2.5 AMBIENT AIR MONITORING DATA

Ambient air monitoring data summaries showing annual geometric mean and maximum daily levels of total arsenic measured at the Yellowknife City Hall monitoring station have been reviewed and along with arsenic deposition data from snow cores has been used as a basis for comparison with model results. Exceedence data for ambient sulfur dioxide levels measured at the city hall monitoring station have been reviewed and are compared to sulfur dioxide modelling results. Hourly average sulfur dioxide monitoring data was provided for a portion of 1992, all of 1993 and 1994. These data were compared to model estimates to evaluate operational performance of the model.

3.0 ATMOSPHERIC DISPERSION MODELING

3.1 MODEL SELECTION

In order for modelling results to accurately characterize actual dispersion and transport of roaster stack emissions, the model used must incorporate those atmospheric processes that controll the dispersion and mixing of the stack discharge. While dispersion often occurs by unimpeded mixing throughout the entire depth of the mixing layer, it may at times be influenced by formation of a localized internal boundary layer which constrains mixing to a lesser depth.

Dispersion influenced by internal boundary layer effects can arise when a moving airmass experiences an abrupt change in surface roughness and/or temperature of the land or water below it. When dispersion is influenced by internal boundary layer effects elevated ground level concentrations can result due either to plume trapping or fumigation. Plume trapping occurs when a stack discharges directly into an internal boundary layer which limits both the vertical rise of the plume and its ability to mix with a larger volume of air. Fumigation occurs when a stack initially discharges above a developing internal boundary layer but the plume, as it travels downwind, eventually intersects the internal boundary layer causing the portion of the plume involved to be brought to ground level.

Of the two principal models considered here, the Industrial Source Complex (ISC2) Model generally models unimpeded mixing throughout the entire depth of the mixing layer, while the Shoreline Dispersion Model (SDM) incorporates internal boundary layer effects specific to the shoreline of a large water body.

1. Industrial Source Complex Model (ISC2)

The Industrial Source Complex Model (ISC2) is a steady-state gaussian plume model which can be used to assess pollutant concentrations from a wide variety of sources associated with industrial complexes. This model can calculate ambient ground level concentrations of gas phase pollutants as well as settling and dry deposition of particulates, incorporate the effects of building wakes on ambient concentrations, and handle limited terrain adjustments. This model was developed and tested by USEPA and has been continuously upgraded and refined over the years. At present it is one of the most thoroughly evaluated and most often recommended of USEPA's steady-state gaussian plume models for industrial sources.

2. Shoreline Dispersion Model (SDM)

The Shoreline Dispersion Model (SDM) is a combination of two models which permits the analysis of both shoreline fumigation and nonfumigation conditions for sources near a shoreline. The Multiple Point Gaussian Dispersion Algorithm with Terrain Adjustment (MPTER) model is used to calculate ground level concentrations of emitted contaminants under ordinary (nonfumigating) dispersion conditions. The Shoreline Fumigation Model (SFM) is used to calculate ground level contaminant concentrations under shoreline fumigation conditions. The SDM operates by evaluating each hour of meteorological input data to determine whether or not a Thermal Internal Boundary Layer (TIBL) is formed, TIBL thickness at the stack location, and whether or not the stack discharges to the atmosphere above or below the TIBL's upper boundary. Shoreline Fumigation, which can produce significantly elevated ambient ground level concentrations, only occurs when a TIBL forms and the stack emits above its upper boundary. Fumigation occurs at a location downwind from the stack where the emitted plume intersects the TIBL upper boundary, which grows with distance downwind until it reaches the mixing height. Based on this evaluation the SDM uses either the MPTER or the SFM to calculate ambient concentrations for each hour of meteorological data.

Since TIBL's tend to occur during early summer when the land heats up while the water remains cool, by far the majority of hours modelled each year will be diagnosed as non-fumigating conditions. That means that most of the time the SDM will be selecting the MPTER model to compute ambient concentrations. Only at those rare times when the atmospheric conditions are just right (onshore winds > 2 m/s; daytime with A, B, or C stability over land; heat flux over land > 20 watts/m^2; stable air over water; and stack height > TIBL height) will SDM choose the SFM model. These conditions require a tall stack located rather close (< 1km) to a shoreline and would occur here for only a narrow range of wind directions (S and SSE). Use of the SDM also requires additional site specific information, which include water temperature, overwater lapse rate, surface sensible heat flux, and mean potential temperatures over land and water. Estimation of the over water lapse rate typically requires measurement of air temperature at two above lake elevations. These data are not presently available. As the great majority of modelled conditions are non-fumigating and since the ISC2 is a more refined and up to date gaussian plume model than the MPTER, the ISC2 model was selected for use here.

