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Final Air Quality Impacts Analysis Modeling Plan

Resolution Copper Project, AZ

PREPARED FOR:
RESOLUTION COPPER MINING, LLC

PROJECT NO. 262
MARCH 2018

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LIST OF ABBREVIATIONS

°F	Degrees Fahrenheit
µg/m^3	Micrograms Per Cubic Meter
µm	Micrometer
µm^3	Cubic Micrometer
AAQS	Ambient Air Quality Standards
ADEQ	Arizona Department of Environmental Quality
ADJ_U*	Adjusted Friction Velocity
AERMET	AERMOD Meteorological Preprocessor
AERMOD	American Meteorological Society/Environmental Protection Agency Regulatory Model
AERSURFACE	AERMOD Land Cover Preprocessor
AMSL	Above Mean Sea Level
AP-42	AP-42 Compilation of Air Pollutant Emission Factors
AQCR	Air Quality Control Region
B_o	Midday Bowen Ratio
BPIP-PRIME	Building Profile Input Program with the Plume Rise Model Enhancement
CAI	Central Arizona Intrastate
CFR	Code of Federal Regulations
CO	Carbon Monoxide
CR	Code of Regulations
EPA	Environmental Protection Agency
EPS	East Plant Site
ET	Evapotranspiration
FP&LF	Filtration Plant and Concentrate Loadout Facility
ft	Foot
g/cm^3	Grams per Cubic Centimeter
GPA	General Project Area
HAPs	Hazardous Air Pollutants
in	Inch
ISR	NO_2/NO_X in-stack ratios
km	Kilometer
LHD	Load-Haul-Dump

LOM	Life-of-Mine
m	Meter
MACT	Maximum Achievable Control Technology
Magma	Magma Junction
MARRCO	Magma Arizona Railroad Company
Modeling Plan	Resolution Copper Project, AZ Air Quality Impacts Analysis Modeling Plan
NAAQS	National Ambient Air Quality Standard
NAD83	North American Datum of 1983
NED	National Elevation Dataset
NLCD92	1992 National Land Cover Data
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NOAA	National Oceanic and Atmospheric Administration
NO_X	Oxides of Nitrogen
NSPS	New Source Performance Standards
NSR	New Source Review
NWS	National Weather Service
O_3	Ozone
OLM	Ozone Limiting Method
Pb	Lead
PCAQCD	Pinal County Air Quality Control District
Plan	Resolution Copper Project, AZ Air Quality Impacts Analysis Modeling Plan
PM	Total Particulate Matter
$PM_{2.5}$	Particulate Matter Less than 2.5 Micrometers in Aerodynamic Diameter
PM_{10}	Particulate Matter Less than 10 Micrometers in Aerodynamic Diameter
ppb	Parts per Billion
ppm	Parts per Million
Project	Resolution Copper Project
PSD	Prevention of Significant Deterioration
r	Midday Albedo
Resolution Copper	Resolution Copper Mining, LLC
Resolution Project	Resolution Copper Project
ROM	Run-of-Mine
SAG	Semi-Autogenous Grinding

SO_2	Sulfur Dioxide
SODAR	Sonic Detection and Ranging
SR	State Route
TNF	Tonto National Forest
TSF	Tailings Storage Facility
u*	Surface Friction Velocity
USFS	United States Forest Service
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
VOC	Volatile Organic Compounds
WPS	West Plant Site
WRCC	Western Regional Climate Center
yr	Year
z_o	Surface Roughness Length

1.0 INTRODUCTION

Resolution Copper Mining, LLC (Resolution Copper) is the operating company and the proponent of the Resolution Copper Project (Resolution Project or Project) in Pinal County in central Arizona, approximately 65 miles east of Phoenix. The proposed project includes underground mining, ore processing operations, and the associated facilities and infrastructure described herein. The name of this document is the Air Quality Impacts Analysis Modeling Plan Resolution Copper Project, AZ (Modeling Plan or Plan).

This Modeling Plan was prepared with the expectation that an ambient air quality impact assessment will be required per "Chapter 3. Permits and Permit Revisions" of the Pinal County Air Quality Control District (PCAQCD) Code of Regulations (CR). The Plan was prepared consistent with the Arizona Department of Environmental Quality (ADEQ) "Air Dispersion Modeling Guidelines for Arizona Air Quality Permits" (ADEQ 2015a) and "Guideline on Air Quality Models" specified in Appendix W to Part 51 of the Code of Federal Regulations (CFR), Title 40 (Protection of Environment).

Resolution Copper intends to conduct air quality modeling to support several efforts during the pre-feasibility and other mine development phases, including environmental assessments required by the National Environmental Policy Act, and Resolution Copper's Class II construction air permit application to the PCAQCD.

This Modeling Plan includes a description of the methods and data sets that are planned to be used in the air quality modeling analyses to estimate the Resolution Project's air quality impacts relative to the applicable Ambient Air Quality Standards (AAQS) for criteria pollutants.

This Modeling Plan is the product of several rounds of review by PCAQCD, including a third-party review. The most recent responses to questions from PCAQCD and their third-party reviewer have been provided as Appendix A and Appendix B. Memoranda that elaborate on select technical issues are provided in Appendix H. PCAQCD provided written approval of this Modeling Plan on March 1, 2018 (Appendix C).

2.0 PROJECT DESCRIPTION

The proposed Resolution Project facilities and attendant infrastructure components will be located in north-central Pinal County. A location map showing proposed Project facility locations, hereafter referred to as the General Project Area (GPA), is presented in Figure 2-1.

The East Plant Site (EPS) encompasses the proposed underground mine, associated shafts, and surface support facilities. The support facilities are located in a previously disturbed area and include a mine site where Shaft 9 was constructed in the 1970s. The EPS is accessed from Highway US 60 by turning south on Magma Mine Road (also known as Forest Road 469), which terminates at the EPS guard gate. The existing mine site and related surface support facilities are currently located on private lands. Expansion associated with the Project will occur on United States Forest Service (USFS) lands, as well as state and private lands. Additional area encompassed by the EPS includes the land surface above the ore body, comprised of unpatented mining claims on lands administered by the USFS, specifically Tonto National Forest (TNF).

The ore processing operations will be located at the West Plant Site (WPS), approximately 6 miles west of the EPS. A copper concentrate Filtration Plant and Concentrate Loadout Facility (FP&LF) will be constructed near Magma Junction (Magma), proximate to the existing disturbed Magma Arizona Railroad Company (MARRCO) right-of-way. The MARRCO right-of-way will be the site of connecting infrastructure, such as water supply pipelines, dewatering pipelines, concentrate pipelines, and power lines. These features and the existing rail line are referred to collectively as the MARRCO Corridor.

A Tailings Storage Facility (TSF) will be situated west of the WPS and north of Queen Station within the TNF. Tailings will arrive at the TSF from the WPS via a pipeline that traverses the intervening area (along with other infrastructure) along the Tailings Corridor. Linear infrastructure elements of the Project will include ore conveyors, roads, power lines, copper concentrate pipelines, tailings pipelines, the MARRCO Railroad, and water supply pipelines; these will be primarily located within the Tailings Corridor, within the MARRCO Corridor alongside existing disturbed land, or underground.

Resolution Copper will use an underground mining method known as panel caving, which is a variation of block caving. Panel caving allows for the mining of large, underground ore bodies by dividing the deposit into smaller strips, or panels, so that the ore can be removed in a safe and efficient manner. Because the ore body ranges from 5,000 to 7,000 feet (ft) below the surface, an open pit is not economically or logistically feasible.

The benefits of a panel cave mine at the Resolution Project include limited development of rock piles at the surface and no large open pits with terraced pit walls. One result of panel cave

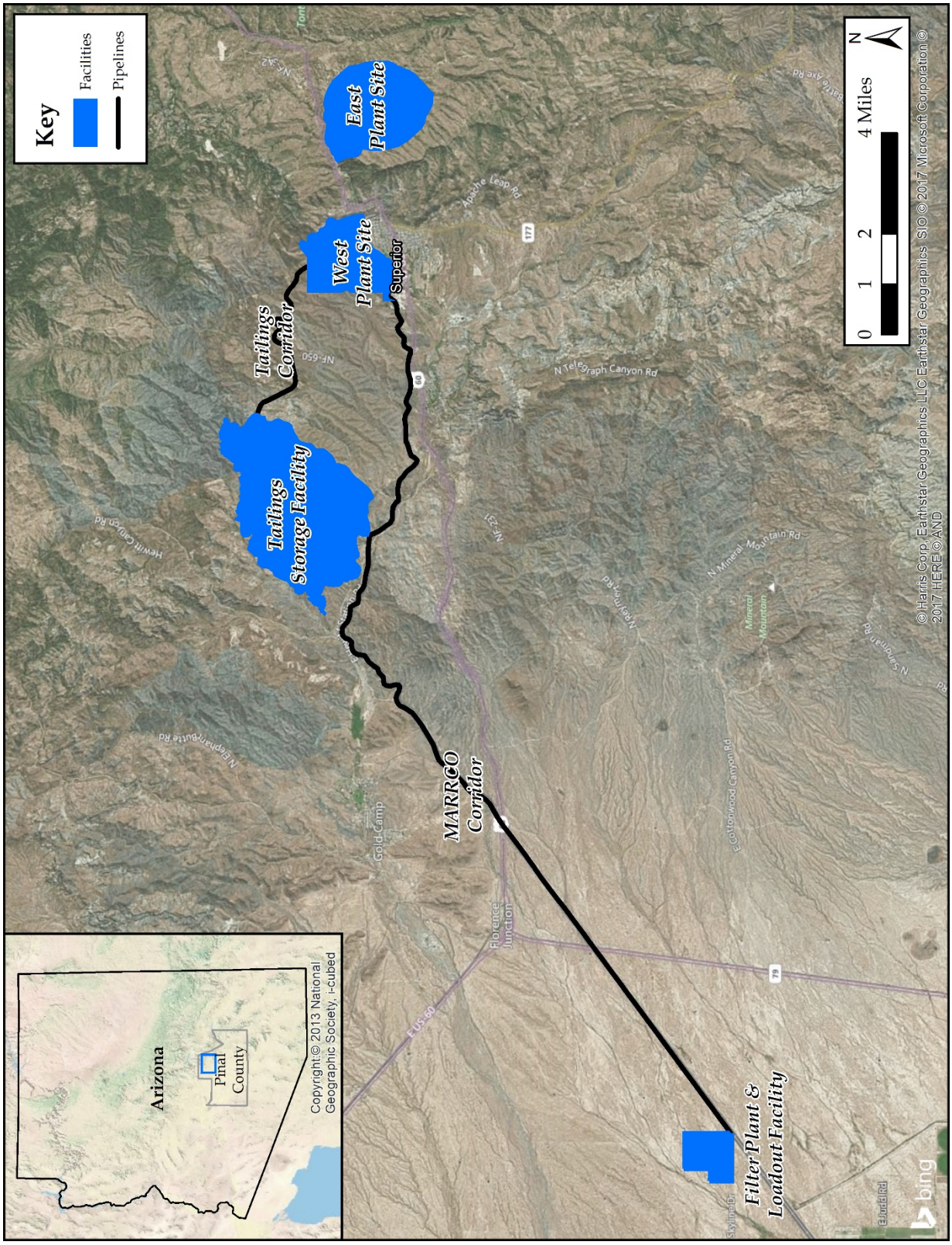
mines is that surface subsidence or settling above the ore deposit is anticipated. Surface subsidence occurs as the material above the ore body gradually moves downward to replace the ore that has been mined. The settling amount is less than the amount of ore removed due to the "bulking" of the rock underground; that is, the volume of the caved rock fragments will be larger relative to the rock's in-place volume, which is a major factor controlling subsidence (Holzer 1984).

Ore production from the underground operations is expected to be a nominal 132,000 tons per day after an extensive construction and ramp-up period, with a maximum throughput of approximately 165,000 tons per day.

Ore material will be crushed underground and then transported by underground haul trucks to two production shafts and hoisted to an underground midway offloading station within the two production shafts at the EPS. The crushed ore will be transferred via underground conveyors to an overland stacker, and stockpiled at the WPS. The stockpiled ore will be transferred to a concentrator facility via apron feeders and a reclaim tunnel located underneath the stockpile, where it will be processed using traditional copper sulfide recovery techniques. The concentrator facility will consist of conventional grinding and flotation circuits, and will produce copper and molybdenum concentrates. Tailings material, the non-economic excess ground rock with a sand-like consistency that remains after concentrates have been removed during ore processing, will be piped as a slurry to the TSF located west of the WPS. The TSF will be located on land administered by the TNF. Molybdenum concentrates will be bagged at the concentrator facility and shipped to market via trucks. Copper concentrates will be transported as slurry via pipeline to FP&LF near Magma for final filtration and train loadout for shipment to domestic and/or global markets for additional processing.

Resolution Copper anticipates that the project will have a total operational life of approximately 40 years, not including initial site construction, which will span approximately 10 years, and not including final reclamation work (demolition, regrading, and revegetation), which could take up to an additional 10 years. In total, the Project will have a lifespan of approximately 60 years. At the peak of the construction phase, it is estimated that this Project will generate over 3,000 jobs. At full mine production, direct workforce requirements are projected to be around 1,400 employees.

Figure 2-1. Resolution Project Location



2.1 Regional Topographical Characteristics

The GPA lies within the Basin and Range physiographic province, generally characterized by a series of smooth-floored basins separated by mountain ranges (Chronic 1983). The northeastern edge of the province is a mountainous region that is transitional to the Central Highlands bordering the Colorado Plateau province. This mountainous region consists of belts of generally linear ridges and valleys, where the rugged ranges predominate over the valleys. This is in contrast to much of the Basin and Range province and the western portion of the GPA, where broad valleys predominate over relatively narrow mountain ranges. As such, the GPA includes a combination of nearly flat terrain of the broad basin to the west and rugged mountainous terrain (Superstition, Dripping Spring, and Pinal Mountains) to the north and east.

The elevations within the GPA range from 1,520 ft above mean sea level (AMSL) at the western terminus of the MARRCO Corridor to 4,648 ft AMSL at Apache Leap.

2.2 Local Topographical Characteristics

The Project features, which include the FP&LF, MARRCO Corridor, TSF and Tailings Corridor, WPS, and EPS, span approximately 31.8 miles from the southwestern corner of the GPA near Magma to the northeastern corner of the GPA at the EPS, east of Superior. The vast majority of Project activity will take place at the EPS, WPS, and TSF. The following discussion describes the Project features as they occur in geographic order across the GPA from northeast to southwest.

2.2.1 EPS

The EPS will be located in the mountains immediately east of the town of Superior in a transition zone on the northeastern edge of the Basin and Range physiographic province, bordering the Central Highlands. The elevation ranges from 3,100 ft AMSL near Queen Creek to 4,648 ft AMSL at a high point on the Apache Leap escarpment, overlooking Superior. The western edge of this area is generally very steep, with the cliffs of the Apache Leap escarpment rising abruptly above Superior. East of Apache Leap, there is an area of parallel ridges and valleys trending northeast. The northeastern portion of the EPS is relatively flat.

2.2.2 WPS

The WPS will be located at the transition from the basin (in which the town of Superior is situated) to the mountains that border the Central Highlands north of Superior. The southwestern part of the site, adjacent to the town of Superior, is moderately sloped with a base elevation of approximately 2,680 ft AMSL. The site ascends into deeply incised canyons in the rocky slopes along the northern portion of the WPS up to an elevation of approximately 3,400 ft AMSL.

2.2.3 TSF and Tailings Corridor

The TSF and Tailings Corridor will be located in a transition zone on the northeastern edge of the Basin and Range physiographic province. The topography in the vicinity is characterized by a series of parallel ridges formed from differential erosion of a tilted fault block dipping to the southeast (Spencer and Richard 1995). The ridges are separated by valleys with thin alluvial deposits in the valley bottoms. The valleys are relatively narrow at higher elevations and widen as elevation decreases toward Queen Creek.

The TSF footprint is bounded by Roblas Canyon on the west and Potts Canyon on the east. Elevations of the TSF footprint range from approximately 2,240 ft AMSL in the southwest portion to 2,920 ft AMSL in the northern extents.

The Tailings Corridor extends 4.7 miles from the northeast corner of the TSF to the WPS, traversing multiple ridges and valleys. The main valleys from west to east are Potts Canyon, Happy Camp Canyon, and Silver King Wash. Elevations along the Tailings Corridor range from approximately 2,690 ft AMSL at the tie-in location on the northeast side of the TSF to 3,050 ft AMSL at the WPS.

2.2.4 MARRCO Corridor

The existing MARRCO Corridor extends northeast from Magma past the highway crossing at US 60 east of Florence Junction to the WPS, a distance of approximately 27 miles. The elevations in this corridor range from a minimum of approximately 1,520 ft AMSL at Magma to a maximum of 3,000 ft AMSL at the WPS. The general trend of the corridor is a gradual increase in elevation from west to east, with minor rises and drops over channels. The western terminus of the corridor in the GPA is at Magma.

2.2.5 FP&LF

The FP&LF will be located approximately 7 miles northeast of Magma and adjacent to the MARRCO Corridor. The site is in a relatively flat area. The elevation of the site is approximately 1,670 ft AMSL.

2.3 Regional Climatology

The regional climate is characterized as semiarid; long periods often occur with little or no precipitation (WRCC 2012). Precipitation falls in a bimodal pattern: most of the annual rainfall within the region occurs during the winter and summer months, with dry periods characterizing spring and fall. The total average annual precipitation varies between 15.7 inches (in) and 18.8 in, with 52 percent of the precipitation occurring between November and April. Although snow may occur at higher elevations, it does not typically accumulate in the region. Precipitation usually occurs with steady, longer-duration frontal storm events during the winter months (December through March). Rain events during the summer months (July to early September) are typically of shorter duration with more intensity due to the convective nature of thunderstorms.

2.4 Local Climatology

The National Oceanic and Atmospheric Administration's (NOAA) Climate Data Online (NOAA 2013) and the Western Regional Climate Center (WRCC 2013) maintain data records for several weather stations that surround the GPA. A summary of weather stations in the Project vicinity is provided in Table 2-1.

Table 2-1. Weather Stations in Project Area

Station Name	Elevation (ft)	Latitude	Longitude	Data Period
Miami	3,560	33.40°	110.87°	Feb. 1914 to Mar. 2013
Superior	2,859	33.30°	111.10°	Jul. 1920 to Aug. 2006
Roosevelt	2,205	33.67°	111.15°	Jul. 1905 to Mar. 2013

Source: NOAA 2013

Table 2-2 presents a summary of climatic conditions at each of the Project areas based on the three nearby weather stations. Weather conditions in this region are strongly influenced by elevation; therefore, these data are primarily based on the weather station closest in elevation rather than closest by distance. The data, unless otherwise noted, were derived from WRCC 2013.

Table 2-2. Project Area Historical Climatological Summary

Project Area	Elevation (ft)	Weather Station	Ann Mean Daily Avg Temp (°F)	Ann Mean Daily Max Temp (°F)	Ann Mean Daily Min Temp (°F)	Ann Mean Total Snow (in)	Ann Mean Total Precip (in)	Ann ET Rate[1] (in)
FP&LF	1,670	Roosevelt	68	81	55	0.2	15.7	67
MARRCO Corridor (west of SR 79)	1,520	Roosevelt	68	81	55	0.2	15.7	67
MARRCO Corridor (east of SR 79)	3,000	Superior	69	79	59	1.4	18.3	63
TSF and Tailings Corridor	2,240 - 3,050	Superior	69	79	59	1.4	18.3	63
WPS	2,680 - 3,400	Superior	69	79	59	1.4	18.3	63
EPS	3,100 - 4,648	Miami	64	77	51	2.6	18.8	55

[1] Yitayew 1990

Ann = Annual, Avg = Average, Temp = Temperature, Max = Maximum, Min = Minimum, Precip = Precipitation, ET = Evapotranspiration, SR = State Route, °F = Degrees Fahrenheit

As shown in Table 2-2, for the three weather stations selected as representative of the GPA, the annual average maximum temperature ranged from 77 degrees Fahrenheit (°F) to 81°F and the average minimum temperature ranged from 51°F to 59°F. The total rainfall per year ranged from 15.7 in to 18.8 inches across the three weather stations (WRCC 2013).

2.5 Process Description and Emission Sources

The Resolution deposit is located between 5,000 and 7,000 ft below the surface and will be mined using a variation of block caving called panel caving. The mine and process operations will operate on a continuous, 24-hour-per-day basis. A process flow diagram showing the underground operations at the EPS is provided in Figure 2-2, and the subsequent ore processing and transport operations are presented in Figure 2-3.

Figure 2-2. Process Flow Diagram – EPS

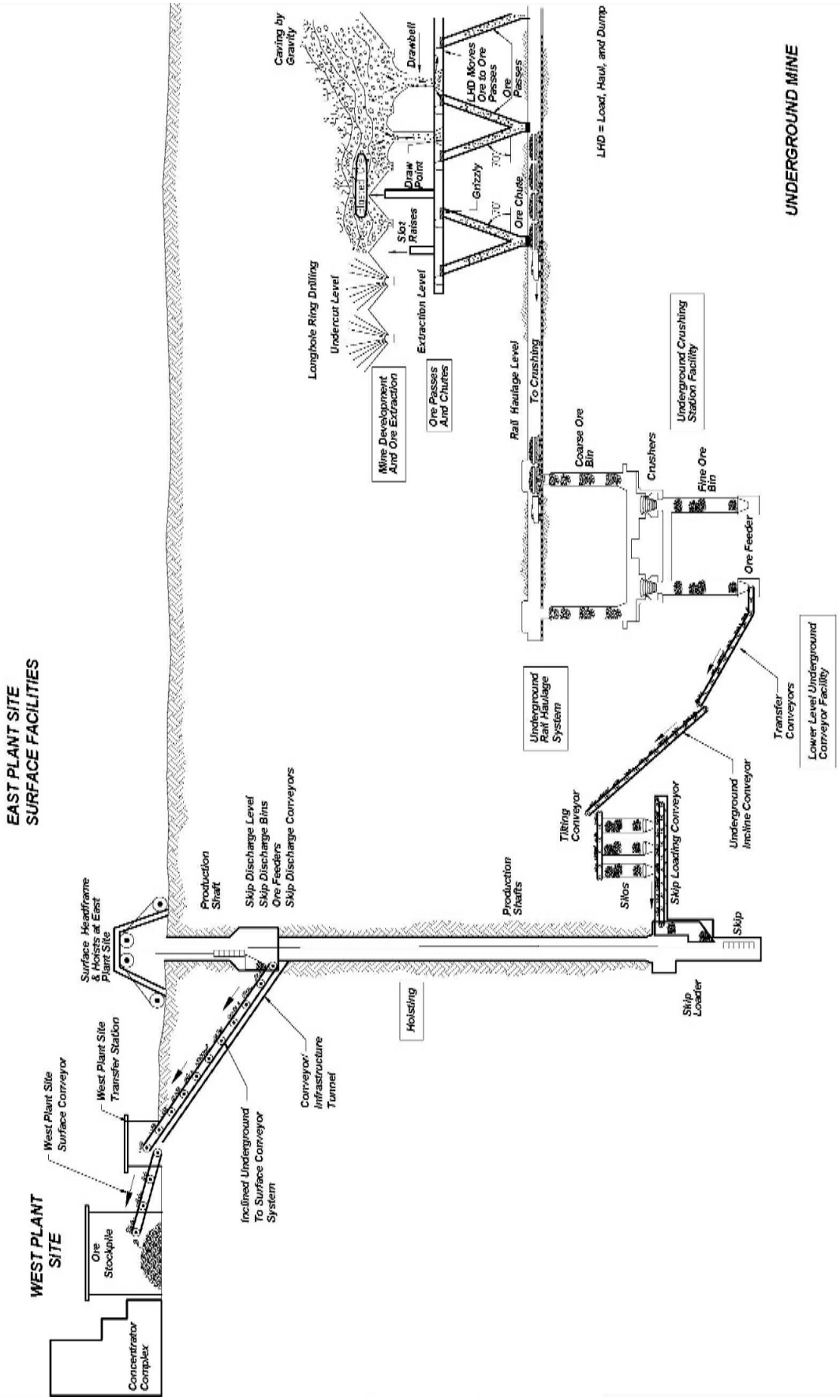
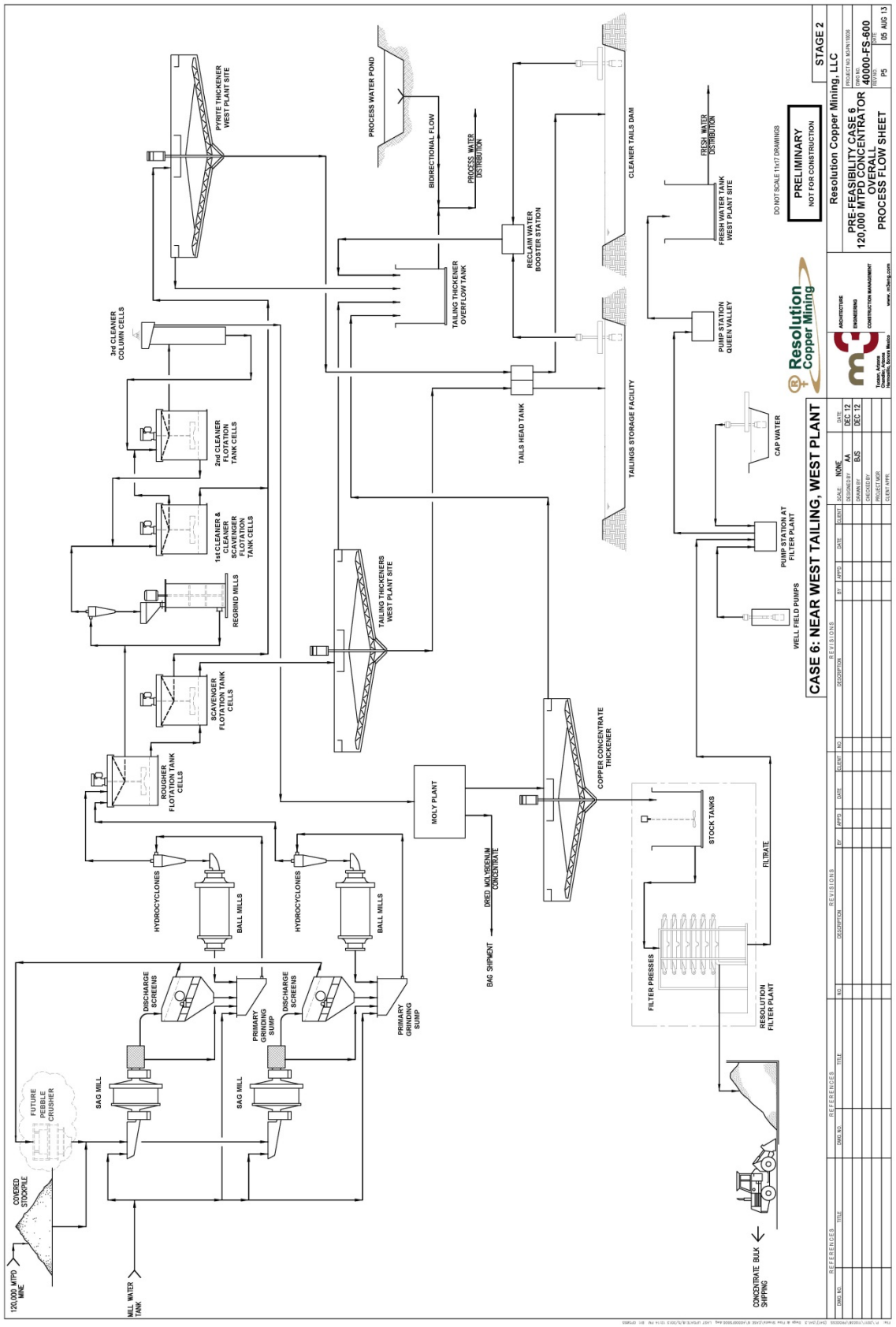


Figure 2-3. Process Flow Diagram – Ore Processing and Transport Operations



2.5.1 EPS Underground Operations – Panel Caving and Ore Preparation

The initial step of the mining process includes preparing the area to be mined. In panel caving, the ore body is mined from the bottom by first breaking up the copper-bearing ore. Once the ore is initially broken up, funnel-shaped cavities are created to direct the broken ore down to be removed and transported. Blasting is used to initially break up the ore body and to create the funnel-shaped openings. Each blast hole is drilled and loaded with an ammonium nitrate and fuel oil-based explosive. Gravity pulls the ore from the ore body down to the draw points where it is loaded into load-haul-dump (LHD) loaders.

The run-of-mine (ROM) ore is transported from the draw points underneath the ore body by LHD loaders to haul trucks. Haul trucks transport the ROM ore underground to one of three gyratory crushers that can process a total of up to 6,889 tons of ore per hour. After a series of underground feeders, conveyors, and bins, the ore is loaded into skips that hoist the ore to an underground midway offloading station, and discharged onto an underground conveyor system that transports coarse (crushed) ore to the WPS.

Pollutant emissions from panel caving mining will consist of fugitive emissions from drilling and blasting, ore hauling, loading, and unloading activities; process dust emissions from ore transfers and crushing; and tailpipe and nonroad engine emissions. Fugitive dust will be controlled by employing dust control measures and best practical methods. Process emissions will be controlled using baghouses and water sprays at process points where feasible. Tailpipe (nonroad engine) emissions will be compliant with applicable EPA emission standards.

Three additional mine features act as controls that reduce modeled particulate emissions from underground sources: water droplets in mine shafts, heat rejection sprays, and gravitational settlement. These features' scrubbing efficiencies, as well as total effective scrubbing efficiencies, are summarized in Table 2-3.

Table 2-3. Effective Control for Underground Sources

	PM	PM_{10}	$PM_{2.5}$
Water Droplets in Shafts (1)	30.9%	30.9%	4.2%
Heat Rejection Sprays (1)	30.0%	30.0%	2.5%
Gravitational Settlement	60.4%	6.7%	0.4%
Effective Control	80.9%	54.9%	7.0%

(1) These control efficiencies were derived using Moreby 2008.
PM = Total Particulate Matter, PM_{10} = Particulate Matter Less than 10 Micrometers (μm) in Aerodynamic Diameter, $PM_{2.5}$ = Particulate Matter Less than 2.5 μm in Aerodynamic Diameter

Due to the saturated nature of the exhaust air, water droplets will form inside the mine shafts and will scrub a fraction of PM from the exhaust air. This, in combination with an approximate shaft depth of 7,000 ft (and the resulting long time for exhaust air to come in contact with these droplets), results in the scrubbing efficiencies summarized in Table 2-3. No significant scrubbing effect for gaseous pollutants is assumed from these droplets.

The underground heat rejection sprays serve as another control for underground emissions. The heat rejection sprays are employed underground to reject heat from the underground refrigeration plant. A large fraction of the exhaust air will pass through these chambers where heat rejection will occur. It is assumed that 50 percent of all exhaust air will pass through these spray chambers. No significant scrubbing effect for gaseous pollutants is assumed from these sprays. The scrubbing efficiencies for particulates are presented in Table 2-3.

The final control measure assumed for underground sources is gravitational settlement. The exhaust chambers are very long; therefore, gravitational settlement for PM will occur. Using the terminal settling velocity in Perry's Chemical Engineering Handbook (Perry and Green 1997), an efficiency due to gravitational settlement was determined. These efficiencies for PM, PM_{10}, and $PM_{2.5}$ are presented in Table 2-3.

2.5.2 EPS Surface Operations

The surface operations at the EPS will consist of support for underground operations above the ore body. Such activities include underground operation ventilation systems, including cooling towers; miscellaneous nonroad equipment; and wind erosion of exposed areas, including the subsidence zone. Particulate matter from roads will be controlled with periodic water and/or chemical dust suppressant application. Figure 2-4 shows the locations of the modeled sources at the EPS surface operations.

2.5.3 WPS – Ore Processing

The coarse ore transported from the EPS via an underground conveyor system drops onto an overland stockpile feed conveyor at WPS, which transfers the ore to a covered stockpile. The stockpiled coarse ore is drawn through a series of apron feeders and a reclaim tunnel located underneath the stockpile for further processing in the concentrator building. The ore reclaim and transfer operations will be equipped with dust collectors to control particulate emissions.

The overall grinding configuration at the concentrator building will consist of two semi-autogenous grinding (SAG) mills, in parallel, followed by a chemical flotation circuit. Each SAG mill will be designed to operate at a maximum rate of 5,512 tons per hour. Process water will be added to the SAG mill feed to provide the correct slurry density for grinding. Chemical additives will also be added to the SAG mill feed. The SAG mill discharge will be screened, and oversized pebbles will be conveyed to one of two pebble crushers. Crushed pebbles will be returned to the SAG mill feed conveyors. All conveyor transfer points will be enclosed in the concentrator building which will control dust emissions. The flotation circuit following the SAG mill will consist of a primary ball mill and flotation circuits followed by thickeners. Figure 2-5 shows the locations of the modeled sources at the WPS.

Figure 2-4. EPS Modeled Source Locations

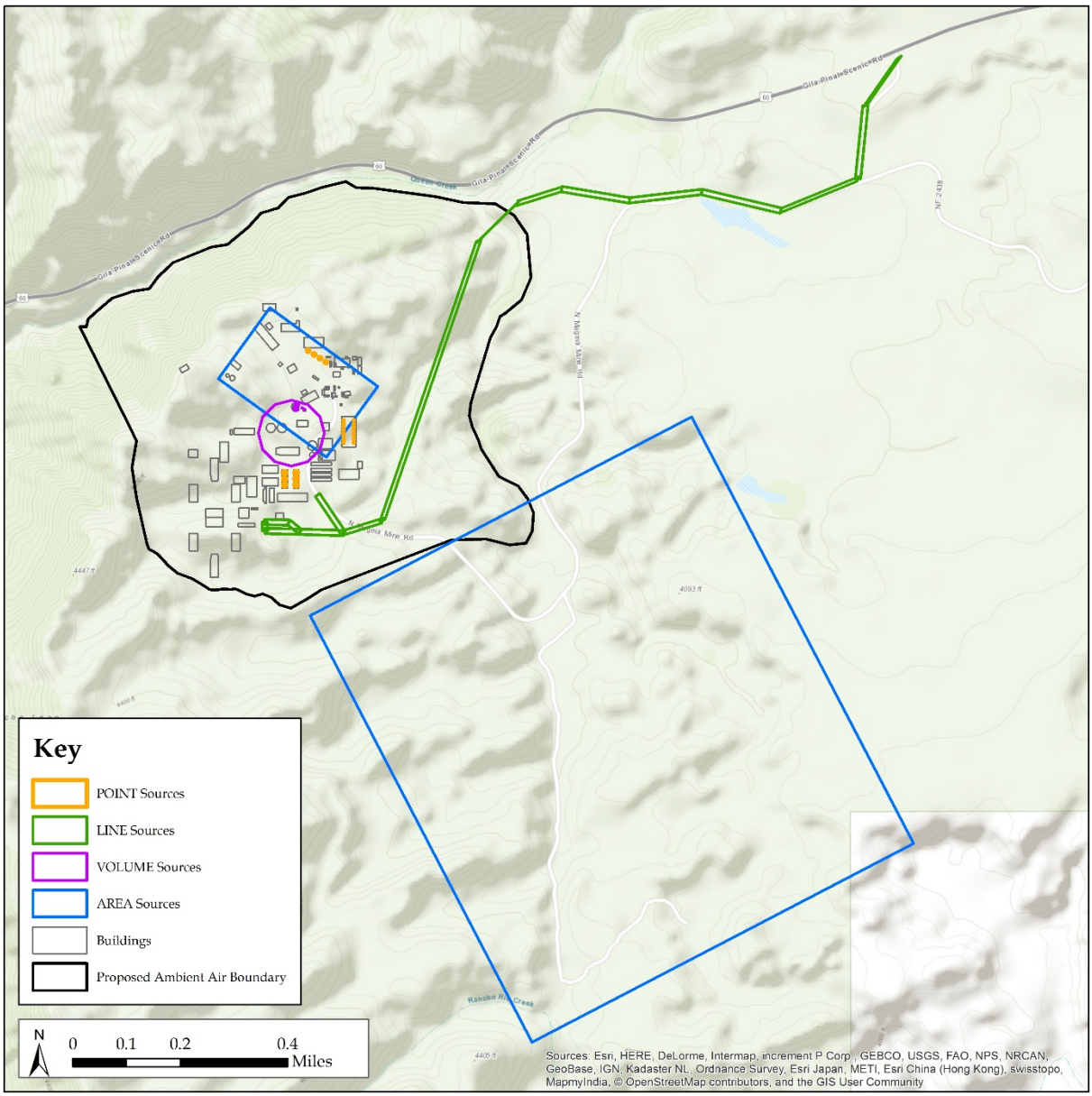
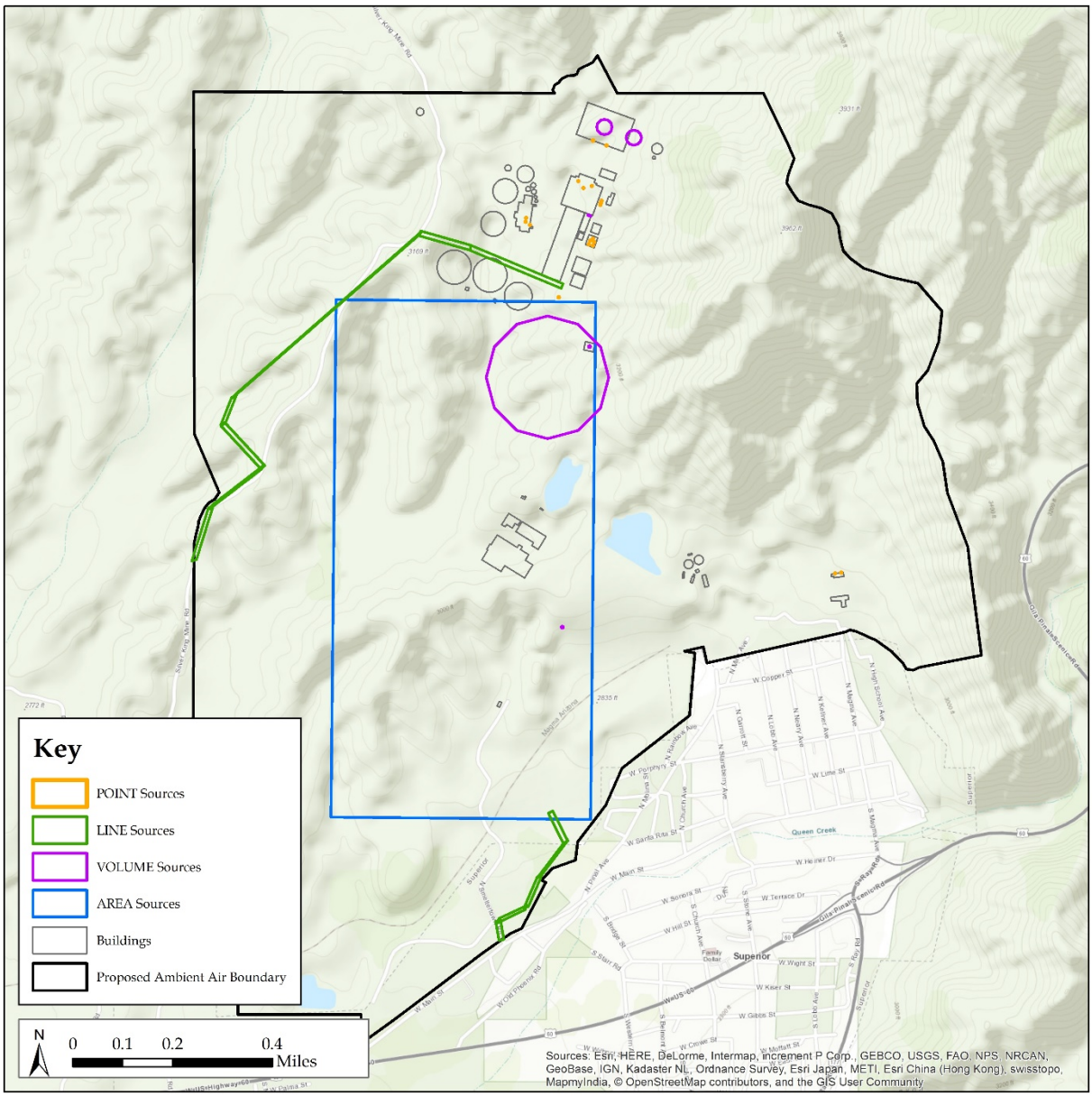


Figure 2-5. WPS Modeled Source Locations



Several reagents will be added during different processing stages to condition the concentrate slurry. Particulate emissions from dry reagent handling and mixing will occur and will be enclosed in the concentrator building to control dust emissions. The end product from the Resolution Project will include copper and molybdenum concentrates.

A small filter plant will be located at the WPS for the purpose of filtering and drying molybdenum concentrate. The molybdenum concentrate will be pumped to additional processing to remove the majority of the liquid before entering a dryer. The dried molybdenum

concentrate will be packaged and shipped offsite. Particulate emissions from concentrate handling will be controlled by an enclosure of the concentrator building. SO_2 emissions from the processing of molybdenum concentrate will be controlled by a gas quencher and packed bed scrubber.

The copper concentrate, in a slurry form, will be pumped via an approximately 20-mile-long pipeline along the MARRCO Corridor to the FP&LF near Magma. Sandy slurry containing tailings material will be transferred through an approximately 6-mile-long pipeline along the Tailings Corridor to the TSF.

2.5.4 FP&LF

The liquid concentrate slurry arriving at the FP&LF will be pumped to a series of filters to remove the majority of the liquid. Following filtering, the copper concentrate will be loaded onto a series of conveyors to the dry copper concentrate storage and loadout shed. A front-end loader will transfer the copper concentrate from the storage shed into hoppers that feed rail cars to ship the dried copper concentrate offsite. Particulate emissions from concentrate handling will be enclosed in the loadout building and storage shed to minimize emissions. Figure 2-6 shows the locations of the modeled sources at the FP&LP.

2.5.5 TSF

The TSF will receive tailings slurry from the concentrator at the WPS. An intricate series of piping and valves will control the location of tailings placement. Over time, the TSF will form a beach area, mainly at the perimeter. Wind erosion emissions from the beach area and other un-reclaimed areas on the surface of the TSF dam will be controlled with sprinklers. The tailings dam will be constructed as needed, and will be continuously reclaimed as the dam grows. Figure 2-7 shows the locations of modeled sources at the TSF.

2.5.6 Emergency Equipment

Fourteen diesel-fired emergency generators, rated at 3,263 kilowatts each, will be installed to provide power to the EPS in the event of emergency situations. These generators will power critical systems (ventilation, personnel transport, etc.). Additional diesel-fired emergency generators rated at 500 kilowatts each will be located at other process areas. Three generators located at the WPS, one generator at the TSF, and one generator located at the FP&LF will be used to provide power to critical operations in emergency situations.

Figure 2-6. Filter Plant & Load-out Facility Modeled Source Locations

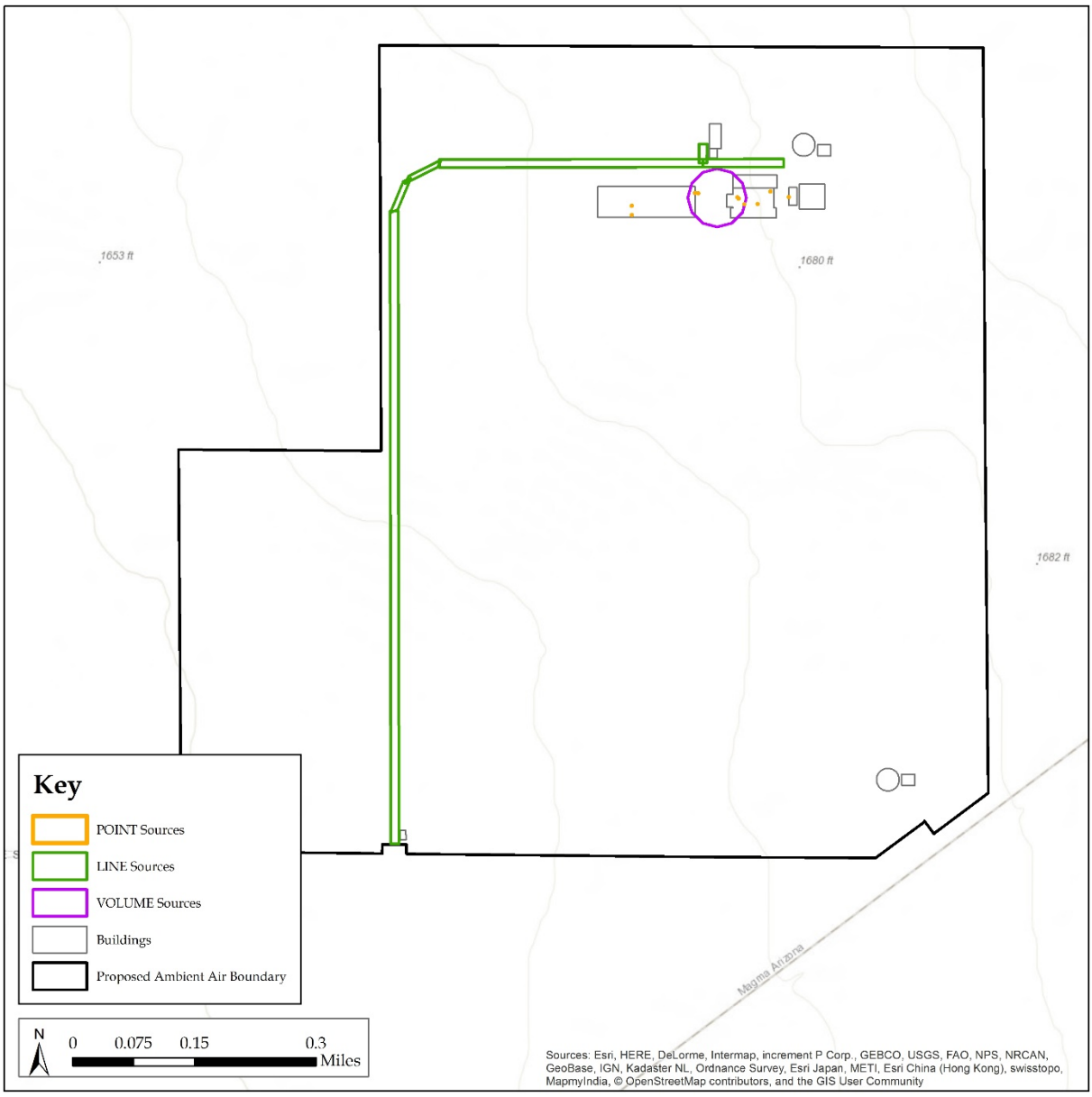
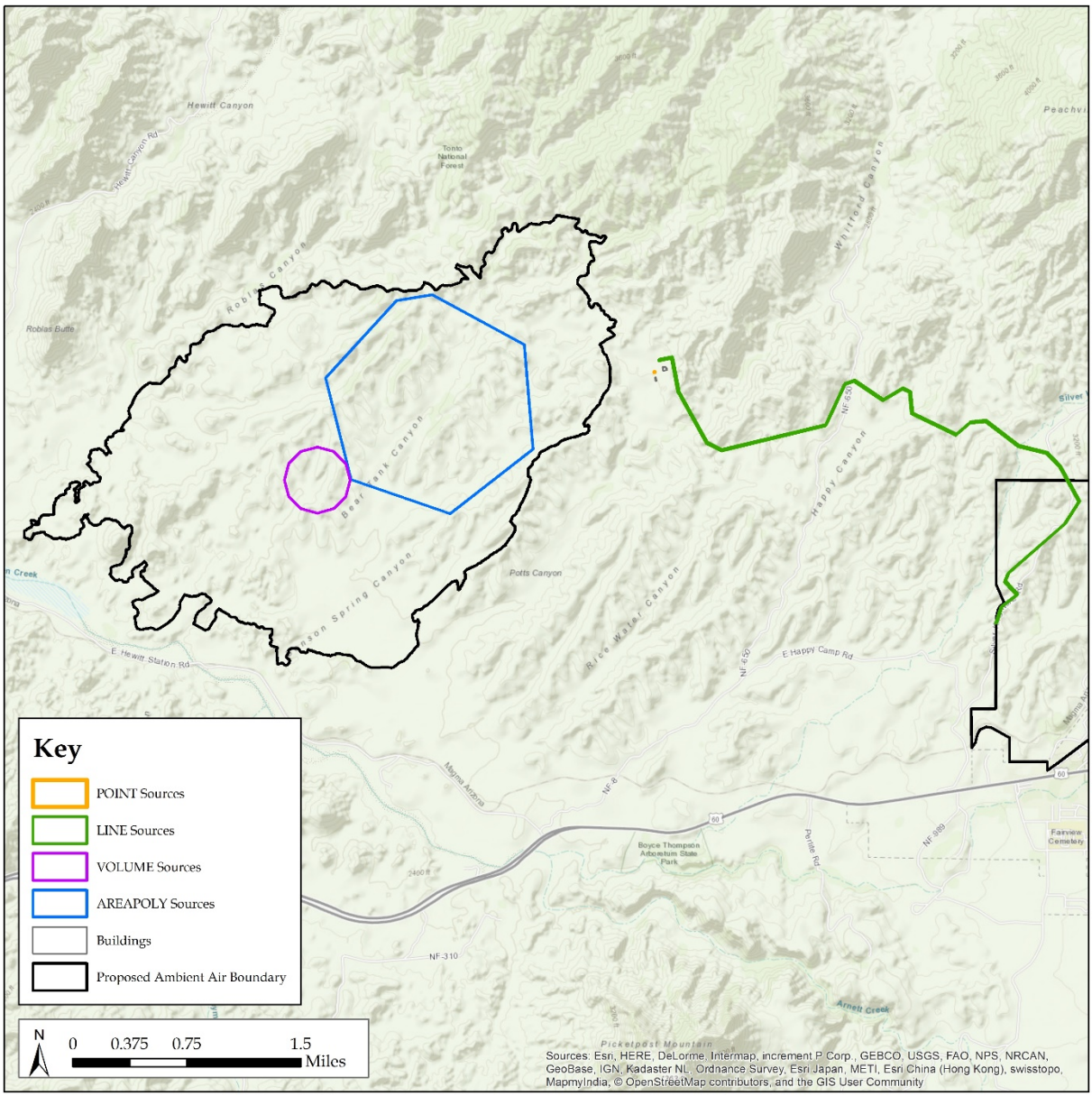


Figure 2-7. Tailings Storage Facility Modeled Source Locations



2.6 Pollutants and Emissions

Emissions due to underground sources at the EPS will include: dust emissions[1] from underground mining activities (drilling, blasting, material handling and transfers, and crushing) and combustion emissions[2] from blasting, operation of underground mining and transport equipment. Emissions from underground sources will exit the underground workings via the mine ventilation system near the surface activities at the EPS. Emissions from surface activities at the EPS include light vehicle travel, backup power generation, and wind-blown dust from disturbed surfaces (subsidence). Sources of particulate emissions from ore preparation activities at the WPS will include ore and reagent handling. Sources of combustion emissions will be limited to fuel and freight transportation and light vehicle travel. The maximum potential Project total annual emissions in short tons per year (ton/yr) are provided in Table 2-4.

Table 2-4. Resolution Project Maximum Potential Emissions Summary (ton/yr)

Project Facility	Emissions Type	CO	NO_X	$PM_{2.5}$	PM_{10}	SO_2	VOC
EPS	Process	8.1	33.5	23.1	64.3	0.2	3.3
	Fugitive	26.7	5.1	21.7	215.6	1.6	0.02
	Mobile	170.0	17.7	0.9	1.0	0.2	8.3
	Subtotal	204.8	56.2	45.7	280.8	2.0	11.7
WPS	Process	10.6	10.8	7.7	17.1	14.8	66.0
	Fugitive	2.1	0.4	3.2	20.6	0.1	0.02
	Mobile	30.6	4.6	0.2	0.2	0.1	2.9
	Subtotal	43.3	15.8	11.1	37.9	15.0	68.9
Loadout	Process	1.0	0.1	0.2	1.4	0.002	0.004
	Fugitive	0	0	0.1	0.9	0	0.01
	Mobile	20.6	2.3	0.1	0.1	0.04	1.1
	Subtotal	21.5	2.4	0.4	2.4	0.05	1.1
TSF	Process	1.0	0.1	0.002	0.002	0.002	0.004
	Fugitive	0	0	17.4	121.5	0	0.1
	Mobile	139.9	16.0	0.8	0.8	0.3	7.9
	Subtotal	140.9	16.1	18.2	122.3	0.3	8.0
Facility Wide	Process	20.6	44.4	31.1	82.8	15.0	69.3
	Fugitive	28.8	5.5	42.4	358.5	1.8	0.1
	Mobile	361.1	40.7	2.0	2.1	0.5	20.3
	Total	410.5	90.5	75.5	443.3	17.3	89.7

The emissions provided in Table 2-4 are the maximum expected potential emissions from the Resolution Project. The emissions shown in this table represent the maximum mining activity

[1] PM, $PM_{2.5}$, and PM_{10}

[2] $PM_{2.5}$, PM_{10}, Carbon Monoxide (CO), Oxides of Nitrogen (NO_X), Sulfur Dioxide (SO_2), Volatile Organic Compounds (VOC), and greenhouse gases

(fugitive and mobile machinery) expected to occur during the life-of-mine (LOM) year 14 and process sources operating at maximum design capacity. However, the blasting activity will wane by LOM year 14. Further, the maximum area susceptible to wind erosion at the TSF is expected to occur during LOM year 27. Therefore, to be comprehensive and conservative, the peak blasting activity that will occur during development and the maximum susceptible TSF area have been combined with LOM year 14 and used in this analysis. A detailed emissions inventory for the Resolution Project is provided in Appendix D.

In addition to the criteria pollutant emissions discussed in this section, there will be small amounts of Hazardous Air Pollutants (HAPs) emitted from the proposed Resolution Project sources. The estimated potential HAP emissions from the Project are less than the Maximum Achievable Control Technology (MACT) thresholds of 10 ton/yr of a single HAP or 25 ton/yr of combined HAPs. Therefore, the Resolution Project will be classified as an area (or minor) source and will not be subject to MACT review required by 40 CFR 63. The HAP emissions inventory and calculations are also provided in Appendix D.

2.7 Regulatory Basis

The Resolution Project is located in the Central Arizona Intrastate (CAI) Air Quality Control Region (AQCR). The current attainment status of the CAI AQCR and location of Resolution Project facilities are presented in Figure 2-8. This figure shows that the EPS will be partially located in the Hayden PM_{10} Nonattainment area. The FP&LF will be located in the West Pinal PM_{10} Nonattainment area. All remaining facilities will be located in areas that are unclassifiable or in attainment for all criteria pollutants. Table 2-5 compares the facility-wide[3] process emissions[4] to the major source thresholds. Since some of the sources will be located in moderate PM_{10} nonattainment areas, a 100 ton/yr major source threshold is used for PM_{10}. For all other air pollutants, the Prevention of Significant Deterioration (PSD) major source threshold of 250 ton/yr is used.

Table 2-5. Resolution Project Major Source Status Determination

Parameter	CO	NO_X	$PM_{2.5}$	PM_{10}	SO_2	VOC
Process Source Emissions (ton/yr)	20.6	44.4	31.1	82.8	15.0	69.3
PSD/NSR Major Source Threshold (ton/yr)	250	250	250	100	250	250
PSD/NSR Review Triggered	No	No	No	No	No	No

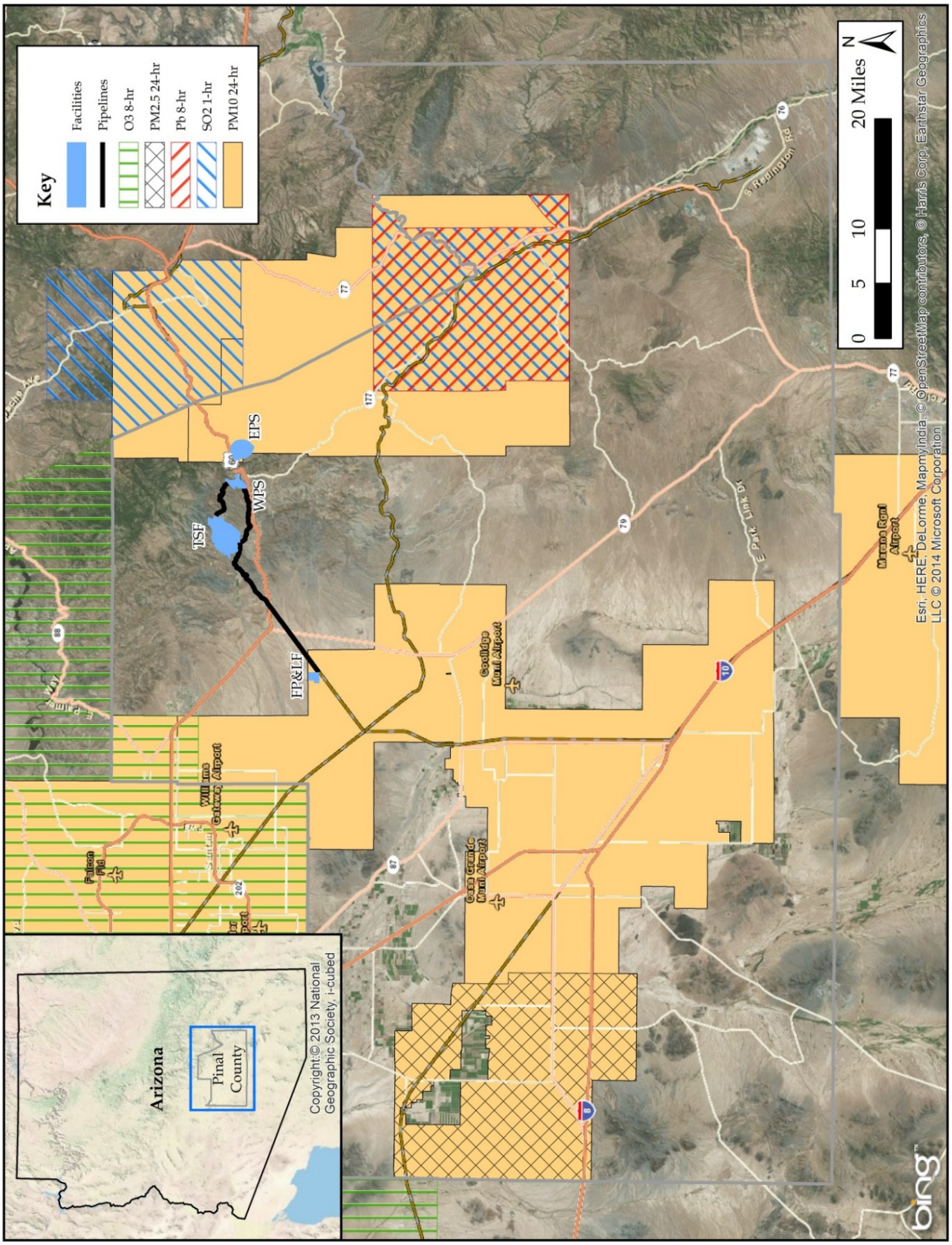
NSR = New Source Review

This table shows that the Resolution Project's potential process source emissions are less than the applicable major source thresholds; therefore, it is not a major source, and the proposed air quality analysis will follow the guidelines for non-major (minor) sources set forth in ADEQ 2015a.

[3] While the various operational areas (EPS, WPS, TSF, and FP&LF) constitute distinct sources, for purposes of this comparison, their emissions are combined.

[4] For purposes of this comparison, all process emissions are assumed to be "point" source emissions. Fugitive and tailpipe/nonroad emissions are not included for major source determination per 40 CFR 52.21(b)(1)(iii) (PSD) and 40 CFR 21.165(a)(1)(iv)(C) (major nonattainment NSR).

Figure 2-8. CAI AQCR Attainment Status and GPA Location



Based on the permit application requirements provided in Chapter 3 of PCAQCD CR and ADEQ 2015a, the proposed air quality analysis for the Resolution Project will include dispersion modeling to demonstrate compliance with the applicable PCAQCD (Chapter 2 of PCAQCD CR) and national (40 CFR 50) AAQS provided in Table 2-6, in units of micrograms per cubic meter ($\mu g/m^3$) and/or parts per million (ppm). If a PCAQCD standard differs from the corresponding national standard, only the more stringent standard is provided in this table and will be used for compliance demonstration.

Table 2-6. AAQS for Compliance Demonstration

Pollutant	Averaging Period	AAQS (ppm)	AAQS ($\mu g/m^3$)	AAQS Form
CO	8-Hour	9	10,000	Not to be exceeded more than once per year
	1-Hour	35	40,000	
Nitrogen Dioxide (NO_2)	Annual	0.053	100	Annual mean
	1-Hour	0.1	188	98th percentile, averaged over 3 years
$PM_{2.5}$	Annual (1)	--	12	Annual mean, averaged over 3 years
	24-Hour (2)	--	35	98th percentile, averaged over 3 years/second-high (2)
PM_{10}	Annual (3)	--	50	Annual mean
	24-Hour	--	150	Not to be exceeded more than once per year on average over 3 years
SO_2	Annual (3)	0.03	80	Annual mean
	24-Hour (3)	0.14	365	Not to be exceeded more than once per year
	3-Hour (4)	0.5	1,300	Not to be exceeded more than once per year
	1-Hour	0.075	196	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
Lead	Rolling 3-Month (5)	--	0.15	Not to be exceeded

(1) PCAQCD standard is 15 $\mu g/m^3$.

(2) PCAQCD standard is 65 $\mu g/m^3$.

(3) PCAQCD standard only, no national standard.

(4) Secondary standard only, no primary standard.

(5) The potential lead emissions are well below the significant increase thresholds defined in 40 CFR 52.21.

(6) Secondary standard only, no primary standard.

Pb emissions at the Resolution Project are well below the significant increase thresholds defined in 40 CFR 52.21. Therefore, Pb is not addressed further.

Additionally, there is a PCAQCD and national 8-hour AAQS for O_3. Unlike the other criteria pollutants, O_3 is not directly emitted from emission sources; rather, it is formed through a series of complex photochemical reactions involving VOC, NO_X, and other gases in the atmosphere on

a regional scale. Because of this, applicants for permits for new or modified sources are not required to address the O_3 National Ambient Air Quality Standard (NAAQS) through modeling.[5] Furthermore, the emissions of VOC and NO_X are relatively minor on a regional basis as seen in Table 2-4.

Consistently, the ADEQ modeling guidelines assert that, "*Modeling involving pollutant transformations (i.e. ozone, sulfates, etc.) is not generally required for new or modified sources and is not addressed in this guidance document*" (ADEQ 2015a).

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[5] See, for example, 77 Fed. Reg. 38557, 38563/3 (June 28, 2012) ("*[G]iven the regional nature of ambient O_3 concentrations, applicants for permits for new or modified stationary sources are not required to show, through dispersion modeling techniques, that the O_3 precursor emissions from the source or modification would not violate the standard.*").

2.8 Baseline Conditions

Resolution Copper has been monitoring and collecting ambient meteorological and air quality data since April 2012 at the EPS and WPS to establish baseline conditions for the air quality analysis. These monitoring data are anticipated to be reviewed and approved by PCAQCD for the proposed air quality analysis.

In 2015, Resolution Copper began meteorological monitoring, including surface and boundary layer (Sonic Detection and Ranging [SODAR]) observations at the Hewitt station, located near the base of the proposed site of the TSF. Data from the Hewitt station will be available to support future modeling of particulate emissions from the TSF. Details and data summaries for the Hewitt station data have been provided to PCAQCD quarterly.

The quality control procedures for metrological ambient air data include weekly site checks, as well as quarterly sampler audits and calibrations. Multi-point calibrations of the PM_{10}, $PM_{2.5}$, NO_X, SO_2, and O_3 analyzers occurred upon installation and are now conducted biannually and in the event of malfunction, equipment relocation, or audit failures. Multi-point calibrations are used to assess the linearity of the analyzers. Multi-point audits of the NO_X, SO_2, and O_3 analyzers are conducted quarterly or as needed. Multi-point audits are used to assess the data accuracy and analyzer performance using certified, traceable standards different than those used for quality control calibration operations. Flow audits are performed on the PM_{10} and $PM_{2.5}$ samplers on a monthly basis. A more detailed description of these quality control procedures can be found in the Monitoring Plan (which has been approved by PCAQCD on November 15, 2011 and July 28, 2016) which have been designed to meet the quality system requirements in 40 CFR Part 58, Appendix A.

The ambient air monitoring sites were primarily selected due to the representativeness of the locations and areas of potential emission sources at the Project as well as the distance from large terrain features. Criterion of secondary importance included the availability of line power and cellular communications. The site selection followed the EPA siting requirements outlined in 40 CFR Part 58, Appendix E.

Data summaries for the EPS and WPS meteorological data are provided in Section 0, and pollutant- and averaging-period-specific baseline air quality data are discussed in Section 3.7.

3.0 AIR QUALITY ANALYSIS

This section describes the modeling methods, procedures, and data sets that will be used for the Resolution Copper air quality analysis.

3.1 Model Selection

The most recent version of the American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) modeling system will be used for this air quality analysis. AERMOD is an enhanced steady-state, Gaussian plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain (EPA 2004). The AERMOD modeling system is listed as the recommended model for short-range analysis (up to 50 km) in 40 CFR 51, Appendix W.

3.2 Pollutants and Averaging Periods

The proposed air quality analysis will include dispersion modeling for the pollutants and averaging periods presented in Table 3-1. This table also shows the short-term (up to 24-hour) modeled design values that will be used for compliance demonstration.

Table 3-1. Pollutants and Averaging Periods

Pollutant	Averaging Period	Compliance Design Value
CO	8-Hour	2nd High
	1-Hour	
NO_2	Annual	
	1-Hour	8th High (98th percentile, averaged over 3 years)
$PM_{2.5}$	Annual	
	24-Hour	8th High (98th percentile, averaged over 3 years)
PM_{10}	Annual	
	24-Hour	Not to be exceeded more than once per year on average over 3 years
SO_2	Annual	
	24-Hour	2nd High
	3-Hour	2nd High
	1-Hour	4th High (99th percentile, averaged over 3 years)

3.3 Building Downwash

The effects of the building-induced downwash will be incorporated into this analysis. The building downwash parameters will be calculated using the most recent version of the Building Profile Input Program with the Plume Rise Model Enhancement (BPIP-PRIME, version 04274). Planned building locations and dimensions will be acquired from Resolution Copper.

3.4 Ambient Air Boundary

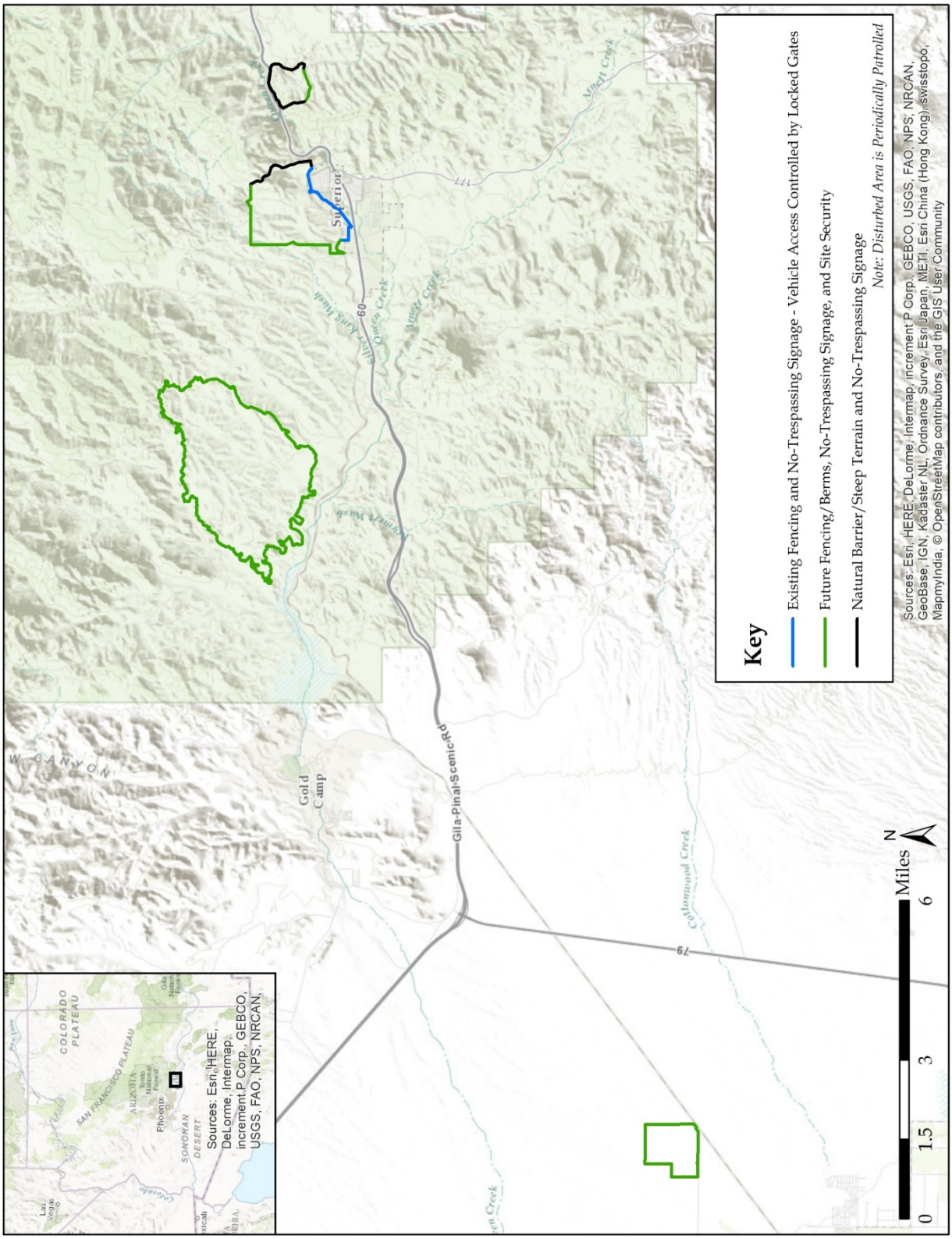
To demonstrate compliance with federal and state ambient air standards, industry standard air dispersion models are used to simulate the atmospheric dispersion of an air pollutant to determine air pollution concentrations that result from a source's emissions. As part of the modeling setup process, Resolution Copper has determined ambient air boundaries (AAB) that delineate where public access is effectively precluded. Future air quality modeling will include receptors along Resolution's ambient air boundary and receptor grids outside the ambient air boundary.

Pursuant to EPA guidance, and consistent with ADEQ 2015a, Section 3.4, the effective ambient air boundary can consist of a combination of fences and gates, physical barriers (including natural barriers), warning signage, manned guard shacks, and periodic security patrols. Each project area may use a combination of the following measures to preclude public access:

- Fencing, Berms, and Locking Gates – Fencing and locking gates will be used along public access roads and other locations near areas of heavy recreational use.
- Signage – Warning and/or no-trespassing signage will be posted on fences and near areas of natural barriers, trails, and recreation.
- Natural Barrier/Steep Terrain – Steep slopes around the project areas will serve as natural barriers or impediments to site access. In general, steep terrain is considered to be terrain with a grade of 25 to 30 percent or greater.
- Periodic Patrols – Mine security will routinely patrol the mine facilities and roads for unauthorized individual(s). In addition, all onsite personnel will be briefed on the necessity of restricting public access to areas within the AAB. Any suspected trespassing will be immediately reported to security.
- Site Security – Authorized access will be controlled by guard shacks, where a check-in/check-out system will be implemented. All mine personnel and visitors must gain access to the site through one of these points.

The proposed ambient air boundaries and their methods for precluding public access can be found in Figure 3-1.

Figure 3-1. Ambient Air Boundaries and Preclusion of Public Access



3.5 Receptors

A series of nested receptor grids will be used for this analysis to estimate ambient pollutant concentrations resulting from the potential emissions. The following receptor spacing and extents around each facility, in accordance with ADEQ 2015a, Section 3.6, will be used for this analysis:

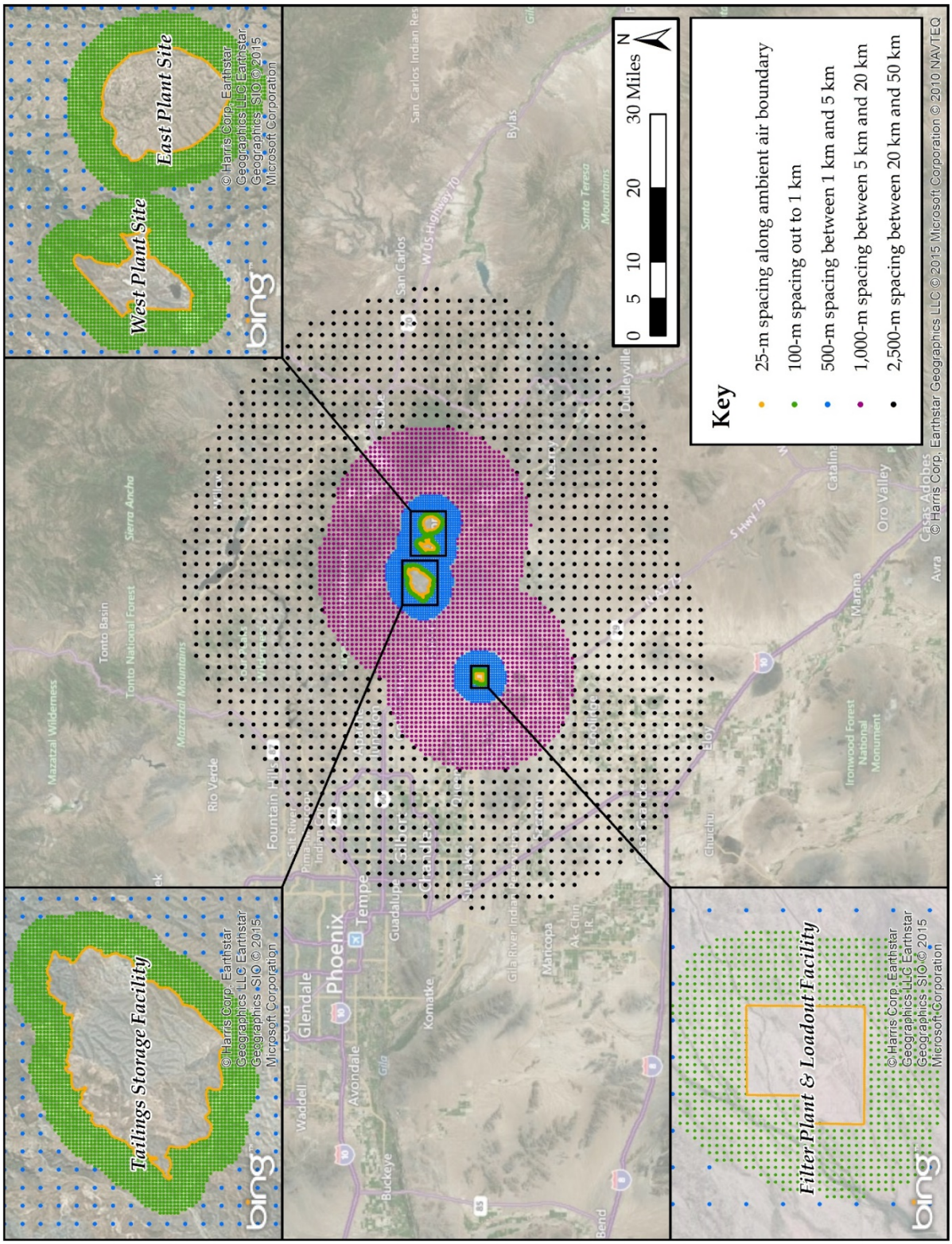
- 25-meter (m) spacing along the AAB
- 100-m spacing out to 1 km from the AAB
- 500-m spacing between 1 km and 5 km from the AAB
- 1,000-m spacing between 5 km and 20 km from the AAB
- 2,500-m spacing between 20 km and 50 km from the AAB

The receptor grid extents will be determined taking into consideration the results from preliminary model runs and time required to complete those runs. Hot-spot analyses using a finer 25-m spacing receptor grid will be performed to ensure that the highest impacts are captured within the modeled receptor grids. Receptors will not be placed within the AAB at each facility.

The most recent version of the AERMOD terrain preprocessor, AERMAP (version 11103), will be used to develop the receptor elevations and hill heights. A 30-m resolution United States Geological Survey (USGS) National Elevation Dataset (NED) file will be used for this processing.

A sample receptor network is presented in Figure 3-2.

Figure 3-2. Sample Receptor Network



3.6 Meteorological Data

AERMOD requires an input of hourly meteorological data to estimate pollutant concentrations in ambient air resulting from modeled source emissions. The EPA's Guideline on Air Quality Models states that "*5 years of NWS meteorological data or at least l year of site specific data is required*" for an air quality modeling analysis (40 CFR 51, Appendix W, 8.3.1.2 b.).

For this analysis, Resolution Copper is proposing to use two years of site-specific hourly surface meteorological data collected at the EPS, WPS, and Hewitt monitoring stations January 1, 2015, through December 31, 2016. These monitoring stations were sited and have been operated per the Resolution Copper Mining Monitoring Plan that has been prepared according to applicable Arizona Department of Environmental Quality and U.S. Environmental Protection Agency guidance and submitted to the PCAQCD for review and approval. The site-specific data sets to be used as input to modeling are anticipated to be approved by the PCAQCD for this analysis. The EPS sources will be modeled using the EPS meteorological data (tower sensors mounted at 10 meter height), the tailings facility will be modeled using the Hewitt meteorological data (SoDAR data collected at 10 meter increments from 20 meters to 190 meters),[6] and the remaining facilities will be modeled using the WPS meteorological data (tower sensors mounted at 10 meter height).

The most recent version of the AERMOD meteorological preprocessor (AERMET) will be used to generate AERMOD-input-ready hourly meteorological files for this analysis. Each of the site-specific data sets will be supplemented with cloud cover data from a representative National Weather Service (NWS) station (e.g., Phoenix-Mesa located approximately 35 miles west of the GPA) and twice-daily upper-air data from the Tucson NWS station, located approximately 75 miles south of the GPA.

The locations of the onsite monitoring and related NWS stations in relation to the Resolution Project facilities are provided in Figure 3-3. The wind frequency distribution diagrams for the onsite monitoring stations are presented in Figure 3-4 through Figure 3-6.

3.6.1 Adjusted Friction Velocity Calculation Method

EPA has acknowledged poor AERMOD performance during low wind-speed conditions (Robinson and Brode 2007). Qian and Venkatram (2010) demonstrated that AERMET tends to grossly under-predict surface friction velocity (u*) under low wind speed conditions (less than two meters per second). This underprediction of u* leads directly to calculation of inappropriately low mechanical mixing heights, which, when simulating impacts from low contaminant emissions, can result in overly conservative (excessively high) ambient

[6] In the absence of valid SoDAR data, the 20-meter Hewitt tower wind speed and direction will be substituted.

concentrations predicted by AERMOD (EPA 2014b, Paine and Connors 2013, Qian and Venkatram 2010).

Qian and Venkatram (2010) suggest an adjusted method for calculating u* and show results that support improved u* and model concentration predictions in the low wind speed regime. EPA has incorporated this calculation methodology (ADJ_U*) as a regulatory default option in AERMET version 16216. ADJ_U* is a processing option that affects the meteorology for low wind speeds during stable (nighttime) conditions (EPA 2014a). Several study results support the conclusion that application of ADJ_U* significantly improves AERMOD performance for low wind speed conditions while maintaining a conservatively high bias in predicted concentrations (Brode 2013, EPA 2014b, EPA 2014d, Paine and Connors 2013). Based on a series of model evaluation studies, the ADJ_U* option improves model performance for low release height sources whose impacts occur under low wind speed conditions (EPA 2017).

Resolution Copper believes that the application of the ADJ_U* method is appropriate in the AERMOD modeling analysis for the Resolution Project as its terrain, meteorological, and emission characteristics meet the criteria under which the default option in AERMOD (i.e., no low wind speed correction) is known to overpredict ambient concentrations. The ADJ_U* method is intended to significantly improve AERMOD's performance for sites and sources similar to the Resolution Project, where emissions are released at low heights (typical of mining sources), low wind speeds are present for significant periods (as indicated in the wind roses presented in Figure 3-4, Figure 3-5, and Figure 3-6), and the project is located in a region with complex terrain.

Figure 3-3. Location of Monitoring Stations

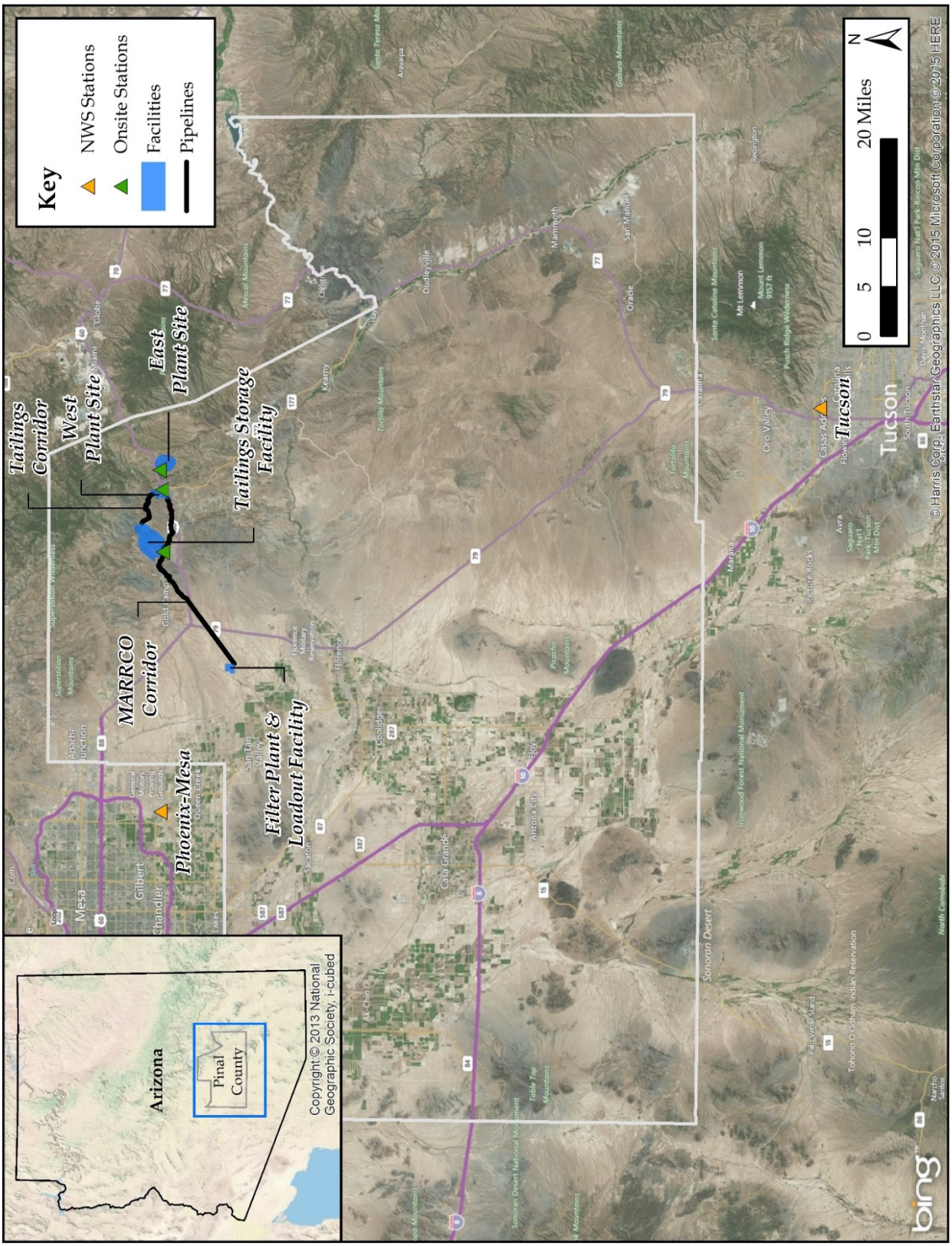


Figure 3-4. Wind Frequency Distribution for EPS Monitoring Station, 2015-2016

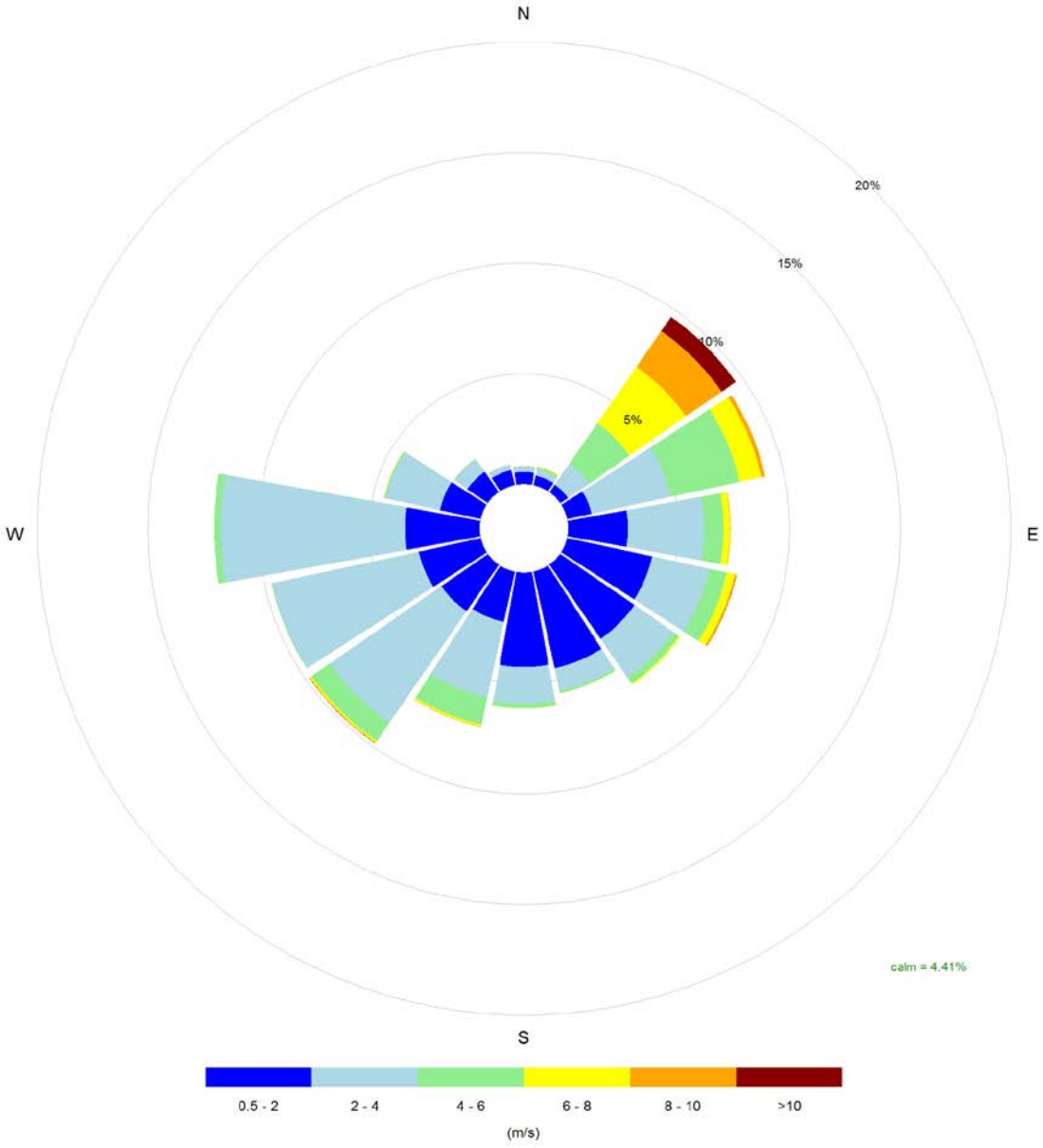


Figure 3-5. Wind Frequency Distribution for WPS Monitoring Station, 2015-2016

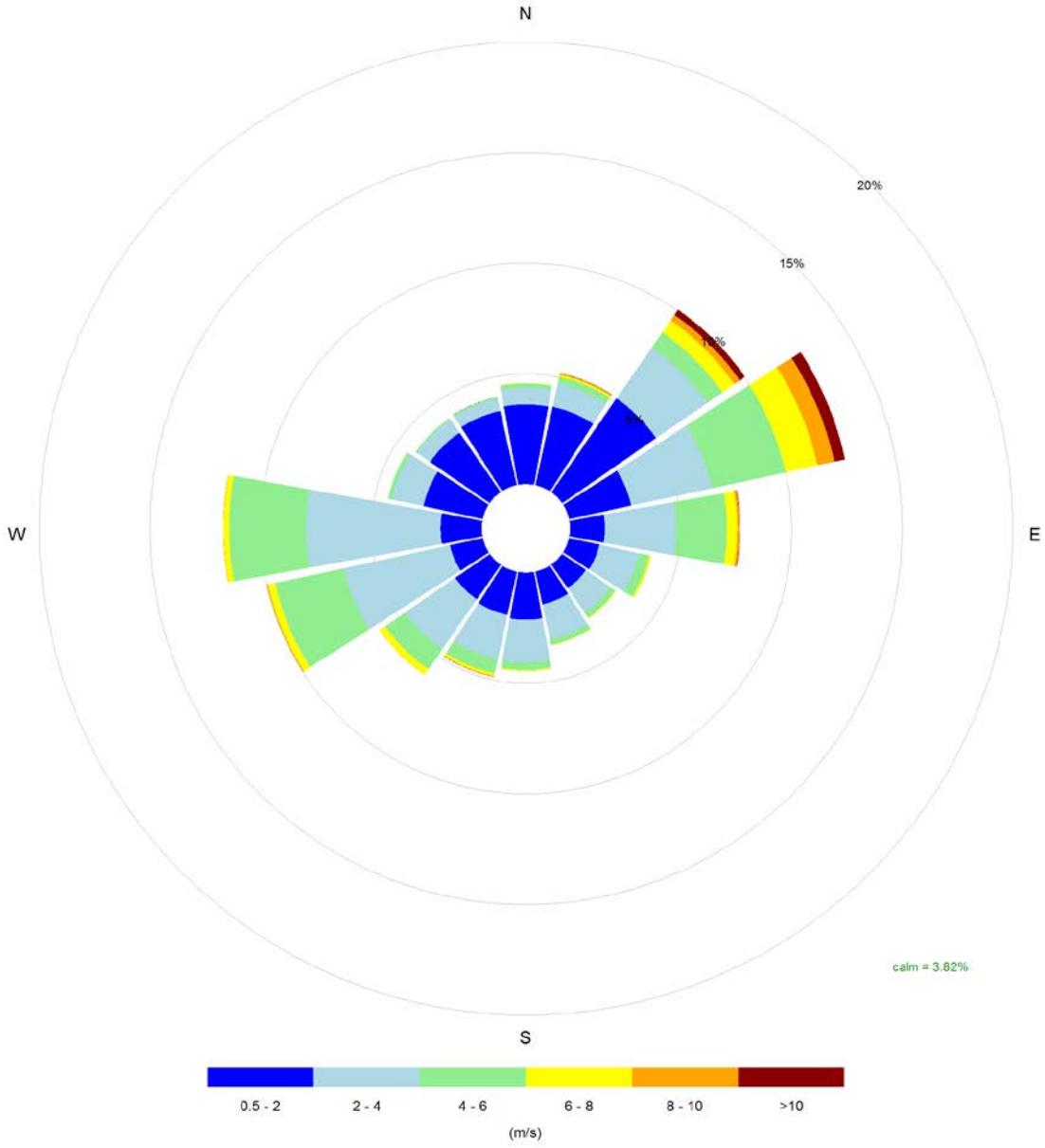
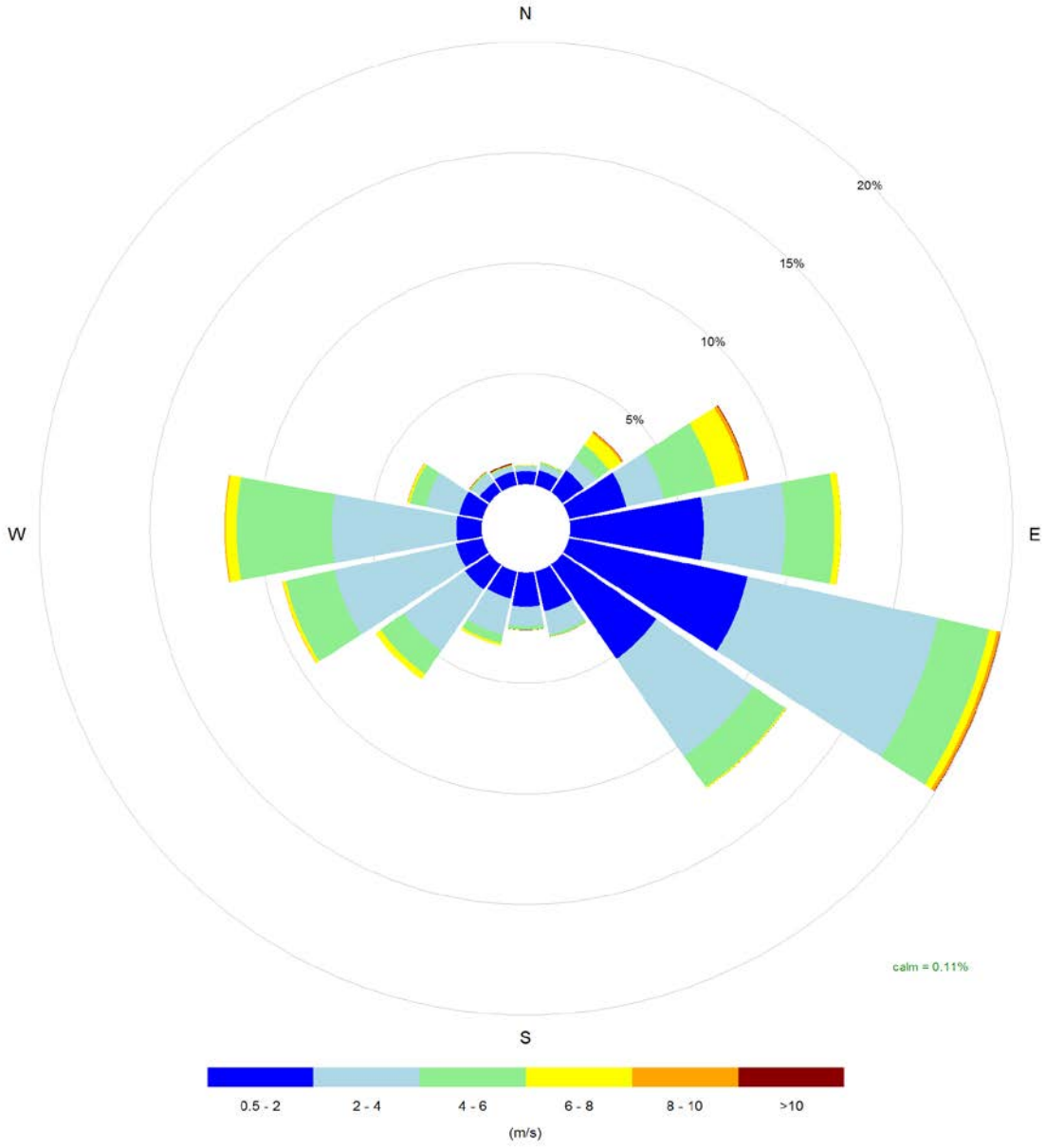


Figure 3-6. 20-m Wind Frequency Distribution for Hewitt Monitoring Station, 2015-2016



In the 2017 Revisions to Appendix W to CFR 40 Part 51 and AERMOD version 16216r, EPA adopted the ADJ_U* method as a regulatory default option. EPA has stated that AERMOD may possibly under predict impacts when the ADJ_U* option is combined with site-specific turbulence data. Therefore, EPA adopted ADJ_U* as a default option only when used without turbulence data (EPA 2017).

Considering the poor performance of the non-ADJ_U* method for low release height sources and the significant improvement by the ADJ_U* method, Resolution Copper proposes to use the ADJ_U* option for modeling. When processing the meteorological data with AERMET and ADJ_U*, Resolution Copper proposes to remove site-specific turbulence parameters so that AERMOD may be run in the default mode. This adjustment to the meteorological data addresses two important matters to improve the model:

1. AERMOD may be run in the default mode.

2. The possibility that AERMOD will under predict impacts when the ADJ_U* option is used is reduced.

3.6.2 Surface Characteristics for AERMET Processing

AERMET requires the input of three surface boundary layer parameters: midday Bowen ratio (B_o), midday albedo (r), and surface roughness length (z_o). These parameters are dependent on the land use and vegetative cover of the area being evaluated. The EPA has provided the recommended methods for determining these surface parameters based on 1992 National Land Cover Data (NLCD92) and released an AERMOD land cover preprocessor (AERSURFACE) for this purpose.

The most recent version of AERSURFACE will be used to estimate the surface characteristic parameters for meteorological data processing. AERSURFACE requires the input of land cover data from the USGS NLCD92 archives, which it uses to determine the land cover types for the user-specified location. Each of the land cover categories in the NLCD92 archive is linked within AERSURFACE to a set of seasonal surface characteristics.

AERSURFACE will be run for each onsite meteorological tower location with 12 sectors (30-degree increments starting at north). High-resolution aerial photographs showing a 10-km radius and the surface roughness length segments around the three onsite meteorological towers are provided in Figure 3-7, Figure 3-8, and Figure 3-9.

Figure 3-7. Aerial Photograph – EPS Monitoring Station

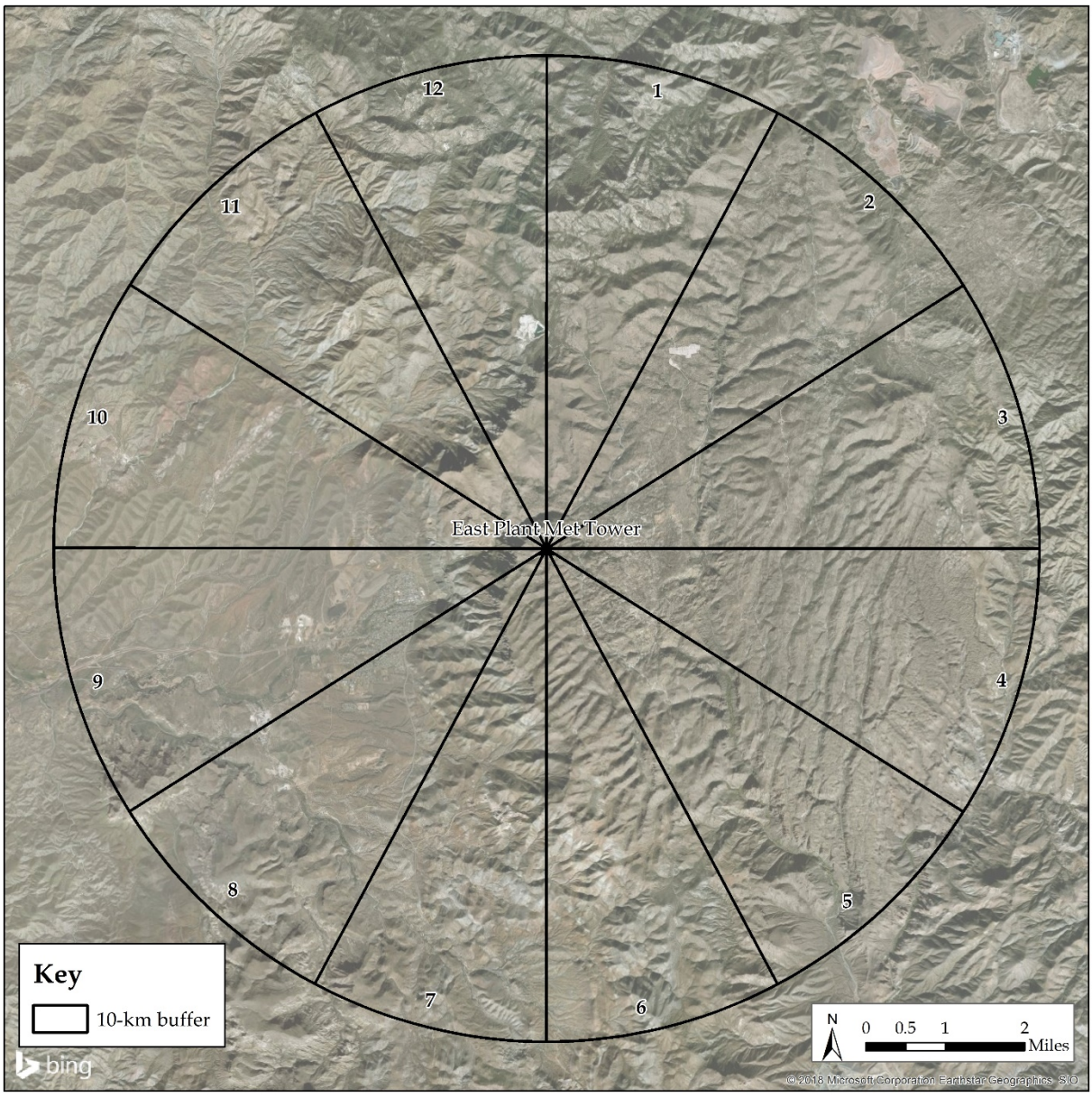
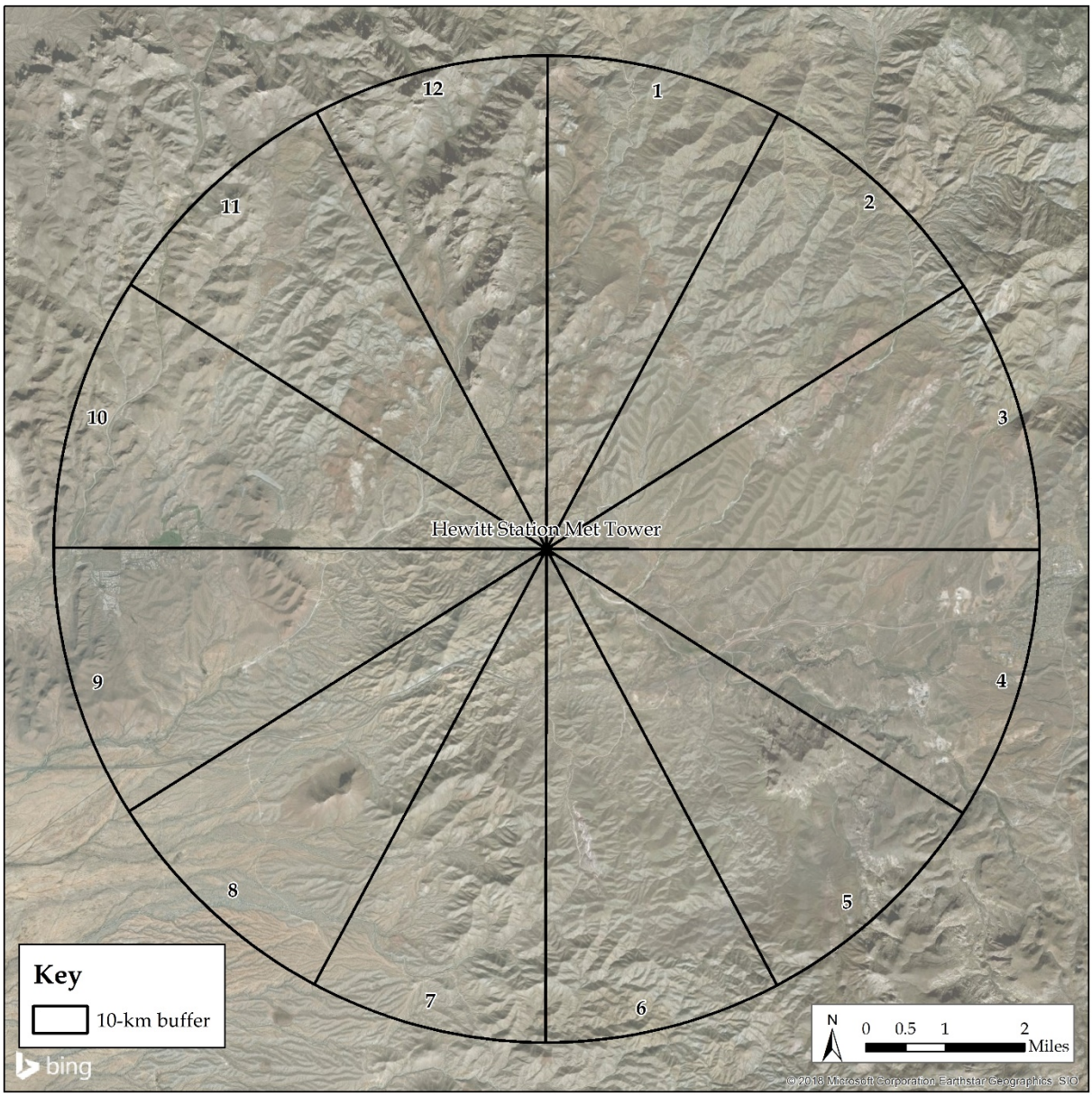


Figure 3-8. Aerial Photograph – WPS Monitoring Station

Figure 3-9. Aerial Photograph – Hewitt Monitoring Station



The determination of B_o is dependent on ambient moisture conditions (i.e., wet, average, or dry). For this purpose, historic 30-year precipitation data from the representative nearby NWS station shown in Table 2-2 will be used. The 70th and 30th percentile values estimated from the 30-year precipitation data will be used to assign a moisture class to each calendar month per the following scheme: monthly precipitation greater than 70th percentile as wet, between 70th and 30th percentile as average, and less than 30th percentile as dry. (Source: U.S. EPA, 2013. AERSURFACE User's Guide.) The monthly estimated B_o and the seasonal estimated z_o for the EPS (r = 0.23), WPS (r = 0.24), and Hewitt (r = 0.25) are presented in Table 3-2 to Table 3-7.

Table 3-2. Bowen Ratio (B_o) by Month – EPS

Year	Month	Moisture Class	Bowen Ratio
2015	January	Wet	1.51
2015	February	Dry	7.42
2015	March	Average	4.34
2015	April	Wet	0.84
2015	May	Wet	0.84
2015	June	Wet	0.84
2015	July	Average	2.76
2015	August	Average	2.76
2015	September	Wet	1.13
2015	October	Wet	1.51
2015	November	Wet	1.51
2015	December	Average	4.34
2016	January	Wet	1.51
2016	February	Average	4.34
2016	March	Dry	7.42
2016	April	Average	2.33
2016	May	Wet	0.84
2016	June	Wet	0.84
2016	July	Wet	1.13
2016	August	Dry	4.39
2016	September	Dry	4.39
2016	October	Average	4.34
2016	November	Wet	1.51
2016	December	Wet	1.51

Table 3-3. Surface Roughness Length (z_o) by Sector and Season – EPS

Sector	Winter	Spring	Summer	Fall
1	0.196	0.205	0.209	0.209
2	0.177	0.187	0.191	0.191
3	0.187	0.187	0.188	0.188
4	0.187	0.187	0.187	0.187
5	0.166	0.166	0.166	0.166
6	0.163	0.163	0.163	0.163
7	0.162	0.162	0.162	0.162
8	0.156	0.156	0.156	0.156
9	0.154	0.154	0.154	0.154
10	0.161	0.161	0.161	0.161
11	0.16	0.162	0.163	0.163
12	0.187	0.194	0.197	0.197

Source: USGS NLCD92; AERSURFACE

Table 3-4. Bowen Ratio (B_o) by Month – WPS

Year	Month	Moisture Class	Bowen Ratio
2015	January	Wet	1.68
2015	February	Dry	8.23
2015	March	Average	4.87
2015	April	Wet	0.90
2015	May	Wet	0.90
2015	June	Wet	0.90
2015	July	Average	3.16
2015	August	Average	3.16
2015	September	Wet	1.26
2015	October	Wet	1.68
2015	November	Wet	1.68
2015	December	Average	4.87
2016	January	Wet	1.68
2016	February	Average	4.87
2016	March	Dry	8.23
2016	April	Average	2.56
2016	May	Wet	0.90
2016	June	Wet	0.90
2016	July	Wet	1.26
2016	August	Dry	4.91
2016	September	Dry	4.91
2016	October	Average	4.87
2016	November	Wet	1.68
2016	December	Wet	1.68

Table 3-5. Surface Roughness Length (z_o) by Sector and Season – WPS

Sector	Winter	Spring	Summer	Fall
1	0.186	0.188	0.188	0.188
2	0.21	0.218	0.218	0.218
3	0.197	0.21	0.21	0.21
4	0.214	0.245	0.247	0.247
5	0.274	0.334	0.338	0.338
6	0.289	0.354	0.357	0.356
7	0.299	0.344	0.347	0.347
8	0.24	0.248	0.249	0.249
9	0.218	0.222	0.222	0.222
10	0.082	0.082	0.082	0.082
11	0.107	0.108	0.108	0.108
12	0.203	0.209	0.209	0.209

Source: USGS NLCD92; AERSURFACE

Table 3-6. Bowen Ratio (B_o) by Month – Hewitt

Year	Month	Moisture Class	Bowen Ratio
2015	January	Wet	1.97
2015	February	Dry	9.78
2015	March	Average	5.90
2015	April	Wet	0.99
2015	May	Wet	0.99
2015	June	Wet	0.99
2015	July	Average	3.92
2015	August	Average	3.92
2015	September	Wet	1.48
2015	October	Wet	1.97
2015	November	Wet	1.97
2015	December	Average	5.90
2016	January	Wet	1.97
2016	February	Average	5.90
2016	March	Dry	9.78
2016	April	Average	2.96
2016	May	Wet	0.99
2016	June	Wet	0.99
2016	July	Wet	1.48
2016	August	Dry	5.89
2016	September	Dry	5.89
2016	October	Average	5.90
2016	November	Wet	1.97
2016	December	Wet	1.97

Table 3-7. Surface Roughness Length (z_o) by Sector and Season – Hewitt

Sector	Winter	Spring	Summer	Fall
1	0.150	0.150	0.150	0.150
2	0.150	0.150	0.150	0.150
3	0.150	0.150	0.150	0.150
4	0.154	0.154	0.154	0.154
5	0.157	0.158	0.158	0.158
6	0.150	0.150	0.150	0.150
7	0.150	0.150	0.150	0.150
8	0.150	0.150	0.150	0.150
9	0.152	0.152	0.152	0.152
10	0.154	0.155	0.156	0.156
11	0.150	0.150	0.150	0.150
12	0.150	0.150	0.150	0.150

Source: USGS NLCD92; AERSURFACE

3.7 Background Concentrations

Resolution Copper has collected ambient particulate ($PM_{2.5}$ and PM_{10}) concentrations at both the EPS and the WPS monitoring stations, and gaseous (NO_2, O_3, and SO_2) concentrations at the EPS monitoring station, for the period of April 2012 through December 2016 to establish pre-construction baseline concentrations. The monitored pollutant concentrations are considered to be representative of background air quality that is influenced by air pollution from several sources:

- emissions from nearby existing sources;
- air pollution transported to the project area from more distant urban areas and industrial sources; and
- natural sources of pollution.

In the modeling analysis, the monitored background concentrations will be added to the modeled concentrations due to project emissions. The total concentration (background plus modeled impact) will account for air pollution sources that influence air quality in the project area but are not expressly modeled.

Based on the availability and completeness, years were selected on a per-pollutant basis as noted in Table 3-8. The background value for CO was extracted from the 2014, 2015, and 2016 ADEQ Annual Ambient Air Assessment Reports (ADEQ 2015b, ADEQ 2016, ADEQ 2017). These monitored data are anticipated to be approved by PCAQCD for use as background concentrations for this analysis. For NO_2, a temporally varying background developed from the EPS monitoring station hourly data will be used.

A paired-sums approach for PM_{10} and $PM_{2.5}$ will be used. In this method, for total ambient 24-hour $PM_{10}/PM_{2.5}$ concentrations to be compared to the 24-hour NAAQS, the modeled impact for each calendar day is added to the measured onsite $PM_{10}/PM_{2.5}$ concentration for that day in accordance with ADEQ 2015a, Section 7.4.1. This method is appropriate to represent predicted total ambient $PM_{10}/PM_{2.5}$ concentrations because of the correlations between meteorological conditions, monitored $PM_{10}/PM_{2.5}$ concentrations, and modeled concentrations. Typically, high modeled impacts occur on days with multiple hours of low wind speeds from a consistent direction. These hours are represented as stable conditions in AERMOD (i.e., a relatively low vertical height of the surface layer, which results in little vertical mixing and minimal pollutant dispersion). At the Project's monitoring site, similar meteorological conditions generally correspond to relatively low monitored concentrations of $PM_{10}/PM_{2.5}$. On the other hand, higher monitored concentrations generally occur on days with high wind speeds and unstable conditions. The input of such meteorological conditions to AERMOD typically results in relatively low modeled impacts due to higher estimated vertical mixing height of the surface layer and increased dispersion of pollutants. Combining modeled 24-hour impacts with the same-day monitored concentrations is preferred to the method of adding a single "default" monitored background value (typically associated with high wind speeds) to a modeled impact (typically associated with low wind speeds) for comparison with NAAQS. The availability of contemporaneously monitored $PM_{10}/PM_{2.5}$ concentrations and meteorological data allows for the monitored PM concentration to be compared in time with the modeled concentration.

Within the monitored particulate data set for use in the paired-sums approach, there are days of elevated PM_{10} and/or $PM_{2.5}$ concentrations at the EPS and WPS stations. This project is located in a region that occasionally experiences elevated ambient particulate concentrations influenced by natural events such as wind-generated dust storms and wildfires. In addition, elevated particulate concentrations have been influenced by particulate pollution from nearby anthropogenic activities that are temporary and unlikely to reoccur (e.g., major highway construction on the portion of Highway 60 that runs through Superior). Given the purpose of the monitoring data, which is to establish background concentrations for modeling that are considered representative of the project area when mining operations occur, Resolution Copper and PCAQCD have agreed that elevated particulate concentration days (greater than or equal to the concentration that is four (4) times the standard deviation above the median) should be analyzed and PM_{10} and/or $PM_{2.5}$ concentrations may be considered for removal from the background concentration dataset if available information supports the likely influence of natural events or unusual anthropogenic activity on the elevated concentrations. This approach has been determined to be consistent with applicable state and federal guidance, rules, and policy.

In accordance with this decision, ten (10) days showing "atypical" elevated PM_{10} and/or $PM_{2.5}$ 24-hour monitored concentrations were analyzed. Several sources of data and information were used for the analyses, including: pollution roses, onsite meteorological data and

particulate concentrations, surface weather maps, wind fields, images from regional cameras, HYSPLIT forward and reverse trajectory models, particulate monitors from the PCAQCD monitoring network, satellite imagery, radar, regional air quality indexes, and BlueSky smoke models. The analyses were summarized in "dashboards" (Appendix E) that were reviewed by PCAQCD. Based on PCAQCD's review (summarized in a December 7, 2017 letter and included in Appendix F), particulate data from three (3) days (March 7, 2016, March 22, 2016, and April 26, 2016) will be removed from the background data set.

For the paired-sums approach to add monitored background PM_{10}/$PM_{2.5}$ concentrations to modeled impacts, a background concentration is required for every day of the modeling period (January 1, 2015 – December 31, 2016). Particulate data that are missing, invalid, or removed from the background data set will be substituted for using the following two-tier gap-filling procedure specified by PCAQCD (K. Walch email, August 28, 2017):

- Tier 1 - Any missing PM_{10} or $PM_{2.5}$ data should be filled using the measured PM_{10} and/or $PM_{2.5}$ collected data at the closest monitoring site if available. For the Town of Superior sites this would be East Plant and West Plant or vice versa. For the Far West site this would be PCAQCD's Combs School site for PM_{10} (further discussion will be necessary if $PM_{2.5}$ data at the Far West site needs to be gap filled).

- When the monitoring data are missing at the closest monitoring location, a monthly gap-fill value shall be determined for each monitoring site. For PM_{10} the highest monitored concentration for the month averaged over 3 years shall be used. For $PM_{2.5}$ the second-highest monitored concentration for the month averaged over 3 years shall be used.

The design background concentrations developed from the EPS and WPS monitoring data, presented in Table 3-8, will be used for this analysis to account for the prevailing ambient pollutant concentrations. These design concentrations were developed following the guidance provided in ADEQ 2015a.

Table 3-8. Proposed Background Concentrations for this Analysis

Pollutant	Averaging Period	Background Concentration ($\mu g/m^3$)	Value	Unit	Form of Background Concentration
CO	8-Hour	2,519	2.2	ppm	Highest Concentration from 3 years (2014 - 2016)
	1-Hour	3,550	3.1	ppm	
Nitrogen Dioxide (NO_2)	Annual	3.01	1.6	ppb	Highest Concentration from 3 years (Q2 2012 – Q1 2015)
	1-Hour	Profile	--	--	3-Year Average Highest Monthly Hour-of-Day Concentrations (Q2 2012 – Q1 2015)
East Plant $PM_{2.5}$	Annual 24-Hour	Profile	--	--	Hourly Monitored Concentrations (Paired with Meteorology)
East Plant PM_{10}	Annual 24-Hour	Profile	--	--	Hourly Monitored Concentrations (Paired with Meteorology)
West Plant $PM_{2.5}$	Annual 24-Hour	Profile	--	--	Hourly Monitored Concentrations (Paired with Meteorology)
West Plant PM_{10}	Annual 24-Hour	Profile	--	--	Hourly Monitored Concentrations (Paired with Meteorology)
SO_2	Annual	2.1	0.8	ppb	Highest Concentration from 3 years (2013, 2015, 2016)
	24-Hour	11.0	4.2	ppb	Highest Concentration from 3 years (2013, 2015, 2016)
	3-Hour	30.7	11.7	ppb	Highest Concentration from 3 years (2013, 2015, 2016)
	1-Hour	24.4	9.3	ppb	99th Percentile of the Annual Distribution of Daily Maximum 1-Hour Values Averaged Over 3 Years (2013, 2015, 2016)

3.8 Source Emissions and Characterization

A comprehensive emissions inventory for the Resolution Project has been developed and is provided in Appendix D. A variety of sources, including AP-42 emission factors, performance data from similar sources, manufacturer specifications, New Source Performance Standards (NSPS), best operating practices, engineering design of the facility, and technical literature has been utilized to develop the Resolution Project emissions inventory.

A summary of the maximum potential Resolution Project emissions for model input, by source category, is provided in Table 3-9.

Table 3-9. Maximum Potential Emissions Summary by Source Category (ton/yr)

Source Category	CO	NO_X	$PM_{2.5}$	PM_{10}	SO_2
Process (Non-Emergency)	7.7	10.5	29.9	81.6	14.8
Fugitive	28.8	5.5	42.4	358.5	1.8
Mobile	361.1	40.7	2.0	2.1	0.5
Emergency	13.0	33.9	1.1	1.1	0.2
Total	410.5	90.5	75.5	443.3	17.3

The emissions provided in Table 3-9 are based on the maximum design rates for the process (including process fugitive) sources, and the fugitive and mobile machinery emissions represent the maximum annual emissions over the project life (Section 2.6). The emergency equipment emissions are based on 500 hours per year in accordance with PCAQCD guidance.[7]

For process sources, all short-term (up to 24-hour, except for intermittent sources for 1-hour averaging periods, addressed in Section 3.11) and long-term (annual) model input emissions will be based on maximum hourly process rates. For fugitive and mobile sources, both short-term and long-term averaging periods' model input emissions will be calculated based on average annual hourly emissions with the exception of long-term emissions from traffic on unpaved roads, which will be calculated using the precipitation correction factor discussed in AP-42, Chapter 13.2.2.

The process sources with exhaust stacks, such as generators, heaters, and baghouse/dust-collector-equipped sources (crushers, silos, transfer points, apron feeders, etc.), will be modeled as POINT sources with actual release characteristics. The fugitive process sources, such as uncontrolled ore transfers at the WPS, will be characterized as VOLUME sources in the model.

Emissions from underground operations at the EPS will exit through a mine ventilation system (mine shafts). The mine vents, which are discreet points, will be modeled as POINT sources.

Emissions from surface activities at the EPS and TSF (fugitive dust and tailpipe emissions) will be aggregated and assigned to appropriate modeled fugitive activity locations. Each model input fugitive location will be appropriately characterized as a VOLUME or an AREA source. The applicable model input physical parameters for VOLUME and AREA sources will be developed based on appropriate polygons within the actual footprint of each fugitive activity location.

Source-specific model input emission rates in grams per second (or grams per second per meter squared) and release parameters are provided in Appendix G and are subject to change.

[7] Email correspondence with K. Walch (PCAQCD), April 14, 2014.

Hourly emissions profiles for wind erosion from exposed surfaces (tailings dry beach, tailings dam, and subsidence area) will be developed using the fastest-mile method specified in AP-42, Section 13.2.5. Using this method, each hourly wind speed will be converted to a fastest mile by multiplying it by a factor of 1.2.[8] The estimated hourly fastest-mile values will be used to calculate the friction velocity using AP-42, Section 13.2.5, Equation 4. When a friction velocity exceeds the material-specific threshold friction velocity, a wind erosion potential (in grams of particulate per square meter of erodible surface) will be calculated using AP-42, Section 13.2.5, Equation 3. Hourly wind erosion potentials will be multiplied by the applicable erodible surface areas to calculate the particulate emissions for every hour.

The new erodible area (A_{New}) for surface that is not re-disturbed (tailings beach and dam, subsidence) between wind erosion events is calculated, as:

$$A_{New} = A_{Hourly} \times Hr_{Elapsed}$$

Where:

A_{Hourly} is the annual average hourly newly created surface area; and

$Hr_{Elapsed}$ is the number of hours elapsed since the previous wind erosion event.

The hourly emissions profile will be input into AERMOD using an external file and the HOUREMIS keyword in the input file. Sample wind erosion emission calculations are provided in Appendix H.

3.9 Coordinate System

The Universal Transverse Mercator (UTM) coordinate system projected in North American Datum of 1983 (NAD83), Zone 12, will be used in this analysis to define all locations in the modeling domain (sources, buildings, and receptors).

3.10 NO_2 Modeling

The NO_X emissions from the combustion sources are principally composed of nitric oxide (NO) and NO_2. Once in the atmosphere, the NO can convert to NO_2 through chemical reactions with ambient O_3. To address this atmospheric conversion process, the Guideline on Air Quality Models (40 CFR 51, Appendix W) recommends the following three-tiered screening approach for evaluating the NO_2 impacts:

- Tier 1: Assume total conversion of NO to NO_2.
- Tier 2: Assume representative equilibrium NO_2/NO_X ratio (0.75 for annual and 0.80 for 1-hour).

[8] Adopted from EPA's guidance document for modeling fugitive dust impacts from coal mines (EPA 1994).

- Tier 3: Use a detailed screening method on a case-by-case basis.

The default option of the Ozone Limiting Method (OLM), a Tier 3 method from 40 CFR 51, Appendix W, will be used to estimate the NO_2 1-hour and annual impacts for this analysis. This method was chosen because the necessary information is available, and the method is expected to produce more representative model results. The OLM determines the limiting factor for NO_2 formation by comparing the estimated maximum NO_X concentration and the ambient O_3 concentration. The model assumes a total NO-to-NO_2 conversion when the ambient O_3 concentration is greater than the estimated maximum NO_X concentration; otherwise, it is limited by the ambient O_3 concentration (Cole and Summerhays 1979).

The combined plume option (keywords OLMGROUP ALL) of the OLM in AERMOD will be used for this analysis.

The use of the OLM requires the following additional input parameters:

- Background O_3 Concentrations – The use of the OLM option in AERMOD requires the input of O_3 concentrations. The O_3 concentration values may be input as a single value, as hourly values to correspond with the meteorological data, or as temporally varying profiles. This analysis will use the onsite (EPS) monitored hourly O_3 data.

- Ambient Equilibrium NO_2/NO_X Ratio – The AERMOD default NO_2/NO_X ambient equilibrium ratio of 0.9 will be used for this analysis. The equilibrium ratio of 0.9 is the AERMOD default (i.e., AERMOD will automatically use this value if it is not provided in an input file), documented in EPA's Addendum to the AERMOD User's Guide.[9]

- In-Stack NO_2/NO_X Ratio – The majority of NO_X emissions at Resolution Copper are associated with diesel combustion. A literature search and a review of available stack tests, including the EPA database (http://www.epa.gov/scram001/no2_isr_database.htm), was conducted to identify reasonable NO_2/NO_X ratios for different combustion source categories. Based on this research, 0.11 is an appropriate NO_2/NO_X ratio for diesel combustion engines and is therefore proposed for this analysis.

The San Joaquin Valley Air Pollution Control District has provided recommended NO_2/NO_X in-stack ratios (ISR) for a variety of source categories in the California Air Pollution Control

[9] EPA. 2015. *Addendum: User's Guide for the AMS/EPA Regulatory Model – AERMOD (EPA-454/B-03-001, September 2004*. Office of Air Quality Planning and Standards, Air Quality Assessment Division. June 2015. Accessed October 6, 2016. http://www.epa.gov/ttn/scram/models/aermod/aermod_userguide.zip.

Officers Association's guidance document for NO_2 1-hour modeling.[10] This guidance document recommends an ISR in the range of 0.06 to 0.11 for heavy-duty diesel trucks. Further, this proposed ISR is conservative in comparison to EPA's NO_2/NO_X ISR Database.[11] This database consists of EPA reference method source test data from 39 diesel-fired internal combustion engines (excluding the Jenbacher JGS 420 engines, which are landfill/natural gas-fired engines but mistakenly listed as diesel-fired engines in the database) with a maximum ISR of 0.098 and an average ISR of 0.061. A preliminary ISR of 0.11 (the most conservative value from these two sources) is proposed for all mobile engines.

The main stationary emergency diesel generators at the Project are expected to be CAT175-16. EPA's ISR database contains source test ISR values for the CAT175-16 at three engine loads. Resolution Copper is proposing to use the maximum plus one standard deviation of these ISR values (0.04) for these generators. In addition, there are several smaller emergency diesel engines anticipated for the Project for which Resolution Copper proposes to use the preliminary ISR of 0.11.

Due to the timeline of the Project, the majority of the diesel-burning equipment has not yet been purchased. Resolution Copper anticipates that much of the equipment to be purchased will be new and comply with current emission standards. In general, the ISRs are getting smaller as engine technology progresses. Therefore, Resolution Copper anticipates proposing additionally refined (e.g., manufacturer-specified) ISRs representative of each engine on a case-by-case basis.

A temporally varying NO_2 background concentration profile will be integrated into AERMOD using the BACKGRND keyword. For this purpose, a monthly hour-of-day NO_2 concentration profile developed from the onsite (EPS) monitored hourly NO_2 data will be used and is provided in Table 3-10 in ppb. This profile consists of the highest value for each monthly hour-of-day per ADEQ 2015a.

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[10] CAPCOA. 2011. *Modeling Compliance of the Federal 1-Hour NO2 NAAQS*. California Air Pollution Control Officers Association Guidance Document. Prepared by CAPCOA Engineering Managers, October 27. Accessed October 6, 2016. http://www.valleyair.org/busind/pto/tox_resources/CAPCOANO2GuidanceDocument10-27-11.pdf.

[11] EPA. *NO_2/NO_x In-Stack Ratio (ISR) Database*. Accessed October 6, 2016. http://www.epa.gov/scram001/no2_isr_database.htm.

Table 3-10. Monthly Hour-of-Day NO_2 Profile (ppb)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	4.4	3.4	2.4	7.8	6.8	4.1	4.1	6.9	6.0	7.4	8.4	10.3
2	2.5	3.0	3.2	6.3	6.3	4.8	4.0	6.2	6.6	8.7	8.8	9.3
3	2.9	4.2	2.3	9.1	9.9	5.7	4.4	7.0	7.9	12.0	7.1	12.0
4	3.6	4.4	2.2	7.1	10.6	5.3	3.7	5.2	8.0	7.7	8.6	12.3
5	3.0	4.2	2.1	5.9	5.5	6.6	7.2	4.6	6.3	7.8	7.4	7.1
6	3.0	3.9	3.2	9.1	6.2	8.7	5.8	5.8	12.6	10.7	8.4	8.5
7	4.4	4.0	2.6	6.6	8.8	6.9	4.4	11.8	7.0	6.6	10.3	7.9
8	8.1	7.7	3.3	9.3	12.2	5.0	3.7	6.0	5.2	7.6	11.4	8.2
9	8.6	7.1	5.8	4.5	4.5	3.0	2.3	4.4	6.1	10.1	8.5	8.4
10	5.4	8.4	2.5	3.3	4.3	2.7	3.8	6.4	1.5	4.0	6.1	5.7
11	4.5	4.7	5.6	2.4	3.6	2.5	0.8	2.8	1.8	4.0	8.4	5.1
12	5.1	4.0	1.7	1.3	2.0	2.0	1.2	2.5	0.6	3.6	5.8	4.6
13	5.0	4.4	1.5	2.1	1.2	1.0	0.9	1.6	0.8	3.7	4.4	3.4
14	3.7	3.9	1.2	1.6	1.3	1.3	0.8	2.6	1.3	3.3	4.1	3.3
15	3.5	2.4	1.1	2.2	1.1	0.9	0.9	1.6	1.7	2.8	4.9	3.0
16	4.2	2.3	2.0	1.5	0.8	1.0	0.6	3.3	1.0	2.8	4.7	3.9
17	3.9	2.5	1.2	2.1	0.8	0.5	0.6	0.5	0.6	3.0	4.5	3.7
18	5.3	3.0	1.0	2.0	1.7	0.4	1.9	0.4	1.3	2.2	6.8	5.3
19	10.5	4.7	1.3	1.7	2.4	0.3	3.3	1.3	9.5	3.8	6.2	6.2
20	8.0	4.4	1.5	3.0	1.3	0.4	2.5	3.7	2.3	4.9	5.8	5.0
21	4.0	4.7	1.6	5.2	1.8	1.4	2.6	2.7	3.9	5.6	6.7	6.0
22	4.0	3.7	2.5	5.8	2.7	3.3	3.7	2.5	5.3	7.9	6.6	8.5
23	3.6	3.7	3.7	10.5	3.5	7.6	3.0	6.6	6.6	6.7	7.0	7.2
24	4.8	4.3	3.2	7.9	5.9	5.1	4.9	9.0	9.3	8.0	9.1	13.1

3.11 Treatment of Intermittent Sources for NO_2 and SO_2 1-Hour Analysis

In its most recent guidance on NO_2 and SO_2 1-hour modeling (EPA 2011), EPA has recognized that intermittent sources that do not operate continuously or frequently enough (e.g., emergency generators) are less likely to contribute significantly to the annual distribution of daily maximum 1-hour values. EPA recommends "*that compliance demonstrations for the 1-hour NO_2 NAAQS be based on emission scenarios that can logically be assumed to be relatively continuous or which occur frequently enough to contribute significantly to the annual distribution of daily maximum 1-hour concentrations*" (EPA 2011). Also, "*EPA believes the most appropriate data to use for compliance demonstration for the 1-hour NO_2 NAAQS are those based on emission scenarios that are continuous enough or frequent enough to contribute significantly to the annual distribution of daily maximum 1-hour concentrations*" (EPA 2011).

The emergency equipment proposed at the Resolution Project includes backup power generators. This equipment is essential to ensure safety and will power critical systems (ventilation, personnel transport, etc.) in case of unforeseen power failure and/or other

emergency situations. This equipment is proposed to operate for only 500 hours per year for the purpose of determining potential to emit, but it is expected to operate for far fewer hours and on a random schedule. Thus, the operation of the emergency equipment will not be frequent enough, and inclusion of its emissions does not represent a logical emission scenario to contribute significantly to the annual distribution of daily maximum 1-hour concentrations. Therefore, emissions from the proposed emergency equipment will be based on continuous operation at the average hourly rate, that is, the maximum hourly rate times 500 hours per year divided by 8,760 hours per year for the NO_2 and SO_2 1-hour analyses.

3.12 Particulate Modeling

Default particulate modeling methods, including deposition (AERMOD Method 1, to account for depletion due to particulate settling), will be used for estimating PM_{10} and $PM_{2.5}$ impacts for this analysis. In order to account for particulate settling, AERMOD requires the following source-specific variables:

1. Mass-mean aerodynamic particle diameter for each particle size bin
2. Mass fraction for each particle size bin
3. Particle density for each particle size bin

A list of references used to develop broad source-category-based particle size bins and associated mass fractions is provided in Table 3-11. This table also provides the particle densities in grams per cubic centimeter (g/cm^3) for each broad source category and associated reference.

