# Bermingham Development and Production Program

# Air Dispersion Model

September 27, 2017

Prepared for:

ALEXCO KENO HILL MINING CORP.

## ALEXCO ENVIRONMENTAL GROUP INC. SIGNATURES

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# EXECUTIVE SUMMARY

Air quality has been identified as a valued component as part of the Bermingham development and production program (the Project) environmental assessment. Air dispersion modelling was conducted for total suspended particulate (TSP), coarse particulate matter ($PM_{10}$) and fine particulate matter ($PM_{2.5}$) to address potential concerns about dust generation.

Monthly ambient air quality monitoring was initiated by AKHM in 2012 and no exceedances of the YAAQS have been observed near the Keno District Mill site or in Keno City to this date.

Air dispersion modelling was carried out using CALPUFF, a recognized and approved air dispersion model by the United States (US) Environmental Protection Agency (EPA) and the British Columbia Ministry of Environment (BCMOE). Surface meteorological data were taken from the District Mill Campbell Scientific Weather Station for the year 2013. Data from the Calumet HOBO or the Valley Tailings HOBO weather stations were also used to complete the local data record. Meteorological parameters not observed at site were obtained from Environment and Climate Change Canada (EC) Mayo A meteorological station, located about 63 km away from the project area. Upper air data were obtained from the Whitehorse airport upper air station.

Emission sources include fugitive dust from the dry stack tailings facility, mineral processing and unpaved roads. Emission rates were obtained from the US EPA AP-42: *Compilation of Air Emission Factors* (1995). The modelled scenario assumes the concurrent operation of Flame and Moth and Bermingham mines and include design mitigations (e.g. enclosures) and basic operational mitigations (e.g. road watering/dust suppressant application and progressive reclamation).

Ambient concentrations were predicted at six discrete receptors in Keno City and results are also provided graphically as ambient concentration contours.

No exceedances of the Yukon Ambient Air Quality Standards (YAAQS) were predicted at any of the receptors. Higher ambient concentrations could occur in close proximity to the sources. Air dispersion modelling results presented for 24-hour averaging periods represent the maximum predicted value over the one-year period modelled, while the annual values represent the single annual result for the modelling period. Therefore, ambient concentrations are predicted to be below the values reported the rest of the year. Overall, conservative assumptions were made to produce reasonable worst-case scenarios and confidence is high that the model is not under-predicting ambient concentrations.

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# GLOSSARY

**CALPUFF:** Advanced, integrated Lagrangian puff modelling system for the simulation of atmospheric pollution dispersion. The CALPUFF model is designed to simulate the dispersion of buoyant, puff or continuous point and area pollution sources as well as the dispersion of buoyant, continuous line sources.

**Emission Factor:** Average emission rate of a given air contaminant for a given source, relative to units of activity.

**Gaussian Puff Model:** Model assuming that the air pollutant dispersion has a Gaussian distribution, meaning that the pollutant distribution has a normal probability distribution; can be used for predicting the dispersion of non-continuous air pollution plumes (puffs).

**Lagrangian Model:** Dispersion model that mathematically follows pollution plume parcels as the parcels move in the atmosphere and that models the motion of the parcels as a random walk process. The Lagrangian model then calculates the air pollution dispersion by computing the statistics of the trajectories of a large number of the pollution plume parcels. A Lagrangian model uses a moving frame of reference as the parcels move from their initial location. It is said that an observer of a Lagrangian model follows along with the plume.

**Radiosonde:** Balloon-borne instrument platform used to measure and transmit simultaneously meteorological data while ascending through the atmosphere. The instrument consists of sensors for the measurement of pressure, temperature and relative humidity.

**Upper Air:** In synoptic meteorology and in weather observing, that portion of the atmosphere that is above the lower troposphere (the troposphere is the lowest part of the atmosphere, starting at the Earth's surface extending up to a height of 7 to 20 km).

# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AKHM | Alexco Keno Hill Mining Corp. |
| BCMOE | British Columbia Ministry of the Environment |
| DSTF | Dry Stack Tailings Facility |
| CO | Carbon Monoxide |
| EC | Environment Canada |
| ESRL | Earth System Research Laboratory |
| g | gram |
| hp | horsepower |
| hr | hour |
| kW | kilowatt |
| lb | pound |
| IPCC | Intergovernmental Panel on Climate Change |
| Mg | Megagram |
| $NO_2$ | Nitrogen Dioxide |
| NOAA | National Oceanic and Atmospheric Administration |
| $PM_{2.5}$ | Fine Particulate Matter |
| $PM_{10}$ | Coarse Particulate Matter |
| s | second |
| $SO_2$ | Sulphur Dioxide |
| TSP | Total Suspended Particulate |
| $\mu g/m^3$ | Micrograms per Cubic Metre |
| USEPA | United States Environmental Protection Agency |
| VC | Valued Component |
| VMT | Vehicle Mile Travelled |
| WHO | World Health Organization |
| WMO | World Meteorological Organization |
| YAAQS | Yukon Ambient Air Quality Standards |
| YG | Yukon Government |

# 1. INTRODUCTION

Air dispersion modelling was conducted to assess potential Project related air quality effects of the Bermingham Mine development and production program. Air quality was selected as a Valued Component (VC) because of its importance to both humans and wildlife. Specifically, this report focusses on particulate matter to address potential concerns about dust generation. Modelling results will inform effect characterization, evaluate the effectiveness of the mitigation measures and support the identification of residual effects. This report presents the methodology and results for the air dispersion model prepared for the Project.

# 2. YUKON AMBIENT AIR QUALITY STANDARDS

Yukon Government (YG) implemented Ambient Air Quality Standards (YAAQS) for $SO_2$, TSP, CO, $PM_{2.5}$ and $NO_2$ in 2010, and more recently for $PM_{10}$ (YG, 2014). $PM_{10}$ and $PM_{2.5}$ represent the coarse and fine fractions of TSP, respectively. $PM_{10}$ (aerodynamic diameter of less than 10 µm) is the fraction of TSP (total suspended particulate) that is inhalable, and therefore have the potential to cause adverse health effects. Fine particles (aerodynamic diameter of less than 2.5 µm) are able to penetrate deeper into the lungs and are generally considered a stronger risk factor than the coarse fraction of $PM_{10}$ (particles in the 2.5-10 µm range) (WHO, 2013).

YAAQS for TSP, $PM_{10}$ and $PM_{2.5}$ and associated averaging periods are presented in Table 2-1.

**Table 2-1: Yukon Ambient Air Quality Standards (µg/m$^3$)**

| Parameter | 24-hour | Annual |
|---|---|---|
| TSP | 120 | 60 |
| $PM_{10}$ | 50 | n/a |
| $PM_{2.5}$ | 28 | n/a |

# 3. EXISTING CONDITIONS

## 3.1 METEOROLOGY

Local meteorological conditions at site were described in detail as an appendix to the project proposal "2016 Meteorological Data Summary, Keno, YT", and can be summarized as follows:

- Average Annual Temperature between -4°C and -1°C;
- Monthly Maximum Temperature generally in June or July between 17°C and 19°C;
- Monthly Minimum Temperature generally in December or January between -17°C and -27°C;
- Extreme Temperatures ranging from -41°C to 31°C;
- Total Annual Precipitation between 278 and 297 mm;
- Average Wind Speed at 10 meters of about 1.3 m/s;

- Maximum Hourly Wind Speeds up to 19 m/s; and
- Dominant Wind Directions: NNE and SE.