3.2 ISCST2 MODEL DESCRIPTION

The Industrial Source Complex Short-Term (ISCST2) dispersion model used in this project is a restructured and reprogrammed version of the original ISC Short-Term model. It provides options to model simultaneous emissions from multiple sources and includes a wide range of emission source types typical for an industrial source complex. The basis of the model is the steady-state Gaussian plume equation, which is used with some modifications to model emissions from stacks which may experience the effects of aerodynamic downwash due to nearby buildings. Hourly meteorological data records are accepted and used to define the conditions for plume rise, transport and diffusion. Either ambient concentration (ug/m3) or particulate deposition (mg/m2/hour) values can be calculated for each source and receptor combination for each hour of input meteorology, according to user-selected short-term averages. All modeling runs in this study were configured to compute ambient air concentrations.

ISCST2 models dry deposition based on the Dumbauld, et al (1976) deposition model. This model, which is an advanced version of the Cramer, et al (1972) deposition model, which incorporates use of reflection coefficients to account for the possibility that a fraction of the material initially deposited may be reflected back into the atmosphere.

3.3 MODEL SETUP

Setting up data files for input to the ISCST2 requires consideration of model control parameters, source emissions, receptors, meteorology, and desired model output. For this effort, the ISCST2 model was configured to use rural dispersion parameter algorithms, daily averaging times, and to output ground level ambient air concentrations at designated receptor locations. The regulatory default option, which makes use of a calms processor for windspeeds less than 1 m/s, and uses default exponent values for vertical windspeed and temperature gradient was also chosen. Roaster stack emission data, presented in Table 2-1, were used as source input data.

Receptor locations, points on the model grid where model output values are computed and recorded, were chosen to be 300 m. apart in both the North-South and East-West directions. The model grid extends 6000 m. to the east and west of the stack and 6000 m. to the north and south, spanning an area 12 km. by 12 km. In addition, the Yellowknife city hall located at (x=-1000 m. , y=-5350 m.) on the model grid is a receptor.

ISCST2 meteorological input data files were developed for each month of 1992 and 1993. The files require hourly average windspeed, wind direction, air temperature, Pasquill stability class, and mixing height values. Hourly mixing height values were computed from twice daily mixing height data computed from upper air sounding data provided by the Atmospheric Environment Service using PCRAMMET, a meteorological data preprocessor distributed by USEPA. The PCRAMMET fortran code required some modifications to accept the format and units of existing data inputs.

3.4 BASELINE MODELING RESULTS

Model runs were made at a mass emission rate of 65 x 10^3 kg/day for SO_2 and a mass emission rate of 26.8 kg/day for As_2O_3 using existing values of stack height (150 ft), exit gas temperature (112 C), and exit gas velocity (2.7 m/s) to determine maximum ground level SO_2 and As_2O_3 concentrations. ISCST2 model runs were configured so that the 49 highest 1hr average and the 24 highest 24hr average SO_2 and As_2O_3 concentrations computed anywhere on the model grid were tabulated for each monthly meteorological data set. The model grid used for these calculations is a square area (12 km x 12 km) that extends 6 km to the north, south, east, and west of the stack. Ground level concentrations are computed at 300m intervals across the entire grid.

Table 3-2 Predicted Baseline As_2O_3 Concentrations

Meteorological Data Set	Max 1 Hr. Avg. Conc. (ug/m3)	Max 24 hr. Avg. Conc. (ug/m3)
January 1993	1.2	0.38
February 1993	1.6	0.60
March 1993	2.5	0.48
April 1993	2.0	0.57
May 1993	2.6	0.58
June 1993	2.0	0.51
July 1993	2.7	0.65
August 1993	2.2	0.53
September 1993	2.1	0.55
October 1993	1.8	0.39
November 1993	1.3	0.41
December 1993	1.6	0.50

Model results, shown here in Tables 3-2, yield ambient As_2O_3 concentrations that regularly exceed the 24 hr. average Ontario As_2O_3 guideline of 0.3 ug/m3.

