Freeport-McMoRan Sierrita Inc.
6200 W. Duval Mine Rd.
PO Box 527
Green Valley, Arizona 85622-0527

March 31, 2016

Mr. Scott Porter
Compliance Manager
Pima County Department of Environmental Quality
33 North Stone Avenue, Suite 730
Tucson, Arizona 85701

Sierrita Odor Evaluation Comprehensive Report

Beginning in July 2014, residents to the north of the Freeport-McMoRan Sierrita Inc. (Sierrita) property began complaining of odors at or near their property. Sierrita took these reports very seriously and initiated an internal investigation to determine if any processes or facilities on-site could be a potential source of a nuisance odor migrating off-site. Sierrita is not only committed to maintaining compliance with all regulatory permits and requirements, but also to being good neighbors.

To date, six households located north of Sierrita have reported odors directly to Sierrita. Four of these households are located in the Ruby Star Airpark, and two households are located just southwest of the Ruby Star Airpark. (See Map Attachment "Odor Grievances") There are approximately thirteen homes in the Ruby Star Airpark. Four property owners in the Ruby Star Airpark have indicated that they have never experienced an odor. Sierrita has not received any communication from the remaining residents in the Ruby Star Airpark.

In December 2014, after the initial internal investigation, Sierrita engaged Arcadis U.S. Inc. (Arcadis), a premiere consulting firm, to lead an external odor investigation. Sierrita retained Arcadis to provide a non-biased, third party evaluation of the odor complaints. The Arcadis team included an Odor Specialist, a Modeling Specialist, a Principal Toxicologist, and a Principal Environmental Specialist. The Arcadis team's primary objective was to evaluate the processes at Sierrita and determine the possibility of an odor(s) being generated at such a level that it could be a nuisance in the surrounding areas where complaints arose. Please find the following attachments completed by the Arcadis team:

- Summary Report
- St. Croix Sensory, Inc. Odor Panel Report
- PDEQ Odor Observation/Assessment Report Form
- Odor Intensity Reference Scales, St. Croix Sensory, Inc.
- Final Odor Dispersion Modeling Assessment Report
- Evaluation of the Atmospheric Behavior and Odor Thresholds of Carbon Disulfide and Other Sulfur-Containing Constituents

In parallel with the Arcadis evaluation, Sierrita continued to perform an internal investigation. The following actions were conducted by Sierrita personnel:

Responding to Odor Reports

Typically, odor reports were received via email or through Sierrita's 24-hour Community Hotline. When an odor report was submitted within a reasonable time of an odor observation, Sierrita personnel were able to respond quickly. Sierrita personnel drove to the relevant area and generally observed wind speed, wind direction, visibility, and noted whether an odor was present. Sierrita personnel evaluated if any abnormal activities or upset conditions were occurring on-site preceding and during the time of the complaint. Throughout the entire investigation, Sierrita never successfully identified a process, upset or unique activity (loading/unloading material, chemical mixing, equipment operation, etc.) that correlated to the times or dates of odor reports.

In instances when the 24-hour Community Hotline was utilized and a "call-back" was requested, Sierrita Community Relations personnel responded timely and inquired about the observations made. A couple of the complainants often inquired about a site-tour to help identify the odor. However, Sierrita does not offer tours to the general public[1] due to safety concerns on-site and believe such a tour would not assist in the investigation.

On a few occasions, Sierrita personnel engaged with residents regarding the odor observations. Twice, when Sierrita personnel arrived at a residence a short time after an odor report, the resident indicated that the odor was no longer noticeable. Discussions were held with each resident regarding their observations and internal follow-up actions were conducted as a result of each visit. These actions included visiting specific areas of the site mentioned by the residents immediately after reports were received and discussing with senior site personnel whether historic activities or locations of past process facilities may be a source of odors.

Evaluating on-site activities

Sierrita reviewed the day and time of rail car deliveries of reagents/chemicals and other bulk materials and compared them to complaint day and times. No correlation was identified.

Sierrita operates and maintains a Continuous Emissions Monitoring System (CEMS) that continuously monitors Sulfur Dioxide (SO_2) levels emitted from the Molybdenum Roasting process. From July 14, 2014, through December 2, 2014, daily maximum SO_2 readings were extracted on days of odor complaints to determine if there was a correlation between the time of the complaint and the time of the maximum SO_2 reading. There was no correlation observed and Sierrita no longer tracks SO_2 levels on days of complaints. Additionally, the Molybdenum Roaster has not received feed since December 24, 2015 and as a result no SO_2 emissions are currently being generated from this process.

As a result of the odor screening samples collected at Sierrita by the Arcadis team on March 18, 2015, the Xanthate mixing process was identified as a potential source of a nuisance odor. This determination was based on the intensity, persistency, and hedonic tone of the odor. Sierrita personnel began recording the

[1] Sierrita has provided tours to business or government partners. However, we have not granted tours to members of the general public on an ad hoc basis.

time and duration of the Xanthate mixing process to determine if there was a correlation with complaint days and times. To date, there has been no clear correlation between mixing times and complaint times.

Review of on-site Meteorological Data

Sierrita maintains a 60 meter meteorological station on site (31.872830, -111.092048) that collects wind speed, wind direction, temperature, barometric pressure, relative humidity, and precipitation data. Meteorological data was extracted on days of complaints to help aide in understanding the movement of air at the site and specific conditions that may contribute to air dispersion in the area. The prevailing wind direction for the area is typically out of the South/Southwest. Generally, during the time and day of odor complaints wind speeds average between 0-5 miles per hour and wind directions vary from out of the South, Southeast, and Southwest. Therefore, there has been no unique meteorological conditions associated with days and times of complaints.

Performed on-site Industrial Hygiene sampling

In response to odor reports from nearby residents, Sierrita implemented a review of its internal processes. This included air sampling and evaluations to confirm the safety of the processes with respect to Sierrita personnel. Sierrita conducted the following analyses at numerous locations on-site:

- Sierrita conducted screening sampling. These direct reading area samples provide a rapid evaluation and are used for screening purposes to help identify areas where more comprehensive sampling may be warranted. Direct reading area samples were collected with the AreaRae portable multi-gas monitors. The AreaRae monitors used for this evaluation were equipped with 2 chemical sensors (either Cl, SO2, NO2, or H2S), an O2 Sensor, a Lower Explosive Limit sensor and a photoionization detector (PID) sensor. Every sensor has some cross-sensitivity, where the sensor responds to other gases that are not filtered out and can react on the electrode. Thus, the resulting instrument reading can be an overestimation of a given chemical. Additionally, direct reading area samples are used to assist with appropriate exposure control recommendations, and cannot be used to determine worker exposures.
- In addition, while the screening samples were occurring, quantitative samples were collected and analyzed according to applicable National Institute of Occupational Safety and Health (NIOSH), Occupational Safety and Health Administration (OSHA) or Environmental Protection Agency (EPA) sampling Methods. Air sampling pumps, primary calibrators and associated collection media or summa canisters were utilized for air sample collection. Samples were sent Bureau Veritas Laboratory or Atmospheric Analysis & Consulting, Inc. which are American Industrial Hygiene Association accredited laboratories. Results of the quantitative samples are included in attachment "Sierrita Industrial Hygiene Air Sampling Summary."
- Personal air samples were collected from the breathing zone of employees in various work areas at Sierrita to ascertain chemical levels throughout the facility. Personal air samples are used to determine worker exposure. These sample results determine control requirements, medical monitoring and compliance with regulations.

Based on this comprehensive evaluation and the fact that all measured levels were low, Sierrita verified that no additional controls or medical surveillance was required to protect Sierrita employees from the analytes listed in attachment "Sierrita Industrial Hygiene Air Sampling Summary."

Communication with other Freeport Sites

Sierrita personnel have communicated with other Freeport sites in the region to examine their processes and investigate whether any alterations of Sierrita's processes may be warranted. A team of employees traveled to Freeport's site in Bagdad, Arizona to evaluate its facilities. Areas of focus included the reagent mixing process, ore grinding circuit, and the rougher flotation cells. Sierrita objectively reviewed these site processes to determine the feasibility and effectiveness of implementing additional equipment. Sierrita concluded that no facility or operational changes were warranted at this time.

Engagement with Pima County Department of Environmental Quality (PDEQ)

Throughout the odor investigation, Sierrita and PDEQ personnel have maintained a channel of communication and engaged in the following ways:

- Weekly Conference Calls – Sierrita and PDEQ personnel have held between 25 – 30 conference calls to discuss the ongoing odor evaluation. These calls typically include discussion of recent complaints by residents, ongoing activities performed by Sierrita and Arcadis, and future action plans or "next steps."

- Compliance Inspections – PDEQ has conducted three inspections throughout the duration of the odor evaluation. In each case it was determined that Sierrita was in full compliance with Title V Permit #6067.

- Meetings/Discussions –six meetings have been held between Sierrita and PDEQ personnel. The meetings provided a chance to meet in-person and discuss the ongoing efforts dedicated towards the odor evaluation. Many times, the meetings were used to discuss sampling results or provide responses to questions and inquiries from PDEQ regarding the investigation.

PDEQ indicated that Sierrita is in compliance with all permit requirements and they appreciated the efforts and resources dedicated to the odor investigation.

Conclusion

As mentioned, Sierrita takes these odor reports very seriously and beginning at the time they were raised, performed a thorough investigation to determine if any of the processes or facilities on-site could be the source of a potential odor and if so, could be generated in such a concentration to travel off-site and impact the nearby residents. None of Sierrita's processing activities correlate with the date or time of complaints. Even the identified source of on-site odors, xanthate mixing, does not correlate with off-site odor complaints. Moreover, there is no unique meteorology that corresponds to the day and time of odor complaints. While odors do occur at some processing operations at Sierrita, comprehensive air quality

modeling of these odors demonstrates that the off-site odor concentration predicted at the odor complaint locations is below, and generally well below, a level multiple studies suggest is a reasonable threshold at which an odor is considered likely to result in complaints from members of the general public. Likewise, a variety of on-site testing demonstrated that chemicals levels were well below safety standards for mine employees. Additionally, Sierrita's sister facilities that include the same type of operations have not received the same type of complaints. As a result, based upon the extensive analysis conducted by our facility, Sierrita is unable to identify any evidence that we are the source of any nuisance odors at the residences north of the mine.

If you have any questions or require more information, please contact Eric Werner at (520) 393-2087.

Sincerely,

David Rhoades
President and General Manager

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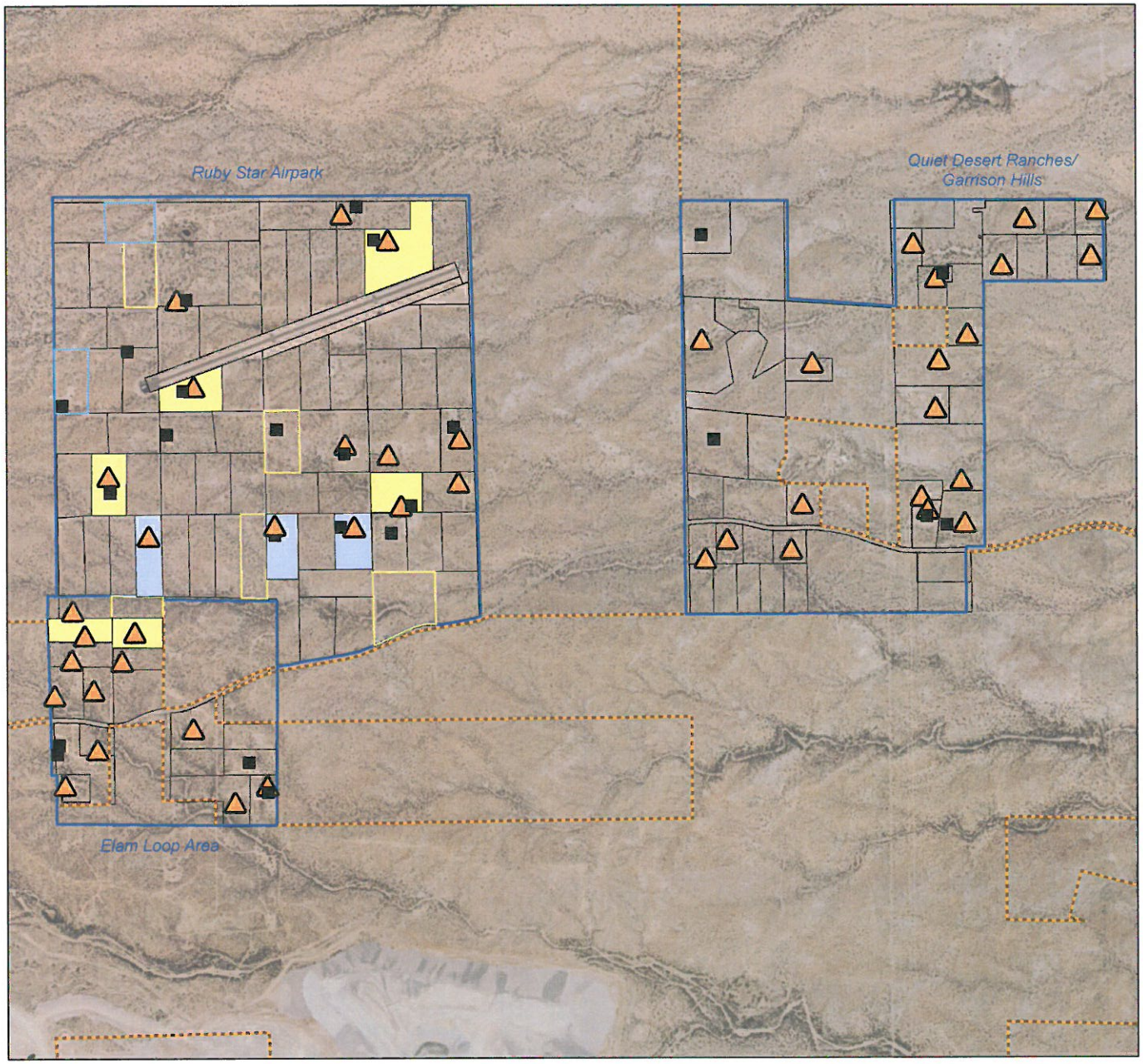


Odor Grievances

For illustrative purposes only.

Parcels displayed as grievances represent only property owners who have communicated directly with Freeport-McMoRan Sierrita Inc. and Arcadis US.

Created March 3, 2016

Legend

House

Building/Hangar

Neighborhoods

Sierrita Property Boundary

139 Parcels

Reported No Nuisance Odor - 4 Property Owners

3 Parcel with Household

2 Vacant Parcel

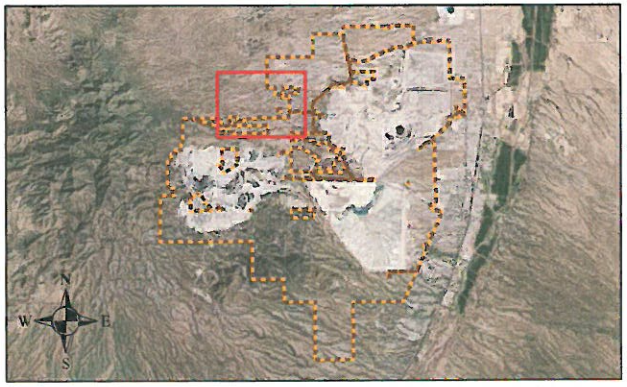
Nuisance Odor Complaint - 6 Property Owners

6 Parcel with Household

5 Vacant Parcel

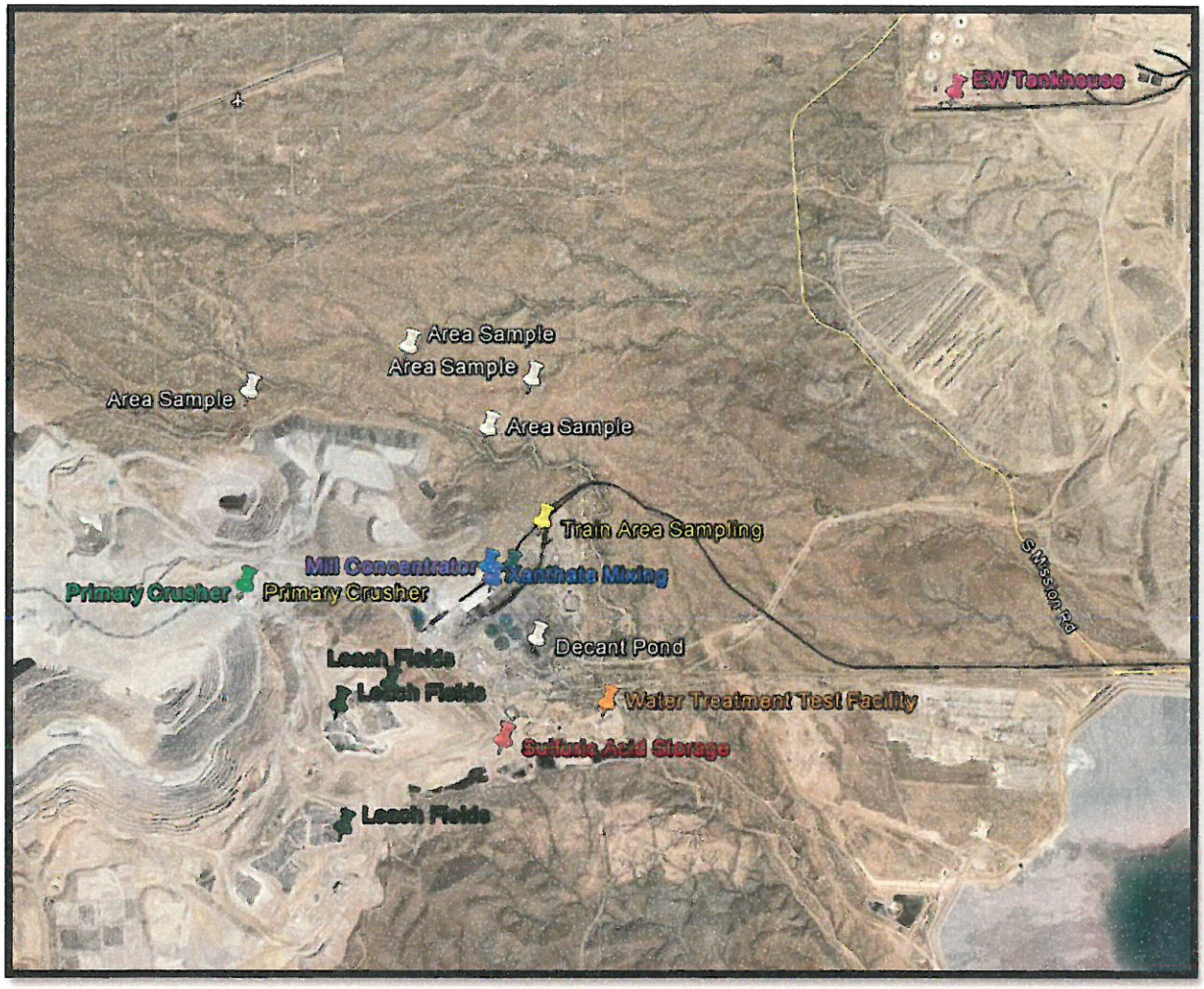
0 0.125 0.25 0.5 0.75 1 Miles

FREEPORT-MCMORAN



SIERRITA INDUSTRIAL HYGIENE AIR SAMPLING SUMMARY

1. DECANT POND
2. MILL/CONCENTRATOR BUILDING
3. XANTHATE MIXING REAGENT BUILDING
4. PRIMARY CRUSHER
5. LEACH FIELDS
6. TRAIN AREA
7. NORTH OF PLANT
8. SULFURIC ACID STORAGE TANKS
9. ELECTRO-WINNING TANKHOUSE
10. WATER TREATMENT TEST FACILITY



Sierrita Industrial Hygiene Air Sampling Strategy

Sample Locations

Air sampling locations were determined based on highest exposure potential, historical air sampling results, and exposure control requirements. In addition, full comprehensive air sampling was completed in September 2015 at the

highest odor source locations identified by Arcadis. The main purpose of these air samples was to determine employee exposure potential and control requirements.

Screening Samples

AreaRaes are direct reading instruments which provide a rapid qualitative evaluation. The AreaRaes used for this evaluation are equipped with 2 toxic sensors, an O2 Sensor, a LEL sensor and a PID (photoionization detector) sensor.

Every sensor has some cross-sensitivity, where the sensor responds to other gases that are not filtered out and can react on the electrode. Thus, the resulting instrument reading can be an overestimation of a given chemical. As a result, although the sampling result tables are labeled with a chemical's name, due to this cross-sensitivity, sensor results set forth in the tables are to be used for qualitative purposes only, do not represent a precise measure of the chemical, and will be used to assist in determining the need for more reliable quantitative analysis.
Area samples cannot be used to determine personnel exposures but serve as a tool to assist with exposure control recommendations

Toxic Sensor	**Range**	**Resolution**	**PEL/OEL (8hr TWA)**	**Ceiling**
H2S	0-100 ppm	1 ppm	1 ppm (ACGIH)	20 ppm (FMI)
SO2	0-20 ppm	0.1 ppm	2 ppm (FMI)	N/A
NO	0-250 ppm	1 ppm	50 ppm (FMI)	N/A
NO2	0-20 ppm	0.1 ppm	0.2 ppm (FMI)	5 ppm (FMI)
VOC	0-200 ppm	0.1 ppm	Varies by specific contaminant	

Quantitative Samples

National Institute of Occupational Safety and Health (NIOSH) or Occupational Safety and Health Administration sampling methods are used for air sample collection and analysis. Air sampling pumps, primary calibrators and associated collection media or summa canisters were utilized for air sample collection. Samples were sent Bureau Veritas Laboratory or Atmospheric Analysis & Consulting, Inc which are American Industrial Hygiene Association accredited laboratories.

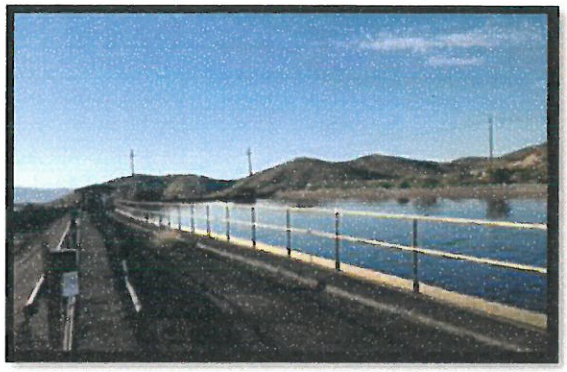
Results from quantitative sampling are compared to the Freeport-McMoRan occupational exposure limit (OEL), or most stringent standard in the absence of an OEL, and is used to determine employee exposures, control requirements and regulatory compliance. Freeport-McMoRan reviews applicable regulatory standards and adopts a standard that is either the same or more stringent than required by OSHA/MSHA.

Air Sampling and Odor Thresholds:

Odor threshold is the lowest concentration that is perceivable by the human sense of smell. These concentrations are unique to each individual and are generally significantly lower than regulatory requirements.

Air sampling results outlined in this document are compared to established health standards without regard to the odor threshold.

1. DECANT POND



Sampling Conducted:

Screening Samples – Samples collected with direct reading AreaRaes, used to determine need for quantitative sampling.

Quantitative Samples – Samples collected with air sampling pump/collection media and sent to a lab for analysis.
Area Samples – Collected in the area of the potential contaminant. **Can't be used for** personal exposures or compliance; used for control recommendations

Personal Samples – Samples collected in the breathing zone of employee and are used to determine health hazard potential and compliance with regulations

Decant Pond Sampling Summary: Screening samples collected in October of 2014 indicated a need for quantitative analysis. Quantitative sampling indicates exposure levels below the standards. No additional PPE or controls are required to control exposures.

Decant Pond Screening Sample Results

Sampling Date	# of Samples	Sample Type	Analyte	Result (Peak)	Occupational Exposure Limit	Conclusion
October 2014	6	Area	Sulfur Dioxide	0-0.4 ppm	2 ppm (TWA)	< OEL
	6	Area	Hydrogen Sulfide	0-3.9 ppm	1 ppm (TWA)	< OEL
	6	Area	Volatile Organic Compounds	0.1-10 ppm	Varies	Low hazard potential
November 2014	10	Area	Sulfur Dioxide	0-0.2 ppm	2 ppm (TWA)	< OEL
	10	Area	Hydrogen Sulfide	0.4-0.8 ppm*	1 ppm (TWA)	< OEL
	10	Area	Volatile Organic Compounds	0-10.7 ppm	Varies	Low hazard potential

*Results below sensor resolution

Decant Pond Quantitative Sample Results

Sampling Date	# of Samples	Sample Type	Analyte	Result	Occupational Exposure Limit	Conclusion
November 2014	1	Personal	Hydrogen Sulfide	0.42 ppm	1 ppm	< OEL
November 2014	4	Area	Hydrogen Sulfide	0.36-0.59 ppm	1 ppm	< OEL
September 2015	1	Area	Sulfuric Acid	0.0273 mg/m^3	1 mg/m^3	< OEL
September 2015	1	Area	Hydrofluoric Acid	< Detection Limit		
September 2015	1	Area	Hydrochloric Acid	< Detection Limit		
September 2015	1	Area	Hydrobromic Acid	< Detection Limit		
September 2015	1	Area	Nitric Acid	< Detection Limit		
September 2015	1	Area	Phosphoric Acid	< Detection Limit		
September 2015	1	Area	Formaldehyde	0.0021 mg/m^3	0.37 mg/m^3	< OEL
September 2015	1	Area	Acetaldehyde	0.0024 mg/m^3	45 mg/m^3	< OEL
September 2015	1	Area	Acetone	0.0033 mg/m^3	2400 mg/m^3	< OEL
September 2015	1	Area	MEK and Butyraldehyde	0.0044 mg/m^3	590 mg/m^3 73.7 mg/m^3	< OEL
September 2015	1	Area	Acrolein	< Detection Limit		
September 2015	1	Area	Propionaldehyde	< Detection Limit		
September 2015	1	Area	Crotonaldehyde	< Detection Limit		
September 2015	1	Area	Methacrolein	< Detection Limit		
September 2015	1	Area	Benzaldehyde	< Detection Limit		
September 2015	1	Area	Valeraldehyde	< Detection Limit		
September 2015	1	Area	m-Tolualdehyde	< Detection Limit		
September 2015	1	Area	Hexaldehyde	< Detection Limit		
September 2015	1	Area	Acenaphthene	< Detection Limit		
September 2015	1	Area	Acenaphthylene	< Detection Limit		
September 2015	1	Area	Anthracene	< Detection Limit		
September 2015	1	Area	Benzo(g,h,i)perylene	< Detection Limit		
September 2015	1	Area	Benzoic Acid	< Detection Limit		
September 2015	1	Area	Benzyl Alcohol	< Detection Limit		
September 2015	1	Area	Bis(2-Chloroethoxy)methane	< Detection Limit		
September 2015	1	Area	Bis(2-Chloroethyl)ether	< Detection Limit		
September 2015	1	Area	Bis(2-chloroisopropyl) ether	< Detection Limit		
September 2015	1	Area	Bis(2-ethylhexyl) phthalate	< Detection Limit		
September 2015	1	Area	4-Bromophenyl phenyl ether	< Detection Limit		
September 2015	1	Area	Butyl benzyl phthalate	< Detection Limit		
September 2015	1	Area	4-Chloro-3-methylphenol	< Detection Limit		
September 2015	1	Area	4-Chloroaniline	< Detection Limit		
September 2015	1	Area	2-Chloronaphthalene	< Detection Limit		
September 2015	1	Area	2-Chlorophenol	< Detection Limit		
September 2015	1	Area	4-Chlorophenyl phenyl ether	< Detection Limit		
September 2015	1	Area	Di-n-butyl phthalate	< Detection Limit		
September 2015	1	Area	Di-n-octyl phthalate (Dioctyl ester)	< Detection Limit		
September 2015	1	Area	Dibenzofuran	< Detection Limit		
September 2015	1	Area	1,2-Dichlorobenzene	< Detection Limit		
September 2015	1	Area	1,3-Dichlorobenzene	< Detection Limit		
September 2015	1	Area	1,4-Dichlorobenzene	< Detection Limit		
September 2015	1	Area	3,3'-Dichlorobenzidine	< Detection Limit		
September 2015	1	Area	2,4-Dichlorophenol	< Detection Limit		
September 2015	1	Area	Diethyl phthalate (Diethyl ester)	< Detection Limit		

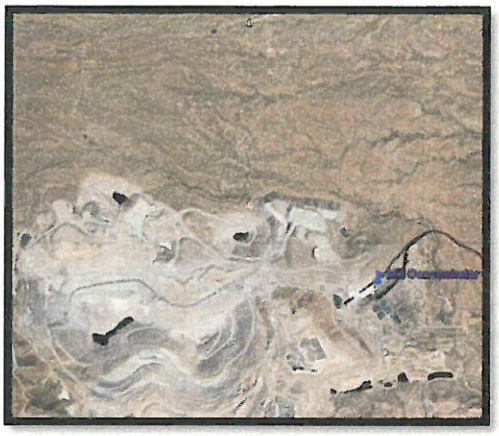
September 2015	1	Area	Dimethyl phthalate (Dimethyl ester)	< Detection Limit		
September 2015	1	Area	2,4-Dimethylphenol	< Detection Limit		
September 2015	1	Area	4,6-Dinitro-2-methylphenol	< Detection Limit		
September 2015	1	Area	2,4-Dinitrophenol	< Detection Limit		
September 2015	1	Area	2,4-Dinitrotoluene	< Detection Limit		
September 2015	1	Area	2,6-Dinitrotoluene (2,6-DNT)	< Detection Limit		
September 2015	1	Area	Fluoranthene	< Detection Limit		
September 2015	1	Area	Fluorene	< Detection Limit		
September 2015	1	Area	Hexachlorobenzene	< Detection Limit		
September 2015	1	Area	Hexachlorobutadiene	< Detection Limit		
September 2015	1	Area	Hexachlorocyclopentadiene	< Detection Limit		
September 2015	1	Area	Hexachloroethane	< Detection Limit		
September 2015	1	Area	Isophorone	< Detection Limit		
September 2015	1	Area	2-Methylnaphthalene	< Detection Limit		
September 2015	1	Area	4-Methylphenol	< Detection Limit		
September 2015	1	Area	2-Methylphenol (2-Cresol)	< Detection Limit		
September 2015	1	Area	3-Methylphenol (3-Cresol)	< Detection Limit		
September 2015	1	Area	N-Nitroso-Di-n-propylamine	< Detection Limit		
September 2015	1	Area	Naphthalene	< Detection Limit		
September 2015	1	Area	2-Nitroaniline	< Detection Limit		
September 2015	1	Area	3-Nitroaniline	< Detection Limit		
September 2015	1	Area	4-Nitroaniline	< Detection Limit		
September 2015	1	Area	Nitrobenzene (NB)	< Detection Limit		
September 2015	1	Area	4-Nitrophenol	< Detection Limit		
September 2015	1	Area	2-Nitrophenol (o-Nitrophenol)	< Detection Limit		
September 2015	1	Area	N-nitrosodiphenylamine	< Detection Limit		
September 2015	1	Area	Pentachlorophenol	< Detection Limit		
September 2015	1	Area	Phenanthrene	< Detection Limit		
September 2015	1	Area	Phenol	< Detection Limit		
September 2015	1	Area	Pyrene	< Detection Limit		
September 2015	1	Area	1,2,4-Trichlorobenzene	< Detection Limit		
September 2015	1	Area	2,4,5-Trichlorophenol	< Detection Limit		
September 2015	1	Area	2,4,6-Trichlorophenol	< Detection Limit		
September 2015	1	Area	Benzo(a)anthracene	< Detection Limit		
September 2015	1	Area	Benzo(a)pyrene	< Detection Limit		
September 2015	1	Area	Benzo(b)fluoranthene	< Detection Limit		
September 2015	1	Area	Benzo(k)fluoranthene	< Detection Limit		
September 2015	1	Area	Chrysene	< Detection Limit		
September 2015	1	Area	Dibenzo(a,h)anthracene	< Detection Limit		
September 2015	1	Area	Indeno(1,2,3-cd)pyrene	< Detection Limit		
September 2015	1	Area	C9-C11 Petroleum Hydrocarbons	12.314 mg/m^3	Not established[2]	Not Established
September 2015	1	Area	C12-C13 Petroleum Hydrocarbons	18.536 mg/m^3	Not established[2]	Not Established
September 2015	1	Area	C14-C15 Petroleum Hydrocarbons	20.821 mg/m^3	Not established[2]	Not Established
September 2015	1	Area	C16-C17 Petroleum Hydrocarbons	13.530 mg/m^3	Not established[2]	Not Established
September 2015	1	Area	C18-C19 Petroleum Hydrocarbons	10.532 mg/m^3	Not established[2]	Not Established
September 2015	1	Area	C20-C21 Petroleum Hydrocarbons	7.251 mg/m^3	Not established[2]	Not Established

September 2015	1	Area	C22-C23 Petroleum Hydrocarbons	4.561 mg/m^3	Not established[2]	Not Established
September 2015	1	Area	C24-C25 Petroleum Hydrocarbons	0.256 mg/m^3	Not established[2]	Not Established
September 2015	1	Area	C26-C27 Petroleum Hydrocarbons	3.476 mg/m^3	Not established[2]	Not Established
September 2015	1	Area	C28-C29 Petroleum Hydrocarbons	4.901 mg/m^3	Not established[2]	Not Established
September 2015	1	Area	C30-C31 Petroleum Hydrocarbons	< Detection Limit		
September 2015	1	Area	C32-C33 Petroleum Hydrocarbons	1.483 mg/m^3	Not established[2]	Not Established
September 2015	1	Area	C34-C35 Petroleum Hydrocarbons	< Detection Limit		
September 2015	1	Area	C36-C37 Petroleum Hydrocarbons	1.588 mg/m^3	Not established[2]	Not Established
September 2015	1	Area	C38-C39 Petroleum Hydrocarbons	< Detection Limit		
September 2015	1	Area	C40-C41 Petroleum Hydrocarbons	< Detection Limit		
September 2015	1	Area	TPH Total (C9-C41)	83.446 mg/m^3	Not established[2]	Not Established
September 2015	1	Area	Hydrogen Sulfide	0.153 ppmV	20 ppm C[1]	< Ceiling
September 2015	1	Area	Carbonyl Sulfide/Sulfur Dioxide	0.241 ppmV	2 ppm	< OEL
September 2015	1	Area	Total Reduced Sulfurs as H2S	0.153 ppmV	Not established[2]	Not Established
September 2015	1	Area	Methyl Mercaptan	< Detection Limit		
September 2015	1	Area	Ethyl Mercaptan	< Detection Limit		
September 2015	1	Area	Dimethyl Sulfide	< Detection Limit		
September 2015	1	Area	Carbon Disulfide	< Detection Limit		
September 2015	1	Area	Isopropyl Mercaptan	< Detection Limit		
September 2015	1	Area	tert-Butyl Mercaptan	< Detection Limit		
September 2015	1	Area	n-Propyl Mercaptan	< Detection Limit		
September 2015	1	Area	Methylethylsulfide	< Detection Limit		
September 2015	1	Area	sec-Butyl Mercaptan	< Detection Limit		
September 2015	1	Area	Thiophene	< Detection Limit		
September 2015	1	Area	iso-Butyl Mercaptan	< Detection Limit		
September 2015	1	Area	Diethyl Sulfide	< Detection Limit		
September 2015	1	Area	n-Butyl Mercaptan	< Detection Limit		
September 2015	1	Area	Dimethyl Disulfide	< Detection Limit		
September 2015	1	Area	2-methylthiophene	< Detection Limit		
September 2015	1	Area	3-Methylthiophene	< Detection Limit		
September 2015	1	Area	Tetrahydrothiophene	< Detection Limit		
September 2015	1	Area	Bromothiophene	< Detection Limit		
September 2015	1	Area	Thiophenol	< Detection Limit		
September 2015	1	Area	Diethyl disulfide	< Detection Limit		
September 2015	1	Area	Total Unidentified Sulfur	< Detection Limit		
September 2015	1	Area	Ethanol	0.0103 ppmV	1000 ppm	< OEL
September 2015	1	Area	Acetone	0.0055 ppmV	250 ppm	< OEL
September 2015	1	Area	Methylene Chloride (DCM)	0.0135 ppmV	25 ppm	< OEL
September 2015	1	Area	Carbon Disulfide	0.0069 ppmV	1 ppm	< OEL
September 2015	1	Area	Chlorodifluoromethane	< Detection Limit		
September 2015	1	Area	Propene	< Detection Limit		
September 2015	1	Area	Dichlorodifluoromethane	< Detection Limit		

September 2015	1	Area	Chloromethane	< Detection Limit
September 2015	1	Area	Dichlorotetrafluoroethane	< Detection Limit
September 2015	1	Area	Vinyl Chloride	< Detection Limit
September 2015	1	Area	Methanol	< Detection Limit
September 2015	1	Area	1,3-Butadiene	< Detection Limit
September 2015	1	Area	Bromomethane	< Detection Limit
September 2015	1	Area	Chloroethane	< Detection Limit
September 2015	1	Area	Dichlorofluoromethane	< Detection Limit
September 2015	1	Area	Vinyl Bromide	< Detection Limit
September 2015	1	Area	Trichlorofluoromethane	< Detection Limit
September 2015	1	Area	2-Propanol	< Detection Limit
September 2015	1	Area	Acrylonitrile	< Detection Limit
September 2015	1	Area	1,1-Dichloroethene	< Detection Limit
September 2015	1	Area	Allyl Chloride	< Detection Limit
September 2015	1	Area	Trichlorotrifluoroethane	< Detection Limit
September 2015	1	Area	trans-1,2-Dichloroethene	< Detection Limit
September 2015	1	Area	1,1-Dichloroethane	< Detection Limit
September 2015	1	Area	Methyl Tert Butyl Ether (MTBE)	< Detection Limit
September 2015	1	Area	Vinyl Acetate	< Detection Limit
September 2015	1	Area	2-Butanone (MEK)	< Detection Limit
September 2015	1	Area	cis-1,2-Dichloroethene	< Detection Limit
September 2015	1	Area	Hexane	< Detection Limit
September 2015	1	Area	Chloroform	< Detection Limit
September 2015	1	Area	Ethyl Acetate	< Detection Limit
September 2015	1	Area	Tetrahydrofuran	< Detection Limit
September 2015	1	Area	1,2-Dichloroethane	< Detection Limit
September 2015	1	Area	1,1,1-Trichloroethane	< Detection Limit
September 2015	1	Area	Benzene	< Detection Limit
September 2015	1	Area	Carbon Tetrachloride	< Detection Limit
September 2015	1	Area	Cyclohexane	< Detection Limit
September 2015	1	Area	1,2-Dichloropropane	< Detection Limit
September 2015	1	Area	Bromodichloromethane	< Detection Limit
September 2015	1	Area	1,4-Dioxane	< Detection Limit
September 2015	1	Area	Trichloroethene (TCE)	< Detection Limit
September 2015	1	Area	2,2,4-Trimethylpentane	< Detection Limit
September 2015	1	Area	Heptane	< Detection Limit
September 2015	1	Area	cis-1,3-Dichloropropene	< Detection Limit
September 2015	1	Area	4-Methyl-2-pentanone (MIBK)	< Detection Limit
September 2015	1	Area	trans-1,3-Dichloropropene	< Detection Limit
September 2015	1	Area	1,1,2-Trichloroethane	< Detection Limit
September 2015	1	Area	Toluene	< Detection Limit
September 2015	1	Area	2-Hexanone (MBK)	< Detection Limit
September 2015	1	Area	Dibromochloromethane	< Detection Limit
September 2015	1	Area	1,2-Dibromoethane	< Detection Limit
September 2015	1	Area	Tetrachloroethene (PCE)	< Detection Limit
September 2015	1	Area	Chlorobenzene	< Detection Limit
September 2015	1	Area	Ethylbenzene	< Detection Limit
September 2015	1	Area	m & p-Xylene	< Detection Limit
September 2015	1	Area	Bromoform	< Detection Limit
September 2015	1	Area	Styrene	< Detection Limit
September 2015	1	Area	1,1,2,2-Tetrachloroethane	< Detection Limit
September 2015	1	Area	o-Xylene	< Detection Limit
September 2015	1	Area	4-Ethyltoluene	< Detection Limit

September 2015	1	Area	1,3,5-Trimethylbenzene	< Detection Limit		
September 2015	1	Area	1,2,4-Trimethylbenzene	< Detection Limit		
September 2015	1	Area	Benzyl Chloride (a-Chlorotoluene)	< Detection Limit		
September 2015	1	Area	1,3-Dichlorobenzene	< Detection Limit		
September 2015	1	Area	1,4-Dichlorobenzene	< Detection Limit		
September 2015	1	Area	1,2-Dichlorobenzene	< Detection Limit		
September 2015	1	Area	1,2,4-Trichlorobenzene	< Detection Limit		
September 2015	1	Area	Hexachlorobutadiene	< Detection Limit		
September 2015	1	Area	TIC[3] - 1-Butanol	0.0029 ppmV	20 ppm	< OEL
September 2015	1	Area	TIC[3] - 2-Ethylhexanal	0.0015 ppmV	Not established[2]	Not Established
September 2015	1	Area	TIC[3] - 2-Ethyl-2-hexenal	0.0017 ppmV	Not established[2]	Not Established

2. MILL/CONCENTRATOR BUILDING



Sampling Conducted:

Quantitative Samples – Samples collected with air sampling pump/collection media and sent to a lab for analysis
Area Samples – Collected in the area of the potential contaminant. **Can't be used for personal exposures or** compliance; used for control recommendations

Personal Samples – Samples collected in the breathing zone of employee and are used to determine health hazard potential and compliance with regulations.

Mill/Concentrator Sampling Summary: Quantitative sampling was completed in various locations of the Mill/Concentrator building. Area monitoring for diesel at the mill reagent addition area indicated the need for additional controls. Covers were installed on the reagent addition area and follow-up sampling was conducted to verify control effectiveness. No additional PPE or controls are required for the Mill/Concentrator.

