MRI REPORT

IRON RANGE AIR QUALITY ANALYSIS

DRAFT FINAL REPORT

MRI Project No. 4523-L(2)

June 5, 1979

For

Minnesota Pollution Control Agency
Division of Air Quality
1935 West County Road B-2
Roseville, Minnesota 55113

Attn: Mr. Gary Eckhardt

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by

Christine M. Maxwell
C. Reed Hodgin

DRAFT FINAL REPORT SECTIONS

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PREFACE

This program was conducted in Midwest Research Institute's Environmental and Materials Sciences Division. Dr. Chatten Cowherd, Head, Air Quality Assessment Section, served as program manager. Ms. Christine Maxwell, Project Leader, was coauthor of this report. She was assisted in this study by Mr. C. Reed Hodgin who coauthored this report and by Mr. John Pilney, Mr. Thomas Cuscino, Dr. Robert Hegarty, Dr. Ralph Keller, Mr. Ralph Forestor, Miss Linda Servoss, and Mr. Mark McLinden.

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Environmental and Materials
Sciences Division

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1.0 INTRODUCTION

1.1 Background

The Environmental Protection Agency (EPA) has indicated criteria which must be met by the states for State Implementation Plan (SIP) approval. In order to meet these criteria, detailed air quality analysis procedures must be used to determine the current and future ambient air quality status of each region. Elements of this analysis include: (a) development of comprehensive, current emission inventory; (b) projection of the effect that growth (positive or negative) will have on emissions; (c) measurement and interpretation of baseline air quality and meteorological data; and (d) the use of appropriate atmospheric dispersion models to project future air quality associated with projected emissions.

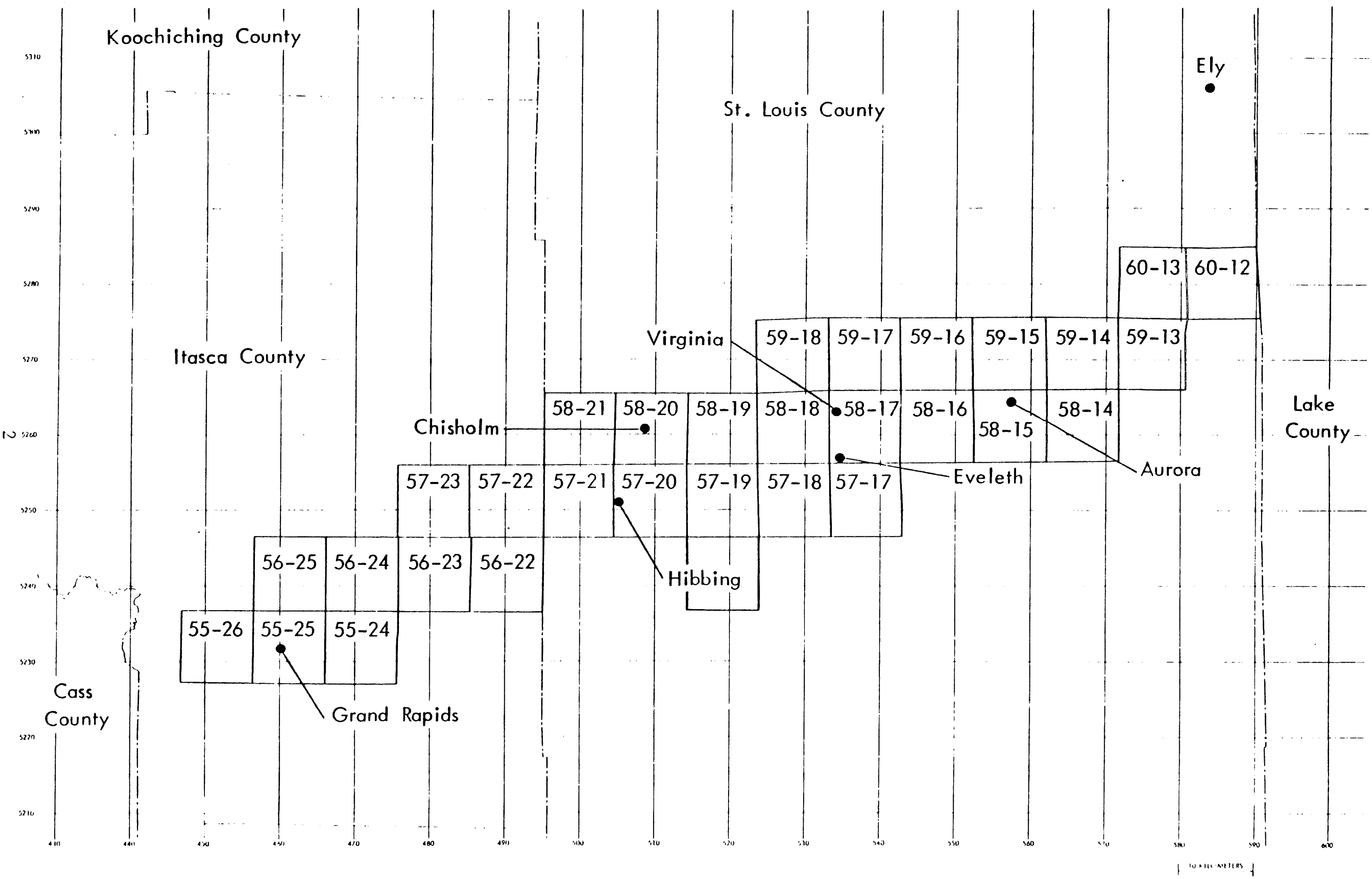
A comprehensive point and area source emission inventory of a regional area serves as the cornerstone for the ensuing air quality analysis. Once the emission inventories for the baseline and forecast periods are developed, appropriate modeling procedures are used to determine the current and projected air quality status of the region under consideration. From this analysis, the overall degree of control required for attainment of the National Ambient Air Quality Standards (NAAQS) can be ascertained. A comprehensive control strategy program can then be implemented to achieve the required emissions reductions.

The study reported herein was directed to the assessment of the air quality of the Mesabi Iron Range in northeastern Minnesota. The primary study area, as shown in Figure 1-1, consisted of 31 townships; the secondary study are consisted of adjacent townships containing emission sources with the potential to impact on the primary area. The air pollutants designated for study were total suspended particulate (TSP) and sulfur dioxide (SO_2).

1.2 Overall Methodology

This study was divided into two principal parts or phases. Figures 1-2 and 1-3 present the work flow diagram for Phases I and II, respectively.

Phase I was directed to (a) development of a comprehensive base-year (1976) area source emission inventory and (b) projection of the effect of regional growth between 1976 and 1982 on the area source emission inventory and on the Minnesota Pollution Control Agency (MPCA) point source emission inventory. More detail on the specific methodology used to compile the baseline and project emission inventories for TSP and SO_2 is given in Section 4.0.



IRON RANGE ANALYSIS STUDY REGION

Figure 1-1

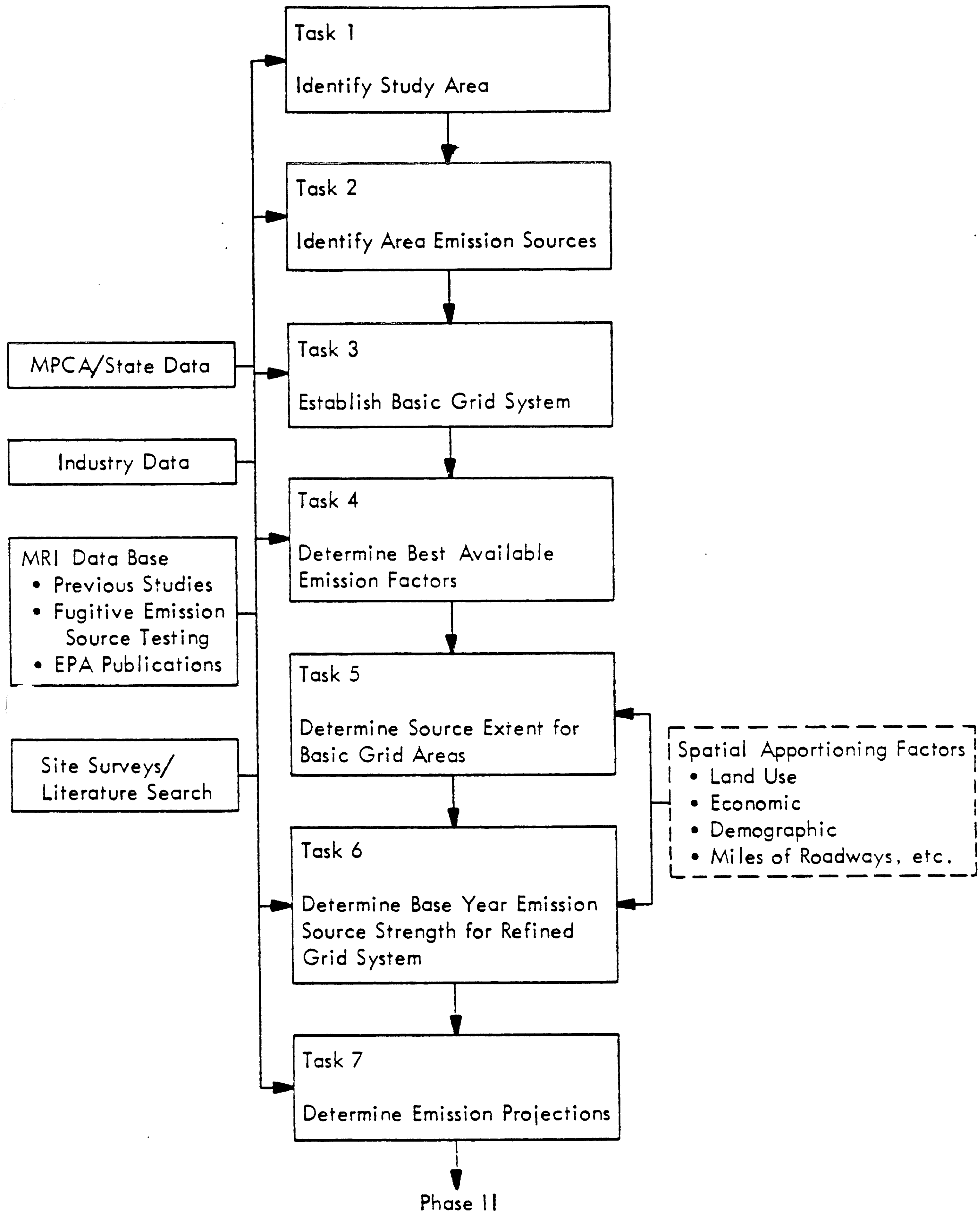


Figure 1-2 - Phase I Work Flow Diagram

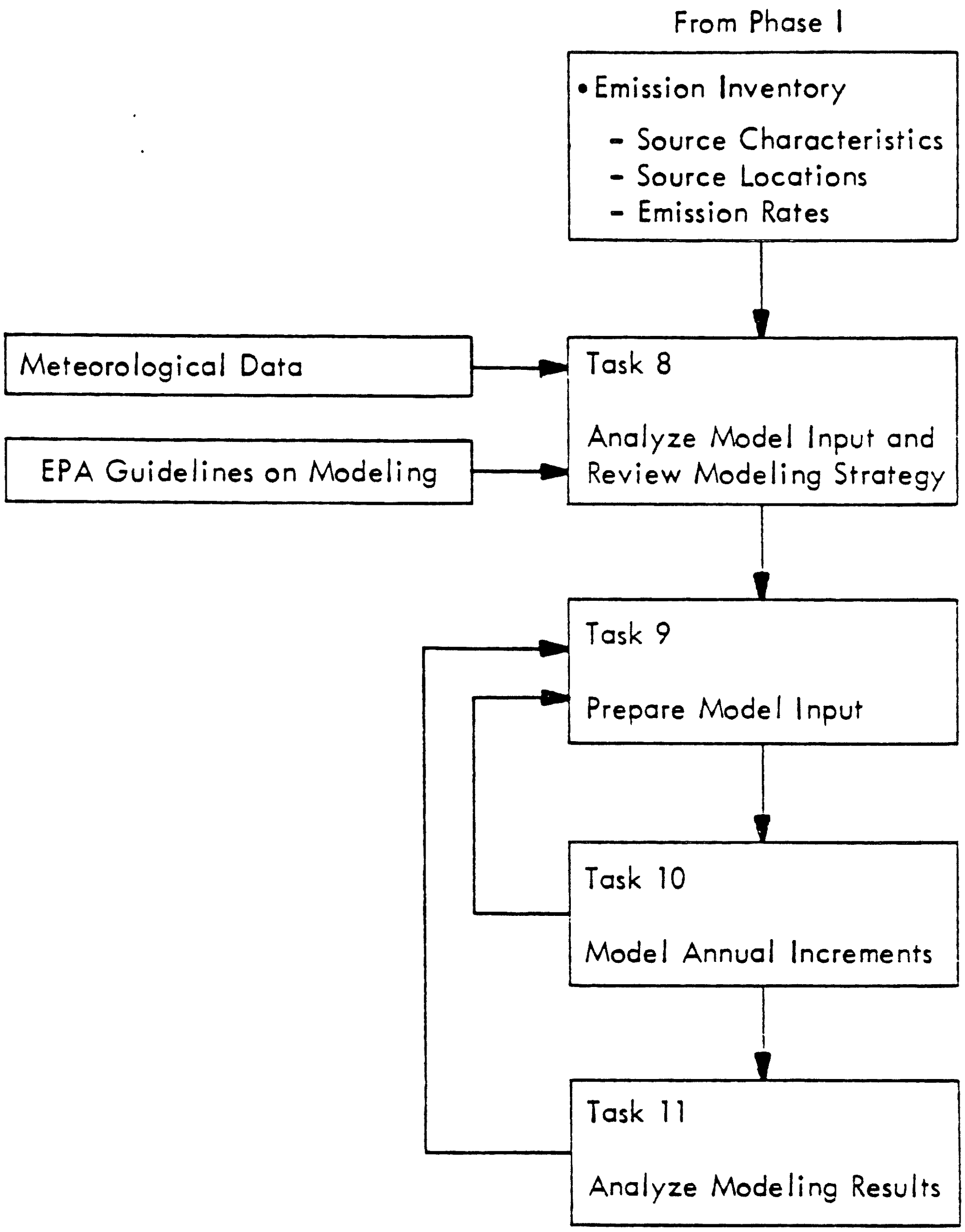


Figure 1-3 - Phase II Work Flow Diagram

The overal objectives of Phase II were to: (a) calibrate an atmospheric dispersion model against the baseline emission inventory and air quality data for 1976; (b) implement the model to forecast TSP and SO_2 concentration levels for 1982; and (c) recommend control strategies based on the level of control needed for attainment and maintenance of air quality standards. Additional detail on the modeling strategy is given in Section 7.0.