Table 3-11. References Used to Develop Deposition Parameters

Source Category	Reference	Density	Density Reference
Underground Fugitive Dust	AP-42, Pg. 13.2.4-4, 11/06, Resolution Exhaust Shaft Emissions Report, 05/08	2.775	Resolution Copper's 2016 geologic model
Ore Handling	AP-42, Pg. 13.2.4-4, 11/06	2.775	Resolution Copper's 2016 geologic model
Road Traffic and Maintenance	AP-42, Sec. 13.2.2, Eqs. 1a and 2, & Tab. 13.2.2-2, 11/06	2.775	Resolution Copper's 2016 geologic model
Baghouses	AP-42, App. B-1, Pg. B.1-77, Sec. 11.21 (Phosphate Rock Processing: Roller Mill and Bowl Mill Grinding), 10/86	2.775	Resolution Copper's 2016 geologic model
Gasoline and Diesel Engines	AP-42, App. B-2, Tab. B.2-2, Pg. B.2-11 (Category 1, Stationary Internal Combustion Engines, Gasoline and Diesel Fuel), 01/95	2.25	Assumption; density of carbon
Boilers	AP-42, App. B-2, Tab. B.2.2, Pg. B.2-12 (Category 2, Combustion, Mixed Fuels, Boilers), 01/95	2.25	Assumption; density of carbon
Wind Erosion	AP-42, Pg. 13.2.5-3, 11/06	2.775	Resolution Copper's 2016 geologic model
Tailings Wind Erosion	AP-42, Pg. 13.2.5-3, 11/06	2.67	Resolution Copper's 2016 geologic model
Cooling Towers	Resolution Water Drop Size Distribution for Low Efficiency Drift Eliminators (Resolution_Surface_Cooling.xlsx, 2018-02-21)	2.7	Density of TDS constituents
Aggregate, Cement, and Sand Handling	AP-42, Pg. 13.2.4-4, 11/06	1.435	Average of cement, sand, lime, gravel from AP-42, App A

An example calculation of deposition parameters for ore handling emissions is provided in Table 3-12. In addition to the proposed deposition parameters, this table also shows the step-by-step calculations to determine mass mean diameter for each bin.

Table 3-12. Proposed Deposition Parameters for Ore Handling Emissions

		PM_{10}				$PM_{2.5}$	
Step	Parameter	Bin 0 (1)	Bin 1	Bin 2	Bin 3	Bin 0 (1)	Bin 1
	Bin Upper Diameter (µm)	1.60	2.50	5.00	10.00	1.60	2.50
	Particle Size Multiplier	--	0.05	0.20	0.35	--	0.05
1	Cumulative Mass Fraction	--	0.15	0.57	1.00	--	1.00
2	Mass Fraction	--	0.15	0.42	0.43	--	1.00
3	Spherical Volume (μm^3)	2.14	8.18	65.45	523.60	2.14	8.18
4	Mean Spherical Volume (μm^3)	--	5.16	36.82	294.52	--	5.16
5	Mass Mean Diameter (µm)	--	2.14	4.13	8.25	--	2.14
	Particle Density (g/cm^3)	--	2.78	2.78	--	--	2.78

(1) Bin 0 is not input to the model. It is only used to estimate the mass mean diameter of Bin 1. The upper diameter for Bin 0 is estimated by linear interpolation of Bins 1 and 2, and by setting the particle size multiplier for Bin 0 to zero.

The calculation steps listed in Table 3-12 are described below. All example calculations provided in these steps are for PM_{10} deposition parameters.

Step 1: The cumulative mass fraction for each bin is calculated by dividing the particle size multiplier by that of the highest bin: Bin 3 in this case. Examples:

- Bin 3 cumulative mass fraction (1.0) = Bin 3 particle size multiplier (0.35) divided by Bin 3 particle size multiplier (0.35)
- Bin 2 cumulative mass fraction (0.57) = Bin 2 particle size multiplier (0.2) divided by Bin 3 particle size multiplier (0.35)

Step 2: The mass fraction for each bin is calculated by subtracting the cumulative mass fraction of the next lower bin from the cumulative mass fraction for that bin. Examples:

- Bin 3 mass fraction (0.43) = Bin 3 cumulative mass fraction (1.0) minus Bin 2 cumulative mass fraction (0.57)
- Bin 2 mass fraction (0.42) = Bin 2 cumulative mass fraction (0.57) minus Bin 1 cumulative mass fraction (0.15)

Step 3: The spherical volume for each bin is calculated as: $4/3 \times \pi \times (\text{Bin Upper Diameter} \div 2)^3$.

Step 4: The mean spherical volume for each bin is calculated as the average of spherical volumes of that bin and the next lower bin. Examples:

- Bin 3 mean spherical volume (294.52) = The average of Bin 3 (523.6) and Bin 2 (65.45) spherical volumes
- Bin 2 mean spherical volume (36.82) = The average of Bin 2 (65.45) and Bin 1 (8.18) spherical volumes

Step 5: The mass mean diameter for each bin is calculated from the mean spherical volume as: $[\text{Mean Spherical Volume} \times 3 \div (4 \times \pi)]^{1/3} \times 2$

The proposed deposition parameters for the source categories are provided in Table 3-13.

Table 3-13. Proposed Deposition Parameters by Source Category

Source Category	Parameter	PM_{10}					$PM_{2.5}$		
		Bin 0 (1)	Bin 1	Bin 2	Bin 3	Bin 4	Bin 0 (1)	Bin 1	Bin 2
Underground Fugitive Dust	Bin Upper Diameter (µm)	1.32	2.50	5.00	10.00	--	1.32	2.50	--
	Mass Fraction	--	0.31	0.67	0.02	--	--	1.00	--
	Mass Mean Diameter (µm)	--	2.08	4.13	8.26	--	--	2.08	--
	Particle Density (g/cm³)	--	2.78	2.78	2.78	--	--	2.78	--
Ore Handling	Bin Upper Diameter (µm)	1.60	2.50	5.00	10.00	--	1.60	2.50	--
	Mass Fraction	--	0.15	0.42	0.43	--	--	1.00	--
	Mass Mean Diameter (µm)	--	2.14	4.13	8.26	--	--	2.14	--
	Particle Density (g/cm³)	--	2.78	2.78	2.78	--	--	2.78	--
Road Traffic and Maintenance	Bin Upper Diameter (µm)	1.67	2.50	10.00	--	--	1.67	2.50	--
	Mass Fraction	--	0.10	0.90	--	--	--	1.00	--
	Mass Mean Diameter (µm)	--	2.16	7.98	--	--	--	2.16	--
	Particle Density (g/cm³)	--	2.78	2.78	--	--	--	2.78	--
Baghouses	Bin Upper Diameter (µm)	0.56	2.50	6.00	10.00	--	0.56	2.50	--
	Mass Fraction	--	0.28	0.50	0.22	--	--	1.00	--
	Mass Mean Diameter	--	1.99	4.87	8.47	--	--	1.99	--
	Particle Density (g/cm³)	--	2.78	2.78	2.78	--	--	2.78	--
Gasoline and Diesel Engines	Bin Upper Diameter (µm)	--	1.00	2.50	6.00	10.00	--	1.00	2.50
	Mass Fraction	--	0.85	0.08	0.03	0.03	--	0.91	0.09
	Mass Mean Diameter (µm)	--	0.79	2.03	4.87	8.47	--	0.79	2.03
	Particle Density (g/cm³)	--	2.25	2.25	2.25	2.25	--	2.25	2.25
Boilers	Bin Upper Diameter (µm)	--	1.00	2.50	6.00	10.00	--	1.00	2.50
	Mass Fraction	--	0.29	0.28	0.32	0.11	--	0.51	0.49
	Mass Mean Diameter (µm)	--	0.79	2.03	4.87	8.47	--	0.79	2.03
	Particle Density (g/cm³)	--	2.25	2.25	2.25	2.25	--	2.25	2.25
Wind Erosion	Bin Upper Diameter (µm)	1.18	2.50	10.00	--	--	1.18	2.50	--
	Mass Fraction	--	0.15	0.85	--	--	--	1.00	--
	Mass Mean Diameter (µm)	--	2.05	7.98	--	--	--	2.05	--
	Particle Density (g/cm³)	--	2.78	2.78	--	--	--	2.78	--
Tailings Wind Erosion	Bin Upper Diameter (µm)	1.18	2.50	10.00	--	--	1.18	2.50	--
	Mass Fraction	--	0.15	0.85	--	--	--	1.00	--
	Mass Mean Diameter (µm)	--	2.05	7.98	--	--	--	2.05	--
	Particle Density (g/cm³)	--	2.67	2.67	--	--	--	2.67	--
Cooling Towers	Bin Upper Diameter (µm)	--	2.28	2.50	6.00	10.00	--	2.28	2.50
	Mass Fraction	--	0.04	0.10	0.53	0.33	--	0.27	0.73
	Mass Mean Diameter (µm)	--	1.81	2.39	4.87	8.47	--	1.81	2.39
	Particle Density (g/cm³)	--	2.70	2.70	2.70	2.70	--	2.70	2.70
Aggregate, Cement, and Sand Handling	Bin Upper Diameter (µm)	1.60	2.50	5.00	10.00	--	1.60	2.50	--
	Mass Fraction	--	0.15	0.42	0.43	--	--	1.00	--
	Mass Mean Diameter (µm)	--	2.14	4.13	8.26	--	--	2.14	--
	Particle Density (g/cm³)	--	1.44	1.44	1.44	--	--	1.44	--

(1) Bin 0 is not input to the model. It is only used to estimate the mass mean diameter of Bin 1. The upper diameter for Bin 0 is estimated by linear interpolation of Bins 1 and 2, and by setting the particle size multiplier for Bin 0 to zero.

3.12.1 Secondary $PM_{2.5}$ Formation

The potential secondary $PM_{2.5}$ formation associated with the Resolution Project's emissions will be addressed qualitatively following the concepts developed/accepted by EPA's Region 10 office for a qualitative assessment of secondary $PM_{2.5}$ impacts for an Alaska project, which is cited as an example in EPA's May 20, 2014, memorandum "Guidance for $PM_{2.5}$ Permit Modeling" (EPA 2014c), and in guidance provided in ADEQ 2015a.

The proposed qualitative assessment will evaluate the following factors:

1. The regional background $PM_{2.5}$ monitoring data and aspects of secondary $PM_{2.5}$ formation from existing sources.

2. The relative ratio of the combined (modeled primary and background) $PM_{2.5}$ concentrations to AAQS.

3. The spatial and temporal correlation of the primary and secondary $PM_{2.5}$ impacts.

4. Meteorological characteristics of the region during periods of precursor emissions.

5. Existing levels of precursor species (sulfates and nitrates).

6. The level of conservatism associated with the modeling of the primary $PM_{2.5}$ component and other elements of conservatism built into the overall AAQS compliance demonstration.

7. Post-construction monitoring.

Based on these factors, and consistent with current guidance, Resolution Copper will make an adequate assessment to demonstrate that the $PM_{2.5}$ AAQS will be protected, accounting for primary $PM_{2.5}$ impacts and potential contributions due to $PM_{2.5}$ precursors from the Project, and that it is not necessary to further evaluate potential secondary $PM_{2.5}$ formation from the Resolution Project emissions.

3.13 Modeling Technique

Each site will be modeled with appropriate meteorological data. The model output files from the two separate model runs will be post-processed to generate combined results and output files for each pollutant and associated averaging periods.

Objectives of the AERMOD model execution and post-processing routines for modeling results include:

- Model each facility's emissions sources with meteorological data that is representative for the facility area.

- Add background pollutant concentrations that are representative for the facility area (and avoid double-counting). This includes adding representative paired-in-time background concentrations of PM_{10} and $PM_{2.5}$.

- Account for impacts from all facilities at every receptor (and avoid double counting).

- Produce appropriate results of modeled impacts (all facilities) plus representative background in the form of the standard to compare to the National Ambient Air Quality Standards (NAAQS).

To accomplish these objectives, Air Sciences has developed a plan for AERMOD model execution and results post-processing that is summarized in Figure 3-10. This schematic displays the key steps in model execution and results post-processing:

1. Each facility (i.e., EPS, WPS, TSF, and FP&LF) will be modeled separately with two years of representative (i.e., facility-specific) meteorological data, as described in Section 0.

2. Each facility's model will produce impacts at each receptor in the entire receptor grid described in Section 3.5 of the Model Plan.

3. The model run for each facility will produce two (2) output files of results in the form of the standard at every receptor in the grid:

   i. Modeled impacts from facility sources.

   ii. Modeled impacts from facility sources plus representative background pollutant concentrations.

      - For those pollutants where a single background concentration value will be used, as described in Table 3-8, the background value will be added to the modeled impact.

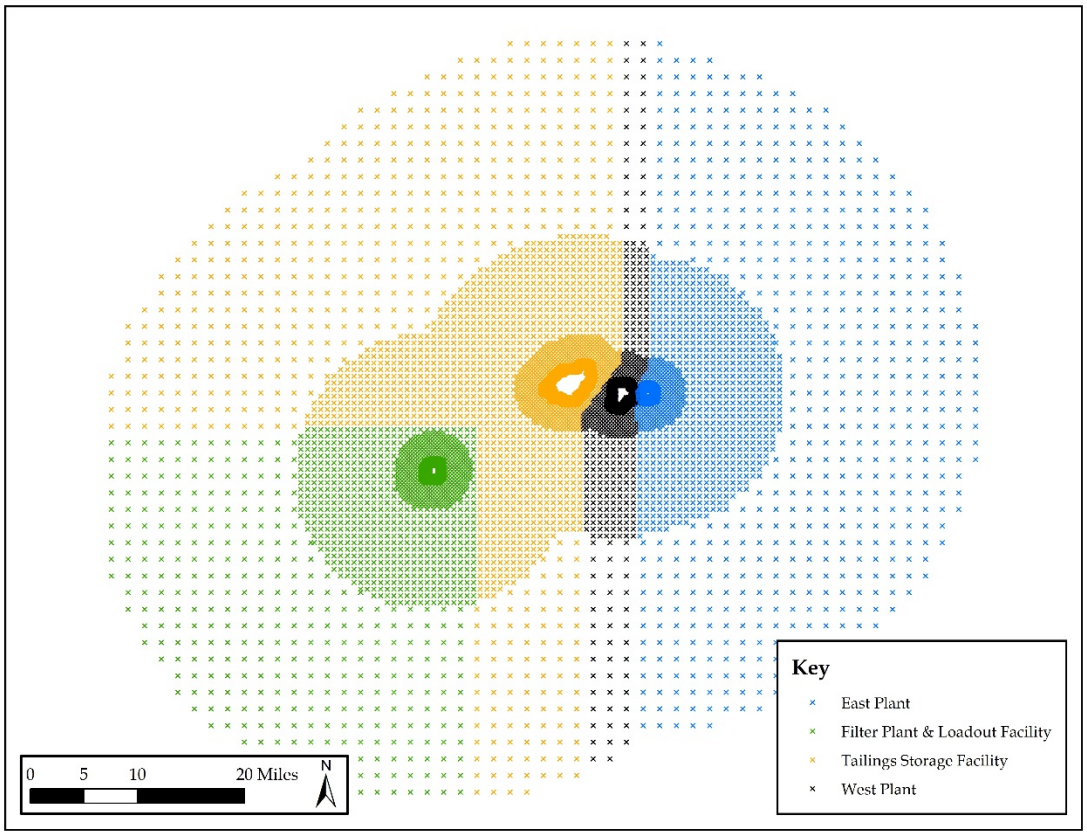
      - For 1-hour NO_2, 24-hour and annual $PM_{2.5}$, and 24-hour and annual PM_{10}, the temporal background profiles provided to AERMOD will be added to the modeled impact.

4. In order to use the most representative background for each receptor, each receptor is assigned to a specific facility as shown in Figure 3-11.

5. Post-processing routines (that are well documented and straightforward to replicate) will be implemented to sum, at every facility-assigned receptor, that facility's modeled impacts, representative background, and the modeled form of the standard impact (e.g., high-3rd-high modeled concentration of 24-hour PM_{10} at the receptor) for each of the other facilities. This method of adding the form of the standard impact is a more conservative approach than adding the paired-in-time modeled impacts from the other facilities.

Figure 3-10. Modeling and Post-Processing Schematic

Figure 3-11. Facility-Specific Paired Impacts-Plus-Background Assignments



3.14 Analysis Report

The proposed air quality analysis including results will be packaged in a report format. An electronic copy of the report and digital modeling files (model input, output, preprocessor files, terrain data, etc.) associated with the analysis will be provided on digital media.

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Appendix A – Response to Questions from PCAQCD on Resolution Copper's NAAQS Modeling Plan

RESPONSE TO QUESTIONS FROM PCAQCD ON RESOLUTION COPPER'S NAAQS MODELING PLAN

PREPARED FOR: Resolution Copper Company (Resolution)

PREPARED BY: D. Randall, N. Tipple

PROJECT NO.: 262-32-2

DATE: February 13, 2018

Pinal County Air Quality Control District's (PCAQCD)3rd-party contractor has provided questions / requests for clarification pertaining to the contractor's review of the Air Quality Impacts Analysis Modeling Plan (Model Plan) for the Resolution Copper Project (December 2017): This technical memo provides answers/additional information in response to the comments/requests. In addition, an electronic copy (EXCEL) of the emission inventory will be provided (via email) after the additional questions/requests for clarification on the emission inventory have been addressed.

Responses to Comments/Questions/Requests

> *Page 47: The protocol states that for fugitive and mobile sources, the same emissions were input to the model for short-term and long-term averages, based on the average annual hourly emissions. However, for example, fugitive emissions for traffic on unpaved roads include a correction factor for the number of days in the year with greater than 0.01 inches of precipitation. For these sources, it would appear that the peak short-term emissions and long-term emissions would be different. For road emissions and similar sources, do the short-term emissions input to the model include the precipitation correction?*

The precipitation correction factor is only applied to annual emission rates. The discussion in the Model Plan will be be augmented to describe how peak short-term and long-term emissions are calculated in the emissions inventory.

> *Page 48: For the wind erosion calculations, the fastest-mile values appear to have been set at 1.2 times the hourly average scalar wind speed. My expectation would be that the peak wind to average wind speed ratio would increase as the average wind speed increases. Does the meteorological monitoring data collected at the project site include shorter term averages that could be used to confirm this relationship?*

The Environmental Protection Agency's AP-42, Section 13.2.5 (EPA 2006) provides a methodology for estimating particulate emissions (all size fractions) from erodible surfaces. Site-specific data required for this methodology include the following:

- Erodible surface area
- Fastest mile wind speed (FMWS)

FMWS data (or the reasonable equivalent) are not collected at Resolution's meteorological monitoring stations (1-second scans are used (but not permanently stored) to calculate 15-minute averages; 15-minute data are averaged (and stored) to calculate hourly average wind speed). EPA considers the maximum value of 2-minute average wind speed during an hour to be reasonably representative of the FMWS (EPA 2006). To convert hourly wind speed to FMWS, Air Sciences uses a conversion factor of 1.2. Other examples of use of this factor plus available technical information indicate that this factor is reasonable for use in the Resolution emissions inventory to calculate FMWS.

Examples of Common Use

- In EPA's guidance document for modeling fugitive dust impacts from coal mines, EPA provides a conversion factor of 1.2 for converting an hourly mean wind speed to a fastest mile wind speed. Page 37 of this document states the following:

  "Assuming that the ratio of the fastest mile to the hourly mean wind speed is 1.2; an hourly mean wind speed of 23 mph will be assumed to produce a fastest mile of 27 mph." (EPA 1994)

- Guidelines for Electrical Transmission Line Structural Loading (Wong and Miller 2010). Appendix D of this Guideline from the American Society of Civil Engineers references a 1960 journal article by C. S. Durst (referenced again, below). Appendix D provides an example conversion from the fastest mile wind gust of 72 miles per hour (mph) (averaging time of 50 seconds) to a mean hourly wind speed of 57 mph using a factor 1.26 (Wong and Miller 2010). As shown in Table 1 in the following section, 1.26 (50-second average) is within the range of the 1-minute average ratio of 1.24 and the 30-second average ratio of 1.32. The 2-minute ratio would be lower than this range.

- Wind Loads: The Nature of Wind (Quimby 2007). In this presentation by Professor T. Bart Quimby, P.E., Ph.D., of the University of Alaska Anchorage, a graph is provided that shows the ratio of the 2-minute wind gust over the hourly mean wind speed to be between 1.15 and 1.20.

- Erosion Potential Tests in the Vicinity of East Helena Using a Portable Wind Tunnel (Wisner et al. 1991). In this report, a gust factor of 1.2 is used "to convert hourly average wind to fastest mile." Note that Helena, Montana, is in an area of complex terrain.

Available Technical Information

In a meteorological journal article authored by C. S. Durst (Durst) in 1960, Durst provides a table of the probable values of the short-term (0.5-second to 10-minute) wind gusts for varying hourly mean wind speeds. Data from the Durst table are used for the technical assessment below.

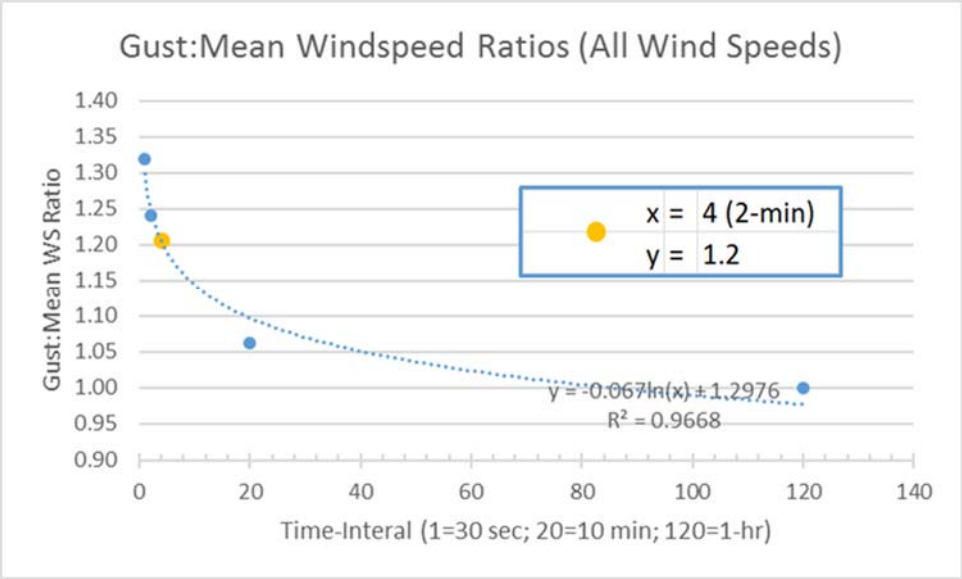
Wind gust data for a given mean hourly wind speed plot along a logarithmic curve. Logarithmically interpolating along the line of average ratios (gust over hourly) for mean wind speeds of 20, 30, 40, 50, 60, 70, and 80 mph yields a value of 1.20 for the 2-minute gust ratio (see Figure 1).

Table 1. Excerpts from Table VIII of the Durst Article (Durst 1960)

Mean Hourly Wind Speed (mph)*	Short-Term Gust*			Ratio: Gust over Hourly		
	10-min	1-min	30-sec	10-min	1-min	30-sec
20	21	25	26	1.05	1.25	1.30
30	32	37	40	1.07	1.23	1.33
40	43	50	53	1.08	1.24	1.33
50	53	62	66	1.06	1.23	1.32
60	64	74	79	1.07	1.24	1.32
70	74	87	92	1.06	1.24	1.31
80	85	99	106	1.06	1.24	1.33
			Ratio Average	**1.06**	**1.24**	**1.32**

*(Durst 1960)

Figure 1. Gust:Hourly-Mean Windspeed Ratios



Findings based on review of this available technical information include:

1. The Durst data table indicates that, for average wind speeds between 20 and 80 mph, it is reasonable to estimate the FMWS with a constant factor (rather than multiple factors that increase with average wind speed).

2. Logarithmic interpolation of the gust:hourly-mean windspeed ratios (averaged across all hourly-mean windspeeds) shows that a factor of 1.2 (for the 2-minute gust) is reasonable to represent FMWS.

These findings and the several examples of common use of the 1.2 factor suggest that it is reasonable to use the 1.2 factor to calculate FMWS from hourly average wind speed in the wind erosion calculations for the Resolution Project.

Page 49: The protocol states that the onsite ozone monitoring data will be used to generate the hourly ozone concentration file for input to the ozone limiting method. What is the data recovery for the ozone monitoring data and how will missing ozone concentration data be handled?

The quarterly recovery rates of the hourly ozone data are presented in Table 2.

Table 2. Hourly Ozone Data Recovery Rates for 2015 and 2016 at the Resolution Project Gaseous Monitoring Site, by Quarterly Periods

Year	Quarter	# Hours per Quarter	# Invalid Hours	Recovery %
2015	1	2,160	16	99%
	2	2,184	17	99%
	3	2,208	121	95%
	4	2,208	43	98%
2016	1	2,184	484	78%
	2	2,184	45	98%
	3	2,208	36	98%
	4	2,208	20	99%

The AERMOD modeling system is capable of handling missing data in the hourly ozone file by substituting (on an hourly basis) the appropriate value from a temporally varying profile provided to the model. For the Resolution Project, the substitution or gap-filling profile will vary by month and hour-of-day. The profile will contain the maximum monitored values for each month-and-hour-of-day from 2015 or 2016; i.e., the profile will be the 2-year maximum monthly-diurnal values from the monitored ozone data (12 months x 24 hours = 288 profile values).

Pages 53-55: Can Table 3-13 be provided showing all of the calculation "steps" as per Table 3-12? Also, can the data reference for the mass fraction inputs for the different source categories be provided? Lastly, how was the Bin 0 diameter determined and why would this value vary based on the source category?

The technical memo "Resolution Copper Project, AZ – Deposition Parameter Calculation Details" (attached as Appendix A) provides responses to the questions and information requests pertaining to deposition parameters.

Page 56: Please provide more detail on how the model output files from the different AERMOD modeling runs are post-processed

Objectives of the AERMOD model execution and post-processing routines for modeling results include:

- Model each facility's emissions sources with meteorological data that is representative for the facility area.
- Add background pollutant concentrations that are representative for the facility area (and avoid double-counting). This includes adding representative paired-in-time background concentrations of PM_{10} and $PM_{2.5}$.
- Account for impacts from all facilities at every receptor (and avoid double counting).
- Produce appropriate results of modeled impacts (all facilities) plus representative background in the form of the standard to compare to the National Ambient Air Quality Standards (NAAQS).

To accomplish these objectives, Air Sciences has developed a plan for AERMOD model execution and results post-processing that is summarized in Figure 1. This schematic displays the key steps in model execution and results post-processing:

1. Each facility (i.e., East Plant, West Plant, Tailings Storage Facility, and Filter Plant/Concentrate Loadout) will be modeled separately with two years of representative (i.e., facility-specific) meteorological data, as described in Section 3.6 of the Model Plan.
2. Each facility's model will produce impacts at each receptor in the entire receptor grid described in Section 3.5 of the Model Plan.
3. The model run for each facility will produce two (2) output files of results in the form of the standard at every receptor in the grid:
    i. Modeled impacts from facility sources.
    ii. Modeled impacts from facility sources plus representative background pollutant concentrations.
        - For those pollutants where a single background concentration value will be used, as described in Table 3-8 of the Model Plan, the background value will be added to the modeled impact.

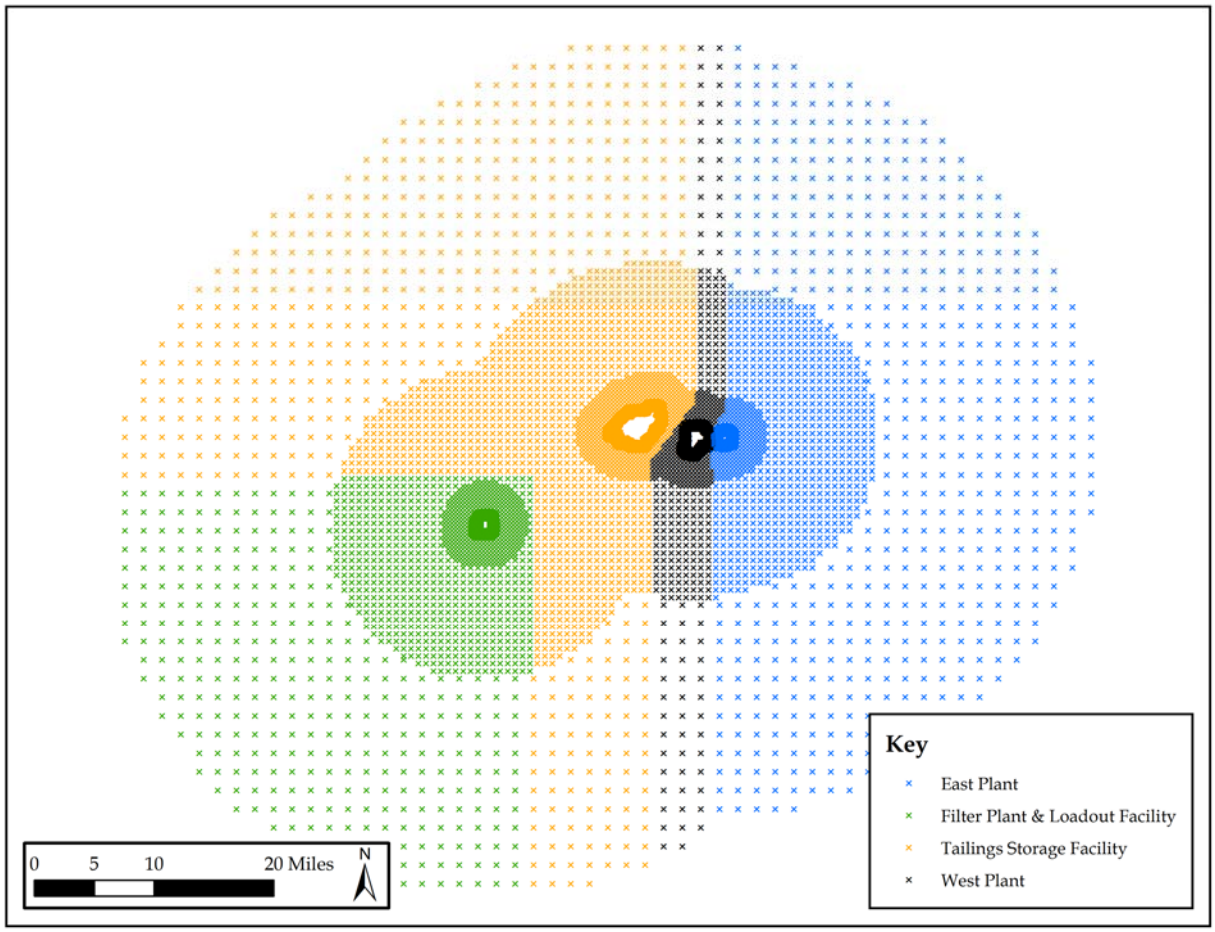
- For NO_2 1-hour, $PM_{2.5}$ 24-hour and annual, and PM_{10} 24-hour and annual modeling, the temporal background profiles provided to AERMOD will be added to the modeled impact.

4. In order to use the most representative background for each receptor, each receptor is assigned to a specific facility as shown in Figure 2.

5. Post-processing routines (that are well documented and straightforward to replicate) will be implemented to sum, at every facility-assigned receptor, that facility's modeled impacts, representative background, and the modeled form-of-the-standard impact (e.g., high-3rd-high modeled concentration of 24-hour PM_{10} at the receptor) for each of the other facilities. This method of adding the form-of-the-standard impact is a more conservative approach than adding the paired-in-time modeled impacts from the other facilities.

Figure 2. Modeling and Post-Processing Schematic

Figure 3. Facility-Specific Paired Impacts-Plus-Background Assignments



Appendix D: Please provide more detail on how the source parameters were determined, especially for the volume and area sources. Given the large number of sources, this response can focus on those emission points or groups of emission points with the greatest emissions."

The AREA or VOLUME sources with the greatest mass emissions are VOLUME sources which represent the combination of various fugitive activities. These grouped fugitive sources combine the dozing, grading, mobile sources, drilling, and blasting emissions at each facility.

The area where the majority of the activities/sources will be located was identified using GIS and approximated as a circle. The activity areas have been defined to be relatively small in

order to conservatively condense emissions. The volume sources' initial lateral dispersion (σ_y) parameters were developed using the procedures suggested in the AERMOD user guide (EPA 2016). For a single volume source, the σ_y is calculated as the diameter divided by 4.3. A representation of the volume sources can be seen in Figures 2-4, 2-5, 2-6, and 2-7 in the Model Plan. The diameter of these VOLUME sources in the figures is plotted with σ_y.

Mobile emissions make up a relatively large proportion of these grouped fugitive sources. Therefore, EPA guidance on characterizing haul roads was used to develop the vertical dispersion parameters (EPA 2012). A vehicle height of six meters was assumed. Following the guidance, the height was multiplied by 1.7 to estimate plume height. The release height was set to the plume height divided by 2, and the initial vertical dispersion parameter (σ_z) was calculated as the plume height divided by 2.15.

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Appendix A – Deposition Parameter Calculation Details

RESOLUTION COPPER PROJECT, AZ – DEPOSITION PARAMETER CALCULATION DETAILS

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PROJECT NO.:	262
COPIES:	D. Randall, Air Sciences Inc.
DATE:	February 9, 2018

This technical memo has been prepared to respond to Pinal County Air Pollution Control District's 3rd-party contractor questions/requests for clarification pertaining to the Air Quality Impacts Analysis Modeling Plan[1] (Model Plan) for the Resolution Copper Project. Specifically, this memo provides:

- All of the calculation steps for Table 3-13 in the Model Plan;
- Data references for the mass fraction inputs for the different source categories; and
- Clarification for the determination and use of the Bin 0 diameter.

Determination and Use of Bin 0 Upper Diameter

The Bin 0 upper diameter was selected as the lowest possible particle diameter for a source category, i.e., below this diameter, the mass fraction is zero. It was determined by extrapolating from the mass fractions trend line developed from the available Bin 1 and Bin 2 diameters for a source category. For example, if particle size diameters are plotted along the y-axis and mass fractions along the x-axis, the Bin 0 upper diameter will be the y-intersect (i.e., x = 0) of the best-fit data line. Sample particle size distribution data are provided in Table 1.

Table 1. Sample Particle Size Distribution

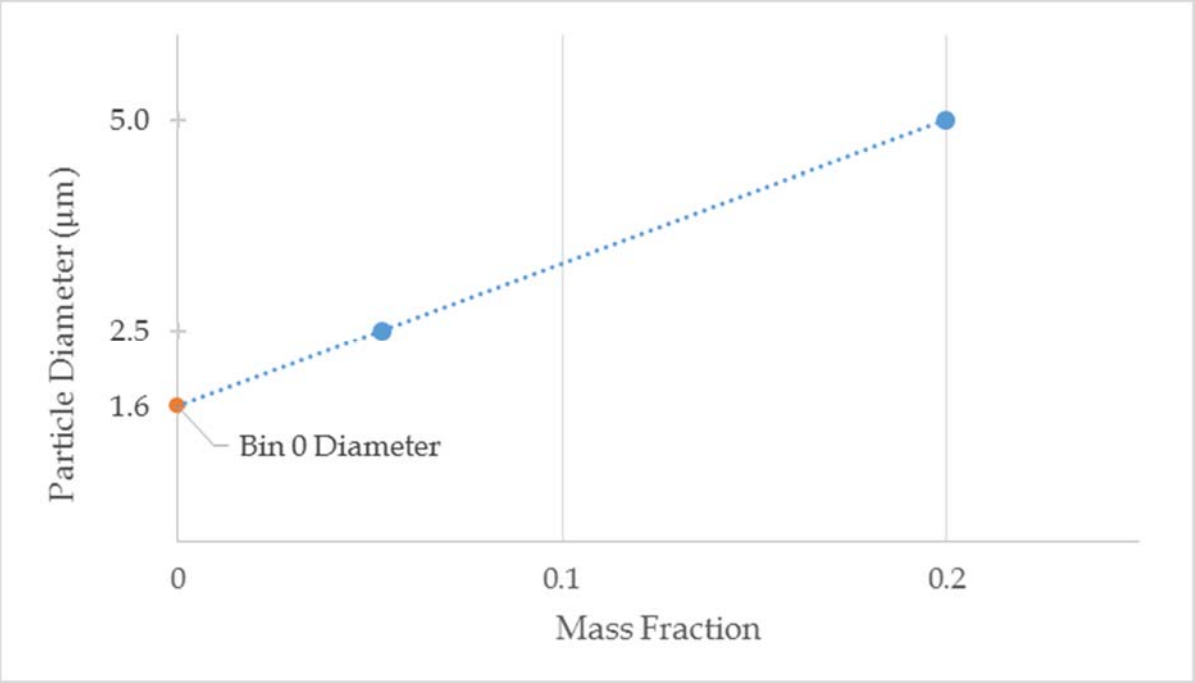
Bin	Particle Diameter (micrometers)	Mass Fraction
1	2.5	0.053
2	5	0.2

An extrapolation of the data provided in Table 1 to determine the Bin 0 upper diameter is demonstrated in Figure 1. As shown in Figure 1, when the trend line obtained from the two

[1] Resolution Copper Project, AZ. Air Quality Impact Analysis Modeling Plan. Project No. 262. January 2018.

data points provided in Table 1 is extended, it intersects the y-axis at 1.6, denoting the particle diameter below which the mass fraction is zero. Therefore, the Bin 0 upper diameter from Figure 1 is 1.6 micrometers (µm).

Figure 1. Example Bin 0 Determination



The Bin 0 upper diameter was only calculated when the Bin 1 upper diameter was 2.5 µm in order to estimate the lower bound diameter for Bin 1. The Bin 0 upper diameter was used to calculate the mass mean diameter for the 2.5-µm bin (Step 4, page 54 of the Modeling Plan). Notes:

1. the mass mean diameter for each bin is calculated as the average of that bin's and the next lower bin's mass diameters (Bin $n_{\text{mass mean diameter}}$ = [Bin $n_{\text{mass mean diameter}}$ + Bin n-$1_{\text{mass mean diameter}}$] ÷ 2);

2. mass mean diameter is a mandatory input parameter in AERMOD modeling for deposition calculations;

3. If the particle diameters and mass fractions are unique for each source category, then the Bin 0 upper diameter will be unique.

Deposition Parameter References and Calculations for Each Source Category

The following subsections provide step-by-step calculations and references used to develop deposition parameters for each source category listed in Table 3-13 of the Model Plan. Detailed explanations for all calculation steps are included for PM_{10} deposition parameters for the first source category that is discussed (Source Category 1: Underground Fugitive Dust) herein. These explanations are applicable for $PM_{2.5}$ deposition parameters and for the other source categories. For brevity, the detailed explanations are not repeated in this memo for the remaining source categories.

Preparation of this memo prompted a review and updating of the particle density values used in the Model Plan:

- For all sources with dust emissions including underground fugitive dust, ore handling, road traffic and maintenance, baghouses, and wind erosion source categories, the particle density was revised from 2.1 grams per cubic centimeter (g/cm^3) to 2.775 g/cm^3 based on Resolution Copper's 2016 geologic model.

- For dust emissions from exposed tailings, the particle density was revised from 2.1 g/cm^3 to 2.67 g/cm^3, also based on the 2016 geologic model.

- For combustion sources (e.g., engines, boilers), the assumed particle density of 1 g/cm^3 (conservative) was revised to 2.25 g/cm^3, the density of carbon, which is a reasonable approximation for combustion particles.

- For baghouses at the reagent handling processes at West Plant, a particle density of 0.938 g/m^3 was added. This is the average particle density for lime pebble and is adopted from AP-42, Appendix A[2] (page A-8).

Source Category 1: Underground Fugitive Dust

The deposition parameters for this source category were developed using the 10, 5, and 2.5 µm particle size multipliers for the predictive equation provided in AP-42, Section 13.2.4, to estimate fugitive emissions from aggregate handling and storage piles. These multipliers are provided in Table 2.

[2] AP-42, Appendix A. Miscellaneous Data and Conversion Factors. 09/85 (Reformatted 1/95).

Table 2. Particle Size Multipliers from AP-42, Section 13.2.4

Bin	Particle Size (μm)	Multiplier
1	2.5	0.053
2	5	0.2
3	10	0.35

The interpretation of the data provided in Table 2 is, for every 350 mass units (mu) of PM_{10}[3] generated from this source category, the mass in each particle size fraction is: 0-2.5 μm (Bin 1) = 53 mu; 2.5-5 μm (Bin 2) = 147 mu; 5-10 μm (Bin 3) = 150 mu.

The particle size multipliers provided in Table 2 were adjusted with the effective control efficiencies for underground sources due to water droplets in shafts, heat rejection sprays, and gravitational settlement (see Model Plan, Table 2-3), provided in Table 3.

Table 3. Combined Underground Scrubbing Efficiency

Bin	Particle Size (μm)	Efficiency
1	2.5	0.07
2	5 (1)	0.23
3	10	0.55

(1) Interpolated from PM_{10} and $PM_{2.5}$ control efficiencies

The adjustment of the particle size multipliers is demonstrated in Table 4.

Table 4. AP-42, Section 13.2.4 Multiplier Adjustment

Bin	Particle Size (μm)	AP-42, Sec. 13.2.4 Multiplier	Efficiency	Adjustment	Adjusted Multiplier
1	2.5	0.053	0.07	0.053 x (1 - 0.07)	0.049
2	5	0.200	0.23	0.2 x (1 - 0.23)	0.154
3	10	0.350	0.55	0.35 x (1 - 0.55)	0.158

By extrapolating the Bin 1 and Bin 2 mass fractions, the Bin 0 upper diameter for this source category was calculated to be 1.32 μm.

The PM_{10} deposition bins for this source category are provided in Table 5.

Table 5. PM_{10} Deposition Bins for Underground Fugitive Dust

Bin	Upper Diameter (μm)
0	1.32
1	2.5
2	5.0
3	10.0

[3] PM_n = Particulate Matter Less than "n" Micrometers in Aerodynamic Diameter

Step 1 – Normalized Cumulative Mass Fraction

The normalized cumulative mass fraction for each bin was calculated by dividing the particle size multiplier/cumulative fraction by that of the highest bin: Bin 3 in this case. Thus, each adjusted multiplier was divided by 0.158. Calculations for normalized cumulative mass fractions are provided in Table 6.

Table 6. PM_{10} Deposition Normalized Cumulative Mass Fraction Calculations

Bin	Upper Diameter (μm)	Adjusted Multiplier	Normalizing	Normalized Cumulative Mass Fraction
0	1.32	0.00	0 ÷ 0.158	0
1	2.5	0.049	0.049 ÷ 0.158	0.31
2	5.0	0.154	0.154 ÷ 0.158	0.98
3	10.0	0.158	0.158 ÷ 0.158	1.00

Step 2 – Mass Fraction

The mass fraction for each bin was calculated by subtracting the normalized cumulative mass fraction of the next lower bin from the normalized cumulative mass fraction for that bin, i.e., Bin $n_{mass\ fraction}$ = [Bin $n_{nor.cum.mass.frac}$ - Bin n-$1_{nor.cum.mass.frac}$]. Calculations for mass fractions are provided in Table 7.

Table 7. PM_{10} Deposition Mass Fraction Calculations

Bin	Upper Diameter (μm)	Normalized Cumulative Mass Fraction	Calculation	Mass Fraction
0	1.32	0		
1	2.5	0.313	0.313 - 0	0.31
2	5.0	0.979	0.979 - 0.313	0.67
3	10.0	1.000	1 - 0.979	0.02

Step 3 – Spherical Volume

The spherical volume for each bin was calculated as: $4/3 \times \pi \times (\text{Bin Diameter} \div 2)^3$. The calculation for spherical volume for each bin is provided in Table 8.

Table 8. PM_{10} Deposition Spherical Volume Calculations

Bin	Upper Diameter (μm)	Calculation	Spherical Volume (μm^3)
0	1.32	$4/3 \times \pi \times (1.32 \div 2)^3$	1.2
1	2.5	$4/3 \times \pi \times (2.5 \div 2)^3$	8.2
2	5.0	$4/3 \times \pi \times (5 \div 2)^3$	65.4
3	10.0	$4/3 \times \pi \times (10 \div 2)^3$	523.6

Step 4 – Mean Spherical Volume

The mean spherical volume for each bin was calculated as the average of spherical volumes of that bin and the next lower bin, i.e., Bin $n_{mean.sph.vol}$ = [Bin $n_{sph.vol}$ + Bin n-$1_{sph.vol}$] ÷ 2. The mean spherical volume calculation for each bin is provided in Table 9.

Table 9. PM_{10} Deposition Mean Spherical Volume Calculations

Bin	Upper Diameter (μm)	Spherical Volume (μm^3)	Calculation	Mean Spherical Volume (μm^3)
0	1.32	1.2		
1	2.5	8.2	(1.2 + 8.2) ÷ 2	4.7
2	5.0	65.4	(8.2 + 65.4) ÷ 2	36.8
3	10.0	523.6	(65.4 + 523.6) ÷ 2	294.5

Step 5 – Mass Mean Diameter

The mass mean diameter for each bin was calculated from the mean spherical volume as: [Mean Spherical Volume × 3 ÷ (4 × π)]$^{1/3}$ × 2. Mass mean diameter calculations are provided in Table 10.

Table 10. PM_{10} Deposition Mass Mean Diameter Calculations

Bin	Upper Diameter (μm)	Mean Spherical Volume (μm^3)	Calculation	Mass Mean Diameter (μm)
0	1.32			
1	2.5	4.7	[4.7 x 3 ÷ (4 x π)]$^{1/3}$ x 2	2.08
2	5.0	36.8	[36.8 x 3 ÷ (4 x π)]$^{1/3}$ x 2	4.13
3	10.0	294.5	[294.5 x 3 ÷ (4 x π)]$^{1/3}$ x 2	8.25

The step-wise $PM_{2.5}$ deposition parameter calculations for this source category are summarized in Table 11.

Table 11. Deposition Parameter Calculations for Underground Fugitive Dust

Step	Parameter	PM_{10}				$PM_{2.5}$	
		Bin 0 (1)	Bin 1	Bin 2	Bin 3	Bin 0 (1)	Bin 1
	Bin Upper Diameter (μm)	1.32	2.50	5.00	10.00	1.32	2.50
	Particle Size Multiplier	--	0.05	0.15	0.16	--	0.05
1	Nor. Cum. Mass Fraction	--	0.31	0.98	1.00	--	1.00
2	Mass Fraction	--	0.31	0.67	0.02	--	1.00
3	Spherical Volume (μm^3)	1.21	8.18	65.45	523.60	1.21	8.18
4	Mean Spherical Volume (μm^3)	--	4.70	36.82	294.52	--	4.70
5	Mass Mean Diameter (μm)	--	2.08	4.13	8.25	--	2.08
	Particle Density (g/cm^3)	--	2.775	2.775	2.775	--	2.775

(1) Bin 0 is not input to the model. It is only used to estimate the mass mean diameter of Bin 1. The upper diameter for Bin 0 is estimated by linear extrapolation of Bins 1 and 2.

Source Category 2: Ore Handling

The deposition parameters for this source category were developed using the 10, 5, and 2.5 µm particle size multipliers for the predictive equation provided in AP-42, Section 13.2.4, to estimate fugitive emissions from aggregate handling and storage piles. These multipliers are provided in Table 2.

By extrapolating the Bin 1 and Bin 2 mass fractions, the Bin 0 upper diameter for this source category was calculated to be 1.6 µm. The step-wise PM_{10} and $PM_{2.5}$ deposition parameter calculations for this source category are presented in Table 12.

Table 12. Deposition Parameter Calculations for Ore Handling

		PM_{10}				$PM_{2.5}$	
Step	**Parameter**	**Bin 0 (1)**	**Bin 1**	**Bin 2**	**Bin 3**	**Bin 0 (1)**	**Bin 1**
	Bin Upper Diameter (µm)	1.60	2.50	5.00	10.00	1.60	2.50
	Particle Size Multiplier	--	0.05	0.20	0.35	--	0.05
1	Nor. Cum. Mass Fraction	--	0.15	0.57	1.00	--	1.00
2	Mass Fraction	--	0.15	0.42	0.43	--	1.00
3	Spherical Volume (μm^3)	2.14	8.18	65.45	523.60	2.14	8.18
4	Mean Spherical Volume (μm^3)	--	5.16	36.82	294.52	--	4.70
5	Mass Mean Diameter (µm)	--	2.14	4.13	8.25	--	2.08
	Particle Density (g/cm^3)	--	2.775	2.775	--	--	2.775

(1) Bin 0 is not input to the model. It is only used to estimate the mass mean diameter of Bin 1. The upper diameter for Bin 0 is estimated by linear extrapolation of Bins 1 and 2.

Source Category 3: Road Traffic and Maintenance

The deposition parameters for this source category were developed using the 10 and 2.5 µm particle size multipliers for the predictive equation provided in AP-42, Section 13.2.2, to estimate fugitive emissions from unpaved roads. Particle size multipliers for this source category are provided in Table 13.

Table 13. Particle Size Multipliers from AP-42, Section 13.2.2

Bin	Particle Size (µm)	Multiplier
1	2.5	0.15
2	10	1.5

By extrapolating the Bin 1 and Bin 2 mass fractions, the Bin 0 upper diameter for this source category was calculated to be 1.67 µm. The step-wise PM_{10} and $PM_{2.5}$ deposition parameter calculations for this source category are presented in Table 14.

Table 14. Deposition Parameter Calculations for Road Traffic and Maintenance

Step	Parameter	PM_{10}				$PM_{2.5}$	
		Bin 0 (1)	Bin 1	Bin 2	Bin 3	Bin 0 (1)	Bin 1
	Bin Upper Diameter (µm)	1.67	2.50	10.00	--	1.67	2.50
	Particle Size Multiplier	--	0.15	1.50	--	--	0.15
1	Nor. Cum. Mass Fraction	--	0.10	1.00	--	--	1.00
2	Mass Fraction	--	0.10	0.90	--	--	1.00
3	Spherical Volume (μm^3)	2.43	8.18	523.60	--	2.43	8.18
4	Mean Spherical Volume (μm^3)	--	5.30	265.89	--	--	5.30
5	Mass Mean Diameter (µm)	--	2.16	7.98	--	--	2.16
	Particle Density (g/cm^3)	--	2.775	2.775	--	--	2.775

(1) Bin 0 is not input to the model. It is only used to estimate the mass mean diameter of Bin 1. The upper diameter for Bin 0 is estimated by linear extrapolation of Bins 1 and 2.

Source Category 4: Baghouses

The deposition parameters for this source category were developed using the 10, 6, and 2.5 µm particle size cumulative mean fractions provided for a fabric filter control for a phosphate rock processing source in AP-42, Appendix B.1,[4] Section 11.21 (page B.1-77). These cumulative mass fractions are provided in Table 15.

Table 15. Particle Size Cumulative Fractions from AP-42, Appendix B.1, Section 11.21

Bin	Particle Size (µm)	Cumulative Fraction
1	2.5	0.25
2	6	0.70
3	10	0.90

By extrapolating the Bin 1 and Bin 2 cumulative fractions, the Bin 0 upper diameter for this source category was calculated to be 0.56 µm. The step-wise PM_{10} and $PM_{2.5}$ deposition parameter calculations for this source category are presented in Table 16.

[4] Appendix B.1. Particle Size Distribution Data and Sized Emission Factors for Selected Sources. 10/86 (Reformatted 1/95).

Table 16. Deposition Parameter Calculations for Baghouses

Step	Parameter	PM_{10}				$PM_{2.5}$	
		Bin 0 (1)	Bin 1	Bin 2	Bin 3	Bin 0 (1)	Bin 1
	Bin Upper Diameter (µm)	0.56	2.50	6.00	10.00	0.56	2.50
	Particle Size Multiplier	--	0.25	0.70	0.90	--	0.25
1	Nor. Cum. Mass Fraction	--	0.28	0.78	1.00	--	1.00
2	Mass Fraction	--	0.28	0.50	0.22	--	1.00
3	Spherical Volume (μm^3)	0.09	8.18	113.10	523.60	0.09	8.18
4	Mean Spherical Volume (μm^3)	--	4.14	60.64	318.35	--	4.14
5	Mass Mean Diameter (µm)	--	1.99	4.87	8.47	--	1.99
	Particle Density – Ore (g/cm^3)	--	2.775	2.775	2.775	--	2.775
	Particle Density – Reagent (g/cm^3)	--	0.938	0.938	0.938	--	0.938

(1) Bin 0 is not input to the model. It is only used to estimate the mass mean diameter of Bin 1. The upper diameter for Bin 0 is estimated by linear extrapolation of Bins 1 and 2.

Source Category 5: Gasoline and Diesel Engines

The deposition parameters for this source category were developed using the 10, 6, 2.5, and 1 µm particle size cumulative mean fractions provided for the stationary combustion engines in AP-42, Appendix B.2[5] (Category 1, page B.2-11). These cumulative fractions are provided in Table 17.

Table 17. Particle Size Cumulative Fractions from AP-42, Appendix B.2, Page B.2-11

Bin	Particle Size (µm)	Cumulative Fraction
1	1	0.82
2	2.5	0.90
3	6	0.93
4	10	0.96

Since Bin 1 diameter is 1 µm which is less than 2.5 µm therefore, Bin 0 is not required for this source category. The step-wise PM_{10} and $PM_{2.5}$ deposition parameter calculations for this source category are presented in Table 18.

[5] Appendix B.2. Generalized Particle Size Distributions. 9/90 (Reformatted 1/95).

Table 18. Deposition Parameter Calculations for Gasoline and Diesel Engines

Step	Parameter	PM_{10}				$PM_{2.5}$	
		Bin 1	Bin 2	Bin 3	Bin 4	Bin 1	Bin 2
	Bin Upper Diameter (μm)	1.00	2.50	6.00	10.00	1.00	2.50
	Particle Size Multiplier	0.82	0.90	0.93	0.96	0.82	0.90
1	Nor. Cum. Mass Fraction	0.85	0.94	0.97	1.00	0.91	1.00
2	Mass Fraction	0.85	0.08	0.03	0.03	0.91	0.09
3	Spherical Volume (μm^3)	0.52	8.18	113.10	523.60	0.52	8.18
4	Mean Spherical Volume (μm^3)	0.26	4.35	60.64	318.35	0.26	4.35
5	Mass Mean Diameter (μm)	0.79	2.03	4.87	8.47	0.79	2.03
	Particle Density (g/cm^3)	2.25	2.25	2.25	2.25	2.25	2.25

Source Category 6: Boilers

The deposition parameters for this source category were developed using the 10, 6, 2.5, and 1 μm particle size cumulative mean fractions provided for the mixed fuel combustion category in AP-42, Appendix B.2 (Category 2, page B.2-12). These cumulative fractions are provided in Table 19.

Table 19. Particle Size Cumulative Fractions from AP-42, Appendix B.2, Page B.2-12

Bin	Particle Size (μm)	Cumulative Fraction
1	1	0.23
2	2.5	0.45
3	6	0.70
4	10	0.79

Because the Bin 1 diameter is 1 μm, which is less than 2.5 μm, Bin 0 is not required for this source category. The step-wise PM_{10} and $PM_{2.5}$ deposition parameter calculations for this source category are presented in Table 20.

Table 20. Deposition Parameter Calculations for Boilers

Step	Parameter	PM_{10}				$PM_{2.5}$	
		Bin 1	Bin 2	Bin 3	Bin 4	Bin 1	Bin 2
	Bin Upper Diameter (μm)	1.00	2.50	6.00	10.00	1.00	2.50
	Particle Size Multiplier	0.23	0.45	0.70	0.79	0.23	0.45
1	Nor. Cum. Mass Fraction	0.29	0.57	0.89	1.00	0.51	1.00
2	Mass Fraction	0.29	0.28	0.32	0.11	0.51	0.49
3	Spherical Volume (μm^3)	0.52	8.18	113.10	523.60	0.52	8.18
4	Mean Spherical Volume (μm^3)	0.26	4.35	60.64	318.35	0.26	4.35
5	Mass Mean Diameter (μm)	0.79	2.03	4.87	8.47	0.79	2.03
	Particle Density (g/cm^3)	2.25	2.25	2.25	2.25	2.25	2.25

Source Category 7: Wind Erosion

The deposition parameters for this source category were developed using the 10 and 2.5 µm particle size multipliers for the predictive equation provided in AP-42, Section 13.2.5, to estimate wind erosion emissions. These multipliers are provided in Table 21.

Table 21. Particle Size Multipliers from AP-42, Section 13.2.5

Bin	Particle Size (µm)	Multiplier
1	2.5	0.075
2	10	0.500

By extrapolating the Bin 1 and Bin 2 mass fractions, the Bin 0 upper diameter for this source category was calculated to be 1.18 µm. The step-wise PM_{10} and $PM_{2.5}$ deposition parameter calculations for this source category are presented in Table 22.

Table 22. Deposition Parameter Calculations for Wind Erosion

Step	Parameter	PM_{10}				$PM_{2.5}$	
		Bin 0 (1)	Bin 1	Bin 2	Bin 3	Bin 0 (1)	Bin 1
	Bin Upper Diameter (µm)	1.18	2.50	10.00	--	1.18	2.50
	Particle Size Multiplier	--	0.075	0.50	--	--	0.08
1	Nor. Cum. Mass Fraction	--	0.15	1.00	--	--	1.00
2	Mass Fraction	--	0.15	0.85	--	--	1.00
3	Spherical Volume (μm^3)	0.85	8.18	523.60	--	0.85	8.18
4	Mean Spherical Volume (μm^3)	--	4.52	265.89	--	--	4.52
5	Mass Mean Diameter (µm)	--	2.05	7.98	--	--	2.05
	Particle Density (g/cm^3)	--	2.775	2.775	--	--	2.775
	Particle Density (g/cm^3) (Exposed Tailings)	--	2.67	2.67	--	--	2.67

(1) Bin 0 is not input to the model. It is only used to estimate the mass mean diameter of Bin 1. The upper diameter for Bin 0 is estimated by linear extrapolation of Bins 1 and 2.

Appendix B – Response to Questions from PCAQCD on Resolution Copper's Emission Inventory

RESPONSE TO QUESTIONS FROM PCAQCD ON RESOLUTION COPPER'S EMISSION INVENTORY

PREPARED FOR: Resolution Copper Company (Resolution)

PREPARED BY: N. Tipple, D. Steen, D. Randall – Air Sciences Inc.

PROJECT NO.: 262-32-2

DATE: 2/28/2018

The Pinal County Air Quality Control District's (PCAQCD) third-party contractor provided requests for clarification pertaining to the contractor's review of the Air Sciences Inc. emission inventory developed for Resolution's permit modeling. This technical memorandum provides answers and additional information in response to these requests. The PCAQCD third-party contractor's comments are presented below in italic font. The responses are found immediately following the comments. In addition to the specific questions addressed below, an electronic copy of the emission inventory and references will be provided.

1. *There appears to be an inconsistency between the calculations that appear on different spreadsheets. The Atty_DISP spreadsheet (Appendix A Page 6) shows PM-10 at the East Plant Underground of 265 tpy. However, the EPS_DISP spreadsheet (Appendix A, Page 9) lists PM-10 of 119 tpy for what appear to be the same subset of emission sources. There is a similar discrepancy in the PM-2.5 emissions.*

For the purposes of this project, there are two different types of underground emissions: underground emissions **without the control efficiency applied** from features that are inherent to the design of the underground mine[1] (shown in the *Atty_DISP* tab, used for rule applicability) and underground emissions **controlled** by features that are inherent to the design of the underground mine (shown in the *EPS_DISP* tab, used for dispersion modeling).

The *EPS_DISP* tab has been updated to match the *Atty_DISP* tab for consistency. This change does not affect any prior rule applicability determinations.

2. *For blasting, the emissions factors in the spreadsheet (32.53 lb/ton CO and 6.20 lb/ton NOx) do not match the AP-42 Section 13.3 factors for blasting using ANFO. Please explain the basis for the emission factors selected.*

[1] These are features of the underground mine design that have an effective control on the out-of-vent emissions. These "effective controls" for particulate include water droplets in shafts, heat rejection sprays, and gravitational settlement. The effective controls and associated control efficiencies have been technically reviewed by PCAQCD.

The ANFO emission factors provided in AP-42 Chapter 13.3 were developed for the coal mining industry, where blasting typically occurs in looser soils.[2] Further, AP-42 Chapter 13.3 does not provide any emission guidance for blasts using emulsion, the primary blast agent expected to be used during production at Resolution, as discussed in Resolution's General Plan of Operations (Resolution Copper 2016). The emission factors for NO_X and CO proposed for the Resolution project are derived from a NIOSH (National Institute for Occupational Safety and Health) study and better represent hard rock mining conditions, especially in wet environments.[2] Emissions from emulsion-based blasts provided in the Australia National Pollutant Inventory (Commonwealth of Australia 2012) were compared to the emulsion-based emission factors derived from the NIOSH study. The NIOSH study emission factors are between 7 and 16 times higher, which are more conservative.

3. *The AP-42 emissions factor for fugitive dust from vehicle traffic depend on the vehicle weight. Please explain more clearly how the mean vehicle weights were derived (e.g., See Appendix A, Page 67). The expectation is that the mean vehicle weight input to the AP-42 equation should be weighted by the mileage traveled for each type of vehicle. Also, any calculation of mean vehicle mean for vehicles hauling materials should account for the average weight of the vehicle loaded vs. unloaded and the distance traveled in each mode. It is not clear if any of these factors were considered when calculating the mean vehicle weight.*

The mean fleet weight, as calculated in the emission inventory, is only based on the total number of vehicles in the fleet. The number of miles a vehicle is expected to travel does not influence the calculation of the emission factor. This is consistent with AP-42, Chapter 13.2.2, which describes the use of the emission factor as follows:

> *It is important to note that the vehicle-related source conditions refer to the average weight, speed, and number of wheels for all vehicles traveling the road. For example, if 98 percent of traffic on the road are 2-ton cars and trucks while the remaining 2 percent consists of 20-ton trucks, then the mean weight is 2.4 tons. More specifically, Equations 1a and 1b are not intended to be used to calculate a separate emission factor for each vehicle class within a mix of traffic on a given unpaved road. That is, in the example, one should not determine one factor for the 2-ton vehicles and a second factor for the 20-ton trucks. Instead, only one emission factor should be calculated that represents the "fleet" average of 2.4 tons for all vehicles traveling the road.*

The mean vehicle weights in the emission inventory were calculated with the following method in accordance with AP-42, Chapter 13.2.2.

Step 1: Each vehicle weight was determined. It was assumed that vehicles carrying a payload would operate 50 percent of the time loaded and 50 percent of the time empty. Therefore, the average of the empty vehicle weight and the loaded vehicle weight was used.

[2] See emission inventory reference folders 72 and 73.

Step 2: Each vehicle was assigned to a project area. Vehicles at the East Plant were divided into two domains: underground and surface.

Step 3: A representative fleet average was determined for each project area by calculating the summed product of each vehicle type's quantity and weight, and then dividing by the total number of vehicles.

4. *It is difficult to follow some of the fugitive dust vehicle calculations in the calculation spreadsheets. The step-by-step calculations for this source category need to be documented more clearly, especially in the EP_Fleet, Mill_Fleet, Tailings_Fleet spreadsheets. For example, in the EP_Fleet spreadsheet (Appendix A, Page 69), the uncontrolled PM-10 is shown to be 4,073 tpy for the East Plant Underground sources. There is no corresponding spreadsheet showing the controlled PM-10. If a 95% control factor is applied, the expected controlled PM-10 would be 203.65 tpy. However, the summary spreadsheet (Appendix A, Page 9) lists the controlled PM-10 emissions from this source category as 92 tpy. Better documentation of the fugitive dust traffic calculations is needed.*

There are two "controlled" emission totals: one for rule applicability and one for dispersion modeling purposes. The emissions from vehicle travel on unpaved roads in each *_Fleet* tab have a control efficiency of either 90 percent or 95 percent, depending on the source location. These control efficiencies have been reviewed by PCAQCD. The emissions for the underground fleet shown in the *EPS_DISP* tab had an additional control applied (for features that are inherent to the design of the underground mine) for modeling purposes only, and they have since been updated in the emission inventory.

As described in Item 1, the *EPS_DISP* tab has been updated to show emissions associated with rule applicability thresholds rather than emission rates used for modeling, to be consistent with the *Atty_DISP* tab.

5. *At the Cement Batch Plant, the largest PM-10 emission source is truck loading, which has a listed PM-10 emission rate of 0.98 tpy. However, using the emissions factor (0.0263 lb/ton) and the material throughput (320,341 ton/yr) from the spreadsheet, the resulting PM-10 emission calculation yields 4.2 tpy. Please check the calculation and/or explain the discrepancy.*

The truck loading emission factor is based on the quantity of cement and cement supplement; however, the emission factor estimates emissions for all loaded material (cement, cement supplement, sand, and aggregate). This is described in AP-42, Table 11.12-2, Footnote g: "the emission factor units are lb of pollutant per ton of cement and cement supplement." The annual controlled emissions from truck loading was estimated using the following calculation:

$$0.0263 \frac{lb\ PM_{10}}{ton\ cement/supplement} \times \left(320{,}341\ \frac{tons\ of\ material\ loaded}{yr} - 245{,}797\ \frac{tons\ of\ sand/aggregate}{yr}\right) \div 2{,}000\ \frac{lb}{ton}$$

$= 0.98 \frac{ton\ PM_{10}}{yr}$

6. *For some of the underground process sources, the AP-42 factor chosen cites to Section 11.9 [sic] which are applicable for aggregate materials. Explain why these factors were chosen over AP-42 Section 11.24, which applies to Metallic Minerals Processing.*

Please note that this response assumes that the comment intends to cite AP-42, Section 11.19 ("Construction Aggregate Processing"), rather than 11.9 ("Western Surface Coal Mining").

There is only one East Plant underground process emission unit that uses AP-42, Chapter 11.19 factors. The underground grizzly emission factors were selected from AP-42, Chapter 11.19 for three reasons:

1. AP-42, Chapter 11.24 does not provide emission factors for dedicated screening operations.

2. The Resolution Deposit is hosted by a variety of rock types including quartzite, limestone, basalt, and granite-like porphyry, which are rock types specified in AP-42, Chapter 11.19.

3. AP-42, Chapter 11.24 assumes that the emission factors are for the material processing operations as a whole.

   AP-42, Chapter 11.24 elaborates:

   > *A single crushing operation likely includes a hopper or ore dump, screen(s), crusher, surge bin, apron feeder, and conveyor belt transfer points…The emission factors provided in Tables 11.24-1 and 11.24-2 for primary, secondary, and tertiary crushing operations are for process units that are typical arrangements of the above equipment.*

   The grizzly located underground at Resolution's East Plant is a coarse separator that feeds the gyratory crushers but is not a part of a typically arranged crushing nd screening system as described in AP-42, Chapter 11.24. Therefore, the emission factor from AP-42, Chapter 11.19 is considered most representative of the processed material and the individual emission unit.

7. *The calculations for the cooling tower emissions apply a different approach than cooling tower emission calculations submitted by other applicants in Pinal County. Please provide a copy of the EPA 1979 reference document cited. As this reference document is almost 40 years old, please discuss why this document would still be applicable to modern cooling towers. Also, please explain/justify the correction factor for "drift mass governed by atmospheric dispersion" and explain/justify the derivation of the PM-10 and PM-2.5 size multipliers.*

Freudenthal, Rubinstein, and Uzzo 1979 (Attachment A) describe methods to calculate emissions that are more realistic but still conservative emissions from cooling towers that are more realistic than the

emissions estimated by AP-42, Chapter 13.4. The overly conservative assumption upon which AP-42, Chapter 13.4 is based is that all total dissolved solids (TDS) in water droplets emitted as drift particles become PM_{10} once the water evaporates. This approach is investigated by a 2001 document that addresses calculating realistic PM_{10} emissions from cooling towers (Reisman and Frisbie 2001; Attachment B). Both the 1979 and 2001 references describe calculating cooling tower emissions based on the size and mass distribution (droplet speciation) of the drift droplets.

The droplet speciation-based calculation method is based on two premises:

- First is the idea that not all droplets are governed by atmospheric dispersion.[3] Droplets exiting cooling towers can be sorted into two categories: larger droplets that settle out of the exhaust air stream (and are deposited near the cooling tower) and smaller droplets that are governed by atmospheric dispersion (that do not settle out and eventually evaporate, leaving only the solids).

- The second premise is the idea that water droplets with only a specific range of diameters will form PM, PM_{10}, or $PM_{2.5}$ (regulated PM) when the water evaporates. Each water droplet emitted from a cooling tower (that does not settle out of the exhaust air stream) evaporates, leaving a single, spherical particle.[4] The size of that particle is determined by the size of the water droplet, the concentration of the TDS in the droplet, and the density of TDS constituents. Only specific combinations of water droplet size and TDS concentration and constituents will result in regulated PM emissions.

Freudenthal, Rubinstein, and Uzzo 1979 (Attachment A) summarize the size and mass distribution of drift droplets from a cooling tower with a total drift loss of 0.001 percent (low-efficiency drift eliminators). Reisman and Frisbie 2001 (Attachment B) provide the same distribution for a cooling tower with a drift loss of 0.0006 percent (high-efficiency drift eliminators). Higher efficiency cooling towers tend to have a higher percentage of droplets that are governed by atmospheric dispersion in comparison to lower efficiency cooling towers. Due to the expected drift loss of 0.002 percent at Resolution Copper's cooling towers, Freudenthal, Rubinstein, and Uzzo 1979 provide more representative conditions than the newer Reisman and Frisbie 2001 reference does.

The factor used to determine the mass of droplets governed by atmospheric dispersion (31.3% of total drift loss, by mass) is discussed in Freudenthal, Rubinstein, and Uzzo 1979. The particle size

[3] Droplets governed by atmospheric dispersion "will be primarily governed by aerodynamic forces; most important of which are wind, buoyancy of the exhaust plume, and vertical eddies or turbulence in the atmosphere…[which] will tend to keep these small droplets in suspension for an extended period" (Freudenthal, Rubinstein, and Uzzo 1979). This 1979 document estimates that droplets with a diameter larger than 450 micrometers will settle out of suspension within a reasonably close distance to the cooling tower while the smaller particles (which make up 31.3% of total drift mass) will not fall out of suspension and are therefore governed by atmospheric dispersion.

[4] The assumption that the dissolved solids form spherical particles conservatively estimates emissions of regulated PM because a particle with equal mass that is not spherical will have a larger diameter.

multiplier for PM_{10} was determined from the ratio of the total mass of drift loss to the mass of droplets that evaporate to form PM_{10}. The particle size multiplier for $PM_{2.5}$ was determined from the ratio of the total mass of drift loss to the mass of droplets that evaporate to form $PM_{2.5}$. There is no available speciation information for droplets with exact diameters of 10 and 2.5 micrometers in diameter; thus, to be conservative, the next largest droplet diameters were used (11.2 and 3.0 micrometers, respectively). A workbook that provides all calculations for both low and high efficiency cooling towers is provided via electronic media.

This calculation methodology using droplet speciation size is widely supported and endorsed by the New Mexico Environment Department Air Quality Bureau, the Minnesota Pollution Control Agency, the California Energy Commission, and the Canadian National Pollutant Release Inventory. Further, this method has been used for permits approved in Colorado, Mississippi, Maryland, California, Texas, Idaho, Florida, and Puerto Rico (Anderson 2011).

References

Anderson, E. A. 2011. Project Report PC-WCTI-2011-00: Alternative PM10 Estimation Methods for Evaporative Cooling Tower Air Pollution Permit Applications. January. Document accessed February 20, 2018.

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Attachment A – Freudenthal, Rubinstein, and Uzzo 1979 Reference

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Effects of Pathogenic and Toxic Materials Transported Via Cooling Device Drift - Volume 1. Technical Report

by

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Program Element No. INE624A

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U.S. ENVIRONMENTAL PROTECTION AGENCY
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Washington, DC 20460

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ABSTRACT

The report describes a mathematical model that predicts the percent of the population affected by a pathogen or toxic substance emitted in a cooling tower plume, and gives specific applications of the model. Eighty-five pathogens (or diseases) are cataloged as potentially occurring in U.S. waters, but there is insufficient data to predict the probability of occurrence or relate their occurrence to public health, population, or pollution. Sixty-five toxic substances are cataloged as potentially occurring in U.S. waters, but the actual number is probably many times the EPA-supplied list. Toxic concentrations to persons, animals, and plants are known for only a few of the chemicals: most toxic levels can be only inferred from animal studies. In the population as a whole, the epidemiological impact of a pathogen is a function of age, sex distribution, racial (genetic) distribution, general health and well-being, prior exposure, and immunological deficiency states. While cooling device drift may not be directly responsible for epidemics, it may potentiate the burden in an already weakened population, raising a segment of the population into the clinical state. The effect of toxic substances is difficult to evaluate because of inadequate data on humans. The effect is a function of concentration in susceptible tissue, and is much less dependent than pathogens on host resistance.

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17. KEY WORDS AND DOCUMENT ANALYSIS

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LIST OF ABBREVIATIONS AND SYMBOLS

BTU	British Thermal Unit
BW	Biological Warfare
Ca	Calcium
Cl	Chlorine
cm	centimeter
DAT	Dynamic Aerosol Toroid
EMV	Encephalomyocarditis Virus
EST	Eastern Standard Time
FD	Forced Draft Cooling Device
Fe	Iron
g	grams
gpm	gallons per minute
HCO_3^-	bicarbonate ion
ID	Induced Draft Cooling Device
K	Kelvin
Km	Kilometer
l	liter
L/G	Water rate/air rate (lbs/time)
m	meter
m^3	cubic meter
mb	millibar
mm	millimeter
mg	milligrams
mw	megawatt
Na	Sodium
O	Oxygen
$(OH)^-$	Hydroxide ion
ppm	parts per million
r	radius
RH	Relative Humidity
SO_4^{2-}	Sulfate
SV_{40}	Simian Virus 40
Teo	ambient temperature near exit from tower
Tpo	plume temperature
μ	micron
VSV	Vesicular Stomatitis virus
WB	Wet Bulb

SECTION 1

INTRODUCTION

The recent trend in the electric power generating industry and major industries has been the use of closed circuit cooling devices. The use of these devices supercedes the use of once-through cooling systems which had the disadvantage of harmful thermal discharges into surface waters and fish impingement or entrainment. However, the closed circuit systems, or cooling towers, have potential problems, too.

Previous studies have shown that a potential health hazard could exist if pathogens were to be dispersed in cooling tower drift (Lewis, 1974; Cummings, 1964; Dvorn and Wilcox, 1972). This could occur as a result of drawing make-up water from highly polluted surface waters or from the use of processed wastewater (reclaimed water) with inadequate microbial control. In addition to the direct effects on plants such aerosols might potentially cause severe environmental damage, and present legal difficulties to the source operator, especially if the aerosol source impacted dense population centers.

Two prior studies were conducted by H2M for the Consolidated Edison Company of New York (Con Ed) and for a midwest utility that prefers to remain anonymous. Under the provisions of the work statement for the Con Ed study, H2M was to:

a. Inventory the sources of possible pathogen pollution in the Hudson, from the Bronx to Albany.

b. Prepare a catalogue of all possible organisms which could reasonably occur in the area and be transported by the cooling tower drift route.

c. Estimate the magnitude of the severity of the problem.

d. Describe the water treatment methods which would be needed to provide positive control over pathogens and totally eliminate the problem.

The one month study, based entirely upon published data and no field observations, drew the following conclusions:

a. Based upon coliform bacterial levels, used as indicators of fecal pollution, the contamination of the Hudson is sufficiently high to present the possibility of the occurrence of pathogens.

b. The physical conditions of temperature, pressure and flow in the cooling tower circuit will not attenuate pathogens, and during some months, may even prolong survival. The biocides which are added for algae control are ineffective against many pathogens (viruses, spores, etc.).

c. Many pathogens will survive aerosolization and can be transported in a virulent condition over thousands of square miles.

On the basis of the findings of this early study, it was concluded that the possibility of disease transmission through cooling tower drift exists. It was also concluded that the probability of this happening is very low. However, it is remotely possible that the proper combination of a badly contaminated slug of water, inadequate biocidal treatment, plus unfavorable atmospheric conditions could disperse millions of virulent organisms. Even if not particularly virulent, the constant loading of the atmosphere with biological and chemical respiratory offenders presented a potential of a general increase in "colds" and allergies, contributing to the overall discomfort and loss of productivity of populated areas.

That study did not produce firm recommendations due to the inadequacy of factual information. It did however conclude that the problem is sufficiently critical to warrant further study.

A study performed by NUS in 1974 for Public Service Gas and Electric Company of New Jersey, on the potential virus hazard from their Bergen, Burlington and Mercer plants concluded that there would be no hazard. But the authors neither sampled virus from the rivers of the respective plants, nor did they discuss any literature addressing specific organisms. Meanwhile, a very comprehensive review of the "health significance of airborne microorganisms from wastewater treatment processes," by Hickey and Reist (1975) stated:

"The body of evidence is persuasive that some as yet undetermined health effects occur from viable wastewater aerosols."

This premise was confirmed by Walka (1976) in a thesis on the distribution of bacterial aerosols from a sewage treatment plant. He concluded that a survey is needed, especially examining the epidemiological effect of aerosols on populations surrounding wastewater treatment facilities. It was not felt that additional microbial monitoring around aeration tanks would be productive.

Work currently in progress by Lewis and Adams (1978) includes development of a sampling program seeking opportunistic bacteria, indicated by coliforms, in cooling device drift. Sampling was performed at five sites, drawing make up water from a variety of polluted sources. One completed study examines asbestos in cooling waters and a subsequent study is planned to sample for asbestos in the ambient environment.

Work has proceeded in examining the chemistry and effects of biocides in cooling towers (Jolley, 1977), and on the health of humans and aquatic organisms. The Electric Power Research Institute (EPRI) has acknowledged the need for further research and has been looking into the state of the art.

SECTION 2

CONCLUSIONS

In summary, the following conclusions may be drawn from this study.

I. OCCURRENCE

1. Pathogens Potentially Present

Eighty-five (85) pathogens (or diseases) have been catalogued as potentially occurring in United States waters. There is insufficient data to predict the probability of occurrence or relate their occurrence to public health, population, or pollution. The coliform test has no proven relationship between the occurrence of coliforms and specific pathogens, except for the one case of Salmonellae in which the frequency of occurrence varied directly with coliform values, (Geldreich and Van Donsel, 1970). It must be assumed that polluted water or sanitary effluent may carry pathogenic viruses, bacteria, fungi, protozoa, or helminths, either as indigenous organisms or introduced through any of several natural or anthropogenci routes.

2. Toxic Substances Potentially Present

Sixty-five (65) toxic substances have been catalogued as potentially occurring in United States waters, although the actual number is probably many times this EPA-supplied list. The occurrence of specific substances has been definitely related to land usage. Toxic concentrations to man, other animals and plants are known for only a few of the chemicals, for most toxic levels can be only inferred from animal studies. Concentrations in natural waters or wastewater effluent are not well documented, but toxic levels have been reported in many parts of the country. Although it is a natural goal to remove these materials from the environment, it must be assumed that they may be present. It must also be assumed that these substances are capable of producing clinical or sub-clinical toxic reactions in humans and other living organisms, even though the relationship has not always been demonstrated.

3. Use of Polluted Natural and Waste Waters as Make-Up Water

If cooling devices draw make-up water from polluted natural

waters or wastewater with less than total purification, it must therefore be assumed that microorganisms and toxic substances capable of producing disease may be incorporated into the circulating water of the device. As major cooling devices withdraw large quantities of water to replace that lost by evaporation (e.g. 16 mgd for a 1,000 megawatt fossil fuel power plant), the probability of taking up pathogens or chemical substances is great if these occur in the source of make-up water.

II. SURVIVAL IN THE COOLING DEVICE

1. Pathogens

Most cooling devices have a mean circulating water temperature close to human body temperature and the temperature which favors the growth of mammalian pathogens. Therefore, in the absence of biocides, the microorganism will survive and may multiply if suitable nutrients are present. Biocides, of the type usually used to control algal growth, may have limited efficiency in destroying, or attenuating pathogens, and even the strongest of commercial disinfectants may have little effect on viruses. The removal of some of the circulating water through "blow-down" may establish a steady state population of viable organisms in the circulating water.

2. Toxic Substances

Dissolved or suspended toxic substances will not normally be attenuated in circulating water within the cooling device. Pretreatment of make-up water, or the use of water "conditioners" may precipitate-out or otherwise attenuate the concentration of these substances. Removal of the substances in the "blow-down" may establish a steady state concentration.

3. Survival and Persistence

It must be assumed that pathogens and toxic substances will survive and persist within the cooling device environment.

III. CONVERSION INTO DRIFT

1. Droplet Size and Composition

As drift is produced as droplets of water, the size of the droplets is adequate to contain almost all pathogenic microorganisms and dissolved or suspended toxic materials. The drift will have essentially the same chemical and biological composition as the circulating water.

2. Quantity of Loss through Drift

Although the loss of water as drift is a small percentage of the circulating water, the quantities are still large in major cooling devices. (e.g. a 1,000 megawatt fossil fuel power plant may release 13 mgd of water as drift, equivalent to the water consumption of a city of 250,000 people.)

3. Passage of Pathogens and Toxic Substances into Aerosol State

The potential is therefore great for the passage of substantial quantities of pathogens and toxins into drift, if these are present in the circulating water.

IV. TRANSPORT IN AEROSOL DRIFT

1. Deposition of Drift

A substantial portion of the drift will be deposited in the vicinity of the cooling device, as demonstrated in drift models and studies with drift generating devices. However, meteorological phenomena could incorporate the drift into strong surface winds, clouds, or the upper atmosphere, resulting in transport over hundreds of miles.

2. Pathogen Transport in Aerosol Drift

Pathogens are of such size that they are capable of being transported in the drift or atmosphere for substantial distances. This transport has been documented.

3. Toxin Transport in Aerosol Drift

Toxic substances will behave as the water droplets in the drift.

V. SURVIVAL IN AEROSOL DRIFT

1. Pathogen Survival in Aerosol Drift

Microorganisms in drift are normally attenuated by dessication, temperature and ultraviolet radiation. A drift produced in an arid climate during the day would show a great reduction of some pathogens, principally bacteria and protozoa. A drift produced in a humid atmosphere, at cold temperatures, and at night would have little attenuation. Drift droplets that freeze would insure survival of almost all pathogens. Dense cloud cover, or the density of the plume itself, would restrict UV penetration, and would reduce attenuation.

2. Toxic Substance Integrity in Aerosol Drift

Few of the toxic substances considered were sensitive to light or moisture. Attenuation in the drift would be negligible. Even if the water of the drift evaporates, most substances would be suspended as gas, aerosols or particles, without modification. In some cases, toxic materials could undergo photochemical reactions, increasing their toxicity.

3. Effect of Ambient Environment on Survival and Integrity

It must be assumed that drift can transport pathogens and toxins without significant attenuation. Ambient site characteristics influence the viability of some microorganisms, but have little effect on toxic molecules as a whole.

VI. PRODUCTION OF DISEASE OR CLINICAL MANIFESTATIONS

1. Human Susceptibility

Pathogens

The pathogens' ability to produce disease or clinical manifestations is a function of arrival of a sufficient number of infective particles at a suitable portal of entry and the susceptibility of the host. Bacterial infectivity is a function of a stoichiometric relationship between the number of organisms and hosts' antibodies, and the number required may vary from a few to several hundred thousand. For viruses, protozoa, fungi, and worms, the number of infective particles may be as few as one. As the half life of pathogens in the environment may be long, accumulation or continuous exposure could bring the number of particles to critical levels.

In the population as a whole, the epidemiological impact is a function of age, sex distribution, racial (genetic) distribution, general health and well-being, prior exposure and immunological deficiency states. While cooling device drift itself may not be directly responsible for epidemics, it may potentiate the burden in an already weakened population, raising a segment of the population into the clinical state.

Toxic Substances

The effect of toxic substances is difficult to evaluate because of inadequate data on humans. The effect is a function of concentration in susceptible tissue, and is much less dependent on host resistance than for pathogens. Immunity can not be acquired either.

Death directly due to most drift borne toxic substances is unlikely, based upon the concentrations implied by the limited data. Cancers are most likely, but the data is also insufficient to draw any conclusions. A highly probable but speculative impact is the weakening of individuals, making them susceptible to infection, or allergic reactions.

2. Animal Susceptibility

Pathogens

The general pathogen considerations for animals are the same as for humans, except that herbivores graze directly on vegetation and therefore have a greater potential for accumulating infectious particles from plants exposed to drift.

Toxic Substances

The accumulation of toxic substances on vegetation presents a greater probability of accumulation to toxic levels within grazing herbivores.

3. Vegetation Susceptibility

Pathogens

Only the fungi and viruses are significant as pathogens, and the usual route of transfer is by vectors or dry wind. Cooling device drift is not a significant factor.

Toxic Substances

The effect of the toxic substances considered is not well documented, but drift transport does not appear to be a significant factor. The water droplets themselves, humidity, or ordinary salts in the drift are documented as causes of plant disease.

VII. PROBABILITY OF OCCURRENCE

In determining the relative probability of host contamination, a number of assumptions and parameters had to be worked into the mathematical model. These specifically include:

a.	Cooling tower height:	400 ft.
b.	Top diameter:	300 ft.
c.	Exit air volume:	23×10^6 cubic feet per min.
d.	Evaporative loss:	13 cubic feet per second
e.	Aerosol loss:	0.01 cubic feet per second
f.	Wind Speed:	30 feet per second
g.	Air temperature:	300 K.
h.	Relative humidity:	70%
i.	Circulating water volume:	5×10^6 cubic feet

j. Blow-down: Complete blow-down @ 1.5:1 concentration ratio

Other parameters which were selected for inclusion in the model were based on typical power plant load profiles and weather conditions for 24 hour periods. Each 24 hour period was divided into four hour segments and it was assumed that conditions remained constant over this period. The numerical values which were chosen and integrated into the model were considered typical for a natural draft cooling tower for a plant of approximately 1000 MW capacity. These parameters include drift fraction e.g. 5×10^{-5} g/g, salt concentration ratios of 30%, weather conditions for typical seasonal, day and evening instances, plant operating capacity and atmospheric stability. The specific values assigned to the parameters are detailed on the printout of each case.

A calculation was then performed to determine the probability of contamination using those assumptions and parameters. The following is a sample of the results achieved for a summer's day case.

---------- 24 HOUR TOTALS ----------

DAILY PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .34

DIST(MI)	ORG/M3/DAY	ORG/M2/DAY
0.10	0.0	0.0
0.15	1107339.0	454345.4
0.20	311119.8	129253.4
0.30	98662.0	41190.6
0.50	105227.0	232410.3
0.75	215556.6	369901.7
1.00	280964.0	379159.9
1.50	155911.4	141004.1
2.00	94571.7	58955.1
2.50	66768.6	33844.5
3.00	50172.2	21953.7
4.00	17523.1	5660.8
5.00	12931.0	3511.6
7.00	8573.2	1983.8
9.00	6487.0	1202.0
10.00	5151.9	756.5
12.00	4226.6	604.1
15.00	1685.0	230.4
20.00	986.8	107.6
25.00	664.9	54.7

---------- SUMMARY OF RESULTS ----------

DIST(MI)	AVG NO. PART. INGESTED/IND.	PERCENT AFFECTED BY EFFLUENT
0.10	0.0	0.000
0.15	1561684.4	18.135
0.20	440373.2	0.486
0.30	139852.6	1.223
0.50	337637.3	20.000
0.75	585458.3	9.244
1.00	660123.9	13.324
1.30	296915.5	18.221
2.00	153526.8	11.626
2.50	100613.1	10.064
3.00	72125.9	5.507
4.00	23183.9	0.486
5.00	16442.5	1.914
7.00	10557.1	0.318
9.00	7689.0	0.006
10.00	5908.4	0.000
12.00	4830.7	0.000
15.00	1915.4	0.000
20.00	1094.5	0.409
25.00	719.6	0.215

SECTION 3
RECOMMENDATIONS

I. General Epidemiology and Microbiology

As in all public health and water supply work, the confidence in health hazard projections is low because of inadequate data. To compensate for the inability to make accurate projections, the United States had adopted a technology of extra caution in water treatment. While this has brought this nation an absence of infectious disease heretofore unknown in the history of mankind, it has imparted cost, energy and environmental penalties, as well as possible health hazards of the non-infectious type.

A. Society must establish the level of public health that it is willing to accept, together with the economic and social cost. This is a political decision beyond the scope of cooling devices alone, but it is incumbent upon science and engineering to develop the costs and benefits of alternative technologies. Studies to develop these, and measure public attitudes, should be performed.

B. The use of the coliform test as an indicator of health hazard is a poor substitute for actual pathogen monitoring, justifiable only when no alternative methods were feasible. Today, equipment and procedures exist for rapidly identifying specific pathogens. The advances of space technology and diagnostic medical microbiology should be applied to water monitoring, for cooling devices and all other water use sciences.

C. Aerobiological and aerochemical studies should be performed in the United States and Europe to determine if the microbiological and chemical load imposed upon the atmosphere by cooling device drift is so significantly above background as to constitute a possible health hazard. Studies using "tagged" organisms and chemicals should be considered in addition to environmental monitoring.

D. Epidemiological studies should be conducted in areas in which major cooling devices have been in use, especially those which use polluted water for make-up. The selection of sites is very critical. They must have adequate health data prior to the use of the cooling device, and

the general level of health should be good. Such study sites may be found in Europe.

E. Laboratory models should be constructed, using polluted water, cooling device drift simulation, and animals, to experimentally derive data on health impact.

F. Special attention should be given to subclinical and allergic manifestations of infection and toxicity produced by cooling device drift and other sources of air pollution. Current health data suggest an increase of health problems directly related to environmental pollution. Those which result in clinical symptoms are easiest to document, however, there appears to be an increase in those conditions which cause discomfort, decrease resistance to infectious disease, initiate autoimmune "cancerous" conditions, and generally shorten life or decrease productivity. These are typified by allergies, "colds," etc., i.e. those conditions which do not call for a medical practitioner, but are nevertheless debilitating or unrecognizable.

II. Cooling Device Technology

A. In as much as cooling devices may be used in close proximity to sources of gaseous or particle emissions, such as smoke stacks, studies should be conducted on the relationship between drift and capture and transport of atmospheric pollutants. These studies should be field monitoring as well as laboratory simulation.

B. The need and means of controlling the emission of pathogens and toxic substances should be investigated, irrespective of any findings under epidemiology. The epidemiological, microbiological, and chemical studies on drift may be inconclusive, and will certainly be of long duration. If public policy is to avoid potential risks, as it does in public water supply, then safety precautions should be imposed on cooling device design and operation. Such precautions should represent a Best Available Control Technology (BACT).

C. The viability of pathogens in drift should be studied to develop biological half-life projections as a function of atmospheric conditions. This is necessary because it does not appear that the historical concepts of aerobiology and attenuation of organisms apply to dense aerosols.

III. Modeling

Procedures should be further refined for mathematical modeling of the health impact of cooling device drift. This requires more precise input on variables which have been only assumed in this study, and better integration of drift and infectivity models.

SECTION 4

OBJECTIVES

The objective of this study was to complete a comprehensive review and analysis of potential hazards to humans, plants and animals that might be caused by pathogens and toxins transported via cooling device drift.

For the purpose of program organization and control, the project was divided into six tasks, which are shown on the following Information Flow Diagram (Figure 1) and detailed in the following sections. Two pathways were postulated. The "normal pathway" represents situations which might occur in the everyday ambient environment under normal conditions. The worst case pathway represents the highest possible concentrations of pathogens or toxic substances in cooling water, failure of water treatment or biocide systems in the cooling device, atmospheric conditions insuring pathogen viability, toxin integrity, and entry into a susceptible host in sufficient concentration to produce disease.

TASK I

The primary function within this task was to inventory the types of pathogens and toxic substances which may be present in cooling device drift. The inventoried pathogens and toxins originate in recycled industrial, municipal and/or agricultural wastewaters, and polluted river waters, which would be used as cooling tower makeup. It was deemed necessary to include polluted river waters because power plants using treated effluent will generally require a back-up source of surface water in case of wastewater treatment failure or supply inadequacy.

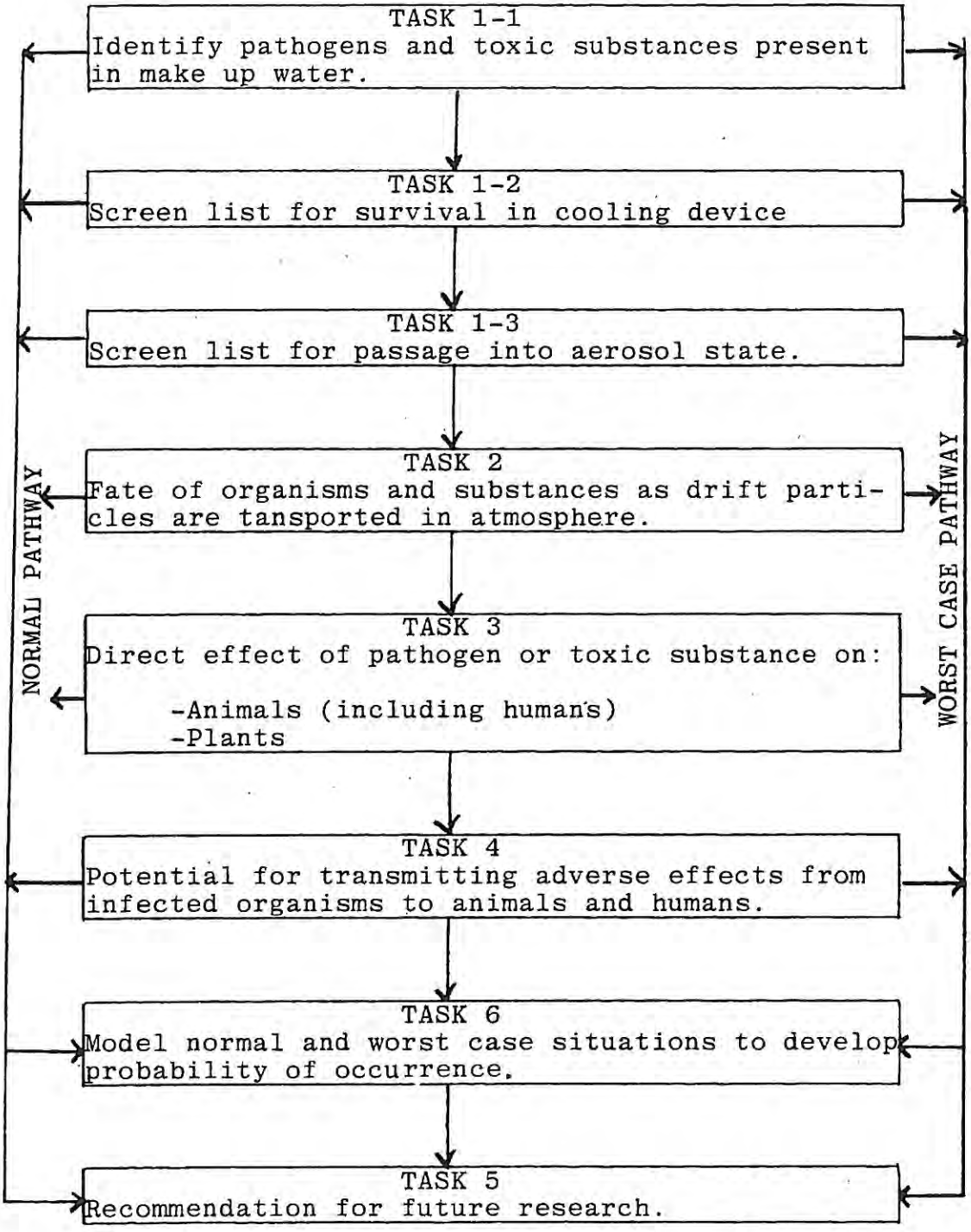
The process of preparing the inventory was to:

1. List most commonly known pathogens and toxic substances found in wastewater and polluted water, with typical concentrations when known. The microorganisms which were surveyed included the following groups:

Viruses	Pleuropneumonia-like Organisms (PPLO)
Richettsia	Protozoa
Bacteria	Invertebrate Parasites
Fungi	

FIGURE 1
INFORMATION FLOW DIAGRAM

Effect of Pathogenic and Toxic Materials
Transported via Cooling Device Drift



Only those organisms which could reasonably be found in America were catalogued. This list also included certain foreign species which are being imported by world travelers, and which are recognized as potential health hazards.

Chemical substances which were surveyed included:

1. Metals
   a. Heavy metals
   b. Transitional metals
2. Macronutrients
3. Micronutrients (Organic and Inorganic)
4. Chlorinated Hydrocarbons
5. Chlorinated and Ozonated Amines
6. Petrochemicals
7. Other toxic organics (e.g. pharmaceuticals)
8. Industrial Chemicals
   a. Plasticizers and other organics
   b. Process wastes
   c. Radioactive wastes.

2. The list was screened and categorized as to the susceptibility of organisms and substances to control by wastewater treatment or natural water purification processes.

3. The list from Step 2 was further screened to characterize only those organisms and substances which could be aerosolized. This step required input and coordination with the aerosol physics aspects of the program.

The end product of this task is a CATALOGUE which lists separately for each organism and toxic substance the following data:

Organism name or chemical substance
Disease name
Medical significance
Location of occurrence
Frequency of occurrence
Survivability in surface water
Survivability in treated effluent
Survivability in air and/or aerosol fomites
Control methods in water or effluents

The catalogue treats microorganisms as both infectious agents and allergens. Chemical irritants were considered in a slightly different manner including concentration as a parameter, when available.

There is also an estimated probability of occur-

rence in water. Except for a few cases where data was available, this was a qualitative judgment.

TASK II

Under this task the transport of pathogens and toxic substances in aerosol drift is assessed. Utilizing the inventory of substances and organisms produced under Task I, Task II investigates three areas:

1. A review and evaluation of the production of drift by cooling devices and the atmospheric physics of drift particles.

2. The transport of toxic substance in drift.

3. The aerobiology of organisms in drift.

Drift Physics

The primary objective here is to define drift as a function of selected cooling device designs. The data provided includes the following:

Drift size distribution
Drift mass distribution
Drift composition
Drift emission rate based on liquid flow to air flow ratio
Parameters as functions of wet-bulb/day, bulb temperature, relative humidity
Heat capacity
Exit velocity.

The matrix on the following page depicts the types of devices that were considered (Table 1).

The analysis concentrated on the cooling devices of larger sizes, from 10^9 to 10^{10} BTU/hr., since these have the greatest impact. Consideration was given to units which are capable of producing drift and of using polluted water. Although spray pond cooling devices do produce drift they were not considered because their impact is extremely localized. Therefore, the emphasis of this task is the examination of large capacity evaporative cooling devices.

Special attention was given to physical size. There is a significant difference between the mechanical type towers and the natural draft towers in the following aspects.

1. The bulk of the towers is conducive to wake entrainment at elevated wind-speeds.

TABLE 1

TYPES OF COOLING TOWERS

	Mechanical Draft		Natural Draft	Mixed
	Forced	Induced		
Wet				
Crossflow	no	yes	yes	yes
Counterflow	yes	yes	yes	yes
Wet-Dry				
Parallel flow	no	yes (note a)	no	no

Note a: This type is to be considered only when in the wet mode.

2. The height of the towers contributes to the drift particle growth and dispersion patterns.

3. The height of the towers and their emissions will determine the potential for scrubbing action of chemicals and microorganisms from the local ambient atmosphere.

Drift emission rate was considered. The amount of drift is a tower design function. Previous design practice has been to use as an upper limit, a guaranteed drift rate not to exceed 0.2% of the water circulation rate. Recent designs of drift eliminators have resulted in drift guarantees of from 0.05% to 0.002% of the circulating water flow. These values may be interpreted in terms of parts per million by using a design ratio, L/G, which is the ratio of the water rate to the air rate, both in pounds per unit of time.

Data was evaluated on the initial drop size distribution. This is an area of great uncertainty. The drop size distribution in the cooling tower drift was related to tower design parameters. Estimates were made of the limiting size, which must be such that the gravitational fall velocity of a droplet is less than the air speed at the exit of the tower. Estimates were also made of the water mass distribution, and finally, the initial composition of the drift particles was described in relation to the make up water.

Transport of Toxic Substances

The transport of toxic substances in the changing structure and composition of the plume, relative to the ambient air, and the distribution of drift over the terrain was evaluated.

The following device parameters were taken into account with respect to the incorporation of toxic substance into drift:

Downwash
Supersaturation
Effect of effluent latent heat on plume rise
Effect of saturated ambient air on plume rise
Prediction of condensation

Existing models were critically screened and typical results were evaluated with respect to the general task objective. Evaluations for transport and fate were made on the basis of the following functions:

Selected cooling device types - considering the range of operational characteristics.
Ambient seasonal climatology.
Terrain characteristics (shoreline, valley, plains, urban, rural, etc.).

Conditions conducive to survival of organisms (humidity, UV screening, temperature).

Deposition rates were evaluated in order to determine the loss of compounds from the plume and concentrations of compounds in the receiving environment.

The effects of oxidation or photochemistry upon toxic materials were assessed. Taken into consideration were atmospheric conditions, plume density, and particles resident time in the atmosphere. This evaluation essentially relates toxic substance concentration to time and distance.

Aerobiology

The ability of each pathogen group to be effectively transmitted by aerosols was reviewed and documented. This process took into account the following factors for the different particle size ranges:

1. Attenuation due to desiccation
2. Attenuation due to solar radiation
3. Protective mechanisms due to dissolved chemicals in the aerosols.

This information was gathered from published scientific and medical literature, and from personal liaison with former participants in biological warfare (BW) study programs which have now become declassified.

TASK III

The potential effects upon inhalation by, or contact with, animals or plants.

The arrival of a pathogen or toxic substance at a plant or animal does not, per se, mean the manifestation of disease. The offender must interact with the body and overcome the body's defense mechanisms.

For each pathogen or toxic substance which was identified in Task I, and which survived aerosol transport, an assessment was made of the probability of initiation or aggravation of disease. This assessment included:

a. A description of the normal means of entry of the offending agent into the body.
b. A description of the normal body susceptibility.

This information was abstracted from epidemiological literature for plants, animals and humans.

The result of this task is an estimate of the probability of a pathogen or toxin producing disease, after arriving within capture range of the host. This probability is expressed in general terms based on an analysis of factors including:

a. Induced or natural immunity
b. Strain resistance
c. Synergistic or antagonistic factors
d. Age
e. Sex
f. Route of entry

These factors were evaluated in relation to occurrence and transmission, and faction. Where possible chronic and acute severity is also discussed for both individuals and population groups.

TASK IV

Potential for transporting adverse effects from affected plants and animals to other animals and humans.

This task is very closely related to the objectives of Task III. For pathogens, literature review and assessment covered zoonoses. Within this epidemiological evaluation, transmission of pathogens from plants to humans considered their role as fomites and vectors.

An effort was made to identify those toxic substances which would be assimilated in edible plant parts and phytoplankton. Consideration was given to detoxification mechanisms in plants and where possible estimates were given for residual concentrations which could be consumed by herbivores.

The data from this task was, as in Task III, incorporated into the catalogue format for a comprehensive review of each pathogen and toxin.

TASK V

Conclusions and recommendations for future research.

Regardless of the specific conclusions which were drawn from the study, it was obvious that there is little data available. Data gaps exist, identifying areas to be researched. Further comments were made in the areas of:

1. Theoretical and analogue simulation, and modeling.
2. Field measurements on the actual occurrence of pathogens in the drift in the vicinity of cooling devices.
3. Technological methods of control.
4. Epidemiology in the vicinity of polluted water cooling towers.

TASK VI

Predicative model development.

One very useful way to evaluate the possible impact of cooling tower drift on public health is by the establishment of suitable predicative mathematical models. It is clear for this case, as in many other systems modeled, that all the desired parameters, constants and variables may not be clearly identifiable or definable. However, this does not at all preclude the development of utilitarian models that can be modified as more data become available and as it becomes apparent that some "tuning" of the model is necessary as a result of experience.

The question approached in the predicative model development was the liklihood of a pathogenic organism or toxic substance reaching and affecting the public. Because answers to this type of inquiry are probabilistic, they should be answered by the development of a stochastic (probabilistic) rather than deterministic model. Less work has been done with stochastic models because they are more difficult to deal with. Even so, their use has become increasingly common as the shortcomings of completely deterministic models became more apparent.

There is a logical sequence involved in evaluating the possible erosion of public health as a result of cooling tower drift. Some of the major events in this sequence, which were discussed are:

1. Probability of occurrence of pathogens or toxic substances in makeup or other input waters.
2. Probability of survival of pathogens or toxic substances in cooling towers.
3. Probability of hazardous materials being carried into the atmosphere.
4. Probability and time duration of survival of hazardous materials in the atmosphere.
5. Probability of interception by an appropriate host or vector.
6. Probability of development of harmful effects.

Each of these events were developed from other events which are probabilistic in and of themselves (e.g. presence of sunlight, air and water temperatures, residence times, wind direction and velocity, etc.). Knowing something about the parameters that affect each event postulated, the predicative model was developed for each event that establishes the possiblity of that event occurring. A serial model, as outlined above has a condition that the possibility of the preceeding event occurring must exist. In the modeling of this system as outlined, it is apparent that there are many similarities to the extensive simulations for reliability and availability predictions for electronic systems. There is

extensive literature on such simulations and predicative models and as applicable serves as a base for the establishment of the proposed predicative model.

The problem of random events was solved by substituting for the actual event or function, a simpler one where the desired probability laws are obtained by drawing random numbers. These methods, based on game theory are called Monte Carlo methods. These techniques have been well developed for the investigation of predicative stochastic models such as are suited to this study and form the basis for aspects of the model development.

In this task, a predicative mathematical model is developed. To the extent possible that known (or suspected) variables can be included, either on the basis of known or hypothetical grounds, the model incorporates them. Areas of question are identified and provisions are made for incorporation of new or speculative items as required. Model testing is accomplished using routine establishment of probabilities using available statistical data, and by using Monte Carlo methods for prediction of probabilities. The models developed are carefully documented in flow chart design and development of algorithms. Also the programming was written in one of the higher level languages (FORTRAN). This allows for future building on the developed model as more data becomes available from future work.

SECTION 5

METHODOLOGY

This study attempts to further define and assess the potential health hazards resulting from cooling tower drift. Although it has already been shown that data is lacking, this study attempts to answer questions and make a valid assessment utilizing existing sources and references. It is certainly hoped that this investigation will provide some answers, but it will also be considered a significant effort to direct the need for future study.

To complete the study a staff of outstanding subcontractors and consultants were assembled. The specialists and their fields are as follows:

1. Aerosol Physics and Cooling Tower Emissions.
   (Subcontract to York Research Corp., Stamford, Conn.)
   Edward J. Kaplin, M.S.: Principal Scientist.
   Alan D. Goldman: Environmental Meterologist.
   Experience in theoretical and applied design of cooling devices, and monitoring emissions.

2. Microbiology.
   Henry David Isenberg, Ph.D.: Chairman, American Board Medical Microbiology; Editor, Journal of Clinical Microbiology; Chief of Microbiology, Long Island Jewish Medical Center.

3. Epidemiology.
   Cyrus C. Hopkins, M.D.: Hospital Epidemiologist, Massachusetts General Hospital; Assistant Physician, Massachusetts General Hospital; Assistant Professor Medicine, Harvard Medical School.

   Robert Harold Rubin, M.D.: Infectious Disease Unit, Massachusetts General Hospital; Assistant Professor of Medicine, Harvard Medical School.

4. Zoology and Animal Pathology.
   Basil P. Tangredi, D.V.M.: Practicing veterinarian.

   Sydney Anderson, Ph.D.: Curator of Mammals, American Museum of Natural History, New York.

5. Botany and Plant Pathology.
Leonard Weinstein, Ph.D.: Director, Environmental Laboratory, Boyce Thompson Institute.

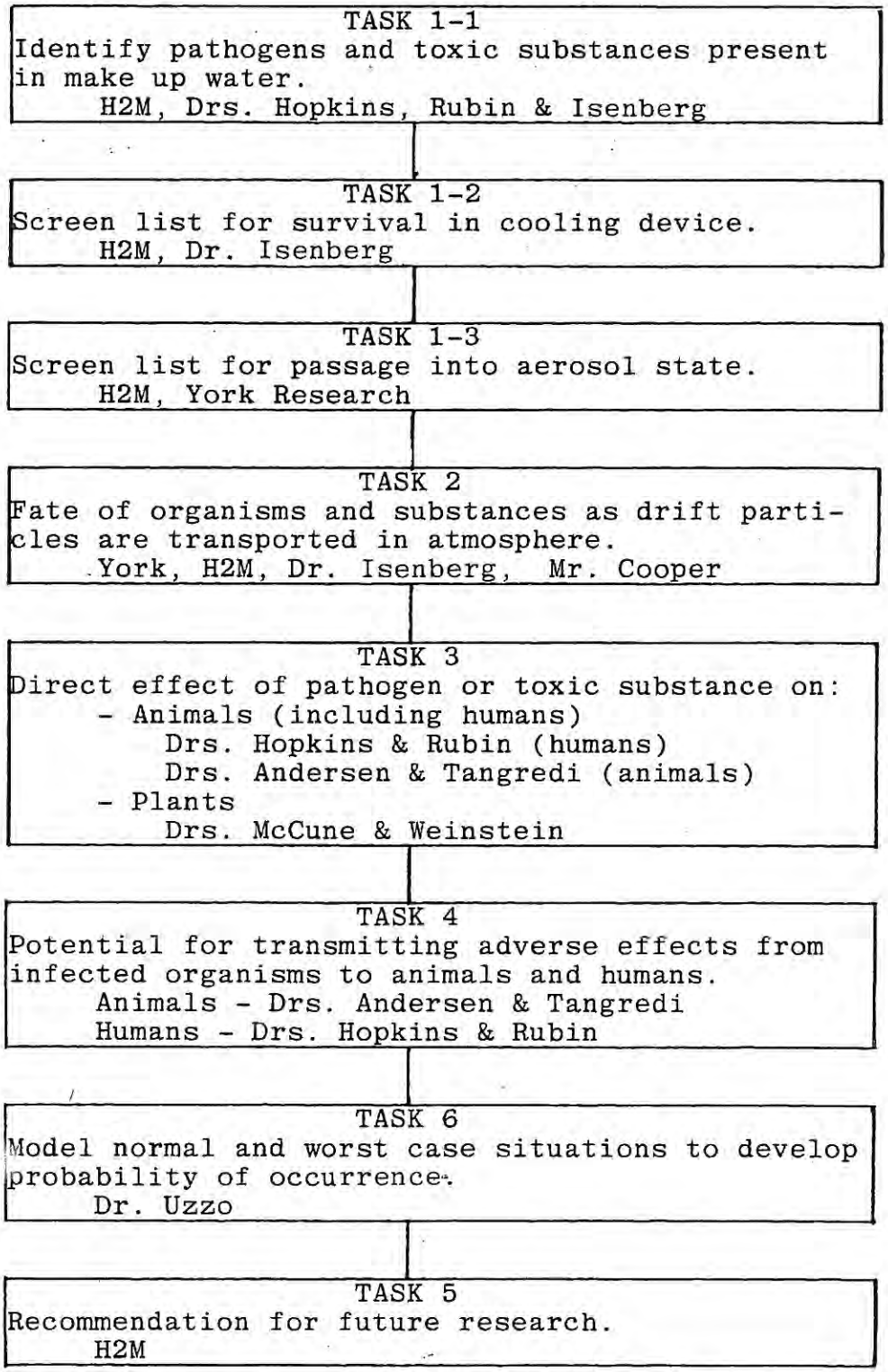
Delbert C. McCune, Ph.D.: Plant physiologist, Boyce Thompson Institute.

6. Aerobiology.
Philip Cooper, M.S.: Formerly a research scientist at the United States Air Force Air Medical Research Laboratory.

These specialists were assigned their scope of work under the task structure described in the Objectives (see Figure 2). All research was secondary, to be taken from known and accepted sources. Data was submitted according to a task schedule and compiled in house.

FIGURE 2
TASK ASSIGNMENT DIAGRAM

Effect of Pathogenic and Toxic Materials
Transported via Cooling Device Drift



SECTION 6

RESULTS

RESULTS OF TASK I - INVENTORY

Disease means any pathological manifestation, caused either by micro-organisms or by nonliving substances. There are several major routes for the transmission of disease:

1. Water
2. Air
3. Vectors (e.g. insects)
4. Fomites (contaminated food, dust, aerosols, etc.)
5. Direct contact with diseased organisms

Of these, water is probably the most serious. Water becomes contaminated easily, it can transport germs or dissolved substances greater distances, and it is universally required in large quantities by all living things.

The principal source of contamination with human pathogens is through fecal discharge, and to a lesser extent, with other products of human metabolism (mucus, pus, etc.). As a solvent and flushing agent, water picks up and carries contaminated road and field sediments, food and industrial wastes, animal feces, etc.

Contamination of surface waters must be accepted as an accomplished fact due to the combination of storm runoff and the lack of adequate sewage treatment. Natural surface and ground waters are also subject to purification mechanisms, such as settling, aeration solar radiation and phagocytosis. The extent to which contaminated waters can purify themselves is a function of the pollution concentration, the time available for action, and the biological properties of the organisms. Whether or not contaminated waters are capable of producing disease in humans is a function of the etiology of either of two types of pathogens which may be present.

1. Certain organisms, such as many of the enteric viruses, are normal inhabitants of the human intestine and continue to exist in a circulating stock so long as humans are present. Illness does not occur, because populations acquire immunity, either naturally or artificially.

The poliomyelitis virus is an example of such an organism. Immunization prevents the appearance of clinical symptoms of the disease, but the threat can never be removed and the unprotected human will continue to develop the disease.

A particular danger with these indigenous organisms is that they change to produce new strains, and there is no assurance that the immunity against one strain will protect against another strain. While many avenues of research are promising, there is still no effective drug or body substance that will confer broad resistance against all present and new pathogens.

2. Other organisms are not indigenous, and can be introduced only from a diseased person. For example, if no cholera is present in the population, there can be no source of the bacterium. Obviously the key to the control of these diseases lies in maintaining a healthy population.

The United States has been very effective in achieving a marked reduction or elimination of diseases which were dreaded less than a century ago. Recently, however, there has been an increase in the incidence of those diseases that were considered things of the past, because of the proliferation of world-wide travel. Tuberculosis, for example, has risen to such an extent that New York hospitals are reopening T. B. clinics that had been closed.

In addition to the importation of foreign diseases, another source of pathogenic organisms is the "carrier," or one who harbors the disease organisms but does not manifest clinical symptoms. Such an individual can continue to contaminate waters and escape detection and cure.

The inventory of diseases which can be transmitted through the water route is substantial. Here in the United States, water borne diseases have been kept under control by meticulous attention to the purification of public water supplies, and health standards for private water supplies, recreational waters and shellfish. Although there is a national effort to purify sewage, the fact remains that most of the country has no sewage treatment or only primary treatment.

Table 2 lists those pathogens which are most likely to be found in polluted waters. Also included in this list are pathogens which are indigenous abroad but may be introduced into the U.S. by travelers. Pathogens that may not naturally occur in surface or ground waters, but may be introduced into waters from external sources, are also included.

Toxic materials are introduced into surface water as a result of raw or inadequately treated wastewater, storm water runoff, solid waste leachate from landfills, rainfall, dredge spoiling, and a variety of other activities. As a result of the recent national effort to reduce point source pollution, the quantity of toxic materials introduced into surface water is being attenuated. However, because of the magnitude of the non-point pollution control problem, it is doubtful that surface water pollution will ever be reduced to zero in the vicinity of human habitation. Cooling devices that draw water from such areas will intake chemical substances which will eventually incorporate into the aerosol drift.

TABLE 2

PATHOGENS MOST LIKELY TO OCCUR IN
COOLING TOWER MAKEUP WATER SOURCES

Absidia corymbifera

Absidia ramosa

Acanthamoeba (Naeglenia)

Actinomyces israeli

Actinomyces keratolytica

Actinomyces spp.

Adenovirus and Para influenza virus

Aspergillus spp.

Aspergillus flavus

Aspergillus fumigatus

Aspergillus nidulans

Aspergillus niger

Aspergillus niveus

Aspergillus restrictus

Aspergillus terreus

Bacillus anthracis

Bacillus cereus

Bacillus subtilis

Bacteriodes spp.

Basidiobolus haptosporus

Blastomyces dermatitidis

Bordetella spp.

Bordetella parapertussis

Brucella abortus

Brucella canis

Brucella melitensis

Brucella suis

Candida albicans

Candida spp.

Cladosporium spp.

Clostridium botolinum

Clostridium perfingens

Coccidioides immitis

Conidiobolus coronatus

Corynebacterium spp.

Corynebacterium diphtheriae

Corynebacterium ulcerans

Cryptococcus neoformans

TABLE 2 cont.

Dermatophilus congolensis

Echo virus, coxsackie A & B, Polio

Enterobacteriaceae

Escherichia coli

Fuscobacterium spp.

Geotricium candidium

Haemophilus aegyptius

Haemophilus influenzae

Klebsiella pneumonia

Listeria monocytogenes

Mucor pusillus

Mucor ramosissimus

Mucor spp.

Mycobacterium spp.

Mycobacterium tuberculosis

Nocardia asteroides

Nocardia brasiliensis

Nocardia caviae

Peptococcus spp.

Peptostreptococcus spp.

Phialophora spp.

Proteus mirabilis

Prototheca spp.

Pseudomonas aeruginosa

Pseudomonas mallei

Pseudomonas pseudomallei

Rhinocladiella spp.

Rhizopus arrhizos

Rhizopus oryzae

Salmonella spp.

Salmonella typhi

Shigella spp.

Shigella boydii

Shigella dysenteriae

Shigella flexneri

Shigella sonnei

Sporothrix schenckii

Staphylococcus agalactiae

Staphylococcus aureus

Staphylococcus spp.

Streptococcus faealis

Streptococcus pneumoniae

Streptococcus pyogenes

Streptococcus pyogenes (Group A)

Streptococus spp.

Torulopsis glabrata

Vibrio parahemolyticus

Yersinia enterocolitica

Yersinia pestis (Pasteurella)

Yersinia pseudotuberculosis

Zygomycetes (Phycomycetes)

Various viruses, nematodes and protozoans

Salt, although it is naturally occurring substance in estuarine waters, might be considered a toxic material for terrestrial plants. Salt drift has been identified as a potentially serious cause of injury to sensitive species of natural foliage and crops in the vicinity of cooling devices.

The effect of airborn toxic material on human health has been intensively studied, but the impact is highly controversial. Toxic substances, including acid sulfates and nitrates, and certain metallic compounds may produce acute or chronic respiratory symptoms, including increased airway resistance, asthma, bronchitis, cardio-pulmonary disease, increased sputum, and even death.

Allergens, although not necessarily toxic, may cause asthma and hay fever, two of man's most annoying diseases. Airborne pollutants may potentiate or mimic allergens on sensitive individuals. "Red tide" aerosols from dinoflagellate blooms have been documented.

Environmental pollutants may also be the principal cause of cancer or may serve as co-carcinogens. This has been documented for the particulates such as asbestos and beryllium, and for self-inflicted gaseous chemicals from smoking tobacco. The extent to which industrial and transportation emissions are related to cancer of the lungs, stomach, intestine, and of the immune system may be related to environmental pollutants.

The origin of most gaseous (or small particle) pollutants is combustion. Since cooling tower aerosols may be generated adjacent to combustion exhausts, or may pass over industrial emissions, they may contribute to the transport of pollutants by solubilizing gases or trapping particles in the aerosol droplets. This is outside the scope of the present study, but it should be recognized that under those conditions, cooling tower drift may potentiate health problems, if not be directly responsible for them.

Toxic chemicals in cooling tower water can also originate directly from the biological and chemical reactions that occur in the system. These reactions are dependent upon the characteristics of the device and the make-up water. All cooling devices can be subject to the following:

1. Scaling on heat exchange surfaces.
   Scaling is a land adherent type of deposit caused by the precipitation of hardness elements from the water in the form of salts or oxides.

Principal scales are calcium carbonate and magnesium silicate. A characteristic of these salts they have inverse water solubilities with respect to temperature. Increased scaling can occur as the water temperature increases in a cooling system or as the concentration of salts increases through evaporation. Factors that determine or control scaling include such analytical values associated with water quality as pH, calcium content, total alkalinity, dissolved solids and temperature.

Scaling is generally controlled by chemical adjustment of the alkalinity and/or recycle times. The alkalinity is controlled by the addition of acid - usually sulfuric acid - to maintain a pH range between 6.0 - 7.0 and/or by using surface active phosphates and organic agents. It is noted that pH also affects corrosion inhibition so that a balance is necessary.

2. Sludge formation on heat exchange surfaces. Sludge formations are caused by combinations of dirt, oil, calcium and magnesium salts, organics, and other chemical products, particularly phosphates. These fouling masses can mechanically filter dust from circulating water and serve as focal points for difficulties in the form of reduced heat transfer and corrosions. Additive control agents function through a physical phenomenon which results in an extremely thin layer of contaminant being deposited on surfaces in the cooling tower system while the rest is maintained in suspension.

3. Corrosion of piping, pumps and heat exchanges. Corrosion is caused primarily by the dissolved oxygen content of the water although a high chloride content in the water will also lead to corrosion. By the very nature of wet cooling towers, the contact of the water with air assures that the circulating water will be continuously saturated with dissolved oxygen and is thus the major single source of corrosion difficulties.

Corrosive inhibitors are generally combinations of chromates, zinc and phosphates. The chromates and phosphates act as anodic inhibitors. They form a surface film which restrains the anodic corrosive reaction:

$$Fe \rightleftharpoons Fe^{++} + 2e$$

When used alone, anodic inhibitors must be present in

a large quantity. This can be substantially reduced with the addition of zinc, a cathodic inhibitor. the cathodic reaction is:

$$O_2 + 2H_2O + 4e \rightleftharpoons 4(OH)^-$$

This reaction is the rate controller and it is limited by the rate at which oxygen can diffuse to the metal surface. The cathodic reaction generates hydroxide ions which increase the pH at the cathodic area. The zinc precipitates with the increased pH and forms a barrier to oxygen diffusion:

4. Biological fouling.
The tremendous potential for biological fouling through slime, algae formation and all forms of microbiological growth exists in a wet tower system because of the high average water temperature, oxygen - saturated environment that is provided. The seed organisms are always in fresh supply by the process of scrubbing from the tower air as well as from any make-up water.

In so far as the cooling tower operation is concerned, biological fouling can greatly decrease heat transfer. This can be attributable not only to the organisms themselves but also to their metabolic products. The bulk, once deposited, serves as a further trap for debris, chemical and otherwise.

The principal microbiological organisms involved are bacteria, fungi and algae. The bacteria are the most troublesome type of organism. Aerobic slime-forming bacteria thrive in tower environs both in the bulkwater and on exposed surfaces.

The control of biological growths in circulating water requires its periodic treatment with biocides. Chlorine, chlorinated phenols and non-oxydizing biocides are effective as growth controls.

Chlorine may in some instances be depleted by its reactions with other treatment chemicals in a system. Non-oxidizing biocides may be used to supplement chlorine treatment or as a replacement. It is noted, however, that for non-oxidizing biocides to be effective they must be present in toxic dosages.

The addition of copper citrate, cholophenates, tribictyl tin, quaternary amines, methylene bisthiocyante and chlorination are only a few of the biological control compounds and methods used.

5. Delignification of wood parts.
Delignification of wood surfaces in a cooling tower proceeds by two basic mechanisms: chemical attack and biological attack.

The chemical attack is a function of high alkalinity content of the circulating water which is generally a function of high alkalinity of make-up water. This condition is alleviated by pH control, usually with sulfuric acid.

A more important delignification mechanism is the attack on the wood or fill cellulose by fungi. Their control is by preservative coatings on wood surfaces, and chlorination and/ or non-oxidizing biocides.

It should be noted that wood preservative methods have included the impregnation of the wood, prior to usage, with a copper salt followed by an arsenic salt to precipitate copper arsenic within the wood or the impregnation of the wood with creosote.

Without specific consideration to the type of make-up water to be used in any given drift-generating cooling device, it is seen that chemical additives are in routine use for reasons which include:

a. The assurance of continued effective heat removal.
b. The reduction of metal and wood deterioration.
c. The minimization of investment and utility costs.
d. The influencing and development of design practices.
e. The making practical of less costly designs

The consideration of make-up water in the form of recycled industrial, municipal and/or agricultural wastewater must now be evaluated in respect to treatment requirements necessary for proper operation of an appropriate cooling device as well as for the presence of pathogens and/or toxic chemicals that will pass through the device. This becomes necessary based on the premise that each drift particle droplet will be a microcosm of the water mixture within the cooling device itself.

In any given operational environs, the make-up water will be a function of local and prior usage by industrial, municipal and agricultural sources. It will be affected by the degree of reclamation treatment by each user prior to their recycle efforts. This

treatment effort may range anywhere from 0-100%. On this basis, specific categorization of any given water source, in general, will be difficult without prior knowledge of its past and present history, and knowledge of constituent residence times. In these considerations radiological waste discharges are also important. Of equal importance is the water source itself, its size (volume), flushing rate and/or drainage, or percolation rate separate from the constituent residence time.

In terms of industrial wastes and to some extent agricultural wastes, broad categories can be defined immediately with some brief delineations:

1. Wastes Containing Mineral Impurities.
   Examples of wastewater containing large and/or detrimental amounts of mineral impurities are steel-pickling liquors, copper-bearing wastes, electroplating wastes, oil-field brines, petroleum refinery wastes and mining wastes.

2. Wastes Containing Organic Impurities.
   The most important organic waste producers are milk-processing plants, meat packing establishments, breweries, distilleries, canneries, and medical institutions (e.g. hospitals, nursing homes).

   It is noted that stock-yards associated with meat-packing are also a source of organics and pathogenic organisms.

3. Wastes Containing Both Organic and Mineral Impurities.
   Some examples include the textile industry, laundries, tanneries and paper mills, as well as the fertilizer industry.

4. Radioactive Wastes.
   The wastes may originate in hospitals and research laboratories and in the laundries serving them; in water-cooled nuclear reactors and chemical plants that process reactor fuels; and from mining operations.

The types of substances potentially present in cooling device drift due to agricultural and industrial wastes, internal reactions, leachate, runoff and other surface waters were considered and incorporated into the inventory of toxic substances. Many of the substances examined are known or suspected carcinogens. A list of such substances was supplied by EPA Corvallis and then expanded to include others of interest. Table 3 is a listing of the toxic substances included in the inventory.

TABLE 3

TOXIC SUBSTANCES POTENTIALLY PRESENT IN

COOLING MAKE-UP WATER

Acenaphthene

Acetone

Acreolein

Acrylonitrile

Aldrin

Antimony and compounds

Arsenic and compounds

Asbestos

Benzene

Beryllium and compounds

Biphenyl

1, 2 Bis-chloroethyoxy ethane (haloether)

Bromochlorobenzene (chlorinated benzene)

Cadmium and compounds

Carbon tetrachloride

Chlordane

Chlorinated benzenes

Chlorinated ethanes

Chlorinated napthalene

Chlorine

Chloroform

2-Chlorophenol

Chromium and compounds

Copper and compounds

Cyanides (barium, calcium, hydrogen, potassium, sodium, zinc)

DDT and metabolites

Diabyl ethers

Dichlorobenzenes

Dichlorobenzidine

Dichloroethylene

2, 4 Dichlorophenol

Dichloropropane and Dichloropropene

Dieldrin

2, 4 Dimethylphenol

2, 6 Dinitrotoluene

Diphenylhydrazine

Endosulfan and metabolites

Endrin and metabolites

Ethylbenze

Haloether

Halomethane

Heptachlor and metabolites

Hexachloro 1,3 Butadiene

Isophorone

Lead and inorganic compounds

Lindane

Mercury and compounds

Methyl ethyl ketone (Butanone)

Naphthalene

Nickel and compounds

Nitrites

Nitrobenzene

Nitrophenols (m,o,p)

Nitrosamines

Pentachlorophenol

Phenols

Polychlorinated biphenyl's (pcb's)

Phthalate esters

Secondary amines

Selenium and compounds

Silver and compounds

Sodium chloride

Styrene

Thallium and compound

Toluene

Toxaphene

Vinyl chloride

Zinc and compounds

RESULTS OF TASK I - ATTENUATION OF ORGANISMS AND SUBSTANCES

Naturally, not every toxin or pathogen found in sources of make-up water will enter the cooling device. As stated earlier, the quantity of toxic materials in surface waters is being attenuated in a effort to reduce point source pollution. "Common" pathogens, generally bacteria, are attenuated through the processes of chlorination, and occasionally sedimentation, filtering or addition of biocides.

The initial inventory of pathogens and toxins was screened for attenuation through water treatment. For the purposes of our study, there are three general classifications of treatment; physical, chemical and biological.

Physical treatment normally includes settling, centrifugation, filtration and UV or nuclear radiation. Conceivably heat or sonic energy could also be used. Chemical treatment is by chlorination, or other biocides (e.g. silver, organic alogens) and control of pH. More specific processes such as addition of corrosion inhibitors, or measures required by specific industries are also included. Biological treatment encompasses any of the methods presently employed in treatment of sludge and sewage.

The following matrices (Tables 4 and 5), screen the inventory of pathogens and toxins indicating those which would not be attenuated by any means of wastewater treatment or natural purification processes. This study is primarily concerned with these substances and organisms. It is expected that due to the inability to control these, cooling device operators should be concerned with their possible dissemination.

Within the tables, the attenuating treatment(s) is identified for each pathogen and toxic substance in our inventory. Because some of these substances may only be treated by one type of treatment process, and others by two or three, there is a distinction made between those retained for a worst case situation.

Under the status column are the letters P,S,T, or W. These indicate the following:

P - Is not attenuated by any treatment process. This pathogen is of primary importance.
S - Attenuated by one process, therefore, the organism or substance is of secondary importance. It would be a significant concern should the appropriate treatment

process fail for any of these.

T - These pathogens or toxins can be controlled by two processes. It is less likely that both treatments should fail, or not be applied. Therefore, these are of tertiary concern.

W - It is least likely that pathogens and toxins which may be treated by all three types of treatment processes will be present in make-up water. These are reserved for a worst case situation.

