REGIONAL HAZE SECOND PLANNING PERIOD FOUR-FACTOR ANALYSIS

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1. EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA) Regional Haze Rule (RHR) is designed to improve visibility at national Class I areas to natural levels by 2064. The program is designed to achieve this goal by assessing visibility during various "planning" periods, demonstrate that visibility improvements are progressing along the Uniform Rate of Progress (URP), and require controls to demonstrate reasonable progress. The current planning period requires that states submit updated implementation plans no later than July 31, 2021. The analysis requires the development of a "Source Screening" approach to remove sources from further consideration. Sources that are not screened out are subject to additional review such as a four-factor analysis (4FA).

The Arizona Department of Environmental Quality (ADEQ) informed the Morenci Mine, owned and operated by Freeport-McMoRan Morenci Inc. (FMMI) that they were selected for a 4FA. ADEQ has also provided FMMI with a list of the processes that are subject to the 4FA. This report details the methodology used to complete the 4FA for these processes and summarize the associated results. Table 1-1 summarizes the results of the 4FA for the Morenci Mine.

Table 1-1. Morenci Mine – Four Factor Analysis Conclusions

Unit Process Description	Pollutant	Conclusion
Haul Truck Travel on Mine Roads	PM_{10}	Compliance with fugitive dust control requirements contained in Arizona Administrative Code (AAC) R18-2-605 "Roadway and Streets" and fugitive dust opacity limitation of 40% contained in R18-2-614
Other Vehicle Travel on Mine Roads	PM_{10}	Compliance with fugitive dust control requirements contained in AAC R18-2-605 "Roadways and Streets" and fugitive dust opacity limitation of 40% contained in AAC R18-2-614
Loading Ore into Haul Trucks	PM_{10}	Compliance with fugitive dust control requirements contained in AAC R18-2-606 "Material Handling" and fugitive dust opacity limitation of 40% contained in AAC R18-2-614

2. INTRODUCTION

In the 1977 amendments to the Clean Air Act (CAA), Congress set a nation-wide goal to restore national parks and wilderness areas to natural conditions by remedying existing anthropogenic visibility impairment and preventing future impairments. On July 1, 1999, the EPA published the final RHR located at Title 40 of the Code of Federal Regulations (40 CFR) §51.308. The objective of the RHR is to restore visibility to natural conditions in 156 specific areas across the United States, known as Federal Class I areas. Pursuant to 40 CFR §51.308(d)(1), the RHR requires states to set goals that provide for reasonable progress towards achieving natural visibility conditions for each Class I area in their jurisdiction. In establishing a reasonable progress goal (RPG) for a Class I area, each state must:

- Pursuant to 40 CFR §51.308(d)(1)(i)(B), *"Analyze and determine the rate of progress needed to attain natural visibility conditions by the year 2064. To calculate this rate of progress, the State must compare baseline visibility conditions to natural visibility conditions in the mandatory Federal Class I area and determine the uniform rate of visibility improvement (measured in deciviews) that would need to be maintained during each implementation period in order to attain natural visibility conditions by 2064. In establishing the reasonable progress goal, the State must consider the uniform rate of improvement in visibility and the emission reduction."* The URP or improvement is also known as the "glidepath".

- Pursuant to 40 CFR §51.308(d)(1)(i)(A), *"Consider the costs of compliance, the time necessary for compliance, the energy and non-air quality environmental impacts of compliance, and the remaining useful life of any potentially affected sources, and include a demonstration showing how these factors were taken into consideration in selecting the goal."* This is known as a four-factor analysis (4FA).

The program is designed to assess visibility at Class I areas during various "planning" periods. As part of the first planning period (for the period between 2004 to 2018) states were required to submit implementation plans (SIPs) no later than December 17, 2007. The second planning period (for the period between 2018 to 2028) requires that states submit updated SIPs no later than July 31, 2021 and is currently underway.

3. REGIONAL HAZE SECOND PLANNING PERIOD & FMMI

Pursuant to 40 CFR 51.308(d)(3)(iv), states are responsible for identifying the sources that contribute to the most impaired days (MID) in the Class I areas. To accomplish this, ADEQ reviewed 2014 emission inventory data for sources of PM_{10}, NO_x, and SO_2, and developed a "source screening" approach using a "Q/d" analysis (i.e. emissions in tons/year divided by the distance to an affected Class I area in miles or kilometers), to remove sources from further consideration. In this analysis "Q" is the aggregate tons per year of PM_{10}, NO_x, and SO_2, and "d" is the distance (km) of a facility to a Class I area. Arizona followed guidance from the Western Regional Air Partnership (WRAP) and screened out any source that had a Q/d ratio less than 10. For remaining sources, ADEQ evaluated 2018 facility operations and emissions to determine which processes have installed an "effective control" within the last five years. Those processes, which have an "effective control" were deferred from further evaluation during this planning period.[1] Based on ADEQ's evaluation of the Q/d ratio and "effective control" analysis, ADEQ identified the Morenci Mine as required to conduct a 4FA. ADEQ determined that the facilities required to conduct a 4FA need only examine processes contributing to the top 80% of haze-causing pollutants. Table 3-1 summarizes the processes ADEQ determined are subject to a 4FA at the Morenci Mine.