Simulations for each month of 1993 were made for both Arsenic and Sulfur dioxide emission. Two sets of simulations were made for each contaminant. In one set 24 hr. average ambient air concentrations were computed for each day of 1993 at the Yellowknife City Hall. This output was meant to be compared with 1993 ambient air monitoring results from the same location. In the second set of simulations maximum 24 hr. average values were determined for the entire grid of receptor locations. This model output was able to demonstrate areas where the highest concentrations could be found as well as the magnitude of these concentration maxima. While particulate deposition runs are intended, they were not completed in time for this report but will be included in the final report. The results of simulations made are discussed in the next section.

Table 3-1 Predicted Baseline SO_2 Concentrations

Meteorological Data Set	Max 1 Hr. Avg. Conc. (ug/m3)	Max 24 hr. Avg. Conc. (ug/m3)
January 1993	2826	932
February 1993	3992	1454
March 1993	5963	1154
April 1993	4850	1388
May 1993	6238	1398
June 1993	4749	1243
July 1993	6461	1575
August 1993	5347	1282
September 1993	5143	1323
October 1993	4462	940
November 1993	3133	997
December 1993	3812	1223

Model results, shown above in Tables 3-1, predict ambient SO_2 concentrations that consistently exceed both the 1 hr. and 24 hr. average provincial SO_2 guidelines (450 ug/m3 and 150 ug/m3 respectively).

Maximum 24 hr. average total arsenic concentrations were estimated at the Yellowknife City Hall location for each month of 1993 and compared to ambient monitoring results reported at that location. These data are presented in Table 3-3.

TABLE 3-3 ARSENIC CONCENTRATIONS AT YELLOWKNIFE CITY HALL

Concentration	ISCST2 Modelling Results for 1993	Ambient Air Monitoring Results for 1993
Maximum 24 hr. Average Arsenic Concentration (ug/m^3)	0.140	0.251
Annual Geometric Mean Arsenic Concentration (ug/m^3)	.009[1]	0.015

1. Arithmetic average, numerous zero values precluded geometric mean calculation.

Maximum daily and annual mean Arsenic values predicted by the ISCST2 model were similar in magnitude but slightly lower than corresponding monitoring data values. Maximum 24 hr. average sulfur dioxide concentrations were also estimated at the Yellowknife City Hall for each month of 1993 and compared to ambient monitoring results. These data are presented in Table 3-4.

TABLE 3-4 SULFUR DIOXIDE AT YELLOWKNIFE CITY HALL

Concentration	ISCST2 Modelling Results for 1993	Ambient Air Monitoring Results Mar 1993 - Feb 1994
Maximum 1 hr. Average SO_2 Concentration (ug/m³)	1402.	1205.
Maximum 24 hr. Average SO_2 Concentration (ug/m³)	144.4	285.
Annual Geometric Mean SO_2 Concentration (ug/m³)	9.6[1]	13

1. Arithmetic average, numerous zero values precluded geometric mean calculation.

Maximum daily and annual mean SO_2 values predicted by the ISCST2 model were similar in magnitude but slightly lower than corresponding monitoring data values.

Neither arsenic nor sulfur dioxide concentrations, measured and predicted, exceeded national air quality guideline for sulfur dioxide or the Ontario arsenic 24 hr. guideline for the downtown Yellowknife area. For arsenic, an area extending 2km to the north of the stack, 2.5 km west, 2 km south, and 1.5 km to the east of the stack contained all 24 hr maximum values that exceeded the 0.3 ug/m³ Ontario guideline value. The corresponding area for SO_2 guideline exceedences is also somewhat centered on the stack but nearly double the size.

4.0 MODEL EVALUATION

4.1 EVALUATION METHODOLOGY

This application of the ISCST2 model has been subjected to a screening test to determine if it meets minimum standards for operational performance. The rationale for the operational component is to measure the model's ability to estimate concentration statistics most directly used for regulatory purposes. For a pollutant such as SO_2 for which short-term ambient standards exist, the statistic of interest is the magnitude of the highest concentrations actually occurring.

Because of the emphasis on highest concentrations, a robust test statistic is calculated that represents a "smoothed" estimate of the highest concentration. As the highest concentration value can be subject to extreme variations, a robust estimate of the highest concentration is preferable because of its stability.