TABLE 4

ATTENUATION OF PATHOGENS

AND STATUS IN MAKE-UP WATER

PATHOGEN	TREATMENT PROCESS			STATUS
	Biological	Chemical	Physical	
Absidia corymbifera	x	x	x	W
Absidia ramosa	x	x	x	W
Acanthamoeba (Naegleria)				
Actinomyces israeli		x	x	T
Actinomyces keratolytica	x	x	x	W
Actinomyces spp.		x	x	T
Adenovirus and Parainfluenza				P
Aspergillus spp.	x	x	x	W
Aspergillus flavus	x	x	x	W
Aspergillus fumigatus	x	x	x	W
Aspergillus nidulans	x	x	x	W
Aspergillus niger	x	x	x	W
Aspergillus niveus	x	x	x	W
Aspergillus restrictus	x	x	x	W
Aspergillus terreus	x	x	x	W
Bacillus anthracis			x	S
Bacillus cereus	x	x	x	W
Bacillus subtilis		x	x	T
Bacteroides spp.	x	x	x	W
Basidiobolus haptosporus	x	x	x	W
Blastomyces dermatitidis	x	x	x	W
Bordettela spp.	x	x	x	W
Bordettela parapertussis	x	x	x	W
Brucella abortus		x		S
Brucella canis		x		S
Brucella melitensis		x		S
Brucella suis		x		S
Candida albicans		x	x	T

P - of primary concern
S - of secondary concern
T - of tertiary concern
W - retain for worst case

TABLE 4

ATTENUATION OF PATHOGENS

AND STATUS IN MAKE-UP WATER

PATHOGEN	TREATMENT PROCESS			STATUS
	Biological	Chemical	Physical	
Candida spp.		x	x	T
Cladosporium spp.		x	x	T
Clostridium botulinum			x	S
Clostridium perfingens	x	x	x	W
Clostridium tetani			x	S
Coccidioides immitis		x	x	T
Conidiobolus coronatus		x	x	T
Corynebacterium diptheriae		x	x	T
Corynebacterium spp.		x	x	T
Corynebacterium ulcerans		x	x	T
Cryptococcus neoformans		x	x	T
Dermatophilus congolensis	x	x	x	W
Echovirus, Coxsackie A & B, Polio				P
Enterobacteriaceae	x	x	x	W
Escherichia coli	x	x	x	W
Fuscobacterium spp.	x	x	x	W
Geotricium candidium	x	x	x	W
Haemophilus aegyptius	x	x	x	W
Haemophilus influenzae	x	x	x	W
Histoplasma capsulatum		x	x	T
Klebsiella pneumonia				
Listeria monocytogenes	x	x	x	W
Mucor pusillus		x	x	T
Mucor ramosissimus		x	x	T
Mucor spp.		x	x	T
Mycobacterium spp.		x	x	T
Mycobacterium tuberculosis	x	x	x	W
Nocardia asteroides		x	x	T

P - of primary concern
S - of secondary concern
T - of tertiary concern
W - retain for worst case

TABLE 4

ATTENUATION OF PATHOGENS

AND STATUS IN MAKE-UP WATER

PATHOGEN	TREATMENT PROCESS			STATUS
	Biological	Chemical	Physical	
Nocardia basiliensis		x	x	T
Nocardia caviae		x	x	T
Peptococcus spp.	x	x	x	W
Peptostreptococcus spp.	x	x	x	W
Phialophora spp.		x	x	T
Proteus mirabilis	x	x	x	W
Prototheca spp.	x	x	x	W
Pseudomonas aeruginosa	x	x	x	W
Pseudomonas mallei		x	x	T
Pseudomonas pseudomallei	x	x	x	W
Rhinocladiella spp.		x	x	T
Rhizopus arrhizus		x	x	T
Rhizopus oryzae		x	x	T
Salmonella spp.	x	x	x	W
Salmonella typhi	x	x	x	W
Shigella boydii	x	x	x	W
Shigella dysenteriae	x	x	x	W
Shigella flexneri	x	x	x	W
Shigella sonnei	x	x	x	W
Shigella spp.	x	x	x	W
Sporothrix schenckii	x	x	x	W
Staphylococcus agalactiae	x	x	x	W
Staphylococcus aureus	x	x	x	W
Staphylococcus spp.	x	x	x	W
Streptococcus faealis	x	x	x	W
Streptococcus pneumoniae		x	x	T
Streptococcus pyogenes		x	x	T
Streptococcus pyogenes (Group A)	x	x	x	W

P - of primary concern
S - of secondary concern
T - of tertiary concern
W - retain for worst case

TABLE 4

ATTENUATION OF PATHOGENS

AND STATUS IN MAKE-UP WATER

PATHOGEN	TREATMENT PROCESS			STATUS
	Biological	Chemical	Physical	
Streptococcus spp.	x	x	x	W
Torulopsis glabrata	x	x	x	W
Vibrio parahemolyticus	x	x	x	W
Yersinia enterocolitica	x	x	x	W
Yersinia pestis (Pasteurella)	x	x	x	W
Yersinia pseudotuberculosis	x	x	x	W
Zygomycetes (Phycomycetes)	x	x	x	W
Var. Nematodes, Protozoans, and viruses				P

P - of primary concern
S - of secondary concern
T - of tertiary concern
W - retain for worst case

TABLE 5

ATTENUATION OF TOXIC SUBSTANCES

AND STATUS IN MAKE-UP WATER

TOXIC SUBSTANCE	TREATMENT PROCESS			STATUS
	Biological	Chemical	Physical	
Acenaphthene			x	S
Acetone	x		x	T
Acrolein			x	S
Acrylonitrile			x	S
Aldrin			x	S
Antimony and compounds		x	x	T
Arsenic and compounds		x		S
Asbestos				S
Benzene	x		x	T
Benzidine			x	S
Beryllium and compounds		x		S
Biphenyl		x	x	T
Cadmium and compounds		x		S
Carbon Tetrachloride			x	S
Chlordane			x	S
Chlorinated Benzene			x	S
Chlorinated Ethanes			x	S
Chlorinated Ethylenes			x	S
Chlorinated Napthalene			x	S
Chlorine			x	S
Chloroform			x	S
2-Chlorophenol			x	S
Chromium and compounds		x		S
Copper and compounds		x		S
Cyanides		x		S
DDT and metabolites			x	S
Diabyl Ethers			x	S
Dichlorobenezenes			x	S

P - of primary concern
S - of secondary concern
T - of tertiary concern
W - retain for worst case

TABLE 5

ATTENUATION OF TOXIC SUBSTANCES

AND STATUS IN MAKE-UP WATER

TOXIC SUBSTANCE	TREATMENT PROCESS			STATUS
	Biological	Chemical	Physical	
Dichlorobenzidine			x	S
Dichloroethylene			x	S
2,4 Dichlorophenol			x	S
Dichloropropane and Dichloropropene			x	S
Dieldrin			x	S
2,4 Dimethyl Phenol	x		x	T
2,6 Dinitrotoluene	x		x	T
Diphenylhydrazine			x	S
Endosulfan and metabolites			x	S
Endrin and metabolites			x	S
Ethylbenzene	x		x	T
Halo Ether			x	S
Halo Methane			x	S
Heptachlor and metabolites			x	S
Hexachloro-1,3-Butadiene			x	S
Isophorone			x	S
Lead & inorganic compounds		x		S
Lindane			x	S
Mercury and compounds		x		S
Methyl Ethyl Ketone (Butanone)	x		x	T
Naphthalene	x		x	T
Nickel and compounds		x		S
Nitrites			x	S
Nitrobenzene	x		x	T

P - of primary concern
S - of secondary concern
T - of tertiary concern
W - retain for worst case

TABLE 5

ATTENUATION OF TOXIC SUBSTANCES

AND STATUS IN MAKE-UP WATER

TOXIC SUBSTANCE	TREATMENT PROCESS			STATUS
	Biological	Chemical	Physical	
Nitrophenols (m,o,p)			x	S
Nitrosamines			x	S
Pentachlorophenol			x	S
Phenols			x	S
Phthalate Esters	x	x	x	W
Polychlorinated Biphenyl's (PCB's)			x	S
Secondary Amines			x	S
Selenium and compounds		x	x	T
Silver and compounds		x		S
Sodium Chloride			x	S
Styrene			x	S
Thallium and compounds		x	x	T
Toluene	x		x	T
Toxaphene			x	S
Vinyl Chloride			x	S
Zinc and compounds		x		S

P - of primary concern
S - of secondary concern
T - of tertiary concern
W - retain for worst case

After screening the lists of pathogens and toxins and their methods of attenuation, a "FAILURE" list was derived. The pathogens included in this list, Table 6, are retained to be used in generating "WORST CASE" probabilities, should all methods of attenuation fail.

The same screening was applied to the list of toxins. It was determined that none may be retained in a "FAILURE" list. The toxic substances which are being examined in this study may only be attenuated by one or two of the possible three types of treatment. Because they have fewer means of control, toxic substances are more subject to treatment system failure.

TABLE 6

PATHOGENS POTENTIALLY PRESENT ONLY IN A WORST CASE SITUATION

Absidia corymbifera
Absidia ramosa
Actinomyces keratolytica
Aspergillus flavus
Aspergillus fumigatus
Aspergillus nidulans
Aspergillus niger
Aspergillus restrictus
Aspergillus terreus
Bacillus cereus
Bacteroides spp.
Basidiobolus haptosporus
Blastomyces dermatitidis
Brodetella spp.
Bordetella parapertussis
Clostridium perfingens
Dermatophilus congolensis
Enterobacteriaceae
Escherichia coli
Fuscobacterium
Geotrichium candidium
Haemophilus aegyptius
Haemophilus influenza
Listeria monocytogenes
Mycobacterium tuberculosis
Peptococcus spp.
Peptostriptococcus spp.
Proteus mirabilis
Prototheca spp.
Pseudomonas aeruginosa
Pseudomonas pseudomallei
Salmonella spp.
Salmonella typhi
Shigella boydii
Shigella dysenteriae
Shigella flexnei
Shigella sonnei
Shigella spp.
Sporothrix schenckii
Staphylococcus agalactiae
Staphylococcus aureus
Staphylococcus spp.
Streptococcus faealis
Streptococcus pyogenes (Group A)
Streptococcus spp.
Torulopsis glabrata
Vibrio parahemolyticus
Yersinia enterocolitica
Yersinia pestis (Pasteurella)
Yersinia pseudotuberculosis
Zygomycetes (Phycomycetes)

Aerosolization of Organisms and Substances.

The next step was to screen the remaining pathogens and all of the toxic substances to determine which could become aerosolized. The results are shown in Tables 7 and 8.

Essentially the pathogens and toxins which are listed in these tables are those with which cooling device operators should be most concerned. These may be controlled by only one or two means of treatment, if any. Should the appropriate means fail, these organisms and substances may become aerosolized. Further evaluation in the study discusses the aerosol transport of, and potential health effects on plant, animal and human life from these pathogens and toxins.

Complete discussion of the treatment methods and aerosolization of each pathogen and toxin is found in the Catalogue of Aerosol Drift Health Hazard Assessment, Appendix A. (Volume II)

TABLE 7

SCREENED PATHOGENS CAPABLE OF BECOMING AEROSOLIZED

Actinomyces israeli
Actinomyces spp.
Bacillus anthracis
Bacillus subtilis

Brucella abortus
Brucella canis
Brucella melitensis
Brucella suis

Candida albincans
Candida spp.
Cladosporium spp.
Clostridium botulinum

Clostridium tetani
Coccicioices immitis
Conidiobolus coronatus
Corynebacterium spp.

Corynebacterium ulcerans
Cryptococcus neoformans
Histoplasma capsulatun
Mucor pusillus

Mucor rámossissimus
Mucor spp.
Mycobacterium spp.
Nocardis asteroides

Nocardia brasiliensis
Nocardia caviae
Phialophora spp.
Pseudomonas aeruginosa

Pseudomonas mallei
Rhinocladiella spp.
Rhizopur arrhizus
Rhizopus oryzae

Streptococcus pneumoniae
Streptococcus pyogenes
Var. nematodes, protozoans and Viruses

TABLE 8

TOXINS CAPABLE OF BECOMING AEROSOLIZED

Acetone
Acrolein
Acrylonitrile
Arsenic and compounds

Asbestos
Benzene
Cadmium and compounds
Carbon Tetrachloride

Chlordane
Chlorinated Ethanes
Chlorinated Ethylenes
Chlorine

Chloroform
2-Chlorophenol
Cyanides
2, 4 - Dichlorophenol

Dieldrin
2, 4 - Dimethylphenol

Endrin and metabolites
Halomethane
Heptachlor and metabolites
Mercury and compounds

Methyl Ethyl Ketone (Butanone)
Napthalene
Nitrites
Nitrobenzenes

Nitrophenols (m,o.p)
Nitrosamines
Pentachlorophenol
Phenols

Secondary Amines
Selenium and compounds
Styrene
Toluene

Vinyl Chloride

RESULTS OF TASK II - TRANSPORT

The function of this task is to provide the necessary information for determining the potential for the transport of pathogenic organisms and toxic substances via atmospheric dispersion of drift produced by cooling systems. The function of a cooling system is to move waste heat from a primary system to a heat sink, usually air or water, where the heat is dissipated. Of the many types of cooling systems, the ones that produce drift utilize evaporative cooling where heat is dissipated to the atmosphere by evaporation of a portion of the water used for cooling. The vast majority of evaporative cooling systems utilize cooling towers.

In the process of circulating water through a cooling tower, a small percentage of the water splashing over the fill becomes entrained in the exiting air flow. The entrained water is in the form of liquid droplets. These droplets constitute the cooling

tower drift and have essentially the same chemical composition as the circulating water. The drift droplets are dispersed into the atmosphere and deposited downwind of the tower. Therefore, if there are pathogenic and/or toxic substances present in the circulating cooling water, these same substances can be transported from the cooling tower into the atmosphere as part of a liquid droplet. A number of droplets reach the ground before they have completely evaporated. Any pathogens or toxins found in the remaining droplets evaporate reaching the ground as dry particles.

In order to evaluate the potential for the transport and survival of pathogenic and toxic substances released in drift it is necessary to know the cooling device and power plant design conditions and the concentrations of pathogenic microorganisms and toxic substances in the make-up water.

Cooling Tower Internal Conditions.

As stated, any one common set of specified internal cooling tower air and water parameters can be duplicated in all types of evaporative cooling towers. Therefore, the air and water conditions that do exist in a cooling tower are primarily dependent on performance criteria specified by the power plant designer, not on the type of cooling tower.

Typical water and air conditions in an evaporative cooling tower used in a large power plant application are as follows:

1. Incoming Air Temperature.

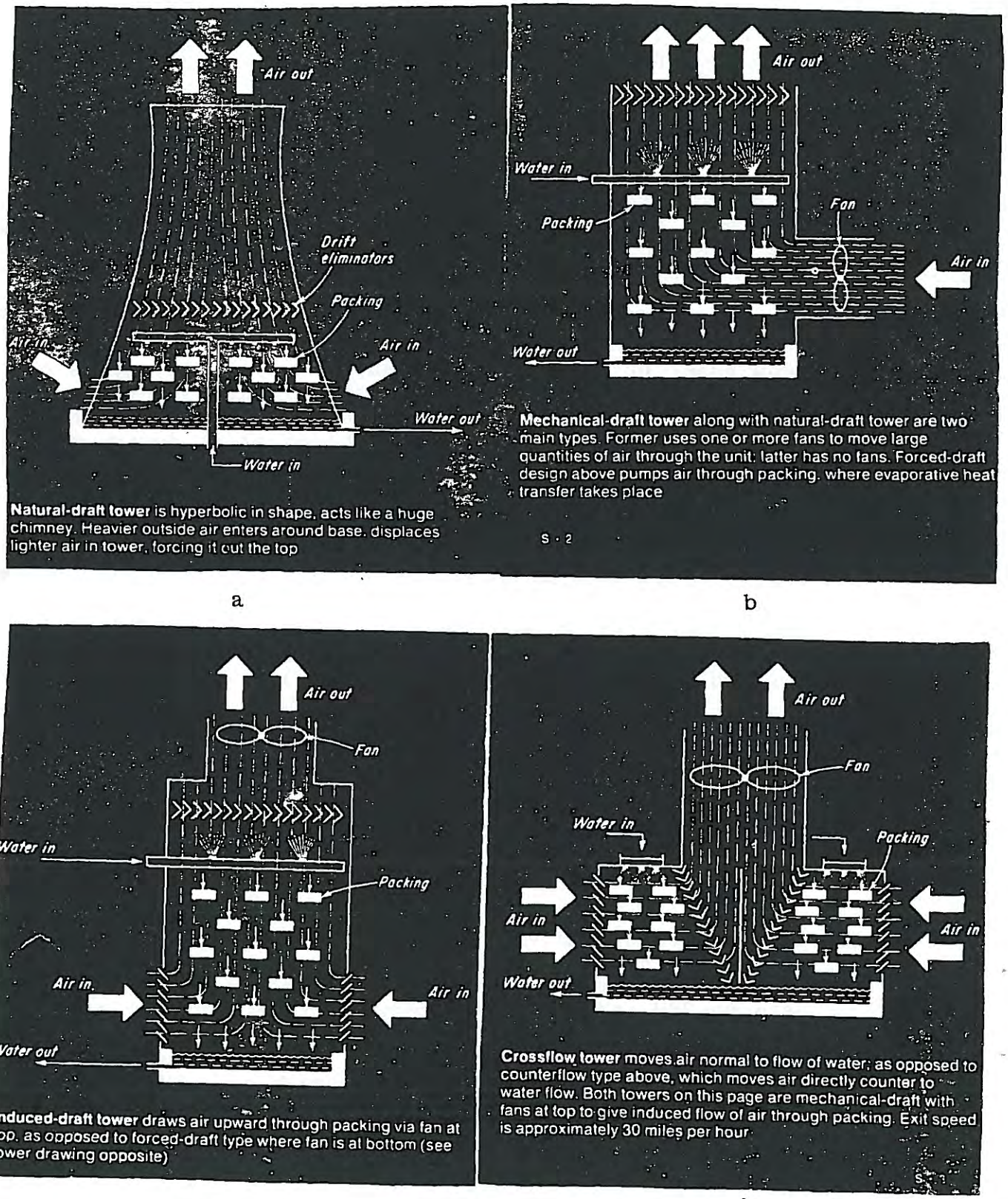
   The incoming air temperature is dependent on geographic location and time of year. Design conditions can range between 19° - 28°C WB (WB = wet bulb). The design condition is the wet bulb temperacure which will not be exceeded more than 5-10 percent of the time.

   Toxins and pathogens will survive in these incoming temperatures. The most common temperatures used to incubate bacteria range from 20°C - 37°C.

2. Cooling Tower Plume Exit Temperature and Relative Humidity.

   The temperature of the plume exiting the cooling tower depends on the incoming air temperature and the temperature of the water entering the cooling tower. Values between 28° and 38°C are common, but higher exit temperatures do occur (43°C would not be abnormal). Under most conditions the plume exiting the tower is very near saturation (or 100 percent relative humidity). Therefore, the temperatures given arè dry bulb and wet bulb.

FIGURE 3
TYPICAL NATURAL AND MECHANICAL DRAFT COOLING TOWERS



SOURCE: (ELLIOT, 1973)

Again these temperatures are within the optimal range of incubation temperatures. The most common temperature used to incubate total coliform bacteria is 35°C; and 45°C for fecal coliforms. The toxins with which we are concerned should remain stable.

3. Plume Exit Velocity.

   Mechanical draft towers emit drift at the rate of 35 ft/sec. Natural draft towers give off plumes at the approximate rate of 5 ft/sec. It is at these speeds that pathogens or toxins entrained in the drift will be emitted.

4. Cooling Tower Exit Water Temperature (cold water temperature).

   This temperature is in practice the same as the temperature of the water in the cooling tower basin. Since the design cooling range of most large towers is 11°C - 17°C, the cold water temperature is usually between 32°C - 38°C, a favorable range for most bacteria. This is not expected to affect chemical substances.

Relevant Power Plant Design Information.

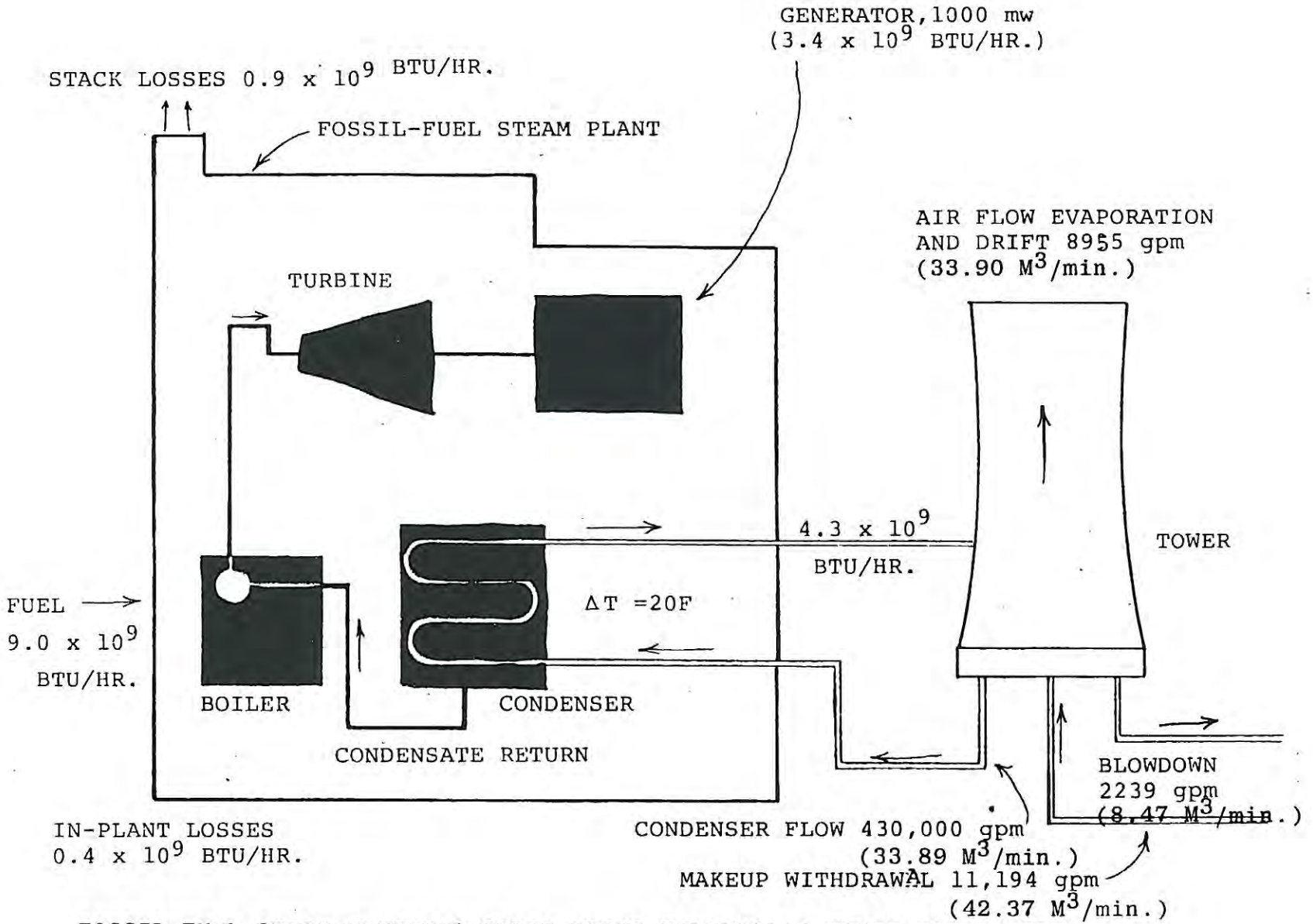
Simplified flow diagrams for typical 1000/MW fossil-fuel and nuclear power plants are given in Figures 4 and 5. The following concepts are pertinent to our discussion of tower design parameters.

1. The circulating water (i.e. the water flowing from the cooling tower to the condenser and back to the cooling tower) never comes in physical contact with the main steam from the turbine or the condensate return.

   Although temperatures do exist in a typical power plant which would thermally destroy pathogens, since the circulating water is not exposed to these conditions, any pathogens present, will not be destroyed by exposure to extreme heat.

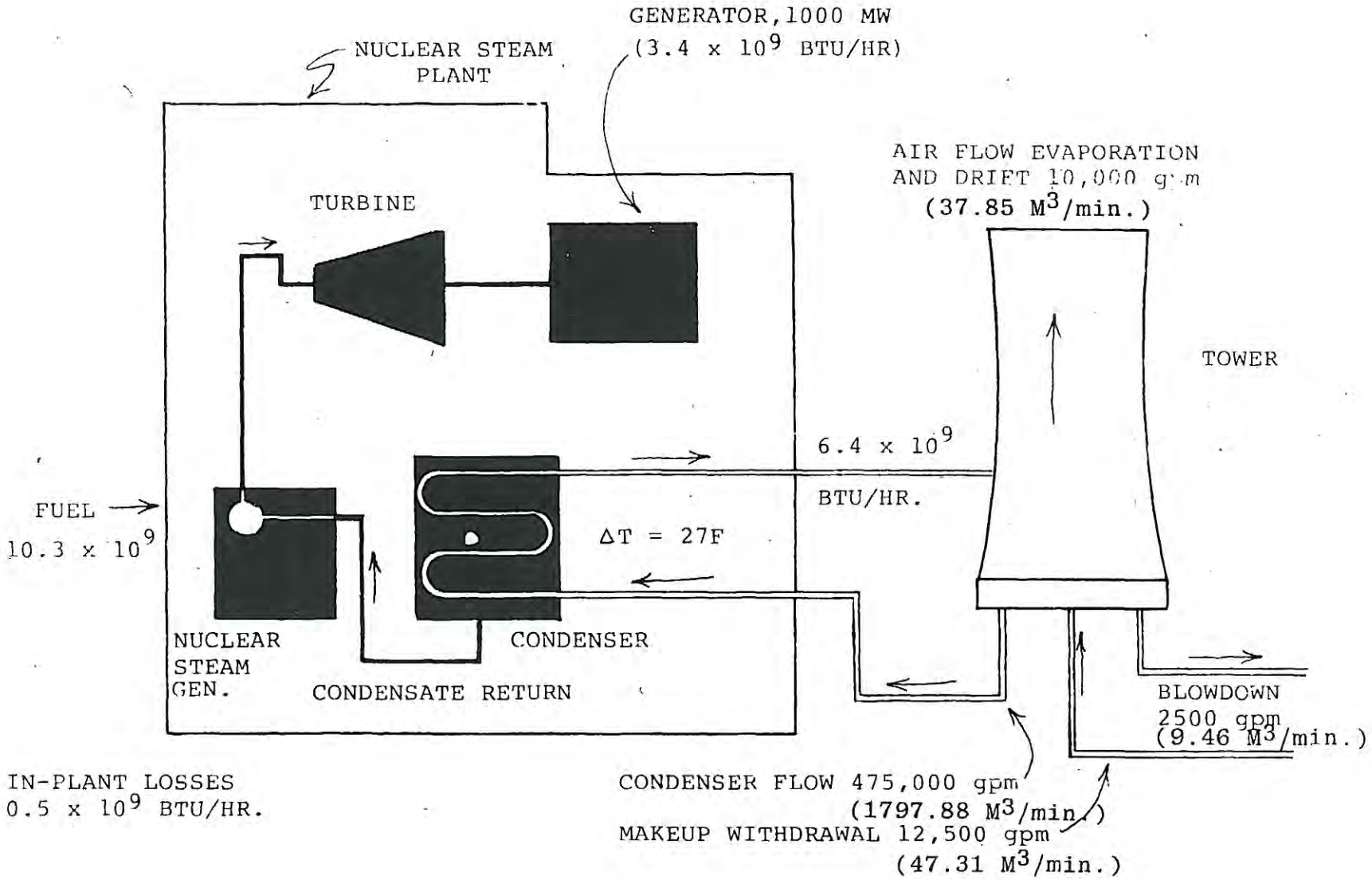
2. The time it takes for the circulating water to make one "round trip" (i.e., from the cooling tower basin to the condenser, back to and through the cooling tower) can vary between 2.5 minutes and approximately 2 hours. This is dependent on the size of the tower basin.

   If pathogens are capable of surviving, and toxins remain stable in water, whether they are exposed for two minutes or two hours should have no effect.



FOSSIL-FUEL STEAM ELECTRIC PLANT USING HYPERBOLIC TOWER HAS A HEAT BALANCE AS SHOWN FOR 1000-MW CAPACITY

FIGURE 4



NUCLEAR STEAM-ELECTRIC PLANT USING HYPERBOLIC TOWER HAS A HEAT BALANCE AS SHOWN FOR 1000-MW CAPACITY.

FIGURE 5

3. The amount of water released as drift is approximately 0.005 percent of the circulating water flow. In a modern cooling tower the drift rate can be as low as 0.001 percent. The amount of water released through evaporation is approximately 2.0 percent of the circulating water flow. The amount of water released as blowdown is approximately 0.5 percent of the circulating water flow. The amount of make-up water (i.e., water usually taken from a river, lake or ocean to replace the water losses given above is approximately 2.5 percent of the circulating water flow.

   These factors may be used in calculating the water loss through drift emission. If the concentrations of pathogens and toxins in the water are known then one can roughly calculate the quantity of these agents emitted in drift.

4. The time that the circulating water is actually circulating through the condenser is on the order of 10-20 seconds. The temperature of the saturated steam entering the condenser is typically about 103°C. The temperature of the condensate return is approximately 88°C - 93°C.

Chemical Treatment of Circulating Water.

A large range of treatment chemicals are available today to meet the four major categories of cooling water problems - corrosion, scale and deposits, fouling, and microbiological growth. Some of the major chemicals used in cooling tower circulating water treatment are identified in Table 9. These are among the candidates for consideration in this study.

The most commonly used chemical corrosion inhibitors are chromates, polyphosphates, zinc, molybdenum, ferro-cyanides, and organics. Chromic acid and its salts provide the base for the most popular and cost/effective corrosion inhibitors in use today. The chromates, considered anodic inhibitors, are often formulated with other inhibitors such as zinc, molybdenum and phosphates. The discharge of chromate, in its hexavalent state, is likely to be severely restricted as we proceed into an era of greater regulatory control and enforcement. The most commonly accepted effluent guideline limits plant chromate discharges to 0.05 mg/l as hexavalent chromium and total chromium to 1.0 mg/l and less in many individual situations.

At the present, chlorine is the most popular oxidizing agent used to control microbiological growth. Chlorine is usually batch fed; an average application might be 0.5 mg/l chlorine for one-half hour every four hours.

TABLE 9

COMMON WATER TREATMENT CHEMICALS

Chemical	Purpose	Concentration
Chlorine (usually batch fed)	microbiocide	1-2 ppm free chlorine for 2-4 hours
chromates	corrosion inhibitor	20-40 ppm
zinc	used in conjunction with chromate	2-3 ppm
Phosphates	corrosion inhibitor (substituted for chromates)	4-6 ppm as total phosphate
Polymers (e.g. poly acrylic acids)	silt dispersion	5-10 ppm
Phosphonates	scale control	5-10 ppm

The phosphonates represent a relatively new and extremely useful class of scale control agents. Several types of these compounds may be found in general cooling water scale control use. Among the most popular versions is an aminomethylene-phosphonate compound that employs the highly stable carbon to phosphorus bond.

Some of the commonly used scale inhibitors are polyphosphates, phosphonates, phosphate esters, polyacrylates, and sulfonated polystyrenes. In addition to being classified as corrosion inhibitors, the polyphosphates may also function as scale inhibitors at "threshold" levels. It is thought that polyphosphate is adsorbed on the growing face of calcite crystals, aborting normal growth patterns and reducing the hard scale normally associated with precipitating calcium carbonate.

Transport of Toxic Substances as a Function of Drift Characterization.

Cooling tower drift is defined as mechanically entrained water droplets which are generated inside the cooling tower and carried along with the air flowing through the tower and exhausted to the environment. (Chen et al. 1977) As defined, these water droplets have essentially the same chemical composition as the circulating water in the cooling tower. Therefore, toxic substances would retain the same concentrations in drift as in the circulating water.

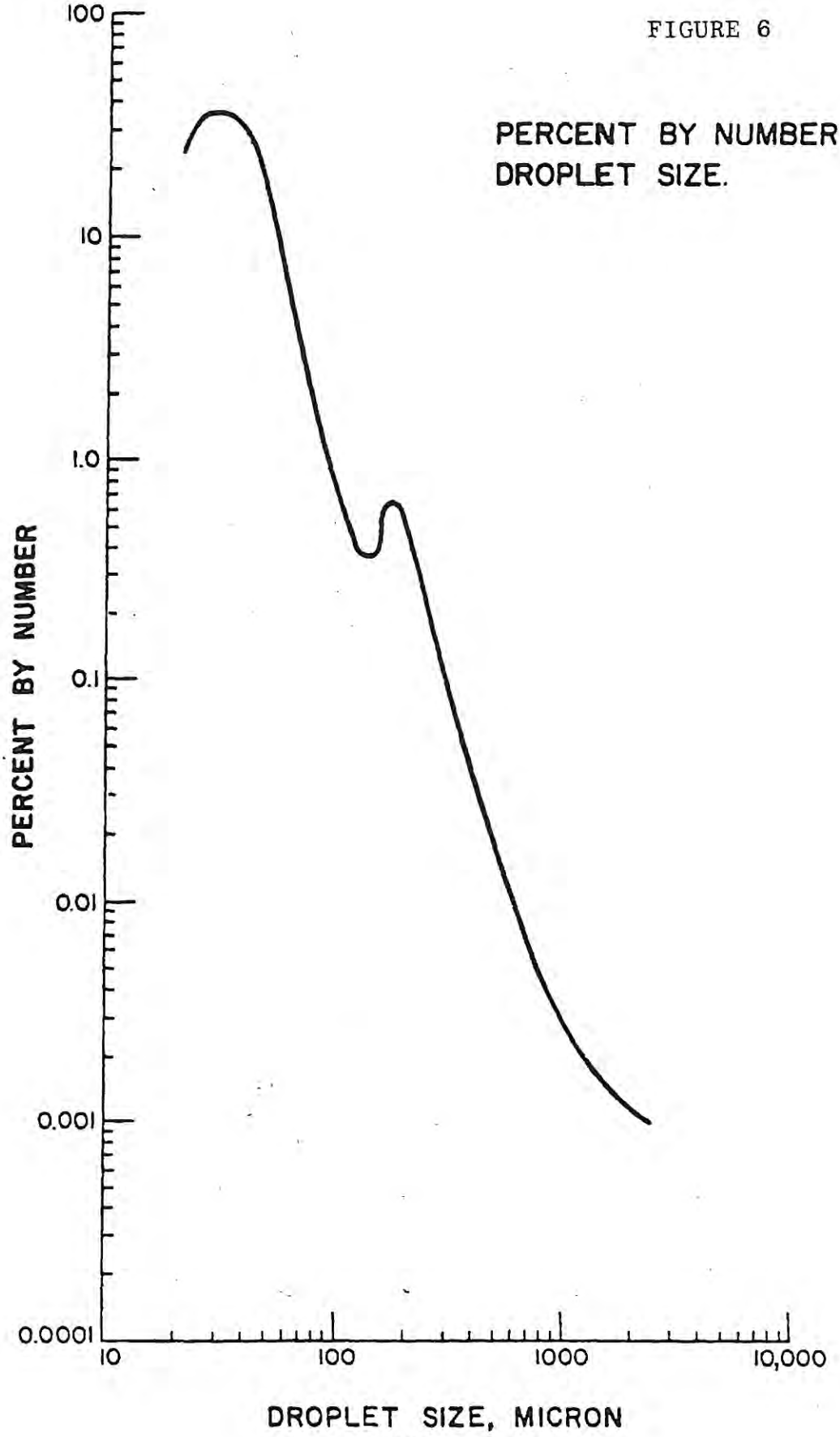
Most drift loss guarantees are quoted as a percent of the circulating water rate with a tacit implication that the drift impurity level is the same as that of the water circulated. We differentiate between drift and the liquid water added to the air due to condensation during the cooling of the tower plume since condensed water is "pure" water. Evaporated water is not objectionable from the standpoint of adding an impurity to the environment. However, the addition of moisture, contributing to a change in relative humidity, may be undesireable. In the evaluation of drift and its potential environmental hazard, we are ultimately interested in the total quantity of drift droplets discharged to the environment, their chemical impurities, and the subsequent behavior of this drift as it interacts with the environment.

To assess the environmental significance of drift it is necessary to establish the actual total drift emission rate from towers of the type found in industry today. The drift particle size and mass distributions must be determined before the dynamic and thermodynamic behavior of the drift as it interacts with the environment can be evaluated.

Particle Size and Mass Distribution.

Figure 6 presents the drift droplet size and mass distribution respectively at the stack discharge based on field tests. (Wistrom and Ovard, 1973). Note that these tests were run on towers where the total drift loss was measured at 0.001 percent of the circulating water rate and therefore, are representative of the current state of the art of drift eliminator designs.

FIGURE 6


PERCENT BY NUMBER VS
DROPLET SIZE.
100
10
1.0
0.1
0.01
0.001
0.0001
PERCENT BY NUMBER
10
100
1000
10,000
DROPLET SIZE, MICRON

KEY TO FIGURE 6

SIZE AND MASS DISTRIBUTION OF DRIFT PARTICLES

DROPLET DIAMETER (MICRON)	% OF SAMPLE BY NUMBER	% MASS BY DROPLET SIZE
22	24.0	0.43
29	36.0	1.49
44	26.0	3.76
58	6.3	2.09
65	4.0	1.86
87	1.4	1.56
108	0.67	1.43
120	0.43	1.26
132	0.28	1.09
144	0.26	1.32
174	0.65	5.81
300	0.11	5.04
450	0.027	4.17
600	0.011	4.01
750	0.0055	4.00
900	0.0033	4.03
1050	0.0024	4.57
1200	0.0019	5.46
1350	0.0016	6.80
2250	0.00095	17.99
2400	0.0010	21.83

Examination of these results reveals several important aspects of drift. First, it is noted that the exhaust drop size distribution is bimodal with peaks in the 35 micrometer and 200 micrometer size ranges respectively. In contrast, natural atmospheric aerosols exhibit a unimodal size distribution. This difference is not surprising when one considers that the air entrained drops in a cooling tower are both generated and removed by mechanical means within a few seconds. Secondly, whether bi-or uni-modally distributed the droplet sizes are capable of carrying two to thousands of particles or bacterium in each droplet.

Fall Velocity of Entrained Droplets

The terminal fall velocity of a drop is established when the aerodynamic drag force is equal to the weight of the drop. It has been shown that larger drops are not spherical, and in fact experience a marked flattening on their lower surface which materially affects fall velocity. The fall velocity drop size relationship is shown in Figures 7 & 8. Droplets smaller than 100 micrometers have fall velocities which are extremely low, indicating that weight of these small drops has a minor influence on their dynamic behavior. Thus, their path and position and that of entrained toxins and pathogens will be primarily governed by aerodynamic forces; most important of which are wind, buoyancy of the exhaust plume, and vertical eddies or turbulence in the atmosphere. Plume buoyancy and vertical atmospheric turbulence will tend to keep these small droplets in suspension for an extended period. The small droplets will essentially follow the plume path and their concentration at any point downwind will be governed by atmospheric dispersion. If the atmosphere is cold, the exhaust air is rapidly cooled and becomes super-saturated. The small drift droplets and entrained particles that remain entrained in the exhaust vapor act as condensation nuclei and tend to grow in size as long as this supersaturated condition remains.

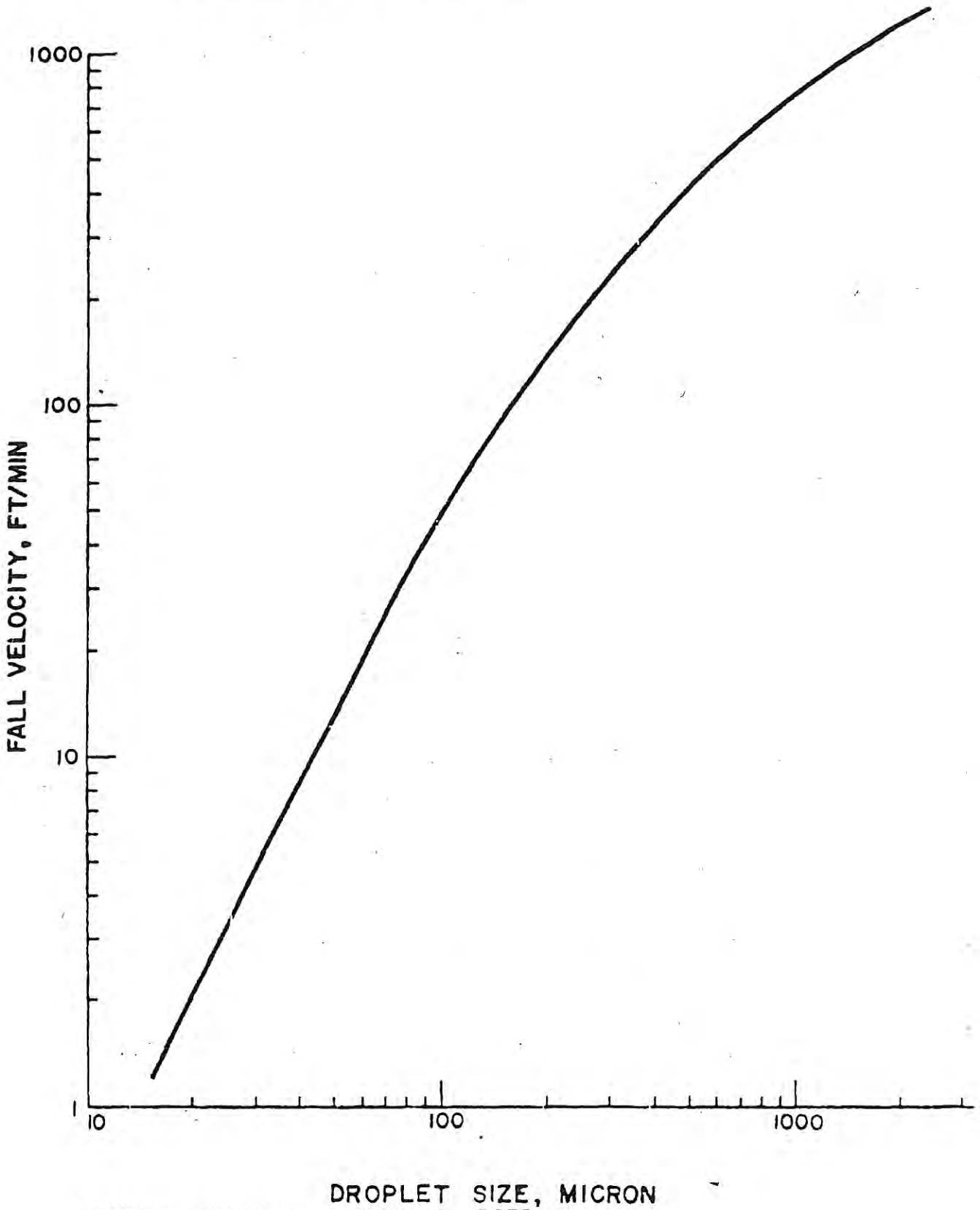
Figure 6 also shows that a few drops in the 1000-2400 micrometer range are present in the exhaust air. Even a casual field observation shows that water droplets in this size range are emitted from a cooling tower since they are clearly visible and easily detected. Field observations and drift size tests conducted directly behind the drift eliminators showed that most of these large droplets are generated in the tower plenum area where impinging drift and vapor condensation accumulates on structural members. Some of this collected moisture is eventually reentrained as larger droplets.

Drift Physics as a Function of Cooling Tower and Power Plant Design Conditions.

In an evaporative cooling tower, the water containing the

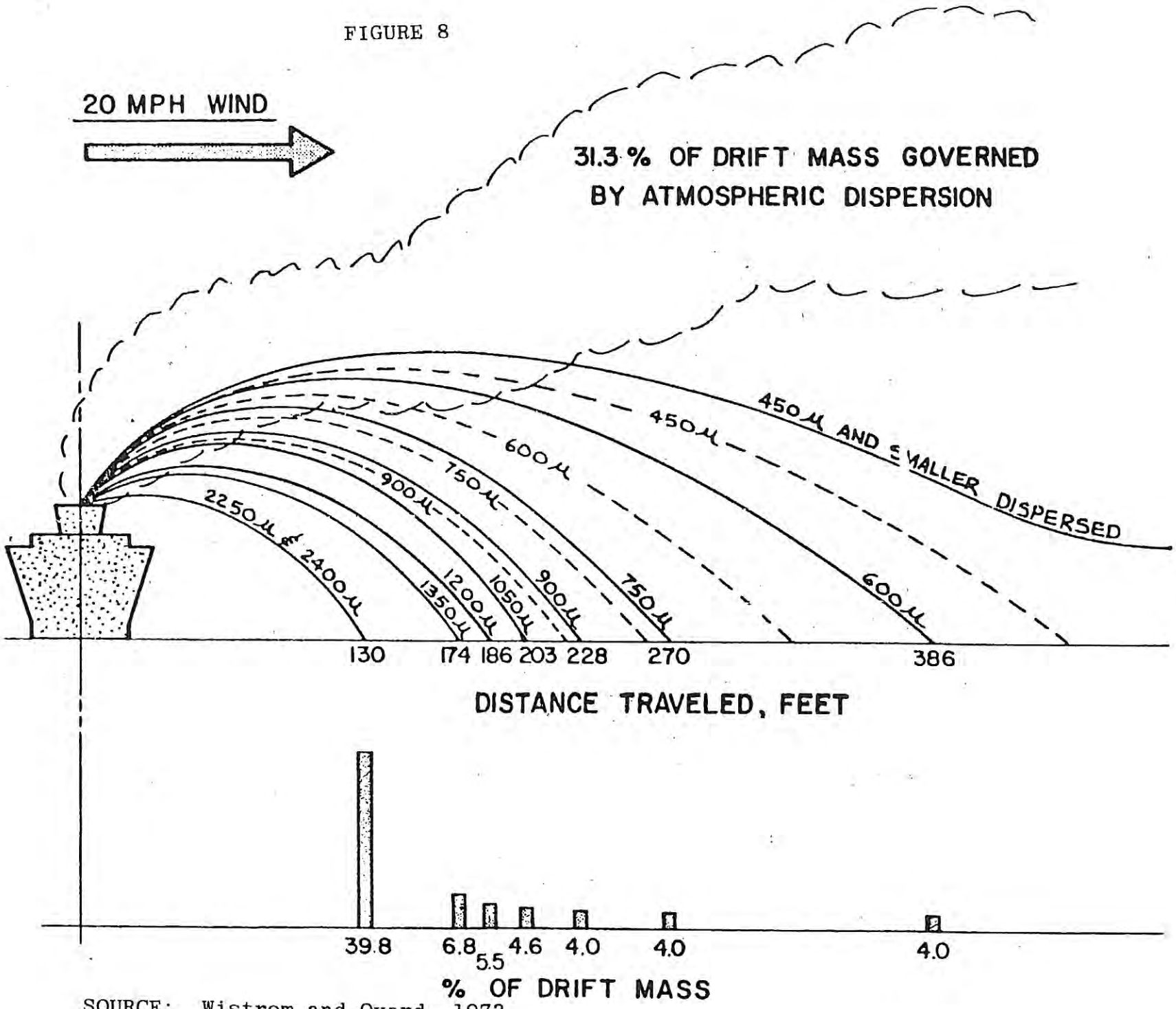
FIGURE 7

FALL VELOCITY OF WATER DROPS
AS FUNCTION OF SIZE



SOURCE: Wistrom and Ovard, 1973

FIGURE 8



SOURCE: Wistrom and Ovard, 1973

waste heat comes in direct contact with the ambient air flowing through the tower. The various types of cooling towers are classified by the method used to create the air movement through them. In natural draft towers, air movement is induced by a large chimney utilizing the density difference between the air inside and outside the chimney. In a mechanical draft tower air is moved by fans; either the induced draft type (ID) that pulls air through the tower or the forced draft type (FD) that pushes air through the tower. Figure 3 (a-c) shows a typical natural draft tower and an induced draft and forced draft mechanical draft cooling tower.

Towers are further classified by the relative flow directions of the air and water in the tower. In a crossflow tower, the air flows perpendicular to the falling water (see Figure 3 (a)). In a counterflow tower the air flows vertically upward, counter to the falling water (see Figure 3 (b, c)).

However, the water and air conditions that exist in a cooling tower are dependent on the performance criteria specified by the design engineer, not on the type of tower or its air flow direction. Any one set of specified internal cooling tower water and air conditions can be duplicated in any of the types of cooling tower described above. The choice of cooling tower is usually made on the basis of economic and environmental considerations rather than on the basis of achieving certain design conditions.

The results presented here are considered typical for most drift eliminator designs. However, variations in the plenum environment and drift eliminator design will have a significant effect on the discharge drop size distribution. The older drift eliminator designs are characterized by the presence of more of the larger drops which appreciably increase the total drift loss and dispersion of a greater quantum of toxins and pathogens.

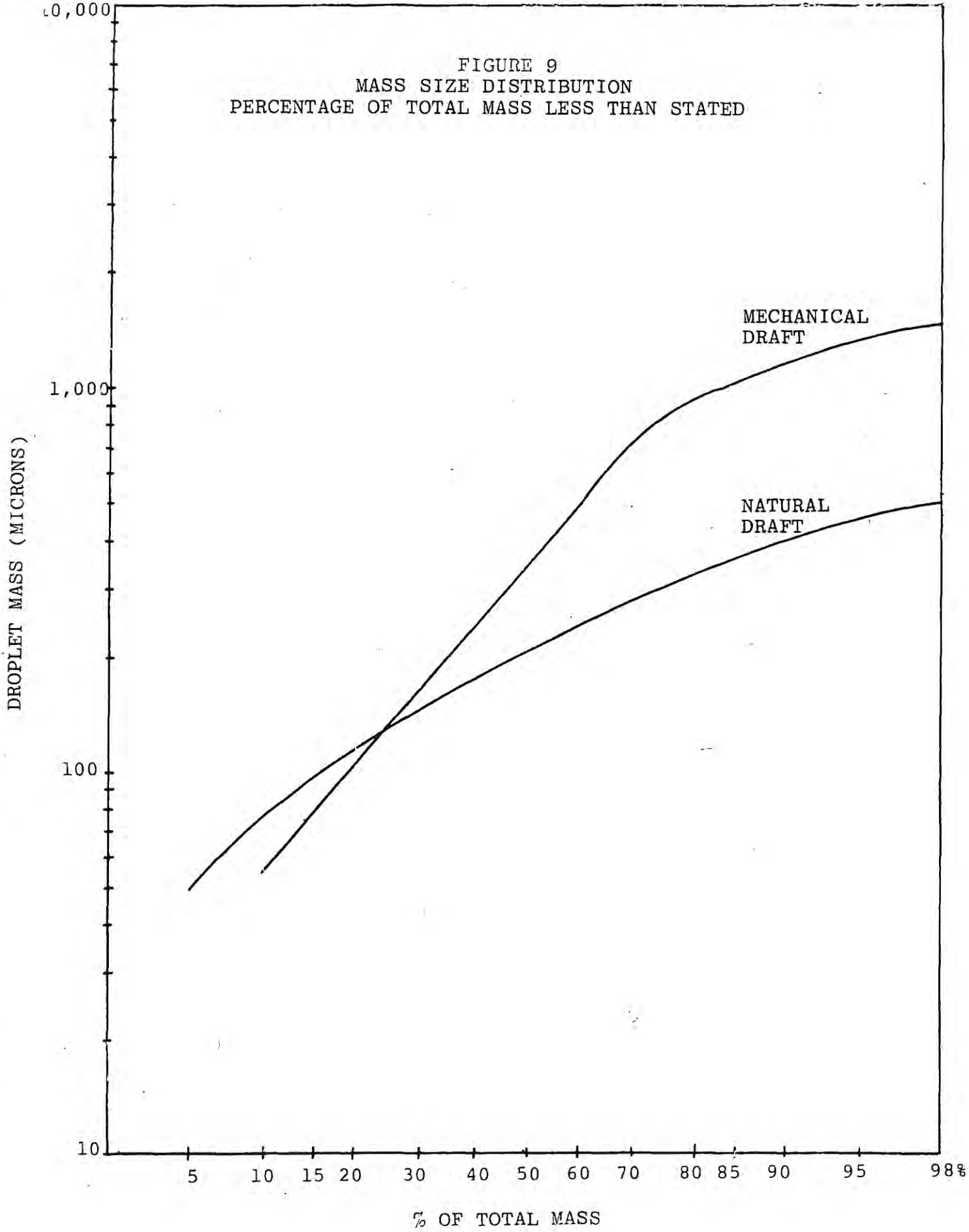
Figure 9 is a drift droplet size distribution after Chen, (1977) averaging 5 different sets of drift dots each for natural draft towers and mechanical draft towers. The only major difference between them is the maximum drop capable of being supported by the plume exit velocity.

Condensation Nuclei

Under ambient atmospheric conditions, natural cloud droplets are formed by the condensation of water vapor onto microscopic particles or condensation nuclei.

In the past, the actual size of these nuclei had only been determined by indirect methods. Recently electron microscopic measurements have been utilized. Presently, condensation nuclei are classified into three size groupings; Aitken, Large and

FIGURE 9
MASS SIZE DISTRIBUTION
PERCENTAGE OF TOTAL MASS LESS THAN STATED



Giant. The size range for each of these classifications is found in Table 10.

Aitken nuclei are the most numerous type in aerosols. Their concentration exceeds that of large nuclei by 2.0 or 2.5 orders. The concentration of giant nuclei is insignificant, on the order of several nuclei per liter of air. The mass of individual nuclei varies between 10^{-15} and 10^{-11} g. Giant nuclei may have a mass as great as 10^{-8}g (see Table 10). Pathogenic and toxic particles, should they form condensation nuclei would constitute aitken nuclei.

Given an initial distribution of particles of every size, particles whose radius is $> 10^{-2}\mu$ become attached to larger particles due to Brownian motion. Those particles with radii greater than 20μ are sufficiently heavy to precipitate out. Both processes result in a distribution of particle size with fixed upper and lower limits. Between these upper and lower limits, the mass is distributed fairly evenly.

Condensation Nuclei Composition

The nature (chemical composition) of condensation nuclei is usually studied via the chemical and spectral analysis of samples of raindrops and cloud droplets. Analysis of rainwater shows the following average composition:

1 mg/l	CI^-
2 mg/l	NA+
3-5 mg/l	CA+
5-10 mg/l	SO_42-
5-15 mg/l	HCO_3^-

Maximum values in the analysis reached 10-15 times greater than these averages, and minimum values 10-20 times smaller. Other substances were also found in smaller amounts.

Impurities may be captured by raindrops during their fall. Analysis of water obtained from cloud droplets indicates the chemical composition of these nuclei. Analyses of aerosol particles collected in various atmospheric layers was carried out by Junge et. al. Chlorides were present in all samples varying between tenths of, and several mg/l.

The most common nuclei were found to contain compounds of chlorine, sulfur, nitrogen, carbon, magnesium, sodium and calcium. Sodium chloride is very frequently encountered in nuclei.

Various types of bacteria and viruses may act as condensation nuclei. A number of species have been determined to be active ice nuclei. They have been observed to initiate ice in supercooled water at -1.3^oC in concentrations of up to 10^8 nuclei active at -5^oC per cubic centimeter of culture. Species

TABLE 10

CHARACTERIZATION OF CONDENSATION NUCLEI

SIZE CLASSIFICATION	RADIUS (cm)	CONCENTRATION (cm^{-3})	MASS (g/M^3)
Aitken	$5X10^{-7}$ - $2X10^{-5}$	42500	17.
Large	$2X10^{-5}$ - $1X10^{-4}$	132	25.
Giant	$1X10^{-4}$ - $10X10^{-4}$	2.195	41.4
Giant distribution	$1X10^{-4}$ - $2X10^{-4}$	2.08	23
	$2X10^{-4}$ - $3X10^{-4}$	0.09	4.2
	$3X10^{-4}$ - $5X10^{-4}$	0.02	5.1
	$5X10^{-4}$ - $10X10^{-4}$	0.005	9.1

that have been specifically identified are Pseudomonas syringae, Pseudomonas fluorescens and Erwinia herbicola. Two other species have not been specifically identified although they have been shown to be active nuclei. Many other species have been tested for their ice nucleating ability, producing negative results.

Condensation and Drop Formation

The essential physics of condensation of water vapor onto acceptable nuclei includes surface tension characteristics, hygroscopic effects, the rate of diffusion of water vapor to the droplet and the rate of conduction of latent heat away from the droplet.

The most important factor involved in the formation of clouds is chilling of humid air, which can happen due to the following causes:

1. adiabatic expansion of air on vertical ascent,
2. turbulent transfer,
3. radiation (radiative chilling).

Cooling of air during adiabatic expansion involves a reduction in pressure. The main factor here is the movement of air into higher atmospheric layers. Average daily drops in atmospheric pressure (5-6 mb/day) chill each layer of air by 1-2° each day. Vertically ascending air, containing unsaturated water vapor, is cooled adiabatically by 1° for each 100 m of ascent.

When convection is well developed the air may rise by a height on the order of kilometers. This would result in a very strong cooling trend. Chilling of the air by turbulent transfer and mixing depends on the vertical distribution of temperature. In a stable stratification the upper portions of the layer in which turbulent transfer takes place will be cooled. If this cooling is accompanied by the transport of nearly saturated water vapor, its condensation may lead to the formation of stratus clouds.

Finally, the third cause of chilling is radiation. This process is manifested by the cooling of air layers containing a large amount of water vapor together with dust particles, condensation nuclei and smoke particles. It is also evident in nighttime chilling of the upper cloud boundary. Radiation often results in the appearance, and sometimes intensification, of the comparatively thin nighttime sub-inversion clouds.

In nature these processes act in combination. However, the prime factor in cloud formation remains the vertical movement of air.

The act of condensation begins, air is cooled and increases the relative humidity. Before the relative humidity reaches 100% (in terms of a plane surface of pure water), condensation begins on larger, more active nuclei. When the humidity approaches 100%, these have become full sized cloud droplets. Generally, the available water vapor is used by the larger nuclei and the smaller, less active nuclei remain unused. Therefore, the number of cloud droplets is greatly exceeded by the number of available nuclei.

An average active salt nucleus is 1 μ in diameter. When condensation occurs on such a particle, 1 second suffices for it to grow to the size of a small cloud droplet (10 μ). It will take about 500 seconds for the droplet to grow to a large cloud droplet (100 μ) and about 10,000 seconds (or 3 hours) for it to grow to the size of a small raindrop (1,000 μ, or 1mm). It would take several days for a large raindrop to form through condensation only. Thus it is seen that although the condensation process is capable of producing cloud droplets, it is far too slow to produce raindrops of the size actually observed. Therefore, there must be present some mechanism or combination of mechanisms that will cause cloud particles to join and form raindrops. Again, large magnitudes are involved. It will take about one million average cloud droplets to account for the water contained in a large raindrop.. The mechanism for increasing the size of cloud droplets to raindrops is called accretion. Accretion occurs when a larger falling drop collides with other smaller droplets. These collisions critically depend on the position and radii of the two drops. Not all droplets that collide with the large drop adhere to it, however this coalescence increases rapidly in effectiveness as the drop size increases in size. This process is more significant than condensation in the ultimate formation of clouds.

Through all of these processes, condensation nuclei of pathogenic organisms and toxic substance particles, and aerosol droplets containing these may be incorporated into larger droplets and clouds. Under these conditions these particles and infectious agents may travel further, potentially governed by the weather patterns as well as local wind currents.

External Conditions Relevant to Drift Behavior

If atmospheric air is cold, the exhausted drift is rapidly cooled and becomes supersaturated. The small drift droplets remain entrained and act as condensation nuclei. As long as the supersaturated condition remains, they become enlarged due to condensation. Drift droplets affected by this phenomenon typically represent less than 12% of the total drift mass. Significant condensation occurs only during brief periods when a prolonged supersaturated plume conditon exists.

The relative humidity of the atmosphere, peripheral to the site of drift emission, may affect aerosol drift transport. In relatively dry areas, any substance or pathogen which is carried by aerosol drift, or constitutes the condensation nucleus of a droplet, will travel over further distances.

In dry areas the moisture in the aerosol or drift will evaporate rapidly. The particle or substance remaining will have a lower fall velocity than the initial droplet. Its transport will not be governed by air currents rather than by the drift itself. The ultimate deposition of these particles will resemble a Gaussian distribution.

In relatively damp areas organisms or substances carried by the aerosol or comprising the condensation nuclei will be transported shorter distances. The droplets will accrete moisture and due to the additional mass, the fall velocity increases. These droplets will fall out of the drift more rapidly, depositing the particles in a more immediate area.

The location and type of cooling device itself will affect local relative humidity. In dry areas, emitted drift will evaporate rapidly creating little if any change in the relative humidity. However, in damp areas, the air is less capable of absorbing this additional moisture. There may be an appreciable difference in the local relative humidity.

Natural draft towers are less likely to affect relative humidity at or near ground level than mechanical towers. Mechanical towers due to their lower height emit drift closer to ground level, and may produce an appreciable difference in the moisture content of the air.

This discussion on relative humidity will be particularly important in our subsequent analysis of direct effects on plants.

Ice-Crystal Process

In damp areas or when the atmosphere is near saturation, there may be problems from precipitation modification resulting from aerosol drift. One manifestation of this problem is the formation of ice crystals. Pathogenic or toxic particles may aid in this process, acting as nuclei.

Observation has shown that cloud droplets do not freeze until the temperature is far below the freezing point. Even as low as -30°C, perhaps one in a thousand droplets freeze. As the temperature approaches -40°C they freeze rapidly and at lower temperatures, clouds consist of crystals.

Liquid water that exists at temperatures below 0°C is said to be "supercooled". Observation has shown that freezing is initiated by a variety of impurities such as organisms or parti-

cles of chemical substances. The cloud droplets are exceptionally pure as compared with water on or in the ground.

Layers of cloud that contain a mixture of water droplets and ice crystals are unique because the saturation vapor pressure over ice is lower than over water. Although the difference is small, it is highly significant. In a cloud that consists of both droplets and crystals, the actual vapor pressure will be a compromise between the two saturation pressures. While the air is not quite saturated in respect to water, it is slightly super-saturated in respect ot ice. This, then, will cause water to evaporate from the droplets and vapor to condense on the ice particles. We have here a process which will cause a few cloud elements (those that consist of ice) to grow at the expense of the other elements.

As condensation is initiated on certain nuclei, freezing in undercooled clouds (between 0 and -40°C) is initiated by freezing nuclei, (a particle that will initiate the growth of an ice crystal out of a liquid water under these conditions). Minute ice particles are excellent freezing nuclei, and a number of other particles (natural or man-made) will also cause such growth.

Approximate estimates and observations show that for supersaturations of the order of 10-12% (assuming a concentration of about 100 per cubic meter) the ice crystals may grow within 4-5 minutes the mass of a crystal will equal that of a water droplet with a radius of about 100-200 μ. This rapid growth by sublimation is the reason why even thin (about 1 km thick) ice-crystal clouds with small velocities of rising air currents can produce precipitation bands. These sometimes reach the earth's surface in the form of fine, light snow or rain.

Substantially different conditions prevail when the ice particle occurs in the vicinity of water droplets, as is the case in mixed clouds. Conditions here are very favorable for sublimation growth, especially if there are many more supercooled droplets than crystals in the cloud. When relative humidity in the cloud decreases as a result of the sublimation of water vapor on ice particles, conditions of phase equilibrium over the droplets are disrupted. The latter start evaporating, thereby adding to the supply of moisture for crystal growth. Thus a special process of "transfer" (distillation) of water from supercooled droplets to crystals begins to operate.

In a supercooled droplet cloud rapid growth by distillation of vapor from droplets will set in as soon as ice particles with a radius of the order of 10^{-6} cm appear. As a result the crystals will be able to grow to large sizes until all the droplets evaporate. The initial excess of water vapor condenses upon the crystals and the cloud has been completely transformed into

an ice-crystal cloud. Calculations show that the role of this process in the initial growth of ice particles occurring in a medium containing supercooled droplets is very great.

The initial stage of ice-crystal growth by sublimation takes place far more rapidly (10-20 times) than the condensational growth of water droplets. The point at which the process of accretion becomes dominant in the further growth of the ice crystals (r=50-60μ) is reached within a few minutes.

When considering the accretion of ice crystals it should be borne in mind that falling crystals have a greater capture surface than droplets for the same mass. At the same time, their fall velocity is lower than that of spherical particles. This accounts for the faster growth of non-spherical ice crystals by accretion and for the diversity of their shapes. It may roughly be estimated that ice particles grow 5-6 times more rapidly than droplets with the same mass.

Precipitation (Snow) From Cooling Tower Plumes.

During the winter of 1975-1976 significant environmental effects were observed from large natural-draft towers. They produced plumes persisting as far as 70 km in which the supercooled water droplets changed to ice crystals and produced light snowfall. Measurable accumulations of snow were observed on the ground. The falling snow restricted visibility to less than 1600 m close to the ground. From December 1975 through March 1976, this conversion of liquid droplets to ice crystals was observed ten times at several power plants. One of these incidents is described below.

During a period of clear weather on 18 January 1976, from 0755 to 1111 E.S.T., a flight test was conducted in the vicinity of a plant, located 25 km northwest of Charleston, West Virginia. This coal-fired plant has three hyperbolic cooling towers serving three generators totaling 2900 Mw. The weather was cold and clear with temperatures of -12°C near the surface, decreasing to -20°C at 1600 m above ground. The plumes from the three cooling towers merged and rose to form a typical liquid droplet cloud between 900 and 1600 m. The plumes mixed with the smokestack effluent at 400 m. The rise of the cooling tower plume stopped at the base of an elevated temperature inversion, also at 1600 m. The change from supercooled droplets to ice crystals began at 5 km and was complete 11 km downwind of the towers. This ice crystal cloud persisted aloft to a distance downwind of 43 km. Snow began descending from the base of the plume when the conversion from droplets to ice crystals started, and it first reached the ground at 13 km. Snowfall on the ground also continued to at least 43 km. The maximum accumulation of snow (very light fluffy snow) was 2.5 cm.

The ground measurements outside of the plume shadow indicated that the plume trajectory had changed from the initial conditions. The visibility in the clear air was greater than 15 km, but it was restricted to approximately 1600 m in the snow near the ground level, as it would be in a natural snowfall.

Snow from cooling tower plumes reached the ground only at considerable distances from the cooling tower (a minimum distance of 8 km was measured in one case).

In some of the tests, natural clouds were present and snow or snow showers came from them. This natural snow occurred before, during, or after the observations of snow from the cooling tower plumes. Snow was observed from the tower plumes, however, when it was not falling from natural clouds. Moreover, the conversion of the tower plumes from liquid drops to ice crystals sometimes induced a similar change in the natural clouds, creating an obvious "hole" in an otherwise unbroken cloud deck.

We cannot specify precisely the conditions required for induced snow. Observations to date have indicated that induced snow has been associated with low temperatures and with plumes diffusing in relatively stable conditions. The key parameters are air temperatures of -12°C or less and relatively stable diffusion conditions at plume height. The rate of water vapor emission from the towers must be critical also, since this is the source of the additional water vapor.

The artificial snowfall occurs when the atmosphere is cloudy and snow would be expected. In tests, natural snow often coincided with tower-induced snow or occurred soon afterward.

However, the observations made during the winter of 1975-1976 are not unique. A similar snowfall was observed at Oak Ridge, Tennessee, in 1960. The water vapor released from clusters of mechanical draft towers at the gaseous diffusion plant at Oak Ridge approximated that from a large power plant, and the weather conditions were similar to those which induced snow in the Charlestown observations. Agee has also described the artificial inducement of snowfall, but the incident he described appears to have been caused by a seeding effect of particles in supercooled fog.

The details of the Oak Ridge case are also presented here. The snow was intermittent and fairly light. Downwind from the cooling towers, snow began falling about 3 miles distant and continued to be deposited noticeably on the ground up to 5 miles. Some very light snow was reported as far as 10 miles from the towers late in the morning, but by noon all activity seemed to have ceased. The snow that was deposited 3 to 5 miles from the cooling towers was normal in appearance with some flakes up to 1/4-inch in size. The snow falling farther downwind was finer

in structure and, in the sun, appeared almost crystalline in nature. Since there were no roads perpendicular to the direction of travel of the plume estimates of the lateral distance of snow deposit were not possible. The valley contour, however, suggested a possible width of approximately one mile.

The snow had been falling during the night, or at least prior to sunrise. Between 0800 and 0900 EST there were no clouds outside the affected area. In the area, the clouds ranged from scattered cumulus at 1,000 to 1,500 feet to low stratus (base less than 300 feet) as it snowed. Moisture from the cooling towers rose to an initial height of about 1,500 feet, then, as it progressed downwind, the resulting cloud decended, intermittently reducing visibility on the ground to less than 500 feet. A freezing nuclei detector operating at the time of the snowfall showed no increase of detectable nuclei.

Ground Level Drift Deposition

The drift deposition problem is a complicated one involving several interrelated processes: the dynamics and thermodynamics of drops in a rising plume, the point of which the drops break free from the plume, dispersal by atmospheric turbulence, and possible evaporation in the ambient atmosphere. To make deposition estimates, the source characteristics of the tower such as tower geometry, amount of water circulated, effluent speed, droplet emission spectra, drift rate, and salt concentration, must be known. Calculations must be made of the plume rise, which in part depends on the initial momentum and buoyancy flux and on the ambient atmospheric conditions. Droplet transport, which depends on meteorological conditions such as the atmospheric relative humidity, turbulence, temperature and its gradient, and wind velocity, must be estimated.

Thus, we see then an already difficult problem of modeling plume dispersion becomes considerably more complicated when we attempt to predict deposition of drift emitted with the plume. In addition, at the present time there is no reliable field data on drift deposition so that existing models cannot be evaluated as to their predictive capabilities. Chen and Hanna (1977) compared the results of ten different drift composition models. Typical natural cooling tower input conditions are given in Table 11. The individual results are given in Chen and Hanna (1977). The results of the ten models were averaged, producing the concentration factors in Table 12. By multiplying the concentration factor in Table 12 by the total mass emission rate of the substance of interest (Kg/month), the ground level concentration of the substance is determined. The concentration is that which would be determined by averaging the ten different model predictions using the input data of Table 11.

TABLE 11

MODEL INPUT PARAMETERS FOR CALCULATION OF TABLE 12

Plume initially saturated

Plume temperature at exit from tower, T_{po} = 305°K

Ambient temperature near exit from tower, T_{eo} = 275°K

Tower height = 100m

Tower exit diameter = 60m

Efflux velocity = 4.3 m/sec

Amount of circulating water = 499,338 gpm (1890 m^3/min.)

Drift rate = 2 X 10^{-5}

Water salinity = 3.45%

Wind speed = 4.3 m/sec.

Calculate salt deposition rate for a sector of 22.5°

Frequency of wind direction which blows toward the sector = 1

Ambient relative humidity = 70% (constant with height)

Isothermal ambient atmosphere (slightly stable atmosphere)

Drop size distribution:

Diameter interval	Mass mean diameter for interval (um)	Mass fraction
0-100	50	0.05
100-200	150	0.3
200-300	250	0.4
300-400	350	0.15
400-500	450	0.075
500-600	550	0.025

TABLE 12 TYPICAL* GROUND LEVEL DISTRIBUTION OF DRIFT PARTICLES FROM NATURAL DRAFT COOLING TOWERS

Downwind Distance (Km)	Area of 22½° Sector (Km^2)	Deposited** within Sector (Kg/month)	% of Total Deposition (%)	Concentration** within Sector (Kg/Km^2-month	Concentration*** Factor
.23 - .6	0.058	1246.	2.1	21483.	.3718
.6 - .8	0.055	810.	1.4	14727.	.2549
.8 -1.0	0.071	732.	1.2	10310.	.1784
1.0 - 1.5	0.254	2585.	4.3	10177.	.1761
1.5 - 2.0	0.344	2324.	3.9	6756.	.1169
2.0 - 4.0	2.356	6933.	11.7	2943.	.0509
4.0 - 10.0	16.493	17566.	29.6	1065.	.0184
10.0 - 30.0	157.081	21291.	35.8	135.	.0023
30.0 - 60.0	530.144	5023.	8.5	9.5	.0016
60.0-100.0	1256.638	870.	1.5	0.7	.0001
Total	1963.494	59380.	100.		

* Average of predicted deposition values of ten models, each using the input parameters of Table 1 (see ref. 1).

Frequency of wind direction which blows toward sector = 1

*** Multiply the total mass emission (Kg/month) from the tower by the concentration factor to immediately determine the ground level concentration (Kg/Km^2) - month) within the distance interval.

A similar analysis was performed for the drift dispersion from a mechanical draft cooling tower. The input data is given in Table 13. The results, given in Table 14 are those predicted by one proprietary model. Therefore, the results are probably not as representative as those given for natural draft towers. A comparison of the results for natural and mechanical draft towers is given in Figure 10.

Aerobiology

The air as a route for the spread of infectious disease has been well documented in microbial and epidemiological literature. It is established, beyond any question, that droplet infection can spread epidemics although the transmission range is relatively short for respiratory diseases.

In recent years, much of the attention on the long range transmission of infectious organisms has been in the area of biological warfare. The information presented here was extracted from unclassified or declassified biological warfare documents, or derived from personal communications with or first hand experience of individuals involved in the subject. Some data, not singled out, had previously been classified or was extracted from classified sources and is now in the open literature, hence the open literature references.

The aerosolization of these wastes via wave action, or other agitation was clearly demonstrated by Claude Zobel (1946) and earlier. Additionally, it has been shown that the air travel and the subsequent dissipation of an aerosol from a given line source while approximating a function of an exponential decay pattern has nevertheless often retained its basic cloud structure and has in this form travelled hundreds of miles due to unique meteorological conditions. (U. S. Army 1966, and Report 219II) However, it must be recognized that due to the nature of the main sources of this data pool that some information has of necessity remained classified.

Data used in this section is from the following sources:

A. Fort Detrick, Maryland. A former United States Army installation dedicated to a variety of investigations dealing with many aspects of microbiological survival, metabolism, destruction and disease prevention.

B. Dugway Proving Grounds, Utah. A chemical warfare site still in existence, that has in the past been used for testing of biological and chemical agents in a variety of forms.

TABLE 13

MODEL INPUT PARAMETERS FOR CALCULATION OF TABLE 14

Cooling Tower Parameters

Cooling Tower Diameter (M)	16.6
Cooling Tower Height (M)	18.21
Plume Exit Velocity (m/sec)	9.35
Circulating Water Flow Rate	717900 gpm (2717.26 M^3/min)
Drift Rate (%)	.008
Plume Exit Temperature, dry bulb (^oK)	297.
Salt concentration (gm/cm^3)	.00135

Particle Diameter - Microns	% of Total Mass Drift
0 - 50	49%
50 - 100	20%
100 - 200	18%
200 - 300	7%
300 - 500	4%
500 & Larger	2%

Ambient Conditions

Wind speed (m/sec)	4.02
Temperature, dry bulb (^oK)	266.
Specific humidity (lbs moisture/lbs dry air)	.00158
Pasquill stability class	4
Frequency of wind direction which blows toward the sector	1

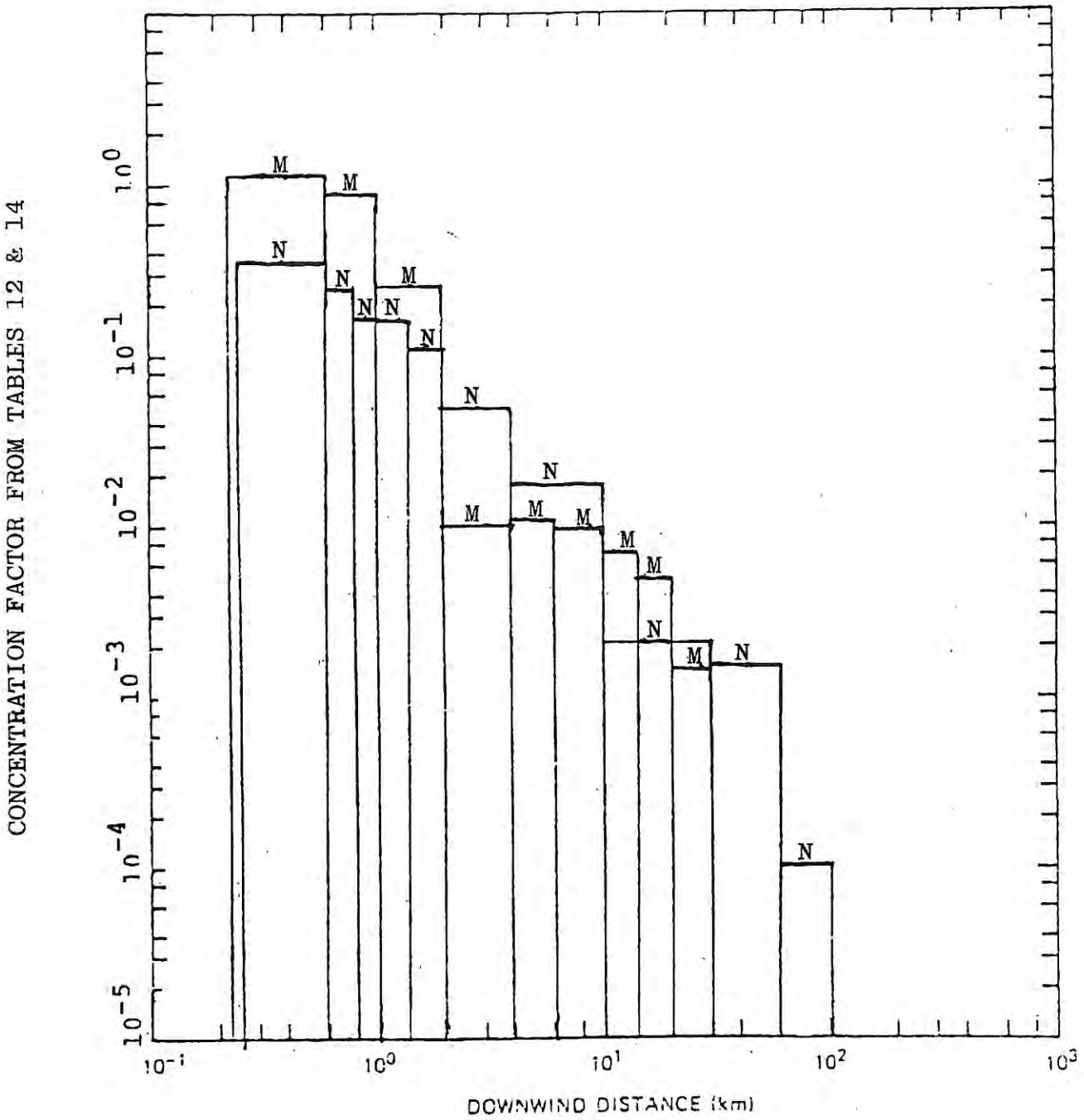
TABLE 14 EXAMPLE* OF GROUND LEVEL DISTRIBUTION OF DRIFT PARTICLES FROM A MECHANICAL DRAFT COOLING TOWER

Downwind Distance (Km)	Area of 22½° Sector (Km^2)	Deposited** within Sector (Kg/month)	% of Total Deposition (%)	Concentration** within Sector (Kg/Km^2-month)	Concentration*** Factor
.22 - .6	.0612	938.	7.2	15328.	1.1928
.6 - 1.0	.1257	1450.	11.2	11534.	.8836
1.0 - 2.0	.5890	1981.	15.3	3363.	.2617
2.0 - 4.0	2.3562	306.	2.4	130.	.0101
4.0 - 6.0	3.9270	565.	4.4	144.	.0112
6.0 - 10.0	12.566	1570.	12.1	125.	.0097
10.0 - 15.0	24.544	2160.	16.7	88.	.0068
15.0 - 20.0	34.361	2130.	16.3	62.	.0048
20.0 - 30.0	98.174	1865.	14.4	19.	.0015
Total	176.7	12965.	100.		

* Calculated from predictions of combined trajectory - Gaussian drift dispersion model for a round mechanical draft cooling tower.

** Frequency of wind direction which blows toward sector = 1

*** Multiply the total mass emission (Kg/month) from the tower by the concentration factor to immediately determine the ground level concentration (Kg/Km^2-month) within the distance interval.



Calibration Factor vs. Downwind Distance For Examples of Natural (N) and Mechanical (M) Draft Cooling Tower Drift Deposition

FIGURE 10

The major mission was long range field testing in a relatively isolated part of the state.

C. Illinois Institute of Technology, Chicago, Illinois. Its research staff has contracts and grants from a large number of government and private sources. The research is variable and in some areas possibly classified.

D. Army Material Command, Washington, D.C. Involved with the logistics inherent in any aspect of the army mission.

E. Edgewood Arsenal, Edgewood, Maryland. At one time the research center for the study of gas, aerosol, and radiological and chemical properties, and the toxicity and protection from all forms of chemical agents.

F. United States Navy. Via direct or contracted efforts the USN was engaged in collaborative efforts with its sister services to investigate various aspects of biological warfare agents, dissemination, detection and protection.

G. Aberdeen Proving Grounds, Maryland. Primarily the army location for hardware testing.

H. Various contracts were in force at different times with organizations as diverse as Booz Allen Inc. and the University of Pennsylvania.

I. Foreign sources include the Canadian experimental station at Suffield, Canada and the British laboratories at Porton, England.

J. Wright Patterson Air Force Base, Ohio. Site of medical, physiological and toxicological testing in conjunction with the USAF mission. At one time it was involved in long range bacteriological tests from the point of view of detection and prevention of a microbiological attack.

The analysis within this task analyzes organisms in relation to attenuation due to dessication, solar radiation and ambient environmental conditions, and to protective chemical mechanisms. The organisms addressed in this task are listed in Table 15.

Results of Data Search

Serratia marcescens had been indicated as the causative agent in the deaths of individuals following a series of Biological Warfare (B.W.) tests. This occurred in two separate incidents, in 1950 near San Francisco and in 1952 near Fort McClellan, Alabama.

TABLE 15

ORGANISMS REVIEWED FOR AEROSOL
SURVIVAL AND TRANSMISSABILITY

1. Rust spores
2. *Bacillus globigii*
3. *Pasteurella pestis*
4. *Pasteurella tularensis*
5. *Coccidioides immitis*
6. *Rickettsia burnetii*
7. *Serratia marcescens*
8. *Sarcina lutea*
9. Venezuelan equine encephalitis
10. *Vibrio cholerae*
11. Enterotoxin B
12. Simian virus
13. Toxic proteins
14. *Klebsiella pneumoniae*
15. *Escherichia coli*

At the time of the actual study, the then current background indicated that this particular organism decayed rapidly and was useful as a tracer. Concurrent use included B.W. tests and air movement studies in hospitals. Serratia is recognized today as a possible pathogen able to produce pneumonia, bacteremia, urinary tract infections and in burns has caused severe, frequently fatal infections. It is effected by temperatures such that survival decreases with an increase beyond 32°C. In a series of studies in which relative humidity was allowed to range from 20 to 80%, temperature differences from -40° to 32°C confirmed the increasing demise beyond 32°C. I.I.T. examined the effect of temperatures ranging from -40°C to 120°C on Serratia marcescens (U.S. Army 1969). Humidity alone was not held to exert any influence at either end of the temperature range. Low humidity was found to generally enhance the death rate.

Escheria coli, Staphylococcus aureus, and Streptococcus salivarius are not prejudiced when challenged with temperatures from 24° to 30°C.

Assuming temperature is held constant, the major factor becomes the relative humidity. The aerosol cloud is at its most hazardous state when it supplies the microorganism with the moisture content that enhances and prolongs the survivability and infectivity of the specific microorganism.

As if to contradict all this, Goetz (1954) showed that S. marcescens was not affected by changes in relative humidity. It has been theorized that perhaps the presence or absence of water in aerosols exerts its influence by its impact on intracellular ions and in doing so determines the demise or survivability of the organism. Studies at Fort Detrick followed the rheological responses of dessicated Serratia marcescens in a variable environment that altered both temperature and humidity. (U. S. Army 1967)

Escheria coli, one of this study's candidate pathogens, can survive increasingly well as the relative humidity is elevated from 40% to 90%. Staphylococcus albas, S. aureus, S. salivarus, and S. marcescens favor environments having less than 10% relative humidity. Staphyloccus pullorum favors a range of 15 to 80% relative humidity.

Serratia has survived well in field trials. It was further tested via a trial conducted in Canada by the Canadian Army using Sarcina lutea as a tracer for the continued survivability of S. marcescens. (U. S. Army 1964). It proved to be viable in a number of environments that depleted the Sarcina.

Pasteurella tularensis has been shown to survive quite well in an aerosol that provides 75% or greater relative humidity. (U. S. Army 1964) Temperature ranges from -40° to 24°C do not significantly alter the natural decay rate. When subjected to temperatures from 24° to 35°C the death rate of P. tularensis increases linearly. A maximum kill temperature appears to be about 49°C (Erlich, 1968).

Klebsiella pneumoniae has been used as a test organism in laboratory studies. The phenotypical and nucleic acid properties indicate a wide range of environmental klebsiellas as compared to klebsiellas of human origin.

A host of environments were examined by Seidler et. al. (1975). The presence of the klebsiella organism is a clue to the deterioration of the microbiological quality of the environment. Therefore, it should be considered significant to the health of man and animals when present. Goldberg (1977) used K. pneumoniae in a series of studies in his Dynamic Aerosol Toroid (DAT). By suspending a known count of the organism he was able to affect survivability and strain alteration by judicious alteration of temperature and relative humidity. Goldberg found that suspensions of feces from K. pneumoniae carriers could produce lethal respiratory effects in mice.

The higher the relative humidity the longer the survival time of Klebsiella. It is reported however, that less than 1% remained viable in fecal specimens if the relative humidity was less than 50% in the first 24 hours.

Aerosolization of Pasteurella pestis was studied by Goldberg and Leif (1951). They concluded that particle size of P.pestis dictated the site of impaction after either inhalation or ingestion by the test animal. Either single cell or larger clumping resulted in infection and death. This indicates that for some pathogens the time of death can be independent of the dosage. Larger particles were found to move rapidly to the lymphatic system while small aerosolized particles entered the alveoli.

Relative humidity shifts from 87% to 61% resulted in a 1 log loss of airborne P. pestis, an actual 90% loss (U.S. Army 1968). This reaction was not duplicated when the aerosol cloud was shifted from 39% RH to 26% RH. Survival was in fact, quite good (U.S. Army 1965).

Bacillus globigii has been used extensively as a test aerosol organism. Leif and Hebert (1977) subjected B. globigii spores to aerosolization and these were recovered efficiently, with close to 100% return. Subjecting the spore to a 4°C storage temperature seemed to lead to an increased count. It is theorized that the effects of the aerosolization trauma which normally would reduce the count are compensated for by the

lowered metabolic activity, permitting damaged cells to survive and even repair, lie dormant or even recuperate from the stress.

B. globiggi has also been used in field trials in the dried spore state, in a slurry and in liquid media. (U. S. Army, 1953).

Survial and Destruction

Levin (1966) has cataloged the persistence of a number of microorganisms in a spectrum of soils and climate. Tests of persistence and variability of persistence, have produced a variety of techniques designed to kill microorganisms. These range from extreme dry heat to the use of mustard gas on E. coli (U. S. Army 1965). Ultra violet light has of course been used against some organisms while other forms of radiation have permitted the ultimate recovery of the cell's capacity to produce DNA.

A study by Lighthart (1972) employed vegetative S. marcescens, Sarcina lutea and B. subtilis spores. The aerosols were challenged by varying humidities at 15°C for 6 hours in a carbon monoxide environment that approximated a high urban concentration. The survivability varied from lethal to protected. For example, S. marcescens was killed off four to sevenfold at low (1-25%) RH. Above this at 90% RH, protections was provided. S. lutea varied from protection during the first hour to death during the next 5 hours, topping a seventy fold increase in the RH range of 0 to 75%. The spores of B. subtilis proved to be hardy in almost all environments.

Viruses and bacteria have been inactivated by ozone (Burleson, 1975) but the truly effective result depends on the water being free of almost all organic waste. River water would be a difficult treatment media by this method, due to the ozone demand of the organic material.

Viruses

Virus aerosol survival studies have lagged behind bacteria or plant spores due to the inherent problems of tracing, trapping and identification. As techniques have improved we have learned that some viruses persist in the airborne state in good numbers for 6 or more hours. Using vesicular stomatitis virus (VSV) Watkins et. al. (1965) studied temperature and humidity variables. He concluded that maximum stability occurred at 20% and 80% RH while minimal stability was to be found at 50% RH. Temperature increments from 50°, 70°, 80° and 90°F all increased the decay rate.

Harper (1961) studied vaccinia, influenza and V.E.E. at temperature ranges of 7-12°C, 21-24°C and 32-34°C and concluded survival was inverse to temperature. Coxsackie A21 aerosols at 25°C and 50 to 60% RH experience a 50% decay rate in the first few seconds of aerosolization.

The persistence inherent in many aerosols of virus origin, depends greatly on the initial concentration. A dry cloud containing virus matter exhibits a longer survival. The medium in which the virus is suspended in prior to, and during aerosolization influences the subsequent behavior. The content has been studied but not the mechanism. Inositol for example decreases the sensitivity of viruses to relative humidity, U.V. light and X-ray, thereby artificially prolonging the viability.

Survivability and inactivation of viruses in air was examined at Wright Patterson Air Force Base, Ohio with the following conclusions. (1974).

Adenoviruses, enteroviruses and Newcastle virus were most stable at room temperature and 50% relative humidity. Para influenza and respiratory syncitial viruses were inactivated rapidly as relative humidity shifted. The decrease in relative humidity decreased the survival rate of the adenoviruses and enteroviruses within 2 hours. At moderate (50%) or high (90%) relative humidity the survival rate varied from 7-24 hours. The para influenza, respiratory syncitial and New Castle viruses were inactivated rapidly at high and medium RH and to a lesser degree at low RH.

In the realm of survival, Lefler and Kott (1974) noted the survivability of polio virus Type I in dry sand for 77 days. Wellings extracted Coxsackie B_4, Polio Type II and I, Coxsackie Type A, (Wellings, 1975) Echo (Snow, 1955; Goetz, 1954; Erlich & Miller, 1968) from ground water. The significance of these findings lies in the appreciation of the ubiquity, and persistence of these microbiological entities with regard to survival.

Inactivation had been attempted by Jensen when he exposed aerosols of Coxsackie, influenza, sindbis, and vaccinia to ultra violet during passage through a tube. The kill percentage is expressed in Table 16. Therefore, one may conclude that by avoiding U.V., as in a dust cloud or debris environment, to some degree, the viability of the aforementioned viruses would be protected.

A number of studies were directed at the behavior of organic entities such as viral nucleic acid from Simian Virus 40 (SV40) (U. S. Army, 1956; Akers, 1972) virus protein and RNA of Encephalomyocarditis Virus (EMV) (DeJong et al, 1974), stability of toxic proteins (U. S. Army, 1965), enterotoxin B (U. S. Army, 1967).

The results concerning the survivability and persistence of these viruses varied greatly so that no general conclusion can be drawn.

For example:

SV40 persisted well at 21°C throughout a spectrum of relative humidities from 22 to 88%. At 32°C viability was practically gone within 60 minutes.

At relative humidities of 50% or less the EMV entity lost its viability, yet the RNA of the virus retained its infectivity.

The same illogicity persists with enterotoxin B and other proteins. However, as long as the substance retains its allergenic or toxic property the debilitating effects common to the entity can occur.

Mycotic Sources

Coccidioides immitus is distinctly hydrophobic when in its arthrospore stage (Levine, 1977). As such, it survives well within the wide ranging termperatures, relative humidity, dessication and even light energies of an infinite variety. Soil conditions that provide Na^+, Ca^{++}, SO_4^-, and Cl^- encourage the survival and growth of this fungus. Therefore, any organic mass able to provide these ions can in turn harbor this pathogen. Moisture enhances the mycelial growth. Dispersion by air is easily accomplished since the intact arthrospore is extremely persistent in air and in soil from which it can be wafted.

Rickettsia

Rickettsia burnetii is linked to Q fever. Aerosols of this agent have infected at distances of over ten miles from the point source (Tigertt, 1961).

Many of the effects of variables on microbiological survival in aerosols are tabulated in Table 17. The effects were arrived at during B.W. tests and research. Some of the variables examined include exposure to U.V. light, temperature and relative humidity.

TABLE 16

KILL PERCENTAGE OF VIRUSES EXPOSED TO ULTRA VIOLET RADIATION

100 ft.^{3}/min. flow		200 ft.^{3}/min. flow
99.9	coxsackie	97.5
99.9	influenza	99.9
99.9	sindbis	96.7
	vaccinia	99.9
96.8	adenovirus	91.3

TABLE 17

EVENTS INFLUENCING MICROBIOLOGICAL SURVIVAL (1 of 5)

ORGANISM	TEMPERATURE °C	RELATIVE HUMIDITY	COMMENTS OR EFFECTS AND REFERENCES
Adenovirus			91.3% survival in an aerosol; exposed to U.V. light (Jensen, 1964).
	70°	50%	Stable at 22°C (USDOA, 1974).
		50-90%	Decay directly proportioned to rise in relative humidity (U.S. Army, 1974).
Bacillus globigii	4°		Increased count of organism 100% survival (Leif and Hebert, 1977).
	ambient	ambient	Carried 12 mi. remained viable in field aerosol (U.S. Army, 1953).
Bacillus subtilis	ambient	ambient	Survived in all environments (Lighthart, 1972).
Coccidioides immitis	10°-45°	5-85%	Arthrospore survives well in all exposures (Levine, 1977).
Coxsackie A21	25°	50-60%	Immediate 50% decay (Jensen, 1964).
		100%	Found in ground water. Aerosol passed through U.V. light at rate of 200'/min.; 97.5% decay (Akers, 1972).
Coxsackie B4		100%	Found in ground water (Wellings, 1975).
Echo 1, 7, 11		100%	Found in ground water (Wellings, 1975).

TABLE 17

EVENTS INFLUENCING MICROBIOLOGICAL SURVIVAL (2 of 5)

ORGANISM	TEMPERATURE °C	RELATIVE HUMIDITY	COMMENTS OR EFFECTS AND REFERENCES
Encephalomyo-caditis		50%	Virus loses viability (DeJong, 1974).
		50%	RNA retains infectibility.
Enterovirus	70°	50%	Stable at 22°C (U.S. Army, 1974).
		50-90%	Direct relationship between increase in relative humidity and survival.
Escherichia coli	24-30°	40-90%	Survives well; mustard gas affects growth (Dimmick, 1965 & U.S. Army, 1965).
Influenza	7-12° 21-24° 32-34°		Survival is inverse to rise in temperature (Harper, 1961).
			When aerosol was exposed to U.V.; 99% decay (Jensen, 1964).
Klebsiella pneumonia	ambient	ambient	Presence is key to poor environment (Seidler, 1975).
		<50%	Only 1% survival after 24 hours (Goldberg, 1977).
		>50%	Survival increased as relative humidity increased (Goldberg, 1977).
Newcastle virus	70°	50%	Stable at 22°C (U.S. Army, 1974).
		50-90%	Rapid deactivation of virus (U.S. Army, 1974).

TABLE 17

EVENTS INFLUENCING MICROBIOLOGICAL SURVIVAL (3 of 5)

ORGANISM	TEMPERATURE °C	RELATIVE HUMIDITY	COMMENTS OR EFFECTS AND REFERENCES
Newcastle virus (Continued)		<50%	Increasing survival rate (U.S. Army, 1974).
Pasteurella Pestis		26-39%	Good survival rate (U.S. Army, 1965).
		61-87%	1 log death rate; actual 90% loss (U.S. Army, 1968).
Pasteurella tularensis	-40-24°	>75%	Survives well (U.S. Army, 1964).
	24-35°		Death rate increases linearly (Erlich, Miller, 1968).
	49°		Maximum kill temperature (Erlich, Miller, 1968).
Polio type I		0%	Survived for 77 days in sand (Leffler & KOH, 1974).
		100%	Found viable in ground water (Wellings, 1975).
Polio type II		100%	Found viable in ground water (Wellings, 1975).
Rickettsia burnetii			Proven to cause Q-fever 10 mi. from origin (Tigertt, 1961).
Sarcina lutea	15°	0-75%	Exposed to CO gas; survival varied (Lighthart, 1972).

TABLE 17

EVENTS INFLUENCING MICROBIOLOGICAL SURVIVAL (4 of 5)

ORGANISM	TEMPERATURE °C	RELATIVE HUMIDITY	COMMENTS OR EFFECTS AND REFERENCES
Serrata marcescens		90%	Protected viability (Lighthart, 1972).
	-40-32°	20-80%	Increase in death over 32°
	-40-120°	20%	Decrease in relative humidity increased death rate (U.S. Army, 1968 and Dimmick, 1965).
	15°	1-25%	Survived for 6 hours while exposed to CO gas; then 4.7 fold death rate (Lightart, 1971).
		10%	Relative humidity not a factor in survival (Goetz, 1954).
Simian virus (SV)	21°	22-88%	Survived well (U.S. Army, 1965).
	32°	22-88%	Decayed within 1 hour (Akers, 1972).
Sindbis virus			96.7% survival when aerosol was exposed to U.V. light (Jensen, 1964).
Staphylococcus aureus	24-30°	<10%	Survives well (Dimmick, 1965).
Staphylococcus pullorum		15-80%	Survivability increases as relative humidity increases (Dimmick, 1965).
Streptococcus salivarius	24-30°	<10%	Survives well (Dimmick, 1965).

TABLE 17

EVENTS INFLUENCING MICROBIOLOGICAL SURVIVAL (5 of 5)

ORGANISM	TEMPERATURE °C	RELATIVE HUMIDITY	COMMENTS OR EFFECTS AND REFERENCES
Toxic Proteins	25-32°		Retains potency (U.S. Army, 1965)
Vaccinia	7-12° 21-24° 32-34°		Survival inverse to temperature (Harper, 1961).
			Aerosol exposed to U.V. light; 99% decay rate (Jensen, 1968).
V.S.V.	50°, 70°, 80°, 90°	20-80%	Increase in decay as temperature increases (Watkins, et. al.).
	7-12° 21-24° 32-34°		Survival inverse to temperature (Harper, 1961).

RESULTS OF TASK III - DIRECT EFFECTS

The potential direct effects of pathogenic organisms and toxic substances on plants, animals and humans were evaluated under this task. The study of conventional epidemiology and pathology concerns itself with the routes by which infection is acquired, considers the transmission of disease from man to man, that arising from contact with environmental sources, as well as the essential nature of the disease and especially the structural and functional changes caused by it. The potential of a given agent to cause disease in any given population, and the existence and pattern of any ensuing epidemic rests upon a number of variables, but particularly the following:

1. Portal of entry for the disease-causing agent.
2. Portal of exit.
3. Incubation period.
4. Gradient of infection.
5. Mode of spread.
6. Survival in nature.
7. Susceptibility of the population at risk.

Portal of Entry

Since the material released from the tower may be carried in a variety of physical forms and in particles of varying size, with different agents being present in differing quantities, three potential portals of entry must be considered:

Inhalation: Inhalation of airborne or droplet-carried organisms may create invasive disease at any site within the respiratory tract. Large particles and droplets are restricted by normal host defenses to deposition on the mucous membranes of the nose, mouth, pharynx, and upper tracheo-bronchial tree. In this instance, high concentrations of the infecting organism are usually required to produce disease, and the mechanism is usually direct contact. In contrast, smaller particles, 1-5 microns in size, will be inhaled into the distal portions of the respiratory tract, including the terminal bronchioles and alveoli, and these can cause disease with very small numbers of particles, occasionally estimated to be as few as a single particle. This is true "inhalation disease". For those few organisms studied, a balance exists between size of inhaled droplet and numbers of organisms required to transmit disease, making specific quantitative estimates of disease risk impossible, except for the few microorganisms well-studied in defined laboratory models of infection.

Contact: Particles of any size on exposed surfaces may cause disease in several specific areas. Whereas contact of even large numbers of most organisms on normal skin or surfaces is un-

likely to cause disease, certain exposed surfaces may be much more susceptible, particularly the following:

1. Abnormal skin or surfaces (sites of burns, abrasions, or open wounds).
2. Mucuous membranes of respiratory tract.
3. Conjunctiva.

Ingestion: Food or water supplies contaminated by cooling-device drift can cause disease in any population ingesting such contaminated materials. In considering the possible role of cooling device drift, primary contamination of food and water supplies, as well as secondary contamination via infection of plants or animals lower down in the food chain must be considered. The risk of both primary and secondary contamination is particularly important for any population ingesting untreated food or unchlorinated water.

Portal of Exit

This is a relatively unimportant facet of this task, and is pertinent to the discussion of secondary propagation of disease through a community. Portals of exit are relevant by providing a means of infecting cooling tower makeup water in the first place. While organisms excreted predominantly by fecal or urinary routes of exit may find their way most readily into polluted river or ground water, virtually any organism in any tissue of any susceptible host, excreted by any route, such as respiratory tract discharges, could, under some natural circumstances, be found there. What is more important, therefore, is the ability of the organism to survive or multiply in such settings.

Incubation Period

This period between first contact of the host with the infecting organism and the development of clinical symptoms plays a major role in determining the shape of epidemic curves, and hence, in the development of appropriate forms of epidemiologic monitoring of the effects of cooling towers. However, consideration of incubation periods is not relevant to this preliminary discussion.

Gradient of Infection

This reflects the proportion of those infected who become symptomatically affected by the disease. It is important in determining the magnitude of an epidemic and in evaluating the public health significance. It is largely determined by the susceptibility of the population and the size of the infecting

inoculum. This will become important in determining modes of epidemiologic monitoring, in which the search for asymptomatic infections may become required.

Mode of Spread

The conventional modes of transmission of epidemic disease are:

1. airborne
2. droplet
3. contact
4. food and/or water
5. vector.

Direct or indirect contact with cooling-device drift will involve all these modes of spread, with the possible exception of vector-borne disease. In the discussion of individual infectious agents that follows, droplet-borne diseases are considered under the respective portals of entry of either contact or inhalation disease depending on the anatomic site of impact of the offending agent and the route by which specific disease might be best acquired.

Survival in Nature

This concept is perhaps the most important in determining the risk from exposure to pathogens in cooling device drift. Survival of the microorganisms includes an analysis of what is present in the water sources used to cool the towers, survival of the initial "inoculum" in the highly unnatural thermal conditions of the tower, and in the aerosol produced. These last two considerations will be the most important factors in determining whether or not disease will ensue from the use of water polluted with any potential pathogen. This was of course, discussed within Task II.

Susceptibility of the Population at Risk

This may be the most difficult variable to define quantitatively, as it will differ for each organism and for each population group. For humans the demographic and medical variable that will need to be considered include the following:

1. Age distribution of the exposed population.
2. Racial distribution of the exposed population.
3. Sex distribution of the exposed population.
4. Presence of malnutrition or exposure to other factors that will affect host defense (e.g., malaria, produc-

ing reticuloendothelial system blockade, and thereby increasing susceptibility to Salmonella infection).
5. Prior experience or exposure to the pathogens and toxins involved.
6. Presence of immunologic deficiency states.

Variables to be considered for animals include these:

1. Age distribution of the exposed population.
2. Sex distribution of the exposed population.
3. Presence of malnutrition or other factors that will affect host defense (e.g., weather conditions, breeding cycles, migration and hibernation patterns).
4. Prior experience or exposure to the pathogens and toxins involved.
5. Presence of immunologic deficiency states.
6. Relative position in the trophic levels, and feeding pattern (e.g., herbivore, carnivore, omnivore).

The environmental and physical variables which predispose vegetation to infection or intoxication are more numerous and varied than those for humans and animals. The factors include:

1. Biological variables; including age, stage of development, species and variety of the exposed population.
2. Edaphic variables; soil conditions such as moisture and nutrition content.
3. Climatic factors; e.g. wind speed, temperature, relative humidity, light intensity and quality.
4. Presence of a second pollutant or toxin, which may modify the effect of the first.
5. Quantity of precipitation.
6. Factors of exposure including the concentration of the toxin, duration and frequency of exposure. (Continuous and intermittant exposures of the same dosage will produce significantly different effects).

General statements as to the relative risk of specific organisms or toxins can be found in Appendix B, Aerosol Drift Direct Effects Assessment Catalogue. Analysis of the actual effects on humans, animals and vegetation is included for each specific toxin or pathogen.

Finally it should be recognized that the risk of cooling device drift to a given population involves not only the direct transmission of disease and toxicity but also indirect transmission (to be discussed under Task IV), and transmission of allergens.

Allergens of many types can be considered, but are generally beyond the scope of this report, although several biologic agents can be so involved. Some, by their ubiquity and because the

unique environmental situation of the cooling tower might potentiate their growth or transmission, might be particularly important, including:

A. Allergic broncho-pulmonary aspergillosis
B. Thermophilic actinomycetes.

Under these conditions, high concentrations of many other organisms, or antigenic fragments of organisms, might also become important. Among these is transmission of toxic substances which might alter the susceptibility of the population to other organisms, and resultant long-term effects of prolonged contact with unusual chemical or biologic materials.

One particular organism which could not be addressed fully within the format of the Aerosol Drift Direct Effects catalog is Mycobacterium tuberculosis. The general effect of this organism is tuberculosis, a chronic infectious disease. It is normally characterized by the formation of avascular nodules of inflamatory tissue.

The organism is carried and transmitted via aerosol formites while infection may occur through inhalation, ingestion or directly through skin. Inhalation is the most frequent means of infection. The route of entry of the infectious fomites may usually be inferred from the location of the characteristic lesions. Further transmission of the disease may occur from discharges from these areas.

There are three common varieties of this organism, var. hominus, var. bovis, var. avium. Each has a different pathogenicity. The bovine type is progressive and sometimes fatal in cattle. Manifestation in horses is progressive and usually associated with infection in cattle. The disease is also progressive in swine who are highly susceptible and in cats, who are usually infected from tuberculous milk. This type rarely affects sheep, goats, dogs, humans and does not affect birds.

The avian type affects all birds. Due to their lowered resistance to disease, disease occurs mostly in domestic or captivated, wild birds. This type produces chronic symptoms in swine and is progressive in sheep. It is the most common form to affect these animals. Rarely are goats, horses, cattle, dogs or cats affected by the avian variety.

Cattle, swine and cats are resistant to the var. hominus. This type doesn't affect horses, sheep, goats or most birds. Only psittacines are not resistant and their infection is usually associated with tuberculous owners. Dogs may also contract the disease from their owners and it manifests itself in the pulmonary form. Var. hominus is of course, the most common form to affect man.

When large animals contract tuberculosis, cattle normally develop lesions in the lungs and in the cephalic and thoracic lymph nodes. Swine develop lesions in the cephalic and abdominal lymph nodes, and it is sometimes fatal. In sheep and goats, the affected areas are the lungs and thoracic lymph nodes.

In smaller animals, dogs are affected in the thoracic organs and cats, initially in the abdominal organs and later in the lungs. Poultry develop the disease slowly. Initially there is intestinal ulceration and then necrosis and ulceration of the spleen and liver.

Wild animals rarely contract the disease except when associated with humanity, zoos or cattle raising areas. Wild birds commonly develop lesions in the spleen and liver. However, outward signs of infection are variable and may be non-existent. Outbreaks among wild animals involving more than one individual, are usually associated with man. Infection stems from exposure to either infected farm animals or sewage outfall.

Humans are quite susceptible to tuberculous infections but rarely manifest tuberculous disease. Generally the route of entry determines the site of primary lesions. Inhalation produces lesions in lungs and tracheobronchial lymph nodes; ingestion: mouth, tonsils, neck lymph nodes, intestine; skin: ulceration at specific site and regional lymph nodes. After a period of days the infecting organisms spread to all parts of the body.

Most of the tubercle bacilli do not find suitable sites for development. Some remain microscopic foci and may promote infection of bones, joints, lungs and other organs as much as ten years later. Disease due to reinfection usually becomes the chronic pulmonary form. This form is the prime cause for morbidity and mortality.

Man may be regarded as the sole carrier. Animal infection stems directly and indirectly from man, and any residual foci of infection in cattle are eliminated through mild pasteurization.

RESULTS OF TASK IV - INDIRECT EFFECTS

The effects of cooling device drift are not limited to direct reactions to and manifestation of disease from toxins and pathogens. The infection of plant and animal and human populations may either be secondarily transmitted or spread to other members of the community or may lead to interruption of human and animal food sources.

The potential of a given agent to indirectly or secondarily cause disease in any given population and the insuring patterns of infection or intoxification relies on the same variables as discussed under Task III.

1. Portal of entry for the disease-causing agent
2. Portal of exit
3. Incubation period
4. Gradient of infection
5. Mode of spread
6. Survival in nature
7. Susceptibility of the population at risk

Essentially all discussion contained in the previous section holds true and only the exceptions will be noted here.

Portal of Exit

Under this task, discussion of this facet takes on new importance. Organisms excreted from infected individuals, predominantly by fecal or urinary routes of exit and perhaps respiratory tract discharges, may find their way quite readily into polluted river or ground water. Virtually any organism in any tissue of any susceptible host, excreted by any route, could be found in water sources or areas of food cultivation. The ability of the organism or disease to survive, multiply or remain virulent in such settings, determines the potential for its transmission to successive individuals.

Mode of Spread

The five conventional modes listed in the previous task are valid considerations within this section as well. The difference lies in the role of vectors as means of transmission. Vector transmission by definition accounts for one living organism carrying a disease to another non-infectious individual. Vectors act in events such as insect bites (mosquitos transferring malaria); food chain transmission (infected plants; low order animals; herbivores; carnivores; and predators). Other instances include contact with open lesions on infected individuals.

Fomites too, play a major role in indirect effects from cooling towers. Ingestion of water contaminated with waste from infected individuals could spread disease. Plants may harbor pathogens on its edible parts or concentrate toxins in its leaves, fruits or roots, as in tuberous plants. Many small wild animals concentrate toxins in their fatty tissue, or may simply be infected with the disease itself. Inclusion of any of these in a food supply would further spread the infection or offending agent. Prior to pasteurization, milk from infected cows was the major cause of the spread of tuberculosis.

Concentration of people in close quarters, such as in schools, encourages person to person transmission. In recent years winter bouts of influenza have reached epidemic proportions and there have been renewed outbreaks of "childhood diseases" (rubella, chicken pox, measles). Rapid transmission would also occur between animals in farm and breeding settings.

Susceptibility of the Population at Risk

Susceptibility to an infection may increase when transmitted from one animal, plant or human to a like individual due to potentiation. Like individuals are susceptible to like organisms, varieties, even concentrations or innocula. As each individual becomes infected the innocula become more refined to meet the specifications necessary to infect subsequent individuals. Populations are therefore more susceptible to the agent being transmitted.

RESULTS OF TASK V - RECOMMENDATIONS

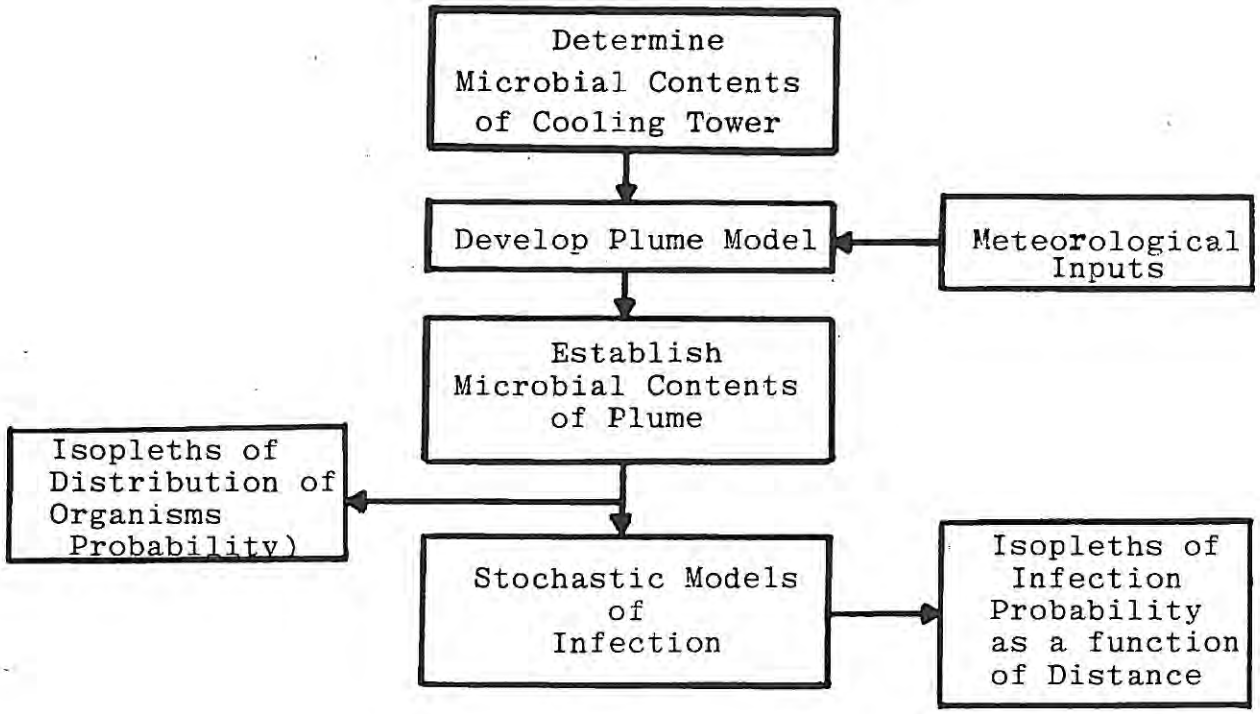
Discussion of the recommendations based on the results of this study, the results of Task V in the scope of the study, may be found in Section 3, Recommendations.

RESULTS OF TASK VI - COMPUTER SIMULATION

A. Introduction

The computer simulation is based on a combination of numerical and Monte Carlo modeling. Basically, the modeling is done in three serial parts for a cooling tower and associated ambient environment that are specified as input parameters. Part 1 develops the microbial environment in the cooling towers based on the data from the consultants. Part 2 develops and distributes the aerosols (micro-microbial environment) from the cooling tower into the environment. Part 3 calculates the microbial environment downwind from the cooling tower, evaluates the possibility of infections based on the results of Part 1 and 2, and prints out results. Figure 11 is a simplified flow chart for the simulation.

FIGURE 11
BASIC FLOW CHART



B. Development of Cooling Tower Microbial Environment

The consultants have developed a list of pathogenic organism that can occur in a polluted water source. This list was used as a basis to establish the microbial content of the cooling tower. To do this, a matrix was established listing each organism from the consultants list versus the following factors:

1. ability to produce disease (epidemiological significance)
2. survival in surface water
3. survival in treated effluent
4. survival in cooling device
5. survival in aerosols
6. integrity in fomites

For each factor a numerical value between 0 and 5 was assigned based on the consultants data. The definitions of these numerical constants are listed in Table 18. Table 19 shows the matrix and the numerical constants assigned for each category, for each organism considered. From the matrix a weighted product for each organism was found as follows:

$$W = \prod_{i=1} a_i f_i$$

Where W is the weighted product, a_i is the weighting factor (0 to 1) for the ith factor and f_i is the numerical constant from the matrix. As a practical initial matter, the weighting factors (a_i) were taken as unity, however, as more information becomes available and it is possible to refine the model, this should be changed. The products were grouped, that is, products with very similar numerical values were considered to be the same and normalized. From these normalized values a histogram was constructed and used as the distribution function for determining the probability that pathogens were present in the make-up water using Monte Carlo methods to evaluate the integral of the distribution function.

The number of organisms present in the make-up water (per unit volume) was modeled somewhat arbitrarily by using the probability from above as the mean of an exponential distribution limited to 10^6 maximum (personal conversation with Dr. H. Freudenthal). This was done by a modified Monte Carlo simulation. Thus, the number of pathogens entering the cooling tower per unit volume of make up water was established. This simulation, was further modulated by including only those results from the exponential distribution when a second selected uniform random variable exceeded the probability value found earlier.

TABLE 18

NUMERICAL CONSTANTS USED IN ESTIMATING PROBABLITIES

OCCURRENCE IN POLLUTED WATER SOURCE

(0) will not occur under any circumstances
(1) rarely occurs
(2) compromised - will occur only if concentration or frequency in surrounding environment significantly increases eg. epidemic, leak from toxic substance storage
(3) will occasionally occur
(4) will frequently occur
(5) will always occur
(x) unknown

SURVIVAL IN A PARTICULAR ENVIRONMENT (SURFACE WATER, TREATED EFFLUENT, COOLING DEVICE)

(0) will not survive under any circumstances
(]) rarely survives
(2) compromised - may survive in this environment only if conditions change eg. type of water treatment, presence of other toxins or pathogens
(3) will occasionally survive
(4) will frequently survive
(5) will always survive
(x) unknown

EPIDEMIOLOGICAL SIGNIFICANCE

(0) will never cause disease or direct effects
(1) rarely causes disease or direct effects
(2) compromised - host may contract the disease or become affected if its immune system has been weakened
(3) may cause non-transmittable effects or allergic responses
(4) usually causes disease
(5) always causes disease
(x) unknown

TABLE 19

SUMMARY OF PATHOGEN/TOXIN PROBABILITIES

PATHOGEN/TOXIN	produce disease	occurrence	Survival in surface water	Survival in treated effluent	Survival in cooling device	aerosolization	integrity in fomites
Absidia corymbifera	4	1	4	4	3	5	4
Absidia ramosa	4	1	4	4	3	5	4
Actinomyces israeli	2	3	4	3	3	4	4
Actinomyces keratolytica	2	1	4	1	4	4	4
Actinomyces naeslundii	1	3	4	1	1	3	3
Actinomyces odontolyticus	1	3	4	1	1	3	3
Actinomyces viscosus	1	3	4	1	1	3	3
Arachina propionica	1	3	4	1	1	3	3
Aspergillus spp.	4	4	4	4	4	5	5
Aspergillus flavus	3	3	4	4	3	5	5
Aspergillus nidulans	2	4	4	3	3	5	5
Aspergillus niveus	2	4	4	3	3	5	5
Aspergillus restrictus	2	4	4	3	3	5	5
Aspergillus terreus	2	4	4	3	3	5	5
Bacillus anthracis	4	1	1	1	1	5	5
Bacillus cereus	4	4	4	3	4	4	5
Bacillus subtilis	2	4	4	2	3	4	5
Bacteriodes fragilis	4	4	4	4	4	5	5
Bacteriodes melaninogenicus	4	4	4	4	4	5	5
Basidiobolus haptosporus	4	1	4	4	3	5	4
Blastomyces dermatitidis							
Bordetella parapertussis	1	1	1	0	1	4	4
Brucella abortus	4	1	1	1	1	5	5
Brucella canis	4	1	1	3	3	5	5
Brucella melitensis	4	1	1	3	3	5	5
Brucella suis	4	1	1	3	3	5	5
Candida albicans	2	3	4	3	3	5	5
Candida guillermondii	2	3	4	3	4	5	5

TABLE 19

SUMMARY OF PATHOGEN/TOXIN PROBABILITIES

PATHOGEN/TOXIN	produce disease	occurrence	Survival in surface water	Survival in treated effluent	Survival in cooling device	aerosolization	integrity in fomites
Candida krusei	2	3	4	3	4	5	5
Candida parapsilosis	2	3	4	3	3	5	5
Candida pseudotropicalis	2	3	4	3	4	5	5
Candida stellatoidea	2	3	4	3	4	5	5
Candida tropicalis	2	3	4	3	4	5	5
Candida utilis	2	3	4	3	5	5	5
Candida viswanthii	2	3	4	3	5	5	5
Candida zeylatoides	2	3	4	3	5	5	5
Cladosporium bantianum	1	1	3	3	3	5	3
Cladosporium carrionii	1	1	3	3	3	5	3
Clostridium botulism	4	1	3	3	3	5	5
Clostridium perfingens	3	4	4	3	5	4	5
Cocciodioides immitis	4	3	3	3	3	5	5
Cocynebacterium spp.	2	4	4	3	3	4	5
Conidiobolus coronatus	1	1	4	4	3	5	4
Corynebacterium diptheriae	2	1	3	3	3	4	5
Corynebacterium ulcerans	2	1	3	3	3	3	5
Cryptococcus neoformans	2	1	4	3	3	4	5
Dermatophilus congolensis	2	3	4	3	3	4	5
Enterobacteriae	2	1	5	1	3	5	5
Enterococci	4	4	4	3	3	5	4
Escherichia coli	3	4	4	3	4	4	5
Fuscobacterium spp.	4	4	4	4	4	5	5
Geotrichium candidium	2	1	3	0	3	5	5
Haemophilus aegyptius	2	4	4	3	4	4	5
Haemophilus influenzae	2	1	1	0	1	4	4
Histoplasma capsulatum	4	4	4	4	4	5	5
Klebsialla pneumonia	4	4	4	4	4	4	4

TABLE 19

SUMMARY OF PATHOGEN/TOXIN PROBABILITIES

PATHOGEN/TOXIN	produce disease	occurrence	Survival in surface water	Survival in treated effluent	Survival in cooling device	aeroso-lization	integrity in fomites
Listeria monocytogenes	2	1	4	1	1	5	4
Mucor spp.	2	1	4	1	1	5	4
Mucor pusillus	2	1	4	4	3	5	4
Mucor ramosissimus	2	1	4	4	3	5	4
Mycobacterium bovis	3	1	4	1	1	5	4
Mycobacterium chelonei	3	1	4	1	1	5	4
Mycobacterium fortuitum	3	1	4	1	1	5	4
Mycobacterium kansasii	3	1	4	1	1	5	4
Mycobacterium marinum	3	1	4	1	1	5	4
Mycobacterium scrofulaceum	3	1	4	1	1	5	4
Mycobacterium simiae	3	1	4	1	1	5	4
Mycobacterium tuberculosis	3	1	4	4	1	5	5
Mycobacterium ulcerans	3	1	4	1	1	5	4
Mycobacterium xenopi	3	1	4	1	1	5	4
Nocardia asteroides	2	1	4	1	1	4	5
Nocardia brasiliensis	2	1	4	1	1	4	5
Nocardia caviae							
Peptococcus spp.	4	4	4	4	4	5	5
Peptostreptococcus spp.	4	4	4	4	4	5	5
Phialophora dermatitidis	1	1	1	1	1	4	3
Phialophora gougerotii	1	1	1	1	1	4	3
Phialophora richardsiae	1	1	1	1	1	4	3
Phialophora spinifera	1	1	1	1	1	4	3
Phialophora verrucosa	1	1	1	1	1	4	3
Proteus mirabilis	4	4	4	1	4	4	5
Prototheca wickerhamii	1	1	4	1	1	0	0
Prototheca zopfi	2	1	4	1	1	0	0
Pseudomonas aeruginosa	2	1	4	1	1	4	4

TABLE 19

SUMMARY OF PATHOGEN/TOXIN PROBABILITIES

PATHOGEN/TOXIN	produce disease	occurrence	Survival in surface water	Survival in treated effluent	Survival in cooling device	aerosolization	integrity in fomites
Pseudomonas mallei	4	1	3	3	3	4	5
Pseudomonas pseudomallei	4	1	4	3	3	3	4
Rhinocladiella compactum	1	1	1	1	1	5	3
Rhinocladiella perosoi	1	1	1	1	1	5	3
Rhizopus arrhizus	4	1	4	4	3	5	4
Rhizopus oryzae	3	1	4	4	3	5	4
Salmonella spp.	4	4	4	1	4	4	5
Salmonella typhi	4	4	4	3	4	4	5
Shigella spp.	4	4	4	1	4	4	5
Shigella boydii	4	4	4	1	4	4	3
Shigella dysenteriae	4	4	3	1	3	4	3
Shigella flexneri	4	4	3	1	3	4	3
Shigella sonnei	4	4	3	1	3	4	3
Sporothrix schenckii	2	3	4	1	1	4	4
Staphylococcus agalactiae	2	1	4	1	1	5	4
Staphylococcus aureus	4	4	4	4	4	5	5
Streptococcus spp.	2	1	1	0	1	4	4
Streptococcus agalactiae	2	1	1	0	1	4	4
Streptococcus faecalis	4	4	4	3	4	4	5
Streptococcus pneumoniae	2	4	4	1	3	4	5
Streptococcus pyogenes	2	1	4	1	1	5	4
Toruplopsis glabrata	2	1	4	1	1	5	4
Vibrio parahemolytica	4	4	4	1	5	4	5
Yersina enterocolitica	4	4	4	1	4	4	5
Yersina pestis	4	4	4	3	3	4	4
Yersina pseudotuberculosis	4	4	4	1	4	4	5
Zygomycetes	2	1	1	1	1	5	4

TABLE 19

SUMMARY OF PATHOGEN/TOXIN PROBABILITIES

PATHOGEN/TOXIN	produce disease	occurrence	Survival in surface water	Survival in treated effluent	Survival in cooling device	aeroso-lization	integrity in fomites
Acenapthene	3	3	4	4	4	1	4
Acetone	3	4	2	3	1	5	4
Acrolein	3	4	1	4	1	5	1
Acrylonitrile	4	4	4	4	1	5	1
Aldrin	4	4	4	4	4	1	4
Antimony	4	3	4	4	4	1	5
Arsenic	4	4	4	4	4	5	3
Asbestos	4	4	5	4	4	3	5
Benzene	3	4	4	5	1	5	4
Benzidene	4	4	4	4	4	1	2
Beryllium	4	4	4	4	4	1	2
Biphenyl (Diphenyl)	4	3	4	4	4	1	4
Cadmium	3	4	4	4	4	4	1
Carbon Tetrachloride	3	1	4	4	1	5	4
Chlordane	4	4	4	4	4	3	4
Chlorinated Benzenes	1	4	4	5	4	1	4
Chlorinated Ethanes	1	4	5	5	1	3	4
Chlorinated Napthalene	3	4	4	4	4	1	2
Chlorine	4	5	1	5	4	4	1
Chloroform	3	4	4	5	4	4	1
Clorophenol	3	1	1	2	4	3	4
Chromium	4	3	4	4	3	2	5
Copper	4	3	4	4	4	2	1
Cyanides	4	3	4	4	4	4	1
DDT & metabolites	4	4	5	5	4	3	4
Diabyl Ethers	4					1	1
Dichlorobenzenes	3	2	5	4	4	2	4
Dichlorobenzidine	3	3	4	4	4	1	4

TABLE 19

SUMMARY OF PATHOGEN/TOXIN PROBABILITIES

PATHOGEN/TOXIN	produce disease	occurrence	Survival in surface water	Survival in treated effluent	Survival in cooling device	aeroso-lization	integrity in fomites
Dichloroethylene	3	4	4	4	4	1	1
Dichlorophenol	3	4	x	x	x	3	4
Dichloropropane, Dichloropropene	1	3	4	4	4	1	4
Dieldrin	4	4	5	4	4	3	4
2,4, Dimethyl Phenol	2	4	3	5	1	3	3
Dinitrotoluene	3	1	x	4	x	1	1
Diphenylhydrazinr	1	3	4	4	4	1	4
Endosulfan	3	x	4	4	4	1	2
Endrin & metabolites	4	4	5	4	4	3	4
Ethylbenzene	3	3	5	4	4	2	4
Haloether	x	x	x	5	1	1	4
Halomethanes	3	3	2	4	4	4	4
Heptachlor & metabolites	4	4	5	4	5	3	4
Hexachloro 1,3 Butadiene	3	3	4	4	4	x	x
Hexachlorocyclohexane (Lindane)	3	1	5	4	4	1	4
Isophorone	3	3	5	4	4	3	4
Lead	4	3	1	4	4	1	1
Mercury & compounds	4	4	2	4	4	4	2
Methyl Ethyl Ketone (Butanone)	3	3	1	1	2	3	4
Napthalene	4	3	5	4	5	5	1
Nickel & compounds	4	4	5	4	4	2	4
Nitrites	3	4	1	4	4	4	2
Nitrobenzene	4	4	2	1	4	3	4
Nitrophenol	1	4	3	4	2	3	x

TABLE 19

SUMMARY OF PATHOGEN/TOXIN PROBABILITIES

PATHOGEN/TOXIN	produce disease	occurrence	Survival in surface water	Survival in treated effluent	Survival in cooling device	aeroso-lization	integrity in fomites
Nitrosamines	3	x	1	x	5	5	4
PCB's	x	x	4	5	4	x	x
Pentachlorophenol	3	3	5	4	4	3	4
Phenol	5	4	1	5	3	4	3
Phthalate Esters	3	3	2	x	4	x	x
Secondary Amines	1	3	4	1	1	5	1
Selenium & compounds	3	4	1	5	4	3	1
Silver & compounds	1	x	4	4	4	2	1
Styrene	3	3	3	4	4	3	1
Tetrachloroethylene	3	4	3	5	4	x	x
Thallium & compounds	4	4	5	4	4	1	1
Toluene	3	4	3	3	3	3	4
Toxaphene	4	4	5	4	4	1	4
Vinyl Chloride	3	3	4	4	4	3	1
Zinc & compounds	4	4	2	2	4	1	x

The value of make up water was estimated as equal to the sum of the evaporation loss and the droplet losses. These losses were calculated on the basis of the cooling tower design parameters and/or the cooling tower operating condition. For the present model, blow-down was assumed to restore the initial (steady-state) operating condition of the cooling tower periodically with respect to salt and the pathogen concentration. The time between blow downs was calculated as:

$$T=(CONC-1.)\ TVOL/_{UMW}$$

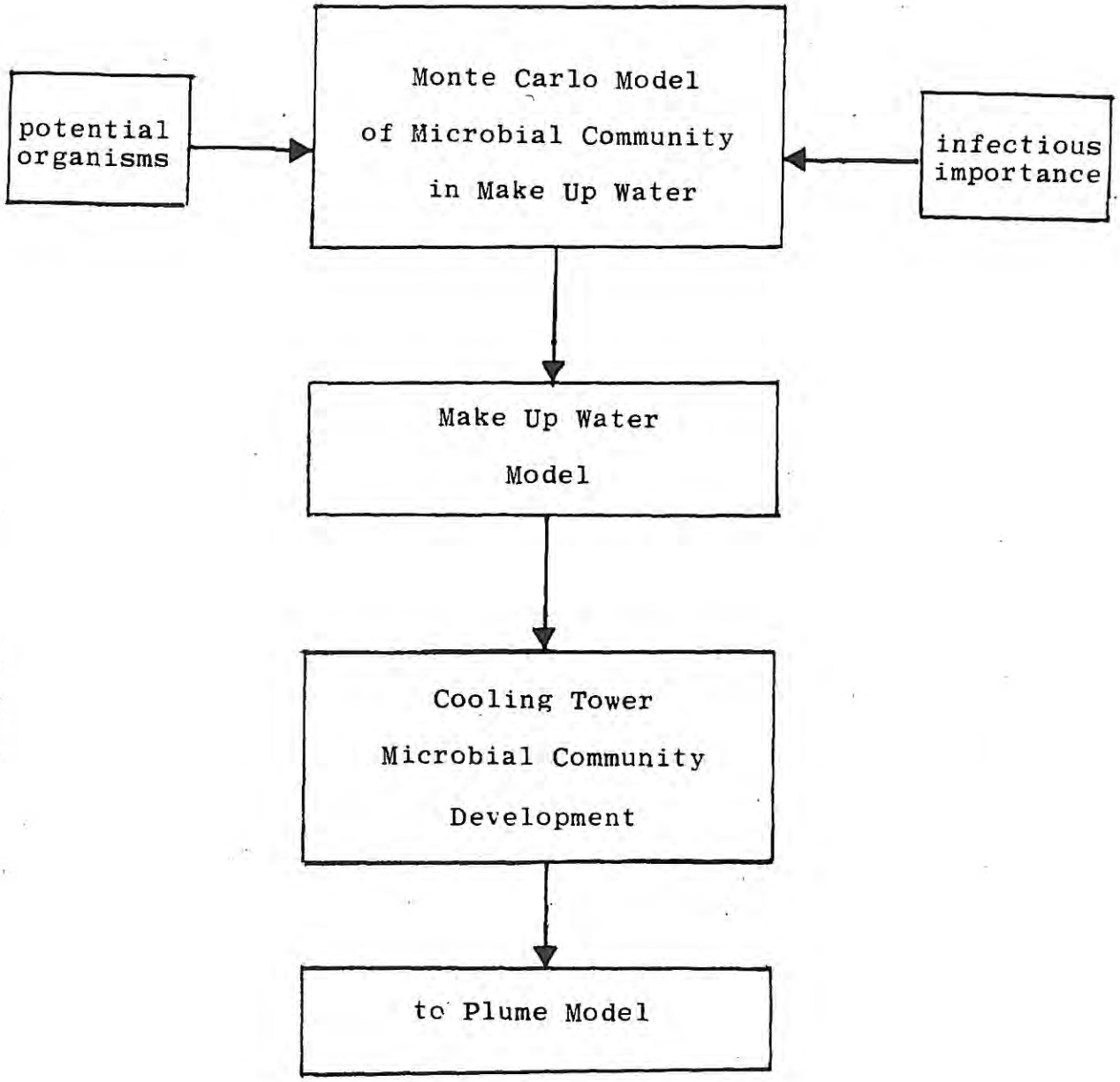
Where T is the time between blow downs, CONC is the maximum allowable concentration (input parameter), TVOL is the tower water value and UMW is the make up water input rates. The total average value of make up water taken in, then was calculated as:

$$BINVOL = UMW \times T/_2$$

where BINVOL is the total amount of water taken in between blow downs. This was multiplied by the number of organisms per unit volume derived earlier to establish the average microbial content of the cooling tower. As can be seen, the microbial content is then the average number of organisms taken in between blow downs diluted by the value of water carried by the tower. In the present model, no specific capability is included for growth or death of pathogenic organisms in the cooling tower. Their concentration is determined purely by input conditions and dilution factors. It is also assumed that the droplets are spherics and are homogeneous samples of the cooling tower microbial environment. Figure 12 shows a simplified flow chart of that portion of the simulation relating to the development of the microbial environment in the cooling tower.

FIGURE 12

MICROBIAL CONTENT OF COOLING TOWER



C. Aerosol Model - The Spatial Distribution of Organisms

The aerosol model that distributes the pathogens in the environment is based on the ORFAD Model (Oak Ridge fog and drift) (Wilson, 1975 & LaVerne 1977). The elements comprising the plume rise, the distribution of the aerosol droplet sizes and their physical distribution have been developed from this model. The model for this portion of the simulation takes cooling tower and environmental parameters (as inputs) and calculates the plume rise from the cooling tower and the plume environment. As in the ORFAD model, the aerosols are assumed to travel in ballistic trajectories set by the rise velocity of the plume centerline and the fall velocity of the droplet with respect to the plume centerline.

Plume rise is calculated as follows:

1. Determination of a buoyancy flux parameter (F)
2. Calculation of atmospheric stability (S)
3. Determination of the plume centerline (trajectory) (PR) based on F, S and wind conditions.

