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IMPACTS OF FUGITIVE DUST EMISSIONS
FROM A MODEL COPPER-NICKEL MINE AND MILL

APRIL 1979

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Minnesota Environmental Quality Board
Regional Copper-Nickel Study

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Draft Report
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INTRODUCTION TO THE REGIONAL COPPER-NICKEL STUDY

The Regional Copper-Nickel Environmental Impact Study is a comprehensive examination of the potential cumulative environmental, social, and economic impacts of copper-nickel mineral development in northeastern Minnesota. This study is being conducted for the Minnesota Legislature and state Executive Branch agencies, under the direction of the Minnesota Environmental Quality Board (MEQB) and with the funding, review, and concurrence of the Legislative Commission on Minnesota Resources.

A region along the surface contact of the Duluth Complex in St. Louis and Lake counties in northeastern Minnesota contains a major domestic resource of copper-nickel sulfide mineralization. This region has been explored by several mineral resource development companies for more than twenty years, and recently two firms, AMAX and International Nickel Company, have considered commercial operations. These exploration and mine planning activities indicate the potential establishment of a new mining and processing industry in Minnesota. In addition, these activities indicate the need for a comprehensive environmental, social, and economic analysis by the state in order to consider the cumulative regional implications of this new industry and to provide adequate information for future state policy review and development. In January, 1976, the MEQB organized and initiated the Regional Copper-Nickel Study.

The major objectives of the Regional Copper-Nickel Study are: 1) to characterize the region in its pre-copper-nickel development state; 2) to identify and describe the probable technologies which may be used to exploit the mineral resource and to convert it into salable commodities; 3) to identify and assess the impacts of primary copper-nickel development and secondary regional growth; 4) to conceptualize alternative degrees of regional copper-nickel development; and 5) to assess the cumulative environmental, social, and economic impacts of such hypothetical developments. The Regional Study is a scientific information gathering and analysis effort and will not present subjective social judgements on whether, where, when, or how copper-nickel development should or should not proceed. In addition, the Study will not make or propose state policy pertaining to copper-nickel development.

The Minnesota Environmental Quality Board is a state agency responsible for the implementation of the Minnesota Environmental Policy Act and promotes cooperation between state agencies on environmental matters. The Regional Copper-Nickel Study is an ad hoc effort of the MEQB and future regulatory and site specific environmental impact studies will most likely be the responsibility of the Minnesota Department of Natural Resources and the Minnesota Pollution Control Agency.

Draft fugitive dust section by Peter Ashbrook 10/2/78

INTRODUCTION

Copper-nickel development would add several new sources of air pollutants to those already existing in the region (see section III.C.3.). The new sources include the construction and operation of mines, mills, smelter, and tailings basins; secondary development such as new roads; and the shut down phase, where abandoned mine areas may contribute to fugitive dusts.

Construction: Construction activities generally expose large areas of soil. Fugitive dust emissions arise during human activities such as excavation and vehicle traffic and from wind erosion of exposed surfaces. Construction of one facility (mine, mill, smelter, or tailings basin) may take up to three years. In some cases facilities are built concurrently; however, some construction may occur for many years. Dust emissions would be expected to increase with human activity and dry and windy conditions. Short-term mitigation may occur naturally by precipitation or artificially through the use of water or other dust control agents. Permanent mitigation of dust emissions can be obtained by regenerating vegetative cover over the previously exposed construction site.

Mine/Mill Operation: Open pit mining exposes large areas of the ground. Both open pit and underground mining generate large volumes of waste rock, which is usually placed in storage piles. These activities combined with wind can generate large volumes of fugitive dust emissions. Water can be used for temporary mitigation, while revegetation of storage piles can provide long-term control. In underground mines dust control is accomplished by venting dust to the surface. Drilling and blasting produce large amounts of dust on an intermittent basis. Transfer of ore from the mine to mill can be the largest source of fugitive dust emissions. Loading of trucks, travel of trucks over unpaved haul roads, and dumping of ore at the mill all produce dust. Dust suppression materials such as water or chemicals provide partial control of dust from unpaved roads. Processing of ore at the mill produces large volumes of dust. Point sources of dust from mills can be controlled by use of wet processes and stack controls; however, fugitive emissions from the mill are difficult to control.

Smelter Operations: Air pollutants from smelters can be classified into three groups: 1) sulfur oxides and 2) particulates, which include 3) metals. Sulfur oxides are produced by roasting of sulfide ores to remove sulfur. Control of sulfur oxides is accomplished by means of a sulfur recovery facility, usually a sulfuric acid plant. Such a control may prevent emission of over 90 percent of the sulfur oxides; however, some sulfur oxides are released through stacks since controls are not 100 percent effective. Sulfur oxides may also be released as fugitive emissions from the smelter or during upset conditions. These latter two cases are difficult to control.

Stack emissions of particulates can be controlled in a number of ways, yielding control efficiencies close to 100 percent. Fugitive emissions from the plant and particulates released during upset conditions are difficult to control. Metals are included in particulates, but are mentioned separately because some of them are concentrated during the processing of ore and may reach significantly high levels by the time they are released from the smelting stage.

Smelting stack emissions warrant special interest even though they are easier to control than fugitive emissions, because the emissions that are released are injected into the atmosphere at a higher elevation and can be transported large distances.

Tailings Basin Operations: Tailings basins can be sources of fugitive dust emissions because of the large open area with a tailing basin and the dike surrounding a basin. Dust can be controlled by keeping the tailing basin under water and through vegetating both the dike and the tailing basin after it is filled.

Secondary Development: Copper-nickel development will spur secondary development which will influence air quality through construction of new roads, homes, and businesses; increased traffic; and energy needs of both industry and individuals.

Shut Down: After the ore body is exhausted, a number of sources of air pollutants may remain for many years. These include the open pit mine, tailings basin, waste rock piles, and other open areas. In many cases, revegetation in these areas will provide long-term control of fugitive dust emissions. Open pit mines are sometimes filled with water to produce lakes.

Potential air pollution impacts may determine where development can be sited. Northeast Minnesota is divided into two air quality regions designated as Class I and Class II. Class I regions, which include the BWCA, have strict limitations on the amount of air pollutants a new industry is permitted to release. Class II regions, which include most of northeast Minnesota, have less stringent limitations on air pollutants from a new industry. Because of the proximity of the BWCA to potential copper-nickel development sites, some development sites may be prohibited because air emissions would exceed the strict limitations of a Class I region (see section III.C.4.).

