frequency from the southeast and lower frequency from the southwest. The expectation is that airborne material will be deposited primarily west, north, northwest, and south of the Project as seen in Figure 3.3-1."* TSP is strongly correlated to dustfall. If dustfall is expected to occur west, north, northwest and south of the Project it is reasonable to expect the maximum TSP values to occur in those directions as well. As such, the locations of the TSP stations may not be located at the most appropriate sites for the 2014-2015 years.
7.	**AQMR, Page 3-10:** *"Fugitive dust generation is expected to be greatest during snow-free periods where and when there is site activity. It was expected that the highest fugitive dust generation and resulting dustfall occurred in areas closest to the Project footprint such as near A21 and the country rock pile between May and September."*

	Although the report states that the dustfall was collected on a quarterly basis, there seems to be a trend of higher dustfall during the spring-summer months. To get a better representation of seasonal trends and effectiveness of dust suppression, dustfall collection on a monthly basis would be useful. TSP concentrations are linked to dustfall, however, TSP concentrations do not show the same seasonal trends (magnitude) which suggests the locations of the TSP monitors were not appropriate for the 2014-2015 monitoring years.
8.	**AQMR, Page 3-12:** *"The 2012 modelling predicted maximum dustfall deposition rates are to be higher on the Project site (222.2 mg/dm2/y) than off-site (4.1 mg/dm2/y) and generally greater than originally predicted in 1998. For example, 100 mg/dm2/y was originally predicted adjacent to A154 pit [Cirrus Consultants 1998]. Dustfall measured in 2014 and 2015 exceeded the modelled predictions in the immediate vicinity of the mine infrastructure, as well as dustfall rates for off-site areas. However, the 2015 dustfall results were expected to be greater than the modelled predictions for operations because of construction activities simultaneously occurring during operations activities."* It states that monitoring values are higher than modelled predictions because construction activities simultaneously occurred during operations activities in 2015. However, on Page 3-11 of the AQMR, it states that the 2015 values are within the historical dustfall values for the site. Since monitoring data can be useful to validate or evaluate air dispersion modelling, it suggests that the appropriate parameters were not used to assess dustfall in dispersion modelling since historical values are consistently higher than model predictions.
9.	**AQMR, Page 3-13:** *"In general, average concentrations of snow water chemistry variables of interest decreased with increasing distance from the Project (ERM 2015; ERM 2016a, Appendix A). However, high and variable concentrations were observed in 2015 for aluminum, chromium, and nickel at Station SS3-8, located in the 251 to 1,000 zone, and SS4-4, located in the 1,001 to 2,500 zone. Station SS3-8 also had among the highest concentrations observed in 2014. Select metal concentrations at these two locations were more than double the concentrations recorded at the other sites, including samples collected in the 101 to 250 zone. Station SS3-8 is located to the southeast and SS4-4 is located northwest of the Project."* There is no explanation as to why aluminum, chromium and nickel have higher values than stations that are closer to the facility. In addition to these sites, a control site also had high values for these metals. It is expected that the lowest level would be recorded at the control stations, which are about 3 to 5 km away from the mine site. No explanation is offered as to why the control snow chemistry is higher than expected compared to closer sites. Control stations are typically used to represent locations where measurements return to baseline or background levels. The fact that the controls are higher suggests that the control stations may not be appropriately located if the intent is to represent background levels.
10.	**DDMDDR (ERM 2016b), page 3-1:** *"Dustfall gauges were placed at 12 stations (including two control stations) around the Project at distances ranging from approximately 25 to 5,655 metres (m) from mining operations (Table 2-1). Each gauge collected dustfall year-round, with samples were collected [sic] every three months."* It is understood based on the June 23, 2016 discussions the sampling was set up to satisfy the requirements of the Aquatic Effects Monitoring Program (AEMP). However, from an air quality