Mill/Concentrator Quantitative Sample Results

Sampling Date	# of Samples	Sample Type	Analyte	Result	Occupational Exposure Limit	Conclusion
March 2015	3	Area	*Diesel*	18-128 mg/m^3	100 mg/m^3	> OEL
March 2015	3	Area	Napthalene	0.004-0.005 mg/m^3	50 mg/m^3	< OEL
March 2015	3	Area	Acenaphthene	< Detection Limit		
March 2015	3	Area	Acenaphthylene	< Detection Limit		
March 2015	3	Area	Anthracene	< Detection Limit		
March 2015	3	Area	Benzo-a-anthracene	< Detection Limit		
March 2015	3	Area	Benzo-b-fluoranthene	< Detection Limit		
March 2015	3	Area	Benzo-k-fluoranthene	< Detection Limit		
March 2015	3	Area	Benzo-a-pyrene	< Detection Limit		
March 2015	3	Area	Benzo-ghi-perylene	< Detection Limit		
March 2015	3	Area	Chrysene	< Detection Limit		
March 2015	3	Area	Dibenzo-a,h-anthracene	< Detection Limit		
March 2015	3	Area	Fluoranthene	< Detection Limit		
March 2015	3	Area	Fluorene	< Detection Limit		
March 2015	3	Area	Indeno-1,2,3-cd-pyrene	< Detection Limit		
March 2015	3	Area	Phenanthrene	< Detection Limit		
March 2015	3	Area	Pyrene	< Detection Limit		

March 2015	3	Area	Butyraldehyde / Isobutyraldehyde	0.014-0.062 ppm	25 ppm	< OEL
March 2015	3	Area	Formaldehyde	0.004-0.005 ppm	0.75 ppm	< OEL
March 2015	3	Area	Acetaldehyde	< Detection Limit		
March 2015	3	Area	Acrolein	< Detection Limit		
March 2015	3	Area	Benzaldehyde	< Detection Limit		
March 2015	3	Area	Crotonaldehyde	< Detection Limit		
March 2015	3	Area	Decanal	< Detection Limit		
March 2015	3	Area	Glutaraldehyde	< Detection Limit		
March 2015	3	Area	Heptaldehyde	< Detection Limit		
March 2015	3	Area	Hexaldehyde	< Detection Limit		
March 2015	3	Area	Isovaleraldehyde	< Detection Limit		
March 2015	3	Area	Nonanal	< Detection Limit		
March 2015	3	Area	Octylaldehyde	< Detection Limit		
March 2015	3	Area	Propionaldehyde	< Detection Limit		
March 2015	3	Area	p-Toluladehyde	< Detection Limit		
March 2015	3	Area	Undecanal	< Detection Limit		
March 2015	3	Area	Valeraldehyde	< Detection Limit		
April 2015	*2*	Area	*Diesel*	0.96-11 mg/m^3	100 mg/m^3	< OEL
April 2015	*2*	Area	*1,1,1-Trichloroethane*	< Detection Limit		
April 2015	*2*	Area	*Acetone*	< Detection Limit		
April 2015	*2*	Area	*Benzene*	< Detection Limit		
April 2015	*2*	Area	*Carbon Tetrachloride*	< Detection Limit		
April 2015	*2*	Area	*Cyclohexanone*	< Detection Limit		
April 2015	*2*	Area	*Ethanol*	< Detection Limit		
April 2015	*2*	Area	*Ethylbenzene*	< Detection Limit		
April 2015	*2*	Area	*Heptane*	< Detection Limit		
April 2015	*2*	Area	*Isopropyl Alcohol*	< Detection Limit		
April 2015	*2*	Area	*Methyl Amyl Ketone*	< Detection Limit		
April 2015	*2*	Area	*Methyl Butyl Ketone*	< Detection Limit		
April 2015	*2*	Area	*Methyl Ethyl Ketone*	< Detection Limit		
April 2015	*2*	Area	*Methyl Isoamyl Ketone*	< Detection Limit		
April 2015	*2*	Area	*Methyl Isobutyl Ketone*	< Detection Limit		
April 2015	*2*	Area	*m-Xylene*	< Detection Limit		
April 2015	*2*	Area	*n-Butanol*	< Detection Limit		
April 2015	*2*	Area	*n-Butyl Acetate*	< Detection Limit		
April 2015	*2*	Area	*n-Hexane*	< Detection Limit		
April 2015	*2*	Area	*o-Xylene*	< Detection Limit		
April 2015	*2*	Area	*Pentane*	< Detection Limit		
April 2015	*2*	Area	*Perchloroethylene*	< Detection Limit		
April 2015	*2*	Area	*Styrene*	< Detection Limit		
April 2015	*2*	Area	*Toluene*	< Detection Limit		
April 2015	*2*	Area	*Trichloroethylene*	< Detection Limit		
April 2015	*2*	Area	*Xylene (Total)*	< Detection Limit		
April 2015	*2*	Area	*Carbon Disulfide*	0.34 mg/m^3	3.11 mgm^3	< OEL
April 2015	*2*	Area	*Napthalene*	< Detection Limit		
April 2015	*2*	Area	*Acenaphthene*	< Detection Limit		
April 2015	*2*	Area	*Acenaphthylene*	< Detection Limit		
April 2015	*2*	Area	*Anthracene*	< Detection Limit		
April 2015	*2*	Area	*Benzo-a-anthracene*	< Detection Limit		
April 2015	*2*	Area	*Benzo-b-fluoranthene*	< Detection Limit		
April 2015	*2*	Area	*Benzo-k-fluoranthene*	< Detection Limit		
April 2015	*2*	Area	*Benzo-a-pyrene*	< Detection Limit		
April 2015	*2*	Area	*Benzo-ghi-perylene*	< Detection Limit		

April 2015	*2*	Area	*Chrysene*	< Detection Limit		
April 2015	*2*	Area	*Dibenzo-a,h-anthracene*	< Detection Limit		
April 2015	*2*	Area	*Fluoranthene*	< Detection Limit		
April 2015	*2*	Area	*Fluorene*	< Detection Limit		
April 2015	*2*	Area	*Indeno-1,2,3-cd-pyrene*	< Detection Limit		
April 2015	*2*	Area	*Phenanthrene*	< Detection Limit		
April 2015	*2*	Area	*Pyrene*	< Detection Limit		
April 2015	*2*	Area	– Butyraldehyde / Isobutyraldehyde	0.012-0.081 ppm	25 ppm	< OEL
April 2015	*2*	Area	Formaldehyde	0.003-0.01 ppm	0.75 ppm	< OEL
April 2015	*2*	Area	Acetaldehyde	< Detection Limit		
April 2015	*2*	Area	Acrolein	< Detection Limit		
April 2015	*2*	Area	Benzaldehyde	< Detection Limit		
April 2015	*2*	Area	Crotonaldehyde	< Detection Limit		
April 2015	*2*	Area	Decanal	< Detection Limit		
April 2015	*2*	Area	Glutaraldehyde	< Detection Limit		
April 2015	*2*	Area	Heptaldehyde	< Detection Limit		
April 2015	*2*	Area	Hexaldehyde	< Detection Limit		
April 2015	*2*	Area	Isovaleraldehyde	< Detection Limit		
April 2015	*2*	Area	Nonanal	< Detection Limit		
April 2015	*2*	Area	Octylaldehyde	< Detection Limit		
April 2015	*2*	Area	Propionaldehyde	< Detection Limit		
April 2015	*2*	Area	p-Toluladehyde	< Detection Limit		
April 2015	*2*	Area	Undecanal	< Detection Limit		
April 2015	*2*	Area	Valeraldehyde	< Detection Limit		
September 2015	*1*	Area	Hydrochloric Acid	0.0308 mg/m^3	7.5 mg/m^3 C[1]	< Ceiling
September 2015	*1*	Area	Sulfuric Acid	0.0309 mg/m^3	1 mg/m^3	<OEL
September 2015	*1*	Area	Hydrofluoric Acid	< Detection Limit		
September 2015	*1*	Area	Hydrobromic Acid	< Detection Limit		
September 2015	*1*	Area	Nitric Acid	< Detection Limit		
September 2015	*1*	Area	Phosphoric Acid	< Detection Limit		
September 2015	*1*	Area	Formaldehyde	0.0033 mg/m^3	0.37 mg/m^3C[1]	< Ceiling
September 2015	*1*	Area	Acetaldehyde	0.0030 mg/m^3	45 mg/m^3C[1]	< Ceiling
September 2015	*1*	Area	Acetone	0.0063 mg/m^3	2375 mg/m^3	<OEL
September 2015	*1*	Area	Propionaldehyde	0.0089 mg/m^3	48 mg/m^3	<OEL
September 2015	*1*	Area	MEK and Butyraldehyde	0.3610 mg/m^3	590 mg/m^3 73.7 mg/m^3	<OEL <OEL
September 2015	*1*	Area	Benzaldehyde	0.0023 mg/m^3	8.7 mg/m^3	<OEL
September 2015	*1*	Area	Valeraldehyde	0.0009 mg/m^3	176 mg/m^3	<OEL
September 2015	*1*	Area	Hexaldehyde	0.0040 mg/m^3	Not established[2]	Not Established
September 2015	*1*	Area	Acrolein	< Detection Limit		
September 2015	*1*	Area	Crotonaldehyde	< Detection Limit		
September 2015	*1*	Area	Methacrolein	< Detection Limit		
September 2015	*1*	Area	m-Tolualdehyde	< Detection Limit		
September 2015	*1*	Area	Carbon Disulfide	0.11 ppmV	1 ppm	<OEL
September 2015	*1*	Area	Total Reduced Sulfurs as H2S	0.11 ppmV	Not established[2]	Not Established
September 2015	*1*	Area	Hydrogen Sulfide	< Detection Limit		
September 2015	*1*	Area	Carbonyl Sulfide/Sulfur Dioxide	< Detection Limit		
September 2015	*1*	Area	Methyl Mercaptan	< Detection Limit		
September 2015	*1*	Area	Ethyl Mercaptan	< Detection Limit		
September 2015	*1*	Area	Dimethyl Sulfide	< Detection Limit		
September 2015	*1*	Area	Isopropyl Mercaptan	< Detection Limit		
September 2015	*1*	Area	tert-Butyl Mercaptan	< Detection Limit		
September 2015	*1*	Area	n-Propyl Mercaptan	< Detection Limit		

September 2015	*1*	Area	Methylethylsulfide	< Detection Limit		
September 2015	*1*	Area	sec-Butyl Mercaptan	< Detection Limit		
September 2015	*1*	Area	Thiophene	< Detection Limit		
September 2015	*1*	Area	iso-Butyl Mercaptan	< Detection Limit		
September 2015	*1*	Area	Diethyl Sulfide	< Detection Limit		
September 2015	*1*	Area	n-Butyl Mercaptan	< Detection Limit		
September 2015	*1*	Area	Dimethyl Disulfide	< Detection Limit		
September 2015	*1*	Area	2-methylthiophene	< Detection Limit		
September 2015	*1*	Area	3-Methylthiophene	< Detection Limit		
September 2015	*1*	Area	Tetrahydrothiophene	< Detection Limit		
September 2015	*1*	Area	Bromothiophene	< Detection Limit		
September 2015	*1*	Area	Thiophenol	< Detection Limit		
September 2015	*1*	Area	Diethyl disulfide	< Detection Limit		
September 2015	*1*	Area	Total Unidentified Sulfur	< Detection Limit		
September 2015	*1*	Area	2-Methylnaphthalene	0.2105 mg/m^3	3 mg/m^3	< OEL
September 2015	*1*	Area	Naphthalene	0.0144 mg/m^3	52 mg/m^3 78.6 mg/m^3	< OEL
September 2015	*1*	Area	Acenaphthene	< Detection Limit		
September 2015	*1*	Area	Acenaphthylene	< Detection Limit		
September 2015	*1*	Area	Anthracene	< Detection Limit		
September 2015	*1*	Area	Benzo(g,h,i)perylene	< Detection Limit		
September 2015	*1*	Area	Benzoic Acid	< Detection Limit		
September 2015	*1*	Area	Benzyl Alcohol	< Detection Limit		
September 2015	*1*	Area	Bis(2-Chloroethoxy)methane	< Detection Limit		
September 2015	*1*	Area	Bis(2-Chloroethyl)ether	< Detection Limit		
September 2015	*1*	Area	Bis(2-chloroisopropyl) ether	< Detection Limit		
September 2015	*1*	Area	Bis(2-ethylhexyl) phthalate	< Detection Limit		
September 2015	*1*	Area	4-Bromophenyl phenyl ether	< Detection Limit		
September 2015	*1*	Area	Butyl benzyl phthalate	< Detection Limit		
September 2015	*1*	Area	4-Chloro-3-methylphenol	< Detection Limit		
September 2015	*1*	Area	4-Chloroaniline	< Detection Limit		
September 2015	*1*	Area	2-Chloronaphthalene	< Detection Limit		
September 2015	*1*	Area	2-Chlorophenol	< Detection Limit		
September 2015	*1*	Area	4-Chlorophenyl phenyl ether	< Detection Limit		
September 2015	*1*	Area	Di-n-butyl phthalate	< Detection Limit		
September 2015	*1*	Area	Di-n-octyl phthalate (Dioctyl ester)	< Detection Limit		
September 2015	*1*	Area	Dibenzofuran	< Detection Limit		
September 2015	*1*	Area	1,2-Dichlorobenzene	< Detection Limit		
September 2015	*1*	Area	1,3-Dichlorobenzene	< Detection Limit		
September 2015	*1*	Area	1,4-Dichlorobenzene	< Detection Limit		
September 2015	*1*	Area	3,3'-Dichlorobenzidine	< Detection Limit		
September 2015	*1*	Area	2,4-Dichlorophenol	< Detection Limit		
September 2015	*1*	Area	Diethyl phthalate (Diethyl ester)	< Detection Limit		
September 2015	*1*	Area	Dimethyl phthalate (Dimethyl ester)	< Detection Limit		
September 2015	*1*	Area	2,4-Dimethylphenol	< Detection Limit		
September 2015	*1*	Area	4,6-Dinitro-2-methylphenol	< Detection Limit		
September 2015	*1*	Area	2,4-Dinitrophenol	< Detection Limit		
September 2015	*1*	Area	2,4-Dinitrotoluene	< Detection Limit		
September 2015	*1*	Area	2,6-Dinitrotoluene (2,6-DNT)	< Detection Limit		
September 2015	*1*	Area	Fluoranthene	< Detection Limit		
September 2015	*1*	Area	Fluorene	< Detection Limit		

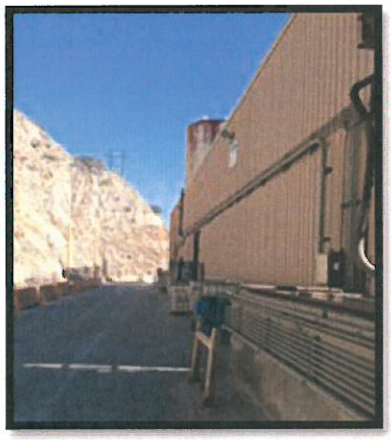
September 2015	*1*	Area	Hexachlorobenzene	< Detection Limit		
September 2015	*1*	Area	Hexachlorobutadiene	< Detection Limit		
September 2015	*1*	Area	Hexachlorocyclopentadiene	< Detection Limit		
September 2015	*1*	Area	Hexachloroethane	< Detection Limit		
September 2015	*1*	Area	Isophorone	< Detection Limit		
September 2015	*1*	Area	4-Methylphenol	< Detection Limit		
September 2015	*1*	Area	2-Methylphenol (2-Cresol)	< Detection Limit		
September 2015	*1*	Area	3-Methylphenol (3-Cresol)	< Detection Limit		
September 2015	*1*	Area	N-Nitroso-Di-n-propylamine	< Detection Limit		
September 2015	*1*	Area	2-Nitroaniline	< Detection Limit		
September 2015	*1*	Area	3-Nitroaniline	< Detection Limit		
September 2015	*1*	Area	4-Nitroaniline	< Detection Limit		
September 2015	*1*	Area	Nitrobenzene (NB)	< Detection Limit		
September 2015	*1*	Area	4-Nitrophenol	< Detection Limit		
September 2015	*1*	Area	2-Nitrophenol (o-Nitrophenol)	< Detection Limit		
September 2015	*1*	Area	N-nitrosodiphenylamine	< Detection Limit		
September 2015	*1*	Area	Pentachlorophenol	< Detection Limit		
September 2015	*1*	Area	Phenanthrene	< Detection Limit		
September 2015	*1*	Area	Phenol	< Detection Limit		
September 2015	*1*	Area	Pyrene	< Detection Limit		
September 2015	*1*	Area	1,2,4-Trichlorobenzene	< Detection Limit		
September 2015	*1*	Area	2,4,5-Trichlorophenol	< Detection Limit		
September 2015	*1*	Area	2,4,6-Trichlorophenol	< Detection Limit		
September 2015	*1*	Area	Benzo(a)anthracene	< Detection Limit		
September 2015	*1*	Area	Benzo(a)pyrene	< Detection Limit		
September 2015	*1*	Area	Benzo(b)fluoranthene	< Detection Limit		
September 2015	*1*	Area	Benzo(k)fluoranthene	< Detection Limit		
September 2015	*1*	Area	Chrysene	< Detection Limit		
September 2015	*1*	Area	Dibenzo(a,h)anthracene	< Detection Limit		
September 2015	*1*	Area	Indeno(1,2,3-cd)pyrene	< Detection Limit		
September 2015	*1*	Area	C9-C11 Petroleum Hydrocarbons	442.28 mg/m^3	Not established[2]	Not Established
September 2015	*1*	Area	C12-C13 Petroleum Hydrocarbons	186.06 mg/m^3	Not established[2]	Not Established
September 2015	*1*	Area	C14-C15 Petroleum Hydrocarbons	657.51 mg/m^3	Not established[2]	Not Established
September 2015	*1*	Area	C16-C17 Petroleum Hydrocarbons	292.49 mg/m^3	Not established[2]	Not Established
September 2015	*1*	Area	C18-C19 Petroleum Hydrocarbons	5.32 mg/m^3	Not established[2]	Not Established
September 2015	*1*	Area	C20-C21 Petroleum Hydrocarbons	4.70 mg/m^3	Not established[2]	Not Established
September 2015	*1*	Area	C22-C23 Petroleum Hydrocarbons	3.00 mg/m^3	Not established[2]	Not Established
September 2015	*1*	Area	C24-C25 Petroleum Hydrocarbons	0.02 mg/m^3	Not established[2]	Not Established
September 2015	*1*	Area	C26-C27 Petroleum Hydrocarbons	2.48 mg/m^3	Not established[2]	Not Established
September 2015	*1*	Area	C28-C29 Petroleum Hydrocarbons	0.82 mg/m^3	Not established[2]	Not Established
September 2015	*1*	Area	C30-C31 Petroleum Hydrocarbons	1.32 mg/m^3	Not established[2]	Not Established
September 2015	*1*	Area	C32-C33 Petroleum Hydrocarbons	0.69 mg/m^3	Not established[2]	Not Established
September 2015	*1*	Area	C34-C35 Petroleum Hydrocarbons	< Detection Limit		
September 2015	*1*	Area	C36-C37 Petroleum Hydrocarbons	< Detection Limit		
September 2015	*1*	Area	C38-C39 Petroleum Hydrocarbons	< Detection Limit		
September 2015	*1*	Area	C40-C41 Petroleum Hydrocarbons	< Detection Limit		
September 2015	*1*	Area	TPH Total (C9-C41)	1600.43 mg/m^3	Not established[2]	Not Established
September 2015	*1*	Area	Ethanol	0.0301 ppmV	1000	OSHA PEL
September 2015	*1*	Area	Acetone	0.0112 ppmV	250	ACGIH TLV
September 2015	*1*	Area	2-Propanol	0.0074 ppmV	200	ACGIH TLV
September 2015	*1*	Area	Methylene Chloride (DCM)	0.0956 ppmV	25	OSHA PEL
September 2015	*1*	Area	Carbon Disulfide	0.0636 ppmV	30 1	FMI Ceiling FMI OEL
September 2015	*1*	Area	2-Butanone (MEK)	0.0042 ppmV	200	ACGIH TLV

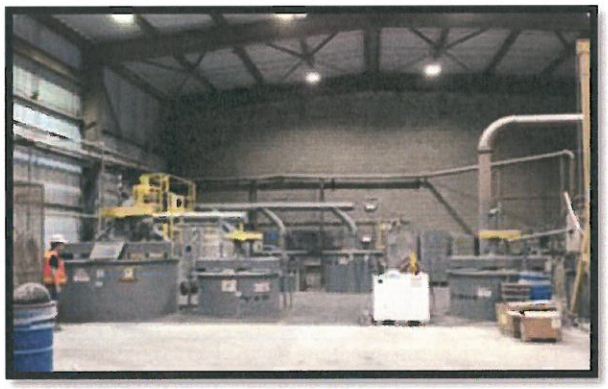
September 2015	*1*	Area	Ethyl Acetate	0.0024 ppmV	400	ACGIH TLV
September 2015	*1*	Area	Tetrahydrofuran	0.0073 ppmV	50	ACGIH TLV
September 2015	*1*	Area	Toluene	0.0113 ppmV	20	FMI OEL
September 2015	*1*	Area	Ethylbenzene	0.0041 ppmV	20	FMI OEL
September 2015	*1*	Area	m & p-Xylene	0.0163 ppmV	100	FMI OEL
September 2015	*1*	Area	o-Xylene	0.0068 ppmV	100	FMI OEL
September 2015	*1*	Area	4-Ethyltoluene	0.0028 ppmV	Not established[2]	Not Established
September 2015	*1*	Area	1,3,5-Trimethylbenzene	0.0048 ppmV	25	ACGIH TLV
September 2015	*1*	Area	1,2,4-Trimethylbenzene	0.0168 ppmV	25	ACGIH TLV
September 2015	*1*	Area	Chlorodifluoromethane	< Detection Limit		
September 2015	*1*	Area	Propene	< Detection Limit		
September 2015	*1*	Area	Dichlorodifluoromethane	< Detection Limit		
September 2015	*1*	Area	Chloromethane	< Detection Limit		
September 2015	*1*	Area	Dichlorotetrafluoroethane	< Detection Limit		
September 2015	*1*	Area	Vinyl Chloride	< Detection Limit		
September 2015	*1*	Area	Methanol	< Detection Limit		
September 2015	*1*	Area	1,3-Butadiene	< Detection Limit		
September 2015	*1*	Area	Bromomethane	< Detection Limit		
September 2015	*1*	Area	Chloroethane	< Detection Limit		
September 2015	*1*	Area	Dichlorofluoromethane	< Detection Limit		
September 2015	*1*	Area	Vinyl Bromide	< Detection Limit		
September 2015	*1*	Area	Trichlorofluoromethane	< Detection Limit		
September 2015	*1*	Area	Acrylonitrile	< Detection Limit		
September 2015	*1*	Area	1,1-Dichloroethene	< Detection Limit		
September 2015	*1*	Area	Allyl Chloride	< Detection Limit		
September 2015	*1*	Area	Trichlorotrifluoroethane	< Detection Limit		
September 2015	*1*	Area	trans-1,2-Dichloroethene	< Detection Limit		
September 2015	*1*	Area	1,1-Dichloroethane	< Detection Limit		
September 2015	*1*	Area	Methyl Tert Butyl Ether (MTBE)	< Detection Limit		
September 2015	*1*	Area	Vinyl Acetate	< Detection Limit		
September 2015	*1*	Area	cis-1,2-Dichloroethene	< Detection Limit		
September 2015	*1*	Area	Hexane	< Detection Limit		
September 2015	*1*	Area	Chloroform	< Detection Limit		
September 2015	*1*	Area	1,2-Dichloroethane	< Detection Limit		
September 2015	*1*	Area	1,1,1-Trichloroethane	< Detection Limit		
September 2015	*1*	Area	Benzene	< Detection Limit		
September 2015	*1*	Area	Carbon Tetrachloride	< Detection Limit		
September 2015	*1*	Area	Cyclohexane	< Detection Limit		
September 2015	*1*	Area	1,2-Dichloropropane	< Detection Limit		
September 2015	*1*	Area	Bromodichloromethane	< Detection Limit		
September 2015	*1*	Area	1,4-Dioxane	< Detection Limit		
September 2015	*1*	Area	Trichloroethene (TCE)	< Detection Limit		
September 2015	*1*	Area	2,2,4-Trimethylpentane	< Detection Limit		
September 2015	*1*	Area	Heptane	< Detection Limit		
September 2015	*1*	Area	cis-1,3-Dichloropropene	< Detection Limit		
September 2015	*1*	Area	4-Methyl-2-pentanone (MiBK)	< Detection Limit		
September 2015	*1*	Area	trans-1,3-Dichloropropene	< Detection Limit		
September 2015	*1*	Area	1,1,2-Trichloroethane	< Detection Limit		
September 2015	*1*	Area	2-Hexanone (MBK)	< Detection Limit		
September 2015	*1*	Area	Dibromochloromethane	< Detection Limit		
September 2015	*1*	Area	1,2-Dibromoethane	< Detection Limit		
September 2015	*1*	Area	Tetrachloroethene (PCE)	< Detection Limit		
September 2015	*1*	Area	Chlorobenzene	< Detection Limit		

September 2015	*1*	Area	Bromoform	< Detection Limit		
September 2015	*1*	Area	Styrene	< Detection Limit		
September 2015	*1*	Area	1,1,2,2-Tetrachloroethane	< Detection Limit		
September 2015	*1*	Area	Benzyl Chloride (a-Chlorotoluene)	< Detection Limit		
September 2015	*1*	Area	1,3-Dichlorobenzene	< Detection Limit		
September 2015	*1*	Area	1,4-Dichlorobenzene	< Detection Limit		
September 2015	*1*	Area	1,2-Dichlorobenzene	< Detection Limit		
September 2015	*1*	Area	1,2,4-Trichlorobenzene	< Detection Limit		
September 2015	*1*	Area	Hexachlorobutadiene	< Detection Limit		
September 2015	*1*	Area	TIC[3] - Butanal *(Butyraldehyde)*	0.029 ppmV	25 ppm	< OEL
September 2015	*1*	Area	TIC[3] - 1-Butanol	0.030 ppmV	20 ppm	< OEL
September 2015	*1*	Area	TIC[3] - Unknown Hydrocarbon #1	0.021 ppmV	Not established[2]	Not Established
September 2015	*1*	Area	TIC[3] - 2-Ethylhexanal	0.179 ppmV	Not established[2]	Not Established
September 2015	*1*	Area	TIC[3] - Butyl Ester butanoic acid	0.023 ppmV	Not established[2]	Not Established
September 2015	*1*	Area	TIC[3] - 2-Ethyl-2-hexenal	0.130 ppmV	Not established[2]	Not Established
September 2015	*1*	Area	TIC[3] - C10H12 Hydrocarbon #1	0.016 ppmV	Not established[2]	Not Established
September 2015	*1*	Area	TIC[3] - C10H12 Hydrocarbon #2	0.019 ppmV	Not established[2]	Not Established
September 2015	*1*	Area	TIC[3] - Naphthalene	0.022 ppmV	10 ppm	< OEL
September 2015	*1*	Area	TIC[3] - 2,6,8-Trimethyl-4-nonanone	0.026 ppmV	Not established[2]	Not Established
September 2015	*1*	Area	TIC[3] - Unknown Hydrocarbon #2	0.056 ppmV	Not established[2]	Not Established
September 2015	*1*	Area	TIC[3] - Unknown Hydrocarbon #3	0.027 ppmV	Not established[2]	Not Established
September 2015	*1*	Area	TIC[3] - Unknown Hydrocarbon #4	0.027 ppmV	Not established[2]	Not Established
September 2015	*1*	Area	TIC[3] - C11H14 Hydrocarbon #1	0.029 ppmV	Not established[2]	Not Established
September 2015	*1*	Area	TIC[3] - C11H14 Hydrocarbon #2	0.034 ppmV	Not established[2]	Not Established
September 2015	*1*	Area	TIC[3] - Unknown Hydrocarbon #5	0.023 ppmV	Not established[2]	Not Established
September 2015	*1*	Area	TIC[3] - C11H14 Hydrocarbon #3	0.016 ppmV	Not established[2]	Not Established
September 2015	*1*	Area	TIC[3] - Unknown Hydrocarbon #6	0.020 ppmV	Not established[2]	Not Established
September 2015	*1*	Area	TIC[3] - Methylnaphthalene #1	0.029 ppmV	Not established[2]	Not Established
September 2015	*1*	Area	TIC[3] - Methylnaphthalene #2	0.019 ppmV	Not established[2]	Not Established

[1]C – Ceiling: The concentration that shall not be exceeded during any part of the working exposure
[2]Not established – PEL/OEL has not been established for this analyte
[3]TIC – Tentatively identified chemicals

3. XANTHATE MIXING REAGENT BUILDING





Sampling Conducted:

Quantitative Samples – Samples collected with air sampling pump/collection media and sent to a lab for analysis

Area Samples – Collected in the area of the potential contaminant. **Can't be used for personal exposures or** compliance; used for control recommendations

Personal Samples – Samples collected in the breathing zone of employee and are used to determine health hazard potential and compliance with regulations.

Xanthate Mixing Sampling Summary: Carbon disulfide is a decomposition product of xanthate. Quantitative sampling was completed in various locations inside and outside of the Xanthate Mixing building. The xanthate storage tank has a passive exhaust that opens above the lime room vault and is where the highest result of 31ppm was collected. Area monitoring has been conducted outside of the Xanthate Mixing building, including the lime room, and did not indicate carbon disulfide above exposure standards. The xanthate storage passive exhaust vent will be redesigned in the future to ventilate to the outside. Sampling conducted in September 2015 was performed at the mixing tank ventilation exhaust at the roof of the xanthate mixing building. Sampling was conducted to identify any additional analytes of concern that may require personal air sampling. No additional analytes were identified, no additional personal air sampling is required.

Xanthate Mixing Quantitative Sample Results

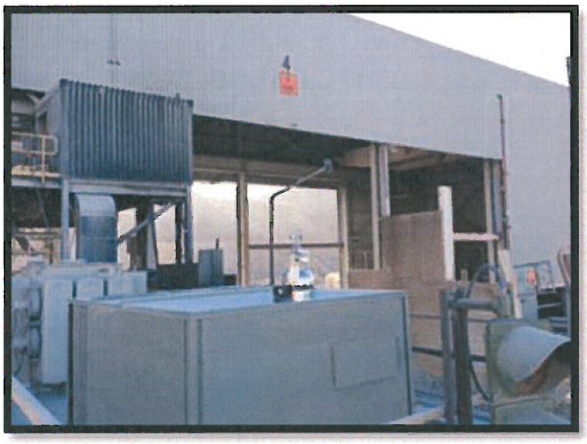
Sampling Date	# of Samples	Sample Type	Analyte	Result	Occupational Exposure Limit	Conclusion
April 2015	1	Personal	Carbon Disulfide	< 0.15 ppm	1 ppm	< OEL
April 2015	3	Area	Carbon Disulfide	< 0.14-0.15 ppm	1 ppm	< OEL
May 2015	4	Area	Carbon Disulfide	0.09-31 ppm	1 ppm	> OEL
September 2015	1	Area	Sulfuric Acid	0.036 mg/m^3	1 mg/m^3	< OEL
September 2015	1	Area	Hydrofluoric Acid	< Detection Limit		
September 2015	1	Area	Hydrochloric Acid	< Detection Limit		
September 2015	1	Area	Hydrobromic Acid	< Detection Limit		
September 2015	1	Area	Nitric Acid	< Detection Limit		
September 2015	1	Area	Phosphoric Acid	< Detection Limit		
September 2015	1	Area	Carbonyl Sulfide/Sulfur Dioxide	0.014 ppmV	5 ppm (COS) 2 ppm (SO_2)	< OEL
September 2015	1	Area	Ethyl Mercaptan	0.016 ppmV	0.5 ppm	< OEL
September 2015	1	Area	Carbon Disulfide	4.230 ppmV	1 ppm	> OEL
September 2015	1	Area	Total Reduced Sulfurs as H2S	4.250 ppmV	Not established[2]	Not Established
September 2015	1	Area	Hydrogen Sulfide	< Detection Limit		
September 2015	1	Area	Methyl Mercaptan	< Detection Limit		
September 2015	1	Area	Dimethyl Sulfide	< Detection Limit		
September 2015	1	Area	Isopropyl Mercaptan	< Detection Limit		
September 2015	1	Area	tert-Butyl Mercaptan	< Detection Limit		
September 2015	1	Area	n-Propyl Mercaptan	< Detection Limit		
September 2015	1	Area	Methylethylsulfide	< Detection Limit		
September 2015	1	Area	sec-Butyl Mercaptan	< Detection Limit		
September 2015	1	Area	Thiophene	< Detection Limit		
September 2015	1	Area	iso-Butyl Mercaptan	< Detection Limit		
September 2015	1	Area	Diethyl Sulfide	< Detection Limit		
September 2015	1	Area	n-Butyl Mercaptan	< Detection Limit		
September 2015	1	Area	Dimethyl Disulfide	< Detection Limit		
September 2015	1	Area	2-methylthiophene	< Detection Limit		
September 2015	1	Area	3-Methylthiophene	< Detection Limit		
September 2015	1	Area	Tetrahydrothiophene	< Detection Limit		
September 2015	1	Area	Bromothiophene	< Detection Limit		
September 2015	1	Area	Thiophenol	< Detection Limit		
September 2015	1	Area	Diethyl disulfide	< Detection Limit		
September 2015	1	Area	Total Unidentified Sulfur	< Detection Limit		
September 2015	1	Area	Ethanol	0.3180 ppmV	1000 ppm	< OEL
September 2015	1	Area	Acetone	0.0071 ppmV	250 ppm	< OEL
September 2015	1	Area	2-Propanol	0.0659 ppmV	200 ppm	< OEL
September 2015	1	Area	Carbon Disulfide	1.8700 ppmV	1 ppm	> OEL
September 2015	1	Area	2-Butanone (MEK)	0.0025 ppmV	200 ppm	< OEL
September 2015	1	Area	Toluene	0.0018 ppmV	20 ppm	< OEL
September 2015	1	Area	Chlorodifluoromethane	< Detection Limit		
September 2015	1	Area	Propene	< Detection Limit		
September 2015	1	Area	Dichlorodifluoromethane	< Detection Limit		
September 2015	1	Area	Chloromethane	< Detection Limit		
September 2015	1	Area	Dichlorotetrafluoroethane	< Detection Limit		
September 2015	1	Area	Vinyl Chloride	< Detection Limit		
September 2015	1	Area	Methanol	< Detection Limit		
September 2015	1	Area	1,3-Butadiene	< Detection Limit		

September 2015	1	Area	Bromomethane	< Detection Limit
September 2015	1	Area	Chloroethane	< Detection Limit
September 2015	1	Area	Dichlorofluoromethane	< Detection Limit
September 2015	1	Area	Vinyl Bromide	< Detection Limit
September 2015	1	Area	Trichlorofluoromethane	< Detection Limit
September 2015	1	Area	Acrylonitrile	< Detection Limit
September 2015	1	Area	1,1-Dichloroethene	< Detection Limit
September 2015	1	Area	Methylene Chloride (DCM)	< Detection Limit
September 2015	1	Area	Allyl Chloride	< Detection Limit
September 2015	1	Area	Trichlorotrifluoroethane	< Detection Limit
September 2015	1	Area	trans-1,2-Dichloroethene	< Detection Limit
September 2015	1	Area	1,1-Dichloroethane	< Detection Limit
September 2015	1	Area	Methyl Tert Butyl Ether (MTBE)	< Detection Limit
September 2015	1	Area	Vinyl Acetate	< Detection Limit
September 2015	1	Area	cis-1,2-Dichloroethene	< Detection Limit
September 2015	1	Area	Hexane	< Detection Limit
September 2015	1	Area	Chloroform	< Detection Limit
September 2015	1	Area	Ethyl Acetate	< Detection Limit
September 2015	1	Area	Tetrahydrofuran	< Detection Limit
September 2015	1	Area	1,2-Dichloroethane	< Detection Limit
September 2015	1	Area	1,1,1-Trichloroethane	< Detection Limit
September 2015	1	Area	Benzene	< Detection Limit
September 2015	1	Area	Carbon Tetrachloride	< Detection Limit
September 2015	1	Area	Cyclohexane	< Detection Limit
September 2015	1	Area	1,2-Dichloropropane	< Detection Limit
September 2015	1	Area	Bromodichloromethane	< Detection Limit
September 2015	1	Area	1,4-Dioxane	< Detection Limit
September 2015	1	Area	Trichloroethene (TCE)	< Detection Limit
September 2015	1	Area	2,2,4-Trimethylpentane	< Detection Limit
September 2015	1	Area	Heptane	< Detection Limit
September 2015	1	Area	cis-1,3-Dichloropropene	< Detection Limit
September 2015	1	Area	4-Methyl-2-pentanone (MiBK)	< Detection Limit
September 2015	1	Area	trans-1,3-Dichloropropene	< Detection Limit
September 2015	1	Area	1,1,2-Trichloroethane	< Detection Limit
September 2015	1	Area	2-Hexanone (MBK)	< Detection Limit
September 2015	1	Area	Dibromochloromethane	< Detection Limit
September 2015	1	Area	1,2-Dibromoethane	< Detection Limit
September 2015	1	Area	Tetrachloroethene (PCE)	< Detection Limit
September 2015	1	Area	Chlorobenzene	< Detection Limit
September 2015	1	Area	Ethylbenzene	< Detection Limit
September 2015	1	Area	m & p-Xylene	< Detection Limit
September 2015	1	Area	Bromoform	< Detection Limit
September 2015	1	Area	Styrene	< Detection Limit
September 2015	1	Area	1,1,2,2-Tetrachloroethane	< Detection Limit
September 2015	1	Area	o-Xylene	< Detection Limit
September 2015	1	Area	4-Ethyltoluene	< Detection Limit
September 2015	1	Area	1,3,5-Trimethylbenzene	< Detection Limit
September 2015	1	Area	1,2,4-Trimethylbenzene	< Detection Limit
September 2015	1	Area	Benzyl Chloride (a-Chlorotoluene)	< Detection Limit

September 2015	1	Area	1,3-Dichlorobenzene	< Detection Limit		
September 2015	1	Area	1,4-Dichlorobenzene	< Detection Limit		
September 2015	1	Area	1,2-Dichlorobenzene	< Detection Limit		
September 2015	1	Area	1,2,4-Trichlorobenzene	< Detection Limit		
September 2015	1	Area	Hexachlorobutadiene	< Detection Limit		
September 2015	1	Area	TIC[3] - Acetaldehyde	0.0074 ppmV	25 ppm C[1]	< Ceiling
September 2015	1	Area	TIC[3] - 2-Methyl-1-propanal	0.4700 ppmV	25 ppm	< OEL
September 2015	1	Area	TIC[3] - 3-Methyl-1-butanol	0.3230 ppmV	100 ppm	< OEL
September 2015	1	Area	TIC[3] - 2-Methyl-1-butanol	0.3220 ppmV	Not Established	
September 2015	1	Area	TIC[3] - 1-Pentanol	0.0130 ppmV	100 ppm	< OEL
September 2015	1	Area	TIC[3] - 2-Ethylhexanal	0.0047 ppmV	Not established[2]	Not Established
September 2015	1	Area	TIC[3] - 4-Methylnonane	0.0197 ppmV	Not established[2]	Not Established
September 2015	1	Area	TIC[3] - 2-Ethyl-2-hexenal	0.0046 ppmV	Not established[2]	Not Established

[1]C – Ceiling: The concentration that shall not be exceeded during any part of the working exposure
[2]Not established – PEL/OEL has not been established for this analyte
[3]TIC – Tentatively identified chemicals

4. PRIMARY CRUSHER



Sampling Conducted:

Quantitative Samples – Samples collected with air sampling pump/collection media and sent to a lab for analysis

Area Samples – Collected in the area of the potential contaminant. **Can't be used for personal exposures or** compliance; used for control recommendations

Primary Crusher Sampling Summary: Quantitative sampling was completed at the primary crusher to determine potential analytes and concentrations from diesel exhaust. Based on the results no personal air sampling or exposure controls are required.

Primary Crusher Quantitative Sample Results

Sampling Date	# of Samples	Sample Type	Analyte	Result	Occupational Exposure Limit	Conclusion
September 2014	1	Area	Hydrogen Sulfide	< Detection Limit		
September 2014	1	Area	Carbonyl Sulfide/Sulfur Dioxide	< Detection Limit		
September 2014	1	Area	Methyl Mercaptan	< Detection Limit		
September 2014	1	Area	Ethyl Mercaptan	< Detection Limit		
September 2014	1	Area	Dimethyl Sulfide	< Detection Limit		
September 2014	1	Area	Carbon Disulfide	< Detection Limit		
September 2014	1	Area	Isopropyl Mercaptan	< Detection Limit		
September 2014	1	Area	tert-Butyl Mercaptan	< Detection Limit		
September 2014	1	Area	n-Propyl Mercaptan	< Detection Limit		
September 2014	1	Area	Methylethylsulfide	< Detection Limit		
September 2014	1	Area	sec-Butyl Mercaptan	< Detection Limit		
September 2014	1	Area	Thiophene	< Detection Limit		
September 2014	1	Area	iso-Butyl Mercaptan	< Detection Limit		
September 2014	1	Area	Diethyl Sulfide	< Detection Limit		
September 2014	1	Area	n-Butyl Mercaptan	< Detection Limit		
September 2014	1	Area	Dimethyl Disulfide	< Detection Limit		
September 2014	1	Area	2-methylthiophene	< Detection Limit		
September 2014	1	Area	3-Methylthiophene	< Detection Limit		

September 2014	1	Area	Tetrahydrothiophene	< Detection Limit
September 2014	1	Area	Bromothiophene	< Detection Limit
September 2014	1	Area	Thiophenol	< Detection Limit
September 2014	1	Area	Diethyl disulfide	< Detection Limit
September 2014	1	Area	Total Unidentified Sulfur	< Detection Limit
September 2014	1	Area	Total Reduced Sulfurs as H2S	< Detection Limit
September 2014	1	Area	Acenaphthene	< Detection Limit
September 2014	1	Area	Acenaphthylene	< Detection Limit
September 2014	1	Area	Anthracene	< Detection Limit
September 2014	1	Area	Benzo(g,h,i)perylene	< Detection Limit
September 2014	1	Area	Benzoic Acid	< Detection Limit
September 2014	1	Area	Benzyl Alcohol	< Detection Limit
September 2014	1	Area	Bis(2-Chloroethoxy)methane	< Detection Limit
September 2014	1	Area	Bis(2-Chloroethyl)ether	< Detection Limit
September 2014	1	Area	Bis(2-chloroisopropyl) ether	< Detection Limit
September 2014	1	Area	Bis(2-ethylhexyl) phthalate	< Detection Limit
September 2014	1	Area	4-Bromophenyl phenyl ether	< Detection Limit
September 2014	1	Area	Butyl benzyl phthalate	< Detection Limit
September 2014	1	Area	4-Chloro-3-methylphenol	< Detection Limit
September 2014	1	Area	4-Chloroaniline	< Detection Limit
September 2014	1	Area	2-Chloronaphthalene	< Detection Limit
September 2014	1	Area	2-Chlorophenol	< Detection Limit
September 2014	1	Area	4-Chlorophenyl phenyl ether	< Detection Limit
September 2014	1	Area	Di-n-butyl phthalate	< Detection Limit
September 2014	1	Area	Di-n-octyl phthalate (Dioctyl ester)	< Detection Limit
September 2014	1	Area	Dibenzofuran	< Detection Limit
September 2014	1	Area	1,2-Dichlorobenzene	< Detection Limit
September 2014	1	Area	1,3-Dichlorobenzene	< Detection Limit
September 2014	1	Area	1,4-Dichlorobenzene	< Detection Limit
September 2014	1	Area	3,3'-Dichlorobenzidine	< Detection Limit
September 2014	1	Area	2,4-Dichlorophenol	< Detection Limit
September 2014	1	Area	Diethyl phthalate (Diethyl ester)	< Detection Limit
September 2014	1	Area	Dimethyl phthalate (Dimethyl ester)	< Detection Limit
September 2014	1	Area	2,4-Dimethylphenol	< Detection Limit
September 2014	1	Area	4,6-Dinitro-2-methylphenol	< Detection Limit
September 2014	1	Area	2,4-Dinitrophenol	< Detection Limit
September 2014	1	Area	2,4-Dinitrotoluene	< Detection Limit
September 2014	1	Area	2,6-Dinitrotoluene (2,6-DNT)	< Detection Limit
September 2014	1	Area	Fluoranthene	< Detection Limit
September 2014	1	Area	Fluorene	< Detection Limit
September 2014	1	Area	Hexachlorobenzene	< Detection Limit
September 2014	1	Area	Hexachlorobutadiene	< Detection Limit
September 2014	1	Area	Hexachlorocyclopentadiene	< Detection Limit
September 2014	1	Area	Hexachloroethane	< Detection Limit
September 2014	1	Area	Isophorone	< Detection Limit
September 2014	1	Area	2-Methylnaphthalene	< Detection Limit
September 2014	1	Area	4-Methylphenol	< Detection Limit
September 2014	1	Area	2-Methylphenol (2-Cresol)	< Detection Limit
September 2014	1	Area	3-Methylphenol (3-Cresol)	< Detection Limit
September 2014	1	Area	N-Nitroso-Di-n-propylamine	< Detection Limit
September 2014	1	Area	Naphthalene	< Detection Limit

September 2014	1	Area	2-Nitroaniline	< Detection Limit		
September 2014	1	Area	3-Nitroaniline	< Detection Limit		
September 2014	1	Area	4-Nitroaniline	< Detection Limit		
September 2014	1	Area	Nitrobenzene (NB)	< Detection Limit		
September 2014	1	Area	4-Nitrophenol	< Detection Limit		
September 2014	1	Area	2-Nitrophenol (o-Nitrophenol)	< Detection Limit		
September 2014	1	Area	N-nitrosodiphenylamine	< Detection Limit		
September 2014	1	Area	Pentachlorophenol	< Detection Limit		
September 2014	1	Area	Phenanthrene	< Detection Limit		
September 2014	1	Area	Phenol	< Detection Limit		
September 2014	1	Area	Pyrene	< Detection Limit		
September 2014	1	Area	1,2,4-Trichlorobenzene	< Detection Limit		
September 2014	1	Area	2,4,5-Trichlorophenol	< Detection Limit		
September 2014	1	Area	2,4,6-Trichlorophenol	< Detection Limit		
September 2014	1	Area	Benzo(a)anthracene	< Detection Limit		
September 2014	1	Area	Benzo(a)pyrene	< Detection Limit		
September 2014	1	Area	Benzo(b)fluoranthene	< Detection Limit		
September 2014	1	Area	Benzo(k)fluoranthene	< Detection Limit		
September 2014	1	Area	Chrysene	< Detection Limit		
September 2014	1	Area	Dibenzo(a,h)anthracene	< Detection Limit		
September 2014	1	Area	Indeno(1,2,3-cd)pyrene	< Detection Limit		
September 2014	1	Area	C9-C11 Petroleum Hydrocarbons	41.931 mg/m^3	Not established[2]	Not Established
September 2014	1	Area	C12-C13 Petroleum Hydrocarbons	11.695 mg/m^3	Not established[2]	Not Established
September 2014	1	Area	C14-C15 Petroleum Hydrocarbons	47.189 mg/m^3	Not established[2]	Not Established
September 2014	1	Area	C16-C17 Petroleum Hydrocarbons	19.491 mg/m^3	Not established[2]	Not Established
September 2014	1	Area	C18-C19 Petroleum Hydrocarbons	15.901 mg/m^3	Not established[2]	Not Established
September 2014	1	Area	C20-C21 Petroleum Hydrocarbons	< Detection Limit		
September 2014	1	Area	C22-C23 Petroleum Hydrocarbons	18.722 mg/m^3	Not established[2]	Not Established
September 2014	1	Area	C24-C25 Petroleum Hydrocarbons	6.283 mg/m^3	Not established[2]	Not Established
September 2014	1	Area	C26-C27 Petroleum Hydrocarbons	3.898 mg/m^3	Not established[2]	Not Established
September 2014	1	Area	C28-C29 Petroleum Hydrocarbons	4.950 mg/m^3	Not established[2]	Not Established
September 2014	1	Area	C30-C31 Petroleum Hydrocarbons	< Detection Limit		
September 2014	1	Area	C32-C33 Petroleum Hydrocarbons	8.809 mg/m^3	Not established[2]	Not Established
September 2014	1	Area	C34-C35 Petroleum Hydrocarbons	< Detection Limit		
September 2014	1	Area	C36-C37 Petroleum Hydrocarbons	< Detection Limit		
September 2014	1	Area	C38-C39 Petroleum Hydrocarbons	< Detection Limit		
September 2014	1	Area	C40-C41 Petroleum Hydrocarbons	< Detection Limit		
September 2014	1	Area	TPH Total (C9-C41)	179.522 mg/m^3	Not established[2]	Not Established

September 2014	1	Area	Toluene	0.001 ppmV	20 ppm	< OEL
September 2014	1	Area	Chlorodifluoromethane	< Detection Limit		
September 2014	1	Area	Propene	< Detection Limit		
September 2014	1	Area	Dichlorodifluoromethane	< Detection Limit		
September 2014	1	Area	Chloromethane	< Detection Limit		
September 2014	1	Area	Dichlorotetrafluoroethane	< Detection Limit		
September 2014	1	Area	Vinyl Chloride	< Detection Limit		
September 2014	1	Area	Methanol	< Detection Limit		
September 2014	1	Area	1,3-Butadiene	< Detection Limit		
September 2014	1	Area	Bromomethane	< Detection Limit		
September 2014	1	Area	Chloroethane	< Detection Limit		
September 2014	1	Area	Dichlorofluoromethane	< Detection Limit		
September 2014	1	Area	Ethanol	< Detection Limit		
September 2014	1	Area	Vinyl Bromide	< Detection Limit		
September 2014	1	Area	Acetone	< Detection Limit		
September 2014	1	Area	Trichlorofluoromethane	< Detection Limit		
September 2014	1	Area	2-Propanol	< Detection Limit		
September 2014	1	Area	Acrylonitrile	< Detection Limit		
September 2014	1	Area	1,1-Dichloroethene	< Detection Limit		
September 2014	1	Area	Methylene Chloride (DCM)	< Detection Limit		
September 2014	1	Area	Allyl Chloride	< Detection Limit		
September 2014	1	Area	Carbon Disulfide	< Detection Limit		
September 2014	1	Area	Trichlorotrifluoroethane	< Detection Limit		
September 2014	1	Area	trans-1,2-Dichloroethene	< Detection Limit		
September 2014	1	Area	1,1-Dichloroethane	< Detection Limit		
September 2014	1	Area	Methyl Tert Butyl Ether (MTBE)	< Detection Limit		
September 2014	1	Area	Vinyl Acetate	< Detection Limit		
September 2014	1	Area	2-Butanone (MEK)	< Detection Limit		
September 2014	1	Area	cis-1,2-Dichloroethene	< Detection Limit		
September 2014	1	Area	Hexane	< Detection Limit		
September 2014	1	Area	Chloroform	< Detection Limit		
September 2014	1	Area	Ethyl Acetate	< Detection Limit		
September 2014	1	Area	Tetrahydrofuran	< Detection Limit		
September 2014	1	Area	1,2-Dichloroethane	< Detection Limit		
September 2014	1	Area	1,1,1-Trichloroethane	< Detection Limit		
September 2014	1	Area	Benzene	< Detection Limit		
September 2014	1	Area	Carbon Tetrachloride	< Detection Limit		
September 2014	1	Area	Cyclohexane	< Detection Limit		
September 2014	1	Area	1,2-Dichloropropane	< Detection Limit		
September 2014	1	Area	Bromodichloromethane	< Detection Limit		
September 2014	1	Area	1,4-Dioxane	< Detection Limit		
September 2014	1	Area	Trichloroethene (TCE)	< Detection Limit		
September 2014	1	Area	2,2,4-Trimethylpentane	< Detection Limit		
September 2014	1	Area	Heptane	< Detection Limit		
September 2014	1	Area	cis-1,3-Dichloropropene	< Detection Limit		
September 2014	1	Area	4-Methyl-2-pentanone (MiBK)	< Detection Limit		
September 2014	1	Area	trans-1,3-Dichloropropene	< Detection Limit		
September 2014	1	Area	1,1,2-Trichloroethane	< Detection Limit		
September 2014	1	Area	2-Hexanone (MBK)	< Detection Limit		
September 2014	1	Area	Dibromochloromethane	< Detection Limit		
September 2014	1	Area	1,2-Dibromoethane	< Detection Limit		
September 2014	1	Area	Tetrachloroethene (PCE)	< Detection Limit		

September 2014	1	Area	Chlorobenzene	< Detection Limit		
September 2014	1	Area	Ethylbenzene	< Detection Limit		
September 2014	1	Area	m & p-Xylene	< Detection Limit		
September 2014	1	Area	Bromoform	< Detection Limit		
September 2014	1	Area	Styrene	< Detection Limit		
September 2014	1	Area	1,1,2,2-Tetrachloroethane	< Detection Limit		
September 2014	1	Area	o-Xylene	< Detection Limit		
September 2014	1	Area	4-Ethyltoluene	< Detection Limit		
September 2014	1	Area	1,3,5-Trimethylbenzene	< Detection Limit		
September 2014	1	Area	1,2,4-Trimethylbenzene	< Detection Limit		
September 2014	1	Area	Benzyl Chloride (a-Chlorotoluene)	< Detection Limit		
September 2014	1	Area	1,3-Dichlorobenzene	< Detection Limit		
September 2014	1	Area	1,4-Dichlorobenzene	< Detection Limit		
September 2014	1	Area	1,2-Dichlorobenzene	< Detection Limit		
September 2014	1	Area	1,2,4-Trichlorobenzene	< Detection Limit		
September 2014	1	Area	Hexachlorobutadiene	< Detection Limit		
September 2014	1	Area	TIC[3] - Acetaldehyde	0.001 ppmV	25 ppm C[1]	< Ceiling

[1]C – Ceiling: The concentration that shall not be exceeded during any part of the working exposure
[2]Not established – PEL/OEL has not been established for this analyte
[3]TIC – Tentatively identified chemicals

5. LEACH FIELDS

Sampling Conducted:

Screening Samples – Samples collected with direct reading AreaRaes, used to determine need for quantitative sampling.