Fugitive Dust (Non-point source)

Air quality impacts resulting from non-point sources of fugitive dust were modeled by means of the Climatological Dispersion Model (Busse and Zimmerman

1973; Brubaker et al. 1977). Fugitive dust emission factors were experimentally determined by Midwest Research Institute as part of a study on the taconite mining industry (Bohn et al. 1978).

Strengths and Limitations of the Model

The Climatological Dispersion Model (CDM) has been widely used in air pollution modeling. The model utilizes local meteorological data, but does not take into account local topography. It has been widely tested and yields results for annual averages which correlate well with actual measurements.

The model is heavily dependent on accurate input of emission factors. These emission factors are often based on a number of assumptions and best guesses, each of which may be off by 50 percent or more. Although fugitive dust emissions constantly occur on a small scale, the bulk of the emissions occur in discrete stages, such as a truck driving over an unpaved road or a gust of wind causing dust lift-off from a tailings basin. Therefore, results from this model must be considered "ballpark" estimates and not highly accurate determinations of ambient dust levels.

Copper-Nickel Model Scenario

Sources of fugitive dust included for this study were blasting, unpaved haul roads, waste rock dumping, crushing/grinding, waste rock piles, ore storage (surge piles) in the mill, conveyors and dumping onto surge piles, and a tailings basin; other sources were considered negligible. The mine model assumed a 20 million metric tons per year open pit mine (see Technical Assessment section). Smaller open pit mines and underground mines would yield lower dust levels.

The mine-mill-waste rock pile-tailings basin site was modeled as follows (Figure 1). The open pit mine covers 200 hectares at maximum development. Haul roads emerge from the east end of the pit to the waste rock piles and to the mill. The tailings basin covers 1,650 hectares and is east of the mill. This orientation is dictated by the fact that to the west of the Duluth Contact is the Mesabi Iron Range and to the north and south of an open pit mine are other mineralized portions of the Duluth Contact. Over the 25 year life of the MODEL mine there ~~will~~ WOULD be a total of 13 waste rock piles of 60 hectares each. Reclamation of waste rock piles and the tailings basin dike was assumed to take five years.

Meteorological data concerning wind direction, speed, and stability class were obtained from International Falls. Average afternoon and nocturnal mixing heights were estimated to be 1,300 and 400 meters, respectively. Emission height of fugitive dust emissions was estimated to be ten meters. Receptor sites were chosen in a grid with the emission sources at the center. Particulate levels were calculated for 36 receptors at three-mile intervals (Figure 1). Estimated dust emissions from the various sources are shown in Table 1 (See Appendix).

III.D.2.d. Results

Estimated annual average increases in particulate levels due to dust emissions generated from the operation of a 20 million metric ton~~s~~ per year open pit mine and a corresponding processing plant as determined by the CDM are illustrated in Figure 1 through 6. The greatest increase, 13.2 ug/m^3, occurred 0.5 mile north of the northern waste rock pile. This was the only receptor site with an increase greater than the background level of 11 ug/m^3. Combining the background level of 11 ug/m^3 with the greatest estimated increase of 13.2 ug/m^3 gives an estimated level of 24.2 ug/m^3. This value of 24.2 ug/m^3 is less than half of both the primary (75 ug/m^3) and secondary (60 ug/m^3) Minnesota Ambient Air Quality Standards.

Annual average concentrations can be statistically converted into 24-hour averages (Larson 1971). Although this conversion method has drawbacks, it is appropriate for use here to estimate whether this mine-mill model would be in compliance with the Prevention of Significant Deterioration (PSD) requirements of the 1977 Clean Air Act Amendments (P.L. 95-95) shown in Table 2. None of the receptor sites exceed the annual average increment permitted for Class II regions; however, four sites exceed the permitted increment of 5 ug/m^3 for a Class I region. Application of Larson's (1971) method of converting annual averages (assuming 60 samples per year, a geometric standard deviation=2; and a z value of 1.94) shows that to meet the 24-hour PSD increments, the annual average increments may not exceed 9.6 ug/m^3 for Class II regions or 2.6 ug/m^3 for Class I regions (see Appendix). Using criteria for Class II regions, two receptor sites would be expected to exceed the 24-hour PSD increment; however, these sites are virtually on the premises of the mine-mill development.

Using criteria for Class I regions, 6 of the 36 receptor sites would be expected to exceed the 24-hour PSD increment.

Discussion

The air quality standards that will be the most difficult to meet are the 24-hour PSD increments. According to this modeling study of dust sources from a large mine-mill development, Class II 24-hour PSD increments may be exceeded in close proximity to industrial activity, while Class I 24-hour PSD increments may be exceeded up to 10 kilometers away from industrial activity in some directions. If such a development were not allowed to use up the entire PSD increment, an even larger area may not be in compliance with permit requirements.

Although the CDM estimates are somewhat crude, they do indicate the relative importance of different sources of dust from potential mine-mill operation and where additional control efforts would be most beneficial.

REFERENCES

Bohn, R., T. Cuscino and C. Cowherd. 1978. Fugitive emissions from integrated iron and steel plants. Publication No. EPA-600/2-78-050. National Technical Information Service, Springfield, Virginia.

Brubaker, K.L., P. Brown and R.R. Cirillo. 1977. Addendum to user's guide for climatological dispersion model. Publication No. EPA-450/3-77-015. National Technical Information Service, Springfield, Virginia.

Busse, A.D. and J.R. Zimmerman. 1973. User's guide for the Climatological Dispersion Model. Publication No. EPA-RA-73-024. National Technical Information Service, Springfield, Virginia.

Larson, R.I. 1971. A mathematical model for converting air quality measurements to air quality standards. Publication No. AP-89. U.S. Government Printing Office, Washington, D.C.

Midwest Research Institute. 1978. Iron Range air quality analysis. MRI Draft Report. Project No. 4523-L(2) August 25, 1978. Prepared for the Minnesota Pollution Control Agency.