The Morenci Mine is located in Greenlee County, Arizona. The nearest Class I area to the mine is the Gila Wilderness, located about 54 kilometers away from the mine. It should be noted that ADEQ is considering the area of influence for PM_{10} sources to only be 50 km when conducting the four factor analysis for nonpoint sources. ADEQ calculated the "Q/d" for the Morenci Mine to be 52. Table 3-1 contains a list of the processes that ADEQ determined contribute the top 80% of haze causing pollutants and are subject to the 4FA based on ADEQ communication.[2]

Table 3-1. Morenci Mine – Processes Subject to Four Factor Analysis

Unit Process Description	Pollutant	Emissions Estimate (tpy) [3]
Haul Truck Travel on Mine Roads	PM_{10}	1,465.8
Other Vehicle Travel on Mine Roads	PM_{10}	631.1
Loading Ore into Haul Trucks	PM_{10}	124.4

Current methodology used in FMMI's emissions inventories does not separate roads on which haul trucks travel from roads on which haul trucks do not travel. As such, any control method that is considered must be compatible with haul truck traffic. As the haul trucks are the limiting factor when determining the feasibility of unpaved road controls, the remainder of the analysis will analyze "haul truck travel" and "other vehicle travel" on mine roads as a single emission source.

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[1] ADEQ 2021 Regional Haze State Implementation Plan Source Screening Methodology

[2] Per "Four Factor Processes" spreadsheet received September 2019.

[3] Ibid.

3.1. PIT RETENTION

Emissions to the atmosphere from mining activities occurring inside the open pit are reduced due to the effect of the pit wall, such that only a fraction of the fugitive dust generated inside the pit escapes to the surface where it can potentially disperse. This phenomenon can be visually observed at any open pit mine. The tendency of dust particles to remain in the pit is referred to as "pit retention."[4] Studies have shown that pit retention can be as high as 80% for PM_{10}.[5,6] Based on this information, FMMI developed and proposed to ADEQ a methodology for estimating pit retention using AERMOD that showed pit retention could be as high as 80%; however, ADEQ suggested a second method of using AERMOD that demonstrated a pit retention value of 5-10%. Due to this discrepancy, FMMI has not included a pit retention control efficiency in its evaluation of potential control options. In addition, because a pit retention factor would decrease emissions from the pit, and thus also potential emission reductions, it would increase the $/ton cost of any potential control. FMMI reserves the right to continue to study the pit retention control efficiency and potentially include the findings of any study in future submittals to ADEQ.

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[4] "Surface mine pit retention", C. F. Cole, A.J. Fabrick, 1984.

[5] Per Master's thesis *"Airflow Patterns and Pit-Retention of Fugitive Dust for the Bingham Canyon Mine"*, only 20% of in-pit PM_{10} emissions escape the Kennecott Utah Copper Bingham Canyon Mine open pit. Kennecott Utah Copper has since been required to validate these retention factors.

[6] Per *"Significant Dust Dispersion Models for Mining Operations"*, W. R. Reed, 2005, multiple models have been conducted concluding that approximately one-third of emissions from mining activities escape from the open pit.

4. FOUR FACTOR ANALYSIS METHODOLOGY & RESULTS

The 4FA completed as part of this report examines the following four factors in 40 C.F.R. 51.308(f)(2)(i):

1. Cost of compliance for the control;
2. Time necessary to comply with the control;
3. Energy and non-air quality impacts of the control; and
4. The remaining useful life of the source.

Factors 1 and 3 are considered by conducting a step-wise review of emission reduction options in a top-down fashion similar to the top-down approach that is included in the EPA RHR guidelines for conducting a review of Best Available Retrofit Technology (BART)[7]. These steps are set forth in 40 C.F.R. Appendix Y to part 51, Section IV.D as follows:

Step 1. Identify all available retrofit control technologies,

- FMMI has identified all possible control technologies through a review of the RACT/BACT/LAER Clearinghouse (RBLC) database, ADEQ guidance, and technical literature. In some cases, this process identified control technologies for which emissions reductions could not be quantified or that do not appear to result in emission reductions. These were carried forward to Step 2 for completeness.

Step 2. Eliminate technically infeasible options,

- FMMI eliminated options that have not been demonstrated in practice, could not physically be accomplished, or which created a safety hazard.

Step 3. Evaluate control effectiveness of remaining control technologies,
Step 4. Evaluate impacts and document the results, and
Step 5. Evaluate visibility impacts.

Factor 4 is also addressed in the step-wise review of the emission reduction options, primarily in the context of the cost of emission reduction options and whether any capitalization of expenses would be impacted by limited equipment life.[8] Once the step-wise review of control options is completed, a review of the timing of the emission reductions are provided to satisfy Factor 2 of the four factors.

4.1. HAUL TRUCK/OTHER VEHICLE TRAVEL ON HAUL ROADS - PM_{10} CONTROLS

This section presents the step-wise review of control options for PM_{10} for the hauling of waste and ore from loading sites with trucks and other vehicle travel on haul roads located at the Morenci Mine.

4.1.1. Haul Road Emission Calculations

The PM_{10} emissions from haul truck travel and other vehicle travel are calculated from AP-42, Section 13.2.2, Equation 1a for vehicles traveling on unpaved surfaces at industrial sites. The emissions factor, *E*, in lb/VMT, is calculated as follows:

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[7] Pursuant to EPA *"Draft Guidance on Progress Tracking Metrics, Long-Term Strategies, Reasonable Progress Goals and Other Requirements for Regional Haze State Implementation Plans for the Second Implementation Period"*, July 2016, page 94, *"many of the statements in the BART Guidelines continue to be relevant as recommendations for how a state should assess facts related to the four statutory factors."*

[8] Pursuant to EPA *" Guidance on Regional Haze State Implementation Plans for the Second Implementation Period"*, August 2019, pg 42.

$$E = 1.5 * \left(\frac{surface\ silt\ content\ [\%]}{12}\right)^{0.9} \left(\frac{mean\ vehicle\ weight\ [tons]}{3}\right)^{0.45} = [\text{lb/VMT}]$$

The critical variables in determination of the emissions are, therefore: surface silt content, vehicle weight, and vehicle miles traveled. The PM_{10} emissions calculation does not take into account vehicle speed.