Area Samples – Collected in the area of the potential contaminant. **Can't be used for personal exposures or** compliance; used for control recommendations

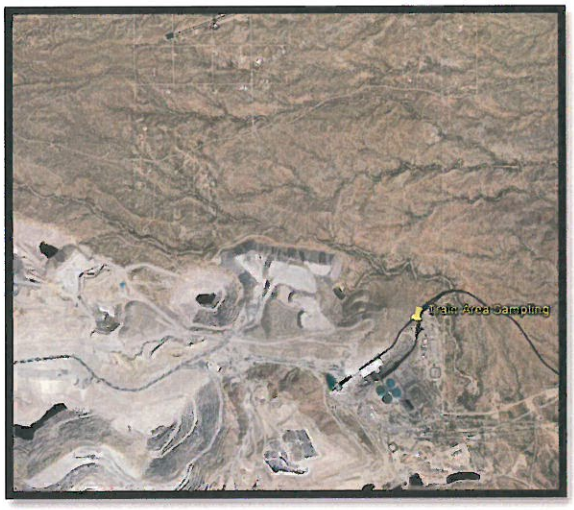
Leach field Sampling Summary: Screening samples collected in October and November of 2014 indicated low health hazard potential for analytes listed below. No quantitative sampling required. No additional PPE or controls are required.

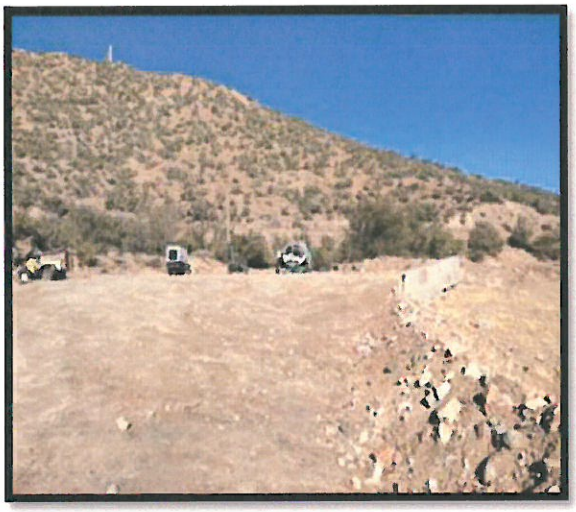
Leach Fields Screening Sample Results

Sampling Date	# of Samples	Sample Type	Analyte	Result (Peak)	Occupational Exposure Limit (Freeport McMoRan)	Conclusion
October 2014	3	Area	Sulfur Dioxide	0-0.1 ppm	2 ppm (TWA)	< OEL
	3	Area	Hydrogen Sulfide	0.1-0.4 ppm*	1 ppm (TWA)	< OEL
	3	Area	Volatile Organic Compounds	0.9-3.9 ppm	Varies	Low hazard potential
November 2014	3	Area	Nitrogen Oxide	0-0.2 ppm*	50 ppm (TWA)	< OEL
	3	Area	Nitrogen Dioxide	0 ppm*	0.2 ppm (TWA) 5 ppm (Ceiling)	< OEL and Ceiling
	3	Area	Volatile Organic Compound	0-1.9 ppm	Varies	Low hazard potential

* Results are less than the sensor resolution

6. TRAIN AREA





Sampling Conducted:

Screening Samples – Samples collected with direct reading AreaRaes, used to determine need for quantitative sampling.

Area Samples – Collected in the area of the potential contaminant. **Can't be used for personal exposures or** compliance; used for control recommendations

Train Area Sampling Summary: Screening samples collected in December 2014 and January 2015 indicated low health hazard potential for analytes listed below. No quantitative sampling required. No additional PPE or controls are required.

Train Area Screening Sample Results

Sampling Date	# of Samples	Sample Type	Analyte	Result (Peak)	Occupational Exposure Limit (Freeport McMoRan)	Conclusion
December 2014 – January 2015	5	Area	Nitrogen Oxide	0-2.8 ppm	50 ppm (TWA)	< OEL
	5	Area	Nitrogen Dioxide	0-0.1 ppm	0.2 ppm (TWA) 5 ppm (Ceiling)	< OEL and Ceiling
	5	Area	Volatile Organic Compound	1.6-10.3 ppm	Varies	Low hazard potential

7. NORTH OF PLANT OPERATIONS

Sampling Conducted:

Screening Samples – Samples collected with direct reading AreaRaes, used to determine need for quantitative sampling.

Area Samples – Collected in the area of the potential contaminant. **Can't be used for personal exposures or** compliance; used for control recommendations

North of Plant Operations Sampling Summary: Screening samples collected in October 2014, January 2015 and May 2015 indicated low health hazard potential for analytes listed below. No quantitative sampling required.

North of Sierrita Screening Sample Results

Sampling Date	# of Samples	Sample Type	Analyte	Result (Peak)	Occupational Exposure Limit	Conclusion
Oct 2014	6	Area	Sulfur Dioxide	0-0.2 ppm	2 ppm (TWA)	< OEL
	6	Area	Hydrogen Sulfide	0.2-0.7 ppm*	1 ppm (TWA)	< OEL
	6	Area	Volatile Organic Compounds	0-5.5 ppm	Varies	Low hazard potential
January 2015	6	Area	Nitrogen Oxide	0-3.5 ppm*	50 ppm (TWA)	< OEL
	6	Area	Nitrogen Dioxide	0-0.2 ppm	0.2 ppm (TWA) 5 ppm (Ceiling)	< OEL and Ceiling
	6	Area	Volatile Organic Compound	0-10.2 ppm	Varies	Low hazard potential
May 2015	2	Area	Sulfur Dioxide	0.1-0.3 ppm	2 ppm (TWA)	< OEL
	2	Area	Nitrogen Dioxide	0 ppm	0.2 ppm (TWA)	< OEL
	2	Area	Volatile Organic Compound	0.1-1.2 ppm	Varies	Low hazard potential

* Results below sensor resolution

8. SULFURIC ACID STORAGE TANKS

Sampling Conducted:

Screening Samples – Samples collected with direct reading AreaRaes.

Area Samples – Collected in the area of the potential contaminant. **Can't be used for personal exposures or** compliance; used for control recommendations

Sulfuric Acid Storage Tank Sampling Summary: Screening samples collected in December of 2013 indicate that sulfur dioxide may be present periodically due to normal venting of the storage tanks. Stationary sensors have been installed to allow employees warning before entering the immediate vicinity of the sulfuric acid storage tanks. Monitoring around the tanks indicates that only the immediate area of the tanks has potential exposures and these levels are significantly reduced based on distance. Employees are trained not to enter area while sensors are alarming, personnel carry portable monitors when performing work around sulfuric acid tanks.

Big Bird Sulfuric Acid Storage Tank Screening Sample Results

Sampling Date	# of Samples	Sample Type	Analyte	Result	Occupational Exposure Limit	Conclusion
December 2013	11	Area	Sulfur Dioxide	0-37.7 ppm (peak) 0-3.1ppm (TWA)	2 ppm (TWA)	> OEL
January 2014	4	Area	Sulfur Dioxide	0-0.6 ppm (peak) 0-0.2 ppm (TWA)	2 ppm (TWA)	< OEL

Esperanza Sulfuric Acid Storage Tank Screening Sample Results

Sampling Date	# of Samples	Sample Type	Analyte	Result	Occupational Exposure Limit	Conclusion
December 2013	4	Area	Sulfur Dioxide	3.5-15.9 ppm (peak) 0.3-3.2 ppm (TWA)	2 ppm (TWA)	> OEL
January 2014	8	Area	Sulfur Dioxide	0.1-7.2 (peak) 0-0.7 ppm (TWA)	2 ppm (TWA)	< OEL

9. ELECTRO-WINNING TANK HOUSE

Sampling Conducted:

Screening Samples – Samples collected with direct reading AreaRaes, used to determine need for quantitative sampling.

Quantitative Samples – Samples collected with air sampling pump/collection media and sent to a lab for analysis
Area Samples – Collected in the area of the potential contaminant. **Can't be used for p**ersonal exposures or compliance; used for control recommendations

Personal Samples – Samples collected in the breathing zone of employee and are used to determine health hazard potential and compliance with regulations

Tank House Sampling Summary: Screening samples collected in Feb-Apr 2015 indicated that further quantitative sampling was needed. Quantitative sampling was completed and indicate exposure levels below the established standards. Employees are currently wearing respirators with organic vapor/acid gas/P100 filter. No additional PPE or controls are required.

Tank House Screening Sample Results

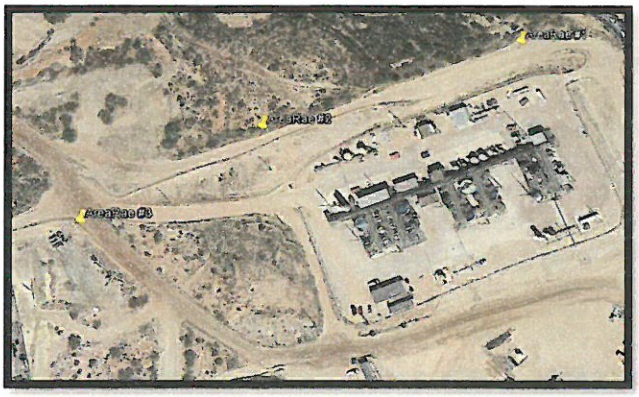
Sampling Date	# of Samples	Sample Type	Analyte	Result	Occupational Exposure Limit	Conclusion
February 2015	3	Area	Chlorine	0.1-0.5 ppm (peak) 0-0.1 ppm (TWA)	0.5 ppm	< OEL
March 2015	2	Area	Chlorine	1.2-1.4 ppm (peak) 0.1-0.6 ppm (TWA)	0.5 ppm	> OEL
April 2015	4	Area	Chlorine	0.1-0.6 ppm (peak) 0-0.2 ppm (TWA)	0.5 ppm	< OEL

TWA – Time Weighted Average
STEL – Short Term Exposure Limit

Tank House Quantitative Sample Results

Sampling Date	# of Samples	Sample Type	Analyte	Result	Occupational Exposure Limit	Conclusion
February	2	Personal	Chlorine	0.02-0.05 ppm	0.5 ppm	< OEL
February	2	Personal	Sulfuric Acid	0.089-0.15 mg/m3	1 mg/m^3	< OEL
February	2	Personal	Hydrochloric Acid	0.038 ppm	5 ppm C[1]	< OEL
February	2	Personal	Hydrobromic Acid	< Detection Limit		
February	2	Personal	Hydrofluoric Acid	< Detection Limit		
February	2	Personal	Nitric Acid	< Detection Limit		
February	2	Personal	Phosphoric Acid	< Detection Limit		
February	2	Area	Chlorine	0.037-0.1 ppm	0.5 ppm 1 ppm C[1]	
February	2	Area	Sulfuric Acid	0.075-0.141 mg/m3	1 mg/m^3	
February	2	Area	Hydrochloric Acid	0.038 ppm	5 ppm	
February	2	Area	Hydrobromic Acid	< Detection Limit		
February	2	Area	Hydrofluoric Acid	< Detection Limit		
February	2	Area	Nitric Acid	< Detection Limit		
February	2	Area	Phosphoric Acid	< Detection Limit		

10. WATER TREATMENT TEST FACILITY



Sampling Conducted:

Screening Samples – Samples collected with direct reading AreaRaes.

Area Samples – Collected in the area of the potential contaminant. **Can't be used for personal exposures or** compliance; used for control recommendations

Water Treatment Test Facility Sampling Summary: Screening samples collected in September 2014 indicated low health hazard potential for analytes listed below. No quantitative sampling required. No additional PPE or controls are required.

Water Treatment Test Facility Screening Sample Results

Sampling Date	# of Samples	Sample Type	Analyte	Result (Peak)	Occupational Exposure Limit	Conclusion
September 2014	6	Area	Sulfur Dioxide	0-0.2 ppm	2 ppm (TWA)	< OEL
	6	Area	Hydrogen Sulfide	0.2-0.7 ppm*	1 ppm (TWA)	< OEL
	6	Area	Volatile Organic Compounds	0.1-5.3 ppm	Varies	Low hazard potential

* Results below sensor resolution

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MEMORANDUM

To:
Eric Werner
Environmental Engineer I
Freeport-McMoRan Sierrita Inc.
6200 West Duval Mine Road
Green Valley, AZ 85622

Copies:

From:
Roger Felty, Arcadis

Date:
March 31, 2016

ARCADIS Project No.:
AZ001233.0017

Subject:
Sierrita Odor Evaluation – Summary Report

In December 2014, Freeport-McMoRan Sierrita Inc. (Sierrita) engaged Arcadis to investigate odor complaints from a few residents of the Ruby Star Airpark, a neighborhood located approximately two miles north-northwest of Sierrita, and to assess whether Sierrita operations could be the source of the alleged odors. This memorandum summarizes the following activities undertaken by Arcadis during this evaluation:

- December 2014 Desktop Review of Sierrita Odor Complaint Records
- January 2015 Site Visit and Pima County Department of Environmental Quality (PDEQ) Meeting
- March 2015 Site Visit and Odor Screening Sample Collection
- Odor Dispersion Modeling
- Evaluation of the Atmospheric Behavior and Odor Thresholds of Carbon Disulfide and Other Sulfur-Containing Constituents

The following attachments are also included with this memorandum:

- St. Croix Sensory, Inc. Odor Panel Report (March 19, 2015)
- PDEQ Odor Observation/Assessment Report Form
- Odor Intensity Reference Scales, St. Croix Sensory, Inc. / McGinley Associates, P.A., 2000
- Odor Dispersion Modeling Assessment Report / Arcadis, March 2016

- Evaluation of the Atmospheric Behavior and Odor Thresholds of Carbon Disulfide and Other Sulfur-Containing Constituents / Arcadis, March 22, 2016

As summarized below and presented in detail in the attached documents, the Arcadis odor investigation at Sierrita has revealed the following results.

Some residents of Ruby Star Airpark have complained about odors allegedly from Sierrita while many residents have not smelled odors or have not smelled odors at a level to cause complaint.

Arcadis staff and Sierrita staff have smelled an odor north of the Sierrita Mine similar to the characteristics of the odor smelled on site, but the odor faded within a few minutes. When detected, the odor was estimated to range from one to two on the PDEQ scale of zero to five; with one being detectable but characteristics not distinguishable and two being distinguishable and definite, but not necessarily objectionable.

Odor dispersion modeling results for seven sources at Sierrita predict odor concentrations at the Ruby Star Airpark that are below the level considered likely to result in complaints from members of the general public.

Maximum concentrations of sulfur-containing constituents measured on-site at Sierrita are below or only slightly above values that the United States Environmental Protection Agency (U.S. EPA) uses for public protection. The on-site concentrations would be diluted via air dispersion during atmospheric transport and Arcadis does not expect that off-site receptors would be exposed to sulfur-containing constituents above the U.S. EPA Acute Exposure Guideline Level values.

December 2014 – Desktop Review of Sierrita Odor Complaint Records

Sierrita provided odor complaint records for the period July 15, 2014, through December 8, 2014, for Arcadis review. Review of these records revealed the following:

- 54 separate odor complaints were received by Sierrita during this time:
  - 35 complaints were received from residents of Ruby Star Airpark, approximately two miles north-northwest of the Sierrita ore processing activities
  - 19 complaints were received from complainants outside of Ruby Star Airpark
- 31 complaints from Ruby Star Airpark noted wind direction:
  - 19 complaints noted wind direction from the southeast
  - 8 complaints noted wind direction from the south or southwest
  - 4 complaints noted variable wind direction
- 26 complaints from Ruby Star Airpark noted wind direction and time of observed odor:
  - 3 complaints noted 5am – 6am; wind direction from the southeast for all complaints

  - 17 complaints noted 7am – 10am; southeast wind – 10 complaints; south wind – 3 complaints; southwest wind – 4 complaints
  - 2 complaints noted 10am – 11am; southeast wind – 1 complaint; southwest wind – 1 complaint
  - 4 complaints noted 12:30pm to 7:30pm; southeast wind – 3 complaints; south-southeast wind – 1 complaint
- None of the complaints from outside Ruby Star Airpark noted wind direction
- 11 complaints from outside Ruby Star Airpark noted time of day; all between 7am and 9am
- 10 complaints from outside Ruby Star Airpark noted a location or area where the odor was perceived: intersection of McGee Ranch Road and Mission Road – 7 complaints; intersection of Continental Road and Duval Mine Road – 2 complaints; intersection of Duval Mine Road and Mission Road – 1 complaint

January 2015 – Site Visit and PDEQ Meeting

From January 20-22, 2015, Arcadis team members were on site for initial meetings with Sierrita Environmental staff, to meet with Ruby Star Airpark residents, and to observe Sierrita process operations.

On the morning of January 20, 2015, a resident of the Ruby Star Airpark reported an odor complaint to Sierrita. Arcadis staff immediately mobilized to McGee Ranch Road south of the Ruby Star Airpark and noted a mild breeze from the south or southeast carrying a mild odor of petroleum or metallic-type character.

On January 21 and 22, 2015, Arcadis met with a total of 11 residents of the Ruby Star Airpark to listen to their experiences regarding odor issues in the area. Four residents stated they had never smelled any noticeable odors. Another resident smelled odors occasionally, but did not find them offensive enough to complain to PDEQ. The remaining six residents stated they frequently smelled foul odors that they believe originate from Sierrita. These six residents are the primary complainants in the Sierrita and PDEQ odor complaint records. These residents noted that odors are usually perceived in the early morning hours when wind direction is from the southeast and wind speeds are less than about five miles per hour. Five of the residents find the odors to be offensive and negatively impacting their quality of life. One resident stated that the odors cause a physical reaction, including burning throat, nose, and mouth with difficulty breathing, forcing the resident indoors.

In between scheduled interviews with Ruby Star Airpark residents on January 21 and 22, 2015, the Arcadis team walked and drove along McGee Ranch Road evaluating local topographic features, wind patterns, development, and searching for unusual odors. During these excursions, no unusual odors were noted by Arcadis. During this time, the team encountered a Sierrita employee conducting fence maintenance on McGee Ranch Road. Arcadis asked the employee if they had ever smelled unusual

odors in the area and the employee replied that occasionally along McGee Ranch Road they had smelled odors similar to those they had also smelled in the mill processes at Sierrita.

During the January site visit, Arcadis staff observed process operations at Sierrita including ore loading and hauling from the pit, ore crushing, conveyor transport of ore, leach stockpiles, overburden stockpiles, flotation processes in the mill building, solvent extraction, thickener tanks, decant ponds, the moly roaster process, and chemical storage facilities.

On January 23, 2015, Arcadis attended a meeting with Sierrita staff and PDEQ staff to discuss the history of odor complaints in the vicinity of Sierrita and the beginning of Arcadis' evaluation of potential odor sources.

On January 28, 2015, PDEQ provided Arcadis with PDEQ records of odor complaints received from residents in the general vicinity of Sierrita.

March 2015 – Site Visit and Odor Screening Sample Collection

From March 16-19, 2015, Arcadis team members were on site to meet with Sierrita Environmental staff, observe Sierrita process operations, and collect screening level odor samples for evaluation by an odor laboratory.

Process operations observed during this visit included the tailings impoundment, the electrowinning tankhouse, the mill building, the reagent building, the tailings thickener tanks, solvent extraction, and a stormwater collection pond.

<u>March 18, 2015 Air Sampling for Odor Analysis</u>

On March 18, 2015, air samples were collected from the following sources at Sierrita:

- Moly Roaster Stack
- Mill Rougher Flotation – Pack 1, Cell 1
- Copper-Moly Thickener Tank C
- Solvent Extraction Plant 1 E-Stripper Tank
- Decant Liquid
- Xanthate Liquid Mix Tank

Air samples from each source were collected into Tedlar® (inert plastic) bags using an evacuation chamber and shipped overnight under Chain-of-Custody record to St. Croix Sensory, Inc. (St. Croix) in Stillwater, Minnesota, for odor evaluation by an odor panel. St. Croix was engaged to evaluate the samples for the following odor parameters:

- Odor Strength – The number of times the original odor sample had to be diluted with an equal volume of odor free air before the average person cannot detect (detection threshold) that an odor is present or recognize (recognition threshold) the odor that is present.

- Odor Intensity – How strong the odor is perceived by the odor panel evaluators rated against an equivalent level of n-butanol and recorded as parts per million by volume in air (ppm) of n-butanol.

- Persistence – The rate at which the intensity of an air sample changed as it was diluted with odor free air. This parameter determines the nature of the air sample to be perceived at greater distances from the source.

- Hedonic Tone – The subjective rating of pleasantness (rating of 0 to +10) or unpleasantness (rating of 0 to -10) of the air sample as observed by the odor panel evaluators.

- Odor character – A list of standard descriptors used by the odor panel evaluators to define what the air sample smelled like, noted in order of significance.

Odor panels consist of individuals (panelists) that are selected and trained following the "Guidelines for Selection and Training of Sensory Panel Members" (ASTM Special Technical Publication 758). Odor panelists are recruited from the community at large and are tested to determine their individual olfactory sensitivity using standard odorants. The panelists receive training in olfactory awareness, sniffing techniques, standardized odor descriptors, and olfactometry responses.

The samples were submitted to St. Croix for analysis by the methods EN 13725, Air Quality - Determination of Odour Concentration by Dynamic Olfactometry, and ASTM E544, Standard Practices for Referencing Suprathreshold Odor Intensity. The European Standard EN 13725 defines a method for the objective determination of the odor concentration of a gaseous sample using dynamic olfactometry with human assessors (an odor panel). The American Standard ASTM E544 establishes practices for referencing the odor intensities of any odorous material in the suprathreshold region on the ASTM Odor Intensity Referencing Scale. The method is based on the reference odorant 1-butanol (n-butanol). The suprathreshold region is an odor of sufficient strength or quantity to produce a perceptible physiological effect.

The air samples were evaluated by St. Croix on March 19, 2015. The odor panel consisted of five evaluators. Odor evaluation results were received from St. Croix on April 2, 2015 and are summarized in Table 1. A copy of the St. Croix report is attached to this memorandum. A discussion of the results

follows after the table. Please note these are screening level results that represent estimated odor parameters and should not be interpreted as absolute results.

Table 1 - Summary Results of Sierrita Odor Samples Collected March 18, 2015
St. Croix Sensory, Inc.

	Odor Strength – European Standard EN13725		ASTM E544	PERSISTENCY	ODOR CHARACTER	
Sample Description	**Detection Threshold Odor Units, OU[1]**	**Recognition Threshold Odor Units, OU[1]**	**Intensity[2] ppm n-butanol [0-5 PDEQ scale equivalent]**	**Dose-Response Slope**	**Hedonic Tone**	**Principal Odor Descriptors**
Moly Roaster Stack - Sample Port	580	310	46 [1 to 2]	-0.55	-1.2	Medicinal, Chemical, Earthy, Offensive
Flotation	330	180	117 [2]	-0.76	-4.0	Chemical, Offensive, Earthy, Fruity, Medicinal
"C" Copper/Moly Thickener Surface	150	85	58 [2]	-0.65	-2.8	Chemical, Offensive, Earthy, Medicinal
SX-1 "E" Stripper Tank - Diluted 10:1[3] (Adjusted Dilution Value)	290 (2,900)	150 (1,500)	95 [2]	-0.82	-3.6	Chemical, Offensive, Earthy, Medicinal
Decant Feed - Bottle Agitation	2,900	1,500	155 [2 to 3]	-0.61	-5.2	Offensive, Chemical, Earthy
Xanthate Mixed Diluted 10:1[3] (Adjusted Dilution Value)	3,100 (31,000)	1,600 (16,000)	195 [3]	-0.63	-5.8	Offensive, Fishy, Earthy

1. The number of times the original odor sample had to be diluted with an equal volume of odor free air before the average person cannot detect (detection threshold) that an odor is present or recognize (recognition threshold) the odor that is present.
2. Reported as the equivalent concentration of n-butanol in ppm.

3. Sample diluted 10:1 due to potential high Detection Threshold values.

Odor Strength - The threshold values obtained from odor testing are derived from dilution ratios, and are therefore dimensionless. However, the pseudo-dimensions of "Odor Units" (OU) are commonly applied to represent the dilution ratios or 'Dilution to Threshold', D-to-T. The results for the Extraction Stripper Tank and Xanthate Mixed are from samples that were diluted 10:1 when they were collected in the field because of their potential high Detection Threshold values. Accordingly, the values posted in Table 1 should be multiplied by 10 to obtain the actual field value. This is noted in the table as the Adjusted Dilution Value in parentheses.

After making this dilution value adjustment, the odor strength values in Table 1 show that the order of the samples from stronger odor to weaker odor is Xanthate Mixing Tank, Decant Feed/Extraction Stripper Tank, Moly Roaster Stack, Flotation, and Copper/Moly Thickener Surface. Odor strength detection threshold values less than 1,000 Odor Units (OU) are generally not considered to be associated with significant off-site nuisance odor sources when emitted from stack or vent sources. When emitted from area wide surface sources, the size and extent of the odor source must be taken into consideration before judging its potential off-site impact. The results for the Moly Roaster Stack, Flotation and Copper/Moly Thickener Surface were considerably less than 1,000 OU. The Extraction Stripper Tank and Decant Feed at 2,900 OU displayed similar levels that have a greater potential for off-site impact. The Xanthate Mixing Tank at 31,000 OU had the highest nuisance odor potential, although it was one of the smallest odor sources sampled in terms of surface area and volumetric flow rate. The Recognition Threshold values were, as typically expected, consistently just over half of the Detection Threshold values.

Intensity - Table 1 displays the n-butanol concentration in ppm as a standard reference compound for odor intensity. The intensity values in Table 1 show that the order of the samples from more intense odor sources to less intense odor sources is the Xanthate Mixing Tank, Decant Feed, Flotation, Extraction Stripper Tank, Copper/Moly Thickener Surface, and the Moly Roaster. Table 1 also displays the estimated equivalent intensity rating using the PDEQ five (5) step odor intensity scale. This memorandum augments the original St. Croix report with the equivalent five step rating system for illustrative purposes.

Based on field application of this five step scale, ratings of 2 or greater have been identified by communities as the level at which they would call to log a nuisance odor complaint. The ratings in Table 1, however, were taken directly from source samples and not at any receptor locations. With the exception of the Moly Roaster Stack sample, all of the results are 2 or greater, with the highest intensity, 3, associated with the Xanthate Mixing Tank. For reference, the PDEQ Odor Observation/Assessment

Report form with the 0-5 scale descriptions is attached to this memorandum, as well as the Odor Intensity Referencing Scale[1] used to estimate the 0-5 values from the n-butanol values derived by St. Croix.

Persistence - Odor sources with flatter slopes, i.e. lower negative values, are more persistent and will tend to retain their odor character over a longer distance than odor sources with steeper slopes, i.e. higher negative values. The dose-response slopes in Table 1 show that the order of the samples from more persistent odor sources to less persistent odor sources is the Moly Roaster, Decant Feed, Xanthate Mixing Tank, Copper/Moly Thickener Surface, Flotation, and the Extraction Stripper Tank.

Hedonic Tone - All six air samples evaluated by the odor laboratory were ranked on the negative side of the scale and were therefore classified as unpleasant. The Xanthate Mixing Tank had the most unpleasant odor at -5.8, and this sample was diluted 10:1. Therefore, an undiluted sample can be expected to be more unpleasant.

Odor Character – Odor character is described by odor descriptors and sensation descriptors. There are eight odor descriptor macro-categories: floral, fruity, vegetable, earthy, offensive, fishy, chemical, and medicinal. Within these macro-categories are 110 specific descriptors, e.g. chlorinous, turpentine, solvent. There are eight sensation descriptors: warm, tingling, itching, metallic, cool, sharp, pungent, and burning. Regarding odor descriptors, all of the odor samples were defined by the odor panel as being offensive and most were also defined as chemical and medicinal. The odor panel also evaluated the odor samples for sensation, where pungent and burning were the two most consistent terms used to describe the odor samples, although the relative strengths recorded for these sensations were low. Details for odor descriptors, sensation descriptors, and their relative strengths for each sample are provided in the St. Croix report.

<u>March 19, 2015 Odor Observation</u>

On the morning of March 19, 2015 the ARCADIS team and Sierrita Environmental staff mobilized to the north side of the Sierrita property south of McGee Ranch Road to inspect a stormwater collection pond designated as the O7 Pond. This pond collects stormwater runoff from the north overburden stockpiles. No odors were detected from the liquid surface of the O7 Pond. Heading south from McGee Ranch road on the dirt road into the O7 Pond, at approximately 11:00 AM and latitude 31°53'17" North, longitude 111°06'05" West, the ARCADIS team and Sierrita Environmental staff noted discernible petroleum-like odors characteristically similar to the general odors of the Sierrita Mill. The odor was noted intermittently for about three to five minutes. The odor was not continuous during this time and was not noticeable after about five minutes. When detected, the odor was estimated to range from one to two on the scale of zero

[1] Figure 3, Odor Intensity Scales for Enforcement, Monitoring, and Testing, St. Croix Sensory, Inc. / McGinley Associates, P.A., 2000

to five; with one being detectable but characteristics not distinguishable and two being distinguishable and definite, but not necessarily objectionable. At the time and location the odors were detected, winds were from the southeast and, although variable in speed, were estimated to be less than five miles per hour.

March 2016 Odor Dispersion Modeling Assessment Report

Arcadis used the CALPUFF modeling system to perform air dispersion modeling of odor emissions from the Sierrita Mine milling and processing activities and estimate off-site odor concentrations. Odor concentrations were estimated for 20 locations corresponding to the locations of odor complaints reported in the vicinity of the Sierrita Mine. The full modeling report is attached to this memorandum.

These seven odor sources at the Sierrita Mine were modeled for this evaluation:

- Moly Roaster Stack;
- Xanthate Mixing Tank Exhaust Stack;
- Decant Pond;
- Mill Copper Flotation Cell;
- Copper/Molybdenum Thickener Tank A;
- Copper/Molybdenum Thickener Tank B; and
- Copper/Molybdenum Thickener Tank C.

Odor emission rates for each modeled odor source were estimated based on measurements of odor concentrations at each source. The source odor emission rates were then modeled in CALPUFF to predict the maximum 10-minute odor concentration at each of the 20 unique locations near Sierrita.

The highest maximum 10-minute odor concentration predicted by the CALPUFF model at the 20 complaint locations is 3.6 odor units per cubic meter (OU/m^3) at a location on Duval Mine Road approximately 1.6 km (1 mi.) east of Sierrita. At the two most frequent complaint locations in the Ruby Star Airpark, the CALPUFF model predicted maximum odor concentrations of 0.39 OU/m^3 approximately 3.6 km (2.2 mi.) northwest of the mine and 0.21 OU/m^3 approximately 4.2 km (2.6 mi.) northwest of the mine.

Arizona has no numerical criteria for evaluating nuisance odor impacts, so the results of the odor dispersion modeling were assessed using 5 OU/m^3 (10-minute average) as a comparison basis. Multiple studies suggest that this odor concentration is a reasonable threshold at which an odor is considered likely to result in complaints from members of the general public. The results of the CALPUFF modeling evaluation indicate that the predicted odor concentrations at the 20 odor complaint locations modeled are less than the 5 OU/m^3 threshold.

Dispersion models are typically considered to have an inherent uncertainty factor of +/-2 to +/-4 between predicted and observed odor unit concentrations. The uncertainty tends toward the higher end of this range for shorter averaging periods (e.g., 1-hour average or less) than for longer averaging periods (24-hour to monthly or annual averages). Due to this inherent uncertainty, the results of the modeling analysis require some caution in their interpretation.

Evaluation of the Atmospheric Behavior and Odor Thresholds of Carbon Disulfide and Other Sulfur-Containing Constituents

Arcadis evaluated the atmospheric behavior and odor thresholds of carbon disulfide (CS_2) and other sulfur containing constituents measured in air samples collected by Sierrita Environmental staff at Sierrita. The evaluation was performed to assess the theory that CS_2 or other sulfur-containing constituents may potentially be sources of odors tied to complaints at off-site locations in proximity to Sierrita. The evaluation consisted of reviewing air sampling data provided to Arcadis by Freeport Minerals Corporation (Freeport) and searching readily available online sources as well as the peer-reviewed literature. Information upon which Arcadis based its evaluation includes: 1) a summary of concentrations measured on-site at the facility, 2) background information linking xanthate use to emissions, 3) a summary of atmospheric behavior, and 4) a summary of odor thresholds. The full report for this evaluation is attached to this memorandum.

As noted in the attached report, CS_2 and other sulfur-containing constituents have been measured in air samples collected from suspected emission sources at Sierrita and in ambient air samples collected north of the operating facility and south of McGee Ranch Road. Xanthates are used at the site and are reported to be sources of carbon disulfide, sulfur dioxide, and other sulfur-containing chemicals.

The atmospheric half-lives of the sulfur-containing constituents measured at Sierrita range from 10 hours (ethyl mercaptan) to 22 years (carbonyl sulfide). The half-lives for the sulfur-containing constituents are sufficiently long enough that they are capable of undergoing atmospheric transport from the facility to nearby locations before degrading.

Odor thresholds found in the literature for the sulfur-containing constituents measured at Sierrita vary so greatly that there is no way from the reported literature to define the concentration at which a typical person or most people in a group of exposed individuals would detect an odor. The literature defines lower levels at which some sensitive people have reported detecting odors, but determining whether sulfur-containing constituents appeared off-site at these concentrations was beyond the scope of this evaluation.

To contextualize potential exposure to emissions of sulfur-containing constituents from the Sierrita Mine, Arcadis compared the maximum concentration of each sulfur-containing constituent measured at Sierrita to the United States Environmental Protection Agency's (U.S. EPA) corresponding Acute Exposure

Guideline Levels (AEGLs). Arcadis made the comparison using 60-minute AEGL-1 values because 1) this criterion is the most protective of the guidance levels, 2) site emissions might linger for as long as an hour during low dispersion events, and 3) the one hour values are more health protective than those derived for shorter exposure durations. Further, the experiences described in connection with AEGL-1 level exposures most closely correspond to the alleged symptoms experienced by complainants near the Sierrita Mine. Maximum concentrations of carbon disulfide, carbonyl sulfide, and ethyl mercaptan measured on-site at Sierrita were typically two or more times lower than their corresponding 60-minute AEGL-1 values, while maximum concentrations of hydrogen sulfide and sulfur dioxide measured on-site were approximately 1.5 times greater than the 60-minute AEGL-1 values for these constituents. Receptors located off-site would not be exposed to maximum concentrations measured on-site due to dilution via air dispersion during atmospheric transport. If concentrations were diluted just two-fold, then potential receptors would not be exposed to any sulfur-containing constituent above 60-minute AEGL-1 values. Based on Arcadis' experience performing air dispersion modeling, however, dilution factors greater than two are expected. Accordingly, Arcadis does not expect that off-site receptors would be exposed to sulfur-containing constituents above their respective 60-minute AEGL-1 values. Thus, symptoms such as notable discomfort or irritation would not be expected in typical individuals.

ATTACHMENTS

- St. Croix Sensory, Inc. Odor Panel Report (March 19, 2015)
- PDEQ Odor Observation/Assessment Report Form
- Odor Intensity Reference Scales, St. Croix Sensory, Inc. / McGinley Associates, P.A., 2000
- Odor Dispersion Modeling Assessment Report / Arcadis, March 2016
- Evaluation of the Atmospheric Behavior and Odor Thresholds of Carbon Disulfide and Other Sulfur-Containing Constituents / Arcadis, March 22, 2016

ATTACHMENT

- **St. Croix Sensory, Inc. Odor Panel Report (March 19, 2015)**

St. Croix Sensory, Inc.

Arcadis US, Inc.

Sierrita Mine

Odor Evaluation Report

Report No. 1507802
03/19/15

Data Release Authorization:

Michelle R Harty

Michelle Harty
Laboratory Associate

Reviewed and Approved:

Charles M McGinley

Charles M. McGinley, P.E.
Technical Director

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St. Croix Sensory, Inc.

Odor Evaluation Report

Client: Arcadis US, Inc.

Project: Sierrita Mine

Report No.: **1507802**

Evaluation Date: 03/19/15

			ASTM E679 & EN13725		ASTM E544	PERSISTENCY	CHARACTERIZATION		
#	Field No.	Sample Description	Detection Threshold	Recognition Threshold	Intensity	Dose-Response Slope	Hedonic Tone	Principal Odor Descriptors	**Comments**
1	1A	Moly Roasta Stack - Sample Port	580	310	46	-0.55	-1.2	Medicinal, Chemical, Earthy, Offensive	
2	2A	Flotation	330	180	117	-0.76	-4.0	Chemical, Offensive, Earthy, Fruity, Medicinal	
3	3A	"C" Copper/Moly Thickener Surface	150	85	58	-0.65	-2.8	Chemical, Offensive, Earthy, Medicinal	
4	4B	SX-1 "E" Stripper Tank - Diluted 10:1	290	150	95	-0.82	-3.6	Chemical, Offensive, Earthy, Medicinal	
5	5A	Decant Feed - Bottle Agitation	2,900	1,500	155	-0.61	-5.2	Offensive, Chemical, Earthy	
6	6B	Xanthate Mixed 10:1 Diluted	3,100	1,600	195	-0.63	-5.8	Offensive, Fishy, Earthy	
7									
8									
9									
10									

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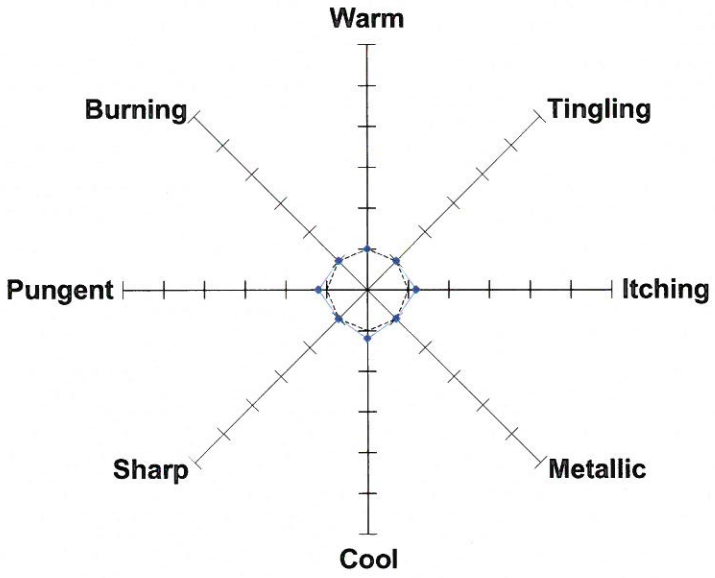
St. Croix Sensory, Inc. **Odor Evaluation Report**

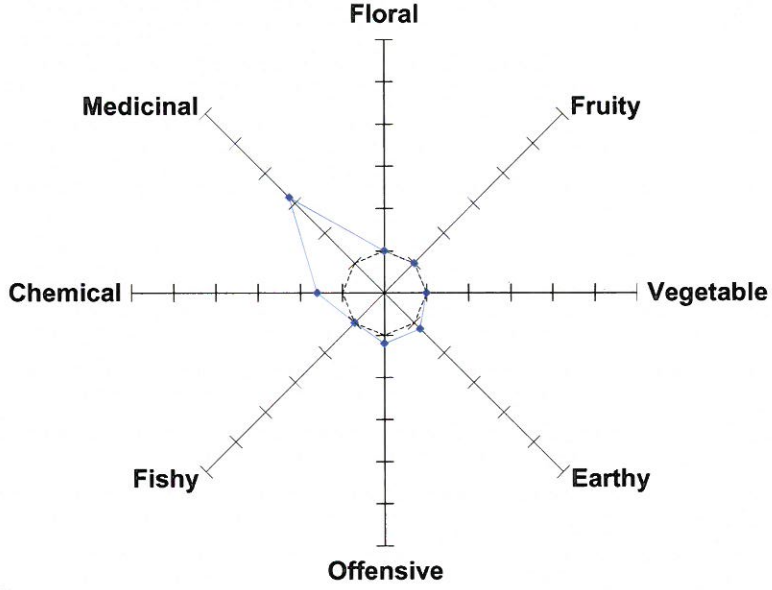
Client:	Arcadis US, Inc.	Field No.:	1A	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	Moly Roasta Stack - Sample Port	Evaluation Date:	03/19/15

Sensation Descriptor Graph

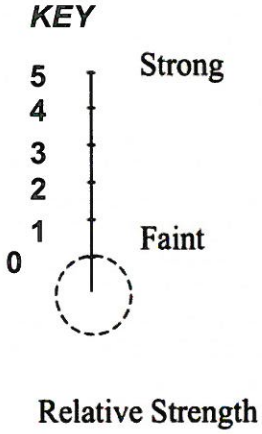


	Average Relative Strength
Warm	0.0
Tingling	0.0
Itching	0.2
Metallic	0.0
Cool	0.2
Sharp	0.0
Pungent	0.2
Burning	0.0

Odor Descriptor Graph



	Average Relative Strength
Floral	0.0
Fruity	0.0
Vegetable	0.0
Earthy	0.2
Offensive	0.2
Fishy	0.0
Chemical	0.6
Medicinal	2.2



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St. Croix Sensory, Inc.

Odor Evaluation Report

Client: Arcadis US, Inc.

Field No.: 1A

Report No.: **1507802**

Project: Sierrita Mine

Description: Moly Roasta Stack - Sample Port

Evaluation Date: 03/19/15

% of Assessors |**********|**********|**********|**********| 100%

Medicinal	**********
Disinfectant	**********
Ammonia	**********
Chlorinous	**********
Chemical	**********
Solvent	**********
Offensive	**********
Decay	**********
Earthy	**********
Stale	**********

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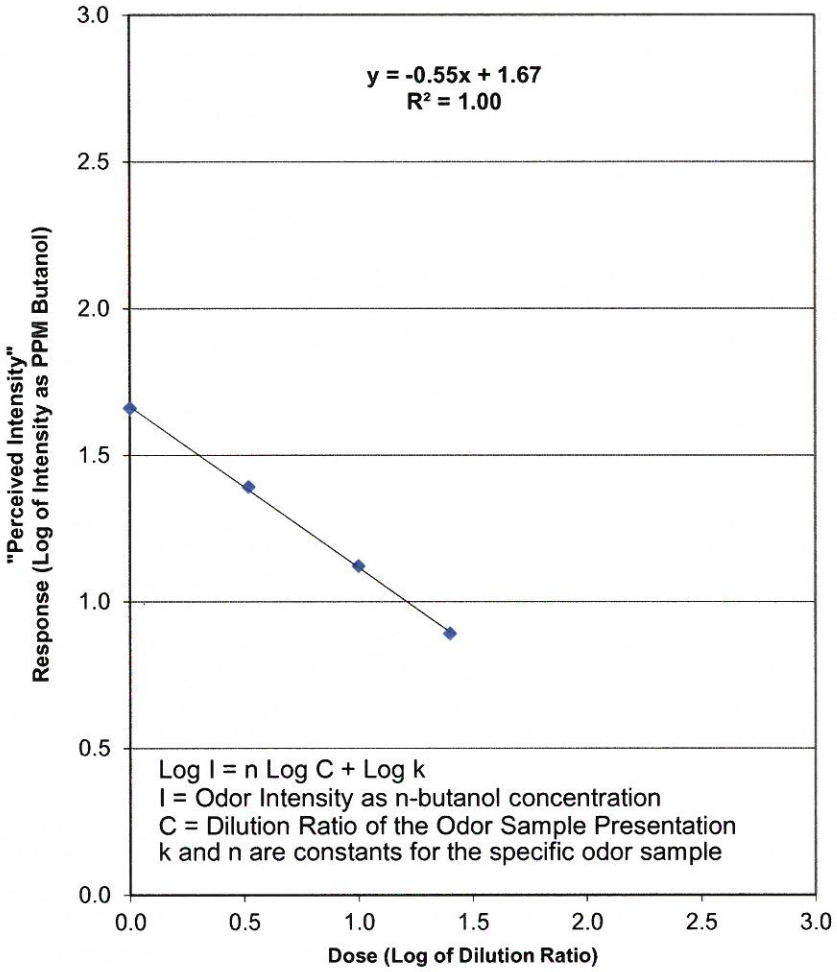
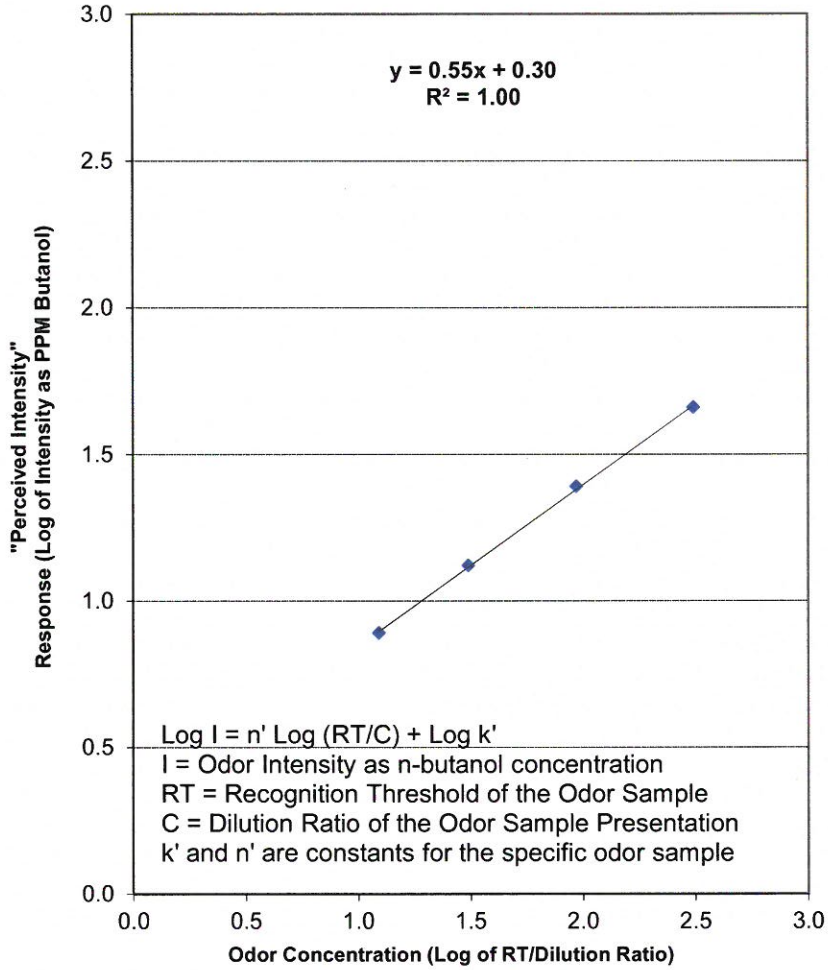
St. Croix Sensory, Inc. **Odor Evaluation Report**

Client:	Arcadis US, Inc.	Field No.:	1A	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	Moly Roasta Stack - Sample Port	Evaluation Date:	03/19/15

Dose-Response



Dose-Response as Power Law



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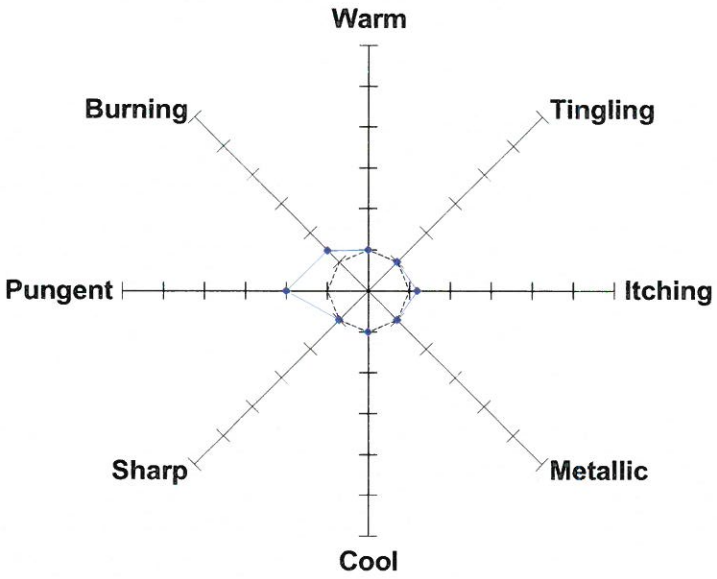
St. Croix Sensory, Inc. **Odor Evaluation Report**

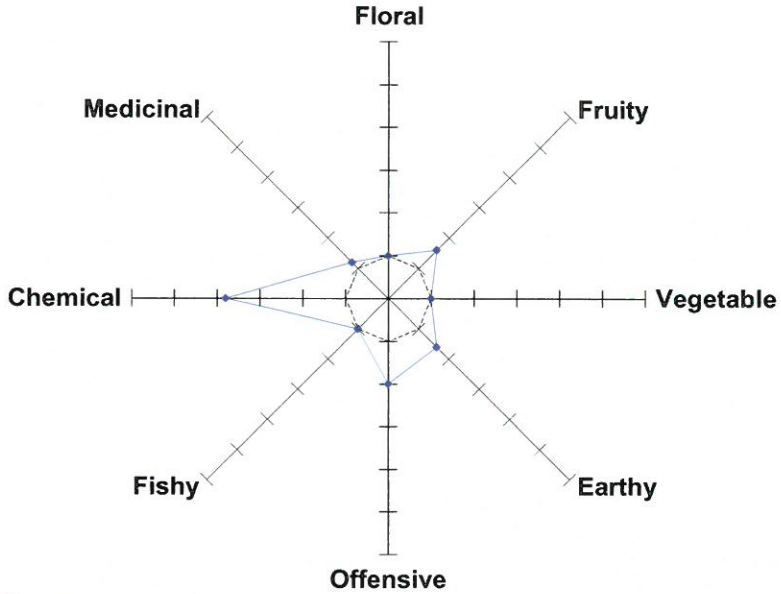
Client:	Arcadis US, Inc.	Field No.:	2A	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	Flotation	Evaluation Date:	03/19/15

Sensation Descriptor Graph

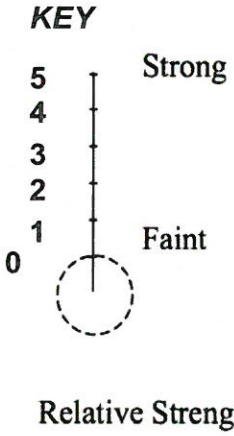


	Average Relative Strength
Warm	0.0
Tingling	0.0
Itching	0.2
Metallic	0.0
Cool	0.0
Sharp	0.0
Pungent	1.0
Burning	0.4

Odor Descriptor Graph



	Average Relative Strength
Floral	0.0
Fruity	0.6
Vegetable	0.0
Earthy	0.6
Offensive	1.0
Fishy	0.0
Chemical	2.8
Medicinal	0.2



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St. Croix Sensory, Inc.