Table 1. Estimated fugitive dust emissions from a mine and mill.*

OPERATION	ESTIMATED RANGE OF EMISSIONS (metric tons/yr)	ESTIMATED USE FOR MODEL (metric tons/yr)	COMMENTS
Mine:			
1) Blasting	1.5-1,600	10	Assumes 100 mtpy is midpoint estimate & 10% of dust escapes the pit
2) Hauling	840-4,200	2,100	Assumes dust control of 50%
3) Waste rock dumping	8-400	10	Uses most recent MRI formula
4) Waste rock piles erosion	2.4-400	60	Uses most recent MRI formula (silt content=0.5%)
Mill:			
5) Ore stora~~t~~ge	2-210	10	Assumes 95% control
6) Conveyors dumping on surge pile	1-100	10	Assumes 90% control
7) Crushing/grinding	200-20,000	500	Based on Minntac's new plant (Stage 3) and conversation with MPCA
8) Tailings basin	0-480	100	Assumes 80% of basin under water

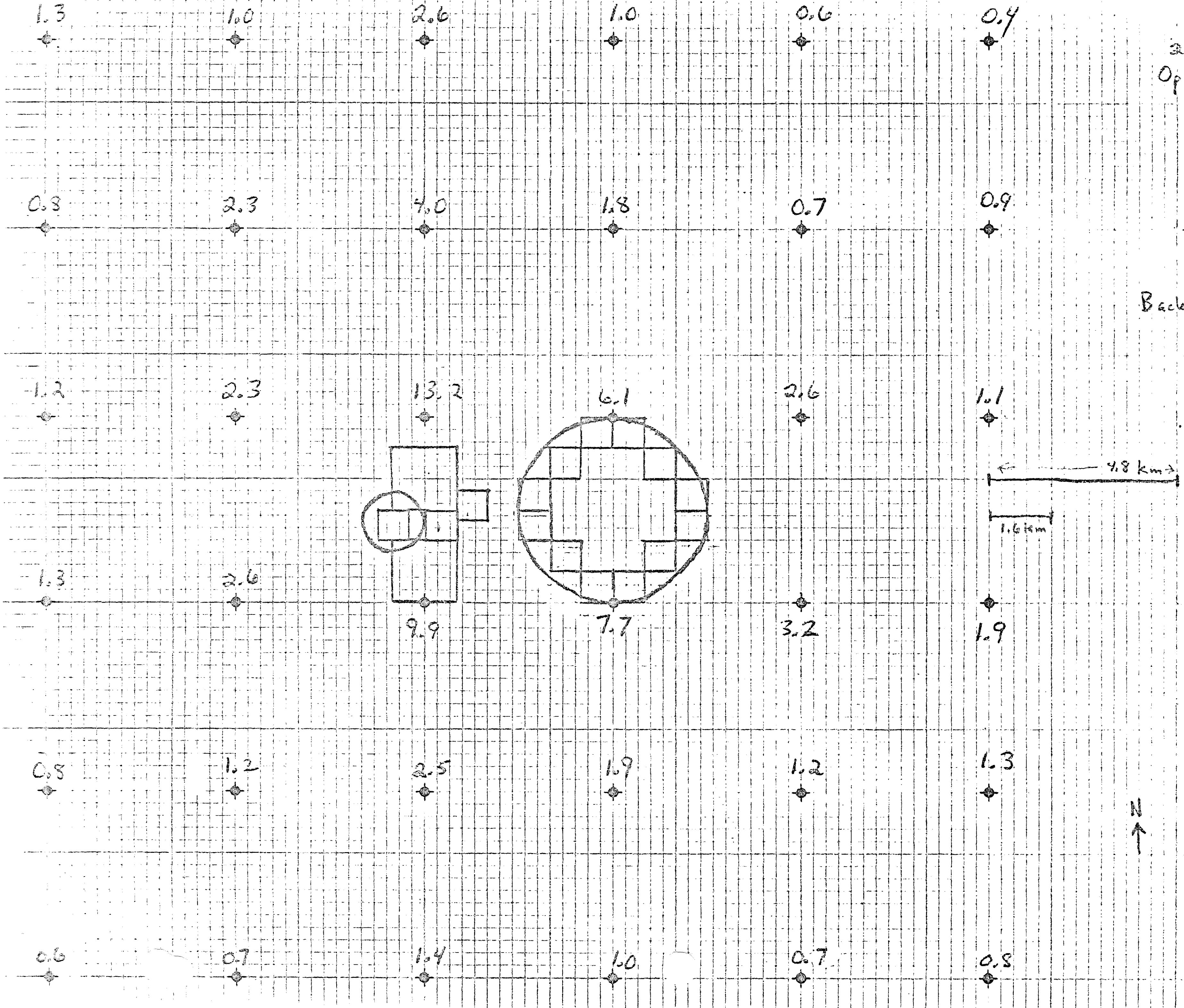
*Assumes an open pit mine producing 20 X 10^6 metric tons of ore per year and removing 26 X 10^6 metric tons of waste rock per year. Estimates are for particulates less than 30 um.

Table 2. PSD permitted increments for total suspended particulates (ug/m^3).

	CLASS I	CLASS II
Annual Average	5	19
24-hour Average	10*	37*

SOURCE: Air Quality Section.

*May be exceeded once per year.