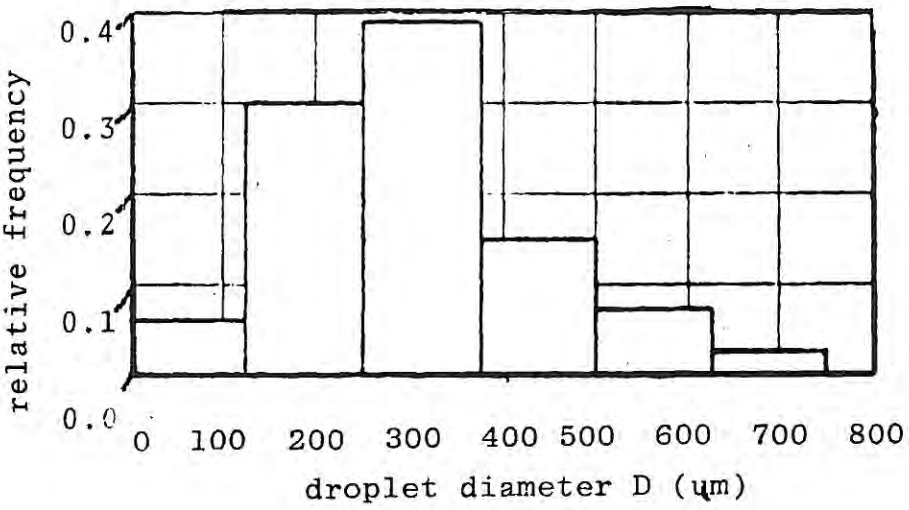
The flux buoyancy parameter (F) is that developed by Hanna (ref. 3). The atmospheric stability parameter is derived from the Pasquill stability class as determined from weather data (input parameters) that determine the atmospheric temperature gradient and the dry and wet bulk temperatures. Wind conditions (input parameters) are taken as 1 m/sec minimum, even for calm ground conditions since the wind velocity, generally is rarely less than this at typical tower heights. The plume is assumed to be disturbed over a 22.5^{o} angle downwind. Unlike ORFAD, this program computes for the downwind condition without regard to specific geographic direction. The day is broken into 4 hour segments starting at 0000 hours, and wind velocity, temperature (dry and wet bulb), stability and percent operating capacity of the plant are inputted for each time segment. Computations are done for each four hours and are summarized daily.

The aerosol drift deposition is based on ballistic
ple as discussed by Laverne. This trajectory model assumes that all particles of a given original size (at the cooling tower) will fall to the ground at the same distance from the cooling tower for a given set of wind, stability and humidity conditions. This distance is such that the total trajectory is equal to the local plume height above the ground.

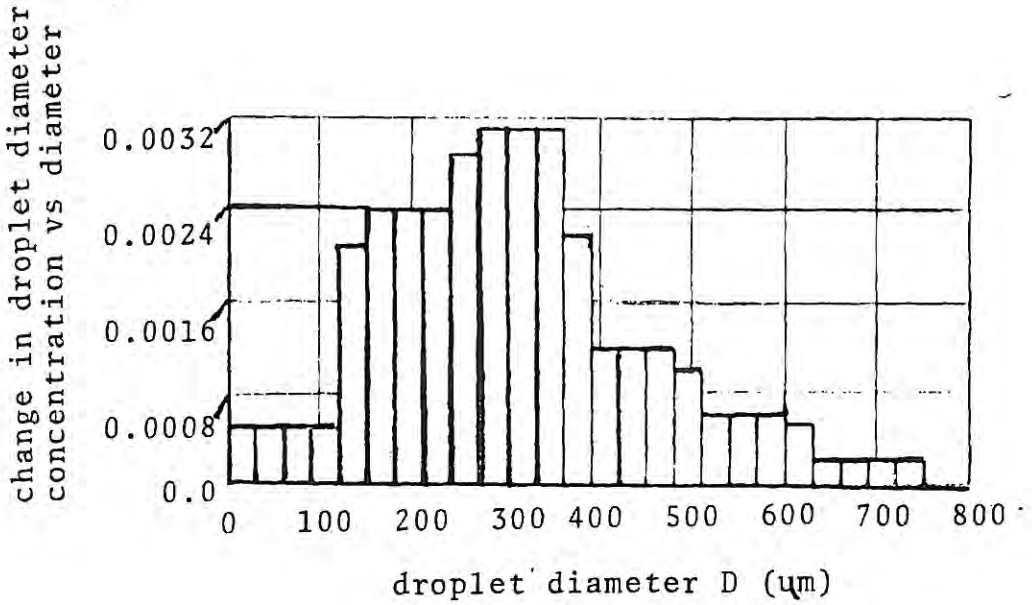
The distribution of aerosol particle sizes within the exit plume is shown in Figure 13(A). As in the ORFAD model, this distribution is recomputed in terms of the cumulative distribution function to obtain a refined droplet size distribution model (Figure 13 (B). Fall velocities are computed by using Stokes' law for particles smaller than about 80 um and a relationship

FIGURE 13

DROPLET SIZE DISTRIBUTION



(A)

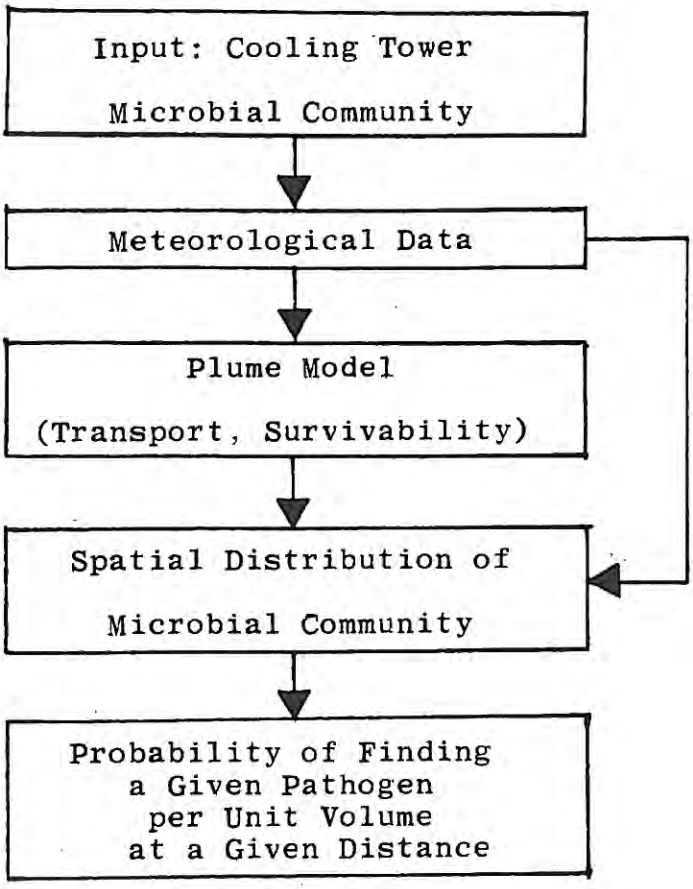


(B)

given in Letester (1966) for particles greater than about 80 μm. Particles in relative humidity environments greater than 76% are assumed not to evaporate, while particles in environments with less than 76% are assumed to evaporate, either to saturation (76%-50% R.H.) or dryness (R.H. 50%). Following the methods outlined in Laverne (1977), particles are distributed downwind in accordance with wind velocity, plume and weather condition. From these data, and the microbial input data from part 1 of the simulation, the total number of organisms impinged per unit area, per unit time, and present per unit volume (steady state), are easily calculated. The flow chart for this phase of the simulation is shown in Figure 14. It is assumed that the organisms that find their way into the aerosol will all survive if there is no evaporation (R. H. 76%) that 50% survive in the R. H. range of 76% to 50% and that 20% survive when the R. H. is 50%. These factors are further modified by 0.2 if there is direct sunlight (0800-0800) present or 0.5 with cloud cover. These factors are rather arbitrarily chosen and should be re-evaluated (perhaps dynamically simulated in further model developments. These results (organisms/M^3 and organisms/M^2) are tabulated for each four hour interval.

FIGURE 14

SPATIAL ORGANIZATION OF ORGANISMS



D. Estimation of Infection Probability

The previous elements of the simulation have established a potential microbial density for distances downwind from the cooling tower. It is now necessary to establish the extent to which these microbial densities are capable of producing infection. Two basic possibilities exist. In one case, inhalation of organisms can create an infection and in another, physical contact (touching or ingestion) will create an infection. In either case, a threshold level establishes a minimum below which nothing will happen. The estimation of this threshold is extremely difficult. Furthermore, the consequences of infection may vary from a general slight malaise to severe symptoms that require extensive care. The model developed here, does not consider the epidemiological affects of interaction between infected and non-infected individuals, but only considers the direct effect of the interaction between the microbial environment and the individual. Figure 15 is a simplified flow chart for Part 3 of the simulation.

The lifetime of deposited (or airborne) microbial particles has (again, rather arbitrarily) been taken to be 24 hours* on the average. The average ventilation value for a population is about 20,000 liters per day (Haup). Therefore, for the airborne organisms, the average number of organisms inhaled/day is calculated. A sticky problem is that of determining the number of organisms required to declare an infection. A randomly distributed variable, exponentially distributed with a mean of .1 X (3×10^6) was used to establish (in a Monte Carlo loop) the basis for estimating the number of organisms required to generate an infection. The same approach is used with respect to the number of particles injested with the assumption that an individual will ingest the microbial flora that falls on one square meter of surface in 24 hours. Results for 24 hours are obtained from the summation or averaging (as required) of the data accumulated for each four hours.

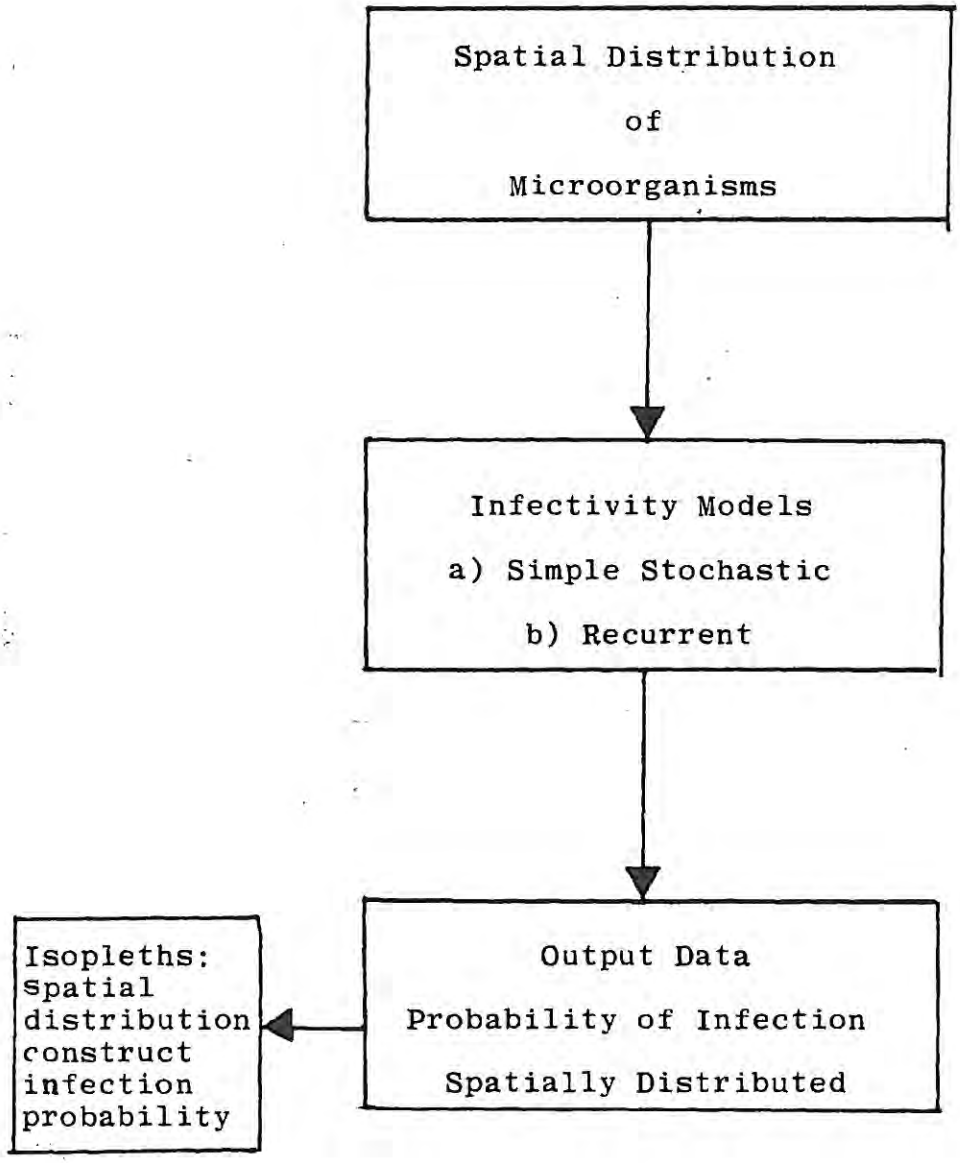
The above data is then used to generate infection probabilities, based on the number of times the infection threshold is pierced during the interval under consideration. This resultant is tabulated as the result for a particular simulation based on given input condition.

---

*It is recognized that many organisms remain viable for periods much longer than 24 hours, even years in some cases. However, it was assumed that the cooling tower, Figures 16-20, environment would not favor encystment or spore formation, and therefore, the cells would be susceptible to die-off due to uv, desiccation, etc. Twenty-four hours was picked as a working number for the purpose of modeling.

FIGURE 15

INFECTIVITY MODEL



E. Input Data Requirements

Table 20 lists the input data requirements and lists some typical values used in the simulations. These are printed for each simulation as part of the data file. Figure 16 shows a typical data file. Figures 17-21 shows the result of simulations under various conditions of cooling tower operation and environment.

Figure 17 simulates a typical summer day. Weather conditions represent the most significant difference in the simulations. Internal parameters on which the model is based, were previously discussed in Section 2. The fixed parameters were selected as typical for a large, natural draft tower. The day was divided into four (4) hour intervals as shown and the environmental parameters are varied as they might be for a summer day. The results of the simulation for each four hour interval are shown along with a summary of operating parameters for that interval. Also, listed for that interval are distance from the cooling tower, plume rise, the average number of organisms per cubic meter of air, the average number of organisms landing per square meter of surface area, all based on the output of the simulation. In addition, there is the Monte Carlo derived probability that the effluent will contain infectious organisms. Following the four hour listings are summaries for the 24 hour period detailing the number of organisms airborn per cubic meter, their incidence on surfaces per square meter, and the average 24 hour probability of effluent containing infectious organisms.

The second summary shows the results of exposure of a population to these infectious organisms with a maximum instantaneous susceptible population of 20%. The organisms are assumed to be ingested from both airborne particles and those picked up by contact with surfaces. This leads to the calculation of the average number of particles ingested assuming the population distributions described in the methodology. These averages are used in a simple infection model to derive the listing of the population fraction affected by the effluent.

The results support the concept that the potential for affecting a downwind population is present, unless measures are taken to control infectious organisms and toxins in the make-up water and the tower to suppress these effects. As pointed out in Section 2, many assumptions have been made because real data does not exist. These data, when available, could be used to considerably strengthen the model. However, even in its present form, the model clearly shows that if infectious organisms are present in the cooling tower environment, they will surely appear in the population downwind from the cooling tower.

Figures 18 and 19 represent the same operating parameters and environmental conditions. In Figure 18, 20% of the population is susceptible to infectious organisms and toxins. Figure 19 represents a worse case situation wherein 100% of the popula-

tion is affected by transmitted pathogens and toxic particles. Figure 20 simulates conditions for a tower with a higher level of output, cooler environmental temperatures and a population which is 20% susceptible. Figure 21 represents a tower operating at 100% capacity with a 20% susceptible population.

TABLE 20
A TYPICAL INPUT PARAMETERS

PARAMETERS	UNITS	TYPICAL VALUES
Cooling tower height	ft	400
Tower inside diameter	ft	200
Temperature range (in tower)	^{o}F	25
Exit air velocity	ft/sec	0-50
Drift fraction	g/g	10^{-4} to 10^{-6}
Wind velocity	knots	50
Dry bulb temperature	^{o}F	-20 to +100
Wet bulb	^{o}F	-20 to +100
Pasquill Stability class	--	1 - 6

These data were inputted via a separated data file called FOR__.DAT. The program is now set to accept FOR28.DAT. These files are shown with each output run shown in Figure 6.

FIGURE 16

Typical Data File

```
TYPE (FILE) FOR26.DAT
450.,200.,5.E-5,12.,1.3,25.,1200.
50.,48.,10.,.8,4.
52.,45.,5.,.8,4.
60.,50.,20.,1.,5.
63.,50.,20.,1.,5.
58.,50.,5.,1.,4.
54.,50.,10.,1.,4.
3,5,7,9,13,223
@
```

FIGURE 17

**********COOLING TOWER FIXED PARAMETERS**********

TOWER HEIGHT (FEET)	450.00
TOWER DIAMETER (FEET)	250.00
HEAT LOSS (MEGACAL/SEC,MAX)	1000.00
TEMPERATURE RANGE (DEG F)	25.00
DRIFT FRACTION (G/G)	0.000050
CONCENTRATION RATIO (G/G)	1.30
EXIT VELOCITY (FT/SEC)	10.00

--COOLING TOWER ENVIRONMENTAL PARAMETERS--

TIME (HRS)	DRY BULB T	WET BULB T	WIND VEL.	OPER CAP	STABILITY
0- 400	70.00	65.00	5.00	.80	5.
400- 800	75.00	70.00	10.00	.90	4.
800-1200	80.00	72.00	8.00	1.00	5.
1200-1600	90.00	83.00	12.00	1.00	5.
1600-2000	80.00	75.00	9.00	1.00	5.
2000-2400	72.00	70.00	10.00	.90	5.

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 0- 400HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .53
HEAT LOSS (MEGACAL/SEC) 800.00
DRY BULB TEMPERATURE (DEG F) 70.00
WET BULB TEMPERATURE (DEG F) 65.00
WIND VELOCITY (KNOTS) 5.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	271.9	0.0	0.0
0.15	356.3	0.0	0.0
0.20	392.9	2403.1	4753.7
0.30	392.9	1443.5	2186.2
0.50	392.9	1254.4	1245.0
0.75	392.9	1689.0	1305.1
1.00	392.9	1085.7	630.1
1.50	392.9	1600.5	665.1
2.00	392.9	1100.6	378.0
2.50	392.9	802.7	223.3
3.00	392.9	539.6	118.6
4.00	392.9	340.0	57.2
5.00	392.9	240.6	29.7
7.00	392.9	149.5	12.8
9.00	392.9	116.2	10.0
10.00	392.9	20.2	1.1
12.00	392.9	16.8	0.9
15.00	392.9	13.5	0.7
20.00	392.9	6.9	0.2
25.00	392.9	5.5	0.2

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 400- 800HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .55
HEAT LOSS (MEGACAL/SEC) 900.00
DRY BULB TEMPERATURE (DEG F) 75.00
WET BULB TEMPERATURE (DEG F) 70.00
WIND VELOCITY (KNOTS) 10.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	136.4	0.0	0.0
0.15	178.7	144965.9	199142.1
0.20	216.5	38423.6	52783.1
0.30	283.7	11914.7	16367.4
0.50	398.8	3730.7	5125.0
0.75	522.6	1642.6	2256.5
1.00	633.0	945.4	1298.7
1.50	829.5	445.8	612.5
2.00	990.9	269.6	370.3
2.50	990.9	1636.7	1821.2
3.00	990.9	1276.9	1267.3
4.00	990.9	1973.4	1524.9
5.00	990.9	1370.0	795.1
7.00	990.9	2178.6	905.3
9.00	990.9	1556.4	534.5
10.00	990.9	1278.2	355.6
12.00	990.9	1065.2	296.3
15.00	990.9	687.6	151.1
20.00	990.9	433.2	72.9
25.00	990.9	306.3	37.9

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 800-1200HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .07
HEAT LOSS (MEGACAL/SEC) 1000.00
DRY BULB TEMPERATURE (DEG F) 80.00
WET BULB TEMPERATURE (DEG F) 72.00
WIND VELOCITY (KNOTS) 8.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	160.3	0.0	0.0
0.15	210.1	17714.7	0.0
0.20	254.5	4695.3	0.0
0.30	318.9	1456.0	0.0
0.50	318.9	4185.4	5749.6
0.75	318.9	2205.1	2188.6
1.00	318.9	3357.9	2594.7
1.50	318.9	1924.8	1117.1
2.00	318.9	2815.7	1392.5
2.50	318.9	2346.7	805.9
3.00	318.9	1955.6	671.6
4.00	318.9	1079.0	237.2
5.00	318.9	725.1	122.0
7.00	318.9	458.1	56.6
9.00	318.9	356.3	44.0
10.00	318.9	278.8	23.9
12.00	318.9	232.3	19.9
15.00	318.9	35.9	2.0
20.00	318.9	26.9	1.5
25.00	318.9	14.7	0.5

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 1200-1600HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .16
HEAT LOSS (MEGACAL/SEC) 1000.00
DRY BULB TEMPERATURE (DEG F) 90.00
WET BULB TEMPERATURE (DEG F) 83.00
WIND VELOCITY (KNOTS) 12.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	110.4	0.0	0.0
0.15	144.7	34723.7	47700.6
0.20	175.3	9731.7	13368.5
0.30	229.7	3069.1	4216.1
0.50	289.6	1165.3	1600.7
0.75	289.6	3302.9	3675.2
1.00	289.6	4145.4	3644.5
1.50	289.6	2791.7	1879.1
2.00	289.6	1932.2	1121.4
2.50	289.6	3005.8	1486.5
3.00	289.6	2838.7	1179.6
4.00	289.6	1950.3	669.8
5.00	289.6	1421.7	395.5
7.00	289.6	688.2	115.8
9.00	289.6	535.3	90.1
10.00	289.6	426.2	52.7
12.00	289.6	355.2	43.9
15.00	289.6	247.2	21.2
20.00	289.6	35.8	2.0
25.00	289.6	28.6	1.6

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 1600-2000HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .54
HEAT LOSS (MEGACAL/SEC) 1000.00
DRY BULB TEMPERATURE (DEG F) 80.00
WET BULB TEMPERATURE (DEG F) 75.00
WIND VELOCITY (KNOTS) 9.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	142.9	0.0	0.0
0.15	187.3	167370.7	207502.7
0.20	226.9	47063.3	58348.1
0.30	297.3	14858.2	18420.9
0.50	307.5	30438.8	33869.6
0.75	307.5	33611.3	29550.4
1.00	307.5	27496.8	21247.2
1.50	307.5	15536.7	9017.4
2.00	307.5	25613.6	10643.7
2.50	307.5	18759.0	6442.4
3.00	307.5	15632.5	5368.7
4.00	307.5	8613.3	1893.1
5.00	307.5	6890.6	1514.5
7.00	307.5	4135.8	696.0
9.00	307.5	2846.5	351.9
10.00	307.5	2229.6	191.4
12.00	307.5	1858.0	159.5
15.00	307.5	287.2	15.8
20.00	307.5	215.4	11.8
25.00	307.5	117.5	3.6

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 2000-2400HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .21
HEAT LOSS (MEGACAL/SEC) 900.00
DRY BULB TEMPERATURE (DEG F) 72.00
WET BULB TEMPERATURE (DEG F) 70.00
WIND VELOCITY (KNOTS) 10.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	135.7	0.0	0.0
0.15	177.9	742564.0	0.0
0.20	215.5	208802.9	0.0
0.30	282.3	65920.5	0.0
0.50	311.7	64452.4	184820.3
0.75	311.7	173105.7	330926.0
1.00	311.7	243932.9	349744.7
1.50	311.7	133611.9	127712.9
2.00	311.7	62840.0	45049.2
2.50	311.7	40217.6	23065.2
3.00	311.7	27928.9	13347.9
4.00	311.7	3567.1	1278.6
5.00	311.7	2282.9	654.6
7.00	311.7	963.1	197.3
9.00	311.7	1076.2	171.5
10.00	311.7	918.9	131.7
12.00	311.7	699.0	83.5
15.00	311.7	413.6	39.5
20.00	311.7	268.6	19.3
25.00	311.7	192.2	11.0

---------- 24 HOUR TOTALS ----------

DAILY PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .34

DIST(MI)	ORG/M3/DAY	ORG/M2/DAY
0.10	0.0	0.0
0.15	1107339.0	454345.4
0.20	311119.8	129253.4
0.30	98662.0	41190.6
0.50	105227.0	232410.3
0.75	215556.6	369901.7
1.00	280964.0	379159.9
1.50	155911.4	141004.1
2.00	94571.7	58955.1
2.50	66768.6	33844.5
3.00	50172.2	21953.7
4.00	17523.1	5660.8
5.00	12931.0	3511.6
7.00	8573.2	1983.8
9.00	6487.0	1202.0
10.00	5151.9	756.5
12.00	4226.6	604.1
15.00	1685.0	230.4
20.00	986.8	107.6
25.00	664.9	54.7

---------- SUMMARY OF RESULTS ----------

DIST(MI)	AVG NO. PART. INGESTED/IND.	PERCENT AFFECTED BY EFFLUENT
0.10	0.0	0.000
0.15	1561684.4	18.135
0.20	440373.2	0.486
0.30	139852.6	1.223
0.50	337637.3	20.000
0.75	585458.3	9.244
1.00	660123.9	13.324
1.50	296915.5	18.221
2.00	153526.8	11.626
2.50	100613.1	10.064
3.00	72125.9	5.507
4.00	23183.9	0.486
5.00	16442.5	1.914
7.00	10557.1	0.318
9.00	7689.0	0.006
10.00	5908.4	0.000
12.00	4830.7	0.000
15.00	1915.4	0.000
20.00	1094.5	0.409
25.00	719.6	0.215

FIGURE 18

**********COOLING TOWER FIXED PARAMETERS**********

TOWER HEIGHT (FEET)	450.00
TOWER DIAMETER (FEET)	200.00
HEAT LOSS (MEGACAL/SEC,MAX)	750.00
TEMPERATURE RANGE (DEG F)	30.00
DRIFT FRACTION (G/G)	0.000050
CONCENTRATION RATIO (G/G)	1.40
EXIT VELOCITY (FT/SEC)	10.00

--COOLING TOWER OPERATING PARAMETERS--

TIME (HRS)	DRY BULB T	WET BULB T	WIND VEL.	OPER CAP	STABILITY
0- 400	72.00	68.00	5.00	1.00	3.
400- 800	70.00	66.00	2.00	1.00	2.
800-1200	72.00	67.00	3.00	.70	2.
1200-1600	75.00	71.00	5.00	1.00	3.
1600-2000	80.00	75.00	8.00	1.00	3.
2000-2400	77.00	74.00	5.00	1.00	4.

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 0- 400HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .54
HEAT LOSS (MEGACAL/SEC) 750.00
DRY BULB TEMPERATURE (DEG F) 72.00
WET BULB TEMPERATURE (DEG F) 68.00
WIND VELOCITY (KNOTS) 5.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	257.6	1157530.7	1753106.5
0.15	337.6	171767.8	260146.2
0.20	409.0	76052.8	115183.7
0.30	535.9	29332.3	44424.5
0.50	753.3	10220.6	15479.3
0.75	987.1	4696.3	7112.7
1.00	1195.8	2757.4	4176.2
1.50	1566.9	24301.0	33382.8
2.00	1788.3	15067.9	18680.9
2.50	1788.3	10665.2	10585.3
3.00	1788.3	16563.4	14562.2
4.00	1788.3	12922.4	8698.3
5.00	1788.3	18873.4	9333.6
7.00	1788.3	15355.8	6381.1
9.00	1788.3	10019.8	2787.3
10.00	1788.3	9017.8	2508.6
12.00	1788.3	6064.6	1333.0
15.00	1788.3	4074.8	685.7
20.00	1788.3	2700.9	333.9
25.00	1788.3	1877.2	161.2

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 400- 800HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .51
HEAT LOSS (MEGACAL/SEC) 750.00
DRY BULB TEMPERATURE (DEG F) 70.00
WET BULB TEMPERATURE (DEG F) 66.00
WIND VELOCITY (KNOTS) 2.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	653.5	418509.4	0.0
0.15	856.4	62103.3	0.0
0.20	1037.4	27497.2	0.0
0.30	1359.4	10605.2	0.0
0.50	1910.9	3695.3	0.0
0.75	2504.0	12797.4	23249.6
1.00	3033.4	2629.6	4777.4
1.50	3974.9	4516.2	6839.8
2.00	4589.6	5681.4	7804.6
2.50	4589.6	4086.2	4546.7
3.00	4589.6	6028.0	5299.7
4.00	4589.6	4735.4	3187.5
5.00	4589.6	3539.1	2054.1
7.00	4589.6	5657.6	2351.0
9.00	4589.6	3696.1	1028.2
10.00	4589.6	3326.5	925.4
12.00	4589.6	2237.4	491.8
15.00	4589.6	1503.2	253.0
20.00	4589.6	996.1	123.2
25.00	4589.6	692.1	59.4

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 800-1200HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .22
HEAT LOSS (MEGACAL/SEC) 525.00
DRY BULB TEMPERATURE (DEG F) 72.00
WET BULB TEMPERATURE (DEG F) 67.00
WIND VELOCITY (KNOTS) 3.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	418.6	182550.8	0.0
0.15	548.6	27089.0	0.0
0.20	664.6	11994.1	0.0
0.30	870.8	4625.9	0.0
0.50	1224.1	8503.4	16821.0
0.75	1604.1	4034.8	7330.1
1.00	1943.2	2357.0	3917.9
1.50	2546.3	1421.7	2158.2
2.00	2847.7	1748.1	2167.2
2.50	2847.7	1249.5	1240.1
3.00	2847.7	1947.8	1712.4
4.00	2847.7	1527.9	1028.5
5.00	2847.7	2239.0	1107.3
7.00	2847.7	1677.0	575.9
9.00	2847.7	1191.0	331.3
10.00	2847.7	1071.9	298.2
12.00	2847.7	720.9	158.5
15.00	2847.7	484.4	81.5
20.00	2847.7	321.0	39.7
25.00	2847.7	223.0	19.1

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 1200-1600HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .33
HEAT LOSS (MEGACAL/SEC) 525.00
DRY BULB TEMPERATURE (DEG F) 75.00
WET BULB TEMPERATURE (DEG F) 71.00
WIND VELOCITY (KNOTS) 5.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	245.7	230699.0	316915.1
0.15	321.9	37656.7	51729.6
0.20	390.0	16870.9	23175.8
0.30	511.0	6554.1	9003.4
0.50	718.4	2293.3	3150.3
0.75	941.3	1055.7	1450.2
1.00	1140.3	620.4	852.2
1.50	1494.3	298.6	410.2
2.00	1641.8	1629.6	1813.3
2.50	1641.8	2278.6	2003.3
3.00	1641.8	2111.1	1631.3
4.00	1641.8	1377.7	799.6
5.00	1641.8	2158.1	1067.2
7.00	1641.8	1613.0	554.0
9.00	1641.8	1145.0	318.5
10.00	1641.8	831.6	182.8
12.00	1641.8	693.0	152.3
15.00	1641.8	465.7	78.4
20.00	1641.8	308.7	38.2
25.00	1641.8	214.6	18.4

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 1600-2000HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS	.54
HEAT LOSS (MEGACAL/SEC)	525.00
DRY BULB TEMPERATURE (DEG F)	80.00
WET BULB TEMPERATURE (DEG F)	75.00
WIND VELOCITY (KNOTS)	8.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	148.5	1462108.5	0.0
0.15	194.6	615833.1	763497.2
0.20	235.7	172227.6	213524.2
0.30	308.8	54280.5	67295.8
0.50	434.1	17112.9	21216.2
0.75	568.9	7553.8	9365.1
1.00	689.1	4352.6	5396.3
1.50	903.0	2055.0	2547.7
2.00	965.8	10592.2	11786.0
2.50	965.8	14689.5	12914.7
3.00	965.8	13568.4	10484.5
4.00	965.8	8817.5	5117.6
5.00	965.8	13793.2	6821.2
7.00	965.8	10293.2	3535.0
9.00	965.8	7304.5	2032.0
10.00	965.8	5304.7	1165.9
12.00	965.8	4420.6	971.6
15.00	965.8	2970.5	499.9
20.00	965.8	1969.5	243.5
25.00	965.8	1369.3	117.6

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 2000-2400HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .11
HEAT LOSS (MEGACAL/SEC) 525.00
DRY BULB TEMPERATURE (DEG F) 77.00
WET BULB TEMPERATURE (DEG F) 74.00
WIND VELOCITY (KNOTS) 5.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	240.7	52706921.0	0.0
0.15	315.4	22199903.0	0.0
0.20	382.1	6208559.4	0.0
0.30	500.7	1956733.1	0.0
0.50	703.9	1160041.0	3116082.4
0.75	922.3	1011519.6	2281934.3
1.00	1117.3	1120061.6	2243878.1
1.50	1464.1	547435.4	933247.5
2.00	1582.6	1343405.2	1844744.9
2.50	1582.6	1462743.0	1606894.3
3.00	1582.6	905710.1	829138.8
4.00	1582.6	477745.8	328016.9
5.00	1582.6	305757.3	167944.6
7.00	1582.6	155998.6	61204.3
9.00	1582.6	21427.3	6538.6
10.00	1582.6	17356.1	4766.6
12.00	1582.6	9966.6	2281.0
15.00	1582.6	6378.6	1167.9
20.00	1582.6	7138.4	980.2
25.00	1582.6	4223.7	464.0

---------- 24 HOUR TOTALS ----------

DAILY PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .38

DIST(MI)	ORG/M3/DAY	ORG/M2/DAY
0.10	56158319.0	2070021.5
0.15	23114353.0	1075373.0
0.20	6513201.9	351883.8
0.30	2062131.1	120723.7
0.50	1201866.5	3172749.3
0.75	1041657.6	2330441.9
1.00	1132778.7	2262998.0
1.50	580027.9	978581.2
2.00	1378124.3	1886996.8
2.50	1495712.0	1638184.5
3.00	945928.8	862828.9
4.00	507126.7	346848.4
5.00	346360.0	188328.0
7.00	190595.2	74601.3
9.00	44783.8	13035.9
10.00	36908.7	9847.5
12.00	24103.2	5388.1
15.00	15877.0	2766.3
20.00	13434.6	1758.7
25.00	8599.9	839.7

---------- SUMMARY OF RESULTS ----------

DIST(MI)	AVG NO. PART. INGESTED/IND.	PERCENT AFFECTED BY EFFLUENT
0.10	58228841.0	20.000
0.15	24189726.0	18.613
0.20	6865085.7	6.878
0.30	2182854.8	12.173
0.50	4374615.7	20.000
0.75	3372099.4	3.674
1.00	3395776.8	7.069
1.50	1558609.1	20.000
2.00	3265121.2	18.308
2.50	3133896.4	20.000
3.00	1808757.8	9.432
4.00	853975.1	6.754
5.00	534688.0	5.787
7.00	265196.5	14.795
9.00	57819.7	1.351
10.00	46756.2	1.133
12.00	29491.3	0.325
15.00	18643.3	0.112
20.00	15193.2	0.420
25.00	9439.6	0.312

FIGURE 19

**********COOLING TOWER FIXED PARAMETERS**********

TOWER HEIGHT (FEET)	450.00
TOWER DIAMETER (FEET)	200.00
HEAT LOSS (MEGACAL/SEC,MAX)	750.00
TEMPERATURE RANGE (DEG F)	30.00
DRIFT FRACTION (G/G)	0.000050
CONCENTRATION RATIO (G/G)	1.40
EXIT VELOCITY (FT/SEC)	10.00

--COOLING TOWER OPERATING PARAMETERS--

TIME (HRS)	DRY BULB T	WET BULB T	WIND VEL.	OPER CAP	STABILITY
0- 400	72.00	68.00	5.00	1.00	3.
400- 800	70.00	66.00	2.00	1.00	2.
800-1200	72.00	67.00	3.00	.70	2.
1200-1600	75.00	71.00	5.00	1.00	3.
1600-2000	80.00	75.00	8.00	1.00	3.
2000-2400	77.00	74.00	5.00	1.00	4.

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 0- 400HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .54
HEAT LOSS (MEGACAL/SEC) 750.00
DRY BULB TEMPERATURE (DEG F) 72.00
WET BULB TEMPERATURE (DEG F) 68.00
WIND VELOCITY (KNOTS) 5.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	257.6	1157530.7	1753106.5
0.15	337.6	171767.8	260146.2
0.20	409.0	76052.8	115183.7
0.30	535.9	29332.3	44424.5
0.50	753.3	10220.6	15479.3
0.75	987.1	4696.3	7112.7
1.00	1195.8	2757.4	4176.2
1.50	1566.9	24301.0	36802.8
2.00	1788.3	15067.9	18680.9
2.50	1788.3	10665.2	10585.3
3.00	1788.3	16563.4	14562.2
4.00	1788.3	12922.4	8698.3
5.00	1788.3	18873.4	9333.6
7.00	1788.3	15355.8	6381.1
9.00	1788.3	10019.8	2787.3
10.00	1788.3	9017.8	2508.6
12.00	1788.3	6064.6	1333.0
15.00	1788.3	4074.8	685.7
20.00	1788.3	2700.9	333.9
25.00	1788.3	1877.2	161.2

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 400- 800HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS	.51
HEAT LOSS (MEGACAL/SEC)	750.00
DRY BULB TEMPERATURE (DEG F)	70.00
WET BULB TEMPERATURE (DEG F)	66.00
WIND VELOCITY (KNOTS)	2.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	653.5	418509.4	0.0
0.15	856.4	62103.3	0.0
0.20	1037.4	27497.2	0.0
0.30	1359.4	10605.2	0.0
0.50	1910.9	3695.3	0.0
0.75	2504.0	12797.4	23249.6
1.00	3033.4	2629.6	4777.4
1.50	3974.9	4516.2	6839.8
2.00	4589.6	5681.4	7804.6
2.50	4589.6	4086.2	4546.7
3.00	4589.6	6028.0	5299.7
4.00	4589.6	4735.4	3187.5
5.00	4589.6	3589.1	2054.1
7.00	4589.6	5657.6	2351.0
9.00	4589.6	3696.1	1028.2
10.00	4589.6	3326.5	925.4
12.00	4589.6	2287.4	491.8
15.00	4589.6	1503.2	253.0
20.00	4589.6	996.1	123.2
25.00	4589.6	692.1	59.4

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 800-1200HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .22
HEAT LOSS (MEGACAL/SEC) 525.00
DRY BULB TEMPERATURE (DEG F) 72.00
WET BULB TEMPERATURE (DEG F) 67.00
WIND VELOCITY (KNOTS) 3.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	418.6	182550.8	0.0
0.15	548.6	27089.0	0.0
0.20	664.6	11994.1	0.0
0.30	870.8	4625.9	0.0
0.50	1224.1	8503.4	16821.0
0.75	1604.1	4034.8	7330.1
1.00	1943.2	2357.0	3917.9
1.50	2546.3	1421.7	2153.2
2.00	2847.7	1748.1	2167.2
2.50	2847.7	1249.5	1240.1
3.00	2847.7	1947.8	1712.4
4.00	2847.7	1527.9	1028.5
5.00	2847.7	2239.0	1107.3
7.00	2847.7	1677.0	575.9
9.00	2847.7	1191.0	331.3
10.00	2847.7	1071.9	298.2
12.00	2847.7	720.9	158.5
15.00	2847.7	484.4	81.5
20.00	2847.7	321.0	39.7
25.00	2847.7	223.0	19.1

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 1200-1600HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .33
HEAT LOSS (MEGACAL/SEC) 525.00
DRY BULB TEMPERATURE (DEG F) 75.00
WET BULB TEMPERATURE (DEG F) 71.00
WIND VELOCITY (KNOTS) 5.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	245.7	230699.0	316915.1
0.15	321.9	37656.7	51729.6
0.20	390.0	16870.9	23175.8
0.30	511.0	6554.1	9003.4
0.50	718.4	2293.3	3150.3
0.75	941.3	1055.7	1450.2
1.00	1140.3	620.4	852.2
1.50	1494.3	298.6	410.2
2.00	1641.8	1629.6	1813.3
2.50	1641.8	2278.6	2003.3
3.00	1641.8	2111.1	1631.3
4.00	1641.8	1377.7	799.6
5.00	1641.8	2158.1	1067.2
7.00	1641.8	1613.0	554.0
9.00	1641.8	1145.0	318.5
10.00	1641.8	831.6	182.8
12.00	1641.8	693.0	152.3
15.00	1641.8	465.7	78.4
20.00	1641.8	308.7	38.2
25.00	1641.8	214.6	18.4

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 1600-2000HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .54
HEAT LOSS (MEGACAL/SEC) 525.00
DRY BULB TEMPERATURE (DEG F) 80.00
WET BULB TEMPERATURE (DEG F) 75.00
WIND VELOCITY (KNOTS) 8.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	148.5	1462108.5	0.0
0.15	194.6	615833.1	763497.2
0.20	235.7	172227.6	213524.2
0.30	308.8	54280.5	67295.8
0.50	434.1	17112.9	21216.2
0.75	568.9	7553.8	9365.1
1.00	689.1	4352.6	5396.3
1.50	903.0	2055.0	2547.7
2.00	965.8	10592.2	11786.0
2.50	965.8	14689.5	12914.7
3.00	965.8	13568.4	10484.5
4.00	965.8	8817.5	5117.6
5.00	965.8	13793.2	6821.2
7.00	965.8	10293.2	3535.0
9.00	965.8	7304.5	2032.0
10.00	965.8	5304.7	1165.9
12.00	965.8	4420.6	971.6
15.00	965.8	2970.5	499.9
20.00	965.8	1969.5	243.5
25.00	965.8	1369.3	117.6

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 2000-2400HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .11
HEAT LOSS (MEGACAL/SEC) 525.00
DRY BULB TEMPERATURE (DEG F) 77.00
WET BULB TEMPERATURE (DEG F) 74.00
WIND VELOCITY (KNOTS) 5.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	240.7	52706921.0	0.0
0.15	315.4	2199903.0	0.0
0.20	382.1	6208559.4	0.0
0.30	500.7	1956733.1	0.0
0.50	703.9	1160041.0	3116082.4
0.75	922.3	1011519.6	2281934.3
1.00	1117.3	1120061.6	2243878.1
1.50	1464.1	547435.4	933247.5
2.00	1582.6	1343405.2	1844744.9
2.50	1582.6	1462743.0	1606894.3
3.00	1582.6	905710.1	829138.8
4.00	1582.6	477745.8	328016.9
5.00	1582.6	305757.3	167944.6
7.00	1582.6	155998.6	61204.3
9.00	1582.6	21427.3	6538.6
10.00	1582.6	17356.1	4766.6
12.00	1582.6	9966.6	2281.0
15.00	1582.6	6378.6	1167.9
20.00	1582.6	7138.4	980.2
25.00	1582.6	4223.7	464.0

---------- 24 HOUR TOTALS ----------

DAILY PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .38

DIST(MI)	ORG/M3/DAY	ORG/M2/DAY
0.10	56158319.0	2070021.5
0.15	23114353.0	1075373.0
0.20	6513201.9	351883.8
0.30	2062131.1	120723.7
0.50	1201866.5	3172749.3
0.75	1041657.6	2330441.9
1.00	1132778.7	2262998.0
1.50	580027.9	978581.2
2.00	1378124.3	1886996.8
2.50	1495712.0	1638184.5
3.00	945928.8	862828.9
4.00	507126.7	346848.4
5.00	346360.0	188328.0
7.00	190595.2	74601.3
9.00	44783.8	13035.9
10.00	36908.7	9847.5
12.00	24103.2	5388.1
15.00	15877.0	2766.3
20.00	13434.6	1758.7
25.00	8599.9	839.7

SUMMARY OF RESULTS

DIST(MI)	AVG NO. PART. INGESTED/IND.	PERCENT AFFECTED BY EFFLUENT
0.10	58228341.0	100.000
0.15	24189726.0	93.064
0.20	6865085.7	34.390
0.30	2182854.8	60.866
0.50	4374615.7	100.000
0.75	3372099.4	18.371
1.00	3395776.8	35.344
1.50	1558609.1	100.000
2.00	3265121.2	91.542
2.50	3133896.4	100.000
3.00	1808757.8	47.158
4.00	853975.1	33.772
5.00	534688.0	28.933
7.00	265196.5	73.977
9.00	57819.7	6.753
10.00	46756.2	5.667
12.00	29491.3	1.625
15.00	18643.3	0.561
20.00	15193.2	2.101
25.00	9439.6	1.559

FIGURE 20

**********COOLING TOWER FIXED PARAMETERS**********

TOWER HEIGHT (FEET)	450.00
TOWER DIAMETER (FEET)	200.00
HEAT LOSS (MEGACAL/SEC,MAX)	1200.00
TEMPERATURE RANGE (DEG F)	25.00
DRIFT FRACTION (G/G)	0.000050
CONCENTRATION RATIO (G/G)	1.30
EXIT VELOCITY (FT/SEC)	12.00

--COOLING TOWER OPERATING PARAMETERS--

TIME (HRS)	DRY BULB T	WET BULB T	WIND VEL.	OPER CAP	STABILITY
0- 400	50.00	48.00	10.00	.80	4.
400- 800	52.00	45.00	5.00	.80	4.
800-1200	60.00	50.00	20.00	1.00	5.
1200-1600	63.00	50.00	20.00	1.00	5.
1600-2000	58.00	50.00	5.00	1.00	4.
2000-2400	54.00	50.00	10.00	1.00	4.

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 0- 400HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .53
HEAT LOSS (MEGACAL/SEC) 960.00
DRY BULB TEMPERATURE (DEG F) 50.00
WET BULB TEMPERATURE (DEG F) 48.00
WIND VELOCITY (KNOTS) 10.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	147.7	0.0	0.0
0.15	193.6	0.0	0.0
0.20	234.5	0.0	0.0
0.30	307.3	0.0	0.0
0.50	431.9	0.0	0.0
0.75	566.0	33588.6	100577.0
1.00	685.6	23065.9	60616.2
1.50	898.4	19152.6	42232.9
2.00	1088.4	21190.9	41473.5
2.50	1144.0	33167.7	54289.9
3.00	1144.0	62080.0	84678.8
4.00	1144.0	43036.0	44026.6
5.00	1144.0	24558.1	20098.8
7.00	1144.0	11749.6	6868.6
9.00	1144.0	7107.8	3231.7
10.00	1144.0	5757.3	2355.9
12.00	1144.0	907.8	309.6
15.00	1144.0	581.0	158.5
20.00	1144.0	270.2	55.3
25.00	1144.0	315.2	51.6

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 400- 800HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .44
HEAT LOSS (MEGACAL/SEC) 768.00
DRY BULB TEMPERATURE (DEG F) 52.00
WET BULB TEMPERATURE (DEG F) 45.00
WIND VELOCITY (KNOTS) 5.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	287.4	0.0	0.0
0.15	376.6	0.0	0.0
0.20	456.3	0.0	0.0
0.30	597.9	0.0	0.0
0.50	840.4	0.0	0.0
0.75	1101.3	6755.1	0.0
1.00	1334.1	4638.8	0.0
1.50	1748.1	3851.8	0.0
2.00	2117.7	4261.7	0.0
2.50	2177.6	6670.4	0.0
3.00	2177.6	12485.0	0.0
4.00	2177.6	785.1	647.6
5.00	2177.6	1390.9	855.8
7.00	2177.6	896.2	441.4
9.00	2177.6	1466.0	562.2
10.00	2177.6	1240.0	414.3
12.00	2177.6	967.3	278.6
15.00	2177.6	1737.2	358.3
20.00	2177.6	1199.8	204.5
25.00	2177.6	877.3	121.1

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 800-1200HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .26
HEAT LOSS (MEGACAL/SEC) 768.00
DRY BULB TEMPERATURE (DEG F) 60.00
WET BULB TEMPERATURE (DEG F) 50.00
WIND VELOCITY (KNOTS) 20.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	67.4	0.0	0.0
0.15	88.3	0.0	0.0
0.20	107.0	0.0	0.0
0.30	140.2	2930.3	2642.1
0.50	197.1	504.6	455.0
0.75	243.9	212.0	191.2
1.00	243.9	159.0	143.4
1.50	243.9	484.0	363.8
2.00	243.9	703.4	479.6
2.50	243.9	507.8	280.4
3.00	243.9	401.2	197.6
4.00	243.9	565.1	246.6
5.00	243.9	476.8	159.3
7.00	243.9	319.4	92.0
9.00	243.9	560.2	115.5
10.00	243.9	504.2	104.0
12.00	243.9	387.9	66.1
15.00	243.9	284.4	39.3
20.00	243.9	172.7	18.8
25.00	243.9	116.4	9.7

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 1200-1600HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS	.56
HEAT LOSS (MEGACAL/SEC)	768.00
DRY BULB TEMPERATURE (DEG F)	63.00
WET BULB TEMPERATURE (DEG F)	50.00
WIND VELOCITY (KNOTS)	20.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	66.1	0.0	0.0
0.15	86.6	12773.5	12540.5
0.20	104.9	4682.3	4596.9
0.30	137.5	1635.0	1605.2
0.50	193.3	540.3	530.4
0.75	239.6	262.3	257.5
1.00	239.6	196.7	193.1
1.50	239.6	687.9	567.5
2.00	239.6	1190.6	811.7
2.50	239.6	905.7	557.3
3.00	239.6	716.8	395.8
4.00	239.6	957.3	417.7
5.00	239.6	858.2	329.1
7.00	239.6	540.7	155.7
9.00	239.6	947.5	195.4
10.00	239.6	852.8	175.9
12.00	239.6	655.8	111.8
15.00	239.6	480.5	66.3
20.00	239.6	291.7	31.8
25.00	239.6	196.4	16.4

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 1600-2000HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS	.29
HEAT LOSS (MEGACAL/SEC)	768.00
DRY BULB TEMPERATURE (DEG F)	58.00
WET BULB TEMPERATURE (DEG F)	50.00
WIND VELOCITY (KNOTS)	5.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	278.8	0.0	0.0
0.15	365.4	15757.6	0.0
0.20	442.6	5776.2	0.0
0.30	580.0	2016.9	0.0
0.50	815.3	666.5	0.0
0.75	1068.3	323.5	0.0
1.00	1294.1	242.6	0.0
1.50	1695.8	848.7	0.0
2.00	2054.3	1468.7	0.0
2.50	2061.7	1117.3	0.0
3.00	2061.7	320.1	314.3
4.00	2061.7	263.3	197.9
5.00	2061.7	390.5	240.2
7.00	2061.7	472.4	206.1
9.00	2061.7	386.8	129.2
10.00	2061.7	348.1	116.3
12.00	2061.7	533.8	131.0
15.00	2061.7	487.7	100.6
20.00	2061.7	336.9	57.4
25.00	2061.7	246.3	34.0

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 2000-2400HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .01
HEAT LOSS (MEGACAL/SEC) 768.00
DRY BULB TEMPERATURE (DEG F) 54.00
WET BULB TEMPERATURE (DEG F) 50.00
WIND VELOCITY (KNOTS) 10.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	142.5	667715.0	1213064.7
0.15	186.8	93190.5	169303.0
0.20	226.2	40975.7	74442.2
0.30	296.5	15737.4	28590.8
0.50	416.7	5470.4	9938.3
0.75	546.1	2511.0	4561.9
1.00	661.5	1473.6	2677.2
1.50	866.9	6882.1	11439.3
2.00	1050.1	5025.6	7611.4
2.50	1072.7	7100.4	8803.0
3.00	1072.7	5563.2	6190.2
4.00	1072.7	8119.3	6273.9
5.00	1072.7	6069.6	4085.6
7.00	1072.7	7910.5	3912.1
9.00	1072.7	6439.5	2211.5
10.00	1072.7	5795.5	1990.3
12.00	1072.7	4408.2	1226.3
15.00	1072.7	2845.9	625.5
20.00	1072.7	1792.7	301.7
25.00	1072.7	1267.5	156.7

---------- 24 HOUR TOTALS ----------

DAILY PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .35

DIST(MI)	ORG/M3/DAY	ORG/M2/DAY
0.10	667715.0	1213064.7
0.15	121721.7	181843.5
0.20	51434.2	79039.1
0.30	22319.7	32838.1
0.50	7181.8	10923.7
0.75	43652.5	105587.5
1.00	29776.7	63629.8
1.50	31907.0	54603.6
2.00	33841.0	50376.2
2.50	49469.3	63930.6
3.00	81566.3	91776.7
4.00	53726.0	51810.4
5.00	33744.1	25768.8
7.00	21888.9	11676.0
9.00	16907.8	6445.6
10.00	14498.0	5156.7
12.00	7860.7	2123.4
15.00	6416.7	1348.5
20.00	4064.0	669.5
25.00	3019.2	389.6

---------- SUMMARY OF RESULTS ----------

DIST(MI)	AVG NO. PART. INGESTED/IND.	PERCENT AFFECTED BY EFFLUENT
0.10	1880779.7	20.000
0.15	303565.1	5.182
0.20	130473.2	0.000
0.30	55157.8	1.640
0.50	18105.4	1.041
0.75	149240.0	7.946
1.00	93406.6	0.127
1.50	86510.6	1.380
2.00	84217.3	0.195
2.50	113399.9	1.183
3.00	173342.9	0.473
4.00	105536.4	5.531
5.00	59513.0	2.343
7.00	33564.9	1.877
9.00	23353.5	1.702
10.00	19654.7	1.159
12.00	9984.1	0.172
15.00	7765.2	0.344
20.00	4733.5	0.001
25.00	3408.7	0.789

FIGURE 21

**********COOLING TOWER FIXED PARAMETERS**********

TOWER HEIGHT (FEET)	450.00
TOWER DIAMETER (FEET)	200.00
HEAT LOSS (MEGACAL/SEC,MAX)	1200.00
TEMPERATURE RANGE (DEG F)	25.00
DRIFT FRACTION (G/G)	0.000100
CONCENTRATION RATIO (G/G)	1.40
EXIT VELOCITY (FT/SEC)	20.00

--COOLING TOWER OPERATING PARAMETERS--

TIME (HRS)	DRY BULB T	WET BULB T	WIND VEL.	OPER CAP	STABILITY
0- 400	55.00	52.00	20.00	1.00	5.
400- 800	55.00	51.00	25.00	1.00	5.
800-1200	60.00	55.00	10.00	1.00	3.
1200-1600	65.00	50.00	20.00	1.00	5.
1600-2000	63.00	61.00	5.00	1.00	6.
2000-2400	58.00	54.00	10.00	1.00	6.

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 0- 400HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .56
HEAT LOSS (MEGACAL/SEC) 1200.00
DRY BULB TEMPERATURE (DEG F) 55.00
WET BULB TEMPERATURE (DEG F) 52.00
WIND VELOCITY (KNOTS) 20.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	82.1	0.0	0.0
0.15	107.5	0.0	0.0
0.20	130.3	0.0	0.0
0.30	170.7	0.0	0.0
0.50	239.9	10434.8	14334.5
0.75	296.0	2174.1	2986.6
1.00	296.0	3504.0	3898.9
1.50	296.0	3857.4	3391.3
2.00	296.0	3152.4	2435.9
2.50	296.0	2319.1	1561.1
3.00	296.0	1778.7	1032.4
4.00	296.0	2589.1	1280.4
5.00	296.0	2344.2	974.1
7.00	296.0	1395.9	388.3
9.00	296.0	875.6	192.4
10.00	296.0	788.0	173.2
12.00	296.0	551.8	92.9
15.00	296.0	441.5	74.3
20.00	296.0	293.0	36.2
25.00	296.0	204.0	17.5

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 400- 800HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS	.55
HEAT LOSS (MEGACAL/SEC)	1200.00
DRY BULB TEMPERATURE (DEG F)	55.00
WET BULB TEMPERATURE (DEG F)	51.00
WIND VELOCITY (KNOTS)	25.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	65.6	0.0	0.0
0.15	86.0	0.0	0.0
0.20	104.2	451920.5	620810.7
0.30	136.5	96629.8	132741.9
0.50	191.8	26797.7	36812.4
0.75	251.4	11319.1	15549.2
1.00	274.6	7428.3	10204.4
1.50	274.6	24613.5	27387.7
2.00	274.6	16962.5	16835.5
2.50	274.6	27216.1	21030.3
3.00	274.6	20955.4	14105.5
4.00	274.6	14516.9	8425.5
5.00	274.6	22598.8	11175.9
7.00	274.6	16770.9	5759.6
9.00	274.6	11887.8	3306.9
10.00	274.6	10699.0	2976.2
12.00	274.6	7191.8	1580.7
15.00	274.6	4834.0	813.5
20.00	274.6	3207.3	396.5
25.00	274.6	2565.8	317.2

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 800-1200HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .55
HEAT LOSS (MEGACAL/SEC) 1200.00
DRY BULB TEMPERATURE (DEG F) 60.00
WET BULB TEMPERATURE (DEG F) 55.00
WIND VELOCITY (KNOTS) 10.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	164.1	0.0	0.0
0.15	215.1	0.0	0.0
0.20	260.5	86868.0	0.0
0.30	341.4	18574.1	0.0
0.50	479.9	5151.0	0.0
0.75	628.8	2175.7	0.0
1.00	761.8	1427.9	0.0
1.50	998.2	2106.5	3827.0
2.00	1209.2	443.7	806.2
2.50	1382.8	865.1	1437.9
3.00	1382.8	1638.4	2250.7
4.00	1382.8	1030.9	1023.2
5.00	1382.8	1539.4	1353.4
7.00	1382.8	1069.4	620.7
9.00	1382.8	1630.3	806.3
10.00	1382.8	1672.1	694.8
12.00	1382.8	1281.0	439.9
15.00	1382.8	935.6	260.3
20.00	1382.8	566.3	124.5
25.00	1382.8	380.5	64.0

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 1200-1600HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .04
HEAT LOSS (MEGACAL/SEC) 1200.00
DRY BULB TEMPERATURE (DEG F) 65.00
WET BULB TEMPERATURE (DEG F) 50.00
WIND VELOCITY (KNOTS) 20.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	76.9	126221.7	123919.0
0.15	100.7	34704.2	34071.1
0.20	122.0	17073.7	16762.2
0.30	159.9	7061.8	6933.0
0.50	224.7	2567.6	2520.8
0.75	279.0	1287.4	1263.9
1.00	279.0	965.5	947.9
1.50	279.0	643.7	632.0
2.00	279.0	2950.7	2434.2
2.50	279.0	5455.8	3719.6
3.00	279.0	4325.4	2661.4
4.00	279.0	2922.2	1439.4
5.00	279.0	4919.6	1886.7
7.00	279.0	3097.5	892.2
9.00	279.0	4741.9	1163.8
10.00	279.0	4881.4	1006.7
12.00	279.0	3751.9	639.5
15.00	279.0	2747.9	379.4
20.00	279.0	1667.2	181.9
25.00	279.0	1122.4	93.7

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

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16. ABSTRACT The report describes a mathematical model that predicts the percent of the population affected by a pathogen or toxic substance emitted in a cooling tower plume, and gives specific applications of the model. Eighty-five pathogens (or diseases) are cataloged as potentially occurring in U.S. waters, but there is insufficient data to predict the probability of occurrence or relate their occurrence to public health, population, or pollution. Sixty-five toxic substances are cataloged as potentially occurring in U.S. waters, but the actual number is probably many times the EPA-supplied list. Toxic concentrations to persons, animals, and plants are known for only a few of the chemicals: most toxic levels can be only inferred from animal studies. In the population as a whole, the epidemiological impact of a pathogen is a function of age, sex distribution, racial (genetic) distribution, general health and well-being, prior exposure, and immunological deficiency states. While cooling device drift may not be directly responsible for epidemics, it may potentiate the burden in an already weakened population, raising a segment of the population into the clinical state. The effect of toxic substances is difficult to evaluate because of inadequate data on humans. The effect is a function of concentration in susceptible tissue, and is much less dependent than pathogens on host resistance.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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```
38100            WRITE(7,1026)
38200            WRITE(7,1028)
38300            DO 770 N=1,20
38400            WRITE(7,1027)XM(N),TOFF(N),ORY(N)
38500    770     CONTINUE
38600    1025    FORMAT('1',///,'-------------   SUMMARY OF RESULTS
38700            1  ----------------')
38800    1026    FORMAT(1X,//,2X,'DIST(MI)',7X,'AVG NO. PART.',7X,'PERCEN
38900            1T AFFECTED')
39000    1028    FORMAT(19X,'INGESTED/IND.',10X,'BY EFFLUENT',/)
39100    1027    FORMAT(2X,F7.2,8X,F12.1,16X,F7.3)
39110    1030    FORMAT(1X,'TEMPERATURE RANGE (DEG F)          ',F10.2)
39120    1031    FORMAT(1X,'DRIFT FRACTION (G/G)               ',F10.6)
39  ',F10.2)



39150    1034    FORMAT(12X,'--COOLING TOWER OPERATING PARAMETERS--')
39160    1035    FORMAT(1X,'TIME (HRS)',4X,'DRY BULB T',4X,'WET BULB T',  4X
39170            1,'WIND VEL.',4X,'OPER CAP',4X,'STABILITY')
39180    1036    FORMAT(1X,I4,'-',I4,2X,F10.2,4X,F10.2,4X,F9.2,7X,F4.2,
39181            16X,F4.0)
39200            END
@
```

```
33000            WRITE(7,1011)


33100            WRITE(7,1016)
33200            DO 600 IR=1,20
33300    600     WRITE(7,1015)XM(IR),PRR(IR),TOMC(IR),TOMS(IR)
33400            LTIME=LTIME+400
33500            NTIME=LTIME+400
33600    800     CONTINUE
33700            PROBB=PROBA/6
33800    1001    FORMAT('1','     COOLINMS',F4.2)
34100    1003    FORMAT(1X,'TOWER HEIGHT (FEET)                    ',F10.2)
34200    1005    FORMAT(1X,'TOWER DIAMETER (FEET)                  ',F10.2)
34300    1006    FORMAT(1X,'HEAT LOSS (MEGACAL/SEC)                ',F10.2)
34400    1007    FORMAT(1X,'HEAT LOSS (MEGACAL/SEC,MAX)            ',F10.2)
34500    1008    FORMAT(1X,'DRY BULB TEMPERATURE (DEG F)           ',F10.2)
34600    1009    FORMAT(1X,'WET BULB TEMPERATURE (DEG F)           ',F10.2)
34700    1010    FORMAT(1X,'WIND VELOCITY (KNOTS)                  ',F10.2)
34800    1011    FORMAT(//)
34900    1000    FORMAT('1',//,'*****************COOLING TOWER FIXED PAR
35000            1AMETERS*****************'//)
35100    1015    FORMAT(2X,F7.2,10X,F8.1,5X,F12.1,5X,F12.1)
35200            WRITE(7,1012)
35300            WRITE(7,1018)
35400            WRITE(7,1020)PROBB
35500            WRITE(7,1019)
35600            DO 700 IM=1,20
35700    700     WRITE(7,1017)XM(IM),TOTC(IM),TOTS(IM)
35800    1012    FORMAT(////)
35900    1016    FORMAT(1X,'DIST(MI)',5X,'PLUME RISE(M)',6X,'ORG/M3/4HRS'
36000            1,6X,'ORG/M2/4HRS')
36100    1018    FORMAT('1',///,'---------------   24 HOUR TOTALS  --
36110            1-----------'/)
36200    1017    FORMAT(2X,F7.2,5X,F12.1,5X,F12.1)
36300    1019    FORMAT(1X,'DIST(MI)',7X,'ORG/M3/DAY',7X,'ORG/M2/DAY')
36400    1020    FORMAT(1X,'DAILY PROBABILITY OF EFFLUENT CONTAINING ORGA
36500            1NISMS',F4.2,/)
36600            DO 750 J=1,20
36700            TOPP(J)=20.*TOTC(J)+TOTS(J)
36800            PL=0.
36900            PK=0.
37000            DO 650 M=1,100
37100            CALL GGEXP(ISED(5),.1,1,R(1))
37200            DURG=3.E6*R(1)
37300            IF(TOPP(J).GT.DURG)PK=PK+1.
37400            PL=PL+1.
37500    650     CONTINUE
37600            AND=ABS(GGNOF(ISED(6)))
37700            ARY(J)=AND*PK*20./PL
37800            IF(ARY(J).GT.20.)ARY(J)=20.
37900    750     CONTINUE
38000            WRITE(7,1025)
38100            WRITE(7,1026)
```

```
27100              IF(RH.LT.0.76) GO TO 410
27200
27300      C       NO EVAPORATION
27400              VFALL=(HT+PR)*U/XME
27500              DIA=37.18+VFALL/.00415
27600              IF(VFALL.LT.0.1655) DIA=SQRT(/3414.*VFALL)
27700              IDIA=DIA/DD+1.
27800              IK(IX)=IDIA
27900              IF(IDIA.GT.25)GO TO 491
28000              DVDR=(VFALL-U*DPR/DXME)/XME
28100              DDDR=DVDR/.0045
28200              IF(VFALL.LT.0.1665)DDDR=.5*DIA*DVDR/VFALL
28300              DCDD=CUMUL(IDIA)/DD
28400              GO TO 440
28500
28600      C       EVAPORATION
28700      410     CONTINUE
28800              H=HT+PR
28900      420     RY=DF(K,IRH)/RHFAC
29000              IF(H.LT.RY) GO TO 450
29100              XR=U*(H-RY)29600                K=K-1
29700              OR=XR
29800              IF(K)491,491,420
29900      430     DCDD=CUMUL(K)
30000              IK(IX)=K
30100              IF(K.GE.25) GO TO 491
30200              VFALL=VF(K,IRH)
30300              DDDR=1./(XR-OR)
30400      440     CHI2=ARLOS*DDDR*DCDD*INCR*8./(XME*PI)
30500              DR(IX)=CHI2/VFALL
30600              DRIFT(IX)=CHI2
30700      491     CONTINUE
30800      460     CONTINUE
30900              IF(NCY.LE.2)AMUD=1.
31000              IF(NCY.GT.2 .AND. NCY.LT.6)AMUD=.2
31100              RANV=GGUBF(ISED(4))
31200              IF(RANV.LT.0.1)AMUD=.5
31300              IF(NCY.GT.5)AMUD=1
31400              IF(RH.GT.0.76)BMUD=1
31500              IF(RH.LE.0.76.AND.RH.GE.0.5)BMUD=.5
31600              IF(RH.LT.0.5)BMUD=.2
31700              DO 470 IY=1,20
31800              TOMS(IY)=DRIFT(IY)*CAORG*AMUD*14400.*BMUD
31900              TOMC(IY)=DR(IY)*CAORG*AMUD*14400.*BMUD
32000              TOTC(IY)=TOTC(IY)+TOMC(IY)
32100              TOTS(IY)=TOTS(IY)+TOMS(IY)
32200      470     CONTINUE
32300              WRITE(7,1012)
32400              WRITE(7,1001)LTIME,NTIME
32500              WRITE(7,1002)PROB
32600              WRITE(7,1006)HEAT0
32700              WRITE(7,1008)DBI
32800              WRITE(7,1009)WBI
32900              WRITE(7,1010)WINDU
```

```
21100           IF(WBT.GE.80.)ENTAL=(WBT-13.85)/(2.77-.016*WBT)
21200           RAPP=TMPR*APP
21300           ENTAL=ENTAL+RAPP
21400           IF(ENTAL.GT.43.7)TS=(2.766*ENTAL+13.85)/(1.+.016*ENTAL)
21500           IF(ENTAL.LE.43.7)TS=(7.92*ENTAL-4.31)/(1.+.0248*ENTAL)
21600           TPO=AB(TS)
21700           DELQ1=EVLOS/(753130*EXVOL)
21800           DELQ=DELQ1*TPO
21900           U=WIND
22000           FC=0.
22100           DO 361 IX=1,20
2STAB)
22600           TEHT=TEO+TG*HT
22700           S=G*(TG+.01)/TEO
22800   300     CONTINUE
22900           FR=G*EXSPD*RAD*RAD*(1.-TEHT/TPO+DELQ*(.61+2545.*FC/TPO))
23000           IF(FR.GE.0.) GO TO 310
23100           TEHT=TPO
23200           GO TO 300
23300   310     CONTINUE
23400           IF(LSTAB.GT.4) GO TO 362
23500           F4=FR**.4
23600           H=AMIN1(HT,304.8)
23700           XS=2.16*F4*H**.6
23800           X=AMIN1(XME,3.*XS)
23900   320     CONTINUE
24000           H=1.6*(FR*X*X)**CUBRT/U
24100           PR=H
24200           GO TO 340
24300   330     CONTINUE
24400           PR=5.*SQRT((SQRT(FR/(S*SQRT(S)))))
24500   340     CONTINUE
24600           PRR(IX)=PR
24700           IF(PR.GT.0.) GO TO 350
24800           GO TO 361
24900     C      CALCULATE DRIFT AND DRIFT PARAMETERS
25600           K=25
25700           DR=0.
25800           DPR=0.
25900           DXME=0.
26000           INCR=1
26100           DO460 IX=1,20
26200           DRIFT(IX)=0.


26300           XME=XM(IX)*1609.3
26400           PR=PRR(IX)
26500           DPR=PR-DPR
26600
26700     C     CALCULATE DRIFT
26800           DXME=XME-DXME
26900           DPR=PR
27000           DXME=XME
```

```
15300                DF(J,2)=DFJ2
15400     215        IF(D-X2)220,220,230
15500     220        CUMUL(J)=F+DRFRAC(K)*(D-X1)/(X2-X1)
15600                GO TO 240
15700     230        F=F+DR5,232
16200     232        K=IDRCL
16300                F=F+DRFRAC(IDRCL)
16400     235        X2=DIAMAX
16500                IF(J.LT.25)GO TO 215
16600                CUMUL(J)=1.
16700     240        CONTINUE
16800                DO 250 J=1,24
16900     250        CUMUL(26-J)=CUMUL(26-J)-CUMUL(25-J)
17000
17100     C          CALCULATE RELATIVE HUMIDITY
17200                TEU=AB(DBT)
17300                TEB=AB(WBT)
17400                JFLAG=0
17500                T=TEU
17600                GO TO 110
17700     130        JFLAG=1
17800                T=TEB
17900     110        CONTINUE
18000                IF(TEU.LT.273.16)GO TO 265
18100                Z=373.16/T
18200                P(1)=A(1)*(Z-1)
18300                P(2)=A(2)*ALOG10(Z)
18400                Z1=A(4)*(1.-1./Z)
18500                P(7)=A(7)*(10**Z1-1)
18600                Z1=A(6)*(Z-1)
18700                P(4)=A(5)*(10**Z1-1)


18800                GO TO 245
18900     265        Z=273.16/T
19000                P(1)=B4))
19400     245        SUM=0.
19500                DO 244 I=1,4
19600     244        SUM=SUM+P(I)
19700                PVSF=14.696*10**SUM
19800                IF(JFLAG)120,120,140
19900     120        PVSD=PVSF*2.068
20000                GO TO 130
20100     140        PVSW=PVSF*2.036
20200                PV=PVSW-(7.67E-4*29.84*(DBT-WBT)*(1.+(WBT-32.)/15/1.))
20300                RH=PV/PVSD
20400                IF(RH.LE.0.)RH=.01
20500                RHFAC=(1.-RH)**1.079
20600                IRH=2
20700                IF(RH.LT.0.5)IRH=1
20800
20900     C          CALCULATE TOWER EFFLUENT TEMPERATURE
21000                IF(WBT.LT.80)ENTAL=(WBT+4.31)/(7.92-.0248*WBT)
```

```
09800    18        Z=.4;GO TO 40
09900    20        Z=.5;GO TO 40
10000    22        Z=.6;GO TO 40
10100    24        Z=.8;GO TO 40
10200    26        Z=.8;GO TO 40
10300    28        Z=.9;GO TO 40
10400    29        Z=1.
10500    40        C=C+Z
10600    30        CONTINUE
10700              PROB=C/2000.
10800              XY=ABS(GGNOF(ISED(3)))
10900              IF(XY.GT.1.)GO TO 2
11000              PROB=XY*PROB
11100    2         PROBA=PROBA+PROB
11200
11300    C         CALCULATE INPUT PARAMETERS
11400              CTORG=0.
11500              NTRY=Y*20
11600              DO 210 I=1,NTRY


11700              CALL GGEXP(ISED(2),PROB,1,R(1))
11800              CNORG=R(1)*1.E5
11900              RV2=GGUBF(ISED(3))
12000              IF(RV2-PROB)200,205
12100    200       CNORG=0.
12200    205       CTNORG=CNORG+CTNORG
12300    210       CONTINUE
12400          -SEE ORFAD MODEL.
12900              DIAMAX=DIAM(IDRCL)*1.5-.5*DIAM(IDRCL-1)
13000              DIAM(IDRCL+1)=DIAMAX
13100              D=0.
13200              DD=DIAMAX/25.
13300              F=0.
13400              X1=0.
13500              X2=.5*(DIAM(1)+DIAM(2))
13600              K=1
13700              CONR=.01
13800              FAC=1.E-4*((1.+.7*CONR)*CONR/.3112)**CUBRT
13900              DO 240 J=1,25
14000              D=D+DD
14100              DIM=FAC*D
14200              VFJ2=3519.2*DIM*DIM
14300              VFJ1=.4963*VFJ2
14400              VIJ=D*D/38414.
14500              IF(D.GT.74.36)VIJ=.00445*(D-37.18)
14600              DFJ=7.415E-6*D**2.667
14700              DFJ1=DFJ*((VIJ-VFJ1)/(VIJ+VFJ1))
14800              DFJ2=DFJ*(VIJ-VFJ2)/(VIJ+VFJ2)
14900              VF(J,1)=VFJ1
15000              VF(J,2)=VFJ2
15100              VI(J)=VIJ
15200              DF(J,1)=DFJ1
```

```
04825                MTIME=0
04826                KTIME=400
04830                DO 3 JK=1,6
04840                WRITE(7,1036)MTIME,KTIME,(TBL(JK,JL),JL=1,5)
04850                MTIME=MTIME+400
04860                KTIME=KTIME+400
04870     3          CONTINUE
04900                DO 800 NCY=1,6


05000                DBT=TBL(NCY,1)
05100                WBT=TBL(NCY,2)
05200                WINDO=TBL(NCY,3)
05300                PCAP=TBL(NCY,4)
05400                STAB=TBL(NCY,5)
05500                HEATO=HEATO*PCAP
05600                LSTAB=STAB
05700
05800     C          CALCULATE TOWER PARAMETERS
05900                HT=HTO*FTM
06000                DIAT=DIATO*FTM
06100                EXSPD=EXSPDO*FTM
06200                WIND=WINDO*.514
06300                RAD=DIAT/2
06400                TAREA=PI*RAD*RAD
06500                EXVOL=EXSPD*TAREA
06600                CWFR=1.8E6*HEATO7)
07100                UMW=EVLOS+ARLOS
07200                APP=2.7
07300                FRACON=0.
07400
07500     C          CALCULATE DILUTION FACTOR TIME--INPUT VOLUME
07600                TAU=(CONC-1.)*TVOL/UMW
07700                ATAU=TAU/2
07800                BINVOL=UMW*ATAU
07900
08000     C          CALCULATE PROB. OF ORG PRESENT
08100                C=0.
08200                DO 30 I=1,2000
08300                Y=GGUBF(ISED(1))
08400                IF (Y-.064)10,11
08500     11         IF(Y-.1380)12,13
08600     13         IF(Y-.2686)14,15
08700     15         IF(Y-.3158)16,17
08800     17         IF(Y-.4044)18,19
08900     19         IF(Y-.4722)20,21
09000     21         IF(Y-.5833)22,23
09100     23         IF(Y-.6944)24,25
09200     25         IF(Y-.7963)26,27
09300     27         IF(Y-.9074)28,29
09400     10         Z=0.;GO TO 40
09500     12         Z=.1;GO TO 40
09600     14         Z=.2;GO TO 40
09700     16         Z=.3;GO TO 40
```

FIGURE 22