Odor Evaluation Report

Client:	Arcadis US, Inc.	Field No.:	2A	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	Flotation	Evaluation Date:	03/19/15

% of Assessors |**********|**********|**********|**********| 100%

Fruity	**********
Citrus	**********
Lemon	**********
Medicinal	**********
Disinfectant	**********
Chemical	**********
Car exhaust	**********
Kerosine	**********
Petroleum	**********
Turpentine	**********
Plastic	**********
Solvent	**********
Offensive	**********
Earthy	**********
Musty	**********
Stale	**********
Smoky	**********

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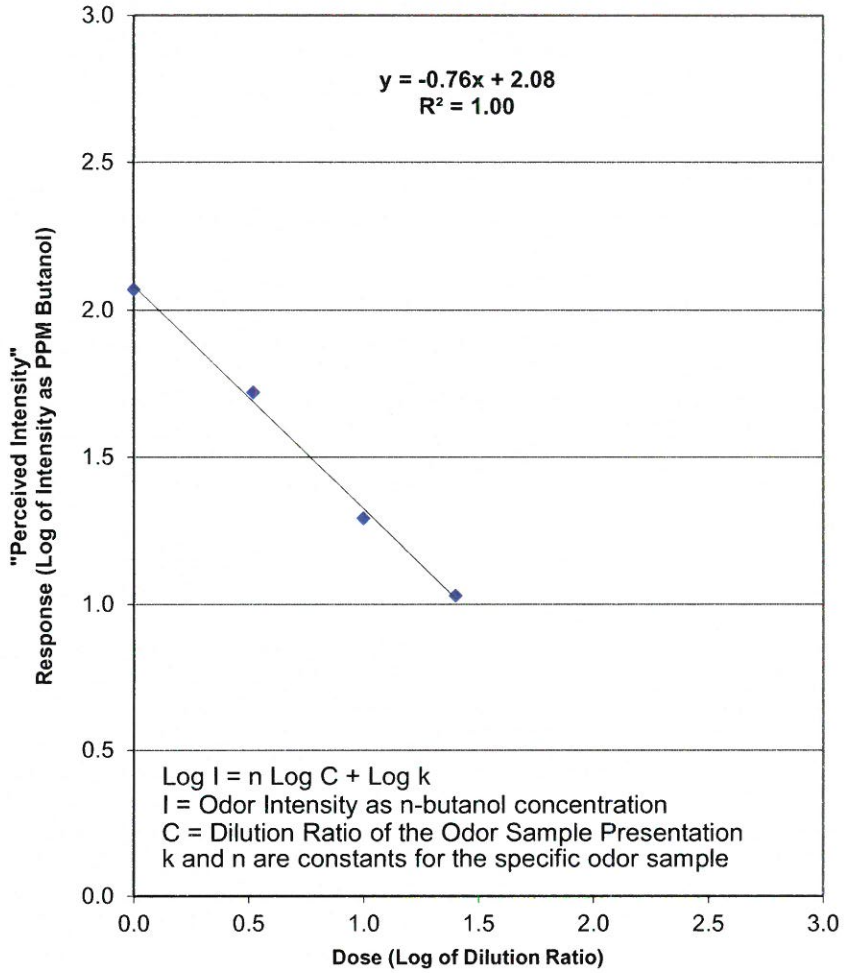
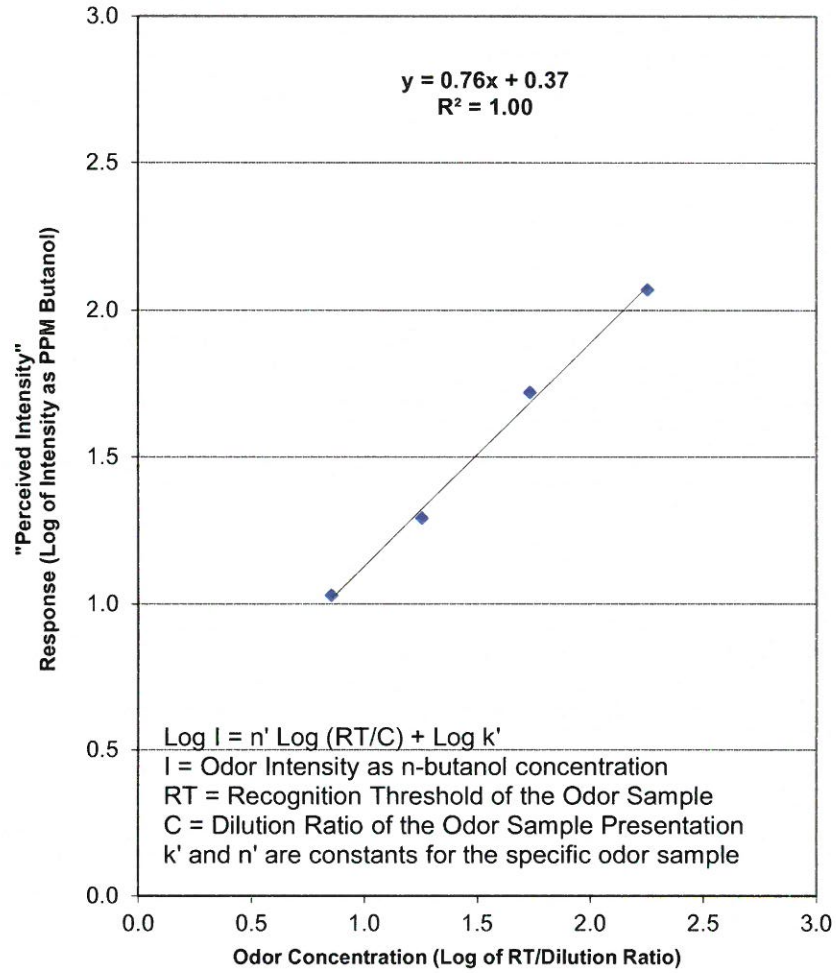
St. Croix Sensory, Inc. **Odor Evaluation Report**

Client:	Arcadis US, Inc.	Field No.:	2A	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	Flotation	Evaluation Date:	03/19/15

Dose-Response



Dose-Response as Power Law



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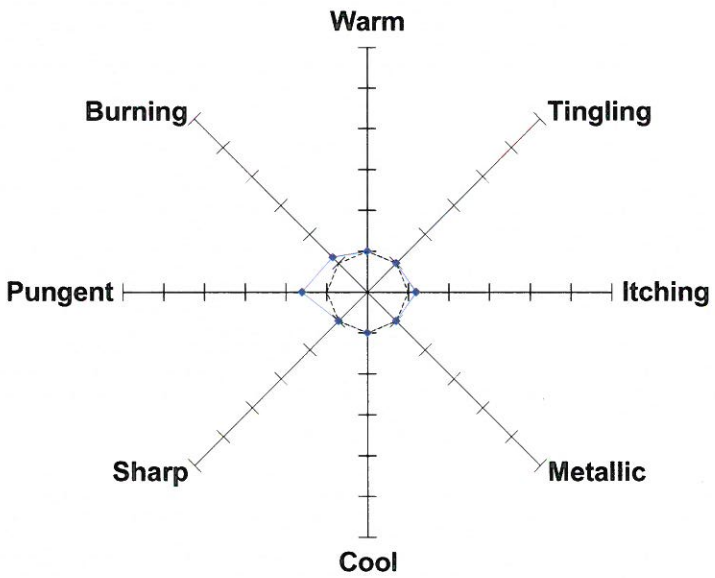
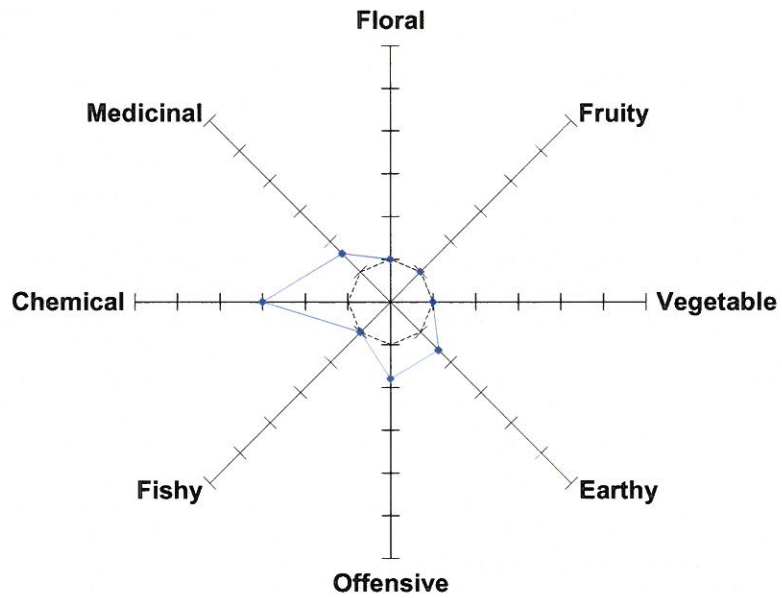
St. Croix Sensory, Inc. **Odor Evaluation Report**

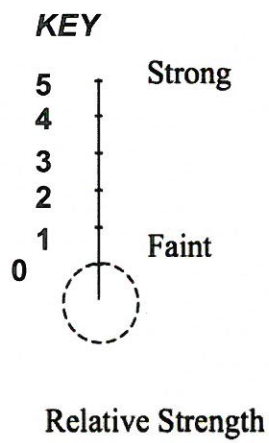
Client:	Arcadis US, Inc.	Field No.:	3A	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	"C" Copper/Moly Thickener Surface	Evaluation Date:	03/19/15

Sensation Descriptor Graph



Odor Descriptor Graph





	Average Relative Strength
Warm	0.0
Tingling	0.0
Itching	0.2
Metallic	0.0
Cool	0.0
Sharp	0.0
Pungent	0.6
Burning	0.2

	Average Relative Strength
Floral	0.0
Fruity	0.0
Vegetable	0.0
Earthy	0.6
Offensive	0.8
Fishy	0.0
Chemical	2.0
Medicinal	0.6

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St. Croix Sensory, Inc.

Odor Evaluation Report

Client: Arcadis US, Inc.

Field No.: 3A

Report No.: **1507802**

Project: Sierrita Mine

Description: "C" Copper/Moly Thickener Surface

Evaluation Date: 03/19/15

% of Assessors |**********|**********|**********|**********| 100%

Medicinal	**********
Disinfectant	**********
Chemical	**********
Paint	**********
Car exhaust	**********
Kerosine	**********
Petroleum	**********
Turpentine	**********
Solvent	**********
Offensive	**********
Decay	**********
Earthy	**********
Musty	**********
Stale	**********

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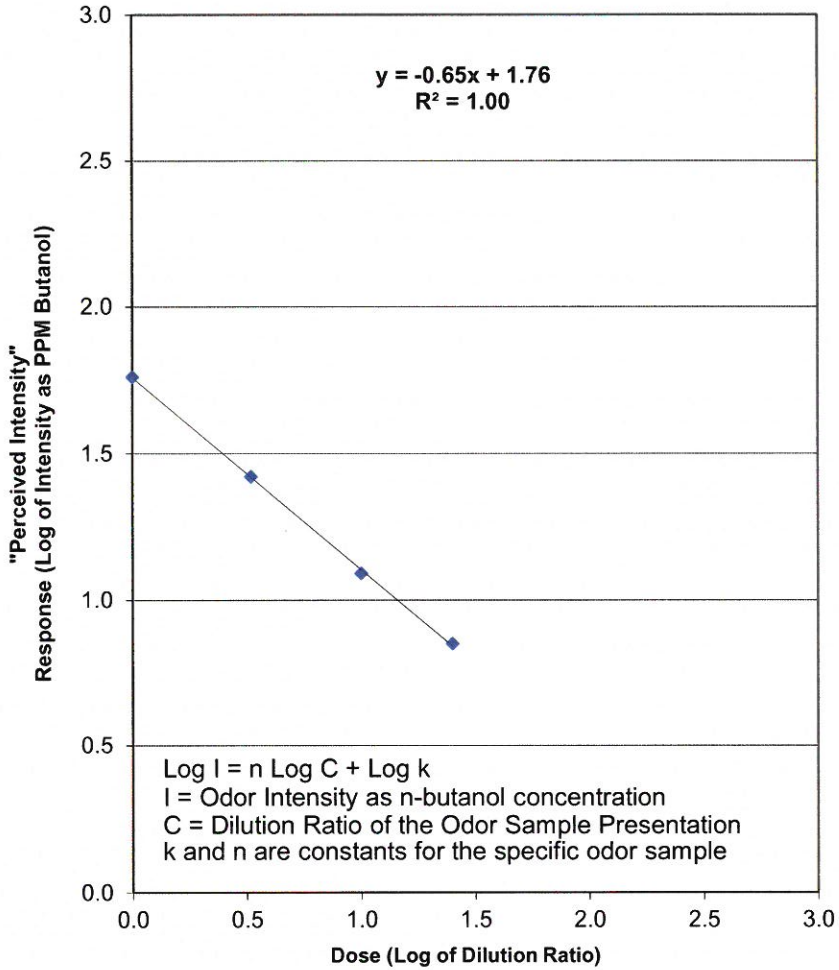
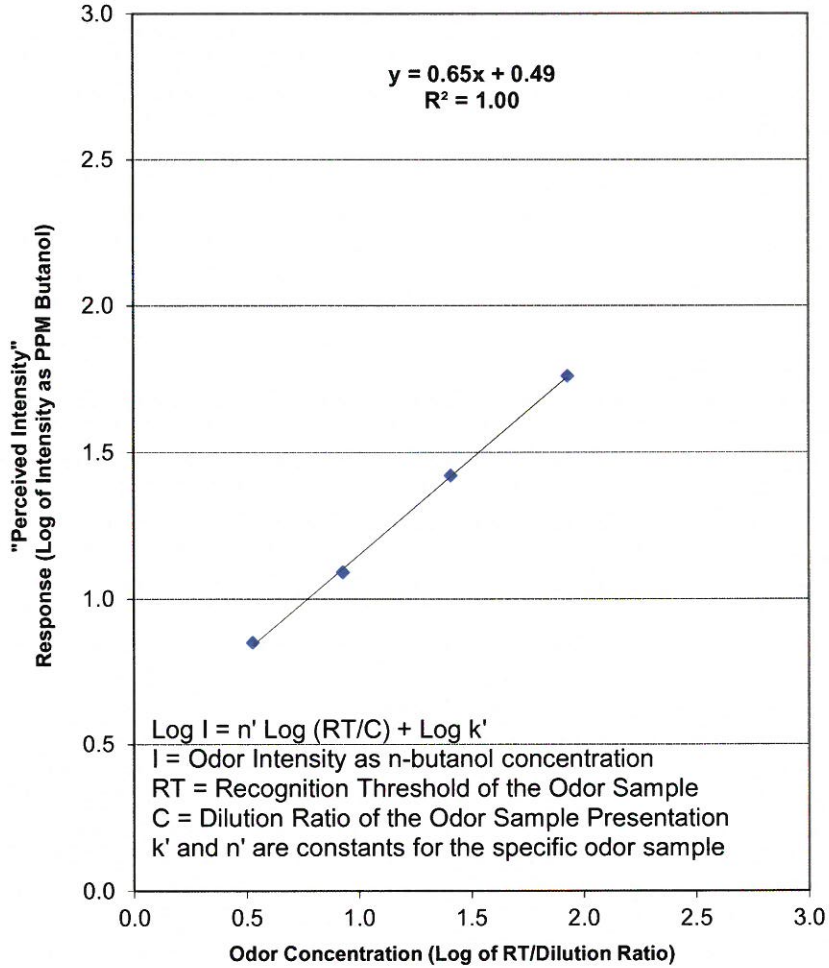
St. Croix Sensory, Inc. **Odor Evaluation Report**

Client:	Arcadis US, Inc.	Field No.:	3A	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	"C" Copper/Moly Thickener Surface	Evaluation Date:	03/19/15

Dose-Response



Dose-Response as Power Law



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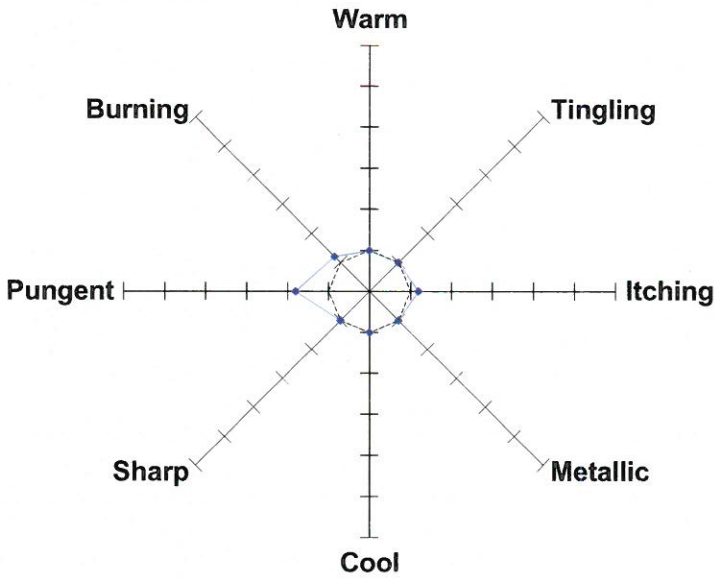
St. Croix Sensory, Inc.

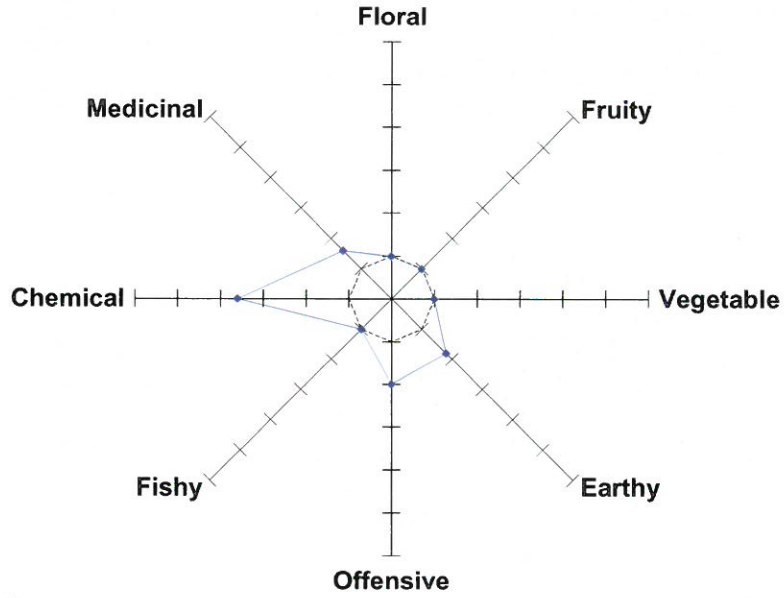
Odor Evaluation Report

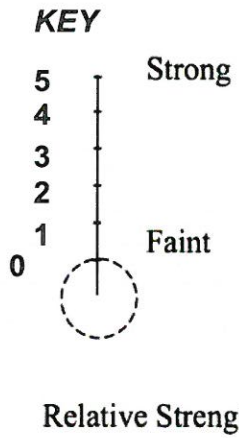
Client:	Arcadis US, Inc.	Field No.:	4B	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	SX-1 "E" Stripper Tank - Diluted 10:1	Evaluation Date:	03/19/15

Sensation Descriptor Graph



Odor Descriptor Graph





	Average Relative Strength
Warm	0.0
Tingling	0.0
Itching	0.2
Metallic	0.0
Cool	0.0
Sharp	0.0
Pungent	0.8
Burning	0.2

	Average Relative Strength
Floral	0.0
Fruity	0.0
Vegetable	0.0
Earthy	0.8
Offensive	1.0
Fishy	0.0
Chemical	2.6
Medicinal	0.6

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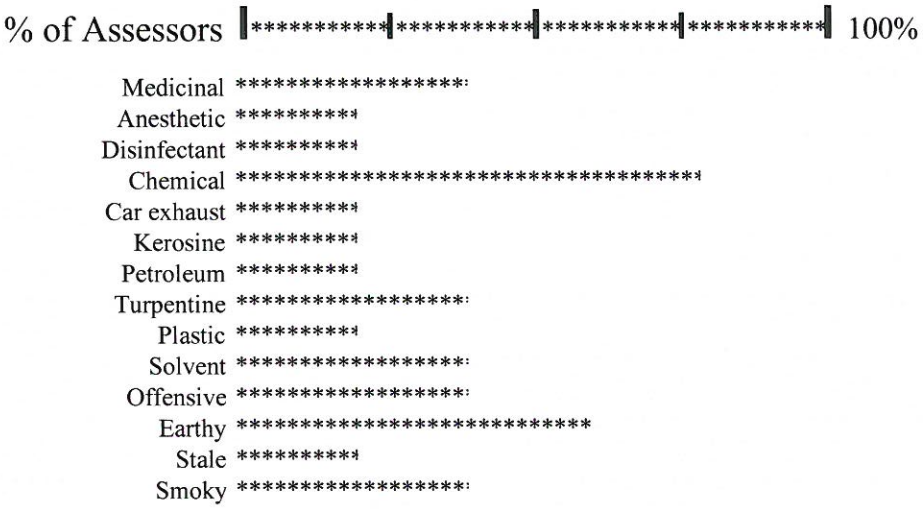
St. Croix Sensory, Inc.

Odor Evaluation Report

Client:	Arcadis US, Inc.	Field No.:	4B	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	SX-1 "E" Stripper Tank - Diluted 10:1	Evaluation Date:	03/19/15



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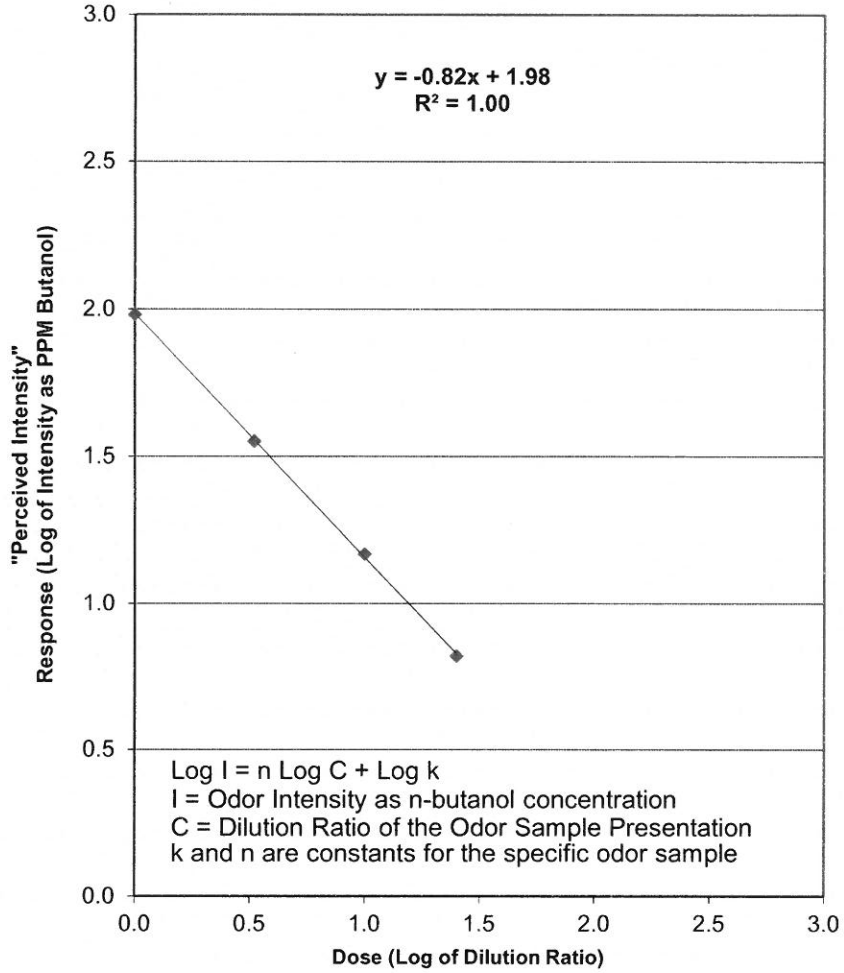
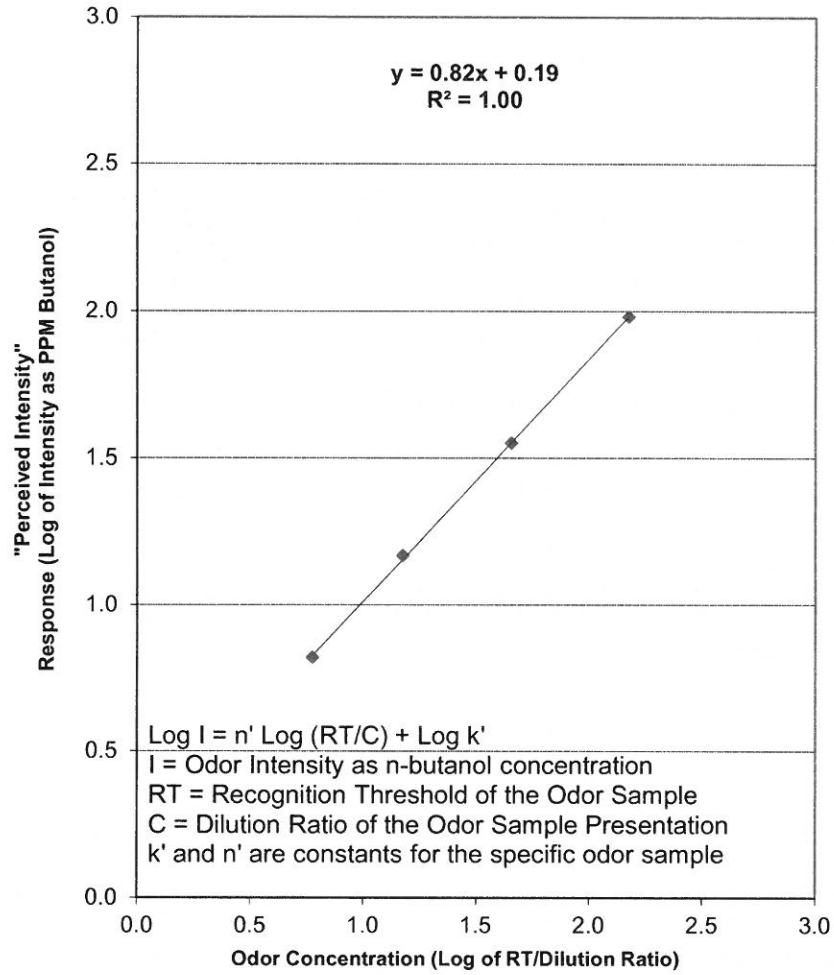
St. Croix Sensory, Inc. **Odor Evaluation Report**

Client:	Arcadis US, Inc.	Field No.:	4B	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	SX-1 "E" Stripper Tank - Diluted 10:1	Evaluation Date:	03/19/15

Dose-Response



Dose-Response as Power Law



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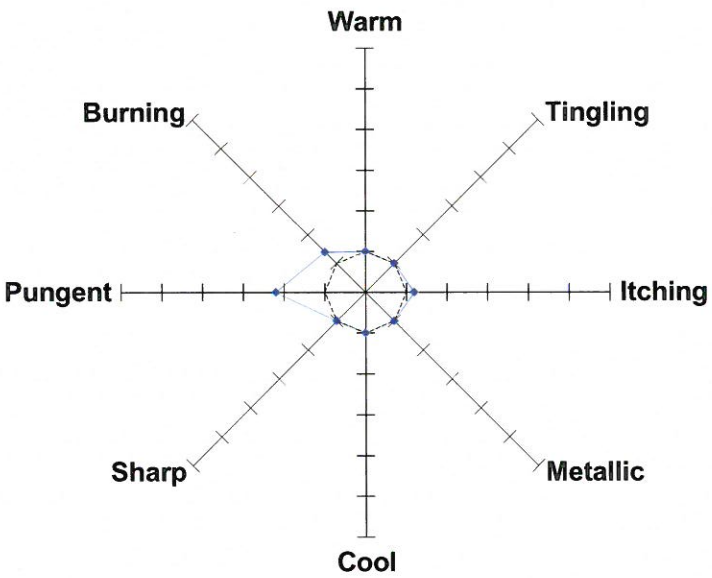
St. Croix Sensory, Inc.

Odor Evaluation Report

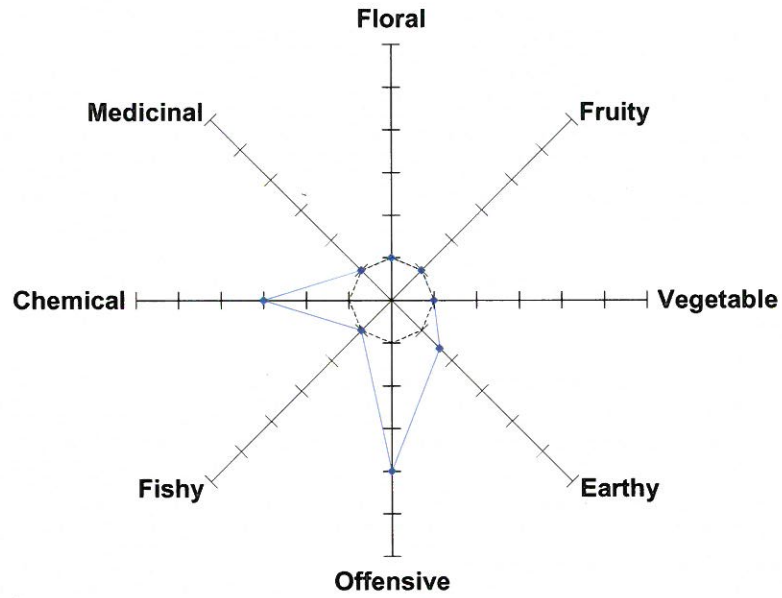
Client:	Arcadis US, Inc.	Field No.:	5A	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	Decant Feed - Bottle Agitation	Evaluation Date:	03/19/15

Sensation Descriptor Graph

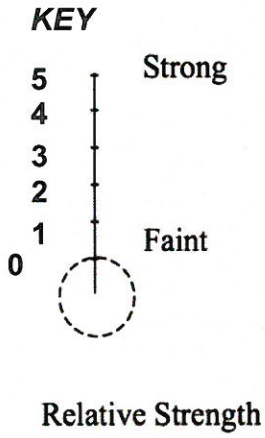


	Average Relative Strength
Warm	0.0
Tingling	0.0
Itching	0.2
Metallic	0.0
Cool	0.0
Sharp	0.0
Pungent	1.2
Burning	0.4

Odor Descriptor Graph



	Average Relative Strength
Floral	0.0
Fruity	0.0
Vegetable	0.0
Earthy	0.6
Offensive	3.0
Fishy	0.0
Chemical	2.0
Medicinal	0.0



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St. Croix Sensory, Inc.

Odor Evaluation Report

Client:	Arcadis US, Inc.	Field No.:	5A	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	Decant Feed - Bottle Agitation	Evaluation Date:	03/19/15

% of Assessors |**********|**********|**********|**********| 100%

Chemical	**********
Petroleum	**********
Plastic	**********
Creosote	**********
Solvent	**********
Sulfur	**********
Offensive	**********
Sewer	**********
Sour	**********
Rotten eggs	**********
Putrid	**********
Septic	**********
Earthy	**********
Musty	**********
Stale	**********

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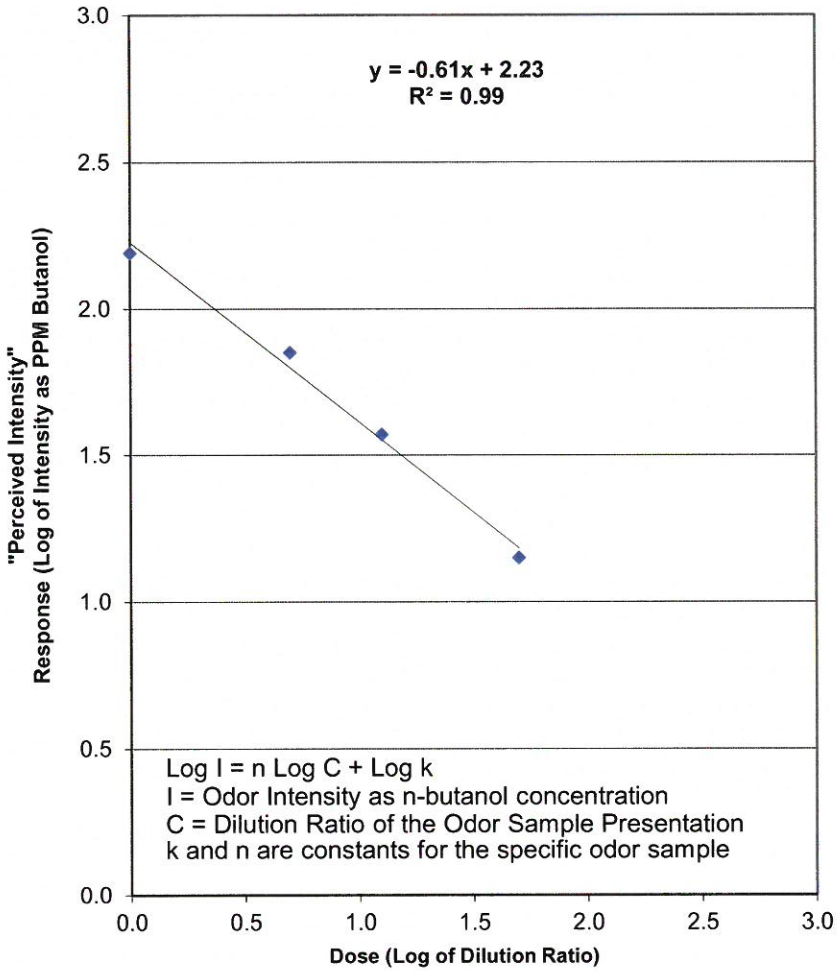
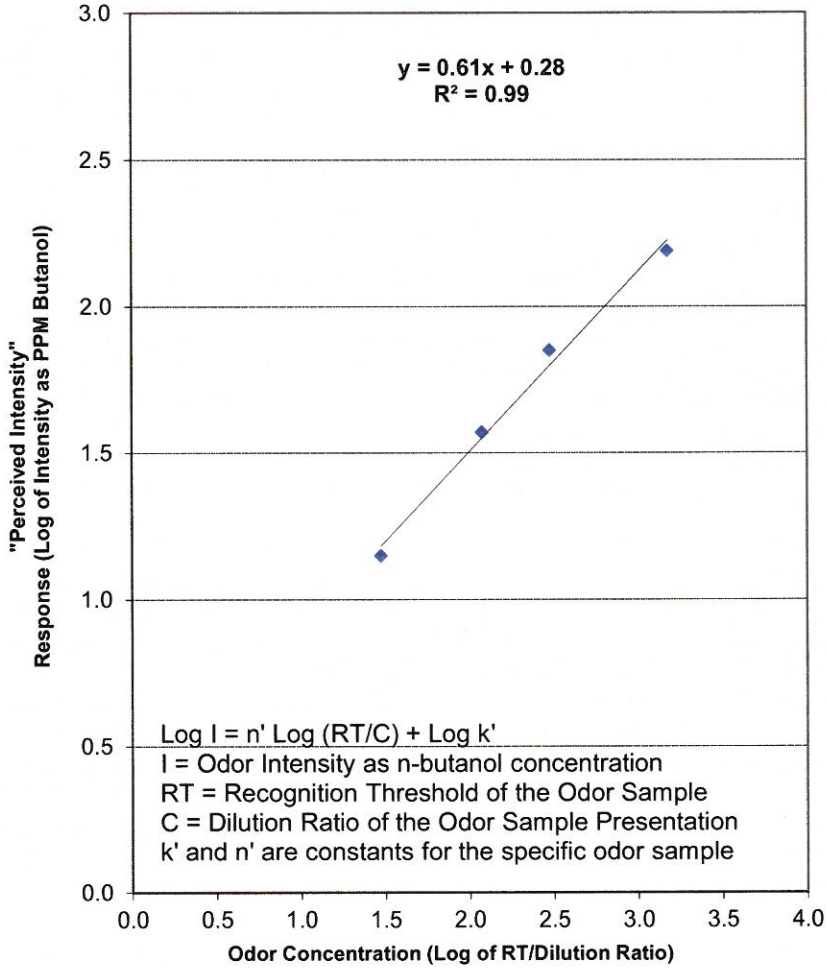
St. Croix Sensory, Inc. **Odor Evaluation Report**

Client:	Arcadis US, Inc.	Field No.:	5A	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	Decant Feed - Bottle Agitation	Evaluation Date:	03/19/15

Dose-Response



Dose-Response as Power Law



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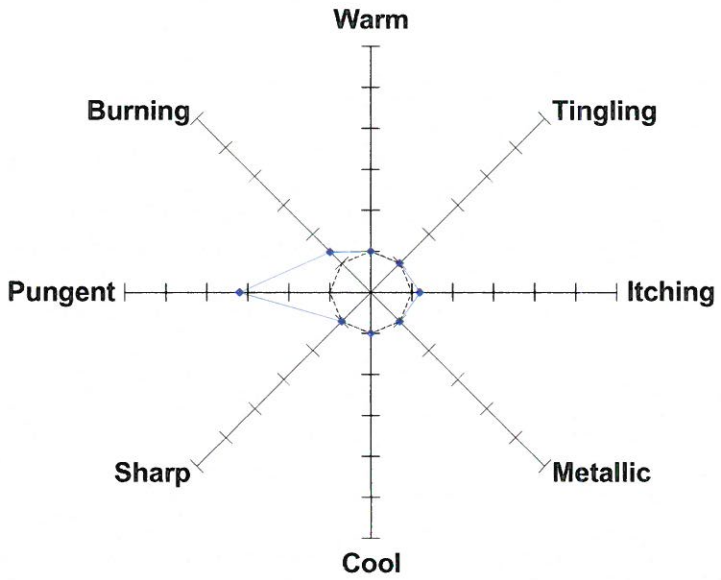
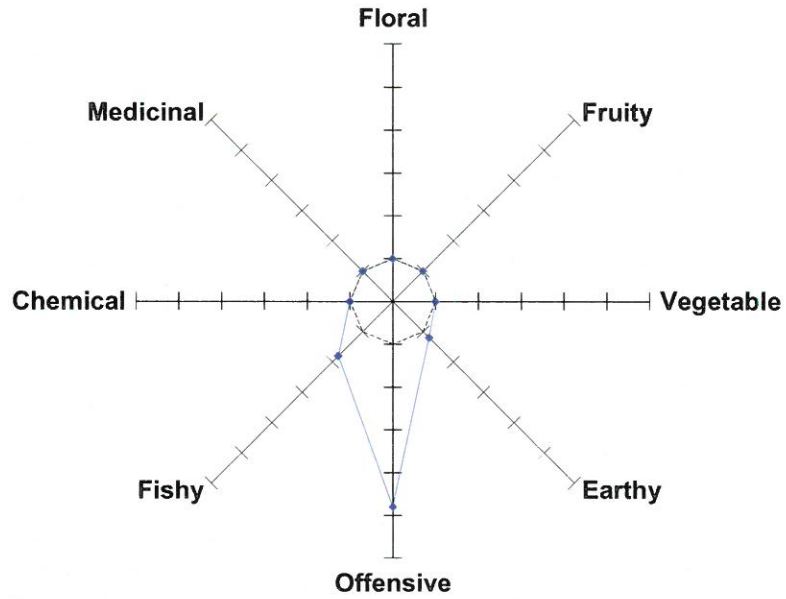
St. Croix Sensory, Inc. **Odor Evaluation Report**

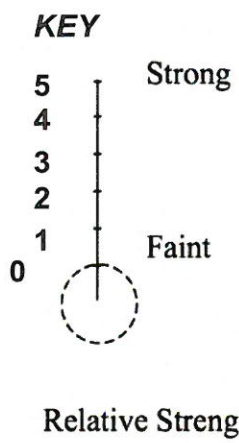
Client:	Arcadis US, Inc.	Field No.:	6B	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	Xanthate Mixed 10:1 Diluted	Evaluation Date:	03/19/15

Sensation Descriptor Graph



Odor Descriptor Graph





	Average Relative Strength
Warm	0.0
Tingling	0.0
Itching	0.2
Metallic	0.0
Cool	0.0
Sharp	0.0
Pungent	2.2
Burning	0.4

	Average Relative Strength
Floral	0.0
Fruity	0.0
Vegetable	0.0
Earthy	0.2
Offensive	3.8
Fishy	0.8
Chemical	0.0
Medicinal	0.0

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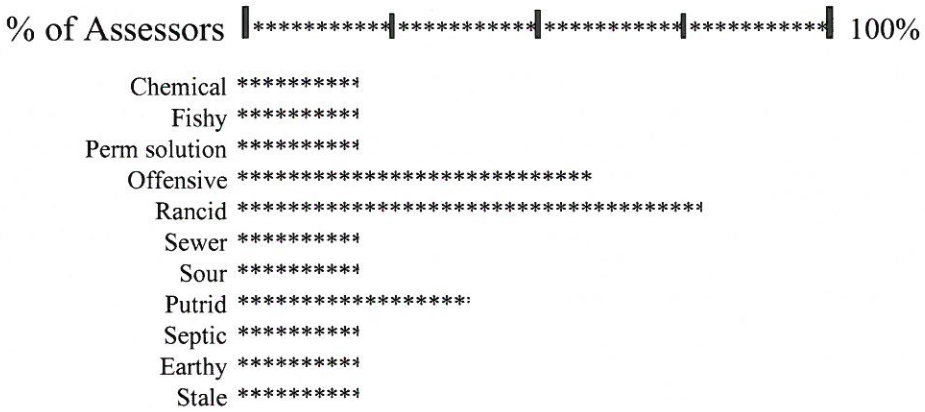
St. Croix Sensory, Inc.

Odor Evaluation Report

Client:	Arcadis US, Inc.	Field No.:	6B	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	Xanthate Mixed 10:1 Diluted	Evaluation Date:	03/19/15



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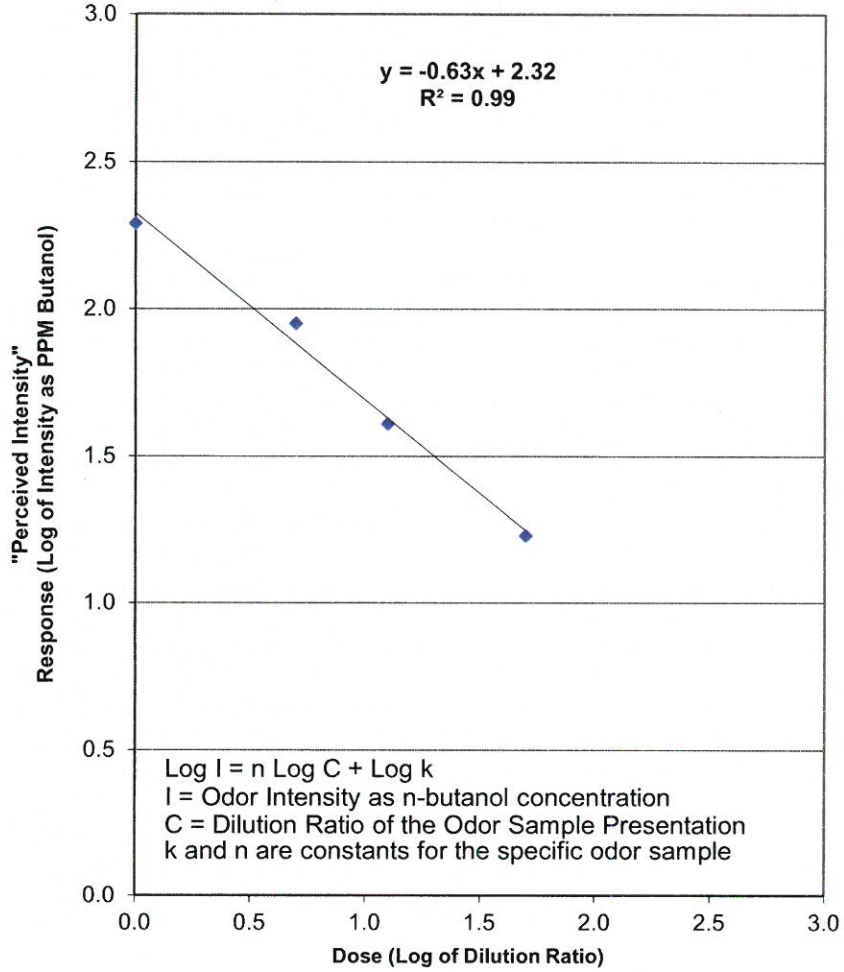
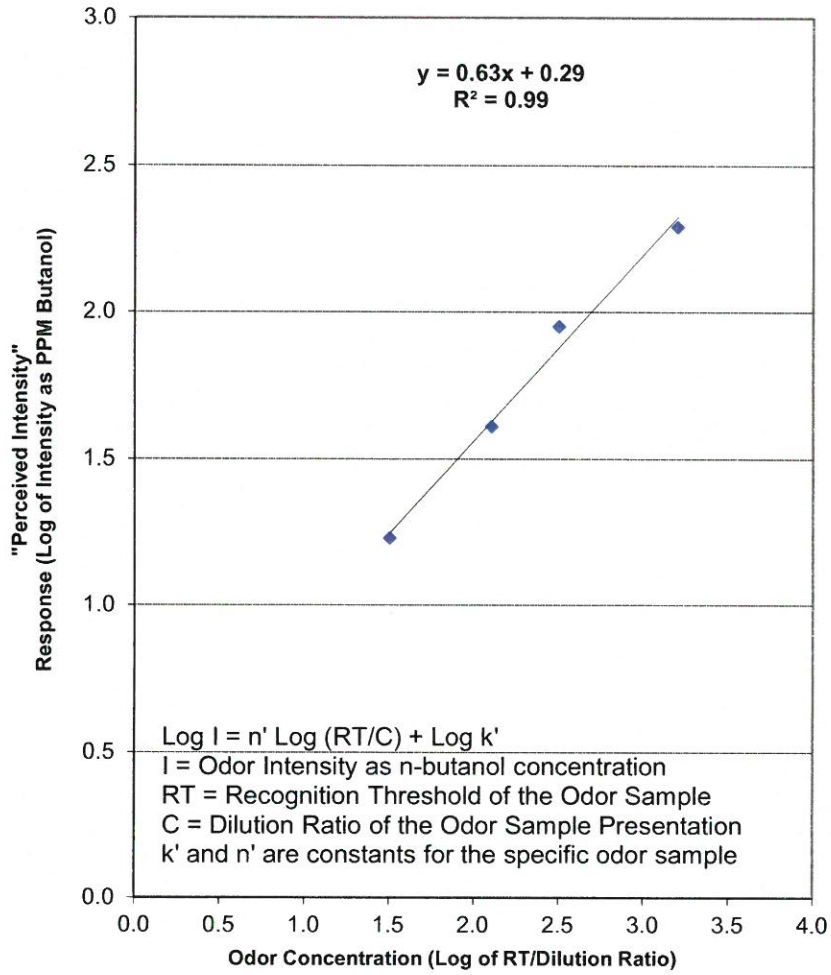
St. Croix Sensory, Inc. **Odor Evaluation Report**

Client:	Arcadis US, Inc.	Field No.:	6B	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	Xanthate Mixed 10:1 Diluted	Evaluation Date:	03/19/15

Dose-Response



Dose-Response as Power Law



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St. Croix Sensory, Inc.