20 x10^6 metric tons/y
Open pit mine
and mill

Background = 11 µg/m3

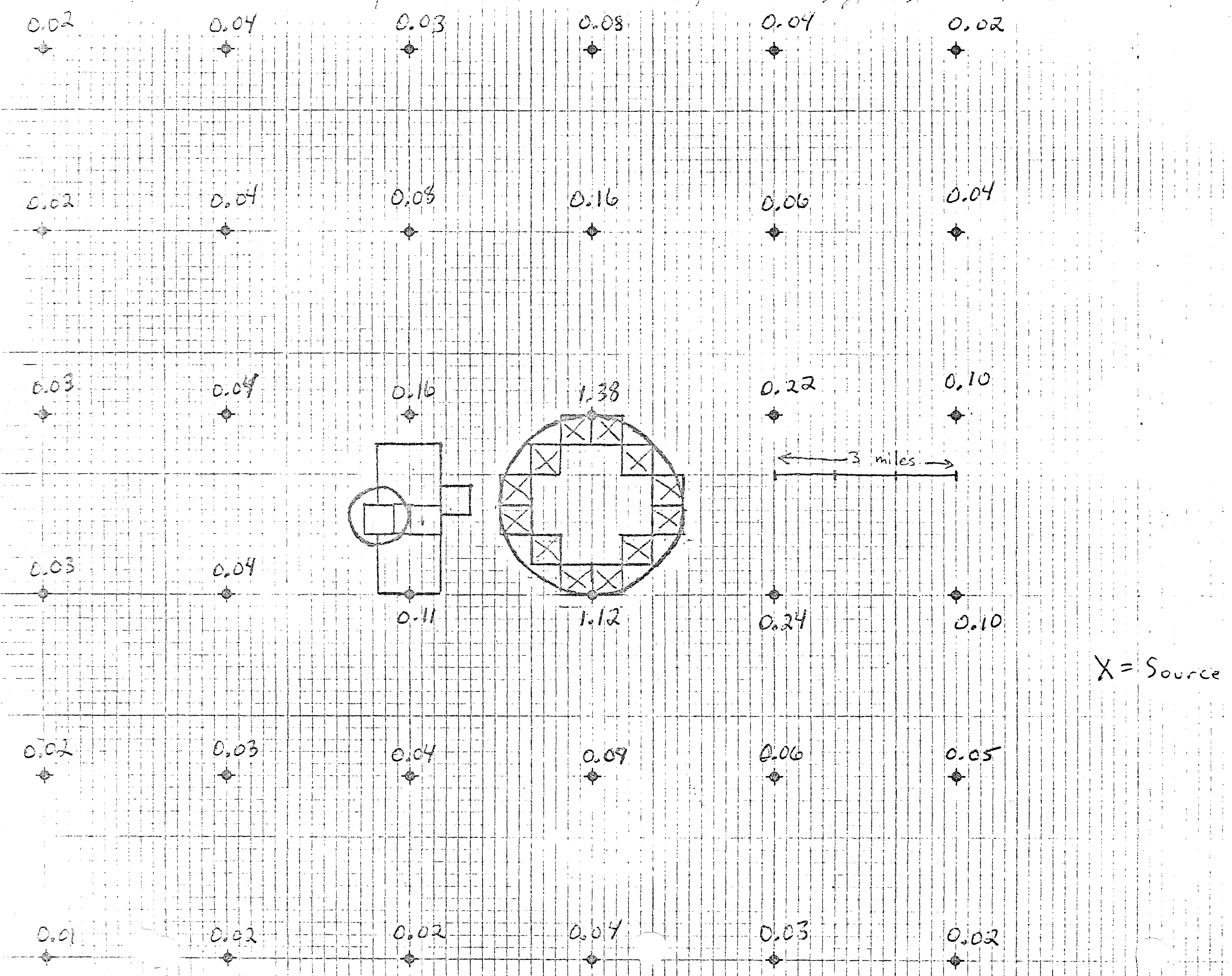

0.02
0.04
0.03
0.08
0.04
0.02
0.02
0.04
0.08
0.16
0.06
0.04
0.03
0.04
0.16
1.38
0.22
0.10
3 miles
0.03
0.04
0.11
1.12
0.24
0.10
X = Source
0.02
0.03
0.04
0.09
0.06
0.05
0.01
0.02
0.02
0.04
0.03
0.02

FIG. 3: Increase in particulates due to blasting (µg/m³). Annual average.

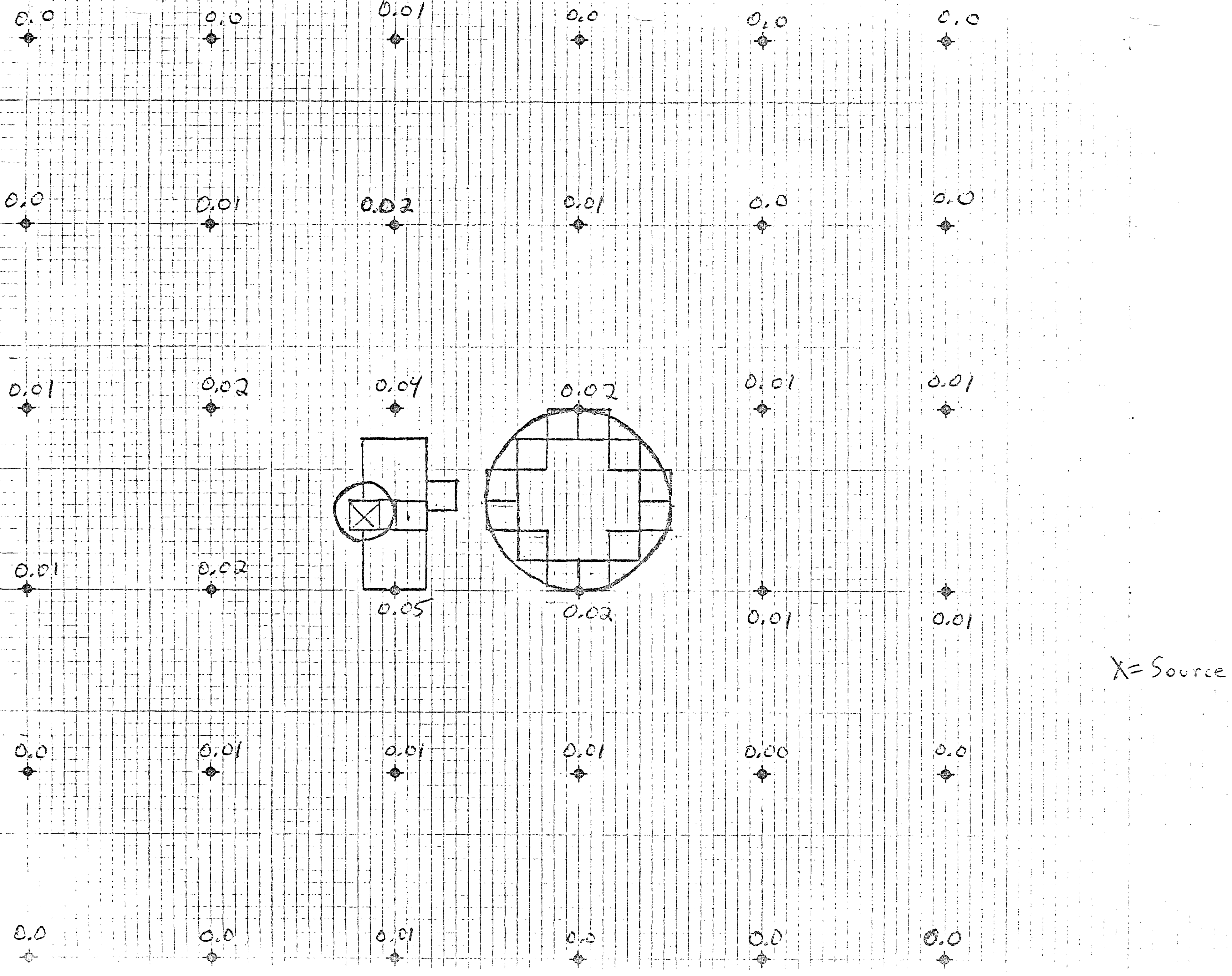


Fig. 4: I[illegible]ease in particulates from waste rock pi[illegible]s and dumping onto piles (μg/m³). Annual [illegible]age