The three local meteorological stations are shown on Figure 3-1 below.

## 3.2 AIR QUALITY

### 3.2.1 MONITORING BY AKHM

Total suspended particulates (TSP) monitoring was initiated by AKHM at two locations near the Keno District Mill site in August 2012 and a third sampler, located in Keno City, was commissioned in December 2014. Additional sampling for coarse and fine fractions of particulate matter ($PM_{10}$ and $PM_{2.5}$ respectively) was instigated in August 2015 at the three stations (see locations on Figure 3-1).

Air quality monitoring results are presented in detail as an Appendix to the Project Proposal, "Air Quality Data Summary, Keno, YT", and are summarized in Table 3-1 below.

**Table 3-1: 24-hour TSP, $PM_{10}$ and $PM_{2.5}$ Summary Statistics, August 2012 – December 2016**

| | TSP (µg/m³) | | | $PM_{10}$ (µg/m³) | | | $PM_{2.5}$ (µg/m³) | | |
|---|---|---|---|---|---|---|---|---|---|
| Yukon Ambient Air Quality Standards | 120 | | | 50 | | | 28 | | |
| Sampling Location | TSP-1* | TSP-2 | TSP-3 | TSP-1 | TSP-2 | TSP-3 | TSP-1 | TSP-2 | TSP-3 |
| Average | 6.0 | 6.8 | 6.1 | 3.2 | 3.3 | 3.1 | 4.1 | 4.2 | 4.0 |
| Count | 168 | 155 | 78 | 43 | 35 | 43 | 41 | 35 | 40 |
| Minimum | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 |
| Maximum | 53.2 | 62.2 | 68.1 | 14.6 | 8.6 | 8.2 | 17.4 | 23.1 | 13.6 |
| Geometric Mean | 4.5 | 4.9 | 4.2 | 3.0 | 3.1 | 3.0 | 3.5 | 3.3 | 3.5 |
| Count <DL | 105 | 90 | 53 | 41 | 32 | 40 | 33 | 31 | 33 |
| Standard Deviation | 6.6 | 7.3 | 9.1 | 1.9 | 1.6 | 1.1 | 3.2 | 4.6 | 3.0 |
| 1st Quartile | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 |
| Median | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 |
| 3rd Quartile | 7.1 | 8.1 | 6.3 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 |
| Count Over Standard | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| % Over Standard | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

** One outlier result was removed (976.4 µg/m³ on July 1, 2015)*

#### *3.2.1.1 Background Concentrations*

Average background ambient 24-hour concentrations were calculated using only data collected during periods when no mining or exploration activities were taking place. Periods of care and maintenance include September 24, 2013 to

March 25, 2014 and November 19, 2014 to December 31, 2016. Because no relevant data are available for longer averaging periods, conversion factors shown in Table 3-2 were used to estimate annual averages, as recommended by the US EPA (EPA, 1992). Resulting background concentrations (averaged over the three stations) used in the model are presented in Table 3-3 below.

**Table 3-2: Averaging Time Conversion Factors (EPA, 1992)**

| Averaging Time | Multiplying Factor (1 hour average x the multiplying factor) |
|---|---|
| 3 hours | 0.9 (±0.1) |
| 8 hours | 0.7 (±0.2) |
| 24 hours | 0.4 (±0.2) |
| Annual | 0.08 (±0.02) |

**Table 3-3: Air Contaminants Background Concentrations used in Model (μg/m$^3$)**

| Contaminant | Background Concentration | |
|---|---|---|
| | 24-hour | Annual |
| TSP | 5.9 | 1.2 |
| $PM_{10}$ | 3.2 | 0.6 |
| $PM_{2.5}$ | 4.1 | 0.8 |

### 3.2.2 Monitoring by Yukon Government (YG)

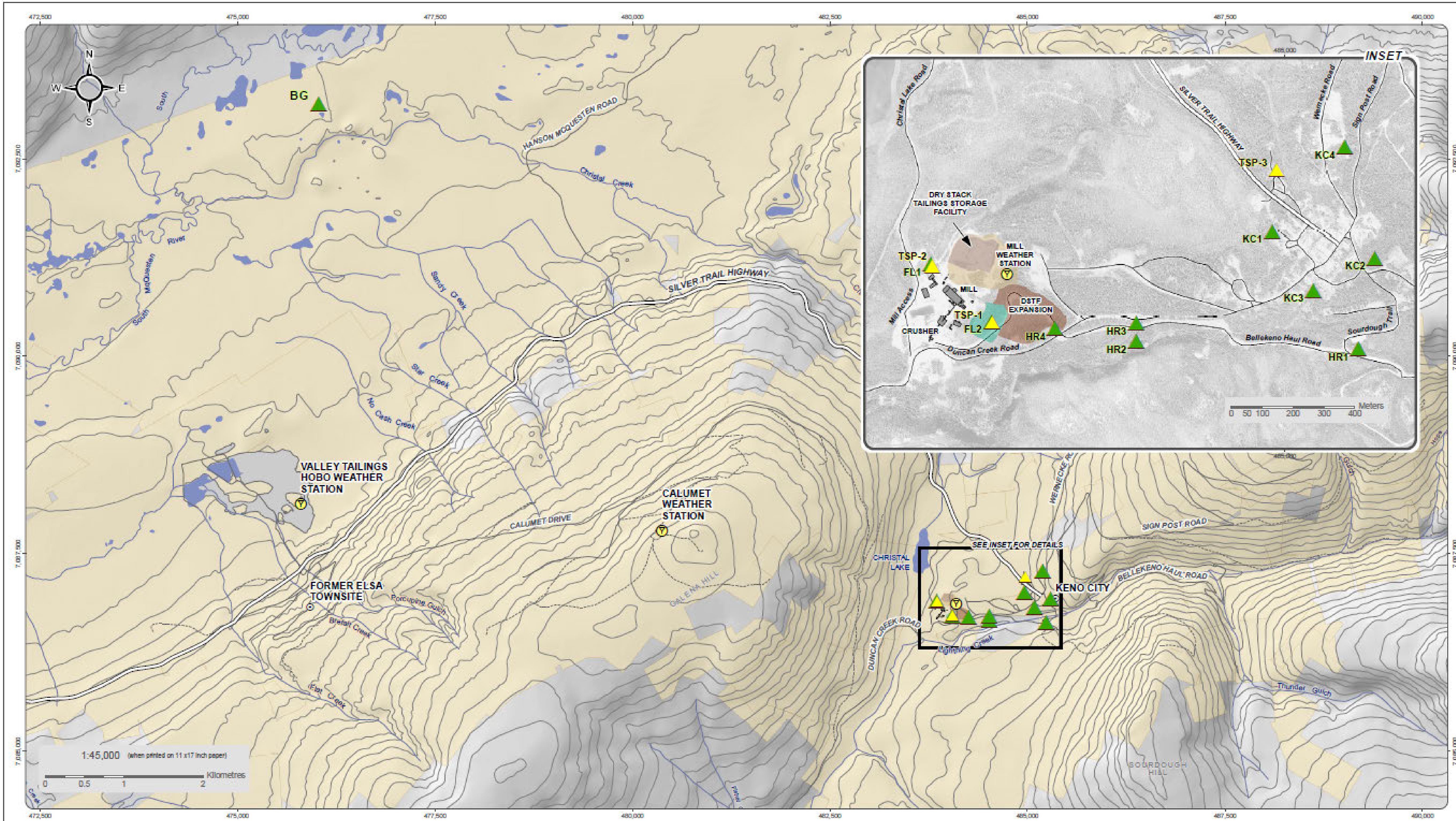
Independent $PM_{10}$ sampling was conducted by Yukon Government in 2013 at the locations shown in Figure 3-1. The station labelled BG represents background (8 km outside of Keno), stations labelled KC are located in Keno City, stations labelled HR are along the Bellekeno Haul Road and stations labelled FL are fence line stations and correspond to TSP-1 and TSP-2 locations. 5-minute data averaged over the different sampling periods are presented in Table 3-4 below. The sampling period varies between sites (ranges from about 14 to 53 hours) but for comparison purposes, the average results are all below the 24-hour YAAQS of 50 μg/m$^3$. Note that in some cases the measured background $PM_{10}$ concentration is higher than that measured at some of the receptors, suggesting that there is some variability in the data and that the difference between background and receptors sites may not be significant.