4.1.2. Identification of Potential Control Technologies

The following PM_{10} control technologies were identified:

- Traffic management (reduction in speed);
- Applying additional water;
- Applying chemical dust suppressant;
- Applying and maintaining surface gravel;
- Requiring haul trucks to be covered;
- Controlling freeboard and spillage; and
- Paving the road surface.

To identify all feasible control technologies, the RACT/BACT/LAER Clearinghouse (RBLC) database, ADEQ guidance, and technical literature was reviewed. Using these sources, potentially applicable PM_{10} control technologies for unpaved haul roads were identified based on the principles of control technology and engineering experience for haul truck travel.

Each control technology is described in detail below, as well as its technical feasibility to satisfy Steps 1 and 2 of the top-down analysis approach. Where the control is deemed technically feasible, control effectiveness is also evaluated to satisfy Step 3.

4.1.2.1. Traffic Management / Speed Reduction

This control method was identified by ADEQ as a potential control option for unpaved roads.[9] For purposes of unpaved haul roads, the only available traffic management method is speed reduction. Emissions from this source, however, are not based on vehicle speed, as shown in the equation above (Section 4.1.1). As such, no control efficiency is calculated for this method. Additionally, reduced speed limits would significantly impact the production rate of the overall operations, considering that haul truck travel is critical to the ore throughput. If stricter speed limits were enforced, FMMI would have to buy additional haul trucks to make up for the loss in production. Increasing the amount of haul trucks on the roads would lead to an increase in PM_{10} emissions, as well as increased tailpipe emissions from additional fuel combustion.

Reduction of speed of the haul trucks is technically feasible at the Morenci Mine. Note that FMMI already self imposes speed limits of 34.5 mph for safety.

4.1.2.2. Additional Water Application

Applying additional water to haul roads is another PM_{10} control method identified by ADEQ. Dust emissions are dependent on the moisture level of the mechanically disturbed material;

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[9] Draft List of Potential PM_{10} Controls for Nonpoint Source Sectors – Paved Road Dust and Unpaved Road Dust

therefore, when water is applied a cohesive crust is formed among the discrete grains of surface material.[10]

While additional water application is a feasible control option, water application is already utilized at FMMI in accordance with Arizona Administrative Code (AAC) regulations and air quality permit conditions. Moreover, FMMI currently applies a 90% control efficiency for water application. While Figure 13.2.2-2 in AP-42 suggests that control efficiencies as high as 95% can be correlated to this control method,[11] it is FMMI's understanding that ADEQ will accept a maximum 90% control efficiency for this control method. Therefore, additional watering will not increase the calculated control efficiency.

4.1.2.3. Applying Chemical Dust Suppressant

Chemical dust suppressants reduce PM_{10} emissions by changing the physical characteristics of the existing road surface material and forming a hardened surface that binds particles together.[12] Common chemical dust suppressants used at mines are magnesium chloride ($MgCl_2$) and lignosulfonate. These are used on sources such as light duty unpaved roads, tailings impoundments, and disturbed open areas. Chemical dust suppressants are not currently used on unpaved haul roads at the Morenci Mine for several reasons. First, the crust formed by the chemicals would be short lived due to the extreme weight and crushing power of the haul trucks, weighing approximately 860,000 pounds loaded. Second, chemical dust suppressants would cause tire slippage during rainy conditions which is a safety hazard. Tire slippage is even more likely when haul trucks make turns or travel on a slope and the haul roads at the Morenci Mine have many turns and slopes. A third concern is the effect that the chemicals could have on the recovery of copper in the floatation process. FMMI has performed many tests to determine the compatibility of $MgCl_2$ and lignosulfonate on the floatation processes. The majority of these tests returned results of poor compatibility and serious upsets. When used on light duty roads, chemicals are strategically placed so that runoff from these areas do not make its way to ponds where it could be pumped back into the process. In contrast, the existing in-pit haul roads will eventually be mined as the open pit is deepened and new haul roads constructed. FMMI is continuing to research chemicals that could be used to control dust from unpaved haul roads, but at present none have been approved for use.

Due to safety concerns, chemical dust suppressant on haul roads is determined to be technically infeasible.

4.1.2.4. Applying and Maintaining Surface Gravel

Although it is feasible to apply gravel to the haul road, it is infeasible to maintain it. Gravel would immediately degrade when driven on by a haul truck. Large ruts would form and haul trucks would likely slip when traveling up or down a slope. This control method will not be pursued further in this analysis due to infeasibility along with potential safety concerns.

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[10] WRAP Fugitive Dust Handbook, 2006

[11] Per EPA *"Control of Open Fugitive Dust Sources"*, September 1988, pages 5-9 to 5-14.

[12] WRAP Fugitive Dust Handbook, 2006

4.1.2.5. Covering Haul Trucks

Covering haul trucks is another control technology suggested by ADEQ.[13] Unpaved road emissions at the Morenci Mine exclusively correspond to the dust that becomes airborne due to the tires of the vehicles that travel on the unpaved roads. The 1993 SIP for the Douglas PM_{10} Nonattainment Area, concluded that emissions that would be controlled by requiring haul trucks to be covered was negligible. Hence, no control efficiency was identified that can be correlated to this control method.