CHAIN OF CUSTODY RECORD FOR ODOR SAMPLES

Page ___ of ___

Client: ARCADIS

Sampled By: Dick Pope, Roger Felty

Project Name: Sierrita Mine

Sampling Date: 3.18.15

Comments: 4A – bag detective O valve – leaked sample.
6A – FOR YOUR REVIEW ONLY – NOT FOR TESTING

Odor Evaluations Requested: (X)

For Laboratory use Only

Odor Evaluation Report No. 1507802

Line No.	Field No.	Sample Description	Sample Time	Field H_2S (ppm)	Odor Concentration* (Detection & Recognition Threshold)	Odor Intensity* (PPM 1-Butanol)	Odor Characterization (Hedonic Tone & Descriptors)	Odor Persistency ("Dose-Response")	Laboratory Sample No. LN	Laboratory Sample No. FN
1	1A	Moly Roasta Stack - sampleport	9:45AM	N/A	X	X	X	X		
2	1B	Duplicate - Moly Roasta Stack - sampling port	9:59AM	N/A	X	X	X	X		
3	2A	Flotation	10:37 ~~10:38~~AM	N/A	X	X	X	X		
4	2B	Duplicate - Flotation	10:49AM	N/A	X	X	X	X		
5	3A	"C" Copper/Moly Thickener Surface	11:31AM	N/A	X	X	X	X		
6	3B	Duplicate - "C" Copper/Moly Thickener Surf.	11:42AM	N/A	X	X	X	X		
7	4A	SX-1 "E" Stripper Tank - sample leaked	N/A	N/A						
8	4B	SX-1 "E" Stripper Tank diluted 10:1	12:38PM	N/A	X	X	X	X		
9	5A	Decant Feed - bottle agitation	2:05PM	N/A	X	X	X	X		
10	5B	Duplicate - Decant Feed - bottle agitation	2:15PM	N/A	X	X	X	X		
11	6A	Xanthate Mixed - undiluted	2:59PM	N/A	X	X	X	X		
12	6B	XANTHATE MIXED 10:1 DILUTED	2:31 PM	N/A	X	X	X	X		
	6C	XANTHATE MIXED DILUTED 100:1	2:43 PM		X	X	X	X		

Transmittal

Number of Shipping Boxes 2

Relinquished By	Date	Time	Accepted By	Date	Time	Comments & Exceptions Noted
ROGER FELTY	3.18.15	4:03 PM				
Received at St. Croix Sensory Laboratory			[signature]	3/19/15	9:30AM	

*Odor Concentration: ASTM E679-04 & EN13725:2003 and Odor Intensity: ASTM E544-10

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CLIENT COPY PINK

ATTACHMENT

- **PDEQ Odor Observation/Assessment Report Form**

Pima County
Department of Environmental Quality
3 N. Stone Avenue, Suite 700, Tucson, Arizona 85701
(520) 724-7400 (520) 838-7432 (FAX)

ODOR OBSERVATION/ASSESSMENT REPORT

DATE: _____ ARRIVAL TIME: _____ COMPLAINT #: _____

COMPLAINANT'S DESCRIPTION OF ODOR: _____

FREQUENCY: _____

WIND SPEED: _____ DIRECTION: _____ ODOR DETECTED: NO ____ YES ____

INSPECTOR'S ODOR OBSERVATIONS:

Location	Monitor Times	Odor Scale	Odor Description

SCALE	DESCRIPTION
0 Not Detected.....	Odor not detected
1 Very Light.....	Odor present and activates the sense of smell but characteristics may not be distinguishable.
2 Light	Odor is present and activates the sense of smell and is distinguishable and definite but not necessarily objectionable in short durations.
3 Moderate.....	Odor present and activates the sense of smell and is distinguishable and may tend to be objectionable and/or irritating in short durations.
4 Strong.....	Odor present is objectionable and causes a person to attempt to avoid it completely.
5 Very Strong.....	Odor is so strong it is overpowering and intolerable for any length of time.

Summary Report

Suspected Source: _____ Permit #: _____ NPR: _____

Address: _____ Contact name: _____

Using Controls: Yes ____ No ____ Type of Control: _____

Additional remedial actions taken by source: _____

Complainant informed of actions: Yes ____ No ____ Further action required: No ____ Yes ____

Comments: _____

Inspector: _____ Phone: _____ Date: _____ Departure Time: _____

ATTACHMENT

- **Odor Intensity Reference Scales, St. Croix Sensory, Inc. / McGinley Associates, P.A., 2000**

Figure 3: Odor Intensity Referencing Scales (OIRS)

N-Butanol Odor Intensity < PPM >

12-Point Scale [GPR: 2]	10-Point Scale [GPR: 2]	8-Point Scale [GPR: 2]	5-Point Scale [GPR: 3]
1 < 10 >			
	1 < 12 >	1 < 12 >	
2 < 20 >			
	2 < 24 >	2 < 24 >	1 < 25 >
3 < 40 >			
	3 < 48 >	3 <48 >	
4 < 80 >			2 < 75 >
	4 < 96 >	4 < 96 >	
5 < 160 >			
	5 < 194 >	5 < 194 >	
			3 < 225 >
6 < 320 >			
	6 < 388 >	6 < 388 >	
7 < 640 >			4 < 675 >
	7 < 775 >	7 < 775 >	
8 < 1280 >			
	8 < 1550 >	8 < 1550 >	
			5 < 2025 >
9 < 2560 >			
	9 < 3100 >		
10 < 5120 >			
	10 < 6200 >		
11 < 10240 >			
12 <20480 >			

GPR: Geometric Progression Ratio

ATTACHMENT

- **Odor Dispersion Modeling Assessment Report / Arcadis, March 2016**

ARCADIS Design & Consultancy for natural and built assets

Freeport-McMoRan Sierrita Inc.

ODOR DISPERSION MODELING ASSESSMENT

Sierrita Mine, Arizona

March 2016

Odor Dispersion Modeling Assessment

Sierrita Mine, Arizona

Svetlana Music
Senior Environmental Scientist

Dan Hrebenyk
Senior Environmental Scientist

Prepared for:

Freeport-McMoRan Sierrita Inc.

Prepared by:

Arcadis Canada Inc.

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Richmond Hill, ON

Tel 905.764.9380

Fax 905.764.9386

Our Ref.:

380253-000

Date:

March 2016

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Issue	Revision No	Date Issued	Page No	Description	Reviewed by

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Figure 5 CALPUFF Predicted Maximum Odor Concentrations (OU/m^3) Exceeding Complaint Threshold 15

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A Model Configuration

B St. Croix Report

ACRONYMS AND ABBREVIATIONS

Sierrita	Freeport-McMoRan Sierrita Inc.
NAM	North American Model
NASA	National Aeronautics and Space Administration
Sierrita Mine	Sierrita Mine Facility
SRTM	Shuttle Radar Topography Mission
USGS	United States Geological Survey
WRF-NMM	Weather Research and Forecasting Non-hydrostatic Meso-scale Model

EXECUTIVE SUMMARY

Freeport-McMoRan Sierrita Inc. (Sierrita) retained Arcadis U.S. (Arcadis) to help it conduct an odor assessment of the Sierrita Mine Facility (Sierrita Mine). The Sierrita Mine is a copper and molybdenum mine located about 20 miles southwest of Tucson, Arizona. As part of the assessment, Sierrita asked Arcadis to perform air dispersion modeling of odor emissions from the Sierrita Mine milling and processing activities and estimate off-site odor concentrations using provided inputs.

The odor dispersion modeling was conducted using the CALPUFF modeling system. One year of meteorological data was developed using the Weather Research and Forecasting Non-hydrostatic Meso-scale Model (WRF-NMM) and used as an input to the CALMET meteorological module of the CALPUFF model. Available observations from two on-site meteorological towers were not used in CALMET because the data quality was deemed unacceptable from one of the towers, and the other tower did not have a complete one-year data set (the minimum acceptable period for dispersion modeling). As a result, CALMET was based on gridded wind fields generated by WRF-NMM in the form of a three-dimensional data file (i.e., CALMET was run in so-called "No-observations" mode). The odor dispersion modeling for the Sierrita Mine was conducted over a modeling domain of approximately 20 kilometers (km) by 20 km (12.4 miles [mi.] by 12.4 mi.). Odor complaints were reported for 20 unique geographic locations in the vicinity of the Sierrita Mine within the 20 km (12.4 mi.) squared area. These compliant locations were designated C1 through C20, and used as discrete receptor locations in the dispersion modeling analysis.

An inspection was conducted on the mine site, and seven potential odor sources were identified for further assessment. These seven odor sources at the Sierrita Mine were modeled for this evaluation:

- Moly Roaster Stack;
- Xanthate Mixing Tank Exhaust Stack;
- Decant Pond;
- Mill Copper Flotation Cell;
- Copper/Molybdenum Thickener Tank A;
- Copper/Molybdenum Thickener Tank B; and
- Copper/Molybdenum Thickener Tank C.

Odor emission rates for each modeled odor source were estimated based on measurements of odor concentrations at each source. The source odor emission rates were then modeled to predict the maximum 10-minute odor concentration at each location C1 through C20.

The highest maximum 10-minute odor concentration predicted by the CALPUFF model at the 20 complaint locations is 3.6 odor units per cubic meter (OU/m^3) at location C14, a location which is on Duval Mine Road approximately 1.6 km (1 mi.) east of the mine. At the two most frequent complaint locations, C1 and C7 (where 69% of all complaints during the one-year period were recorded), the model predicted maximum odor concentrations of 0.39 OU/m^3 and 0.21 OU/m^3, respectively. Locations C1 and C7 are approximately 3.6 km (2.2 mi.) and 4.2 km (2.6 mi.) northwest of the mine, respectively. Since

Arizona has no numerical criteria for evaluating nuisance odor impacts, the results of the odor dispersion modeling were assessed using 5 odor unit per cubic meter (OU/m^3) (10-minute average). Multiple studies suggest that this odor concentration is a reasonable threshold at which an odor is considered likely to result in complaints from members of the general public (Mahin 2003). The results of this CALPUFF modeling evaluation indicate that the predicted odor concentrations at the 20 odor complaint locations modeled are less than the 5 OU/m^3 threshold.

1 INTRODUCTION

The main objective of this modelling assessment was to evaluate the potential correlation between the mine's milling and processing activities and off-site odor concentrations. This evaluation was completed using the advanced CALMET/CALPUFF modeling system coupled with and driven by the mesoscale model WRF-NMM. In addition, a source contribution analysis was performed to evaluate the degree to which each modeled source has the potential to generate complaint-level odors in the area surrounding the mine.

This report is organized in the following manner:

- Section 2.0 provides an general overview of odor impact assessments;
- Section 3.0 describes the on-site sampling methodology used to assess odor concentrations at source, the modeling approach including meteorological data development, and the odor sources modeled;
- Section 4.0 presents the results of the odor dispersion modeling assessment; and
- Appendix A provides additional details about the dispersion modeling approach.

2 OVERVIEW OF ODOR IMPACT ASSESSMENT

The regulation of odor has been, and continues to be a challenging element of air quality to address. The primary reason for this is that the perception of odors is subjective in nature, and is often based on the personal feelings, experiences, and memories of the observer (McGinley *et al.* 2000). Also, people have differing sensitivities to different odors. An odor that is objectionable to one person may be barely noticeable to another. As such, there is little consistency in the definition of what constitutes a nuisance odor impact among regulatory agencies in America, or internationally in other jurisdictions.

Odors are typically viewed as a "nuisance," since exposure to them can be disruptive to one's senses, but generally do not cause negative health effects (many individuals experience health-based symptoms such as nausea, vomiting, headache, etc. due to exposure to odors). Therefore, nuisance odors tend to be treated differently in regulation than are other air contaminants.

2.1 Ambient Odor Detection and Regulatory Criteria

Quantitative odor impact criteria are not ambient air quality standards. Instead, such criteria provide a scientifically-derived benchmark for making informed decisions in the planning, design, environmental management and regulation of sources of odor emission. These criteria are generally based on measurements or samples collected in the field to provide a direct indication of ambient odor levels at specific locations, or ambient concentrations predicted using source emission information and air dispersion models.

Ambient odor detection criteria are based on dynamic dilution olfactometry (DDO), which uses the human nose as a sensor by comparing an odor sample at various levels of dilution with odor-free air. The diluted sample is presented to a panel of assessors (called an odor panel) using an olfactometer in an odor-free room or laboratory, through ports from which the assessors must sniff. The dilution level at which 50% of the odor assessors can just detect the odor is set as the odor detection threshold for the sample. The number of dilutions required to reach this level determines the odor concentration (in OU or OU/m^3) in the original sample. For example, if nine volumes of odor free air are added to one volume of sample, the odor concentration in the sample is 10 OU.

A study conducted for the California Air Resources Board concluded that, for unpleasant odors, the threshold of annoyance is at approximately 5 times the detection threshold (D/T), which would be interpreted as 5 odor units (OU). California's South Coast Air Quality Management District states that at 5 D/T people become consciously aware of the presence of an odor, and that at 5-to-10 D/T odors are strong enough to evoke registered complaints (Mahin 2003). Therefore, 5 OU is generally referred to as the complaint threshold.

There is a wide range of approaches used to manage odors, ranging from no numerical limits, to limits in the range from 1-20 OU with averaging times from 2 minutes to 1 hour. In general, criteria at the state-level tend to be based on 5 D/T or higher, if they have adopted any criteria at all. On the other hand, at the municipal and county-level where agencies are more directly involved in the design and operation of odor sources such as wastewater treatment plants, criteria tend to be set at more stringent levels of 5 D/T or less. Recent examples of very stringent design goals for wastewater treatment plants include:

- Snohomish County, WA (<1 OU single highest 3-minute average per year, no detectable odor)
- King County, WA (<3 OU for normal operations at existing wastewater treatment plants)
- New York City (<2 OU – measured as 1 ppb H_2S 1-hour average)
- Town of Chapel Hill, NC (5 OU, no more than 3 days per year).

Based on the experience of most other jurisdictions, the magnitude of any ambient odor criterion should be set based on an annoyance threshold or annoyance criteria. Many jurisdictions use an annoyance criterion or an odor complaint threshold of 5 OU, which is 5 times the odor detection threshold of 1 OU. Justification for the use of the 5 OU value as an annoyance threshold is available from a community odor survey of livestock odors in The Netherlands, as reported by the Environment Agency (2007). The data indicated that approximately 5% of the general population living in areas without livestock operations (i.e., non-concentration areas) would be annoyed at a level of 5 OU (1-hour average, 98th percentile). The results for intensive swine rearing operations odors in The Netherlands is consistent with research conducted in the United Kingdom in which odor complaints were correlated with modeled odor impacts from nine wastewater treatment plants. In the latter study, only 3% of the odor complaints were recorded in areas where odor concentrations were at levels $\leq$5 OU (1-hour average, 98th percentile). On that basis, the use of an annoyance level of 5 OU would also be consistent with the World Health Organization's definition of a nuisance threshold as being that concentration at which not more than a small proportion of the population (less than 5%) experiences annoyance for a small part of the time (less than 2%) (WHO 2000).

A series of experiments conducted by Stowell *et al.* (2008) in the vicinity of an intensive swine rearing operation in Nebraska, using a mask scentometer to measure instantaneous odor levels, also indicated that while the threshold for any degree of annoyance appears to be between 2 and 15 OU, the threshold for consequential annoyance (i.e., that level of annoyance which is likely to cause a change in behavior or activity level, and instilling some memory of the odor event in the exposed individuals) falls between 7 and 31 OU. On this basis, Stowell *et al.* concluded that candidate thresholds for odor annoyance and consequential odor annoyance could be set at 2 OU and 7 OU, respectively.

According to Nicell (2009), a 1 OU concentration represents a condition where there is a balance between those that may be impacted to some degree and those that are not. By definition, 1 OU is the level at which 50% of the population can just detect the odor. Also, odor response curves from typical compounds such as n-butanol, n-butyl acetate, octane, etc. show that 10% of the population have personal thresholds that are five times lower than the overall population threshold. Therefore, at the 1 OU level, 10% of the population experiences the odor at a level that is at least five times their personal thresholds, which corresponds to the complaint threshold for these individuals. Thus, Nicell contends that even at 1 odor unit, 10% of the population could be considered to be in a state of annoyance sufficient to result in odor complaints. The study represents an evaluation of that portion of the general population that is more sensitive to odor than is the average person, and thus can be viewed as conservative when evaluating the effect of odor on a general population.

The relevant studies suggest that the selection of an annoyance threshold of around 5-7 OU would appear to be appropriate for the Sierrita Mine. If a majority of the populace in the vicinity of the mine is of average sensitivity, day-to-day odor levels in the 2-3 OU range may not be construed as a nuisance, and thus selection of a 5 OU criterion is likely more appropriate.

Apart from the odor concentration, there is a need to define the averaging period over which that concentration occurs. The choice of which averaging period to use should be a balance between the ability to assess the odors and the durations over which odors are deemed to be acceptable (or unacceptable). Ormerod and Best (2000) state that there are essentially two main approaches to setting odor impact criteria:

1. the short-term annoyance threshold approach, invoking concepts such as nose-response time, and
2. the long-term survey-based community annoyance approach which does not explicitly deal with short-term odour fluctuations.

A survey of odor regulations conducted by Arcadis for a confidential client in 2011 indicted that there are a wide range of approaches used to manage odor in the U.S., ranging from no numerical limits, to limits in the range from 1-20 OU, using averaging times from 2 minutes to 1 hour, though 3-to-10 minutes is more typical. It has frequently been noted that it is the short-term high concentration peaks that result in annoyance and complaints in the population surrounding an odor source **because a person's reaction to** an offensive odor occurs within 30 seconds, Experience indicates that modeling odor emissions over shorter averaging periods (i.e., less than 1 hour) better matches the pattern of observed odor incidents, likely as a result of capturing peak concentrations (Drew et al. 2007). Experience has also shown that it

is frequently the fluctuations from the mean concentration and not the actual mean itself that determine how odor is perceived (Best *et al.* 2001). While a single peak may not result in annoyance, repeated high peaks at times of high exposure could be missed by using longer term (i.e., 1 hour) averages. Also, it is unlikely that an odor will be a nuisance until it is detectable for certain periods of time, typically longer than three minutes (Simms et al. 1999). Consequently, 1-hour average odor concentrations predicted by dispersion models must be converted to shorter averaging periods in order to determine their degree of potential offensiveness for odor impacts.

According to an informal survey completed by the Ministry of Ontario, Canada, people will tolerate an offensive odor for approximately 10 minutes before complaining, and experience at Arcadis with modeling odor emissions from wastewater treatment plants in Vancouver, British Columbia has shown that the use of 5 OU over a 10-minute averaging period generally provided a good fit with the location of odor complaints related to all five wastewater treatment plants. A 10-minute average is a short enough duration such that high concentration peaks are not masked to a great extent, yet long enough to allow the odors to persist for a certain period of time at a given level.

In summary, 5 OU (10-minute average) is a reasonable odor impact criterion for the Sierrita odor assessment, squarely within the range of complaint thresholds determined by the studies discussed above. The determination of Stowell *et al.* (consequential odor annoyance at 7 OU) is considered slightly high, while Nicell's suggestion (1 OU) is on the low end. Thus, for the purposes of this report, the results of the odor dispersion modeling assessment are provided for all predicted odor concentrations, subject to a 5 OU (10 minute average) complaint threshold.

3 DISPERSION MODELING METHODOLOGY

With regard to odor dispersion modeling techniques, there is no standard regulatory model for odor emissions. Dispersion modeling of odorous emissions has generally been conducted using standard Gaussian plume dispersion models approved by regulatory agencies for air pollution studies. However, odors frequently occur with light and variable winds (i.e., non-steady state conditions) that result in plume meander and plume breakup into discrete "puffs" of odor which may be transported separately from the source. During periods of calm winds, these puffs may persist over receptors for longer periods of time. Steady state Gaussian plume models such as AERMOD are not designed to address this type of dispersion, whereas non-steady state puff models such as CALPUFF are able to track individual puffs over time. Tracking discrete puffs of odor in complex terrain, such as that which surrounds the Sierrita Mine, is more likely to be accomplished using CALPUFF rather than using AERMOD.

Arcadis has used the CALPUFF dispersion model to estimate the maximum downwind concentrations of odor from the Sierrita Mine. The CALPUFF model is a non-steady state Lagrangian puff model containing modules for evaluating the effects of pollutant dispersion and transport over complex terrain, overwater transport, and shoreline interaction effects. It can accommodate user-defined, arbitrarily-varying point source and gridded area source emissions. Most of the algorithms contain options to treat the physical processes of air dispersion at different levels of detail, depending on the model application. These features, coupled with the capability to calculate dispersion under calm or very low wind speeds

(i.e., less than 1 m/s [2.2 mi./h]), make the CALPUFF model well-suited to model odor emissions from the Sierrita Mine.

The CALPUFF modeling system consists of three sub-systems: 1) a meteorological modeling package (CALMET) with both diagnostic and prognostic wind field generators; 2) a non-steady puff dispersion model (CALPUFF) with chemical removal, wet and dry deposition, complex terrain algorithms, building downwash, plume fumigation, and other effects; and 3) post-processing programs (such as CALPOST) for generating output fields of meteorological data, concentrations and deposition fluxes.

The CALMET model is a meteorological model which includes a diagnostic wind field generator containing objective analysis and parameterized treatments of slope flows, kinematic terrain effects, terrain blocking effects, a divergence minimization procedure, and a micrometeorological model for overland and overwater boundary layers. CALMET develops hourly wind and temperature fields on a three-dimensional gridded modeling domain which incorporates the effects of terrain on wind flow patterns. Associated two-dimensional fields such as mixing heights, surface characteristics and dispersion properties are also included in CALMET. The three-dimensional wind field can be developed in CALMET using observations from meteorological monitoring stations within a domain, prognostic meteorological data or a combination thereof.

CALPUFF is a transport and dispersion model that advects a discrete number of packets of pollutants material (i.e., "puffs") emitted from modeled sources to represent the continuous plume, simulating dispersion and transformation processes along the way. Temporal and spatial variations in the meteorological fields derived from CALMET are explicitly incorporated in the resulting distribution of puffs throughout the simulation period.

The CALPUFF model was initialized and run for one (1) complete year (from July 1, 2014 to June 30, 2015). This is intended to capture the many different meteorological conditions that may affect odor emissions from the Sierrita Mine and helps to ensure that the maximum predicted concentrations are representative of the worst-case possible impacts from the mine. A brief description of the meteorological data used and the CALPUFF emission sources are given below. Additional details about the CALMET/CALPUFF inputs and settings are provided in Appendix A.

3.1 Emission Sources

In January 2015, Arcadis conducted a site-wide screening visit at the Sierrita Mine to observe Sierrita process operations, evaluate odors by sense of smell, and identify potential sources for subsequent odor sampling. In March 2015, Arcadis returned to the Sierrita Mine for further inspection of Sierrita process operations and to collect screening level odor samples for evaluation by an odor laboratory. Process operations observed during this visit were the tailings impoundment, the electrowinning tankhouse, the mill building, the reagent building, the tailings thickener tanks, solvent extraction, and a stormwater collection pond.

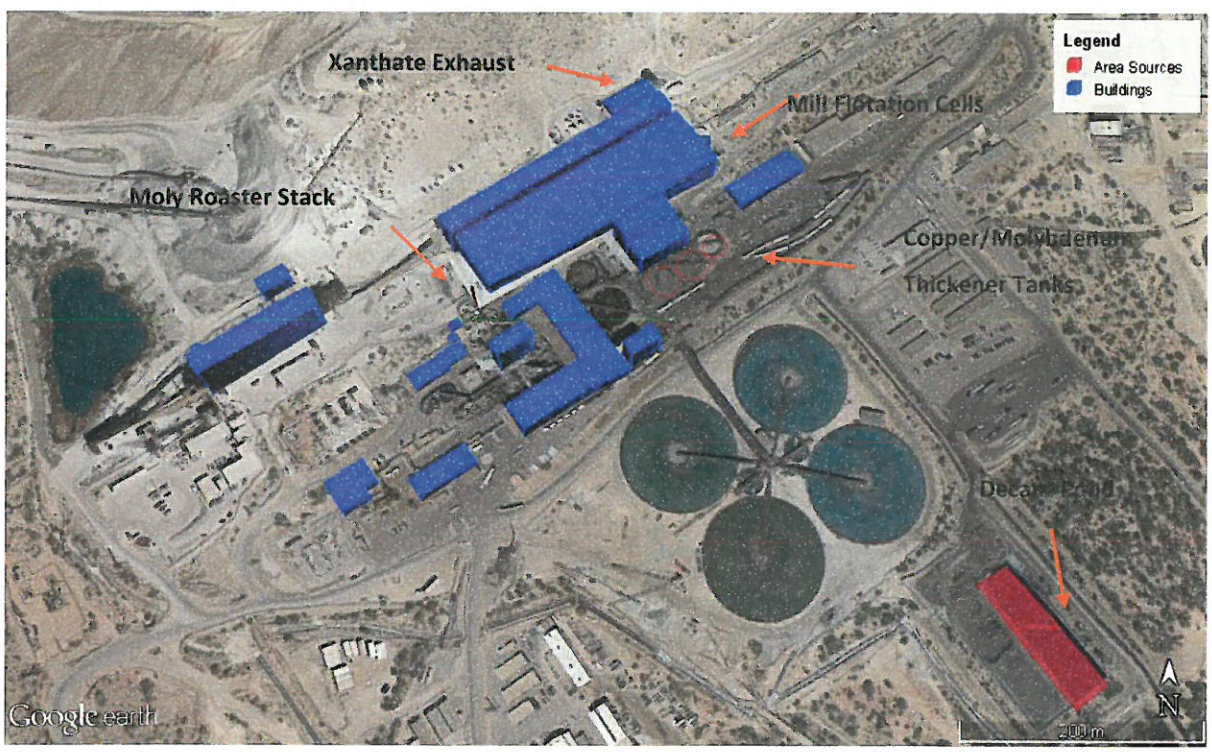
Based on odor observations of these process operations, odor samples were collected from the following sources at the Sierrita Mine:

- Moly Roaster Stack
- Mill Rougher Flotation – Pack 1, Cell 1
- Copper-Moly Thickener Tank C
- Solvent Extraction Plant 1 E-Stripper Tank
- Decant Liquid
- Xanthate Liquid Mix Tank

Air samples from each source were collected into Tedlar® (inert plastic) bags using an evacuation chamber and shipped overnight under Chain-of-Custody record to St. Croix Sensory, Inc. (St. Croix) in Stillwater, Minnesota, for odor evaluation by an odor panel. The St. Croix report is provided in Appendix B. Odor strength results (OU or OU/m^3) from all but one of the sampled sources were used in the modeling for this odor evaluation. The Solvent Extraction Plant Stripper Tanks were not modeled because these sources are covered and their odor emission rates were considered low enough such that they would not significantly impact the immediate surrounding area.

Figure 1 shows odor sources at the Sierrita Mine modeled in CALPUFF.

Figure 1 Odor Sources Modeled by CALPUFF



3.2 Meteorology

3.2.1 WRF-NMM Model

The meteorological dataset used for the Sierrita Mine odor modeling study was derived using the WRF-NMM[1]. WRF-NMM was run over a period of one year, initialized and driven by the North American Model (NAM)[2] meso-scale analyses. The WRF-NMM model used NAM analyses as both the initial conditions (updated every 24 hours) and the boundary conditions (updated every 6 hours). Updating the initial and boundary fields with analyses that are based on actual observations (such as NAM analyses) provides a realistic simulation of past meteorology.[3]

WRF-NMM was applied over a large domain that extends more than 450 km (280 mi.) east to west, and 600 km (373 mi.) north to south, in order to capture large-scale (i.e., synoptic scale) meteorological characteristics in the region (see Figure A1 in Appendix A). A fine horizontal grid spacing of 2 km (1.2 mi.) was applied in order to better resolve realistic meso-scale meteorological features within the WRF-NMM domain. The model used 38 vertical layers, from the surface up to a height of 39 km (24 mi.), with the first model level where wind is calculated being set at a height of 10 m (33 ft.) above the surface. The model's layers were defined more frequently within the first 2-3 km (1.2-1.9 mi.) above the surface, allowing for better resolution of boundary layer characteristics. WRF-NMM combines large-scale weather information from initial and boundary meteorological conditions and a geophysical description of the surface to simulate local-scale meteorology. Geophysical inputs, such as land use characterization and terrain elevations, were set using global geophysical data compiled by the United States Geological Survey (USGS) at 30 arc-seconds (approximately 1 km [0.6 mi.]) spatial resolution. The data was processed by the WRF Pre-processing System (WPS) and assembled on a 2 km (1.2 mi.) model grid. A detailed description of the WRF-NMM setup is given in Appendix A.

3.2.2 CALMET

The CALMET meteorological model (Scire *et al.* 2000) provides the meteorological data necessary to initialize the CALPUFF dispersion model. The CALMET model requires various meteorological and geophysical parameters as inputs. Output from the CALMET model includes hourly temperature and wind fields over the modeling domain, as well as additional two-dimensional variables used by the CALPUFF dispersion model (e.g., mixing heights, atmospheric stability). The description of the CALMET approach and options is given in Appendix A.

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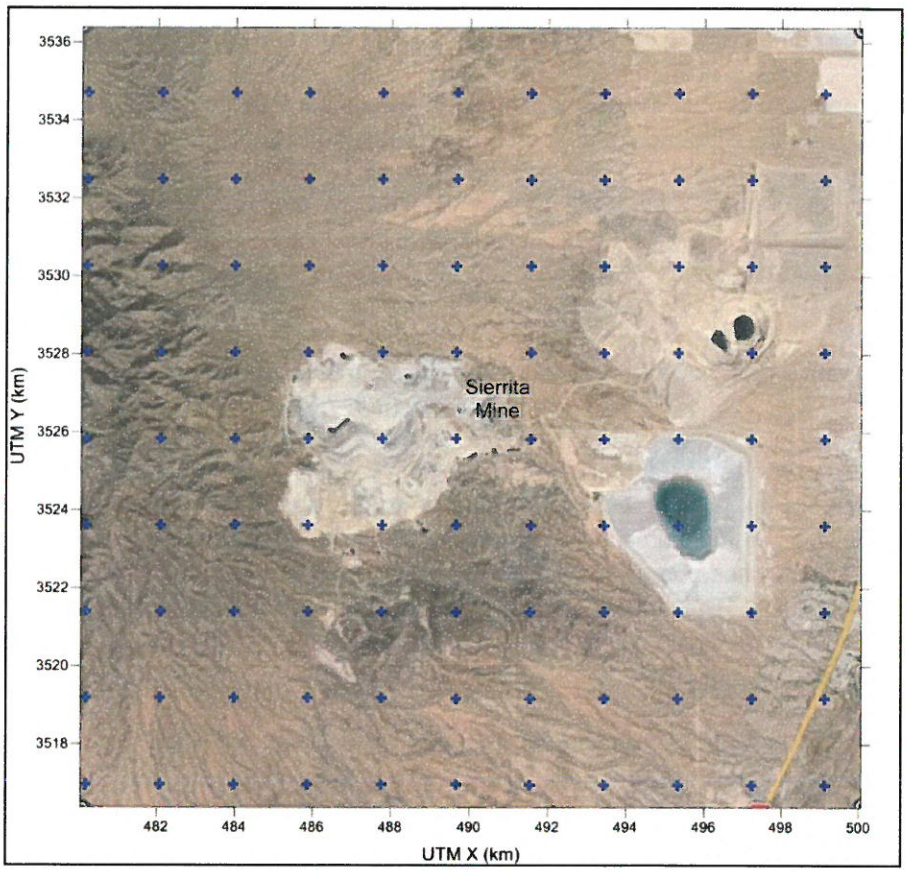
[1] WRF-NMM is a state-of-the-art numerical prediction model developed at the US National Center for Environmental Prediction (NCEP).

[2] The current North American Model is WRF-NMM with 12 km (7.5 mi.) horizontal grid resolution and 6-hour temporal resolution.

[3] Arcadis performed a detailed analysis of the on-site wind data for the period July 1, 2014 through June 30, 2015 collected at two meteorological towers at the Sierrita Mine (Tower 1 and Tower 2) to check for completeness and quality. The analysis showed that data for this period from the on-site observing towers was not acceptable for dispersion modeling purposes because Tower 1 data was missing from July 1, 2014 to September 8, 2014, and the wind data for this period from Tower 2 showed very poor agreement with the data modeled by WRF-NMM. For these reasons, the on-site wind data were not used as input to CALMET.

The CALMET model was run over a 20 km by 20 km (12.4 by 12.4 mi.) modeling domain centered on the mine and shown on Figure 2. CALMET was run with a fine spatial resolution (i.e., grid spacing) of 250 m by 250 m (820 ft. by 820 ft.), in order to adequately capture local terrain features and meso-scale winds, as well as any variability inherent in temperature and stability.

Figure 2 CALMET Model Domain



Note: + WRF-NMM M3D point locations

To properly simulate air dispersion in CALPUFF, it is important to be able to accurately simulate the typical log-linear vertical profile of wind speed, wind direction, temperature, and turbulence intensity within the atmospheric boundary layer (i.e., within about 2 km [1.2 mi.] above the surface). In order to capture this vertical structure, a total of ten vertical layers were used in CALMET with the lowest layer presenting the 10 m (33 ft.) above the ground (see Appendix A for additional detail).

The terrain elevation and land use data used as input to CALMET are outlined in Appendix A.

The CALMET meteorological fields were evaluated by reviewing model outputs to ensure that they capture the key meteorological features within the modeling domain (see Appendix A for more details).

3.3 CALPUFF Source Parameters

Table 1 lists the odor emission sources that were modeled as point sources (i.e., stacks) from the Sierrita Mine along with their modeled source characteristics. Point source characteristics such as stack exit diameter, exit velocity, etc. were provided to Arcadis. Emission rates were based on measured odor concentrations and the flow rate through the stack:

Odor emission rate (OU/s) = Measured Odor Concentration (OU/m^3) x Flow Rate (m^3/s)

Table 2 lists the odor emissions sources that were modeled as area sources. The modeled source characteristics or parameters for each odor source were determined based on the physical dimensions of the source. For the area sources, the volumetric flow rate was calculated based on an assumed surface escape velocity and the surface area of the source. The surface escape velocity was based on reported velocities for quiescent flow in secondary clarifiers and turbulent flow in launders at a waste water treatment plant (WEF/ASCE 1995). Thus, the emission rates for the area sources were calculated as follows;

Odor emission rate (OU/s) = Measured Odor Concentration (OU/m^3) x Source Area (m^2) x Surface Escape Velocity (m/s)

A volume source was used to characterize emissions from the mill building flotation cells (Table 3). The odor emission rate from the flotation cells was calculated using the same methodology as for the area sources (i.e. multiplying the measured odor concentration by the total source area and surface escape velocity). Emissions were based on all flotation cells emitting odor simultaneously from an opening at the east end of the mill building. The volume source characteristics such as effective height and initial lateral (i.e. Sigma-Y) and vertical dimensions (i.e. Sigma Z) were based on the dimensions of the opening at the east end of the mill building.

For all sources, modeled emission rates were assumed to be constant over time.

Table 1 Point Sources Modeled in CALPUFF

Source ID	Emission Source	Stack Height	Stack Diameter	Exit Velocity	Exhaust volumetric flow rate	Odor Concentration (OU/m³)	Odor Emission Rate (OU/s)
MRS	Moly Roaster Stack	38.1 m (125 ft.)	2.13 m (6.99 ft.)	5.9 m/s (19.2 ft./s)	21 m³/s (44,405 cfm)	580	12,155
XTE	Xanthate Mixing Tank Exhaust Stack	7.6 m (25 ft.)	0.15 m (0.49 ft.)	7.2 m/s (23.8 ft./s)	0.132 m³/s (280 cfm)	31,000	4,098

Table 2 Area Sources Modeled in CALPUFF

Source ID	Source Description	Area (m²)	Surface Escape Velocity	Odor Concentration (OU/m³)	Odor Emission Rate (OU/s)
THA	Copper/Molybdenum Thickener Tank A	728.3 m² (7836 f²)	0.0122 m/s (0.04 ft./s)	150	1,333
THB	Copper/Molybdenum Thickener Tank B	728.3 m² (7836 f²)	0.0122 m/s (0.04 ft./s)	150	1,333
THC	Copper/Molybdenum Thickener Tank C	421.7 m² (4539 f²)	0.0122 m/s (0.04 ft./s)	150	772
DCP	Decant Pond	4,047 m² (43561 f²)	0.0030 m/s (0.0098 ft./s)	2,900	35,208

Table 3 Volume Source Modeled in CALPUFF

Source ID	Source Description	Area	Surface Escape Velocity	Odor Concentration (OU/m³)	Odor Emission Rate (OU/s)	Effective Height	Initial Sigma Y	Initial Sigma Z
MILL	Mill Copper Flotation Cells	706.4 m² (7604 ft²)	0.0122 m/s (0.04 ft/s)	330	2,844	15 m (49 ft.)	3.7 m (12.1 ft.)	10.5 (34.4 ft.)

Notes:
*Total area of all mill flotation cells
Sigma-Y = a parameter that identifies the initial horizontal dispersion of the source
Sigma-Z = a parameter that identifies the initial vertical dispersion of the source

3.4 CALPUFF Receptor Locations

A multi-nested grid was applied over the CALPUFF modeling domain using three different horizontal spacing of:

- 100 m (328 ft.) within 1 km (0.62 mi.) of the modeled sources;
- 250 m (820 ft.) within 5 km (3.1 mi.) of the modeled sources; and
- 500 m (1640 ft.) within 10 km (6.2 mi.) of the modeled sources.

The use of a gridded receptor network (Figure 3) facilitates the construction of odor concentration isopleths, which are used to illustrate the maximum possible extent of odor impacts from the Sierrita Mine. In addition to the gridded receptor locations used, 20 discrete receptors were input into the model which represent the locations where complaints were made. The complaint locations are listed in Table 4 and shown on Figure 4. All receptors were modeled for odor unit values at a height of 1.5 m (4.9 ft.) above grade.

Figure 3 CALPUFF Nested Receptor Grid

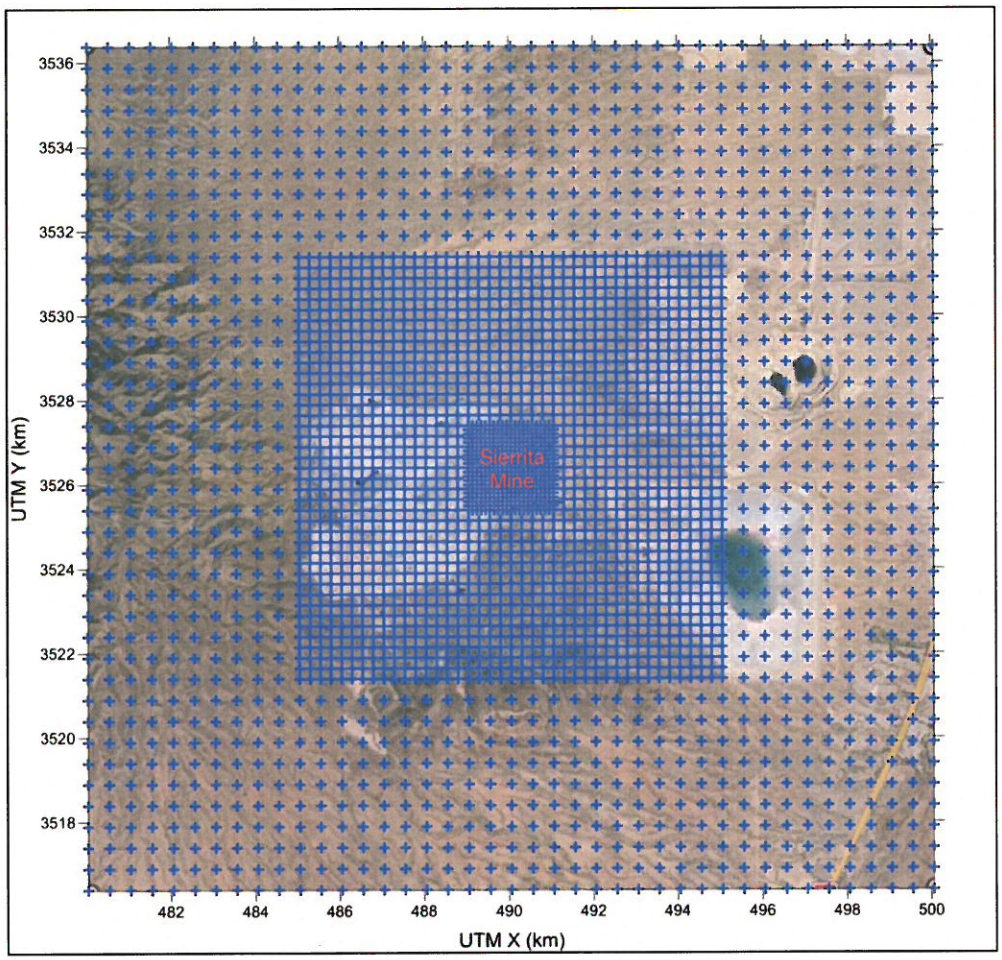
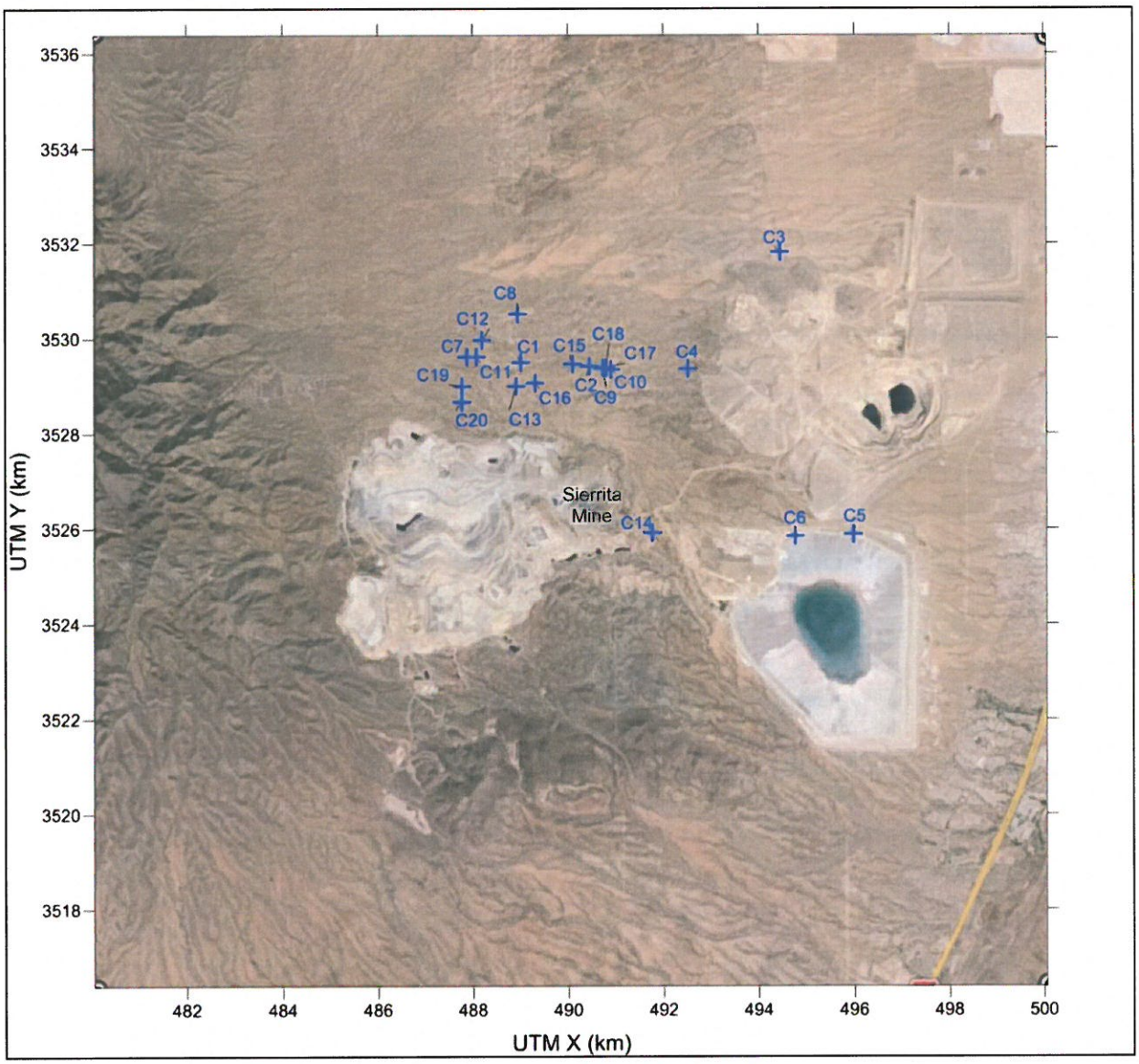


Table 4 Discrete Receptors at Complaint Locations

Location No.	Latitude	Longitude	Location
C1	31° 54' 11.13"N	111° 07' 00.80"W	7160 W. Lost Silver Lane
C2	31° 54' 08.47"N	111° 6' 06.23"W	McGee Ranch Road 1 mile East of Ruby Star Airpark
C3	31° 55' 26.19"N	111° 03' 34.32"W	Mission Rd and mile post 5
C4	31° 54' 07.16"N	111° 04' 47.72"W	Mission Rd and McGee Rd
C5	31° 52' 13.85"N	111° 02' 35.35"W	Continental and Duval Rd
C6	31° 52' 12.29"N	111° 03' 21.37"W	Duval and Mission Road
C7	31° 54' 14.69"N	111° 07' 44.13"W	7702 W. Lost Silver Lane
C8	31° 54' 44.17"N	111° 07' 03.17"W	18615 S. Ruby Star Airpark Drive
C9	31° 54' 07.47"N	111° 05' 55.42"W	driving from Ruby Star to Mission
C10	31° 54' 06.14"N	111° 05' 48.78"W	on McGee Ranch Rd, 1 mile West of Mission Rd
C11	31° 54' 14.88"N	111° 07' 36.41"W	on Copper Cave Drive adjacent to 7702 W. Lost Silver Lane
C12	31° 54' 26.09"N	111° 07' 31.61"W	7600 W. Lost Emerald Lane
C13	31° 53' 54.50"N	111° 07' 04.77"W	Coming into Ruby Star Airpark, at entry gate
C14	31° 52' 14.55"N	111° 05' 15.78"W	Duval Mine Rd., various locations near the pipe and truss conduit crossings
C15	31° 54' 10.36"N	111° 06' 19.95"W	McGee Rd, 0.8 miles east of Ruby Star front gate (near the green school bus stop sign).
C16	31° 53' 57.15"N	111° 06' 49.32"W	while traveling on west on McGee Ranch Road at Aztec Gold
C17	31°54'7.47"N	111° 5'55.42"W	While driving on McGee Ranch Rd 1.2 miles East of Ruby Star Airpark Rd
C18	31° 54' 07.29"N	111° 05' 53.26"W	on McGee Rd about 0.3 mi west of Garrison Rd
C19	31° 53' 54.73"N	111° 07' 47.71"W	7790 W. McGee Ranch Road
C20	31° 53' 44.02"N	111° 07' 47.95"W	3/4 mile west of Ruby Star Airpark front gate

Figure 4 Complaint Locations



4 MODELING RESULTS

Each source of odor emission at the Sierrita Mine was modeled separately in CALPUFF using a unit emission rate of 1 OU/s in order to determine the predicted odor dispersion factor (in odor units per cubic meter per odor unit per second emission [OU/m^3 per OU/s]) at each off-site receptor location, at each hour. The predicted dispersion factor depends on meteorological conditions and changes from hour to hour and with location within the model domain. The resultant odor dispersion factors were then scaled by applying the odor emission rates shown in Table 1 to Table 3, at each hour using the CALSUM post-processing software. For example, odor is emitted from the Moly Roaster Stack at a rate of 12,155 OU/s. The maximum dispersion factor for this source at complaint location C1 on September 6th 2014 at 1800 hours (6 PM) is 3.32 E-06 OU/m^3 per OU/s. The resulting odor concentration (i.e. maximum 1-hour concentration) at C1 on September 6th 2014 at 1800 hours is therefore 0.04 OU/m^3 (i.e. 12155 OU/s x 3.32E-06 OU/m^3/OU/s = 0.04 OU/m^3).