**Table 3-4: Average $PM_{10}$ concentrations (μg/m³)**

| | June 11-13 | July 15-17 | August 21-22 |
|---|---|---|---|
| BG | 2.8 | 10.2 | 3.8 |
| KC1 | 6.2 | | |
| KC2 | 3.8 | | |
| KC3 | 8.3 | | |
| KC4 | 2.1 | | |
| HR1 | | 5.2 | |
| HR2 | | 2.1 | |
| HR3 | | 13.8 | |
| HR4 | | 16.4 | |
| FL1 | | | 0.8 |
| FL2 | | | 39.3 |

*Source: Yukon Government, 2014*

Data presented in Table 3-4 were obtained from Yukon Government and not collected by Alexco, therefore details of the collection have not been presented within this report. Data are assumed to be accurate and valid, but potentially not representative of all conditions observed over a year due to the limited dataset.

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- Alexco TSP Monitoring Stations
- YG PM10 Monitoring Sites 2013
- Weather Station
- Alexco/ERDC Quartz Claims
- Proposed Features
- DSTF 322k Tonnes Design
- Current DSTF
- DSTF Phase II Expansion
- Existing Building
- Valley Tailings
- Waterbody
- Watercourse
- Silver Trail Highway
- Other Road
- Limited-Use Road

AKHM

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**FIGURE 3-1**

**METEOROLOGICAL AND AIR QUALITY MONITORING STATIONS LOCATION**

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# 4. AIR DISPERSION MODELLING

"CALPUFF" is a Gaussian puff model that can account for time- and space-varying meteorological conditions, different source configurations and contaminants, and chemical transformations. […] It can be applied to model near field effects (in the order of tens of metres) to transport distances of hundreds of kilometres." (BCMOE, 2008). The modelling system consists of three main components and a set of preprocessing and postprocessing programs. The main components of the modelling system are CALMET (a diagnostic 3-dimensional meteorological model), CALPUFF (an air quality dispersion model), and CALPOST (a postprocessing package).

CALPUFF is recommended in the B.C. Guidelines for Air Quality Dispersion Modelling in British Columbia (BCMOE, 2008) and by the U.S. Environmental Protection Agency in its Guideline on Air Quality Models (USEPA, 2014). As such, it was selected for this modelling exercise.

## 4.1 INPUT DATA

### 4.1.1 METEOROLOGICAL DATA

#### *4.1.1.1 Surface Data*

Surface meteorological data were taken from the District Mill Campbell Scientific Weather Station for the year 2013. Of the three weather stations on site, it has the most complete data record for that year, and the anemometer height is 10 m, which is the height recommended for air dispersion modelling. Data from the Calumet HOBO or the Valley Tailings HOBO weather stations were also used to complete the local data record (wind speed measured at 3 m was corrected for a 10 m height). Meteorological parameters not observed at site (cloud ceiling height and cloud opacity) were obtained from Environment Canada Mayo A meteorological station (Climate ID: 2100700), located about 63 km away from the project area.

#### *4.1.1.2 Upper Air Data*

Twice daily upper air radiosonde data for 2013 were obtained from the Whitehorse airport upper air station (WMO Station ID: 71964) through the NOAA/ESRL Radiosonde Database.

### 4.1.2 DUST SOURCES

#### *4.1.2.1 Dry Stack Tailings Facility (DSTF)*

The permitted but yet to be constructed DSTF phase II area (see Figure 4-1) was modelled as an area sources in CALPUFF. It was assumed that the existing DSTF would be fully reclaimed and that no more than 50% of the area of the phase II DSTF (corresponding to about 13 ha) would be exposed at any given time, due to progressive reclamation. The average height of the DSTF was assumed to be 10 m.

Emission factors for wind erosion of exposed surfaces were obtained from EPA's AP-42 Table 11.9-4 (EPA, 1998), and particle size multipliers were provided in Section 13.2.5.3 of EPA's AP-42 (EPA, 2006). They are presented in Table 4-1 below.

**Table 4-1: Emission Factors for Wind Erosion of Exposed Surfaces**

| Contaminant | Emission Factor (Mg/hectare/yr) | Emission Factor (kg/m$^2$/h) |
|---|---|---|
| TSP | 0.850 | 9.703E-06 |
| $PM_{10}$ | 0.425 | 4.852E-06 |
| $PM_{2.5}$ | 0.064 | 7.277E-07 |

#### *4.1.2.2 Mineral Processing*

The main processes taking place at the mill and crusher include primary and secondary crushing, wet grinding and various material transfers and handling. EPA's AP-42 Table 11.24-1 (EPA, 1998) provides emissions factors for metallic minerals processing for TSP and for $PM_{10}$. Emission factors for $PM_{2.5}$ were obtained applying the particle size multiplier provided in Section 13.2.5.3 of EPA's AP-42 (EPA, 2006). Because the average moisture content of the ore entering the crusher is 4%-5%, it is considered high-moisture ore according to the definition in Section 11.24.2 of EPA's AP-42 and the corresponding emission factors were used. It was assumed that material was transferred on average three times throughout the process, and that the average throughput would be 400 tonne/day. The crusher was modelled as a volume source in CALPUFF.

As a dust mitigation measure, Alexco plans and commits to enclose the crusher in a ventilated building prior to resuming operations at the Keno District Mill. Theoretically, a total enclosure would reduce dust emissions by close to 100% (WRAP Handbook, 2006); however, a control efficiency of 75% was assumed in the model, for conservatism and to account for traffic in and out of the building and other potential fugitive sources. Table 4-2 presents the resulting emissions factors.