```
          @TYPE (FILE) PLUMUD.FOR
00100     C      PROGRAM PLUMUD --A. UZZU-- 10/25//8
00200     C      THIS PROGRAM SIMULATES THE PROBABILITY OF OCCURRENCE
00300     C      THE DOWNWIND DISTRIBUTION AND POSSIBLE INFECTION IN
00400     C      A POPULATION BY POTENTIALLY INFECTIOUS ORGANISMS FROM
00500     C      COOLING TOWER DRIFT.  THE DISTRIBUTION AND POTENTIAL
00600     C      EFFECTS OF THESE ORGANISMS ARE BASED ON DATA FROM
00700     C      THIS REPORT.  THE DRIFT COMPUTATIONS ARE BASED ON THE
00800     C      ORFAD MODEL AS DESCRIBED BY M. E. LAVERNE IN REPORT
00900     C      ORNL/TM-5201 (OAK RIDGE NATIONAL LABORATORY).
01000
01100           DIMENSION TBL(6,5),DIAM(7),R(1),XM(21),V1(25),VF(25,2)
01200           DIMENSION DF(25,2),CUMUL(25),DRFRAC(7),TGI(6),ISED(6)
01300           DIMENSION DRIFT(20),DR(20),IK(20),PRR(20),A(6),P(4),B(4)
01400           DIMENSION TOMS(20),TOMC(20),TOTC(20),TOTS(20)
01500           DIMENSION ARY(20),TOPP(20)
01600
01700           DATA TGI/-.0263,-.0173,-.0146,-.01,.0046,.0263/
01800           DATA A/-7.9,5.03,-1.38E-7,11.3,8.13E-3,-3.49/
01900           DATA B/-9.1,-3.57,.88,.006/
02000           DATA DIAM/70.,175.,300.,425.,550.,700.,0./
02100           DATA DRFRAC/.06,.3,.39,.15,.07,.03,0./
02200           DATA G,PI,CUBRT,FTM/9.81,3.1416,.33333,.3048/
02300           DATA XM/.1,.15,.2,.3,.5,.75,1.,1.5,2,2.5,3.,
02400           14.,5.,7.,9.,10.,12.,15.,20.,25.,0./
02500           AB(Y)=255.37+.5555*Y
02600           OPEN(UNIT=7,ACCESS='SEQOUT',FILE='PLUM.DAT')
02700           LR=26
02800
02900           PROBA=0.
03000           DO 8 I=1,20
03100           TOTS(I)=0.
03200           TOTC(I)=0.
03300     8     CONTINUE
03400
03500     C     READ INPUT DATA AND WRITE FIXED DATA
03600           READ(LR,*)HTU,DIATO,FRACDR,EXSPDU,CUNC,TMPR,HEATU
03700     C     WRITE FIXED PARAMETERS
03800           WRITE(7,1000)
03900           WRITE(7,1003)HTU
04000           WRITE(7,1005)DIATU
04100           WRITE(7,1007)HEATU
04110           WRITE(7,1030)TMPR
04120           WRITE(7,1031)FRACDR
04130           WRITE(7,1032)CUNC
04140           WRITE(7,1033)EXSPDU
04200           WRITE(7,1012)
04300           DO 5 I=1,6
04400           READ(LR,*)(TBL(I,J),J=1,5)
04500     5     CONTINUE
04600           READ(LR,*)(ISED(I),I=1,6)
04700           LTIME=0
04800           NTIME=400
04810           WRITE(7,1034)
04820           WRITE(7,1035)
```

F. Program History

Figure 22 is a listing of the simulation program. The program is written in Fortran IV for use with the DEC-20 system. Data is inputted via a data file (e.g. FOR 28. DAT) that contains the input data in free format.

---------- SUMMARY OF RESULTS ----------

DIST(MI)	AVG NO. PART. INGESTED/IND.	PERCENT AFFECTED BY EFFLUENT
0.10	3013036.4	20.000
0.15	541427.2	11.257
0.20	1408933.6	19.958
0.30	3523821.4	20.000
0.50	4603432.4	0.311
0.75	2039873.3	7.159
1.00	1054298.0	4.150
1.50	494074.6	7.704
2.00	281059.2	1.682
2.50	257050.1	15.002
3.00	185449.4	15.660
4.00	120834.3	1.400
5.00	104158.4	2.561
7.00	62308.1	6.319
9.00	46024.9	1.991
10.00	39307.6	3.284
12.00	29052.9	1.169
15.00	13325.3	2.601
20.00	8491.2	1.955
25.00	5958.0	0.000

---------- 24 HOUR TOTALS ----------

DAILY PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .37

DIST(MI)	ORG/M3/DAY	ORG/M2/DAY
0.10	1429408.0.	1583628.4
0.15	285206.3	256220.9
0.20	672704.5	736229.1
0.30	1078670.3	2445151.2
0.50	1891580.5	2711851.9
0.75	1029981.0	1009892.3
1.00	601900.6	452397.4
1.50	312868.0	181206.7
2.00	182851.9	98207.3
2.50	173853.9	83196.3
3.00	131110.6	54338.8
4.00	89971.1	30863.2
5.00	78802.0	25356.5
7.00	50160.4	12147.7
9.00	38278.0	7746.9
10.00	33179.6	6128.0
12.00	25262.0	3790.9
15.00	11655.8	1669.5
20.00	7658.1	833.2
25.00	5430.5	527.5

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 2000-2400HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .53
HEAT LOSS (MEGACAL/SEC) 1200.00
DRY BULB TEMPERATURE (DEG F) 58.00
WET BULB TEMPERATURE (DEG F) 54.00
WIND VELOCITY (KNOTS) 10.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	155.9	878180.6	1459709.3
0.15	204.3	133648.3	222149.8
0.20	247.4	59352.9	98656.2
0.30	261.9	34801.3	57846.7
0.50	261.9	196764.4	243944.4
0.75	261.9	109327.0	108508.1
1.00	261.9	163549.8	126377.5
1.50	261.9	92746.8	53829.8
2.00	261.9	135216.3	66869.6
2.50	261.9	122557.0	50928.5
3.00	261.9	93545.9	32126.4
4.00	261.9	63924.4	17782.4
5.00	261.9	41248.0	9066.1
7.00	261.9	24755.7	4165.9
9.00	261.9	17035.9	2106.2
10.00	261.9	13340.6	1145.4
12.00	261.9	11117.1	954.5
15.00	261.9	1717.9	94.4
20.00	261.9	1288.4	70.8
25.00	261.9	702.8	21.7

COOLING TOWER AND ENVIRONMENTAL PARAMETERS 1600-2000HRS

PROBABILITY OF EFFLUENT CONTAINING ORGANISMS .02
HEAT LOSS (MEGACAL/SEC) 1200.00
DRY BULB TEMPERATURE (DEG F) 63.00
WET BULB TEMPERATURE (DEG F) 61.00
WIND VELOCITY (KNOTS) 5.00

DIST(MI)	PLUME RISE(M)	ORG/M3/4HRS	ORG/M2/4HRS
0.10	302.2	425005.7	0.0
0.15	321.0	116853.8	0.0
0.20	321.0	57489.4	0.0
0.30	321.0	921603.3	2247629.7
0.50	321.0	1649865.0	2414239.9
0.75	321.0	903697.7	881584.5
1.00	321.0	425025.1	310968.6
1.50	321.0	188900.0	92138.8
2.00	321.0	24126.3	8826.0
2.50	321.0	15440.8	4518.9
3.00	321.0	8866.7	2162.4
4.00	321.0	4987.5	912.3
5.00	321.0	6152.0	900.2
7.00	321.0	3071.0	321.0
9.00	321.0	2106.5	171.2
10.00	321.0	1798.6	131.6
12.00	321.0	1368.2	83.4
15.00	321.0	979.0	47.8
20.00	321.0	635.9	23.3
25.00	321.0	455.0	13.3

Attachment B – Reisman and Frisbie 2001 Reference


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Calculating Realistic PM_{10} Emissions from Cooling Towers

Abstract No. 216 Session No. AM-1b

Joel Reisman and Gordon Frisbie
Greystone Environmental Consultants, Inc., 650 University Avenue, Suite 100, Sacramento, California 95825

ABSTRACT

Particulate matter less than 10 micrometers in diameter (PM_{10}) emissions from wet cooling towers may be calculated using the methodology presented in EPA's AP-42[1] , which assumes that all total dissolved solids (TDS) emitted in "drift" particles (liquid water entrained in the air stream and carried out of the tower through the induced draft fan stack.) are PM_{10}. However, for wet cooling towers with medium to high TDS levels, this method is overly conservative, and predicts significantly higher PM_{10} emissions than would actually occur, even for towers equipped with very high efficiency drift eliminators (e.g., 0.0006% drift rate). Such over-prediction may result in unrealistically high PM_{10} modeled concentrations and/or the need to purchase expensive Emission Reduction Credits (ERCs) in PM_{10} non-attainment areas. Since these towers have fairly low emission points (10 to 15 m above ground), over-predicting PM_{10} emission rates can easily result in exceeding federal Prevention of Significant Deterioration (PSD) significance levels at a project's fenceline. This paper presents a method for computing realistic PM_{10} emissions from cooling towers with medium to high TDS levels.

INTRODUCTION

Cooling towers are heat exchangers that are used to dissipate large heat loads to the atmosphere. Wet, or evaporative, cooling towers rely on the latent heat of water evaporation to exchange heat between the process and the air passing through the cooling tower. The cooling water may be an integral part of the process or may provide cooling via heat exchangers, for example, steam condensers. Wet cooling towers provide direct contact between the cooling water and air passing through the tower, and as part of normal operation, a very small amount of the circulating water may be entrained in the air stream and be carried out of the tower as "drift" droplets. Because the drift droplets contain the same chemical impurities as the water circulating through the tower, the particulate matter constituent of the drift droplets may be classified as an emission. The magnitude of the drift loss is influenced by the number and size of droplets produced within the tower, which are determined by the tower fill design, tower design, the air and water patterns, and design of the drift eliminators.

AP-42 METHOD OF CALCULATING DRIFT PARTICULATE

EPA's AP-42[1] provides available particulate emission factors for wet cooling towers, however, these values only have an emission factor rating of "E" (the lowest level of confidence acceptable). They are also rather high, compared to typical present-day manufacturers' guaranteed drift rates, which are on the order of 0.0006%. (Drift emissions are typically

expressed as a percentage of the cooling tower water circulation rate). AP-42 states that "a *conservatively high* PM_{10} emission factor can be obtained by (a) multiplying the total liquid drift factor by the TDS fraction in the circulating water, and (b) assuming that once the water evaporates, all remaining solid particles are within the PM_{10} range." (Italics per EPA).

If TDS data for the cooling tower are not available, a source-specific TDS content can be estimated by obtaining the TDS for the make-up water and multiplying it by the cooling tower cycles of concentration. [The cycles of concentration is the ratio of a measured parameter for the cooling tower water (such as conductivity, calcium, chlorides, or phosphate) to that parameter for the make-up water.]

Using AP-42 guidance, the total particulate emissions (PM) (after the pure water has evaporated) can be expressed as:

PM = Water Circulation Rate x Drift Rate x TDS [1]

For example, for a typical power plant wet cooling tower with a water circulation rate of 146,000 gallons per minute (gpm), drift rate of 0.0006%, and TDS of 7,700 parts per million by weight (ppmw):

PM = 146,000 gpm x 8.34 lb water/gal x 0.0006/100 x 7,700 lb solids/10^6 lb water x 60 min/hr = <u>3.38 lb/hr</u>

On an annual basis, this is equivalent to almost 15 tons per year (tpy). Even for a state-of-the-art drift eliminator system, this is not a small number, especially if assumed to all be equal to PM_{10}, a regulated criteria pollutant. However, as the following analysis demonstrates, only a very small fraction is actually PM_{10}.

COMPUTING THE PM_{10} FRACTION

Based on a representative drift droplet size distribution and TDS in the water, the amount of solid mass in each drop size can be calculated. That is, for a given initial droplet size, assuming that the mass of dissolved solids condenses to a spherical particle after all the water evaporates, and assuming the density of the TDS is equivalent to a representative salt (e.g., sodium chloride), the diameter of the final solid particle can be calculated. Thus, using the drift droplet size distribution, the percentage of drift mass containing particles small enough to produce PM_{10} can be calculated. This method is conservative as the final particle is assumed to be perfectly spherical; hence as small a particle as can exist.

The droplet size distribution of the drift emitted from the tower is critical to performing the analysis. Brentwood Industries, a drift eliminator manufacturer, was contacted and agreed to provide drift eliminator test data from a test conducted by Environmental Systems Corporation (ESC) at the Electric Power Research Institute (EPRI) test facility in Houston, Texas in 1988 (Aull[2], 1999). The data consist of water droplet size distributions for a drift eliminator that achieved a tested drift rate of 0.0003 percent. As we are using a 0.0006 percent drift rate, it is reasonable to expect that the 0.0003 percent drift rate would produce smaller droplets, therefore,

this size distribution data can be assumed to be conservative for predicting the fraction of PM_{10} in the total cooling tower PM emissions.

In calculating PM_{10} emissions the following assumptions were made:

- Each water droplet was assumed to evaporate shortly after being emitted into ambient air, into a single, solid, spherical particle.
- Drift water droplets have a density (ρ_w) of water; $1.0\ g/cm^3$ or $1.0 * 10^{-6}\ \mu g/\mu m^3$.
- The solid particles were assumed to have the same density (ρ_{TDS}) as sodium chloride, (i.e., 2.2 g/cm^3).

Using the formula for the volume of a sphere, $V = 4\pi r^3/3$, and the density of pure water, $\rho_w = 1.0\ g/cm^3$, the following equations can be used to derive the solid particulate diameter, D_p, as a function of the TDS, the density of the solids, and the initial drift droplet diameter, D_d :

$$\text{Volume of drift droplet} = (4/3)\pi(D_d/2)^3 \qquad [2]$$

$$\text{Mass of solids in drift droplet} = (TDS)(\rho_w)(\text{Volume of drift droplet}) \qquad [3]$$

substituting,

$$\text{Mass of solids in drift} = (TDS)(\rho_w)(4/3)\pi(D_d/2)^3 \qquad [4]$$

Assuming the solids remain and coalesce after the water evaporates, the mass of solids can also be expressed as:

$$\text{Mass of solids} = (\rho_{TDS})(\text{solid particle volume}) = (\rho_{TDS})(4/3)\pi(D_p/2)^3 \qquad [5]$$

Equations [4] and [5] are equivalent:

$$(\rho_{TDS})(4/3)\pi(D_p/2)^3 = (TDS)(\rho_w)(4/3)\pi(D_d/2)^3 \qquad [6]$$

Solving for D_p:

$$D_p = D_d\ [(TDS)(\rho_w/\rho_{TDS})]^{1/3} \qquad [7]$$

Where,

TDS is in units of ppmw
D_p = diameter of solid particle, micrometers (μm)
D_d = diameter of drift droplet, μm

Using formulas [2] – [7] and the particle size distribution test data, Table 1 can be constructed for drift from a wet cooling tower having the same characteristics as our example; 7,700 ppmw TDS and a 0.0006% drift rate. The first and last columns of this table are the particle size distribution derived from test results provided by Brentwood Industries. Using straight-line interpolation for a solid particle size 10 μm in diameter, we conclude that approximately 14.9 percent of the mass emissions are equal to or smaller than PM_{10}. The balance of the solid

particulate are particulate greater than 10 μm. Hence, PM_{10} emissions from this tower would be equal to PM emissions x 0.149, or 3.38 lb/hr x 0.149 = 0.50 lb/hr. The process is repeated in Table 2, with all parameters equal except that the TDS is 11,000 ppmw. The result is that approximately 5.11 percent are smaller at 11,000 ppm. Thus, while total PM emissions are larger by virtue of a higher TDS, overall PM_{10} emissions are actually lower, because more of the solid particles are larger than 10 μm.

Table 1. Resultant Solid Particulate Size Distribution (TDS = 7700 ppmw)

EPRI Droplet Diameter (μm)	Droplet Volume (μm^3) [2][1]	Droplet Mass (μg) [3]	Particle Mass (Solids) (μg) [4]	Solid Particle Volume (μm^3)	Solid Particle Diameter (μm) [7]	EPRI % Mass Smaller
10	524	5.24E-04	4.03E-06	1.83	1.518	0.000
20	4189	4.19E-03	3.23E-05	14.66	3.037	0.196
30	14137	1.41E-02	1.09E-04	49.48	4.555	0.226
40	33510	3.35E-02	2.58E-04	117.29	6.073	0.514
50	65450	6.54E-02	5.04E-04	229.07	7.591	1.816
60	113097	1.13E-01	8.71E-04	395.84	9.110	5.702
70	179594	1.80E-01	1.38E-03	628.58	10.628	21.348
90	381704	3.82E-01	2.94E-03	1335.96	13.665	49.812
110	696910	6.97E-01	5.37E-03	2439.18	16.701	70.509
130	1150347	1.15E+00	8.86E-03	4026.21	19.738	82.023
150	1767146	1.77E+00	1.36E-02	6185.01	22.774	88.012
180	3053628	3.05E+00	2.35E-02	10687.70	27.329	91.032
210	4849048	4.85E+00	3.73E-02	16971.67	31.884	92.468
240	7238229	7.24E+00	5.57E-02	25333.80	36.439	94.091
270	10305995	1.03E+01	7.94E-02	36070.98	40.994	94.689
300	14137167	1.41E+01	1.09E-01	49480.08	45.549	96.288
350	22449298	2.24E+01	1.73E-01	78572.54	53.140	97.011
400	33510322	3.35E+01	2.58E-01	117286.13	60.732	98.340
450	47712938	4.77E+01	3.67E-01	166995.28	68.323	99.071
500	65449847	6.54E+01	5.04E-01	229074.46	75.915	99.071
600	113097336	1.13E+02	8.71E-01	395840.67	91.098	100.000

[1] Bracketed numbers refer to equation number in text.

The percentage of PM_{10}/PM was calculated for cooling tower TDS values from 1000 to 12000 ppmw and the results are plotted in Figure 1. Using these data, Figure 2 presents predicted PM_{10} emission rates for the 146,000 gpm example tower. As shown in this figure, the PM emission rate increases in a straight line as TDS increases, however, the PM_{10} emission rate increases to a maximum at around a TDS of 4000 ppmw, and then begins to decline. The reason is that at higher TDS, the drift droplets contain more solids and therefore, upon evaporation, result in larger solid particles for any given initial droplet size.

CONCLUSION

The emission factors and methodology given in EPA's AP-42[1] Chapter 13.4 *Wet Cooling Towers*, do not account for the droplet size distribution of the drift exiting the tower. This is a critical factor, as more than 85% of the mass of particulate in the drift from most cooling towers will result in solid particles larger than PM_{10} once the water has evaporated. Particles larger than PM_{10} are no longer a regulated air pollutant, because their impact on human health has been shown to be insignificant. Using reasonable, conservative assumptions and a realistic drift

droplet size distribution, a method is now available for calculating realistic PM_{10} emission rates from wet mechanical draft cooling towers equipped with modern, high-efficiency drift eliminators and operating at medium to high levels of TDS in the circulating water.

Table 2. Resultant Solid Particulate Size Distribution (TDS = 11000 ppmw)

EPRI Droplet Diameter (μm)	Droplet Volume (μm^3) [2][1]	Droplet Mass (μg) [3]	Particle Mass (Solids) (μg) [4]	Solid Particle Volume (μm^3)	Solid Particle Diameter (μm) [7]	EPRI % Mass Smaller
10	524	5.24E-04	5.76E-06	2.62	1.710	0.000
20	4189	4.19E-03	4.61E-05	20.94	3.420	0.196
30	14137	1.41E-02	1.56E-04	70.69	5.130	0.226
40	33510	3.35E-02	3.69E-04	167.55	6.840	0.514
50	65450	6.54E-02	7.20E-04	327.25	8.550	1.816
60	113097	1.13E-01	1.24E-03	565.49	10.260	5.702
70	179594	1.80E-01	1.98E-03	897.97	11.970	21.348
90	381704	3.82E-01	4.20E-03	1908.52	15.390	49.812
110	696910	6.97E-01	7.67E-03	3484.55	18.810	70.509
130	1150347	1.15E+00	1.27E-02	5751.73	22.230	82.023
150	1767146	1.77E+00	1.94E-02	8835.73	25.650	88.012
180	3053628	3.05E+00	3.36E-02	15268.14	30.780	91.032
210	4849048	4.85E+00	5.33E-02	24245.24	35.909	92.468
240	7238229	7.24E+00	7.96E-02	36191.15	41.039	94.091
270	10305995	1.03E+01	1.13E-01	51529.97	46.169	94.689
300	14137167	1.41E+01	1.56E-01	70685.83	51.299	96.288
350	22449298	2.24E+01	2.47E-01	112246.49	59.849	97.011
400	33510322	3.35E+01	3.69E-01	167551.61	68.399	98.340
450	47712938	4.77E+01	5.25E-01	238564.69	76.949	99.071
500	65449847	6.54E+01	7.20E-01	327249.23	85.499	99.071
600	113097336	1.13E+02	1.24E+00	565486.68	102.599	100.000

Figure 1: Percentage of Drift PM that Evaporates to PM10

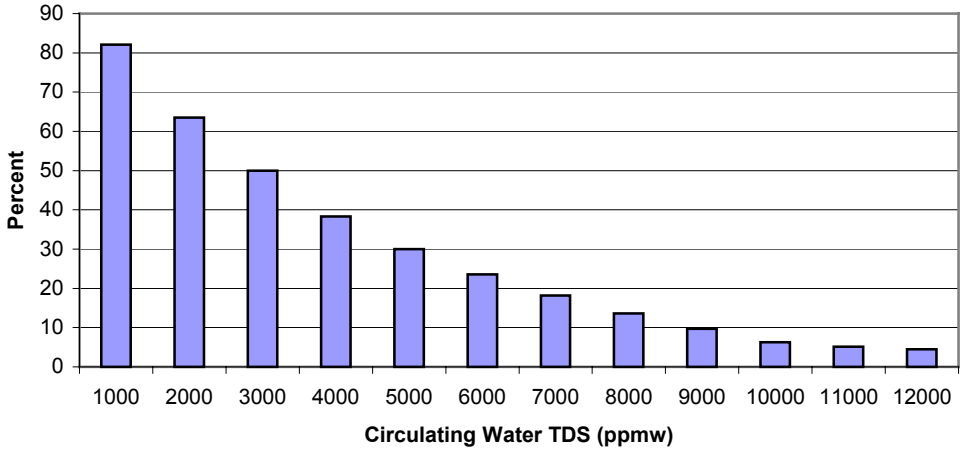
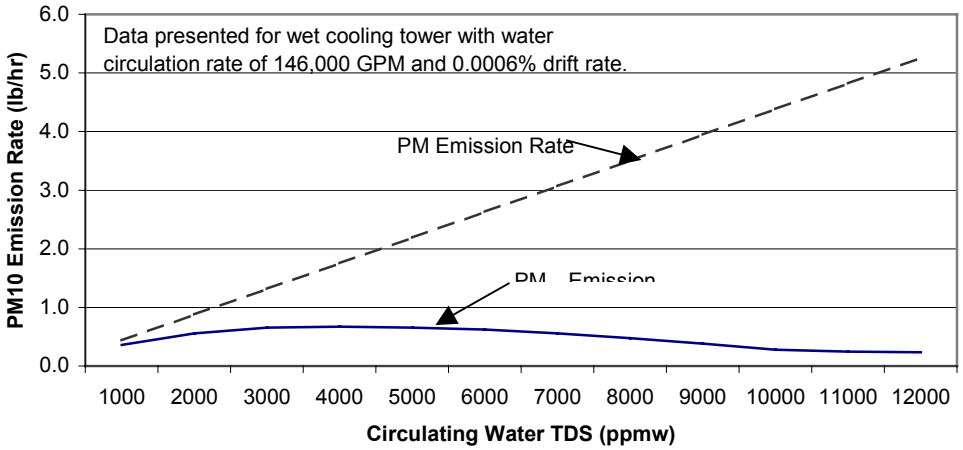


Figure 2: PM_{10} Emission Rate vs. TDS



REFERENCES

1. EPA, 1995. Compilation of Air pollutant Emission Factors, AP-42 Fifth edition, Volume I: *Stationary Point and Area Sources*, Chapter 13.4 Wet Cooling Towers, http://www.epa.gov/ttn/chief/ap42/, United States Environmental Protection Agency, Office of Air Quality Planning and Standards, January.

2. Aull, 1999. Memorandum from R. Aull, Brentwood Industries to J. Reisman, Greystone, December 7, 1999.

KEY WORDS

Drift
Drift eliminators
Cooling tower
PM_{10} emissions
TDS

Appendix C – PCAQCD's Approval of Resolution Copper's Modeling Plan

Michael Sundblom
Air Quality Director

Greg Stanley
County Manager

PINAL COUNTY
WIDE OPEN OPPORTUNITY

March 1, 2018

Resolution Copper Mining, LLC
Attn: Victoria Peacey
P.O. Box 1944
Superior, AZ 85173

Re: Response to Air Quality Impact Analysis Modeling Protocol

Dear Ms. Peacey,

Pinal County Air Quality Control District (PCAQCD) has completed our review of the Resolution Copper Project modeling protocol, including review by a 3rd party contractor. Based upon this review and responses and supplemental information provided by Resolution Copper, we conclude that the modeling protocol is acceptable.

Thank you for the opportunity to review and comment on the modeling protocol. If you or your staff have question regarding this response please contact me at (520)866-6915 or Anu Jain at (520)866-6931.

Regards,

Mike Sundblom
Director
Pinal County Air Quality Control

AIR QUALITY

31 North Pinal Street, Building F, PO Box 987, Florence, AZ 85132 T 520-866-6929 FREE 888-431-1311 F 520-866-6967
www.pinalcountyaz.gov

Appendix D – Detailed Emission Calculations

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 1	OF: 2	SHEET: Gen Info
AIR EMISSION CALCULATIONS	SUBJECT: General Mining and Milling Information	DATE: March 15, 2018		

Mining Information

Mine Throughput

	Production	
tonne/hr	8,940	*Resolution*
tonne/day	143,750	*Resolution*
tonne/yr	45,625,000	*Resolution*
ton/hr	9,855	
ton/day	158,457	
ton/yr	50,292,894	

Material Moisture Content and Wind Speed

Location	Solids* %	Ore Moisture* Content %		Air/Wind Speed* *mph*	*m/s*
EAST PLANT					
LHD/Ore Pass/Grizzly		4.0		1.4	0.6
Haulage Ore Flow		4.0		2.2	1.0
Primary Crushing Ore Flow		4.0		4.0	1.8
Lower Level Conveyor Ore Flow		4.0		2.4	1.1
Hoisting System Ore Flow		4.0		1.3	0.6
Upper Level Conveyor System Ore Flow		4.0		4.5	2.0
MILL					
Incline Conveyor to Mine Transfer Conveyor	96.0	4.0		1.3	**
Enclosed Stockpile	95.8	4.2		1.3	**
Stockpile Reclaim	95.8	4.2		1.3	**
SAG Feeder Conveyors		4.8	**	1.3	**
Pebble Recycle		4.8	**	1.3	**
Holoflite Dryer - In		4.8	**	1.3	**
Holoflite Dryer - Out		4.8	**	1.3	**
LOADOUT					
All		4.8	**	1.3	**

** Resolution*

*** AP-4, Ch. 13.2.4*

Silt Content		
Surface	3.0%	*AP-42, Chapter 13.2.2, Related Information, r13s0202_dec03.xls*

Conversions	
1.10231	*ton/tonne*
907.185	*kg/ton*
2.237	*mph/mps*
24	*hr/day*
365	*day/yr*
8,760	*hr/yr*

Blue values are input; black values are calculated or linked

Milling Information

Mill Throughput

	Coarse Ore Stockpile	Entering Each SAG Mill (2)	Each SAG Mill Processing (2)	Each Screen Screen O'Size (2)	Entering Each Ball Mill (4)
tonne/hr	8,940	4,296	4,296	1,060	7,011
tonne/day	143,750	94,875	94,875	23,390	154,808
tonne/yr	45,625,000	30,112,500	30,112,500	7,424,100	49,134,616
ton/hr	9,855	4,736	4,736	1,168	7,728
ton/day	158,457	104,582	104,582	25,783	170,646
ton/yr	50,292,894	33,193,310	33,193,310	8,183,660	54,161,579

Mill Throughput Continued

	Pebble Circuit	Moly Filter Cake to Dryer	Dried Moly Concentrate	Cu Concentrate Loadout
tonne/hr	1,042	10.0	9.0	414
tonne/day	23,000	238.0	213.0	9,942
tonne/yr	7,300,000	41,176.0	36,842.0	3,338,889
ton/hr	1,149	11	10	456
ton/day	25,353	262	235	10,959
ton/yr	8,046,863	45,389	40,611	3,680,491

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 1	OF: 2	SHEET: Summary_DISP
AIR EMISSION CALCULATIONS	SUBJECT: Facility-Wide Emissions	DATE: March 15, 2018		

FACILITY - CONTROLLED - EMISSIONS SUMMARY (INCLUDING FUGITIVES)

	Potential Emissions											
	CO		NO_X		SO_2		PM_{10}		$PM_{2.5}$		VOC	
Location	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*
EP Surface Subtotal	*34.6*	*11.6*	*134*	*33.8*	*0.80*	*0.21*	*13.5*	*15.6*	*5.7*	*2.9*	*13.4*	*3.4*
EP UG Subtotal	*265*	*193*	*35.4*	*22.4*	*6.9*	*1.8*	*182*	*265*	*22.5*	*42.8*	*6.9*	*8.3*
Mill Subtotal	*42.0*	*43.3*	*10.1*	*15.8*	*5.2*	*15.0*	*30.8*	*37.9*	*5.3*	*11.1*	*23.3*	*68.9*
Loadout Subtotal	*12.2*	*21.5*	*1.3*	*2.4*	*2.8E-2*	*4.7E-2*	*0.62*	*2.4*	*0.13*	*0.42*	*0.46*	*1.1*
Tailings Subtotal	*99.1*	*141*	*12.0*	*16.1*	*0.21*	*0.29*	*89.2*	*122*	*14.1*	*18.2*	*6.1*	*8.0*
FACILITY TOTAL	***453***	***411***	***193***	***90.5***	***13.1***	***17.3***	***316***	***443***	***47.7***	***75.5***	***50.2***	***89.7***

FACILITY - UNCONTROLLED - EMISSIONS SUMMARY (INCLUDING FUGITIVES)

	Potential Emissions											
	CO		NO_X		SO_2		PM_{10}		$PM_{2.5}$		VOC	
Location	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*
EP Surface Subtotal	*34.6*	*11.6*	*134*	*33.8*	*0.80*	*0.21*	*136*	*130*	*22.0*	*16.1*	*13.4*	*3.4*
EP UG Subtotal	*265*	*193*	*35.4*	*22.4*	*6.9*	*1.8*	*3,277*	*4,440*	*429*	*700*	*6.9*	*8.3*
Mill Subtotal	*42.0*	*43.3*	*10.1*	*15.8*	*84.9*	*272*	*388*	*642*	*130*	*362*	*175*	*558*
Loadout Subtotal	*12.2*	*21.5*	*1.3*	*2.4*	*2.8E-2*	*4.7E-2*	*2.7*	*10.2*	*0.35*	*1.2*	*0.46*	*1.1*
Tailings Subtotal	*99.1*	*141*	*12.0*	*16.1*	*0.21*	*0.29*	*811*	*1,131*	*86.4*	*119*	*6.1*	*8.0*
FACILITY TOTAL	***453***	***411***	***193***	***90.5***	***92.8***	***274***	***4,615***	***6,353***	***667***	***1,199***	***202***	***579***

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 2	OF: 2	SHEET: Summary_DISP
AIR EMISSION CALCULATIONS	SUBJECT: Facility-Wide Emissions	DATE: March 15, 2018		

FACILITY - CONTROLLED - EMISSIONS SUMMARY (EXCLUDING FUGITIVES)

	Potential Emissions											
	CO		NO_X		SO_2		PM_{10}		$PM_{2.5}$		VOC	
Location	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*
*EP Surface Subtotal (NF)**	*32.6*	*8.1*	*134*	*33.5*	*0.80*	*0.20*	*8.2*	*5.2*	*5.1*	*1.8*	*13.3*	*3.3*
*EP UG Subtotal (NF)**							*20.3*	*59.0*	*5.7*	*21.4*		
*Mill Subtotal (NF)**	*16.1*	*10.6*	*3.8*	*10.8*	*4.5*	*14.8*	*5.4*	*17.1*	*2.2*	*7.7*	*20.6*	*66.0*
*Loadout Subtotal (NF)**	*3.9*	*0.96*	*0.35*	*8.7E-2*	*9.0E-3*	*2.2E-3*	*0.35*	*1.4*	*5.9E-2*	*0.21*	*1.7E-2*	*4.3E-3*
*Tailings Subtotal (NF)**	*3.9*	*0.96*	*0.35*	*8.7E-2*	*9.0E-3*	*2.2E-3*	*7.7E-3*	*1.9E-3*	*7.7E-3*	*1.9E-3*	*1.7E-2*	*4.3E-3*
FACILITY TOTAL	***56.4***	***20.6***	***138***	***44.4***	***5.3***	***15.0***	***34.3***	***82.8***	***13.1***	***31.1***	***33.9***	***69.3***

(NF) no fugitive or mobile emissions*

FACILITY - UNCONTROLLED - EMISSIONS SUMMARY (EXCLUDING FUGITIVES)

	Potential Emissions											
	CO		NO_X		SO_2		PM_{10}		$PM_{2.5}$		VOC	
Location	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*
*EP Surface Subtotal (NF)**	*32.6*	*8.1*	*134*	*33.5*	*0.80*	*0.20*	*86.7*	*38.2*	*17.0*	*6.8*	*13.3*	*3.3*
*EP UG Subtotal (NF)**							*138*	*352*	*114*	*290*		
*Mill Subtotal (NF)**	*16.1*	*10.6*	*3.8*	*10.8*	*84.2*	*272*	*144*	*454*	*105*	*342*	*172*	*555*
*Loadout Subtotal (NF)**	*3.9*	*0.96*	*0.35*	*8.7E-2*	*9.0E-3*	*2.2E-3*	*0.35*	*1.4*	*5.9E-2*	*0.21*	*1.7E-2*	*4.3E-3*
*Tailings Subtotal (NF)**	*3.9*	*0.96*	*0.35*	*8.7E-2*	*9.0E-3*	*2.2E-3*	*7.7E-3*	*1.9E-3*	*7.7E-3*	*1.9E-3*	*1.7E-2*	*4.3E-3*
FACILITY TOTAL	***56.4***	***20.6***	***138***	***44.4***	***85.0***	***272***	***369***	***845***	***236***	***639***	***186***	***558***

(NF) no fugitive or mobile emissions*

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 1	OF: 3	SHEET: Atty_DISP
AIR EMISSION CALCULATIONS	SUBJECT: Emission by Class	DATE: March 15, 2018		

FACILITY - CONTROLLED - EMISSIONS SUMMARY (INCLUDING FUGITIVES)

	Potential Emissions											
	CO		NO_X		SO_2		PM_{10}		$PM_{2.5}$		VOC	
Location	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*
East Plant Surface												
*Stack**	*32.6*	*8.1*	*134*	*33.5*	*0.80*	*0.20*	*5.2*	*3.9*	*4.6*	*1.6*	*13.3*	*3.3*
*Process Fugitive**							*3.0*	*1.3*	*0.46*	*0.20*		
Fugitive							*5.3*	*10.3*	*0.55*	*1.1*	*3.3E-4*	*1.4E-3*
Mobile	*2.0*	*3.4*	*0.32*	*0.35*	*3.3E-3*	*6.8E-3*	*5.3E-2*	*8.3E-2*	*2.0E-2*	*2.4E-2*	*9.7E-2*	*0.11*
Subtotal	*34.6*	*11.6*	*134*	*33.8*	*0.80*	*0.21*	*13.5*	*15.6*	*5.7*	*2.9*	*13.4*	*3.4*
East Plant Underground												
Stack							*3.9*	*17.1*	*3.8*	*16.4*		
Process Fugitive							*16.4*	*41.9*	*1.9*	*5.0*		
Fugitive	*109*	*26.7*	*20.9*	*5.1*	*6.7*	*1.6*	*160*	*205*	*16.0*	*20.6*	*4.8E-3*	*2.1E-2*
Mobile	*155*	*167*	*14.6*	*17.3*	*0.14*	*0.15*	*0.73*	*0.87*	*0.73*	*0.87*	*6.9*	*8.2*
Subtotal	*265*	*193*	*35.4*	*22.4*	*6.9*	*1.8*	*182*	*265*	*22.5*	*42.8*	*6.9*	*8.3*
Mill												
*Stack**	*16.1*	*10.6*	*3.8*	*10.8*	*4.5*	*14.8*	*1.8*	*6.6*	*1.7*	*6.1*	*20.6*	*65.9*
*Process Fugitive**							*3.6*	*10.5*	*0.55*	*1.6*	*1.7E-2*	*7.2E-2*
Fugitive	*0.67*	*2.1*	*2.1*	*0.40*	*0.67*	*0.13*	*25.1*	*20.6*	*2.9*	*3.2*	*4.0E-3*	*1.7E-2*
Mobile	*25.3*	*30.6*	*4.3*	*4.6*	*4.8E-2*	*5.6E-2*	*0.22*	*0.22*	*0.17*	*0.20*	*2.7*	*2.9*
Subtotal	*42.0*	*43.3*	*10.1*	*15.8*	*5.2*	*15.0*	*30.8*	*37.9*	*5.3*	*11.1*	*23.3*	*68.9*
Loadout												
*Stack**	*3.9*	*0.96*	*0.35*	*8.7E-2*	*9.0E-3*	*2.2E-3*	*7.7E-3*	*1.9E-3*	*7.7E-3*	*1.9E-3*	*1.7E-2*	*4.3E-3*
*Process Fugitive**							*0.34*	*1.4*	*5.1E-2*	*0.21*		
Fugitive							*0.23*	*0.87*	*2.4E-2*	*9.2E-2*	*3.1E-3*	*1.3E-2*
Mobile	*8.4*	*20.6*	*0.94*	*2.3*	*1.9E-2*	*4.5E-2*	*4.8E-2*	*0.12*	*4.7E-2*	*0.12*	*0.44*	*1.1*
Subtotal	*12.2*	*21.5*	*1.3*	*2.4*	*2.8E-2*	*4.7E-2*	*0.62*	*2.4*	*0.13*	*0.42*	*0.46*	*1.1*
Tailings												
*Stack**	*3.9*	*0.96*	*0.35*	*8.7E-2*	*9.0E-3*	*2.2E-3*	*7.7E-3*	*1.9E-3*	*7.7E-3*	*1.9E-3*	*1.7E-2*	*4.3E-3*
*Process Fugitive**												
Fugitive							*88.6*	*121*	*13.6*	*17.4*	*2.0E-2*	*8.7E-2*
Mobile	*95.2*	*140*	*11.6*	*16.0*	*0.20*	*0.29*	*0.55*	*0.79*	*0.55*	*0.79*	*6.1*	*7.9*
Subtotal	*99.1*	*141*	*12.0*	*16.1*	*0.21*	*0.29*	*89.2*	*122*	*14.1*	*18.2*	*6.1*	*8.0*
FACILITY TOTAL	***453***	***411***	***193***	***90.5***	***13.1***	***17.3***	***316***	***443***	***47.7***	***75.5***	***50.2***	***89.7***

**Stack and process fugitive sources considered "process" sources*

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 2	OF: 3	SHEET: Atty_DISP
AIR EMISSION CALCULATIONS	SUBJECT: Emission by Class	DATE: March 15, 2018		

FACILITY - UNCONTROLLED - EMISSIONS SUMMARY (INCLUDING FUGITIVES)

	Potential Emissions											
	CO		NO_X		SO_2		PM_{10}		$PM_{2.5}$		VOC	
Location	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*
East Plant Surface												
*Stack**	*32.6*	*8.1*	*134*	*33.5*	*0.80*	*0.20*	*5.2*	*3.9*	*4.6*	*1.6*	*13.3*	*3.3*
*Process Fugitive**							*81.6*	*34.3*	*12.4*	*5.2*		
Fugitive							*49.6*	*91.9*	*5.0*	*9.3*	*3.3E-4*	*1.4E-3*
Mobile	*2.0*	*3.4*	*0.32*	*0.35*	*3.3E-3*	*6.8E-3*	*5.3E-2*	*8.3E-2*	*2.0E-2*	*2.4E-2*	*9.7E-2*	*0.11*
Subtotal	*34.6*	*11.6*	*134*	*33.8*	*0.80*	*0.21*	*136*	*130*	*22.0*	*16.1*	*13.4*	*3.4*
East Plant Underground												
*Stack**							*42.9*	*110*	*26.6*	*67.9*		
*Process Fugitive**							*94.9*	*242*	*87.2*	*222*		
Fugitive	*109*	*26.7*	*20.9*	*5.1*	*6.7*	*1.6*	*3,138*	*4,088*	*314*	*409*	*4.8E-3*	*2.1E-2*
Mobile	*155*	*167*	*14.6*	*17.3*	*0.14*	*0.15*	*0.73*	*0.87*	*0.73*	*0.87*	*6.9*	*8.2*
Subtotal	*265*	*193*	*35.4*	*22.4*	*6.9*	*1.8*	*3,277*	*4,440*	*429*	*700*	*6.9*	*8.3*
Mill												
*Stack**	*16.1*	*10.6*	*3.8*	*10.8*	*84.2*	*272*	*111*	*359*	*94.3*	*305*	*172*	*555*
*Process Fugitive**							*32.8*	*94.2*	*10.7*	*36.9*	*1.7E-2*	*7.2E-2*
Fugitive	*0.67*	*2.1*	*2.1*	*0.40*	*0.67*	*0.13*	*244*	*188*	*24.8*	*19.9*	*4.0E-3*	*1.7E-2*
Mobile	*25.3*	*30.6*	*4.3*	*4.6*	*4.8E-2*	*5.6E-2*	*0.22*	*0.22*	*0.17*	*0.20*	*2.7*	*2.9*
Subtotal	*42.0*	*43.3*	*10.1*	*15.8*	*84.9*	*272*	*388*	*642*	*130*	*362*	*175*	*558*
Loadout												
*Stack**	*3.9*	*0.96*	*0.35*	*8.7E-2*	*9.0E-3*	*2.2E-3*	*7.7E-3*	*1.9E-3*	*7.7E-3*	*1.9E-3*	*1.7E-2*	*4.3E-3*
*Process Fugitive**							*0.34*	*1.4*	*5.1E-2*	*0.21*		
Fugitive							*2.3*	*8.7*	*0.24*	*0.92*	*3.1E-3*	*1.3E-2*
Mobile	*8.4*	*20.6*	*0.94*	*2.3*	*1.9E-2*	*4.5E-2*	*4.8E-2*	*0.12*	*4.7E-2*	*0.12*	*0.44*	*1.1*
Subtotal	*12.2*	*21.5*	*1.3*	*2.4*	*2.8E-2*	*4.7E-2*	*2.7*	*10.2*	*0.35*	*1.2*	*0.46*	*1.1*
Tailings												
*Stack**	*3.9*	*0.96*	*1.9E-3*	*1.9E-3*	*9.0E-3*	*2.2E-3*	*8.7E-2*	*7.7E-3*	*1.9E-3*	*7.7E-3*	*1.7E-2*	*4.3E-3*
*Process Fugitive**												
Fugitive			*119*	*5,730*				*811*	*1,130*	*85.8*	*2.0E-2*	*8.7E-2*
Mobile	*95.2*	*140*	*0.79*	*0.79*	*0.20*	*0.29*	*16.0*	*0.55*	*0.79*	*0.55*	*6.1*	*7.9*
Subtotal	*99.1*	*141*	*119*	*5,731*	*0.21*	*0.29*	*16.1*	*811*	*1,131*	*86.4*	*6.1*	*8.0*
FACILITY TOTAL	***453***	***411***	***300***	***5,805***	***92.8***	***274***	***3,820***	***6,034***	***1,712***	***1,166***	***202***	***579***

**Stack and process fugitive sources considered "process" sources*

Resolution Copper Project
Annual Emissions Inventory - Summary Table
Revision - March 15, 2018

	CO *ton/yr*	NO_X *ton/yr*	SO_2 *ton/yr*	PM_{10} *ton/yr*	$PM_{2.5}$ *ton/yr*	VOC *ton/yr*
Total - Facility-Wide	*411*	*90.5*	*17.3*	*443*	*75.5*	*89.7*
All Facilities - Process	*20.6*	*44.4*	*15.0*	*82.8*	*31.1*	*69.3*
Major Source Threshold	**100**	**100**	**100**	**100**	**100**	**100**
All Facilities - Fugitive	*28.8*	*5.5*	*1.8*	*358*	*42.4*	*0.14*
All Facilities - Mobile	*361*	*40.7*	*0.55*	*2.1*	*2.0*	*20.3*
East Plant						
Process	*8.1*	*33.5*	*0.20*	*64.3*	*23.1*	*3.3*
Fugitive	*26.7*	*5.1*	*1.6*	*216*	*21.7*	*2.3E-2*
Mobile	*170*	*17.7*	*0.15*	*0.95*	*0.89*	*8.3*
Mill						
Process	*10.6*	*10.8*	*14.8*	*17.1*	*7.7*	*66.0*
Fugitive	*2.1*	*0.40*	*0.13*	*20.6*	*3.2*	*1.7E-2*
Mobile	*30.6*	*4.6*	*5.6E-2*	*0.22*	*0.20*	*2.9*
Loadout						
Process	*0.96*	*8.7E-2*	*2.2E-3*	*1.4*	*0.21*	*4.3E-3*
Fugitive				*0.87*	*9.2E-2*	*1.3E-2*
Mobile	*20.6*	*2.3*	*4.5E-2*	*0.12*	*0.12*	*1.1*
Tailings						
Process	*0.96*	*8.7E-2*	*2.2E-3*	*1.9E-3*	*1.9E-3*	*4.3E-3*
Fugitive				*121*	*17.4*	*8.7E-2*
Mobile	*140*	*16.0*	*0.29*	*0.79*	*0.79*	*7.9*

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 1	OF: 18	SHEET: EPS_DISP
AIR EMISSION CALCULATIONS	SUBJECT: East Plant	DATE: March 15, 2018		

EAST PLANT - CONTROLLED UNDERGROUND - EMISSIONS SUMMARY

	Potential Emissions											
	CO		NO_X		SO_2		PM_{10}		$PM_{2.5}$		VOC	
Source ID	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*
2_EP_UG_DB	*Drilling & Blasting*											
EP_UG_DRILL							*0.12*	*9.1E-2*	*0.12*	*9.1E-2*		
EP_UG_BLAST	*109*	*26.7*	*20.9*	*5.1*	*6.7*	*1.6*	*3.6*	*0.87*	*0.21*	*5.0E-2*		
2_EP_UG_EXTRACT	*Extraction Level Ore Flow*											
EP_UG_OVER							*7.9E-2*	*0.20*	*7.9E-2*	*0.20*		
2_EP_UG_OREPASS	*LHD/Ore Pass/Grizzly*											
EP_UG_GRIZ							*7.3*	*18.6*	*0.49*	*1.3*		
2_EP_UG_RAIL	*Haulage Ore Flow*											
EP_UG_TRAIN							*1.5*	*3.8*	*0.22*	*0.57*		
EP_UG_COARSE							*0.78*	*3.4*	*0.78*	*3.4*		
2_EP_UG_1CRUSH	*Primary Crushing Ore Flow*											
EP_UG_FINE												
2_EP_UG_LOW_ORE	*Lower Level Conveyor Ore Flow*											
EP_UG_CV103												
EP_UG_CV104							*0.18*	*0.78*	*0.18*	*0.78*		
EP_UG_CV105							*1.6*	*4.1*	*0.24*	*0.62*		
EP_UG_SILO							*0.78*	*3.4*	*0.78*	*3.4*		
EP_UG_FEED												
EP_UG_CV106_111												
EP_UG_Chute							*1.6*	*4.1*	*0.24*	*0.62*		
EP_UG_FLASK							*1.2*	*5.2*	*1.2*	*5.2*		
2_EP_UG_HOIST	*Hoisting System Ore Flow*											
EP_UG_SKIP												
EP_UG_BIN							*0.76*	*1.9*	*0.11*	*0.29*		
2_EP_UG_UP_ORE	*Upper Level Conveyor System Ore Flow*											
EP_UG_FEED112_115							*0.79*	*3.5*	*0.79*	*3.5*		
EP_UG_CV102_105												
EP_UG_INC_CONV115							*3.6*	*9.2*	*0.55*	*1.4*		
2_EP_UG_D	*Non-Emergency Underground Diesel Fleet*											
EP_UG_D_C	*155*	*167*	*14.6*	*17.3*	*0.14*	*0.15*	*0.73*	*0.87*	*0.73*	*0.87*	*6.9*	*8.2*
EP_UG_D_DOZ							*5.6E-2*	*2.4E-2*	*3.7E-2*	*1.6E-2*		
EP_UG_D_FUG							*157*	*204*	*15.7*	*20.4*		
2_EP_UG_REF	*Underground Refrigeration Plant*											
EP_UG_COOL							*0.19*	*0.82*	*2.9E-2*	*0.12*		
2_EP_UG_FUEL	*Diesel Storage Tanks*											
EP_UG_FUEL1											*4.8E-3*	*2.1E-2*
3_EP_UG_TOTAL	***265***	***193***	***35.4***	***22.4***	***6.9***	***1.8***	***182***	***265***	***22.5***	***42.8***	***6.9***	***8.3***

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 2	OF: 18	SHEET: EPS_DISP
AIR EMISSION CALCULATIONS	SUBJECT: East Plant	DATE: March 15, 2018		

EAST PLANT - CONTROLLED SURFACE - EMISSIONS SUMMARY

	Potential Emissions											
	CO		NO_X		SO_2		PM_{10}		$PM_{2.5}$		VOC	
Source ID	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr
2_EP_S_EGEN	*Emergency Generators (Total)*											
E_GEN1	15.1	3.8	27.7	6.9	3.3E-2	8.2E-3	0.86	0.22	0.86	0.22	5.6	1.4
E_GEN2	2.6	0.65	4.9	1.2	5.6E-3	1.4E-3	0.15	3.7E-2	0.15	3.7E-2	0.96	0.24
E_GEN3	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN4	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN5	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN6	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN7	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN8	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN9	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN10	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN11	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN12	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN13	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN14	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN15	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN16	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
2_EP_S_REF	*Surface Refrigeration Plant*											
E_COOL1							0.10	0.46	1.6E-2	7.0E-2		
E_COOL2							0.10	0.46	1.6E-2	7.0E-2		
E_COOL3							0.10	0.46	1.6E-2	7.0E-2		
E_COOL4							0.10	0.46	1.6E-2	7.0E-2		
E_COOL5							0.10	0.46	1.6E-2	7.0E-2		
E_COOL6							0.10	0.46	1.6E-2	7.0E-2		
2_EP_S_CBP	*Cement Batch Plant*											
B_AGDEL							0.21	0.12	3.2E-2	1.8E-2		
B_SNDEL							0.11	6.1E-2	1.6E-2	9.3E-3		
B_AGCHUT							1.6E-2	1.1E-2	2.5E-3	1.6E-3		
B_SNCHUT							1.3E-2	5.3E-3	2.0E-3	8.5E-4		
B_AGSTOR							1.6E-2	1.1E-2	2.5E-3	1.6E-3		
B_SNSTOR							1.3E-2	5.3E-3	2.0E-3	8.5E-4		
B_WHOPLD							0.18	8.6E-2	2.7E-2	1.3E-2		
B_WHOPAG							1.6E-2	1.1E-2	2.5E-3	1.6E-3		
B_WHOPSN							1.3E-2	5.3E-3	2.0E-3	8.5E-4		
B_CEMSLO							2.6E-2	1.1E-2	3.9E-3	1.6E-3		
B_FLYSLO							4.8E-2	2.4E-2	7.2E-3	3.7E-3		
B_SILSLO							1.9E-2	5.2E-3	2.9E-3	7.9E-4		
B_SLOHOP							2.5E-3	1.0E-3	3.8E-4	1.6E-4		
B_SLOCNY							2.5E-3	1.0E-3	3.8E-4	1.6E-4		
B_SLOTRK							2.4	0.98	0.36	0.15		
2_EP_S_FUEL	*Diesel Storage Tanks*											
EP_S_FUEL1											3.3E-4	1.4E-3
2_EP_S_WE	*Miscellaneous Fugitives*											
W_WE_RD							3.3E-2	0.14	4.9E-3	2.2E-2		
E_WE_EXP							3.7E-3	1.6E-2	5.6E-4	2.4E-3		
E_WE_SUB							0.35	1.2	5.2E-2	0.19		
EP_S_EFD							1.9	6.8	0.19	0.68		
EP_S_E_C	0.45	2.0	2.1E-2	9.2E-2	1.1E-3	4.9E-3	1.1E-2	5.0E-2	2.0E-3	8.9E-3	4.9E-3	2.1E-2
EP_S_DFD							1.8	1.1	0.18	0.11		
EP_S_D_C	4.3E-2	3.3E-2	0.13	9.9E-2	4.0E-4	3.1E-4	3.2E-2	2.5E-2	9.3E-3	7.1E-3	9.6E-3	7.4E-3
2_EP_S_D	*Non-Emergency Surface Diesel Fleet*											
EP_S_F_C	1.5	1.4	0.17	0.16	1.8E-3	1.6E-3	8.7E-3	8.1E-3	8.7E-3	8.1E-3	8.3E-2	7.7E-2
EP_S_D_DOZ												
EP_S_D_FUG							1.2	0.92	0.12	9.2E-2		
3_EP_S_TOTAL	**34.6**	**11.6**	**134**	**33.8**	**0.80**	**0.21**	**13.5**	**15.6**	**5.7**	**2.9**	**13.4**	**3.4**

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 3	OF: 18	SHEET: EPS_DISP
AIR EMISSION CALCULATIONS	SUBJECT: East Plant	DATE: March 15, 2018		

EAST PLANT - UNCONTROLLED UNDERGROUND - EMISSIONS SUMMARY

	Potential Emissions											
	CO		NO_X		SO_2		PM_{10}		$PM_{2.5}$		VOC	
Source ID	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*
2_EP_UG_DB	*Drilling & Blasting*											
EP_UG_DRILL							*0.12*	*9.1E-2*	*0.12*	*9.1E-2*		
EP_UG_BLAST	*109*	*26.7*	*20.9*	*5.1*	*6.7*	*1.6*	*3.6*	*0.87*	*0.21*	*5.0E-2*		
2_EP_UG_EXTRACT	*Extraction Level Ore Flow*											
EP_UG_OVER							*7.9E-2*	*0.20*	*7.9E-2*	*0.20*		
2_EP_UG_OREPASS	*LHD/Ore Pass/Grizzly*											
EP_UG_GRIZ							*85.7*	*219*	*85.7*	*219*		
2_EP_UG_RAIL	*Haulage Ore Flow*											
EP_UG_TRAIN							*1.5*	*3.8*	*0.22*	*0.57*		
EP_UG_COARSE							*1.5*	*3.8*	*0.22*	*0.57*		
2_EP_UG_1CRUSH	*Primary Crushing Ore Flow*											
EP_UG_FINE							*23.7*	*60.4*	*23.7*	*60.4*		
2_EP_UG_LOW_ORE	*Lower Level Conveyor Ore Flow*											
EP_UG_CV103							*1.6*	*4.1*	*0.24*	*0.62*		
EP_UG_CV104							*1.6*	*4.1*	*0.24*	*0.62*		
EP_UG_CV105							*1.6*	*4.1*	*0.24*	*0.62*		
EP_UG_SILO							*1.6*	*4.1*	*0.24*	*0.62*		
EP_UG_FEED							*1.6*	*4.1*	*0.24*	*0.62*		
EP_UG_CV106_111							*1.6*	*4.1*	*0.24*	*0.62*		
EP_UG_Chute							*1.6*	*4.1*	*0.24*	*0.62*		
EP_UG_FLASK							*1.6*	*4.1*	*0.24*	*0.62*		
2_EP_UG_HOIST	*Hoisting System Ore Flow*											
EP_UG_SKIP							*0.76*	*1.9*	*0.11*	*0.29*		
EP_UG_BIN							*0.76*	*1.9*	*0.11*	*0.29*		
2_EP_UG_UP_ORE	*Upper Level Conveyor System Ore Flow*											
EP_UG_FEED112_115							*3.6*	*9.2*	*0.55*	*1.4*		
EP_UG_CV102_105							*3.6*	*9.2*	*0.55*	*1.4*		
EP_UG_INC_CONV115							*3.6*	*9.2*	*0.55*	*1.4*		
2_EP_UG_D	*Non-Emergency Underground Diesel Fleet*											
EP_UG_D_C	*155*	*167*	*14.6*	*17.3*	*0.14*	*0.15*	*0.73*	*0.87*	*0.73*	*0.87*	*6.9*	*8.2*
EP_UG_D_DOZ							*1.1*	*0.48*	*0.74*	*0.32*		
EP_UG_D_FUG							*3,133*	*4,086*	*313*	*409*		
2_EP_UG_REF	*Underground Refrigeration Plant*											
EP_UG_COOL							*0.19*	*0.82*	*2.9E-2*	*0.12*		
2_EP_UG_FUEL	*Diesel Storage Tanks*											
EP_UG_FUEL1											*4.8E-3*	*2.1E-2*
3_EP_UG_TOTAL	***265***	***193***	***35.4***	***22.4***	***6.9***	***1.8***	***3,277***	***4,440***	***429***	***700***	***6.9***	***8.3***

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 4	OF: 18	SHEET: EPS_DISP
AIR EMISSION CALCULATIONS	SUBJECT: East Plant	DATE: March 15, 2018		

EAST PLANT - UNCONTROLLED SURFACE - EMISSIONS SUMMARY

	Potential Emissions											
	CO		NO_X		SO_2		PM_{10}		$PM_{2.5}$		VOC	
Source ID	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr
2_EP_S_EGEN	*Emergency Generators (Total)*											
E_GEN1	15.1	3.8	27.7	6.9	3.3E-2	8.2E-3	0.86	0.22	0.86	0.22	5.6	1.4
E_GEN2	2.6	0.65	4.9	1.2	5.6E-3	1.4E-3	0.15	3.7E-2	0.15	3.7E-2	0.96	0.24
E_GEN3	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN4	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN5	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN6	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN7	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN8	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN9	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN10	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN11	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN12	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN13	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN14	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN15	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
E_GEN16	1.1	0.27	7.2	1.8	5.4E-2	1.4E-2	0.25	6.3E-2	0.25	6.3E-2	0.48	0.12
2_EP_S_REF	*Surface Refrigeration Plant*											
E_COOL1							0.10	0.46	1.6E-2	7.0E-2		
E_COOL2							0.10	0.46	1.6E-2	7.0E-2		
E_COOL3							0.10	0.46	1.6E-2	7.0E-2		
E_COOL4							0.10	0.46	1.6E-2	7.0E-2		
E_COOL5							0.10	0.46	1.6E-2	7.0E-2		
E_COOL6							0.10	0.46	1.6E-2	7.0E-2		
2_EP_S_CBP	*Cement Batch Plant*											
B_AGDEL							0.27	0.15	4.1E-2	2.3E-2		
B_SNDEL							0.13	7.6E-2	2.0E-2	1.2E-2		
B_AGCHUT							0.23	0.15	3.5E-2	2.3E-2		
B_SNCHUT							0.18	7.6E-2	2.8E-2	1.2E-2		
B_AGSTOR							0.23	0.15	3.5E-2	2.3E-2		
B_SNSTOR							0.18	7.6E-2	2.8E-2	1.2E-2		
B_WHOPLD							0.72	0.34	0.11	5.2E-2		
B_WHOPAG							0.23	0.15	3.5E-2	2.3E-2		
B_WHOPSN							0.18	7.6E-2	2.8E-2	1.2E-2		
B_CEMSLO							35.8	14.7	5.4	2.2		
B_FLYSLO							10.7	5.5	1.6	0.83		
B_SILSLO							4.3	1.2	0.65	0.18		
B_SLOHOP							0.25	0.10	3.8E-2	1.6E-2		
B_SLOCNY							0.25	0.10	3.8E-2	1.6E-2		
B_SLOTRK							27.9	11.6	4.2	1.7		
2_EP_S_FUEL	*Diesel Storage Tanks*											
EP_S_FUEL1											3.3E-4	1.4E-3
2_EP_S_WE	*Miscellaneous Fugitives*											
W_WE_RD							0.33	1.4	4.9E-2	0.22		
E_WE_EXP							3.7E-2	0.16	5.6E-3	2.4E-2		
E_WE_SUB							0.35	1.5	5.2E-2	0.23		
EP_S_EFD							18.9	68.1	1.9	6.8		
EP_S_E_C	0.45	2.0	2.1E-2	9.2E-2	1.1E-3	4.9E-3	1.1E-2	5.0E-2	2.0E-3	8.9E-3	4.9E-3	2.1E-2
EP_S_DFD							18.0	11.4	1.8	1.1		
EP_S_D_C	4.3E-2	3.3E-2	0.13	9.9E-2	4.0E-4	3.1E-4	3.2E-2	2.5E-2	9.3E-3	7.1E-3	9.6E-3	7.4E-3
2_EP_S_D	*Non-Emergency Surface Diesel Fleet*											
EP_S_F_C	1.5	1.4	0.17	0.16	1.8E-3	1.6E-3	8.7E-3	8.1E-3	8.7E-3	8.1E-3	8.3E-2	7.7E-2
EP_S_D_DOZ												
EP_S_D_FUG							12.0	9.2	1.2	0.92		
3_EP_S_TOTAL	**34.6**	**11.6**	**134**	**33.8**	**0.80**	**0.21**	**136**	**130**	**22.0**	**16.1**	**13.4**	**3.4**

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 5	OF: 18	SHEET: EPS_DISP
AIR EMISSION CALCULATIONS	SUBJECT: East Plant	DATE: March 15, 2018		

EAST PLANT - CONTROLLED UNDERGROUND - EMISSION FACTORS

	Emission Factors						
Source ID	CO	NO_x	SO_2	PM_{10}	$PM_{2.5}$	VOC	Units & Notes
2_EP_UG_DB	*Drilling & Blasting*						
EP_UG_DRILL							*See "Drill & Blast" Sheet*
EP_UG_BLAST							*See "Drill & Blast" Sheet*
2_EP_UG_EXTRACT	*Extraction Level Ore Flow*						
EP_UG_OVER				*8.0E-5*	*8.0E-5*		*lb/ton*
2_EP_UG_OREPASS	*LHD/Ore Pass/Grizzly*						
EP_UG_GRIZ				*7.4E-4*	*5.0E-5*		*lb/ton*
2_EP_UG_RAIL	*Haulage Ore Flow*						
EP_UG_TRAIN				*1.5E-4*	*2.3E-5*		*lb/ton*
EP_UG_COARSE							*Dust Collectors (915,420 dscf/hr, 0.002 gr/dscf)*
2_EP_UG_1CRUSH	*Primary Crushing Ore Flow*						
EP_UG_FINE							*Emissions accounted for in EP_UG_COARSE*
2_EP_UG_LOW_ORE	*Lower Level Conveyor Ore Flow*						
EP_UG_CV103							*Emissions accounted for in EP_UG_COARSE*
EP_UG_CV104							*Dust Collectors (207,495 dscf/hr, 0.002 gr/dscf)*
EP_UG_CV105				*1.6E-4*	*2.5E-5*		*lb/ton*
EP_UG_SILO							*Dust Collectors (915,420 dscf/hr, 0.002 gr/dscf)*
EP_UG_FEED							*Emissions accounted for in EP_UG_SILO*
EP_UG_CV106_111							*Emissions accounted for in EP_UG_SILO*
EP_UG_Chute				*1.6E-4*	*2.5E-5*		*lb/ton*
EP_UG_FLASK							*Dust Collectors (691,651 dscf/hr, 0.002 gr/dscf)*
2_EP_UG_HOIST	*Hoisting System Ore Flow*						
EP_UG_SKIP							*Emissions accounted for in EP_UG_FLASK*
EP_UG_BIN				*7.7E-5*	*1.2E-5*		*lb/ton*
2_EP_UG_UP_ORE	*Upper Level Conveyor System Ore Flow*						
EP_UG_FEED112_115							*Dust Collectors (691,651 dscf/hr, 0.002 gr/dscf)*
EP_UG_CV102_105							*Emissions accounted for in EP_UG_FEED112_115*
EP_UG_INC_CONV115				*3.7E-4*	*5.6E-5*		*lb/ton*
2_EP_UG_D	*Non-Emergency Underground Diesel Fleet*						
EP_UG_D_C							*See "EP_Fleet" Sheet*
EP_UG_D_DOZ							*See "EP_Fleet" Sheet*
EP_UG_D_FUG							*See "EP_Fleet" Sheet*
2_EP_UG_REF	*Underground Refrigeration Plant*						
EP_UG_COOL							*See "EP Cooling" Sheet*
2_EP_UG_FUEL	*Diesel Storage Tanks*						
EP_UG_FUEL1							*See "Fuel Tanks" Sheet*

EAST PLANT - CONTROLLED SURFACE - EMISSION FACTORS

	Emission Factors						
Source ID	CO	NO_X	SO_2	PM_{10}	$PM_{2.5}$	VOC	Units & Notes
2_EP_S_EGEN	*Emergency Generators (Total)*						
E_GEN1							*See "E_Gen" Sheet*
E_GEN2							*See "E_Gen" Sheet*
E_GEN3							*See "E_Gen" Sheet*
E_GEN4							*See "E_Gen" Sheet*
E_GEN5							*See "E_Gen" Sheet*
E_GEN6							*See "E_Gen" Sheet*
E_GEN7							*See "E_Gen" Sheet*
E_GEN8							*See "E_Gen" Sheet*
E_GEN9							*See "E_Gen" Sheet*
E_GEN10							*See "E_Gen" Sheet*
E_GEN11							*See "E_Gen" Sheet*
E_GEN12							*See "E_Gen" Sheet*
E_GEN13							*See "E_Gen" Sheet*
E_GEN14							*See "E_Gen" Sheet*
E_GEN15							*See "E_Gen" Sheet*
E_GEN16							*See "E_Gen" Sheet*
2_EP_S_REF	*Surface Refrigeration Plant*						
E_COOL1							*See "Cooling" Sheet*
E_COOL2							*See "Cooling" Sheet*
E_COOL3							*See "Cooling" Sheet*
E_COOL4							*See "Cooling" Sheet*
E_COOL5							*See "Cooling" Sheet*
E_COOL6							*See "Cooling" Sheet*
2_EP_S_CBP	*Cement Batch Plant*						
B_AGDEL							*See "BatchPlant" Sheet*
B_SNDEL							*See "BatchPlant" Sheet*
B_AGCHUT							*See "BatchPlant" Sheet*
B_SNCHUT							*See "BatchPlant" Sheet*
B_AGSTOR							*See "BatchPlant" Sheet*
B_SNSTOR							*See "BatchPlant" Sheet*
B_WHOPLD							*See "BatchPlant" Sheet*
B_WHOPAG							*See "BatchPlant" Sheet*
B_WHOPSN							*See "BatchPlant" Sheet*
B_CEMSLO							*See "BatchPlant" Sheet*
B_FLYSLO							*See "BatchPlant" Sheet*
B_SILSLO							*See "BatchPlant" Sheet*
B_SLOHOP							*See "BatchPlant" Sheet*
B_SLOCNY							*See "BatchPlant" Sheet*
B_SLOTRK							*See "BatchPlant" Sheet*
2_EP_S_FUEL	*Diesel Storage Tanks*						
EP_S_FUEL1							*See "Fuel Tanks" Sheet*
2_EP_S_WE	*Miscellaneous Fugitives*						
W_WE_RD				*0.2*	*0.0*		*ton/acre-yr*
E_WE_EXP							*See Wind Workbook*
E_WE_SUB							*See Wind Workbook*
EP_S_EFD							*See "Employees" Sheet*
EP_S_E_C							*See "Employees" Sheet*
EP_S_DFD							*See "Deliveries" Sheet*
EP_S_D_C							*See "Deliveries" Sheet*
2_EP_S_D	*Non-Emergency Surface Diesel Fleet*						
EP_S_F_C							*See "EP_Fleet" Sheet*
EP_S_D_DOZ							*See "EP_Fleet" Sheet*
EP_S_D_FUG							*See "EP_Fleet" Sheet*

EAST PLANT - UNCONTROLLED UNDERGROUND - EMISSION FACTORS

	Emission Factors						
Source ID	**CO**	**NO_X**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**	**VOC**	**Units & Notes**
2_EP_UG_DB	*Drilling & Blasting*						
EP_UG_DRILL							*See "Drill & Blast" Sheet*
EP_UG_BLAST							*See "Drill & Blast" Sheet*
2_EP_UG_EXTRACT	*Extraction Level Ore Flow*						
EP_UG_OVER				*8.0E-5*	*8.0E-5*		*lb/ton*
2_EP_UG_OREPASS	*LHD/Ore Pass/Grizzly*						
EP_UG_GRIZ				*8.7E-3*	*8.7E-3*		*lb/ton*
2_EP_UG_RAIL	*Haulage Ore Flow*						
EP_UG_TRAIN				*1.5E-4*	*2.3E-5*		*lb/ton*
EP_UG_COARSE				*1.5E-4*	*2.3E-5*		*lb/ton*
2_EP_UG_1CRUSH	*Primary Crushing Ore Flow*						
EP_UG_FINE				*2.4E-3*	*2.4E-3*		*lb/ton*
2_EP_UG_LOW_ORE	*Lower Level Conveyor Ore Flow*						
EP_UG_CV103				*1.6E-4*	*2.5E-5*		*lb/ton*
EP_UG_CV104				*1.6E-4*	*2.5E-5*		*lb/ton*
EP_UG_CV105				*1.6E-4*	*2.5E-5*		*lb/ton*
EP_UG_SILO				*1.6E-4*	*2.5E-5*		*lb/ton*
EP_UG_FEED				*1.6E-4*	*2.5E-5*		*lb/ton*
EP_UG_CV106_111				*1.6E-4*	*2.5E-5*		*lb/ton*
EP_UG_Chute				*1.6E-4*	*2.5E-5*		*lb/ton*
EP_UG_FLASK				*1.6E-4*	*2.5E-5*		*lb/ton*
2_EP_UG_HOIST	*Hoisting System Ore Flow*						
EP_UG_SKIP				*7.7E-5*	*1.2E-5*		*lb/ton*
EP_UG_BIN				*7.7E-5*	*1.2E-5*		*lb/ton*
2_EP_UG_UP_ORE	*Upper Level Conveyor System Ore Flow*						
EP_UG_FEED112_115				*3.7E-4*	*5.6E-5*		*lb/ton*
EP_UG_CV102_105				*3.7E-4*	*5.6E-5*		*lb/ton*
EP_UG_INC_CONV115				*3.7E-4*	*5.6E-5*		*lb/ton*
2_EP_UG_D	*Non-Emergency Underground Diesel Fleet*						
EP_UG_D_C							*See "EP_Fleet" Sheet*
EP_UG_D_DOZ							*See "EP_Fleet" Sheet*
EP_UG_D_FUG							*See "EP_Fleet" Sheet*
2_EP_UG_REF	*Underground Refrigeration Plant*						
EP_UG_COOL							*See "EP Cooling" Sheet*
2_EP_UG_FUEL	*Diesel Storage Tanks*						
EP_UG_FUEL1							*See "Fuel Tanks" Sheet*

EAST PLANT - UNCONTROLLED SURFACE - EMISSION FACTORS

	Emission Factors						
Source ID	CO	NO_X	SO_2	PM_{10}	$PM_{2.5}$	VOC	Units & Notes
2_EP_S_EGEN	*Emergency Generators (Total)*						
E_GEN1							*See "E_Gen" Sheet*
E_GEN2							*See "E_Gen" Sheet*
E_GEN3							*See "E_Gen" Sheet*
E_GEN4							*See "E_Gen" Sheet*
E_GEN5							*See "E_Gen" Sheet*
E_GEN6							*See "E_Gen" Sheet*
E_GEN7							*See "E_Gen" Sheet*
E_GEN8							*See "E_Gen" Sheet*
E_GEN9							*See "E_Gen" Sheet*
E_GEN10							*See "E_Gen" Sheet*
E_GEN11							*See "E_Gen" Sheet*
E_GEN12							*See "E_Gen" Sheet*
E_GEN13							*See "E_Gen" Sheet*
E_GEN14							*See "E_Gen" Sheet*
E_GEN15							*See "E_Gen" Sheet*
E_GEN16							*See "E_Gen" Sheet*
2_EP_S_REF	*Surface Refrigeration Plant*						
E_COOL1							*See "Cooling" Sheet*
E_COOL2							*See "Cooling" Sheet*
E_COOL3							*See "Cooling" Sheet*
E_COOL4							*See "Cooling" Sheet*
E_COOL5							*See "Cooling" Sheet*
E_COOL6							*See "Cooling" Sheet*
2_EP_S_CBP	*Cement Batch Plant*						
B_AGDEL							*See "BatchPlant" Sheet*
B_SNDEL							*See "BatchPlant" Sheet*
B_AGCHUT							*See "BatchPlant" Sheet*
B_SNCHUT							*See "BatchPlant" Sheet*
B_AGSTOR							*See "BatchPlant" Sheet*
B_SNSTOR							*See "BatchPlant" Sheet*
B_WHOPLD							*See "BatchPlant" Sheet*
B_WHOPAG							*See "BatchPlant" Sheet*
B_WHOPSN							*See "BatchPlant" Sheet*
B_CEMSLO							*See "BatchPlant" Sheet*
B_FLYSLO							*See "BatchPlant" Sheet*
B_SILSLO							*See "BatchPlant" Sheet*
B_SLOHOP							*See "BatchPlant" Sheet*
B_SLOCNY							*See "BatchPlant" Sheet*
B_SLOTRK							*See "BatchPlant" Sheet*
2_EP_S_FUEL	*Diesel Storage Tanks*						
EP_S_FUEL1							*See "Fuel Tanks" Sheet*
2_EP_S_WE	*Miscellaneous Fugitives*						
W_WE_RD				*0.2*	*0.0*		*ton/acre-yr*
E_WE_EXP							*See Wind Workbook*
E_WE_SUB							*See Wind Workbook*
EP_S_EFD							*See "Employees" Sheet*
EP_S_E_C							*See "Employees" Sheet*
EP_S_DFD							*See "Deliveries" Sheet*
EP_S_D_C							*See "Deliveries" Sheet*
2_EP_S_D	*Non-Emergency Surface Diesel Fleet*						
EP_S_F_C							*See "EP_Fleet" Sheet*
EP_S_D_DOZ							*See "EP_Fleet" Sheet*
EP_S_D_FUG							*See "EP_Fleet" Sheet*

EAST PLANT - UNDERGROUND - PROCESS RATES

	Process Rates		
Source ID	Unit/Hr	Unit/Yr	Units & Notes
2_EP_UG_DB *Drilling & Blasting*			
EP_UG_DRILL			*See "Drill & Blast" Sheet*
EP_UG_BLAST			*See "Drill & Blast" Sheet*
2_EP_UG_EXTRA *Extraction Level Ore Flow*			
EP_UG_OVER	*985*	*5,029,289*	*ton*
2_EP_UG_OREP *LHD/Ore Pass/Grizzly*			
EP_UG_GRIZ	*9,855*	*50,292,894*	*ton*
2_EP_UG_RAIL *Haulage Ore Flow*			
EP_UG_TRAIN	*9,855*	*50,292,894*	*ton*
EP_UG_COARSE	*9,855*	*50,292,894*	*ton*
2_EP_UG_1CRUS *Primary Crushing Ore Flow*			
EP_UG_FINE	*9,855*	*50,292,894*	*ton*
2_EP_UG_LOW_ *Lower Level Conveyor Ore Flow*			
EP_UG_CV103	*9,855*	*50,292,894*	*ton*
EP_UG_CV104	*9,855*	*50,292,894*	*ton*
EP_UG_CV105	*9,855*	*50,292,894*	*ton*
EP_UG_SILO	*9,855*	*50,292,894*	*ton*
EP_UG_FEED	*9,855*	*50,292,894*	*ton*
EP_UG_CV106_111	*9,855*	*50,292,894*	*ton*
EP_UG_Chute	*9,855*	*50,292,894*	*ton*
EP_UG_FLASK	*9,855*	*50,292,894*	*ton*
2_EP_UG_HOIST *Hoisting System Ore Flow*			
EP_UG_SKIP	*9,855*	*50,292,894*	*ton*
EP_UG_BIN	*9,855*	*50,292,894*	*ton*
2_EP_UG_UP_OI *Upper Level Conveyor System Ore Flow*			
EP_UG_FEED112_115	*9,855*	*50,292,894*	*ton*
EP_UG_CV102_105	*9,855*	*50,292,894*	*ton*
EP_UG_INC_CONV115	*9,855*	*50,292,894*	*ton*
2_EP_UG_D *Non-Emergency Underground Diesel Fleet*			
EP_UG_D_C			*See "EP_Fleet" Sheet*
EP_UG_D_DOZ			*See "EP_Fleet" Sheet*
EP_UG_D_FUG			*See "EP_Fleet" Sheet*
2_EP_UG_REF *Underground Refrigeration Plant*			
EP_UG_COOL			*See "EP Cooling" Sheet*
2_EP_UG_FUEL *Diesel Storage Tanks*			
EP_UG_FUEL1	*937*	*1,594,904*	*gal*

EAST PLANT - SURFACE - PROCESS RATES

Source ID	Process Rates Unit/Hr	Unit/Yr	Units & Notes
2_EP_S_EGEN	*Emergency Generators (Total)*		
E_GEN1			*See "E_Gen" Sheet*
E_GEN2			*See "E_Gen" Sheet*
E_GEN3			*See "E_Gen" Sheet*
E_GEN4			*See "E_Gen" Sheet*
E_GEN5			*See "E_Gen" Sheet*
E_GEN6			*See "E_Gen" Sheet*
E_GEN7			*See "E_Gen" Sheet*
E_GEN8			*See "E_Gen" Sheet*
E_GEN9			*See "E_Gen" Sheet*
E_GEN10			*See "E_Gen" Sheet*
E_GEN11			*See "E_Gen" Sheet*
E_GEN12			*See "E_Gen" Sheet*
E_GEN13			*See "E_Gen" Sheet*
E_GEN14			*See "E_Gen" Sheet*
E_GEN15			*See "E_Gen" Sheet*
E_GEN16			*See "E_Gen" Sheet*
2_EP_S_REF	*Surface Refrigeration Plant*		
E_COOL1			*See "Cooling" Sheet*
E_COOL2			*See "Cooling" Sheet*
E_COOL3			*See "Cooling" Sheet*
E_COOL4			*See "Cooling" Sheet*
E_COOL5			*See "Cooling" Sheet*
E_COOL6			*See "Cooling" Sheet*
2_EP_S_CBP	*Cement Batch Plant*		
B_AGDEL			*See "BatchPlant" Sheet*
B_SNDEL			*See "BatchPlant" Sheet*
B_AGCHUT			*See "BatchPlant" Sheet*
B_SNCHUT			*See "BatchPlant" Sheet*
B_AGSTOR			*See "BatchPlant" Sheet*
B_SNSTOR			*See "BatchPlant" Sheet*
B_WHOPLD			*See "BatchPlant" Sheet*
B_WHOPAG			*See "BatchPlant" Sheet*
B_WHOPSN			*See "BatchPlant" Sheet*
B_CEMSLO			*See "BatchPlant" Sheet*
B_FLYSLO			*See "BatchPlant" Sheet*
B_SILSLO			*See "BatchPlant" Sheet*
B_SLOHOP			*See "BatchPlant" Sheet*
B_SLOCNY			*See "BatchPlant" Sheet*
B_SLOTRK			*See "BatchPlant" Sheet*
2_EP_S_FUEL	*Diesel Storage Tanks*		
EP_S_FUEL1	*12.2*	*22,621*	*gal*
2_EP_S_WE	*Miscellaneous Fugitives*		
W_WE_RD		*7.6*	*acre*
E_WE_EXP		*21.3*	*acre*
E_WE_SUB		*279*	*acre*
EP_S_EFD			*See "Employees" Sheet*
EP_S_E_C			*See "Employees" Sheet*
EP_S_DFD			*See "Deliveries" Sheet*
EP_S_D_C			*See "Deliveries" Sheet*
2_EP_S_D	*Non-Emergency Surface Diesel Fleet*		
EP_S_F_C			*See "EP_Fleet" Sheet*
EP_S_D_DOZ			*See "EP_Fleet" Sheet*
EP_S_D_FUG			*See "EP_Fleet" Sheet*

EAST PLANT - UNDERGROUND - CONTROLS

Source ID	Control Technology	Control Efficiency	Notes
2_EP_UG_DB			
EP_UG_DRILL		*0%*	
EP_UG_BLAST		*0%*	
2_EP_UG_EXTRA			
EP_UG_OVER		*0%*	
2_EP_UG_OREP/			
EP_UG_GRIZ	*moisture*	*0%*	*Control accounted for in EF*
2_EP_UG_RAIL			
EP_UG_TRAIN	*moisture*	*0%*	*Control accounted for in EF*
EP_UG_COARSE	*3 dust collectors*		*Control accounted for in emission calculation*
2_EP_UG_1CRUS			
EP_UG_FINE			*Emissions accounted for in EP_UG_COARSE*
2_EP_UG_LOW_(			
EP_UG_CV103			*Emissions accounted for in EP_UG_COARSE*
EP_UG_CV104	*3 dust collectors*		*Control accounted for in emission calculation*
EP_UG_CV105	*moisture*	*0%*	*Control accounted for in EF*
EP_UG_SILO	*3 dust collectors*		*Control accounted for in emission calculation*
EP_UG_FEED			*Emissions accounted for in EP_UG_SILO*
EP_UG_CV106_111			*Emissions accounted for in EP_UG_SILO*
EP_UG_Chute	*moisture*	*0%*	*Control accounted for in EF*
EP_UG_FLASK	*6 dust collectors*		*Control accounted for in emission calculation*
2_EP_UG_HOIST			
EP_UG_SKIP			*Emissions accounted for in EP_UG_FLASK*
EP_UG_BIN	*moisture*	*0%*	*Control accounted for in EF*
2_EP_UG_UP_OI			
EP_UG_FEED112_115	*4 dust collectors*		*Control accounted for in emission calculation*
EP_UG_CV102_105			*Emissions accounted for in EP_UG_FEED112_115*
EP_UG_INC_CONV115	*moisture*	*0%*	*Control accounted for in EF*
2_EP_UG_D			
EP_UG_D_C		*0%*	
EP_UG_D_DOZ	*water suppression*	*95%*	
EP_UG_D_FUG	*water suppression*	*95%*	*AP-42, Figure 13.2.2-2, Rev. 11/06*
2_EP_UG_REF			
EP_UG_COOL	*drift eliminators*		*Control accounted for in EF*
2_EP_UG_FUEL			
EP_UG_FUEL1		*0%*	

EAST PLANT - SURFACE - CONTROLS

Source ID	Control Technology	Control Efficiency	Notes
2_EP_S_EGEN			
E_GEN1		*0%*	
E_GEN2		*0%*	
E_GEN3		*0%*	
E_GEN4		*0%*	
E_GEN5		*0%*	
E_GEN6		*0%*	
E_GEN7		*0%*	
E_GEN8		*0%*	
E_GEN9		*0%*	
E_GEN10		*0%*	
E_GEN11		*0%*	
E_GEN12		*0%*	
E_GEN13		*0%*	
E_GEN14		*0%*	
E_GEN15		*0%*	
E_GEN16		*0%*	
2_EP_S_REF			
E_COOL1	*drift eliminators*	*0%*	
E_COOL2	*drift eliminators*	*0%*	
E_COOL3	*drift eliminators*	*0%*	
E_COOL4	*drift eliminators*	*0%*	
E_COOL5	*drift eliminators*	*0%*	
E_COOL6	*drift eliminators*	*0%*	
2_EP_S_CBP			
B_AGDEL		*0%*	*See "BatchPlant" Sheet*
B_SNDEL		*0%*	*See "BatchPlant" Sheet*
B_AGCHUT		*0%*	*See "BatchPlant" Sheet*
B_SNCHUT		*0%*	*See "BatchPlant" Sheet*
B_AGSTOR		*0%*	*See "BatchPlant" Sheet*
B_SNSTOR		*0%*	*See "BatchPlant" Sheet*
B_WHOPLD		*0%*	*See "BatchPlant" Sheet*
B_WHOPAG		*0%*	*See "BatchPlant" Sheet*
B_WHOPSN		*0%*	*See "BatchPlant" Sheet*
B_CEMSLO		*0%*	*See "BatchPlant" Sheet*
B_FLYSLO		*0%*	*See "BatchPlant" Sheet*
B_SILSLO		*0%*	*See "BatchPlant" Sheet*
B_SLOHOP		*0%*	*See "BatchPlant" Sheet*
B_SLOCNY		*0%*	*See "BatchPlant" Sheet*
B_SLOTRK		*0%*	*See "BatchPlant" Sheet*
2_EP_S_FUEL			
EP_S_FUEL1		*0%*	
2_EP_S_WE			
W_WE_RD	*chemical suppression*	*90%*	*AP-42, Figure 13.2.2-2, Rev. 11/06*
E_WE_EXP	*chemical suppression*	*90%*	*AP-42, Figure 13.2.2-2, Rev. 11/06*
E_WE_SUB	*precipitation*	*18%*	
EP_S_EFD	*chemical suppression*	*90%*	*AP-42, Figure 13.2.2-2, Rev. 11/06*
EP_S_E_C		*0%*	*AP-42, Figure 13.2.2-2, Rev. 11/06*
EP_S_DFD	*chemical suppression*	*90%*	
EP_S_D_C		*0%*	
2_EP_S_D			
EP_S_F_C		*0%*	
EP_S_D_DOZ		*0%*	
EP_S_D_FUG	*chemical suppression*	*90%*	*AP-42, Figure 13.2.2-2, Rev. 11/06*

EAST PLANT - UNDERGROUND - SOURCE IDENTIFICATION

Source ID	Source Identification
2_EP_UG_DB	***Drilling & Blasting***
EP_UG_DRILL	*Drilling*
EP_UG_BLAST	*Blasting*
2_EP_UG_EXTRACT	***Extraction Level Ore Flow***
EP_UG_OVER	*Oversize Rock Drill Rig*
2_EP_UG_OREPASS	***LHD/Ore Pass/Grizzly***
EP_UG_GRIZ	*Grizzly with Rock Breaker and associated transfers in (LHD) & out (Chute via Ore Pass)*
2_EP_UG_RAIL	***Haulage Ore Flow***
EP_UG_TRAIN	*Chute to Haul Truck*
EP_UG_COARSE	*Haul Truck to Coarse Ore Bin*
2_EP_UG_1CRUSH	***Primary Crushing Ore Flow***
EP_UG_FINE	*Gyratory Crushers (3) and associated transfers in (Coarse Ore Bin) and out (Feeders)*
2_EP_UG_LOW_ORE	***Lower Level Conveyor Ore Flow***
EP_UG_CV103	*Feeders (FE-101 - 103) to Conveyors (CV-101 - 103) and Spillage Chute*
EP_UG_CV104	*Conveyors (CV-101 - 103) to Conveyor (CV-104)*
EP_UG_CV105	*Conveyor (CV-104) to Tilt Conveyor (CV-105)*
EP_UG_SILO	*Tilt Conveyor (CV-105) to Silos (S1-101 - 103)*
EP_UG_FEED	*Silos S1-101 thru S1-103 to Feeders FE-106 thru FE-111*
EP_UG_CV106_111	*Feeders (FE-106 - 111) to Conveyors (CV-106 - 111)*
EP_UG_Chute	*Conveyors (CV-106 - 111) to Shuttle Chutes (A - F)*
EP_UG_FLASK	*Shuttle Chutes (A - F) to Flasks (101 - 112)*
2_EP_UG_HOIST	***Hoisting System Ore Flow***
EP_UG_SKIP	*Flasks (101 - 112) to Skips (SS-101 - 112)*
EP_UG_BIN	*Skips (SS-101 - 112) to Bins (1 - 4) and Spillage Chute*
2_EP_UG_UP_ORE	***Upper Level Conveyor System Ore Flow***
EP_UG_FEED112_115	*Bins (1 - 4) to Discharge Feeders (12)*
EP_UG_CV102_105	*Discharge Feeders (12) to Conveyors (CV-112 - 115)*
EP_UG_INC_CONV115	*Conveyors (CV-112 - 115) to Incline Conveyor (CV-201)*
2_EP_UG_D	***Non-Emergency Underground Diesel Fleet***
EP_UG_D_C	*Underground Combustion*
EP_UG_D_DOZ	*Underground Fugitive Dust (Dozing)*
EP_UG_D_FUG	*Underground Fugitive Dust (Grading, Vehicle Travel)*
2_EP_UG_REF	***Underground Refrigeration Plant***
EP_UG_COOL	*Underground Cooling Towers*
2_EP_UG_FUEL	***Diesel Storage Tanks***
EP_UG_FUEL1	*Underground Usage and Volume Estimated (Estimated Quantity: 6)*
3_EP_UG_TOTAL	***EP UG Subtotal***

EAST PLANT - SURFACE - SOURCE IDENTIFICATION

Source ID	Source Identification
2_EP_S_EGEN	***Emergency Generators (Total)***
E_GEN1	*Cat 516B - Diesel*
E_GEN2	*Cat 3046C - Diesel*
E_GEN3	*Caterpillar C175-16*
E_GEN4	*Caterpillar C175-16*
E_GEN5	*Caterpillar C175-16*
E_GEN6	*Caterpillar C175-16*
E_GEN7	*Caterpillar C175-16*
E_GEN8	*Caterpillar C175-16*
E_GEN9	*Caterpillar C175-16*
E_GEN10	*Caterpillar C175-16*
E_GEN11	*Caterpillar C175-16*
E_GEN12	*Caterpillar C175-16*
E_GEN13	*Caterpillar C175-16*
E_GEN14	*Caterpillar C175-16*
E_GEN15	*Caterpillar C175-16*
E_GEN16	*Caterpillar C175-16*
2_EP_S_REF	***Surface Refrigeration Plant***
E_COOL1	*Surface Cooling Towers*
E_COOL2	*Surface Cooling Towers*
E_COOL3	*Surface Cooling Towers*
E_COOL4	*Surface Cooling Towers*
E_COOL5	*Surface Cooling Towers*
E_COOL6	*Surface Cooling Towers*
2_EP_S_CBP	***Cement Batch Plant***
B_AGDEL	*Batch Plant Aggregate Delivery to Ground Storage*
B_SNDEL	*Batch Plant Sand Delivery to Ground Storage*
B_AGCHUT	*Batch Plant Aggregate Transfer to Conveyor Belt via Chute*
B_SNCHUT	*Batch Plant Sand Transfer to Conveyor Belt via Chute*
B_AGSTOR	*Batch Plant Aggregate Transfer to Elevated Storage*
B_SNSTOR	*Batch Plant Sand Transfer to Elevated Storage*
B_WHOPLD	*Batch Plant Weigh Hopper Loading (Aggregate & Sand)*
B_WHOPAG	*Batch Plant Weigh Hopper Discharge to Truck Loading Conveyor (Agg)*
B_WHOPSN	*Batch Plant Weigh Hopper Discharge to Truck Loading Conveyor (Sand)*
B_CEMSLO	*Batch Plant Cement Unloading to Silo*
B_FLYSLO	*Batch Plant Flyash Unloading to Silo*
B_SILSLO	*Batch Plant Silica Fume Unloading to Silo*
B_SLOHOP	*Batch Plant Cement & Flyash Discharge to Silo Weigh Hopper*
B_SLOCNY	*Batch Plant Silo Weigh Hopper Discharge to Truck Loading Conveyor*
B_SLOTRK	*Batch Plant Truck Loading*
2_EP_S_FUEL	***Diesel Storage Tanks***
EP_S_FUEL1	*Surface Usage and Volume Estimated (Estimated Quantity: 1)*
2_EP_S_WE	***Miscellaneous Fugitives***
W_WE_RD	*EPS Secondary Sources from Access Roads (Wind Erosion)*
E_WE_EXP	*EPS Exposed Areas*
E_WE_SUB	*EPS Exposed Subsidence Area*
EP_S_EFD	*EPS Employee Fugitives*
EP_S_E_C	*EPS Employee Combustion*
EP_S_DFD	*EPS Delivery Fugitives*
EP_S_D_C	*EPS Delivery Combustion*
2_EP_S_D	***Non-Emergency Surface Diesel Fleet***
EP_S_F_C	*Surface Combustion*
EP_S_D_DOZ	*Surface Fugitive Dust (Dozing)*
EP_S_D_FUG	*Surface Fugitive Dust (Grading, Vehicle Travel)*
3_EP_S_TOTAL	***EP Surface Subtotal***

EAST PLANT - CONTROLLED UNDERGROUND - EF REFERENCE

Source ID	Emission Factor Reference
2_EP_UG_DB	
EP_UG_DRILL	*See "Drill & Blast" Sheet*
EP_UG_BLAST	*See "Drill & Blast" Sheet*
2_EP_UG_EXTRACT	
EP_UG_OVER	*AP-42, Table 11.19.2-2, Wet Drilling, Rev. 8/04*
2_EP_UG_OREPASS	
EP_UG_GRIZ	*AP-42, Table 11.19.2-2, Screening (controlled), Rev. 8/04*
2_EP_UG_RAIL	
EP_UG_TRAIN	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 2.2 mph)*
EP_UG_COARSE	*Assumed Grain Loading (0.002 gr/dscf)*
2_EP_UG_1CRUSH	
EP_UG_FINE	*Emissions accounted for in EP_UG_COARSE*
2_EP_UG_LOW_ORE	
EP_UG_CV103	*Emissions accounted for in EP_UG_COARSE*
EP_UG_CV104	*Assumed Grain Loading (0.002 gr/dscf)*
EP_UG_CV105	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 2.4 mph)*
EP_UG_SILO	*Assumed Grain Loading (0.002 gr/dscf)*
EP_UG_FEED	*Emissions accounted for in EP_UG_SILO*
EP_UG_CV106_111	*Emissions accounted for in EP_UG_SILO*
EP_UG_Chute	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 2.4 mph)*
EP_UG_FLASK	*Assumed Grain Loading (0.002 gr/dscf)*
2_EP_UG_HOIST	
EP_UG_SKIP	*Emissions accounted for in EP_UG_FLASK*
EP_UG_BIN	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 1.3 mph)*
2_EP_UG_UP_ORE	
EP_UG_FEED112_115	*Assumed Grain Loading (0.002 gr/dscf)*
EP_UG_CV102_105	*Emissions accounted for in EP_UG_FEED112_115*
EP_UG_INC_CONV115	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 4.5 mph)*
2_EP_UG_D	
EP_UG_D_C	*See "EP_Fleet" Sheet*
EP_UG_D_DOZ	*See "EP_Fleet" Sheet*
EP_UG_D_FUG	*See "EP_Fleet" Sheet*
2_EP_UG_REF	
EP_UG_COOL	*See "EP Cooling" Sheet*
2_EP_UG_FUEL	
EP_UG_FUEL1	*See "Fuel Tanks" Sheet*

EAST PLANT - CONTROLLED SURFACE - EF REFERENCE

Source ID	Emission Factor Reference
2_EP_S_EGEN	
E_GEN1	*See "E_Gen" Sheet*
E_GEN2	*See "E_Gen" Sheet*
E_GEN3	*See "E_Gen" Sheet*
E_GEN4	*See "E_Gen" Sheet*
E_GEN5	*See "E_Gen" Sheet*
E_GEN6	*See "E_Gen" Sheet*
E_GEN7	*See "E_Gen" Sheet*
E_GEN8	*See "E_Gen" Sheet*
E_GEN9	*See "E_Gen" Sheet*
E_GEN10	*See "E_Gen" Sheet*
E_GEN11	*See "E_Gen" Sheet*
E_GEN12	*See "E_Gen" Sheet*
E_GEN13	*See "E_Gen" Sheet*
E_GEN14	*See "E_Gen" Sheet*
E_GEN15	*See "E_Gen" Sheet*
E_GEN16	*See "E_Gen" Sheet*
2_EP_S_REF	
E_COOL1	*See "Cooling" Sheet*
E_COOL2	*See "Cooling" Sheet*
E_COOL3	*See "Cooling" Sheet*
E_COOL4	*See "Cooling" Sheet*
E_COOL5	*See "Cooling" Sheet*
E_COOL6	*See "Cooling" Sheet*
2_EP_S_CBP	
B_AGDEL	*See "BatchPlant" Sheet*
B_SNDEL	*See "BatchPlant" Sheet*
B_AGCHUT	*See "BatchPlant" Sheet*
B_SNCHUT	*See "BatchPlant" Sheet*
B_AGSTOR	*See "BatchPlant" Sheet*
B_SNSTOR	*See "BatchPlant" Sheet*
B_WHOPLD	*See "BatchPlant" Sheet*
B_WHOPAG	*See "BatchPlant" Sheet*
B_WHOPSN	*See "BatchPlant" Sheet*
B_CEMSLO	*See "BatchPlant" Sheet*
B_FLYSLO	*See "BatchPlant" Sheet*
B_SILSLO	*See "BatchPlant" Sheet*
B_SLOHOP	*See "BatchPlant" Sheet*
B_SLOCNY	*See "BatchPlant" Sheet*
B_SLOTRK	*See "BatchPlant" Sheet*
2_EP_S_FUEL	
EP_S_FUEL1	*See "Fuel Tanks" Sheet*
2_EP_S_WE	
W_WE_RD	*AP-42, Table 11.9-4, Wind Erosion, Rev. 7/98*
E_WE_EXP	*AP-42, Chapter 13.2.5, Industrial Wind Erosion, Rev. 11/06*
E_WE_SUB	*AP-42, Chapter 13.2.5, Industrial Wind Erosion, Rev. 11/06*
EP_S_EFD	*See "Employees" Sheet*
EP_S_E_C	*See "Employees" Sheet*
EP_S_DFD	*See "Deliveries" Sheet*
EP_S_D_C	*See "Deliveries" Sheet*
2_EP_S_D	
EP_S_F_C	*See "EP_Fleet" Sheet*
EP_S_D_DOZ	*See "EP_Fleet" Sheet*
EP_S_D_FUG	*See "EP_Fleet" Sheet*

EAST PLANT - UNCONTROLLED UNDERGROUND - EF REFERENCE

Source ID	Emission Factor Reference
2_EP_UG_DB	
EP_UG_DRILL	*See "Drill & Blast" Sheet*
EP_UG_BLAST	*See "Drill & Blast" Sheet*
2_EP_UG_EXTRACT	
EP_UG_OVER	*AP-42, 11.19.2, Wet Drilling, Rev. 8/04*
2_EP_UG_OREPASS	
EP_UG_GRIZ	*AP-42, Table 11.19.2-2, Screening (uncontrolled), Rev. 8/04*
2_EP_UG_RAIL	
EP_UG_TRAIN	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 2.2 mph)*
EP_UG_COARSE	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 2.2 mph)*
2_EP_UG_1CRUSH	
EP_UG_FINE	*AP-42, Table 11.19.2-2, Tertiary Crushing (uncontrolled), Rev. 8/04*
2_EP_UG_LOW_ORE	
EP_UG_CV103	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 2.4 mph)*
EP_UG_CV104	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 2.4 mph)*
EP_UG_CV105	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 2.4 mph)*
EP_UG_SILO	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 2.4 mph)*
EP_UG_FEED	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 2.4 mph)*
EP_UG_CV106_111	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 2.4 mph)*
EP_UG_Chute	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 2.4 mph)*
EP_UG_FLASK	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 2.4 mph)*
2_EP_UG_HOIST	
EP_UG_SKIP	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 1.3 mph)*
EP_UG_BIN	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 1.3 mph)*
2_EP_UG_UP_ORE	
EP_UG_FEED112_115	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 4.5 mph)*
EP_UG_CV102_105	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 4.5 mph)*
EP_UG_INC_CONV115	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 4.5 mph)*
2_EP_UG_D	
EP_UG_D_C	*See "EP_Fleet" Sheet*
EP_UG_D_DOZ	*See "EP_Fleet" Sheet*
EP_UG_D_FUG	*See "EP_Fleet" Sheet*
2_EP_UG_REF	
EP_UG_COOL	*See "EP Cooling" Sheet*
2_EP_UG_FUEL	
EP_UG_FUEL1	*See "Fuel Tanks" Sheet*

EAST PLANT - UNCONTROLLED SURFACE - EF REFERENCE

Source ID	Emission Factor Reference
2_EP_S_EGEN	
E_GEN1	*See "E_Gen" Sheet*
E_GEN2	*See "E_Gen" Sheet*
E_GEN3	*See "E_Gen" Sheet*
E_GEN4	*See "E_Gen" Sheet*
E_GEN5	*See "E_Gen" Sheet*
E_GEN6	*See "E_Gen" Sheet*
E_GEN7	*See "E_Gen" Sheet*
E_GEN8	*See "E_Gen" Sheet*
E_GEN9	*See "E_Gen" Sheet*
E_GEN10	*See "E_Gen" Sheet*
E_GEN11	*See "E_Gen" Sheet*
E_GEN12	*See "E_Gen" Sheet*
E_GEN13	*See "E_Gen" Sheet*
E_GEN14	*See "E_Gen" Sheet*
E_GEN15	*See "E_Gen" Sheet*
E_GEN16	*See "E_Gen" Sheet*
2_EP_S_REF	
E_COOL1	*See "Cooling" Sheet*
E_COOL2	*See "Cooling" Sheet*
E_COOL3	*See "Cooling" Sheet*
E_COOL4	*See "Cooling" Sheet*
E_COOL5	*See "Cooling" Sheet*
E_COOL6	*See "Cooling" Sheet*
2_EP_S_CBP	
B_AGDEL	*See "BatchPlant" Sheet*
B_SNDEL	*See "BatchPlant" Sheet*
B_AGCHUT	*See "BatchPlant" Sheet*
B_SNCHUT	*See "BatchPlant" Sheet*
B_AGSTOR	*See "BatchPlant" Sheet*
B_SNSTOR	*See "BatchPlant" Sheet*
B_WHOPLD	*See "BatchPlant" Sheet*
B_WHOPAG	*See "BatchPlant" Sheet*
B_WHOPSN	*See "BatchPlant" Sheet*
B_CEMSLO	*See "BatchPlant" Sheet*
B_FLYSLO	*See "BatchPlant" Sheet*
B_SILSLO	*See "BatchPlant" Sheet*
B_SLOHOP	*See "BatchPlant" Sheet*
B_SLOCNY	*See "BatchPlant" Sheet*
B_SLOTRK	*See "BatchPlant" Sheet*
2_EP_S_FUEL	
EP_S_FUEL1	*See "Fuel Tanks" Sheet*
2_EP_S_WE	
E_WE_EXP	*AP-42, Chapter 13.2.5, Industrial Wind Erosion, Rev. 11/06*
E_WE_SUB	*AP-42, Chapter 13.2.5, Industrial Wind Erosion, Rev. 11/06*
EP_S_EFD	*See "Employees" Sheet*
EP_S_E_C	*See "Employees" Sheet*
EP_S_DFD	*See "Deliveries" Sheet*
EP_S_D_C	*See "Deliveries" Sheet*
2_EP_S_D	
EP_S_F_C	*See "EP_Fleet" Sheet*
EP_S_D_DOZ	*See "EP_Fleet" Sheet*
EP_S_D_FUG	*See "EP_Fleet" Sheet*

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 1	OF: 18	SHEET: WPS_DISP
AIR EMISSION CALCULATIONS	SUBJECT: Mill	DATE: March 15, 2018		

MILL - CONTROLLED - EMISSIONS SUMMARY

	Potential Emissions											
	CO		NO_X		SO_2		PM_{10}		$PM_{2.5}$		VOC	
Source ID	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*
2_M_DRLBST	*Drilling & Blasting*											
WPS_DRILL							*0.12*	*7.2E-3*	*0.12*	*7.2E-3*		
WPS_BLAST	*0.67*	*2.1*	*2.1*	*0.40*	*0.67*	*0.13*	*0.13*	*2.5E-2*	*7.4E-3*	*1.4E-3*		
2_M_MAT	*Material Handling - Stockpile & SAG*											
W_CVYXF1							*0.73*	*1.9*	*0.11*	*0.28*		
W_CVYXF2							*0.73*	*1.9*	*0.11*	*0.28*		
M_TRIPPR							*0.73*	*1.9*	*0.11*	*0.28*		
M_STOCKP							*6.8E-3*	*1.7E-2*	*1.0E-3*	*2.6E-3*		
M1_FEED												
M1_XFER							*0.30*	*1.3*	*0.30*	*1.3*		
M2_FEED												
M2_XFER							*0.30*	*1.3*	*0.30*	*1.3*		
2_M_SAG1	*SAG Line 1*											
M1_LOAD							*0.27*	*0.95*	*4.1E-2*	*0.14*		
M1_SAG												
M1_TROML												
M1_VIBRT												
M1_BALLA												
M1_BALLB												
2_M_SAG2	*SAG Line 2*											
M2_LOAD							*0.27*	*0.95*	*4.1E-2*	*0.14*		
M2_SAG												
M2_TROML												
M2_VIBRT												
M2_BALLA												
M2_BALLB												
2_M_PEBB	*Pebble Recycle*											
M_SCREEN							*0.42*	*1.5*	*2.9E-2*	*0.10*		
M_PEBREC							*6.6E-2*	*0.23*	*9.9E-3*	*3.5E-2*		
M_PEBBIN							*6.6E-2*	*0.23*	*9.9E-3*	*3.5E-2*		
M1_PEBFD							*6.6E-2*	*0.23*	*9.9E-3*	*3.5E-2*		
M2_PEBFD							*6.6E-2*	*0.23*	*9.9E-3*	*3.5E-2*		
M1_PEBCV							*6.6E-2*	*0.23*	*9.9E-3*	*3.5E-2*		
M2_PEBCV							*6.6E-2*	*0.23*	*9.9E-3*	*3.5E-2*		

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 2	OF: 18	SHEET: WPS_DISP
AIR EMISSION CALCULATIONS	SUBJECT: Mill	DATE: March 15, 2018		

MILL - CONTROLLED - EMISSIONS SUMMARY CONT.

	Potential Emissions											
	CO		NO_X		SO_2		PM_{10}		$PM_{2.5}$		VOC	
Source ID	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*
2_M_MOLY_FL	*Moly Flotation*											
M_MLYFLT							*6.3E-4*	*1.3E-3*	*9.5E-5*	*2.0E-4*		
M_MLYBIN							*5.6E-4*	*1.2E-3*	*8.5E-5*	*1.8E-4*		
M_MLYBAG							*5.6E-4*	*1.2E-3*	*8.5E-5*	*1.8E-4*		
2_M_LIME	*Lime System*											
M1_LIMBN							*1.4E-3*	*4.6E-3*	*1.4E-3*	*4.6E-3*		
M1_LIMVM							*1.2E-2*	*3.8E-2*	*1.2E-2*	*3.8E-2*		
M1_LIMTK							*1.2E-2*	*3.8E-2*	*1.2E-2*	*3.8E-2*		
M2_LIMBN							*1.4E-3*	*4.6E-3*	*1.4E-3*	*4.6E-3*		
M2_LIMVM							*1.2E-2*	*3.8E-2*	*1.2E-2*	*3.8E-2*		
M2_LIMTK							*1.2E-2*	*3.8E-2*	*1.2E-2*	*3.8E-2*		
2_M_TALC	*Moly/Talc Heat Treatment Process*											
M_MLYHTR					*4.2*	*13.6*					*20.2*	*65.1*
M_KILN_P							*1.1*	*3.4*	*0.90*	*2.9*		
M_KILN_C	*1.3*	*5.9*	*2.3*	*10.2*	*0.29*	*1.3*	*0.13*	*0.55*	*0.13*	*0.55*	*0.14*	*0.63*
2_M_EGEN	*Emergency Generators*											
W_GEN1	*3.9*	*0.96*	*0.35*	*8.7E-2*	*9.0E-3*	*2.2E-3*	*7.7E-3*	*1.9E-3*	*7.7E-3*	*1.9E-3*	*1.7E-2*	*4.3E-3*
W_GEN2	*3.9*	*0.96*	*0.35*	*8.7E-2*	*9.0E-3*	*2.2E-3*	*7.7E-3*	*1.9E-3*	*7.7E-3*	*1.9E-3*	*1.7E-2*	*4.3E-3*
W_GEN3	*3.9*	*0.96*	*0.35*	*8.7E-2*	*9.0E-3*	*2.2E-3*	*7.7E-3*	*1.9E-3*	*7.7E-3*	*1.9E-3*	*1.7E-2*	*4.3E-3*
2_M_FUEL	*Diesel Storage Tanks*											
M_FUEL1											*4.0E-3*	*1.7E-2*
2_M_REAG	*Reagent Storage, Handling, and Use*											
M_SIPX							*4.9E-3*	*1.9E-2*	*4.9E-3*	*1.9E-2*		
M_MIBC											*1.5E-2*	*6.7E-2*
M_NAHS												
M_FLOC1							*9.3E-4*	*3.6E-3*	*9.3E-4*	*3.6E-3*		
M_FLOC2							*2.4E-4*	*8.6E-4*	*2.4E-4*	*8.6E-4*		
M_CYTEC											*1.1E-5*	*5.0E-5*
M_MCO											*1.1E-3*	*4.8E-3*
2_M_D	*Non-Emergency Diesel Fleet (mobile and stationary)*											
M_CMBSTN	*3.2*	*1.7*	*0.36*	*0.20*	*6.9E-3*	*3.8E-3*	*1.8E-2*	*1.0E-2*	*1.8E-2*	*1.0E-2*	*0.17*	*9.5E-2*
M_D_C_MOB	*25.1*	*30.3*	*4.0*	*4.5*	*4.7E-2*	*5.5E-2*	*0.15*	*0.19*	*0.15*	*0.19*	*2.7*	*2.9*
M_D_DOZ							*0.56*	*2.0*	*0.37*	*1.3*		
M_D_FUG							*19.9*	*16.6*	*2.0*	*1.7*		
2_M_HEAT	*Propane Building Heaters*											
W_HEAT1	*3.7E-3*	*1.6E-2*	*6.5E-3*	*2.8E-2*	*7.9E-4*	*3.5E-3*	*3.5E-4*	*1.5E-3*	*3.5E-4*	*1.5E-3*	*4.0E-4*	*1.7E-3*
W_HEAT2	*5.4E-3*	*2.4E-2*	*9.3E-3*	*4.1E-2*	*1.1E-3*	*5.0E-3*	*5.0E-4*	*2.2E-3*	*5.0E-4*	*2.2E-3*	*5.7E-4*	*2.5E-3*
2_M_WE	*Miscellaneous Fugitives*											
W_WE_EXP							*9.3E-3*	*4.1E-2*	*1.4E-3*	*6.1E-3*		
M_S_EFD							*0.23*	*0.84*	*2.3E-2*	*8.4E-2*		
M_S_E_C	*5.4E-2*	*0.24*	*2.5E-3*	*1.1E-2*	*1.3E-4*	*5.9E-4*	*1.4E-3*	*6.1E-3*	*2.5E-4*	*1.1E-3*	*5.9E-4*	*2.6E-3*
M_S_DFD							*4.2*	*1.1*	*0.42*	*0.11*		
M_S_D_C	*0.10*	*3.2E-2*	*0.30*	*9.5E-2*	*9.4E-4*	*3.0E-4*	*7.7E-2*	*2.4E-2*	*2.2E-2*	*6.9E-3*	*2.3E-2*	*7.2E-3*
3_M_TOTAL	***42.0***	***43.3***	***10.1***	***15.8***	***5.2***	***15.0***	***30.8***	***37.9***	***5.3***	***11.1***	***23.3***	***68.9***

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 3	OF: 18	SHEET: WPS_DISP
AIR EMISSION CALCULATIONS	SUBJECT: Mill	DATE: March 15, 2018		

MILL - UNCONTROLLED - EMISSIONS SUMMARY

	Potential Emissions											
	CO		NO_X		SO_2		PM_{10}		$PM_{2.5}$		VOC	
Source ID	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*
2_M_DRLBST	*Drilling & Blasting*											
WPS_DRILL							*0.12*	*7.2E-3*	*0.12*	*7.2E-3*		
WPS_BLAST	*0.67*	*2.1*	*2.1*	*0.40*	*0.67*	*0.13*	*0.13*	*2.5E-2*	*7.4E-3*	*1.4E-3*		
2_M_MAT	*Material Handling - Stockpile & SAG*											
W_CVYXF1							*5.4*	*13.9*	*0.11*	*0.28*		
W_CVYXF2							*5.4*	*13.9*	*0.11*	*0.28*		
M_TRIPPR							*5.4*	*13.9*	*0.11*	*0.28*		
M_STOCKP							*5.4*	*13.9*	*0.10*	*0.26*		
M1_FEED							*0.33*	*1.1*	*4.9E-2*	*0.17*		
M1_XFER							*0.33*	*1.1*	*4.9E-2*	*0.17*		
M2_FEED							*0.33*	*1.1*	*4.9E-2*	*0.17*		
M2_XFER							*0.33*	*1.1*	*4.9E-2*	*0.17*		
2_M_SAG1	*SAG Line 1*											
M1_LOAD							*0.27*	*0.95*	*4.1E-2*	*0.14*		
M1_SAG												
M1_TROML												
M1_VIBRT												
M1_BALLA												
M1_BALLB												
2_M_SAG2	*SAG Line 2*											
M2_LOAD							*0.27*	*0.95*	*4.1E-2*	*0.14*		
M2_SAG												
M2_TROML												
M2_VIBRT												
M2_BALLA												
M2_BALLB												
2_M_PEBB	*Pebble Recycle*											
M_SCREEN							*10.0*	*35.0*	*10.0*	*35.0*		
M_PEBREC							*6.6E-2*	*0.23*	*9.9E-3*	*3.5E-2*		
M_PEBBIN							*6.6E-2*	*0.23*	*9.9E-3*	*3.5E-2*		
M1_PEBFD							*6.6E-2*	*0.23*	*9.9E-3*	*3.5E-2*		
M2_PEBFD							*6.6E-2*	*0.23*	*9.9E-3*	*3.5E-2*		
M1_PEBCV							*6.6E-2*	*0.23*	*9.9E-3*	*3.5E-2*		
M2_PEBCV							*6.6E-2*	*0.23*	*9.9E-3*	*3.5E-2*		

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 4	OF: 18	SHEET: WPS_DISP
AIR EMISSION CALCULATIONS	SUBJECT: Mill	DATE: March 15, 2018		

MILL - UNCONTROLLED - EMISSIONS SUMMARY CONT.

	Potential Emissions											
	CO		NO_X		SO_2		PM_{10}		$PM_{2.5}$		VOC	
Source ID	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*
2_M_MOLY_FL	*Moly Flotation*											
M_MLYFLT							*6.3E-4*	*1.3E-3*	*9.5E-5*	*2.0E-4*		
M_MLYBIN							*5.6E-4*	*1.2E-3*	*8.5E-5*	*1.8E-4*		
M_MLYBAG							*5.6E-4*	*1.2E-3*	*8.5E-5*	*1.8E-4*		
2_M_LIME	*Lime System*											
M1_LIMBN							*1.9*	*6.4*	*1.9*	*6.4*		
M1_LIMVM							*1.2E-2*	*3.8E-2*	*1.2E-2*	*3.8E-2*		
M1_LIMTK							*1.2E-2*	*3.8E-2*	*1.2E-2*	*3.8E-2*		
M2_LIMBN							*1.9*	*6.4*	*1.9*	*6.4*		
M2_LIMVM							*1.2E-2*	*3.8E-2*	*1.2E-2*	*3.8E-2*		
M2_LIMTK							*1.2E-2*	*3.8E-2*	*1.2E-2*	*3.8E-2*		
2_M_TALC	*Moly/Talc Heat Treatment Process*											
M_MLYHTR					*83.9*	*270*					*172*	*554*
M_KILN_P							*106*	*341*	*90.0*	*291*		
M_KILN_C	*1.3*	*5.9*	*2.3*	*10.2*	*0.29*	*1.3*	*0.13*	*0.55*	*0.13*	*0.55*	*0.14*	*0.63*
2_M_EGEN	*Emergency Generators*											
W_GEN1	*3.9*	*0.96*	*0.35*	*8.7E-2*	*9.0E-3*	*2.2E-3*	*7.7E-3*	*1.9E-3*	*7.7E-3*	*1.9E-3*	*1.7E-2*	*4.3E-3*
W_GEN2	*3.9*	*0.96*	*0.35*	*8.7E-2*	*9.0E-3*	*2.2E-3*	*7.7E-3*	*1.9E-3*	*7.7E-3*	*1.9E-3*	*1.7E-2*	*4.3E-3*
W_GEN3	*3.9*	*0.96*	*0.35*	*8.7E-2*	*9.0E-3*	*2.2E-3*	*7.7E-3*	*1.9E-3*	*7.7E-3*	*1.9E-3*	*1.7E-2*	*4.3E-3*
2_M_FUEL	*Diesel Storage Tanks*											
M_FUEL1											*4.0E-3*	*1.7E-2*
2_M_REAG	*Reagent Storage, Handling, and Use*											
M_SIPX							*4.9E-3*	*1.9E-2*	*4.9E-3*	*1.9E-2*		
M_MIBC											*1.5E-2*	*6.7E-2*
M_NAHS												
M_FLOC1							*2.7E-2*	*0.10*	*2.7E-2*	*0.10*		
M_FLOC2							*6.9E-3*	*2.4E-2*	*6.9E-3*	*2.4E-2*		
M_CYTEC											*1.1E-5*	*5.0E-5*
M_MCO											*1.1E-3*	*4.8E-3*
2_M_D	*Non-Emergency Diesel Fleet (mobile and stationary)*											
M_CMBSTN	*3.2*	*1.7*	*0.36*	*0.20*	*6.9E-3*	*3.8E-3*	*1.8E-2*	*1.0E-2*	*1.8E-2*	*1.0E-2*	*0.17*	*9.5E-2*
M_D_C_MOB	*25.1*	*30.3*	*4.0*	*4.5*	*4.7E-2*	*5.5E-2*	*0.15*	*0.19*	*0.15*	*0.19*	*2.7*	*2.9*
M_D_DOZ							*0.56*	*2.0*	*0.37*	*1.3*		
M_D_FUG							*199*	*166*	*19.8*	*16.5*		
2_M_HEAT	*Propane Building Heaters*											
W_HEAT1	*3.7E-3*	*1.6E-2*	*6.5E-3*	*2.8E-2*	*7.9E-4*	*3.5E-3*	*3.5E-4*	*1.5E-3*	*3.5E-4*	*1.5E-3*	*4.0E-4*	*1.7E-3*
W_HEAT2	*5.4E-3*	*2.4E-2*	*9.3E-3*	*4.1E-2*	*1.1E-3*	*5.0E-3*	*5.0E-4*	*2.2E-3*	*5.0E-4*	*2.2E-3*	*5.7E-4*	*2.5E-3*
2_M_WE	*Miscellaneous Fugitives*											
W_WE_EXP							*9.3E-2*	*0.41*	*1.4E-2*	*6.1E-2*		
M_S_EFD							*2.3*	*8.4*	*0.23*	*0.84*		
M_S_E_C	*5.4E-2*	*0.24*	*2.5E-3*	*1.1E-2*	*1.3E-4*	*5.9E-4*	*1.4E-3*	*6.1E-3*	*2.5E-4*	*1.1E-3*	*5.9E-4*	*2.6E-3*
M_S_DFD							*42.4*	*11.2*	*4.2*	*1.1*		
M_S_D_C	*0.10*	*3.2E-2*	*0.30*	*9.5E-2*	*9.4E-4*	*3.0E-4*	*7.7E-2*	*2.4E-2*	*2.2E-2*	*6.9E-3*	*2.3E-2*	*7.2E-3*
3_M_TOTAL	***42.0***	***43.3***	***10.1***	***15.8***	***84.9***	***272***	***388***	***642***	***130***	***362***	***175***	***558***

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 5	OF: 18	SHEET: WPS_DISP
AIR EMISSION CALCULATIONS	SUBJECT: Mill	DATE: March 15, 2018		

MILL - CONTROLLED - EMISSION FACTORS

		Emission Factors						
Source ID		CO	NO_X	SO_2	PM_{10}	$PM_{2.5}$	VOC	Units & Notes
2_M_DRLBST	*Drilling & Blasting*							
WPS_DRILL								*See "Drill & Blast" Sheet*
WPS_BLAST								*See "Drill & Blast" Sheet*
2_M_MAT	*Material Handling - Stockpile & SAG*							
W_CVYXF1					*7.4E-5*	*1.1E-5*		*lb/ton*
W_CVYXF2					*7.4E-5*	*1.1E-5*		*lb/ton*
M_TRIPPR					*7.4E-5*	*1.1E-5*		*lb/ton*
M_STOCKP					*6.9E-5*	*1.0E-5*		*lb/ton*
M1_FEED								*Emissions accounted for in M1_XFER*
M1_XFER								*Dust Collector (1045398 dscf/hr, 0.002 gr/dscf)*
M2_FEED								*Emissions accounted for in M2_XFER*
M2_XFER								*Dust Collector (1045398 dscf/hr, 0.002 gr/dscf)*
2_M_SAG1	*SAG Line 1*							
M1_LOAD					*5.7E-5*	*8.6E-6*		*lb/ton*
M1_SAG								*wet process*
M1_TROML								*wet process*
M1_VIBRT								*wet process*
M1_BALLA								*wet process*
M1_BALLB								*wet process*
2_M_SAG2	*SAG Line 2*							
M2_LOAD					*5.7E-5*	*8.6E-6*		*lb/ton*
M2_SAG								*wet process*
M2_TROML								*wet process*
M2_VIBRT								*wet process*
M2_BALLA								*wet process*
M2_BALLB								*wet process*
2_M_PEBB	*Pebble Recycle*							
M_SCREEN					*7.4E-4*	*5.0E-5*		*lb/ton*
M_PEBREC					*5.7E-5*	*8.6E-6*		*lb/ton*
M_PEBBIN					*5.7E-5*	*8.6E-6*		*lb/ton*
M1_PEBFD					*5.7E-5*	*8.6E-6*		*lb/ton*
M2_PEBFD					*5.7E-5*	*8.6E-6*		*lb/ton*
M1_PEBCV					*5.7E-5*	*8.6E-6*		*lb/ton*
M2_PEBCV					*5.7E-5*	*8.6E-6*		*lb/ton*

MILL - CONTROLLED - EMISSION FACTORS CONT.

		Emission Factors						
Source ID		CO	NO_X	SO_2	PM_{10}	$PM_{2.5}$	VOC	Units & Notes
2_M_MOLY_FL	*Moly Flotation*							
M_MLYFLT					*5.7E-5*	*8.6E-6*		*lb/ton*
M_MLYBIN					*5.7E-5*	*8.6E-6*		*lb/ton*
M_MLYBAG					*5.7E-5*	*8.6E-6*		*lb/ton*
2_M_LIME	*Lime System*							
M1_LIMBN					*3.4E-4*	*3.4E-4*		*lb/ton*
M1_LIMVM					*2.8E-3*	*2.8E-3*		*lb/ton*
M1_LIMTK					*2.8E-3*	*2.8E-3*		*lb/ton*
M2_LIMBN					*3.4E-4*	*3.4E-4*		*lb/ton*
M2_LIMVM					*2.8E-3*	*2.8E-3*		*lb/ton*
M2_LIMTK					*2.8E-3*	*2.8E-3*		*lb/ton*
2_M_TALC	*Moly/Talc Heat Treatment Process*							
M_MLYHTR								*See "MolyTalc" Sheet*
M_KILN_P								*See "MolyTalc" Sheet*
M_KILN_C								*See "MolyTalc" Sheet*
2_M_EGEN	*Emergency Generators*							
W_GEN1								*See "E_Gen" Sheet*
W_GEN2								*See "E_Gen" Sheet*
W_GEN3								*See "E_Gen" Sheet*
2_M_FUEL	*Diesel Storage Tanks*							
M_FUEL1								*See "Fuel Tanks" Sheet*
2_M_REAG	*Reagent Storage, Handling, and Use*							
M_SIPX					*0.16*	*0.16*		*lb/ton*
M_MIBC								*See "Reagents" Sheet*
M_NAHS								*See "Reagents" Sheet*
M_FLOC1					*5.5E-3*	*5.5E-3*		*lb/ton*
M_FLOC2					*5.5E-3*	*5.5E-3*		*lb/ton*
M_CYTEC								*See "Reagents" Sheet*
M_MCO								*See "Reagents" Sheet*
2_M_D	*Non-Emergency Diesel Fleet (mobile and stationary)*							
M_CMBSTN								*See "Mill_Fleet" Sheet*
M_D_C_MOB								*See "Mill_Fleet" Sheet*
M_D_DOZ								*See "Mill_Fleet" Sheet*
M_D_FUG								*See "Mill_Fleet" Sheet*
2_M_HEAT	*Propane Building Heaters*							
W_HEAT1		*7.5*	*13.0*	*1.6*	*0.70*	*0.70*	*0.80*	*lb/k-gal*
W_HEAT2		*7.5*	*13.0*	*1.6*	*0.70*	*0.70*	*0.80*	*lb/k-gal*
2_M_WE	*Miscellaneous Fugitives*							
W_WE_EXP								*See Wind Workbook*
M_S_EFD								*See "Employees" Sheet*
M_S_E_C								*See "Employees" Sheet*
M_S_DFD								*See "Deliveries" Sheet*
M_S_D_C								*See "Deliveries" Sheet*

MILL - UNCONTROLLED - EMISSION FACTORS

		Emission Factors						
Source ID		CO	NO_X	SO_2	PM_{10}	$PM_{2.5}$	VOC	Units & Notes
2_M_DRLBST	*Drilling & Blasting*							
WPS_DRILL								*See "Drill & Blast" Sheet*
WPS_BLAST								*See "Drill & Blast" Sheet*
2_M_MAT	*Material Handling - Stockpile & SAG*							
W_CVYXF1					*5.5E-4*	*1.1E-5*		*lb/ton*
W_CVYXF2					*5.5E-4*	*1.1E-5*		*lb/ton*
M_TRIPPR					*5.5E-4*	*1.1E-5*		*lb/ton*
M_STOCKP					*5.5E-4*	*1.0E-5*		*lb/ton*
M1_FEED					*6.9E-5*	*1.0E-5*		*lb/ton*
M1_XFER					*6.9E-5*	*1.0E-5*		*lb/ton*
M2_FEED					*6.9E-5*	*1.0E-5*		*lb/ton*
M2_XFER					*6.9E-5*	*1.0E-5*		*lb/ton*
2_M_SAG1	*SAG Line 1*							
M1_LOAD					*5.7E-5*	*8.6E-6*		*lb/ton*
M1_SAG								*No emissions - Wet Process*
M1_TROML								*No emissions - Wet Process*
M1_VIBRT								*No emissions - Wet Process*
M1_BALLA								*No emissions - Wet Process*
M1_BALLB								*No emissions - Wet Process*
2_M_SAG2	*SAG Line 2*							
M2_LOAD					*5.7E-5*	*8.6E-6*		*lb/ton*
M2_SAG								*No emissions - Wet Process*
M2_TROML								*No emissions - Wet Process*
M2_VIBRT								*No emissions - Wet Process*
M2_BALLA								*No emissions - Wet Process*
M2_BALLB								*No emissions - Wet Process*
2_M_PEBB	*Pebble Recycle*							
M_SCREEN					*8.7E-3*	*8.7E-3*		*lb/ton*
M_PEBREC					*5.7E-5*	*8.6E-6*		*lb/ton*
M_PEBBIN					*5.7E-5*	*8.6E-6*		*lb/ton*
M1_PEBFD					*5.7E-5*	*8.6E-6*		*lb/ton*
M2_PEBFD					*5.7E-5*	*8.6E-6*		*lb/ton*
M1_PEBCV					*5.7E-5*	*8.6E-6*		*lb/ton*
M2_PEBCV					*5.7E-5*	*8.6E-6*		*lb/ton*

MILL - UNCONTROLLED - EMISSION FACTORS CONT.

		Emission Factors						
Source ID		CO	NO_X	SO_2	PM_{10}	$PM_{2.5}$	VOC	Units & Notes
2_M_MOLY_FL	*Moly Flotation*							
M_MLYFLT					*5.7E-5*	*8.6E-6*		*lb/ton*
M_MLYBIN					*5.7E-5*	*8.6E-6*		*lb/ton*
M_MLYBAG					*5.7E-5*	*8.6E-6*		*lb/ton*
2_M_LIME	*Lime System*							
M1_LIMBN					*0.47*	*0.47*		*lb/ton*
M1_LIMVM					*2.8E-3*	*2.8E-3*		*lb/ton*
M1_LIMTK					*2.8E-3*	*2.8E-3*		*lb/ton*
M2_LIMBN					*0.47*	*0.47*		*lb/ton*
M2_LIMVM					*2.8E-3*	*2.8E-3*		*lb/ton*
M2_LIMTK					*2.8E-3*	*2.8E-3*		*lb/ton*
2_M_TALC	*Moly/Talc Heat Treatment Process*							
M_MLYHTR								*See "MolyTalc" Sheet*
M_KILN_P								*See "MolyTalc" Sheet*
M_KILN_C								*See "MolyTalc" Sheet*
2_M_EGEN	*Emergency Generators*							
W_GEN1								*See "E_Gen" Sheet*
W_GEN2								*See "E_Gen" Sheet*
W_GEN3								*See "E_Gen" Sheet*
2_M_FUEL	*Diesel Storage Tanks*							
M_FUEL1								*See "Fuel Tanks" Sheet*
2_M_REAG	*Reagent Storage, Handling, and Use*							
M_SIPX					*0.16*	*0.16*		*lb/ton*
M_MIBC								*See "Reagents" Sheet*
M_NAHS								*See "Reagents" Sheet*
M_FLOC1					*0.16*	*0.16*		*lb/ton*
M_FLOC2					*0.16*	*0.16*		*lb/ton*
M_CYTEC								*See "Reagents" Sheet*
M_MCO								*See "Reagents" Sheet*
2_M_D	*Non-Emergency Diesel Fleet (mobile and stationary)*							
M_CMBSTN								*See "Mill_Fleet" Sheet*
M_D_C_MOB								*See "Mill_Fleet" Sheet*
M_D_DOZ								*See "Mill_Fleet" Sheet*
M_D_FUG								*See "Mill_Fleet" Sheet*
2_M_HEAT	*Propane Building Heaters*							
W_HEAT1		*7.5*	*13.0*	*1.6*	*0.70*	*0.70*	*0.80*	*lb/k-gal*
W_HEAT2		*7.5*	*13.0*	*1.6*	*0.70*	*0.70*	*0.80*	*lb/k-gal*
2_M_WE	*Miscellaneous Fugitives*							
W_WE_EXP								*See Wind Workbook*
M_S_EFD								*See "Employees" Sheet*
M_S_E_C								*See "Employees" Sheet*
M_S_DFD								*See "Deliveries" Sheet*
M_S_D_C								*See "Deliveries" Sheet*

MILL - PROCESS RATES

		Process Rates		
Source ID	Unit/Hr	Unit/Yr	Units & Notes	
2_M_DRLBST	*Drilling & Blasting*			
WPS_DRILL			*See "Drill & Blast" Sheet*	
WPS_BLAST			*See "Drill & Blast" Sheet*	
2_M_MAT	*Material Handling - Stockpile & SAG*			
W_CVYXF1	*9,855*	*50,292,894*	*ton*	
W_CVYXF2	*9,855*	*50,292,894*	*ton*	
M_TRIPPR	*9,855*	*50,292,894*	*ton*	
M_STOCKP	*9,855*	*50,292,894*	*ton*	
M1_FEED	*4,736*	*33,193,310*	*ton*	
M1_XFER	*4,736*	*33,193,310*	*ton*	
M2_FEED	*4,736*	*33,193,310*	*ton*	
M2_XFER	*4,736*	*33,193,310*	*ton*	
2_M_SAG1	*SAG Line 1*			
M1_LOAD	*4,736*	*33,193,310*	*ton*	
M1_SAG	*4,736*	*33,193,310*	*ton*	
M1_TROML	*4,736*	*33,193,310*	*ton*	
M1_VIBRT	*4,736*	*33,193,310*	*ton*	
M1_BALLA	*7,728*	*54,161,579*	*ton*	
M1_BALLB	*7,728*	*54,161,579*	*ton*	
2_M_SAG2	*SAG Line 2*			
M2_LOAD	*4,736*	*33,193,310*	*ton*	
M2_SAG	*4,736*	*33,193,310*	*ton*	
M2_TROML	*4,736*	*33,193,310*	*ton*	
M2_VIBRT	*4,736*	*33,193,310*	*ton*	
M2_BALLA	*7,728*	*54,161,579*	*ton*	
M2_BALLB	*7,728*	*54,161,579*	*ton*	
2_M_PEBB	*Pebble Recycle*			
M_SCREEN	*1,149*	*8,046,863*	*ton*	
M_PEBREC	*1,149*	*8,046,863*	*ton*	
M_PEBBIN	*1,149*	*8,046,863*	*ton*	
M1_PEBFD	*1,149*	*8,046,863*	*ton*	
M2_PEBFD	*1,149*	*8,046,863*	*ton*	
M1_PEBCV	*1,149*	*8,046,863*	*ton*	
M2_PEBCV	*1,149*	*8,046,863*	*ton*	

MILL - PROCESS RATES CONT.

Source ID		Process Rates Unit/Hr	Unit/Yr	Units & Notes
2_M_MOLY_FL	*Moly Flotation*			
M_MLYFLT		*11.0*	*45,389*	*ton*
M_MLYBIN		*9.9*	*40,611*	*ton*
M_MLYBAG		*9.9*	*40,611*	*ton*
2_M_LIME	*Lime System*			
M1_LIMBN		*4.1*	*27,279*	*ton*
M1_LIMVM		*4.1*	*27,279*	*ton*
M1_LIMTK		*4.1*	*27,279*	*ton*
M2_LIMBN		*4.1*	*27,279*	*ton*
M2_LIMVM		*4.1*	*27,279*	*ton*
M2_LIMTK		*4.1*	*27,279*	*ton*
2_M_TALC	*Moly/Talc Heat Treatment Process*			
M_MLYHTR				*See "MolyTalc" Sheet*
M_KILN_P				*See "MolyTalc" Sheet*
M_KILN_C				*See "MolyTalc" Sheet*
2_M_EGEN	*Emergency Generators*			
W_GEN1				*See "E_Gen" Sheet*
W_GEN2				*See "E_Gen" Sheet*
W_GEN3				*See "E_Gen" Sheet*
2_M_FUEL	*Diesel Storage Tanks*			
M_FUEL1		*318*	*741,883*	*gal*
2_M_REAG	*Reagent Storage, Handling, and Use*			
M_SIPX		*3.2E-2*	*241*	*ton*
M_MIBC		*1,392*	*441,713*	*gal*
M_NAHS		*8,749*	*2,776,973*	*gal*
M_FLOC1		*0.17*	*1,296*	*ton*
M_FLOC2		*4.4E-2*	*314*	*ton*
M_CYTEC		*240*	*76,078*	*gal*
M_MCO		*422*	*133,835*	*gal*
2_M_D	*Non-Emergency Diesel Fleet (mobile and stationary)*			
M_CMBSTN				*See "Mill_Fleet" Sheet*
M_D_C_MOB				*See "Mill_Fleet" Sheet*
M_D_DOZ				*See "Mill_Fleet" Sheet*
M_D_FUG				*See "Mill_Fleet" Sheet*
2_M_HEAT	*Propane Building Heaters*			
W_HEAT1		*5.0E-4*	*4.4*	*k-gal*
W_HEAT2		*7.2E-4*	*6.3*	*k-gal*
2_M_WE	*Miscellaneous Fugitives*			
W_WE_EXP			*70.0*	*acre*
M_S_EFD				*See "Employees" Sheet*
M_S_E_C				*See "Employees" Sheet*
M_S_DFD				*See "Deliveries" Sheet*
M_S_D_C				*See "Deliveries" Sheet*

MILL - CONTROLS

Source ID	Control Technology	Control Efficiency	Notes
2_M_DRLBST	*Drilling & Blasting*		
WPS_DRILL		*0%*	
WPS_BLAST		*0%*	
2_M_MAT	*Material Handling - Stockpile & SAG*		
W_CVYXF1	*moisture, enclosure*	*0%*	*Control accounted for in EF*
W_CVYXF2	*moisture, enclosure*	*0%*	*Control accounted for in EF*
M_TRIPPR	*moisture, enclosure*	*0%*	*Moist. & Enc. accounted for in EF*
M_STOCKP	*moisture, enclosure with filter vents*	*99%*	*Moist. & Enc. accounted for in EF*
M1_FEED		*0%*	*Emissions accounted for in M1_XFER*
M1_XFER	*1 dust collector*	*0%*	*Control accounted for in emission calculation*
M2_FEED		*0%*	*Emissions accounted for in M2_XFER*
M2_XFER	*1 dust collector*	*0%*	*Control accounted for in emission calculation*
2_M_SAG1	*SAG Line 1*		
M1_LOAD	*moisture, enclosure*	*0%*	*Control accounted for in EF*
M1_SAG	*wet process*	*100%*	
M1_TROML	*wet process*	*100%*	
M1_VIBRT	*wet process*	*100%*	
M1_BALLA	*wet process*	*100%*	
M1_BALLB	*wet process*	*100%*	
2_M_SAG2	*SAG Line 2*		
M2_LOAD	*moisture, enclosure*	*0%*	*Control accounted for in EF*
M2_SAG	*wet process*	*100%*	
M2_TROML	*wet process*	*100%*	
M2_VIBRT	*wet process*	*100%*	
M2_BALLA	*wet process*	*100%*	
M2_BALLB	*wet process*	*100%*	
2_M_PEBB	*Pebble Recycle*		
M_SCREEN	*moisture, enclosure*	*50%*	*Control accounted for in EF*
M_PEBREC	*moisture, enclosure*	*0%*	*Control accounted for in EF*
M_PEBBIN	*moisture, enclosure*	*0%*	*Control accounted for in EF*
M1_PEBFD	*moisture, enclosure*	*0%*	*Control accounted for in EF*
M2_PEBFD	*moisture, enclosure*	*0%*	*Control accounted for in EF*
M1_PEBCV	*moisture, enclosure*	*0%*	*Control accounted for in EF*
M2_PEBCV	*moisture, enclosure*	*0%*	*Control accounted for in EF*

MILL - CONTROLS CONT.

Source ID	Control Technology	Control Efficiency	Notes
2_M_MOLY_FL	*Moly Flotation*		
M_MLYFLT	*moisture, enclosure*	*0%*	*Control accounted for in EF*
M_MLYBIN	*moisture, enclosure*	*0%*	*Control accounted for in EF*
M_MLYBAG	*moisture, enclosure*	*0%*	*Control accounted for in EF*
2_M_LIME	*Lime System*		
M1_LIMBN	*bin vent*	*0%*	*Control accounted for in EF*
M1_LIMVM		*0%*	
M1_LIMTK		*0%*	
M2_LIMBN	*bin vent*	*0%*	*Control accounted for in EF*
M2_LIMVM		*0%*	
M2_LIMTK		*0%*	
2_M_TALC	*Moly/Talc Heat Treatment Process*		
M_MLYHTR		*SO2: 95%, VOC: 88%*	
M_KILN_P		*99%*	
M_KILN_C		*0%*	
2_M_EGEN	*Emergency Generators*		
W_GEN1		*0%*	
W_GEN2		*0%*	
W_GEN3		*0%*	
2_M_FUEL	*Diesel Storage Tanks*		
M_FUEL1		*0%*	
2_M_REAG	*Reagent Storage, Handling, and Use*		
M_SIPX		*0%*	
M_MIBC		*0%*	
M_NAHS		*0%*	
M_FLOC1		*0%*	
M_FLOC2		*0%*	
M_CYTEC		*0%*	
M_MCO		*0%*	
2_M_D	*Non-Emergency Diesel Fleet (mobile and stationary)*		
M_CMBSTN		*0%*	
M_D_C_MOB		*0%*	
M_D_DOZ	*enclosure with filter vents*	*0%*	
M_D_FUG	*chemical suppression*	*90%*	*AP-42, Figure 13.2.2-2, Rev. 11/06*
2_M_HEAT	*Propane Building Heaters*		
W_HEAT1		*0%*	
W_HEAT2		*0%*	
2_M_WE	*Miscellaneous Fugitives*		
W_WE_EXP	*chemical suppression*	*90%*	*AP-42, Figure 13.2.2-2, Rev. 11/06*
M_S_EFD	*chemical suppression*	*90%*	*AP-42, Figure 13.2.2-2, Rev. 11/06*
M_S_E_C		*0%*	*AP-42, Figure 13.2.2-2, Rev. 11/06*
M_S_DFD	*chemical suppression*	*90%*	*AP-42, Figure 13.2.2-2, Rev. 11/06*
M_S_D_C		*0%*	*AP-42, Figure 13.2.2-2, Rev. 11/06*

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	PROJECT NO: 262	PAGE: 13	OF: 18	SHEET: WPS_DISP
AIR EMISSION CALCULATIONS	SUBJECT: Mill	DATE: March 15, 2018		

MILL - SOURCE IDENTIFICATION

Source ID	Source Identification
2_M_DRLBST	***Drilling & Blasting***
WPS_DRILL	*Drilling*
WPS_BLAST	*Blasting*
2_M_MAT	***Material Handling - Stockpile & SAG***
W_CVYXF1	*Incline Conveyor to Mine Conveyor*
W_CVYXF2	*Mine Conveyor to Mine Transfer Conveyor (CV-002)*
M_TRIPPR	*Mine Transfer Conveyor (CV-002) to Stockpile Tripper Conveyor (CV-003)*
M_STOCKP	*Stockpile Tripper Conveyor (CV-003) to Covered SAG Mill Stockpile*
M1_FEED	*SAG Mill Stockpile to Reclaim Tunnel Feeders (FE-001 - 004) - SAG 1*
M1_XFER	*Reclaim Tunnel Feeders (FE001 - 004) to SAG 1 Conveyor (CV-004)*
M2_FEED	*SAG Mill Stockpile to Reclaim Tunnel Feeders (FE-005 - 008) - SAG 2*
M2_XFER	*Reclaim Tunnel Feeders (FE005 - 008) to SAG 2 Conveyor (CV-104)*
2_M_SAG1	***SAG Line 1***
M1_LOAD	*SAG 1 Conveyor (CV-004) to SAG Mill 1 (ML-001)*
M1_SAG	*SAG Mill 1 (ML-001)*
M1_TROML	*Trommel Screen 1 (SR-001) and associated transfer out (SR-002)*
M1_VIBRT	*Vibrating Screen (SR-002) and associated transfer out (oversize to CV-012)*
M1_BALLA	*Ball Mill 1A (ML-002) and associated transfers in and out*
M1_BALLB	*Ball Mill 1B (ML-003) and associated transfers in and out*
2_M_SAG2	***SAG Line 2***
M2_LOAD	*SAG 2 Conveyor (CV-104) to SAG Mill 2 (ML-001)*
M2_SAG	*SAG Mill 2 (ML-101)*
M2_TROML	*Trommel Screen 2 (SR-101) and associated transfer out (SR-003)*
M2_VIBRT	*Vibrating Screen (SR-003) and associated transfer out (oversize to CV-012)*
M2_BALLA	*Ball Mill 2A (ML-102) and associated transfers in and out*
M2_BALLB	*Ball Mill 2B (ML-103) and associated transfers in and out*
2_M_PEBB	***Pebble Recycle***
M_SCREEN	*SAG Mill Discharge Screens (SR-002 - 003) and associated transfers in (CV-012) and out (CV-013)*
M_PEBREC	*Recycle Conveyor 2 (CV-013) to Recycle Conveyor 3 (CV-014)*
M_PEBBIN	*Recycle Conveyor 3 (CV-014) to Pebble Bin (BN-002)*
M1_PEBFD	*Pebble Bin (BN-002) to Pebble Feeder 1 (FE-009)*
M2_PEBFD	*Pebble Bin (BN-002) to Pebble Feeder 2 (FE-109)*
M1_PEBCV	*Pebble Feeder 1 (FE-009) to SAG 1 Conveyor (CV-004)*
M2_PEBCV	*Pebble Feeder 2 (FE-109) to SAG 2 Conveyor (CV-104)*

MILL - SOURCE IDENTIFICATION CONT.

Source ID	Source Identification
2_M_MOLY_FL	***Moly Flotation***
M_MLYFLT	*Moly Concentrate Filter (FL-001) to Holoflite Dryers (DR001 - 002)*
M_MLYBIN	*Holoflite Dryers (DR-001 - 002) to Moly Concentrate Day Bins (BN001 - 003)*
M_MLYBAG	*Moly Concentrate Day Bins (BN001 - 003) to Moly Bagging System (MS-001)*
2_M_LIME	***Lime System***
M1_LIMBN	*Lime Bin 1 (BN-801) Loading (Discharge to Enclosed Screw Feeder)*
M1_LIMVM	*Screw Feeder 1 (CV-801) to Vertimill 1 (ML-801)*
M1_LIMTK	*Vertimill 1 (ML-801) to Milk of Lime Tank (TK-156)*
M2_LIMBN	*Lime Bin 2 (BN-802) Loading (Discharge to Enclosed Screw Feeder)*
M2_LIMVM	*Screw Feeder 2 (CV-802) to Vertimill 2 (ML-802)*
M2_LIMTK	*Vertimill 2 (ML-802) to Milk of Lime Tank (TK-156)*
2_M_TALC	***Moly/Talc Heat Treatment Process***
M_MLYHTR	*Moly/Talc Heat Treatment Process*
M_KILN_P	*Moly/Talc Rotary Dryer Process*