CALSUM was then used to combine the predicted output concentrations from each source/model run in order to create a single data file containing the cumulative concentrations from all sources at each receptor for each hour of meteorological data. The CALPOST post-processor was then run in order to calculate the maximum 1-hour odor concentration (in OU/m^3) at each receptor. The 10-minute odor concentrations were then calculated from the hourly odor concentrations by applying a conversion coefficient of 1.65 derived from the following equation (MOE, 2009):

$$f(t,t_0) = (t_0/t)^{0.28}$$

Where:

(t) is the averaging time of interest (10 minutes)

(t_0) is the averaging time consistent with the dispersion rates used to obtain the mean 1-hour odor concentration from the CALPUFF model (60 minutes).

Figure 5 represents the maximum 10-minute concentrations based on predicted odor emission sources and local meteorological conditions. It is important to note that the contours shown in Figure 5 do not represent a snapshot in time as the maximum concentrations at each receptor typically occur during different meteorological conditions (i.e., different hours and/or days) and do not occur simultaneously. For example, at a point south of a source, winds blowing from the north may give rise to the maximum concentration, whereas for a point north of the source, the worst meteorological conditions may occur with a different wind direction. Figure 5 also shows the two most frequent complaint locations, C1 and C7 (where 69% of all complaints during the one-year period were recorded), as well as complaint location C14, which had the highest predicted maximum odor 10-minute concentration (3.6 OU/m^3) out of all 20 complaint locations.

Predicted maximum 10-minute odor concentrations at each complaint location are shown in Table 5.

Figure 5 CALPUFF Predicted Maximum Odor Concentrations (OU/m³) Exceeding Complaint Threshold

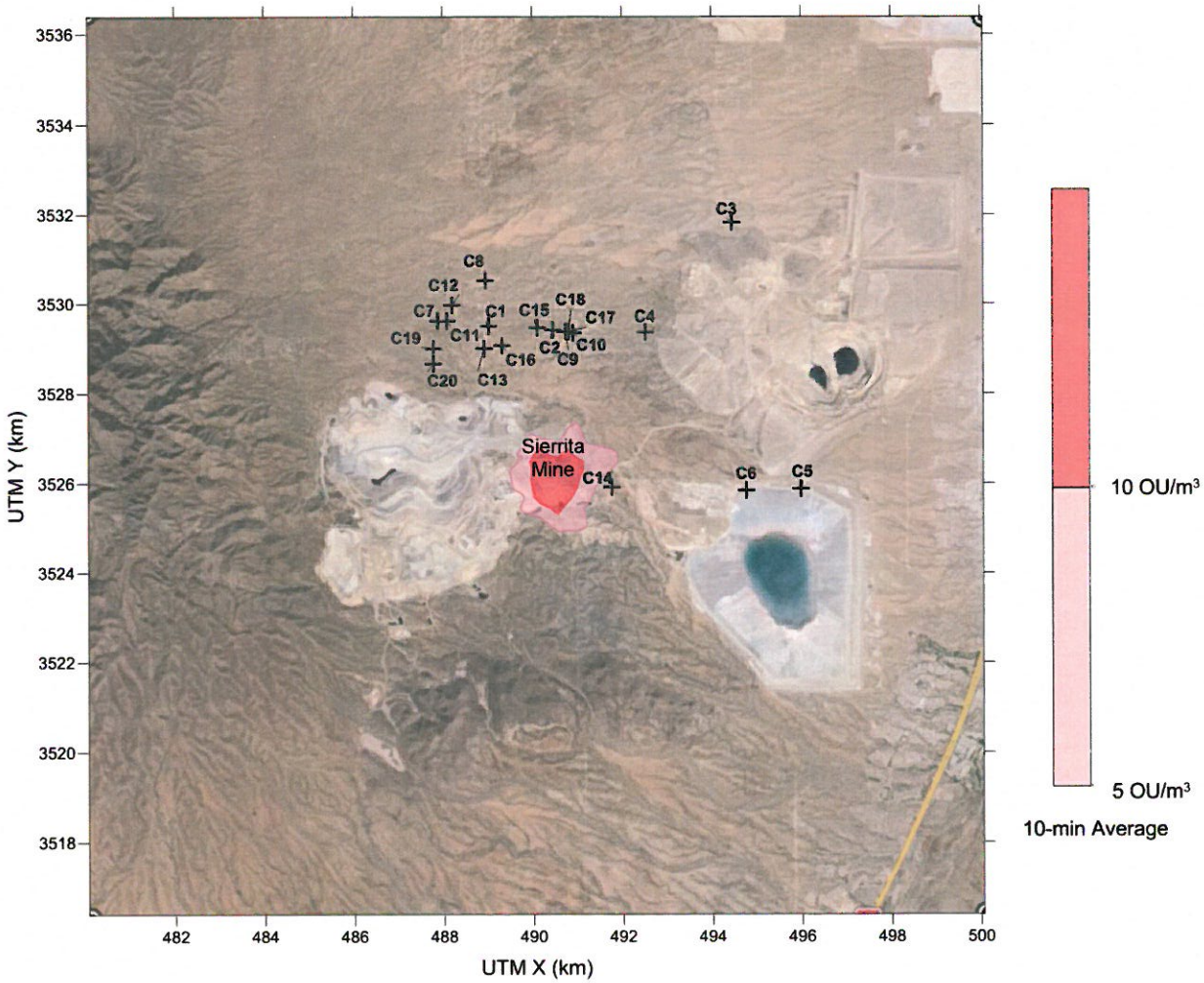


Table 5 Predicted Maximum 10-minute Odor Concentrations (OU/m³) at Complaint Locations

Complaint ID	UTM Coordinates		10-min Odor Concentration (OU/m³)
	X (km)	Y (km)	
C1	489.01	3529.50	0.39
C2	490.45	3529.42	1.11
C3	494.44	3531.81	0.19
C4	492.51	3529.37	0.57
C5	495.98	3525.88	0.24
C6	494.77	3525.84	0.51
C7	487.87	3529.61	0.21
C8	488.95	3530.52	0.21
C9	490.73	3529.38	1.19
C10	490.90	3529.34	1.20
C11	488.08	3529.62	0.28
C12	488.20	3529.96	0.22
C13	488.91	3528.99	0.81
C14	491.77	3525.91	3.58
C15	490.09	3529.47	0.84
C16	489.31	3529.07	0.52
C17	490.73	3529.38	1.19
C18	490.79	3529.38	1.19
C19	487.78	3529.00	0.36
C20	487.77	3528.67	0.34

To evaluate the degree to which each modeled source has the potential to generate complaint-level odors (5 OU or greater) in the area surrounding the Sierrita Mine, a source contribution analysis of the modeled odor sources was performed for the locations C1, C7 and C14. Based on the model results, the largest potential contributor to odor concentrations at these three locations is the Decant Pond (approximately 81%, 62% and 95%, respectively) as shown in Table 6. Although the Decant Pond appears to be the primary contributor to the odor concentrations at C1, C7 and C14, it should be noted that the CALPUFF-predicted odor concentrations at these locations are below the 5 OU complaint-level threshold identified for this evaluation.

Table 6 Odor Source Contribution (%) at Complaint Locations C1, C7 and C14

SOURCE	Contribution (%)		
	C14	C1	C7
Decant Pond	94.8%	81.1%	62.2%
C/M Thickener A	1.5%	3.5%	3.1%
C/M Thickener B	1.4%	3.2%	3.3%
Mill Copper Flotation Cell	0.9%	6.6%	8.8%
C/M Thickener C	0.8%	2.2%	1.8%
Moly Roaster Stack	0.3%	2.1%	15.4%
Xanthate Mixing Exhaust	0.3%	1.4%	5.5%

4.1 Model Uncertainty

Dispersion models are typically considered to have an inherent uncertainty factor of +/-2 to +/-4 between predicted and observed odor unit concentrations. The uncertainty tends toward the higher end of this range for shorter averaging periods (e.g., 1-hour average or less) than for longer averaging periods (24-hour to monthly or annual averages). Due to this inherent uncertainty, the results of the modeling analysis require some caution in their interpretation.

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APPENDIX A

Model Configurations

APPENDIX A: Model Configurations

A1 – WRF-NMM Model

The WRF-NMM model solves fundamental equations of atmospheric motion on a three-dimensional grid. The model incorporates parameters that influence atmospheric conditions, such as turbulence, convection and cloud formation, precipitation, radiation, surface heat transfer, and moisture. The WRF-NMM model configuration is summarized in Table A1.

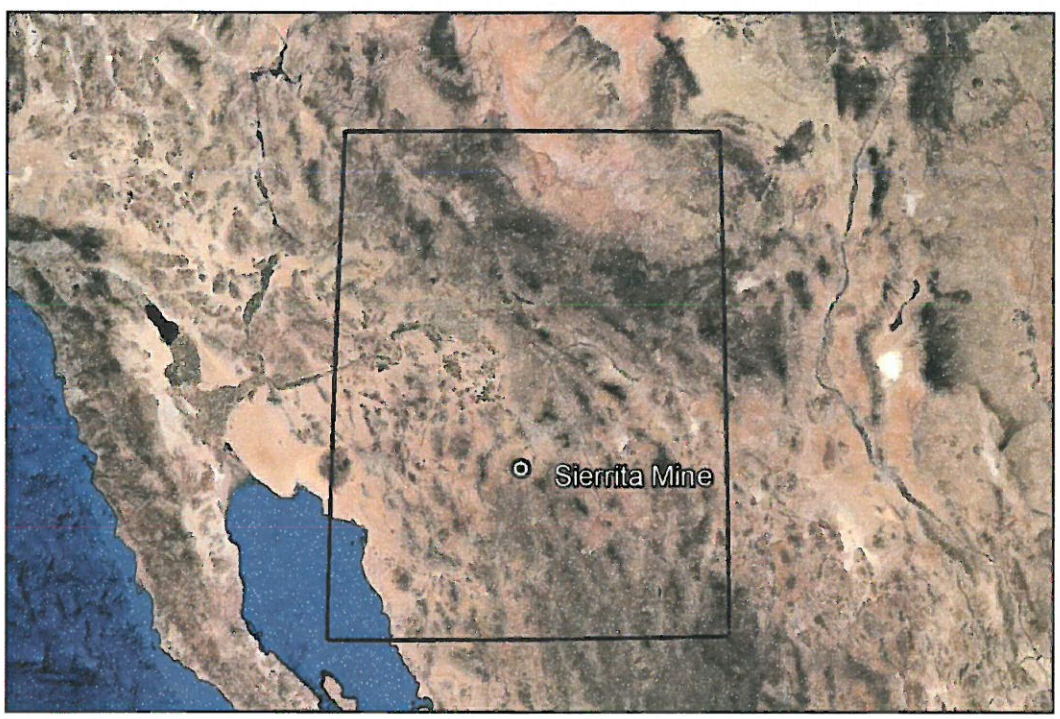
Table A1 WRF-NMM Model Configuration

Description	Configuration Option
Time step:	6 s
Microphysics:	Ferrier scheme
Long-wave radiation/ Short-wave radiation:	GFDL scheme/ GFDL scheme
Boundary Layer:	Mellor-Yamada-Janjic TKE scheme
Surface Layer:	Janjic Scheme
Cumulus parameterization:	Betts-Miller-Janjic scheme
Dynamics:	NMM v3.4.1

The model is able to produce a complete three-dimensional estimate of the wind, temperature, humidity and several other variables for each hour throughout the period modeled. Observations, on the other hand, only provide information of actual meteorology for a single point and vertical profile data are sparsely available.

Figure A1 shows the WRF-NMM model domain.

Figure A1 WRF-NMM Model Domain



A2 – CALMET Model

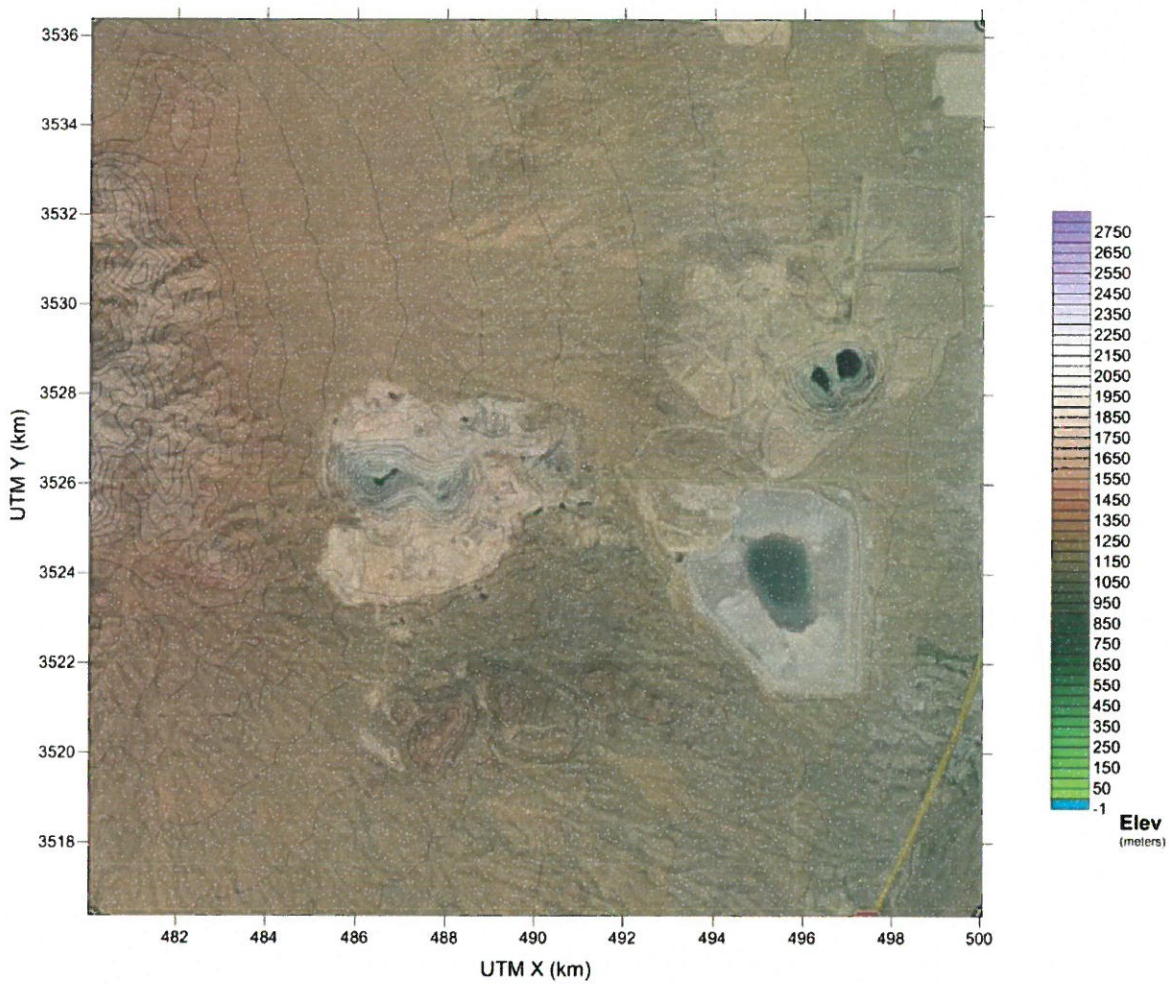
CALMET requires a physical description of the surface, in order to characterize the meteorological parameters in the boundary layer (i.e., near the surface). The geophysical parameters are outlined below:

- Terrain elevation data;
- Land use data;
- Surface roughness length;
- Albedo;
- Bowen ratio;
- Soil heat flux;
- Vegetation leaf area index; and
- Anthropogenic heat flux.

Terrain Elevation Data

Gridded terrain elevations for the modeling domain were derived from SRTM3-Shuttle Radar Topography Mission Global Coverage data, produced by the National Aeronautics and Space Administration (NASA). The spacing of the elevation data is 3 arc-seconds (approximately 90 m [295 ft.]). The raw terrain data were processed in each gridded cell (i.e., 250 m by 250 m [820 ft. by 820 ft.] within the CALMET modeling domain and the resulting terrain elevations are presented in Figure A2. The CALMET terrain data was modified using site-specific data in the vicinity of the Sierrita Mine northeast waste rock pile to effectively resolve all major land features within the modeling domain.

Figure A2 CALMET Terrain



Land Use Data

Land use and land cover data for the CALMET modeling domain were gathered from U.S. Geological Survey National Land Cover Dataset 1992 (USGS NLCD92).

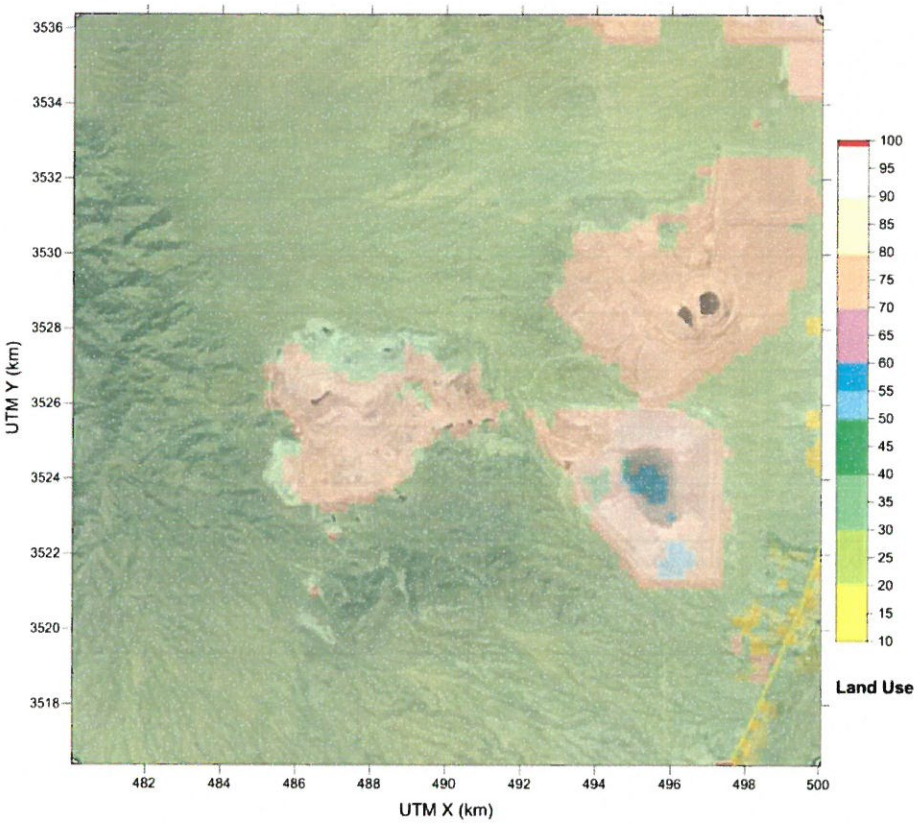
CALMET defines 14 default land use categories using the USGS system (Table A2). Surface properties such as albedo, Bowen ratio, roughness length, and soil heat flux and leaf area index are computed proportionately to the fractional land use category within each grid cell. The default values for these land use related parameters are listed in Table A2. The generated land use categories for each CALMET grid cell are also shown in Figure A3.

Table A2 CALMET Land Use Categories

Land Use	Description	Surface Roughness (m)	Albedo	Bowen Ratio	Soil Heat Flux Parameter	Anthropogenic Heat Flux (m)	Leaf Area Index
10	Urban or Built-up Land	1	0.18	1.5	0.25	0	0.2
20	Agricultural Land – Unirrigated	0.25	0.15	1	0.15	0	3
-20*	Agricultural Land – Irrigated	0.25	0.15	0.5	0.15	0	3
30	Rangeland	0.05	0.25	1	0.15	0	0.5
40	Forest Land	1	0.1	1	0.15	0	7
50	Water	0.001	0.1	0	1	0	0
54	Small Water Body	0.001	0.1	0	1	0	0
55	Large Water Body	0.001	0.1	0	1	0	0
60	Wetland	1	0.1	0.5	0.25	0	2
61	Forested Wetland	1	0.1	0.5	0.25	0	2
62	Nonforested Wetland	0.2	0.1	0.1	0.25	0	1
70	Barren Land	0.05	0.3	1	0.15	0	0.05
80	Tundra	0.2	0.3	0.5	0.15	0	0
90	Perennial Snow or Ice	0.05	0.7	0.5	0.15	0	0

Note: Based on the U.S. Geological Survey Land Use and Land Cover Classification System (52-Categories).

Figure A3 CALMET Land Use



All other geophysical parameters listed above are based on default values outlined in the CALMET modeling guidelines (Scire *et al.* 2000).

Ten vertical layers were used in CALMET and presented in Table A3.

Table A3 Vertical Layers Used in the CALMET Model

Depth of Layer (m)	Height of Layer (m)	Comments
20 (66 ft.)	20 (66 ft.)	10-m (33 ft.) meteorology at center of layer
20 (66 ft.)	40 (131 ft.)	
40 (131 ft.)	80 (262 ft.)	
80 (262 ft.)	160 (525 ft.)	
160 (525 ft.)	320 (1,050 ft.)	
320 (1,050 ft.)	640 (2,100 ft.)	
560 (1,837 ft.)	1,200 (3,937 ft.)	
800 (2,625 ft.)	2,000 (6,262 ft.)	
1,000 (3,280 ft.)	3,000 (9,843 ft.)	
1,000 (3,280 ft.)	4,000 (13,123 ft.)	

CALMET Model Options

CALMET requires a number of specific model options and user-defined parameters to be defined in the input file. In most cases, the technical options for the CALMET model run used in this study were set to default values. CALMET uses gridded wind fields generated by a numerical prognostic model in the form of a three dimensional data file. The three-dimensional wind field reflects local terrain and meso-scale winds, temperature and stability variations and offers advantages in terms of representing horizontal and vertical spatial variability over point (observation) measurements. The 3D.DAT file contains three-dimensional hourly profiles of wind speed, wind direction, temperature, humidity and pressure, and usually contains precipitation, solar and long wave radiation, and, if relevant, sea surface temperature. Ceiling height and cloud amount are derived variables in CALMET in "No-Observations" mode. The preferred option is to use prognostic data as the initial guess field. In this approach the coarse grid scale prognostic data are interpolated to the CALMET fine-scale grid. The diagnostic module in CALMET will then adjust the initial guess field for kinematic effects for terrain, slope flows and terrain blocking effects using the fine-scale CALMET terrain data to produce a Step 1 wind field.

The CALMET user-defined Input Group 4 and 5 switch settings is presented below:

- ICLOUD=4 (i.e. Gridded cloud cover from Prognostic relative humidity at all levels;
- IPROG=14 (i.e. The prognostic data is input as the initial guess field;
- TERRAD, the terrain radius of influence, was set at 6 km (3.7 mi.).

CALMET Model Validation

The objective of evaluating the CALMET meteorology derived from a prognostic meteorological model (such as WRF-NMM) for use in air quality dispersion modeling is to determine whether or not that data set captures the features that might affect air dispersion in the area being assessed.

Figure A4 presents a snapshot in time of the wind field at 10 m (33 ft.) height (May 1st, 2015 at 00:00 hours). This figure shows that CALMET wind flow follows the local terrain features in the vicinity of the Sierrita Mine.

The wind rose plot generated from CALMET at the location of the mill building at the Sierrita Mine is shown on Figure A5.

Figure A4 CALMET 10-m (33 ft.) Wind Field on May 1st, 2015 at 00 LST

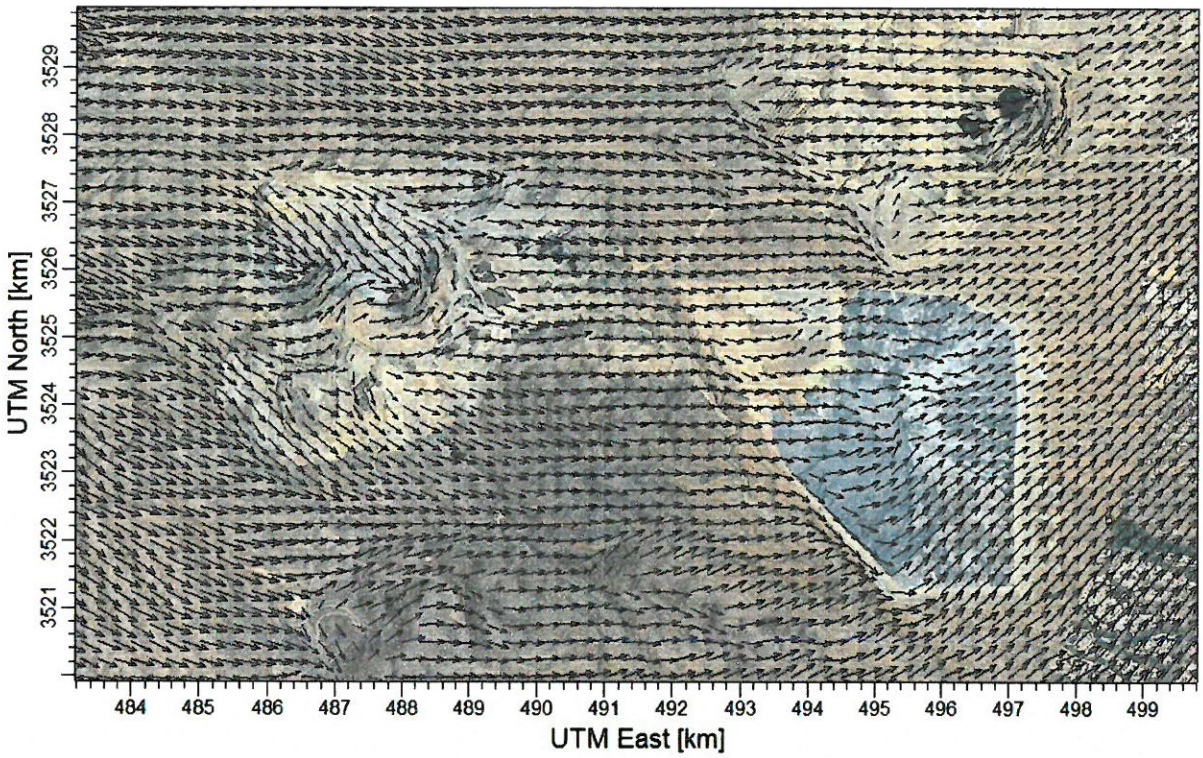
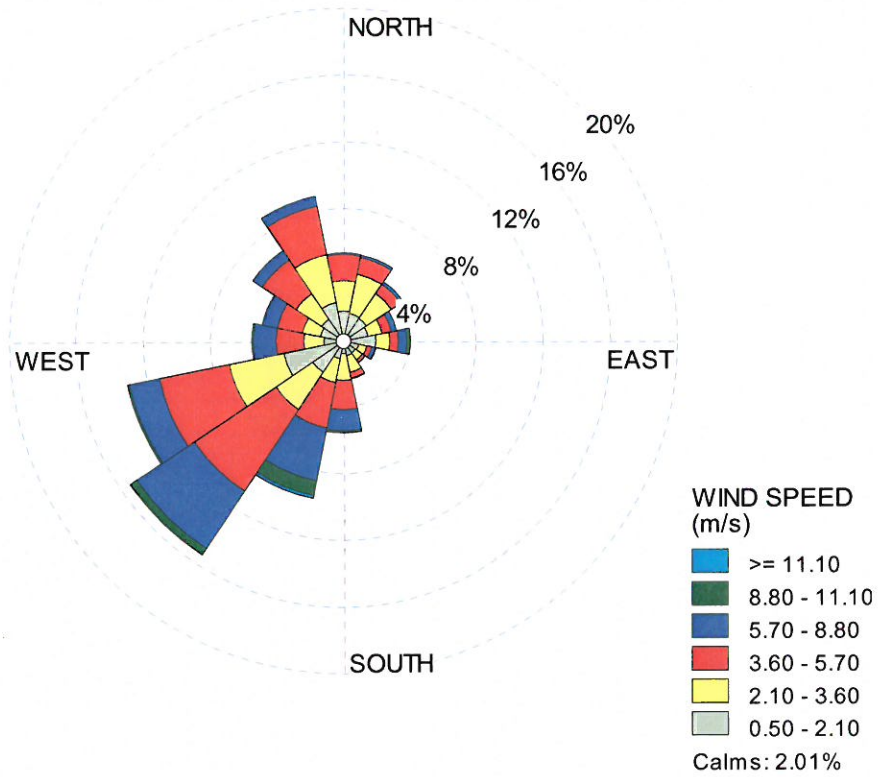


Figure A5 CALMET Wind Rose

July 1, 2014 to June 30, 2015 at the Mill location



Average wind speed =3.61 m/s (8.08 mi./h)

CALMET modeled 2-m (6.7 ft.) temperature was compared to the on-site observations from Tower 1 and presented in Figure A6 and Figure A7 as monthly averages and by hour-of-day, respectively.

Figure A8 shows the diurnal profile of 10-m (33 ft.) wind speed modeled by CALMET and observed at on-site station Tower 1. As can be seen from these comparisons, there is very good agreement between observed surface temperature and wind speed and those generated by CALMET at the on-site station. In addition, average monthly distribution and diurnal profile are presented for the modeled mixing height at the on-site location in Figure A9 and

Figure A10. The frequency of occurrence of each stability class, as predicted by CALMET at the on-site location is presented in Figure A11.

Evaluation of CALMET model results indicates that the wind data developed by CALMET are representative of the local meteorological conditions. CALMET also accurately reproduces the hourly and monthly distribution of observed average temperatures and wind speed.

Figure A6 Monthly Average Temperature Comparison: CALMET vs. On-site

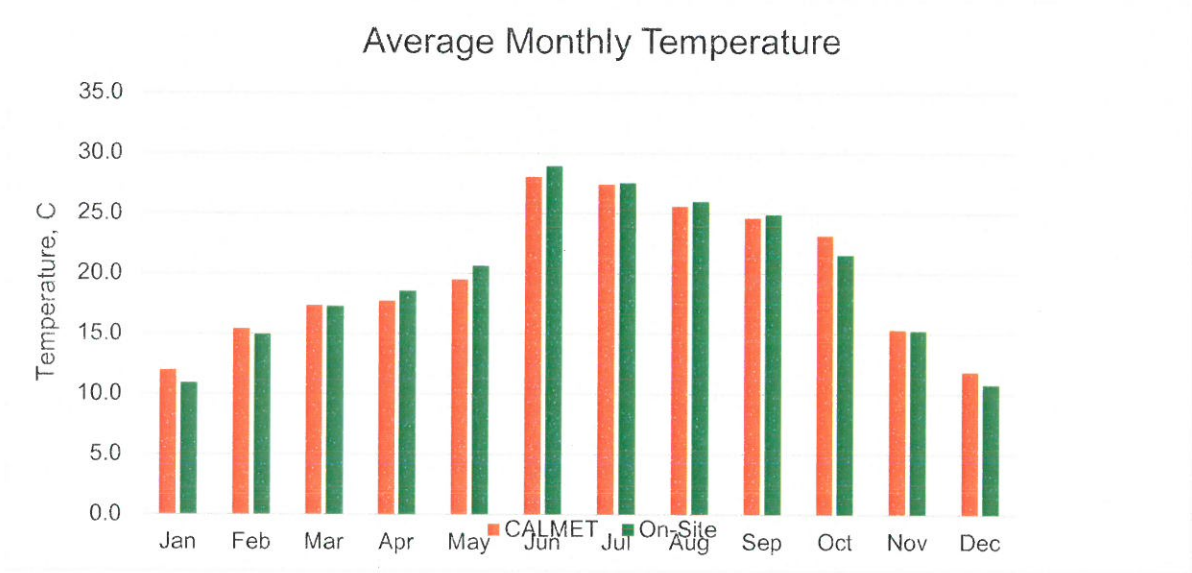


Figure A7 Diurnal Temperature Profile: CALMET vs. On-site

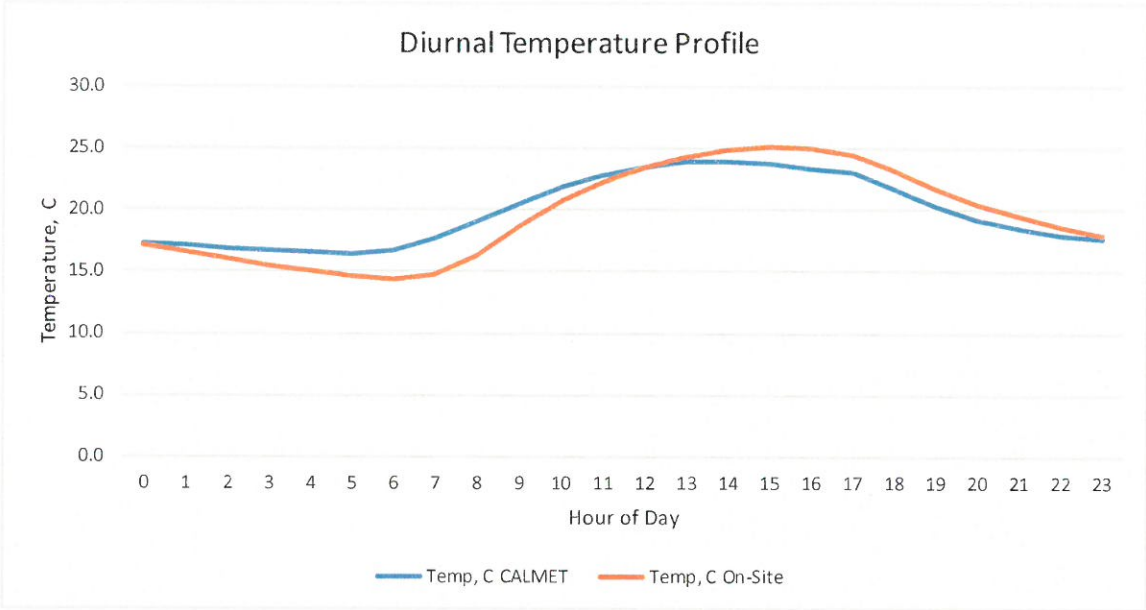


Figure A8 Diurnal 10-m (33 ft.) Wind Speed Profile: CALMET vs. On-site

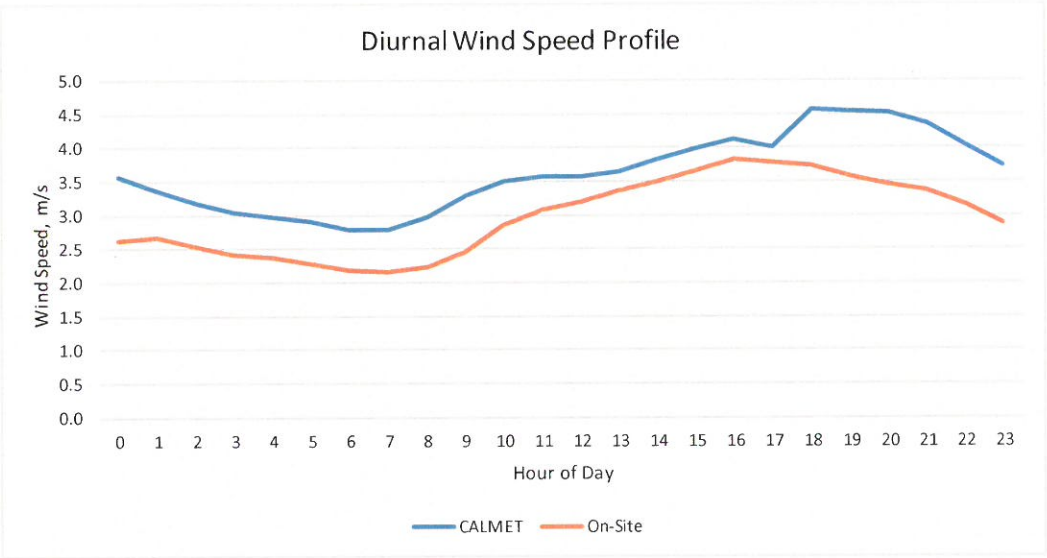


Figure A9 CALMET Average Mixing Height

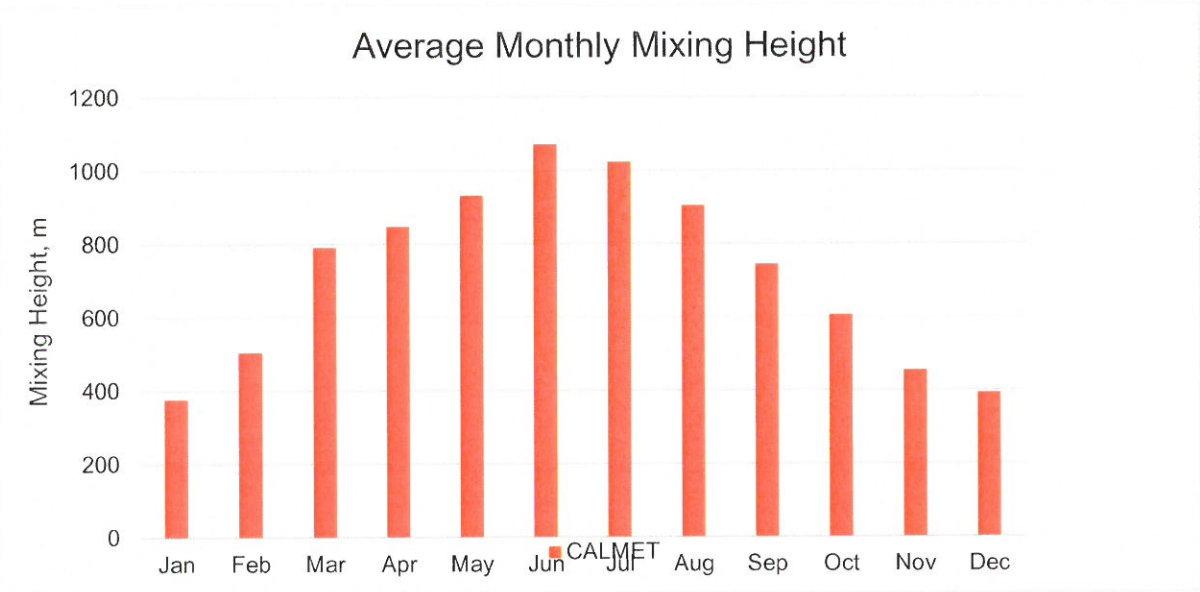


Figure A10 Diurnal Variations of CALMET Mixing Height

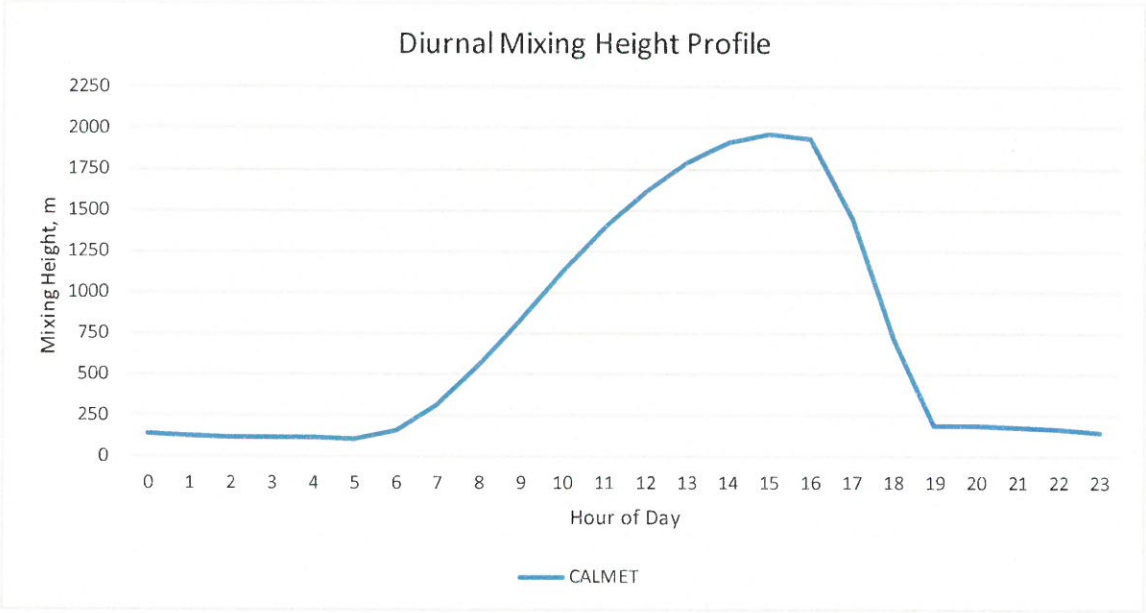


Figure A11 CALMET Stability Class Distribution

CALPUFF Model Options

The CALPUFF model provides multiple options for evaluating modeling scenarios. For the Sierrita Mine odor analysis, the model was run using model default settings for most parameters. Table A4 shows the user-defined CALPUFF parameters used in this assessment.

Table A4 CALPUFF User-Defined Parameters

Parameter	Value	Description
MDISP	2	Dispersion coefficients calculated from CALMET micrometeorological variables
MBDW	2	PRIME Method
MDRY	0	Dry removal not modeled
MWET	0	Wet removal not modeled
MCHEM	0	Chemical transformation not modeled

Figure A12 through A15 provide examples of the odor plume and wind field simulated by CALPUFF for three (3) events:

- February 7, 2015: the day with the highest number of complaints recorded. Seven (7) complaints were made between 9 a.m. and 10 a.m.
    - C1 at 9 a.m.
    - C8 at 9:30 a.m.
    - C7 at 10 a.m.
    - C13 at 10 a.m.
    - C2 at 10 a.m.
    - C14 at 10 a.m.
    - C15 at 10 a.m.
- June 7, 2015: the day with the second highest number of complaints recorded. Five (5) complaints were made between 4:30 a.m. and 8:13 a.m.
    - C1 at 4:30 a.m. and 5:00 a.m.
    - C7 at 6:50 a.m.
    - C13 at 7:25 a.m.
    - C20 at 8:13 a.m.

- September 15, 2014: a day with one complaint recorded at C1 at 7:15 a.m. This is also the day that CALPUFF predicts the maximum odor concentrations at C1 and C7. The maximum occurs at 6 p.m.

Four (4) figures for each event are provided to show how the plume changes over time.