**Table 4-2: Emission Factors for Metallic Mineral Processing**

| Process | TSP | | $PM_{10}$ | | $PM_{2.5}$ | |
|---|---|---|---|---|---|---|
| | kg/Mg | kg/hr | kg/Mg | kg/hr | kg/Mg | kg/hr |
| Primary Crushing | 0.01 | 0.17 | 0.004 | 0.067 | 0.00075 | 0.0125 |
| Secondary Crushing | 0.03 | 0.5 | 0.012 | 0.2 | 0.00225 | 0.0375 |
| Wet Grinding | Negligible | Negligible | Negligible | Negligible | Negligible | Negligible |
| Material Handling and Transfer | 0.005 | 0.083 | 0.002 | 0.033 | 0.000375 | 0.00625 |
| TOTAL (no control) | 5.500E-02 | 0.917 | 2.200E-02 | 0.367 | 4.125E-03 | 0.069 |
| TOTAL (with control) | 1.375E-02 | 0.22917 | 5.500E-03 | 0.09167 | 1.031E-03 | 0.01719 |

#### *4.1.2.3 Unpaved Roads*

Mine related traffic on unpaved roads was modelled according to estimated traffic volumes presented in the Traffic Management Plan included as an Appendix to the Project Proposal for Bermingham. The modelled scenario assumed the concurrent operation of Flame and Moth and Bermingham mines.

Roads included in the model are shown on Figure 4-1 and consist of Christal Lake Road, the road between the F&M adit and the crusher and the road between Bermingham and the crusher.

Emissions factors from traffic on unpaved roads were calculated using the equation provided in EPA's AP-42 Section 13.2.2.2, Industrial Roads (EPA, 2006):

$$E = k\left(\frac{s}{12}\right)^a\left(\frac{W}{3}\right)^b$$

*where:*

*k, a and b are size-specific empirical constants and*

*E = size-specific emission factor (lb/Vehicle Mile Travelled (VMT))*

*s = surface material silt content (%)*

*W = mean vehicle weight (tons)*

Results assume a silt content of 8.0% (WRAP Handbook, 2006). The mean vehicle weight was calculated based on estimated traffic volume tables in the Traffic Management Plan.

Natural mitigation under the form of rain or other precipitation can be accounted for according to the equation below (WRAP Handbook, 2006):

$$Eext = E\left[\frac{(365 - P)}{365}\right]$$

*where:*

*Eext = annual size-specific emission factor extrapolated for natural mitigation (lb/VMT)*

*E = emission factor from Equation 1a or 1b (EPA, AP-42 Section 13.2.2.2)*

*P = number of days in a year with at least 0.254 mm of precipitation*

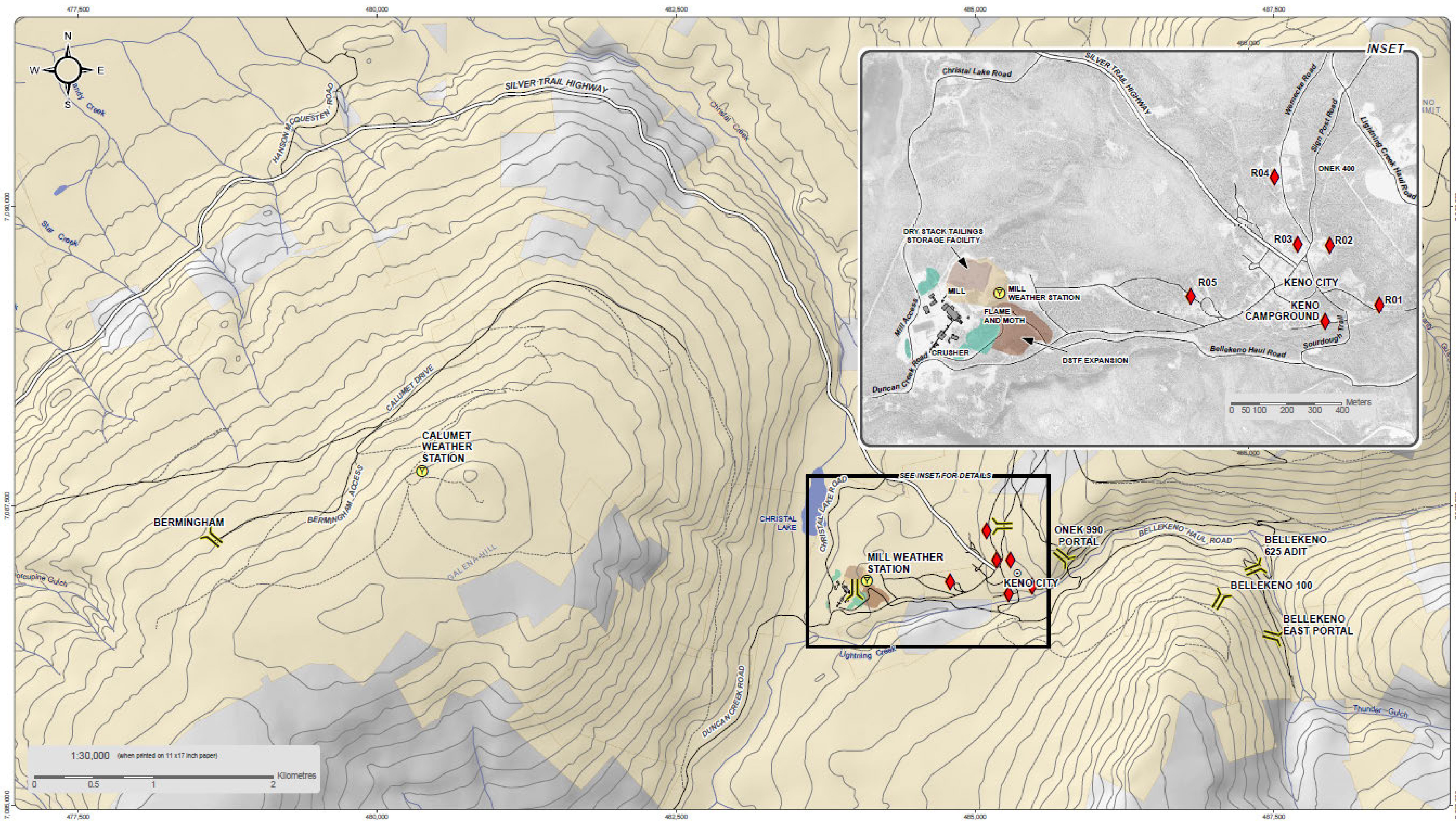
In the case of Keno, P was equal to 105 in 2013, yielding a natural control rate of 29% (i.e. Eext = 0.71*E). This estimate is conservative as only rainfall was measured until October 15, 2013, date after what total precipitation started to be measured.

Alexco also commits to using dust suppressant agents (calcium chloride or similar) and watering the roads as part of the dust mitigation measures presented in the Dust Abatement and Monitoring Plan. The control efficiency of such measures varies with the rate and frequency of application, dilution ratio, traffic volume and prevailing meteorological conditions. However, "past field testing of emissions from controlled unpaved roads has shown that chemical dust suppressants provide a $PM_{10}$ control efficiency of about 80% when applied at regular intervals of 2 weeks to 1 month." (WRAP Handbook, 2006). A summary table of published $PM_{10}$ control efficiency suggest a control efficiency of 84% for dust suppressant on unpaved roads (WRAP Handbook, 2006), but the more conservative figure of 80% was used in the model.