Covering haul trucks is a technically infeasible control option because covers are not readily available to accommodate the size of the haul trucks at the Morenci Mine. Covers would either have to be made in-house, or a new type of cover would have to be sourced. In addition, the covers would have to accommodate the varying sizes of the material that is transferred in the haul trucks. Often times, large boulders can be placed in the haul truck which exceed the height of the bed, making it impossible to place a flat cover directly on top of the haul truck bed.

4.1.2.6. Controlling Freeboard and Spillage

Controlling freeboard and spillage is another control method identified by ADEQ.[14] The freeboard refers to the distance between the top of the load to the rim of the bed of the haul truck. Reducing freeboard could potentially reduce the amount of spillage onto haul roads. Unpaved road emissions at the Morenci mine exclusively correspond to the dust that becomes airborne due to the tires of the vehicles that travel on the unpaved roads. Material that spills from a haul truck could potentially increase the silt content on the road, although this is impossible to quantify and can reasonably be assumed to have a negligible effect.

Controlling freeboard and spillage are technically feasible control options. However, reducing freeboard would reduce the capacity hauled per truck and would require additional haul trucks to be purchased to make up for the loss in production. This would increase the total vehicle miles traveled per year and would lead to an increase in PM_{10} emissions, as well as an increase in tailpipe emissions from additional fuel combustion. Similar to the control method of covering haul trucks, emissions potentially controlled by implementing this method would be negligible; hence, no control efficiency was identified that can be correlated to this control method.

4.1.2.7. Paving the Road Surface

Paving the road surface is another control method identified by ADEQ.[15] Pavement has the potential to reduce PM_{10} emissions by changing the physical characteristics of the existing road surface material and forming a hardened surface that binds particles together.

Current federal laws allow vehicles up to the maximum of 80,000 pounds gross vehicle weight on the Interstate System.[16] This limit is in place to prevent serious damage to the infrastructure of the paved roads. Haul trucks at the Morenci Mine would immediately damage any pavement due to their size since they can weigh up to 860,000 pounds. Maintenance would be required on a regular basis and ore throughput would be adversely impacted due to the rerouting of haul

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[13] Draft List of Potential PM_{10} Controls for Nonpoint Source Sectors – Non-Residential Construction Dust (Industrial, Commercial, Institutional)

[14] Ibid.

[15] Draft List of Potential PM_{10} Controls for Nonpoint Source Sectors – Paved Road Dust and Unpaved Road Dust

[16] ADOT *"Estimating the Cost of Overweight Vehicle Travel on Arizona Highways"* Final Report 528, January 2006.

trucks during maintenance of paved roads. Due to these considerations, paving haul roads is not technically feasible.

4.1.3. Rank of Remaining Control Technologies Based on Control Effectiveness

Table 4-1 lists the controls and their corresponding control efficiencies, satisfying Step 3 of the top-down analysis.

Table 4-1. Vehicle Travel - Remaining PM_{10} Control Technologies

Rank	Control Technology	Potential PM_{10} Control Efficiency [1]
1	Speed Reduction	0%
2	Additional Water	0%
3	Control Freeboard/Spillage	0%

[1] PM_{10} control efficiencies calculated as detailed in Appendix A

4.1.4. Evaluation of Impacts for Remaining Control Technologies

The fourth step of the top-down control review is the impact analysis. The impact analysis considers the:

- Cost of compliance;
- Time necessary to comply with the control;
- Energy impacts and non-air quality impacts; and
- The remaining useful life of the source.

The cost of compliance in summarized in Table 4-2 . The cost of compliance for all of the controls does not include a "$/ton" value as there is no quantifiable emissions reduction that could be associated with the controls. However, an annualized cost is still provided. The energy and non-air quality impacts are considered negligible for each of the controls. Per EPA guidance[17], the remaining useful life of the source is considered to be 20 years, although the concept of remaining useful source is typically used in the context of a discrete emission unit. As a haul road is a fugitive dust source and is frequently torn up and moved, they don't have a remaining useful life that can be accurately estimated. See Appendix A for the detailed analysis for the cost of compliance for each control.

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[17] See EPA Control Cost Manual, Sixth Edition, page 2-26, available from http://www.epa.gov/ttncatc1/dir1/c_allchs.pdf.

Table 4-2. Vehicle Travel - Annualized Cost of Controls

	Control Method		
	Speed Reduction	**Additional Water**	**Control Freeboard/Spillage**
Tons Reduced	0	0	0
Annualized Cost ($/year)	52,095,363	1,104,485	153,681,322
$/Ton	N/A	N/A	N/A

4.2. LOADING ORE - PM_{10} CONTROLS

This section presents the step-wise review of control options for PM_{10} for haul truck loading located at FMMI.

4.2.1. Loading Ore Emission Calculations

The PM_{10} emissions from ore loading are calculated from AP-42, Section 13.2.4 – Aggregate Handling and Storage Piles. The emissions factor, *E*, in lb/ton of material loaded, is calculated as follows:

$$E = 0.00112 * \frac{\left(\frac{mean\ wind\ speed\ [mph]}{5}\right)^{1.3}}{\left(\frac{material\ moisture\ content\ [\%]}{2}\right)^{1.4}} = [\mathrm{lb/ton}]$$

The critical variables in determination of the emissions are, therefore:

- Mean wind speed (FMMI uses wind speed recorded from the Town Site Meteorological Monitor, 6.91 mph in 2018); and
- Material moisture content (FMMI uses average ore moisture, 3.2% in 2018)

4.2.2. Identification of Potential Control Technologies

The following PM_{10} control technologies were identified:

- Regularly applying water;
- Altering loading procedures; and
- Ceasing operations during high winds.