The test statistic used to evaluate model performance is a robust estimate of the highest concentration (RHC) which is computed using the highest concentrations within a given monitoring or model predicted monthly data set. The robust estimate is based on a tail exponential fit to the upper end of the concentration cumulative probability distribution and is computed as follows:

$$RHC = X(N) + [\bar{X} - X(N)] \ln \left[\frac{3N - 1}{2}\right] ,$$

where:

X = average of the N-1 largest values
X(N) = Nth largest value
N = number of values exceeding the threshold value ($N \leq 26$)

The value of N is nominally set equal to 26 so that the number of values averaged (X) is arbitrarily 25. The value of N may be lower than 26 whenever the number of values exceeding the threshold is lower than 26. Whenever N is less than 3, the RHC statistic should be set equal to the threshold value where the threshold is defined as a concentration near background which has no impact on the determination of the robust highest concentration.

The robust estimator of the highest value is related to the mean and standard deviation of the 25 highest values in each data set. Increases in the central location and spread tends to increase the magnitude of the highest value within the 25 highest concentrations. The robust highest value in effect is a direct measurable result of the composite impact of the central location of the highest values and their spread about that central location.

A performance measure is calculated which compares observed ambient air quality and model predicted values of the test statistic, RHC. The fractional bias is used as the performance measure. The general expression for the fractional bias (FB) is given by:

$$FB = 2\left[\frac{OB - PR}{OB + PR}\right]$$

The fractional bias of the RHC is computed using this equation where OB and PR refer to RHCs of the observed (monitoring data) and model predicted highest 25 values. The fractional bias has been selected as the basic measure of performance in this evaluation because it is symmetrical and bounded. Values for the fractional bias range between -2.0 (extreme overprediction) and +2.0 (extreme underprediction). Values of the fractional bias that are equal to -0.67 are equivalent to overpredictions by a factor-of-two, while values that are equal to +0.67 are equivalent to an underprediction by a factor-of-two.

4.2 COMPARISON OF MODELING AND MONITORING RESULTS

Robust highest concentrations (RHC) for 14 months of ambient SO_2 monitoring data (Yellowknife City Hall Monitoring Station) are compared in Table 4-1 with corresponding model simulated values. These model predictions are found to have a fractional bias less than the maximum permissable value of 0.67 for 12 of the 14 months tested. The fractional bias, a measure of deviation from complete model accuracy, was found to be zero for three of the 14 months. These three monthly meteorological data sets were then used to make predictions of compliance with proposed provincial air quality guidelines.

Table 4-1 Model Performance Evaluation Based on Observed and Predicted 1 hr. Average SO_2 Concentrations (ug/m3)

Meteorological Data Set	Robust Highest Concentration (OBS.)	Robust Highest Concentration (PRED.)	Fractional Bias
August 1992	342	579	-0.51
September 1992	947	797	0.17
October 1992	500	443	0.12
November 1992	1307	1301	0.004
March 1993	717	811	-0.12
April 1993	592	1028	-0.54
May 1993	421	718	-0.52
June 1993	530	874	-0.49
July 1993	844	848	-0.004
August 1993	1000	994	0.006
September 1993	348	815	-0.80
October 1993	478	1137	-0.82
November 1993	926	1447	-0.44
December 1993	685	1203	-0.55

5.0 SENSITIVITY ANALYSIS

5.1 OVERVIEW

Recognizing that ground level SO_2 concentrations can be reduced by either reducing the mass emission rate of SO_2 or by enhancing the dispersion of emitted SO_2, the ability to meet provincial ambient air quality requirements by reducing the mass emission rate and/or enhancing atmospheric dispersion is evaluated. As the extent to which stack emissions are mixed and diluted by atmospheric dispersion is influenced by both meteorological factors and stack discharge parameters, this effort is aimed at characterizing the influence of both the SO_2 mass emission rate and stack discharge parameters (stack height, exit gas velocity, and exit gas temperature) on ground level concentrations of SO_2.

Model runs were made over a wide range of values of mass emission rate, stack height, exit gas temperature, and exit gas velocity to determine the effect these parameters have on maximum ground level SO_2 concentrations. A series of model runs were made with SO_2 mass emission rate reduced from its maximum value of $65 \times 10_3$ kg/hr by 25%, 50%, 75%, 90%, and 95%. Likewise, model runs were made with stack discharge parameter values individually increased by 25%, 50%, 75%, and 100%. ISCST2 model runs were configured so that the 49 highest 1hr avg SO_2 concentrations computed anywhere on the model grid were tabulated for each monthly meteorological data set. Monthly meteorological data sets that showed essentially zero model bias (November 1992, July 1993, and August 1993) were chosen for use in each sequence of sensitivity analysis model runs. For these model runs the model grid is a square area (12 km x 12 km) that extends 6 km to the north, south, east, and west of the stack. Ground level concentrations are computed at 300m intervals across the entire grid.