Unpaved roads were modelled as line area sources in CALPUFF, with an average width of 10m, and the uncontrolled emission factors used are summarized in Table 4-3 below. Natural control as per the equation above, as well as a control efficiency of 80% for dust suppressant application were subsequently applied to the emission factors in Table 4-3 before running the model.

## Table 4-3: Uncontrolled Emission Factors for Unpaved Roads

| Road | TSP | | $PM_{10}$ | | $PM_{2.5}$ | |
|---|---|---|---|---|---|---|
| | lb/VMT | kg/m²/h | lb/VMT | kg/m²/h | lb/VMT | kg/m²/h |
| **Bermingham** | | | | | | |
| Bermingham to crusher | 7.28 | 8.37E-04 | 2.05 | 2.36E-04 | 0.21 | 2.36E-05 |
| **Flame & Moth** | | | | | | |
| F&M adit to crusher | 12.42 | 8.17E-04 | 3.5 | 2.31E-04 | 0.35 | 2.31E-05 |
| Christal Lake Road | 3.65 | 2.49E-04 | 1.03 | 7.02E-05 | 0.103 | 7.02E-06 |

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Receptor
Weather Station
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Proposed Features
DSTF 322k Tonnes Design
Current DSTF
DSTF Phase II Expansion
Existing Building
Waterbody
Watercourse
Silver Trail Highway
Other Road
Limited-Use Road

AKHM

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**FIGURE 4-1**

**DUST SOURCES AND RECEPTORS**

SEPTEMBER 2017

### 4.1.3 DOMAIN AND RECEPTORS

#### *4.1.3.1 Domain and Sampling Grid*

The modelling domain was chosen to be 40 km by 40 km, centred on the expanded phase II DSTF. The sampling grid was set at 1 km x 1km.

#### *4.1.3.2 Nested Grid and Discrete Receptors*

A nested grid with the following spacing was used, as recommended in the B.C. Guidelines for Air Dispersion Modelling (BCMOE, 2008):

- 50 m spacing within 500 m of source;
- 250 m spacing within 2 km of source;
- 500 m spacing within 5 km of source; and
- 1000 m spacing beyond 5 km of source.

In addition, in order to better assess potential effects of particulate matter, discrete receptors in Keno City were used. Table 4-4 presents the coordinates and description of the six receptors, while they are shown on Figure 4-1. Those same receptors were used in the Noise Impact Assessment and are part of the Noise Monitoring Program.

**Table 4-4: Discrete Receptors in Keno City**

| Monitoring Location | Coordinates | Description |
|---|---|---|
| R01 | N63.90827 W135.29599 | East end Residence, north side of Lightning Creek Road |
| R02 | N63.91019 W135.29968 | Residence, east side of Sign Post Road |
| R03 | N63.91023 W135.30205 | Town Center, north from the Snack Bar |
| R04 | N63.91239 W135.30376 | Residence, west side of Wernecke Road |
| R05 | N63.90851 W135.30993 | Residence, about 850m east from the Mill |
| Cmpgrnd | N63.90772 W135.29998 | Keno City campground |

## 4.2 MODEL VALIDATION

In order to validate the modelling parameters, the model was run for three 2-day periods in 2013, with existing conditions as input (existing DSTF area, crusher throughput and traffic volumes for the specific dates). Those periods correspond to dates when $PM_{10}$ data were collected by YG (Table 3-4) and results of the model could be compared to measured levels at the different receptors. This comparison provides a validation of the model against actual independent monitoring data.

Table 4-5 below presents the average model results over the entire run period, compared to the measured concentrations. Model results did not account for background concentrations, so the average measured background concentrations (from YG data presented in Table 3-4) for each period was added to the model results. Because measured background is sometimes higher than measured concentrations at the receptors, this method has limitations and both model results with and without background are presented in the table below. Also note that the measured

$PM_{10}$ concentrations include non-mine related emission sources such as local and tourist traffic, which were not included in the model.

**Table 4-5: Modelled versus Measured $PM_{10}$ Concentrations (µg/m³)**

| Receptor | Modelled $PM_{10}$ concentrations | Modelled $PM_{10}$ concentrations + Measured Background Concentration | Measured $PM_{10}$ concentrations |
|---|---|---|---|
| June 11-13, 2013 (Background = 2.8 µg/m³) | | | |
| KC1 | 5.68 | 8.48 | 6.2 |
| KC2 | 5.85 | 8.65 | 3.8 |
| KC3 | 6.97 | 9.77 | 8.3 |
| KC4 | 2.97 | 5.77 | 2.1 |
| July 15-18, 2013 (Background = 10.3 µg/m³) | | | |
| HR1 | 16.95 | 27.25 | 5.25 |
| HR2 | 16.73 | 27.03 | 2.08 |
| HR3 | 25.94 | 36.24 | 13.82 |
| HR4 | 5.45 | 15.75 | 16.39 |
| August 11-12, 2013 (Background = 3.8 µg/m³) | | | |
| FL1 | 20.0 | 23.8 | 0.8 |
| FL2 | 0.47 | 4.27 | 39.3 |

The June model results agree relatively well with the measurements, while the July model results are overestimating actual concentrations. August model results are variable for the two receptors. Specific local conditions can cause a wide variation for short modelling periods and can explain why some of the model results are not in perfect agreement with the measurements. For example, the fact that rain fell during the modelling period was considered, but the timing of the rainfall versus that of the traffic could not be incorporated in the model. Similarly, emission factors are averaged over a longer period and specific timing of emissions in relation to wind speed and direction can also cause some divergence. Overall, because most results were within the range of measurements or overestimating the actual concentrations, the modelling parameters were considered to provide a conservative estimate and are validated.