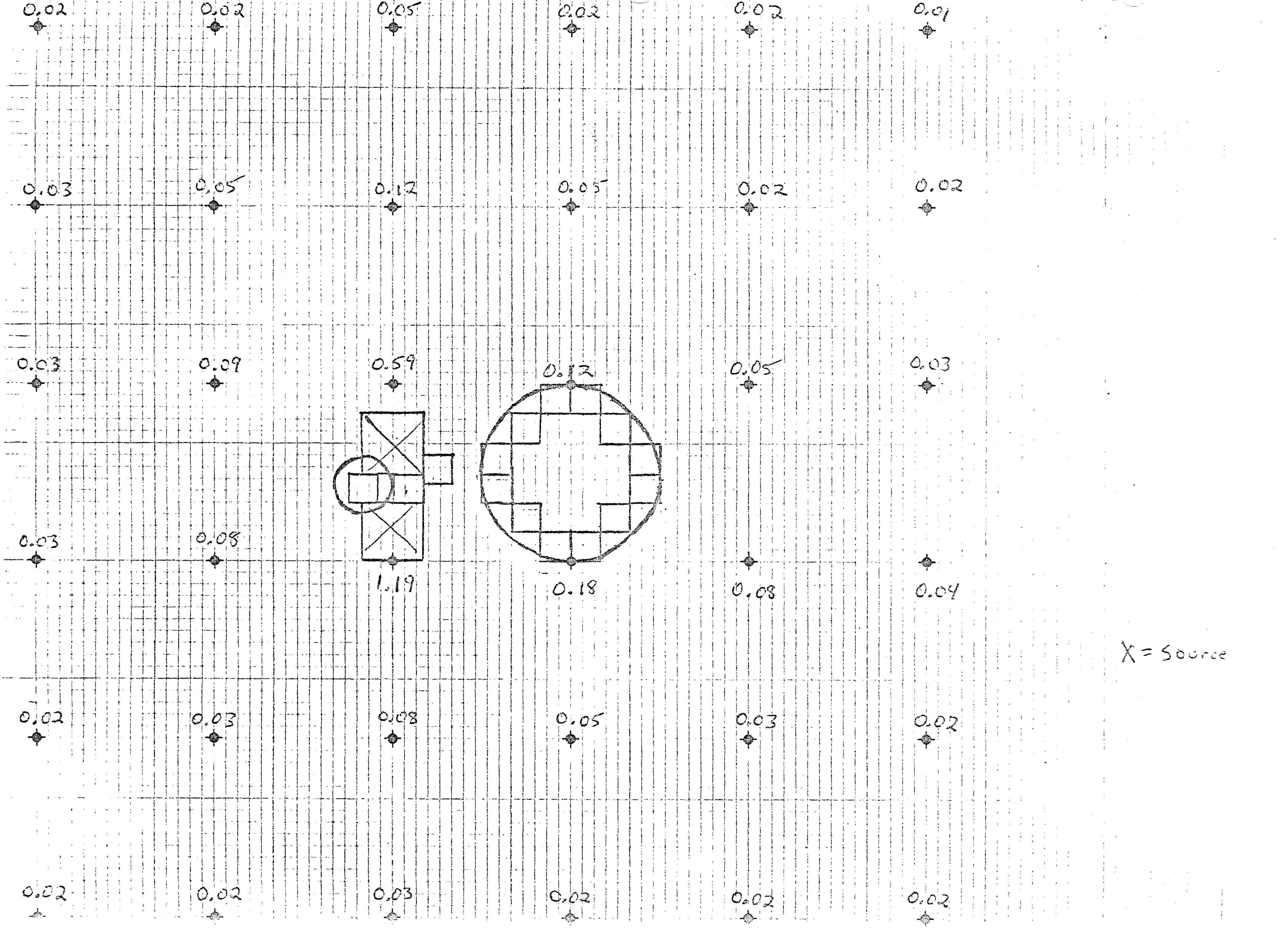


Fig. [illegible] Increase in particulates from ore storage, conveyors, and crushing and griding ([illegible]) annual average