5.2 EFFECTS OF MASS EMISSION RATE VARIATIONS

The SO_2 mass emission rate was varied with all other parameters held constant to determine its impact on ground level SO_2 concentrations. The objective was to identify a range of mass emission rates which would produce ambient SO_2 concentrations that did not exceed the 1 hr. average provincial SO_2 guideline value of 450 ug/m3. The results of these model runs are presented in Table 5-1.

Table 5-1 Effect of SO_2 Mass Emission Rate Variations on Ambient 1 hr. Average SO_2 Concentrations (ug/m3)

Mass Emission Rate(g/s)	Percent Reduction	Max 1 hr. Avg. Conc.(ug/m3) Nov 92	Max 1 hr. Avg. Conc.(ug/m3) Jul 93	Max 1 hr. Avg. Conc.(ug/m3) Aug 93
752.3	0	3304	6461	5347
564.2	25	2478	4846	4010
376.2	50	1652	3231	2674
188.1	75	826	1616	1337
75.2	90	330	646	535
37.6	95	165	323	267

As shown in Table 5-1, a reduction in the SO_2 mass emission rate of nearly 95 percent is required to reduce maximum ambient 1 hr average SO_2 concentrations to levels that do not exceed the proposed provincial air quality guideline of 450 ug/m3.

5.3 EFFECTS OF VARIATIONS IN STACK DISCHARGE PARAMETERS

Stack discharge parameters (stack height, exit gas velocity, and exit gas temperature) were varied individually in model runs made using the three low bias monthly meteorological data sets. The objective was to identify a range of parameter values which would yield ambient SO_2 concentrations that did not exceed the 1 hr. provincial SO_2 guidelines of 450 ug/m3. All model runs were made at a mass emission rate of 65×10^3 kg/day for SO_2.

The effects of stack height increases, shown in Table 5-2, up to 100% of the existing height only reduce the maximum ambient SO_2 concentrations by 40 - 45 % leaving them well above the proposed provincial guidelines.

The effects of exit gas temperature increases, shown in Table 5-3, up to 100% of existing temperature only reduce maximum ambient SO_2 concentrations by 30% in November and by 50 - 60 % during the warmer months, leaving ambient concentrations well above the proposed provincial guideline value for all three months.

Table 5-2 Effect of Stack Height Variations on Ambient 1 hr. Average SO_2 Concentrations (ug/m3)

Stack Height (m.)	Percent Variation	Max 1 hr. Avg. Conc.(ug/m3) Nov 92	Max 1 hr. Avg. Conc.(ug/m3) Jul 93	Max 1 hr. Avg. Conc.(ug/m3) Aug 93
45.7	0	3304	6461	5347
57.13	+ 25	3157	4514	5116
68.55	+ 50	2387	3993	5005
79.88	+ 75	2061	3799	3642
91.40	+ 100	1833	3635	3277

Table 5-3 Effect of Exit Gas Temperature Variations on Ambient 1 hr. Average SO_2 Concentrations (ug/m3)

Exit Gas Temperature (C)	Percent Variation	Max 1 hr. Avg. Conc.(ug/m3) Nov 92	Max 1 hr. Avg. Conc.(ug/m3) Jul 93	Max 1 hr. Avg. Conc.(ug/m3) Aug 93
112	0	3304	6461	5347
140	+ 25	3282	4124	3986
168	+ 50	3279	3953	3411
196	+ 75	2451	3899	2966
224	+ 100	2417	2719	2782

The effects of reductions in stack diameter and the corresponding increase in exit gas velocity, shown in Table 5-4, are effectively zero and demonstrate the fact that plume rise is dominated by the buoyancy flux rather than by the momentum flux. Ambient air SO_2 concentrations remain well above the proposed provincial guideline value for all three months.

Table 5-4 Effect of Stack Diameter and Exit Gas Velocity Variations on Ambient 1 hr. Avg. SO_2 Concentrations (ug/m3)

Stack Diameter (m)	Percent Reduction	Exit Gas Velocity (m/s)	Max 1 hr. Avg. Conc.(ug/m3) Nov 92	Max 1 hr. Avg. Conc.(ug/m3) Jul 93	Max 1 hr. Avg. Conc.(ug/m3) Aug 93
2.7	0	2.7	3304	6461	5347
2.03	25	4.8	3287	6461	5346
1.35	50	10.8	3280	6461	5347
1.00	63	19.8	3280	6460	5346
0.68	75	42.6	3280	6461	5347