	standpoint the sampling frequency does not follow guidelines and does not provide information that may be useful to an air quality analysis. While it is likely that the mean annual dustfall rate is not significantly affected by using quarterly sampling, a reduced frequency will make it difficult to analyze monthly or seasonal trends in dustfall, as well as the effectiveness of dust suppression. It is also not appropriate to compare quarterly samples against the B.C. dustfall objective [B.C. MOE, 2013] which is intended to assess the mean daily dustfall rate averaged over a one-month period. A high reading in one month that may have exceeded the B.C. dustfall objective may be counterbalanced with lower readings in the other two months of the quarterly dustfall sample. This may result in the apparent attainment of the dustfall objective over the quarter, while entirely missing the monthly exceedance of the objective level. Quarterly sampling also does not follow the ASTM International D1739-98 (2010) Standard Test Method for Collection and Measurement of Dustfall (Settable Particulate Matter). While it is understandable that monthly dustfall sampling may be more difficult to achieve in winter months when access to the sampling sites may be restricted, this does not justify the lack of monthly sampling during the snow-free months. When practicable, adherence to the standard dustfall sampling protocols should be considered the norm.
11.	**DDMDDR (ERM 2016b):** Section 3 and *Figure 3.1-5 Dust Deposition Box Plot* It is not entirely clear how the dustfall estimates were examined. Section 3.1 suggests that the dustfall gauge values were examined separately from those measured from the snow core samples. The Box Plot (Figure 3.1-5) summarizes dustfall measured in each year, however, only one value of dustfall is examined. It is assumed that the values of the dustfall gauges and snow cores were compared some way. A clearer description of how the data were analyzed and presented would be useful.
12.	**DDMDDR (ERM 2016b):** *Table 3.1-1 2013 Dustfall and Snow Water Chemistry Results* Some of the snow water chemistry results show that the highest reported values are observed in the 251-1,000 m zone instead of the 101-250 m zone. In addition, there are some contaminants like chromium, nickel and zinc that have the lowest reported concentrations in the 1,001-2,500 m zone instead of the control zone. No explanation is provided as to why these trends are observed and if they are anomalous compared to the historical data record. An examination into potential other sources of these metals should be examined as to the potential cause of these unexpected observations. If the purpose of the sampling is to understand the impact of the Diavik mine then a better understanding of the background is important.
13.	**DDMDDR (ERM 2016b), page 3-19:** *"Of the calculated RPD values, 14 of 26 RPD values were greater than 20%, and 4 of 26 RPD values were greater than 40%. Duplicate samples from sites SS1-5 and SS3-7 had generally higher RPD values than the duplicate sample from SS4-5, which indicated that within-site variability was not correlated with distance from the mine."* Table 3.4-1 of the ERM [2016b] report provides relative percent difference (RPD) values for duplicate snow core samples. June 23, 2016 discussions provided a reasoning of natural variability as the cause of the high RPD values. A reference should be provided to support the authors' selection of an acceptable RPD threshold of 40%, particularly since the selected RPD threshold is in disagreement with available guidance. For example, the B.C. MOE field sampling manual [B.C. MOE, 2016] states that for field duplicates/replicates *"…RPD values >20% indicate*