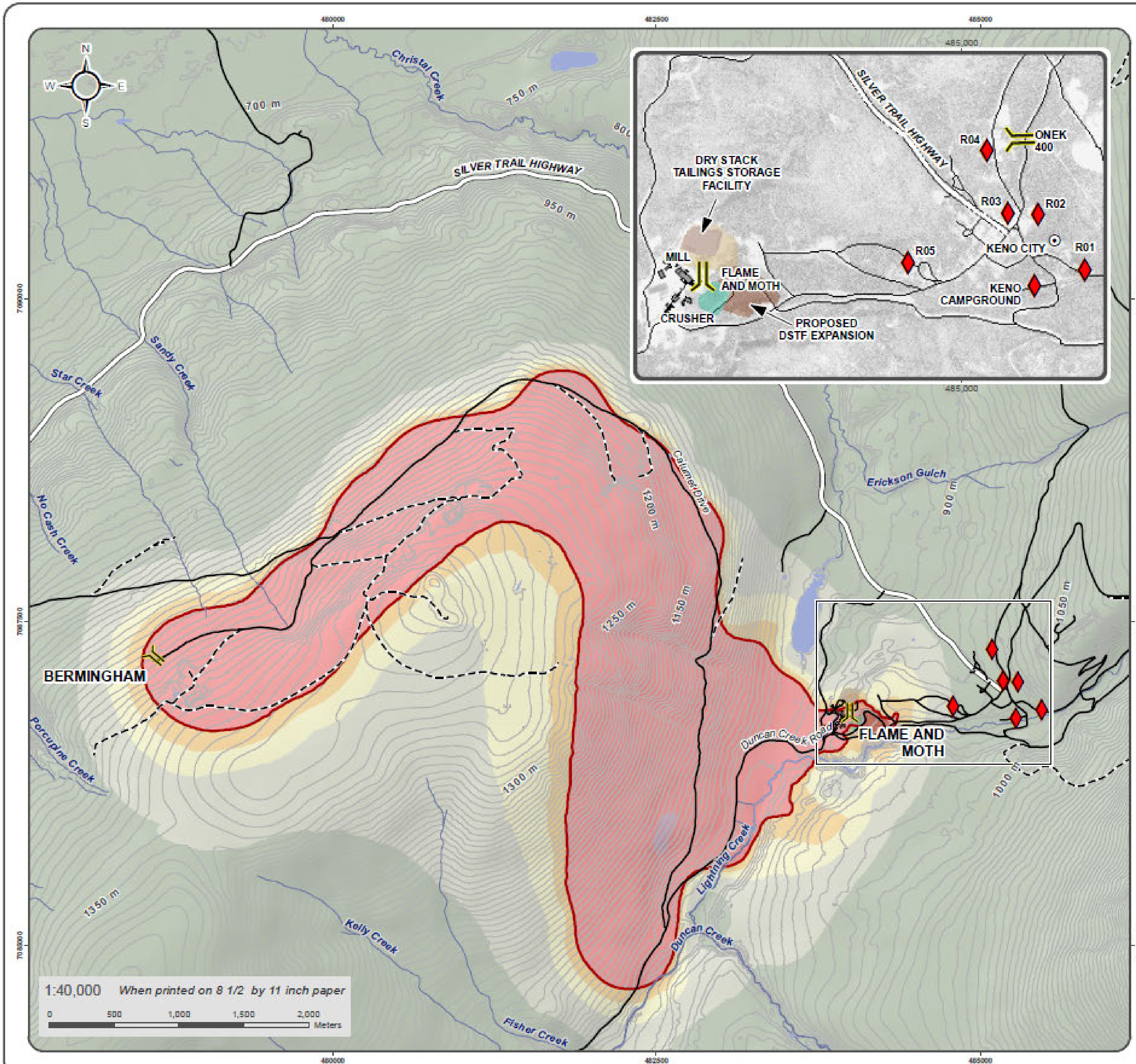
## 4.3 MODELLING RESULTS

Results presented in the following Sections are modelled ambient concentrations resulting from Project activities, to which background concentrations presented in Table 3-3 were added. For 24-hour averaging periods, the maximum predicted ambient concentrations are presented, while the annual values represent averages calculated for the entire modelling period. Results are presented for the six receptors and the spatial distribution of ambient concentrations is presented graphically for each contaminant.

**Table 4-6: Predicted TSP, $PM_{10}$ and $PM_{2.5}$ Concentrations (µg/m³)**

| Receptor | TSP | | $PM_{10}$ | | $PM_{2.5}$ | |
|---|---|---|---|---|---|---|
| | Max 24-hr Concentration | Annual Concentration | Max 24-hr Concentration | Annual Concentration | Max 24-hr Concentration | Annual Concentration |
| R01 | 20.9 | 2.7 | 7.6 | 1.1 | 4.6 | 0.8 |
| R02 | 20.9 | 2.9 | 7.7 | 1.1 | 4.6 | 0.9 |
| R03 | 21.9 | 3.0 | 8.1 | 1.1 | 4.7 | 0.9 |
| R04 | 22.2 | 3.0 | 8.3 | 1.1 | 4.7 | 0.9 |
| R05 | 47.9 | 4.8 | 16.7 | 1.7 | 5.8 | 0.9 |
| Cmpgrnd | 20.9 | 3.0 | 8.1 | 1.1 | 4.6 | 0.9 |
| YAAQS | 120 | 60 | 50 | n/a | 28 | n/a |

No exceedances of the applicable YAAQS are predicted at any of the six discrete receptors located in Keno City. Higher concentrations than those shown in the above table are predicted to occur closer to the sources, as shown on Figures 4-2, 4-3 ad 4-4 which present the maximum predicted 24-hr concentrations for TSP, $PM_{10}$ and $PM_{2.5}$ respectively. Although some exceedances of the YAAQS are possible for TSP and $PM_{10}$ in a very localised area near the sources and under the worst case meteorological and operational conditions, it should be noted that they are unlikely due to the conservatism of the model (choice of conservative control efficiencies, wet deposition not accounted for in the computational method, etc.).




**ALEXCO KENO HILL MINING CORP.**

## FIGURE 4-2

## PREDICTED MAXIMUM 24-hr TSP CONCENTRATIONS

NOVEMBER 2017

**TSP CONCENTRATION LEVEL (µg /m³)**

- <50
- 50 - 80
- 80- 100
- 100 - 120
- 120- 300
- 300 - 3,000
- Standard Boundary Contour at 120 µg /m³ (according to YAAQS)

**OTHER MAP FEATURES**

- Dust Receptors
- Adit
- Proposed Features
- DSTF 322k Tonnes Design
- Current DSTF
- DSTF Phase II Expansion
- Existing Building
- Silver Trail Highway
- Road
- Limited-Use Road

Predicted ambient concentrations shown on this map were produced with CALPUFF Version 5.8.5