M_KILN_C	*Moly/Talc Rotary Dryer Combustion*
2_M_EGEN	***Emergency Generators***
W_GEN1	*Caterpillar C18 Generator Set*
W_GEN2	*Caterpillar C18 Generator Set*
W_GEN3	*Caterpillar C18 Generator Set*
2_M_FUEL	***Diesel Storage Tanks***
M_FUEL1	*Mill Usage and Volume Estimated (Estimated Quantity: 5)*
2_M_REAG	***Reagent Storage, Handling, and Use***
M_SIPX	*SIPX (Sodium Isopropyl Xanthate)*
M_MIBC	*MIBC (Methyl isobutyl carbonal)*
M_NAHS	*NaHS (Sodium hydrosulfide solution)*
M_FLOC1	*Flocculent (CIBA Magnafloc 155)*
M_FLOC2	*Flocculent (CIBA Magnafloc 10)*
M_CYTEC	*CYTEC 8989*
M_MCO	*MCO (Non-polar flotation oil)*
2_M_D	***Non-Emergency Diesel Fleet (mobile and stationary)***
M_CMBSTN	*Mill Combustion (Stationary)*
M_D_C_MOB	*Mill Combustion (Mobile)*
M_D_DOZ	*Mill Fugitive Dust (Dozing)*
M_D_FUG	*Mill Fugitive Dust (Grading, Vehicle Travel)*
2_M_HEAT	***Propane Building Heaters***
W_HEAT1	*Hydro House Propane Heater (0.045 MMBtu/hr)*
W_HEAT2	*Hydro House Propane Heater (0.065 MMBtu/hr)*
2_M_WE	***Miscellaneous Fugitives***
W_WE_EXP	*WPS Exposed Areas*
M_S_EFD	*WPS Employee Fugitives*
M_S_E_C	*WPS Employee Combustion*
M_S_DFD	*WPS Delivery Fugitives*
M_S_D_C	*WPS Delivery Combustion*
3_M_TOTAL	***Mill Subtotal***

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
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MILL - CONTROLLED - EF REFERENCE

Source ID	Emission Factor Reference
2_M_DRLBST	*Drilling & Blasting*
WPS_DRILL	*See "Drill & Blast" Sheet*
WPS_BLAST	*See "Drill & Blast" Sheet*
2_M_MAT	*Material Handling - Stockpile & SAG*
W_CVYXF1	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 1.3 mph)*
W_CVYXF2	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 1.3 mph)*
M_TRIPPR	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 1.3 mph)*
M_STOCKP	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.2% moist, 1.3 mph)*
M1_FEED	*Emissions accounted for in M1_XFER*
M1_XFER	*Manufacturer (Donaldson Torit) Specified Grain Loading*
M2_FEED	*Emissions accounted for in M2_XFER*
M2_XFER	*Manufacturer (Donaldson Torit) Specified Grain Loading*
2_M_SAG1	*SAG Line 1*
M1_LOAD	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
M1_SAG	*No emissions - Wet Process*
M1_TROML	*No emissions - Wet Process*
M1_VIBRT	*No emissions - Wet Process*
M1_BALLA	*No emissions - Wet Process*
M1_BALLB	*No emissions - Wet Process*
2_M_SAG2	*SAG Line 2*
M2_LOAD	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
M2_SAG	*No emissions - Wet Process*
M2_TROML	*No emissions - Wet Process*
M2_VIBRT	*No emissions - Wet Process*
M2_BALLA	*No emissions - Wet Process*
M2_BALLB	*No emissions - Wet Process*
2_M_PEBB	*Pebble Recycle*
M_SCREEN	*AP-42, Table 11.19.2-2, Screening (controlled), Rev. 8/04*
M_PEBREC	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
M_PEBBIN	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
M1_PEBFD	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
M2_PEBFD	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
M1_PEBCV	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
M2_PEBCV	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*

MILL - CONTROLLED - EF REFERENCE CONT.

Source ID	Emission Factor Reference
2_M_MOLY_FL	*Moly Flotation*
M_MLYFLT	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
M_MLYBIN	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
M_MLYBAG	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
2_M_LIME	*Lime System*
M1_LIMBN	*AP-42, Table 11.12-2, Cement Unloading to Elevated Storage Silo (pneumatic, controlled), Rev. 6/06*
M1_LIMVM	*AP-42, Table 11.12-2, Weigh Hopper Loading (uncontrolled), Rev. 6/06*
M1_LIMTK	*AP-42, Table 11.12-2, Weigh Hopper Loading (uncontrolled), Rev. 6/06*
M2_LIMBN	*AP-42, Table 11.12-2, Cement Unloading to Elevated Storage Silo (pneumatic, controlled), Rev. 6/06*
M2_LIMVM	*AP-42, Table 11.12-2, Weigh Hopper Loading (uncontrolled), Rev. 6/06*
M2_LIMTK	*AP-42, Table 11.12-2, Weigh Hopper Loading (uncontrolled), Rev. 6/06*
2_M_TALC	*Moly/Talc Heat Treatment Process*
M_MLYHTR	*See "MolyTalc" Sheet*
M_KILN_P	*See "MolyTalc" Sheet*
M_KILN_C	*See "MolyTalc" Sheet*
2_M_EGEN	*Emergency Generators*
W_GEN1	*See "E_Gen" Sheet*
W_GEN2	*See "E_Gen" Sheet*
W_GEN3	*See "E_Gen" Sheet*
2_M_FUEL	*Diesel Storage Tanks*
M_FUEL1	*See "Fuel Tanks" Sheet*
2_M_REAG	*Reagent Storage, Handling, and Use*
M_SIPX	*AP-42, Table 11.12-2, Mixer Loading (uncontrolled), Rev. 6/06*
M_MIBC	*See "Reagents" Sheet*
M_NAHS	*See "Reagents" Sheet*
M_FLOC1	*AP-42, Table 11.12-2, Mixer Loading (controlled), Rev. 6/06*
M_FLOC2	*AP-42, Table 11.12-2, Mixer Loading (controlled), Rev. 6/06*
M_CYTEC	*See "Reagents" Sheet*
M_MCO	*See "Reagents" Sheet*
2_M_D	*Non-Emergency Diesel Fleet (mobile and stationary)*
M_CMBSTN	*See "Mill_Fleet" Sheet*
M_D_C_MOB	*See "Mill_Fleet" Sheet*
M_D_DOZ	*See "Mill_Fleet" Sheet*
M_D_FUG	*See "Mill_Fleet" Sheet*
2_M_HEAT	*Propane Building Heaters*
W_HEAT1	*AP-42, Table 1.5-1 (industrial, propane boilers), Rev. 7/08*
W_HEAT2	*AP-42, Table 1.5-1 (industrial, propane boilers), Rev. 7/08*
2_M_WE	*Miscellaneous Fugitives*
W_WE_EXP	*AP-42, Chapter 13.2.5, Industrial Wind Erosion, Rev. 11/06*
M_S_EFD	*See "Employees" Sheet*
M_S_E_C	*See "Employees" Sheet*
M_S_DFD	*See "Deliveries" Sheet*
M_S_D_C	*See "Deliveries" Sheet*

MILL - UNCONTROLLED - EF REFERENCE

Source ID	Emission Factor Reference
2_M_DRLBST	*Drilling & Blasting*
WPS_DRILL	*See "Drill & Blast" Sheet*
WPS_BLAST	*See "Drill & Blast" Sheet*
2_M_MAT	*Material Handling - Stockpile & SAG*
W_CVYXF1	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 6.1 mph)*
W_CVYXF2	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 6.1 mph)*
M_TRIPPR	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 6.1 mph)*
M_STOCKP	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4% moist, 6.1 mph)*
M1_FEED	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.2% moist, 1.3 mph)*
M1_XFER	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.2% moist, 1.3 mph)*
M2_FEED	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.2% moist, 1.3 mph)*
M2_XFER	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.2% moist, 1.3 mph)*
2_M_SAG1	*SAG Line 1*
M1_LOAD	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
M1_SAG	*No emissions - Wet Process*
M1_TROML	*No emissions - Wet Process*
M1_VIBRT	*No emissions - Wet Process*
M1_BALLA	*No emissions - Wet Process*
M1_BALLB	*No emissions - Wet Process*
2_M_SAG2	*SAG Line 2*
M2_LOAD	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
M2_SAG	*No emissions - Wet Process*
M2_TROML	*No emissions - Wet Process*
M2_VIBRT	*No emissions - Wet Process*
M2_BALLA	*No emissions - Wet Process*
M2_BALLB	*No emissions - Wet Process*
2_M_PEBB	*Pebble Recycle*
M_SCREEN	*AP-42, Table 11.19.2-2, Screening (uncontrolled), Rev. 8/04*
M_PEBREC	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
M_PEBBIN	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
M1_PEBFD	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
M2_PEBFD	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
M1_PEBCV	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
M2_PEBCV	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*

MILL - UNCONTROLLED - EF REFERENCE CONT.

Source ID	Emission Factor Reference
2_M_MOLY_FL	*Moly Flotation*
M_MLYFLT	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
M_MLYBIN	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
M_MLYBAG	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
2_M_LIME	*Lime System*
M1_LIMBN	*AP-42, Table 11.12-2, Cement Unloading to Elevated Storage Silo (pneumatic, uncontrolled), Rev. 6/06*
M1_LIMVM	*AP-42, Table 11.12-2, Weigh Hopper Loading (uncontrolled), Rev. 6/06*
M1_LIMTK	*AP-42, Table 11.12-2, Weigh Hopper Loading (uncontrolled), Rev. 6/06*
M2_LIMBN	*AP-42, Table 11.12-2, Cement Unloading to Elevated Storage Silo (pneumatic, uncontrolled), Rev. 6/06*
M2_LIMVM	*AP-42, Table 11.12-2, Weigh Hopper Loading (uncontrolled), Rev. 6/06*
M2_LIMTK	*AP-42, Table 11.12-2, Weigh Hopper Loading (uncontrolled), Rev. 6/06*
2_M_TALC	*Moly/Talc Heat Treatment Process*
M_MLYHTR	*See "MolyTalc" Sheet*
M_KILN_P	*See "MolyTalc" Sheet*
M_KILN_C	*See "MolyTalc" Sheet*
2_M_EGEN	*Emergency Generators*
W_GEN1	*See "E_Gen" Sheet*
W_GEN2	*See "E_Gen" Sheet*
W_GEN3	*See "E_Gen" Sheet*
2_M_FUEL	*Diesel Storage Tanks*
M_FUEL1	*See "Fuel Tanks" Sheet*
2_M_REAG	*Reagent Storage, Handling, and Use*
M_SIPX	*AP-42, Table 11.12-2, Mixer Loading (uncontrolled), Rev. 6/06*
M_MIBC	*See "Reagents" Sheet*
M_NAHS	*See "Reagents" Sheet*
M_FLOC1	*AP-42, Table 11.12-2, Mixer Loading (uncontrolled), Rev. 6/06*
M_FLOC2	*AP-42, Table 11.12-2, Mixer Loading (uncontrolled), Rev. 6/06*
M_CYTEC	*See "Reagents" Sheet*
M_MCO	*See "Reagents" Sheet*
2_M_D	*Non-Emergency Diesel Fleet (mobile and stationary)*
M_CMBSTN	*See "Mill_Fleet" Sheet*
M_D_C_MOB	*See "Mill_Fleet" Sheet*
M_D_DOZ	*See "Mill_Fleet" Sheet*
M_D_FUG	*See "Mill_Fleet" Sheet*
2_M_HEAT	*Propane Building Heaters*
W_HEAT1	*AP-42, Table 1.5-1 (industrial, propane boilers), Rev. 7/08*
W_HEAT2	*AP-42, Table 1.5-1 (industrial, propane boilers), Rev. 7/08*
2_M_WE	*Miscellaneous Fugitives*
W_WE_EXP	*AP-42, Chapter 13.2.5, Industrial Wind Erosion, Rev. 11/06*
M_S_EFD	*See "Employees" Sheet*
M_S_E_C	*See "Employees" Sheet*
M_S_DFD	*See "Deliveries" Sheet*
M_S_D_C	*See "Deliveries" Sheet*

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TAILINGS - CONTROLLED - EMISSIONS SUMMARY

	Potential Emissions											
	CO		NO_X		SO_2		PM_{10}		$PM_{2.5}$		VOC	
Source ID	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*
2_T_FUEL	*Diesel Storage Tanks*											
T_FUEL1											*2.0E-2*	*8.7E-2*
2_T_D	*Non-Emergency Diesel Fleet (mobile and stationary)*											
T_CMBSTN												
T_D_C_MOB	*95.2*	*140*	*11.6*	*16.0*	*0.20*	*0.29*	*0.55*	*0.79*	*0.55*	*0.79*	*6.1*	*7.9*
T_D_DOZ							*8.4*	*9.4*	*5.5*	*6.2*		
T_D_FUG							*80.0*	*111*	*8.0*	*11.1*		
2_T_GEN	*Emergency Generators*											
T_GEN1	*3.9*	*0.96*	*0.35*	*8.7E-2*	*9.0E-3*	*2.2E-3*	*7.7E-3*	*1.9E-3*	*7.7E-3*	*1.9E-3*	*1.7E-2*	*4.3E-3*
2_T_WE	*Miscellaneous Fugitives*											
T_WE_RD							*6.6E-2*	*0.29*	*9.9E-3*	*4.3E-2*		
T_WE_BCH							*0.11*	*0.49*	*1.7E-2*	*7.4E-2*		
T_WE_DAM							*1.4E-2*	*6.3E-2*	*2.1E-3*	*9.4E-3*		
T_S_EFD							*6.5E-2*	*0.24*	*6.5E-3*	*2.4E-2*		
T_S_E_C	*1.6E-2*	*6.8E-2*	*7.2E-4*	*3.2E-3*	*3.8E-5*	*1.7E-4*	*4.0E-4*	*1.7E-3*	*7.0E-5*	*3.1E-4*	*1.7E-4*	*7.4E-4*
T_S_DFD												
T_S_D_C												
3_T_TOTAL	***99.1***	***141***	***12.0***	***16.1***	***0.21***	***0.29***	***89.2***	***122***	***14.1***	***18.2***	***6.1***	***8.0***

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TAILINGS - UNCONTROLLED - EMISSIONS SUMMARY

	Potential Emissions											
	CO		NO_X		SO_2		PM_{10}		$PM_{2.5}$		VOC	
Source ID	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*
2_T_FUEL	*Diesel Storage Tanks*											
T_FUEL1											*2.0E-2*	*8.7E-2*
2_T_D	*Non-Emergency Diesel Fleet (mobile and stationary)*											
T_CMBSTN												
T_D_C_MOB	*95.2*	*140*	*11.6*	*16.0*	*0.20*	*0.29*	*0.55*	*0.79*	*0.55*	*0.79*	*6.1*	*7.9*
T_D_DOZ							*8.4*	*9.4*	*5.5*	*6.2*		
T_D_FUG							*800*	*1,110*	*79.9*	*111*		
2_T_GEN	*Emergency Generators*											
T_GEN1	*3.9*	*0.96*	*0.35*	*8.7E-2*	*9.0E-3*	*2.2E-3*	*7.7E-3*	*1.9E-3*	*7.7E-3*	*1.9E-3*	*1.7E-2*	*4.3E-3*
2_T_WE	*Miscellaneous Fugitives*											
T_WE_RD							*0.66*	*2.9*	*9.9E-2*	*0.43*		
T_WE_BCH							*1.1*	*4.9*	*0.17*	*0.74*		
T_WE_DAM							*0.14*	*0.63*	*2.1E-2*	*9.4E-2*		
T_S_EFD							*0.65*	*2.4*	*6.5E-2*	*0.24*		
T_S_E_C	*1.6E-2*	*6.8E-2*	*7.2E-4*	*3.2E-3*	*3.8E-5*	*1.7E-4*	*4.0E-4*	*1.7E-3*	*7.0E-5*	*3.1E-4*	*1.7E-4*	*7.4E-4*
T_S_DFD												
T_S_D_C												
3_T_TOTAL	***99.1***	***141***	***12.0***	***16.1***	***0.21***	***0.29***	***811***	***1,131***	***86.4***	***119***	***6.1***	***8.0***

TAILINGS - CONTROLLED - EMISSION FACTORS

	Emission Factors						
Source ID	**CO**	**NO_X**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**	**VOC**	**Units & Notes**
2_T_FUEL	*Diesel Storage Tanks*						
T_FUEL1							*See "Fuel Tanks" Sheet*
2_T_D	*Non-Emergency Diesel Fleet (mobile and stationary)*						
T_CMBSTN							*See "Tailings_Fleet" Sheet*
T_D_C_MOB							*See "Tailings_Fleet" Sheet*
T_D_DOZ							*See "Tailings_Fleet" Sheet*
T_D_FUG							*See "Tailings_Fleet" Sheet*
2_T_GEN	*Emergency Generators*						
T_GEN1							*See "E_Gen" Sheet*
2_T_WE	*Miscellaneous Fugitives*						
T_WE_RD				*2E-01*	*3E-02*		*ton/acre-yr*
T_WE_BCH							*ton/acre-yr*
T_WE_DAM							*ton/acre-yr*
T_S_EFD							*See "Employees" Sheet*
T_S_E_C							*See "Employees" Sheet*
T_S_DFD							*See "Deliveries" Sheet*
T_S_D_C							*See "Deliveries" Sheet*

TAILINGS - UNCONTROLLED - EMISSION FACTORS

	Emission Factors						
Source ID	**CO**	**NO_X**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**	**VOC**	**Units & Notes**
2_T_FUEL	*Diesel Storage Tanks*						
T_FUEL1							*See "Fuel Tanks" Sheet*
2_T_D	*Non-Emergency Diesel Fleet (mobile and stationary)*						
T_CMBSTN							*See "Tailings_Fleet" Sheet*
T_D_C_MOB							*See "Tailings_Fleet" Sheet*
T_D_DOZ							*See "Tailings_Fleet" Sheet*
T_D_FUG							*See "Tailings_Fleet" Sheet*
2_T_GEN	*Emergency Generators*						
T_GEN1							*See "E_Gen" Sheet*
2_T_WE	*Miscellaneous Fugitives*						
T_WE_RD				*2E-01*	*3E-02*		*ton/acre-yr*
T_WE_BCH							*ton/acre-yr*
T_WE_DAM							*ton/acre-yr*
T_S_EFD							*See "Employees" Sheet*
T_S_E_C							*See "Employees" Sheet*
T_S_DFD							*See "Deliveries" Sheet*
T_S_D_C							*See "Deliveries" Sheet*

TAILINGS - PROCESS RATES

	Process Rates		
Source ID	Unit/Hr	Unit/Yr	Units & Notes
2_T_FUEL	*Diesel Storage Tanks*		
T_FUEL1	*1,360*	*3,993,028*	*gal*
2_T_D	*Non-Emergency Diesel Fleet (mobile and stationary)*		
T_CMBSTN			*See "Tailings_Fleet" Sheet*
T_D_C_MOB			*See "Tailings_Fleet" Sheet*
T_D_DOZ			*See "Tailings_Fleet" Sheet*
T_D_FUG			*See "Tailings_Fleet" Sheet*
2_T_GEN	*Emergency Generators*		
T_GEN1			*See "E_Gen" Sheet*
2_T_WE	*Miscellaneous Fugitives*		
T_WE_RD		*15.2*	*acre*
T_WE_BCH		*934*	*dry acre*
T_WE_DAM		*119*	*dry acre*
T_S_EFD			*See "Employees" Sheet*
T_S_E_C			*See "Employees" Sheet*
T_S_DFD			*See "Deliveries" Sheet*
T_S_D_C			*See "Deliveries" Sheet*

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TAILINGS - CONTROLS

Source ID	Control Technology	Control Efficiency	Notes
2_T_FUEL	*Diesel Storage Tanks*		
T_FUEL1		*0%*	
2_T_D	*Non-Emergency Diesel Fleet (mobile and stationary)*		
T_CMBSTN		*0%*	
T_D_C_MOB		*0%*	
T_D_DOZ		*0%*	
T_D_FUG	*chemical suppression*	*90%*	*AP-42, Figure 13.2.2-2, Rev. 11/06*
2_T_GEN	*Emergency Generators*		
T_GEN1		*0%*	*AP-42, Figure 13.2.2-2, Rev. 11/06*
2_T_WE	*Miscellaneous Fugitives*		
T_WE_RD	*chemical suppression*	*90%*	*AP-42, Figure 13.2.2-2, Rev. 11/06*
T_WE_BCH	*chemical suppression*	*90%*	*AP-42, Figure 13.2.2-2, Rev. 11/06*
T_WE_DAM	*chemical suppression*	*90%*	*AP-42, Figure 13.2.2-2, Rev. 11/06*
T_S_EFD	*chemical suppression*	*90%*	*AP-42, Figure 13.2.2-2, Rev. 11/06*
T_S_E_C		*0%*	*AP-42, Figure 13.2.2-2, Rev. 11/06*
T_S_DFD	*chemical suppression*	*90%*	*AP-42, Figure 13.2.2-2, Rev. 11/06*
T_S_D_C		*0%*	*AP-42, Figure 13.2.2-2, Rev. 11/06*

TAILINGS - SOURCE IDENTIFICATION

Source ID	Source Identification
2_T_FUEL	***Diesel Storage Tanks***
T_FUEL1	*Tailings Usage and Volume Estimated (Estimated Quantity: 12)*
2_T_D	***Non-Emergency Diesel Fleet (mobile and stationary)***
T_CMBSTN	*Tailings Combustion (Stationary)*
T_D_C_MOB	*Tailings Combustion (Mobile)*
T_D_DOZ	*Tailings Fugitive Dust (Dozing)*
T_D_FUG	*Tailings Fugitive Dust (Grading, Vehicle Travel)*
2_T_GEN	***Emergency Generators***
T_GEN1	*Caterpillar C18 Generator Set*
2_T_WE	***Miscellaneous Fugitives***
T_WE_RD	*TSF Secondary Sources from Access Roads (Wind Erosion)*
T_WE_BCH	*TSF Exposed Areas - Beach*
T_WE_DAM	*TSF Exposed Areas - Dam*
T_S_EFD	*TSF Employee Fugitives*
T_S_E_C	*TSF Employee Combustion*
T_S_DFD	*TSF Delivery Fugitives*
T_S_D_C	*TSF Delivery Combustion*
3_T_TOTAL	***Tailings Subtotal***

TAILINGS - CONTROLLED - EF REFERENCE

Source ID	Emission Factor Reference
2_T_FUEL	*Diesel Storage Tanks*
T_FUEL1	*See "Fuel Tanks" Sheet*
2_T_D	*Non-Emergency Diesel Fleet (mobile and stationary)*
T_CMBSTN	*See "Tailings_Fleet" Sheet*
T_D_C_MOB	*See "Tailings_Fleet" Sheet*
T_D_DOZ	*See "Tailings_Fleet" Sheet*
T_D_FUG	*See "Tailings_Fleet" Sheet*
2_T_GEN	*Emergency Generators*
T_GEN1	*See "E_Gen" Sheet*
2_T_WE	*Miscellaneous Fugitives*
T_WE_RD	*AP-42, Table 11.9-4, Wind Erosion, Rev. 7/98*
T_WE_BCH	*AP-42, Chapter 13.2.5, Industrial Wind Erosion, Rev. 11/06*
T_WE_DAM	*AP-42, Chapter 13.2.5, Industrial Wind Erosion, Rev. 11/06*
T_S_EFD	*See "Employees" Sheet*
T_S_E_C	*See "Employees" Sheet*
T_S_DFD	*See "Deliveries" Sheet*
T_S_D_C	*See "Deliveries" Sheet*

TAILINGS - UNCONTROLLED - EF REFERENCE

Source ID	Emission Factor Reference
2_T_FUEL	*Diesel Storage Tanks*
T_FUEL1	*See "Fuel Tanks" Sheet*
2_T_D	*Non-Emergency Diesel Fleet (mobile and stationary)*
T_CMBSTN	*See "Tailings_Fleet" Sheet*
T_D_C_MOB	*See "Tailings_Fleet" Sheet*
T_D_DOZ	*See "Tailings_Fleet" Sheet*
T_D_FUG	*See "Tailings_Fleet" Sheet*
2_T_GEN	*Emergency Generators*
T_GEN1	*See "E_Gen" Sheet*
2_T_WE	*Miscellaneous Fugitives*
T_WE_RD	*AP-42, Table 11.9-4, Wind Erosion, Rev. 7/98*
T_WE_BCH	*AP-42, Table 11.9-4, Wind Erosion, Rev. 7/98*
T_WE_DAM	*AP-42, Table 11.9-4, Wind Erosion, Rev. 7/98*
T_S_EFD	*See "Employees" Sheet*
T_S_E_C	*See "Employees" Sheet*
T_S_DFD	*See "Deliveries" Sheet*
T_S_D_C	*See "Deliveries" Sheet*

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LOADOUT - CONTROLLED - EMISSIONS SUMMARY

	Potential Emissions											
	CO		NO_X		SO_2		PM_{10}		$PM_{2.5}$		VOC	
Source ID	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*
2_L_CU_CONC	*Copper Concentrate Loadout*											
F_LDSTL							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_STLBLD							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_STLCOL							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_COLBLT							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_LDGHOP							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_HOPFED							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_FEDBLT							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_BLTTRP							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_TRPSTO							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_LDRHOP							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_HOPBLT							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_BLTCNV							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_CNVTRN							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
2_L_FUEL	*Diesel Storage Tanks*											
L_FUEL1											*3.1E-3*	*1.3E-2*
2_L_GEN	*Emergency Generators*											
F_GEN1	*3.9*	*0.96*	*0.35*	*8.7E-2*	*9.0E-3*	*2.2E-3*	*7.7E-3*	*1.9E-3*	*7.7E-3*	*1.9E-3*	*1.7E-2*	*4.3E-3*
2_L_D	*Non-Emergency Diesel Fleet (mobile and stationary)*											
F_CMBSTN												
L_D_C_MOB	*8.3*	*20.4*	*0.94*	*2.3*	*1.9E-2*	*4.4E-2*	*4.7E-2*	*0.12*	*4.7E-2*	*0.12*	*0.44*	*1.1*
2_L_S_WE	*Miscellaneous Fugitives*											
L_WE_RD							*2.4E-2*	*0.11*	*3.6E-3*	*1.6E-2*		
L_S_EFD							*0.21*	*0.76*	*2.1E-2*	*7.6E-2*		
L_S_E_C	*4.9E-2*	*0.21*	*2.3E-3*	*1.0E-2*	*1.2E-4*	*5.3E-4*	*1.3E-3*	*5.5E-3*	*2.2E-4*	*9.7E-4*	*5.3E-4*	*2.3E-3*
L_S_DFD												
L_S_D_C												
3_L_TOTAL	***12.2***	***21.5***	***1.3***	***2.4***	***2.8E-2***	***4.7E-2***	***0.62***	***2.4***	***0.13***	***0.42***	***0.46***	***1.1***

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LOADOUT - UNCONTROLLED - EMISSIONS SUMMARY

	Potential Emissions											
	CO		NO_X		SO_2		PM_{10}		$PM_{2.5}$		VOC	
Source ID	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*
2_L_CU_CONC	*Copper Concentrate Loadout*											
F_LDSTL							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_STLBLD							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_STLCOL							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_COLBLT							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_LDGHOP							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_HOPFED							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_FEDBLT							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_BLTTRP							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_TRPSTO							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_LDRHOP							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_HOPBLT							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_BLTCNV							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
F_CNVTRN							*2.6E-2*	*0.11*	*3.9E-3*	*1.6E-2*		
2_L_FUEL	*Diesel Storage Tanks*											
L_FUEL1											*3.1E-3*	*1.3E-2*
2_L_GEN	*Emergency Generators*											
F_GEN1	*3.9*	*0.96*	*0.35*	*8.7E-2*	*9.0E-3*	*2.2E-3*	*7.7E-3*	*1.9E-3*	*7.7E-3*	*1.9E-3*	*1.7E-2*	*4.3E-3*
2_L_D	*Non-Emergency Diesel Fleet (mobile and stationary)*											
F_CMBSTN												
L_D_C_MOB	*8.3*	*20.4*	*0.94*	*2.3*	*1.9E-2*	*4.4E-2*	*4.7E-2*	*0.12*	*4.7E-2*	*0.12*	*0.44*	*1.1*
2_L_S_WE	*Miscellaneous Fugitives*											
L_WE_RD							*0.24*	*1.1*	*3.6E-2*	*0.16*		
L_S_EFD							*2.1*	*7.6*	*0.21*	*0.76*		
L_S_E_C	*4.9E-2*	*0.21*	*2.3E-3*	*1.0E-2*	*1.2E-4*	*5.3E-4*	*1.3E-3*	*5.5E-3*	*2.2E-4*	*9.7E-4*	*5.3E-4*	*2.3E-3*
L_S_DFD												
L_S_D_C												
3_L_TOTAL	***12.2***	***21.5***	***1.3***	***2.4***	***2.8E-2***	***4.7E-2***	***2.7***	***10.2***	***0.35***	***1.2***	***0.46***	***1.1***

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AIR EMISSION CALCULATIONS	SUBJECT: Loadout	DATE: March 15, 2018		

LOADOUT - CONTROLLED - EMISSION FACTORS

	Emission Factors						
Source ID	**CO**	**NO_X**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**	**VOC**	**Units & Notes**
2_L_CU_CONC	*Copper Concentrate Loadout*						
F_LDSTL				*5.7E-5*	*8.6E-6*		*lb/ton*
F_STLBLD				*5.7E-5*	*8.6E-6*		*lb/ton*
F_STLCOL				*5.7E-5*	*8.6E-6*		*lb/ton*
F_COLBLT				*5.7E-5*	*8.6E-6*		*lb/ton*
F_LDGHOP				*5.7E-5*	*8.6E-6*		*lb/ton*
F_HOPFED				*5.7E-5*	*8.6E-6*		*lb/ton*
F_FEDBLT				*5.7E-5*	*8.6E-6*		*lb/ton*
F_BLTTRP				*5.7E-5*	*8.6E-6*		*lb/ton*
F_TRPSTO				*5.7E-5*	*8.6E-6*		*lb/ton*
F_LDRHOP				*5.7E-5*	*8.6E-6*		*lb/ton*
F_HOPBLT				*5.7E-5*	*8.6E-6*		*lb/ton*
F_BLTCNV				*5.7E-5*	*8.6E-6*		*lb/ton*
F_CNVTRN				*5.7E-5*	*8.6E-6*		*lb/ton*
2_L_FUEL	*Diesel Storage Tanks*						
L_FUEL1							*See "Fuel Tanks" Sheet*
2_L_GEN	*Emergency Generators*						
F_GEN1							*See "E_Gen" Sheet*
2_L_D	*Non-Emergency Diesel Fleet (mobile and stationary)*						
F_CMBSTN							*See "Loadout_Fleet" Sheet*
L_D_C_MOB							*See "Loadout_Fleet" Sheet*
2_L_S_WE	*Miscellaneous Fugitives*						
L_WE_RD				*0.2*	*0.0*		*ton/acre-yr*
L_S_EFD							*See "Employees" Sheet*
L_S_E_C							*See "Employees" Sheet*
L_S_DFD							*See "Deliveries" Sheet*
L_S_D_C							*See "Deliveries" Sheet*

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AIR EMISSION CALCULATIONS	SUBJECT: Loadout	DATE: March 15, 2018		

LOADOUT - UNCONTROLLED - EMISSION FACTORS

	Emission Factors						
Source ID	CO	NO_X	SO_2	PM_{10}	$PM_{2.5}$	VOC	Units & Notes
2_L_CU_CONC	*Copper Concentrate Loadout*						
F_LDSTL				*5.7E-5*	*8.6E-6*		*lb/ton*
F_STLBLD				*5.7E-5*	*8.6E-6*		*lb/ton*
F_STLCOL				*5.7E-5*	*8.6E-6*		*lb/ton*
F_COLBLT				*5.7E-5*	*8.6E-6*		*lb/ton*
F_LDGHOP				*5.7E-5*	*8.6E-6*		*lb/ton*
F_HOPFED				*5.7E-5*	*8.6E-6*		*lb/ton*
F_FEDBLT				*5.7E-5*	*8.6E-6*		*lb/ton*
F_BLTTRP				*5.7E-5*	*8.6E-6*		*lb/ton*
F_TRPSTO				*5.7E-5*	*8.6E-6*		*lb/ton*
F_LDRHOP				*5.7E-5*	*8.6E-6*		*lb/ton*
F_HOPBLT				*5.7E-5*	*8.6E-6*		*lb/ton*
F_BLTCNV				*5.7E-5*	*8.6E-6*		*lb/ton*
F_CNVTRN				*5.7E-5*	*8.6E-6*		*lb/ton*
2_L_FUEL	*Diesel Storage Tanks*						
L_FUEL1							*See "Fuel Tanks" Sheet*
2_L_GEN	*Emergency Generators*						
F_GEN1							*See "E_Gen" Sheet*
2_L_D	*Non-Emergency Diesel Fleet (mobile and stationary)*						
F_CMBSTN							*See "Loadout_Fleet" Sheet*
L_D_C_MOB							*See "Loadout_Fleet" Sheet*
2_L_S_WE	*Miscellaneous Fugitives*						
L_WE_RD				*0.2*	*0.0*		*ton/acre-yr*
L_S_EFD							*See "Employees" Sheet*
L_S_E_C							*See "Employees" Sheet*
L_S_DFD							*See "Deliveries" Sheet*
L_S_D_C							*See "Deliveries" Sheet*

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LOADOUT - PROCESS RATES

	Process Rates		
Source ID	Unit/Hr	Unit/Yr	Units & Notes
2_L_CU_CONC	*Copper Concentrate Loadout*		
F_LDSTL	*456*	*3,680,491*	*ton*
F_STLBLD	*456*	*3,680,491*	*ton*
F_STLCOL	*456*	*3,680,491*	*ton*
F_COLBLT	*456*	*3,680,491*	*ton*
F_LDGHOP	*456*	*3,680,491*	*ton*
F_HOPFED	*456*	*3,680,491*	*ton*
F_FEDBLT	*456*	*3,680,491*	*ton*
F_BLTTRP	*456*	*3,680,491*	*ton*
F_TRPSTO	*456*	*3,680,491*	*ton*
F_LDRHOP	*456*	*3,680,491*	*ton*
F_HOPBLT	*456*	*3,680,491*	*ton*
F_BLTCNV	*456*	*3,680,491*	*ton*
F_CNVTRN	*456*	*3,680,491*	*ton*
2_L_FUEL	*Diesel Storage Tanks*		
L_FUEL1	*119*	*555,866*	*gal*
2_L_GEN	*Emergency Generators*		
F_GEN1			*See "E_Gen" Sheet*
2_L_D	*Non-Emergency Diesel Fleet (mobile and stationary)*		
F_CMBSTN			*See "Loadout_Fleet" Sheet*
L_D_C_MOB			*See "Loadout_Fleet" Sheet*
2_L_S_WE	*Miscellaneous Fugitives*		
L_WE_RD		*5.6*	*acre*
L_S_EFD			*See "Employees" Sheet*
L_S_E_C			*See "Employees" Sheet*
L_S_DFD			*See "Deliveries" Sheet*
L_S_D_C			*See "Deliveries" Sheet*

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AIR EMISSION CALCULATIONS	SUBJECT: Loadout	DATE: March 15, 2018		

LOADOUT - CONTROLS

Source ID	Control Technology	Control Efficiency	Notes
2_L_CU_CONC	*Copper Concentrate Loadout*		
F_LDSTL	*moisture, enclosure*	*0%*	*Control accounted for in EF*
F_STLBLD	*moisture, enclosure*	*0%*	*Control accounted for in EF*
F_STLCOL	*moisture, enclosure*	*0%*	*Control accounted for in EF*
F_COLBLT	*moisture, enclosure*	*0%*	*Control accounted for in EF*
F_LDGHOP	*moisture, enclosure*	*0%*	*Control accounted for in EF*
F_HOPFED	*moisture, enclosure*	*0%*	*Control accounted for in EF*
F_FEDBLT	*moisture, enclosure*	*0%*	*Control accounted for in EF*
F_BLTTRP	*moisture, enclosure*	*0%*	*Control accounted for in EF*
F_TRPSTO	*moisture, enclosure*	*0%*	*Control accounted for in EF*
F_LDRHOP	*moisture, enclosure*	*0%*	*Control accounted for in EF*
F_HOPBLT	*moisture, enclosure*	*0%*	*Control accounted for in EF*
F_BLTCNV	*moisture, enclosure*	*0%*	*Control accounted for in EF*
F_CNVTRN	*moisture, enclosure*	*0%*	*Control accounted for in EF*
2_L_FUEL	*Diesel Storage Tanks*		
L_FUEL1		*0%*	
2_L_GEN	*Emergency Generators*		
F_GEN1		*0%*	
2_L_D	*Non-Emergency Diesel Fleet (mobile and stationary)*		
F_CMBSTN		*0%*	
L_D_C_MOB		*0%*	
2_L_S_WE	*Miscellaneous Fugitives*		
L_WE_RD	*chemical suppression*	*90%*	
L_S_EFD	*chemical suppression*	*90%*	
L_S_E_C		*0%*	
L_S_DFD	*chemical suppression*	*90%*	
L_S_D_C		*0%*	

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AIR EMISSION CALCULATIONS	SUBJECT: Loadout	DATE: March 15, 2018		

LOADOUT - SOURCE IDENTIFICATION

Source ID	Source Identification
2_L_CU_CONC	***Copper Concentrate Loadout***
F_LDSTL	*Concentrate Filters (FL-001 - 006) to Shuttle Conveyors (CV-001 - CV-006)*
F_STLBLD	*Shuttle Conveyors (CV-001 - CV-006) to Filter Building (BG-011)*
F_STLCOL	*Shuttle Conveyors (CV-001 - CV-006) to Collecting Conveyor (CV-010)*
F_COLBLT	*Collecting Conveyor (CV-010) to Belt Conveyor (CV-020)*
F_LDGHOP	*Concentrate Hopper (HP-011) Loading*
F_HOPFED	*Concentrate Hopper (HP-011) to Concentrate Feeder (FE-011)*
F_FEDBLT	*Concentrate Feeder (FE-011) to Belt Conveyor (CV-020)*
F_BLTTRP	*Belt Conveyor (CV-020) to Tripper Conveyor (CV-030)*
F_TRPSTO	*Tripper Conveyor (CV-030) to Storage and Loadout Shed (BG-012)*
F_LDRHOP	*Front End Loader (MS-002) to Load Out Hoppers (HP-012 - 015)*
F_HOPBLT	*Load Out Hoppers (HP-012 - 015) to Weigh Belt Feeders (FE-012 -015)*
F_BLTCNV	*Weigh Belt Feeders (FE-012 -015) to Load Out Conveyors (CV-031 - 034)*
F_CNVTRN	*Load Out Conveyors (CV-031 - 034) to Rail Cars*
2_L_FUEL	***Diesel Storage Tanks***
L_FUEL1	*Loadout Usage and Volume Estimated (Estimated Quantity: 4)*
2_L_GEN	***Emergency Generators***
F_GEN1	*Caterpillar C18 Generator Set*
2_L_D	***Non-Emergency Diesel Fleet (mobile and stationary)***
F_CMBSTN	*Loadout Combustion (Stationary)*
L_D_C_MOB	*Loadout Combustion (Mobile)*
2_L_S_WE	***Miscellaneous Fugitives***
L_WE_RD	*Loadout Secondary Sources from Access Roads (Wind Erosion)*
L_S_EFD	*Loadout Employee Fugitives*
L_S_E_C	*Loadout Employee Combustion*
L_S_DFD	*Loadout Delivery Fugitives*
L_S_D_C	*Loadout Delivery Combustion*
3_L_TOTAL	***Loadout Subtotal***

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AIR EMISSION CALCULATIONS	SUBJECT: Loadout	DATE: March 15, 2018		

LOADOUT - CONTROLLED - EF REFERENCE

Source ID	Emission Factor Reference
2_L_CU_CONC	*Copper Concentrate Loadout*
F_LDSTL	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_STLBLD	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_STLCOL	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_COLBLT	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_LDGHOP	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_HOPFED	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_FEDBLT	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_BLTTRP	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_TRPSTO	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_LDRHOP	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_HOPBLT	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_BLTCNV	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_CNVTRN	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
2_L_FUEL	*Diesel Storage Tanks*
L_FUEL1	*See "Fuel Tanks" Sheet*
2_L_GEN	*Emergency Generators*
F_GEN1	*See "E_Gen" Sheet*
2_L_D	*Non-Emergency Diesel Fleet (mobile and stationary)*
F_CMBSTN	*See "Loadout_Fleet" Sheet*
L_D_C_MOB	*See "Loadout_Fleet" Sheet*
2_L_S_WE	*Miscellaneous Fugitives*
L_WE_RD	*AP-42, Table 11.9-4, Wind Erosion, Rev. 7/98*
L_S_EFD	*See "Employees" Sheet*
L_S_E_C	*See "Employees" Sheet*
L_S_DFD	*See "Deliveries" Sheet*
L_S_D_C	*See "Deliveries" Sheet*

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AIR EMISSION CALCULATIONS	SUBJECT: Loadout	DATE: March 15, 2018		

LOADOUT - UNCONTROLLED - EF REFERENCE

Source ID	Emission Factor Reference
2_L_CU_CONC	*Copper Concentrate Loadout*
F_LDSTL	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_STLBLD	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_STLCOL	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_COLBLT	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_LDGHOP	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_HOPFED	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_FEDBLT	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_BLTTRP	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_TRPSTO	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_LDRHOP	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_HOPBLT	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_BLTCNV	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
F_CNVTRN	*AP-42, Equation 13.2.4 (1), Rev. 11/06 (4.8% moist, 1.3 mph)*
2_L_FUEL	*Diesel Storage Tanks*
L_FUEL1	*See "Fuel Tanks" Sheet*
2_L_GEN	*Emergency Generators*
F_GEN1	*See "E_Gen" Sheet*
2_L_D	*Non-Emergency Diesel Fleet (mobile and stationary)*
F_CMBSTN	*See "Loadout_Fleet" Sheet*
L_D_C_MOB	*See "Loadout_Fleet" Sheet*
2_L_S_WE	*Miscellaneous Fugitives*
L_WE_RD	*AP-42, Table 11.9-4, Wind Erosion, Rev. 7/98*
L_S_EFD	*See "Employees" Sheet*
L_S_E_C	*See "Employees" Sheet*
L_S_DFD	*See "Deliveries" Sheet*
L_S_D_C	*See "Deliveries" Sheet*

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
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AIR EMISSION CALCULATIONS	SUBJECT: Diesel Fleet Calculations - East Plant	DATE: March 15, 2018		

East Plant Diesel Machinery (Non-Emergency) Year 14

Equipment*	Rating kW	Rating hp	Quantity	EPA Tier**	Fuel gal/hr	Ann. Op. Hours***	Load Factor (%)*
Surface Loader - CAT 962K	165	221	2	4	6	1,862	60%
Surface Shotcrete Truck - Highway Legal	128	172	0	4	1	0	60%
Development LHD - Sandvik LH514	256	343	9	4	12	2,182	60%
Development Drill - Atlas Copco M2C	120	161	6	4	7	741	10%
Production Drill - Simba M6C	112	150	17	4	7	3,454	10%
Blind Bore Machine - Redbore 50 MDUR	0	0	1	X	0	2,443	0%
Powder Truck - Normet Charmec MF 605 DA	110	148	13	4	6	612	90%
Bolter - Atlas Copco Boltec MC	120	161	6	4	7	2,780	10%
Mechanized Shotcrete Sprayers - Normet Spraymec 6050 WP	96	129	6	4	7	860	60%
Transmixer Trucks - Normet Utimec LF 600	155	208	4	4	11	2,275	90%
UG Haul Trucks (40T)	375	503	4	4	20	3,115	90%
Scissor Trucks - Getman A64	129	173	5	4	6	1,225	90%
Cable Bolters - Atlas Copco Cabletec LC	120	161	10	4	7	1,704	10%
Production LHD - Sandvik LH514e	132	177	30	X	0	4,768	60%
2.3 yd LHD - Atlas Copco ST2G	86	115	3	4	2	701	60%
3.5 yd LHD - Atlas Copco ST3.5	136	182	4	4	3	701	60%
Mobile Rock Breaker - Sandvik LH514	256	343	5	4	12	0	90%
Medium Reach Rig - MacLean BH-3 Blockholer	147	197	2	4	7	372	10%
Water Cannon - Getman A64	120	161	3	4	6	745	90%
Fuel/Lube Truck - Normet Utimec	120	161	4	4	6	745	90%
Crane Truck - Getman A64	129	173	4	4	6	1,489	50%
Man Haul Vans - Miller Toyota	128	172	19	4	1	1,117	90%
Flat Deck Truck - Getman A64	129	173	4	4	6	701	90%
Crane Truck - Miller Toyota	128	172	4	4	1	1,117	50%
Generator Truck (LHD) - GETMAN A64	120	161	2	4	6	701	60%
UG Grader - CAT 140M2	144	193	3	4	6	1,402	60%
Forklift - CAT P36000	110	148	4	4	3	1,402	60%
UG Water Trucks - Getman A64	129	173	3	4	6	1,402	60%
Conveyor Maint Vehicle - Miller Crane Truck	128	172	2	4	1	1,730	90%
Scissor Lift - Miller Toyota	128	172	9	4	1	1,117	50%
Skid Steer Loader - CAT272D	71	95	2	4	3	745	60%
Raise Bore - Redbore 60	0	0	5	X	0	0	0%
UG Dozer - 2.9m Blade - CAT D6N	112	150	2	4	3	745	60%
Ore Haul Trucks - Powertrans T954 *	388	520	18	4	8	5,061	60%

* *Resolution*

** *Minimum Tier 4 assumed. X denotes a unit with 0 kW rating, electric assumed*

*** *Per unit, including availability and utilization factors*

Conversions	
453.592	*g/lb*
2,000	*lb/ton*
0.0015%	*ppm S in ULSD (GPA 2140)*
7.05	*lb/gal*
1.00E+06	*Btu/MMBtu*
1.998	SO_2/S
1.341	*hp/kw*

Blue values are input; black values are calculated or linked.

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East Plant Diesel Machinery (Non-Emergency) - Emission Factors **Year 14**

Equipment	Rating *kW*	Quantity	CO* *g/kW-hr*	NO_x* *g/kW-hr*	SO_2** *g/kW-hr*	PM* *g/kW-hr*	VOC* *g/kW-hr*
Surface Loader - CAT 962K	165	2	3.5	0.40	-	2.0E-2	0.19
Surface Shotcrete Truck - Highway Legal	128	0	5.0	0.40	-	2.0E-2	0.19
Development LHD - Sandvik LH514	256	9	3.5	0.40	-	2.0E-2	0.19
Development Drill - Atlas Copco M2C	120	6	5.0	0.40	-	2.0E-2	0.19
Production Drill - Simba M6C	112	17	5.0	0.40	-	2.0E-2	0.19
Blind Bore Machine - Redbore 50 MDUR	0	1	electric	electric	electric	electric	electric
Powder Truck - Normet Charmec MF 605 DA	110	13	5.0	0.40	-	2.0E-2	0.19
Bolter - Atlas Copco Boltec MC	120	6	5.0	0.40	-	2.0E-2	0.19
Mechanized Shotcrete Sprayers - Normet Spraymec 6050 WP	96	6	5.0	0.40	-	2.0E-2	0.19
Transmixer Trucks - Normet Utimec LF 600	155	4	3.5	0.40	-	2.0E-2	0.19
UG Haul Trucks (40T)	375	4	3.5	0.40	-	2.0E-2	0.19
Scissor Trucks - Getman A64	129	5	5.0	0.40	-	2.0E-2	0.19
Cable Bolters - Atlas Copco Cabletec LC	120	10	5.0	0.40	-	2.0E-2	0.19
Production LHD - Sandvik LH514e	132	30	electric	electric	electric	electric	electric
2.3 yd LHD - Atlas Copco ST2G	86	3	5.0	0.40	-	2.0E-2	0.19
3.5 yd LHD - Atlas Copco ST3.5	136	4	3.5	0.40	-	2.0E-2	0.19
Mobile Rock Breaker - Sandvik LH514	256	5	3.5	0.40	-	2.0E-2	0.19
Medium Reach Rig - MacLean BH-3 Blockholer	147	2	3.5	0.40	-	2.0E-2	0.19
Water Cannon - Getman A64	120	3	5.0	0.40	-	2.0E-2	0.19
Fuel/Lube Truck - Normet Utimec	120	4	5.0	0.40	-	2.0E-2	0.19
Crane Truck - Getman A64	129	4	5.0	0.40	-	2.0E-2	0.19
Man Haul Vans - Miller Toyota	128	19	5.0	0.40	-	2.0E-2	0.19
Flat Deck Truck - Getman A64	129	4	5.0	0.40	-	2.0E-2	0.19
Crane Truck - Miller Toyota	128	4	5.0	0.40	-	2.0E-2	0.19
Generator Truck (LHD) - GETMAN A64	120	2	5.0	0.40	-	2.0E-2	0.19
UG Grader - CAT 140M2	144	3	3.5	0.40	-	2.0E-2	0.19
Forklift - CAT P36000	110	4	5.0	0.40	-	2.0E-2	0.19
UG Water Trucks - Getman A64	129	3	5.0	0.40	-	2.0E-2	0.19
Conveyor Maint Vehicle - Miller Crane Truck	128	2	5.0	0.40	-	2.0E-2	0.19
Scissor Lift - Miller Toyota	128	9	5.0	0.40	-	2.0E-2	0.19
Skid Steer Loader - CAT272D	71	2	5.0	0.40	-	2.0E-2	0.19
Raise Bore - Redbore 60	0	5	electric	electric	electric	electric	electric
UG Dozer - 2.9m Blade - CAT D6N	112	2	5.0	0.40	-	2.0E-2	0.19
Ore Haul Trucks - Powertrans T954	388	18	3.5	0.40	-	2.0E-2	0.19

* *40 CFR §1039.101, Table 1; 40 CFR § 89.112, Table 1*

** *SO_2 emissions - mass balance based on 15 ppm S content (ULSD)*

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East Plant Diesel Machinery (Non-Emergency) - Short-Term Emission **Year 14**

Equipment	CO *lb/hr*	NO_X *lb/hr*	SO_2* *lb/hr*	PM *lb/hr*	VOC *lb/hr*
Surface Loader - CAT 962K	1.5	0.17	1.8E-3	8.7E-3	8.3E-2
Surface Shotcrete Truck - Highway Legal					
Development LHD - Sandvik LH514	10.7	1.2	1.6E-2	6.1E-2	0.58
Development Drill - Atlas Copco M2C	0.79	6.3E-2	1.0E-3	3.2E-3	3.0E-2
Production Drill - Simba M6C	2.1	0.17	2.9E-3	8.4E-3	8.0E-2
Blind Bore Machine - Redbore 50 MDUR					
Powder Truck - Normet Charmec MF 605 DA	14.2	1.1	1.7E-2	5.7E-2	0.54
Bolter - Atlas Copco Boltec MC	0.79	6.3E-2	1.0E-3	3.2E-3	3.0E-2
Mechanized Shotcrete Sprayers - Normet Spraymec 6050 WP	3.8	0.30	6.2E-3	1.5E-2	0.14
Transmixer Trucks - Normet Utimec LF 600	4.3	0.49	9.2E-3	2.5E-2	0.23
UG Haul Trucks (40T)	10.4	1.2	1.7E-2	6.0E-2	0.57
Scissor Trucks - Getman A64	6.4	0.51	6.6E-3	2.6E-2	0.24
Cable Bolters - Atlas Copco Cabletec LC	1.3	0.11	1.7E-3	5.3E-3	5.0E-2
Production LHD - Sandvik LH514e					
2.3 yd LHD - Atlas Copco ST2G	1.7	0.14	9.2E-4	6.8E-3	6.5E-2
3.5 yd LHD - Atlas Copco ST3.5	2.5	0.29	1.8E-3	1.4E-2	0.14
Mobile Rock Breaker - Sandvik LH514					
Medium Reach Rig - MacLean BH-3 Blockholer	0.23	2.6E-2	3.5E-4	1.3E-3	1.2E-2
Water Cannon - Getman A64	3.6	0.29	4.0E-3	1.4E-2	0.14
Fuel/Lube Truck - Normet Utimec	4.8	0.38	5.3E-3	1.9E-2	0.18
Crane Truck - Getman A64	2.8	0.23	3.0E-3	1.1E-2	0.11
Man Haul Vans - Miller Toyota	24.1	1.9	4.4E-3	9.7E-2	0.92
Flat Deck Truck - Getman A64	5.1	0.41	5.3E-3	2.0E-2	0.19
Crane Truck - Miller Toyota	2.8	0.23	5.1E-4	1.1E-2	0.11
Generator Truck (LHD) - GETMAN A64	1.6	0.13	1.8E-3	6.3E-3	6.0E-2
UG Grader - CAT 140M2	2.0	0.23	2.7E-3	1.1E-2	0.11
Forklift - CAT P36000	2.9	0.23	1.5E-3	1.2E-2	0.11
UG Water Trucks - Getman A64	2.6	0.20	2.7E-3	1.0E-2	9.7E-2
Conveyor Maint Vehicle - Miller Crane Truck	2.5	0.20	4.6E-4	1.0E-2	9.7E-2
Scissor Lift - Miller Toyota	6.3	0.51	1.2E-3	2.5E-2	0.24
Skid Steer Loader - CAT272D	0.94	7.5E-2	8.5E-4	3.8E-3	3.6E-2
Raise Bore - Redbore 60					
UG Dozer - 2.9m Blade - CAT D6N	1.5	0.12	7.7E-4	5.9E-3	5.6E-2
Ore Haul Trucks - Powertrans T954	32.3	3.7	2.1E-2	0.18	1.8
East Plant Underground	**155**	**14.6**	**0.14**	**0.73**	**6.9**
East Plant Surface	**1.5**	**0.17**	**1.8E-3**	**8.7E-3**	**8.3E-2**
East Plant Total	**157**	**14.7**	**0.14**	**0.74**	**7.0**

* *Calculated by mass balance using a 15% fuel contingency*

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East Plant Diesel Machinery (Non-Emergency) - Long-Term Emission **Year 14**

Equipment	CO *ton/yr*	NO_X *ton/yr*	SO_2* *ton/yr*	PM *ton/yr*	VOC *ton/yr*
Surface Loader - CAT 962K	1.4	0.16	1.6E-3	8.1E-3	7.7E-2
Surface Shotcrete Truck - Highway Legal					
Development LHD - Sandvik LH514	11.6	1.3	1.7E-2	6.6E-2	0.63
Development Drill - Atlas Copco M2C	0.29	2.4E-2	3.9E-4	1.2E-3	1.1E-2
Production Drill - Simba M6C	3.6	0.29	5.1E-3	1.4E-2	0.14
Blind Bore Machine - Redbore 50 MDUR					
Powder Truck - Normet Charmec MF 605 DA	4.3	0.35	5.3E-3	1.7E-2	0.16
Bolter - Atlas Copco Boltec MC	1.1	8.8E-2	1.4E-3	4.4E-3	4.2E-2
Mechanized Shotcrete Sprayers - Normet Spraymec 6050 WP	1.6	0.13	2.7E-3	6.6E-3	6.2E-2
Transmixer Trucks - Normet Utimec LF 600	4.9	0.56	1.1E-2	2.8E-2	0.27
UG Haul Trucks (40T)	16.2	1.9	2.7E-2	9.3E-2	0.88
Scissor Trucks - Getman A64	3.9	0.31	4.1E-3	1.6E-2	0.15
Cable Bolters - Atlas Copco Cabletec LC	1.1	9.0E-2	1.5E-3	4.5E-3	4.3E-2
Production LHD - Sandvik LH514e					
2.3 yd LHD - Atlas Copco ST2G	0.60	4.8E-2	3.2E-4	2.4E-3	2.3E-2
3.5 yd LHD - Atlas Copco ST3.5	0.88	0.10	6.5E-4	5.0E-3	4.8E-2
Mobile Rock Breaker - Sandvik LH514					
Medium Reach Rig - MacLean BH-3 Blockholer	4.2E-2	4.8E-3	6.5E-5	2.4E-4	2.3E-3
Water Cannon - Getman A64	1.3	0.11	1.5E-3	5.3E-3	5.1E-2
Fuel/Lube Truck - Normet Utimec	1.8	0.14	2.0E-3	7.1E-3	6.7E-2
Crane Truck - Getman A64	2.1	0.17	2.2E-3	8.5E-3	8.0E-2
Man Haul Vans - Miller Toyota	13.5	1.1	2.5E-3	5.4E-2	0.51
Flat Deck Truck - Getman A64	1.8	0.14	1.9E-3	7.2E-3	6.8E-2
Crane Truck - Miller Toyota	1.6	0.13	2.9E-4	6.3E-3	6.0E-2
Generator Truck (LHD) - GETMAN A64	0.56	4.4E-2	6.2E-4	2.2E-3	2.1E-2
UG Grader - CAT 140M2	1.4	0.16	1.9E-3	8.0E-3	7.6E-2
Forklift - CAT P36000	2.0	0.16	1.1E-3	8.2E-3	7.7E-2
UG Water Trucks - Getman A64	1.8	0.14	1.9E-3	7.2E-3	6.8E-2
Conveyor Maint Vehicle - Miller Crane Truck	2.2	0.18	4.0E-4	8.8E-3	8.3E-2
Scissor Lift - Miller Toyota	3.5	0.28	6.5E-4	1.4E-2	0.13
Skid Steer Loader - CAT272D	0.35	2.8E-2	3.2E-4	1.4E-3	1.3E-2
Raise Bore - Redbore 60					
UG Dozer - 2.9m Blade - CAT D6N	0.55	4.4E-2	2.9E-4	2.2E-3	2.1E-2
Ore Haul Trucks - Powertrans T954	81.8	9.3	5.3E-2	0.47	4.4
East Plant Underground	**167**	**17.3**	**0.15**	**0.87**	**8.2**
East Plant Surface	**1.4**	**0.16**	**1.6E-3**	**8.1E-3**	**7.7E-2**
East Plant Total	**168**	**17.5**	**0.15**	**0.87**	**8.3**

* *Calculated by mass balance using a 15% fuel contingency*

East Plant Diesel Machinery (Non-Emergency) - Fugitive Emissions from Vehicle Travel - Vehicle Specifications **Year 14**

Equipment	Quantity	Ann. Op. Hours[a]	Speed[b] *mph*	Silt[c] %	Weight[b] *ton*
Surface Loader - CAT 962K	2	1,862	5.0	3.0	29.4
Surface Shotcrete Truck - Highway Legal	0	0	5.0	3.0	4.0
Development LHD - Sandvik LH514	9	2,182	12.0	3.0	49.7
Development Drill - Atlas Copco M2C	6	741	5.0	3.0	29.8
Production Drill - Simba M6C	17	3,454	5.0	3.0	23.0
Blind Bore Machine - Redbore 50 MDUR	1	2,443	0.0	3.0	34.2
Powder Truck - Normet Charmec MF 605 DA	13	612	5.0	3.0	19.8
Bolter - Atlas Copco Boltec MC	6	2,780	5.0	3.0	23.8
Mechanized Shotcrete Sprayers - Normet Spraymec 6050 WP	6	860	5.0	3.0	14.9
Transmixer Trucks - Normet Utimec LF 600	4	2,275	15.0	3.0	23.5
UG Haul Trucks (40T)	4	3,115	15.0	3.0	44.1
Scissor Trucks - Getman A64	5	1,225	12.0	3.0	12.5
Cable Bolters - Atlas Copco Cabletec LC	10	1,704	5.0	3.0	33.1
Production LHD - Sandvik LH514e	30	4,768	15.0	3.0	50.2
2.3 yd LHD - Atlas Copco ST2G	3	701	12.0	3.0	16.5
3.5 yd LHD - Atlas Copco ST3.5	4	701	12.0	3.0	22.2
Mobile Rock Breaker - Sandvik LH514	5	0	12.0	3.0	16.0
Medium Reach Rig - MacLean BH-3 Blockholer	2	372	5.0	3.0	21.5
Water Cannon - Getman A64	3	745	10.0	3.0	20.0
Fuel/Lube Truck - Normet Utimec	4	745	15.0	3.0	12.5
Crane Truck - Getman A64	4	1,489	15.0	3.0	16.5
Man Haul Vans - Miller Toyota	19	1,117	15.0	3.0	4.0
Flat Deck Truck - Getman A64	4	701	15.0	3.0	12.0
Crane Truck - Miller Toyota	4	1,117	15.0	3.0	17.0
Generator Truck (LHD) - GETMAN A64	2	701	5.0	3.0	17.0
UG Grader - CAT 140M2		*grader-specific fugitive emissions on p. 8*			
Forklift - CAT P36000	4	1,402	5.0	3.0	30.2
UG Water Trucks - Getman A64	3	1,402	15.0	3.0	17.0
Conveyor Maint Vehicle - Miller Crane Truck	2	1,730	15.0	3.0	17.0
Scissor Lift - Miller Toyota	9	1,117	15.0	3.0	4.4
Skid Steer Loader - CAT272D	2	745	5.0	3.0	5.1
Raise Bore - Redbore 60	5	0	0.0	3.0	13.5
UG Dozer - 2.9m Blade - CAT D6N		*dozer-specific fugitive emissions on p. 8*			
Ore Haul Trucks - Powertrans T954	18	5,061	17.1	3.0	211.1
Surface Mean Fleet Weight					29.4
Underground Mean Fleet Weight					40.9

[a] *Per unit, including availability and utilization factors*

[b] *Resolution*

[c] *AP-42, Chapter 13.2.2*

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East Plant Diesel Machinery (Non-Emergency) - Fugitive Emissions from Vehicle Travel - Emission Factors **Year 14**

Equipment	PM* *lb/VMT*	PM_{10}* *lb/VMT*	$PM_{2.5}$* *lb/VMT*
Surface Loader - CAT 962K	5.2	1.2	0.12
Surface Shotcrete Truck - Highway Legal	5.2	1.2	0.12
Development LHD - Sandvik LH514	6.0	1.4	0.14
Development Drill - Atlas Copco M2C	6.0	1.4	0.14
Production Drill - Simba M6C	6.0	1.4	0.14
Blind Bore Machine - Redbore 50 MDUR	6.0	1.4	0.14
Powder Truck - Normet Charmec MF 605 DA	6.0	1.4	0.14
Bolter - Atlas Copco Boltec MC	6.0	1.4	0.14
Mechanized Shotcrete Sprayers - Normet Spraymec 6050 WP	6.0	1.4	0.14
Transmixer Trucks - Normet Utimec LF 600	6.0	1.4	0.14
UG Haul Trucks (40T)	6.0	1.4	0.14
Scissor Trucks - Getman A64	6.0	1.4	0.14
Cable Bolters - Atlas Copco Cabletec LC	6.0	1.4	0.14
Production LHD - Sandvik LH514e	6.0	1.4	0.14
2.3 yd LHD - Atlas Copco ST2G	6.0	1.4	0.14
3.5 yd LHD - Atlas Copco ST3.5	6.0	1.4	0.14
Mobile Rock Breaker - Sandvik LH514	6.0	1.4	0.14
Medium Reach Rig - MacLean BH-3 Blockholer	6.0	1.4	0.14
Water Cannon - Getman A64	6.0	1.4	0.14
Fuel/Lube Truck - Normet Utimec	6.0	1.4	0.14
Crane Truck - Getman A64	6.0	1.4	0.14
Man Haul Vans - Miller Toyota	6.0	1.4	0.14
Flat Deck Truck - Getman A64	6.0	1.4	0.14
Crane Truck - Miller Toyota	6.0	1.4	0.14
Generator Truck (LHD) - GETMAN A64	6.0	1.4	0.14
UG Grader - CAT 140M2			
Forklift - CAT P36000	6.0	1.4	0.14
UG Water Trucks - Getman A64	6.0	1.4	0.14
Conveyor Maint Vehicle - Miller Crane Truck	6.0	1.4	0.14
Scissor Lift - Miller Toyota	6.0	1.4	0.14
Skid Steer Loader - CAT272D	6.0	1.4	0.14
Raise Bore - Redbore 60	6.0	1.4	0.14
UG Dozer - 2.9m Blade - CAT D6N			
Ore Haul Trucks - Powertrans T954	6.0	1.4	0.14

* *Control from precip and water & chemical dust suppressant applied to emission factors*

Unpaved Roads - Predictive Emission Factor Equation & Constants*

$E = k \times (s / 12)^a \times (W / 3)^b \times (365 - P) / 365$

k, a, b - empirical constants

s - surface material silt content %

W - mean vehicle wt ton

P - Days of >0.01" Precip

	Empirical Constants for Industrial Roads			
Constant	PM	PM_{10}	$PM_{2.5}$
k	4.9	1.5	0.15
a	0.7	0.9	0.9
b	0.45	0.45	0.45

* *AP-42, 13.2.2, Equation 1a & 2, Table 13.2.2-2, Industrial Roads, Rev. 8/04*

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East Plant Diesel Machinery (Non-Emergency) - Fugitive Emissions from Vehicle Travel - Emissions (Short-Term & Long-Term) **Year 14**

Equipment	PM *lb/hr*	PM_{10} *lb/hr*	$PM_{2.5}$ *lb/hr*	PM *ton/yr*	PM_{10} *ton/yr*	$PM_{2.5}$ *ton/yr*
Surface Loader - CAT 962K	51.9	12.0	1.2	39.8	9.2	0.92
Surface Shotcrete Truck - Highway Legal						
Development LHD - Sandvik LH514	649	151	15.1	708	164	16.4
Development Drill - Atlas Copco M2C	180	41.8	4.2	66.8	15.5	1.6
Production Drill - Simba M6C	511	119	11.9	883	205	20.5
Blind Bore Machine - Redbore 50 MDUR						
Powder Truck - Normet Charmec MF 605 DA	391	90.7	9.1	120	27.7	2.8
Bolter - Atlas Copco Boltec MC	180	41.8	4.2	251	58.2	5.8
Mechanized Shotcrete Sprayers - Normet Spraymec 6050 WP	180	41.8	4.2	77.5	18.0	1.8
Transmixer Trucks - Normet Utimec LF 600	361	83.7	8.4	410	95.2	9.5
UG Haul Trucks (40T)	361	83.7	8.4	562	130	13.0
Scissor Trucks - Getman A64	361	83.7	8.4	221	51.3	5.1
Cable Bolters - Atlas Copco Cabletec LC	301	69.7	7.0	256	59.4	5.9
Production LHD - Sandvik LH514e	2,706	628	62.8	6,451	1,497	150
2.3 yd LHD - Atlas Copco ST2G	216	50.2	5.0	75.9	17.6	1.8
3.5 yd LHD - Atlas Copco ST3.5	289	67.0	6.7	101	23.5	2.3
Mobile Rock Breaker - Sandvik LH514						
Medium Reach Rig - MacLean BH-3 Blockholer	60.1	13.9	1.4	11.2	2.6	0.26
Water Cannon - Getman A64	180	41.8	4.2	67.2	15.6	1.6
Fuel/Lube Truck - Normet Utimec	361	83.7	8.4	134	31.2	3.1
Crane Truck - Getman A64	361	83.7	8.4	269	62.3	6.2
Man Haul Vans - Miller Toyota	1,714	398	39.8	957	222	22.2
Flat Deck Truck - Getman A64	361	83.7	8.4	126	29.3	2.9
Crane Truck - Miller Toyota	361	83.7	8.4	201	46.7	4.7
Generator Truck (LHD) - GETMAN A64	60.1	13.9	1.4	21.1	4.9	0.49
UG Grader - CAT 140M2						
Forklift - CAT P36000	120	27.9	2.8	84.3	19.6	2.0
UG Water Trucks - Getman A64	271	62.8	6.3	190	44.0	4.4
Conveyor Maint Vehicle - Miller Crane Truck	180	41.8	4.2	156	36.2	3.6
Scissor Lift - Miller Toyota	812	188	18.8	453	105	10.5
Skid Steer Loader - CAT272D	60.1	13.9	1.4	22.4	5.2	0.52
Raise Bore - Redbore 60						
UG Dozer - 2.9m Blade - CAT D6N						
Ore Haul Trucks - Powertrans T954	1,849	429	42.9	4,680	1,086	109
Vehicle Travel - East Plant Underground	**13,437**	**3,117**	**312**	**17,557**	**4,073**	**407**
Vehicle Travel - East Plant Surface	**51.9**	**12.0**	**1.2**	**39.8**	**9.2**	**0.92**
Vehicle Travel - East Plant Total	**13,488**	**3,129**	**313**	**17,597**	**4,082**	**408**

Annual Unpaved Road Controls

	Surface	UG	Reference
Days of >0.01" Precip	64	0**	*EPS Precip Data (days >0.01'')*
Water & Chemical Suppression*	90%*	95%	*AP-42, Figure 13.2.2-2, Rev. 11/06*

* *Control efficiency is based on AP-42 Chapter 13.2.2, Unpaved Roads. Figure 13.2.2-2 provides the control efficiencies achievable with watering.*

** *Control efficiency is based on AP-42 Chapter 13.2.2, Unpaved Roads. Underground will be constantly watered due to wet conditions.*

East Plant Diesel Machinery (Non-Emergency) - Fugitive Emissions from Grading/Dozing - Emissions (Short-Term & Long-Term) **Year 14**

Emission Factors

Grading	PM	PM_{10}	$PM_{2.5}$	EF Unit
UG Grader - CAT 140M2	3.0	0.96	9.2E-2	*lb/VMT*
Dozing				
UG Dozer - 2.9m Blade - CAT D6N	3.5	0.56	0.37	*lb/hr*

Emissions

	Quantity	Operation *hr/yr*	PM *lb/hr*	PM_{10} *lb/hr*	$PM_{2.5}$ *lb/hr*	PM *ton/yr*	PM_{10} *ton/yr*	$PM_{2.5}$ *ton/yr*
Grading								
UG Grader - CAT 140M2	3	1,612	49.6	16.1	1.5	40.0	12.9	1.2
Dozing								
UG Dozer - 2.9m Blade - CAT D6N	2	856	7.0	1.1	0.74	3.0	0.48	0.32
Grading - East Plant Underground			**49.6**	**16.1**	**1.5**	**40.0**	**12.9**	**1.2**
Grading - East Plant Surface								
Dozing - East Plant Underground			**7.0**	**1.1**	**0.74**	**3.0**	**0.48**	**0.32**
Dozing - East Plant Surface								
Grading/Dozing - East Plant Total			**56.7**	**17.2**	**2.3**	**43.0**	**13.4**	**1.6**

East Plant Underground Fleet - Uncontrolled Fugitive Dust Emissions

	PM *lb/hr*	PM_{10} *lb/hr*	$PM_{2.5}$ *lb/hr*	PM *ton/yr*	PM_{10} *ton/yr*	$PM_{2.5}$ *ton/yr*
Vehicle Travel & Grading - East Plant Underground	**13,486**	**3,133**	**313**	**17,597**	**4,086**	**409**
Dozing - East Plant Underground	**7.0**	**1.1**	**0.74**	**3.0**	**0.48**	**0.32**
Fugitive Dust - East Plant Underground Total	**13,493**	**3,134**	**314**	**17,600**	**4,087**	**409**

East Plant Surface Fleet - Uncontrolled Fugitive Dust Emissions

	PM *lb/hr*	PM_{10} *lb/hr*	$PM_{2.5}$ *lb/hr*	PM *ton/yr*	PM_{10} *ton/yr*	$PM_{2.5}$ *ton/yr*
Vehicle Travel & Grading - East Plant Surface	**51.9**	**12.0**	**1.2**	**39.8**	**9.2**	**0.92**
Dozing - East Plant Surface						
Fugitive Dust - East Plant Surface Total	**51.9**	**12.0**	**1.2**	**39.8**	**9.2**	**0.92**

Dozing and Grading Emission Factor Equations *AP-42, 11.9, Table 11.9-1 (overburden), Rev. 7/98*

		Scaling Factor PM_{10}	Scaling Factor $PM_{2.5}$	
Dozing (PM)	$E = (5.7 * s^{1.2}) / (M^{1.3})$		0.105	
Dozing (PM_{15})	$E = (1.0 * s^{1.5}) / (M^{1.4})$	0.75		
Grading (PM)	$E = 0.040 * S^{2.5}$		0.031	
Grading (PM_{15})	$E = 0.051 * S^{2.0}$	0.6		
s = material silt content %			3.0	*AP-42, Chapter 13.2.2, Related Information, r13s0202_dec03.xls*
M = material moisture content %			4.0	*Resolution Copper*
S = mean vehicle speed mph			5.59	*Phone Meeting with C. Pascoe 10/11/12 (9 km/hr)*
Fuel Contingency			15%	*RCM Mine Data for Ari Modelling 2012.xlsx*

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Mill Diesel Machinery (Non-Emergency)

Mobile Equipment	Rating *kW*	Rating *hp*	Quantity	EPA Tier	Fuel *gal/hr*	Ann. Op. Hours	Load Factor (%)**
Dozer (Coarse Ore Stockpile)	219	294	1	4	15	6,132	60%
Boom Truck (Pebble Crusher)	219	294	1	4	15	2,190	60%
Wheel Loader (2 yrs) - 992 class	189	254	2	4	13	6,130	60%
Forklift (Maintenance)	58	78	1	4	4	2,190	60%
Bobcat	58	78	2	4	4	2,920	60%
Flatbed Truck	146	196	1	4	10*	2,190	90%
Forklift (Moly Plant-Lg)	146	196	1	4	10*	2,920	60%
Stormwater Mgmt. Pump	153	205	3	4	10	1,095	90%
Stormwater Mgmt. Pump	388	520	0	4	27	1,095	90%
Flatbed Truck (1 ton, nonroad)	287	385	2	4	20	1,095	90%
Grader	117	157	1	4	8	2,190	60%
Backhoe	112	150	1	4	4	2,190	60%
Water Truck	219	294	2	4	15	2,190	60%
Boom Truck	117	157	1	4	8	2,190	60%
Fuel Lube Truck	224	300	1	4	3	4,380	90%
20T Crane	75	100	1	4	8	1,752	50%
60T Crane	117	157	1	4	8	876	50%
Mobile Air Compressor	44	59	2	4	3	1,095	90%
Light Tower	7	10	2	4	1	4,380	90%
Fusion Machine	44	59	1	4	3	2,190	90%
Lg Forklift (Warehouse)	146	196	1	4	10*	2,190	60%
Sm Forklift (Warehouse)	146	196	1	4	10*	2,190	60%
Highrail Maintenance Vehicle	146	196	1	4	10*	876	80%
Bucket Truck (Electrical)	146	196	1	4	10*	876	90%
Vacuum Truck	146	196	1	4	10*	876	90%
Man/Boom Lifts	146	196	2	4	10*	2,190	50%
Loader (Clean-up)-972 Class	146	196	1	4	10*	2,190	60%

* *Conservative Assumption*

** *Resolution*

Conversions		
453.592	*g/lb*	
2,000	*lb/ton*	
0.0015%	*ppm S in ULSD (GPA 2140)*	
7.05	*lb/gal*	
1.00E+06	*Btu/MMBtu*	
1.998	SO_2/S	
1.341	*hp/kw*	
7,000	*Btu/hp-hr*	*AP-42, Table 3.4-1, Footnote e, Diesel, Rev. 10/96*
137,000	*Btu/gal*	*AP-42, Appendix A, Diesel, Rev. 9/85*
8,760	*hr/yr*	

Blue values are input; black values are calculated or linked.

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Mill Diesel Machinery (Non-Emergency) - Emission Factors

Equipment	Rating *kW*	Quantity	CO* *g/kW-hr*	NO_x* *g/kW-hr*	SO_2** *g/kW-hr*	PM* *g/kW-hr*	VOC* *g/kW-hr*
Dozer (Coarse Ore Stockpile)	219	1	3.5	0.40	-	2.0E-2	0.19
Boom Truck (Pebble Crusher)	219	1	3.5	0.40	-	2.0E-2	0.19
Wheel Loader (2 yrs) - 992 class	189	2	3.5	0.40	-	2.0E-2	0.19
Forklift (Maintenance)	58	1	5.0	0.40	-	2.0E-2	0.19
Bobcat	58	2	5.0	0.40	-	2.0E-2	0.19
Flatbed Truck	146	1	3.5	0.40	-	2.0E-2	0.19
Forklift (Moly Plant-Lg)	146	1	3.5	0.40	-	2.0E-2	0.19
Stormwater Mgmt. Pump	153	3	3.5	0.40	-	2.0E-2	0.19
Stormwater Mgmt. Pump	388	0	3.5	0.40	-	2.0E-2	0.19
Flatbed Truck (1 ton, nonroad)	287	2	3.5	0.40	-	2.0E-2	0.19
Grader	117	1	5.0	0.40	-	2.0E-2	0.19
Backhoe	112	1	5.0	0.40	-	2.0E-2	0.19
Water Truck	219	2	3.5	0.40	-	2.0E-2	0.19
Boom Truck	117	1	5.0	0.40	-	2.0E-2	0.19
Fuel Lube Truck	224	1	3.5	0.40	-	2.0E-2	0.19
20T Crane	75	1	5.0	0.40	-	2.0E-2	0.19
60T Crane	117	1	5.0	0.40	-	2.0E-2	0.19
Mobile Air Compressor	44	2	5.0	4.7	-	3.0E-2	4.7
Light Tower	7	2	6.6	7.5	-	0.40	7.5
Fusion Machine	44	1	5.0	4.7	-	3.0E-2	4.7
Lg Forklift (Warehouse)	146	1	3.5	0.40	-	2.0E-2	0.19
Sm Forklift (Warehouse)	146	1	3.5	0.40	-	2.0E-2	0.19
Highrail Maintenance Vehicle	146	1	3.5	0.40	-	2.0E-2	0.19
Bucket Truck (Electrical)	146	1	3.5	0.40	-	2.0E-2	0.19
Vacuum Truck	146	1	3.5	0.40	-	2.0E-2	0.19
Man/Boom Lifts	146	2	3.5	0.40	-	2.0E-2	0.19
Loader (Clean-up)-972 Class	146	1	3.5	0.40	-	2.0E-2	0.19

* *40 CFR §1039.101, Table 1*

** *SO_2 emissions - mass balance based on 15 ppm S content (ULSD)*

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Mill Diesel Machinery (Non-Emergency) - Short-Term Emission

Equipment	CO *lb/hr*	NO_X *lb/hr*	SO_2* *lb/hr*	PM *lb/hr*	VOC *lb/hr*
Dozer (Coarse Ore Stockpile)	1.0	0.12	2.2E-3	5.8E-3	5.5E-2
Boom Truck (Pebble Crusher)	1.0	0.12	2.2E-3	5.8E-3	5.5E-2
Wheel Loader (2 yrs) - 992 class	1.8	0.20	3.8E-3	1.0E-2	9.5E-2
Forklift (Maintenance)	0.39	3.1E-2	5.8E-4	1.5E-3	1.5E-2
Bobcat	0.77	6.2E-2	1.2E-3	3.1E-3	2.9E-2
Flatbed Truck	1.0	0.12	2.2E-3	5.8E-3	5.5E-2
Forklift (Moly Plant-Lg)	0.68	7.7E-2	1.5E-3	3.9E-3	3.7E-2
Stormwater Mgmt. Pump	3.2	0.36	6.9E-3	1.8E-2	0.17
Stormwater Mgmt. Pump					
Flatbed Truck (1 ton, nonroad)	4.0	0.46	8.6E-3	2.3E-2	0.22
Grader	0.77	6.2E-2	1.2E-3	3.1E-3	2.9E-2
Backhoe	0.74	5.9E-2	5.8E-4	3.0E-3	2.8E-2
Water Truck	2.0	0.23	4.4E-3	1.2E-2	0.11
Boom Truck	0.77	6.2E-2	1.2E-3	3.1E-3	2.9E-2
Fuel Lube Truck	1.6	0.18	6.6E-4	8.9E-3	8.4E-2
20T Crane	0.41	3.3E-2	9.7E-4	1.6E-3	1.6E-2
60T Crane	0.64	5.1E-2	9.7E-4	2.6E-3	2.4E-2
Mobile Air Compressor	0.87	0.82	1.3E-3	5.2E-3	0.82
Light Tower	0.19	0.22	2.2E-4	1.2E-2	0.22
Fusion Machine	0.43	0.41	6.6E-4	2.6E-3	0.41
Lg Forklift (Warehouse)	0.68	7.7E-2	1.5E-3	3.9E-3	3.7E-2
Sm Forklift (Warehouse)	0.68	7.7E-2	1.5E-3	3.9E-3	3.7E-2
Highrail Maintenance Vehicle	0.90	0.10	1.9E-3	5.1E-3	4.9E-2
Bucket Truck (Electrical)	1.0	0.12	2.2E-3	5.8E-3	5.5E-2
Vacuum Truck	1.0	0.12	2.2E-3	5.8E-3	5.5E-2
Man/Boom Lifts	1.1	0.13	2.4E-3	6.4E-3	6.1E-2
Loader (Clean-up)-972 Class	0.68	7.7E-2	1.5E-3	3.9E-3	3.7E-2
Mill Stationary	**3.2**	**0.36**	**6.9E-3**	**1.8E-2**	**0.17**
Mill Mobile	**25.1**	**4.0**	**4.7E-2**	**0.15**	**2.7**
Mill Total	**28.3**	**4.4**	**5.4E-2**	**0.16**	**2.8**

* *Calculated by mass balance using a 15% fuel contingency*

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Mill Diesel Machinery (Non-Emergency) - Long-Term Emission

Equipment	CO *ton/yr*	NO_X *ton/yr*	SO_2* *ton/yr*	PM *ton/yr*	VOC *ton/yr*
Dozer (Coarse Ore Stockpile)	3.1	0.36	6.7E-3	1.8E-2	0.17
Boom Truck (Pebble Crusher)	1.1	0.13	2.4E-3	6.3E-3	6.0E-2
Wheel Loader (2 yrs) - 992 class	5.4	0.61	1.2E-2	3.1E-2	0.29
Forklift (Maintenance)	0.42	3.4E-2	6.4E-4	1.7E-3	1.6E-2
Bobcat	1.1	9.0E-2	1.7E-3	4.5E-3	4.3E-2
Flatbed Truck	1.1	0.13	2.4E-3	6.3E-3	6.0E-2
Forklift (Moly Plant-Lg)	0.99	0.11	2.1E-3	5.6E-3	5.4E-2
Stormwater Mgmt. Pump	1.7	0.20	3.8E-3	1.0E-2	9.5E-2
Stormwater Mgmt. Pump					
Flatbed Truck (1 ton, nonroad)	2.2	0.25	4.7E-3	1.2E-2	0.12
Grader	0.85	6.8E-2	1.3E-3	3.4E-3	3.2E-2
Backhoe	0.81	6.5E-2	6.4E-4	3.2E-3	3.1E-2
Water Truck	2.2	0.25	4.8E-3	1.3E-2	0.12
Boom Truck	0.85	6.8E-2	1.3E-3	3.4E-3	3.2E-2
Fuel Lube Truck	3.4	0.39	1.4E-3	1.9E-2	0.18
20T Crane	0.36	2.9E-2	8.5E-4	1.4E-3	1.4E-2
60T Crane	0.28	2.3E-2	4.3E-4	1.1E-3	1.1E-2
Mobile Air Compressor	0.48	0.45	7.2E-4	2.9E-3	0.45
Light Tower	0.42	0.48	4.8E-4	2.5E-2	0.48
Fusion Machine	0.48	0.45	7.2E-4	2.9E-3	0.45
Lg Forklift (Warehouse)	0.74	8.5E-2	1.6E-3	4.2E-3	4.0E-2
Sm Forklift (Warehouse)	0.74	8.5E-2	1.6E-3	4.2E-3	4.0E-2
Highrail Maintenance Vehicle	0.39	4.5E-2	8.5E-4	2.3E-3	2.1E-2
Bucket Truck (Electrical)	0.44	5.1E-2	9.6E-4	2.5E-3	2.4E-2
Vacuum Truck	0.44	5.1E-2	9.6E-4	2.5E-3	2.4E-2
Man/Boom Lifts	1.2	0.14	2.7E-3	7.0E-3	6.7E-2
Loader (Clean-up)-972 Class	0.74	8.5E-2	1.6E-3	4.2E-3	4.0E-2
Mill Stationary	**1.7**	**0.20**	**3.8E-3**	**1.0E-2**	**9.5E-2**
Mill Mobile	**30.3**	**4.5**	**5.5E-2**	**0.19**	**2.9**
Mill Total	**32.0**	**4.7**	**5.9E-2**	**0.20**	**3.0**

* *Calculated by mass balance using a 15% fuel contingency*

Mill Diesel Machinery (Non-Emergency) - Fugitive Emissions from Vehicle Travel - Vehicle Specifications

Equipment	Quantity	Ann. Op. Hours[a]	Speed[b] *mph*	Silt[c] *%*	Weight[b] *ton*
Dozer (Coarse Ore Stockpile)		*dozer-specific fugitive emissions on p. 8*			
Boom Truck (Pebble Crusher)	1	2,190	15	3.0	27
Wheel Loader (2 yrs) - 992 class			*paved surface*		
Forklift (Maintenance)			*paved surface*		
Bobcat			*paved surface*		
Flatbed Truck	1	2,190	25	3.0	27
Forklift (Moly Plant-Lg)			*paved surface*		
Stormwater Mgmt. Pump			*stationary*		
Stormwater Mgmt. Pump			*stationary*		
Flatbed Truck (1 ton, nonroad)	2	1,095	15	3.0	2
Grader		*grader-specific fugitive emissions on p. 8*			
Backhoe	1	2,190	5	3.0	12
Water Truck	2	2,190	15	3.0	10
Boom Truck	1	2,190	15	3.0	17
Fuel Lube Truck	1	4,380	15	3.0	50
20T Crane	1	1,752	10	3.0	27
60T Crane	1	876	10	3.0	45
Mobile Air Compressor	2	1,095	5	3.0	4
Light Tower	2	4,380	5	3.0	1
Fusion Machine	1	2,190	1	3.0	2
Lg Forklift (Warehouse)			*paved surface*		
Sm Forklift (Warehouse)			*paved surface*		
Highrail Maintenance Vehicle	1	876	5	3.0	2
Bucket Truck (Electrical)	1	876	15	3.0	12
Vacuum Truck	1	876	15	3.0	2
Man/Boom Lifts	2	2,190	5	3.0	12
Loader (Clean-up)-972 Class	1	2,190	5	3.0	23
Mean Vehicle Weight					13.8

[a] *Per unit, including availability and utilization factors*

[b] *Resolution*

[c] *AP-42, Chapter 13.2.2*

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Mill Diesel Machinery (Non-Emergency) - Fugitive Emissions from Vehicle Travel - Emission Factors

Equipment	PM *lb/VMT*	PM_{10} *lb/VMT*	$PM_{2.5}$ *lb/VMT*
Dozer (Coarse Ore Stockpile)			
Boom Truck (Pebble Crusher)	3.7	0.85	8.5E-2
Wheel Loader (2 yrs) - 992 class			
Forklift (Maintenance)			
Bobcat			
Flatbed Truck	3.7	0.85	8.5E-2
Forklift (Moly Plant-Lg)			
Stormwater Mgmt. Pump			
Stormwater Mgmt. Pump			
Flatbed Truck (1 ton, nonroad)	3.7	0.85	8.5E-2
Grader			
Backhoe	3.7	0.85	8.5E-2
Water Truck	3.7	0.85	8.5E-2
Boom Truck	3.7	0.85	8.5E-2
Fuel Lube Truck	3.7	0.85	8.5E-2
20T Crane	3.7	0.85	8.5E-2
60T Crane	3.7	0.85	8.5E-2
Mobile Air Compressor	3.7	0.85	8.5E-2
Light Tower	3.7	0.85	8.5E-2
Fusion Machine	3.7	0.85	8.5E-2
Lg Forklift (Warehouse)			
Sm Forklift (Warehouse)			
Highrail Maintenance Vehicle	3.7	0.85	8.5E-2
Bucket Truck (Electrical)	3.7	0.85	8.5E-2
Vacuum Truck	3.7	0.85	8.5E-2
Man/Boom Lifts	3.7	0.85	8.5E-2
Loader (Clean-up)-972 Class	3.7	0.85	8.5E-2

Unpaved Roads - Predictive Emission Factor Equation & Constants*

$E = k \times (s / 12)^a \times (W / 3)^b \times (365 - P) / 365$

k, a, b - empirical constants

s - surface material silt content %

W - mean vehicle wt ton

P - Days of >0.01" Precip

	Empirical Constants for Industrial Roads			
Constant	PM	PM_{10}	$PM_{2.5}$
k	4.9	1.5	0.15
a	0.7	0.9	0.9
b	0.45	0.45	0.45

* *AP-42, 13.2.2, Equation 1a & 2, Table 13.2.2-2, Industrial Roads, Rev. 8/04*

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Mill Diesel Machinery (Non-Emergency) - Fugitive Emissions from Vehicle Travel - Emissions (Short-Term & Long-Term)

Equipment	PM *lb/hr*	PM_{10} *lb/hr*	$PM_{2.5}$ *lb/hr*	PM *ton/yr*	PM_{10} *ton/yr*	$PM_{2.5}$ *ton/yr*
Dozer (Coarse Ore Stockpile)						
Boom Truck (Pebble Crusher)	55.3	12.8	1.3	50.9	11.8	1.2
Wheel Loader (2 yrs) - 992 class						
Forklift (Maintenance)						
Bobcat						
Flatbed Truck	92.1	21.4	2.1	84.8	19.7	2.0
Forklift (Moly Plant-Lg)						
Stormwater Mgmt. Pump						
Stormwater Mgmt. Pump						
Flatbed Truck (1 ton, nonroad)	111	25.6	2.6	50.9	11.8	1.2
Grader						
Backhoe	18.4	4.3	0.43	17.0	3.9	0.39
Water Truck	111	25.6	2.6	102	23.6	2.4
Boom Truck	55.3	12.8	1.3	50.9	11.8	1.2
Fuel Lube Truck	55.3	12.8	1.3	102	23.6	2.4
20T Crane	36.8	8.5	0.85	27.1	6.3	0.63
60T Crane	36.8	8.5	0.85	13.6	3.1	0.31
Mobile Air Compressor	36.8	8.5	0.85	17.0	3.9	0.39
Light Tower	36.8	8.5	0.85	67.9	15.7	1.6
Fusion Machine	3.7	0.85	8.5E-2	3.4	0.79	7.9E-2
Lg Forklift (Warehouse)						
Sm Forklift (Warehouse)						
Highrail Maintenance Vehicle	18.4	4.3	0.43	6.8	1.6	0.16
Bucket Truck (Electrical)	55.3	12.8	1.3	20.4	4.7	0.47
Vacuum Truck	55.3	12.8	1.3	20.4	4.7	0.47
Man/Boom Lifts	36.8	8.5	0.85	33.9	7.9	0.79
Loader (Clean-up)-972 Class	18.4	4.3	0.43	17.0	3.9	0.39
Vehicle Travel - Mill Total	**833**	**193**	**19.3**	**685**	**159**	**15.9**

Daily Unpaved Road Controls

	Surface
days of <0.01" Precip	307

Daily Unpaved Road EF Multiplier

	Surface
days of <0.01" Precip	1

Annual Unpaved Road Controls

	Surface	Reference
Days of >0.01" Precip	58	*WPS Precip Data (days >0.01'')*
Water & Chemical Suppression*	90%	*AP-42, Figure 13.2.2-2, Rev. 11/06*

* *Control efficiency is based on AP-42 Chapter 13.2.2, Unpaved Roads. Figure 13.2.2-2 provides the control efficiencies achievable with watering*

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI		BY: N. Tipple	
	PROJECT NO: 262	PAGE: 8	OF: 8	SHEET: Mill_Fleet
AIR EMISSION CALCULATIONS	SUBJECT: Diesel Fleet Calculations - Mill		DATE: March 15, 2018	

Mill Diesel Machinery (Non-Emergency) - Fugitive Emissions from Grading/Dozing - Emissions (Short-Term & Long-Term)

Emission Factors

Grading	PM	PM_{10}	$PM_{2.5}$	EF Unit
Grader	3.0	0.96	9.2E-2	*lb/VMT*
Dozing				
Dozer (Coarse Ore Stockpile)	3.5	0.56	0.37	*lb/hr*

Emissions

	Quantity	Operation *hr/yr*	PM *lb/hr*	PM_{10} *lb/hr*	$PM_{2.5}$ *lb/hr*	PM *ton/yr*	PM_{10} *ton/yr*	$PM_{2.5}$ *ton/yr*
Grading								
Grader	1.0	2,519	16.5	5.4	0.51	20.8	6.7	0.65
Dozing								
Dozer (Coarse Ore Stockpile)*	1.0	7,052	3.5	0.56	0.37	12.4	2.0	1.3
Grading - Mill			**16.5**	**5.4**	**0.51**	**20.8**	**6.7**	**0.65**
Dozing - Mill			**3.5**	**0.56**	**0.37**	**12.4**	**2.0**	**1.3**
Grading/Dozing - Tailings Total			**20.1**	**5.9**	**0.88**	**33.2**	**8.7**	**1.9**

Mill Fleet - Uncontrolled Fugitive Dust Emissions

	PM *lb/hr*	PM_{10} *lb/hr*	$PM_{2.5}$ *lb/hr*	PM *ton/yr*	PM_{10} *ton/yr*	$PM_{2.5}$ *ton/yr*
Vehicle Travel & Grading - Mill	**849**	**199**	**19.8**	**706**	**166**	**16.5**
Dozing - Mill	**3.5**	**0.56**	**0.37**	**12.4**	**2.0**	**1.3**
Fugitive Dust - Mill Total	**853**	**199**	**20.2**	**719**	**168**	**17.8**

Dozing and Grading Emission Factor Equations *AP-42, 11.9, Table 11.9-1 (overburden), Rev. 7/98*

		Scaling Factor PM_{10}	Scaling Factor $PM_{2.5}$	
Dozing (PM)	$E = (5.7 * s^{1.2}) / (M^{1.3})$		0.105	
Dozing (PM_{15})	$E = (1.0 * s^{1.5}) / (M^{1.4})$	0.75		
Grading (PM)	$E = 0.040 * S^{2.5}$		0.031	
Grading (PM_{15})	$E = 0.051 * S^{2.0}$	0.6		
s = material silt content %			3.0	*AP-42, Chapter 13.2.2, Related Information, r13s0202_dec03.xls*
M = material moisture content %			4.0	*Resolution Copper*
S = mean vehicle speed mph			5.59	*Phone Meeting with C. Pascoe 10/11/12 (9 km/hr)*
Fuel Contingency			15%	*RCM Mine Data for Ari Modelling 2012.xlsx*

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 1	OF: 8	SHEET: Tailings_Fleet
AIR EMISSION CALCULATIONS	SUBJECT: Diesel Fleet Calculations - Tailings	DATE: March 15, 2018		

Tailings Diesel Machinery (Non-Emergency)

Mobile Equipment	Rating *kW*	Rating *hp*	Quantity	EPA Tier	Fuel *gal/hr*	Ann. Op. Hours	Load Factor (%)**
Flat Bed Truck (1 Ton, Tailings)	287	385	1	4	20	1,095*	90%
Boom Truck (Tailings)	179	240	3	4	12	2,190	60%
Excavator (Tailings)-345 Class	295	396	7	4	20	1,950	60%
Bulldozer (Tailings)	236	317	15	4	16	1,950	60%
Loader-980 Class	295	396	8	4	20	1,950	60%
Grader	193	259	2	4	13	1,095*	60%
Water Truck	130	174	1	4	9	1,095*	60%
Compactor - 10 ton	75	100	15	4	5	3,900	60%
Skid Steer (Bobcat)	54	73	2	4	4	1,095	60%
Pipe Fusion Machine	15	20	2	4	1	1,095	90%
40-Ton Class Haul Truck	441	592	21	4	30	3,900	60%

* *Conservative Assumption*

** *Resolution*

Conversions		
453.592	*g/lb*	
2,000	*lb/ton*	
0.0015%	*ppm S in ULSD (GPA 2140)*	
7.05	*lb/gal*	
1.00E+06	*Btu/MMBtu*	
1.998	SO_2/S	
1.341	*hp/kw*	
7,000	*Btu/hp-hr*	*AP-42, Table 3.4-1, Footnote e, Diesel, Rev. 10/96*
137,000	*Btu/gal*	*AP-42, Appendix A, Diesel, Rev. 9/85*
8,760	*hr/yr*	

Blue values are input; black values are calculated or linked.

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI		BY: N. Tipple		
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AIR EMISSION CALCULATIONS	SUBJECT: Diesel Fleet Calculations - Tailings		DATE: March 15, 2018		

Tailings Diesel Machinery (Non-Emergency) - Emission Factors

Equipment	Rating *kW*	Quantity	CO* *g/kW-hr*	NO_x* *g/kW-hr*	SO_2** *g/kW-hr*	PM* *g/kW-hr*	VOC* *g/kW-hr*
Flat Bed Truck (1 Ton, Tailings)	287	1	3.5	0.40	-	2.0E-2	0.19
Boom Truck (Tailings)	179	3	3.5	0.40	-	2.0E-2	0.19
Excavator (Tailings)-345 Class	295	7	3.5	0.40	-	2.0E-2	0.19
Bulldozer (Tailings)	236	15	3.5	0.40	-	2.0E-2	0.19
Loader-980 Class	295	8	3.5	0.40	-	2.0E-2	0.19
Grader	193	2	3.5	0.40	-	2.0E-2	0.19
Water Truck	130	1	3.5	0.40	-	2.0E-2	0.19
Compactor - 10 ton	75	15	5.0	0.40	-	2.0E-2	0.19
Skid Steer (Bobcat)	54	2	5.0	4.7	-	3.0E-2	4.7
Pipe Fusion Machine	15	2	6.6	7.5	-	0.40	7.5
40-Ton Class Haul Truck	441	21	3.5	0.40	-	2.0E-2	0.19

* *40 CFR §1039.101, Table 1*

** *SO_2 emissions - mass balance based on 15 ppm S content (ULSD)*

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI		BY: N. Tipple		
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AIR EMISSION CALCULATIONS	SUBJECT: Diesel Fleet Calculations - Tailings		DATE: March 15, 2018		

Tailings Diesel Machinery (Non-Emergency) - Short-Term Emission

Equipment	CO *lb/hr*	NO_X *lb/hr*	SO_2* *lb/hr*	PM *lb/hr*	VOC *lb/hr*
Flat Bed Truck (1 Ton, Tailings)	2.0	0.23	4.3E-3	1.1E-2	0.11
Boom Truck (Tailings)	2.5	0.28	5.4E-3	1.4E-2	0.13
Excavator (Tailings)-345 Class	9.6	1.1	2.1E-2	5.5E-2	0.52
Bulldozer (Tailings)	16.4	1.9	3.5E-2	9.4E-2	0.89
Loader-980 Class	10.9	1.2	2.4E-2	6.2E-2	0.59
Grader	1.8	0.20	3.9E-3	1.0E-2	9.7E-2
Water Truck	0.60	6.9E-2	1.3E-3	3.4E-3	3.3E-2
Compactor - 10 ton	7.4	0.59	1.1E-2	3.0E-2	0.28
Skid Steer (Bobcat)	0.72	0.68	1.1E-3	4.3E-3	0.68
Pipe Fusion Machine	0.38	0.43	4.4E-4	2.3E-2	0.43
40-Ton Class Haul Truck	42.9	4.9	9.3E-2	0.25	2.3
Tailings Stationary					
Tailings Mobile	**95.2**	**11.6**	**0.20**	**0.55**	**6.1**
Tailings Total	**95.2**	**11.6**	**0.20**	**0.55**	**6.1**

* *Calculated by mass balance using a 15% fuel contingency*

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI		BY: N. Tipple		
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AIR EMISSION CALCULATIONS	SUBJECT: Diesel Fleet Calculations - Tailings		DATE: March 15, 2018		

Tailings Diesel Machinery (Non-Emergency) - Long-Term Emission

Equipment	CO *ton/yr*	NO_X *ton/yr*	SO_2* *ton/yr*	PM *ton/yr*	VOC *ton/yr*
Flat Bed Truck (1 Ton, Tailings)	1.1	0.12	2.4E-3	6.2E-3	5.9E-2
Boom Truck (Tailings)	2.7	0.31	5.9E-3	1.6E-2	0.15
Excavator (Tailings)-345 Class	9.3	1.1	2.0E-2	5.3E-2	0.51
Bulldozer (Tailings)	16.0	1.8	3.5E-2	9.1E-2	0.87
Loader-980 Class	10.7	1.2	2.3E-2	6.1E-2	0.58
Grader	0.98	0.11	2.1E-3	5.6E-3	5.3E-2
Water Truck	0.33	3.8E-2	7.1E-4	1.9E-3	1.8E-2
Compactor - 10 ton	14.4	1.2	2.2E-2	5.8E-2	0.55
Skid Steer (Bobcat)	0.39	0.37	6.0E-4	2.4E-3	0.37
Pipe Fusion Machine	0.21	0.24	2.4E-4	1.3E-2	0.24
40-Ton Class Haul Truck	83.7	9.6	0.18	0.48	4.5
Tailings Stationary					
Tailings Mobile	**140**	**16.0**	**0.29**	**0.79**	**7.9**
Tailings Total	**140**	**16.0**	**0.29**	**0.79**	**7.9**

* *Calculated by mass balance using a 15% fuel contingency*

Tailings Diesel Machinery (Non-Emergency) - Fugitive Emissions from Vehicle Travel - Vehicle Specifications

Equipment	Quantity	Ann. Op. Hours[a]	Speed[b] *mph*	Silt[c] *%*	Weight[b] *ton*
Flat Bed Truck (1 Ton, Tailings)	1	1,095	25	3.0	3
Boom Truck (Tailings)	3	2,190	15	3.0	12
Excavator (Tailings)-345 Class	7	1,950	10	3.0	23
Bulldozer (Tailings)	*dozer-specific fugitive emissions on p. 8*				
Loader-980 Class	8	1,950	5	3.0	23
Grader	*grader-specific fugitive emissions on p. 8*				
Water Truck	1	1,095	15	3.0	27
Compactor - 10 ton	15	3,900	2	3.0	36
Skid Steer (Bobcat)	2	1,095	5	3.0	1
Pipe Fusion Machine	2	1,095	1	3.0	2
40-Ton Class Haul Truck	21	3,900	25	3.0	41
Mean Vehicle Weight					30.3

[a] *Per unit, including availability and utilization factors*

[b] *Resolution*

[c] *AP-42, Chapter 13.2.2*

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AIR EMISSION CALCULATIONS	SUBJECT: Diesel Fleet Calculations - Tailings	DATE: March 15, 2018		

Tailings Diesel Machinery (Non-Emergency) - Fugitive Emissions from Vehicle Travel - Emission Factors

Equipment	PM *lb/VMT*	PM_{10} *lb/VMT*	$PM_{2.5}$ *lb/VMT*
Flat Bed Truck (1 Ton, Tailings)	5.3	1.2	0.12
Boom Truck (Tailings)	5.3	1.0	0.10
Excavator (Tailings)-345 Class	5.3	1.0	0.10
Bulldozer (Tailings)			
Loader-980 Class	5.3	1.0	0.10
Grader			
Water Truck	5.3	1.0	0.10
Compactor - 10 ton	5.3	1.0	0.10
Skid Steer (Bobcat)	5.3	1.0	0.10
Pipe Fusion Machine	5.3	1.0	0.10
40-Ton Class Haul Truck	5.3	1.0	0.10

Unpaved Roads - Predictive Emission Factor Equation & Constants*

$E = k \times (s / 12)^a \times (W / 3)^b$	Empirical Constants for Industrial Roads			
	Constant	PM	PM_{10}	$PM_{2.5}$
k, a, b - empirical constants	k	4.9	1.5	0.15
s - surface material silt content %	a	0.7	0.9	0.9
W - mean vehicle wt ton	b	0.45	0.45	0.45
P - Days of >0.01" Precip				

* *AP-42, 13.2.2, Equation 1a & 2, Table 13.2.2-2, Industrial Roads, Rev. 8/04*

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
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AIR EMISSION CALCULATIONS	SUBJECT: Diesel Fleet Calculations - Tailings	DATE: March 15, 2018		

Tailings Diesel Machinery (Non-Emergency) - Fugitive Emissions from Vehicle Travel - Emissions (Short-Term & Long-Term)

Equipment	PM *lb/hr*	PM_{10} *lb/hr*	$PM_{2.5}$ *lb/hr*	PM *ton/yr*	PM_{10} *ton/yr*	$PM_{2.5}$ *ton/yr*
Flat Bed Truck (1 Ton, Tailings)	131	30.5	3.0	60.7	14.1	1.4
Boom Truck (Tailings)	237	46.3	4.6	219	42.8	4.3
Excavator (Tailings)-345 Class	368	72.1	7.2	303	59.3	5.9
Bulldozer (Tailings)						
Loader-980 Class	210	41.2	4.1	173	33.9	3.4
Grader						
Water Truck	78.9	15.4	1.5	36.4	7.1	0.71
Compactor - 10 ton	158	30.9	3.1	260	50.8	5.1
Skid Steer (Bobcat)	52.6	10.3	1.0	24.3	4.8	0.48
Pipe Fusion Machine	10.5	2.1	0.21	4.9	0.95	9.5E-2
40-Ton Class Haul Truck	2,760	540	54.0	4,542	889	88.9
Vehicle Travel - Tailings Total	**4,007**	**789**	**78.9**	**5,623**	**1,103**	**110**

Daily Unpaved Road Controls

	Surface
days of <0.01" Precip	308

Daily Unpaved Road EF Multiplier

E = EF(unctl) x (365 -P) / 365	Surface
days of <0.01" Precip	1

Unpaved Road Controls

	Surface	Reference
E = EF(unctl) x (365 -P) / 365		
Days of >0.01" Precip	57	*TSF Precip Data (days >0.01'')*
Water & Chemical Suppression*	90%	*AP-42, Figure 13.2.2-2, Rev. 11/06*

* *Control efficiency is based on AP-42 Chapter 13.2.2, Unpaved Roads. Figure 13.2.2-2 provides the control efficiencies achievable with watering.*

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 8	OF: 8	SHEET: Tailings_Fleet
AIR EMISSION CALCULATIONS	SUBJECT: Diesel Fleet Calculations - Tailings	DATE: March 15, 2018		

Tailings Diesel Machinery (Non-Emergency) - Fugitive Emissions from Grading/Dozing - Emissions (Short-Term & Long-Term)

Emission Factors

Grading	PM	PM_{10}	$PM_{2.5}$	EF Unit
Grader	3.0	0.96	9.2E-2	*lb/VMT*
Dozing				
Bulldozer (Tailings)	3.5	0.56	0.37	*lb/hr*

Emissions

	Quantity	Operation *hr/yr*	PM *lb/hr*	PM_{10} *lb/hr*	$PM_{2.5}$ *lb/hr*	PM *ton/yr*	PM_{10} *ton/yr*	$PM_{2.5}$ *ton/yr*
Grading								
Grader	2.0	1,259	33.1	10.7	1.0	20.8	6.7	0.65
Dozing								
Bulldozer (Tailings)	15.0	2,243	52.7	8.4	5.5	59.1	9.4	6.2
Grading - Mill			**33.1**	**10.7**	**1.0**	**20.8**	**6.7**	**0.65**
Dozing - Mill			**52.7**	**8.4**	**5.5**	**59.1**	**9.4**	**6.2**
Grading/Dozing - Tailings Total			**85.8**	**19.1**	**6.6**	**79.9**	**16.2**	**6.9**

Tailings Fleet - Uncontrolled Fugitive Dust Emissions

	PM *lb/hr*	PM_{10} *lb/hr*	$PM_{2.5}$ *lb/hr*	PM *ton/yr*	PM_{10} *ton/yr*	$PM_{2.5}$ *ton/yr*
Vehicle Travel & Grading - Tailings	**4,040**	**800**	**79.9**	**5,643**	**1,110**	**111**
Dozing - Tailings	**52.7**	**8.4**	**5.5**	**59.1**	**9.4**	**6.2**
Fugitive Dust - Tailings Total	**4,092**	**808**	**85.5**	**5,703**	**1,119**	**117**

Dozing and Grading Emission Factor Equations *AP-42, 11.9, Table 11.9-1 (overburden), Rev. 7/98.*

		Scaling Factor PM_{10}	Scaling Factor $PM_{2.5}$	
Dozing (PM)	$E = (5.7 * s^{1.2}) / (M^{1.3})$		0.105	
Dozing (PM_{15})	$E = (1.0 * s^{1.5}) / (M^{1.4})$	0.75		
Grading (PM)	$E = 0.040 * S^{2.5}$		0.031	
Grading (PM_{15})	$E = 0.051 * S^{2.0}$	0.6		
s = material silt content %			3.0	*AP-42, Chapter 13.2.2, Related Information, r13s0202_dec03.xls*
M = material moisture content %			4.0	*Resolution Copper*
S = mean vehicle speed mph			5.59	*Phone Meeting with C. Pascoe 10/11/12 (9 km/hr)*
Fuel Contingency			15%	*RCM Mine Data for Ari Modelling 2012.xlsx*

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 1	OF: 4	SHEET: Loadout_Fleet
AIR EMISSION CALCULATIONS	SUBJECT: Diesel Fleet Calculations - Loadout	DATE: March 15, 2018		

Loadout Diesel Machinery (Non-Emergency)

Mobile Equipment	References & Notes	Rating *kW*	Rating *hp*	Quantity	EPA Tier	Fuel *gal/hr*	Ann. Op. Hours	Load Factor (%)**
Loader	a	248	333	3	4	17	5,913	60%
Switch Engine	a	438	587	1	4	30	5,203	80%
Track Mobile	a	219	294	1	4	15	5,203	60%
Wheel Loader	a	75	100	1	4	13	876	60%
Sweeper	b	146	196	1	4	10*	876	60%

* *Conservative Assumption*

** *Resolution*

Conversions		
453.592	*g/lb*	
2,000	*lb/ton*	
0.0015%	*ppm S in ULSD (GPA 2140)*	
7.05	*lb/gal*	
1.00E+06	*Btu/MMBtu*	
1.998	SO_2/S	
1.341	*hp/kw*	
7,000	*Btu/hp-hr*	*AP-42, Table 3.4-1, Footnote e, Diesel, Rev. 10/96*
137,000	*Btu/gal*	*AP-42, Appendix A, Diesel, Rev. 9/85*

References & Notes	
a, b	*Resolution*

Blue values are input; black values are calculated or linked.

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
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AIR EMISSION CALCULATIONS	SUBJECT: Diesel Fleet Calculations - Loadout	DATE: March 15, 2018		

Loadout Diesel Machinery (Non-Emergency) - Emission Factors

Equipment	Rating *kW*	Quantity	CO* *g/kW-hr*	NO_x* *g/kW-hr*	SO_2** *g/kW-hr*	PM* *g/kW-hr*	VOC* *g/kW-hr*
Loader	248	3	3.5	0.40	-	2.0E-2	0.19
Switch Engine	438	1	3.5	0.40	-	2.0E-2	0.19
Track Mobile	219	1	3.5	0.40	-	2.0E-2	0.19
Wheel Loader	75	1	5.0	0.40	-	2.0E-2	0.19
Sweeper	146	1	3.5	0.40	-	2.0E-2	0.19

* *40 CFR §1039.101, Table 1*

** *SO_2 emissions - mass balance based on 15 ppm S content (ULSD)*

Loadout Diesel Machinery (Non-Emergency) - Short-Term Emission

Equipment	CO *lb/hr*	NO_x *lb/hr*	SO_2* *lb/hr*	PM *lb/hr*	VOC *lb/hr*
Loader	3.4	0.39	7.4E-3	2.0E-2	0.19
Switch Engine	2.7	0.31	5.8E-3	1.5E-2	0.15
Track Mobile	1.0	0.12	2.2E-3	5.8E-3	5.5E-2
Wheel Loader	0.49	3.9E-2	1.9E-3	2.0E-3	1.9E-2
Sweeper	0.68	7.7E-2	1.5E-3	3.9E-3	3.7E-2
Loadout Stationary					
Loadout Mobile	**8.3**	**0.94**	**1.9E-2**	**4.7E-2**	**0.44**
Loadout Total	**8.3**	**0.94**	**1.9E-2**	**4.7E-2**	**0.44**

* *Calculated by mass balance using a 15% fuel contingency*

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
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AIR EMISSION CALCULATIONS	SUBJECT: Diesel Fleet Calculations - Loadout	DATE: March 15, 2018		

Loadout Diesel Machinery (Non-Emergency) - Long-Term Emission

Equipment	CO *ton/yr*	NO_X *ton/yr*	SO_2* *ton/yr*	PM *ton/yr*	VOC *ton/yr*
Loader	10.2	1.2	2.2E-2	5.8E-2	0.55
Switch Engine	7.0	0.80	1.5E-2	4.0E-2	0.38
Track Mobile	2.6	0.30	5.7E-3	1.5E-2	0.14
Wheel Loader	0.22	1.7E-2	8.3E-4	8.6E-4	8.2E-3
Sweeper	0.30	3.4E-2	6.4E-4	1.7E-3	1.6E-2
Loadout Stationary					
Loadout Mobile	**20.4**	**2.3**	**4.4E-2**	**0.12**	**1.1**
Loadout Total	**20.4**	**2.3**	**4.4E-2**	**0.12**	**1.1**

* *Calculated by mass balance using a 15% fuel contingency*

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 1	OF: 3	SHEET: Employees
AIR EMISSION CALCULATIONS	SUBJECT: Employee Fugitives	DATE: March 15, 2018		

Summary of Employee Commuting

CONTROLLED EMISSIONS (SHORT-TERM)

Location	PM	PM_{10}	$PM_{2.5}$	NO_X	SO_2	CO	VOC
	lb/hr	*lb/hr*	*lb/hr*	*lb/hr*	*lb/hr*	*lb/hr*	*lb/hr*
East Plant	8.1	1.9	0.19	2.1E-2	1.1E-3	0.45	4.9E-3
Mill	0.99	0.23	2.3E-2	2.5E-3	1.3E-4	5.4E-2	5.9E-4
Tailings Storage Facility	0.28	6.5E-2	6.6E-3	7.2E-4	3.8E-5	1.6E-2	1.7E-4
Filter Plant and Loadout Facility	0.89	0.21	2.1E-2	2.3E-3	1.2E-4	4.9E-2	5.3E-4

CONTROLLED EMISSIONS (LONG-TERM)

Location	PM	PM_{10}	$PM_{2.5}$	NO_X	SO_2	CO	VOC
	ton/yr	*ton/yr*	*ton/yr*	*ton/yr*	*ton/yr*	*ton/yr*	*ton/yr*
East Plant	29.4	6.9	0.69	9.2E-2	4.9E-3	2.0	2.1E-2
Mill	3.6	0.85	8.5E-2	1.1E-2	5.9E-4	0.24	2.6E-3
Tailings Storage Facility	1.0	0.24	2.4E-2	3.2E-3	1.7E-4	6.8E-2	7.4E-4
Filter Plant and Loadout Facility	3.3	0.77	7.7E-2	1.0E-2	5.3E-4	0.21	2.3E-3

UNCONTROLLED EMISSIONS (SHORT-TERM)

Location	PM	PM_{10}	$PM_{2.5}$	NO_X	SO_2	CO	VOC
	lb/hr	*lb/hr*	*lb/hr*	*lb/hr*	*lb/hr*	*lb/hr*	*lb/hr*
East Plant	81.3	18.9	1.9	2.1E-2	1.1E-3	0.45	4.9E-3
Mill	9.8	2.3	0.23	2.5E-3	1.3E-4	5.4E-2	5.9E-4
Tailings Storage Facility	2.8	0.65	6.5E-2	7.2E-4	3.8E-5	1.6E-2	1.7E-4
Filter Plant and Loadout Facility	8.9	2.1	0.21	2.3E-3	1.2E-4	4.9E-2	5.3E-4

UNCONTROLLED EMISSIONS (LONG-TERM)

Location	PM	PM_{10}	$PM_{2.5}$	NO_X	SO_2	CO	VOC
	ton/yr	*ton/yr*	*ton/yr*	*ton/yr*	*ton/yr*	*ton/yr*	*ton/yr*
East Plant	294	68.2	6.8	9.2E-2	4.9E-3	2.0	2.1E-2
Mill	36.3	8.4	0.84	1.1E-2	5.9E-4	0.24	2.6E-3
Tailings Storage Facility	10.4	2.4	0.24	3.2E-3	1.7E-4	6.8E-2	7.4E-4
Filter Plant and Loadout Facility	32.8	7.6	0.76	1.0E-2	5.3E-4	0.21	2.3E-3

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
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AIR EMISSION CALCULATIONS	SUBJECT: Employee Fugitives	DATE: March 15, 2018		

Fugitive Dust from Employee Commuting

Location	Daily Number of Vehicles*	Average Distance Travelled: *one way VMT, ea**	*RT VMT/day*	*RT VMT/yr*
East Plant	332	1.9	1,262	460,484
Mill	318	0.2	153	55,714
Tailings Storage Facility	17	1.3	44	15,885
Filter Plant and Loadout Facility	18	3.8	138	50,195

* *Resolution*

Unpaved Roads - Equation & Constants*

$E = k \times (s / 12)^a \times (W / 3)^b \times (365 - P) / 365$

	Empirical Constants for Industrial Roads			
	Constant	PM	PM_{10}	$PM_{2.5}$
k, a, b - empirical constants	k	4.9	1.5	0.15
s - surface material silt content %	a	0.7	0.9	0.9
W - mean vehicle wt ton	b	0.45	0.45	0.45

* *AP-42, 13.2.2, Equation 1a & 2, Table 13.2.2-2, Unpaved Roads, Rev. 11/06*

EMISSION FACTORS

Location	Paved/Unpaved	Silt *%**	Vehicle Weight *ton***	PM *lb/VMT*	PM_{10} *lb/VMT*	$PM_{2.5}$ *lb/VMT*
East Plant	Paved & Unpaved***	3.0	2.0	1.5	0.36	3.6E-2
Mill	Unpaved	3.0	2.0	1.5	0.36	3.6E-2
Tailings Storage Facility	Unpaved	3.0	2.0	1.5	0.36	3.6E-2
Filter Plant and Loadout Facility	Unpaved	3.0	2.0	1.5	0.36	3.6E-2

* *AP-42, Chapter 13.2.2*

** *Estimate*

*** *Emissions calculated for worst case (all unpaved)*

CONTROLLED EMISSIONS

Location	PM *lb/hr*	PM_{10} *lb/hr*	$PM_{2.5}$ *lb/hr*	PM *ton/yr*	PM_{10} *ton/yr*	$PM_{2.5}$ *ton/yr*
East Plant	8.1	1.9	0.19	29.4	6.8	0.68
Mill	0.98	0.23	2.3E-2	3.6	0.84	8.4E-2
Tailings Storage Facility	0.28	6.5E-2	6.5E-3	1.0	0.24	2.4E-2
Filter Plant and Loadout Facility	0.89	0.21	2.1E-2	3.3	0.76	7.6E-2

UNCONTROLLED EMISSIONS

Location	PM *lb/hr*	PM_{10} *lb/hr*	$PM_{2.5}$ *lb/hr*	PM *ton/yr*	PM_{10} *ton/yr*	$PM_{2.5}$ *ton/yr*
East Plant	81.3	18.9	1.9	294	68.1	6.8
Mill	9.8	2.3	0.23	36.2	8.4	0.84
Tailings Storage Facility	2.8	0.65	6.5E-2	10.4	2.4	0.24
Filter Plant and Loadout Facility	8.9	2.1	0.21	32.8	7.6	0.76

Conversions & Assumptions	
365	*days of operation/yr*
2,000	*lb/ton*
24	*hr/day*
90%	*Control (Chemical Suppressant)*

Days of >0.01" Precip		
EP	64	*EPS Precip Data (days >0.01'')*
Mill	58	*WPS Precip Data (days >0.01'')*
TSF	57	*TSF Precip Data (days >0.01'')*
FPLF	57	*TSF Precip Data (days >0.01'')*

Blue values are input; black values are calculated or linked.

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 3	OF: 3	SHEET: Employees
AIR EMISSION CALCULATIONS	SUBJECT: Employee Fugitives	DATE: March 15, 2018		

Combustion Emissions from Employee Commuting

Location	VMT/day	PM lb/hr	PM_{10} lb/hr	$PM_{2.5}$ lb/hr	NO_X lb/hr	SO_2 lb/hr	CO lb/hr	VOC lb/hr
East Plant	1,262	1.1E-2	1.1E-2	2.0E-3	2.1E-2	1.1E-3	0.45	4.9E-3
Mill	153	1.4E-3	1.4E-3	2.5E-4	2.5E-3	1.3E-4	5.4E-2	5.9E-4
Tailings Storage Facility	44	4.0E-4	4.0E-4	7.0E-5	7.2E-4	3.8E-5	1.6E-2	1.7E-4
Filter Plant and Loadout Facility	138	1.3E-3	1.3E-3	2.2E-4	2.3E-3	1.2E-4	4.9E-2	5.3E-4

Location	VMT/yr	PM ton/yr	PM_{10} ton/yr	$PM_{2.5}$ ton/yr	NO_X ton/yr	SO_2 ton/yr	CO ton/yr	VOC ton/yr
East Plant	460,484	5.0E-2	5.0E-2	8.9E-3	9.2E-2	4.9E-3	2.0	2.1E-2
Mill	55,714	6.1E-3	6.1E-3	1.1E-3	1.1E-2	5.9E-4	0.24	2.6E-3
Tailings Storage Facility	15,885	1.7E-3	1.7E-3	3.1E-4	3.2E-3	1.7E-4	6.8E-2	7.4E-4
Filter Plant and Loadout Facility	50,195	5.5E-3	5.5E-3	9.7E-4	1.0E-2	5.3E-4	0.21	2.3E-3

Emission Factor*	PM g/VMT	PM_{10} g/VMT	$PM_{2.5}$ g/VMT	NO_X g/VMT	SO_2 g/VMT	CO g/VMT	VOC g/VMT
	9.9E-2	9.9E-2	1.8E-2	0.18	9.6E-3	3.9	4.2E-2

* *MOVES 2014a*

Conversions & Assumptions	
453.592	*g/lb*
2,000	*lb/ton*

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 1	OF: 6	SHEET: E_Gen
AIR EMISSION CALCULATIONS	SUBJECT: Emergency Power Generation Emissions	DATE: March 15, 2018		

Emergency Generator - Emissions Summary

Emergency Power Generation Emissions Summary - Short-Term

Source	CO	NO_X	PM	SO_2	VOC
	lb/hr	*lb/hr*	*lb/hr*	*lb/hr*	*lb/hr*
East Plant - Existing Generators	17.7	32.5	1.0	3.8E-2	6.6
East Plant - New Generators	14.9	101	3.5	0.76	6.8
Mill Generators	11.6	1.0	2.3E-2	2.7E-2	5.1E-2
Tailings Generator	3.9	0.35	7.7E-3	9.0E-3	1.7E-2
Filter Plant (Loadout) Generator	3.9	0.35	7.7E-3	9.0E-3	1.7E-2
Emergency Power Generation Total	**51.9**	**136**	**4.6**	**0.84**	**13.4**

Emergency Power Generation Emissions Summary - Long-Term

Source	CO	NO_X	PM	SO_2	VOC
	ton/yr	*ton/yr*	*ton/yr*	*ton/yr*	*ton/yr*
East Plant - Existing Generators	4.4	8.1	0.25	9.6E-3	1.6
East Plant - New Generators	3.7	25.3	0.88	0.19	1.7
Mill Generators	2.9	0.26	5.7E-3	6.7E-3	1.3E-2
Tailings Generator	0.96	8.7E-2	1.9E-3	2.2E-3	4.3E-3
Filter Plant (Loadout) Generator	0.96	8.7E-2	1.9E-3	2.2E-3	4.3E-3
Emergency Power Generation Total	**13.0**	**33.9**	**1.1**	**0.21**	**3.4**

Conversions

1.341	*hp/kW*	
453.592	*g/lb*	
2,000	*lb/ton*	
15	*ppm S in ULSD (GPA 2140)*	
7.05	*lb/gal*	*AP-42, Appendix A (Distillate Oil), Rev. 9/85*
1.00E+06	*Btu/MMBtu*	

Blue values are input; black values are calculated or linked.

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 2	OF: 6	SHEET: E_Gen
AIR EMISSION CALCULATIONS	SUBJECT: Emergency Power Generation Emissions	DATE: March 15, 2018		

Emergency Power Generation

East Plant - Existing Generators

Cat 516B - Diesel	2,628	*hp*	*Resolution*
	1,960	*kW*	
Model Year	2006		*Assuming Tier II*
Cat 3046C - Diesel	449	*hp*	*Resolution*
	335	*kW*	
Model Year	2001		*Assuming Tier II*
Break-Specific Fuel Consumption	7,000	*Btu/hp-hr*	*AP-42, Table 3.4-1, Footnote e, Rev. 10/96*
Diesel Heat Value	137,000	*Btu/gal*	*AP-42, Appendix A, Rev. 9/85*
Operation	500	*hr/yr*	*Resolution*
Power (All Engines)	21.5	*MMBtu/hr*	

Total Diesel Fuel Consumption	*gal/hr*	*gal/yr*
Cat 516B - Diesel	134	67,139
Cat 3046C - Diesel	23	11,471

Emission Factors	**Cat 516B - Diesel**	**Cat 3046C - Diesel**	**Reference**
CO	3.50 *g/kW-h*	3.50 *g/kW-h*	*40 CFR § 89.112, Table 1, Tier II*
NO_X	6.40 *g/kW-h*	6.60 *g/kW-h*	*40 CFR § 89.112, Table 1, Tier II*
PM	0.20 *g/kW-h*	0.20 *g/kW-h*	*40 CFR § 89.112, Table 1, Tier II*
VOC	1.30 *g/kW-h*	1.30 *g/kW-h*	*40 CFR § 89.112, Table 1, Tier II*
SO_2	-	-	*Mass balance based on 15 ppm S content (below)*

Emissions		**Cat 516B - Diesel**		**Cat 3046C - Diesel**		**Total**	
		lb/hr	***ton/yr***	***lb/hr***	***ton/yr***	***lb/hr***	***ton/yr***
CO		15.1	3.8	2.6	0.65	17.7	4.4
NO_X		27.7	6.9	4.9	1.2	32.5	8.1
PM		0.86	0.22	0.15	3.7E-2	1.0	0.25
VOC		5.6	1.4	0.96	0.24	6.6	1.6
SO_2	*	3.3E-2	8.2E-3	5.6E-3	1.4E-3	3.8E-2	9.6E-3

* *Calculated by mass balance using a 15% fuel contingency*

SO2 Mass Balance (Single Cat 516B - Diesel)

$$\frac{134\ \cancel{gal}}{hr} \times \frac{7.05\ \cancel{lb}}{\cancel{gal}} \times 0.0015\%\ \cancel{S} \times \frac{64.06\ lb\ SO_2}{32.07\ \cancel{lb\ S}} \times (1+15\%) = \frac{0.03\ lb\ SO_2}{hr}$$

$$\frac{0.03\ \cancel{lb}\ SO_2}{\cancel{hr}} \times \frac{500\ \cancel{hr}}{yr} \times \frac{ton}{2{,}000\ \cancel{lb}} = \frac{0.008\ ton\ SO_2}{yr}$$

SO2 Mass Balance (Single Cat 3046C - Diesel)

$$\frac{23\ \cancel{gal}}{hr} \times \frac{7.05\ \cancel{lb}}{\cancel{gal}} \times 0.0015\%\ \cancel{S} \times \frac{64.06\ lb\ SO_2}{32.07\ \cancel{lb\ S}} \times (1+15\%) = \frac{0.006\ lb\ SO_2}{hr}$$

$$\frac{0.01\ \cancel{lb}\ SO_2}{\cancel{hr}} \times \frac{500\ \cancel{hr}}{yr} \times \frac{ton}{2{,}000\ \cancel{lb}} = \frac{0.0014\ ton\ SO_2}{yr}$$

Emergency Power Generation - Continued

East Plant - New Generators

Engine Make and Model	Caterpillar C175-16		*Caterpillar Standby 3100 kW Tier 4i Performance Data*
Engine Output	3,263	*kW*	
	4,376	*hp*	*Resolution*
Break-Specific Fuel Consumption	7,000	*Btu/hp-hr*	*AP-42, Table 3.4-1, Footnote e, Rev. 10/96*
Diesel Heat Value	137,000	*Btu/gal*	*AP-42, Appendix A, Rev. 9/85*
Quantity	14		*Resolution*
Operation	500	*hr/yr*	*Resolution*
Power (All Engines)	428.8	*MMBtu/hr*	

Total Diesel Fuel Consumption	*gal/hr*	*gal/yr*
Single Generator	224	111,796
14 Generators	3,130	1,565,139

Emission Factors	**Performance Data***		**Reference**
CO	0.11	*g/hp-h*	*Caterpillar Standby 3100 kW Tier 4i Performance Data (worst case)*
NO_X	0.75	*g/hp-h*	*Caterpillar Standby 3100 kW Tier 4i Performance Data (worst case)*
PM**	0.05	*g/hp-h*	*Caterpillar Standby 3100 kW Tier 4i Performance Data (worst case)*
VOC	0.05	*g/hp-h*	*Caterpillar Standby 3100 kW Tier 4i Performance Data (worst case)*
SO_2	-		*Mass balance based on 15 ppm S content (below)*

**Performance data: Rated Speed Potential Site Variation: 1800 RPM*
***Worst case emissions at 50% power (2,284 hp)*

Emissions		**Single Generator**		**14 Generators**	
		lb/hr	***ton/yr***	***lb/hr***	***ton/yr***
CO		1.1	0.27	14.9	3.7
NO_X		7.2	1.8	101	25.3
PM		0.25	6.3E-2	3.5	0.88
VOC		0.48	0.12	6.8	1.7
SO_2	*	5.4E-2	1.4E-2	0.76	0.19

* *Calculated by mass balance using a 15% fuel contingency*

SO2 Mass Balance (Single Caterpillar C175-16)

$$\frac{224\ \cancel{gal}}{hr} \times \frac{7.05\ \cancel{lb}}{\cancel{gal}} \times 0.0015\%\ \cancel{S} \times \frac{64.06\ lb\ SO_2}{32.07\ \cancel{lb\ S}} \times (1 + 15\%) = \frac{0.05\ lb\ SO_2}{hr}$$

$$\frac{0.05\ \cancel{lb}\ SO_2}{\cancel{hr}} \times \frac{500\ \cancel{hr}}{yr} \times \frac{ton}{2{,}000\ \cancel{lb}} = \frac{0.014\ ton\ SO_2}{yr}$$

Emergency Power Generation - Continued

Mill Generators

Engine Make and Model	*Caterpillar C18 Generator Set*		*Resolution*
Diesel Generator	671 *hp*		
	500 *kW*		*Cat Specs*
Model Year	2016		
Quantity	3		*Resolution*
Break-Specific Fuel Consumption	7,000 *Btu/hp-hr*		*AP-42, Table 3.4-1, Footnote e, Rev. 10/96*
Diesel Heat Value	137,000 *Btu/gal*		*AP-42, Appendix A, Rev. 9/85*
Operation	500 *hr/yr*		*Resolution*
Power (All Engines)	14.1 *MMBtu/hr*		
Fuel Consumption (Single Generator)	37	*gal/hr*	*Cat Specs*
	18,500	*gal/yr*	
Fuel Consumption (3 Generators)	55,500	*gal/yr*	

Emission Factors	Emission Factor	Reference
CO	3.5 *g/kW-h*	*40 CFR § 1039.101, Table 1*
NO_X	0.2 *g/hp-hr*	*Cat Specs*
PM	0.005 *g/hp-hr*	*Cat Specs*
VOC	0.01 *g/hp-hr*	*Cat Specs*
SO_2	-	*Mass balance based on 15 ppm S content (below)*

Emissions	Diesel Generators (3)	
	lb/hr	*ton/yr*
CO	11.6	2.9
NO_X	1.0	0.26
PM	2.3E-2	5.7E-3
VOC	5.1E-2	1.3E-2
SO_2*	2.7E-2	6.7E-3

* *Calculated by mass balance using a 15% fuel contingency*

SO2 Mass Balance (Single Diesel Generator)

$$\frac{37\ \cancel{gal}}{hr} \times \frac{7.05\ \cancel{lb}}{\cancel{gal}} \times 0.0015\%\ \cancel{S} \times \frac{64.06\ lb\ SO_2}{32.07\ \cancel{lb\ S}} \times (1+15\%) = \frac{0.009\ lb\ SO_2}{hr}$$

$$\frac{0.009\ \cancel{lb}\ SO_2}{\cancel{hr}} \times \frac{500\ \cancel{hr}}{yr} \times \frac{ton}{2{,}000\ \cancel{lb}} = \frac{0.0022\ ton\ SO_2}{yr}$$

Emergency Power Generation - Continued

Tailings Generator

Engine Make and Model	*Caterpillar C18 Generator Set*		*Resolution*
Diesel Generator	671 *hp*		
	500 *kW*		*Cat Specs*
Model Year	2016		
Quantity	1		*Resolution*
Break-Specific Fuel Consumption	7,000 *Btu/hp-hr*		*AP-42, Table 3.4-1, Footnote e, Rev. 10/96*
Diesel Heat Value	137,000 *Btu/gal*		*AP-42, Appendix A, Rev. 9/85*
Operation	500 *hr/yr*		*Resolution*
Power (All Engines)	4.7 *MMBtu/hr*		
Fuel Consumption (Single Generator)	37	*gal/hr*	*Cat Specs*
	18,500	*gal/yr*	

Emission Factors	Emission Factor	Reference
CO	3.5 *g/kW-h*	*40 CFR § 1039.101, Table 1*
NO_X	0.2 *g/hp-hr*	*Cat Specs*
PM	0.005 *g/hp-hr*	*Cat Specs*
VOC	0.01 *g/hp-hr*	*Cat Specs*
SO_2	-	*Mass balance based on 15 ppm S content (below)*

Emissions	Diesel Generator	
	lb/hr	*ton/yr*
CO	3.9	0.96
NO_X	0.35	8.7E-2
PM	7.7E-3	1.9E-3
VOC	1.7E-2	4.3E-3
SO_2*	9.0E-3	2.2E-3

* *Calculated by mass balance using a 15% fuel contingency*

SO2 Mass Balance (Single Diesel Generator)

$$\frac{37\ gal}{hr} \times \frac{7.05\ lb}{gal} \times 0.0015\%\ S \times \frac{64.06\ lb\ SO_2}{32.07\ lb\ S} \times (1+15\%) = \frac{0.009\ lb\ SO_2}{hr}$$

$$\frac{0.009\ lb\ SO_2}{hr} \times \frac{500\ hr}{yr} \times \frac{ton}{2{,}000\ lb} = \frac{0.0022\ ton\ SO_2}{yr}$$

Emergency Power Generation - Continued

Filter Plant (Loadout) Generator

Engine Make and Model	*Caterpillar C18 Generator Set*		*Resolution*
Diesel Generator	671 *hp*		
	500 *kW*		*Cat Specs*
Model Year	2016		
Quantity	1		*Resolution*
Break-Specific Fuel Consumption	7,000 *Btu/hp-hr*		*AP-42, Table 3.4-1, Footnote e, Rev. 10/96*
Diesel Heat Value	137,000 *Btu/gal*		*AP-42, Appendix A, Rev. 9/85*
Operation	500 *hr/yr*		*Resolution*
Power (All Engines)	4.7 *MMBtu/hr*		
Fuel Consumption (Single Generator)	37	*gal/hr*	*Cat Specs*
	18,500	*gal/yr*	

Emission Factors	**Emission Factor**	**Reference**
CO	3.5 *g/kW-h*	*40 CFR § 1039.101, Table 1*
NO_X	0.2 *g/hp-hr*	*Cat Specs*
PM	0.005 *g/hp-hr*	*Cat Specs*
VOC	0.01 *g/hp-hr*	*Cat Specs*
SO_2	-	*Mass balance based on 15 ppm S content (below)*

Emissions	**Diesel Generator**	
	lb/hr	***ton/yr***
CO	3.9	0.96
NO_X	0.35	8.7E-2
PM	7.7E-3	1.9E-3
VOC	1.7E-2	4.3E-3
SO_2*	9.0E-3	2.2E-3

* *Calculated by mass balance using a 15% fuel contingency*

SO2 Mass Balance (Single Diesel Generator)

$$\frac{37\ \cancel{gal}}{hr} \times \frac{7.05\ \cancel{lb}}{\cancel{gal}} \times 0.0015\%\ \cancel{S} \times \frac{64.06\ lb\ SO_2}{32.07\ \cancel{lb\ S}} \times (1+15\%) = \frac{0.009\ lb\ SO_2}{hr}$$

$$\frac{0.009\ \cancel{lb}\ SO_2}{\cancel{hr}} \times \frac{500\ \cancel{hr}}{yr} \times \frac{ton}{2{,}000\ \cancel{lb}} = \frac{0.0022\ ton\ SO_2}{yr}$$

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 1	OF: 1	SHEET: Fuel Tanks
AIR EMISSION CALCULATIONS	SUBJECT: Emergency Power Generation Emissions	DATE: March 15, 2018		

Diesel Storage Tanks

		EP Surface	EP UG[a]	Mill	Loadout	Tailings
Per Tank Fuel Usage[b]	*gal/hr*	12	156	64	30	113
Per Tank Fuel Usage[b]	*gal/mo*	1,885	22,151	12,365	11,581	27,729
Per Tank Fuel Usage[b]	*gal/yr*	22,621	265,817	148,377	138,966	332,752
Total Fuel Usage[b]	*gal/hr*	12	937	318	119	1,360
Total Fuel Usage[b]	*gal/mo*	1,885	132,909	61,824	46,322	332,752
Total Fuel Usage[b]	*gal/yr*	22,621	1,594,904	741,883	555,866	3,993,028
Fuel Tank Quantity		1	6	5	4	12
Fuel Tank Volume	*gal*	5,000	20,000	10,000	10,000	20,000
Fills Per Tank, Per Year		5	14	15	14	17
Diameter	*ft*	8	13	8	12	12
Length	*ft*	13	20	27	12	24
Orientation		Horizontal	Horizontal	Horizontal	Horizontal	Horizontal
Tank Contents		Diesel	Diesel	Diesel	Diesel	Diesel
Location		Superior, Arizona				
Per Tank VOC Emissions	*lb/hr*	3.3E-4	8.0E-4	7.9E-4	7.7E-4	1.7E-3
Per Tank VOC Emissions	*lb/yr*	2.87	7.03	6.94	6.72	14.57
Per Tank VOC Emissions	*ton/yr*	1.4E-3	3.5E-3	3.5E-3	3.4E-3	7.3E-3
Total VOC Emissions	*lb/hr*	3.3E-4	4.8E-3	4.0E-3	3.1E-3	2.0E-2
Total VOC Emissions	*ton/yr*	1.4E-3	2.1E-2	1.7E-2	1.3E-2	8.7E-2

[a] *Resolution 6562 (2,000 m) ft below surface*

[b] *Including 15% contingency*

Conversions	
7.48052	ft^3/gal
2,000	*lb/ton*
8,760	*hr/yr*
12	*mo/yr*

Blue values are input; black values are calculated or linked.

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 1	OF: 2	SHEET: Cooling
AIR EMISSION CALCULATIONS	SUBJECT: Cooling Tower Emissions	DATE: March 15, 2018		

COOLING TOWERS - PM/PM_{10}/$PM_{2.5}$ EMISSION RATES

Operation			Reference
Surface Cooling Circulation	4,200 *l/s*	1,110 *gal/s*	*Resolution*
Surface Drift Loss	0.005%		*Resolution*
Cooling Capacity	135.0 *MW*		*Resolution*
Underground Cooling Circulation	1,250 *l/s*	330 *gal/s*	*Resolution*
Underground Drift Loss	0.005%		*Resolution*

Cooling Tower Water Quality		Reference
Total Dissolved Solids (TDS)	3,000 *ppm*	*Resolution*

Drift		Reference
Drift Mass Governed by Atmospheric Dispersion	31.3%	*EPA Document: Effects of Pathogenic and Toxic Material Transport Via Cooling Device Drift - Vol. 1 Technical Report EPA 600 7-79-251a, 11/1979*

Surface Towers

$$\frac{1{,}110\ \cancel{gal}}{\cancel{sec}} \times \frac{8.33\ lb}{\cancel{gal}\ water} \times \frac{3{,}600\ \cancel{sec}}{hr} \times 0.005\%\ (drift) = \frac{1663.62\ lb\ water}{hr}$$

Underground Towers

$$\frac{330\ \cancel{gal}}{\cancel{sec}} \times \frac{8.33\ lb}{\cancel{gal}\ water} \times \frac{3{,}600\ \cancel{sec}}{hr} \times 0.005\%\ (drift) = \frac{495.12\ lb\ water}{hr}$$

PM Emissions