The following sections of the report present:

a. A description of regional climatology for the Iron Range.

b. A summary of the existing levels of air pollution.

c. An assessment of point and area sources of air pollution in the region.

d. An analysis of growth projections.

e. The methodology and results of atmospheric dispersion modeling.

f. A final analysis of predicted air quality results.

2.0 CLIMATIC SETTING

The primary factors affecting the climate of northeastern Minnesota are the movements of polar air from the north and west during the mid-fall to mid-spring period and the breezes from Lake Superior in the late spring and summer months. These conditions tend to produce cold winters with prolonged periods of freezing temperatures and generally mild summers.

Frequent and marked changes in the weather are brought about by the passage of a succession of high and low pressure systems that continually move across the country from west to east. The passage of low pressure cells with trailing cold fronts signals rapid temperature drops, brisk shifting winds and, frequently, precipitation. High pressure cells bring clear skies, light winds, and temperature inversions (stable thermal conditions).

2.1 Data Requirements

Meteorological data was required for input to fugitive dust source emission factor determinations, and for implementation of the dispersion model. Data were needed to represent two different study conditions; a year during which ambient air quality data existed to validate and calibrate the model, and a meteorological worst-case year for use in projecting air quality to 1980.

The year 1976 was chosen for calibration/validation because it provided the most extensive point source and ambient air quality data base available at the time of the study. Based on advice from the MPCA and general guidelines found in EPA modeling documents,[1/] a 5-year period (1970 to 1974) was chosen for worst-case analysis. As described below, a single year was then selected from the period to represent worst-case meteorological conditions for the study.

2.2 Meteorological Stations

Little climatic data are available for the immediate vicinity of the Iron Range. At Hibbing, measurements are made of wind speed and direction, temperature, and precipitation. The nearest National Weather Service stations which record more detailed meteorological data are at Duluth and International Falls. Duluth is located about 75 miles to the south, and International Falls is about 125 miles to the north. Duluth is located on Lake Superior and is often under the influence of local conditions created by the lake. International Falls is located near several bodies of water which affect local weather. The effects of the water areas on International Falls are sufficiently small that, for certain meteorological parameters, the data might be used to represent the area.

Because of the importance of meteorological data in the study, and because of the sparcity of data available, considerable effort was applied to the development of an appropriate meteorological data base. The services of Mr. Bruce F. Watson, consulting meteorologist, were retained for this purpose. Mr. Watson maintains a large climatic data base for the Mesabi Iron Range area, and has important personal experience with the climate of the region. Combining the expertise provided by Mr. Watson with assessments performed by MRI personnel, a meteorological data base was compiled which best represented the Mesabi Iron Range.

The meteorological variables of interest are wind speed and direction, temperature and precipitation, mixing height, and atmospheric stability. The following subsections present these data.

2.3 Wind Speed and Direction

Because the land in the vicinity of the study area for the most part has the character of a slightly rolling plateau, the movement of air masses across the region is relatively unimpeded by physiographic influences. Some minor channeling of the wind in the area of Virginia due to the ridges north of Virginia may occur; otherwise, the area is relatively smooth to the wind. In the absence of cyclonic storms and associated frontal systems, atmospheric ventilation patterns follow gently curving stream lines. Only near Lake Superior, where hills rise abruptly and lake breezes exists, are the wind patterns significantly altered.

In Figure 2-1, annual wind roses are presented for Hibbing[2/] and International Falls,[3/] the most representative locations in the region. Figure 2-2 presents a direct comparison of the wind occurrences from each direction. Monthly wind data for International Falls and Hibbing are given in Table 2-1. Frequency distribution of wind speed and direction for Hibbing are given in Table 2-2.

Data compiled for the Hibbing Airport[4/] were substantially different from wind data observed at International Falls.[5/] It was concluded that Hibbing data, rather than International Falls data should be used for this modeling study to represent conditions in the Iron Range. As indicated in Figure 2-1, the International Falls wind rose is characterized by a prevalence of westerly and southerly directions. The Hibbing wind rose indicates a prevalence of north-northwesterly and south erly directions.

In general, the shape of the Hibbing wind rose remains much the same when individual years are examined. Figures 2-3 through 2-8 give annual wind roses for 1970 through 1974 and 1976.[2/] The shape of each is characteristic of a 10-year average Hibbing wind rose, with its characteristic prevalence of north-northwesterlies and southeasterlies, and general lack of southwesterlies and northeasterlies.

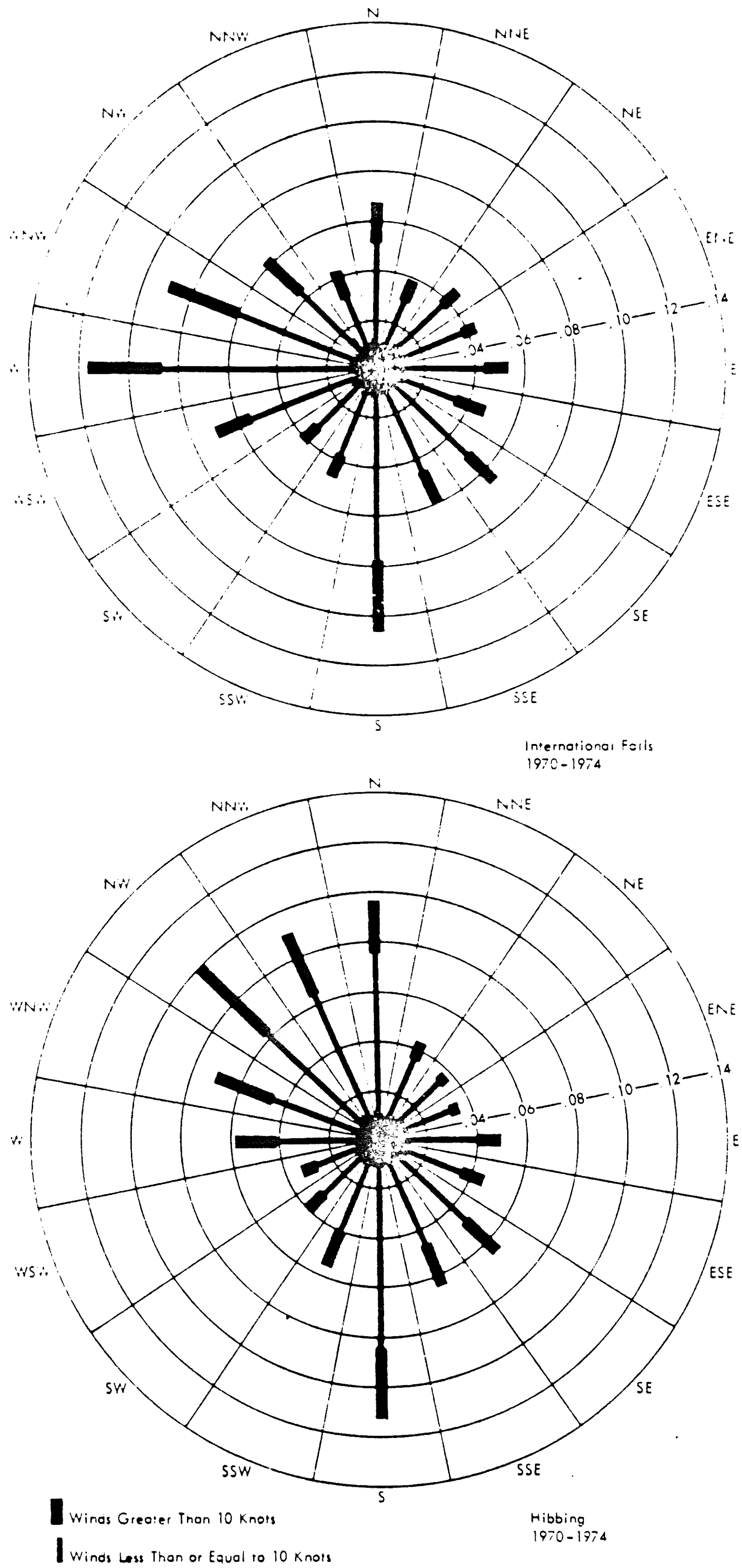


Figure 2-1. Annual Wind Roses for Hibbing and International Falls (1970-1974).

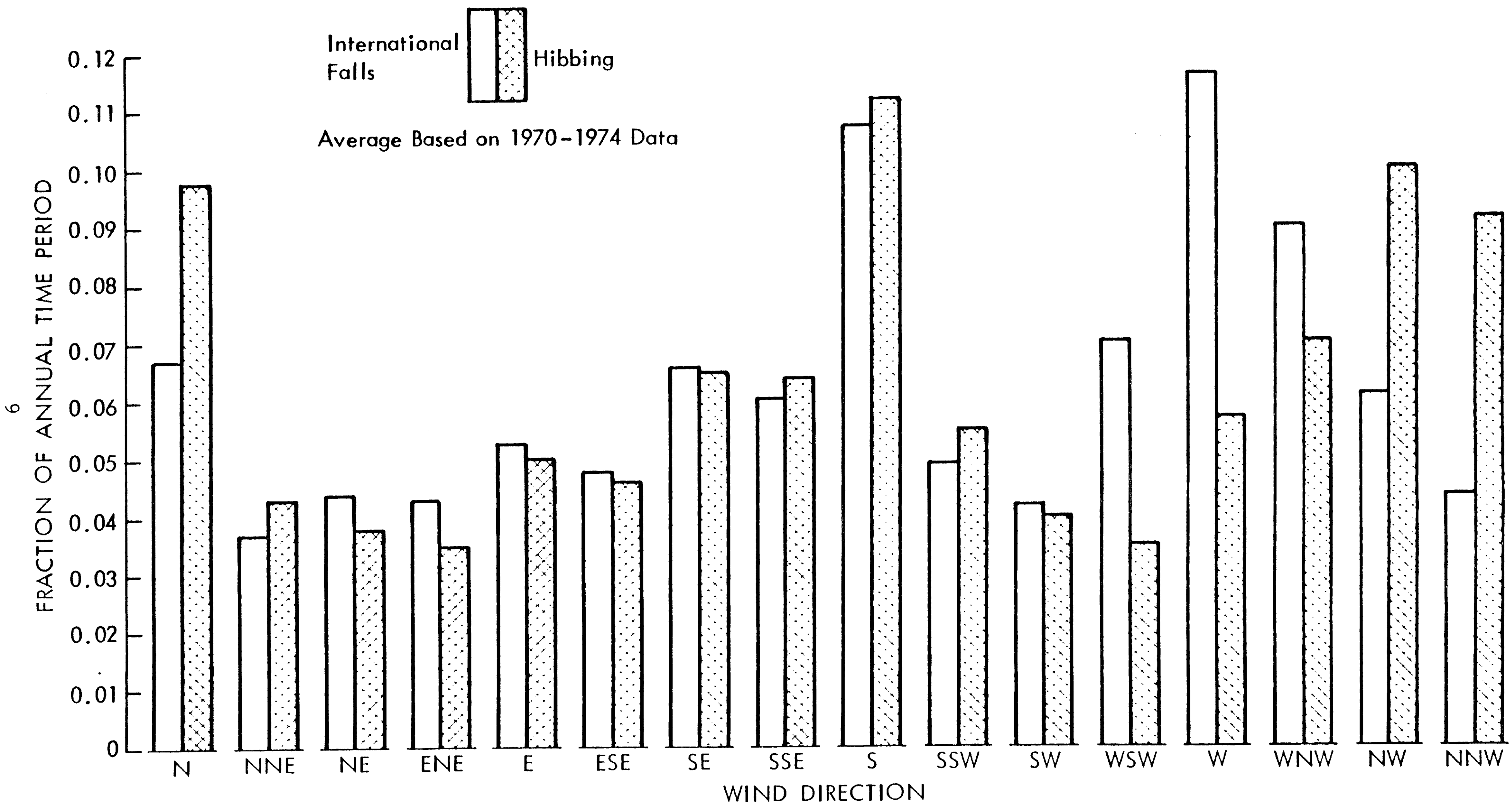


Figure 2-2 - Comparison of 1970-1974 Wind Direction Data for International Falls and Hibbing