Datum: NAD 83; Map Projection: UTM Zone 8N



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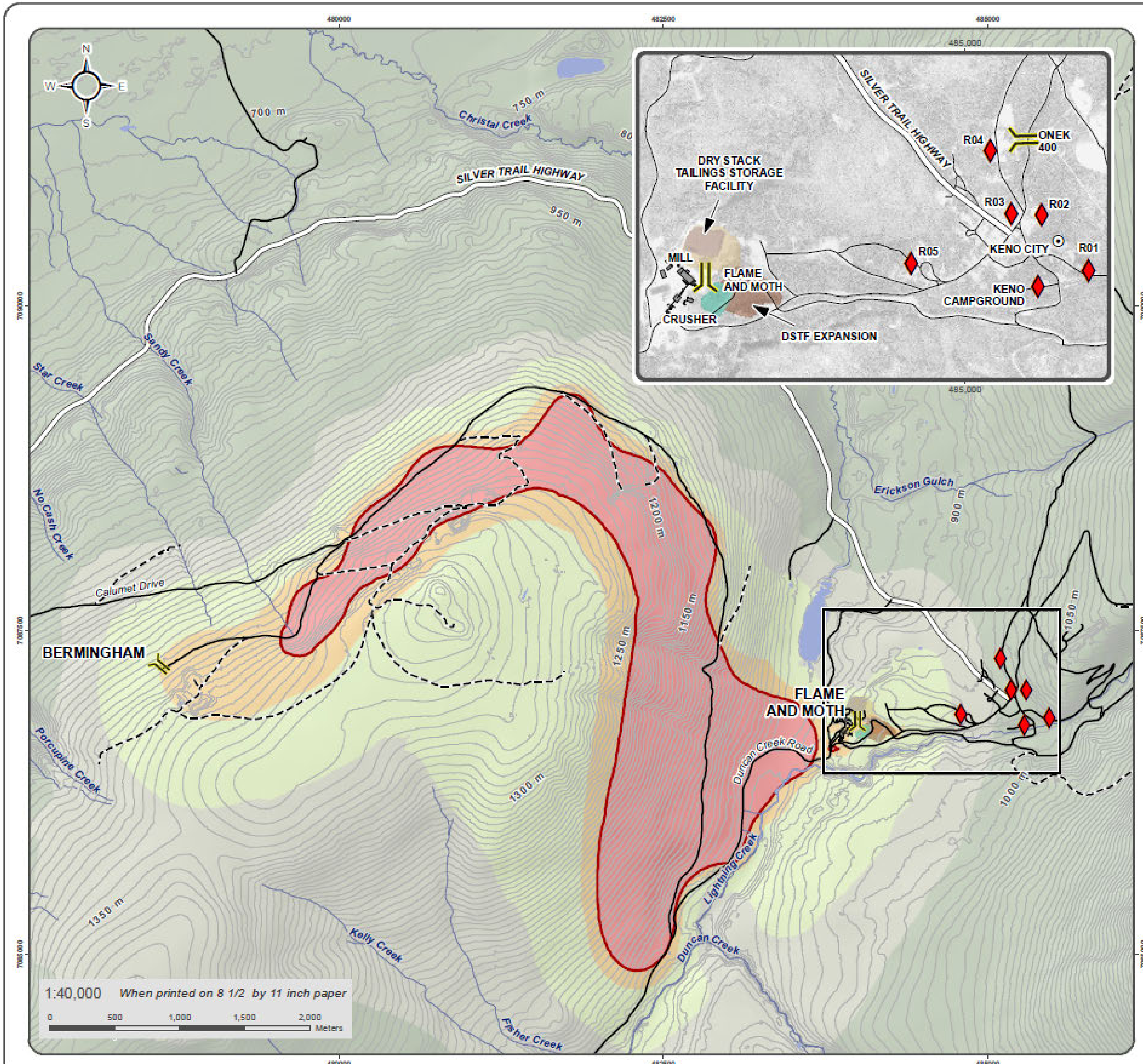
ALEXCO KENO HILL MINING CORP.

**FIGURE 4-3**

**PREDICTED MAXIMUM 24-hr $PM_{10}$ CONCENTRATIONS**

NOVEMBER 2017




**$PM_{10}$ CONCENTRATION LEVEL (µg /m³)**

- < 10
- 10 - 20
- 20 - 40
- 40 - 50
- 50 - 100
- Standard Boundary Contour at 50 µg /m³ (according to YAAQS)

**OTHER MAP FEATURES**

- Receptor
- Adit
- Proposed Features
- DSTF 322k Tonnes Design
- Current DSTF
- DSTF Phase II Expansion
- Existing Building
- Silver Trail Highway
- Road
- Limited-Use Road

Predicted ambient concentrations shown on this map were produced with CALPUFF Version 5.8.5

Datum: NAD 83; Map Projection: UTM Zone 8N



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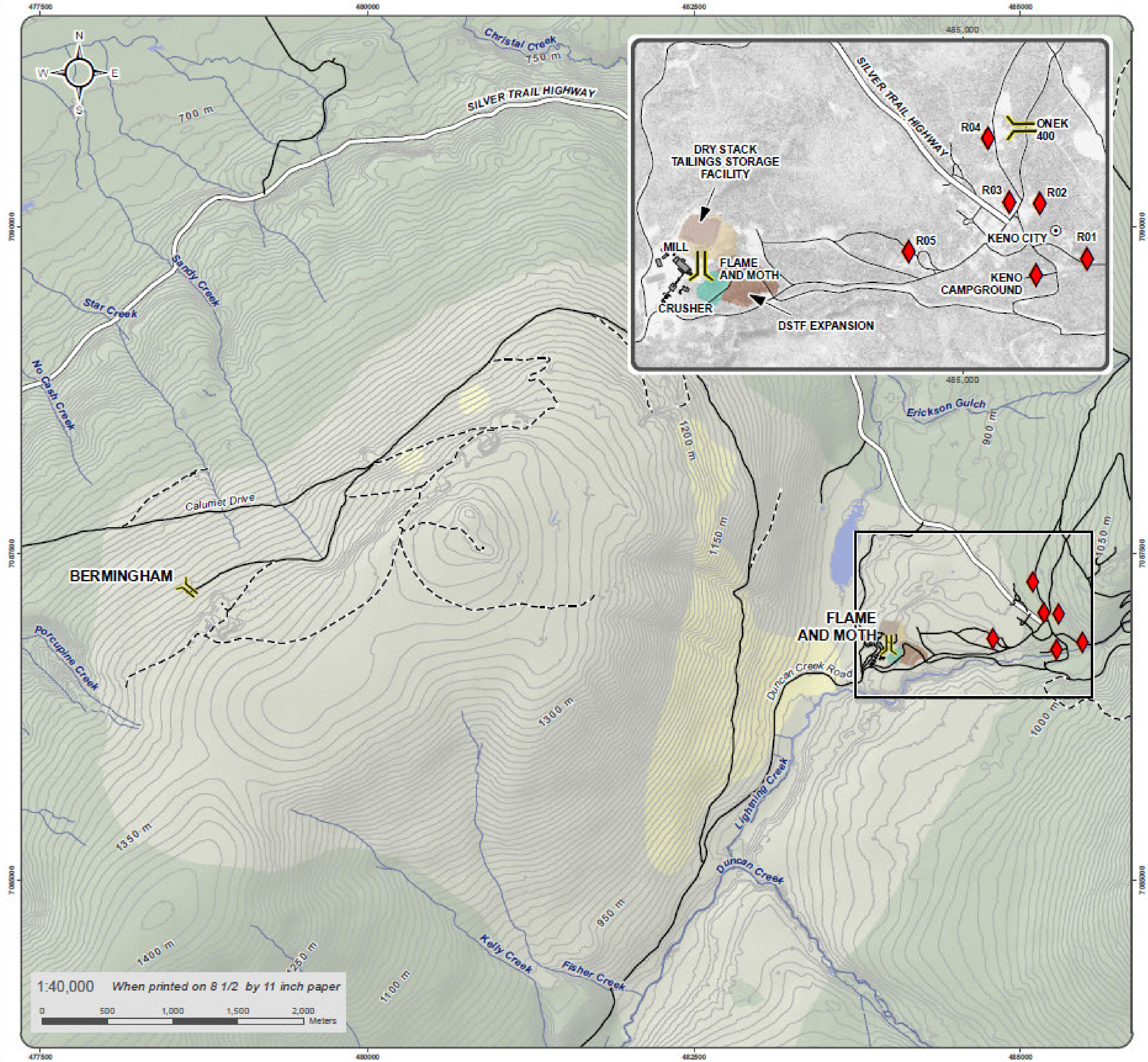


ALEXCO KENO HILL MINING CORP.