Figure A12 Snapshots of CALPUFF Modeled Plume and Wind Field on February 7, 2015

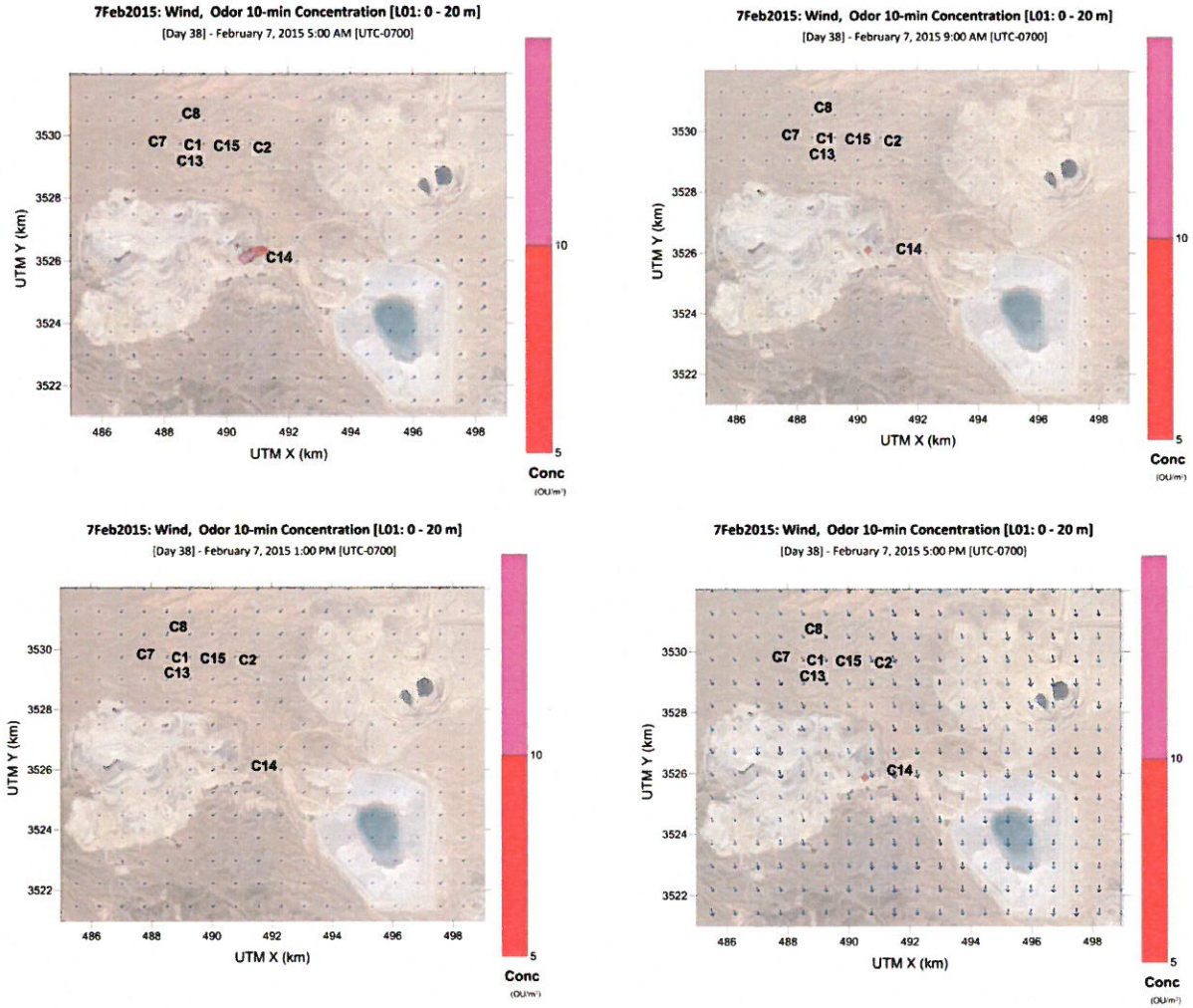


Figure A134 Snapshots of CALPUFF Modeled Plume and Wind Field on June 7, 2015

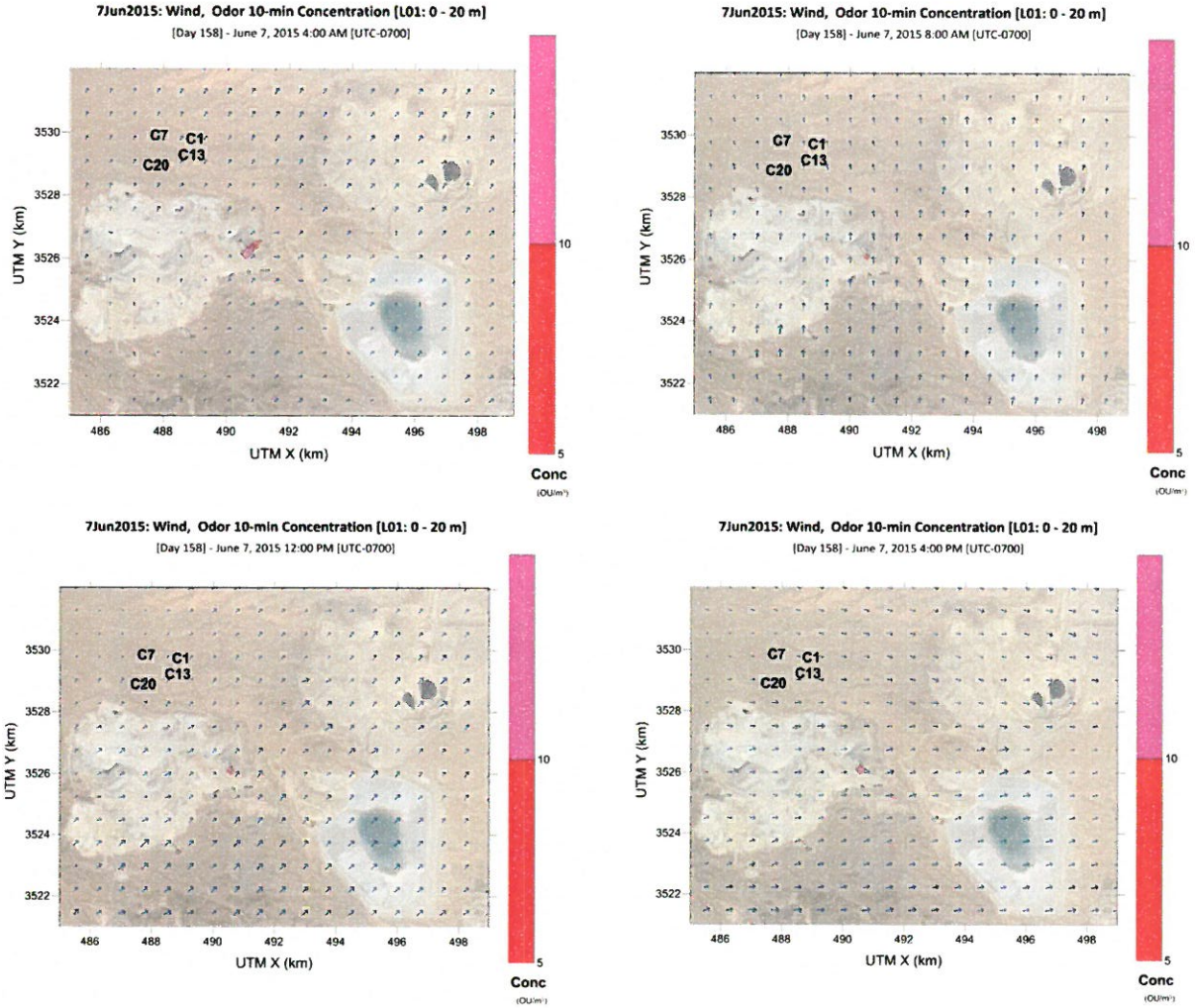
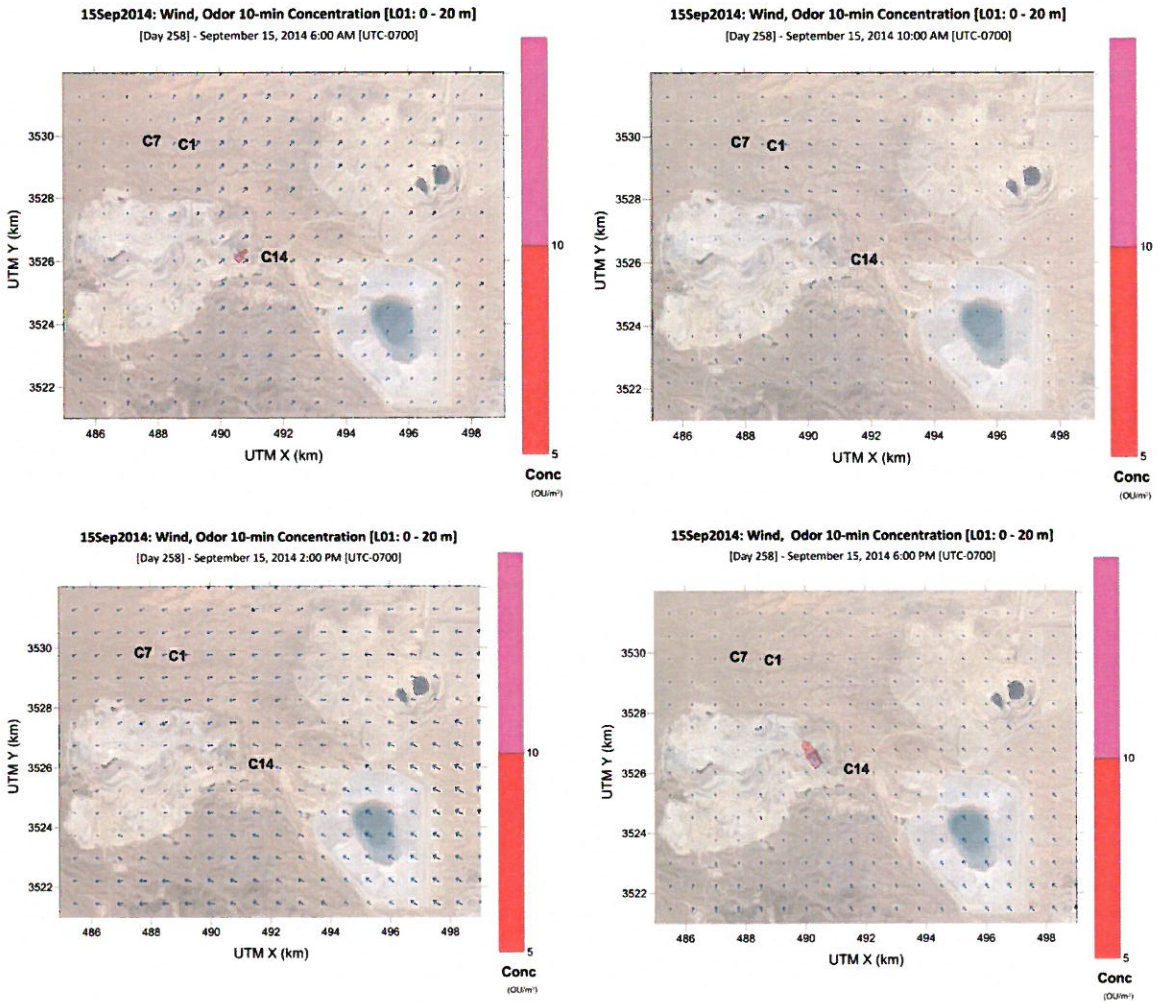


Figure A14 Snapshots of CALPUFF Modeled Plume and Wind Field on September 15, 2014



APPENDIX B

St. Croix Report

St. Croix Sensory, Inc.

Arcadis US, Inc.

Sierrita Mine

Odor Evaluation Report

Report No. 1507802
03/19/15

Data Release Authorization:

Michelle L Harty

Michelle Harty
Laboratory Associate

Reviewed and Approved:

Charles M McGinley

Charles M. McGinley, P.E.
Technical Director

St. Croix Sensory is a laboratory dedicated to practicing state-of-the-art sensory evaluation and to advancing the science of sensory perception.

We are a family owned and operated business providing our clients with personal customer service, flexible scheduling, timely results.

Our focus is to provide the best professional services available to help make your project or product a success.

ISO/IEC 17025:2005 Accredited

PJLA
Testing

Accreditation #81047

1150 Stillwater Boulevard North
Stillwater, Minnesota 55082 U.S.A

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Tel: 800-879-9231
Fax: 651-439-1065
Email: stcroix@fivesenses.com

St. Croix Sensory, Inc.

Odor Evaluation Report

Client: Arcadis US, Inc.

Project: Sierrita Mine

Report No.: **1507802**

Evaluation Date: 03/19/15

			ASTM E679 & EN13725		ASTM E544	PERSISTENCY	CHARACTERIZATION		
#	Field No.	Sample Description	Detection Threshold	Recognition Threshold	Intensity	Dose-Response Slope	Hedonic Tone	Principal Odor Descriptors	**Comments**
1	1A	Moly Roasta Stack - Sample Port	580	310	46	-0.55	-1.2	Medicinal, Chemical, Earthy, Offensive	
2	2A	Flotation	330	180	117	-0.76	-4.0	Chemical, Offensive, Earthy, Fruity, Medicinal	
3	3A	"C" Copper/Moly Thickener Surface	150	85	58	-0.65	-2.8	Chemical, Offensive, Earthy, Medicinal	
4	4B	SX-1 "E" Stripper Tank - Diluted 10:1	290	150	95	-0.82	-3.6	Chemical, Offensive, Earthy, Medicinal	
5	5A	Decant Feed - Bottle Agitation	2,900	1,500	155	-0.61	-5.2	Offensive, Chemical, Earthy	
6	6B	Xanthate Mixed 10:1 Diluted	3,100	1,600	195	-0.63	-5.8	Offensive, Fishy, Earthy	
7									
8									
9									
10									

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St. Croix Sensory, Inc.

Odor Evaluation Report

Client: Arcadis US, Inc.

Field No.: 1A

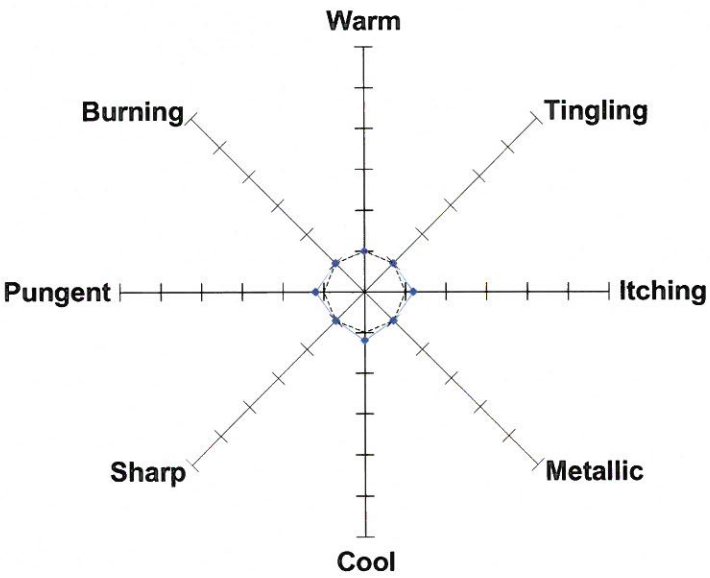
Report No.: **1507802**

Project: Sierrita Mine

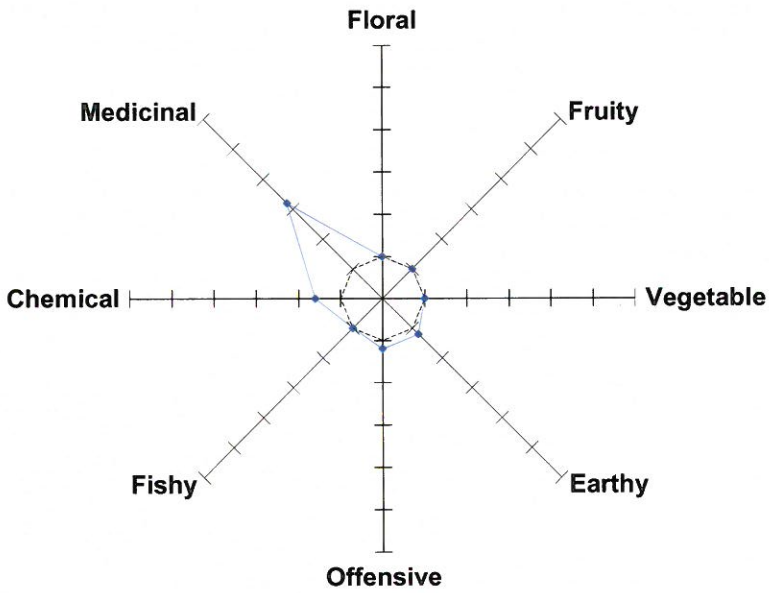
Description: Moly Roasta Stack - Sample Port

Evaluation Date: 03/19/15

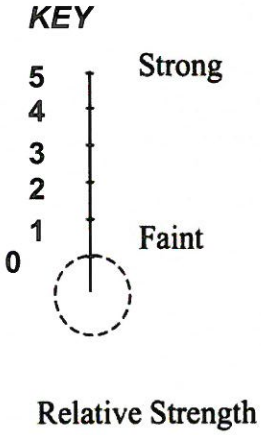
Sensation Descriptor Graph



Odor Descriptor Graph



	Average Relative Strength
Warm	0.0
Tingling	0.0
Itching	0.2
Metallic	0.0
Cool	0.2
Sharp	0.0
Pungent	0.2
Burning	0.0



	Average Relative Strength
Floral	0.0
Fruity	0.0
Vegetable	0.0
Earthy	0.2
Offensive	0.2
Fishy	0.0
Chemical	0.6
Medicinal	2.2

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St. Croix Sensory, Inc.

Odor Evaluation Report

Client: Arcadis US, Inc.

Field No.: 1A

Report No.: **1507802**

Project: Sierrita Mine

Description: Moly Roasta Stack - Sample Port

Evaluation Date: 03/19/15

% of Assessors |**********|**********|**********|**********| 100%

Medicinal **********
Disinfectant **********
Ammonia **********
Chlorinous **********
Chemical **********
Solvent **********
Offensive **********
Decay **********
Earthy **********
Stale **********

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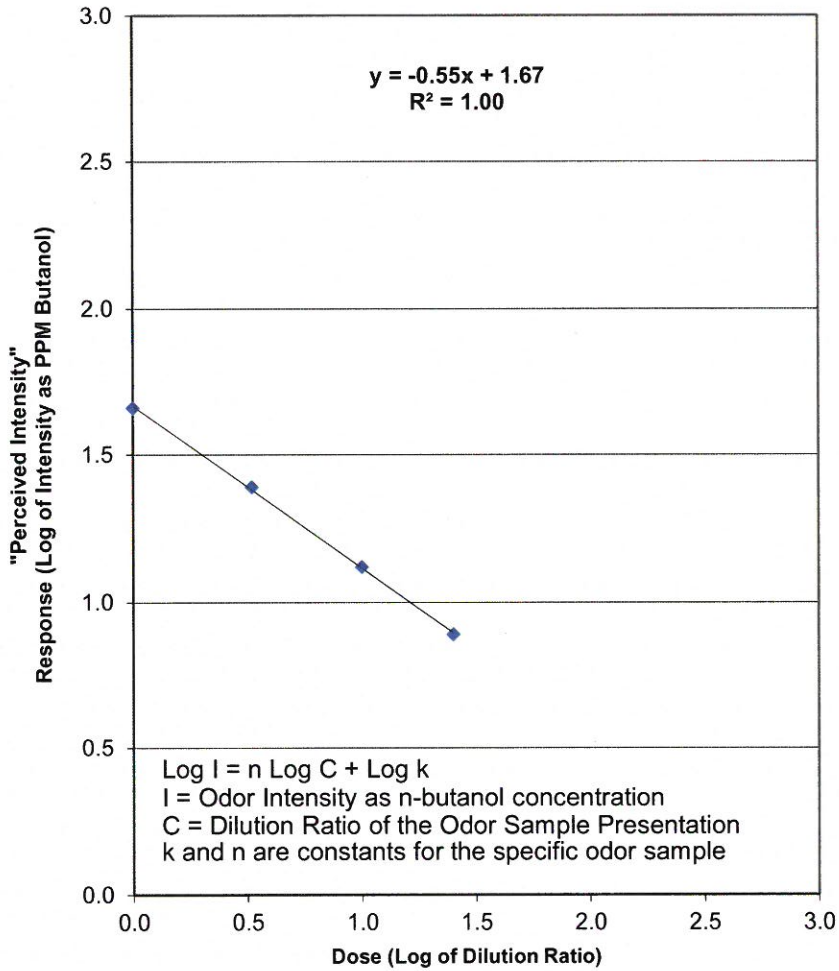
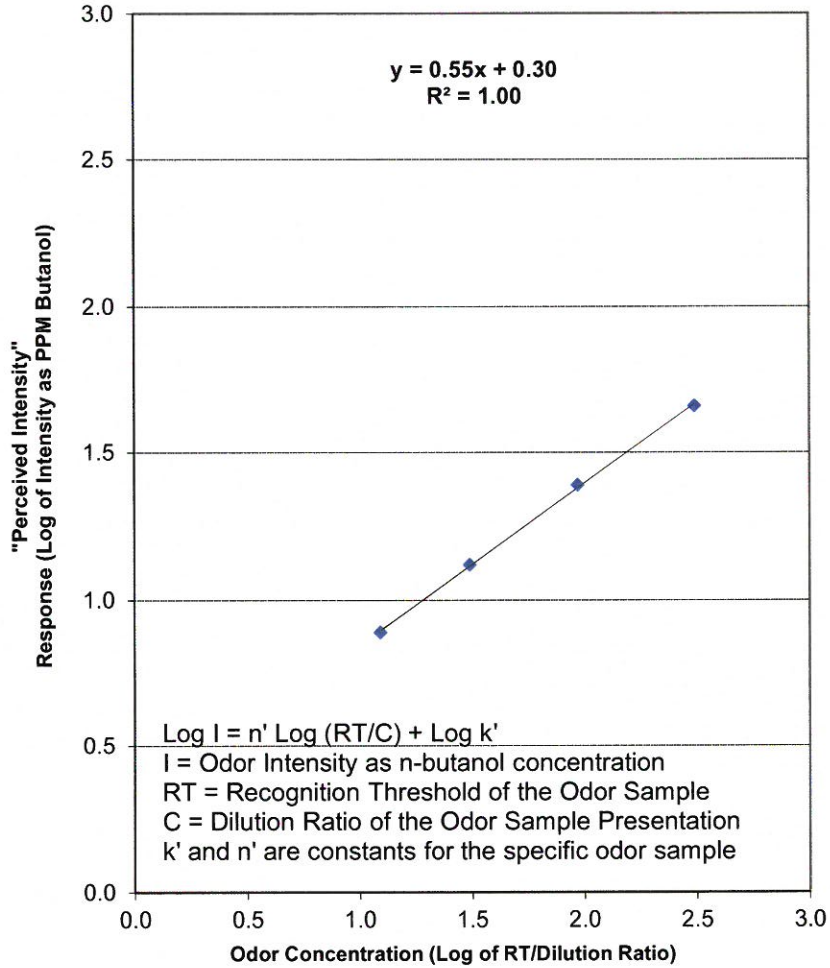
St. Croix Sensory, Inc. **Odor Evaluation Report**

Client:	Arcadis US, Inc.	Field No.:	1A	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	Moly Roasta Stack - Sample Port	Evaluation Date:	03/19/15

Dose-Response



Dose-Response as Power Law



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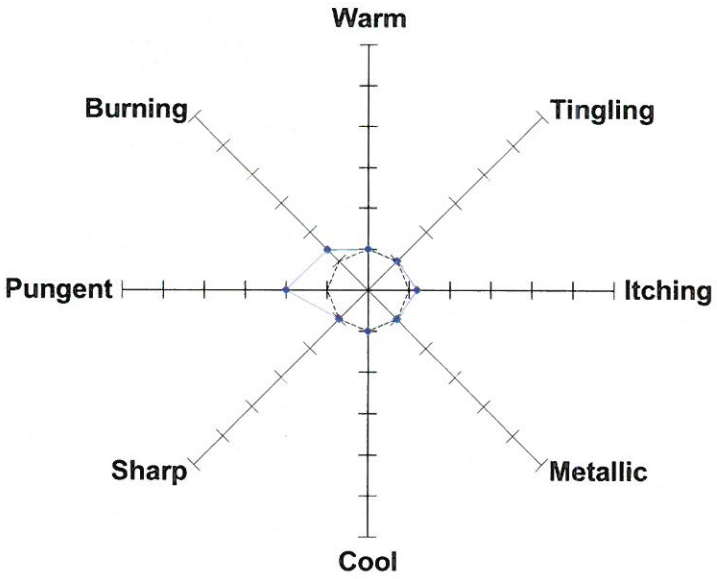
St. Croix Sensory, Inc.

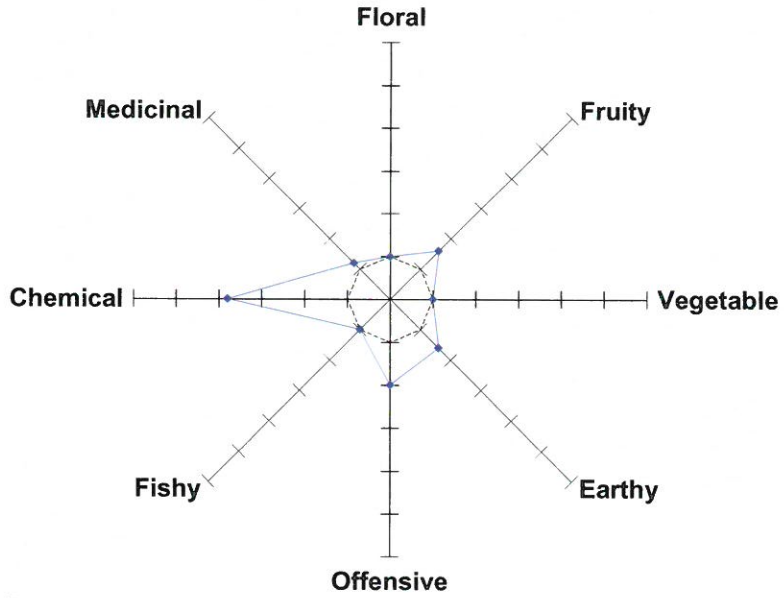
Odor Evaluation Report

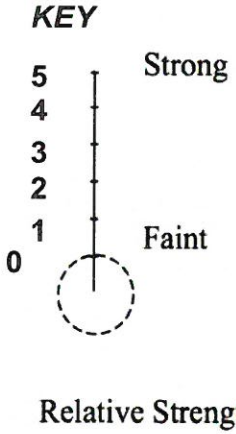
Client:	Arcadis US, Inc.	Field No.:	2A	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	Flotation	Evaluation Date:	03/19/15

Sensation Descriptor Graph



Odor Descriptor Graph





	Average Relative Strength
Warm	0.0
Tingling	0.0
Itching	0.2
Metallic	0.0
Cool	0.0
Sharp	0.0
Pungent	1.0
Burning	0.4

	Average Relative Strength
Floral	0.0
Fruity	0.6
Vegetable	0.0
Earthy	0.6
Offensive	1.0
Fishy	0.0
Chemical	2.8
Medicinal	0.2

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St. Croix Sensory, Inc.

Odor Evaluation Report

Client:	Arcadis US, Inc.	Field No.:	2A	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	Flotation	Evaluation Date:	03/19/15

% of Assessors |**********|**********|**********|**********| 100%

Fruity	**********
Citrus	**********
Lemon	**********
Medicinal	**********
Disinfectant	**********
Chemical	**********
Car exhaust	**********
Kerosine	**********
Petroleum	**********
Turpentine	**********
Plastic	**********
Solvent	**********
Offensive	**********
Earthy	**********
Musty	**********
Stale	**********
Smoky	**********

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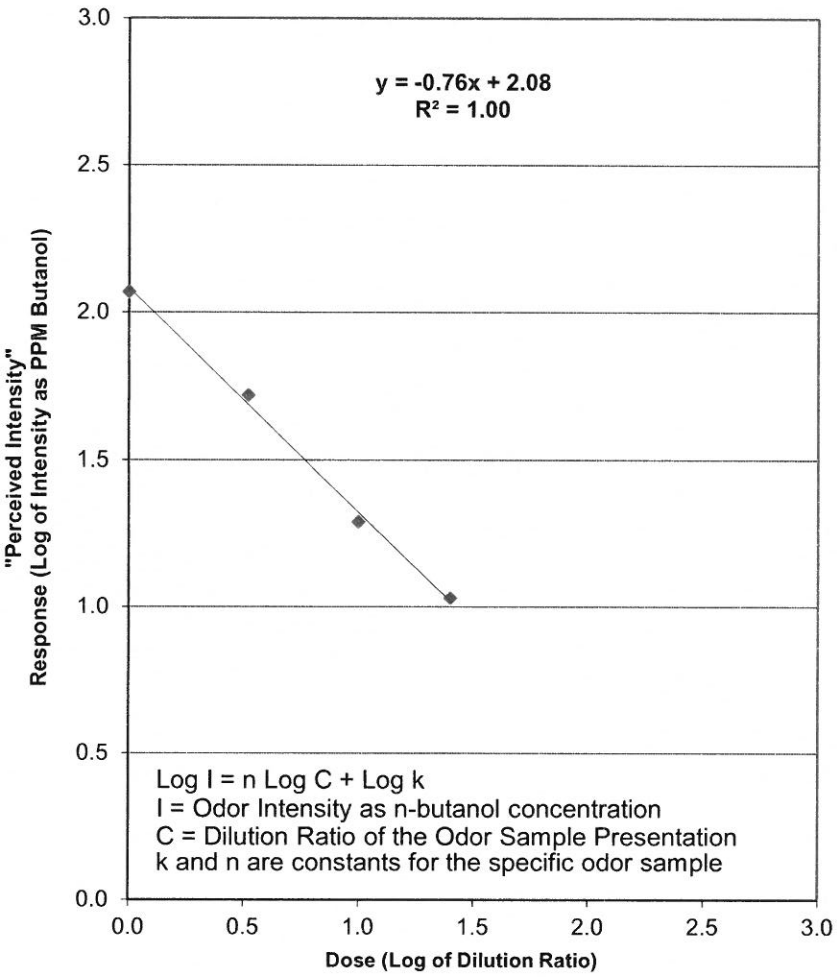
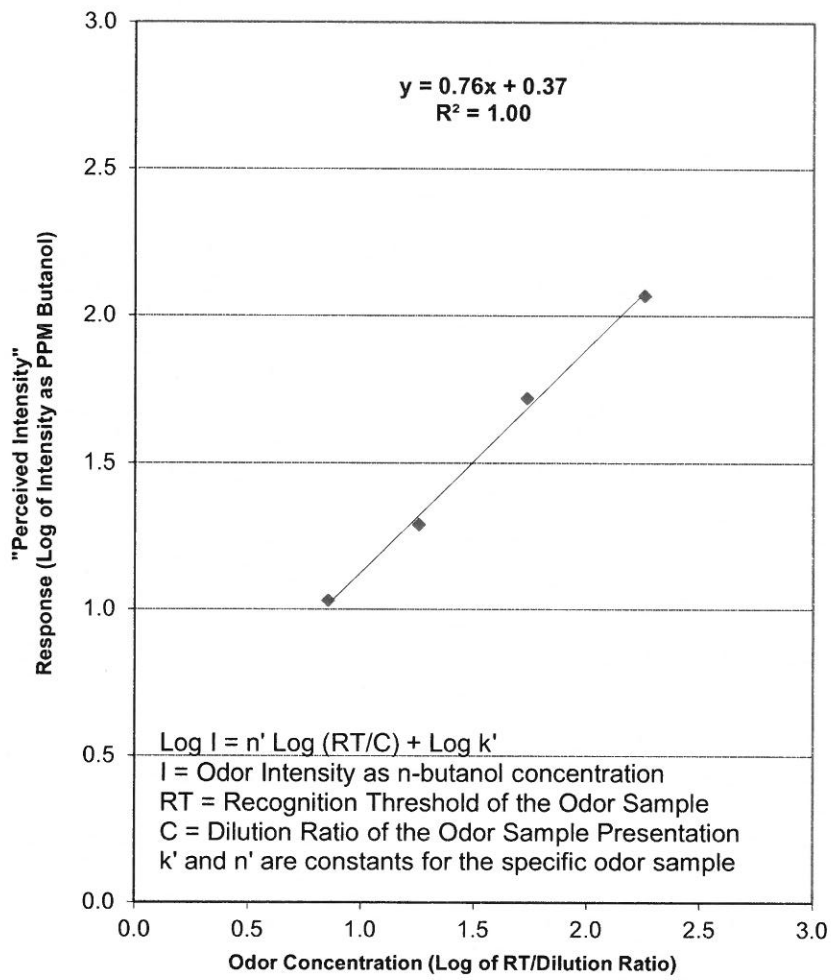
St. Croix Sensory, Inc. **Odor Evaluation Report**

Client:	Arcadis US, Inc.	Field No.:	2A	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	Flotation	Evaluation Date:	03/19/15

Dose-Response



Dose-Response as Power Law



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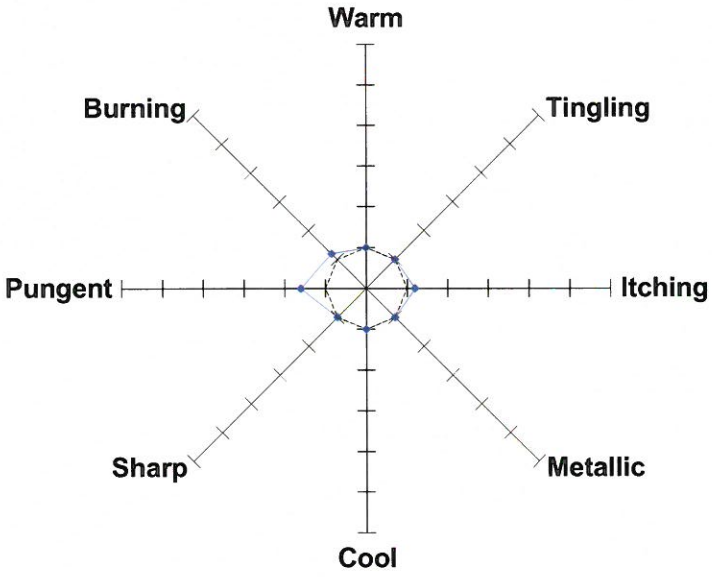
St. Croix Sensory, Inc.

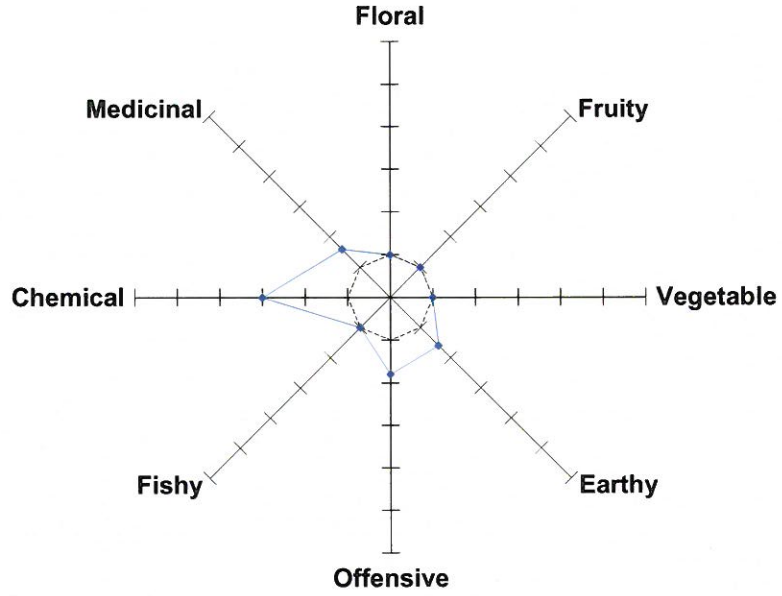
Odor Evaluation Report

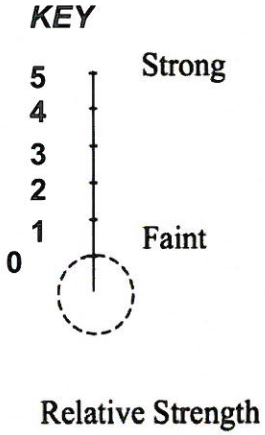
Client:	Arcadis US, Inc.	Field No.:	3A	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	"C" Copper/Moly Thickener Surface	Evaluation Date:	03/19/15

Sensation Descriptor Graph



Odor Descriptor Graph





	Average Relative Strength
Warm	0.0
Tingling	0.0
Itching	0.2
Metallic	0.0
Cool	0.0
Sharp	0.0
Pungent	0.6
Burning	0.2

	Average Relative Strength
Floral	0.0
Fruity	0.0
Vegetable	0.0
Earthy	0.6
Offensive	0.8
Fishy	0.0
Chemical	2.0
Medicinal	0.6

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St. Croix Sensory, Inc.

Odor Evaluation Report

Client:	Arcadis US, Inc.	Field No.:	3A	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	"C" Copper/Moly Thickener Surface	Evaluation Date:	03/19/15

% of Assessors |**********|**********|**********|**********| 100%

Medicinal	**********
Disinfectant	**********
Chemical	**********
Paint	**********
Car exhaust	**********
Kerosine	**********
Petroleum	**********
Turpentine	**********
Solvent	**********
Offensive	**********
Decay	**********
Earthy	**********
Musty	**********
Stale	**********

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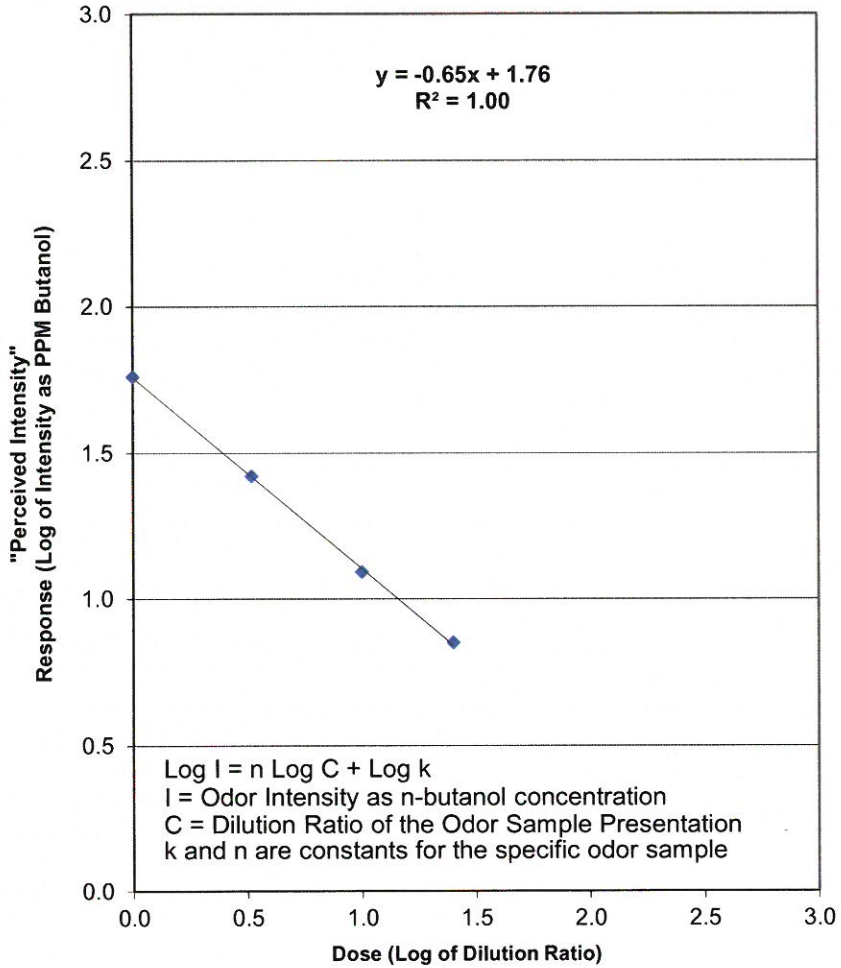
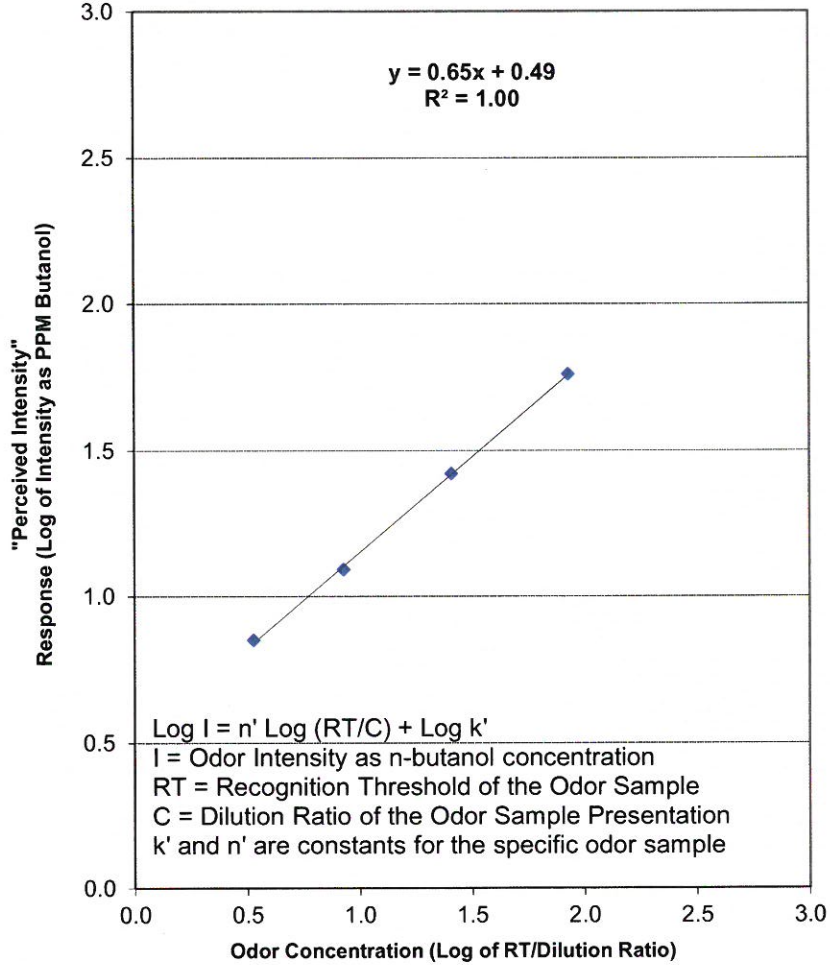
St. Croix Sensory, Inc. **Odor Evaluation Report**

Client:	Arcadis US, Inc.	Field No.:	3A	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	"C" Copper/Moly Thickener Surface	Evaluation Date:	03/19/15

Dose-Response



Dose-Response as Power Law



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St. Croix Sensory, Inc.

Odor Evaluation Report

Client: Arcadis US, Inc.

Field No.: 4B

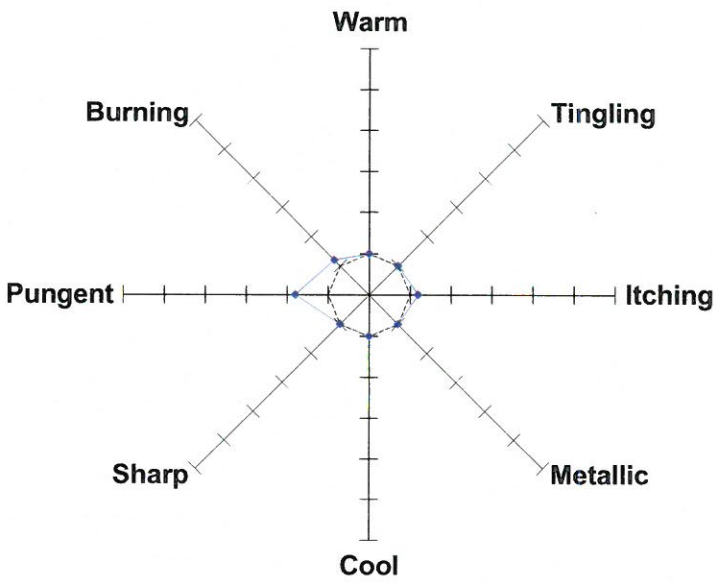
Report No.: **1507802**

Project: Sierrita Mine

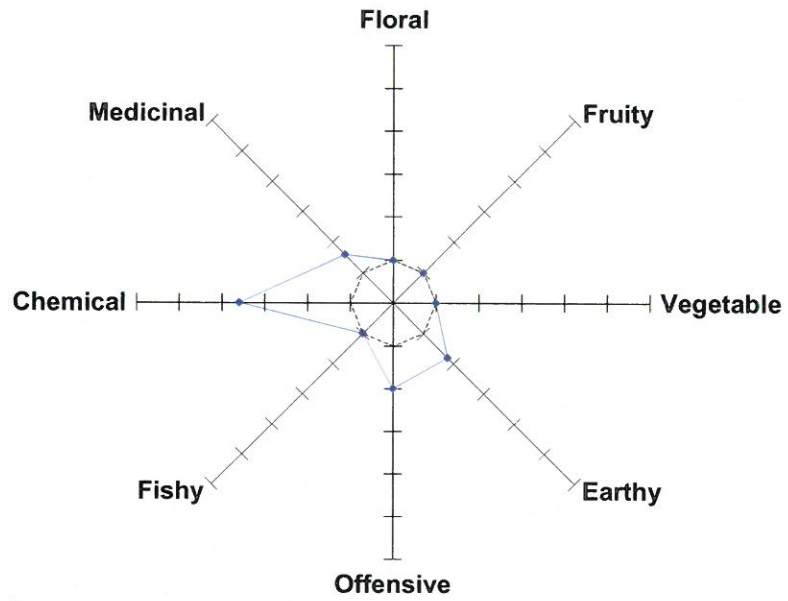
Description: SX-1 "E" Stripper Tank - Diluted 10:1

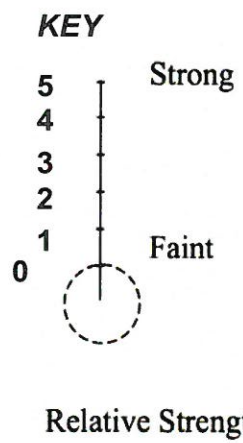
Evaluation Date: 03/19/15

Sensation Descriptor Graph



Odor Descriptor Graph





	Average Relative Strength
Warm	0.0
Tingling	0.0
Itching	0.2
Metallic	0.0
Cool	0.0
Sharp	0.0
Pungent	0.8
Burning	0.2

	Average Relative Strength
Floral	0.0
Fruity	0.0
Vegetable	0.0
Earthy	0.8
Offensive	1.0
Fishy	0.0
Chemical	2.6
Medicinal	0.6

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St. Croix Sensory, Inc.

Odor Evaluation Report

Client:	Arcadis US, Inc.	Field No.:	4B	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	SX-1 "E" Stripper Tank - Diluted 10:1	Evaluation Date:	03/19/15

% of Assessors |**********|**********|**********|**********| 100%

Medicinal	**********
Anesthetic	**********
Disinfectant	**********
Chemical	**********
Car exhaust	**********
Kerosine	**********
Petroleum	**********
Turpentine	**********
Plastic	**********
Solvent	**********
Offensive	**********
Earthy	**********
Stale	**********
Smoky	**********

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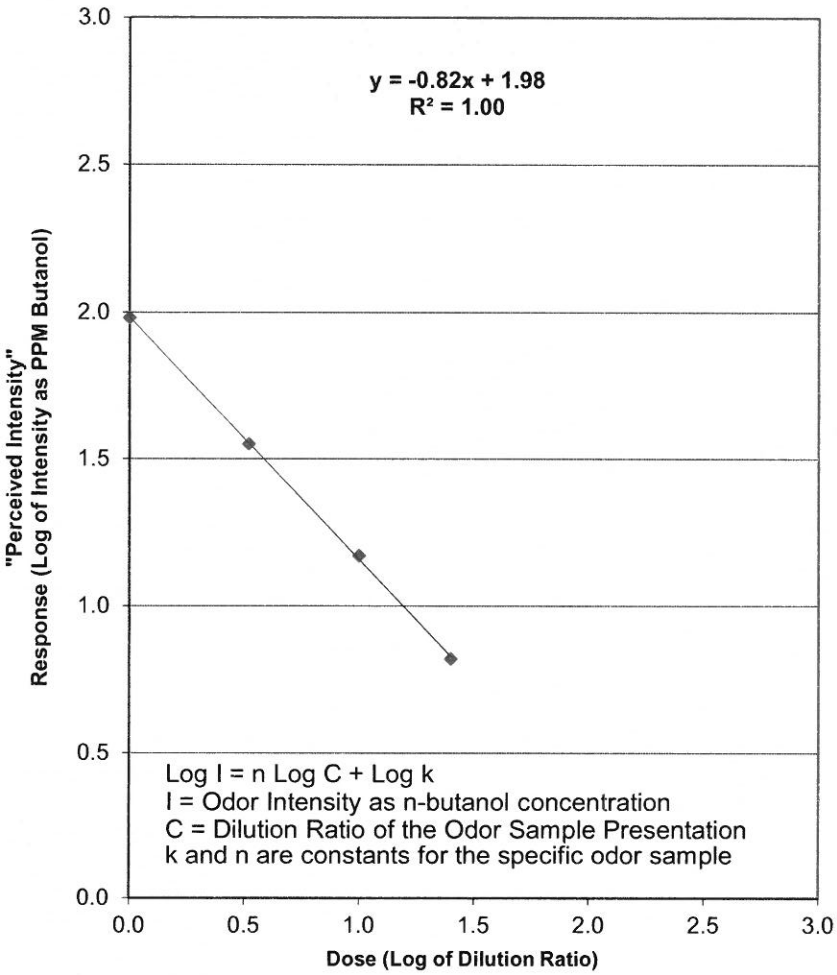
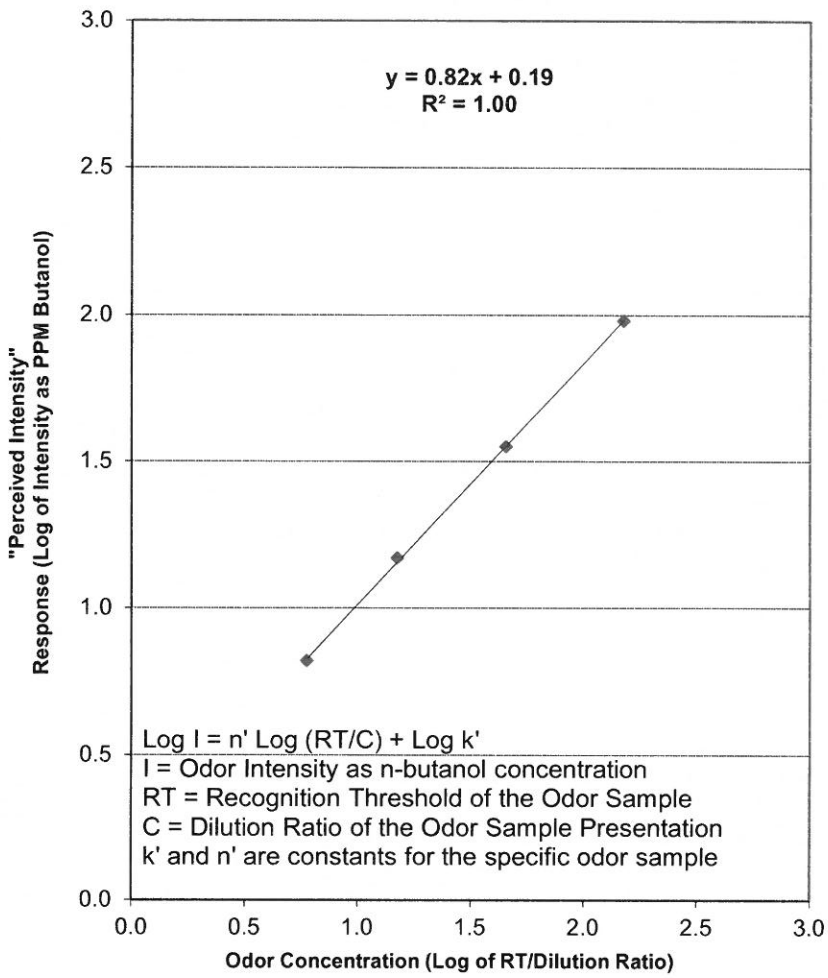
St. Croix Sensory, Inc. **Odor Evaluation Report**

Client:	Arcadis US, Inc.	Field No.:	4B	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	SX-1 "E" Stripper Tank - Diluted 10:1	Evaluation Date:	03/19/15

Dose-Response



Dose-Response as Power Law



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St. Croix Sensory, Inc.