TABLE 2-1

MONTHLY WIND DATA--INTERNATIONAL FALLS AND HIBBING

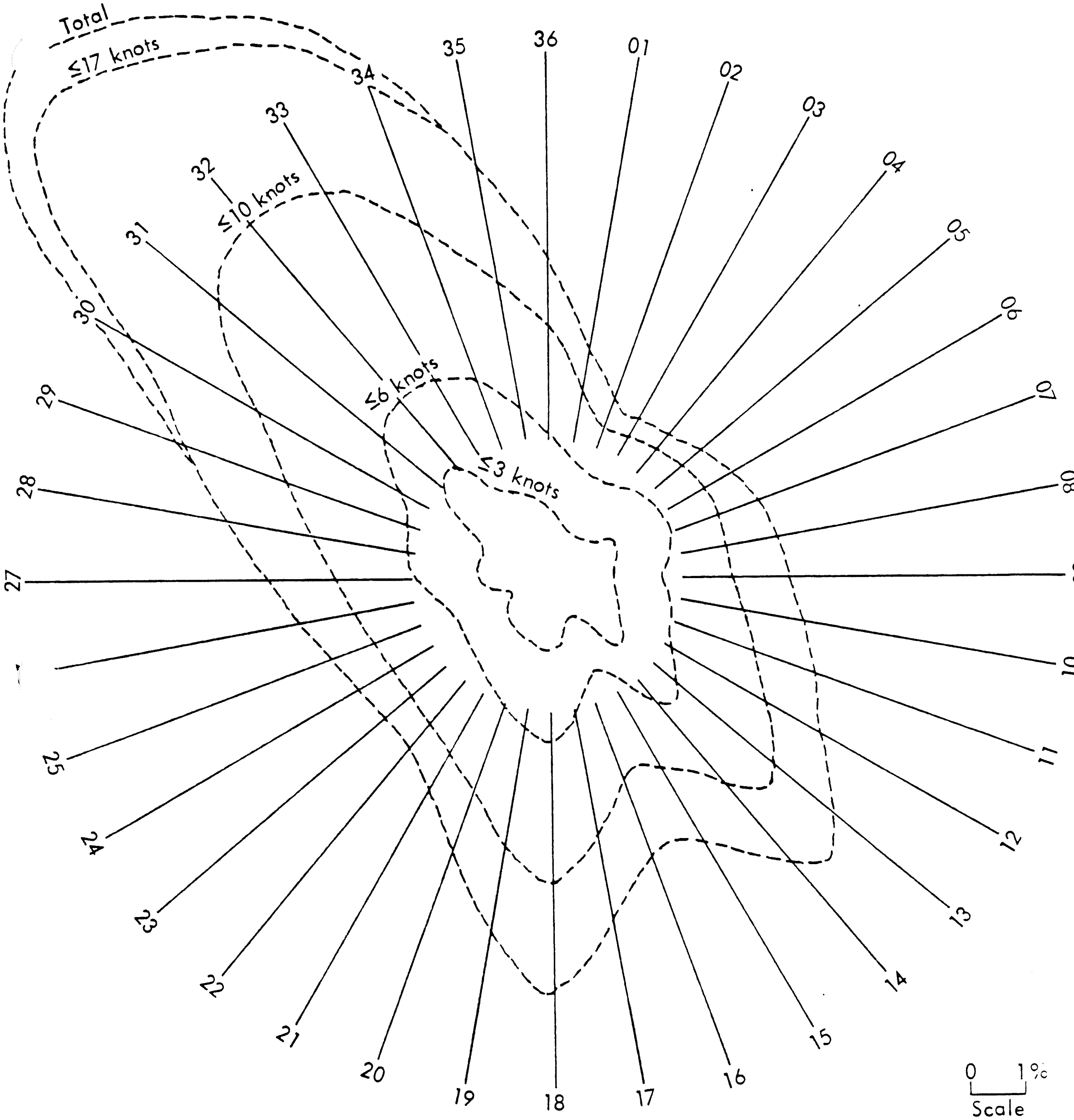
Month	Mean Speed (mph)		Prevailing Direction	
	International Falls (1953-1974)	Hibbing (1953-1974)	International Falls (1953-1974)	Hibbing (1953-1974)
January	9.3	9.2	W	NNW
February	9.2	9.2	W	NNW
March	9.5	9.4	W	NNW
April	10.6	10.4	NW	NW
May	10.2	10.1	NW	NW
June	8.7	8.8	SE	NW/S
July	8.0	8.2	W	NW
August	7.7	7.8	SE	NW/S
September	8.9	8.5	SE	NW/S
October	9.7	9.9	SE	NW
November	10.0	9.3	W	NW
December	9.2	8.9	W	NW
Annual	9.2	9.1	W	NW

Source: References 2 and 5.

TABLE 2-2

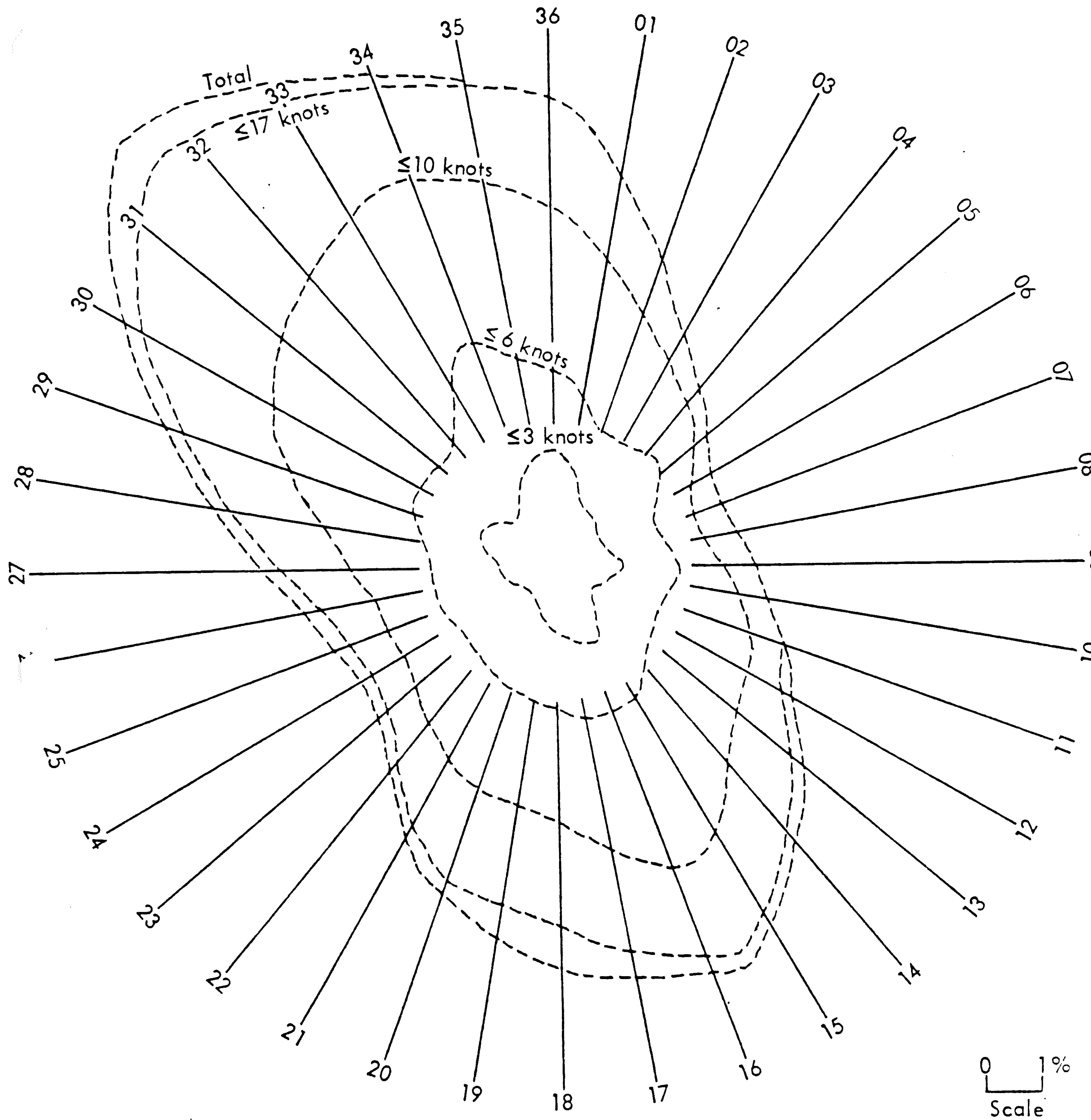
ANNUAL WIND DIRECTION DISTRIBUTION--HIBBING
(1970-1974 Average)

Direction	Fraction of Time Wind is from Specific Direction						
	Wind Speed (knots)						
	0-3	4-6	7-10	11-16	17-21	21+	Total
N	0.017038	0.024048	0.036490	0.021866	0.000929	0.000000	0.100371
NNE	0.007312	0.011374	0.017061	0.006801	0.000162	0.000000	0.042710
NE	0.008101	0.012837	0.010864	0.003830	0.000070	0.000000	0.035702
ENE	0.010980	0.010330	0.009401	0.003877	0.000487	0.000000	0.035075
E	0.011049	0.013510	0.014206	0.009099	0.000836	0.000046	0.048746
ESE	0.007010	0.010608	0.014044	0.008890	0.000534	0.000023	0.041109
SE	0.008682	0.013417	0.022981	0.015599	0.000487	0.000000	0.061166
SSE	0.010794	0.012837	0.023538	0.017224	0.000952	0.000000	0.065345
S	0.017688	0.021611	0.041110	0.032266	0.001857	0.000070	0.114602
SSW	0.008217	0.012581	0.022006	0.015390	0.001114	0.000162	0.059470
SW	0.008380	0.011026	0.013231	0.008914	0.000186	0.000046	0.041783
WSW	0.007544	0.009633	0.011676	0.006569	0.000696	0.000116	0.036234
W	0.009076	0.013022	0.019499	0.014740	0.002136	0.000139	0.058612
WNW	0.008473	0.010771	0.024002	0.021379	0.003018	0.000186	0.067829
NW	0.010515	0.014229	0.035980	0.035724	0.003853	0.000395	0.100696
NNW	0.010631	0.019104	0.032985	0.026161	0.001509	0.000162	0.090552
Total	0.161490	0.220938	0.349074	0.248329	0.018826	0.001345	1.000002