5.4 COMBINED EFFECTS

Model results, shown here in Table 5-5, were made with all three discharge parameters set jointly to significantly increased values (stack ht. = 400 ft., EGT = 200 C., and EGVel. = 24.2 m/s). Even at these significantly increased discharge parameter values, exceedences of the 1 hr and 24 hr SO_2 guideline values were not eliminated for almost all of the ten months considered. While maximum ground level SO_2 were reduced by increasing these parameter values, the effect was not enough to eliminate exceedences. The 1 hr. guidline concentration was exceeded by all 49 high values for each of the ten months. Likewise, the 24 hr. guidline concentration was exceeded by all 24 high values for eight of the ten months. The base case model run shows that a 14 fold reduction in maximum grid 1 hr average concentration was required to avoid exceedences, while the largest reduction afforded by increasing stack height, exit gas velocity, and exit gas temperature for any one month ranged from 5 to 10 fold.

Table 5-5 Predicted SO_2 Concentrations at Increased Stack Discharge Parameter Values

Meteorological Data Set	Max 1 Hr. Avg. Conc. (ug/m3)	Max 24 hr. Avg. Conc. (ug/m3)
March 1993	1597	287
April 1993	1775	299
May 1993	1811	524
June 1993	2014	272
July 1993	2116	491
August 1993	1910	334
September 1993	1644	276
October 1993	1320	241
November 1993	883	147
December 1993	853	127

These model results demonstrate that adjustments to dispersion alone will not eliminate exceedences of provincial air quality guidelines. To achieve the ambient concentration reductions required to meet 1 hr. average provincial SO_2 guidelines, it will be necessary to reduce the mass emission rate of SO_2.

6.0 AIR POLLUTION CONTROL OPTIONS

There are two basic removal efficiency catagories for treatment systems used to remove SO_2 from process offgases. Wet and dry scrubbers, which typically use limestone , remove approximately 90 % of emitted SO_2 whereas methods such as dry sorbent injection typically remove only 50 % of emitted SO_2. The evaluation of air pollution control options is limited greatly by (1) a large SO_2 mass emission rate and (2) the rather poor ability of stack discharge parameters to reduce ambient SO_2 concentrations. As noted above, variations in stack discharge parameters alone will not reduce ambient concentrations enough to meet provincial air quality criteria. Some effort to reduce SO_2 mass emission rate is required. Lesser efficient (50%) SO_2 removal methods will likely not be adequate, even when combined with variations to stack discharge parameters, to reduce ambient concentrations enough to not exceed provincial air quality standards. The only apparant option is to use a high (90% +) efficiency SO_2 removal process, such as a wet or dry scrubber, and this may need to be combined with either increased stack height or increased exit gas temperature to attain the 95% effective removal required.

7.0 CONCLUSIONS AND RECOMMENDATIONS

ISCST2 modeling results compared relatively well with fourteen months of ambient SO_2 monitoring data provided. Three months of meteorological data produced effectively zero bias model results, and were therefore used to conduct the sensitivity analysis. The anticipated effects of shoreline fumigation, which would cause the ISCST2 to underpredict ground level concentrations, were not experienced perhaps due to the location of the City Hall monitoring station. During onshore flows, this monitoring station is upwind of the stack, so that even if fumigation were occuring downwind of the stack, it would not be detected at the monitoring station.

As the mass emission rate of SO_2 is a very important parameter in the control of ground level SO_2 concentrations, it is recommended that the mass emission rate of sulfur dioxide be checked regularly by mass balance computations. Mass inputs to the roaster (from the sulfide concentrate feed and perhaps the spray water used in the second stage) minus the sum of mass lost via the main roaster discharge, removal by ESPs, and removal by the Baghouse should equal the mass emitted to the atmosphere. These mass balance computations could serve as a check on stack test results, particularly if samples were taken during the time of the stack tests.

To comply with the territorial ~~provincial~~ ambient air quality guideline ~~standard~~ for SO_2, it will be necessary to reduce significantly the mass emission rate of SO_2. A high removal efficiency offgas treatment process, such as a wet or dry scrubber, is needed to provide removals necessary for proper offgas treatment.