**FIGURE 4-4**

**PREDICTED MAXIMUM 24-hr $PM_{2.5}$ CONCENTRATIONS**

NOVEMBER 2017

**$PM_{2.5}$ CONCENTRATION LEVEL(µg /m³)**

- < 5
- 5 - 10
- 10 - 20

**OTHER MAP FEATURES**

- Receptor
- Adit
- Proposed Features
- DSTF 322k Tonnes Design
- Current DSTF
- DSTF Phase II Expansion
- Existing Building
- Silver Trail Highway
- Road
- Limited-Use Road

Predicted ambient concentrations shown on this map were produced with CALPUFF Version 5.8.5

Datum: NAD 83; Map Projection: UTM Zone 8N



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# 5. MODEL LIMITATIONS AND UNCERTAINTY

The overall accuracy of the model predictions depends on the accuracy of the data input and the accuracy of the air dispersion model.

In terms of the input emission data, emission factors provided in the EPA AP-42 have associated ratings ranging from A (Excellent) to E (Poor). A-rated emission factors are developed primarily from A and B rated source test data taken from many randomly chosen facilities in the industry population and the source category population is sufficiently specific to minimize variability. On the contrary, E-rated emission factors are developed from C and D rated test data from a very few number of facilities, and there may be reason to suspect that the facilities tested do not represent a random sample of the industry. There also may be evidence of variability in the source category population. Table 5-1 summarizes the emission factors ratings for the various sources types used in this study.

### Table 5-1: Emission Factors Ratings (EPA, 1995)

| Source Type | AP-42 Section | TSP | $PM_{10}$ | $PM_{2.5}$ |
|---|---|---|---|---|
| Wind erosion of exposed areas | 11.9 | C | C | C |
| Material Handling and Transfer | 11.19 | E | E | E |
| Unpaved Industrial Roads | 13.2 | B | B | B |
| Primary crushing | 11.24 | C | C | C |

*Note: A = Excellent, B = Above Average, C = Average, D = Below Average, E = Poor*

The accuracy of the meteorological data input into the model is a function of the accuracy of the measuring instruments and sensors. Table 5-2 presents the published accuracy of the Project Campbell Scientific meteorological station's sensors.

### Table 5-2: Meteorological Station Components Accuracy

| Component | Model | Accuracy |
|---|---|---|
| Air Temperature and Relative Humidity Sensor | HMP45C212 | ± 0.1°C<br>± 2-3% RH |
| Tipping Bucket Rain Gauge | TE525M | ±1 % up to 10 mm/hr<br>+0, –3 % from 10 to 20 mm/hr<br>+0, –5 % from 20 to 30 mm/hr |
| Wind Speed and Direction Sensor | RM Young 05103AP-10-L | ± 0.3 m/s; ± 3° |
| Pyranometer | SP Lite2 | Not specified |

The accuracy of the air dispersion model depends largely on the modelling options selected and on the objectives of the study. A model validation run was conducted (see section 4.2) and allowed to determine that the chosen modelling parameters and options do not underestimate ambient concentrations. Various independent studies have evaluated the performance of different air dispersion models and results generally indicate that models predicting capabilities vary with conditions. Rodd (2014) found that Lagrangian puff models (such as CALPUFF) generally exhibit smaller variances, higher correlation, and higher percentage of predictions within a factor of two compared to the steady-state models.

Overall, conservative assumptions were made to produce reasonable worst-case scenarios and confidence is high that the model is not under-predicting ambient concentrations.

# 6. CONCLUSION

In summary, results of the air dispersion model, as well as results from monitoring conducted at site and in Keno City to date demonstrate that predicted and measured particulate matter levels are well below the applicable Yukon Ambient Air Quality Standard at all sensitive receptors. Based on the results of this assessment, potentially adverse effects on ambient air quality and human health associated with the Project air emissions are not expected to occur. Air quality monitoring will continue as described in Section 3.2.1.

# 7. REFERENCES

B.C. Ministry of Environment (MOE). 2008. Guidelines for Air Dispersion Modelling in British Columbia. Environmental Protection Division, Environmental Quality Branch, Air Protection Section. Version: March 2008.

Countess Environmental. 2006. WRAP Fugitive Dust Handbook. Prepared for Western Governor's Association. September 7, 2006. http://www.wrapair.org/forums/dejf/fdh/content/FDHandbook_Rev_06.pdf

Environment Australia. 1999. Australian National pollutant inventory Emission Estimation Technique Manual for Fugitive Emissions. http://www2.unitar.org/cwm/publications/cbl/prtr/pdf/cat5/Australia_ffugitive.pdf

Environment Australia. 2012. Australian National pollutant inventory Emission Estimation Technique Manual for Mining Version 3.1 January 2012 http://www.npi.gov.au/system/files/resources/7e04163a-12ba-6864-d19a-f57d960aae58/files/mining.pdf

Environment Canada. 2014. Hourly Data Report for Mayo A.

Environment Canada. 2008. Unpaved Industrial Road Dust Calculator.

Environment Yukon. 2014. Yukon Ambient Air Quality Standards. Implemented April 22, 2010. Updated March 6, 2014.

Lakes Environmental. 2013. CALPUFF Course, Long Range Puff Air Dispersion Model. Air Dispersion Modelling Workshop. Course Slides.

National Oceanic and Atmospheric Administration (NOAA). 2014. NOAA/ESRL Radiosonde Database. http://www.esrl.noaa.gov/raobs/

Rodd, Arthur S. 2014. Performance Evaluation of AERMOD, CALPUFF, and legacy air dispersion models using the Winter Validation Tracer Study dataset. *Atmospheric Environment*. Volume 89, June 2014, Pages 707-720.

Sinclair Knight Merz. 2005. Improvement of NPI Fugitive Particulate Matter Emission Estimation Techniques. RFQ NO. 0027/2004. May 2005. http://www.npi.gov.au/system/files/resources/d9d46a4c-f76e-fdc4-5d59-fd3f8181c5b8/files/pm10may05.pdf

U.S. Environmental Protection Agency (EPA). 2014. Preferred/Recommended Models. Technology Transfer Network. Support Center for Regulatory Atmospheric Modelling. Office of Air Quality Planning and Standards. Updated on 19/05/2014.

U.S. Environmental Protection Agency (EPA). 2006. Compilation of Air Pollutant Emissions Factors. Volume I: Stationary Point and Area Sources. Fifth Edition. Office of Air Quality Planning and Standards. January 1995. Updated 2006.

U.S. Environmental Protection Agency (EPA). 1995. *Compilation of Air Pollutant Emissions Factors. Volume I: Stationary Point and Area Sources.* AP-42 Fifth Edition. Office of Air Quality Planning and Standards. January 1995.

U.S. Environmental Protection Agency (EPA). 1992. Fugitive Dust Background Document and Technical Information Document for Best Available Control Measures. Office of Air Quality Planning and Standards. September 1992.

U.S. Environmental Protection Agency (EPA). 1988. Control of Open Fugitive Dust Sources. Final Report. Office of Air Quality Planning and Standards. September 1988.

World Health Organization (WHO). 2013. Health Effects of Particulate Matter. Policies implications for countries in Eastern Europe, Caucasus and central Asia