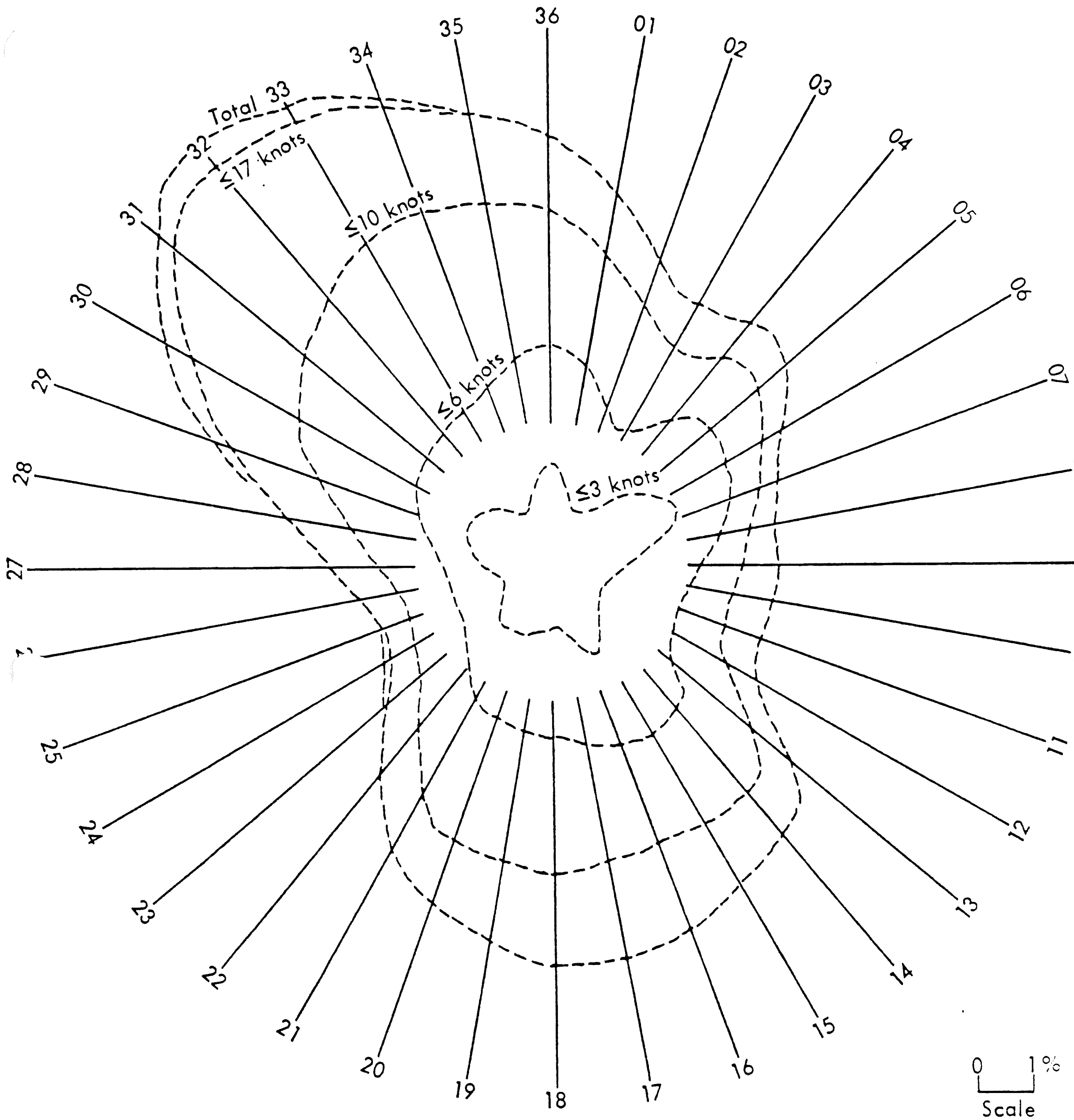
Hibbing Cumulative Wind Rose - - 1970

Figure 2-3



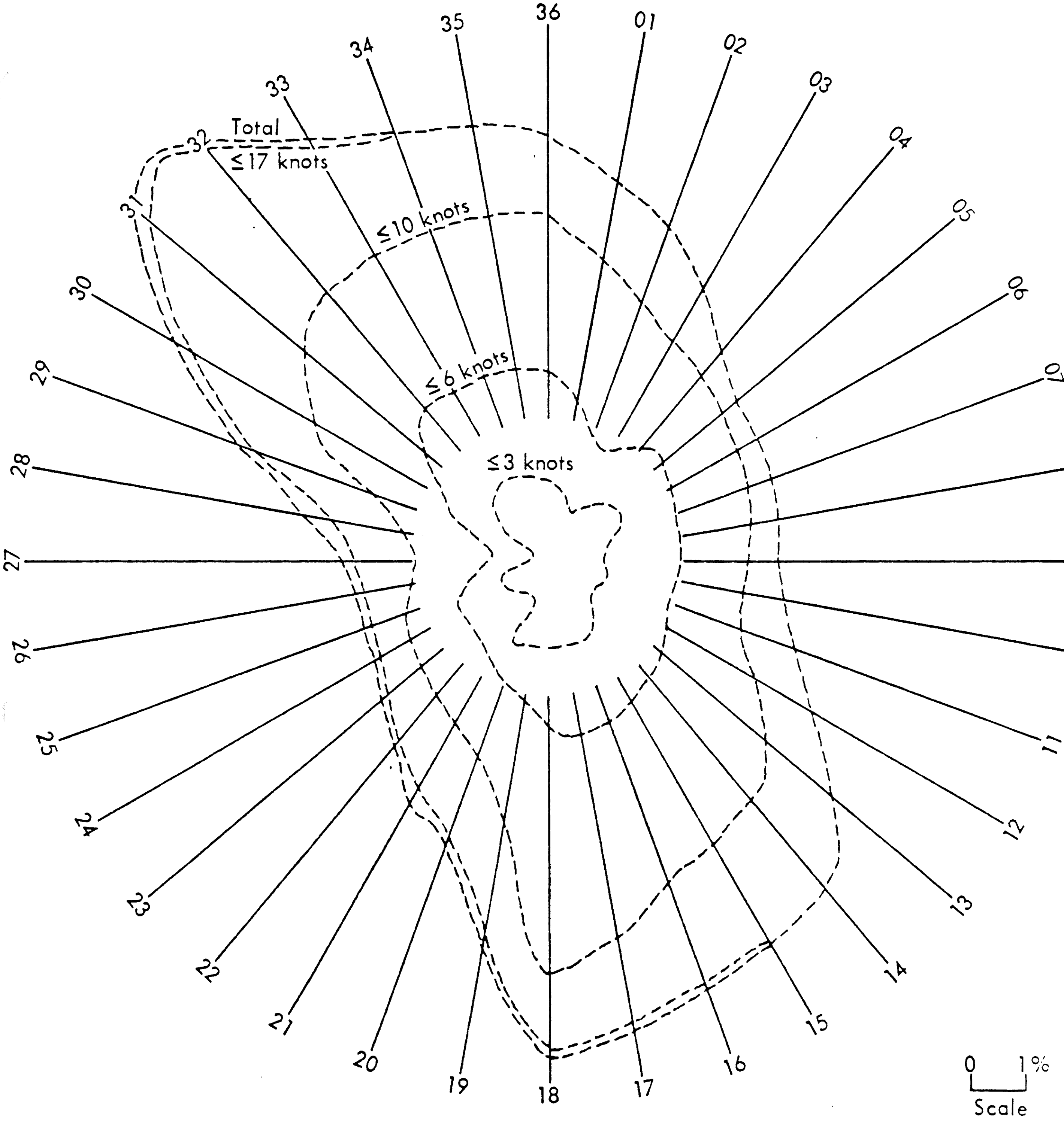
Hibbing Cumulative Wind Rose - - 1971

Figure 2-4



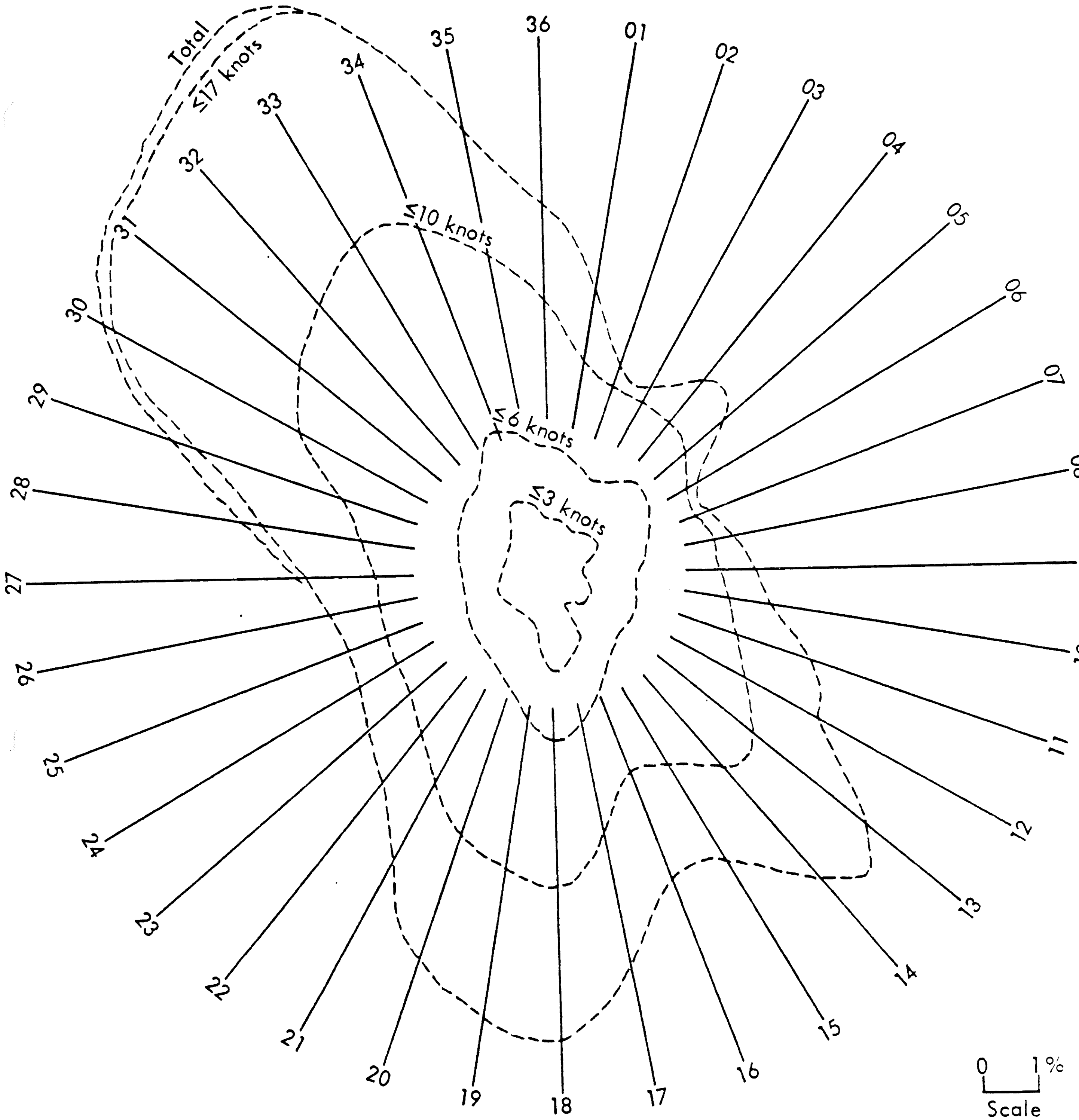
Hibbing Cumulative Wind Rose -- 1972

Figure 2-5



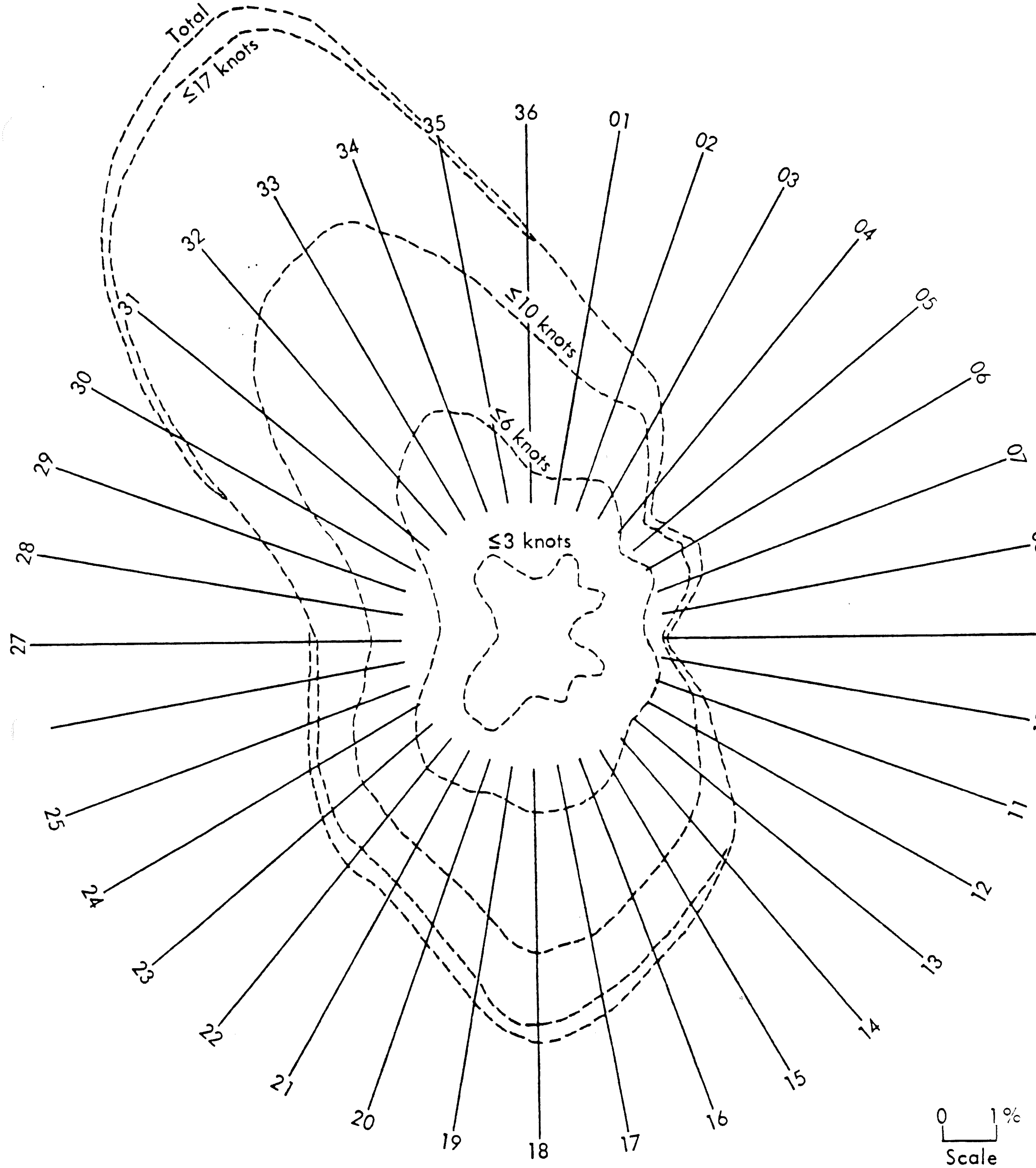
Hibbing Cumulative Wind Rose - - 1973

Figure 2-6



Hibbing Cumulative Wind Rose - - 1974

Figure 2-7



Hibbing Cumulative Wind Rose - - 1976

Figure 2-8

In Figures 2-3 through 2-8, the distance from the center to a particular point indicates the percentage of the time the conditions represented by the point occur. Each of the irregular circles represents a wind speed range identical to those in Table 2-2. The roses were plotted from data using 16 points of the compass with "bias" removed by using a two-third scale for the north, south, east, and west categories, which include three 10-degree sectors instead of two such sectors for the other 12 points of the compass.

2.4 Temperature/Precipitation

Normal daily temperature extremes and means by month for Hibbing and International Falls are given in Table 2-3. On the average, the temperature is slightly warmer in Hibbing than it is in International Falls. The Hibbing data were used to represent the Iron Range.

Table 2-4 gives average annual Hibbing temperature and total Hibbing precipitation for the years represented in Figures 2-3 through 2-8.

Comparison of the warmest year (1973 at 39.6°F) with the coldest (1972 at 34.9°F) reveals more southwesterly winds and fewer north-northwesterlies, than would be expected--warmer air moves in from the southeast and cold air moves in from the northwest.

As indicated in Table 2-5, precipitation in the study region is well distributed throughout the year and is adequate for vegetation. The heaviest rainfall occurs during the warm summer months, from showers and thunderstorms. The area is also subject to heavy snowfall, with snow occurring most frequently between December and March. Snowcover usually remains until about April.

Comparison of the driest year, 1976, at 16.13 in. with the wettest year, 1974, at 32.92 in., shows more southwesterly winds and fewer southeasterlies in the drier years. Southwesterlies are associated with the flow of warm, dry air off the plain; southeasterlies are associated with the flow of moister air from the more humid eastern United States.

Three years had exactly the same mean annual temperature of 36.9°F--1971, 1974, and 1976. The wind roses for 1971 and 1974, both wet years, are similar. Because of a hot warm season and a cold January, the 1976 wind rose shows more southwesterly winds and more north-northwesterlies.

TABLE 2-3

MONTHLY TEMPERATURE DATA--HIBBING AND INTERNATIONAL FALLS

	Mean Daily Maximum (°F)		Mean Daily Minimum (°F)		Monthly Mean (°F)	
Month	Hibbing[a/]	International Falls (1941-1970)	Hibbing[a/]	International Falls (1941-1970)	Hibbing[a/]	International Falls (1941-1970
January	17.6	12.8	- 6.7	- 9.1	5.6	1.9
February	20.8	19.4	0.0	- 5.5	10.4	7.0
March	32.0	32.3	13.6	8.9	22.8	20.6
April	52.0	49.1	30.4	27.3	41.2	38.2
May	63.0	62.5	40.0	37.7	51.5	50.1
June	72.8	72.4	51.8	48.3	62.3	60.4
July	77.4	78.2	56.0	53.4	66.7	65.8
August	76.0	75.5	54.9	50.9	65.5	63.2
September	64.0	64.2	42.6	41.7	53.3	53.0
October	54.4	54.0	32.8	32.9	43.6	43.5
November	36.3	32.5	16.5	17.3	26.4	24.9
December	23.2	18.1	4.2	- 0.8	13.7	8.7
Annual	49.1	47.6	28.0	25.3	38.6	36.5

Source: Refs. 4 and 5.

a/ Long-term averages compiled from data by Bruce Watson.

TABLE 2-4

ANNUAL TEMPERATURE AND PRECIPITATION DATA--
HIBBING, MINNESOTA

Year	Temperature (°F)	Precipitation (in.)
1970	36.7	19.28
1971	36.9	29.74
1972	34.9	22.03
1973	39.6	27.01
1974	36.9	32.92
1976	36.9	16.13

TABLE 2-5

MONTHLY PRECIPITATION DATA--HIBBING AND INTERNATIONAL FALLS

Month	Measurable Precipitation (Days)	Mean Precipitation (Equivalent in. of Water)		Mean Snowfall (in.)	
	International Falls (1940-1974)	Hibbing[a/]	International Falls (1941-1970)	Hibbing[a/]	International Falls (1940-1974)
January	12	0.67	0.85	9.6	10.4
February	9	0.58	0.71	8.2	8.4
March	10	1.17	1.10	8.2	9.3
April	10	1.90	1.67	3.9	6.6
May	12	3.08	2.75	0.4	1.0
June	12	3,83	3.91	0.0	0.0
July	11	3.67	3.98	0.0	0.0
August	12	3.62	3.39	0.0	0.0
September	12	3.33	3.32	0.0	0.1
October	9	1.80	1.69	1.6	1.3
November	11	1.29	1.30	6.6	10.5
December	12	0.68	0.98	8.6	10.6
Annual	133	25.62	25.65	47.1	58.2

Source: References 5 and 6.

a/ Long-term greater than 50-year averages compiled from data by Bruce Watson.