Surface Towers

$$\frac{1663.62\ \cancel{lb\ water}}{hr} \times 31.3\%\ (dispersion\ factor)^* \times \frac{3{,}000\ lb\ PM}{1.0E{+}06\ \cancel{lb\ water}} = \frac{1.56\ lb\ PM}{hr} = \frac{6.84\ ton\ PM}{yr}$$

Underground Towers

$$\frac{495.12\ \cancel{lb\ water}}{hr} \times 31.3\%\ (dispersion\ factor)^* \times \frac{3{,}000\ lb\ PM}{1.0E{+}06\ \cancel{lb\ water}} = \frac{0.47\ lb\ PM}{hr} = \frac{2.04\ ton\ PM}{yr}$$

PM_{10} Emissions

Surface Towers

$$\frac{1.56\ \cancel{lb\ PM}}{hr} \times \frac{0.403\ lb\ PM_{10}{}^*}{\cancel{lb\ PM}} = \frac{0.63\ lb\ PM_{10}}{hr} = \frac{2.76\ ton\ PM_{10}}{yr}$$

Underground Towers

$$\frac{0.47\ \cancel{lb\ PM}}{hr} \times \frac{0.403\ lb\ PM_{10}{}^*}{\cancel{lb\ PM}} = \frac{0.19\ lb\ PM_{10}}{hr} = \frac{0.82\ ton\ PM_{10}}{yr}$$

$PM_{2.5}$ Emissions

Surface Towers

$$\frac{1.56\ \cancel{lb\ PM}}{hr} \times \frac{0.061\ lb\ PM_{2.5}{}^*}{\cancel{lb\ PM}} = \frac{0.096\ lb\ PM_{2.5}}{hr} = \frac{0.420\ ton\ PM_{2.5}}{yr}$$

Underground Towers

$$\frac{0.47\ \cancel{lb\ PM}}{hr} \times \frac{0.061\ lb\ PM_{2.5}{}^*}{\cancel{lb\ PM}} = \frac{0.029\ lb\ PM_{2.5}}{hr} = \frac{0.125\ ton\ PM_{2.5}}{yr}$$

**See size fraction calculation on Page 2.*

Blue values are input; black values are calculated or linked.

COOLING TOWERS - PM/PM_{10}/$PM_{2.5}$ EMISSION RATES - Continued

PM_{10}, $PM_{2.5}$ Multiplier Calculation

Operation		Reference
Water TDS	3,000 *ppm*	*Resolution*
Calcium Carbonate Density	2.7 *g/cc*	*Perry's Chemical Engineer's Handbook, Sixth Edition, p. 3-10.*
Volume of a Sphere	$V = 4 / 3 * \pi * r^3$	

Water Drop Size and Mass Distribution*

Droplet Dia. (micron)	(% mass)	Water Droplet Vol. (cc)	Water Droplet Mass (g)	Solids Mass (g)	Solids Vol. (cc)	Solids Dia. (micron)	% mass <10, <2.5 (microns)
22	0.4	5.6E-09	5.6E-09	1.7E-11	6.2E-12	2.3	
29	1.5	1.3E-08	1.3E-08	3.8E-11	1.4E-11	3.0	1.9
44	3.8	4.5E-08	4.5E-08	1.3E-10	5.0E-11	4.6	
58	2.1	1.0E-07	1.0E-07	3.1E-10	1.1E-10	6.0	
65	1.9	1.4E-07	1.4E-07	4.3E-10	1.6E-10	6.7	
87	1.6	3.4E-07	3.4E-07	1.0E-09	3.8E-10	9.0	
108	1.4	6.6E-07	6.6E-07	2.0E-09	7.3E-10	11.2	12.6
120	1.3	9.0E-07	9.0E-07	2.7E-09	1.0E-09	12.4	
132	1.1	1.2E-06	1.2E-06	3.6E-09	1.3E-09	13.7	
144	1.3	1.6E-06	1.6E-06	4.7E-09	1.7E-09	14.9	
174	5.8	2.8E-06	2.8E-06	8.3E-09	3.1E-09	18.0	
300	5.0	1.4E-05	1.4E-05	4.2E-08	1.6E-08	31.1	
450**	4.2	4.8E-05	4.8E-05	1.4E-07	5.3E-08	46.6	
Total	31.3						

* *Effects of Pathogenic and Toxic Material Transport Via Cooling Device Drift - Vol. 1 Technical Report. EPA 600 7-79-251a, Nov. 1979.*

** *Maximum droplet size governed by atmospheric dispersion.*

PM_{10}/PM multiplier = 0.40

$PM_{2.5}$/PM multiplier = 0.06

Conversions	
8,760	*hr/yr*
60	*min/hr*
2,000	*lb/ton*
3.78541	*l/gal*
8.33	*lb/gal water*

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 1	OF: 1	SHEET: Reagents
AIR EMISSION CALCULATIONS	SUBJECT: Liquid Reagent Tanks & Solid Reagent Usage	DATE: March 15, 2018		

LIQUID REAGENT STORAGE TANK CHARACTERISTICS AND EMISSIONS

TANK EMISSIONS	VOC* (lb/yr)	VOC lb/hr	VOC ton/yr
MIBC (Methyl isobutyl carbonal)	134.9	1.5E-02	6.7E-02
MCO (Non-polar flotation oil)	9.5	1.1E-03	4.8E-03
CYTEC 8989	0.1	1.1E-05	5.0E-05
NaHS (Sodium hydrosulfide solution)			

* *Calculated using EPA Tanks 4.0.9d*

MIBC (Methyl isobutyl carbonal)		Notes
Design Throughput	5,268 *l/day*	2
	1,392 *gal/day*	
Average Throughput	4,581 *l/day*	2
	441,713 *gal/yr*	
Tank Diameter	4.4 *m*	2
	14.4 *ft*	
Tank Height	5.4 *m*	2
	17.7 *ft*	
Tank Volume	67.3 m^3	2
	17,779 *gal*	

1 *Assuming 100% $(CH_3)_2CHCH_2CH(OH)CH_3$*
2 *Resolution*

MCO (Non-polar flotation oil)		Notes
Design Throughput	1,597 *l/day*	2
	422 *gal/day*	
Average Throughput	1,388 *l/day*	2
	133,835 *gal/yr*	
Tank Diameter	3.9 *m*	2
	12.8 *ft*	
Tank Height	4.9 *m*	2
	16.1 *ft*	
Tank Volume	45.6 m^3	2
	12,046 *gal*	

1 *Emissions calculated based on 100% Distillate fuel oil no. 2*
2 *Resolution*

Solid Reagent Use (Resolution)	(tonne/day) (design)	(tonne/day) (average)	(ton/hr)	(ton/yr)
Lime	89.7	67.8	4.1	27,279
SIPX*	690*	600*	0.03	241
CIBA 155	3.70	3.22	0.17	1,296
CIBA 10	0.96	0.78	0.04	314

* *Units: kg/day*

Conversions			
3.78541	*l/gal*	24	*hr/day*
264.172	*gal/m^3*	365	*days/yr*
8.35	*lb/gal water*	2,204.62	*lb/tonne*
3.28084	*ft/m*	907.185	*kg/ton*
1.10231	*ton/tonne*	2,000	*lb/ton*
8,760	*hr/yr*		

Blue values are input; black values are calculated or linked.

CYTEC 8989		Notes
Design Throughput	908 *l/day*	2
	240 *gal/day*	
Average Throughput	789 *l/day*	2
	76,078 *gal/yr*	
Tank Diameter	3.7 *m*	2
	12.1 *ft*	
Tank Height	4.7 *m*	2
	15.4 *ft*	
Tank Volume	39.8 m^3	2
	10,514 *gal*	

1 *Dithiophosphate, Cresol -p, & Non-Organic Components*
2 *Resolution*

NaHS (Sodium hydrosulfide solution)		Notes
Design Throughput	41.4 *tonnes/day*	2, 3
	8,749 *gal/day*	
Average Throughput	36.0 *tonnes/day*	2, 3
	2,776,973 *gal/yr*	
Tank Diameter	7.5 *m*	1, 2
	24.6 *ft*	
Tank Height	8.5 *m*	1, 2
	27.9 *ft*	
Tank Volume	334.4 m^3	1, 2
	88,339 *gal*	
Specific Gravity	1.25	2

1 *Stainless Steel Heated and Insulated Tank*
2 *Resolution*
3 *As shipped concentration 40% - 45% NaHS*

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 1	OF: 4	SHEET: Drill & Blast
AIR EMISSION CALCULATIONS	SUBJECT: Drilling and Blasting	DATE: March 15, 2018		

East Plant Drilling

Emission Factors			Reference
PM_{10}	8.0E-5	*lb/ton*	*AP-42, Table 11.19.2-2 (wet drilling), Rev. 8/04*
PM Scaling Factors			
PM	2.1		*Ratio calculated based on particle size multiplier from AP-42, 13.2.4*
PM_{10}	1		
$PM_{2.5}$	1		

Production Drilling - Activity Information		
Ore Quantity	2,065,200	*tonne/yr*
	1,414	*tonne/hr*
	2,276,491	*ton/yr*
	1,559	*ton/hr*

Production Drilling - Emissions	*lb/hr*	*ton/yr*
PM	0.26	0.19
PM_{10}	0.12	9.1E-2
$PM_{2.5}$	0.12	9.1E-2

Conversions	
1.10231	*ton/tonne*
907.185	*kg/ton*
3.28084	*ft/m*
10.7639	ft^2/m^2
8,760	*hr/yr*
2,000	*lb/ton*

Blue values are input; black values are calculated or linked.

West Plant Drilling

Emission Factors			Reference
PM_{10}	8.0E-5	*lb/ton*	*AP-42, Table 11.19.2-2 (wet drilling), Rev. 8/04*
PM Scaling Factors			
PM	2.1		*Ratio calculated based on particle size multiplier from AP-42, 13.2.4*
PM_{10}	1		
$PM_{2.5}$	1		

Production Drilling - Activity Information		
Ore Quantity	164,300	*tonne/yr*
	1,414	*tonne/hr*
	181,110	*ton/yr*
	1,559	*ton/hr*

Production Drilling - Emissions	*lb/hr*	*ton/yr*
PM	0.26	1.5E-2
PM_{10}	0.12	7.2E-3
$PM_{2.5}$	0.12	7.2E-3

East Plant Blasting			Reference
Activity Information			
Blasting Agent Use	1,487,000	*kg/yr*	*Resolution*
	1,639	*ton/yr*	
No. of Blasts	487	*blasts/yr*	*Resolution*
	2	*max blasts/day*	*Resolution*
Operation	365	*days/yr*	
	24	*hr/day*	

Emission Factors			Reference
Emission Factor Equation	$TSP = 0.000014 \times A^{1.5}$	*lb/blast*	*AP-42, Table 11.9-1 (blasting, overburden), Rev. 7/98*
Where, A = Area per Blast	580	m^2 *(max per blast)*	*Resolution*
	6,243	ft^2 *(max per blast)*	*Based on maximum blasts per day*
TSP	6.91	*lb/blast*	
Where, A = Area per Blast	141,200	m^2 *(annual)*	*Resolution*
	1,519,863	ft^2 *(annual)*	
TSP	3,363	*lb/yr*	
CO	32.53	*lb/ton*	*Resolution*
NO_X	6.20	*lb/ton*	*Resolution*
SO_2	2	*lb/ton*	*AP-42, Table 13.3-1 (ANFO), Rev. 2/80*

PM Scaling Factors		Reference
PM	1	*AP-42, Table 11.9-1 (blasting, overburden), Rev. 7/98*
PM_{10}	0.52	*AP-42, Table 11.9-1 (blasting, overburden), Rev. 7/98*
$PM_{2.5}$	0.03	*AP-42, Table 11.9-1 (blasting, overburden), Rev. 7/98*

Emissions	*(lb/blast)**	*lb/hr**	*(lb/day)**	*ton/yr*
PM	6.9	6.9	13.8	1.7
PM_{10}	3.6	3.6	7.2	0.87
$PM_{2.5}$	0.21	0.21	0.41	5.0E-2
CO	109	109	219	26.7
NO_X	20.9	20.9	41.7	5.1
SO_2	6.7	6.7	13.5	1.6

* *Based on maximum of 2 blasts per day*

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 4	OF: 4	SHEET: Drill & Blast
AIR EMISSION CALCULATIONS	SUBJECT: Drilling and Blasting	DATE: March 15, 2018		

West Plant Blasting			Reference
Activity Information			
Blasting Agent Use	118,300	*kg/yr*	*Resolution*
	130	*ton/yr*	
No. of Blasts	390	*blasts/yr*	*Resolution*
	2	*max blasts/day*	*Resolution*
Operation	365	*days/yr*	
	24	*hr/day*	

Emission Factors			Reference
Emission Factor Equation	$TSP = 0.000014 \times A^{1.5}$	*lb/blast*	*AP-42, Table 11.9-1 (blasting, overburden), Rev. 7/98*
Where, A = Area per Blast	63	m^2 *(max per blast)*	*Resolution*
	678	ft^2 *(max per blast)*	*Based on maximum blasts per day*
TSP	0.25	*lb/blast*	
Where, A = Area per Blast	14,400	m^2 *(annual)*	*Resolution*
	155,000	ft^2 *(annual)*	
TSP	96	*lb/yr*	
CO	32.53	*lb/ton*	*Resolution*
NO_X	6.20	*lb/ton*	*Resolution*
SO_2	2	*lb/ton*	*AP-42, Table 13.3-1 (ANFO), Rev. 2/80*

PM Scaling Factors		Reference
PM	1	*AP-42, Table 11.9-1 (blasting, overburden), Rev. 7/98*
PM_{10}	0.52	*AP-42, Table 11.9-1 (blasting, overburden), Rev. 7/98*
$PM_{2.5}$	0.03	*AP-42, Table 11.9-1 (blasting, overburden), Rev. 7/98*

Emissions	*(lb/blast)**	*lb/hr**	*(lb/day)**	*ton/yr*
PM	0.25	0.25	0.49	4.8E-2
PM_{10}	0.13	0.13	0.26	2.5E-2
$PM_{2.5}$	7.4E-3	7.4E-3	1.5E-2	1.4E-3
CO	10.9	10.9	21.8	2.1
NO_X	2.1	2.1	4.1	0.40
SO_2	0.67	0.67	1.3	0.13

* *Based on maximum of 2 blasts per day*

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 1	OF: 1	SHEET: Flow
AIR EMISSION CALCULATIONS	SUBJECT: Flow Calculations (EPA Method 19)	DATE: March 15, 2018		

Stockpile Reclaim Dust Collectors *(Donaldson Torit DFO 4-32)*

Linear Interpolation (Pressure Based on Elevation)

Elevation	Pressure	Pressure	
ft	*kPa*	*atm*	
2,500*	92.5*	0.91	
2,888**	91.2	0.90	*West Plant Elevation/Pressure*
3,000*	90.8*	0.90	

* *www.engineeringtoolbox.com/air-altitude-pressure-d_462.html*
** *Google Earth*

56.77	F (WP Met Data)
0.90	atm
68.0	F, standard temp.
18,950	acfm*
17,423	scfm
1,045,398	

* Resolution *Reference 76 - Email from Eric Pedersen (M3) 3/27/14*

Underground Reclaim Dust Collectors

Linear Interpolation (Pressure Based on Elevation)

Elevation	*Pressure*	*Pressure*	
ft	kPa	atm	
-2,000*	109*	1.08	
-2,386	110.5	1.09	Mine Elevation/Pressure
-2,500*	111*	1.10	

* www.engineeringtoolbox.com/air-altitude-pressure-d_462.html

Elevation Calculation

4,176	EP Elevation*
6,562	Mine Depth**
-2,386	Mine Elevation

* *Google Earth*
** Resolution

40.0	*°C*	Resolution
1.09	*atm*	
68	*F, standard temp.*	
22,500	*a m³/hr*	Resolution
794,581	*acfh*	for crushers
915,420	*scfh*	
5,100	*a m³/hr*	Resolution
180,105	*acfh*	for conveyor transfer
207,495	*scfh*	
22,500	*a m³/hr*	Resolution
794,581	*acfh*	for silos
915,420	*scfh*	
17,000	*a m³/hr*	Resolution
600,350	*acfh*	for skip loading
691,651	*scfh*	
17,000	*a m³/hr*	Resolution
600,350	*acfh*	for bin unloading
691,651	*scfh*	

Conversions

101.3	*kPa/atm*
60	min/hr
35.31	ft^3/m^3

Blue values are input; black values are calculated or linked.

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 1	OF: 1	SHEET: MolyTalc
AIR EMISSION CALCULATIONS	SUBJECT: Moly/Talc Heat Treatment	DATE: March 15, 2018		

Molybdenite / Talc Concentrate Heat Treatment Emissions

	Long-Term Emissions*				Short-Term Emissions*	
SO_2 Emissions						
Uncontrolled SO_2 Emissions	245	*tonne/yr*	270	*ton/yr*	83.9	*lb/hr*
SO_2 Control Efficiency	95%				95%	
Controlled SO_2 Emissions	12.3	*tonne/yr*	13.6	*ton/yr*	4.2	*lb/hr*
VOC Emissions						
Uncontrolled VOC Emissions	503	*tonne/yr*	554	*ton/yr*	172	*lb/hr*
VOC Control Efficiency	88%				88%	
Controlled VOC Emissions	59.1	*tonne/yr*	65.1	*ton/yr*	20.2	*lb/hr*

* *Resolution*

Molybdenite / Talc Rotary Dryer - Throughput Rates and Process Emission Factors

Dryer Throughput		62,603	*tonne/yr*	*Resolution*
		69,008	*ton/yr*	
		9.7	*tonne/hr*	*Resolution*
		10.7	*ton/hr*	
Dryer Heat Capacity		16.25	*MMBtu/hr*	*Resolution*
Dryer Propane Usage		180	*gal/hr*	
		1,572,928	*gal/yr*	
Emission Factors	PM	10	*lb/ton*	*AP-42, Table 12.3-3, Rev. 10/86*
	PM_{10}	9.9	*lb/ton*	*AP-42, Table 12.3-3, Rev. 10/86, With Particle Size Ratio*
	$PM_{2.5}$	8.4	*lb/ton*	*AP-42, Table 12.3-3, Rev. 10/86, With Particle Size Ratio*
PM Control Efficiency		99.0%		*EPA Air Pollution Control Technology Fact Sheet, Wet Electrostatic Precipitator*

Molybdenite / Talc Rotary Dryer - Process Emissions

		lb/hr	*ton/yr*
Uncontrolled	PM	107	345
	PM_{10}	106	341
	$PM_{2.5}$	90.0	291
Controlled	PM	1.1	3.5
	PM_{10}	1.1	3.4
	$PM_{2.5}$	0.90	2.9

Molybdenite / Talc Rotary Dryer - Combustion Emissions

Pollutant	*lb/k-gal* *	*lb/hr*	*ton/yr*
PM	0.7	0.13	0.55
SO_2	1.6	0.29	1.3
NO_X	13	2.3	10.2
CO	7.5	1.3	5.9
VOC	0.8	0.14	0.63

* *AP-42, Table 1.5-1, Rev. 07/08*

Conversions

90.5	*MMBtu/k-gal (AP-42, Appendix A)*
7,000	*gr/lb*
0.0185%	*S in Propane (GPA 2140-97)*
44.08	*lb/mol* C_3H_8
359.05	*SCF/lb-mol (0° F)*
100	*SCF/100 SCF*
1.10231	*ton/tonne*
2.20462	*lb/kg*
2,000	*lb/ton*

Blue values are input; black values are calculated or linked.

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 1	OF: 3	SHEET: Deliveries
AIR EMISSION CALCULATIONS	SUBJECT: Delivery Fugitives	DATE: March 15, 2018		

Summary of Material and Equipment Deliveries

CONTROLLED EMISSIONS (SHORT-TERM)

Location	PM *lb/hr*	PM_{10} *lb/hr*	$PM_{2.5}$ *lb/hr*	NO_X *lb/hr*	SO_2 *lb/hr*	CO *lb/hr*	VOC *lb/hr*
East Plant	7.8	1.8	0.2	0.1	4.0E-4	4.3E-2	9.6E-3
Mill	18.3	4.3	0.4	0.3	9.4E-4	0.1	2.3E-2
Tailings Storage Facility*							
Filter Plant and Loadout Facility*							

* *Regular deliveries not scheduled for production phase.*

CONTROLLED EMISSIONS (LONG-TERM)

Location	PM *ton/yr*	PM_{10} *ton/yr*	$PM_{2.5}$ *ton/yr*	NO_X *ton/yr*	SO_2 *ton/yr*	CO *ton/yr*	VOC *ton/yr*
East Plant	4.9	1.2	0.1	9.9E-2	3.1E-4	3.3E-2	7.4E-3
Mill	4.9	1.1	0.1	9.5E-2	3.0E-4	3.2E-2	7.2E-3
Tailings Storage Facility*							
Filter Plant and Loadout Facility*							

* *Regular deliveries not scheduled for production phase.*

UNCONTROLLED EMISSIONS (SHORT-TERM)

Location	PM *lb/hr*	PM_{10} *lb/hr*	$PM_{2.5}$ *lb/hr*	NO_X *lb/hr*	SO_2 *lb/hr*	CO *lb/hr*	VOC *lb/hr*
East Plant	77.5	18.0	1.8	0.1	4.0E-4	4.3E-2	9.6E-3
Mill	183	42.5	4.3	0.3	9.4E-4	0.1	2.3E-2
Tailings Storage Facility*							
Filter Plant and Loadout Facility*							

* *Regular deliveries not scheduled for production phase.*

UNCONTROLLED EMISSIONS (LONG-TERM)

Location	PM *ton/yr*	PM_{10} *ton/yr*	$PM_{2.5}$ *ton/yr*	NO_X *ton/yr*	SO_2 *ton/yr*	CO *ton/yr*	VOC *ton/yr*
East Plant	49.2	11.4	1.1	9.9E-2	3.1E-4	3.3E-2	7.4E-3
Mill	48.5	11.3	1.1	9.5E-2	3.0E-4	3.2E-2	7.2E-3
Tailings Storage Facility*							
Filter Plant and Loadout Facility*							

* *Regular deliveries not scheduled for production phase.*

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 2	OF: 3	SHEET: Deliveries
AIR EMISSION CALCULATIONS	SUBJECT: Delivery Fugitives	DATE: March 15, 2018		

Fugitive Dust from Material and Equipment Deliveries

Deliveries by Location	*trips/yr*	*trips/day*	*trips/hr*	*one way VMT, ea***	*VMT/yr*	*VMT/hr*
East Plant	6,166	20	4	1.9	23,431	15
Mill	6,935	19	11	1.6	22,608	36
Tailings Storage Facility*	0	0		3.8	0	0
Filter Plant and Loadout Facility*	0	0		1.3	0	0

* *Regular deliveries not scheduled for production phase.*

** *Resolution*

Unpaved Roads - Equation & Constants*

$E = k \times (s / 12)^a \times (W / 3)^b \times (365 - P) / 365$

		Empirical Constants for Industrial Roads		
	Constant	**PM**	**PM_{10}**	**$PM_{2.5}$**
k, a, b - empirical constants	k	4.9	1.5	0.15
s - surface material silt content %	a	0.7	0.9	0.9
W - mean vehicle wt ton	b	0.45	0.45	0.45

* *AP-42, 13.2.2, Equations 1a & 2, Table 13.2.2-2, Unpaved Roads, Rev. 11/06*

EMISSION FACTORS

Location	**Paved/Unpaved**	**Silt** *%**	**Vehicle Weight** ***ton****	**PM** *lb/VMT*	**PM_{10}** *lb/VMT*	**$PM_{2.5}$** *lb/VMT*
East Plant	Paved & Unpaved***	3.0	28.3	5.1	1.2	0.12
Mill	Unpaved	3.0	28.3	5.1	1.2	0.12
Tailings Storage Facility	Unpaved	3.0	28.3	5.1	1.2	0.12
Filter Plant and Loadout Facility	Unpaved	3.0	28.3	5.1	1.2	0.12

* *AP-42, Chapter 13.2.2*

** *Representative 18-Wheeler Weight (16.5 ton) and 40-ton Highway Limit*

*** *Emissions calculated for worst case (all unpaved)*

CONTROLLED EMISSIONS

Location	**PM** *lb/hr*	**PM_{10}** *lb/hr*	**$PM_{2.5}$** *lb/hr*	**PM** *ton/yr*	**PM_{10}** *ton/yr*	**$PM_{2.5}$** *ton/yr*
East Plant	7.7	1.8	0.18	4.9	1.1	0.11
Mill	18.3	4.2	0.42	4.8	1.1	0.11
Tailings Storage Facility*						
Filter Plant and Loadout Facility*						

* *Regular deliveries not scheduled for production phase.*

UNCONTROLLED EMISSIONS

Location	**PM** *lb/hr*	**PM_{10}** *lb/hr*	**$PM_{2.5}$** *lb/hr*	**PM** *ton/yr*	**PM_{10}** *ton/yr*	**$PM_{2.5}$** *ton/yr*
East Plant	77.4	18.0	1.8	49.2	11.4	1.1
Mill	183	42.4	4.2	48.4	11.2	1.1
Tailings Storage Facility*						
Filter Plant and Loadout Facility*						

* *Regular deliveries not scheduled for production phase.*

Conversions & Assumptions	
453.592	*g/lb*
2,000	*lb/ton*
24	*hr/day*
90%	*Control (Chemical Suppressant)*

Days of >0.01" Precip		
EP	64	*EPS Precip Data (days >0.01'')*
Mill	58	*WPS Precip Data (days >0.01'')*
TSF	57	*TSF Precip Data (days >0.01'')*
FPLF	57	*TSF Precip Data (days >0.01'')*

Blue values are input; black values are calculated or linked.

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 3	OF: 3	SHEET: Deliveries
AIR EMISSION CALCULATIONS	SUBJECT: Delivery Fugitives	DATE: March 15, 2018		

Combustion Emissions from Deliveries

Location	VMT/hr	PM lb/hr	PM_{10} lb/hr	$PM_{2.5}$ lb/hr	NO_X lb/hr	SO_2 lb/hr	CO lb/hr	VOC lb/hr
East Plant	15	3.2E-2	3.2E-2	9.3E-3	0.1	4.0E-4	4.3E-2	9.6E-3
Mill	36	7.7E-2	7.7E-2	2.2E-2	0.3	9.4E-4	0.1	2.3E-2
Tailings Storage Facility*	0							
Filter Plant and Loadout Facility*	0							

* *Regular deliveries not scheduled for production phase.*

Location	VMT/yr	PM ton/yr	PM_{10} ton/yr	$PM_{2.5}$ ton/yr	NO_X ton/yr	SO_2 ton/yr	CO ton/yr	VOC ton/yr
East Plant	23,431	2.5E-2	2.5E-2	7.1E-3	9.9E-2	3.1E-4	3.3E-2	7.4E-3
Mill	22,608	2.4E-2	2.4E-2	6.9E-3	9.5E-2	3.0E-4	3.2E-2	7.2E-3
Tailings Storage Facility*	0							
Filter Plant and Loadout Facility*	0							

* *Regular deliveries not scheduled for production phase.*

Combustion Emission Factor*	PM g/VMT	PM_{10} g/VMT	$PM_{2.5}$ g/VMT	NO_X g/VMT	SO_2 g/VMT	CO g/VMT	VOC g/VMT
	1.0	1.0	0.3	3.8	1.2E-2	1.3	0.3

* *MOVES 2014a*

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
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AIR EMISSION CALCULATIONS	SUBJECT: Concrete Batch Plant	DATE: March 15, 2018		

CONTROLLED EMISSIONS

	PM		PM_{10}		$PM_{2.5}$	
Source Description	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*
Aggregate Delivery to Ground Storage	0.45	0.25	0.21	0.12	3.2E-2	1.8E-2
Sand Delivery to Ground Storage	0.23	0.13	0.11	6.1E-2	1.6E-2	9.3E-3
Aggregate Transfer to Conveyor Belt via Chute	3.5E-2	2.2E-2	1.6E-2	1.1E-2	2.5E-3	1.6E-3
Sand Transfer to Conveyor Belt via Chute	2.8E-2	1.2E-2	1.3E-2	5.3E-3	2.0E-3	8.5E-4
Aggregate Transfer to Elevated Storage	3.5E-2	2.2E-2	1.6E-2	1.1E-2	2.5E-3	1.6E-3
Sand Transfer to Elevated Storage	2.8E-2	1.2E-2	1.3E-2	5.3E-3	2.0E-3	8.5E-4
Weigh Hopper Loading (Aggregate & Sand)	0.31	0.15	0.18	8.6E-2	2.7E-2	1.3E-2
Weigh Hopper Discharge to Truck Loading Conveyor (Agg)	3.5E-2	2.2E-2	1.6E-2	1.1E-2	2.5E-3	1.6E-3
Weigh Hopper Discharge to Truck Loading Conveyor (Sand)	2.8E-2	1.2E-2	1.3E-2	5.3E-3	2.0E-3	8.5E-4
Cement Unloading to Silo	7.5E-2	3.1E-2	2.6E-2	1.1E-2	3.9E-3	1.6E-3
Flyash Unloading to Silo	8.7E-2	4.4E-2	4.8E-2	2.4E-2	7.2E-3	3.7E-3
Silica Fume Unloading to Silo	3.5E-2	9.5E-3	1.9E-2	5.2E-3	2.9E-3	7.9E-4
Cement & Flyash Discharge to Silo Weigh Hopper	4.3E-3	1.8E-3	2.5E-3	1.0E-3	3.8E-4	1.6E-4
Silo Weigh Hopper Discharge to Truck Loading Conveyor	4.3E-3	1.8E-3	2.5E-3	1.0E-3	3.8E-4	1.6E-4
Truck Loading*	8.8	3.7	2.4	0.98	0.36	0.15
Total	**10.2**	**4.4**	**3.0**	**1.3**	**0.46**	**0.20**

**Emissions for truck loading are based on quantity of cement and cement supplement, per AP-42 Chapter 11.12.*

UNCONTROLLED EMISSIONS

	PM		PM_{10}		$PM_{2.5}$	
Source Description	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*	*lb/hr*	*ton/yr*
Aggregate Delivery to Ground Storage	0.56	0.32	0.27	0.15	4.1E-2	2.3E-2
Sand Delivery to Ground Storage	0.28	0.16	0.13	7.6E-2	2.0E-2	1.2E-2
Aggregate Transfer to Conveyor Belt via Chute	0.49	0.32	0.23	0.15	3.5E-2	2.3E-2
Sand Transfer to Conveyor Belt via Chute	0.39	0.16	0.18	7.6E-2	2.8E-2	1.2E-2
Aggregate Transfer to Elevated Storage	0.49	0.32	0.23	0.15	3.5E-2	2.3E-2
Sand Transfer to Elevated Storage	0.39	0.16	0.18	7.6E-2	2.8E-2	1.2E-2
Weigh Hopper Loading (Aggregate & Sand)	1.2	0.59	0.72	0.34	0.11	5.2E-2
Weigh Hopper Discharge to Truck Loading Conveyor (Agg)	0.49	0.32	0.23	0.15	3.5E-2	2.3E-2
Weigh Hopper Discharge to Truck Loading Conveyor (Sand)	0.39	0.16	0.18	7.6E-2	2.8E-2	1.2E-2
Cement Unloading to Silo	55.6	22.8	35.8	14.7	5.4	2.2
Flyash Unloading to Silo	30.7	15.6	10.7	5.5	1.6	0.83
Silica Fume Unloading to Silo	12.3	3.3	4.3	1.2	0.65	0.18
Cement & Flyash Discharge to Silo Weigh Hopper	0.43	0.18	0.25	0.10	3.8E-2	1.6E-2
Silo Weigh Hopper Discharge to Truck Loading Conveyor	0.43	0.18	0.25	0.10	3.8E-2	1.6E-2
Truck Loading*	100	41.7	27.9	11.6	4.2	1.7
Total	**205**	**86.3**	**81.6**	**34.3**	**12.4**	**5.2**

**Emissions for truck loading are based on quantity of cement and cement supplement, per AP-42 Chapter 11.12.*

Conversions	
2,000	*lb/ton*

Blue values are input; black values are calculated or linked.

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AIR EMISSION CALCULATIONS	SUBJECT: Concrete Batch Plant	DATE: March 15, 2018		

Max Emission Scenario: Shotcrete

ACTIVITY RATES

Source Description	Capacity[1] ton/hr	Capacity[1] ton/yr	Control Description		Reference
Aggregate Delivery to Ground Storage	81.0	91,386	*Water Sprays*	20%	2
Sand Delivery to Ground Storage	135	154,412	*Water Sprays*	20%	2
Aggregate Transfer to Conveyor Belt via Chute	70.8	91,386	*Wind Break*		
Sand Transfer to Conveyor Belt via Chute	185	154,412	*Wind Break*		
Aggregate Transfer to Elevated Storage	70.8	91,386	*Wind Break*		
Sand Transfer to Elevated Storage	185	154,412	*Wind Break*		
Weigh Hopper Loading (Aggregate & Sand)	255	245,797	*Enclosure*	75%	3
Weigh Hopper Discharge to Truck Loading Conveyor (Agg)	70.8	91,386	*Enclosure*		
Weigh Hopper Discharge to Truck Loading Conveyor (Sand)	185	154,412	*Enclosure*		
Cement Unloading to Silo	76.2	62,467	*Dust Collector*		
Flyash Unloading to Silo	9.8	9,947	*Dust Collector*		
Silica Fume Unloading to Silo	3.9	2,130	*Dust Collector*		
Cement & Flyash Discharge to Silo Weigh Hopper	89.8	74,544	*Vent Filter*	99%	4
Silo Weigh Hopper Discharge to Truck Loading Conveyor	89.8	74,544			
Truck Loading	345	320,341	*Dust Collector*		

1 *Resolution Copper*
2 *AP-42, Table B2.-3, Spray Tower ($PM_{2.5}$), Rev. 9/90*
3 *Stationary Source Control Techniques Document for Fine Particulate Matter (EPA 1998), Table 6.1, Telescoping Chute*
4 *Stationary Source Control Techniques Document for Fine Particulate Matter (EPA 1998), Figure 5.3-2*

EMISSION FACTORS

	Uncontrolled			Controlled			Reference
Source Description	PM lb/ton	PM_{10} lb/ton	$PM_{2.5}$ lb/ton	PM lb/ton	PM_{10} lb/ton	$PM_{2.5}$ lb/ton	
Aggregate Delivery to Ground Storage	0.0069	0.0033	0.0005	0.00552	0.00264	0.0004	1
Sand Delivery to Ground Storage	0.0021	0.00099	0.00015	0.00168	0.000792	0.00012	2
Aggregate Transfer to Conveyor Belt via Chute	0.0069	0.0033	0.00050	0.00049	0.00023	0.000035	3
Sand Transfer to Conveyor Belt via Chute	0.0021	0.00099	0.00015	0.00015	0.000069	0.000011	4
Aggregate Transfer to Elevated Storage	0.0069	0.0033	0.0005	0.00049	0.00023	0.000035	3
Sand Transfer to Elevated Storage	0.0021	0.00099	0.00015	0.00015	0.000069	0.000011	4
Weigh Hopper Loading (Aggregate & Sand)	0.0048	0.0028	0.0004	0.0012	0.0007	0.000106	5
Weigh Hopper Discharge to Truck Loading Conveyor (Agg)	0.0069	0.0033	0.00050	0.00049	0.00023	0.000035	3
Weigh Hopper Discharge to Truck Loading Conveyor (Sand)	0.0021	0.00099	0.00015	0.00015	0.000069	0.000011	4
Cement Unloading to Silo	0.73	0.47	0.07	0.00099	0.00034	0.0001	6
Flyash Unloading to Silo	3.14	1.1	0.2	0.0089	0.0049	0.001	7
Silica Fume Unloading to Silo	3.14	1.1	0.2	0.0089	0.0049	0.001	7
Cement & Flyash Discharge to Silo Weigh Hopper	0.0048	0.0028	0.0004	0.000048	0.000028	0.00000424	5
Silo Weigh Hopper Discharge to Truck Loading Conveyor	0.0048	0.0028	0.0004	0.000048	0.000028	0.00000424	5
Truck Loading	1.118	0.31	0.0469	0.0980	0.0263	0.004	8

1 *AP-42 Table 11.12-2 based on section 13.2.4 equation 1 (Aggregate Transfers); Controlled 20% with water sprays*
2 *AP-42 Table 11.12-2 based on section 13.2.4 equation 1 (Sand Transfers); Controlled 20% with water sprays*
3 *AP-42 Table 11.12-2 based on section 13.2.4 equation 1 (Aggregate Transfers); Controlled wind speed (1.3 mph)*
4 *AP-42 Table 11.12-2 based on section 13.2.4 equation 1 (Sand Transfers); Controlled wind speed (1.3 mph)*
5 *AP-42 Table 11.12-2 (weigh hopper loading); $PM_{2.5}$ factors based on Chapter 13.2.4 particle size multipliers*
6 *AP-42 Table 11.12-2 (cement unloading to elevated storage silo); $PM_{2.5}$ factors based on Chapter 13.2.4 particle size multipliers*
7 *AP-42 Table 11.12-2 (cement supplement unloading to elevated storage silo); $PM_{2.5}$ factors based on Chapter 13.2.4 particle size multipliers*
8 *AP-42 Table 11.12-2 (Truck Loading - truck mix); $PM_{2.5}$ factors based on Chapter 13.2.4 particle size multipliers*

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AIR EMISSION CALCULATIONS	SUBJECT: Hazardous Air Pollutants	DATE: March 15, 2018		

Hazardous Air Pollutants Emissions Summary

CAS No.	Pollutant	ULSD Engines *ton/yr*	Process & Fug. Dust *ton/yr*	Reagents *ton/yr*	Diesel Tanks *ton/yr*	Propane Combustion *ton/yr*	Total *ton/yr*	POM
106990	1,3-Butadiene	2.36E-02					**2.36E-02**	
83329	Acenaphthene	1.49E-03					**1.49E-03**	POM
208968	Acenaphthylene	4.30E-03					**4.30E-03**	POM
75070	Acetaldehyde	4.66E-01					**4.66E-01**	
107028	Acrolein	5.68E-02					**5.68E-02**	
120127	Anthracene	1.29E-03					**1.29E-03**	POM
7440382	Arsenic	2.95E-03	4.79E-03			9.45E-08	**7.74E-03**	
56553	Benzo(a)anthracene	1.10E-03					**1.10E-03**	POM
71432	Benzene	6.68E-01			1.13E-06	9.92E-07	**6.68E-01**	
50328	Benzo(a)pyrene	1.48E-04					**1.48E-04**	POM
205992	Benzo(b)fluoranthene	2.11E-04					**2.11E-04**	POM
191242	Benzo(g,h,l)perylene	3.70E-04					**3.70E-04**	POM
207089	Benzo(k)fluoranthene	1.23E-04					**1.23E-04**	POM
7440417	Beryllium	2.22E-03	3.35E-04			5.67E-09	**2.55E-03**	
92524	Biphenyl				1.41E-04		**1.41E-04**	POM
7440439	Cadmium	2.22E-03	1.65E-04			5.20E-07	**2.38E-03**	
7440473	Chromium	2.22E-03	2.66E-02			6.61E-07	**2.88E-02**	
218019	Chrysene	4.21E-04					**4.21E-04**	POM
7440484	Cobalt		3.55E-03			3.97E-08	**3.55E-03**	
53703	Dibenzo(a,h)anthracene	3.98E-04					**3.98E-04**	POM
100414	Ethylbenzene				1.83E-05		**1.83E-05**	
206440	Fluoranthene	5.13E-03					**5.13E-03**	POM
86737	Fluorene	1.93E-02					**1.93E-02**	POM
50000	Formaldehyde	7.22E-01				3.54E-05	**7.22E-01**	
110543	Hexane				1.41E-03	8.50E-04	**2.26E-03**	
193395	Indeno(1,2,3-c,d)pyrene	2.82E-04					**2.82E-04**	POM
7439921	Lead	6.65E-03	1.06E-02				**1.72E-02**	
7439965	Manganese	4.43E-03	2.98E-02			1.79E-07	**3.42E-02**	
7439976	Mercury	2.22E-03	5.67E-02			1.23E-07	**5.89E-02**	
91203	Naphthalene	6.88E-02			7.74E-04	2.88E-07	**6.95E-02**	POM
7440020	Nickel	2.22E-03	4.58E-03			9.92E-07	**6.79E-03**	
85018	Phenanthrene	2.33E-02			1.76E-04		**2.34E-02**	POM
108952	Phenol				9.01E-05		**9.01E-05**	
129000	Pyrene	3.38E-03					**3.38E-03**	POM
7782492	Selenium	1.11E-02	1.19E-03			1.13E-08	**1.23E-02**	
100425	Styrene				4.50E-05		**4.50E-05**	
108883	Toluene	2.85E-01			4.50E-05	1.61E-06	**2.85E-01**	
1330207	Xylene	1.98E-01					**1.98E-01**	
95636	1,2,4-trimethylbenzene							
7783064	Hydrogen sulfide			2.57E-02			**2.57E-02**	
106445	p-Cresol			2.50E-05			**2.50E-05**	
79061	Acrylamide			1.48E-02			**1.48E-02**	
106467	Dichlorobenzene					5.67E-07	**5.67E-07**	
7440360	Antimony		3.69E-04				**3.69E-04**	
POM	POM (aggregated)					4.17E-08	**4.17E-08**	POM
POM	*Polycylic Organic Matter Subtotal*	*1.30E-01*	*0.00E+00*	*0.00E+00*	*1.09E-03*	*3.30E-07*	*1.31E-01*	
HAPs	All HAPs	2.58E+00	1.39E-01	4.05E-02	2.70E-03	8.92E-04	2.77E+00	

Conversions

137,000	*Btu/gal*	*AP-42, Appendix A, Diesel, Rev. 9/85*
1,000,000	*Btu/MMBtu*	
2,000	*lb/ton*	

Blue values are input; black values are calculated or linked

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AIR EMISSION CALCULATIONS	SUBJECT: Hazardous Air Pollutants	DATE: March 15, 2018		

HAPs Emissions for ULSD Engines (Small & Large)

			Small ULSD Engines* 1,204,949 MMBtu/yr***		Large ULSD Engines** 271,739 MMBtu/yr***	
CAS No.	**Pollutant**	**POM**	***lb/MMBtu***	***ton/yr***	***lb/MMBtu***	***ton/yr***
106990	1,3-Butadiene		3.91E-05	2.36E-02		
83329	Acenaphthene	POM	1.42E-06	8.56E-04	4.68E-06	6.36E-04
208968	Acenaphthylene	POM	5.06E-06	3.05E-03	9.23E-06	1.25E-03
75070	Acetaldehyde		7.67E-04	4.62E-01	2.52E-05	3.42E-03
107028	Acrolein		9.25E-05	5.57E-02	7.88E-06	1.07E-03
120127	Anthracene	POM	1.87E-06	1.13E-03	1.23E-06	1.67E-04
56553	Benzo(a)anthracene	POM	1.68E-06	1.01E-03	6.22E-07	8.45E-05
71432	Benzene		9.33E-04	5.62E-01	7.76E-04	1.05E-01
50328	Benzo(a)pyrene	POM	1.88E-07	1.13E-04	2.57E-07	3.49E-05
205992	Benzo(b)fluoranthene	POM	9.91E-08	5.97E-05	1.11E-06	1.51E-04
191242	Benzo(g,h,l)perylene	POM	4.89E-07	2.95E-04	5.56E-07	7.55E-05
207089	Benzo(k)fluoranthene	POM	1.55E-07	9.34E-05	2.18E-07	2.96E-05
218019	Chrysene	POM	3.53E-07	2.13E-04	1.53E-06	2.08E-04
53703	Dibenzo(a,h)anthracene	POM	5.83E-07	3.51E-04	3.46E-07	4.70E-05
206440	Fluoranthene	POM	7.61E-06	4.58E-03	4.03E-06	5.48E-04
86737	Fluorene	POM	2.92E-05	1.76E-02	1.28E-05	1.74E-03
50000	Formaldehyde		1.18E-03	7.11E-01	7.89E-05	1.07E-02
193395	Indeno(1,2,3-c,d)pyrene	POM	3.75E-07	2.26E-04	4.14E-07	5.62E-05
91203	Naphthalene	POM	8.48E-05	5.11E-02	1.30E-04	1.77E-02
85018	Phenanthrene	POM	2.94E-05	1.77E-02	4.08E-05	5.54E-03
129000	Pyrene	POM	4.78E-06	2.88E-03	3.71E-06	5.04E-04
108883	Toluene		4.09E-04	2.46E-01	2.81E-04	3.82E-02
1330207	Xylene		2.85E-04	1.72E-01	1.93E-04	2.62E-02
POM	*Polycylic Organic Matter Subtotal*			*1.01E-01*		*2.87E-02*
HAPs	**All HAPs**			**2.33E+00**		**2.14E-01**

* *AP-42, Table 3.3-2, Rev. 10/96, diesel engines (≤ 600 hp)*

** *AP-42, Tables 3.4-3 & 3.4-4, Rev. 10/96, large diesel engines (> 600 hp)*

*** *Calculated using a 15% fuel contingency*

Diesel Combustion Metal Emissions

CAS No.	**Pollutant**	**HAP**	***lb/10^{12} Btu****	***lb/MMBtu***	***ton/yr***
7440382	Arsenic	HAP	4	4.00E-06	2.95E-03
7440417	Beryllium	HAP	3	3.00E-06	2.22E-03
7440439	Cadmium	HAP	3	3.00E-06	2.22E-03
7440473	Chromium	HAP	3	3.00E-06	2.22E-03
	Copper		6	6.00E-06	4.43E-03
7439921	Lead	HAP	9	9.00E-06	6.65E-03
7439976	Mercury	HAP	3	3.00E-06	2.22E-03
7439965	Manganese	HAP	6	6.00E-06	4.43E-03
7440020	Nickel	HAP	3	3.00E-06	2.22E-03
7782492	Selenium	HAP	15	1.50E-05	1.11E-02
	Zinc		4	4.00E-06	2.95E-03
Total Diesel Combustion Metal Emissions					**4.36E-02**

* *AP-42, Table 1.3-10, Rev. 5/10*

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 3	OF: 4	SHEET: HAPs
AIR EMISSION CALCULATIONS	SUBJECT: Hazardous Air Pollutants	DATE: March 15, 2018		

HAPs Emissions for Propane Combustion

Propane Sources

Source	Operation *hr/yr*	Throughput *MMBtu/hr*	*MMBtu/yr*
Hydro House Propane Heater (0.045 MMBtu/hr)	8,760	0.045	394.2
Hydro House Propane Heater (0.065 MMBtu/hr)	8,760	0.065	569.4
Total		**0.11**	**963.6**

Propane HAP & Metal Emissions

CAS No.	Pollutant	Emission Factor* *lb/MMScf*	*lb/MMBtu***	Emissions *ton/yr*
71432	Benzene	2.10E-03	2.06E-06	9.92E-07
106467	Dichlorobenzene	1.20E-03	1.18E-06	5.67E-07
50000	Formaldehyde	7.50E-02	7.35E-05	3.54E-05
110543	Hexane	1.80E+00	1.76E-03	8.50E-04
91203	Naphthalene	6.10E-04	5.98E-07	2.88E-07
108883	Toluene	3.40E-03	3.33E-06	1.61E-06
POM	POM (aggregated)	8.82E-05	8.65E-08	4.17E-08
7440382	Arsenic	2.00E-04	1.96E-07	9.45E-08
7440417	Beryllium	1.20E-05	1.18E-08	5.67E-09
7440439	Cadmium	1.10E-03	1.08E-06	5.20E-07
7440473	Chromium	1.40E-03	1.37E-06	6.61E-07
7440484	Cobalt	8.40E-05	8.24E-08	3.97E-08
7439965	Manganese	3.80E-04	3.73E-07	1.79E-07
7439976	Mercury	2.60E-04	2.55E-07	1.23E-07
7440020	Nickel	2.10E-03	2.06E-06	9.92E-07
7782492	Selenium	2.40E-05	2.35E-08	1.13E-08
	Total HAPs			**8.92E-04**

**AP-42, Table 1.4-3 & 1.4-4 (7/98) Natural Gas Combustion*

***Natural Gas Higher Heating Value* 1,020 *Btu/scf*

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HAPs Emissions from Process & Fugitive Dust

Ore HAPs Concentrations & Emissions

CAS No.		Pollutant	Concentration* %	Emissions ton/yr
7440360	Sb	Antimony	0.0003%	3.69E-04
7440382	As	Arsenic	0.0040%	4.79E-03
7440417	Be	Beryllium	0.0003%	3.35E-04
7440439	Cd	Cadmium	0.0001%	1.65E-04
7440473	Cr	Chromium	0.0222%	2.66E-02
7440484	Co	Cobalt	0.0030%	3.55E-03
7439921	Pb	Lead	0.0088%	1.06E-02
7439965	Mn	Manganese	0.0248%	2.98E-02
7439976	Hg	Mercury	0.0473%	5.67E-02
7440020	Ni	Nickel	0.0038%	4.58E-03
7782492	Se	Selenium	0.0010%	1.19E-03

* *Resolution*

PM Emissions

	PM ton/yr
East Plant	36.8
Mill	21.9
Loadout	0.0
Tailings	61.2
Total	**120.0**

HAPs Emissions from Reagent Handling & Storage

CAS No.	Pollutant	lb/yr	ton/yr	Source
7783064	Hydrogen sulfide*	51.4	2.57E-02	NaHS (Sodium hydrosulfide solution)
106445	p-Cresol*	0.05	2.50E-05	CYTEC 8989
79061	Acrylamide**		1.48E-02	Flocculent (CIBA Magnafloc 10 & 155)

* *Calculated using EPA Tanks 4.0.9d*

** *Assuming all PM emitted from material transfer is Acrylamide*

HAPs Emissions from Diesel Storage Tanks

CAS No.	Pollutant	Weight Percent*	Emissions ton/yr	POM
71432	Benzene	0.001%	1.13E-06	
92524	Biphenyl	0.100%	1.41E-04	POM
100414	Ethyl benzene	0.013%	1.83E-05	
110543	Hexane	1.000%	1.41E-03	
91203	Naphthalene	0.550%	7.74E-04	POM
108952	Phenol	0.064%	9.01E-05	
100425	Styrene	0.032%	4.50E-05	
108883	Toluene	0.032%	4.50E-05	
85018	Phenanthrene	0.125%	1.76E-04	POM
POM	*Polycylic Organic Matter Subtotal*	7.75E-03	1.09E-03	

* *Resolution*

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AIR EMISSION CALCULATIONS	SUBJECT: Direct Greenhouse Gases & CO_2e	DATE: March 15, 2018		

DIRECT GREENHOUSE GAS & CO_2 EQUIVALENT CALCULATIONS - PRELIMINARY

GHG Emission Factors

Pollutant	Fuel	EF kg/MMBtu	Reference
CO_2	Propane	61.71	*40 CFR Part 98, Table C-1 to Subpart C (11/13) LPG*
CH_4	Propane	3.0E-3	*40 CFR Part 98, Table C-2 to Subpart C (11/13) Petroleum*
N_2O	Propane	6.0E-4	*40 CFR Part 98, Table C-2 to Subpart C (11/13) Petroleum*
CO_2	Diesel	73.96	*40 CFR Part 98, Table C-1 to Subpart C (11/13) Distillate Fuel Oil #2*
CH_4	Diesel	3.0E-3	*40 CFR Part 98, Table C-2 to Subpart C (11/13) Petroleum*
N_2O	Diesel	6.0E-4	*40 CFR Part 98, Table C-2 to Subpart C (11/13) Petroleum*

Propane Fuel Use & Direct GHG Emissions

Contributor	*MMBtu/hr*	*hr/yr*	*MMBtu/yr*	CO_2 *tonne/yr**	CH_4 *tonne/yr**	N_2O *tonne/yr**
Hydro House Heaters	0.11	8,760	964	59.5	2.9E-3	5.8E-4
Total			**964**	**59.5**	**2.9E-3**	**5.8E-4**

**metric tons per year*

Diesel Fuel Use & Direct GHG Emissions

Contributor	Diesel Cons. *gal/yr*	+15% *gal/yr*	*MMBtu/yr*	CO_2 *tonne/yr***	CH_4 *tonne/yr***	N_2O *tonne/yr***
East Plant Fleet	2,345,797	2,697,666	369,580	27,334	1.1	0.22
Mill Fleet	741,883	853,166	116,884	8,645	0.35	7.0E-2
Loadout Fleet	555,866	639,246	87,577	6,477	0.26	5.3E-2
Tailings Fleet	3,993,028	4,591,982	629,102	46,528	1.9	0.38
East Plant Emergency Generators	1,643,748	1,890,310	258,973	19,154	0.78	0.16
Mil Emergency Generators	55,500	63,825	8,744	647	2.6E-2	5.2E-3
Tailings Emergency Generators	18,500	21,275	2,915	216	8.7E-3	1.7E-3
Filter Plant Emergency Generators	18,500	21,275	2,915	216	8.7E-3	1.7E-3
Total	**9,372,822**	**10,778,745**	**1,476,688**	**109,216**	**4.4**	**0.89**

**Calculated by mass balance using a 15% fuel contingency*

***metric tons per year*

Direct CO_2e Emissions

Greenhouse Gas	Emissions *tonne/yr**	Global Warming Potential**	CO_2e *tonne/yr**
Carbon Dioxide (CO_2)	109,275	1	109,275
Methane (CH_4)	4.4	25	111
Nitrous Oxide (N_2O)	0.89	298	264
Total			**109,650**

direct emissions > 25,000 metric tons per year

** metric tons per year*

*** 40 CFR Part 98, Table A-1 to Subpart A (11/13) Chemical-Specific GWPs*

The revised draft guidance sets forth a reference point of 25,000 metric tons CO2-equivalent GHG emissions on an annual basis below which a quantitative analysis of GHG emissions is not recommended unless quantification is easily accomplished, in light of the availability of quantification tools and appropriate input data.

Conversions

1,000	*kg/metric tons*	
7,000	*MMBtu/hp-hr**	
137,000	*Btu/gal*	*AP42, Appendix A*
1,000,000	*Btu/MMBtu*	

** AP-42 Table 3.3-1, Footnote a & AP-42 Table 3.4-1, Footnote e*

Blue values contain input, black values are calculated or linked

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AIR EMISSION CALCULATIONS	SUBJECT: Underground Scrubbing	DATE: March 15, 2018		

Underground Control Summary - Control Efficiencies (MODELING ONLY)

Combined Underground Scrubbing Efficiency for Particulate Pollutants

	PM	PM_{10}	$PM_{2.5}$
Water Droplets in Shafts	31.0%	31.0%	4.1%
Heat Rejection Sprays	30.0%	30.0%	2.5%
Gravitational Settlement	60.4%	6.7%	0.4%
Effective Control	**80.9%**	**55.0%**	**6.9%**

Underground Control Summary - Emissions

Emissions for Particulate Pollutants (*lb/hr*)

	PM	PM_{10}	$PM_{2.5}$
Controlled UG Emissions	140.3	82.2	21.6
Vented to Atmosphere	26.8	37.0	20.1

Emissions for Particulate Pollutants (*ton/yr*)

	PM	PM_{10}	$PM_{2.5}$
Controlled UG Emissions	192.7	119.6	40.2
Vented to Atmosphere	36.8	53.9	37.4

Air Sciences Inc.	PROJECT TITLE: Resolution Copper	BY: N. Tipple		
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AIR EMISSION CALCULATIONS	SUBJECT: Underground Scrubbing	DATE: March 15, 2018		

Exhaust Shaft Dust Scrubbing Efficiency for PM_{10} and $PM_{2.5}$

Water droplets in the shaft will remove at least:

90% Particulate matter greater than 10 µm*
40% Particulate matter between 4 and 10 µm*
10% Particulate matter less than 4 µm*

* *Resolution (Moreby 2008)*

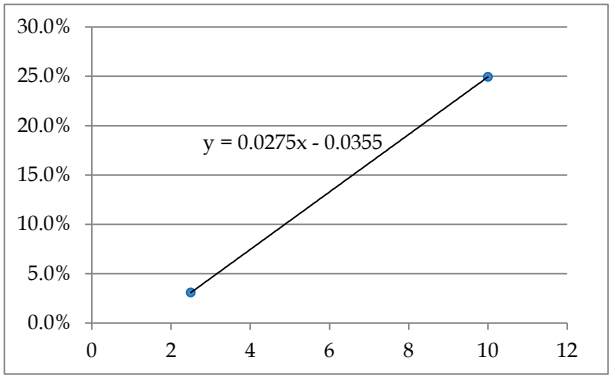
PM_4 Scrubbing Efficiency: 10%
PM_{10} Scrubbing Efficiency: Between 10% and 40%

To find PM_{10} scrubbing efficiency, solve for particulate distribution:

PM_{10}	$PM_{2.5}$	PM
lb/hr	*lb/hr*	*lb/hr*
182	22.5	728

* *RESO EI 20140404.xlsx*

	Maximum particle size (µm)		
	2.5	10	30
Distribution:	3.1%	24.9%	100.0%



Fraction of particles with max size of 4 µm (x = 4) is 7.5%

PM_4/PM_{10} Ratio 29.9%
$PM_{2.5}/PM_4$ Ratio 41.4%

Exhaust Shaft Dust Scrubbing Efficiency	
PM_{10}	31.0%
$PM_{2.5}$	4.1%

Air Sciences Inc.	PROJECT TITLE: Resolution Copper	BY: N. Tipple		
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AIR EMISSION CALCULATIONS	SUBJECT: Underground Scrubbing	DATE: March 15, 2018		

Heat Rejection Sprays Scrubbing Efficiency for Particulate and Gaseous Pollutants

Pollutant	Scrubbing Efficiency*	Overall Efficiency**
$PM_{2.5}$	5.0%	2.5%
PM_7	45.0%	22.5%
PM_{10}	60.0%	30.0%

* *Resolution (Moreby 2008)*

** *Efficiency assuming* 50% *of air passes through heat rejection sprays*

Gravitational Settlement

Terminal Settling Velocity

Stokes' Law

$$\mu_t = \frac{d^2\, g\,(\rho_s - \rho_a)}{18\,\mu_a}$$

$$\eta = \frac{W_n L u_t}{Q_n}$$ *Air Pollution Control Theory, p. 240*

Where	Value	Unit	Reference
g = gravitational constant	9.81	m/s^2	
ρ_s = particle density (ore)	3,463	kg/m^3	*McPherson, Ch. 20*
ρ_a = air density	1,000	kg/m^3	
μ_a = air viscosity	1.8E-5	Ns/m^2	*McPherson, Ch. 20*
W_9 = width of shaft 9	6.7	*m*	*Resolution*
W_{10} = width of shaft 10	8.5	*m*	*Resolution*
W_{14} = width of shaft 14	10	*m*	*Resolution*
L = length of chamber	> 2,000	*m*	*Resolution*
Q_n = chamber air flow rate	622	m^3/s	*Resolution*

Particle Size (d_p)			u_t	Efficiency, η (Settlement in Shafts)			
	μm	*m*	*m/s*	Shaft 9	Shaft 10	Shaft 14	Avg
$PM_{2.5}$	≤ 2.5	2.5E-6	4.66E-4	0.3%	0.4%	0.5%	0.4%
PM_{10}	≤ 10	1.0E-5	7.46E-3	5.4%	6.8%	8.0%	6.7%
PM	≤ 30	3.0E-5	6.71E-2	48.2%	61.1%	71.9%	60.4%

List of References

Ref No	Value	Unit	Description	Location in EI	Reference
1	0.63	*m/s*	LHD/Ore Pass/Grizzly Wind Speed	Gen Info L26	EI Info Request, Resolution Copper
2	1.00	*m/s*	Rail Haulage Ore Flow Wind Speed	Gen Info L27	EI Info Request, Resolution Copper
3	1.79	*m/s*	Primary Crushing Ore Flow Wind Speed	Gen Info L28	EI Info Request, Resolution Copper
4	1.07	*m/s*	Lower Level Conveyor Ore Flow Wind Speed	Gen Info L29	EI Info Request, Resolution Copper
5	0.60	*m/s*	Hoisting System Ore Flow Wind Speed	Gen Info L30	EI Info Request, Resolution Copper
6	2.00	*m/s*	Upper Level Conveyor System Ore Flow Wind Speed	Gen Info L31	RCM Pre-feasibility Refrigeration and Ventilation Study, 2012, Pg. 25
7	4	*%*	UG Ore Moisture Content	Gen Info I26 - I31	General Plan of Operations, Section 4.4.4
8	96	*%*	Incline Conveyor to Mine Transfer Conveyor Solids Content	Gen Info G33	Mill Flowcharts (40000-FS-601 through 623)
9	95.8	*%*	Enclosed Stockpile Solids Content	Gen Info G34	Mill Flowcharts (40000-FS-601 through 623)
10	95.8	*%*	Stockpile Reclaim Solids Content	Gen Info G35	Mill Flowcharts (40000-FS-601 through 623)
11	4.8	*%*	Mill Moisture Content	Gen Info I36 - I39	Largest moisture content listed in AP-42, Ch. 13.2.4
12	4.8	*%*	Loadout Moisture Content	Gen Info I41	Largest moisture content listed in AP-42, Ch. 13.2.4
13	1.3	*mph*	Incline Conveyor to Mine Transfer Conveyor Wind Speed	Gen Info K33	Enclosure, Lowest wind speed listed in AP-42, Ch. 13.2.4
14	1.3	*mph*	General Enclosed Transfer Wind Speed	Gen Info K34 - K41	Enclosure, Lowest Wind Speed listed in AP-42, Ch. 13.2.4
15	8,940	*tonne/hr*	Coarse Ore Stockpile Throughput	Gen Info V17	Technical Memo: Process Plant Mass Balance Calculations for EI
16	143,750	*tonne/day*	Coarse Ore Stockpile Throughput	Gen Info V18	Technical Memo: Process Plant Mass Balance Calculations for EI
17	45,625,000	*tonne/yr*	Coarse Ore Stockpile Throughput	Gen Info V19	Technical Memo: Process Plant Mass Balance Calculations for EI
18	4,296	*tonne/hr*	Sag Mill Throughput	Gen Info	Technical Memo: Process Plant Mass Balance Calculations for EI
19	94,875	*tonne/day*	Sag Mill Throughput	Gen Info	Technical Memo: Process Plant Mass Balance Calculations for EI
20	30,112,500	*tonne/yr*	Sag Mill Throughput	Gen Info	Technical Memo: Process Plant Mass Balance Calculations for EI
21	10	*tonne/hr*	Moly Cake Throughput (WET)	Gen Info	Technical Memo: Process Plant Mass Balance Calculations for EI
22	238	*tonne/day*	Moly Cake Throughput (WET)	Gen Info	Technical Memo: Process Plant Mass Balance Calculations for EI
23	41,176	*tonne/yr*	Moly Cake Throughput (WET)	Gen Info	Technical Memo: Process Plant Mass Balance Calculations for EI
24	8.95	*tonne/hr*	Moly Cake Throughput (DRIED)	Gen Info	Technical Memo: Process Plant Mass Balance Calculations for EI
25	213	*tonne/day*	Moly Cake Throughput (DRIED)	Gen Info	Technical Memo: Process Plant Mass Balance Calculations for EI
26	36,842	*tonne/yr*	Moly Cake Throughput (DRIED)	Gen Info	Technical Memo: Process Plant Mass Balance Calculations for EI
27	multiple parameters		Batch Plant Info	BatchPlant	Tech Memo - Batch Plant Data
28	0.002	*grain/dscf*	Baghouse grain loading	East Plant_CALC, Column J	Manufacturer (Donaldson Torit) Specifications
29	0.0185	*%*	S in Propane	Mill_CALC B97	Standard: GPA 2140-97
30	0.002	*grain/dscf*	Baghouse grain loading	Mill_CALC, Column J	Manufacturer (Donaldson Torit) Specifications
31	0.045	*MMBtu/hr*	Hydro House Heater Rating	Mill_CALC BH75	EI Info Request, Resolution Copper
32	0.065	*MMBtu/hr*	Hydro House Heater Rating	Mill_CALC BH76	EI Info Request, Resolution Copper
33	10	*[quantity]*	Quantity of Cable Bolters	EP_Fleet K24	EI Info Request, Resolution Copper
34	multiple parameters		East Plant Equipment List	EP_Fleet	RCM Mine Data for Ari Modelling 2012.xlsx
35	4	*[tier]*	Minimum Engine Tier Rating	EP_Fleet, Column L	EI Info Request, Resolution Copper
36	15%	*%*	Fuel Contingency	Fleet & Egen SO2, Tank VOC, GHG, HAPs	RCM Mine Data for Ari Modelling 2012.xlsx
37	multiple parameters		Vehicle Speeds	EP_Fleet, Column CA	EI Info Request, Resolution Copper Best Management Practices
38	3	*%*	Road Silt Content	EP_Fleet, Column CB	AP-42, Chapter 13.2.2, Related Information, r13s0202_dec03.xls
39	multiple parameters		Vehicle Weights	All Fleets	Meeting with C. Pascoe 5/7/14, Phone Meeting K. Ballard 5/14/14, Spec Sheets

List of References

Ref No	Value	Unit	Description	Location in EI	Reference
40	90	%	Control of Unpaved Roads with Chemical Suppressant	Loadout Fleet	Chem_Suppressant_Memo_20150225.pdf
41	4	[tier]	Minimum Engine Tier Rating	Mill_Fleet, Column L	EI Info Request, Resolution Copper
42	multiple parameters		Miscellaneous Mill Fleet Updates/Edits (ratings, hours, etc.)	Mill_Fleet	EquipmentHREst1252013.xlsx, Updated based on feedback from K. Ballard and R. Heig 4/16/14.
43	multiple parameters		Vehicle Speeds	Mill_Fleet, Column CA	EI Info Request, Resolution Copper Best Management Practices
44	3	%	Road Silt Content	Mill_Fleet, Column CB	AP-42, Chapter 13.2.2, Related Information, r13s0202_dec03.xls
45	90	%	Control of Unpaved Roads	EP Fleet, Mill Fleet	Chem_Suppressant_Memo_20150225.pdf
46	4	[tier]	Minimum Engine Tier Rating	Loadout_Fleet, Column L	EI Info, Request, Resolution Copper
47	multiple parameters		Miscellaneous Mill Fleet Updates/Edits (ratings, hours, etc.)	Loadout_Fleet	Per RCM Mine Data for Ari Modelling 2012.xlsx, Updated based on feedback from K. Ballard and R. Heig 4/16/14.
48	4	[tier]	Minimum Engine Tier Rating	Tailings_Fleet, Column L	EI Info Request, Resolution Copper
49	multiple parameters		Miscellaneous Tailings Fleet Updates/Edits (ratings, hours, etc.)	Tailings_Fleet	Per RCM Mine Data for Ari Modelling 2012.xlsx, and EquipmentHREst1252013.xlsx and phone call with K. Ballard 4/25/14., Updated based on feedback from K. Ballard and R. Heig 4/16/14.
50	multiple parameters		Vehicle Speeds	Tailings_Fleet, Column CA	EI Info Request, Resolution Copper Best Management Practices
51	3	%	Road Silt Content	Tailings_Fleet, Column CB	AP-42, Chapter 13.2.2, Related Information, r13s0202_dec03.xls
52	90	%	Control of Unpaved Roads	Tailings Fleet	Chem_Suppressant_Memo_20150225.pdf
53	332	[quantity]	Number of Employees at East Plant	Employees E12	General Plan of Operations, Section 3.7.2
54	318	[quantity]	Number of Employees at Mill	Employees E13	General Plan of Operations, Section 3.7.2
55	17	[quantity]	Number of Employees at Loadout	Employees E14	General Plan of Operations, Section 3.7.2
56	18	[quantity]	Number of Employees at Tailings	Employees E15	General Plan of Operations, Section 3.7.2
57	3	%	Road Silt Content	Employees G32 - G35	AP-42, Chapter 13.2.2, Related Information, r13s0202_dec03.xls
58	2	ton	Average Vehicle Weight	Employees I32 - I35	Average Vehicle Weight in 2010, Time Magazine
59	90	%	Control of Unpaved Roads	Employees C62	AP-42, Figure 13.2.2-5, Rev. 11/06
60	14	[quantity]	East Plant Emergency Generator Quantity	E_Gen AN16	EI Info Request, Resolution Copper
61	500	hr/yr	East Plant Emergency Generator Hours of Operation	E_Gen W19, AN17, BE18, BV18, CM18	Email from K. Walch, 4/14/2014
62	6,562	ft	Depth of Mine	Fuel Tanks C30	2000 m, RCM Pre-feasibility Refrigeration and Ventilation Study, 2012, p. 9
63	4,200	l/s	Surface Cooling Tower Circulation Rate	Cooling G11	RCM Pre-feasibility Refrigeration and Ventilation Study, 2012, Section 8.3
64	0.005%	%	Drift Loss	Cooling G12, G16	Hatch. Condenser Cooling Tower Blowdown and Make-Up Water Requirement Review

List of References

Ref No	Value	Unit	Description	Location in EI	Reference
65	1,250	*l/s*	UG Cooling Tower Circulation Rate	Cooling G15	RCM Pre-feasibility Refrigeration and Ventilation Study, 2012; 2 towers @ 625 l/s, each
66	3,000	*ppm*	Total Dissolved Solids Content	Cooling G20	RCM Pre-feasibility Refrigeration and Ventilation Study, 2012, Section 11.2
67			Reagent Tank Volumes	Reagents	Design Criteria 2013 08 6.pdf (pg 25-27)
68	487	*blasts/yr*	East Plant Number of Blasts	Drill & Blast AN12	Tech Memo: Underground Blasting Face Area for Emissions Calculation
69	2	*max blasts/day*	East Plant Number of Blasts	Drill & Blast AN13	Tech Memo: Underground Blasting Face Area for Emissions Calculation
70	580	m^2 *(max daily)*	East Plant Blast Area	Drill & Blast AN20	Tech Memo: Underground Blasting Face Area for Emissions Calculation
71	141,200	m^2 *(annual)*	East Plant Blast Area	Drill & Blast AN23	Tech Memo: Underground Blasting Face Area for Emissions Calculation
72	32.53	*lb/ton*	CO EF	Drill & Blast AN26, BE26	NIOSH - Fumes Studies - Richard Mainiero, Emulsion
73	6.2	*lb/ton*	NOX EF	Drill & Blast AN27, BE27	NIOSH - Fumes Studies - Richard Mainiero, Emulsion
74	40	°C	Underground Temp	Flow C47	RCM Pre-feasibility Refrigeration and Ventilation Study, 2012, p. 12
75	6,562	*ft*	Depth of Mine	Flow I39	RCM Pre-feasibility Refrigeration and Ventilation Study, 2012, p. 9
76	18,950	*acfm*	Stockpile Reclaim Dust Collector Flow	Flow C27	Email from Eric Pedersen (M3) 3/27/14
77	22,500	*a* m^3*/hr*	Crusher Dust Collector Flow	Flow C51	UG Flowsheet 0000
78	5,100	*a* m^3*/hr*	Conveyor Transfer Dust Collector Flow	Flow C55	UG Flowsheet 0000
79	22,500	*a* m^3*/hr*	Silos Dust Collector Flow	Flow C59	UG Flowsheet 0000
80	17,000	*a* m^3*/hr*	Skip Loading Dust Collector Flow	Flow C63	UG Flowsheet 0000
81	17,000	*a* m^3*/hr*	Bin Unloading Dust Collector Flow	Flow C67	UG Flowsheet 0000
82	64	*days/year*	EPS Precip Data (days >0.01")	Precip	2015-2016 Processed AERMET Precip Data (EP)
83	58	*days/year*	WPS Precip Data (days >0.01")	Precip	2015-2016 Processed AERMET Precip Data (WP)
84	57	*days/year*	TSF Precip Data (days >0.01")	Precip	2015-2016 Processed AERMET Precip Data (Hewitt)
85	57	*days/year*	TSF Precip Data (days >0.01")	Precip	2015-2016 Processed AERMET Precip Data (Hewitt)
86	21.3	*acre*	Exposed area at East Plant	WindblownDust B2	GIS Analysis with K. Ballard
87	279	*acre*	Exposed area at Subsidence Area	WindblownDust D15	RCML GTC 2017_09 GPO Estimated Areas of Caved Zones Based on Itasca July 2017 Report.pdf
88	70	*acre*	Exposed area at Mill	WindblownDust I2	GIS Analysis with K. Ballard
89	934	*acre*	Dry Beach	WindblownDust AJ5	Near West Areas.xlsx
90	119	*acre*	Change in Dam Slope	WindblownDust AJ6	Near West Areas.xlsx
91	90	%	PM>10 Control (Water Droplet Scrubbing)	UG Control S12	RCM Exhaust Shaft Scrubbing Efficiency.pdf
92	40	%	PM4-10 Control (Water Droplet Scrubbing)	UG Control S13	RCM Exhaust Shaft Scrubbing Efficiency.pdf
93	10	%	PM<4 Control (Water Droplet Scrubbing)	UG Control S14	RCM Exhaust Shaft Scrubbing Efficiency.pdf
94	60	%	PM7 Control (Heat Rejection Sprays)	UG Control AN14	RCM Exhaust Shaft Scrubbing Efficiency.pdf
95	45	%	PM7 Control (Heat Rejection Sprays)	UG Control AN13	RCM Exhaust Shaft Scrubbing Efficiency.pdf
96	5	%	PM7 Control (Heat Rejection Sprays)	UG Control AN12	RCM Exhaust Shaft Scrubbing Efficiency.pdf
97	1.8E-5	Ns/m^2	Dynamic Viscosity of Air	UG Control AO45	The Aerodynamics, Sources, and Control of Airborne Dust Chapter 20.pdf
98	50	%	Air that Flows Through the Heat Rejection Sprays	UG Control AN16	RCM Exhaust Shaft Scrubbing Efficiency.pdf

List of References

Ref No	Value	Unit	Description	Location in EI	Reference
99	6.7	*m*	width of shaft 9	UG Control AN46	RCM Pre-feasibility Refrigeration and Ventilation Study, 2012, p. 9
100	8.5	*m*	width of shaft 10	UG Control AN47	RCM Pre-feasibility Refrigeration and Ventilation Study, 2012, p. 9
101	10	*m*	width of shaft 14	UG Control AN48	RCM Pre-feasibility Refrigeration and Ventilation Study, 2012, p. 9
102	2,000	*m*	length of chamber	UG Control AN49	RCM Pre-feasibility Refrigeration and Ventilation Study, 2012, p. 9
103	622	m^3/s	chamber air flowrate (all vents)	UG Control AN50	RCM Pre-feasibility Refrigeration and Ventilation Study, 2012, p. 49
104	multiple parameters		Concentration of HAPs/Metals in Ore	HAPs, Column BF	Average of 6 ore body samples (RES-009A, 017L, 017M, 023D, 025D, 002B).
105	multiple parameters		HAP emissions Weight Percent	HAPs, Column BF	Default data - EPCRA Section 313 Industry Guidance - Metal Mining Facilities, January 1999 (EPA 745-B-99-001), Table 3-8
106	multiple parameters		Ore Haul Trucks - Powertrans T954	EP_Fleet J45-N45	160T Powertrans Double RT Concept Underground.xlsx, units converted
107	multiple parameters		Average Distance Travelled, one way VMT, ea	Employees & Deliveries	GIS estimation with K. Ballard
108	2,628	*hp*	HP of Egen	E_Gen W11	Pinal County Air Quality, Permit Number B30993.0000
109	449	*hp*	HP of Egen	E_Gen W14	Pinal County Air Quality, Permit Number B30993.0000
110	4,376	*hp*	HP of Egens	E_Gen AN13	Caterpillar Standby 3100 kW Tier 4i Performance Data
111	multiple parameters		VOC Emission Calculations	Fuel Tanks G26 through K26	Calculated using by EPA Tanks 4.0.9d, 05/02/2014
112	135	*MW*	Cooling capacity	Cooling G13	RCM Pre-feasibility Refrigeration and Ventilation Study, 2012, Section 8.3
113	multiple parameters		MOVES Results (Deliveries & Employees)	Deliveries & Employees	MOVES 2014a
114	134.91	*lb/yr*	MIBC (Methyl isobutyl carbonal) - VOC Emissions	Reagents G13	MIBC (Methyl isobutyl carbonal) - EPA Tank 4.0.9d calculations
115	9.53	*lb/yr*	MCO (Non-polar flotation oil) - VOC Emissions	Reagents G14	MCO (Non-polar flotation oil) - EPA Tank 4.0.9d calculations
116	0.10	*lb/yr*	CYTEC 8989 - VOC Emissions	Reagents G15	CYTEC 8989 - EPA Tank 4.0.9d calculations
117	multiple parameters		Load Factors	All Fleets	Resolution, engine factor.xlsx
118	multiple parameters		West Plant and Filter Plant Mobile Equipment Specs	Mill_Fleet and Loadout_Fleet	West Plant & Filter Plant Mobile Eq.xlsx (R. Heig 2/16/13)
119	multiple parameters		West Plant, Filter Plant, Tailings Mobile Equipment Specs	Mill_Fleet Loadout_Fleet Tailings_Fleet	RCM Mine Data for Ari Modelling 2012.xlsx
120	1,500	*kW*	West Plant Egen demand	E_Gen Pg 4	9/30/2016, M3 Tech. Memo & CAT C18 Specs
121	500	*kW*	Filter Plant Egen demand	E_Gen Pg 6	9/30/2016, M3 Tech. Memo & CAT C18 Specs
122	500	*kW*	TSF Egen demand	E_Gen Pg 5	9/30/2016, M3 Tech. Memo & CAT C18 Specs
123	390	*blasts/yr*	West Plant Number of Blasts	Drill & Blast BE12	Tech Memo: Underground Blasting Face Area for Emissions Calculation
124	2	*max blasts/day*	West Plant Number of Blasts	Drill & Blast BE13	Tech Memo: Underground Blasting Face Area for Emissions Calculation
125	63	m^2 *(max daily)*	West Plant Blast Area	Drill & Blast BE20	Tech Memo: Underground Blasting Face Area for Emissions Calculation
126	14,400	m^2 *(annual)*	West Plant Blast Area	Drill & Blast BE23	Tech Memo: Underground Blasting Face Area for Emissions Calculation
127	164,300	*tonne/yr*	WP development rock drill and blast	Drill & Blast V21	Tech Memo: Underground Blasting Face Area for Emissions Calculation
128	1,414	*tonne/hr*	WP development rock drill and blast	Drill & Blast E22	Tech Memo: Underground Blasting Face Area for Emissions Calculation
129	118,300	*kg/yr*	WP blasting agent usage	Drill & Blast V22	Tech Memo: Underground Blasting Face Area for Emissions Calculation
130	2,065,200	*tonne/yr*	EP development rock drill and blast	Drill & Blast V22	Tech Memo: Underground Blasting Face Area for Emissions Calculation
131	1,414	*tonne/hr*	EP development rock drill and blast	Drill & Blast V22	Tech Memo: Underground Blasting Face Area for Emissions Calculation
132	1,487,000	*kg/yr*	EP blasting agent usage	Drill & Blast V22	Tech Memo: Underground Blasting Face Area for Emissions Calculation
133	502.6	*tonne/yr*	Long-Term uncontrolled fuel oil vapor	MolyTalc	Tech Memo: Molybdenite / Talc Concentrate Heat Treatment Emissions
134	59.1	*tonne/yr*	Long-Term controlled fuel oil vapor	MolyTalc	Tech Memo: Molybdenite / Talc Concentrate Heat Treatment Emissions
135	171.9	*lb/hr*	Short-Term uncontrolled fuel oil vapor	MolyTalc	Tech Memo: Molybdenite / Talc Concentrate Heat Treatment Emissions
136	20.2	*lb/hr*	Short-Term controlled fuel oil vapor	MolyTalc	Tech Memo: Molybdenite / Talc Concentrate Heat Treatment Emissions
137	245.3	*tonne/yr*	Long-Term uncontrolled SO2	MolyTalc	Tech Memo: Molybdenite / Talc Concentrate Heat Treatment Emissions
138	12.3	*tonne/yr*	Long-Term controlled SO2	MolyTalc	Tech Memo: Molybdenite / Talc Concentrate Heat Treatment Emissions
139	83.9	*lb/hr*	Short-Term uncontrolled SO2	MolyTalc	Tech Memo: Molybdenite / Talc Concentrate Heat Treatment Emissions
140	4.2	*lb/hr*	Short-Term controlled SO2	MolyTalc	Tech Memo: Molybdenite / Talc Concentrate Heat Treatment Emissions
141	62,603	*tonne/yr*	Long-Term filter cake throughput (through rotary dryer)	MolyTalc	Tech Memo: Molybdenite / Talc Concentrate Heat Treatment Emissions
142	9.7	*tonne/hr*	Short-Term filter cake throughput (through rotary dryer)	MolyTalc	Tech Memo: Molybdenite / Talc Concentrate Heat Treatment Emissions
143	99%		wet ESP control efficiency	MolyTalc	EPA Air Pollution Control Technology Fact Sheet, Wet Electrostatic Precipitator
144	10	*lb/ton*	Emission Factor for Concentrate Dryer	MolyTalc	AP-42 Chapter 12.3

List of References

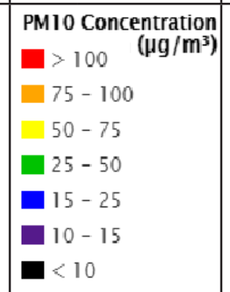
Ref No	Value	Unit	Description	Location in EI	Reference
145	1,042	*tonne/hr*	Pebble Recycle	Gen Info	Technical Memo: Process Plant Mass Balance Calculations for EI
146	23,000	*tonne/day*	Pebble Recycle	Gen Info	Technical Memo: Process Plant Mass Balance Calculations for EI
147	7,300,000	*tonne/yr*	Pebble Recycle	Gen Info	Technical Memo: Process Plant Mass Balance Calculations for EI
148	414	*tonne/hr*	Copper Concentrate Throughput	Gen Info	Technical Memo: Process Plant Mass Balance Calculations for EI
149	9,942	*tonne/day*	Copper Concentrate Throughput	Gen Info	Technical Memo: Process Plant Mass Balance Calculations for EI
150	3,338,889	*tonne/yr*	Copper Concentrate Throughput	Gen Info	Technical Memo: Process Plant Mass Balance Calculations for EI
151	1,060	*tonne/hr*	SAG Trommel Oversize	Gen Info	Technical Memo: Process Plant Mass Balance Calculations for EI
152	23,390	*tonne/day*	SAG Trommel Oversize	Gen Info	Technical Memo: Process Plant Mass Balance Calculations for EI
153	7,424,100	*tonne/yr*	SAG Trommel Oversize	Gen Info	Technical Memo: Process Plant Mass Balance Calculations for EI
154	7,011	*tonne/hr*	Ball Mill Feed	Gen Info	Technical Memo: Process Plant Mass Balance Calculations for EI
155	154,808	*tonne/day*	Ball Mill Feed	Gen Info	Technical Memo: Process Plant Mass Balance Calculations for EI
156	49,134,616	*tonne/yr*	Ball Mill Feed	Gen Info	Technical Memo: Process Plant Mass Balance Calculations for EI
157	6,166	*trip/yr*	EP Materials/Equipment Deliveries	Deliveries	GPO Section 3.4.2
158	20	*trips/day*	EP Materials/Equipment Deliveries	Deliveries	GPO Section 3.4.2
159	6,935	*trip/yr*	WP Materials/Equipment Deliveries	Deliveries	GPO Section 3.4.2
160	19	*trips/day*	WP Materials/Equipment Deliveries	Deliveries	GPO Section 3.4.2
161	0	*trip/yr*	TSF Materials/Equipment Deliveries	Deliveries	GPO Section 3.4.2
162	0	*trips/day*	TSF Materials/Equipment Deliveries	Deliveries	GPO Section 3.4.2
163	0	*trip/yr*	FPLF Materials/Equipment Deliveries	Deliveries	GPO Section 3.4.2
164	0	*trips/day*	FPLF Materials/Equipment Deliveries	Deliveries	GPO Section 3.4.2
165	11	*trips/hr*	WP Materials/Equipment Deliveries	Deliveries	GPO Section 3.4.2
166	16.25	*MMBtu*	Heat Capacity of Moly/Talc Rotary Dryer	MolyTalc	Tech Memo: Molybdenite / Talc Concentrate Heat Treatment Emissions

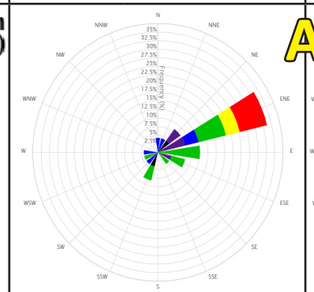
Appendix E – Dashboards Identifying Days with Elevated PM_{10} or $PM_{2.5}$ Concentrations

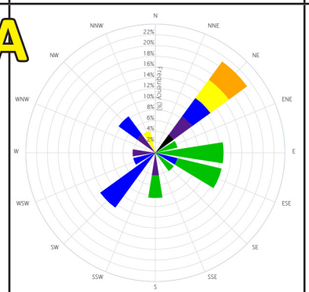
2015-06-24 – Elevated PM Influenced by Elevated Winds

	WPS	EPS
PM_{10} Conc	38.2 µg/m³ 95.2 Percentile	32 µg/m³ 96.2 Percentile
$PM_{2.5}$ Conc	14.5 µg/m³ 99.1 Percentile	8.33 µg/m³ 98.0 Percentile

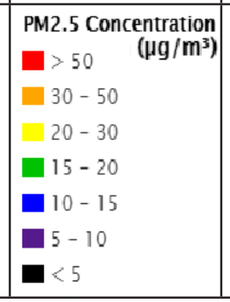
PM_{10} Roses

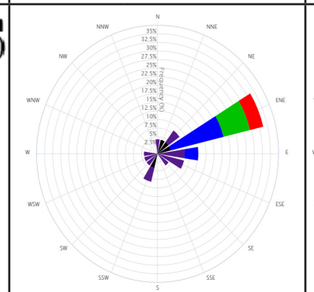


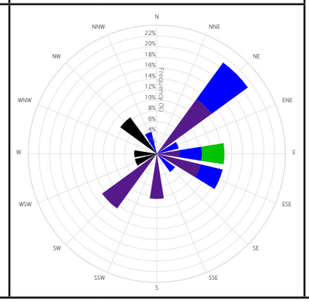




$PM_{2.5}$ Roses







Summary

A. PM roses from WPS and EPS for 06-24 show several hours of elevated PM concentrations during hours of NE and ENE winds. Potential active sources of PM emissions to the NE and ENE are identified.

B. Radar maps before and during elevated monitored concentrations show storm cell movement from eastern Arizona toward the monitors.

C. Wind field maps show high winds immediately prior to and during the elevated monitored concentrations. Hourly PM concentrations were most elevated between 1600 and 1900 MST.

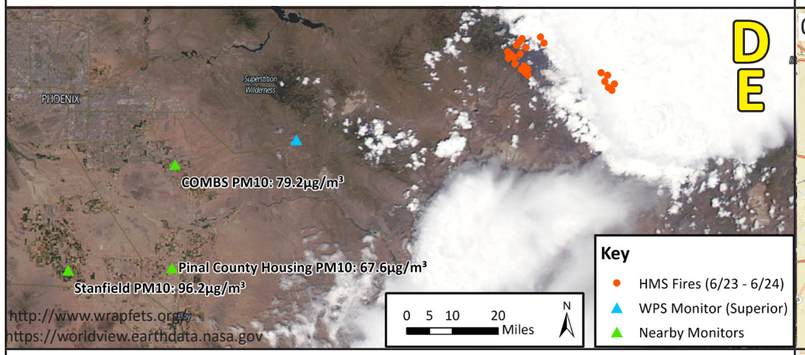
D. A satellite image with HMS-detected fires overlaid confirms the presence of the storm and the occurrence of active fires within 40 miles east of monitors.

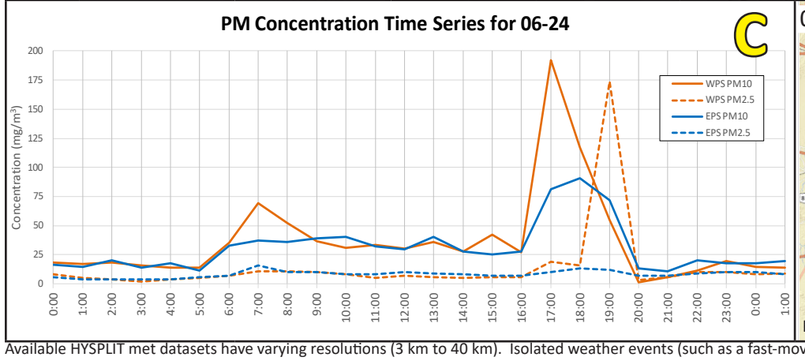
E. Elevated PM_{10} concentrations at nearby PCAQCD monitors indicate elevated regional PM.

F. High winds in and near Globe, AZ, which has extensive areas of disturbed land and mine tailings that are known to be sources of wind-blown dust, are a likely source of PM emissions northeast of the monitors.

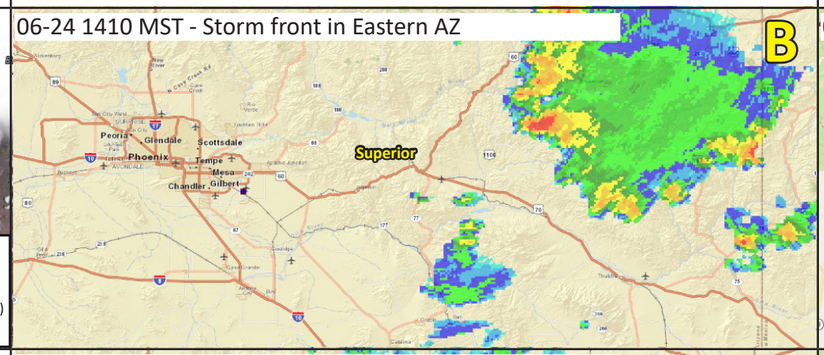
<u>Conclusion:</u> Storm cells and associated high winds over active sources of PM emissions (fire and disturbed mining areas/historic tailings) transported PM SW toward the monitors and contributed to elevated concentrations of $PM_{2.5}$ and PM_{10}. Resolution and other nearby meteorology stations monitored high wind speeds from the NE and ENE, which corroborates the event. The elevated $PM_{2.5}$ and PM_{10} concentrations should be removed from the data sets used to prepare background PM concentration profiles for the project.

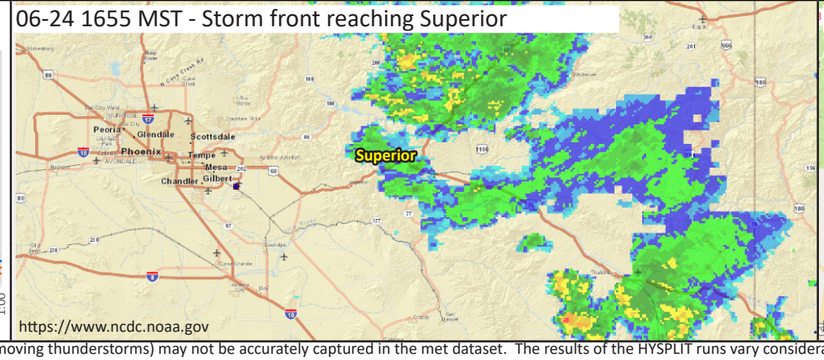
Fire Activity, Satellite & Nearby Monitors



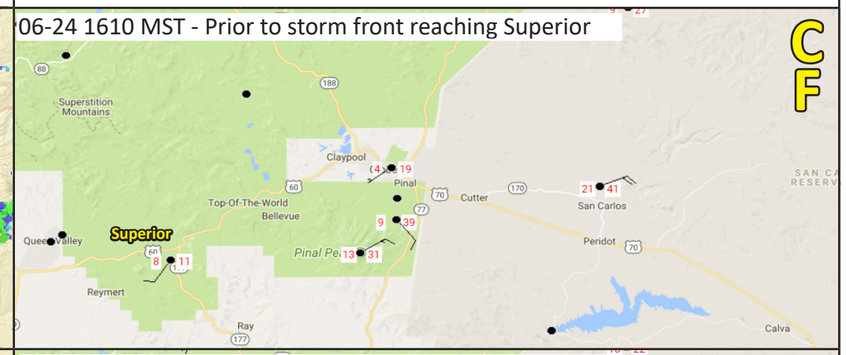


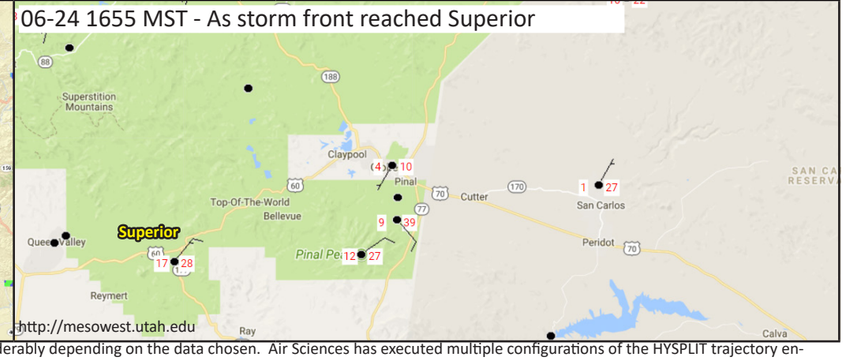
Radar





Wind Fields





Available HYSPLIT met datasets have varying resolutions (3 km to 40 km). Isolated weather events (such as a fast-moving thunderstorms) may not be accurately captured in the met dataset. The results of the HYSPLIT runs vary considerably depending on the data chosen. Air Sciences has executed multiple configurations of the HYSPLIT trajectory ensemble model for this elevated PM concentration scenario. Configurations have included: forward- and reverse-trajectories, different met datasets, different periods for the trajectories, modifying the trajectory height, and changing the vertical motion scheme. The results from HYSPLIT are mixed (that is, some configurations support the cause-and-effect relationship of specific event(s) to the elevated monitored concentrations and some do not) and are not presented in this dashboard. HYSPLIT run results are provided in the file titled 2015-06-24_Distribution.zip.

2015-06-29 – Elevated PM at WPS & EPS Influenced by Thunderstorm Activity

	WPS	EPS
PM_{10} Conc	81.2 µg/m³ 99.3 Percentile	62.6 µg/m³ 99.6 Percentile
$PM_{2.5}$ Conc	12.6 µg/m³ 98.7 Percentile	8.63 µg/m³ 98.1 Percentile

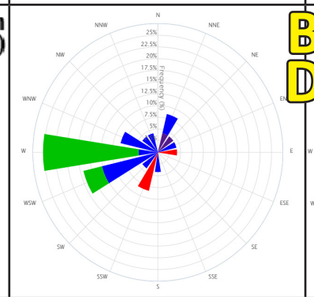
PM_{10} Roses

PM10 Concentration (µg/m³)
- > 100
- 75 – 100
- 50 – 75
- 25 – 50
- 15 – 25
- 10 – 15
- < 10

$PM_{2.5}$ Roses

PM2.5 Concentration (µg/m³)
- > 50
- 30 – 50
- 20 – 30
- 15 – 20
- 10 – 15
- 5 – 10
- < 5

WPS



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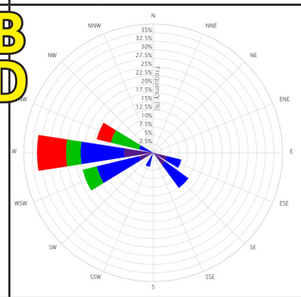
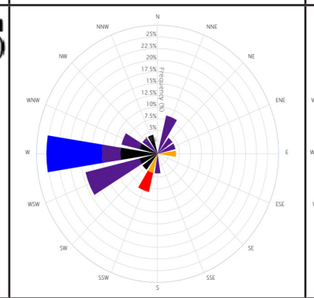


B D

WPS



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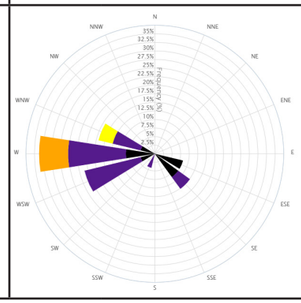


Summary

A. A radar map of the Phoenix area shows severe weather in the area on the afternoon & evening of 06-29. Multiple media references document the occurrence & magnitude of the winds associated with these cells.

B. Regional (PCAQCD's Coolidge, Pinal County Housing, & Eloy PM_{10} monitors) & on-site PM monitors show elevated 24-hour concentrations on this day, indicating transport of PM from the south & west.

C. A wind field map shows elevated wind speeds (up to 23 mph sustained winds & 31 mph gusts) blowing from the SW, leading up to the elevated concentrations at the on-site monitors. Further, the highest wind speeds shown during this time occur at the Coolidge station, near an area known for frequent dusty conditions.

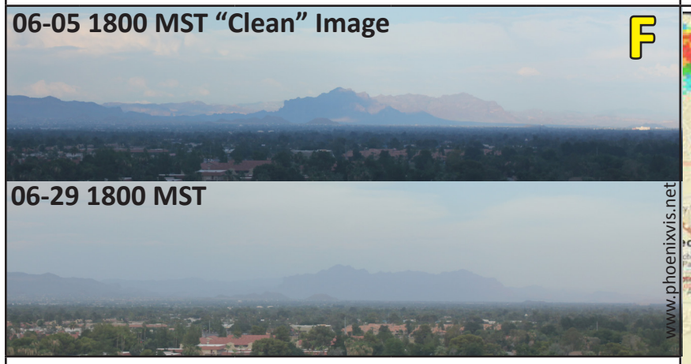
D. PM_{10} & $PM_{2.5}$ roses for both monitors on 06-29 show high frequency of winds & associated PM concentrations from the West, WSW, & SW from the direction of the storm cell and a known source of wind-blown dust.

E. A reverse trajectory model (HYSPLIT) ending on 06-29 at 2100 MST, during the peak of the high monitored PM concentrations, indicates transport from the Coolidge, AZ region (approximately 30 miles SW of Superior).

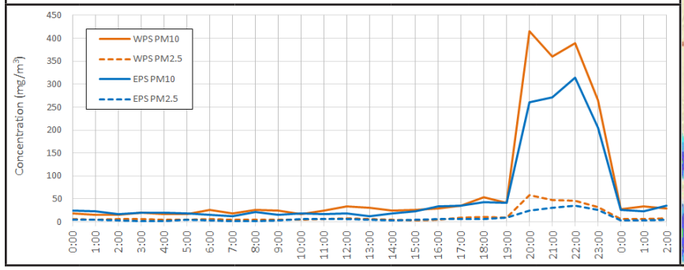
F. The visibility images from Phoenixvis.net immediately preceding the high monitored concentrations, as compared with a "clean" day, indicate reduced visibility, corroborating possible regional dust transport due to high winds from thunderstorms.

<u>CONCLUSION:</u> A regional dust event caused by high winds preceding thunderstorm cells that moved through Coolidge, AZ, an area known to be a source of wind-blown dust, contributed to elevated concentrations of PM_{10} & $PM_{2.5}$ at the Resolution WPS & EPS monitors. The Elevated PM concentrations should be removed from the data sets used to prepare background PM concentration profiles for the project.

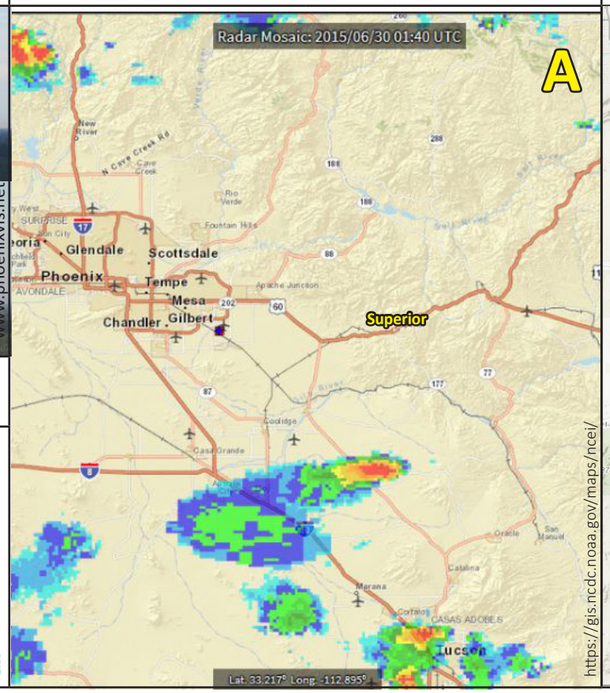
Visibility Images



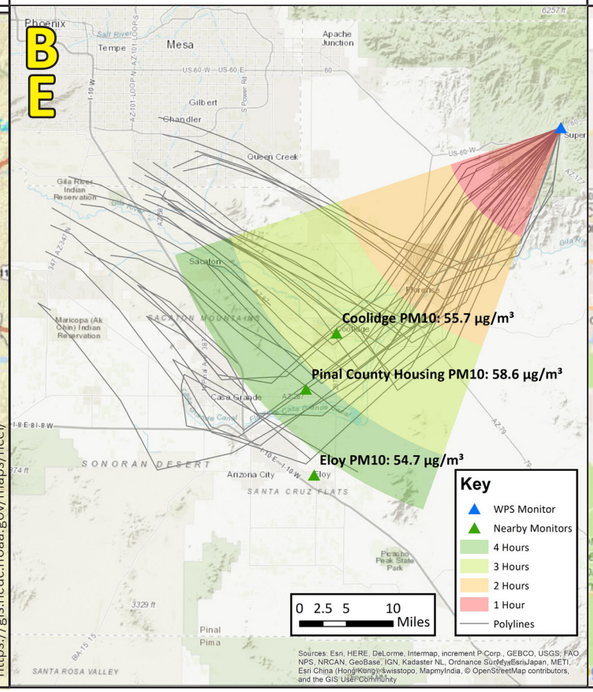
PM Conc Time Series



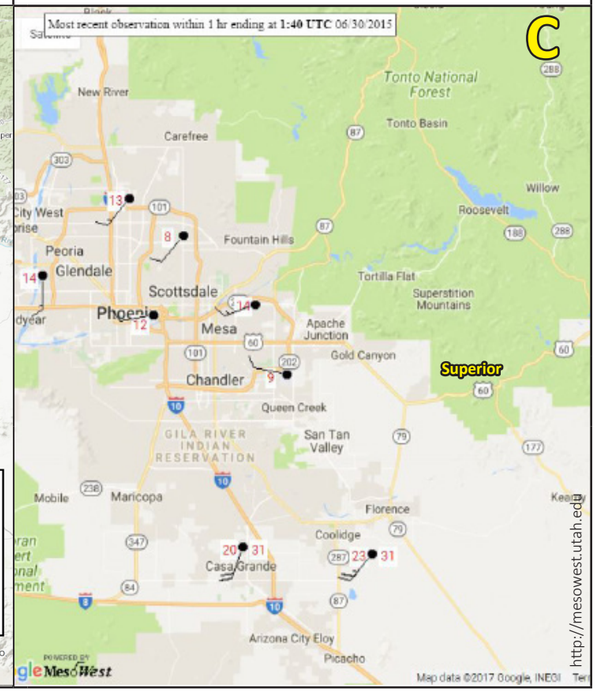
Radar (06-29 1740 MST)



HYSPLIT (06-29 2100 MST)



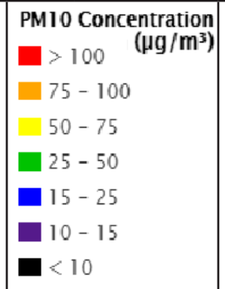
Wind Field (06-29 1740 MST)



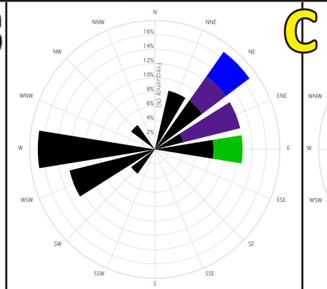
2015-07-03 – Elevated $PM_{2.5}$ at WPS Influenced by Local Source and/or Smoke

	WPS	EPS
PM_{10} Conc	7.0 µg/m³ 24.9 Percentile	9.0 µg/m³ 29.4 Percentile
$PM_{2.5}$ Conc	17.8 µg/m³ 99.6 Percentile	Invalid Day

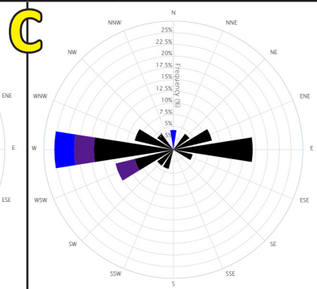
PM_{10} Roses



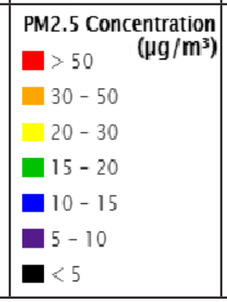
WPS

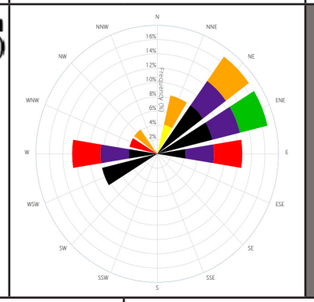


EPS



$PM_{2.5}$ Roses





Summary

The same suite of datasets were reviewed for this event (including radar reflectivity, satellite imagery, HYSPLIT trajectories, surface weather, upper-air data, PCAQCD monitors, IMPRPOVE monitors, surface wind fields, regional & local fire activity datasets, federal smoke modeling simulations, visibility cameras of the Superstition Mountains, regional air quality index, local media & onsite monitored data).

A. The surface weather map shows little variation in the proximate areas of high & low barometric pressure indicating very stable conditions.

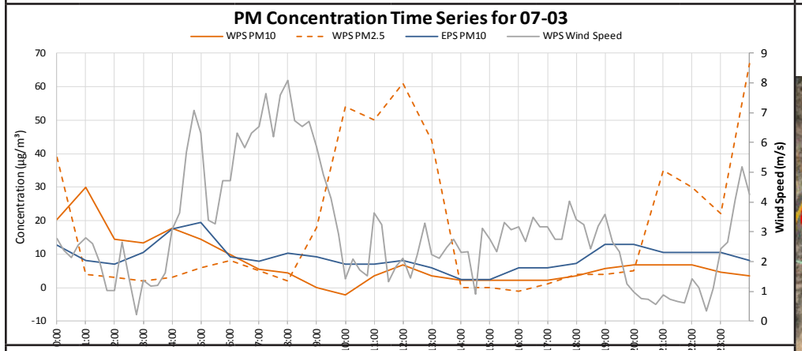
B. A sudden drop in onsite wind speeds correlates with a decrease in mechanical mixing height (from AIRMET output of WPS met data) & several hours of elevated monitored concentrations of $PM_{2.5}$ at WPS. Low wind speeds & low mechanical mixing heights are associated with stagnant conditions & poor dispersion of locally generated particulates.

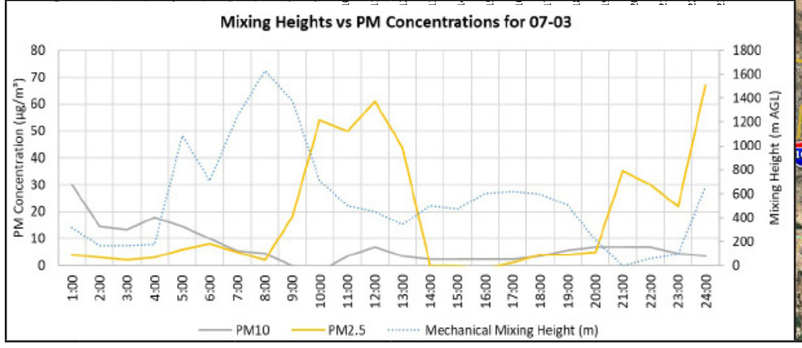
C. The $PM_{2.5}$ rose shows elevated concentrations during periods of winds from several directions W, N, & E and the time series plots (B) show that the elevated concentrations occurred in consecutive hours (0900 through 1300).

D. Many wildfires were active N & NW of the project during the period 07-02 – 07-06. USDA – FS BlueSky Production Runs for 07-03 – 07-04 show predicted $PM_{2.5}$ emissions over much of central Arizona including over the Project Area.

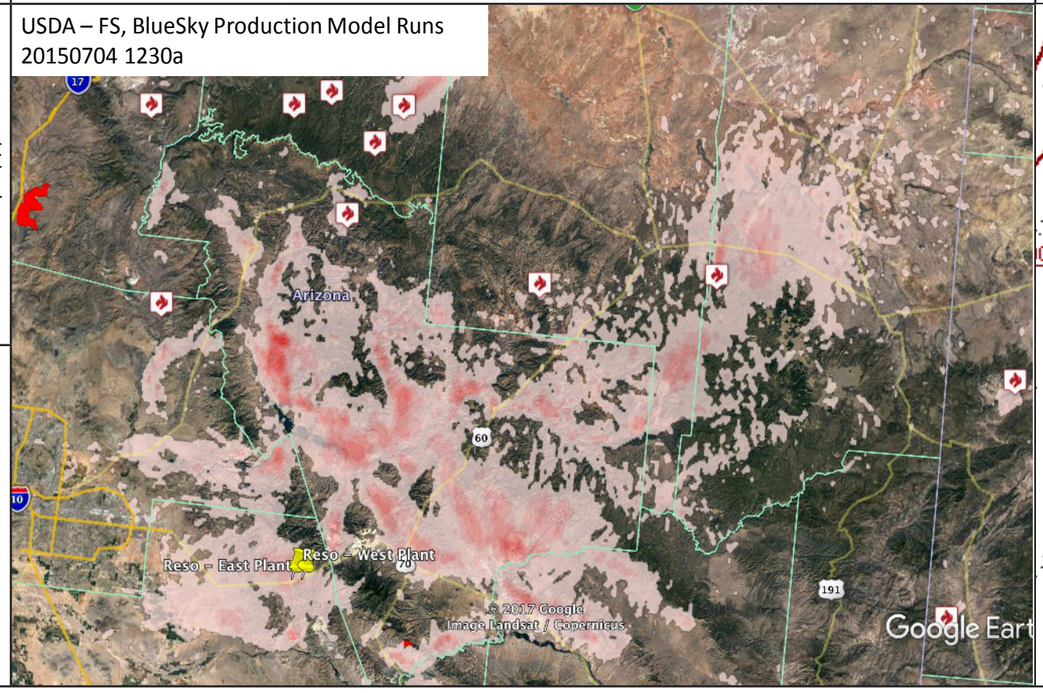
Conclusion: There are two potential explanations for the elevated $PM_{2.5}$ concentration at WPS on 07-03. The lack of elevated concentrations at nearby PCAQCD monitors, the calm/stable onsite meteorological conditions, & the elevated hourly concentrations of $PM_{2.5}$ coming from several disparate wind directions indicate that a local source of $PM_{2.5}$ could have influenced the measurement. Regional modeling data indicate that the project area could have been impacted by smoke from considerable fire activity. Either unusual & local sources of PM_{10} and/or smoke from wildfires influenced the elevated $PM_{2.5}$ concentration from WPS & the $PM_{2.5}$ concentration for 07-03 should be removed from the data set used to prepare background PM concentration profiles for the project.

Time Series (07-03) B

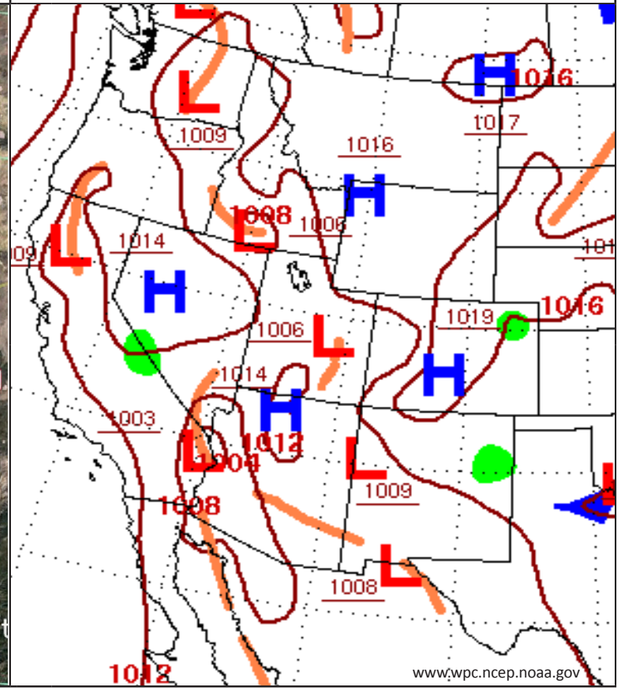




BlueSky Model Run $PM_{2.5}$ (07-04) D



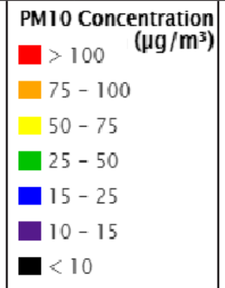
Surface Weather (07-03) A



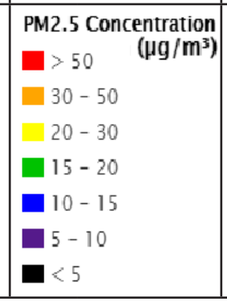
2015-07-05 – Elevated $PM_{2.5}$ at WPS Influenced by Local Source and/or Smoke

	WPS	EPS
PM_{10} Conc	10.3 µg/m³ 41.6 Percentile	16.2 µg/m³ 70.8 Percentile
$PM_{2.5}$ Conc	19 µg/m³ 99.7 Percentile	Invalid Day

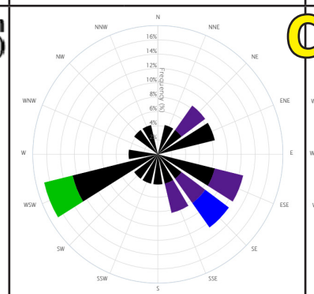
PM_{10} Roses

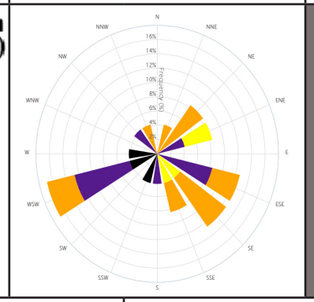


$PM_{2.5}$ Roses

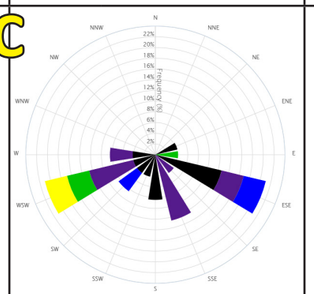


WPS





EPS



Summary

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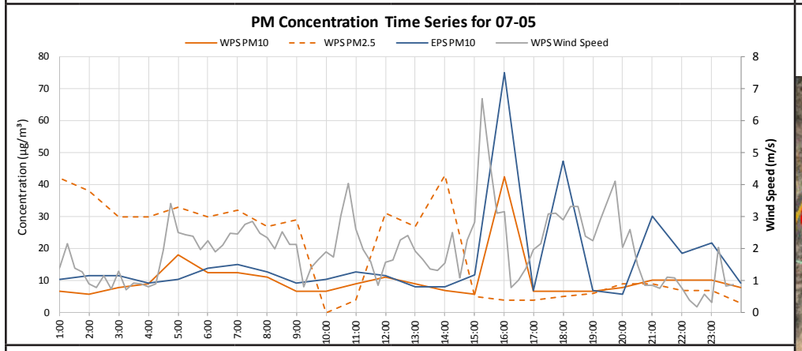
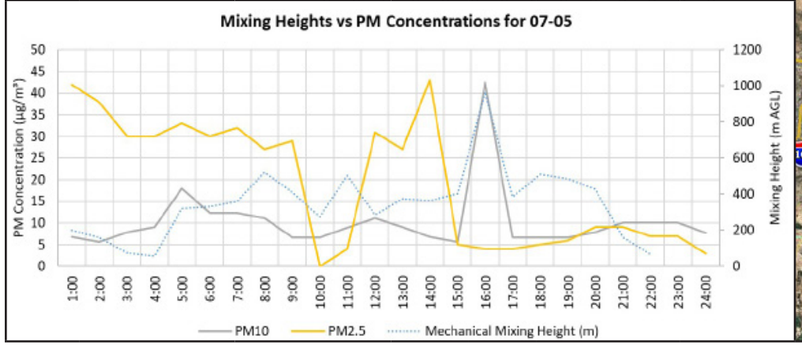
C. The $PM_{2.5}$ rose shows elevated concentrations during periods of winds from several directions WSW, SE, and NE through NNW the time series plots (B) show that the elevated concentrations occurred throughout the first half of the day when wind speeds & mechanical mixing heights were low.

D. Many wildfires were active N & NW of the project during the period 07-02 – 07-06. USDA – FS BlueSky Production Runs for 07-03 – 07-04 show predicted $PM_{2.5}$ emissions over much of central Arizona including over the Project Area.

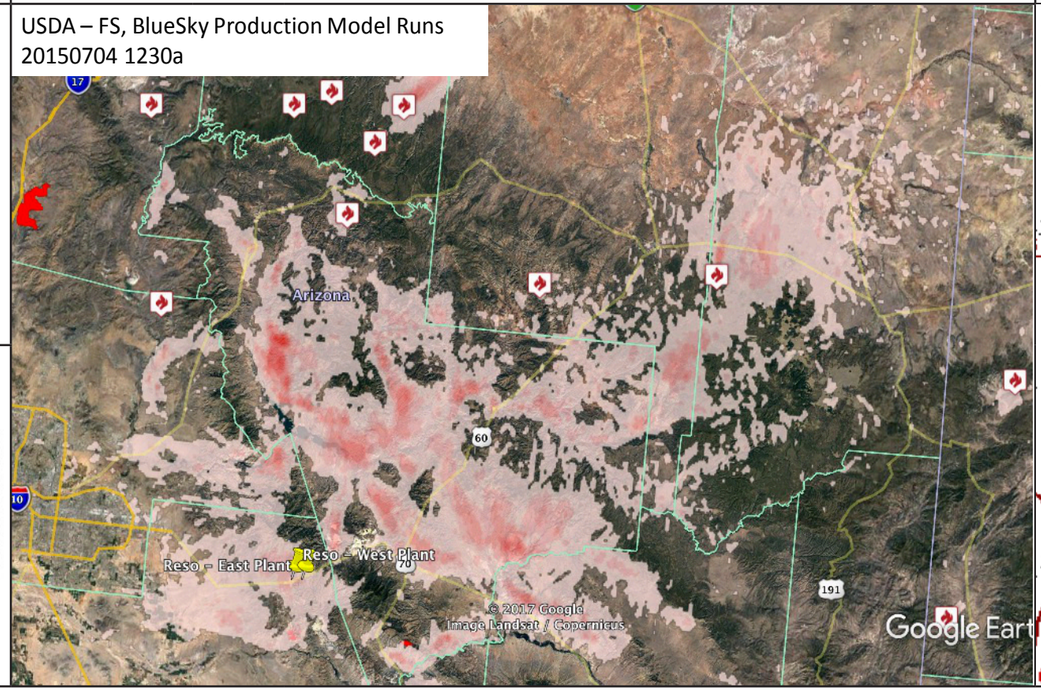
Conclusion: There are two potential explanations for the elevated $PM_{2.5}$ concentration at WPS on 07-05. The lack of elevated concentrations at nearby PCAQCD monitors, the calm/stable onsite meteorological conditions, & the elevated hourly concentrations of $PM_{2.5}$ coming from several disparate wind directions indicate that a local source of $PM_{2.5}$ could have influenced the measurement. Regional modeling data indicate that the project area could have been impacted by smoke from considerable fire activity. Either unusual & local sources of PM_{10} and/or smoke from wildfires influenced the elevated $PM_{2.5}$ concentration from WPS & the $PM_{2.5}$ concentration for 07-05 should be removed from the data set used to prepare background PM concentration profiles for the project.

Time Series (07-05) B

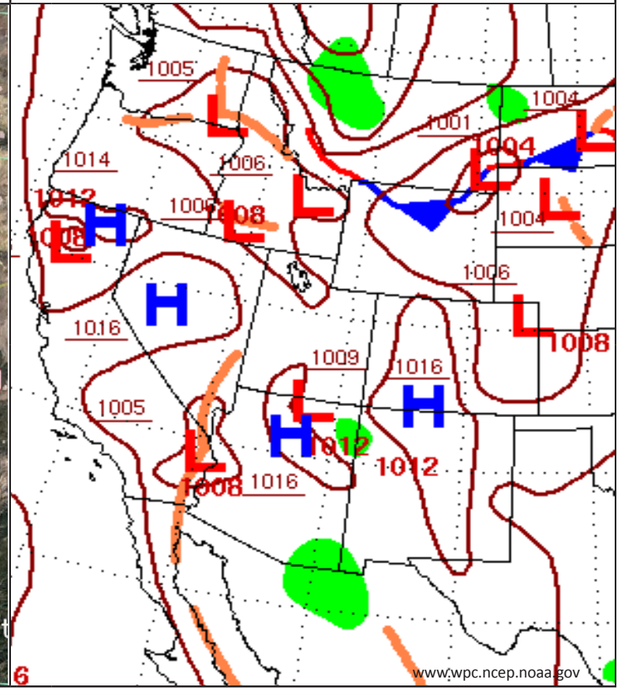




BlueSky Model Run $PM_{2.5}$ (07-04) D



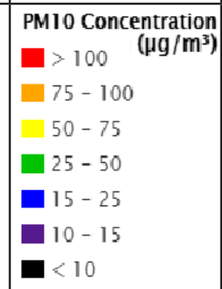
Surface Weather (07-05) A



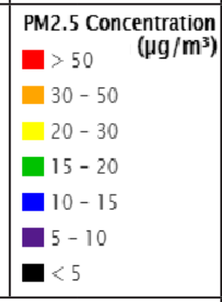
2016-02-05 – Elevated PM Influenced by High Winds & Transport From Nearby PM Sources

	WPS	EPS
PM_{10} Conc	28.4 µg/m³ 88.5 Percentile	40.6 µg/m³ 98.2 Percentile
$PM_{2.5}$ Conc	3.88 µg/m³ 44.9 Percentile	23.9 µg/m³ 99.9 Percentile

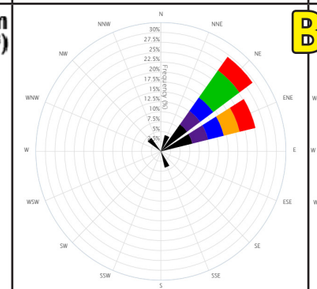
PM_{10} Roses



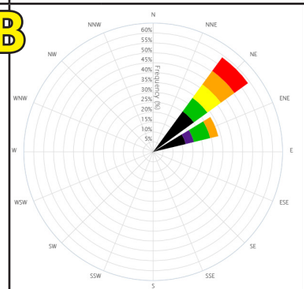
$PM_{2.5}$ Roses

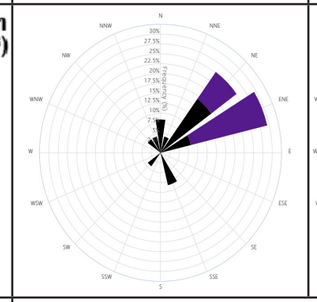


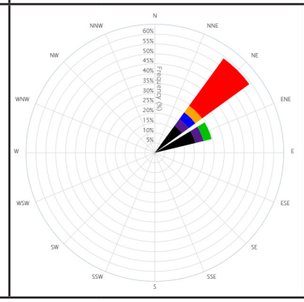
WPS



EPS







Summary

A. As a result of a high pressure system centered over Nevada, the surface pressure gradient increased over the two days prior to the event and strong surface winds occurred on 02-05.

B. PM roses from WPS and EPS for 02-05 show elevated PM concentrations during hours of high wind speeds from the NE and ENE. Potential active sources of PM emissions to the NE and ENE.

C. Wind field maps show high winds during the hours of elevated monitored concentrations. Hourly PM concentrations were most elevated between 0000 and 1300 MST.

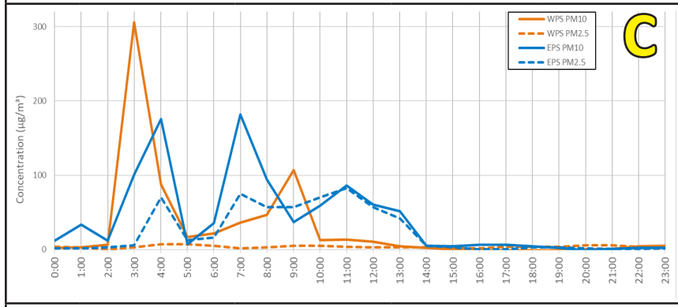
D. A forward trajectory HYSPLIT model indicates the possible transport of fines from historic mining and tailings facilities near Miami, AZ, an area with disturbed areas known to be sources of wind-blown dust.

E. A time series chart of the EPS wind speed, gust, and direction shows sustained wind speeds ranging from 17 to 40 mph, gusts up to 60 mph, and consistent winds from the NE.

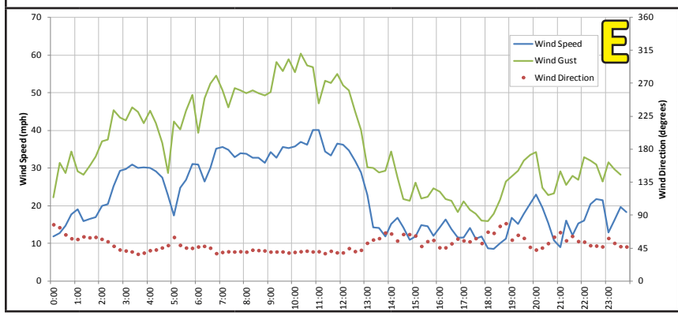
F. High winds near Globe, AZ, which has extensive areas of disturbed land and mine tailings that are known to be sources of wind-blown dust, are a likely source of PM emissions NE of the monitors.

<u>Conclusion:</u> High winds over active sources of PM emissions (disturbed mining areas/historic tailings) transported PM SW toward the monitors and contributed to elevated concentrations of $PM_{2.5}$ and PM_{10}. The forward trajectory HYSPLIT models support transport of dust from areas known to have high fines content towards the EPS monitor. Resolution's and other nearby meteorology stations monitored high wind speeds from the NE and ENE, which corroborates the event. The elevated $PM_{2.5}$ concentration monitored at EPS should be removed from the data sets used to prepare background PM concentration profiles for the project.

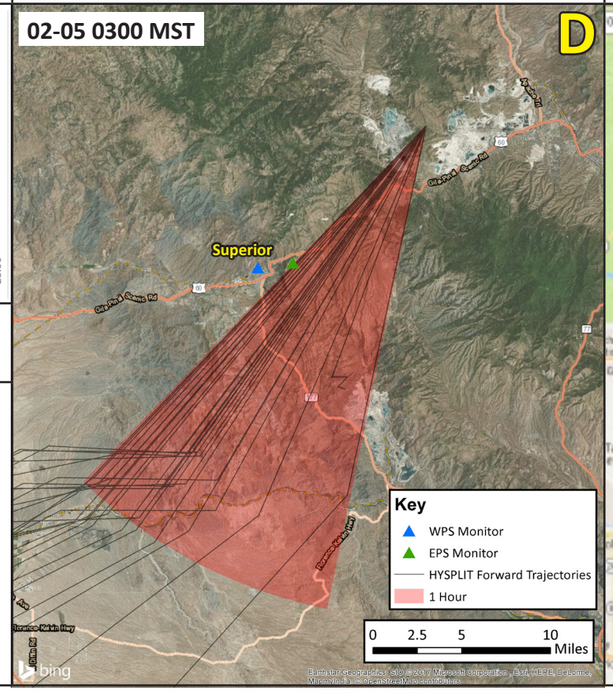
PM Conc Time Series



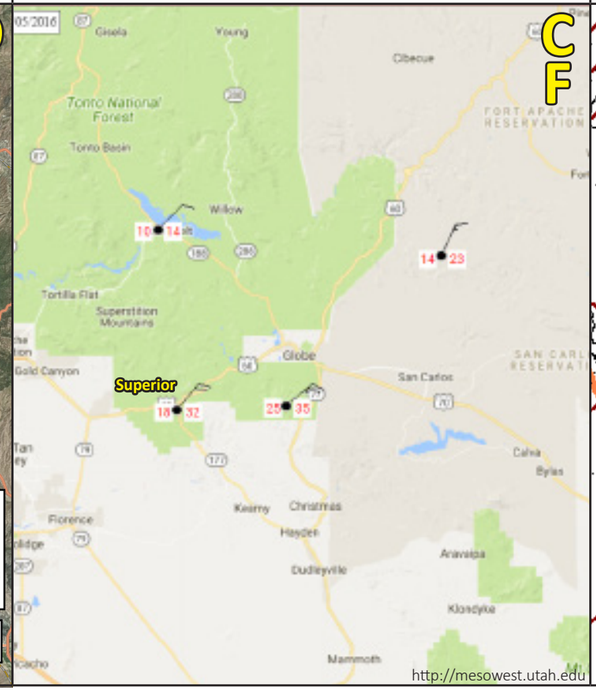
EPS Wind Data Time Series



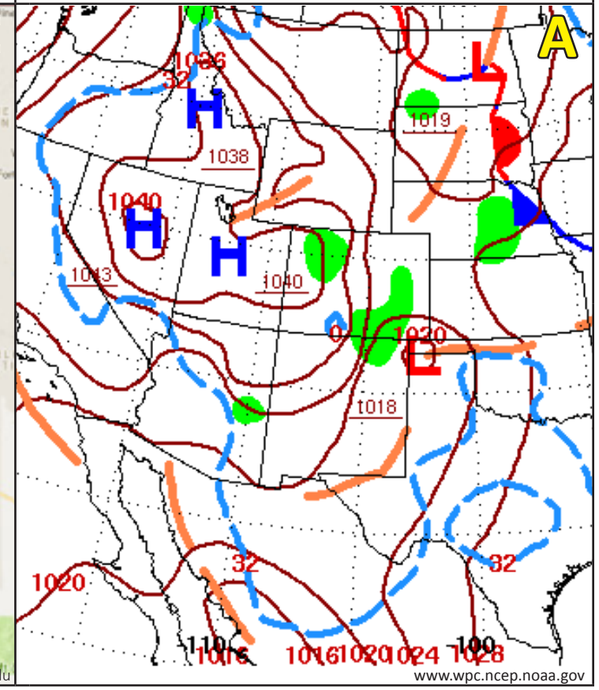
HYSPLIT (Forward Trajectory)



Wind Field (02-05 0530 MST)



Surface Weather Map



2016-03-07 – Elevated PM at WPS & EPS Influenced by Regional Transport

	WPS	EPS
PM_{10} Conc	85.8 µg/m³ 99.6 Percentile	81.3 µg/m³ 99.9 Percentile
$PM_{2.5}$ Conc	14 µg/m³ 99.0 Percentile	12.4 µg/m³ 99.6 Percentile

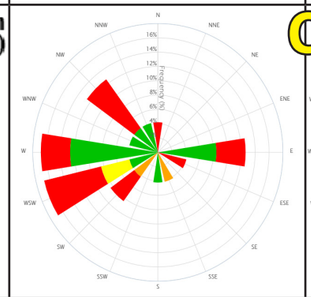
PM_{10} Roses

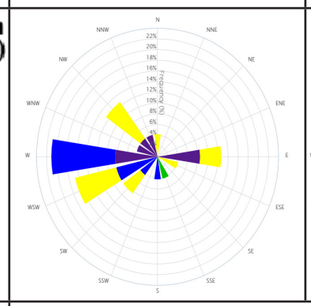
PM10 Concentration (µg/m³)
- > 100
- 75 – 100
- 50 – 75
- 25 – 50
- 15 – 25
- 10 – 15
- < 10

$PM_{2.5}$ Roses

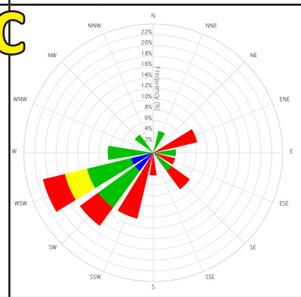
PM2.5 Concentration (µg/m³)
- > 50
- 30 – 50
- 20 – 30
- 15 – 20
- 10 – 15
- 5 – 10
- < 5

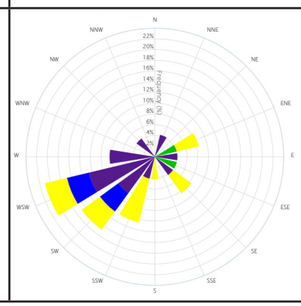
WPS





EPS





Summary

A. A surface weather map of the western United States indicates a significant cold front and a low-pressure system moving through AZ on 03-07. Spring cold fronts are associated with high winds, which can cause dust-generating events. High wind gusts (from the afternoon through midnight on 03-06) immediately preceded the increase in PM concentrations.

B. Widespread elevated PM 24-hour concentrations at nearby PCAQCD monitors on 03-07 indicate elevated regional PM.

C. PM roses from WPS and EPS for 03-07 show many hours of elevated PM concentrations during hours of SW and WSW winds.

D. A wind field map from the day before (pre-frontal passage) the event (03-06) shows elevated winds from the west in the greater Phoenix Area.

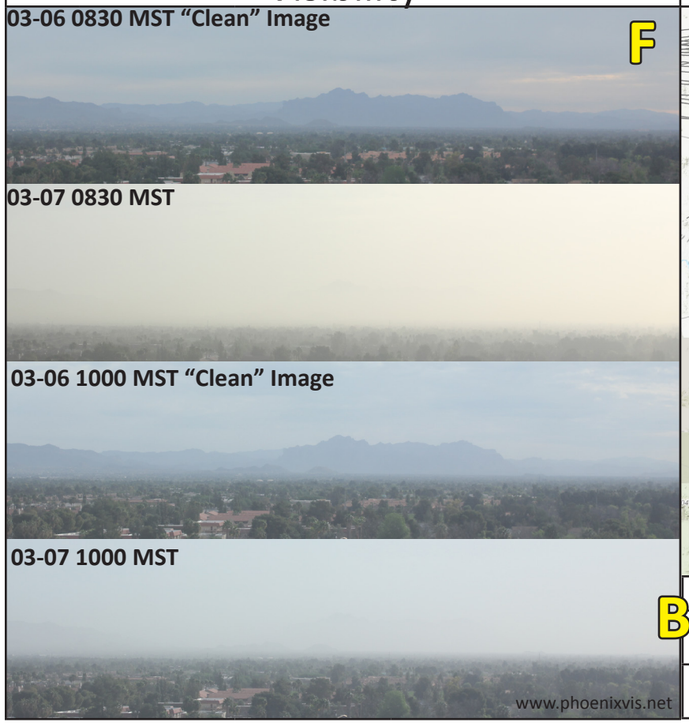
E. A wind field map for 03-07 (post-frontal passage) shows light winds from the west.

F. Visibility images from Phoenixvis.net at two times during the high monitored concentrations on 03-07, compared to the previous "clean" day, indicate reduced visibility, corroborating possible regional dust transport due to high winds from a cold frontal passage.

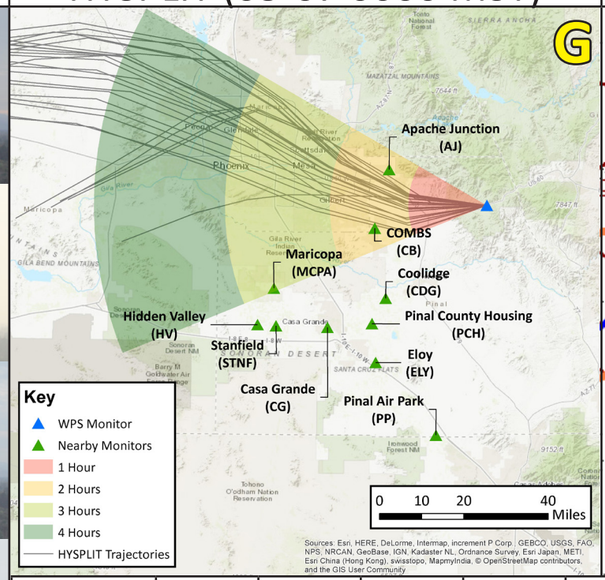
G. HYSPLIT reverse trajectory models indicate that sources of PM that contributed to elevated concentrations (starting at 0000 at WPS) were to the west of Superior in the hours leading up to the elevated concentrations. Data supporting items A-F corroborate the presence of airborne PM in the areas along the HYSPLIT trajectories.

<u>Conclusion:</u> Regional high winds associated with a cold frontal passage on 03-06 support the transport of regional airborne dust. Calmer winds on 03-07 support the transport of PM east toward the monitors and the contribution to elevated concentrations of $PM_{2.5}$ and PM_{10}. The wind field maps indicate pre-frontal elevated winds and post-frontal calmer winds, which corroborate the event. The elevated $PM_{2.5}$ and PM_{10} concentrations should be removed from the data sets used to prepare background PM concentration profiles for the project.

Visibility



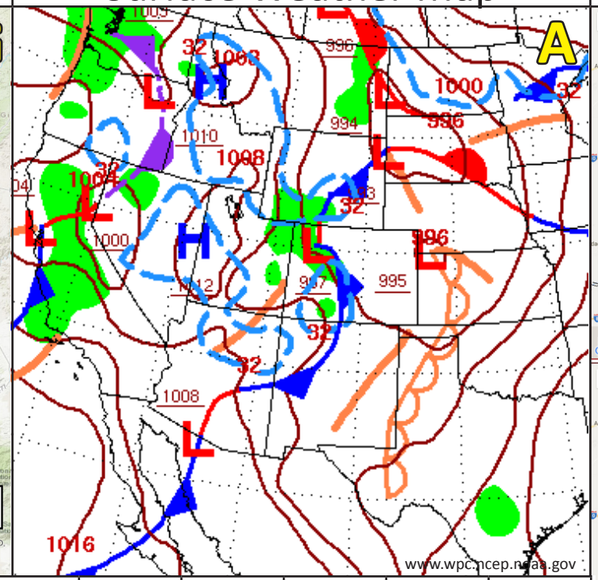
HYSPLIT (03-07 0000 MST)



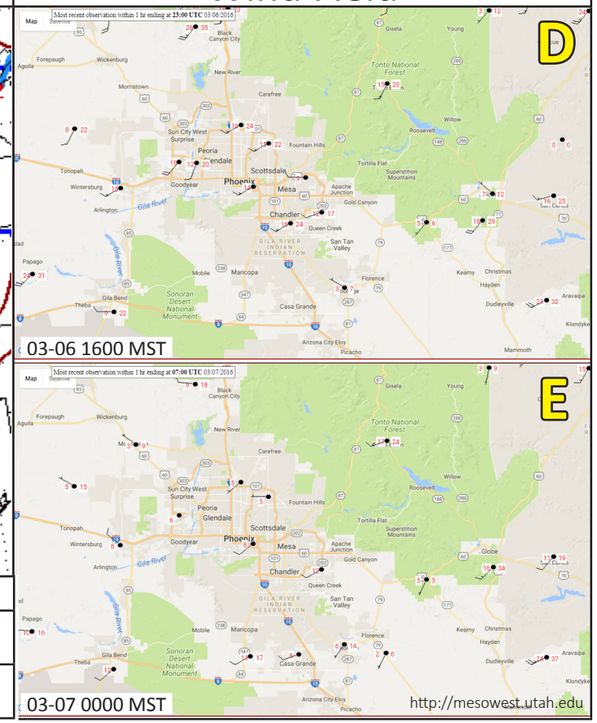
B

Station	AJFS	CGD	CB	CLDG	ELY	HV	MCPA	PP	PCH	STNF
PM_{10} (µg/m³)	87.7	105.4	102	109.8	76.9	89.3	114.4	54.8	107.4	108.1
$PM_{2.5}$ (µg/m³)	14.6	20.6	-	-	-	16.3	-	-	-	-

Surface Weather Map



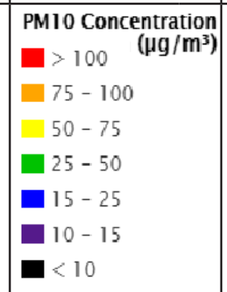
Wind Field



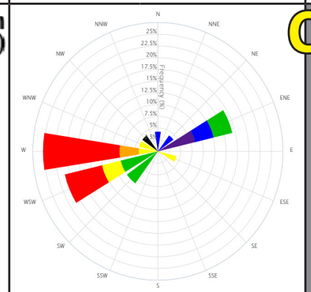
2016-03-22 – Elevated PM at WPS & EPS Influenced by Regional High Winds

	WPS	EPS
PM_{10} Conc	182 µg/m³ 99.9 Percentile	Invalid Day
$PM_{2.5}$ Conc	19.9 µg/m³ 99.9 Percentile	9.77 µg/m³ 98.7 Percentile

PM_{10} Roses

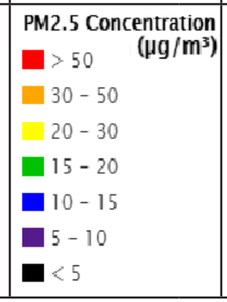


WPS



EPS

$PM_{2.5}$ Roses



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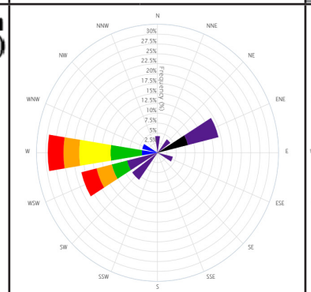
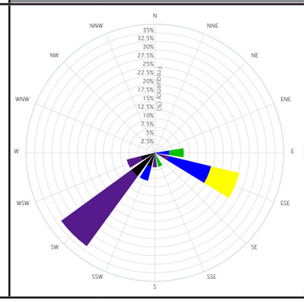


EPS



Summary

A. A surface weather map of the western United States indicates a significant cold front moving through northern Arizona on 03-22. These spring cold fronts are associated with high winds, which can cause dust-generating events.

B. A time series chart shows WPS PM_{10} hourly concentrations above 750 µg/m³ from 1500 to 1700 MST. Regional (PCAQCD's COMBS, Maricopa, Stanfield and Pinal County Housing PM stations and the regional AQI) and on-site met and PM data show high wind speeds and elevated PM concentrations on 03-22, indicating transport from the W and WSW. The COMBS monitor's concentrations were elevated above the NAAQS for PM_{10} and the Maricopa monitor measured a PM_{10} concentration just below the NAAQS.

C. PM roses for WPS and EPS on 03-22 indicate elevated concentrations during hours of W and WSW winds, from the direction of areas where wind blown dust storms frequently occur.

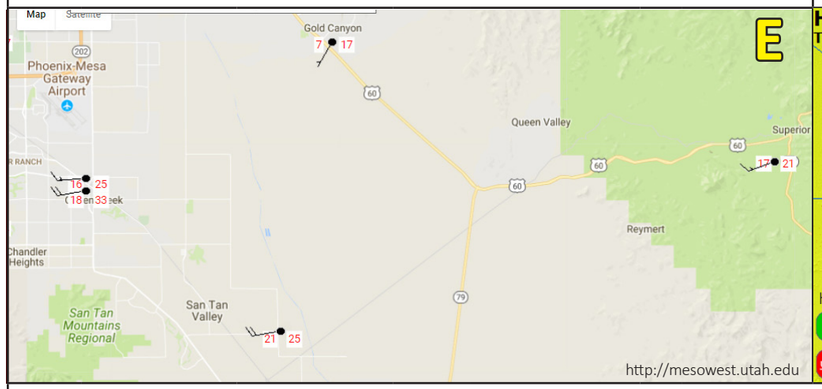
D. Visibility images from the Phoenixvis.net camera (from Phoenix toward the Superstition Mountains) indicate reduced visibility during evening hours on 03-22, when compared to the "clean" image corroborating possible regional dust transport due to high winds.

E. A wind field map on 03-22 shows high winds and gusts blowing from the direction of the San Tan Valley, a region known for frequent dusty conditions, W and WSW toward the monitors near Superior.

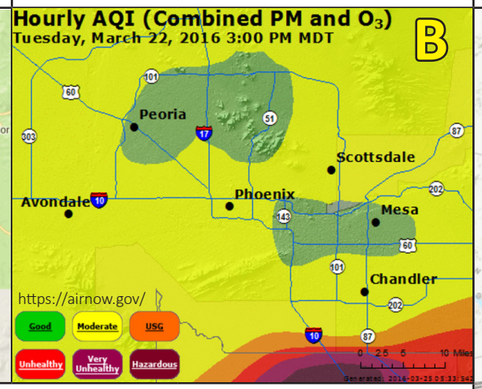
F. HYSPLIT reverse trajectory models indicate that sources of PM that contributed to elevated concentrations (starting at 1300) were to the W and SW of Superior in the hours leading up to the elevated concentrations. Data supporting items B-E corroborate the presence of airborne PM in the areas along the HYSPLIT trajectories.

Conclusion: A regional dust event caused by a fast-moving cold front that moved through AZ on 03-22 contributed to elevated concentrations of $PM_{2.5}$ and PM_{10} at the Resolution WPS and EPS monitors. The elevated $PM_{2.5}$ and PM_{10} concentrations at WPS and EPS on 03-22 were influenced by these naturally occurring events and should be removed from the data sets used to prepare background PM concentration profiles for the project.

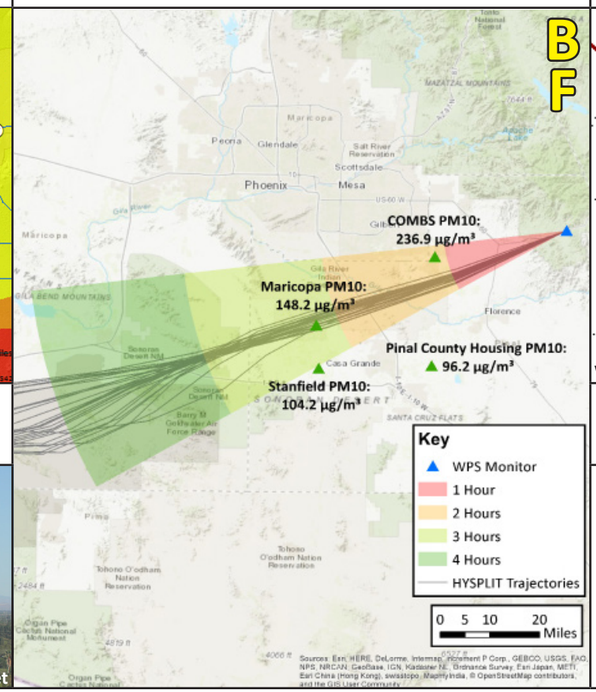
Wind Field (03-22 1447 MST)



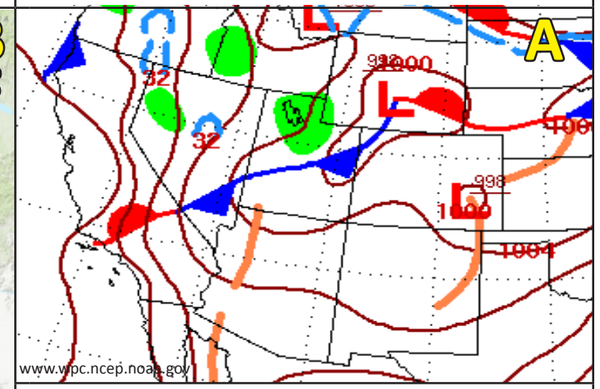
Air Quality Index



HYSPLIT (03-22 1300 MST)

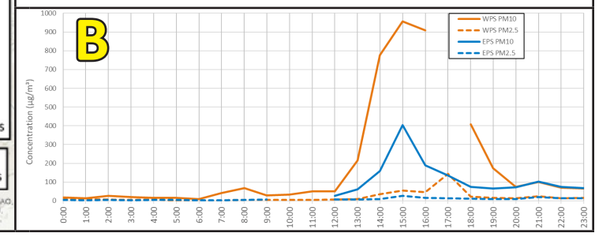


Surface Weather Map



Visibility Images

PM Conc Time Series



2016-04-26 – Elevated PM at WPS and EPS Influenced by Regional Dust Event

	WPS	EPS
PM_{10} Conc	84.4 µg/m³ 99.7th Percentile	80.1 µg/m³ 99.7th Percentile
$PM_{2.5}$ Conc	17.6 µg/m³ 99.4th Percentile	17.8 µg/m³ 99.4th Percentile

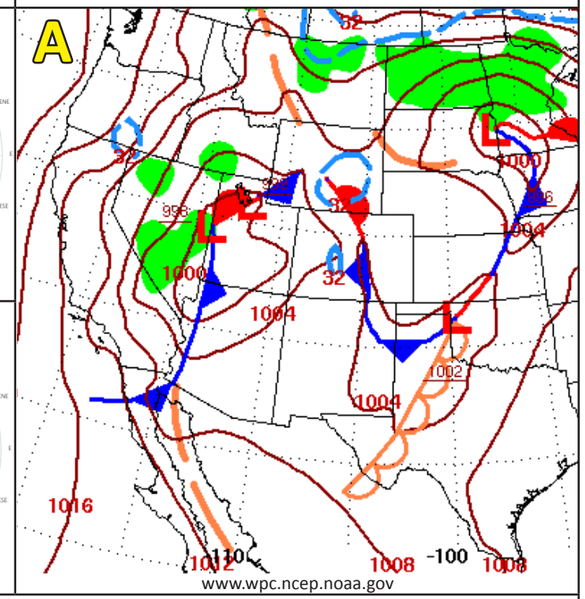
PM_{10} Roses — PM10 Concentration (µg/m³): > 100; 75 – 100; 50 – 75; 25 – 50; 15 – 25; 10 – 15; < 10

$PM_{2.5}$ Roses — PM2.5 Concentration (µg/m³): > 50; 30 – 50; 20 – 30; 15 – 20; 10 – 15; 5 – 10; < 5

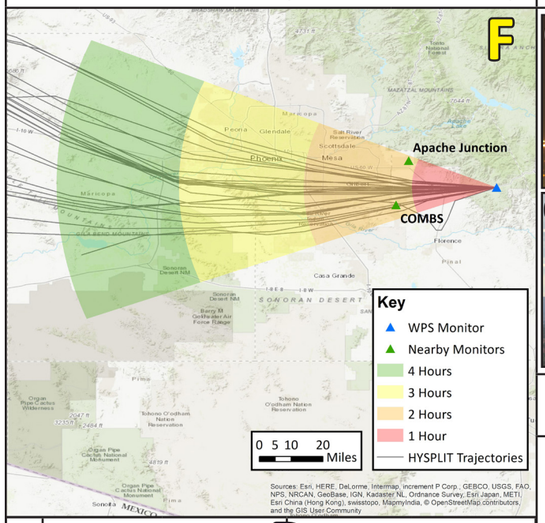
WPS (04-25) | EPS (04-25) | WPS (04-26) | EPS (04-26)

D

Surface Weather Map (04-25)



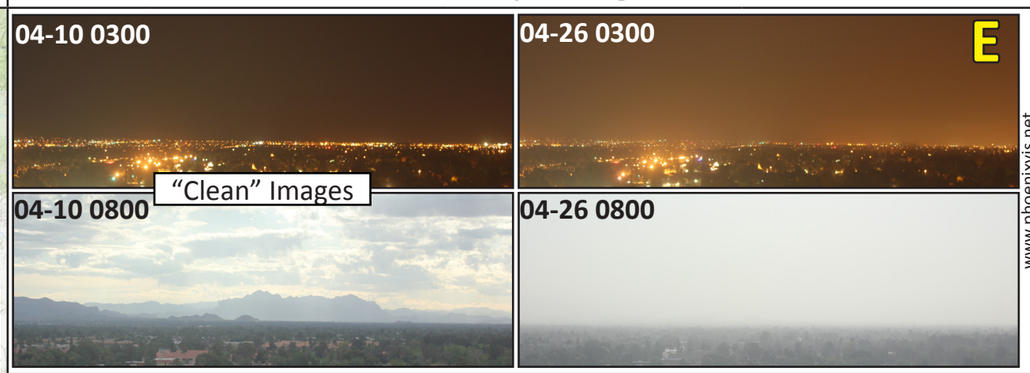
WPS HYSPLIT (04-26 0200)



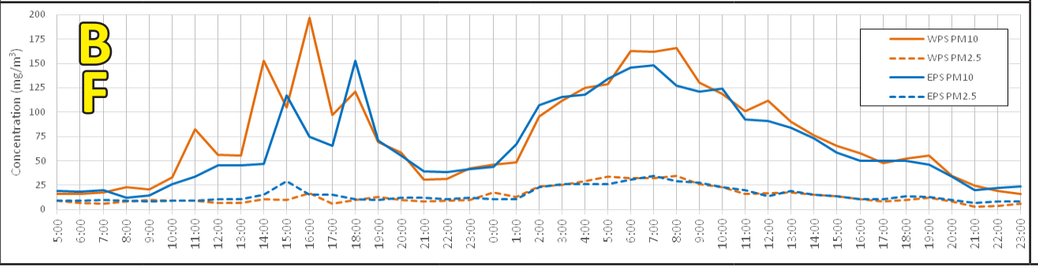
PM_{10} Conc	Apache Junction 04-25	Apache Junction 04-26	COMBS 04-25	COMBS 04-26
	76.4 µg/m³	90.0 µg/m³	103.1 µg/m³	104.3 µg/m³

B C

Visibility Images



Particulate Concentration Time Series (04-25 – 04-26)



Summary

A. A surface weather map of the western United States indicates a significant cold front & a low-pressure system moving through western & central AZ on April 25. These spring cold fronts are associated with high winds, which can cause dust-generating events.

B. Regional (PCAQCD's COMBS & Apache Junction PM stations) & on-site met & PM data show high wind speeds & elevated PM concentrations on April 25. Local news articles report high wind speeds & large dust storms (that caused road closures) on April 25.

C. Continued elevated concentrations of PM_{10} were measured on April 26 at the COMBS & Apache Junction stations, corroborating the occurrence of a regional dust event & subsequent PM transport.

D. Pollution roses of West Plant Site (WPS) & East Plant Site (EPS) PM data on April 25 & April 26 indicate elevated concentrations associated with winds from the west & southwest.

E. Photographs from the Phoenixvis.net camera (from Phoenix toward the Superstition Mountains) indicate reduced visibility during morning hours on April 26.

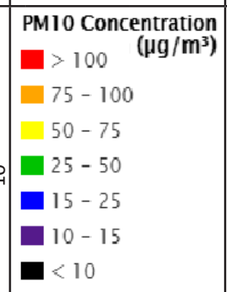
F. HYSPLIT reverse trajectory models indicate that sources of PM that contributed to elevated concentrations (starting at 0200 at WPS) were to the west of Superior in the hours leading up to the elevated concentrations. Data supporting items B-E corroborate the presence of airborne PM in the areas along the HYSPLIT trajectories.

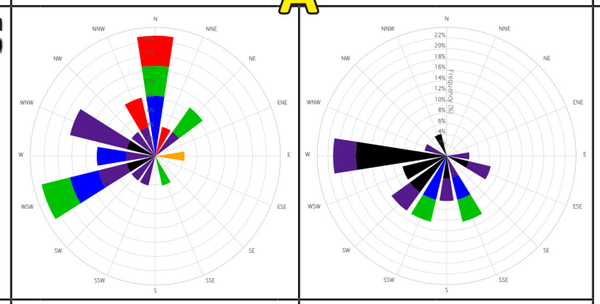
CONCLUSION: A regional dust event caused by a fast-moving cold front that moved through central AZ on April 25 contributed to elevated concentrations of $PM_{2.5}$ & PM_{10} at the Resolution WPS & EPS monitors. The elevated $PM_{2.5}$ & PM_{10} concentrations at WPS & EPS on April 26 were influenced by these naturally occurring events & should be removed from the data sets used to prepare background PM concentration profiles for the project.

2016-06-17 – Elevated PM at WPS Influenced by Fire Activity

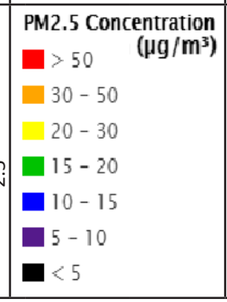
	WPS	EPS
PM_{10} Conc	101.0 µg/m³ 99.7 Percentile	14.1 µg/m³ 61.0 Percentile
$PM_{2.5}$ Conc	15.2 µg/m³ 93.3 Percentile	3.43 µg/m³ 49.8 Percentile

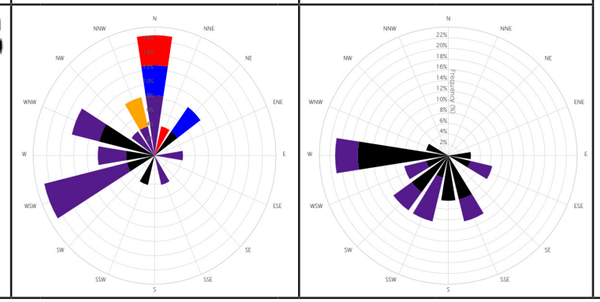
PM_{10} Roses





$PM_{2.5}$ Roses



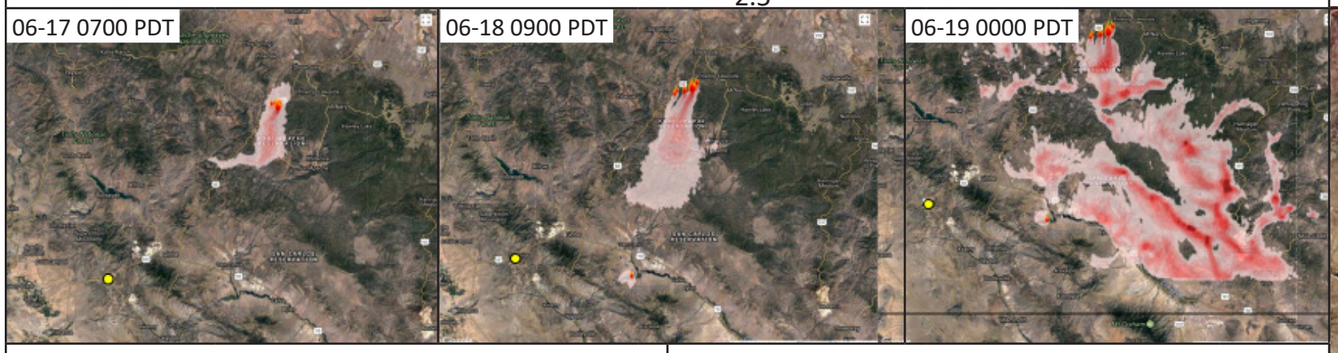


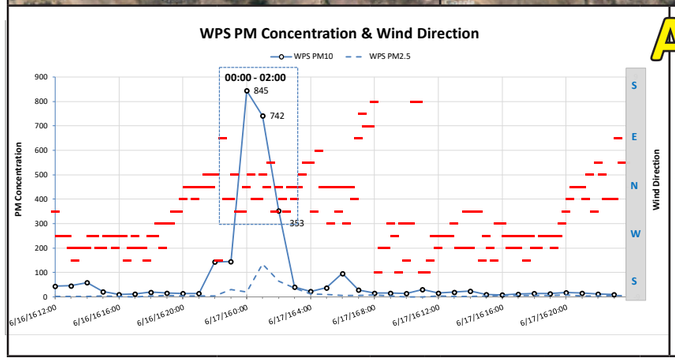
Summary

A. A valley/drainage flow pattern can be seen in the wind directions on 6-16 and 6-17. At WPS during these drainage flow conditions, the winds blow from the N, NE, and NW during the nighttime hours and shift to a westerly flow during the daytime. At EPS, the winds generally blow from ESE and S directions (not northerly like WPS) during the nighttime hours and shift to a westerly flow during the day. The pollution roses for 6-16 indicate high PM impacts at WPS from the N and NE directions and the time series plots of wind direction and wind speed show that these winds occur in the very early morning hours. In contrast, the pollution roses at EPS on 6-16, show predominately southerly winds at night and lower PM impacts than WPS.

B. On 6-16 Arizona news agencies documented the Cedar Fire with rapid fire activity growth and associated widespread smoke. This wildfire was actively managed for almost a month and consumed nearly 46,000 acres of timber and brush south of Show Low, AZ. Smoke plume activity for the Cedar Fire was typical. Daytime smoke plumes were large, elevated, well defined and usually transported by prevailing winds to the northeast. Nighttime and early morning, when fire activity typically lessens, smoke plumes tend to have less heat (buoyancy), remain lower to the ground due to more stable atmospheric conditions, and are more likely to be transported over terrain by valley/drainage flow conditions. The Cedar Fire's location on the Mogollon Rim, upgradient from Roosevelt Reservoir and Superior, and along the predominant Salt River drainage, made it possible for lighter winds, calm conditions, and valley/drainage flows to move smoke to the southwest toward the Phoenix metropolitan area. The USDA-FS conducted regional air quality modeling during this event. Modeling results for the early days of the Cedar Fire predict southwesterly, down-drainage flows toward Superior during nighttime and early morning hours. Visual spectrum satellite images also show this plume movement in the direction of Superior.

BlueSky Model Runs $PM_{2.5}$ (06-17 – 06-19) B





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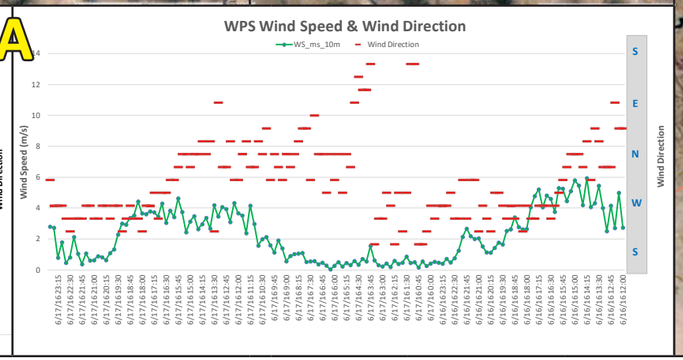
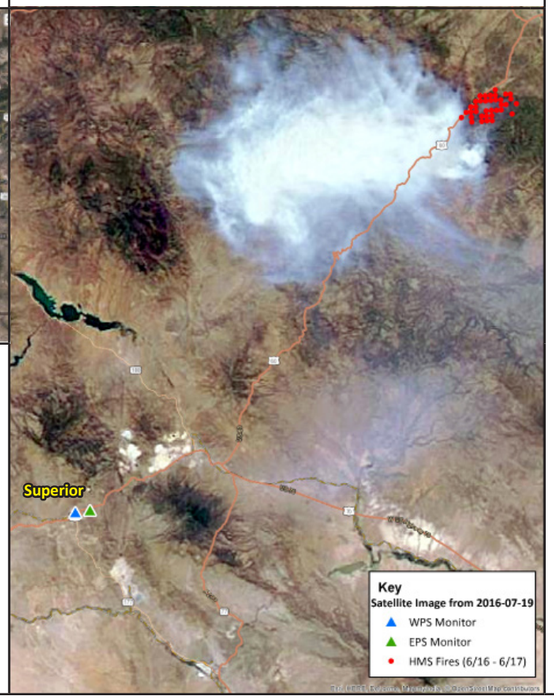


Satellite (06-19) B



Conclusion: Down-drainage flow conditions during nighttime and early morning hours when fire activity lessens and smoke plumes tend to follow terrain occurred during the first few days of the Cedar Fire. Monitored PM concentrations at the WPS monitor were elevated compared to those at the EPS monitor. This is likely due to the difference in terrain between the two sites and differences in nighttime valley-flow wind patterns. Low speed winds from the north started just before midnight on 6-16 and persisted well into the early morning hours of 6-17. Elevated PM_{10} concentrations were monitored at WPS during the hours of 0000 (845 µg/m³), 0100 (742 µg/m³) and 0200 (353 µg/m³). The fire activity, meteorological conditions, satellite imagery, and smoke modeling simulations indicate that down-gradient flow during nighttime and early morning hours were responsible for transporting smoke toward Superior. Due to the likely influence of transported smoke from a large wildfire, the elevated PM_{10} concentration measured at WPS on 06-17, should be removed from the data set used to prepare background PM concentration profiles for the project.

2016-07-23 – Elevated PM at WPS & EPS Influenced by Monsoonal Activity

	WPS	EPS
PM_{10} Conc	71.2 µg/m³ 99.1 Percentile	53.1 µg/m³ 99.4 Percentile
$PM_{2.5}$ Conc	7.25 µg/m³ 90.4 Percentile	7.46 µg/m³ 96.0 Percentile

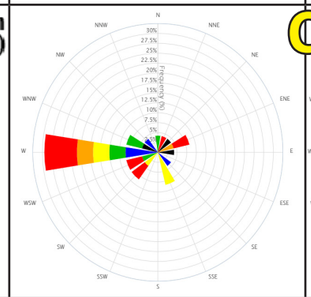
PM_{10} Roses

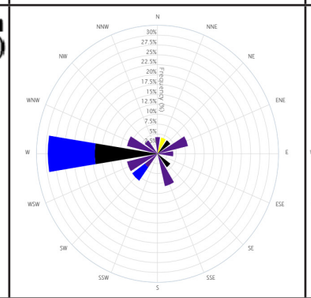
PM10 Concentration (µg/m³)
- > 100
- 75 – 100
- 50 – 75
- 25 – 50
- 15 – 25
- 10 – 15
- < 10

$PM_{2.5}$ Roses

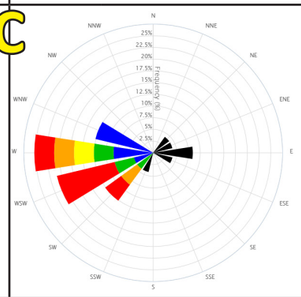
PM2.5 Concentration (µg/m³)
- > 50
- 30 – 50
- 20 – 30
- 15 – 20
- 10 – 15
- 5 – 10
- < 5

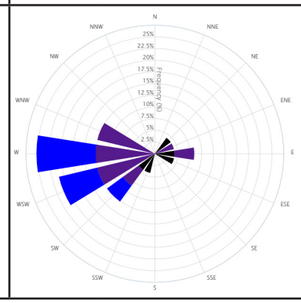
WPS





EPS





Summary

A. A surface weather map of the western United States indicates pressure systems indicative of monsoon conditions in AZ (thermal low to the west of Arizona and high pressure in Arizona) on 07-22 as also confirmed by radar. These monsoonal conditions can cause high speed winds and can generate dust. High winds (from the afternoon through midnight on 07-22) preceded the increase in PM concentrations (during several hours of the morning and early afternoon on 07-23).

B. Elevated PM 24-hour concentrations at nearby PCAQCD monitors on 07-23 indicate elevated regional PM.

C. PM roses from WPS and EPS for 07-23 show many hours of elevated PM concentrations during hours of W, WSW, and SW winds.

D. A wind field map from the day before the event (07-22) shows winds with elevated speeds in the greater Phoenix Area.

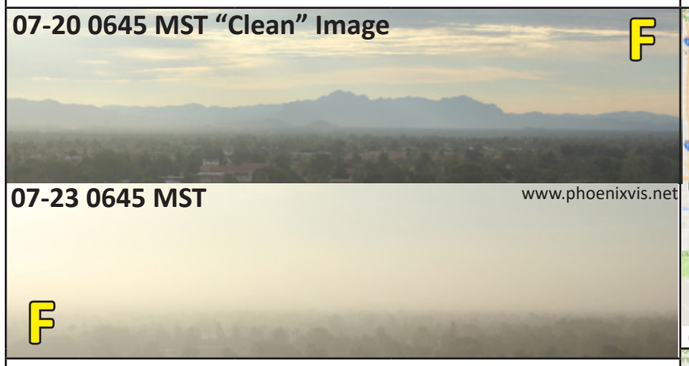
E. A wind field map for 07-23 shows light winds from the SW in Queen Creek and Superior.

F. Visibility images from Phoenixvis.net during the high monitored concentrations on 07-23, compared to a "clean" day, indicate reduced visibility, corroborating possible regional dust transport due to high winds due to monsoonal activity.

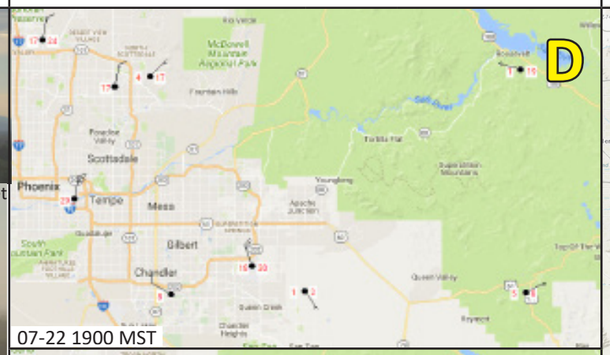
G. 17 of the 27 HYSPLIT reverse trajectory paths (shown in the hour cone) indicate that sources of PM that contributed to elevated concentrations (ending at 0700 at WPS) were to the W and WSW of Superior in the hours leading up to the elevated concentrations. Data supporting items A-F corroborate the presence of airborne PM in the areas along the HYSPLIT trajectories.

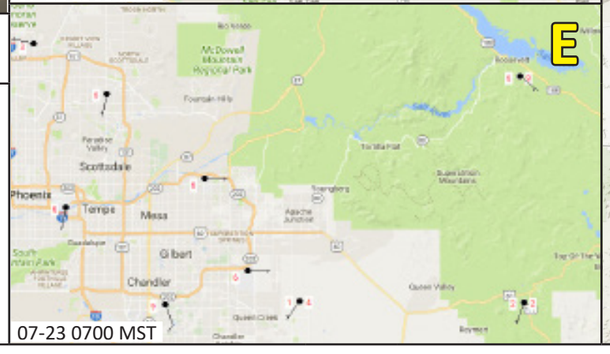
Conclusion: Regional high winds associated with summer monsoonal activity on 07-22 support the transport of regional airborne dust. Calmer winds on 07-23 support the transport of PM east toward the monitors and the contribution to elevated concentrations of PM. The wind field maps indicate monsoonal elevated winds and post-monsoonal calmer winds, which corroborate the event. The elevated PM_{10} concentrations should be removed from the data sets used to prepare background PM concentration profiles for the project.

Visibility Images

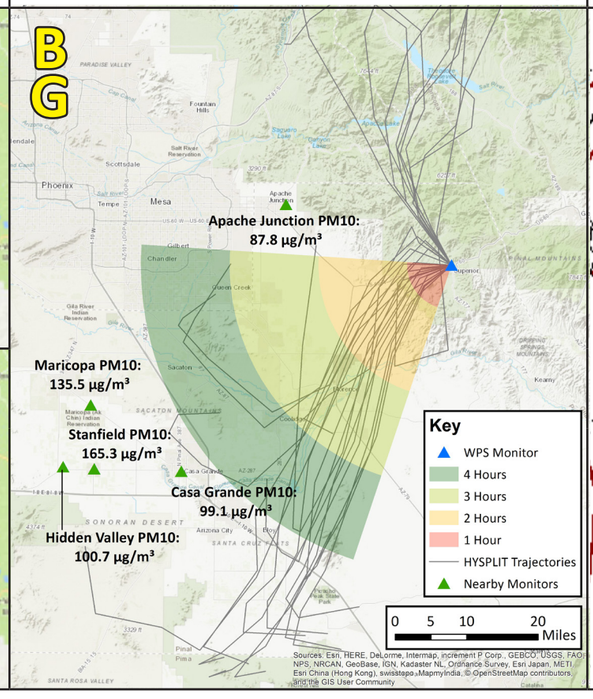


Wind Fields

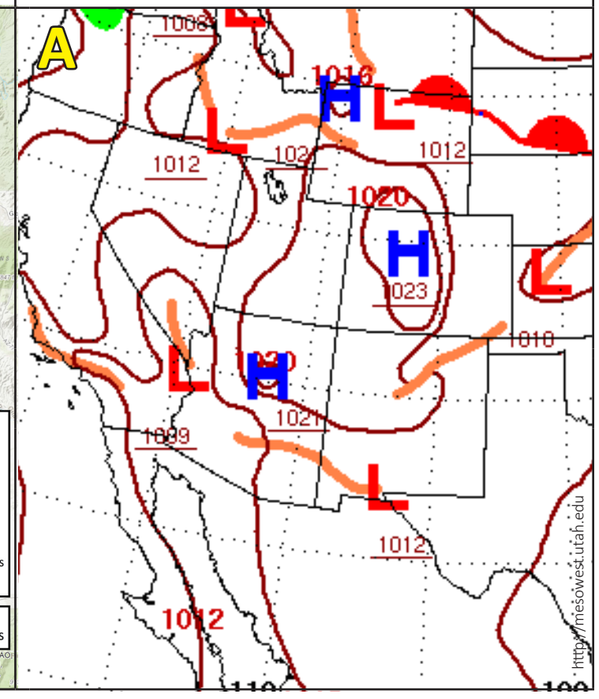




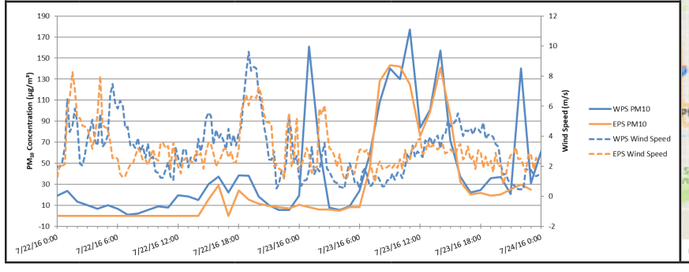
HYSPLIT (07-23 0700 MST)



Surface Weather Map (07-22)



PM Conc & WS Time Series



Appendix F – PCAQCD Dashboard Review and Data Exclusion Determination

Michael Sundblom
Air Quality Director

Greg Stanley
County Manager

PINAL COUNTY
WIDE OPEN OPPORTUNITY

December 7, 2017

Resolution Copper Mining, LLC
Attn: Victoria Peacey
P.O. Box 1944
Superior, AZ 85173

Re: Response to Atypical PM10 Day Package

Dear Ms. Peacey,

Pinal County Air Quality Control District (PCAQCD) has reviewed a package of 10 PM_{10} and $PM_{2.5}$ days identified by Resolution Copper as being atypical and not representative of background concentrations. Further, the "dashboard" for each identified day recommends that each day be removed from the data sets used to prepare background profiles for the project.

PCAQCD evaluated each date considering ADEQ Modeling Guidance (2017) and EPA's Exceptional Event Rule (Federal Register / Vol. 81, No. 191 / Monday, October 3, 2016). The Exceptional Event Rule outlines 5 determinations needed in a demonstration, but EPA indicates these do not apply to "predicted future" exceedances determined by modeling results and the addition of background data. Future guidance referenced is not available as of December 2017.

ADEQ modeling guidance requires all daily data to be used in the paired sums analysis unless the data point was "flagged as an exceptional event". Additionally, high concentrations cannot be excluded if "caused by a non-exceptional event process". ADEQ's guidance regarding exclusion of "flagged exceptional events" prior to exclusion does not address EPA's conclusion that modeling exercises do not need to conform to the 5 steps defined in the rule. This suggests that identifying the event as being influence by an exceptional event (flagging) allows exclusion of the data from the analysis. Flagging of ambient data is typically the responsibility of the entity responsible for collection of the data and is done through internal review of conditions leading to the measured value being considered. The ADEQ guidance does not indicate that the data point in question be approved or concurred with by EPA or other regulatory body. Further, the ADEQ guidance does not suggest that the data point be an exceedance of a NAAQS.

Lacking any guidance from EPA regarding exclusion of data points in modeling analysis, a reasonable interpretation of both citations suggests that a data point being considered for exclusion need only provide adequate evidence and receive concurrence by the reviewing regulatory agency that the that the exceedance or elevated value was not reasonably controllable or preventable whether caused by human activity or a natural event. Without EPA guidance it is reasonable to conclude that a weight of evidence approach is sufficient to make a data exclusion determination.

AIR QUALITY

31 North Pinal Street, Building F, PO Box 987, Florence, AZ 85132 T 520-866-6929 FREE 888-431-1311 F 520-866-6967
www.pinalcountyaz.gov

Using this process, PCAQCD has reviewed the 10 dates submitted and offers the following conclusion with respect to each:

April 26, 2016

- Windblown dust impacts were adequately demonstrated as evident in the supporting information provided.
- WPS and EPS readings are on the outer edge of the distribution.
- Regional wind impacts are evident at WPS, EPS, and PCAQCD monitors due to a frontal system.
- A regional event is demonstrated which in our review was found not to be reasonably controllable or preventable.

Conclusion: Concur

June 29, 2015

- Coolidge (55.7µg/m^3), Eloy 54.7 (55.7µg/m^3), and PCH (58.6µg/m^3) do not indicate 24-hour average concentrations of PM10 significantly above typical concentrations. Although, PCH hourly data shows one elevated hour (594.1µg/m^3) at 1800 local time indicating a brief impact from thunderstorm activity.
- Paragraph E suggested contribution from the Coolidge area which is not supported by radar loop and East to West movement of thunderstorms.
- Radar loop does illustrates periodic thunderstorms cells in the area but the analysis does not indicate a significant contribution from the event.

Conclusion: Do not concur

February 5, 2016

- PCAQCD PM10 network does not demonstrate elevated concentrations on February 2, 2016.
- Paragraph F of the Dashboard concludes that upwind sources influenced the elevated measurements. This is inconsistent with the large difference between WPS and EPS $PM_{2.5}$ concentrations. A regional wind event with transport from 15-20 miles away would likely result in similar $PM_{2.5}$ concentrations which are not apparent in the analysis.
- Analysis does not further investigate why similar impacts would not occur anytime the wind blows across the identified upwind controllable sources.
- Analysis does not further investigate differences in $PM_{2.5}$ ratio to PM_{10} as suggested in prior comments.

Conclusion: Do not concur

March 7, 2016

- Windblown dust impacts were adequately demonstrated as evident in the supporting information provided.
- WPS and EPS readings are on the outer edge of the distribution.
- Regional wind impacts are evident at WPS, EPS, and PCAQCD monitoring sites due to a frontal system.
- A regional event is demonstrated which in our review was found not to be reasonably controllable or preventable.

Conclusion: Concur

March 22, 2016

- Windblown dust impacts were adequately demonstrated as evident in the supporting information provided.
- WPS and EPS readings are on the outer edge of the distribution.
- Regional wind impacts are evident at WPS, EPS, and PCAQCD monitoring sites due to a frontal system.
- A regional event is demonstrated which in our review was found not to be reasonably controllable or preventable.

Conclusion: Concur

June 24, 2015

- Combs (79.2µg/m^3), Stanfield 54.7 (96.2µg/m^3), and PCH (67.6µg/m^3) do not indicate 24-hour average concentrations of PM_{10} significantly above typical concentrations. Combs and Stanfield each measured one hour values between 218.42µg/m^3 at 1700 and 281.62µg/m^3 at 2000, respectively while other sites had late day peaks less than 120µg/m^3
- The analysis indicates a minor influence from thunderstorms originating from the NE.

Conclusion: Do not concur

July 5, 2015

- The information provided regarding the BlueSky Model run for $PM_{2.5}$ is time stamped 20150704 while the evaluation considers July, 5 2015. It is unclear how the BlueSky model is demonstrative of the July 5th measurements.
- The BlueSky graphic in the dashboard does not include a scale to inform the level of potential impact.
- While the elevated PM2.5 concentrations could have been influenced by local activities the documentation does not explore this.

Conclusion: Do not concur (insufficient data provided)

July 3, 2015

- The information provided regarding the BlueSky Model run for $PM_{2.5}$ is time stamped 20150704 while the evaluation considers July, 3 2015. It is unclear how is the BlueSky model demonstrative of the July 3rd measurements.