	a possible problem, and > 50% indicate a definite problem, most likely either contamination or lack of sample representativeness." There are several samples in Table 3.4-1 with RPDs greater than 20% which according to B.C. MOE guidance, should be investigated. No other explanation is given other than that within-site variability is not correlated to the distance from the mine. Reasoning for inclusion of these samples with high RPD values should be included.
14.	**DDMDDR (ERM 2016b), Appendix E and Appendix F** Standard operating procedures (SOP) for dust gauge collection and snow core sampling are provided in Appendix E and F, respectively, of the ERM [2016b] report. While Section 6.3 of the snow survey SOP outlines QA/QC measures to follow in the field, including collecting duplicates and blanks, there is no mention of such QA/QC procedures in the dust gauge collection SOP. A QA/QC procedure should be adopted in the dust gauge collection SOP to ensure the field sampling does not contain any significant in-situ variability. The dust gauge and snow survey SOPs refer to an external SOP for the total suspended solids (TSS) laboratory procedure. Without the TSS SOP or detailed laboratory records, Arcadis is unable to comment on whether the DDMI laboratory uses acceptable standards/methods on par with an accredited laboratory. For example, an accredited laboratory would adhere to a filter preparation method that requires calibration of the scale traceable to a National Institute of Standards and Technology (NIST) standard. This should be part of the DDMI TSS SOP. The TSS SOP and all laboratory calibration certificates and/or records should be included with the AQMP report to demonstrate that laboratory calibrations and laboratory QA/QC have been completed as appropriate.
15.	**DDMDDR (ERM 2016b), Appendix "B"** Appendix "B" Total Suspended Particulates Sampler Support Memorandum (note, this should be Appendix G) provides details on the acknowledgement that TSP monitoring is not being operated efficiently. It provides details on the number of negative values measured at the TSP monitoring sites. All values between -5.0 and 0.0 µg/m^3 were set to zero and values below this were removed from the data set. However, since it is acknowledged that the TSP monitors were not functioning properly, setting values between -5.0 and 0.0 µg/m^3 may be artificially producing lower 24-hour and annual TSP values. In 2015, the A154 site and CB site had 20% and 11% of the values set to zero, respectively.
16.	**DDMDDR (ERM 2016b), Appendix "A" Field Data Calibration Sheets, Appendix "B" TSP Sampler Standard Operating Procedures and "Appendix C" CD Nova Service Report** The author provides draft versions of calibration reports, TSP monitoring SOP and Service Reports. These documents should be finalized and used during the operation of the TSP monitoring station. All SOP documents should be finalized and included in Air Monitoring Reports in order for the reviewer to assess methods and ensure compliance with relevant guidance.

2.3 NPRI and GHG Emission Inventories

Emissions for CO, SO_2, NO_X, VOC, TSP, PM_{10} and $PM_{2.5}$ were estimated for 2014 and 2015 and reported to Environment Canada under the NPRI reporting system. In addition, GHG emissions were calculated and reported to the federal system through Environment Canada.

Our comments with respect to NPRI and GHG emission inventories are presented in Table 3.

Table 3. Review of NPRI and GHG Inventories

No.	Comment
17.	**AQMR - Section 4: National Pollutant Release Inventory** and **Section 5: Greenhouse Gas Reporting** The results of the NPRI and GHG emissions inventories are discussed in Sections 4 and 5 of the AQMR, respectively. The AQMR does not include any detailed information about the emission factors or calculation methodologies used for either of the inventories and, as a result, Arcadis is unable to comment on the appropriateness of the calculations used in the inventories. However, upon comparison with other mines in the NWT, namely EKATI and Snap Lake, it was found that DDMI emissions are similar in magnitude to these sites. Based on this finding, Arcadis considers the values reported by DDMI to be reasonably correct, although a review of the methods used to derive these estimates would be required to confirm their appropriateness.

3 CONCLUSIONS AND RECOMMENDATIONS

3.1 Conclusions

There are a number of improvements that could be made in monitoring procedures and analysis noted in the review of the DDMI *2014-2015 Consolidated Environmental Air Quality Monitoring Report* and some generalizations and comments made that are not supported by the data. The main points of concern are summarized below:

<u>General Comments</u>

- Many of the comments provided in the previous review of the 2013 Air Quality Monitoring Report were not sufficiently addressed in the 2014-2015 report.
- There was not enough information provided in the AQMR to draw any conclusions about the validity of the revised dispersion modelling or the effectiveness of dust suppression activities.
- The AQMR provided little or no discussion about temporal variability in the TSP and dustfall data, other than to say that there was increased TSP and dustfall during operations. This type of analysis would help to evaluate the effectiveness of dust suppression efforts at the mine.
- Even though there were some attempts to include QA/QC protocols and SOPs for some aspects of monitoring, the report lacks detailed and final QA/QC procedures for the continuous TSP monitor and dustfall sampling program, including the laboratory procedures used to analyze TSS.