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```
SEEC - V1   Giant Mine - 50 tonnes/day
          =====================================================

          SITE:        GIANT MINE 50
           ----------------------------------------------------
     Site Discription:
                LATITUDE:               62.50 ½N
                AMBIENT TEMP:           10.00 ½C     = 283.16 K
                ROUGHNESS:             100    cm
                AVERAGING TIME:          1.00  h
                ELEVATION ASL:          170. m
                POLLUTANT MOL WT:        64.1

     Options:
                WIND DIRECTIONS:         1
                CALCULATION PLANE:        .00 m
                GRID DENSITY:          1.0DW x 1.0CW
                WINDOW:                 from   .Auto. to  .Auto.
                POLLUTANT:              SO2

     Building  1:       DUMMY BUILDING
                CORNERS AT:                .0 mN           .0 mE
                                          1.0 mN           .0 mE
                                          1.0 mN          1.0 mE
                                           .0 mN          1.0 mE
                HEIGHT:                    .0 m
          Stack  1:     ROASTER
                LOCATION:                  .0 mN           .0 mE
                HEIGHT:                 45.70 m
                DIAMETER:                2.70 m
                GAS TEMPERATURE:        93.70 ½C  =    366.86 K
                GAS VELOCITY:           13.91 m/s
                POLLUTANT FLOW:    573.150000 G/S
                  AT REF. TEMP:         25.00 ½C     = 298.16 K
          =====================================================
```

SEEC - V1 Giant Mine - 50 tonnes/day

SITE: GIANT MINE 50

65 tonnes #1 = 456 ppb at 4303.

1

Maximum	Conditions		
347.83 PPB SO2	WDir = N	Wind Speed = 1. m/s	
	Stability = E		
	Location = -4303.3 mN,	.0 mE	

Contribution of Stacks

Stack:	Eff.Height	SO2
1:ROASTER	127.1 m	347.83 PPB
TOTAL:		347.83 PPB

2

Maximum	Conditions		
244.88 PPB SO2	WDir = N	Wind Speed = 8. m/s	
	Stability = C		
	Location = -615.5 mN,	.0 mE	

Contribution of Stacks

Stack:	Eff.Height	SO2
1:ROASTER	84.8 m	244.88 PPB
TOTAL:		244.88 PPB

3

Maximum	Conditions		
239.52 PPB SO2	WDir = N	Wind Speed = 2. m/s	
	Stability = E		
	Location = -3606.3 mN,	.0 mE	

Contribution of Stacks

Stack:	Eff.Height	SO2
1:ROASTER	110.3 m	239.52 PPB
TOTAL:		239.52 PPB

SEEC - V1   Giant Mine - 50 tonnes/day

SITE: GIANT MINE 50

```
4--------------------------------------------------------------------
 |      Maximum        |                Conditions                   |
 | 238.10   PPB   SO2  | WDir        = N       Wind Speed =  3. m/s  |
 |                     | Stability   = A                             |
 |                     | Location    =   -515.6 mN,       .0 mE      |
 |-------------------------------------------------------------------|
 |                   Contribution of Stacks                          |
 |  Stack:                                 Eff.Height       SO2      |
 | 1:ROASTER                                 158.1 m    238.10 PPB   |
 |                                                      ----------   |
 |       TOTAL:                                         238.10 PPB   |
 --------------------------------------------------------------------

5--------------------------------------------------------------------
 |      Maximum        |                Conditions                   |
 | 236.07   PPB   SO2  | WDir        = N       Wind Speed =  7. m/s  |
 |                     | Stability   = C                             |
 |                     | Location    =   -734.6 mN,       .0 mE      |
 |-------------------------------------------------------------------|
 |                   Contribution of Stacks                          |
 |  Stack:                                 Eff.Height       SO2      |
 | 1:ROASTER                                  91.5 m    236.07 PPB   |
 |                                                      ----------   |
 |       TOTAL:                                         236.07 PPB   |
 --------------------------------------------------------------------