2.5 Atmospheric Stability and Mixing

The air pollution potential of the study area is directly related to the capacity of the atmosphere to transport and disperse pollutants. The primary meteorological parameters which determine this capacity are wind speed and atmospheric stability. Atmospheric stability near ground level is affected by surface roughness and solar heating. The optimum condition for dispersion of emissions from a ground level source consists of a high degree of ventilation combined with a relatively unstable atmosphere. Conversely, atmospheric mixing is minimal in the presence of a ground-based temperature inversion.

Stability classes are necessarily very much related to wind speed since atmospheric motion strongly affects atmospheric structure. In the Pasquill-Turner model, slight departures from reality do exist, for example, in that E stability is never permitted at wind speeds above 10 knots and, as another example, no provision is made for the presence of snowcover. However, the model-calculated classes appear to reflect actual stability quite well at Hibbing.

Analysis of wind rose plots for stability regression in January and June was performed by Bruce Watson.[2/] As would be expected, higher velocity dominates the D stability roses, low wind speeds dominate the EFG rose. In January, C stability is associated with winds under 10 knots, while in July a fair amount of cases have higher velocities. Although the model does not "permit" C stability to occur with higher wind velocities at January's low sun angles, C stability is surely a rarity during the snowcovered winter. Thus, the rarity of this category in January as compared to July is not surprising.

Throughout the year, A stability is negligible at Hibbing, and the frequency of B stability is low. In a location that is so far north, where the air remains in motion so much of the time, very unstable air has difficulty sustaining itself for very long.

Directional preferences do exist at Hibbing. In January, EFG stabilities have an affinity for southwesterlies that the D categories do not. Much of this is likely due to the phenomenon of light night winds that favor southwesterly to westerly directions at night over Minnesota as a whole. D-day is quite similar to D-night.

In July, the relationships are much the same, with D-day and D-night being roughly similar and EFG being strongly dominated by light night winds from the southwest quadrant. (The comparative sizes of D-day/D-night are different because the nighttime is twice as long as the daytime in the winter, and daytime is twice as long as night in the summer.) More southwesterlies occur with the July D categories than with the winter D categories due to the generally greater incidence of these winds in the summer.

The annual frequency distributions of stability classes for International Falls are given in Table 2-6.[3] Neutral stability, the most mon class, occurs under cloudy conditions. Surface-based temperature inversions are very common during nighttime hours in the study region, occurring 50 to 60% of the time.

Typically, during afternoon hours and otherwise in the absence of a low-level temperature inversion, vertical mixing in the atmosphere is confined to a ground-based "mixing layer." Limited mixing, i.e., the persistence of shallow mixing layers, occurs with the passage of anticyclones through the region.

Table 2-7 shows the distributions of mean morning and afternoon mixing height for the reporting meteorological station at International Falls and St. Cloud, Minnesota.[7] The associated mean wind speeds averaged through the mixing layers are also given in the table. In the absence of Hibbing data for daily mixing depth, data for International Falls (the closest station) were used.

2.6 Worst-Case Meteorological Conditions

Once meteorological data had been gathered and analyzed, an assessment of worst-case climatic conditions was made for the period 1970 to 1974. Since the necessary data had already been compiled for calibration/validation poses, 1976 was also included in the analysis.

Precipitation (measured at the Hibbing Airport) was used as the main indicator because it acts as an important natural control for fugitive dust emissions. As shown in Table 2-4, the driest year during the 6 years was 1976, with 16.13 in. (water equivalent) recorded. This value was 9.49 in. below the long-term Hibbing average. The next driest year was 1970, with 19.28 in. recorded.

Another factor which influenced the choice of the worst-case year was the frequency of occurrence of E-type stability. Again, 1976 was highest of the years considered at 0.3100, to an average of 0.2683.

Based on these considerations, 1976 was chosen as the worst-case baseline year for projecting air quality to 1982.

TABLE 2-6

ANNUAL STABILITY CLASS OCCURRENCES--INTERNATIONAL FALLS

Stability Class	Frequency of Time Stability Class Occurs — Year: 1970	1971	1972	1973	1974	Average 1970-1974	1976
A	0.0049	0.0044	0.0051	0.0042	0.0037	0.0045	0.0042
B	0.0283	0.0307	0.0374	0.0238	0.0119	0.0264	0.0423
C	0.0824	0.0867	0.0909	0.0710	0.0557	0.0828	0.1004
D-Day	0.3136	0.2942	0.2679	0.3514	0.4315	0.3317	0.2840
D-Night	0.2656	0.2849	0.2709	0.3197	0.3179	0.2918	0.2591
E	0.3052	0.2991	0.3277	0.2299	0.1794	0.2683	0.3100

TABLE 2-7

MEAN SEASONAL AND ANNUAL MORNING AND AFTERNOON MIXING HEIGHTS AND WIND SPEEDS

	Time Period	International Falls, Minnesota All	NOP	% NOP	St. Cloud, Minnesota All	NOP	% NOP
Mean Morning Mixing Height (meters)	Winter	347	251	54.0	393	338	74.8
	Spring	411	319	66.3	469	404	77.6
	Summer	337	266	75.2	351	328	89.4
	Autumn	513	406	70.6	429	389	87.0
	Annual	402	310	66.4	411	364	82.2
Mean Afternoon Mixing Height (meters)	Winter	656	584	52.7	607	537	59.7
	Spring	1,646	1,540	68.3	1,432	1,344	75.7
	Summer	1,747	1,688	78.9	1,646	1,595	82.8
	Autumn	1,146	1,054	69.9	1,006	952	80.7
	Annual	1,299	1,216	67.4	1,173	1,107	74.7
Mean Morning Wind Speed (m/sec)	Winter	5.6	4.3	54.0	6.1	5.4	74.8
	Spring	5.6	4.6	66.3	6.3	5.6	77.6
	Summer	4.1	3.3	75.2	4.2	3.9	89.4
	Autumn	6.0	5.1	70.6	5.5	5.1	87.0
	Annual	5.3	4.3	66.5	5.5	5.0	82.2
Mean Afternoon Wind Speed (m/sec)	Winter	7.0	6.3	52.7	7.3	6.6	59.7
	Spring	7.5	7.1	68.3	8.0	7.7	75.7
	Summer	6.9	6.6	78.9	6.9	6.6	82.8
	Autumn	7.4	7.0	69.9	7.7	7.4	80.7
	Annual	7.2	6.8	67.4	7.5	7.1	74.7

NOP = Nonprecipitation.
Source: Ref. 7.

3.0 EXISTING AIR QUALITY

This section describes the existing ambient air quality in the vicinity of the 31-township study area. The discussion focuses on the pollutants which reflect the atmospheric impact from the existing and projected sources in the area.

The two pollutants considered in this study were TSP and SO_2. State of Minnesota and National Ambient Air Quality Standards (NAAQS) are given in Table 3-1. The standards for TSP and SO_2 cover averaging times of 3 hr to 1 year. Primary standards are designed to protect the public health, whereas secondary standards are designed to protect the public welfare from air pollution effects on vegetation and other materials.

The following subsections present: (a) the ambient air quality monitoring stations and (b) a description of the existing air quality for each pollutant (TSP and SO_2).

3.1 Ambient Air Quality Monitoring Network

State-operated ambient air quality stations within the 31-township study region and the surrounding area are listed in Table 3-2. A summary of the characteristics of each station in the area network is presented, including: (a) the MPCA site number; (b) the universal transverse mercator (UTM) coordinates; (c) type of area monitored; and (d) elevation of the sampling intake above grade, in feet. The station addresses for these sites are given in Table 3-3, and Figure 3-1 shows the locations of the stations. For all stations, observations were made over 24-hr periods (midnight to midnight) and measurements taken approximately every 6th day.

In addition, data were compiled on private/industrial air quality stations within the study area. These station characteristics are summarized in Table 3-4.

3.2 Measured Ambient Air Quality

The following subsections present details on available air quality monitoring data for TSP and SO_2, respectively.

TABLE 3-1

NATIONAL AND STATE OF MINNESOTA AMBIENT AIR QUALITY STANDARDS FOR TSP AND SO_2

Criteria Pollutant	Averaging Time	Standard Type	Allowable Excursion Frequency	Allowable Limit
TSP	1 year	Primary	(geometric mean)	75 $\mu g/m^3$
	1 year	Secondary	(geometric mean)	60 $\mu g/m^3$
	24 hr	Primary	1/year	260 $\mu g/m^3$
	24 hr	Secondary	1/year	150 $\mu g/m^3$
SO_2	1 year	Primary	(arithmetic mean)	80 $\mu g/m^3$ (0.03 ppm)[a] 52 $\mu g/m^3$ (0.02 ppm)[b]
	24 hr	Primary	1/year	365 $\mu g/m^3$ (0.14 ppm)[a] 260 $\mu g/m^3$ (0.10 ppm)[b]
	3 hr	Secondary	1/year	1,300 $\mu g/m^3$ (0.5 ppm)[a] 650 $\mu g/m^3$ (0.25 ppm)[b]

a/ National standard.
b/ State of Minnesota standard.

TABLE 3-2

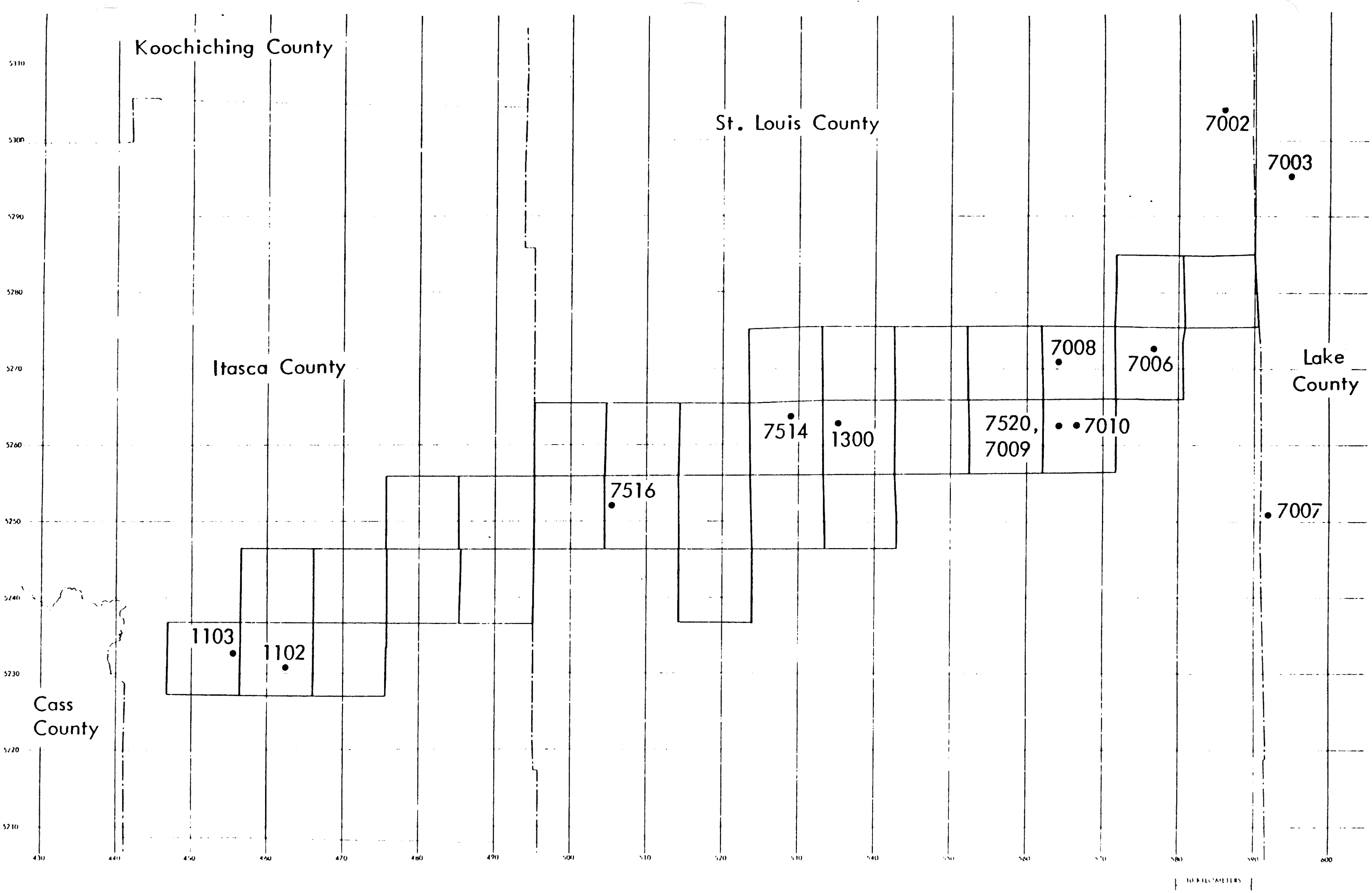
MPCA AIR QUALITY MONITORING STATION CHARACTERISTICS

MPCA Site No.	UTM Coordinates (km) Easting	UTM Coordinates (km) Northing	Station Type	Sampling Elevation (ft)	Dates Measured
7002	586	5305	Center city-residential	46	1976-1977
7008	564	5271	Rural-industrial	23	1976-1977
1102	462	5231	Rural-near urban	15	1973-1976
7516	506	5253	Suburban-residential	27	1973-1977
7010	567	5263	Rural	10	1976-1977
7520	564	5263	Suburban-residential	3	1973-1976
7514	529	5264	Center city-commercial	15	1974-1977
1300	535	5263	Center city-residential	60	1973-1977
7009	564	5263	Center city-residential	17	1977
1103	456	5233	Rural	15	1977
7003	595	5296	Rural	14	1976-1977
7006	577	5273	Rural	10	1976-1977
7007	592	5251	Rural	10	1976-1977