Continuous TSP Monitoring Program

- QA/QC issues are evident in the continuous TSP monitoring program. Calibration issues are apparent with the BAM used to measure TSP, as there were several instances throughout the 2014-2015 monitoring period where concentrations were less than zero. This data quality issue makes the validity of the entire TSP data set questionable. The author has recognized this as an issue and has produced a recent memorandum describing the issues.
- The locations of the TSP monitoring stations may not be adequately placed as dustfall monitoring suggested high values in the west, north and south. It is expected that TSP would follow the same pattern.
- The authors provided the possible cause for one TSP exceedance as being ice fog, with that value considered to be an outlier. Further analysis into ice fog impacts should be conducted to determine frequency and magnitude of interference from ice fog. This type of analysis would help to identify whether or not other on-site or off-site activities, or operational issues, are leading to spikes in TSP concentrations that may be indicative of a potential problem with dust generation at the mine site.

Dustfall Monitoring Program

- Quarterly dust gauge sampling does not follow standard reference methods and makes it difficult to examine air quality trends in the data or evaluate the effectiveness of dust suppression.
- The representativeness of the snow core sampling program is questionable. The control stations do not always show the lowest snow chemistry results which suggests that the control stations are not a good representation of background values. In addition, the RPD values presented for duplicate snow cores indicate a potential problem with sampling representativeness according to B.C. MOE guidelines [B.C. MOE, 2003].
- It is our opinion that the ERM [2016b] report incorrectly combines data from the dust gauge and snow core samples when completing the statistical analysis and may under-report annual average dustfall rates shown in the box plots.
- There was no attempt to evaluate or explain temporal/spatial trends in the dustfall data or use the dustfall results to evaluate the effectiveness of the dust suppression efforts, other than to state that dustfall is highest during operations.

3.2 Recommendations

Based on the above conclusions of the review, Arcadis has the following recommendations for future AQMP activities and reporting:

- Going forward, DDMI needs to include a detailed summary of QA/QC practices in the report for each aspect of the monitoring program, including all laboratory procedures.
- Calibration records need to be provided for all equipment (i.e., laboratory scale, continuous monitoring equipment, etc.).
- Final SOPs need to be provided for all field sampling and laboratory methods.
- QA/QC and calibration procedures need to be reviewed for the continuous TSP monitor and a determination made where improvements may be made to ensure the measurements are reliable.

- The dust gauge collection SOP needs to be updated to include QA/QC requirements similar to the QA/QC procedure used for snow core sampling (i.e., field duplicates and blanks).
- All samples for measuring TSS need to be sieved and, if not already included, quality checking procedures need to be added to the TSS SOP to ensure that they meet the same standard that an accredited laboratory would meet.
- The sampling representativeness of the snow core sampling program needs to be investigated based on RPD values greater than 40% and issues with distant sampling locations having higher measurements of specific metals.
- The TSP monitor locations need to be re-evaluated using historical meteorology and measured dustfall, since the locations do not seem to agree with 2015 meteorology or dustfall values. Locations based on modelling cannot be validated as modelling results are not presented.
- Should consider returning to monthly dustfall sampling or, at a minimum, perform monthly sampling during the snow-free periods, so that dust suppression efforts can be better evaluated.
- A clearer statistical analysis for the dust gauge and snow core dustfall data should be completed and presented.
- The current and historical dustfall monitoring results should be used to evaluate the effectiveness of dust suppression efforts.
- Available meteorological data and records of on-site activity should be used to investigate higher concentrations of ambient TSP.
- A comparison of monitored and modelled TSP/dustfall should be reported on.
- Details of the NPRI or GHG calculations should be included, or a reference to an external document containing such details provided.

4 REFERENCES

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