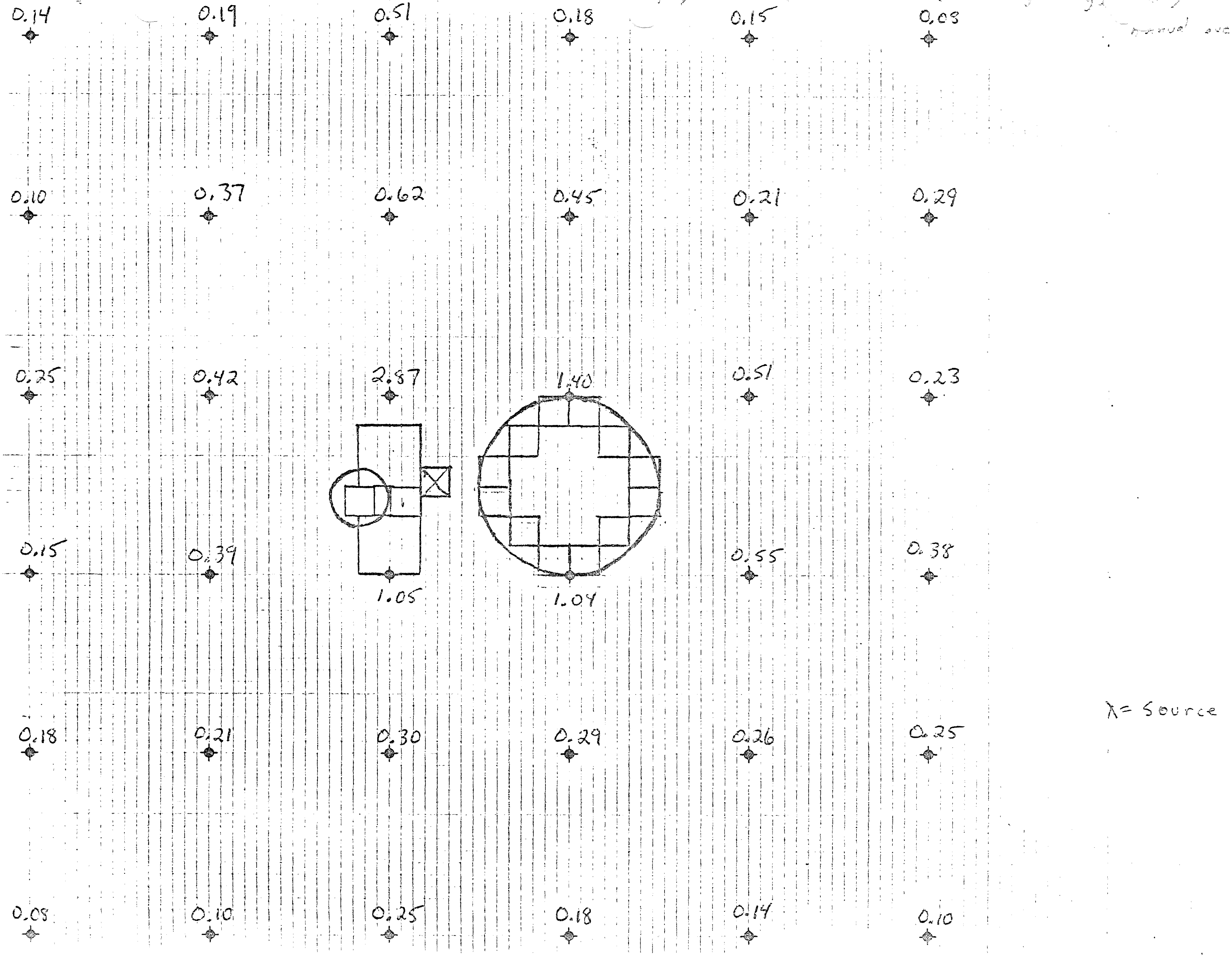
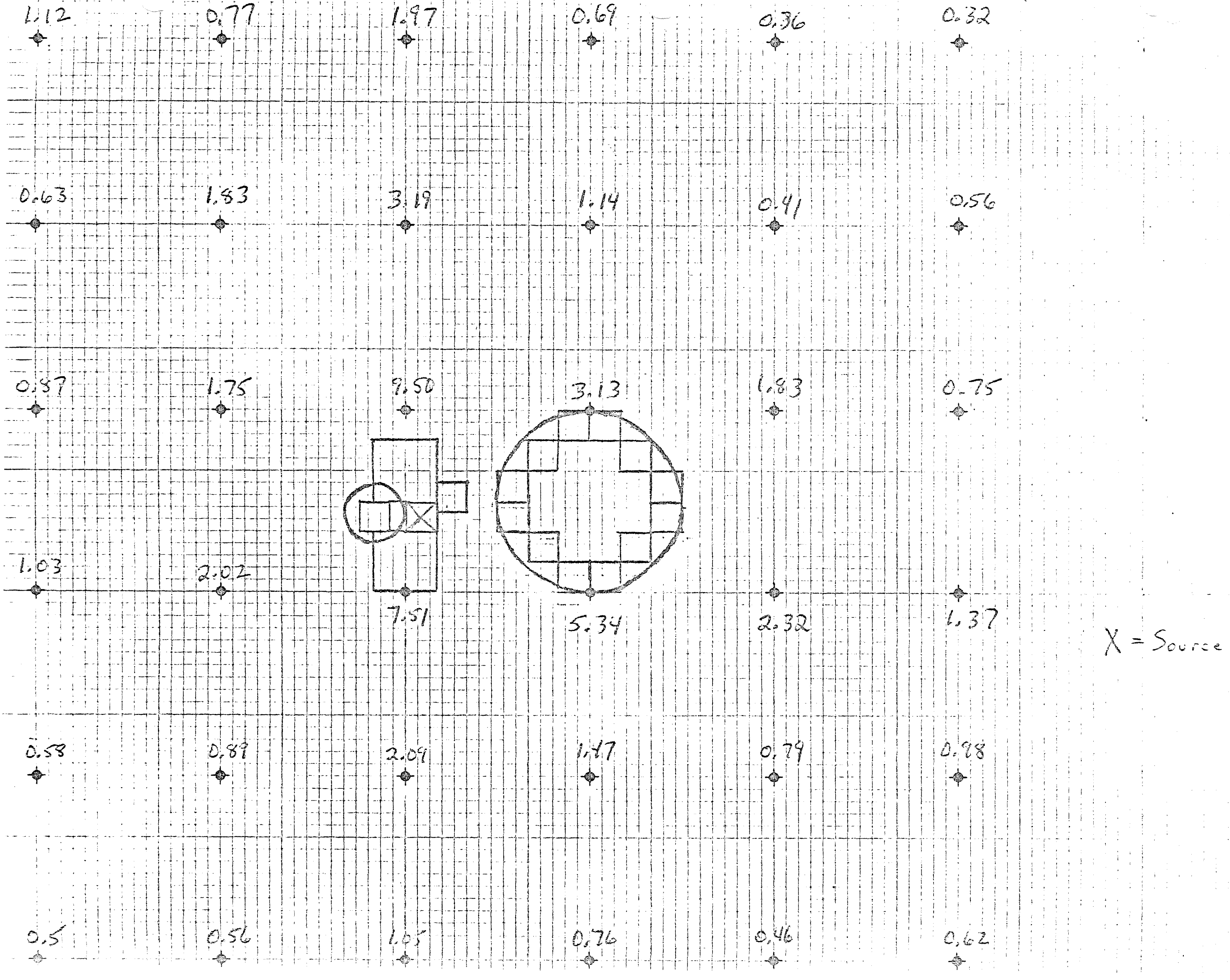
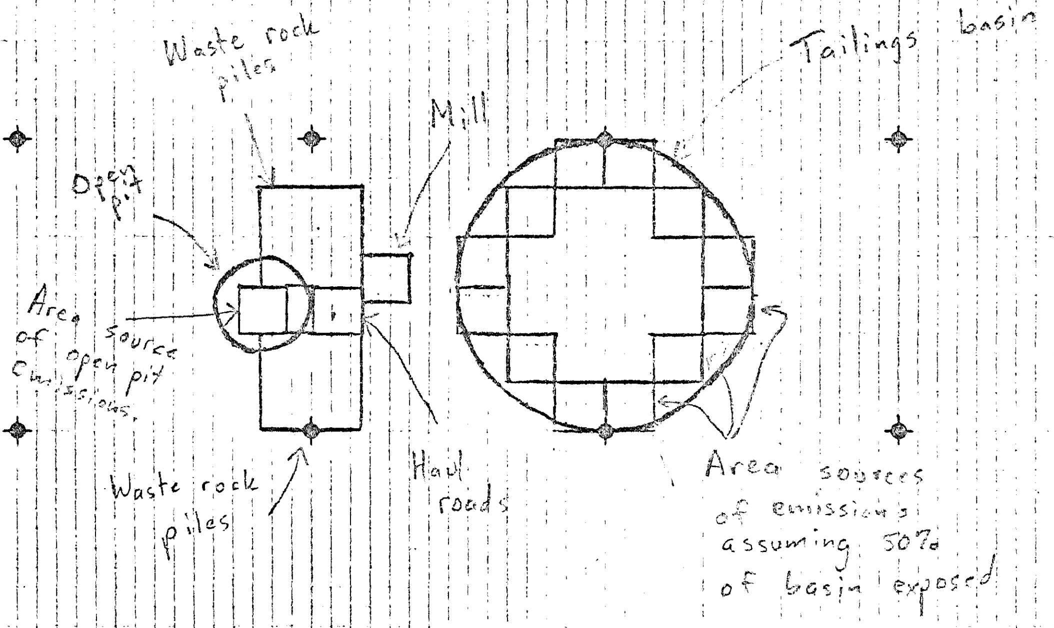