Odor Evaluation Report

Client: Arcadis US, Inc.

Field No.: 5A

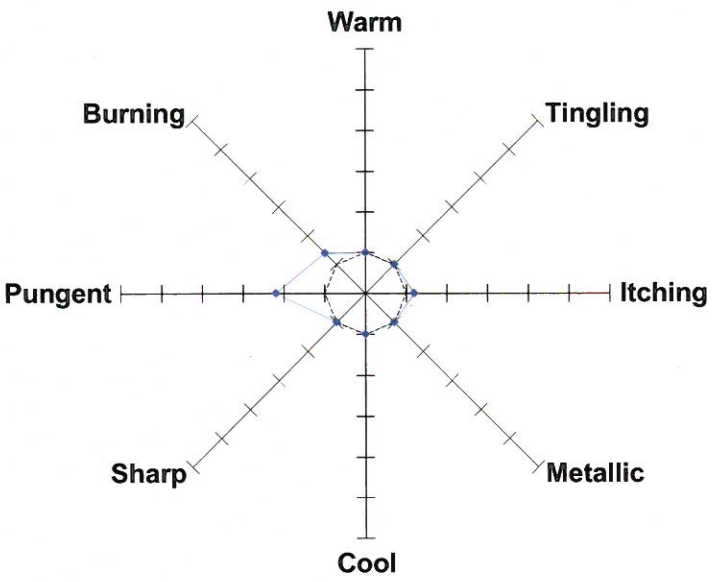
Report No.: **1507802**

Project: Sierrita Mine

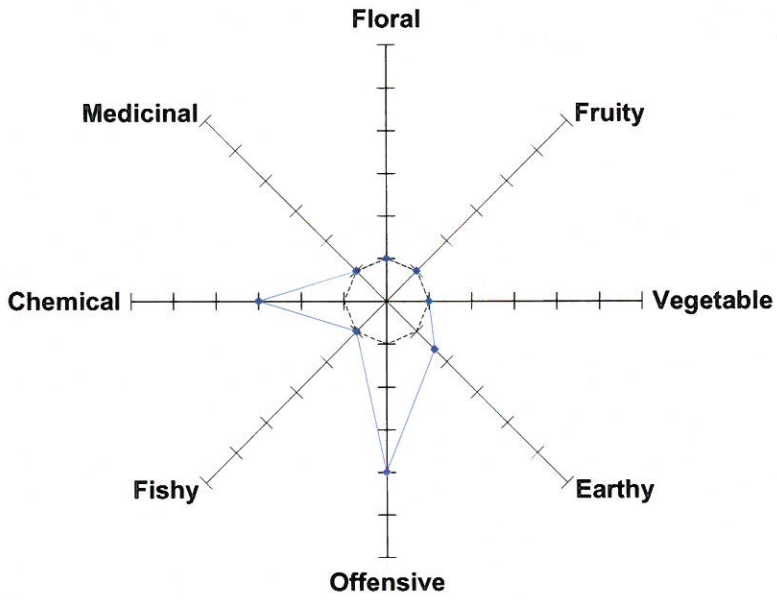
Description: Decant Feed - Bottle Agitation

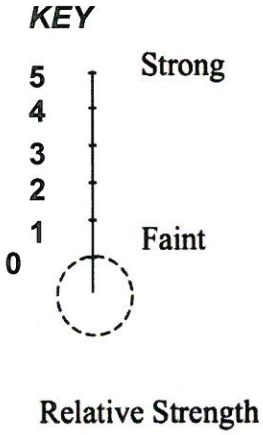
Evaluation Date: 03/19/15

Sensation Descriptor Graph



Odor Descriptor Graph





	Average Relative Strength
Warm	0.0
Tingling	0.0
Itching	0.2
Metallic	0.0
Cool	0.0
Sharp	0.0
Pungent	1.2
Burning	0.4

	Average Relative Strength
Floral	0.0
Fruity	0.0
Vegetable	0.0
Earthy	0.6
Offensive	3.0
Fishy	0.0
Chemical	2.0
Medicinal	0.0

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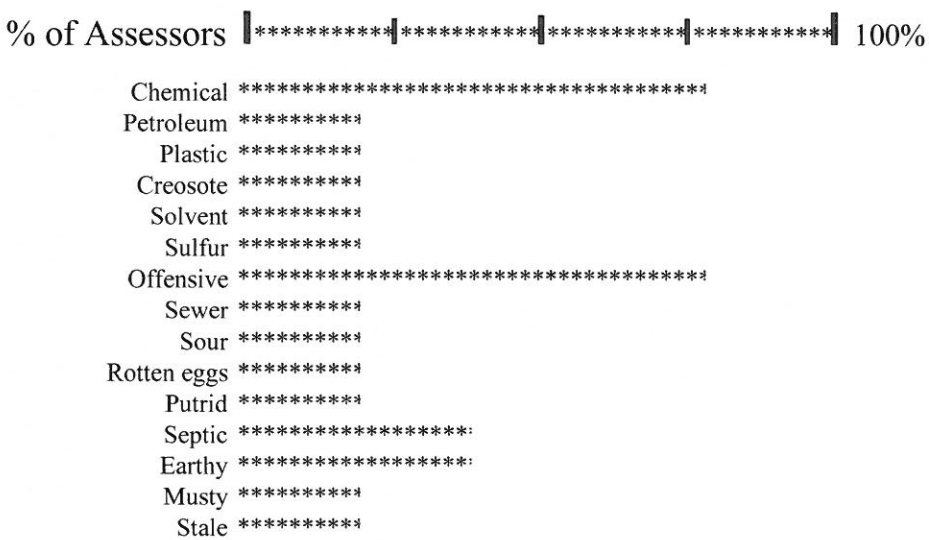
St. Croix Sensory, Inc.

Odor Evaluation Report

Client:	Arcadis US, Inc.	Field No.:	5A	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	Decant Feed - Bottle Agitation	Evaluation Date:	03/19/15



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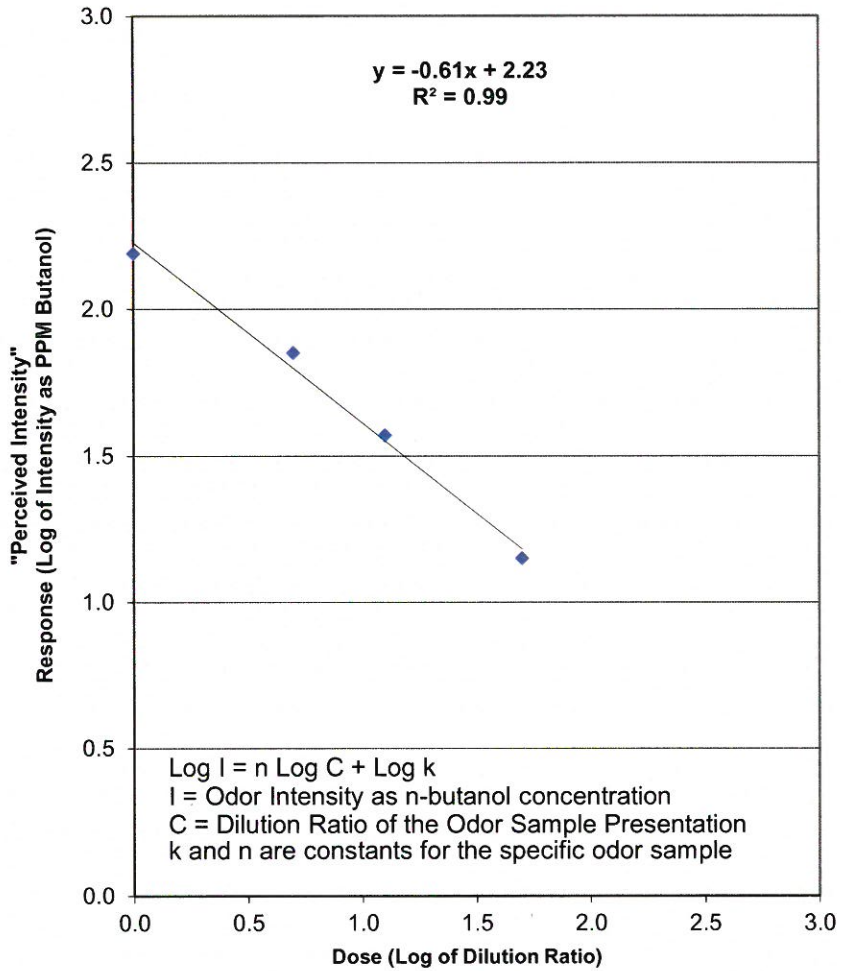
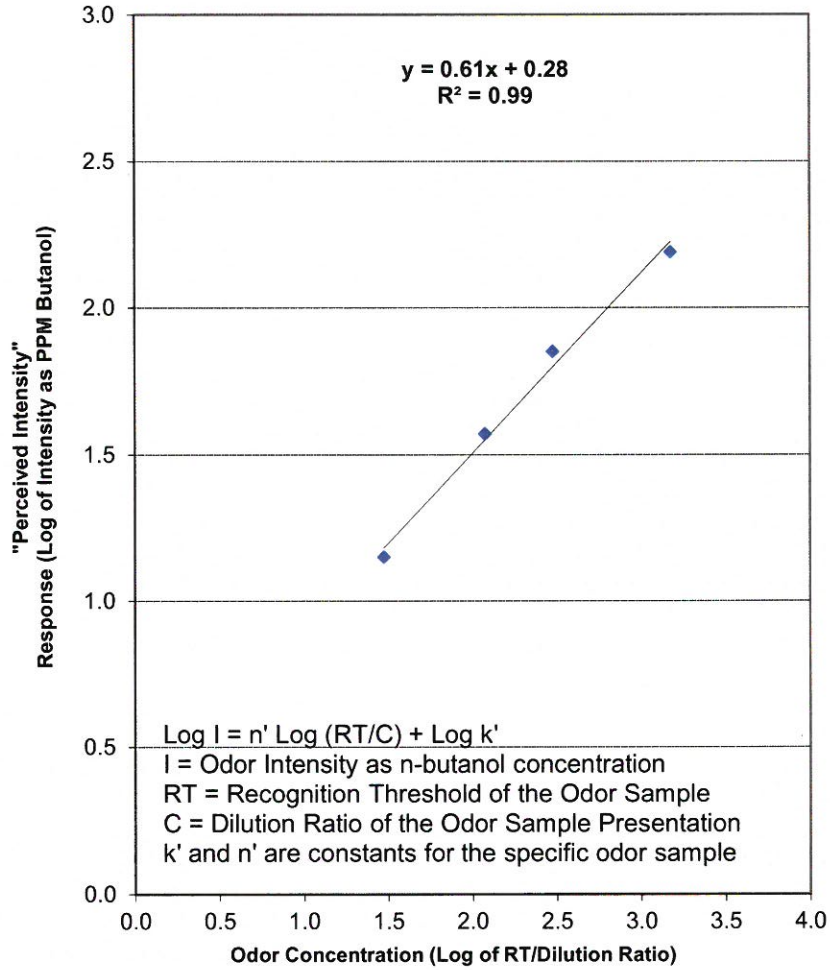
St. Croix Sensory, Inc. **Odor Evaluation Report**

Client:	Arcadis US, Inc.	Field No.:	5A	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	Decant Feed - Bottle Agitation	Evaluation Date:	03/19/15

Dose-Response



Dose-Response as Power Law



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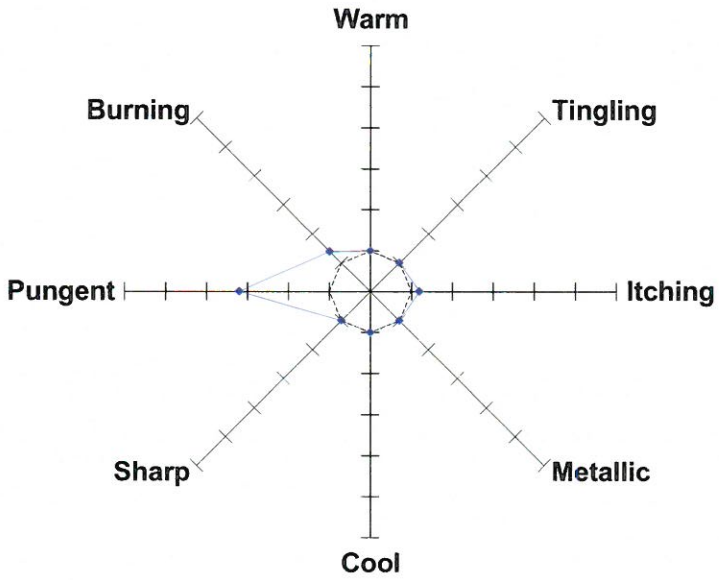
St. Croix Sensory, Inc. **Odor Evaluation Report**

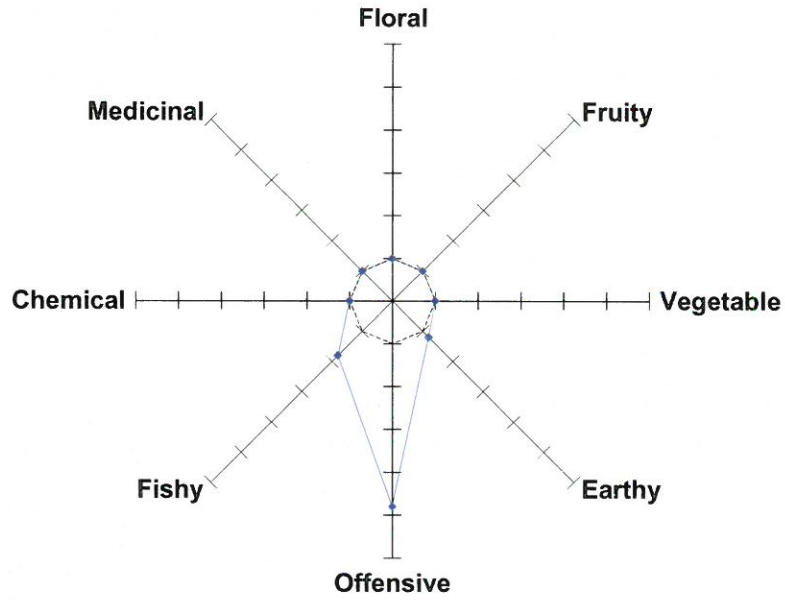
Client:	Arcadis US, Inc.	Field No.:	6B	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	Xanthate Mixed 10:1 Diluted	Evaluation Date:	03/19/15

Sensation Descriptor Graph

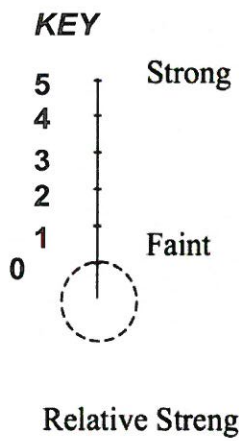


	Average Relative Strength
Warm	0.0
Tingling	0.0
Itching	0.2
Metallic	0.0
Cool	0.0
Sharp	0.0
Pungent	2.2
Burning	0.4

Odor Descriptor Graph



	Average Relative Strength
Floral	0.0
Fruity	0.0
Vegetable	0.0
Earthy	0.2
Offensive	3.8
Fishy	0.8
Chemical	0.0
Medicinal	0.0



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St. Croix Sensory, Inc.

Odor Evaluation Report

Client:	Arcadis US, Inc.	Field No.:	6B	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	Xanthate Mixed 10:1 Diluted	Evaluation Date:	03/19/15

% of Assessors |**********|**********|**********|**********| 100%

Chemical	**********
Fishy	**********
Perm solution	**********
Offensive	**********
Rancid	**********
Sewer	**********
Sour	**********
Putrid	**********
Septic	**********
Earthy	**********
Stale	**********

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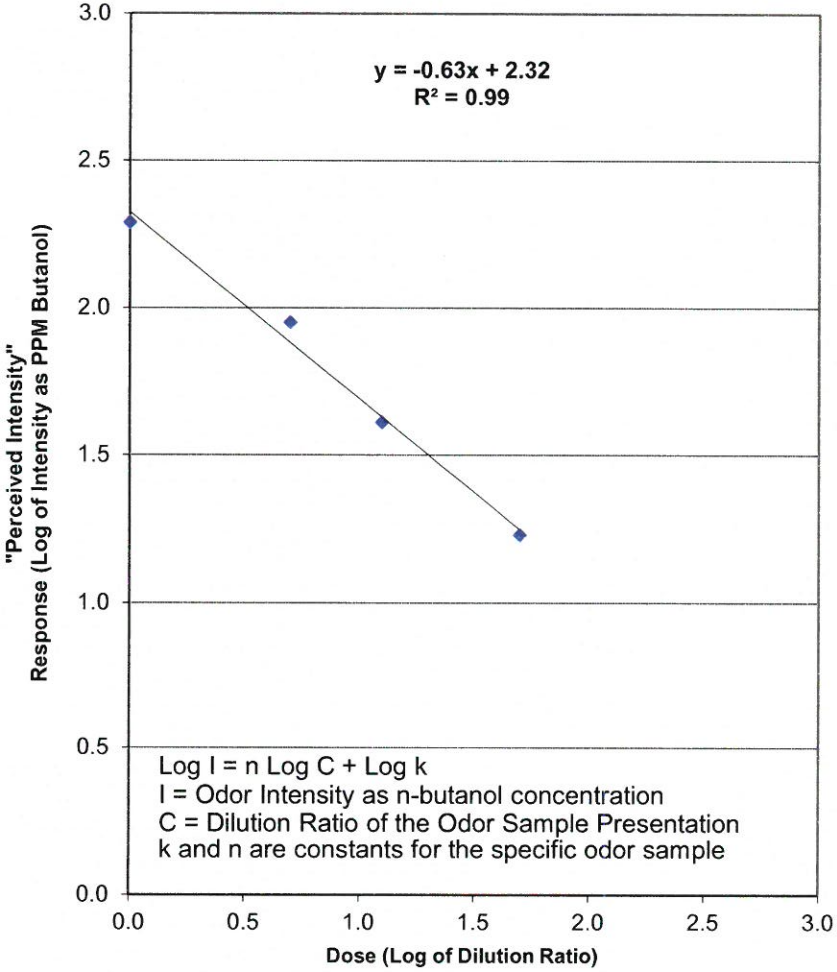
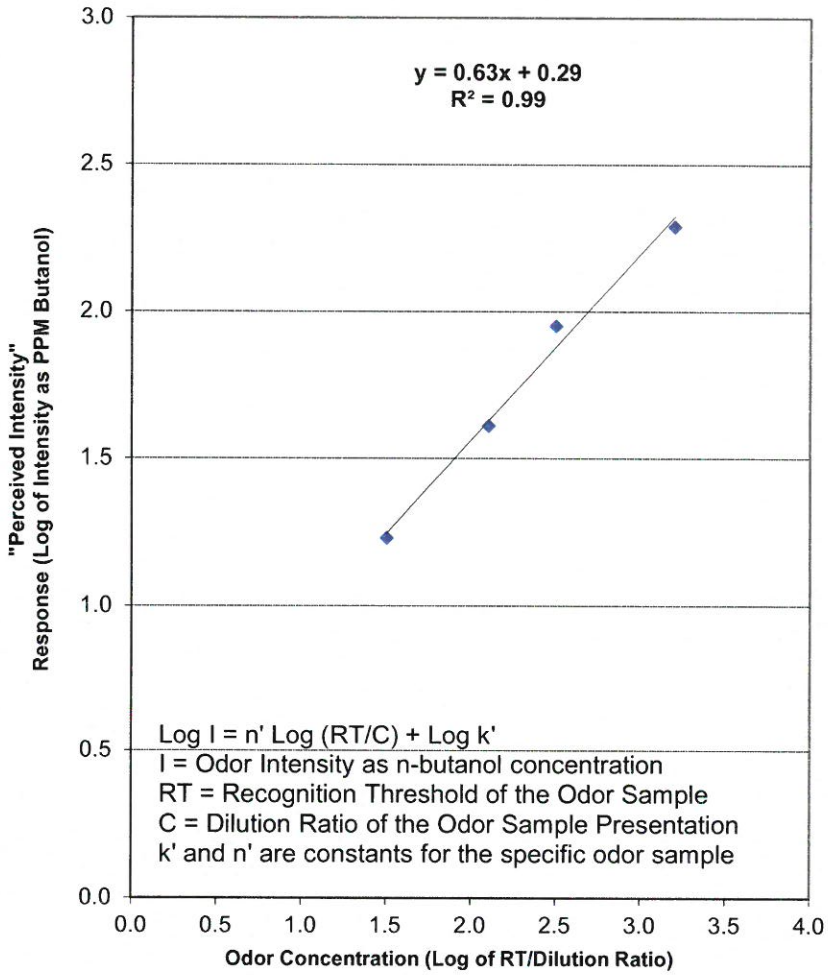
St. Croix Sensory, Inc. **Odor Evaluation Report**

Client:	Arcadis US, Inc.	Field No.:	6B	Report No.:	**1507802**
Project:	Sierrita Mine	Description:	Xanthate Mixed 10:1 Diluted	Evaluation Date:	03/19/15

Dose-Response



Dose-Response as Power Law



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St. Croix Sensory, Inc.

CHAIN OF CUSTODY RECORD FOR ODOR SAMPLES

Page ___ of ___

Client: ARCADIS

Sampled By: Dick Pope, Roger Felty

Project Name: Sierrita Mine

Sampling Date: 3.18.15

Comments: 4A – bag detective O valve – leaked sample.
6A – FOR YOUR REVIEW ONLY – NOT FOR TESTING

Odor Evaluations Requested: (X)

For Laboratory use Only

Odor Evaluation Report No. 1507802

Line No.	Field No.	Sample Description	Sample Time	Field H_2S (ppm)	Odor Concentration* (Detection & Recognition Threshold)	Odor Intensity* (PPM 1-Butanol)	Odor Characterization (Hedonic Tone & Descriptors)	Odor Persistency ("Dose-Response")	Laboratory Sample No. LN	Laboratory Sample No. FN
1	1A	Moly Roaster Stack - sample port	9:45AM	N/A	X	X	X	X		
2	1D	Duplicate - Moly Roaster Stack - sampling port	9:59AM	N/A	X	X	X	X		
3	2A	Flotation	10:37 ~~10:38~~ AM	N/A	X	X	X	X		
4	2D	Duplicate - Flotation	10:49AM	N/A	X	X	X	X		
5	3A	"C" Copper/Moly Thickener Surface	11:31AM	N/A	X	X	X	X		
6	3B	Duplicate - "C" Copper/Moly Thickener Surf.	11:42AM	N/A	X	X	X	X		
7	4A	SX-1 "E" Stripper Tank - sample leaked	N/A	N/A						
8	4B	SX-1 "E" Stripper Tank diluted 10:1	12:38PM	N/A	X	X	X	X		
9	5A	Decant Feed - bottle agitation	2:05PM	N/A	X	X	X	X		
10	5B	Duplicate - Decant Feed - bottle agitation	2:15PM	N/A	X	X	X	X		
11	6A	Xanthate Mixed - undiluted	2:59PM	N/A	X	X	X	X		
12	6B	XANTHATE MIXED 10:1 DILUTED	2:31 PM	N/A	X	X	X	X		
	6C	XANTHATE MIXED DILUTED 100:1	2:43 PM		X	X	X	X		

Transmittal

Number of Shipping Boxes 2

Relinquished By	Date	Time	Accepted By	Date	Time	Comments & Exceptions Noted
ROGER FELTY	3.18.15	4:03 PM				
Received at St. Croix Sensory Laboratory			[signature]	3/19/15	9:30AM	

*Odor Concentration: ASTM E679-04 & EN13725:2003 and Odor Intensity: ASTM E544-10

St. Croix Sensory, Inc. ◆ 1150 Stillwater Blvd. N. ◆ Stillwater, MN 55082 U.S.A. ◆ Tel:800-879-9231 ◆ Fax:651-439-1065 ◆ Email:reports@fivesenses.com ◆ Web:www.fivesenses.com

LAB COPIES WHITE & YELLOW

CLIENT COPY PINK

Arcadis Canada Inc.

121 Granton Drive, Suite 12

Richmond Hill, ON L4B 3N4

Tel 905.764.9389

Fax 905.764.9386

Arcadis.com

ATTACHMENT

- **Evaluation of the Atmospheric Behavior and Odor Thresholds of Carbon Disulfide and Other Sulfur-Containing Constituents / Arcadis, March 22, 2016**

MEMORANDUM

ARCADIS Design & Consultancy for natural and built assets

To:

Eric Werner, Freeport-McMoRan Sierrita Inc.

Copies:

Arcadis U.S., Inc.
1 Executive Drive
Suite 303
Chelmsford
Massachusetts 01824
Tel 978 937 9999
Fax 978 937 7555

From:

Norman D. Forsberg, Ph.D.
Staff Toxicologist

Brian H. Magee, Ph.D.
Principal Toxicologist

Date:

March 22, 2016

Arcadis Project No.:

AZ001233.0017

Subject:

Evaluation of the Atmospheric Behavior and Odor Thresholds of Carbon Disulfide and Other Sulfur-Containing Constituents

---

This memorandum presents Arcadis US, Inc.'s (Arcadis') evaluation of the atmospheric behavior and odor thresholds of carbon disulfide (CS_2) and other sulfur-containing constituents measured in air samples collected from the Sierrita Mine facility in Pima County, Arizona. The evaluation was performed to assess the theory that CS_2 or other sulfur-containing constituents (hereinafter collectively referred to as sulfur-containing constituents) may potentially be sources of odors tied to complaints at off-site locations in proximity to the Sierrita Mine facility. The information presented and summarized in this memorandum was obtained by reviewing materials provided to Arcadis by Freeport Minerals Corporation (Freeport) and searching readily available online sources as well as the peer-reviewed literature. A detailed reference list is provided at the end of this memorandum. Information upon which Arcadis based its evaluation includes the following for sulfur-containing constituents: 1) a summary of concentrations measured on-site at the Sierrita Mine facility, 2) background information linking xanthate use to emissions, 3) a summary of atmospheric behavior, and 4) a summary of odor thresholds.

The results of Arcadis' evaluation indicate that sulfur-containing constituents are chemically stable in the atmosphere for days to years. Specifically CS_2 has an atmospheric half-life of a week or two. A review of relevant literature did not identify definitive odor thresholds for the sampled sulfur-containing constituents; instead there appear to be widely ranging odor thresholds. Included in the reported ranges were thresholds at which sensitive individuals detected odors. Thus, if a concentration of a sulfur-containing constituent at an off-site location exceeded a lower threshold, a sensitive individual may be able to detect an odor.

The United States Environmental Protection Agency (U.S. EPA) has developed Acute Exposure Guideline Levels (AEGLs) for identifying the concentrations associated with certain effects of exposure to airborne chemicals, including sulfur-containing constituents. At or above the lowest level AEGL (AEGL-1), a typical receptor may experience notable, but transient irritation. An analysis of the maximum on-site concentrations of the sampled sulfur-containing constituents and the expected dilution of those constituents through atmospheric transport suggests that off-site receptors would not be exposed to sulfur-containing constituents above their respective 60-minute AEGL-1 values. Thus, it is unlikely that typical off-site receptors were exposed to sulfur-containing constituents in such concentrations as to produce notable, but transient, reactions, such as irritation.

Concentrations of Sulfur-Containing Constituents Measured at the Sierrita Mine Facility

Freeport provided Arcadis with an analysis report (AAC 2015) for five area air samples that were collected in September 2015 and analyzed for total reduced sulfur compounds using the South Coast Air Quality Management District's gas chromatography sulfur chemiluminescence detector (GC/SCD) method 307-91 (SCAQMD 307-91). The analytical results show that CS_2 was detected in two out of five area air samples (**Table 1**). Air samples were collected at the primary crusher (diesel exhaust), decant pond, outside the concentrator building, in the mill concentrator building flotation area (mill pack cells), and the mill reagent building (xanthate mixing exhaust). Samples with detectible levels of CS_2 were collected from "Mill pack cells" in the mill concentrator building and exhaust from "Xanthate mix." Concentrations of CS_2 were 0.11 part-per-million by volume (ppmV) in the "Mill pack cell" sample and 4.23 ppmV in the "Xanthate mix" sample. Air concentrations of CS_2 were below reporting limits at all other locations. Maximum air concentrations of other sulfur containing constituents in this dataset ranged from <0.011 to 0.241 ppmV.

Table 1. Concentrations of Sulfur-Containing Constituents Measured in Air at Five Area Sampling Locations at the Sierrita Mine Facility (ppmV).

Constituent	Primary Crusher	Decant Pond	Mill Pack Cells	Xanthate Mixing Exhaust	Outside Concentrator Building
Carbon Disulfide	<RL[b]	<RL	0.11	4.23	<RL
Carbonyl Sulfide/Sulfur Dioxide[a]	<RL	(0.241)	<RL	(0.014)	<RL
Ethyl Mercaptan	<RL	<RL	<RL	0.016	<RL
Hydrogen Sulfide[c]	<RL	(0.153)	<RL	<RL	<RL

a. Analytical method could not distinguish carbonyl sulfide and sulfur dioxide.
b. <RL = less than reporting limit of 0.011 ppmV.
c. Nominally identified as hydrogen sulfide.

Results from area air sampling conducted by Freeport north of Sierrita operations and south of McGee Ranch Road in October 2014 and May 2015 are summarized in **Table 2**. Measurements were made using a direct reading AreaRAE transportable monitor. Maximum air concentrations of sulfur dioxide (nominal) (0.3 ppmV) measured during the two sampling events that occurred north of the facility were similar to the concentrations of carbonyl sulfide/sulfur dioxide measured near the decant pond and higher than levels measured in exhaust from xanthate mixing presented in **Table 1**. Air concentrations of hydrogen sulfide (nominal) measured north of the operating facility were higher than those measured at the decant pond.

The sensors used in the AreaRAE monitors have cross-sensitivities where the sensor will react to gases other than the target gas. Depending on the specific gas, this can cause positive and negative cross-sensitivities and therefore, the sensor readings should be considered nominal approximations of the target gas.

Table 2. Air concentrations of Sulfur-Containing Constituents Measured North of the Sierrita Mine Facility (ppmV).

Constituent	October 2014	May 2015
Hydrogen Sulfide[a]	(0.2-0.7)	-
Sulfur Dioxide[a]	(0-0.2)	(0.1-0.3)

[a] Nominal identifications

Xanthates as a Source of Sulfur-Containing Chemicals:

A material safety data sheet for "Flottec PAX Collector" (i.e., potassium amyl xanthate) (Flottec 2012) indicates that the product is composed of 1) > 90% carbonodithionic acid, O-(3-methylbutyl) ester, potassium salt, 2) ~1% potassium sulfide, and 3) 0-1% potassium hydroxide on a weight-by-weight (w/w) basis. It also states that, "exposure [of xanthates] to heat and moisture can cause decomposition to… carbon disulfide" and that CS_2 is a decomposition product of the xanthate material.

Atmospheric Behavior

Upon release to the atmosphere, CS_2 is reported to undergo transformative reactions that result in its degradation and formation of new sulfur-containing chemical species. The World Health Organization reports (WHO 2005) that CS_2 is "primarily degraded through photo-oxidation by reactions with hydroxyl radicals and by a secondary route involving triplet oxygen ($O(^3P)$)," is degraded to carbonyl sulfide and sulfur dioxide, and has an estimated atmospheric half-life that ranges from 5.5 to 14 days. The National Library of Medicine's Hazardous Substances Database (HSDB) reports that CS_2 released to the atmosphere will exist solely as a vapor, react with photochemically-produced hydroxyl radicals, and degrade with an estimated half-life of 5.5 days in air (HSDB 2016). Laboratory-based irradiation experiments performed with CS_2 in the presence of hydroxyl-radical donors show that degradation of CS_2 results in the formation of carbonyl sulfide (OCS) and sulfur dioxide (SO_2) at equal molar concentrations (Jones et al. 1983; Arnts et al. 1989).

Atmospheric half-lives for CS_2, OCS, SO_2, and other sulfur-containing constituents measured at Sierrita are presented in **Table 3**. Half-lives reported in the literature were found to range from 10 hours (ethyl mercaptan) to 22 years (OCS). Based on this information, it is expected that carbonyl sulfide is the most persistent odorant of these compounds followed by CS_2, hydrogen sulfide, and ethyl mercaptan. The half-lives for the sulfur-containing constituents presented here indicate that the sulfur-containing constituents measured at Sierrita are capable of undergoing atmospheric transport from the facility to nearby locations before degrading. For instance, assuming no removal from the atmosphere by any meterological processes, which was outside of the scope of this investigation, 50% of the initially released CS_2 would be present after 5.5 days, 25% after 11 days, etc.

Table 3. Atmospheric Half-Lives for Sulfur-Containing Constituents.

Constituent	Atmospheric Half-Life	Source
Carbon Disulfide	5.5 days 5.5-14 days 1-2 weeks	HSDB (2016a) WHO (2005) Environment Canada (2000)
Carbonyl Sulfide	>1 to 2 – 10 years (Lifetime)* 22 years ≥2 years	ATSDR (2014) HSDB (2016b) Cal EPA (2014)
Ethyl Mercaptan	10 hours	HSDB (2016c)
Hydrogen Sulfide	1 – 42 days (Lifetime)* 3.3 days	ATSDR (2016) HSDB (2016d)
Sulfur Dioxide	Not evaluated	NA

* Lifetime reported instead of half-life.

Odor Thresholds

Air concentrations at which odors are perceived in humans are typically quantified using two metrics: a detection threshold and a recognition threshold. However, odor thresholds available in the literature and summarized in this report do not always indicate whether a particular concentration represents a detection or a recognition threshold. The American Industrial Hygiene Association (AIHA) defines the detection threshold as "the lowest concentration of odorant that will elicit a sensory response in the olfactory receptors of a specified percentage of a given population," where the percentage of panelists detecting stimulation is typically 50 % (AIHA 1993). The recognition threshold is "the minimum concentration that is recognized as having a characteristic odor quality by X percent (usually 50 percent) of the population" (AIHA 1993). Odor sensing in humans is generally described as following a normal distribution, where about 96% of the population have a "normal" sense of smell, 2% are insensitive, and 2% are hypersensitive (AIHA 1993). The hypersensitive population includes individuals that are innately hyperosmic (very sensitive) as well as those who develop sensitivity to a particular odor following repeated exposure (AIHA 1993). Across the human population, it is known that the sensory property of an odorant is concentration dependent. For example, at low concentrations (less than 1 ppm) carbonyl sulfide has been described as having a "fireworks" or "burnt" smell, but having a "rotten egg" smell at higher levels (AIHA 1993).

Tables 4 through **8** summarize odor thresholds for sulfur-containing constituents. Threshold values were obtained from several literature sources and include descriptions of what type of threshold was presented and the sensory description associated with the threshold. Odor thresholds reported in the literature for CS_2 ranged from 0.01 to 7.4 ppmV, with additional observations up to 20 ppmV not eliciting complaints in test subjects. Most of the odor thresholds located for CS_2 did not indicate whether the concentration was for detection or recognition. However, several summary documents reported that odor thresholds for CS_2 begin around 0.02 ppmV. Odor thresholds for carbonyl sulfide (OCS) were found to range from 0.055 to 0.1 ppmV, however the sources referenced did not indicate whether these concentrations represented detection or recognition thresholds. In general, if an odor threshold is unidentified, it is likely a detection threshold. Odor thresholds reported for ethyl mercaptan showed a wide range of values, where the lowest threshold found (0.0000087 ppmV, detection threshold) was over 4,000 times lower than the highest threshold (0.036 ppmV). Most sources reported that the odor threshold for ethyl mercaptan was greater than or equal to 0.0001 ppmV. The odor thresholds located for hydrogen sulfide ranged from 0.00047 to 0.13 ppmV, with detection thresholds being greater than or equal to 0.0005 ppmV and recognition occurring at concentrations greater than 0.004 ppmV. Odor thresholds for sulfur dioxide ranged from 0.33 to 5 ppmV, with detection thresholds typically being greater than or equal to 0.33 ppmV. All chemicals are reported to impart unpleasant odors at threshold levels, with odors that are typically described as "disagreeable", "foul smelling", "rotten", "sulfide", "irritating", and/or "rotten eggs".

There are no governmental or nongovernmental consensus standards for odor thresholds. The reported odor thresholds for sulfur-containing constituents vary so greatly that there is no way from the reported literature to define the concentration at which a typical person or most people in a group of exposed individuals would detect an odor. The lower values presented in Tables 4 through 8 define the levels at which some sensitive people have reported detecting odors in the literature, but determining whether sulfur-containing constituents appeared off-site at these concentrations is beyond the scope of this memorandum.

Table 4. Odor Thresholds for Carbon Disulfide Reported by Various Sources.

Threshold (ppmV)	Threshold Description	Odor Description	Source
0.01	Low	Disagreeable, sweet	Ruth (1986)
0.02 - 0.1	"Most people can smell"	Unpleasant foul smelling, characteristic of hydrogen sulfide	ATSDR (2016)
0.016	Range found in literature - Low	Vegetable sulfide, medicinal	AIHA (1993)
0.02	Perception in humans	Foul smelling	ATSDR (1996)
0.04	Nonperception, adverse reflex response in humans	-	ATSDR (1996)
0.096	-	-	3M (2010)
0.1	Low	Rotting radishes	ATSDR (1996)
0.1	50% of subjects	Foul smelling	ATSDR (1996)
0.1 - 0.2	-	Rotten cabbage or radish	Cal EPA (1999)
0.11	-	-	Amoore (1983)
0.2	High	Rotting radishes	ATSDR (1996)
0.2	100% of subjects	Foul smelling	ATSDR (1996)
0.21	-	Vegetable sulfide	Leonardos (1969)
0.21	Recognition	-	Fazzalari (1978)
0.42	Range found in literature - High	Vegetable sulfide, medicinal	AIHA (1993)
0.84	Detection	-	Fazzalari (1978)
7.4	High	Disagreeable, sweet	Ruth (1986)
10 - 20	"No complaints"	-	NAS (2009)
180 - 240	"Moderate Odor Annoyance"	-	NAS (2009)
No acceptable values	Geometric mean	Vegetable sulfide, medicinal	AIHA (1993)

Table 5. Odor Thresholds for Carbonyl Sulfide Reported by Various Sources.

Threshold (ppmV)	Threshold Description	Odor Description	Source
0.055	-	Typical sulfide odor	ATSDR (2014)
0.1	-	Sulfur odor	Cal EPA (2014), U.S. EPA (1992)

Table 6. Odor Thresholds for Ethyl Mercaptan Reported by Various Sources.

Threshold (ppmV)	Threshold Description	Odor Description	Source
0.0000087	Level of distinct odor awareness – *Detection threshold*	-	U.S. EPA (2016d), NAS (2009)
0.000013	Low	Garlic	Ruth (1986)
0.000098	Acceptable Detect Range - Low	Rotten cabbage	AIHA (1993)
0.00014	Level of distinct odor awareness - *Final*	-	NAS (2009)
0.00035	Geometric Mean Detect	Rotten cabbage	AIHA (1993)
0.0004	Geometric Mean Recognition	Rotten cabbage	AIHA (1993)
0.00076	-	-	Amoore (1983)
0.001	-	Earthy, sulfidy	Leonardos (1969)
0.001	-	-	3M (2010)
0.003	Acceptable Detect Range - High	Rotten cabbage	AIHA (1993)
0.036	High	Garlic	Ruth (1986)

Table 7. Odor Thresholds for Hydrogen Sulfide Reported by Various Sources.

Threshold (ppmV)	Threshold Description	Odor Description	Source
0.00047 - 0.0047	-	Eggy sulfide	Leonardos (1969)
0.0005	Low	Rotten eggs	Ruth (1986)
0.0005	-	-	3M (2010)
0.001	Acceptable Detect Range - Low	Rotten eggs	AIHA (1993)
0.0045[a]	Geometric mean: Recognition	Rotten eggs	AIHA (1993)
0.0047	Recognition	-	Fazzalari (1978)
0.0094[a]	Geometric mean: Detection	Rotten eggs	AIHA (1993)
0.01	High	Rotten eggs	Ruth (1986)
0.015	-	-	Amoore (1983)
0.13	Detection	-	Fazzalari (1978)
0.13	Acceptable Detect Range - High	Rotten eggs	AIHA (1993)

a. Detection threshold higher than recognition threshold due to being reported by different sources.

Table 8. Odor Thresholds for Sulfur Dioxide Reported by Various Sources.

Threshold (ppmV)	Threshold Description	Odor Description	Source
0.33	All Detect Range - Low	Metallic taste/sharp irritating	AIHA (1993)
0.45	Low	"Yech!"	Ruth (1986)
0.47	-	-	Leonardos (1969)
0.47	Recognition	-	Fazzalari (1978)
0.47	Detection	-	Fazzalari (1978)
0.708	-	-	3M (2010)
1.1	-	-	Amoore (1983)
2.7	Geometric Mean: Detection	Metallic taste/sharp irritating	AIHA (1993)
3.8	All Recognition Range - Low	Metallic taste/sharp irritating	AIHA (1993)
4.4	Geometric Mean: Recognition	Metallic taste/sharp irritating	AIHA (1993)
4.8	High	Yech!	Ruth (1986)
5	All Detect Range - High	Metallic taste/sharp irritating	AIHA (1993)
5	All Recognition Range - High	Metallic taste/sharp irritating	AIHA (1993)

To contextualize potential exposure to emissions of sulfur-containing constituents from the Sierrita Mine, Arcadis compared the maximum concentration of each sulfur-containing constituent measured at Sierrita to the U.S. EPA's corresponding AEGLs (Table 9). Arcadis made the comparison using 60-minute AEGL-1 values because 1) this criterion is the most protective of the guidance levels, 2) site emissions might linger for as long as an hour during low dispersion events, and 3) the one hour values are more health protective than those derived for shorter exposure durations. Further, the experiences described in connection with AEGL-1 level exposures most closely correspond to the alleged symptoms experienced by complainants near the Sierrita Mine. According to U.S. EPA (2016a):

> "Acute Exposure Level Guidelines [AEGLs] are used by emergency planners and responders worldwide as guidance in dealing with rare, usually accidental, releases of chemicals into the air. AEGLS are expressed as specific concentrations of airborne chemicals at which health effects may occur. They are designed to protect the elderly and children, and other individuals who may be susceptible."...
>
> "All levels are expressed as parts per million or milligrams per cubic meter (ppm or mg/m^3) of a substance above which it is predicted that the general population could experience, including susceptible individuals:

Level 1: Notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure...."

"*Airborne concentrations below the AEGL-1 represent exposure levels that could produce mild and progressively increasing but transient and non-disabling odor, taste, and sensory irritation or certain asymptomatic, non-sensory effects. With increasing airborne concentrations above each AEGL, there is a progressive increase in the likelihood of occurrence and the severity of effects described for each corresponding AEGL.*"

"*AEGL values represent threshold levels for the general public. As mentioned, that includes susceptible subpopulations, such as infants, children, the elderly, persons with asthma, and those with other illnesses. However, it is recognized that individuals, subject to unique or idiosyncratic responses, could experience the effects described at concentrations below the corresponding AEGL.*"

Maximum concentrations of CS_2, OCS, and ethyl mercaptan measured on-site at the Sierrita Mine facility were typically 2 or more times lower than their corresponding 60-minute AEGL-1 values, while maximum concentrations of hydrogen sulfide and sulfur dioxide measured on-site were approximately 1.5 times greater than the 60-minute AEGL-1 values for these constituents. Receptors located off-site would not be exposed to maximum concentrations measured on-site due to dilution via air dispersion during atmospheric transport. If concentrations were diluted just two-fold, then potential receptors would not be exposed to any sulfur-containing constituent above 60-minute AEGL-1 values. Based on Arcadis' experience performing air dispersion modeling, dilution factors greater than two are expected. Accordingly, Arcadis does not expect that off-site receptors would be exposed to sulfur-containing constituents above their respective 60-minute AEGL-1 values. Thus, symptoms such as notable discomfort or irritation would not be expected in typical individuals.

Table 9. Maximum Concentrations of Constituents Compared to Acute Exposure Guideline Levels.

Constituent	Maximum Concentration (ppmV)	Sampling Location	AEGL-1, 60-min. (ppmV)	Ratio of Maximum Concentration to AEGL-1
Carbon Disulfide	4.23	Xanthate mix	13[a]	0.3
Carbonyl Sulfide	(0.241)*	Decant pond	4 [b]	0.06
Ethyl Mercaptan	0.016	Xanthate mix	1.0[c]	0.02
Hydrogen Sulfide	0.7	North Area	0.51[d]	1.4
Sulfur Dioxide	(0.3)**	North Area	0.2[e]	1.5

* Analytical method could not distinguish carbonyl sulfide and sulfur dioxide. ** Nominal identification.

a. NAS (2009) and U.S. EPA (2016b)
b. U.S. EPA (2016c). AEGL-1 estimated from AEGL-2 using ratio from AEGLs-1 and -2 for CS_2
c. NAS (2009) and U.S. EPA (2016d)
d. NAS (2010a) and U.S. EPA (2016e)
e. NAS (2010b) and U.S. EPA (2016f)

Conclusions

CS_2 or other sulfur-containing chemicals have been measured in air samples collected from suspected sources at the Sierrita Mine facility. Sulfur-containing chemicals have also been nominally identified in ambient air samples collected to the north of Sierrita. Xanthates are used at the site and are reported to be sources of CS_2, SO_2, and other sulfur-containing constituents. Sulfur-containing constituents are chemically stable in the atmosphere for days to years. Specifically CS_2 has an atmospheric half-life of a week or two. A review of relevant literature did not identify definitive odor thresholds for the sampled sulfur-containing constituents; instead, there appear to be widely ranging odor thresholds. Included in the range were thresholds at which sensitive individuals detected odors. Thus, if a sulfur-containing constituent at an off-site location exceeded a lower threshold, a sensitive individual may be able to detect an odor.

The U.S. EPA has developed AEGLs for identifying the concentrations associated with certain effects of exposure to airborne chemicals, including sulfur-containing constituents. At or above the lowest level AEGL (AEGL-1), a typical receptor may experience notable, but transient irritation. An analysis of the maximum on-site concentrations of the sampled sulfur-containing constituents and the expected dilution of those constituents through atmospheric transport suggests that off-site receptors would not be exposed to sulfur-containing constituents above their respective 60-minute AEGL-1 values. Thus, it is unlikely that typical off-site receptors were exposed to sulfur-containing constituents in such concentrations as to produce notable, but transient, reactions, such as irritation.

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