To identify all feasible control technologies, the RBLC database, ADEQ guidance, as well as technical literature was reviewed. Using these sources, potentially applicable PM_{10} control technologies for loading ore at FMMI were identified based on the principles of control technology and engineering experience.

Each control technology is described in detail below as well as its technical feasibility to satisfy Steps 1 and 2 of the top-down analysis approach. Where the control is deemed technically feasible, control effectiveness is also evaluated to satisfy Step 3.

4.2.2.1. Regularly Applying Water

Applying additional water is a potential control method that is feasible. Many of the locations where loading operations occur are already watered as necessary to stay in compliance with AAC and permit conditions limiting opacity. Control from the water addition, however, is not taken into account when calculating emissions from these sources. The Morenci Mine can operate up to 15 loading sites at a time. To apply the amount of water needed to increase the moisture content to a level that would reduce emissions on a continuous basis, Morenci would need to employ a water truck at each loading site to ensure that the moisture content in the ore during loading procedures is sufficient.

4.2.2.2. Altering Loading Procedures

In the context of ADEQ's non-point four-factor analysis, ADEQ has suggested altering loading procedures, such as loading trucks on the downwind side of loading equipment. This is a control option presumably because the loading equipment itself forms a windbreak. While this may be feasible with the types of equipment seen in the aggregate industry, the massive electric shovels and haul trucks used in the copper mining industry cannot be moved whenever the wind shifts directions. This would not be a feasible control at the Morenci Mine.

4.2.2.3. Ceasing Operations During High Winds

Ceasing operations during high winds (sustained wind speeds over 25 mph[18]) is a potential control method used to reduce PM_{10} emissions that is feasible. This would reduce calculated emissions by assuming there are no emissions from loading during high winds. Loading operations are critical to the operation of the mine and ceasing operations during high wind speeds would shut down production.

4.2.3. Rank of Remaining Control Technologies Based on Control Effectiveness

Table 4-13 lists the remaining controls and their corresponding control efficiencies.

Table 4-3. Truck Loading - Remaining PM_{10} Control Technologies

Rank	Control Technology	Potential NO_x Control Efficiency [1]
1	Regular Water Application	43%
2	Cease Operations During High Winds	0.05%

[1] PM_{10} control efficiencies calculated as detailed in Appendix A

4.2.4. Evaluation of Impacts for Remaining Control Technology

The fourth step of the top-down control review is the impact analysis. The impact analysis considers the:

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[18] WRAP Fugitive Dust Handbook, 2006 Pg 11-13

- Cost of compliance;
- Time necessary to comply with the control;
- Energy impacts and non-air quality impacts; and
- The remaining useful life of the source.

The cost of compliance in summarized in Table 4-4. The energy and non-air quality impacts are considered negligible for each of the controls. Per EPA guidance, the remaining useful life of the source is considered to be 20 years, although the concept of remaining useful source is typically used in the context of a discrete emission unit. See Appendix A for the detailed analysis for the cost of compliance for each control.

Table 4-4. Truck Loading - Annualized Cost of Controls

	Control Method	
	Regular Water Application	**Limiting Operations During High Winds**
Tons Reduced	52.06	0.05
Annualized Cost ($/year)	5,052,277	878,995
$/Ton	97,043	16,015,522

5. VISIBILITY IMPACTS

Pursuant to EPA guidance,[19] a back-trajectory analysis was completed to determine if the emissions from the Morenci Mine might affect visibility at the nearest Class I area. For the Morenci Mine, the assessment was completed for possible impacts at the Gila Wilderness Area. The trajectory analysis was completed using the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model based on ADEQ feedback and guidance regarding details of model execution.[20]

5.1. HYSPLIT MODEL - OVERVIEW

HYSPLIT is a hybrid model using both the Lagrangian approach, which uses a moving frame of reference for the advection and diffusion calculations as the trajectories or air parcels move from their initial location, and the Eulerian methodology, which uses a fixed three-dimensional grid as a frame of reference to compute pollutant air concentrations. The dispersion of a pollutant is calculated by assuming either puff or particle dispersion. The back-trajectory analysis utilized applies a particle model, where a fixed number of particles are advected about the model domain by the mean wind field and spread by a turbulent component. The model's default configuration assumes a 3-dimensional particle distribution (horizontal and vertical).

5.2. HYSPLIT MODEL - EXECUTION DETAILS

HYSPLIT was applied in back-trajectory mode with the starting location as the Class I Interagency Monitoring of Protected Visual Environments (IMPROVE) monitor location or the approximate center of the Class I area if IMPROVE data was not available. The starting locations listed below were used for this analysis.

Table 5-1. HYSPLIT Assessment Locations

Class I Area	Assessment Location		
	Monitor Name	Latitude	Longitude
Gila Wilderness Area	- [1]	33.2205	-108.2357

[1] Monitoring data reflecting the 20% most impacted days (MIDs) for the Gila Wilderness area were not received from ADEQ for this study so the MIDs from the Chiricuhua Wilderness Area were used for this analysis.

While EPA[21] and ADEQ guidance[22] recommend a 72-hour look back period, a 48-hour look back period was more than adequate to capture the back trajectories given the short distances between the Class I area and the source. As the figures show in Appendix B, the 48-hour period was sufficient for the plume to travel out of the general area of the source and often out of the state. The sigma height option was used with an initial target height of 0.5 sigma per ADEQ recommendation.[23] ADEQ provided a list of

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[19] EPA Memorandum, "*Guidance on Regional Haze State Implementation Plans for the Second Implementation Period,*" Section II.B.3, August 20, 2019

[20] Based on multiple email communications between Stephen Ochs, Trinity Consultants, and Hao Zhou, ADEQ, in November 2019.