FIG. 6 Increase in particulates from haul roads ($\mu g/m^3$) Annual average




Waste rock piles
Open pit
Area source of open pit emissions,
Waste rock piles
Mill
Haul roads
Tailings basin
Area sources of emissions assuming 50% of basin exposed

APPENDIX

Estimates of dust emissions from a 20 million metric tons per year open pit mine, ~~and~~ processing plant and associated activities.

A. Calculations used for the CDM model. pp. 1-8

B. Extrapolations of annual averages to 24-hour averages. p. 9.

Peter Ashbrook
September, 1978

Blasting

Minimum estimate: 0.00015 lb/short ton

$$(0.00015 \text{ lb/ton})(20\times10^{6} \text{ metric tons})\left(\frac{2205 \text{ metric tons}}{2000 \text{ short tons}}\right) = 3307.5 \text{ lbs}$$

$\underline{\underline{\text{or}}}$ 1,5 metric tons/yr.

B. Maximum estimate: 0.16 lbs/short ton

$$(0.16 \text{ lb/ton})(20\times10^{6} \text{ metric tons})\left(\frac{2205}{2000}\right) = 3{,}528{,}000 \text{ lbs/yr}$$

$\underline{\underline{\text{or}}}$

1600 metric tons/yr

C. Estimate for CDM model.

1. Approximate geometric mean = 100 metric tons/yr
2. Assume 10% of dust escapes the pit
3. Therefore <u>10 Metric tons/yr emitted</u>

SOURCE: MRI, August 1978.

Haul Roads

Formula: $5.9\left(\frac{s}{12}\right)\left(\frac{S}{30}\right)\left(\frac{W}{3}\right)^{0.8}\left(\frac{d}{365}\right)$ lbs/vehicle mile

s = silt content of road dust = 6% (2% < 5 μm; 4% 5-30 μm)
S = average vehicle speed = 16 mph
W = vehicle weight = 100 tons (formula has not been tested above 100 tons
d = dry days per year = 240

Calculation:

$$\frac{(5.9)(6)(16)\left(\frac{100}{3}\right)^{0.8}(240)}{(12)(30)(365)} = 17.1 \text{ lbs/vehicle mile}$$

A. Hauling ore to mill: 18 one-mile trips/hr; 24 hrs/day; 350 days/yr.

Dust emitted = (17.1)(18)(24)(350) = 2,585,520 lbs/yr
or 1173 metric tons/yr

B. Hauling waste rock to piles: 23.4 two-mile trips/hr; 24 hrs/day; 350 days/yr.

Dust emitted = (17.1)(23.4)(2)(24)(350) = 6,722,352 lbs/yr
or 3049 metric tons/yr.

Total dust emitted = 1173 + 3049 = 4200 metric tons/yr (no controls)

Estimate for CDM model

Assume 50% dust control; therefore 2100 metric tons/yr

SOURCE: MEI, March 1978

Dumping waste rock on piles

Minimum estimate (SOURCE: MRI, March 1978):

$$\frac{0.0018\left(\frac{s}{5}\right)\left(\frac{U}{5}\right)}{\left(\frac{M}{2}\right)^2\left(\frac{Y}{6}\right)}$$ lbs/ton of material

s = silt content of waste rock = 1%
U = average wind speed = 8.84
M = moisture content of ore = 0.5%
Y = loader bucket capacity = 100 yd^3

$$\frac{0.0018\left(\frac{1}{5}\right)\left(\frac{8.84}{5}\right)}{\left(\frac{0.5}{2}\right)^2\left(\frac{100}{6}\right)} = 0.00061021$$ lbs/ton of material

$(0.00061021 \text{ lbs/short ton})(26 \times 10^6 \text{ metric tons})\left(\frac{2205}{2000}\right) = 17{,}535$ lbs/yr

<u>or</u>

8 metric tons/yr

B. Maximum estimate (SOURCE: Shell report)

$$\frac{0.33(x)}{\left(\frac{P-E}{100}\right)^2}$$ lbs/ton of material

x = Proportion of formula for dumping = 0.12
P-E = Thornthwaite's Precipitation-Evaporation Index = 112

$$\frac{(0.33)(0.12)}{\left(\frac{112}{100}\right)^2} = 0.0315688$$ lbs/ton of material

$(0.0315688 \text{ lbs/short ton})(26 \times 10^6 \text{ metric tons})\left(\frac{2205}{2000}\right) = 904{,}919.63$ lbs

<u>or</u>

400 metric tons

Estimate for CDM model:

10 metric tons/yr (maximum formula based on earlier MRI work)

Waste rock pile dust emissions

A. Minimum estimate (MRI, March 1978)

$$\frac{3400\left(\frac{e}{50}\right)\left(\frac{s}{15}\right)\left(\frac{f}{25}\right)}{\left(\frac{P-E}{50}\right)^2}$$ pounds/acre/year

e = surface erodability = 3.4 tons/acre/year
s = silt content of waste rock = 5 %
f = % of time wind exceeds 12 mph = 30%
P-E = Thornthwaite's Precipitation-Evaporation Index = 112

$$\frac{3400\left(\frac{3.4}{50}\right)\left(\frac{5}{15}\right)\left(\frac{30}{25}\right)}{\left(\frac{112}{50}\right)^2} = 18.43$$ lbs/acre/yr.

Assuming revegetation takes 5 years and one waste pile = 160 acres, a maximum of 1.75 piles would be exposed.