TABLE 3

MPCA AIR QUALITY MONITORING STATIONS

MPCA Site No.	SAROAD Site Code	AQCR	County	City	Address	Support Agency
7002	241100002F01	129	St. Louis	Ely	Ely High School	PCA
7008	243260010F01	129	St. Louis	Rural	Erie Mining Office Building	PCA
1102	241400003F01	129	Itaska	Grand Rapids	Itaska Junior College	PCA
7516	241500001G01	129	St. Louis	Hibbing	County Courthouse	DUL
7010	241560005F01	129	St. Louis	Hoyt Lakes	Pump House 1, Golf Course	PCA
7520	241560001G01	129	St. Louis	Hoyt Lakes	Village Hall	DUL
7514	243260001G01	129	St. Louis	Mountain Iron	Post Office	DUL
1300	243860001G01	129	St. Louis	Virginia	City Hall	DUL
7009	241560004F01	129	St. Louis	Hoyt Lakes	Police Station	PCA
1103	241660003F01	129	Itaska	Rural	Pokegama Dam	PCA
7003	241840002F01	129	Lake	Rural	Hwy. 1 and Kawishiwi River	PCA
7006	243260009F01	129	St. Louis	Rural	1,000 ft south of Dunka Road and Milepost 9	PCA
7007	241840004F01	129	Lake	Rural	7 miles west of Hwy. 2 on County Road 16	PCA



Locations of MPCA Air Quality Monitoring Stations

Figure 3-1

TABLE 3-4

INDUSTRIAL AIR QUALITY MONITORING STATIONS

MPCA Site No.	UTM Coordinates[a/] Easting	UTM Coordinates[a/] Northing	AQCR	County	Dates	Address	Support Agency
1	532.4	5255.6	129	St. Louis	1975-1977	Southwest of Eveleth	Eveleth
2	535.1	5256.2	129	St. Louis	1975-1977	Eveleth	Eveleth
3	531.6	5252.2	129	St. Louis	1975-1977	South of tailings pond	Eveleth
4	535.9	5353.1	129	St. Louis	1975-1977	South of Eveleth	Eveleth
5	531.0	5246.5	129	St. Louis	1975-1977	7-1/2 miles south of Eveleth	Eveleth
6	535.3	5246.7	129	St. Louis	1975-1977	6 miles south of Eveleth	Eveleth
7	531.5	5243.5	129	St. Louis	1975-1977	8 miles southwest of Eveleth	Eveleth
8	537.3	5240.2	129	St. Louis	1975-1977	11 miles south of Eveleth	Eveleth
13	509	5259	129	St. Louis	1975-1977	Chisholm	Hibbing Taconite
18	505	5251	129	St. Louis	1975-1977	Hibbing	Hibbing Taconite
21	541.2	5273.0	129	St. Louis	1976-1977	South of plant	Inland Steel
22	535.0	5273.5	129	St. Louis	1976-1977	Four Seasons Resort	Inland Steel
23	535.5	5265.8	129	St. Louis	1976-1977	General office building	Inland Steel
24	534.0	5266.0	129	St. Louis	1976-1977	Wouri Creek	Inland Steel
25	536.5	5261.8	129	St. Louis	1976-1977	Higgins mine building	Inland Steel
31	487	5246	129	Itaska	1975-1977	Nashwauk site (Butler Taconite)	Hanna Mining
32	486	5242	129	Itaska	1975-1977	Swan Lake site (Butler Taconite)	Hanna Mining
34	497	5249	129	Itaska	1975-1977	Hwy. 169 (National Steel Pellet)	Hanna Mining
35	494	5249	129	Itaska	1975-1977	Carlz (National Steel Pellet)	Hanna Mining

a/ Coordinate values from MPCA.

3.2.1 TSP: Annual geometric mean concentrations of TSP for 1975 :ough 1977 are presented in Tables 3-5 and 3-6 for the state-operated and private/industrial-operated stations, respectively. Station Nos. 1300 and 25 indicated annual geometric mean concentrations that exceeded the secondary NAAQS of 60 $\mu g/m^3$ for 1976. In most cases the 1976 annual geometric mean concentrations exceeded the concentrations for 1975 and 1977. One explanation for this is the significant reduction in rainfall for 1976 (in particular, during the summer months).

Tables 3-7 and 3-8 present maximum and second-maximum 24-hr concentrations for the state-operated and private/industrial-operated stations, respectively. As indicated, the secondary 24-hr TSP was exceeded at MPCA Station Nos. 7516, 7514, 1300, 7009, 7006, 1, 2, 3, 7, 24, 25, and 31. Many of these violations occurred during 1976. Similarly, the primary 24-hr TSP was exceeded at Station Nos. 2, 24, and 25.

3.2.2 SO_2: In 1976, SO_2 was not reported for stations within the immediate study area. The nearest air quality monitoring stations are located in Duluth and International Falls. Also, an SO_2 monitoring station was installed at Grand Rapids in April 1977. Limited data indicate that SO_2 is not an existing problem at any of these locations.

TABLE 3-5

MEASURED ANNUAL GEOMETRIC MEAN CONCENTRATIONS OF TOTAL SUSPENDED PARTICULATES (MPCA Stations)

MPCA Site No.	Annual Geometric Mean ($\mu g/m^3$) 1975	1976[a/]	1977
7002		24.3 (1.4)	21.2 (1.8)
7008		34.6 (2.0)	17.3 (2.4)
1102	21.2 (1.6)	19.5 (1.4)	
7516	36.6 (1.8)	46.1 (1.8)	36.3 (1.9)
7010		27.7 (2.0)	15.4 (1.9)
7520	36.6 (1.8)	37.8 (1.7)	
7514	47.2 (1.8)	53.0 (1.7)	43.6 (2.0)
1300	45.2 (1.8)	61.9 (1.9)	53.9 (2.3)
7009		-	28.9 (2.3)
1103		-	24.4 (1.6)
7003		15.5 (3.2)	10.0 (2.0)
7006		26.4 (1.6)	20.3 (2.6)
7007		9.5 (1.3)	10.8 (2.0)

a/ Values in parentheses indicate standard geometric deviation.

TABLE 3-6

MEASURED ANNUAL GEOMETRIC MEAN CONCENTRATIONS OF TOTAL SUSPENDED PARTICULATES (Industrial Stations)

MPCA	Annual Geometric Mean ($\mu g/m^3$)[a]			
Site No.	1975	1976	1977	Average
1	26	33	29	29
2	29	60	40	43
3	25	34	27	29
4	28	38	26	31
5	27	32	22	27
6	19	27	21	22
7	19	26	20	22
8	17	25	20	21
13	21	24	17	21
18	38	41	29	36
21		42	32	36
22		33	24	27
23		49	39	44
24		53	34	37
25		65[b]	27	45
31	23	28	19	22
32	19	30	18	20
34	30	38	24	27
35	24	26	20	23

a/ Values from personal communication from MPCA, March 15, 1978.
b/ Exceeds secondary TSP standard.

TABLE 3-7

MEASURED 24-HR CONCENTRATIONS OF TSP (MPCA Stations)

MPCA Site No.	Maximum (second-maximum) Observation ($\mu g/m^3$) 1975		1976		1977		Ratio of Valid Values Exceeding National Standard/Total Valid Values 1976 Sec[a]	1976 Pri[b]	1977 Sec[a]	1977 Pri[b]
7002			44	(43)	84	(73)	0/10	0/10	0/54	0/54
7008			84	(67)	95	(89)	0/13	0/13	0/46	0/46
1102	87	(68)	49	(37)			0/18	0/18		
7516	153	(74)	175	(153)	279	(125)	2/50	0/50	0/58	1/58
7010			109	(34)	69	(48)	0/14	0/14	0/57	0/57
7520	153	(111)	101	(89)			0/35	0/35		
7514	143	(135)	180	(136)	201	(179)	2/56	1/56	2/56	0/56
1300	205	(149)	367	(161)	310	(232)	2/50	1/50	8/57	1/57
7009					191	(178)			2/48	0/48
1103					98	(61)				
7003			150	(24)	61	(35)	0/14	0/14		
7006			48	(46)	243	(174)				
[illegible]7			11	(10)	57	(55)	0/3	0/3		

a/ Sec = Secondary standard; number of violations of secondary standard (excluding those exceeding primary standard).

b/ Pri = Primary standard.

TABLE 3-8

MEASURED 24-HR CONCENTRATIONS OF TSP
(Industrial Stations)

MPCA Site No.	Maximum (second-maximum) Observation ($\mu g/m^3$) 1975		1976		1977	
1	150	(81)	-	(155)	-	(101)
2	72	(68)	-	(302)	-	(190)
3	65	(58)	-	(209)	-	(109)
4	103	(98)	-	(149)	-	(136)
5	81	(77)	-	(132)	-	(121)
6	78	(77)	-	(121)	-	(104)
7	109	(55)	-	(113)	-	(176)
8	56	(43)	-	(131)	-	(87)
13	100	(60)	-	(141)	-	(82)
18	111	(104)	294	(113)	125	(119)
21			268	(150)	115	(114)
22			161	(148)	66	(63)
23			163	(142)	131	(103)
24			329	(295)	290	(186)
25			541	(349)	154	(152)
31	104	(89)	212	(175)	98	(67)
32	134	(72)	207	(113)	110	(86)
34	460	(132)	153	(140)	100	(95)
35	94	(90)	142	(134)	92	(85)

4.0 EMISSION INVENTORY METHODOLOGY

An emission inventory requires the compilation of a detailed data base consisting of specific information on each source including location (in this case, UTM coordinates) and emission rate (by pollutant, determined from source extent data and emission factors, or actual emissions data). In large part, the precise form of the data base is dependent on the atmospheric dispersion model used. For this study, an improved Climatological Dispersion Model (CDMQC) was used. The format for this model is described in Section 7.0.

Specifically, this study considered:

* Pollutants: TSP
SO_2

* Types of sources: Point
Area (conventional and fugitive)

* Resolution: Spatial (2 x 2 km basic grid)
Temporal (1976, 1982)

* Emission projections: Based on regional growth patterns

Two classes of sources were considered in this study: point sources and area sources. The methodology used in deriving the data base for each is described in the following subsections.

Point source emissions can be defined as emissions originating from a stack, duct, or flue (i.e., a confined flow stream). Data requirements for point sources include:

X,Y coordinates of emission source;

Emission rate for each pollutant, in grams per second;

Emission height, in meters;

Stack diameter, in meters;

Exit velocity, in meters per second; and

Stack temperature, in degrees Celsius.

For purposes of this study, area sources consist of either separate small emission sources (i.e., conventional area sources) or fugitive dust sources (including line sources of emissions such as unpaved roads). In all cases, these sources are impractical to consider as individual point or line sources. Area sources are generally coded for modeling in a network of square grid areas, and pollutant emissions are assumed to be uniformly distributed across each grid square.

The data input requirements for computer modeling consist of:

X,Y coordinates (southwest coordinates of square grid);

Width of grid square, in meters;

Emission rate for each pollutant, in grams per second; and

Emission height, in meters.

Emission rates can be determined from the equation:

$$ER = SE \times EF \times \left(1 - \frac{CE}{100}\right)$$

where ER = emission rate

SE = source extent

EF = emission factor

CE = percent control efficiency

4.1 Delineation of Study Area Grid System

The study focused on the 31 townships located on the map in Figure 1-1. The study also included point and area sources outside of the primary study area with the potential to affect the air quality attainment and maintenance status of the 31-township area. The secondary study area included (a) additional major point sources within 25 miles (40 km) of the 31-township study area and (b) public roads and population related area sources adjoining the study area. MPCA supplied MRI with computer listings of point source emissions data.

The primary study area was divided into 10 x 10 km (6 x 6 mile) grid squares based on the UTM coordinate system. This grid breakdown is given in Figure 1-1. These grids were further divided into 2 x 2 km (1.1 x 1.1 mile) grids to obtain better resolution. This size grid was selected based on the resolution of source extent data from available maps. For final modeling purposes, area source data were coded in such a way that the 2-km grids could be easily combined to make larger grids. In addition, point sources were located within the appropriate grids to the nearest tenth of a kilometer.

4.2 Review of MPCA Point Source Emission Inventory

Computer listings of 1976 point source data, one page per source, were obtained from MPCA for the Minnesota counties of Aitkin, Cass, Itasca, Koochiching, Lake, and St. Louis. These listings were in standard EPA format, requiring units conversion for many of the aforementioned data parameters.

The sources were reviewed and edited. Sources emitting TSP and SO_2 were coded separately. Data gaps were filled in based on comparison with similar sources, i.e., sources with the same source classification code.

4.3 Development of Area Source Emission Inventory

The major area sources in the Iron Range were identified using literature references and the initial results of MRI's taconite study for MPCA.[8/] As indicated in Table 4-1, major area emission sources were subdivided into three major categories: (a) surface mining activities; (b) public paved and unpaved roads; and (c) combustion sources.

4.3.1 Surface mining: All potentially significant sources of particulate emissions from mining operations were initially considered (see Table 4-2). A final listing of the major sources (Table 4-1) was formulated based on analysis for this study and the MRI taconite study.[8/] This listing is based on a ranking of emissions using source extent data and emission factors for Erie Mining Company and incorporating additional mining sources not found at Erie in order to best quantify emissions from the entire Iron Range study region.

Source extent data (see Appendix A) were obtained primarily on personal communication with knowledgeable mining company personnel. In addition, site surveys were conducted at Butler Taconite, National Steel, U.S. Steel-Minntac, Eveleth Taconite, Inland Steel, and Reserve Mining. Finally, source extent data for Erie Mining Company were obtained as part of the MRI taconite study.[8/]

TABLE 4-1

MAJOR AREA SOURCES AND ANNUAL SOURCE EXTENT UNITS

Source Category	Annual Source Extent Units
MINING	
1. Unpaved roads	Vehicle miles traveled
2. Paved roads	Vehicle miles traveled
3. Wind erosion of surface dumps	Acres
4. Wind erosion of waste and lean ore stockpiles	Acres
5. Wind erosion of pellet stockpiles	Short tons
6. Wind erosion of tailings beaches	Acres
7. Wind erosion of tailings slopes	Acres
8. Wind erosion of concentrate piles	Acres
9. Load-in of pellets into railcars from loading pockets, bins, or silos	Long tons
10. Pellet stacking (onto pile)	Long tons
11. Load-in of pellets into railcars with power shovel	Long tons
12. Load-in of crushed ore into piles	Long tons
13. Blasting (waste rock and ore)	Long tons
14. Wind erosion of crushed ore stockpiles	Short tons
PUBLIC ROADS	
15. Unpaved roads	Vehicle miles traveled
16. Paved roads	Vehicle miles traveled
COMBUSTION SOURCES	
17. Open burning	Short tons; population
18. Residential fuel oil	10^3 gal.; population
19. Residential natural gas	MCF;[a] population
20. Railroads	10^3 gal.; miles
21. Airports	LTO cycles[b]

a/ Million cubic feet.

b/ Landing and takeoff cycles.