[21] EPA Memorandum, "*Guidance on Regional Haze State Implementation Plans for the Second Implementation Period,*" Section II.B.3, August 20, 2019

[22] Ibid.

[23] Based on multiple email communications between Stephen Ochs, Trinity Consultants, and Hao Zhou, ADEQ, in November 2019.

MIDs and a 5 year look back period from 2014 – 2018 was analyzed. Per ADEQ recommendation,[24] each hour of the MID was run (24 runs per day).

5.3. HYSPLIT MODEL - RESULTS

ArcGIS shape files of the trajectory hourly location (points) and path (lines) were created for each hourly run. A plot showing the percentage of the back-trajectory paths that pass within a 1 km x 1 km grid centered around the Morenci Mine was produced using all hourly MID back trajectories over the 5-year period, and is contained in Appendix B. For example, approximately 2,700 back-trajectory paths were created for MIDs in the 5-year assessment period for Gila Wilderness Area. However, less than 1% of these paths entered the 1 km x 1 km grid centered around the Gila Wilderness Area. Therefore, the plot indicates the probability of the emissions from the Morenci Mine impacting the Gila Wilderness Area is between 0.5% and 1.0%.

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[24] Based on multiple email communications between Stephen Ochs, Trinity Consultants, and Hao Zhou, ADEQ, in November 2019.

APPENDIX A: FOUR FACTOR ANALYSIS WORKSHEETS

Regional Haze - Four-Factor Analysis
Summary

Table 1a. FMI - Morenci - RH 2PP - 4FA - Summary of Sources with Feasible Controls

Source Characteristics			Baseline Operations		Baseline PM_{10} Emissions
Type	**Morenci ID**	**Process ID**	**2016-2018 Avg. Throughput**	**Throughput unit**	**(tpy) [1]**
HAUL TRUCK TRAVEL ON MINE ROADS	1	1	6,894,544	Miles	1,552.4
OTHER VEHICLE TRAVEL ON MINE ROADS	1	45	1,114,970	Miles	229.2
LOADING ORE INTO HAUL TRUCKS	1	2	286,723,309	Tons	120.2

[1] Per 2028 projections.

Table 1b. FMI - Morenci - Inputs

Parameter	Value	Units	Notes
Estimated yearly revenue of Morenci Mine	1,925,000,000	USD/year	Per 10 K report (2018) assuming a price of copper of $2.75 based on average of 52 week high and 52 week low found at: http://www.infomine.com/investment/metal-prices/copper/5-year/
Number of haul trucks in fleet	132		
Number of water trucks in fleet	13		
Average cost of haul trucks	4,500,000	$/truck	Per FMSI estimates
Average cost to rebuild haul truck	2,000,000	$/rebuild	Per FMSI estimates
Average cost of water trucks	2,500,000	$/truck	Per FMSI estimates
Average capacity of water trucks	23,750	gallons	Per FMSI Operations
Annual water usage on roads	7,315,000	gallons/year	Per FMSI water log
Annual spending on water for dust control	12,542	USD/year	Calculated using water rate per ton
Height of haul truck bed	8	ft	Estimate
Average height of the pile of rock over the rim of the bed	6	ft	Per FMSI estimates
Speed reduction if using traffic management as a control	15%		Assumed 15% speed reduction.
Increase in volume of water added to unpaved roads	25%		Per EPA "Dust Suppression on Wyoming's Coal Mine Haul Roads". 2.5x the amount of water is needed to increase control efficiency from 75% to 95%. FMI already utilizes an 90% control efficiency, thus it was assumed that there would be a 25% increase in the amount of water needed.
Maximum number of haul truck loading sites at any given time	15		Estimate
Amount of freeboard to achieve control	0.25	ft	
Annual hours above the high wind threshold (25 mph)	4	hours	Per 2018 Townsite Data
Cost of water in Tucson	0.007	$/gal	https://www.tucsonaz.gov/water/residential-rates-and-monthly-charges

Regional Haze - Four-Factor Analysis
Haul Truck Travel

Table 2a. FMI - Morenci - RH 2PP - 4FA - Haul Truck Travel and Other Vehicle Travel on Mine Roads - Control Review & Cost Analysis (Using 2028 Projected Emissions)

Parameter		Speed Reduction		Additional Water Application to Unpaved Roads		Control Freeboard and Spillage	
Value	Units	Value	Reference	Value	Reference	Value	Reference
Potential PM_{10} Reduction							
PM_{10} Reduction	%	0%	[8]	0%	Calculated	0%	[8]
PM_{10} - pre control	tpy	1,781.63	[1]	1,781.63	[1]	1,781.63	[1]
PM_{10} - post control	tpy	1,781.63	Calculated	1,781.63	[9]	1,781.63	Calculated
PM_{10} Reduced	tpy	0.00	Calculated	0.00	Calculated	0.00	Calculated
Capital Implementation Costs							
Total Capital Cost	$	$90,000,000	[5]	$8,125,000	[6] , [11]	$265,500,000	[5] , [7]
Capital Recovery Factor	%	9.44%	[2]	9.44%	[2]	9.44%	[2]
Annualized Cost	$/yr	$8,495,363	Calculated	$766,943	Calculated	$25,061,322	Calculated
Admin, Taxes, Insurance	$/yr	$3,600,000	[3]	$325,000	[3]	$10,620,000	[3]
Operating Cost	$/yr	$40,000,000	[4]	$12,542	[11]	$118,000,000	[4]
Total Annual Cost	$/yr	$52,095,363	Calculated	$1,104,485	Calculated	$153,681,322	Calculated

Regional Haze - Four-Factor Analysis
Haul Truck Travel

Table 2a. FMI - Morenci - RH 2PP - 4FA - Haul Truck Travel and Other Vehicle Travel on Mine Roads - Control Review & Cost Analysis (Using 2028 Projected Emissions)

Parameter		Speed Reduction		Additional Water Application to Unpaved Roads		Control Freeboard and Spillage	
Value	Units	Value	Reference	Value	Reference	Value	Reference
Cost of Compliance (Statutory Factor 1)							
Cost of Control	$/ton removed	N/A	[10]	N/A	[10]	N/A	[10]

[1] 2028 Projected Emissions per ADEQ Emissions Projection Methodology. Estimate includes emissions from haul truck travel and other vehicle travel on mine roads.