(18.43)(1.75)(160) = 5308 lbs/yr <u>or</u> 2.4 metric tons/yr

B. Maximum estimate (MRI, August 1978)

$$3.5\left(\frac{s}{1.5}\right)\left(\frac{d}{235}\right)(D)$$ lbs/acre/year

s = silt content of waste rock = 0.5 %
d = dry days per year = 240
D = duration of material storage = 365 days

$$3.5\left(\frac{0.5}{1.5}\right)\left(\frac{240}{235}\right)(365) = 434.88$$ lbs/acre/yr.

Assuming all 13 waste rock piles exposed.

(434.88)(13)(160) = 904,550 lbs/yr <u>or</u> 400 metric tons/yr

Estimate for CDM model:

Takes maximum estimate, but assumes maximum of 1.75 waste rock piles exposed.

Therefore <u>60 metric tons/yr</u>

Mill storage pile (surge pile)

Formula: $0.05\left(\frac{s}{1.5}\right)\left(\frac{d}{235}\right)\left(\frac{f}{15}\right)\left(\frac{D}{90}\right)$ lbs/ton of material)

s = silt content of ore = 4%

d = dry days per year = 240

f = % of time wind exceeds 12 mph = 30%

D = duration of material storage = maximum of 7, usually 1-3.

$$0.05\left(\frac{4}{1.5}\right)\left(\frac{240}{235}\right)\left(\frac{30}{15}\right)\left(\frac{7}{90}\right) = 0.021182$$ lbs/ton of material

A. Maximum estimate: assumes no controls

$(0.021182$ lbs/short ton$)(20 \times 10^6$ metric tons$)\left(\frac{2205}{2000}\right) = 423,640$ lbs/yr

or

210 metric tons/yr

B. Minimum estimate: assumes 99% control

$210 \times 0.01 = $ 2 metric tons per yr

Estimate for CDM model

Assumes 95% control

Therefore 10 metric tons/yr

SOURCE: MRI, March 1978

Conveyors in mill (stacker)

Formula: $\dfrac{0.0018\left(\frac{s}{5}\right)\left(\frac{U}{5}\right)}{\left(\frac{M}{2}\right)^2}$ lb/ton of material

s = silt content of ore = 4% (crushed to $-\frac{1}{2}$")

U = average wind speed = 8.84 mph

M = moisture content of ore = 1%

$$\frac{(0.0018)\left(\frac{4}{5}\right)\left(\frac{8.84}{5}\right)}{\left(\frac{1}{2}\right)^2} = 0.0101836 \text{ lbs/ton of material}$$

A. Maximimum estimate (no controls):

(0.0101836 lbs/ton)(20x10^6 metric tons/yr)($\frac{2205 \text{ lbs/metric ton}}{2000 \text{ lbs/short ton}}$) = 224,548 lbs/yr

or

100 metric tons/yr

B. Minimum estimate (99% control):

(100)(0.01) = 1 metric ton/yr.

Estimate for CDM model

Assume 90% control

Therefore 10 metric tons/yr

SOURCE: MRI, March 1978

Crushing, grinding in the mill

A Estimates based on new Minntac plant (Stage 3). About 1000 tons/yr particulate emissions from primary + secondary crusher, milling, and concentrator.

B. This plant produces 6×10^6 tons/yr pellets from approximately 18×10^6 tons/yr of ore (approximately the same as 20×10^6 MTPY for Cu-Ni).

C. Minntac uses mostly scrubbers which are not as efficient as the baghouse filters proposed for Cu-Ni. Baghouse filters would reduce figure of 1000 tons/yr to 200-500 tons/yr.

D. Estimate that Minntac's controls are 90-99% efficient. Therefore 10,000 - 100,000 tons/yr of dust generated

E. Based on these numbers I estimated a range of 200 - 20,000 tons/yr emissions for Cu-Ni.

Estimate for CDM model

Used 500 metric tons/yr based on information in C.

SOURCE: Conversation with Bill Rottschaefer at PCA on 9/13/76
phone: 296-7393

Tailings Basin

Formula:

$$\frac{3400\left(\frac{e}{50}\right)\left(\frac{s}{15}\right)\left(\frac{f}{25}\right)}{\left(\frac{P\text{-}E}{50}\right)^2}$$ lbs/acre exposed land

e = surface erodability = 3.4 pounds/acre/yr.
s = silt content = 70% for fine tails
f = % of time wind exceeds 12 mph = 30%
P-E = Thornthwaite's Precipitation-Evaporation Index = 112

$$\frac{3400\left(\frac{3.4}{50}\right)\left(\frac{70}{15}\right)\left(\frac{30}{25}\right)}{\left(\frac{112}{50}\right)^2} = 258 \text{ lbs/acre/yr.}$$

A. Maximum estimate:

Basin = 4016 acres, all tails exposed are fine tails, 100% exposure

(258 lbs/acre)(4016 acres) = 1,036,220 lbs/yr <u>or</u> 480 metric ton/yr

B. Minimum estimate:

Basin completely under water

Therefore 0 metric tons/yr

Estimate for CDM model

Assume 20% exposure

Therefore <u>100 metric tons/yr</u>

SOURCE: MRI, March 1978

Conversion of annual averages to 24-hr averages

ormula:

$$c = m_g \, s_g^{\,z}$$

c = calculated concentration

m_g = annual geometric mean

s_g = geometric standard deviation = 2.0

z = number of standard deviations from the mean.

24-hr PSD permitted increments for particulates:

Class I = 10 μg/m³

Class II = 37 μg/m³

**** May be exceeded once per year

A. P.C.A samples 60 times per year.

To estimate highest reading $z = 2.33$

To estimate 2nd highest reading $z = 1.94$ (Shell report).

B. <u>To meet Class I PSD</u> ($c = 10$ μg/m³)

$$10 = m_g (2)^{1.94} \quad \text{or} \quad \underline{m_g = 2.6 \ \mu g/m^3}$$

This means that any CDM increment above 2.6 μg/m³ annual average would be expected to exceed the Class I 24-hr PSD increment.

C. <u>To meet Class II PSD</u> ($c = 37$ μg/m³)

$$37 = m_g (2)^{1.94} \quad \text{or} \quad \underline{m_g = 9.6 \ \mu g/m^3}$$

This means that any CDM increment above 9.6 μg/m³ annual average would be expected to exceed the Class II 24-hr PSD increment.

SOURCE: Larson, R.I. 1971. A mathematical model for converting air quality measurements to air quality standards. Publication No. AP-89. U.S. Government Printing Office, Washington, D.C.