APPENDIX D

Airflow Patterns and Pit-Retention of Fugitive Dust for the Bingham Canyon Mine

APPENDIX D-1

Study Summary

Summary of "Airflow Patterns and Pit-Retention of Fugitive Dust for the Bingham Canyon Mine"

This memo is a summary of the 1996 report "Airflow Patterns and Pit-Retention of Fugitive Dust for the Bingham Canyon Mine" by Ragula Bhaskar and Navin Tandon, Department of Mining Engineering, University of Utah.

When particles, such as fugitive dust, are emitted within a mining pit, only a fraction of what is originally emitted ever escapes the top of the pit to enter the general atmosphere (the so-called escape fraction). Being able to predict the escape fraction for different mine characteristics (such as shape, size, and depth) and different meteorological conditions is an active area of research.

In this report the authors use a well established, commercially available Computational Fluid Dynamics (CFD) model to examine airflow patterns and pit-retention in a fully three-dimensional digital representation of the Bingham Canyon Mine. In the horizontal direction an area of 23,000 feet in the north-south direction by 20,000 feet in the east–west direction was represented. Vertically the model extended up to nearly 10,000 feet above the ground and one-half mile down to the bottom of the pit. This area, which includes the Bingham Canyon Mine and part of Bingham Canyon, was digitally entered into the model from topographic data. This was represented in the model by 19,872 nodal points and 22,862 three-dimensional elements.

The authors examine the influence that varying wind speed, wind direction, atmospheric stability, source location, source height, and particle size have on the calculated escape fraction. For the simulations they did for the Bingham Canyon Mine, the escape fraction for the pit ranged from about 10 to 20 percent. Some important points to remember are:

- Use of a standard CFD packages (FIDAP) ensures the fundaments of the Finite Element Method (FEM) code have been tested and validated.
- The FEM is more technically rigorous – with generally fewer simplifying assumptions – than used in the regulatory model, AERMOD.
- The part of the authors work that examines results from real pit geometry in comparison to results from idealized pit geometries (as were used in the development of the pit retention algorithms used in AERMOD) indicates a possibly very important limitation to the pit retention algorithm used in EPA's ISC and AERMOD models.

Selecting an Escape Factor for Use in AERMOD Modeling

Table D-1 below provides a summary of the six sensitivity analyses done by the authors. The fixed variables of the "Base Case," around which the sensitivity analyses varied, are given in the "Base Case" column. Except for source location and source height, all variations produce escape fractions of 12.6 percent or less.

TABLE D-1
Summary of Sensitivity Analyses

Variable	Base Case	Range	Escape Fraction
Wind Speed (miles per hour)	6	4	10.2%
		6	11.8%
		10	12.4%
		30	12.6%
Wind Direction	North	North	11.8%
		South	12.6%
		East	12.2%
		West	12.4%
Atmospheric Stability	D (neutrally stable)	A (unstable)	12.6%
		D (neutrally stable)	11.8%
		F (stable)	12.2%
Source Location	Pit bottom	Pit bottom	11.8%
		Pit boundary in downwind direction	19.2%
		Near in-pit crusher	16.6%
Source Height (feet)	7	7	11.8
		30	13.4
Particle Size (microns)	10	1	12.6%
		2	12.5%
		5	12.4%
		7	12.2%
		10	11.8%

In Appendix A of the study, the authors compare two so-called "worst-case" scenarios. Table D-2 summarizes the conditions and resulting escaped fractions. The authors chose the parameters for all the "worst case" results from the sensitivity results and examined the influence of another condition, the assumption used for deposition. As the authors point out, it is physically impossible to have a stability class of A (unstable) in combination with a high wind speed of 30 mph. However, this physical impossibility was modeled so as to combine all the worst case conditions from all of the sensitivity studies.

In the first of the two worst case scenarios they used the so-called "trap" condition - where 100 percent of the particles that collide with the ground are deposited. In the second worst case scenario the authors used the opposite extreme, the so-called "ricochet" condition – where all particles reflect back with the same velocity as the incoming velocity on collision with the ground. The escape fractions were 22 percent for trap and 33 percent for ricochet.

TABLE D-2
Comparison of "Trap" and "Ricochet" deposition

"Worst Case" Scenario	Wind Speed (mph)	Wind Direction	Atmospheri c Stability	Source Location	Source Height (feet)	Particle Size (microns)	Escape Fraction
100% Trap	30	From the South	A (unstable)	Pit boundary in downwind direction	30	10	22%
100% Ricochet	30	From the South	A (unstable)	Pit boundary in downwind direction	30	10	33%

To estimate emissions and perform the current AERMOD modeling for the 24-hour PM_{10} impact, the approach of applying one escape fraction to all sources in the pit and for all times is being taken. This approach requires the selection of a single value for the escape fraction that is representative but also conservative. While the conditions modeled for the two "worst-case" scenarios are not realistic and too conservative to be considered representative, they may indicate the difference between results for 100 percent trap and 100 percent ricochet is approximately 5.5 percent. All other cases were run with the 100 percent trap boundary condition. In reality the percentage of particles that deposit lays between the two extreme that were modeled.

For all but two cases the maximum escape fraction from the sensitivity analyses is 12.6 percent or less. Therefore a value of 12.6 percent - once adjusted upwards to represent a more realistic percentage of the particles that deposit – would be the most representative of real conditions at the mine. As noted earlier, the change from 100 percent trapped to 100 percent ricochet is 5.5 percentage points. Adjusting 12.5 percent upwards by 5.5 percentage points yields 18.0 percent. To be even more conservative and adjust for the level of uncertainty, an escape fraction of 20 percent was chosen for the emission estimates and the AERMOD modeling of PM_{10} impacts for comparison with the NAAQS.

Using similar reasoning, an escape fraction of 21 percent was chosen for $PM_{2.5}$. As discussed above, using the available data from the 1996 report by Bhaskar and Tandon, an escape fraction of 20 percent was selected to be conservatively representative for AERMOD modeling of PM_{10} impacts for comparison with the NAAQS. Just as PM_{10} represents all particles with aerodynamic diameters of 10 microns and smaller, $PM_{2.5}$ represents all particles with aerodynamic diameters of 2.5 microns and smaller. Since larger particles have larger settling velocities, the escape fraction for larger particles is expected to be smaller. The sensitivity study for particle size showed this expected relationship (see Table 1 above). Of the particles sizes examined in the sensitivity study, two are smaller than 2.5 microns: 1 micron and 2 microns. These had escape fraction 0.6 and 0.5 percent larger, respectively, than the 11.8 percent escape fraction for the base case 10 micron particle. As $PM_{2.5}$ represents all particles equal to or smaller than 2.5 microns, this would include particles even smaller than 1 micron, which would presumably have even larger escape fractions. Fortunately, it is known that the relationship of decreasing deposition with decreasing particle size only continues until particles with size on the order of 0,1 microns. At that point deposition values begin to increase for even smaller particles due to other physical phenomena in addition to gravitational settling. Consequently, to account for particles down to 0.1 microns, an upward adjustment of 1 percentage point from the 20.0 percent escape fraction used for PM_{10} was chosen for the escape fraction chosen to use in the AERMOD modeling of $PM_{2.5}$ impacts for comparison to the NAAQS.