[2] Capital Recovery factor (CRF) calculated as follows

Interest Rate	7%
Remaining useful life of source	20
Capital Recovery Factor	9.44%

Note that the number of years corresponds to the remaining life of the unit after 2028, the earliest time that controls are expected to be installed. Per EPA "Guidance on Regional Haze State Implementation Plans for the Second Implementation Period" dated August 20, 2019:

"Typically, the remaining useful life of the source itself will be longer than the useful life of the emission control system under consideration unless there is an enforceable requirement for the source to cease operation sooner ... annualized compliance costs are typically based on the useful life of the control equipment rather than the life of the source, unless the source is under an enforceable requirement to cease operation"

[3] Admin, Taxes, Insurance assumed to be: 4.00% Per EPA Air Pollution Control Cost Manual, Seventh Ed., 2017, Sect. 2.6.5.8, pg 2-35

[4] Per haul truck maintenance staff, each haul truck must undergo a scheduled rebuild every 12 - 16 months costing $2 million. For purposes of this calculation, it was assumed that the maintenance cost would be $2 million per year.

[5] Calculated based on the amount that the control would slow down the production process, since haul truck travel is a bottleneck process. The cost reflects the number of additional new haul trucks needed to make up for the slowdown in production rate. Cost of new haul trucks = cost per new truck * # of current trucks * %speed reduction (or %load reduction). The calculated number of new haul trucks required is rounded up to the nearest integer. It is assumed that the decrease in production rate is proportional to the decrease in speed.

[6] Calculated based on the number of additional water trucks to be purchased to fulfill greater water application requirements. Water trucks are currently used at full capacity during the summer months.

[7] When adding freeboard: % load reduction= new height of material in haul truck/current height of material in haul truck = 44.6%

[8] Emissions for unpaved road travel based on AP-42 Section 13.2.2, Equation 1a, which incorporates silt content and weight of the vehicle. This control method would have no impact on the emission factor and would not reduce emissions based on Equation 1a.

[9] FMI currently implements a 90% control efficiency at the Morenci Mine. The post control emission rate as well as the emission reductions take this into account.

[10] A "$/ton" amount could not be calculated as there is no control efficiency related to this control; hence, PM_{10} emissions are not reduced.

[11] Per EPA "Dust Suppression on Wyoming's Coal Mine Haul Roads", 2.5x the amount of water is needed to increase control efficiency from 75% to 95%. Morenci already utilizes an 90% control efficiency. So, for illustrative purposes, it was assumed that twice the amount of water would be necessary.

Table 2b. FMI - Morenci - RH 2PP - 4FA - Loading Ore Into Haul Trucks - Control Review & Cost Analysis (Using 2028 Projected Emissions)

Parameter		**Regular Water Application**		**Limit Operations During High Winds**	
Value	**Units**	**Value**	**Reference**	**Value**	**Reference**
Potential PM_{10} Reduction					
PM_{10} Reduction	%	43%	[7]	0.05%	[8]
PM_{10} - pre control	tpy	120.20	[1]	120.20	[1]
PM_{10} - post control	tpy	68.13	Calculated	120.14	Calculated
PM_{10} Reduced	tpy	52.06	Calculated	0.05	Calculated

Regional Haze - Four-Factor Analysis
Loading Ore into Haul Trucks

Table 2b. FMI - Morenci - RH 2PP - 4FA - Loading Ore Into Haul Trucks - Control Review & Cost Analysis (Using 2028 Projected Emissions)

Parameter		Regular Water Application		Limit Operations During High Winds	
Value	**Units**	**Value**	**Reference**	**Value**	**Reference**
Capital Implementation Costs					
Total Cost	$	$37,500,000	[4]	-	-
Capital Recovery Factor	%	9.44%	[2]	-	-
Annualized Cost	$/yr	$3,539,735	Calculated	-	-
Admin, Taxes, Insurance	$/yr	$1,500,000	[3]	-	-
Operating Cost	$/yr	$12,542	[5]	$878,995	[6]
Total Annual Cost	$/yr	$5,052,277	Calculated	$878,995	Calculated
Cost of Compliance (Statutory Factor 1)					
Cost of Control	$/ton removed	$97,043	Calculated	$16,015,522	Calculated

Regional Haze - Four-Factor Analysis
Loading Ore into Haul Trucks

Table 2b. FMI - Morenci - RH 2PP - 4FA - Loading Ore Into Haul Trucks - Control Review & Cost Analysis (Using 2028 Projected Emissions)

Parameter		Regular Water Application		Limit Operations During High Winds	
Value	Units	Value	Reference	Value	Reference

[1] 2028 Projected Emissions per ADEQ Emissions Projection Methodology

[2] Capital Recovery factor (CRF) calculated as follows

Interest Rate	7%
Remaining useful life of source	20
Capital Recovery Factor	9.44%

Note that the number of years corresponds to the remaining life of the unit after 2028, the earliest time that controls are expected to be installed. Per EPA "Guidance on Regional Haze State Implementation

Plans for the Second Implementation Period" dated August 20, 2019:

"Typically, the remaining useful life of the source itself will be longer than the useful life of the emission control system under consideration unless there is an enforceable requirement for the source to cease operation sooner ... annualized compliance costs are typically based on the useful life of the control equipment rather than the life of the source, unless the source is under an enforceable requirement to cease operation"

[3] Admin, Taxes, Insurance assumed to be:	4.00%	Per EPA Air Pollution Control Cost Manual, Seventh Ed., 2017, Sect. 2.6.5.8, pg 2-35

[4] Assumes that a new water truck must be purchased for each loading site (maximum of fifteen) in order to keep material saturated.