6--------------------------------------------------------------------
 |      Maximum        |                Conditions                   |
 | 230.87   PPB   SO2  | WDir        = N       Wind Speed =  6. m/s  |
 |                     | Stability   = C                             |
 |                     | Location    =   -734.6 mN,       .0 mE      |
 |-------------------------------------------------------------------|
 |                   Contribution of Stacks                          |
 |  Stack:                                 Eff.Height       SO2      |
 | 1:ROASTER                                  99.4 m    230.87 PPB   |
 |                                                      ----------   |
 |       TOTAL:                                         230.87 PPB   |
 --------------------------------------------------------------------
```

SEEC - V1 Giant Mine - 50 tonnes/day

SITE: GIANT MINE 50

7

Maximum	Conditions	
222.40 PPB SO2	WDir = N	Wind Speed = 5. m/s
	Stability = C	
	Location = -876.7 mN,	.0 mE

Contribution of Stacks

Stack:	Eff.Height	SO2
1:ROASTER	110.1 m	222.40 PPB
TOTAL:		222.40 PPB

8

Maximum	Conditions	
216.60 PPB SO2	WDir = N	Wind Speed = 11. m/s
	Stability = D	
	Location = -876.7 mN,	.0 mE

Contribution of Stacks

Stack:	Eff.Height	SO2
1:ROASTER	68.5 m	216.60 PPB
TOTAL:		216.60 PPB

9

Maximum	Conditions	
216.34 PPB SO2	WDir = N	Wind Speed = 10. m/s
	Stability = D	
	Location = -876.7 mN,	.0 mE

Contribution of Stacks

Stack:	Eff.Height	SO2
1:ROASTER	71.5 m	216.34 PPB
TOTAL:		216.34 PPB

SEEC - V1 Giant Mine - 50 tonnes/day

SITE: GIANT MINE 50

10

Maximum	Conditions			
215.83 PPB SO_2	WDir	= N	Wind Speed = 13. m/s	
	Stability	= D		
	Location	=	-734.6 mN,	.0 mE

Contribution of Stacks

Stack:	Eff.Height	SO_2
1:ROASTER	63.7 m	215.83 PPB
TOTAL:		215.83 PPB

SEEC - V1 Giant Mine - 25 tonnes/day

SITE: GIANT MINE

Site Discription:

LATITUDE:	62.50 ½N	
AMBIENT TEMP:	10.00 ½C	= 283.16 K
ROUGHNESS:	10 cm	
AVERAGING TIME:	1.00 h	
ELEVATION ASL:	170. m	
POLLUTANT MOL WT:	64.1	

Options:

WIND DIRECTIONS:	1
CALCULATION PLANE:	.00 m
GRID DENSITY:	1.0DW x 1.0CW
WINDOW:	from .Auto. to .Auto.
POLLUTANT:	SO2

Building 1: DUMMY BUILDING

CORNERS AT:	.0 mN	.0 mE
	1.0 mN	.0 mE
	1.0 mN	1.0 mE
	.0 mN	1.0 mE
HEIGHT:	.0 m	

Stack 1: ROASTER

LOCATION:	.0 mN	.0 mE
HEIGHT:	45.70 m	
DIAMETER:	2.70 m	
GAS TEMPERATURE:	82.70 ½C	= 355.86 K
GAS VELOCITY:	16.50 m/s	
POLLUTANT FLOW:	289.350000 G/S	
AT REF. TEMP:	21.10 ½C	= 294.26 K

SEEC - V1   Giant Mine - 25 tonnes/day

SITE: GIANT MINE

1

Maximum	Conditions
172.19 PPB SO2	WDir = N Wind Speed = 1. m/s
	Stability = E
	Location = -6127.6 mN, .0 mE

Contribution of Stacks

Stack:	Eff.Height	SO2
1:ROASTER	131.3 m	172.19 PPB
TOTAL:		172.19 PPB

2

Maximum	Conditions
117.25 PPB SO2	WDir = N Wind Speed = 2. m/s
	Stability = E
	Location = -5135.1 mN, .0 mE

Contribution of Stacks

Stack:	Eff.Height	SO2
1:ROASTER	113.6 m	117.25 PPB
TOTAL:		117.25 PPB

3

Maximum	Conditions
100.56 PPB SO2	WDir = N Wind Speed = 1. m/s
	Stability = F
	Location = -12423.1 mN, .0 mE

Contribution of Stacks

Stack:	Eff.Height	SO2
1:ROASTER	110.3 m	100.56 PPB
TOTAL:		100.56 PPB

SEEC - V1 Giant Mine - 25 tonnes/day

SITE: GIANT MINE

4

Maximum	Conditions
93.32 PPB SO2	WDir = N Wind Speed = 8. m/s Stability = C Location = -1046.3 mN, .0 mE

Contribution of Stacks

Stack:	Eff.Height	SO2
1:ROASTER	93.6 m	93.32 PPB
TOTAL:		93.32 PPB

5

Maximum	Conditions
93.12 PPB SO2	WDir = N Wind Speed = 7. m/s Stability = C Location = -1248.7 mN, .0 mE

Contribution of Stacks

Stack:	Eff.Height	SO2
1:ROASTER	100.4 m	93.12 PPB
TOTAL:		93.12 PPB