- While the elevated $PM_{2.5}$ concentrations could have been influenced by local activities the documentation does not explore this.
- The BlueSky graphic in the dashboard does not include a scale to inform the level of potential impact.

Conclusion: Do not concur (insufficient data provided)

June 17, 2016

- BlueSky Model Run does not indicate impact on WPS or EPS.

Conclusion: Do not concur

July 23, 2016

- Early morning influence from thunderstorm activity apparent in PCAQCD network and WPS and EPS data.
- Radar loop does illustrates thunderstorms cells in the area but the analysis does not indicate a significant contribution from the event.

Conclusion: Do not concur

Thank you for the opportunity to review and comment on atypical particulate matter days. If you or your staff have question regarding this response please contact me at (520)866-6915 or Kale Walch at (520)866-6860.

Regards,

Mike Sundblom
Director
Pinal County Air Quality Control

Appendix G – Model Input Parameters

POINT Source Release Parameters

Model ID	Description	Facility	UTM X (m, Zone 12)	UTM Y (m, Zone 12)	Elevation (m)	Release Height (m)	Temperature (°C)	Exit Velocity (m/s)	Stack Dia (m)
E_VENT1	EPS Exhaust Vent 1	EPS	493,683	3,685,100	1,272	21.1	24.0	19.1	7.4
E_VENT2	EPS Exhaust Vent 2	EPS	493,701	3,685,089	1,269	21.1	24.0	19.1	7.4
E_VENT3	EPS Exhaust Vent 3	EPS	493,718	3,685,078	1,268	21.1	24.0	19.1	7.4
E_VENT4	EPS Exhaust Vent 4	EPS	493,736	3,685,066	1,267	21.1	24.0	19.1	7.4
E_GEN1	EPS Cat 516B - Diesel	EPS	493,790	3,684,824	1,261	5.0	490.0	64.5	0.30
E_GEN2	EPS Cat 3046C - Diesel	EPS	493,820	3,684,824	1,255	5.0	490.0	11.0	0.30
E_GEN3	EPS Caterpillar C175-16 1	EPS	493,790	3,684,834	1,263	5.0	472.3	112.0	0.36
E_GEN4	EPS Caterpillar C175-16 2	EPS	493,790	3,684,843	1,267	5.0	472.3	112.0	0.36
E_GEN5	EPS Caterpillar C175-16 3	EPS	493,790	3,684,853	1,270	5.0	472.3	112.0	0.36
E_GEN6	EPS Caterpillar C175-16 4	EPS	493,790	3,684,862	1,272	5.0	472.3	112.0	0.36
E_GEN7	EPS Caterpillar C175-16 5	EPS	493,790	3,684,872	1,273	5.0	472.3	112.0	0.36
E_GEN8	EPS Caterpillar C175-16 6	EPS	493,790	3,684,882	1,274	5.0	472.3	112.0	0.36
E_GEN9	EPS Caterpillar C175-16 7	EPS	493,790	3,684,891	1,274	5.0	472.3	112.0	0.36
E_GEN10	EPS Caterpillar C175-16 8	EPS	493,820	3,684,834	1,255	5.0	472.3	112.0	0.36
E_GEN11	EPS Caterpillar C175-16 9	EPS	493,820	3,684,843	1,256	5.0	472.3	112.0	0.36
E_GEN12	EPS Caterpillar C175-16 10	EPS	493,820	3,684,853	1,257	5.0	472.3	112.0	0.36
E_GEN13	EPS Caterpillar C175-16 11	EPS	493,820	3,684,862	1,260	5.0	472.3	112.0	0.36
E_GEN14	EPS Caterpillar C175-16 12	EPS	493,820	3,684,872	1,264	5.0	472.3	112.0	0.36
E_GEN15	EPS Caterpillar C175-16 13	EPS	493,820	3,684,882	1,268	5.0	472.3	112.0	0.36
E_GEN16	EPS Caterpillar C175-16 14	EPS	493,820	3,684,891	1,269	5.0	472.3	112.0	0.36
E_COOL1	EPS Surface Cooling Towers 1	EPS	493,613	3,684,698	1,268	11.7	100.0	12.2	9.7
E_COOL2	EPS Surface Cooling Towers 2	EPS	493,613	3,684,716	1,268	11.7	100.0	12.2	9.7
E_COOL3	EPS Surface Cooling Towers 3	EPS	493,613	3,684,734	1,268	11.7	100.0	12.2	9.7
E_COOL4	EPS Surface Cooling Towers 4	EPS	493,647	3,684,698	1,268	11.7	100.0	12.2	9.7
E_COOL5	EPS Surface Cooling Towers 5	EPS	493,647	3,684,716	1,268	11.7	100.0	12.2	9.7
E_COOL6	EPS Surface Cooling Towers 6	EPS	493,647	3,684,734	1,268	11.7	100.0	12.2	9.7
M1_FEED	SAG Mill Stockpile to Reclaim Tunnel Feeders (FE-001 - 004) - SAG 1	WPS	490,184	3,686,096	960	46.4	Ambient	28.2	0.61
M1_XFER	Mill Reclaim Tunnel Feeders (FE001 - 004) to SAG 1 Conveyor (CV-004)	WPS	490,147	3,685,992	958	46.4	Ambient	28.2	0.61
M2_FEED	SAG Mill Stockpile to Reclaim Tunnel Feeders (FE-005 - 008) - SAG 2	WPS	490,228	3,686,080	973	46.4	Ambient	28.2	0.61
M2_XFER	Mill Reclaim Tunnel Feeders (FE005 - 008) to SAG 2 Conveyor (CV-104)	WPS	490,191	3,685,977	957	46.4	Ambient	28.2	0.61
M1_LOAD	Mill SAG 1 Conveyor (CV-004) to SAG Mill 1 (ML-001)	WPS	490,100	3,685,862	951	22.2	Ambient	0.001	0.001
M1_SAG	SAG Mill 1 (ML-001)	WPS	490,089	3,685,834	947	22.2	Ambient	0.001	0.001
M1_TROML	Mill Trommel Screen 1 (SR-001) and associated transfer out (SR-002)	WPS	490,089	3,685,834	947	22.2	Ambient	0.001	0.001
M1_VIBRT	Mill Vibrating Screen (SR-002) and associated transfer out (oversize to CV-012)	WPS	490,089	3,685,834	947	22.2	Ambient	0.001	0.001
M1_BALLA	Ball Mill 1A (ML-002) and associated transfers in and out	WPS	490,089	3,685,834	947	22.2	Ambient	0.001	0.001
M1_BALLB	Ball Mill 1B (ML-003) and associated transfers in and out	WPS	490,089	3,685,834	947	22.2	Ambient	0.001	0.001
M2_LOAD	Mill SAG 2 Conveyor (CV-104) to SAG Mill 2 (ML-001)	WPS	490,143	3,685,846	961	22.2	Ambient	0.001	0.001
M2_SAG	SAG Mill 2 (ML-101)	WPS	490,133	3,685,818	954	22.2	Ambient	0.001	0.001
M2_TROML	Mill Trommel Screen 2 (SR-101) and associated transfer out (SR-003)	WPS	490,133	3,685,818	954	22.2	Ambient	0.001	0.001
M2_VIBRT	Mill Vibrating Screen (SR-003) and associated transfer out (oversize to CV-012)	WPS	490,133	3,685,818	954	22.2	Ambient	0.001	0.001
M2_BALLA	WPS Fugitive Surface Emissions	WPS	490,133	3,685,818	954	22.2	Ambient	0.001	0.001
M2_BALLB	WPS Fugitive Surface Emissions	WPS	490,133	3,685,818	954	22.2	Ambient	0.001	0.001
M_SCREEN	WPS Fugitive Surface Emissions	WPS	490,116	3,685,839	952	22.2	Ambient	0.001	0.001
M_PEBREC	Mill Recycle Conveyor 2 (CV-013) to Recycle Conveyor 3 (CV-014)	WPS	490,116	3,685,839	952	22.2	Ambient	0.001	0.001
M_PEBBIN	Mill Recycle Conveyor 3 (CV-014) to Pebble Bin (BN-002)	WPS	490,116	3,685,839	952	22.2	Ambient	0.001	0.001
M1_PEBFD	Mill Pebble Bin (BN-002) to Pebble Feeder 1 (FE-009)	WPS	490,116	3,685,839	952	22.2	Ambient	0.001	0.001
M2_PEBFD	Mill Pebble Bin (BN-002) to Pebble Feeder 2 (FE-109)	WPS	490,116	3,685,839	952	22.2	Ambient	0.001	0.001

POINT Source Release Parameters

Model ID	Description	Facility	UTM X (m, Zone 12)	UTM Y (m, Zone 12)	Elevation (m)	Release Height (m)	Temperature (°C)	Exit Velocity (m/s)	Stack Dia (m)
M1_PEBCV	Mill Pebble Feeder 1 (FE-009) to SAG 1 Conveyor (CV-004)	WPS	490,116	3,685,839	952	22.2	Ambient	0.001	0.001
M2_PEBCV	Mill Pebble Feeder 2 (FE-109) to SAG 2 Conveyor (CV-104)	WPS	490,116	3,685,839	952	22.2	Ambient	0.001	0.001
M_MLYFLT	Mill Moly Concentrate Filter (FL-001) to Holoflite Dryers (DR001 - 002)	WPS	489,931	3,685,743	927	22.2	Ambient	0.001	0.001
M_MLYBIN	Mill Holoflite Dryers (DR-001 - 002) to Moly Concentrate Day Bins (BN001 - 003)	WPS	489,929	3,685,730	928	1.8	Ambient	0.001	0.001
M_MLYBAG	Mill Moly Concentrate Day Bins (BN001 - 003) to Moly Bagging System (MS-001)	WPS	489,929	3,685,730	928	1.8	Ambient	0.001	0.001
M1_LIMBN	Mill Lime Bin 1 (BN-801) Loading (Discharge to Enclosed Screw Feeder)	WPS	490,147	3,685,653	963	9.0	Ambient	0.001	0.001
M1_LIMVM	Mill Screw Feeder 1 (CV-801) to Vertimill 1 (ML-801)	WPS	490,133	3,685,658	959	9.0	Ambient	0.001	0.001
M1_LIMTK	Mill Vertimill 1 (ML-801) to Milk of Lime Tank (TK-156)	WPS	490,147	3,685,676	959	9.0	Ambient	0.001	0.001
M2_LIMBN	Mill Lime Bin 2 (BN-802) Loading (Discharge to Enclosed Screw Feeder)	WPS	490,151	3,685,665	961	9.0	Ambient	0.001	0.001
M2_LIMVM	Mill Screw Feeder 2 (CV-802) to Vertimill 2 (ML-802)	WPS	490,137	3,685,669	960	9.0	Ambient	0.001	0.001
M2_LIMTK	Mill Vertimill 2 (ML-802) to Milk of Lime Tank (TK-156)	WPS	490,147	3,685,676	959	9.0	Ambient	0.001	0.001
M_MLYHTR	Mill Moly/Talc Heat Treatment Process	WPS	489,945	3,685,729	928	22.3	10.0	0.3	0.30
M_KILN_P	Moly/Talc Rotary Dryer Process	WPS	489,944	3,685,720	929	22.3	10.0	0.3	0.30
M_KILN_C	Moly/Talc Rotary Dryer Combustion	WPS	489,944	3,685,720	929	22.3	10.0	0.3	0.30
W_GEN1	WPS Caterpillar C18 Generator Set 1	WPS	490,175	3,685,798	963	2.8	447.1	35.9	0.20
W_GEN2	WPS Caterpillar C18 Generator Set 2	WPS	490,173	3,685,792	962	2.8	447.1	35.9	0.20
W_GEN3	WPS Caterpillar C18 Generator Set 3	WPS	490,170	3,685,785	962	2.8	447.1	35.9	0.20
M_CMBSTN	Mill Combustion (Stationary)	WPS	490,036	3,685,487	955	3.8	204.0	135.9	0.10
W_HEAT1	WPS Hydro House Propane Heater (0.045 MMBtu/hr)	WPS	490,929	3,684,596	912	3.8	204.0	0.9	0.10
W_HEAT2	WPS Hydro House Propane Heater (0.065 MMBtu/hr)	WPS	490,948	3,684,599	913	3.8	204.0	1.3	0.10
F_LDSTL	FPLF Concentrate Filters (FL-001 - 006) to Shuttle Conveyors (CV-001 - CV-006)	FPLF	461,713	3,673,879	512	1.8	Ambient	0.001	0.001
F_STLBLD	FPLF Shuttle Conveyors (CV-001 - CV-006) to Filter Building (BG-011)	FPLF	461,687	3,673,854	512	1.8	Ambient	0.001	0.001
F_STLCOL	FPLF Shuttle Conveyors (CV-001 - CV-006) to Collecting Conveyor (CV-010)	FPLF	461,660	3,673,854	512	1.8	Ambient	0.001	0.001
F_COLBLT	FPLF Collecting Conveyor (CV-010) to Belt Conveyor (CV-020)	FPLF	461,649	3,673,865	512	1.8	Ambient	0.001	0.001
F_LDGHOP	FPLF Concentrate Hopper (HP-011) Loading	FPLF	461,647	3,673,868	512	1.8	Ambient	0.001	0.001
F_HOPFED	FPLF Concentrate Hopper (HP-011) to Concentrate Feeder (FE-011)	FPLF	461,647	3,673,868	512	1.8	Ambient	0.001	0.001
F_FEDBLT	FPLF Concentrate Feeder (FE-011) to Belt Conveyor (CV-020)	FPLF	461,647	3,673,868	512	1.8	Ambient	0.001	0.001
F_BLTTRP	FPLF Belt Conveyor (CV-020) to Tripper Conveyor (CV-030)	FPLF	461,569	3,673,876	511	1.8	Ambient	0.001	0.001
F_TRPSTO	FPLF Tripper Conveyor (CV-030) to Storage and Loadout Shed (BG-012)	FPLF	461,563	3,673,876	511	1.8	Ambient	0.001	0.001
F_LDRHOP	FPLF Front End Loader (MS-002) to Load Out Hoppers (HP-012 - 015)	FPLF	461,437	3,673,851	510	1.8	Ambient	0.001	0.001
F_HOPBLT	FPLF Load Out Hoppers (HP-012 - 015) to Weigh Belt Feeders (FE-012 -015)	FPLF	461,437	3,673,851	510	1.8	Ambient	0.001	0.001
F_BLTCNV	FPLF Weigh Belt Feeders (FE-012 -015) to Load Out Conveyors (CV-031 - 034)	FPLF	461,437	3,673,851	510	1.8	Ambient	0.001	0.001
F_CNVTRN	FPLF Load Out Conveyors (CV-031 - 034) to Rail Cars	FPLF	461,437	3,673,832	510	1.8	Ambient	0.001	0.001
F_GEN1	FPLF Caterpillar C18 Generator Set 4	FPLF	461,749	3,673,868	512	2.8	447.1	35.9	0.20
T_GEN1	TSF Caterpillar C18 Generator Set 5	TSF	485,241	3,687,293	805	2.8	447.1	35.9	0.20

VOLUME Source Release Parameters

Model ID	Description	Facility	UTM X (m, Zone 12)	UTM Y (m, Zone 12)	Elevation (m)	Release Height (m)	σ_{yo} (m)	σ_{zo} (m)
B_AGDEL	Batch Plant Aggregate Delivery to Ground Storage	EPS	493,671	3,684,924	1,272	1.8	1.0	1.6
B_SNDEL	Batch Plant Sand Delivery to Ground Storage	EPS	493,673	3,684,924	1,272	1.8	1.0	1.6
B_AGCHUT	Batch Plant Aggregate Transfer to Conveyor Belt via Chute	EPS	493,665	3,684,928	1,274	1.8	1.1	1.6
B_SNCHUT	Batch Plant Sand Transfer to Conveyor Belt via Chute	EPS	493,665	3,684,928	1,274	1.8	1.1	1.6
B_AGSTOR	Batch Plant Aggregate Transfer to Elevated Storage	EPS	493,651	3,684,923	1,275	1.8	1.1	1.6
B_SNSTOR	Batch Plant Sand Transfer to Elevated Storage	EPS	493,651	3,684,928	1,275	1.8	0.2	1.6
B_WHOPLD	Batch Plant Weigh Hopper Loading (Aggregate & Sand)	EPS	493,650	3,684,926	1,275	1.8	0.3	1.6
B_WHOPAG	Batch Plant Weigh Hopper Discharge to Truck Loading Conveyor (Agg)	EPS	493,650	3,684,929	1,275	1.8	1.1	1.6
B_WHOPSN	Batch Plant Weigh Hopper Discharge to Truck Loading Conveyor (Sand)	EPS	493,650	3,684,929	1,275	1.8	1.1	1.6
B_CEMSLO	Batch Plant Cement Unloading to Silo	EPS	493,645	3,684,929	1,277	1.8	3.3	1.6
B_FLYSLO	Batch Plant Flyash Unloading to Silo	EPS	493,645	3,684,926	1,277	1.8	5.8	1.6
B_SILSLO	Batch Plant Silica Fume Unloading to Silo	EPS	493,650	3,684,935	1,275	1.8	3.3	1.6
B_SLOHOP	Batch Plant Cement & Flyash Discharge to Silo Weigh Hopper	EPS	493,650	3,684,938	1,275	1.8	5.8	1.6
B_SLOCNY	Batch Plant Silo Weigh Hopper Discharge to Truck Loading Conveyor	EPS	493,649	3,684,941	1,275	1.8	1.2	1.6
B_SLOTRK	Batch Plant Truck Loading	EPS	493,650	3,684,945	1,276	1.8	1.1	1.6
W_CVYXF1	WPS Incline Conveyor to Mine Conveyor	WPS	490,048	3,684,423	892	3.5	3.3	1.6
W_CVYXF2	WPS Mine Conveyor to Mine Transfer Conveyor (CV-002)	WPS	490,136	3,685,328	957	3.5	3.3	1.6
M_TRIPPR	Mill Mine Transfer Conveyor (CV-002) to Stockpile Tripper Conveyor (CV-003)	WPS	490,279	3,686,002	975	44.4	24.6	20.7
M_STOCKP	Mill Stockpile Tripper Conveyor (CV-003) to Covered SAG Mill Stockpile	WPS	490,184	3,686,036	969	44.4	24.6	20.7
M_SIPX	Mill SIPX (Sodium Isopropyl Xanthate)	WPS	490,131	3,685,752	951	15.0	1.1	7.0
M_MIBC	Mill MIBC (Methyl isobutyl carbonal)	WPS	490,132	3,685,754	951	15.0	1.1	7.0
M_NAHS	Mill NaHS (Sodium hydrosulfide solution)	WPS	490,135	3,685,753	951	15.0	1.1	7.0
M_FLOC1	Mill Flocculent (CIBA Magnafloc 155)	WPS	490,134	3,685,751	951	15.0	1.1	7.0
M_FLOC2	Mill Flocculent (CIBA Magnafloc 10)	WPS	490,138	3,685,749	952	15.0	1.1	7.0
M_CYTEC	Mill CYTEC 8989	WPS	490,139	3,685,752	952	15.0	1.1	7.0
M_MCO	Mill MCO (Non-polar flotation oil)	WPS	490,142	3,685,749	952	15.0	1.1	7.0
E_FUGS	EPS Fugitive Surface Emissions	EPS	493,633	3,684,853	1,281	5.0	98.8	4.7
W_FUGS	WPS Fugitive Surface Emissions	WPS	490,000	3,685,229	936	5.0	197.7	4.7
F_FUGS	FPLF Fugitive Surface Emissions	FPLF	461,606	3,673,866	512	5.0	58.1	4.7
T_FUGS	TSF Fugitive Surface Emissions	TSF	481,673	3,686,150	746	5.0	348.8	4.7

AREA Source Release Parameters

Model ID	Description	Facility	UTM X (m, Zone 12)	UTM Y (m, Zone 12)	UTM X (m, Zone 12)*	UTM Y (m, Zone 12)*	Elevation (m)	Release Height (m)	σ_{xo} (m)	σ_{yo} (m)	σ_{zo} (m)**	Rotation (°)**
E_WE_EXP	EPS Exposed Areas	EPS	493,738	3,684,781			1,231	1.0	262.4	399.6	0.9	-54.0
E_WE_SUB	EPS Exposed Subsidence Area	EPS	494,354	3,683,028			1,278	1.0	1290.1	1,440.8	0.9	-27.5
W_WE_EXP	WPS Exposed Areas	WPS	489,301	3,683,810			899	1.0	838.4	1,669.0	0.9	0.5
T_WE_BCH	TSF Exposed Areas - Beach	TSF	482,268	3,685,749			777	1.0	3412.9	2,234.9	0.9	-18.9
T_WE_DAM	TSF Exposed Areas - Dam	TSF	482,268	3,685,749			777	1.0	3412.9	2,234.9	0.9	-18.9
E_RD01	EPS Delivery & Employee road emissions	EPS	495,456	3,685,978	495,355	3,685,835	1,220	2.6	16.0	2.4		
E_RD02	EPS Delivery & Employee road emissions	EPS	495,355	3,685,835	495,333	3,685,614	1,214	2.6	16.0	2.4		
E_RD03	EPS Delivery & Employee road emissions	EPS	495,333	3,685,614	495,101	3,685,520	1,202	2.6	16.0	2.4		
E_RD04	EPS Delivery & Employee road emissions	EPS	495,101	3,685,520	494,863	3,685,575	1,197	2.6	16.0	2.4		
E_RD05	EPS Delivery & Employee road emissions	EPS	494,863	3,685,575	494,647	3,685,550	1,190	2.6	16.0	2.4		
E_RD06	EPS Delivery & Employee road emissions	EPS	494,647	3,685,550	494,444	3,685,584	1,183	2.6	16.0	2.4		
E_RD07	EPS Delivery & Employee road emissions	EPS	494,444	3,685,584	494,310	3,685,542	1,184	2.6	16.0	2.4		
E_RD08	EPS Delivery & Employee road emissions	EPS	494,310	3,685,542	494,195	3,685,430	1,181	2.6	16.0	2.4		
E_RD09	EPS Delivery & Employee road emissions	EPS	494,195	3,685,430	493,906	3,684,591	1,224	2.6	16.0	2.4		
E_RD10	EPS Delivery & Employee road emissions	EPS	493,906	3,684,591	493,788	3,684,554	1,270	2.6	16.0	2.4		
E_RD11	EPS Delivery road emissions	EPS	493,788	3,684,554	493,659	3,684,558	1,270	2.6	16.0	2.4		
E_RD12	EPS Delivery road emissions	EPS	493,659	3,684,558	493,554	3,684,560	1,277	2.6	16.0	2.4		
E_RD13	EPS Delivery road emissions	EPS	493,554	3,684,560	493,553	3,684,587	1,286	2.6	16.0	2.4		
E_RD14	EPS Delivery road emissions	EPS	493,553	3,684,587	493,626	3,684,585	1,276	2.6	16.0	2.4		
E_RD15	EPS Delivery road emissions	EPS	493,626	3,684,585	493,659	3,684,558	1,268	2.6	16.0	2.4		
E_RD16	EPS Employee road emissions	EPS	493,788	3,684,554	493,711	3,684,668	1,266	2.6	16.0	2.4		
E_TP01	EPS Delivery & Employee road tailpipe emissions	EPS	495,456	3,685,978	495,355	3,685,835	1,220	2.6	16.0	2.4		
E_TP02	EPS Delivery & Employee road tailpipe emissions	EPS	495,355	3,685,835	495,333	3,685,614	1,214	2.6	16.0	2.4		
E_TP03	EPS Delivery & Employee road tailpipe emissions	EPS	495,333	3,685,614	495,101	3,685,520	1,202	2.6	16.0	2.4		
E_TP04	EPS Delivery & Employee road tailpipe emissions	EPS	495,101	3,685,520	494,863	3,685,575	1,197	2.6	16.0	2.4		
E_TP05	EPS Delivery & Employee road tailpipe emissions	EPS	494,863	3,685,575	494,647	3,685,550	1,190	2.6	16.0	2.4		
E_TP06	EPS Delivery & Employee road tailpipe emissions	EPS	494,647	3,685,550	494,444	3,685,584	1,183	2.6	16.0	2.4		
E_TP07	EPS Delivery & Employee road tailpipe emissions	EPS	494,444	3,685,584	494,310	3,685,542	1,184	2.6	16.0	2.4		
E_TP08	EPS Delivery & Employee road tailpipe emissions	EPS	494,310	3,685,542	494,195	3,685,430	1,181	2.6	16.0	2.4		
E_TP09	EPS Delivery & Employee road tailpipe emissions	EPS	494,195	3,685,430	493,906	3,684,591	1,224	2.6	16.0	2.4		
E_TP10	EPS Delivery & Employee road tailpipe emissions	EPS	493,906	3,684,591	493,788	3,684,554	1,270	2.6	16.0	2.4		
E_TP11	EPS Delivery road tailpipe emissions	EPS	493,788	3,684,554	493,659	3,684,558	1,270	2.6	16.0	2.4		
E_TP12	EPS Delivery road tailpipe emissions	EPS	493,659	3,684,558	493,554	3,684,560	1,277	2.6	16.0	2.4		
E_TP13	EPS Delivery road tailpipe emissions	EPS	493,554	3,684,560	493,553	3,684,587	1,286	2.6	16.0	2.4		
E_TP14	EPS Delivery road tailpipe emissions	EPS	493,553	3,684,587	493,626	3,684,585	1,276	2.6	16.0	2.4		
E_TP15	EPS Delivery road tailpipe emissions	EPS	493,626	3,684,585	493,659	3,684,558	1,268	2.6	16.0	2.4		
E_TP16	EPS Employee road tailpipe emissions	EPS	493,788	3,684,554	493,711	3,684,668	1,266	2.6	16.0	2.4		
W_RD01	WPS Employee road emissions	WPS	489,852	3,683,414	489,840	3,683,476	832	2.6	16.0	2.4		
W_RD02	WPS Employee road emissions	WPS	489,840	3,683,476	489,931	3,683,519	834	2.6	16.0	2.4		
W_RD03	WPS Employee road emissions	WPS	489,931	3,683,519	489,974	3,683,619	837	2.6	16.0	2.4		
W_RD04	WPS Employee road emissions	WPS	489,974	3,683,619	490,058	3,683,730	841	2.6	16.0	2.4		
W_RD05	WPS Employee road emissions	WPS	490,058	3,683,730	490,010	3,683,826	843	2.6	16.0	2.4		
W_RD06	WPS Delivery road emissions	WPS	488,859	3,684,639	488,912	3,684,810	887	2.6	16.0	2.4		
W_RD07	WPS Delivery road emissions	WPS	488,912	3,684,810	489,081	3,684,939	906	2.6	16.0	2.4		
W_RD08	WPS Delivery road emissions	WPS	489,081	3,684,939	488,952	3,685,077	910	2.6	16.0	2.4		
W_RD09	WPS Delivery road emissions	WPS	488,952	3,685,077	488,987	3,685,168	893	2.6	16.0	2.4		
W_RD10	WPS Delivery road emissions	WPS	488,987	3,685,168	489,588	3,685,693	922	2.6	16.0	2.4		
W_RD11	WPS Delivery road emissions	WPS	489,588	3,685,693	489,751	3,685,646	944	2.6	16.0	2.4		
W_RD12	WPS Delivery road emissions	WPS	489,751	3,685,646	490,047	3,685,523	940	2.6	16.0	2.4		
W_TP01	WPS Employee road tailpipe emissions	WPS	489,852	3,683,414	489,840	3,683,476	832	2.6	16.0	2.4		
W_TP02	WPS Employee road tailpipe emissions	WPS	489,840	3,683,476	489,931	3,683,519	834	2.6	16.0	2.4		
W_TP03	WPS Employee road tailpipe emissions	WPS	489,931	3,683,519	489,974	3,683,619	837	2.6	16.0	2.4		
W_TP04	WPS Employee road tailpipe emissions	WPS	489,974	3,683,619	490,058	3,683,730	841	2.6	16.0	2.4		

AREA Source Release Parameters

Model ID	Description	Facility	UTM X (m, Zone 12)	UTM Y (m, Zone 12)	UTM X (m, Zone 12)*	UTM Y (m, Zone 12)*	Elevation (m)	Release Height (m)	σ_{xo} (m)	σ_{yo} (m)	σ_{zo} (m)**	Rotation (°)**
W_TP05	WPS Employee road tailpipe emissions	WPS	490,058	3,683,730	490,010	3,683,826	843	2.6	16.0	2.4		
W_TP06	WPS Delivery road tailpipe emissions	WPS	488,859	3,684,639	488,912	3,684,810	887	2.6	16.0	2.4		
W_TP07	WPS Delivery road tailpipe emissions	WPS	488,912	3,684,810	489,081	3,684,939	906	2.6	16.0	2.4		
W_TP08	WPS Delivery road tailpipe emissions	WPS	489,081	3,684,939	488,952	3,685,077	910	2.6	16.0	2.4		
W_TP09	WPS Delivery road tailpipe emissions	WPS	488,952	3,685,077	488,987	3,685,168	893	2.6	16.0	2.4		
W_TP10	WPS Delivery road tailpipe emissions	WPS	488,987	3,685,168	489,588	3,685,693	922	2.6	16.0	2.4		
W_TP11	WPS Delivery road tailpipe emissions	WPS	489,588	3,685,693	489,751	3,685,646	944	2.6	16.0	2.4		
W_TP12	WPS Delivery road tailpipe emissions	WPS	489,751	3,685,646	490,047	3,685,523	940	2.6	16.0	2.4		
F_RD01	FPLF Delivery & Employee road emissions	FPLF	460,966	3,672,584	460,965	3,673,840	506	2.6	16.0	2.4		
F_RD02	FPLF Delivery & Employee road emissions	FPLF	460,965	3,673,840	460,991	3,673,902	507	2.6	16.0	2.4		
F_RD03	FPLF Delivery & Employee road emissions	FPLF	460,991	3,673,902	461,055	3,673,935	508	2.6	16.0	2.4		
F_RD04	FPLF Delivery & Employee road emissions	FPLF	461,055	3,673,935	461,578	3,673,935	510	2.6	16.0	2.4		
F_RD05	FPLF Employee road emissions	FPLF	461,578	3,673,935	461,579	3,673,973	511	2.6	16.0	2.4		
F_RD06	FPLF Delivery road emissions	FPLF	461,578	3,673,935	461,739	3,673,935	512	2.6	16.0	2.4		
F_TP01	FPLF Delivery & Employee road tailpipe emissions	FPLF	460,966	3,672,584	460,965	3,673,840	506	2.6	16.0	2.4		
F_TP02	FPLF Delivery & Employee road tailpipe emissions	FPLF	460,965	3,673,840	460,991	3,673,902	507	2.6	16.0	2.4		
F_TP03	FPLF Delivery & Employee road tailpipe emissions	FPLF	460,991	3,673,902	461,055	3,673,935	508	2.6	16.0	2.4		
F_TP04	FPLF Delivery & Employee road tailpipe emissions	FPLF	461,055	3,673,935	461,578	3,673,935	510	2.6	16.0	2.4		
F_TP05	FPLF Employee road tailpipe emissions	FPLF	461,578	3,673,935	461,579	3,673,973	511	2.6	16.0	2.4		
F_TP06	FPLF Delivery road tailpipe emissions	FPLF	461,578	3,673,935	461,739	3,673,935	512	2.6	16.0	2.4		
T_RD01	TSF Delivery & Employee road emissions	TSF	488,859	3,684,639	488,912	3,684,810	887	2.6	16.0	2.4		
T_RD02	TSF Delivery & Employee road emissions	TSF	488,912	3,684,810	489,081	3,684,939	906	2.6	16.0	2.4		
T_RD03	TSF Delivery & Employee road emissions	TSF	489,081	3,684,939	488,952	3,685,077	910	2.6	16.0	2.4		
T_RD04	TSF Delivery & Employee road emissions	TSF	488,952	3,685,077	488,987	3,685,168	893	2.6	16.0	2.4		
T_RD05	TSF Delivery & Employee road emissions	TSF	488,987	3,685,168	489,588	3,685,693	922	2.6	16.0	2.4		
T_RD06	TSF Delivery & Employee road emissions	TSF	489,588	3,685,693	489,736	3,685,925	949	2.6	16.0	2.4		
T_RD07	TSF Delivery & Employee road emissions	TSF	489,736	3,685,925	489,537	3,686,288	939	2.6	16.0	2.4		
T_RD08	TSF Delivery & Employee road emissions	TSF	489,537	3,686,288	489,396	3,686,436	934	2.6	16.0	2.4		
T_RD09	TSF Delivery & Employee road emissions	TSF	489,396	3,686,436	489,098	3,686,509	927	2.6	16.0	2.4		
T_RD10	TSF Delivery & Employee road emissions	TSF	489,098	3,686,509	488,747	3,686,776	921	2.6	16.0	2.4		
T_RD11	TSF Delivery & Employee road emissions	TSF	488,747	3,686,776	488,585	3,686,760	916	2.6	16.0	2.4		
T_RD12	TSF Delivery & Employee road emissions	TSF	488,585	3,686,760	488,434	3,686,630	910	2.6	16.0	2.4		
T_RD13	TSF Delivery & Employee road emissions	TSF	488,434	3,686,630	487,968	3,686,855	903	2.6	16.0	2.4		
T_RD14	TSF Delivery & Employee road emissions	TSF	487,968	3,686,855	487,946	3,687,082	890	2.6	16.0	2.4		
T_RD15	TSF Delivery & Employee road emissions	TSF	487,946	3,687,082	487,870	3,687,119	882	2.6	16.0	2.4		
T_RD16	TSF Delivery & Employee road emissions	TSF	487,870	3,687,119	487,660	3,686,995	886	2.6	16.0	2.4		
T_RD17	TSF Delivery & Employee road emissions	TSF	487,660	3,686,995	487,356	3,687,200	880	2.6	16.0	2.4		
T_RD18	TSF Delivery & Employee road emissions	TSF	487,356	3,687,200	487,257	3,687,166	874	2.6	16.0	2.4		
T_RD19	TSF Delivery & Employee road emissions	TSF	487,257	3,687,166	487,054	3,686,730	870	2.6	16.0	2.4		
T_RD20	TSF Delivery & Employee road emissions	TSF	487,054	3,686,730	485,956	3,686,466	854	2.6	16.0	2.4		
T_RD21	TSF Delivery & Employee road emissions	TSF	485,956	3,686,466	485,795	3,686,545	843	2.6	16.0	2.4		
T_RD22	TSF Delivery & Employee road emissions	TSF	485,795	3,686,545	485,497	3,687,081	833	2.6	16.0	2.4		
T_RD23	TSF Delivery & Employee road emissions	TSF	485,497	3,687,081	485,426	3,687,447	824	2.6	16.0	2.4		
T_RD24	TSF Delivery & Employee road emissions	TSF	485,426	3,687,447	485,289	3,687,419	819	2.6	16.0	2.4		
T_TP01	TSF Delivery & Employee road tailpipe emissions	TSF	488,859	3,684,639	488,912	3,684,810	887	2.6	16.0	2.4		
T_TP02	TSF Delivery & Employee road tailpipe emissions	TSF	488,912	3,684,810	489,081	3,684,939	906	2.6	16.0	2.4		
T_TP03	TSF Delivery & Employee road tailpipe emissions	TSF	489,081	3,684,939	488,952	3,685,077	910	2.6	16.0	2.4		
T_TP04	TSF Delivery & Employee road tailpipe emissions	TSF	488,952	3,685,077	488,987	3,685,168	893	2.6	16.0	2.4		
T_TP05	TSF Delivery & Employee road tailpipe emissions	TSF	488,987	3,685,168	489,588	3,685,693	922	2.6	16.0	2.4		
T_TP06	TSF Delivery & Employee road tailpipe emissions	TSF	489,588	3,685,693	489,736	3,685,925	949	2.6	16.0	2.4		
T_TP07	TSF Delivery & Employee road tailpipe emissions	TSF	489,736	3,685,925	489,537	3,686,288	939	2.6	16.0	2.4		
T_TP08	TSF Delivery & Employee road tailpipe emissions	TSF	489,537	3,686,288	489,396	3,686,436	934	2.6	16.0	2.4		
T_TP09	TSF Delivery & Employee road tailpipe emissions	TSF	489,396	3,686,436	489,098	3,686,509	927	2.6	16.0	2.4		

AREA Source Release Parameters

Model ID	Description	Facility	UTM X (m, Zone 12)	UTM Y (m, Zone 12)	UTM X (m, Zone 12)*	UTM Y (m, Zone 12)*	Elevation (m)	Release Height (m)	σ_{xo} (m)	σ_{yo} (m)	σ_{zo} (m)**	Rotation (°)**
T_TP10	TSF Delivery & Employee road tailpipe emissions	TSF	489,098	3,686,509	488,747	3,686,776	921	2.6	16.0	2.4		
T_TP11	TSF Delivery & Employee road tailpipe emissions	TSF	488,747	3,686,776	488,585	3,686,760	916	2.6	16.0	2.4		
T_TP12	TSF Delivery & Employee road tailpipe emissions	TSF	488,585	3,686,760	488,434	3,686,630	910	2.6	16.0	2.4		
T_TP13	TSF Delivery & Employee road tailpipe emissions	TSF	488,434	3,686,630	487,968	3,686,855	903	2.6	16.0	2.4		
T_TP14	TSF Delivery & Employee road tailpipe emissions	TSF	487,968	3,686,855	487,946	3,687,082	890	2.6	16.0	2.4		
T_TP15	TSF Delivery & Employee road tailpipe emissions	TSF	487,946	3,687,082	487,870	3,687,119	882	2.6	16.0	2.4		
T_TP16	TSF Delivery & Employee road tailpipe emissions	TSF	487,870	3,687,119	487,660	3,686,995	886	2.6	16.0	2.4		
T_TP17	TSF Delivery & Employee road tailpipe emissions	TSF	487,660	3,686,995	487,356	3,687,200	880	2.6	16.0	2.4		
T_TP18	TSF Delivery & Employee road tailpipe emissions	TSF	487,356	3,687,200	487,257	3,687,166	874	2.6	16.0	2.4		
T_TP19	TSF Delivery & Employee road tailpipe emissions	TSF	487,257	3,687,166	487,054	3,686,730	870	2.6	16.0	2.4		
T_TP20	TSF Delivery & Employee road tailpipe emissions	TSF	487,054	3,686,730	485,956	3,686,466	854	2.6	16.0	2.4		
T_TP21	TSF Delivery & Employee road tailpipe emissions	TSF	485,956	3,686,466	485,795	3,686,545	843	2.6	16.0	2.4		
T_TP22	TSF Delivery & Employee road tailpipe emissions	TSF	485,795	3,686,545	485,497	3,687,081	833	2.6	16.0	2.4		
T_TP23	TSF Delivery & Employee road tailpipe emissions	TSF	485,497	3,687,081	485,426	3,687,447	824	2.6	16.0	2.4		
T_TP24	TSF Delivery & Employee road tailpipe emissions	TSF	485,426	3,687,447	485,289	3,687,419	819	2.6	16.0	2.4		

** A second coordinate indicates a LINE source, a subtype of the AREA source.*

*** Presence of these parameters indicate an AREA source that is not a LINE source.*

Appendix H – Technical Memoranda

DEFINING THE AMBIENT AIR BOUNDARY FOR DISPERSION MODELING

PREPARED FOR: Kami Ballard, Resolution Copper

PREPARED BY: Nate Tipple and Dave Randall, Air Sciences Inc.

This technical memorandum is one of several that has served as a platform for Pinal County Air Quality Control District (PCAQCD) and Resolution Copper (Resolution) to address issues raised during PCAQCD's review of Resolution's draft Air Quality Impacts Analysis Modeling Plan (Modeling Plan).[1]

Introduction

To demonstrate compliance with federal and state ambient air standards, industry-standard air dispersion models are used to simulate the atmospheric dispersion of an air pollutant to determine air pollution concentrations that result from a source's emissions. As part of the modeling setup process, Resolution has determined ambient air boundaries (AAB) that delineate where "public access is effectively precluded."[2] Future air quality modeling will include receptors along Resolution's ambient air boundary and in receptor grids outside/beyond the ambient air boundary.

Pursuant to EPA guidance, and consistent with ADEQ 2013, Section 3.4, the effective ambient air boundary can consist of a combination of fences and gates, physical barriers (including natural barriers), warning signage, manned guard shacks, and periodic security patrols.

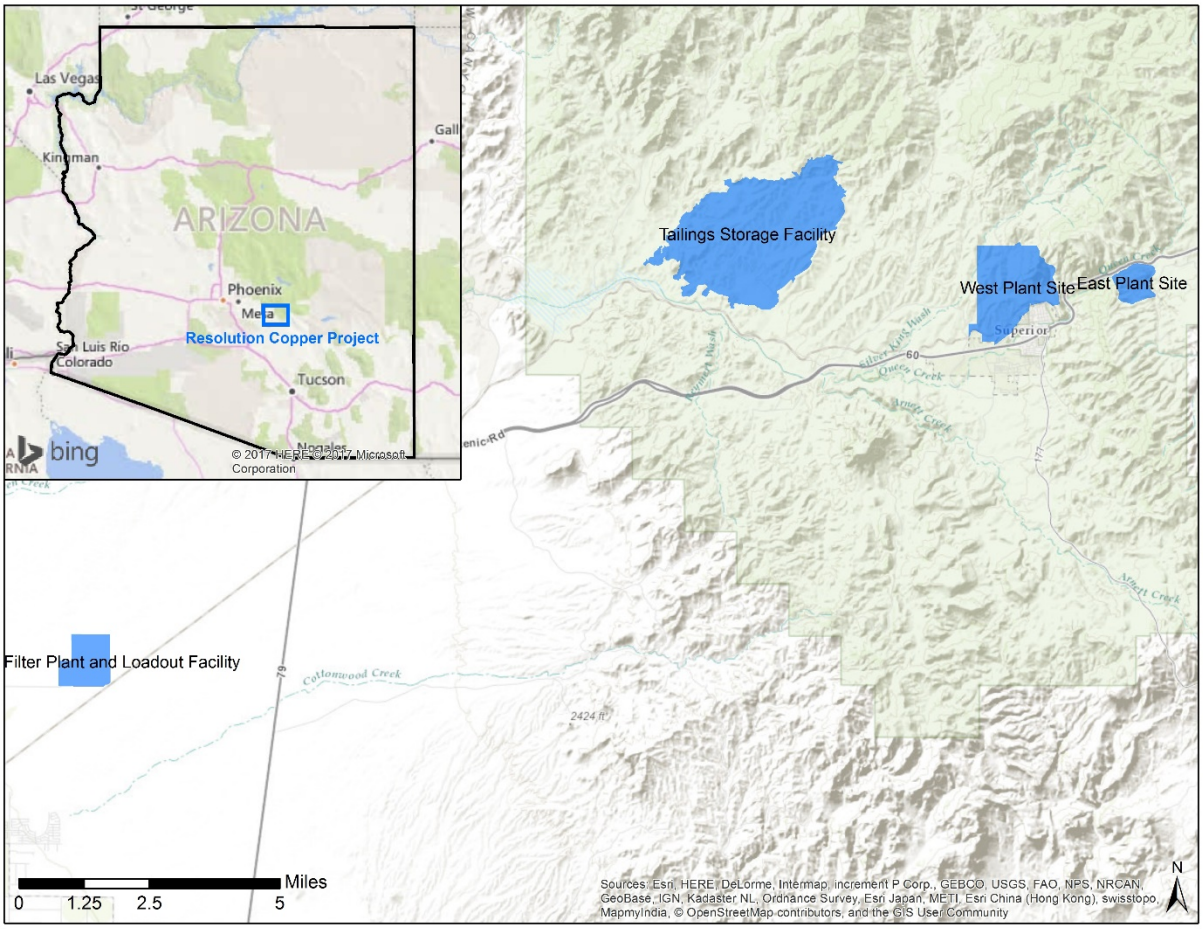
Discussion

There are four distinct operations areas at Resolution with the potential to emit air emissions: The East Plant Site, the West Plant Site, the Tailings Storage Facility, and the Filter Plant and Loadout Facility. A map presenting each of the four project areas and their proximity to one another is provided in Figure 1. Each proposed AAB is discussed individually in the following sections.

[1] Air Sciences Inc. 2015. Draft Air Quality Impacts Analysis Modeling Plan. Prepared for Resolution Copper Mining, LLC. July.

[2] Arizona Department of Environmental Quality. 2013. Air Dispersion Modeling Guidelines for Arizona Air Quality Permits. September 23.

Figure 1. Location of Resolution Copper Project Sites



Each project area may use a combination of the following measures to preclude public access:

- Fencing, Berms, and Locking Gates – Fencing and locking gates will be used along public access roads and other locations near areas of heavy recreational use.

- Signage – Warning and/or no-trespassing signage will be posted on fences and near areas of natural barriers, trails, and recreation.

- Natural Barrier/Steep Terrain – Steep slopes around the project areas will serve as natural barriers or impediments to site access. In general, steep terrain is considered to be terrain with a grade of 25 to 30 percent or greater.

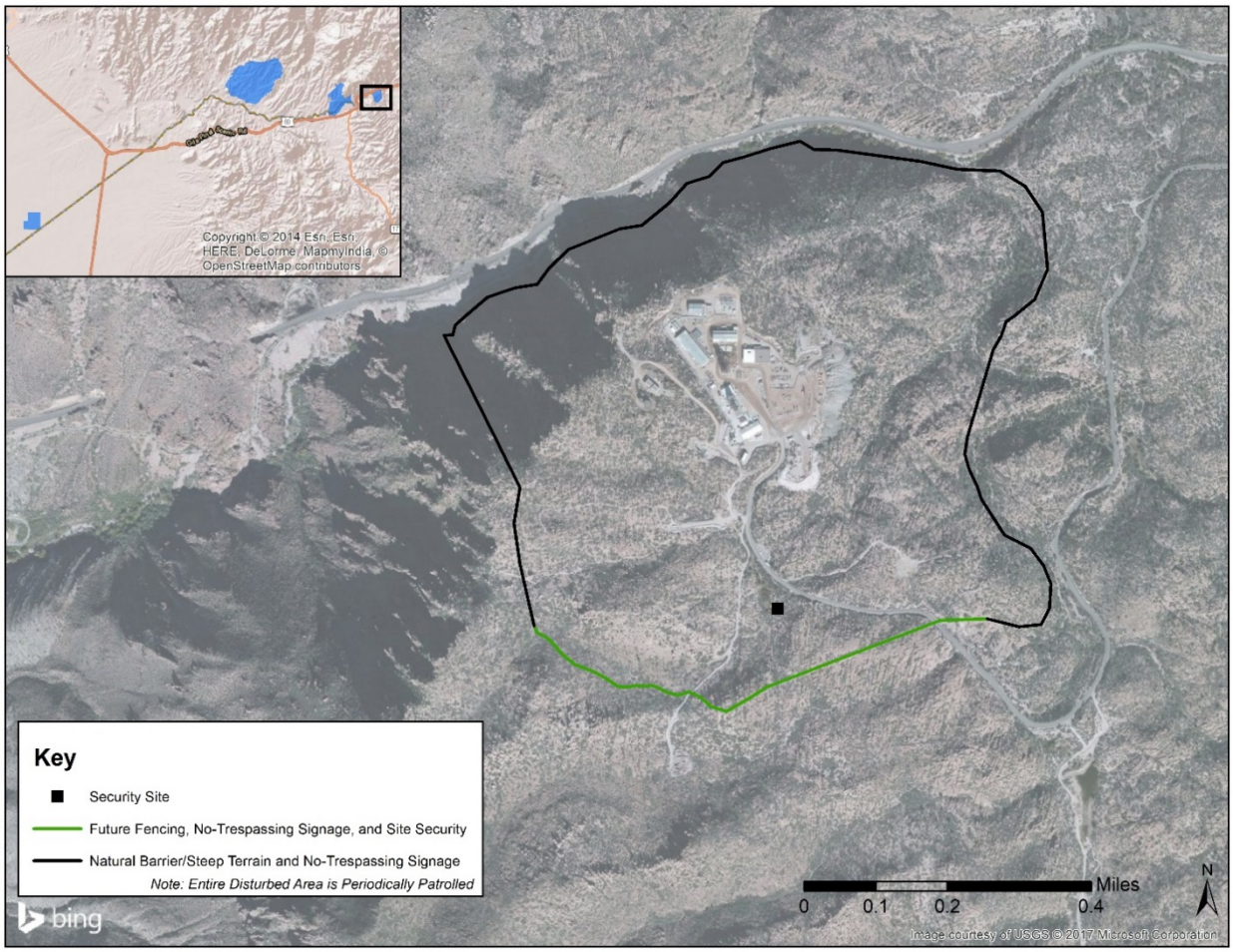
- Periodic Patrols – Mine security will routinely patrol the mine facilities and roads for unauthorized individual(s). In addition, all onsite personnel will be briefed on the necessity of restricting public access to areas within the AAB. Any suspected trespassing will be immediately reported to security.

- Site Security – Authorized access will be controlled by guard shacks, where a check-in/check-out system will be implemented. All mine personnel and visitors must gain access to the site through one of these points.

East Plant Site

The proposed AAB at the East Plant Site surrounds the proposed infrastructure to support underground mining operations. This boundary was selected for several reasons. First, this boundary is necessary to preclude public access, not only for air quality reasons, but in order for Resolution to keep the public out of the area for safety reasons. Second, this boundary also provides for an economical and realistic border to install effective boundaries and to conduct periodic patrols. The effective boundary at the East Plant Site consists of natural barrier/steep terrain, fencing, locking gates, no-trespassing signage, site security, and periodic vehicle patrols. Figure 2 provides a map of the East Plant's AAB, which shows the location of the proposed boundary as well as the proposed methods of precluding public access.

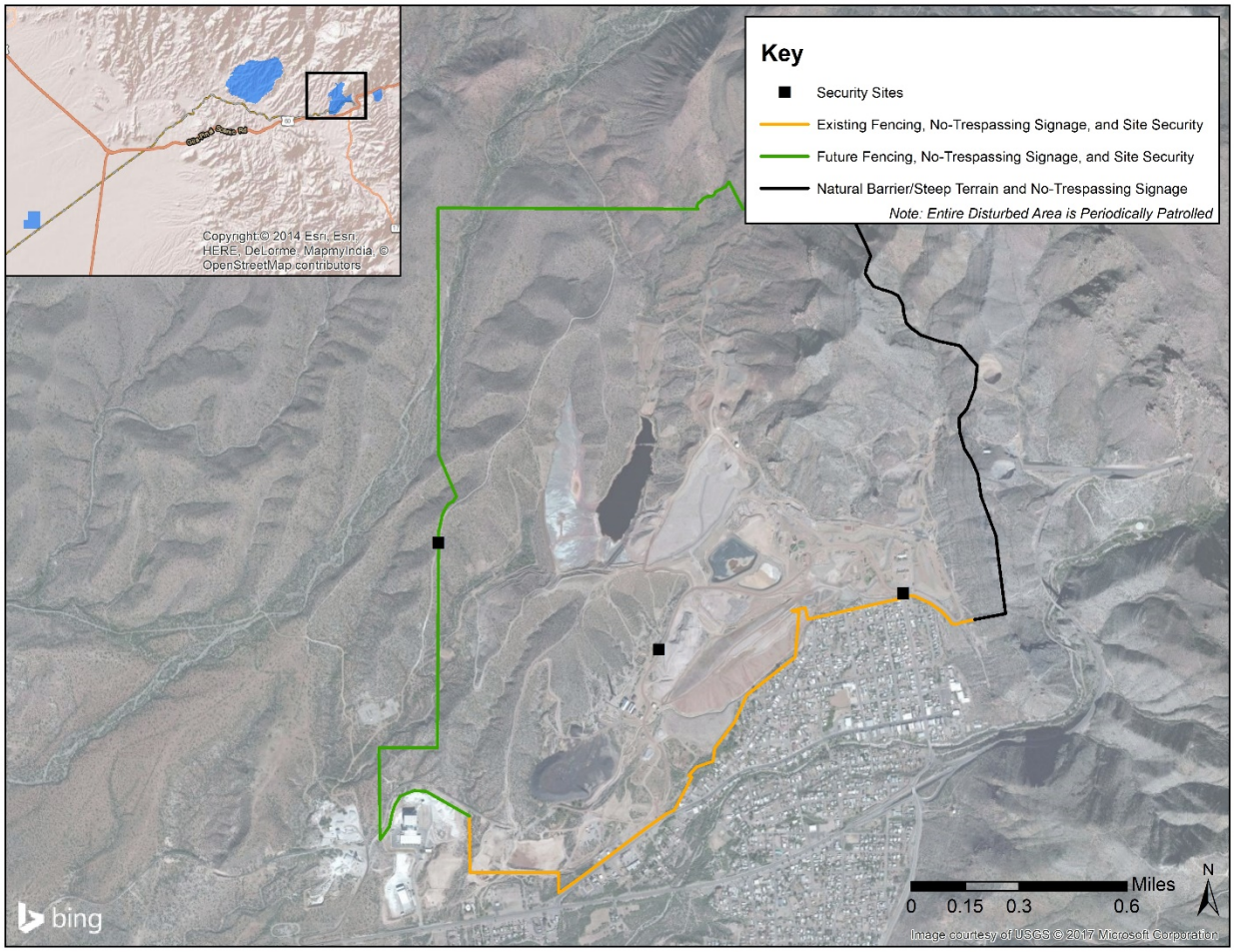
Figure 2. Proposed East Plant Site Ambient Air Boundary



West Plant Site

The West Plant Site's AAB utilizes natural barrier/steep terrain, fencing, locking gates, no-trespassing signage, site security, and periodic vehicle patrols to preclude public access. The AAB is located around the offices and future mill facilities located north of Superior, AZ. Figure 3 provides a map of the West Plant Site's AAB, which shows the location of the proposed boundary as well as the proposed methods of precluding public access.

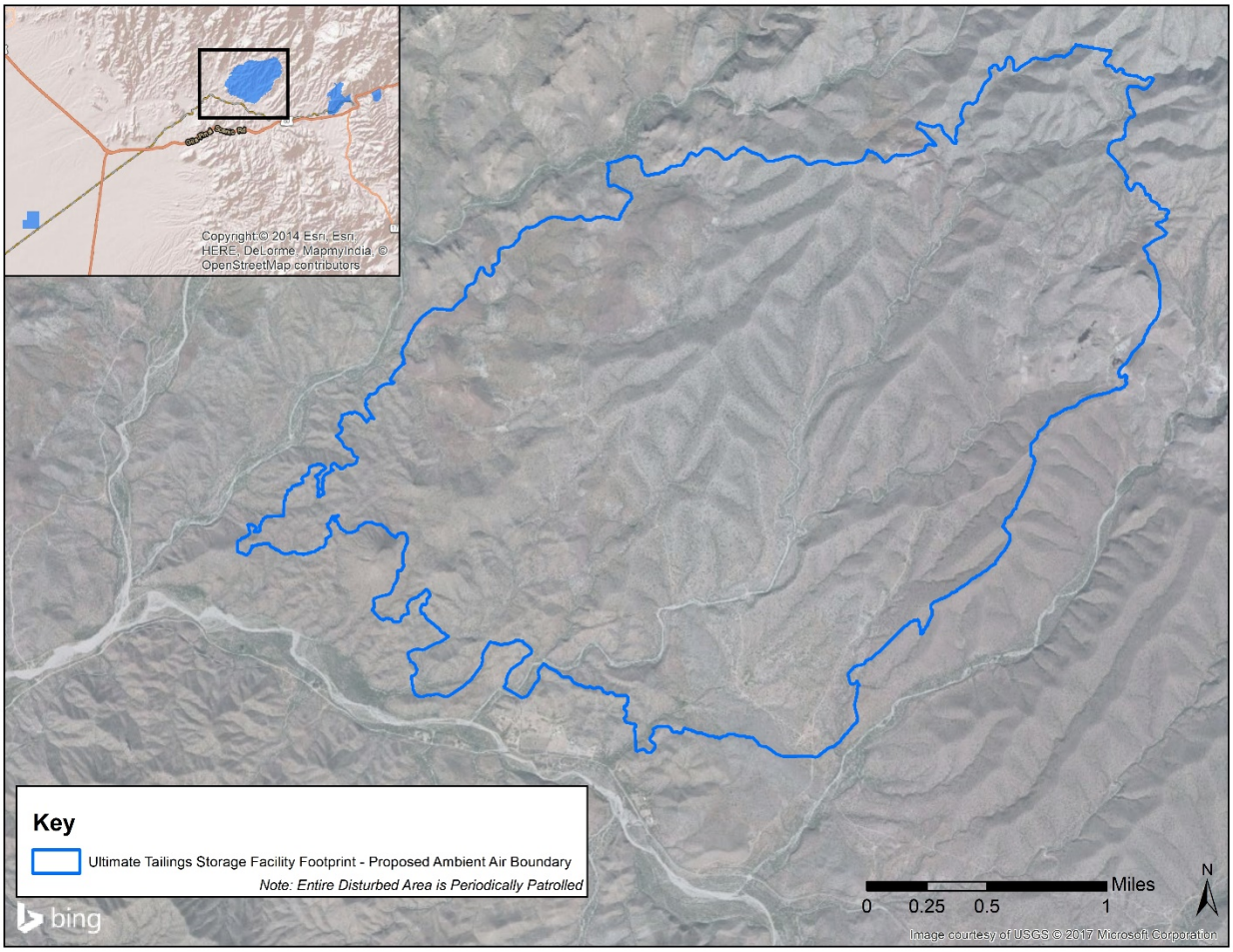
Figure 3. Proposed West Plant Site Ambient Air Boundary



Tailings Storage Facility

Resolution has committed in their General Plan of Operations to preclude public access using either perimeter fencing or berms in combination with no-trespassing signage. The exact location of the future fence will encompass the entire footprint of the Tailings Storage Facility, with the exception of locations where terrain is steeper than 25 to 30 percent. To be conservative, Resolution is proposing to use the ultimate tailings footprint as seen in Figure 4 as the ambient air boundary. Vehicle access at the Tailings Storage Facility will be controlled by locked gates. As with the other facilities at the Resolution Project, periodic security patrols will be conducted around the facility as it will have a perimeter road.

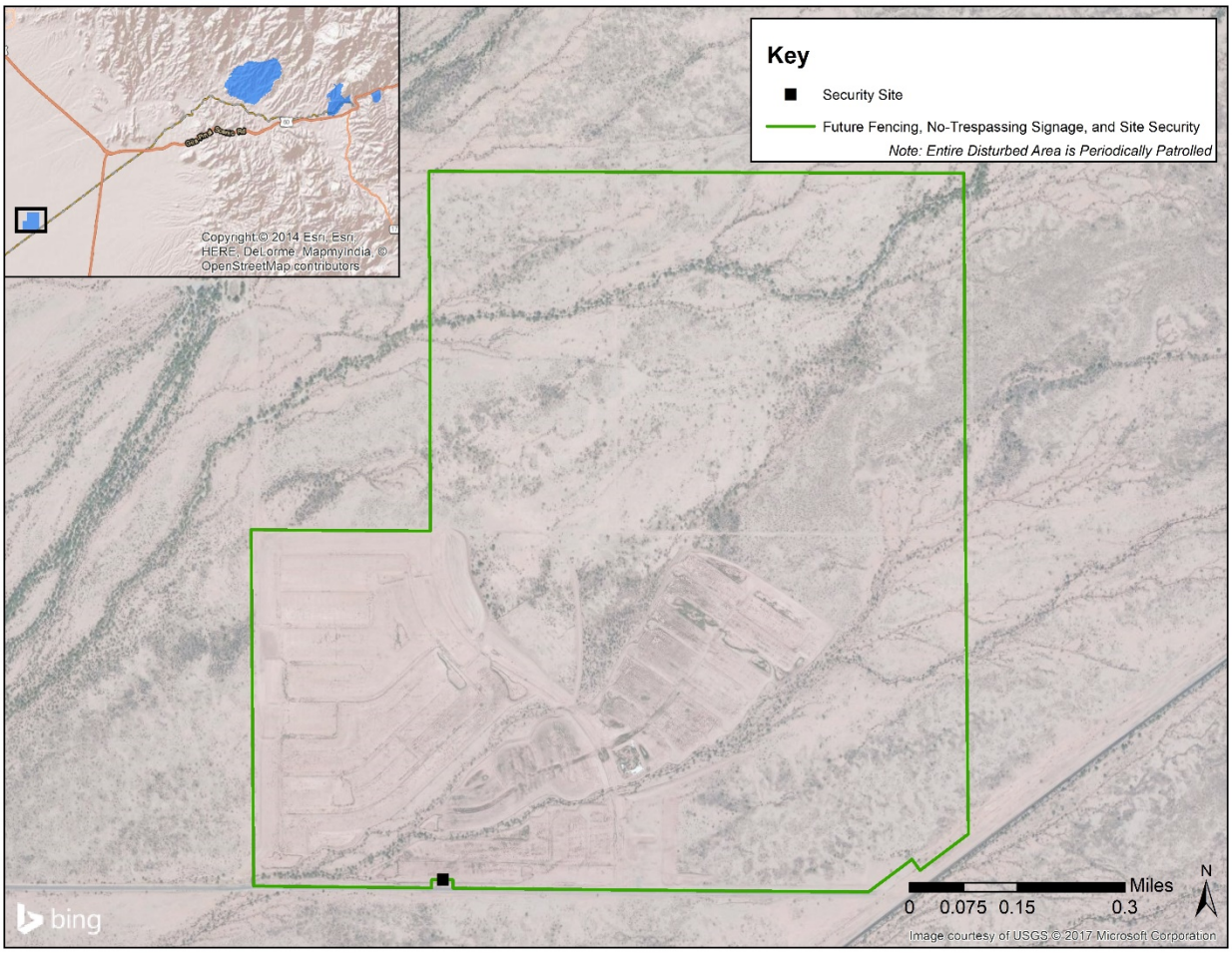
Figure 4. Proposed Tailings Storage Facility Ambient Air Boundary



Filter Plant and Loadout Facility

The Filter Plant and Loadout Facility's AAB will be defined by fencing, locking gates, no-trespassing signage, site security, and periodic perimeter patrols. Due to the size of this project area, fencing around the whole project area is practical. Figure 5 provides a map of the Filter Plant and Loadout Facility's AAB, which shows the location of the proposed boundary as well as the proposed methods of precluding public access.

Figure 5. Proposed Filter Plant and Loadout Facility Ambient Air Boundary



Conclusion

Resolution will employ long-standing, tried, and tested methods to limit public access to each of its four project areas using a combination of fences, berms, and gates; natural barrier/steep terrain; warning signage; and manned site security. Further, periodic security patrols and sufficiently trained mine personnel will also assist in limiting public access to Resolution's facilities. All of these factors will be used to define Resolution's AAB for air dispersion modeling purposes.

METEOROLOGICAL DATA PERIOD

PREPARED FOR: Kami Ballard, Resolution Copper

PREPARED BY: Nate Tipple and Dave Randall, Air Sciences Inc.

This technical memorandum is one of several that has served as a platform for Pinal County Air Quality Control District (PCAQCD) and Resolution Copper (Resolution) to address issues raised during PCAQCD's review of Resolution's draft Air Quality Impacts Analysis Modeling Plan (Modeling Plan).[1]

Introduction

The Resolution Copper project's four non-contiguous operations—the East Plant (EP), the West Plant (WP), the Tailings Storage Facility (TSF), and the Filter Plant (FP)—are shown in Figure 1.[2] These operations are dispersed across approximately 20 miles of northeastern Pinal County, Arizona. Resolution has been collecting meteorological data for air quality impact dispersion modeling at five locations that coincide with the operational areas of the project. The monitoring stations' locations are shown in Figure 1 and the stations' names and location data are listed in Table 1.

Table 1. Resolution Meteorological Monitoring Stations

Station Name	Abbreviated Name	Location	Latitude (Deg)	Longitude (Deg)	Elevation (ft)	Method of Determination
East Plant	EP met	S32 T1S R13E	33.3037	-111.0674	4,176	GPS
West Plant	WP met	S35 T1S R12E	33.2994	-111.102	2,968	GPS
Hewitt Meteorological	HW met	S35 T1S R11E	33.2978	-111.2109	2,235	GPS
Hewitt SoDAR	HW sodar	S35 T1S R11E	33.2981	-111.2114	2,236	GPS
Far West	FW met	S36 T2S R9E	33.2107	-111.3769	1,754	GPS

As stipulated in the draft Modeling Plan, the monitoring stations have been located at these locations to collect meteorological data that are representative of the four operational areas, as listed in Table 2.

[1] Air Sciences Inc. 2015. Draft Air Quality Impacts Analysis Modeling Plan. Prepared for Resolution Copper Mining, LLC. July.

[2] This technical memorandum includes discussion of the Far West meteorological station to collect representative data for modeling of the Filter Plant. However, the Filter Plant may be an insignificant source of emissions that does not warrant stand-alone AERMOD modeling.

Table 2. Meteorological Monitoring Stations and Representative Operation Area

Station Name	Representative Operation
EP met	East Plant
WP met	West Plant
HW met (surface data)	Tailings Storage Facility
HW sodar (elevated data)	Tailings Storage Facility
FW met	Filter Plant

The QA/QC'd meteorological data set from each station is to be used as input for air quality impact dispersion modeling (using AERMOD) for the representative operation area.

Figure 1. Resolution Copper Project Vicinity and Locations of Operational Areas

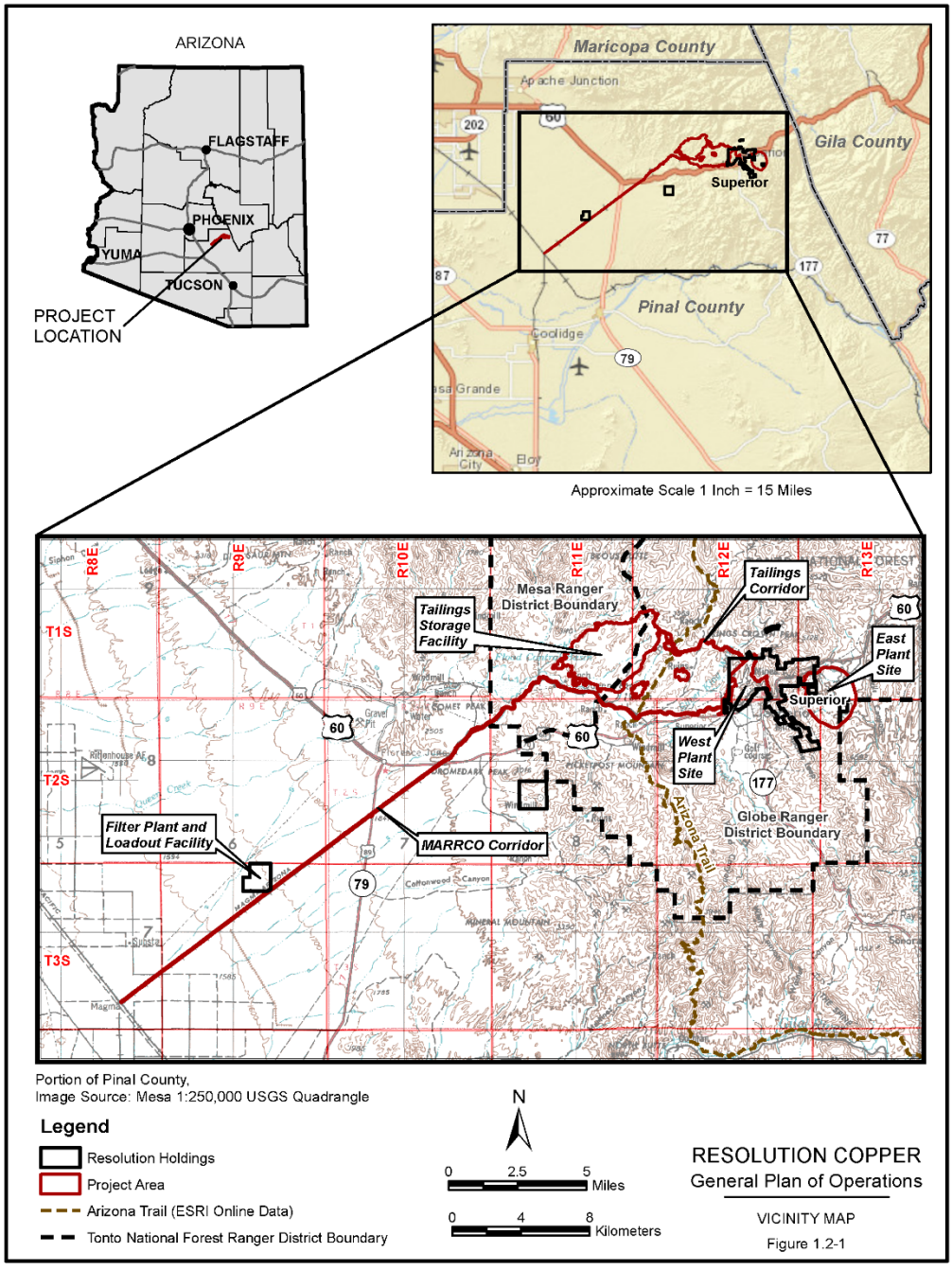
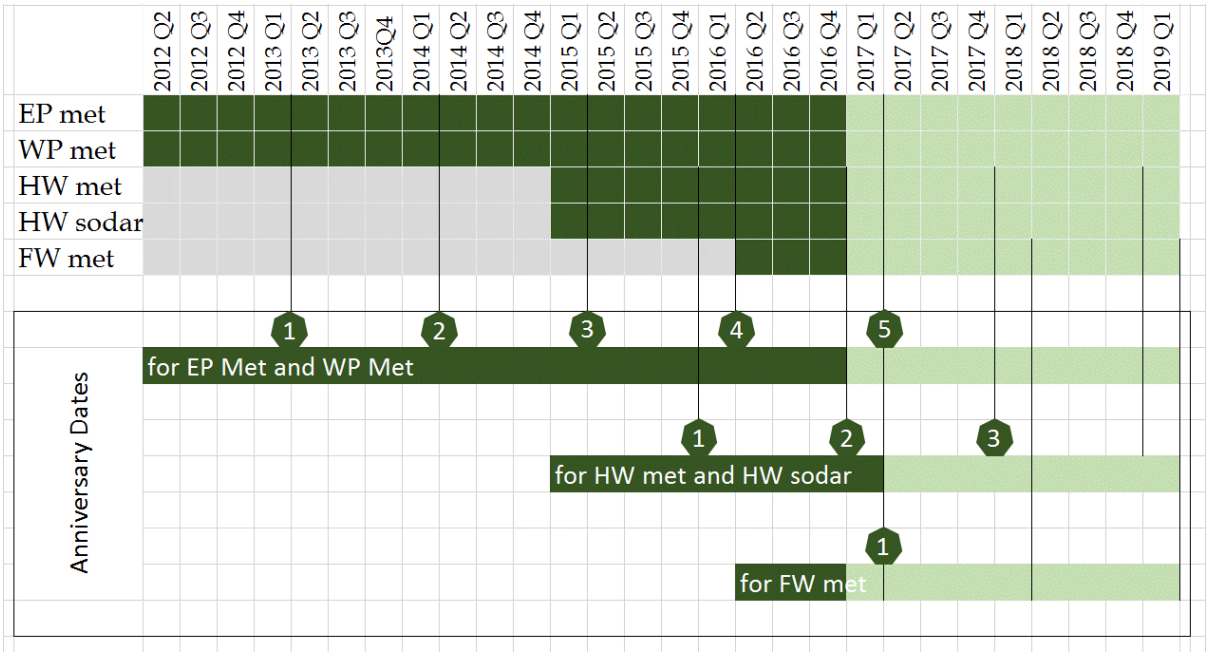


Figure 2. Resolution Meteorological Station Locations

Data collection at these sites began on different dates. Figure 3 presents the data collection periods for the meteorological stations.

Figure 3. Monitoring Periods for Resolution Meteorological Monitoring Stations



Meteorological Data collection continues at all five stations as of March 14, 2017.

In its comment number 7 on the Modeling Plan, PCAQCD has asked:

a) if it would be possible for Resolution to use 2015 – 2018 meteorological data for EP, WP, and HW stations, or

b) to elaborate on why using 2012 – 2015 data from EP and WP and 2015 – 2018 data from HW (as proposed in the Modeling Plan) is appropriate.

Discussion

Considerations to Select Data Periods

The considerations to commit to a specific duration and period of meteorological data sets for AERMOD modeling of the Resolution project include the following:

- EPA's Appendix W to 40 CFR Part 51 – Guideline on Air Quality Models, Section 8.3.1.2 (Guideline) includes the following statements:
  - Only a single year of meteorological data is required if that data is site-specific.
  - The model user should acquire enough meteorological data to ensure that worst-case meteorological conditions are adequately represented in the model results.
  - A recommendation to use additional years of data (up to five) if available.[3]

[3] EPA has also published a proposed Revision to the Guideline on Air Quality Models. That revision does not alter the requirements or recommendations for the meteorological data period for modeling.

- Technical aspects of monitoring:
  - Unpredictable data collection errors that result in failure to meet regulatory minimum (90 percent) valid data collection requirements in future quarter(s).
    - Monitoring, communication, and/or data storage equipment failure.
    - Power loss.
    - Human error.
- Technical aspects of the modeling analysis:
  - Different model runs for the different operational areas.
  - Using a paired-sums approach for combining representative background concentrations with modeled impacts. This approach likely produces more representative modeling analysis results to compare to applicable air quality standards but also depends on high rates of data capture for ambient air pollution monitoring data as well as meteorological data.
  - Effects on interpretation and clear communication of modeling results.
- Logistical aspects:
  - Timing of permit (and NEPA) submittals and approvals.
  - Considerable cost of continuing/extending monitoring program.

As shown in Figure 3, Resolution has collected 8 quarters (2015 Q1 – 2016 Q4) of contemporaneous meteorological data that meet regulatory data collection requirements at EP met, WP met, HW met, and HW SoDAR. According to EPA's Appendix W, this data period (1-year or greater) could be considered minimally sufficient.

If Resolution commits to AERMOD modeling with three years of contemporaneous data at EP met, WP met, and HW met, a subsequent quarter that does not meet minimum data collection requirements at any site during the third year could necessitate the continued collection of data at all locations.

Technically Sufficient to Use Different Meteorological Data Periods for Different Operational Areas

AERMOD runs can be executed for each operational area using the representative meteorological data set for each run. The receptor grid for each model run can be extended so that receptor grids overlap. Cumulative impacts can be estimated by summing modeled impacts from the different operational areas through post-processing using agreed-upon computational routines. Because we have contemporaneous meteorological data sets for EP and WP, modeled impacts can be paired in time and space. Because the TSF and Filter Plant (small source) are quite distant from sources at WP and EP, it is likely that modeled impacts from these operational areas will not show significant impacts at the eastern-most receptors of their modeling grids, regardless of the meteorological period that is used. Therefore, estimating the total impacts from all four operational areas should be straightforward.

Solution

Resolution commits to model the most recent, complete, and adequate years of contemporaneous periods for East Plant, West Plant, and Hewitt site/proposed Tailings Facility location. As of the time of this writing (March 14, 2017), two years (January 1, 2015 through December 31, 2016) of QA/QC'd site-specific data that meet the EPA's data completeness requirements are already available. Resolution plans to continue monitoring at all three sites and plans to have a third year of adequate contemporaneous data available after January 1st, 2017 if the data completeness requirements continue to be met.

Conclusion

The site-specific meteorological (and particulate) data sufficiently meet the requirements stated in available guidance documents. If the data for WP, EP, and HW to be used for the model must span an identical period, then a two-year period is currently available. Resolution continues to monitor at the sites and has a reasonable expectation to have a third year of cotemporaneous data available after January 1, 2018. If that were to be the case, Resolution will model:

- 3 years of data from EP, WP, and HW: January 1, 2015 through December 31, 2017.

However, if during 2017 a full year of adequate data is not collected, Resolution requests that the most recent contemporaneous data from the three sites be approved for use in the modeling compliance demonstration.

- 2 years of data from EP, WP, and HW: January 1, 2015 through December 31, 2016.

References

ADEQ. 2013. Air Dispersion Modeling Guidelines for Arizona Air Quality Permits. September 2013. Accessed January 4, 2018. http://legacy.azdeq.gov/environ/air/download/modeling.pdf.

EPA. 2005. Guideline on Air Quality Models. 40 CFR Part 51, Appendix W. November 2005. Accessed January 4, 2018. http://www.gpo.gov/fdsys/pkg/CFR-2011-title40-vol2/pdf/CFR-2011-title40-vol2-part51-appW.pdf.

EPA. 2015. 40 CFR Part 51, Revision to the Guideline on Air Quality Models: Enhancements to the AERMOD Dispersion Modeling System and Incorporation of Approaches To Address Ozone and Fine Particulate Matter; Proposed Rule. Federal Register. Vol. 80. No. 145. July 29, 2015. Accessed January 4, 2018. http://www.epa.gov/ttn/scram/11thmodconf/EPA-HQ-OAR-2015-0310-0001.pdf.

TAILINGS EMISSIONS AND MODELING METHODS

PREPARED FOR: Kami Ballard, Resolution Copper

PREPARED BY: Nate Tipple and Dave Randall, Air Sciences Inc.

This technical memorandum is one of several that has served as a platform for Pinal County Air Quality Control District (PCAQCD) and Resolution Copper (Resolution) to address issues raised during PCAQCD's review of Resolution's draft Air Quality Impacts Analysis Modeling Plan (Modeling Plan).[1]

Introduction

In response to Resolution's draft modeling plan, PCAQCD requested that Resolution provide support for two issues identified in the draft modeling plan. The first issue raised by PCAQCD was regarding the silt content used at the tailings storage facility (TSF). The second issue raised by PCAQCD was regarding how the new erodible area is calculated between wind erosion events for surfaces that are not re-disturbed. Resolution has responded to these issues. However, to further support PCAQCD's review and approval of the methods used to estimate emissions from the TSF, Resolution had prepared this memo describing the methods employed to calculate and model particulate emissions from the TSF. This memo will address the anticipated issues in two parts: emission calculations and modeling methods.

Since PCAQCD originally addressed these issues, Resolution has reviewed the calculations for the wind erosion at the TSF and modified the method to quantify these emissions. This modified method was selected because of its technical justification, application to the Resolution Copper mining project (project), and endorsement of the method in AP-42. As identified in Resolution's original response to PCAQCD, neither the original method nor the modified method of emission calculation requires silt content as an input to the calculation.

[1] Air Sciences Inc. 2015. Draft Air Quality Impacts Analysis Modeling Plan. Prepared for Resolution Copper Mining, LLC. July.

Background

Emission Calculations

Resolution has reviewed and considered several industrial wind erosion emission calculation methods for the TSF before selecting the method of calculation presented here. Several sources that detail calculation methods were reviewed, including the following: AP-42 Chapter 13.2.4, Aggregate Handling and Storage Piles; AP-42 Chapter 13.2.5, Industrial Wind Erosion; and AP-42 Chapter 11.19, Western Surface Coal Mining. Upon completion of this review, Resolution determined that the most appropriate method of calculation was from AP-42 Chapter 13.2.5, Industrial Wind Erosion. This method is provided by the Environmental Protection Agency (EPA) as a method for calculating wind erosion and relies on site-specific meteorological data to calculate emissions. Further, the surface friction velocity, a parameter required for this calculation method, may be updated with a region or industry-specific value, if available.

This method of calculating emissions from wind erosion is outlined below using hourly wind speed data.

Step 1

Calculate the fastest-mile wind speed in meters per second (m/s) for the reference anemometer ($u_{10}+$).

$$u_{10}+ = 1.2 \times u_{10}$$

Where:

- u_{10} is the measured average hourly wind speed at the 10-meter anemometer (m/s)
- 1.2 is the conversion factor from hourly to 2-minute wind speed (adopted from EPA 454/R-94-025, October 1994)

Step 2

Calculate the friction velocity (u*, m/s).

- $u^* = (U_s/U_r) \times 0.1 \times u_{10}+$ for material piles (AP-42, Sec. 13.2.5, Eqs. 6 & 7, 11/06)
- $u^* = 0.053 \times u_{10}+$ for flat surfaces (AP-42, Sec. 13.2.5, Eq. 4, 11/06)

Where:

- U_s/U_r is the equivalent friction velocity for each surface wind classification (Figure 13.2.5-3, AP-42, Sec. 13.2.5, pg. 10, 11/06)
- $u_{10}+$ is the fastest-mile wind speed calculated in Step 1

Step 3

For each surface classification (area IDs A, B, and C, see Figure 13.2.5-3, AP-42, Sec. 13.2.5, pg. 10, 11/06), calculate the wind erosion potential ($P_{A, B, \text{ or } C}$) in grams per meter square (g/m^2).

- For $u^* > u_t^*$, $P_{A, B, \text{ or } C} = 58 (u^*_{A, B, \text{ or } C} - u_t^*)2 + 25 (u^*_{A, B, \text{ or } C} - u_t^*)$
- For $u^* \leq u_t^*$, $P_{A, B, \text{ or } C} = 0$ (AP-42, Sec. 13.2.5, Eq. 3, 11/06)

Where:

- $u^*_{A, B, \text{ or } C}$ is the surface-classification-specific friction velocity (m/s) calculated in Step 2
- u_t^* is the threshold friction velocity = 1.02 m/s (AP-42, Sec. 13.2.5, Table 13.2.5-2, value for overburden, 11/06)

Step 4

For each surface classification (area IDs A, B, and C, see Figure 1), calculate the newly disturbed area ($A_{new\ A, B, \text{ or } C}$).

$$A_{new\ A, B, \text{ or } C} = A_{hourly\ A, B, \text{ or } C} \times H_{relapsed\ A, B, \text{ or } C}$$

Where:

- $A_{hourly\ A, B, \text{ or } C}$ is the annual average hourly newly created surface area for surface classification A, B, or C
- $H_{relapsed\ A, B, \text{ or } C}$ is the surface-classification-specific number of hours elapsed since the previous erosion event

Step 5

Calculate event wind erosion PM emissions ($E_{A, B, \text{ or } C}$) for each surface classification.

- $E_{A, B, \text{ or } C}$ (lb) = $P_{A, B, \text{ or } C}$ (lb/acre, converted from g/m^2) × $A_{new\ A, B, \text{ or } C}$ (acre)
- Event total PM emissions (E, lb) = E_A (lb) + E_B (lb) + E_C (lb)

Step 6

Calculate annual emissions as the sum of all event emissions that occur during a year. If emissions for multiple meteorological years are calculated, an average may also be determined.

Step 7

Once the average annual emission rate is determined, a control efficiency will be applied. Resolution has committed to using a sprinkler system to control dust from the TSF as necessary. This system will change as the TSF is built and be activated as necessary given the conditions. The control efficiency achieved with these sprinklers is addressed in a separate technical memo.

Modeling Methods

An emission rate is calculated for every hour of the meteorological data period with a valid monitored wind speed. AERMOD is equipped to handle emissions in several formats, including in this hourly format. Therefore, Resolution expects to model the wind erosion emissions from the TSF using this hourly emission file option.

The AERMOD User's Guide states, "The AERMOD area source algorithm is used to model low level or ground level releases with no plume rise (e.g., storage piles, slag dumps, and lagoons)."[2] The AERMOD source characterization for many of the fugitive emissions at the TSF, including wind erosion emissions, is therefore expected to be characterized as an AREA source with a surface area similar to that of the ambient air boundary for the TSF.

Solution

Emission Calculations

The hourly, meteorological-data-based calculations used to determine wind erosion emissions at the TSF are considered both appropriate and defensible for several reasons. First, the method of calculation utilized at the project is provided by the EPA in their reputable compilation of emission factors. This source for emission factors is generally accepted as vetted and conservative. Secondly, this calculation method is considered conservative because a more conservative threshold friction velocity more appropriate to the project type and location was used in lieu of the AP-42-provided value. The proposed surface friction velocity is 0.172 m/s (as compared to 1.02 m/s, as listed in AP-42 Chapter 13.2.5) based on documentation specific to TSFs at copper mines in Arizona.[3] Further, the implementation of this calculation method requires site-specific meteorological data to calculate emissions. Resolution is currently monitoring meteorological conditions (using mechanical sensors and SoDAR) near the future TSF site with the intention to use this data for modeling and to support other applications (i.e., calculating wind erosion).

[2] EPA, 2016. User's Guide for the AMS/EPA Regulatory Model (AERMOD). Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.

[3] Nickling, W.G. and Gillies, J.A. 1986. Evaluation of aerosol production potential of type surfaces in Arizona. Submitted to Engineering-Science 125 W. Huntington Drive Arcadia California. Prepared for US Environmental Protection Agency.

Modeling Methods

Because emissions are calculated every hour based on meteorological data, Resolution believes that the use of an hourly emission file is an appropriate characterization to represent the TSF. Additionally, due to the clearly defined use of AREA sources in the AERMOD User's Guide, Resolution believes that this source type is the most appropriate way to characterize the TSF.

Conclusion

Resolution is confident that these methods of emissions quantification and source characterization will be sufficient to address the issues the public may have regarding dispersion modeling from wind erosion at the TSF.

CLASSIFICATION OF EMISSIONS FROM UNDERGROUND MINE VENTILATION SHAFTS

PREPARED FOR: Kami Ballard, Resolution Copper

PREPARED BY: Michael Tomko, Parsons Behle & Latimer

This technical memorandum is one of several that has served as a platform for Pinal County Air Quality Control District (PCAQCD) and Resolution Copper (Resolution) to address issues raised during PCAQCD's review of Resolution's draft Air Quality Impacts Analysis Modeling Plan (Modeling Plan).[1]

Overview: This paper responds to Pinal County's request for an explanation of why the EPS mine vent shaft emissions should be considered fugitive based on law and policy determinations. In doing so, it examines the applicable rule language, EPA guidance rulemakings, recent state determinations, and adjudications of the issue. A review of all of these authorities supports the conclusion that emissions entrained and discharge through mine ventilation shafts are properly classified as fugitive emissions. And, such a conclusion comports with a common sense notion of the term fugitive emissions.

Description of Emission Activities: Emissions from the EPS will be comprised of three distinct types:

- Process – These are emissions that are associated with distinct and discrete processes such as crushers, screens, and conveyors. These are typically classified as point sources or process fugitive emission sources.
- Mobile – These are emissions associated with mobile equipment such as dozers, grading equipment and miscellaneous vehicles. These sources typically meet the definition of "non-road engines" and are subject to Title II emission requirements under the CAA.[2]
- Fugitive – These are emissions associated with activities such as blasting and dust emissions off of the wheels of non-road vehicles operating underground.

[1] Air Sciences Inc. 2015. Draft Air Quality Impacts Analysis Modeling Plan. Prepared for Resolution Copper Mining, LLC. July.

[2] Under Title II of the Clean Air Act, EPA has established emission standards that manufacturers must comply with for all new nonroad engines.

These are well accepted classifications and for purposes of this response we are assuming that Pinal County would agree with the foregoing classifications were these activities taking place in an above ground mining operations.

Framing the Question: Whether occurring above or underground, the emissions identified above are directly emitted into a large volume of ambient air. The concentration of the air contaminants quickly becomes diluted to trace concentrations not reasonably amenable to capture and control. At this point, the emissions are diffuse and uncaptured, in other words, fugitive. The question becomes whether the emissions, if occurring at an underground mining operation, somehow become transformed into point source emissions by their subsequent entrainment in the ventilation air circulated through the underground mine ("UGM") operations and ultimately discharged through large diameter shafts? For the reasons discussed below, we believe that the fugitive character of these emissions remains unchanged and is not altered by their discharge through a series of large ventilation shafts.[3]

Fugitive Emissions: The term "**fugitive emissions**" is defined as "**those emissions which could not reasonably pass through a stack, chimney, vent, or other functionally equivalent opening**." 40 CFR § 51.166(b)(20). Based on a superficial reading of this definition, the fact that the emissions generated underground will ultimately pass through one of several large ventilation shafts could be construed as supporting a conclusion that such emissions are not fugitive in nature. However, a more considered application of this definition results in the conclusion that emissions that are otherwise classified as fugitive or mobile emissions are not transformed into point source emissions by their being commingled in a large volume of ventilation air and discharged out of ventilation shafts.

A ventilation shaft is not a "stack, chimney, vent, or other functionally equivalent opening" for air pollution control purposes: Placed in the proper context of the air permit program, a ventilation shaft that is designed to handle the large quantity of air being moved is not "a stack, chimney, vent, or other functionally equivalent opening." UGM ventilation systems are not equivalent to a stack used to collect emissions from an emission unit. There is an intuitive, common-sense notion of what constitutes an emission stack on an emission unit. Where emissions are captured for air pollution control purposes, the emissions are captured in immediate proximity to their generation and usually directed into ducting which is routed to a stack discharge or air pollution control equipment that discharges through a stack that is specifically designed for the conveyance of the captured emissions. Often times only the

[3] This is not, of course, to say that the air quality impacts associated with these emissions – whether point source, fugitive or mobile – should not be evaluated. As indicated in the draft protocol, all of the emissions associated with the Resolution Project – regardless of their classification – are proposed to be included in the air quality modeling demonstration.

emissions from the emission unit are captured; for example, the combustion gases from a boiler. Sometimes, as is the case with a process ventilation hood, some ambient air will be captured along with the emissions from the process; however, these are relatively limited quantities that are incidental to capturing the emissions. In short, the "functionality" of the "opening" is to capture emissions.

UGM ventilation systems, on the other hand, bear no resemblance to these types of emission collection systems. They are designed to facilitate ventilation of a large underground mining space with ambient air. Relative to the amount of air being moved through the ventilation system, the quantity of entrained air contaminants is incidental. For example, the preliminary design for Resolution includes three separate ventilation shafts with diameters ranging from 22 feet to 34 feet. The total amount of ventilation air is estimated to be 2,200 kg/s, only a small fraction – about 0.08 kg/s – of which constitutes air contaminants. The emissions are not captured and the shafts are not designed for, or reasonably amenable to, the installation of air pollution control equipment. There functionality is ventilation of a large underground mining space and not the capture of emissions. Accordingly, the emissions entrained in the ventilation air are not passing through "a stack, chimney, vent, or other functionally equivalent opening" as commonly understood for air pollution control purposes.

The UGM fugitive emissions are not captured or collected as required by EPA guidance: EPA guidance emphasizes that a simplistic reading of the fugitive definition is not appropriate. Rather, determining whether any particular emission is fugitive is a case-by-case determination that considers the practicability of capturing and controlling the emissions. In the case of the fugitive and tailpipe sources, their emissions are not captured but are, instead, swept up and entrained in a large volume of ventilation air which is "blown through" the underground mine workings to manage underground temperatures and provide a safe working environment. The emissions are not discretely gathered and are not reasonably amenable to control in view of the large volume of entrained air with which they are mixed.

In 2008, EPA provided "guiding principles for determining fugitive emissions" as part of a rulemaking known as the Fugitive Emissions Rule that addressed the requirements of the major NSR programs regarding the treatment of fugitive emissions.[4] In that guidance, EPA explained

[4] *See* 73 Fed. Reg. 77882 (Dec. 19, 2008). After EPA finalized the Fugitive Emissions Rule, the Natural Resources Defense Council (NRDC) submitted a petition for reconsideration of the final rule on February 17, 2009. EPA granted the petition, issuing a stay of the Fugitive Emissions Rule until it completes a reconsideration of the rule. *See* 74 Fed. Reg. 50115 (Sept. 30, 2009). EPA subsequently issued an interim final rule to effectuate and extend the stay of the Fugitive Emissions Rule, *see* 74 Fed. Reg. 65692 (Dec. 11, 2009) and 76 Fed. Reg. 17548 (March 30, 2011), and has requested public comment on the interim final rule. *See* e.g., 76 Fed. Reg. 23489 (April 27, 2011). After it completes its reconsideration of the Fugitive Emissions Rule, EPA intends to issue a proposed and final rule addressing the inclusion of fugitive emissions in the Federal NSR program. EPA indicated that it intended to propose and finalize

that, "[i]n practice, we interpret the phrase 'could not reasonably pass' by determining whether such emissions can be reasonably ***collected or captured*** (e.g., enclosures or hoods)."[5] EPA's guidance further explains that, "[i]f it is not technically or economically feasible to control the emissions, then collection or capture of such emissions may not be reasonable."[6] Based on preliminary designs, the mine ventilation system will move approximately 2,200 kilograms of air per second through three large (up to 34 feet in diameter) ventilation shafts. Only a minuscule portion of the total vent shaft emissions will consist of particulates or other air pollutants, the vast majority (approximately 99.996%) consisting of air. Under these circumstances, the massive volume of air passing through these vents and the very low concentration of pollutants entrained in that air would make it technically and economically infeasible to collect or capture and control the pollutants.

Furthermore, in the guidance, EPA provided an example that closely tracks with the circumstances surrounding the EPS ventilation shafts, an example that concludes that such emissions should be treated as fugitive emissions.

> [A]s technology improve[s], the technical feasibility to collect or capture virtually any source of emissions [will] likewise evolve[]. For example, it is technically feasible to build a large capture device to collect virtually any type of process emissions. Yet, these captured emissions may contain air pollutants in such small concentrations that there is no technically or economically-feasible method to control the emissions once captured. Yet, under a strict interpretation of whether emissions are 'reasonably collected,' we could find that such emissions are non-fugitive because they are reasonably collectable. Nonetheless this would fail to provide meaning to the term 'fugitive emissions' as intended by Congress.[7]

EPA concluded by explaining that, "the purpose of the fugitive emissions inquiry is to determine which emissions should count for determining source size with a view towards

such a rule by October 4, 2012, *see* 76 Fed. Reg. at 17551, but it has not yet issued a proposed rule. Importantly, however, the stay and interim rule affect only the regulatory language in the Fugitive Emissions Rule, not the "guiding principles for determining fugitive emissions" (addressed hereafter in the text), which were specifically adopted as guidance. In fact, EPA specifically noted that a rulemaking action was not required to effectuate its interpretation. *See* 73 Fed. Reg. at 77891/2.

[5] 73 Fed. Reg. at 77891 (emphasis added).

[6] *Id*. ("Although costs have always been a consideration in determining whether emissions are fugitive, we historically focused on the cost of collection or capture and not the cost of control. Notwithstanding our past practice, we believe that it is reasonable to consider the cost and economic feasibility of control in determining whether emissions can be reasonably captured or collected. * * * Thus, with this action, we are allowing that the reviewing authority may consider the reasonableness of the combined costs of capture or collection and control as an alternative to considering only the cost of collection or capture.").

[7] *Id*.

requiring large sources to install pollution controls. If the emissions cannot be controlled, then it is reasonable to consider this factor in determining whether such emissions can be 'reasonably' collected or captured."[8] Consistent with this example, any emissions entrained in UGM ventilation air at Resolution cannot be said to be collected or captured.

Following are several decisions and determinations that support the conclusion that emissions have not been collected or captured by virtue of their being entrained in ventilation air so as to constitute a point source for regulatory purposes.

State Treatment of UGM Ventilation Systems: An informal survey of available permits via the internet shows that state permitting authorities have generally, by default or otherwise, treated emissions entrained in air discharged from UGM ventilation systems as fugitive. While these permits typically do not offer a detailed explanation of the underlying rationale for these determinations, it appears that the permitting authorities have simply reached a common-sense conclusion that the emissions are fugitive. There is one notable and recent exception where states have offered a detailed explanation for their basis for concluding that UGM ventilation emissions are fugitive.

In a letter written to EPA by the State of Ohio, on its behalf and on behalf of the States of Illinois, Indiana, Kentucky, Ohio, Virginia, and West Virginia, Ohio EPA informed the federal EPA that this group of eastern states would treat methane emissions from underground coal mines that are emitted through ventilation shafts as fugitive. The principal basis for this conclusion was that, notwithstanding that the methane emissions were vented through a ventilation system, the emissions were not, and could not reasonably be, captured. This issue was raised by the eastern states in response to a statement by EPA indicating that its "initial thoughts are that these emissions need to be considered point source emissions as they are captured and vented through ductwork out of the mine." In reaching the opposite conclusion, and in the face of then impending deadlines, the eastern states requested that EPA provide a "prompt response" in the event it disagreed with the conclusion reached by the eastern states. EPA has not challenged the conclusion of the eastern states that the ventilation emissions are fugitive.

EPA Greenhouse Reporting Rule: Notwithstanding EPA's "initial thoughts" that it might find UGM ventilation emissions to be non-fugitive (*see* previous paragraph), EPA reached a more definitive and opposite conclusion in the greenhouse gas ("GHG") reporting rulemaking. During that rulemaking, EPA concluded that "[v]entilation air from underground mines, which contains dilute concentrations of CH4" is one of the "five primary sources of fugitive CH4

[8] *Id*. at 77892.

emissions from coal mining operations."[9] EPA went on to say that, "[m]ine ventilation emissions from underground coal mines account for the largest share of fugitive CH4 emissions …."[10]

Legal Precedent: We are aware of only two adjudications that have addressed the fugitive/point source distinction in circumstances similar to those presented by an UGM ventilation system. First is a case involving Nucor Steel Company. That case involved whether a Nucor Steel plant that manufactured joists had point source emissions above major source applicability thresholds. The operations included the use of paints and solvents inside of a manufacturing building. Emissions from the building ultimately passed through vents and openings in the building. One part of EPA's contention was that the building emissions were captured by vents and could not, therefore, be considered to be fugitive emissions.[11] The court ultimately concluded that, "it cannot accept [EPA's] explicit and implicit argument that all emissions which can pass thorough a stack, vent, etc. are ergo, non-fugitive emissions."[12] The court framed the issue as "whether the emissions were fugitive. This required that [EPA] prove that there was a reasonable system to collect and discharge, not just whether or not gasses can physically pass through a hole."[13] In declining to find that all emissions taking place inside a building are necessarily non-fugitive, the court noted that, "[t]he situation seems to cry out for more definitive regulations and/or guidance interpretation. As late as 1997, [EPA's] expert-representative was expressing an opinion that perhaps there should be a new policy that all indoor emissions be considered non-fugitive."[14] Thus, the court recognized that nothing in law or policy pointed to an *ipso facto* conclusion that just because emissions are ultimately ventilated from a building they are necessarily non-fugitive. Such a conclusion would seem to be even more obvious for emissions into a cavernous underground mining operation.

The second adjudication involved a challenge in a state administrative proceeding brought by Seagram & Sons challenging the Indiana Department of Environmental Management's ("IDEM") determination that Seagram's whiskey warehouses constituted a major source

[9] EPA OAR, Technical Support Document for Underground Coal Mines: Proposed Rule for Mandatory Reporting of Greenhouse Gases (Feb. 4, 2009) at 3, available at http://nepis.epa.gov/Exe/ZyPDF.cgi/P1009F2Q.PDF?Dockey=P1009F2Q.PDF.

[10] *Id*. at 4.

[11] *U.S. v. Nucor Corp*., CV-95-PT-2275-M, slip op. at 15 (N.D. of Al. 1997) (memorandum opinion denying summary judgment).

[12] *U.S. v. Nucor Corp*., CV-95-PT-2275-M, slip op. at 1 (N.D. of Al. 1997) (Findings of Fact and Conclusions of Law).

[13] *Id*.

[14] *Id*. at 2.

requiring a Title V operating permit.[15] The facility emitted more than 100 tpy (the Title V major source threshold) of VOC emissions. The issued to be decided was whether the emission were fugitive and, therefore, would not count towards the major source threshold. Ventilation in the warehouse was provided by 17-inch by 48-inch screen-covered openings along the bottom of the warehouse walls. IDEM argued that "the mere fact that the emissions pass through the opening is enough to determine that the emissions are not fugitive."[16] The Environmental Law Judge disagreed, finding that, notwithstanding that the emissions were emitted through vents, "whether the emissions can be reasonably *collected* is essential to the determination of whether the emissions are fugitive.[17] The Judge reached this conclusion by construing EPA guidance, concluding that "IDEM's interpretation is inconsistent with the regulations and with U.S. EPA's national policy …" and that, "it is clear that the U.S. EPA contemplates that whether the emissions can be reasonably *collected* is the main consideration in the analysis."[18] The Judge held that because the emissions could not reasonably be collected they were fugitive.

[15] *In re: Objection to the Issuance of Part 70 Operating Permit No. T-137-6928-00011 for Joseph E. Seagram & Sons, Inc.*, Ripley County, Indiana 2004 OEA 58 (03-A-J-3003) (Indiana Office of Environmental Adjudication 2004).
[16] *Id*. at 5.
[17] *Id*. (emphasis in original).
[18] *Id*. (emphasis in original).

CONTROL EFFICIENCIES FOR FUGITIVE DUST CONTROL TREATMENT

PREPARED FOR: Kami Ballard, Resolution Copper

PREPARED BY: Nate Tipple and Dave Randall, Air Sciences Inc.

This technical memo is one of several that has served as a platform for Pinal County Air Quality Control District (PCAQCD) and Resolution Copper (Resolution) to address issues raised during PCAQCD's review of Resolution's draft Air Quality Impacts Analysis Modeling Plan (Modeling Plan).[1]

Introduction

In response to Resolution's draft modeling plan, PCAQCD requested that Resolution provide support for the proposed control efficiencies to treat fugitive dust emissions due to vehicular and equipment traffic on unpaved roads and other sources at the Project. A control efficiency is the percentage of control achieved by an emissions control measure. A higher control efficiency percentage represents a higher level of emissions control and therefore lower emissions. Resolution's General Plan of Operation (GPO, September 2014) emphasizes Resolution's commitment to implement best practices for dust control. (GPO, pp. 102, 104, 177, 178, 200, 206, 251, 285). Resolution will always endeavor to minimize levels of respirable dust in the underground working areas (for MSHA, worker-safety, explosion risk, and environmental concerns) and due to travel over unpaved roads and other sources at the Project. This white paper will address PCAQCD's request for additional information to support the control efficiency values used in the emissions inventory for the Project.

Pinal County's fugitive dust rules limit emissions of dust from anthropogenic sources throughout the County, thereby reducing ambient concentrations of particulate matter and protecting the public from adverse health effects associated with inhalation of fine particulate (PM10 and PM2.5). For the Resolution emission inventory, the fugitive dust emission estimates and dust control efficiencies are based on Resolution's presumed continuous compliance with Pinal County's fugitive dust rules.

As part of Resolution's plan to effectively maintain its properly engineered, constructed, and well-maintained unpaved roads and tailings storage facility (TSF), Resolution will control fugitive dust utilizing surface treatments including watering and/or chemical stabilization. This white paper address fugitive dust emission generation potential and dust control for three

[1] Air Sciences Inc. 2015. Draft Air Quality Impacts Analysis Modeling Plan. Prepared for Resolution Copper Mining, LLC. July.

categories of surfaces at Resolution: underground roads associated with ore extraction and haulage, the TSF, and industrial unpaved roads. Unpaved road maintenance and dust control objectives at the Project will always include:

- Effective control of fugitive dust (which includes compliance with all applicable provisions in the air permit and the Fugitive Dust Control Plan [FDCP] for the Project).
- Appropriate frequency and rates of application of water and/or chemical stabilization based on surface conditions, topography, and meteorological conditions.
- Proper maintenance of the unpaved roads.
- Proper maintenance of sprinkler systems.
- Maintaining safe conditions for operators of vehicular and equipment traffic on unpaved roads.

A summary of the dust control treatment types and their associated control efficiencies are shown in **Error! Reference source not found.**.

Table 1. Proposed Dust Control Treatment Tyupes and Control Efficiencies

Fugitive Dust Source Category	Dust Control Treatment Type	Proposed Control Efficiency
Underground Roads (Ore Extraction and Haulage)*	Natural Conditions (humid and moist) / Water Sprays	95%
TSF	Watering (Sprinklers)	90%
Industrial Unpaved Roads	Chemical Stabilization	90%

*Negligible quantities of fugitive dust will be generated.

This technical memo examines the design and attributes of Resolution's three fugitive dust source categories and corroborates the appropriate and technically defensible dust control efficiencies used in the emissions inventory.

Dust Emissions and Surface Treatments

Underground Roads Associated with Ore Extraction and Haulage

The underground unpaved roads will accommodate vehicular and equipment traffic and primarily be used for the extraction and haulage of ore at the lowest level of the underground mining operations (approximately 7,000 feet below sea level (FBSL)). The conditions of the underground environment at the Project are very different from the dry conditions of the Sonoran Desert at the surface. The temperature of the rock at 7,000 BSL is 180 °F. Dewatering of the underground mine at a rate of between 2 and 4 million gallons per day will be necessary throughout the life of the project. (GPSResolution must install, operate, and maintain extensive infrastructure to reduce temperatures (cooling systems) and remove water (pumps) in the

working areas underground. The normal (and constant) operating conditions for ore handling and hauling activities underground will be very humid and moist.

The GPO states that control of respirable dust and particulates from underground unpaved roadways will be accomplished with, "water suppression sprays installed in all roadways for routine and controlled wetting" and "road base maintenance and dust suppression" (GPO, p. 206). Use of water sprays on the underground unpaved roads will take into account the humidity of the underground workings and the moisture content of the surface of the roads. Resolution's objectives will be to monitor and maintain the high moisture content of the road surfaces at an adequate level to minimize the generation of respirable dust and to maintain safe operating conditions for vehicular and equipment travel.

The unusual and extreme ambient conditions underground warrant accounting for essentially zero fugitive dust emissions from unpaved roads at the 7,000 FBSL level. The utilization (and other characteristics) of the underground vehicles and equipment are shown in Figure 1 (from Resolution's emission inventory). These sources will operate at low speed (15 miles per hour or below). All of the underground roads will be subject to natural mitigation due to the presence of high humidity and water in the underground environment.

Tailings Storage Facility

As stated in Resolution's GPO, "Fugitive dust emissions will be monitored during operations at the TSF and actively managed with sprinklers…as necessary" (p. 123). These sprinklers will deliver the necessary amount of water for the given time of day and season of year for adequate dust suppression.

Industrial Unpaved Roads

The onsite industrial unpaved roads will support all non-underground operations at the Project and will be engineered, constructed, and maintained using road base and/or other aggregate material. For these roads, Resolution plans to periodically apply chemical dust suppressant in order to achieve a high-degree of fugitive dust control.

Figure 1.Underground Equipment and Vehicles Utilization

Air Sciences Inc.	PROJECT TITLE: Resolution Copper EI	BY: N. Tipple		
	PROJECT NO: 262	PAGE: 5	OF: 8	SHEET: EP_Fleet
AIR EMISSION CALCULATIONS	SUBJECT: Diesel Fleet Calculations - East Plant	DATE: April 5, 2017		

East Plant Diesel Machinery (Non-Emergency) - Fugitive Emissions from Vehicle Travel - Vehicle Specifications — **Year -4**

Equipment	Quantity	Ann. Op. Hours[a]	Speed[b] mph	Silt[c] %	Weight[b] ton	LOC
Surface Loader - CAT 962K	2	1,862	5.0	3.0	29.4	S
Surface Shotcrete Truck - Highway Legal	2	1,752	5.0	3.0	4.0	S
Development LHD - Sandvik LH514	16	1,487	12.0	3.0	49.7	UG
Development Drill - Atlas Copco M2C	13	938	5.0	3.0	29.8	UG
Production Drill - Simba M6C	0	0	5.0	3.0	23.0	UG
Blind Bore Machine - Redbore 50 MDUR	0	0	0.0	3.0	34.2	UG
Powder Truck - Normet Charmec MF 605 DA	13	584	5.0	3.0	19.8	UG
Bolter - Atlas Copco Boltec MC	13	3,253	5.0	3.0	23.8	UG
Mechanized Shotcrete Sprayers - Normet Spraymec 6050 WP	13	743	5.0	3.0	14.9	UG
Transmixer Trucks - Normet Utimec LF 600	10	2,366	15.0	3.0	23.5	UG
UG Haul Trucks (40T)	5	2,905	15.0	3.0	44.1	UG
Scissor Trucks - Getman A64	11	869	12.0	3.0	12.5	UG
Cable Bolters - Atlas Copco Cabletec LC	10	6,571	5.0	3.0	33.1	UG
Production LHD - Sandvik LH514e	0	0	15.0	3.0	50.2	UG
2.3 yd LHD - Atlas Copco ST2G	0	0	12.0	3.0	16.5	UG
3.5 yd LHD - Atlas Copco ST3.5	3	701	12.0	3.0	22.2	UG
Mobile Rock Breaker - Sandvik LH514	0	0	12.0	3.0	16.0	UG
Medium Reach Rig - MacLean BH-3 Blockholer	0	0	5.0	3.0	21.5	UG
Water Cannon - Getman A64	0	0	10.0	3.0	20.0	UG
Fuel/Lube Truck - Normet Utimec	3	745	15.0	3.0	12.5	UG
Crane Truck - Getman A64	4	1,489	15.0	3.0	16.5	UG
Man Haul Vans - Miller Toyota	13	1,117	15.0	3.0	4.0	UG
Flat Deck Truck - Getman A64	4	701	15.0	3.0	12.0	UG
Crane Truck - Miller Toyota	4	1,117	15.0	3.0	17.0	UG
Generator Truck (LHD) - GETMAN A64	0	0	5.0	3.0	17.0	UG
UG Grader - CAT 140M2	2	1,402	8.0	3.0	27.4	UG
Forklift - CAT P36000	4	1,402	5.0	3.0	30.2	UG
UG Water Trucks - Getman A64	2	1,402	15.0	3.0	17.0	UG
Conveyor Maint Vehicle - Miller Crane Truck	0	0	15.0	3.0	17.0	UG
Scissor Lift - Miller Toyota	4	1,117	15.0	3.0	4.4	UG
Skid Steer Loader - CAT272D	0	0	5.0	3.0	5.1	UG
Raise Bore - Redbore 60	0	0	0.0	3.0	13.5	UG
UG Dozer - 2.9m Blade - CAT D6N	0	0	5.0	3.0	19.8	UG
Ore Haul Trucks - Powertrans T954	18	5,061	17.1	3.0	211.1	UG
Surface Mean Fleet Weight					16.7	
Underground Mean Fleet Weight					43.8	

[a] *Per unit, including availability and utilization factors*

[b] *Resolution* *References 40 & 42*

[c] *AP-42, Chapter 13.2.2* *Reference 41 - AP-42, Chapter 13.2.2, Related Information, r13s0202_dec03.xls*

Solution

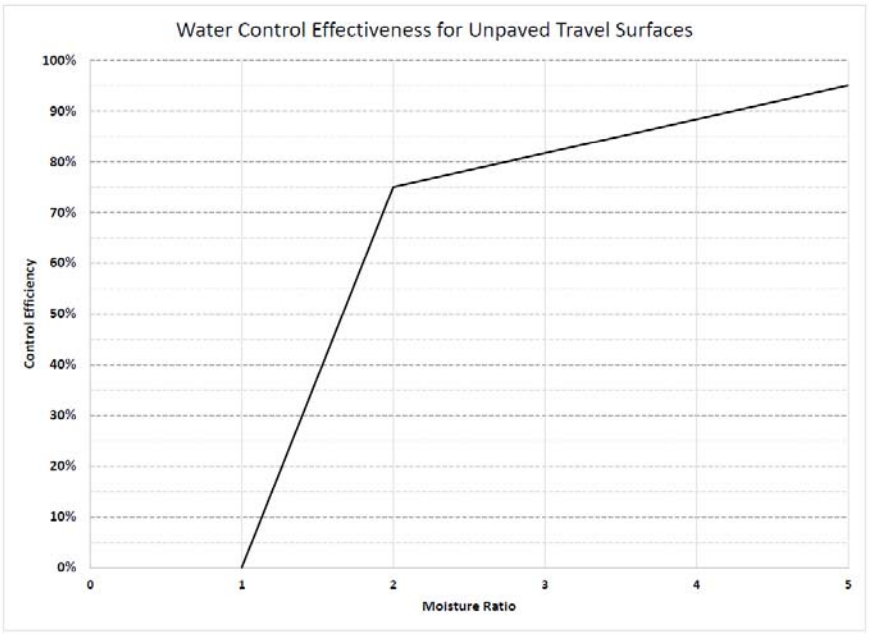
PCAQCD requested that Resolution "provide rule citations and/or policy determinations that support using a 90-95% control efficiency…for water suppression instead of utilizing site specific data to calculate the moisture ratio…as described in AP 42, Chapter 13."

Watering

The control of fugitive dust on unpaved roads is dependent on several factors including amount of water applied per unit area of road surface; period of time between applications; traffic characteristics (weight, speed, and number of vehicles); and the prevailing meteorological conditions.[2] The above discussion that the quantity of fugitive dust emissions from underground unpaved roads is expected to be negligible zero given Resolution's planned dust mitigation practices and the unusual and extremely humid and wet conditions of the underground environment justifies the 95 percent control efficiency for the water sprays on the underground roads. In accordance with the GPO, Resolution will have water sprays available to control any unusual occurrence of fugitive dust produced underground.

For the TSF, the proposed 90% control efficiency can be justified based on AP-42, Chapter 13.2-2. AP-42 presents the metric "Moisture Ratio" for determining control efficiency. The Moisture Ratio is calculated by dividing the moisture content of the surface post-controls (i.e., after surface treatment using water) by the moisture content of the surface pre-controls. Figure 2, which is also presented in AP-24, Section 13.2.2, presents the effectiveness of control by applying water on unpaved roads.

Figure 2 – Watering Control Effectiveness for Unpaved Travel Surfaces



[2] AP-42, Chapter 13.2.2

As shown in Figure 2, in order to achieve a control efficiency of 90 percent, a Moisture Ratio of between 4.0 and 4.5 must be achieved. The uncontrolled moisture content of the dry area of the TSF that may be subject to disturbance is expected to be 0.5 percent. This is the same value used in air quality planning analyses/documents prepared by the Maricopa Area Governments and Arizona DEQ for the moisture content of unpaved roads in the Phoenix-area (MAG 2012 Five Percent Plan for PM_{10} for the Maricopa County Nonattainment Area, Appendices Volume One, p. 120). In order to Achieve a Moisture ratio in the 4-4.5 range, the moisture content after water application must be greater than or equal to 2.5 percent. This TSF surface moisture content is reasonable to accomplish with Resolution's planned water application rates and frequency.

It is expected that the The FDCP for the Project will include enforceable conditions achieve a dust control efficiency of 90 percent on exposed, dry areas subject to disturbance at the TSF.

Chemical Stabilization

Considering the same factors (amount of water/chemical suppressant applied per unit area of road surface; period of time between applications; traffic characteristics (weight, speed, and number of vehicles); and the prevailing meteorological conditions) for the other unpaved roads at the Project, Resolution has determined that periodic applications of chemical suppressants will be the most effective method to control dust on the industrial unpaved roads. Surface treatment with chemical suppressants will be a cost-effective approach for Resolution compared to more frequent applications of water alone. The use of chemical suppressants will conserve water, conserve fuel, reduce the frequency of applications, and achieve the desired control efficiency.

After review of the literature regarding the level of dust control afforded by the application of chemical dust suppressants to unpaved industrial roads, a representative and conservative control efficiency was determined. Through this review, multiple studies were identified that directly measured the control effectiveness of chemical dust suppressants. These studies show that the application of chemical dust suppressants can reasonably achieve over 90 percent control of both total suspended particulates and PM_{10}. A summary of the review of this literature is provided as **Error! Reference source not found.**. As further evidence that this control efficiency is supported by policy determinations, the Maricopa County Air Quality Department Emissions Inventory Unit routinely allows a 90% control efficiency for "regular watering or use of a chemical palliative (dust suppressant)" on unpaved roads in the PM_{10} Non-attainment area. (Maricopa County "Emissions Inventory Help Sheet for Vehicle Travel on Unpaved Roads.")

The FDCP for the Project is expected to include enforceable conditions for chemical stabilization of industrial unpaved roads that will maintain a dust control efficiency of 90 percent.

Conclusion

Resolution's planned dust mitigation practices and the unusual and extremely humid and wet conditions of the underground environment justifies the 95 percent control efficiency for the water sprays on the underground roads. High control efficiencies (90 percent for the TSF and 90 percent for industrial unpaved roads at the surface operations) for fugitive dust are achievable at the Resolution Project due to the engineering, construction, and maintenance of unpaved roads and careful implementation of the surface treatment practices planned for the Project. EPA guidance and MAG policy determinations support that these control efficiencies are achievable. Resolution will work with PCAQCD to develop enforceable operational, monitoring, recordkeeping, and reporting conditions for the Class II air permit and/or the FDCP to ensure compliance with Pinal County's fugitive dust rules and to achieve these control efficiencies.

Works Cited

AP-42, Chapter 13.2.2

Resolution General Plan of Operations (2016)

Resolution Emission Inventory

MAG 2012 Five Percent Plan for PM_{10} for the Maricopa County Nonattainment Area

Attachment A - Unpaved Road Dust Control Efficiency from Chemical Dust Suppressants

UNPAVED ROAD DUST CONTROL EFFICIENCY FROM CHEMICAL SUPPRESSANTS

PREPARED BY: Kevin Lewis, Air Sciences Inc.

DATE: February 25, 2015

Air Sciences Inc. (Air Sciences) has reviewed the literature regarding the level of dust control afforded by the application of chemical dust suppressants to unpaved industrial roads. From this review, multiple studies were identified that directly measured the control effectiveness of chemical dust suppressants. These studies show that the application of chemical dust suppressants can reasonably achieve over 90 percent control of both total suspended particulates (TSP) and particulate matter less than 10 microns in diameter (PM_{10}). A summary of the studies is provided in Table 1.

It is important to note that many of the studies also reported that the control efficiency of chemical dust suppressant application decreases with time, the number of vehicle passes, road maintenance, and/or weather conditions. Therefore, a Fugitive Dust Control Plan (FDCP) is recommended to maintain a dust control efficiency of 90 percent or greater from the periodic application of chemical dust suppressants.

Table 1. Unpaved Road Dust Emissions Studies and Control Efficiencies from Chemical Dust Suppressants

Study	TSP Control Efficiency	PM_{10} Control Efficiency	Comments
MRI and RTI 2005	87%	90%	The performance of a dust suppressant product on unpaved roads was evaluated over a one-year period based on tests conducted by Research Triangle Institute International (RTI) and the Midwest Research Institute (MRI). The report was verified by the Environmental Protection Agency's (EPA's) Environmental Technology Verification Program. The control efficiencies provided here are from the Maricopa County (MC) location test.[1]
CARB 2000	ND[2]	92%	A dust suppressant product composed of petroleum resins, water, emulsifiers, surfactants, and vacuum residuum was evaluated by the California Air Resources Board (CARB). The evaluation was based on tests conducted by MRI at 11, 12, 26, and 28 days after the second application of the dust suppressant on an unpaved road. The initial control efficiency was 99 percent, which dropped to 85 percent after 28 days and 7,000 vehicle passes (average of 92 percent).

[1] See Table 3, page iv of the verification statement (MRI and RTI 2005) for the MC location test results. The Fort Leonard Wood (FLW) location test results in this table (MRI and RTI 2005) were biased low by rain events.

[2] ND = No Data

DRI 1996	ND	99%	Of the four chemical dust suppressants studied by the Desert Research Institute (DRI), the petroleum emulsion and polymer mixture showed a control efficiency of 99 percent four to ten days after application on unpaved roads/shoulders.
		94%	Of the four chemical dust suppressants studied by DRI, polymer emulsions showed a control efficiency of 94 percent four to ten days after application on unpaved roads/shoulders.
		92%	Of the four chemical dust suppressants studied by DRI, non-hazardous crude-oil-containing materials (NHCOCM) showed a control efficiency of 92 percent eight months after application on unpaved roads/shoulders.[3]
EPA 1987	90%	93%	Of the four chemical dust suppressants studied by MRI, calcium chloride ($CaCl_2$) showed an average control efficiency of 90 percent for TSP and 93 percent for PM_{10} on unpaved roads across the two sites tested. The study also reported that without chemical reapplication, the control efficiency would decrease over time.
	85%	90%	Of the four chemical dust suppressants studied by MRI, petroleum resins, an emulsified asphalt, and an acrylic adhesive showed an average control efficiency of 85 percent for TSP and 90 percent for PM_{10} on unpaved roads across the two sites tested. The study reported that without chemical reapplication, the control efficiency decreased over time.
MRI 1983a	94%	97%	This MRI study measured the long-term control effectiveness of petroleum resin application on unpaved roads. The control efficiencies shown here represent the test data after reapplication. The control efficiency after initial application was lower. The study reported that without chemical reapplication, the control efficiency decreased over time and with vehicle passes.
	82%	93%	This MRI study measured the long-term control effectiveness of emulsified asphalt application on unpaved roads. The study reported that without chemical reapplication, the control efficiency decreased over time and with vehicle passes.

[3] The fourth chemical studied was a biocatalyst product. This chemical was shown to be "ineffective in reducing PM_{10} emissions" (DRI 1996). Test results for this product showed a negative control efficiency after initial product application (for one of the six tests) and a negative control efficiency three to eleven months after product application (for all tests averaged) (DRI 1996).

MRI 1983b	96% – 97%	95%	Control efficiencies for this MRI study were measured after the application of petroleum resins on unpaved roads. The study reported that without chemical reapplication, the control efficiency would decrease over time and with vehicle passes.
PEDCo and MRI 1981	95%	95%	This study by PEDCo Environmental, Inc. and MRI indicated that 95 percent control efficiency was attained after three months following the application of $CaCl_2$ and subsequent watering on an unpaved access road.
EPA 1979	97%	ND	For this EPA report, initial control efficiency after application of petroleum resins on unpaved roads was 97 percent for TSP, which decreased with vehicle passes.
MRI 1979	88%	ND	Three tests of the application of lignin sulfate on unpaved roads showed TSP control efficiencies of 83 percent, 89 percent, and 91 percent (average of 88 percent).
Average	**91%**	**94%**	Average of all studies.

EPA AP-42, Section 13.2.2

The most commonly used resource in the U.S. for estimating uncontrolled particulate emissions from unpaved industrial roads is EPA AP-42, Section 13.2.2, Unpaved Roads (EPA 2006). This document provides an equation (Equation 1a) for calculating uncontrolled particulate emissions (all size fractions) from unpaved industrial roads, such as haul roads at a mine site, based on site-specific conditions. This document also provides some general, but limited, information on control efficiency values, which can be applied to the uncontrolled particulate emissions equation to estimate the reduction in particulate emissions when utilizing chemical dust suppressants or water to manage road dust. For chemical dust suppressants, AP-42, Section 13.2.2 provides the following general information:

1. "The control effectiveness of chemical dust suppressants appears to depend on (a) the dilution rate used in the mixture; (b) the application rate (volume of solution per unit road surface area); (c) the time between applications; (d) the size, speed and amount of traffic during the period between applications; and (e) meteorological conditions (rainfall, freeze/thaw cycles, etc.) during the period. Other factors that affect the performance of dust suppressants include other traffic characteristics (e. g., cornering, track-on from unpaved areas) and road characteristics (e. g., bearing strength, grade). The variabilities in the above factors and differences between individual dust control products make the control efficiencies of chemical dust suppressants difficult to

estimate. Past field testing of emissions from controlled unpaved roads has shown that chemical dust suppressants provide a PM-10 control efficiency of about 80 percent when applied at regular intervals of 2 weeks to 1 month" (EPA 2006).

2. Figure 13.2.2-5 shows maximum control efficiencies for TP and PM_{10} of 81 percent and 91 percent, respectively, from the application of petroleum resins (EPA 2006).

With regard to Item 1 above, in which EPA states a control efficiency of "about 80 percent," EPA does not provide a reference for this value or the chemical type. Nonetheless, the test studies referenced in AP-42, Section 13.2.2[4] demonstrate that control efficiencies of greater than 90 percent are achievable.

With regard to Item 2 above, the document referenced for Figure 13.2.2-5 is the 1987 report prepared by MRI for the EPA (EPA 1987). As shown in Table 1 for EPA 1987, the control efficiencies provided in this study are 85 to 90 percent for TSP and 90 to 93 percent for PM_{10}.

In summary, the limited general information on control efficiency provided in AP-42, Section 13.2.2 appears to be a conservatively low approximation of the control effectiveness afforded by chemical dust suppressant application. An examination of the nine studies summarized in Table 1 showed that the control efficiency range was 82 to 97 percent (average of 91 percent) for TSP, and 90 to 99 percent (average of 94 percent) for PM_{10}.

Conclusion

Based on the studies described above, Air Sciences recommends the following approach for estimating particulate emissions from unpaved industrial roads that are controlled by the periodic application of chemical dust suppressants in accordance with a site-specific FDCP:

1. Use AP-42, Section 13.2.2, Equation 1a to estimate uncontrolled particulate emissions.

2. Apply a 91-percent control factor for TSP (i.e., 1-0.91) and a 94-percent control factor for PM_{10} (i.e., 1-0.94) to estimate controlled particulate emissions.

[4] See all studies in Table 1 from EPA 1987 on.

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