TABLE 4-2

LIST OF POTENTIAL FUGITIVE PARTICULATE EMISSION SOURCES AT IRON ORE MINES

Source Type
Heavy duty traffic hauling surface material on unpaved roads
Heavy duty traffic hauling waste rock on unpaved roads
Heavy duty traffic hauling crude ore on unpaved roads
Light and medium duty traffic on unpaved roads
Light and medium duty traffic on paved roads
Load-in of surface material into dumps
Load-in of waste rock into dumps
Load-in of ore into trucks with power shovels
Load-in of ore into trucks with front-end loaders
Load-in of ore into railcars with power shovels
Load-in of ore into railcars with front-end loaders
Load-in of ore into railcars from loading pocket, bins, or silos
Load-out of ore from trucks
Load-out of ore from railcars
Wind erosion of surface dumps
Wind erosion of waste and lean ore dumps
Wind erosion of pellet stockpiles
Wind erosion of crushed ore stockpiles
Wind erosion of coal stockpiles
Wind erosion of tailings basin beaches
Wind erosion of tailings basin exterior slopes
Wind erosion of concentrate piles
Blasting
Drilling blast holes
Road grading
Load-in of coal into stockpiles
Load-in of pellets into railcars from loading pocket
Load-in of pellets into railcars with power shovels
Load-in of pellets into railcars with front-end loaders
Dozing ore
Dozing waste rock
Dozing surface
Dozing pellets
Crushing road material
Hauling road material
Dumping road material
Conveyor transfer stations
Stacking of pellets in pile
Loading of crushed ore into pile

Predictive emission factor equations developed by MRI under EPA contracts,[9-11] along with input from the MRI taconite study[8] and analysis of surface material samples obtained during MRI site surveys, formed the primary basis for the final uncontrolled emission factors used for fugitive dust sources (Table 4-3). The emission factor used for blasting was an average of values reported in the literature for various materials.

Emission factors derived from the equations in Table 4-3 were corrected to local conditions based on laboratory analysis of road, tailings, and exposed area material samples collected during site surveys (see Appendix A, Section 4). These results of silt and moisture analysis performed on 35 samples collected early in this study are presented in Table 4-4. Data collection forms, as developed for this effort, are provided in Appendix B.

Two general categories of control measures were considered: natural controls and anthropogenic controls. Natural controls include snowcover and precipitation in the form of rain and snow. Anthropogenic controls include road watering or chemical dust suppressant application, control equipment such as rotoclones and enclosures such as storage buildings around piles.

Control efficiencies for anthropogenic controls were estimated based on what little testing data there are. Climatic characteristics such as number of dry days, mean annual wind speed, percent of the time the wind exceeds 12 mph, and Thornthwaite's precipitation evaporation index were obtained from varied sources. A detailed discussion of control efficiency development is presented in Appendix A.

The area source extent values and the associated emission inventories for each mining company were most easily calculated on a company-wide basis due to the type of records routinely kept by mine operators. Once computed, the total emissions for each mining source category were apportioned over appropriate 2 x 2 km grids. The apportioning was accomplished using detailed maps supplied to MRI by the various mine owner/operators. Often these maps included specialized data, such as delineation of major haul roads, indications of traffic density, and outlines of proposed expansions.

Emissions from each mining source category were assigned to grids by relating them to easily recognized map features. For instance, blasting emissions (Category No. 13) were apportioned to 2 x 2 km grids based on the portion of each grid covered by active mining pits. Likewise, pellet-related emissions (Category Nos. 5, 9, 10, and 11) were generally assigned to the grid containing the agglomerator.

TABLE 4-3

MRI EXPERIMENTALLY DETERMINED EMISSION FACTORS FOR OPEN DUST SOURCES

Source Category	Measure of Extent	Emission Factor[a/] (lb/unit of source extent)	Reliability[b/]
1. Unpaved roads	Vehicle-miles traveled	$5.9 \left(\frac{s}{12}\right)\left(\frac{S}{30}\right)\left(\frac{W}{3}\right)^{0.8}$	A-B
2. Paved roads	Vehicle-miles traveled	$0.45 \left(\frac{4}{N}\right)\left(\frac{s}{10}\right)\left(\frac{L}{5,000}\right)\left(\frac{W}{3}\right)^{0.8}$	B-C
3. Continuous load-in to storage piles (e.g., stacker, transfer station)	Tons of material put through storage	$0.0018 \frac{\left(\frac{s}{5}\right)\left(\frac{U}{5}\right)}{\left(\frac{M}{2}\right)^{2}}$	B
4. Active storage pile maintenance and traffic	Tons of material put through storage	$0.10\ K \left(\frac{s}{1.5}\right)\left(\frac{d}{235}\right)$	C
5. Active storage pile wind erosion	Tons of material put through storage	$0.05 \left(\frac{s}{1.5}\right)\left(\frac{d}{235}\right)\left(\frac{f}{15}\right)\left(\frac{D}{90}\right)$	C
6. Inactive storage pile wind erosion	Acres of storage per year	$1,280 \left(\frac{s}{1.5}\right)\left(\frac{d}{235}\right)\left(\frac{f}{15}\right)$	C
7. Batch load-out from storage piles (e.g., front-end loader to truck)	Tons of material put through storage	$0.0018 \frac{\left(\frac{s}{5}\right)\left(\frac{U}{5}\right)}{\left(\frac{M}{2}\right)^{2}\left(\frac{Y}{6}\right)}$	B
8. Wind erosion of exposed areas	Acre-years of exposed land	$3,400 \frac{\left(\frac{e}{50}\right)\left(\frac{s}{15}\right)\left(\frac{f}{25}\right)}{\left(\frac{P-E}{50}\right)^{2}}$	C

Correction Parameters

- s = Silt content of road surface material, aggregate, or eroding surface (%)
- S = Average vehicle speed (mph)
- W = Average vehicle weight (short tons)
- L = Surface dust loading on traveled portion of road (lb/mile)
- U = Mean wind speed (mph)
- M = Unbound moisture content of aggregate (%)
- Y = Dumping device capacity (cu yd)
- K = Activity factor (= 1 for operation with truck traffic intensity of 50 trips/day)
- d = Number of dry days per year
- f = Percentage of time wind speed exceeds 12 mph
- D = Duration of material in storage (days)
- e = Surface erodibility (short tons/acre/year)
- P-E = Thornthwaite's precipitation-evaporation index
- N = Number of traveled lanes

a/ Emission factors for dust particles smaller than 30 μm in diameter based on particle density of 2.5 g/cm^3.

b/ A = Excellent; numerous field measurements.
B = Above average; limited number of field measurements.
C = Average; limited data and/or published emission factors where the accuracy is not stated.
D = Below average; engineering estimates made by knowledgeable personnel.
E = Poor; estimated value; assumptions not given.

TABLE 4-4

RESULTS OF SILT/MOISTURE ANALYSES OF SITE SURVEY SAMPLES

Mining company	Date of Sample	MRI Sample No.	Sample Type	% Silt	% Moisture
National Steel	4/25/78	1	Tailings (1)	33.3	18.0
	4/25/78	2	Tailings (2)	25.7	13.8
	4/25/78	3	Tailings (3)	13.8	4.0
	4/25/78	4	Tailings (4)	11.5	1.4
	4/25/78	5	Tailings (5)	11.7	1.4
	4/25/78	6	Main haul road	15.4	0.6
	4/25/78	27	Concentrator pile	81.0	7.3
	4/25/78	30	Pellets	2.3	<0.5
	4/25/78	31	Overburden	10.5	3.8
Butler Taconite	4/25/78	7	Tailings (1)	43.2	8.4
	4/25/78	8	Tailings (2)	28.8	<1
	4/25/78	9	Tailings (3)	47.7	3.6
	4/25/78	10	Tailings (4)	10.4	<1
	4/25/78	11	Tailings (5)	5.8	<1
	4/25/78	20	Main haul road	13.7	1.8
	4/25/78	23	Concentrator pile	85.1	6.1
	4/25/78	29	Pellets	5.1	<0.5
	4/25/78	25	Overburden (1)	11.8	3.8
	4/25/78	33	Overburden (2)	12.2	10.2
U.S. Steel-Minntac	4/26/78	13	Tailings (fine)	21.1	0.5
	4/26/78	14	Tailings (fine)	23.2	0.9
	4/26/78	15	Tailings (fine)	29.9	2.9
	4/26/78	16	Tailings (fine)	10.3	1.0
	4/26/78	17	Tailings (fine)	12.8	0.7
	4/26/78	18	Tailings (fine)	24.4	2.8
	4/26/78	19	Tailings (fine)	44.7	7.2
	4/26/78	32	Tailings (coarse)	2.5	1.2
	4/26/78	24	Unpaved roads	7.8	0.3
	4/26/78	34	Unpaved road	3.7	1.8
	4/26/78	35	Unpaved road	3.0	2.1
	4/26/78	12	Concentrator pile	80.2	3.1
	4/26/78	28	Pellets	3.9	<0.5
	4/26/78	26	Overburden	9.1	3.6
Other	4/25/78	21	Unpaved road - Site 1	6.5	0.7
	4/25/78	22	Unpaved road - Site 2	4.8	0.5

Table 4-5 shows the apportioning methodology developed for each of the mining source emissions categories. These apportioning techniques were used whenever the data received from the mine operators and the MPCA were sufficiently detailed. When the data compiled for a mine were inadequate, modifications were made to the preferred apportioning technique. In this way, the most accurate possible delineation of emissions was determined.

4.3.2 Public roads: Source extent data for paved and unpaved public roads consists of annual vehicle miles traveled (VMT). These data were derived using 2 x 2 km grid overlays over Minnesota Department of Transportation maps for those portions of Itasca and St. Louis counties surrounding the 31-township study region. The specific maps studied were:

1975 traffic map, St. Louis County, sheets 3 and 4;

1971 traffic map, Itasca County, sheet 1;

1977 general highway maps, St. Louis County, sheets 1 through 7; and

1977 general highway maps, Itasca County, sheets 1 through 3.

The traffic maps provided average daily traffic (ADT) on most roads. Annual VMT was calculated as follows:

365 x ADT x length of road segment within a particular grid square.

Emission factors were corrected to local conditions based on silt and moisture analysis of road surface samples collected by MRI at sites judged from site surveys to be representative of the area. Silt and moisture analyses were performed on unpaved road samples collected by MRI early in the study. These results are listed as "other" in Table 4-4. Data collection forms developed for the effort are provided in Appendix B.

Iron Range wide unpaved and paved road emission factors were developed using the predictive equations in Table 4-3. To calculate the unpaved road emission factor, a value of 6% was used for surface silt content, 30 mph for average vehicle speed, and 3 tons for average vehicle weight. An emission factor of 2.95 lb/VMT was derived.

Separate emission factors were developed for highway and nonhighway paved roads. This was done because of the considerable difference in surface dust loadings between the two types of roadways. An ADT of 2,500 was used for the cutoff value, greater than 2,500 representing paved highways and less than 2,500 representing typical residential paved streets.

TABLE 4-5

AREA SOURCE EMISSIONS APPORTIONING METHODOLOGY

Source Category Identification	Source Category Description	Apportioned
Mining	1. Unpaved roads	By miles of primary unpaved haul and auxiliary roads in each grid
	2. Paved roads	By miles of primary paved roads in each grid
	3. Wind erosion of surface dumps	By portion of each grid covered by storage areas
	4. Wind erosion of waste and lean ore stockpiles	By portion of each grid covered by storage areas
	5. Wind erosion of pellet stockpiles	To grids containing labeled pellet piles or to grids containing agglomerators
	6. Wind erosion of tailings beaches	By portion of each grid covered by tailings
	7. Wind erosion of tailings slopes	By portion of each grid covered by tailings
	8. Wind erosion of concentrate piles	To grids containing labeled concentrate piles or to grids containing concentrators
	9. Load-in of pellets into railcars from loading pocket	To grids containing labeled pellet piles or to grids containing agglomerators
	10. Pellet stacking (onto pile)	To grids containing labeled pellet piles or to grids containing agglomerators
	11. Load-in of pellets into railcars with power shovel	To grids containing labeled pellet piles or to grids containing agglomerators
	12. Load-in of crushed ore into piles	To grids containing labeled crushed ore piles or to grids containing crushers
	13. Blasting	By portion of each grid covered by active pit workings
	14. Wind erosion of crushed ore stockpiles	To grids containing labeled crushed ore piles or to grids containing crushers
Public roads	15. Unpaved roads	Directly to each grid by vehicle miles traveled
	16. Paved roads	Directly to each grid by vehicle miles traveled
Combustion sources	17. Open burning	By population in each grid
	18. Residential fuel oil	By population in each grid
	19. Residential natural gas	By population in each grid
	20. Railroads	By miles of railroad in each grid
	21. Airports	By LTO's in each grid

Correction parameters used in the highway emission factor equation included four lanes for road width, 10% for surface silt content, 90 lb/mile for surface dust loading, and 3 tons for vehicle weight. A public paved highway emission factor of 0.008 lb/VMT was thus developed.

Correction parameters were identical in the residential paved road equation, with the exception of surface dust loading, set at 170 lb/mile. The emission factor for public paved residential streets was 0.015 lb/VMT.

4.3.3 Combustion sources: Combustion sources considered in this study were open burning, residential/commercial fuel oil usage, residential/commercial natural gas usage, railroads, and aircraft. The emission factor for open burning is 16 lb/ton.[12/]

The emission factor is for open burning on nonagricultural material. In order to apportion emissions, the emission factor is desirable in units of pounds per person per day. Assuming 5 lb is burned per person per day, the emission factor is equivalent to 0.04 lb/person per day.

Development of residential/commercial fuel oil usage emission factors was more difficult. The basic emission factors are straightforward, 2.5 lb/1,000 gal. for residential use and 2.0 lb/1,000 gal. for industrial/commercial use.[12/]

However, in order to spatially apportion emissions, it was necessary to determine the emission factors in units of pounds per person per year.