[5] Additional cost of water to keep all material during loading/unloading operations sufficiently moist.

[6] Annual hours with high winds (greater than 25 mph) per Townsite Met Station. Cost obtained by reducing overall site revenue by the proportional amount of windy hours.

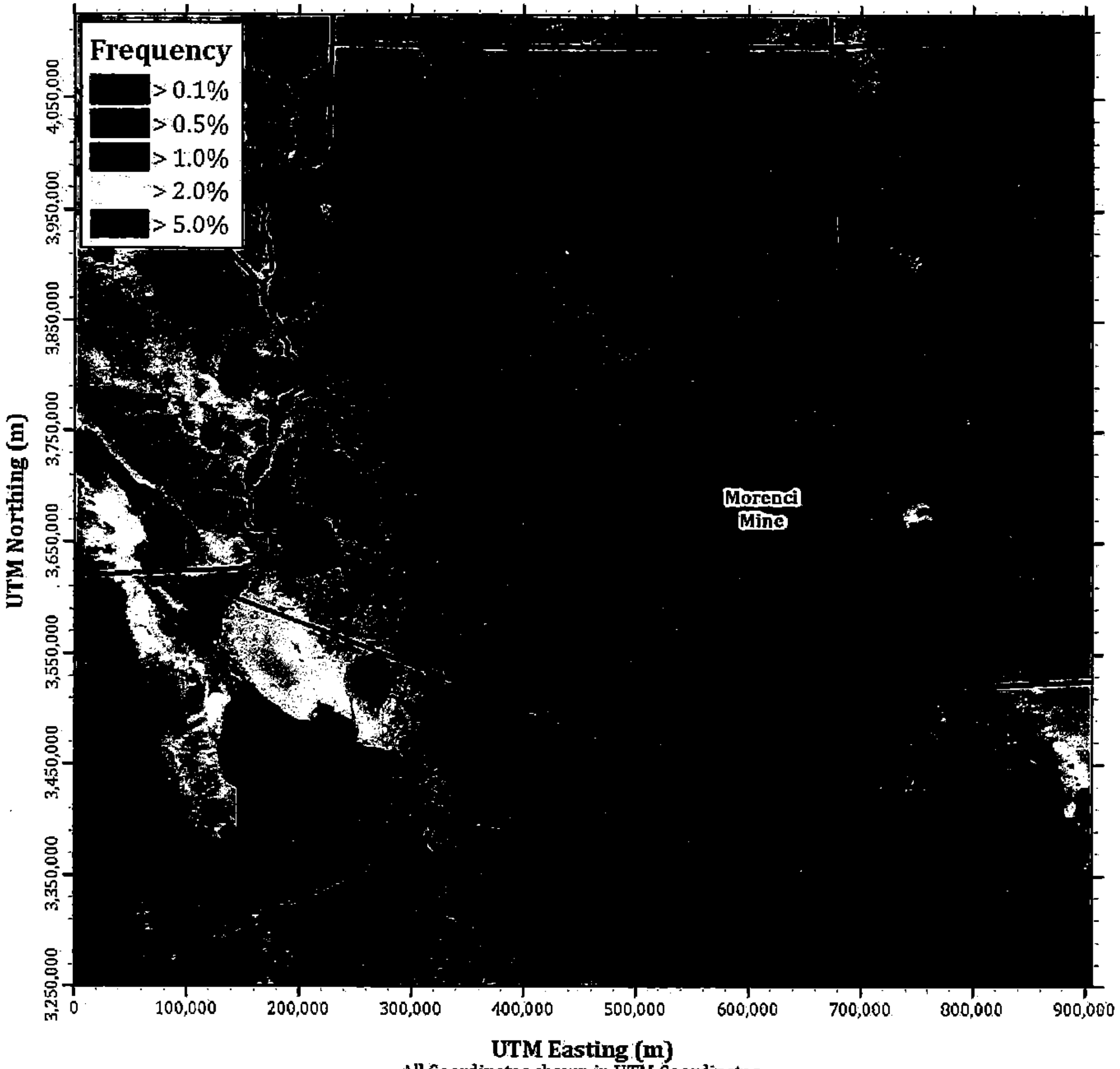
[7] Control efficiency based on highest achievable moisture content as seen in AP-42 Section 13.2.4 applied to the emission factor and compared to the old emission factor:

Original moisture content:	3.2 %
New moisture content:	4.8 %

[8] Control efficiency based on proportion of hours that loading and dumping would not be in operation. High wind hours are those that average more than 25 mph per the Townsite Met Station.

APPENDIX B: HYSPLIT ANALYSIS

Gila Wilderness HYSPLIT Back-Trajectory Analysis (2014-2018)



All Coordinates shown in UTM Coordinates,
Zone 12, NAD 83 Datum

Gila Wilderness HYSPLIT Back-Trajectory Analysis (2014-2018)