For Itasca County, fuel oil consumption in 1973 was 22,778,000 gal.[13/] The population for the county, projected to 1976, is 40,800.[14/]

Thus:

$$EF_{AI} = \frac{(8,551 \times 10^3 \text{ gal/year})\ (2.5 \text{ lb/1,000 gal.})}{(40,800 \text{ persons})} = 0.524 \text{ lb/person/year}$$

$$EF_{BI} = \frac{(14,227 \times 10^3 \text{ gal/year})\ (2.0 \text{ lb/1,000 gal.})}{(40,800 \text{ persons})} = 0.697 \text{ lb/person/year}$$

Total 1.221

For St. Louis County, fuel oil consumption in 1973 was 144,146,000 gal.[13] The population for the county, projected to 1976, is 219,400.[14]

Thus:

$$EF_{AS} = \frac{(46,327 \times 10^3 \text{ gal/year})\ (2.5 \text{ lb/1,000 gal.})}{(219,400 \text{ persons})} = 0.528 \text{ lb/person/year}$$

$$EF_{BS} = \frac{(87,819 \times 10^3 \text{ gal/year})\ (2.0 \text{ lb/1,000 gal.})}{(219,400 \text{ persons})} = 0.892 \text{ lb/person/year}$$

Total 1.420

Residential/commercial natural gas emission factors were calculated as shown below. The basic emission factor is 10 lb/10^6 cu ft.[12]

For Itasca County, natural gas consumption for 1976 was 3,364 x 10^6 cu ft.[13] Thus, the emission factor can be calculated similar to the procedure described above for fuel oil.

$$EF_{I} = \frac{(3,364 \times 10^6 \text{ cu ft/year})\ (10 \text{ lb}/10^6 \text{ cu ft})}{(40,800 \text{ persons})} = 0.825 \text{ lb/person/year}$$

For St. Louis County, natural gas consumption for 1976 was 9,057 x 10^6 cu ft.[13] Thus:

$$EF_{S} = \frac{(9,057 \times 10^6 \text{ cu ft/year})\ (10 \text{ lb}/10^6 \text{ cu ft})}{(219,400 \text{ persons})} = 0.413 \text{ lb/person/year}$$

As shown above, the sources of open burning, fuel oil, and natural gas usage have evaluated in units of pounds of pollutant emitted per person per year. Thus, the source extent for these sources is the grid population. Grid population was determined for each 2 x 2 km grid using: (a) 1970 township populations;[15] (b) 1970 city populations;[16] (c) 1970, 1976, 1982, and 1990 county population estimates;[14] and (d) United States Geological Survey (USGS) maps.

Railroad source extent was determined for each 2 x 2 km grid using overlays to USGS maps. Data were compiled on miles of railroad in each grid for each of the following five railroads indicated on the USGS maps: Burlington Northern; Duluth, Missabe, and Iron Range; Duluth, Winnipeg and Pacific; Erie Mining Company; and Reserve Mining Company. Calculation of a railroad emission factor was based on the U.S. EPA emission factor of 25 lb/10^3 gal. (diesel fuel).[12]

In order to spatially apportion emission, the emission factor was needed in units of pounds per railroad miles per day.

From contact with the Duluth-Missabe-Iron Range Railroad Company, the following emission factor was developed:

$$EF = 25\ \text{lb}/10^3\ \text{gal.} \times \frac{2.08\ \text{gal.}}{1{,}000\ \text{gross ton-miles}}$$

$$\times \frac{1{,}875{,}000{,}000\ \text{gross ton-miles (in 1976)}}{\text{year}}$$

$$\times \frac{1}{\begin{array}{c}\text{150 miles track}\\ \text{(within region)}\end{array}} \times \frac{1\ \text{year}}{365\ \text{days}}$$

$$= 1.8\ \text{lb/mile/day.}$$

Finally, aircraft source extent data for each airplane type (as designated in EPA Publication No. AP-42) were obtained from personal communication with representatives of the respective airports. Aircraft emission factors were determined for each airport based on the distribution of aircraft types using the facilities. Table 4-6 shows the aircraft categories and standard emission factors used in the determinations, while Table 4-7 presents the final emission factors developed for each airport.

TABLE 4-6

STANDARD AIRCRAFT EMISSION FACTORS[12]

Aircraft Type	Emission Factor (lb/engine/LTO)
Jumbo jet	1.30
Long range jet	1.21
Medium range jet	0.41
Air carrier turboprop	1.1
Business jet	0.11
General aviation turboprop	0.20
General aviation piston	0.02
Piston transport	0.56
Helicopter	0.25
Military transport	1.1
Military jet	0.31
Military piston	0.28

a/ LTO = Land-takeoff cycle.

TABLE 4-7

AIRCRAFT EMISSION FACTOR

Airport/Airplane Type	TSP Emission Factor (lb/LTO)
Hibbing Airport	
Commercial	
Twin engine jet	0.82
Twin engine turbo	2.2
General aviation	
Single engine	0.02
Twin engine	0.04
Business jet (two engine)	0.22
Grand Rapids Airport	
Single engine	0.02
Twin engine	0.04
Twin engine (business)	0.22
Eveleth Airport	
Single engine	0.02
Twin engine	0.04
Twin engine (business)	0.22

5.0 1976 EMISSIONS INVENTORY

A 1976 emissions inventory was developed for the Mesabi Iron Range using the methodology described in Section 4.0. Source extents and correction factors were determined using information obtained from governmental, private, and literature sources, as well as in-house data maintained at MRI. The inventory included information on source location, emission rate, injection height, and other parameters for input into the modeling effort.

5.1 Point Source Inventory

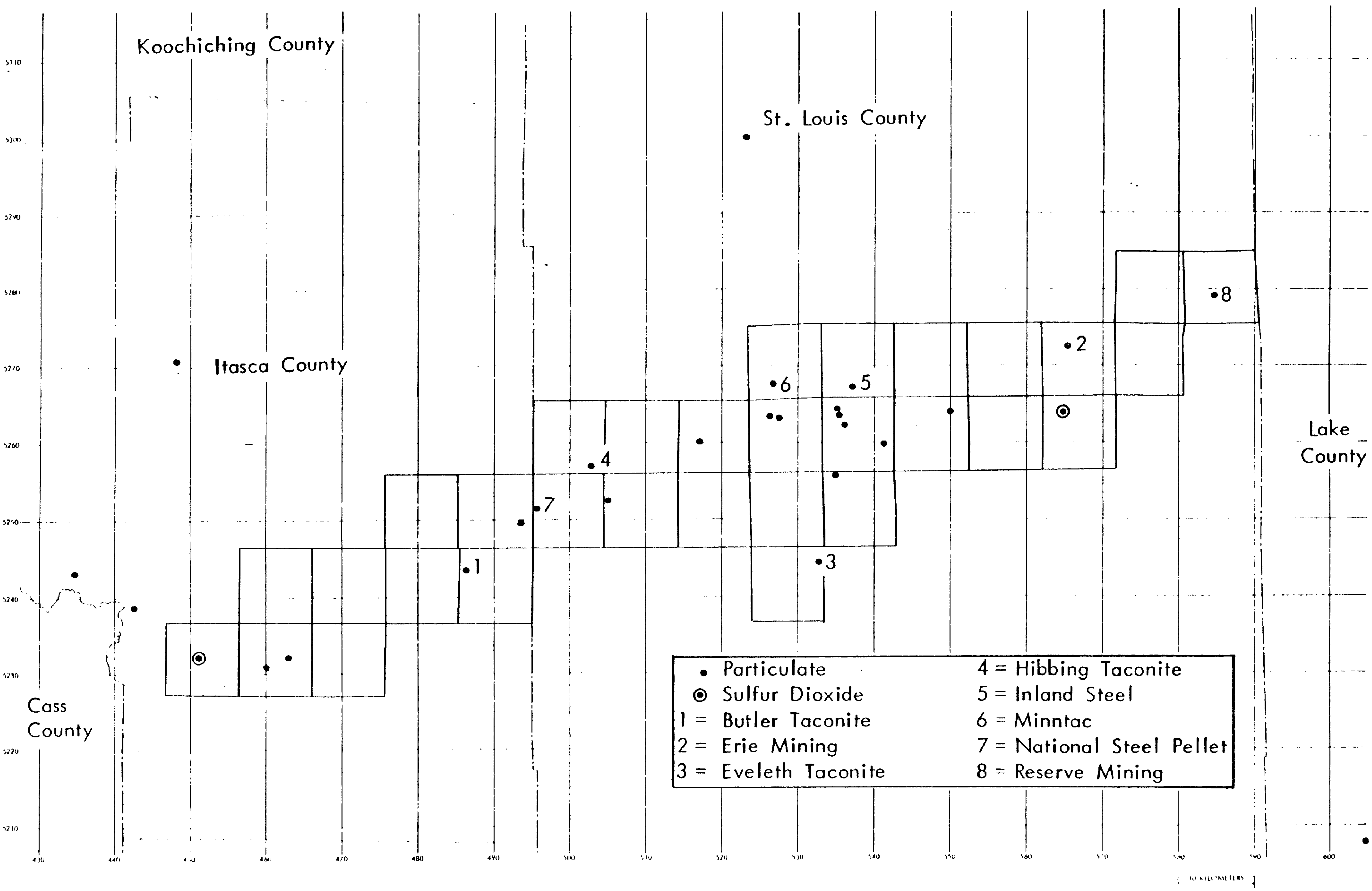
A 1976 point source emissions inventory was developed from computer listings supplied by MPCA. Figure 5-1 presents a map of the locations of major TSP and SO_2 sources. Taconite facilities are identified by company (Butler Taconite, Erie Mining Company, Eveleth Taconite, Minntac, National Steel Pellet, and Reserve Mining). Hibbing Taconite and Inland Steel were just starting up in 1976. No point sources were listed for the eight natural ore mines treated in the study. Also shown in Figure 5-1 are two major sources of sulfur dioxide emissions: Minnesota Power and Light, Clay Boswell Station, and Minnesota Power and Light, Aurora.

Table 5-1 summarizes the 1976 emissions of TSP and SO_2 by county and by plant. These data comprise all data in the MPCA point source emission inventory. No point source emissions were specified for Aitkin County. The final point sources compiled for modeling were: (a) sources with nonzero emissions of TSP and/or SO_2 and (b) sources within the primary and secondary Iron Range study regions or major sources outside the 25-mile secondary region.

Review of Table 5-1 indicates that the major point sources in the Iron Range are:

TSP	SO_2
1. Mining (primary metal)	1. Electrical generation
2. Electrical generation	2. Mining (primary metal)
3. Wood products	

The data in Table 5-1 compare very well with 1975-1976 baseline year data provided by the MEQC Regional Copper-Nickel Study Group. Those data were compiled from 1975 computerized MPCA listings, the Wisconsin Department of Natural Resources, and the Ontario Ministry of the Environment data.



LOCATIONS OF MAJOR POINT SOURCES

Figure 5-1

TABLE 5-1

SUMMARY OF POINT SOURCE EMISSIONS (1976)

County	Plant	City Code	UTM Coordinates Easting	UTM Coordinates Northing	Emissions (tons/year) TSP	Emissions (tons/year) SO_2	No. of Point Sources
0060 (Cass)	Ah Gwah Ching Nursing	0600	380.8	5214.0	14	32	6
	St. Regis Paper		379.3	5248.2	16	9	2
	Total				30	41	
1660 (Itasca)	Blandin Paper	1400	459.9	5230.9	13	1	2
	Lakehead Pipeline	1660	435.8	5242.3	20	26	1
	Hanna Mining (National)	1660	495.3	5250.8	1,500	0	44
	Minnesota Power and Light (Clay Boswell)	1040	451.0	5233.5	7,934	32,725	3
	Hanna Mining (Butler)	1660	485.0	5244.3	1,615	1	24
	Hawkinson Construction[a/]		461.0	5232.0	16	0	1
	Marcell Mill and Limber		448.5	5270.3	84	1	1
	Total				11,182	32,754	
1780 (Koochiching)	Boise Cascade (Intl. Falls)	1620	470.1	5383.5	2,568	922	9
	Boise Cascade (Big Falls)		441.2	5338.3	80	1	1
	Green Forest		458.8	5360.4	50	5	1
	Total				2,698	928	
1840 (Lake)	J. C. Campbell	3840	600.4	5207.9	32	0	1
	Two Harbors Water and Lites	3840	600.4	5207.9	245	96	1
	Reserve Mining	3520	631.4	5238.1	30,773	3,525	99
	Total				31,050	3,621	

TABLE 5-1 (Continued)

County	Plant	City Code	UTM Coordinates Easting	UTM Coordinates Northing	Emissions (tons/year) TSP	Emissions (tons/year) SO_2	No. of Point Sources
3260	Arrowhead Blacktop No. 1	1040	555.0	5172.0	1	0	1
(St. Louis)	Hallett Minerals		536.0	5194.1	85	0	1
	Arrowhead Sand and Gravel	1040	544.8	5195.6	1,032	0	1
	Elliot Packing	1040	566.5	5178.5	0	1	1
	U.S. Steel - Minntac		527.0	5268.0	17,582	45	15
	Universal Atlas Cement[b]	1040	567.6	5179.6	50	0	2
	Northern Blacktoppers	3860	535.0	5264.0	0	0	1
	Erie Mining	3260	564.6	5271.6	14,798	1,230	99
	Eveleth Taconite	1120	532.0	5244.0	1,201	3	17
	General Mills	1040	567.9	5179.8	270	0	5
	Minnesota Power and Light (Aurora)	0140	563.0	5264.2	710	6,704	2
	Minnesota Power and Light (Hibbard)	1120	564.3	5176.2	21	1,710	4
	Hyman Michaels	1040	568.4	5178.9	[c]	4	1
	E. W. Coons Company[a]	1500	550.0	5264.8	179	0	1
	Keewatin Sawmill	3260	493.6	5249.9	0	0	1
	Echo Timber Products	3260	535.6	5321.0	0	0	1
	Cargill, Inc., Elevator B	1040	568.6	5178.6	550	0	3
	Duluth Steam Corporation	1040	569.0	5181.0	164	460	4
	Mt. Iron Water and Light	3260	528.8	5264.4	24	30	1
	Buhl Public Utilities[b]	3260	516.8	5259.9	0	0	1
	Hibbing Public Utility	1500	505.5	5252.3	57	1,110	3
	Virginia Department of Public Utilities	3860	534.8	5263.2	1,029	189	4
	Hill Wood Products, Inc.	3260	523.6	5300.9	454	17	2
	Superwood Corporation	1040	567.8	5180.0	307	153	8
	Reserve Mining (Babbitt)	0180	584.0	5279.0	150	100	8

TABLE 5-1 (Concluded)

County	Plant	City Code	UTM Coordinates Easting	UTM Coordinates Northing	Emissions (tons/year) TSP	Emissions (tons/year) SO_2	No. of Point Sources
3260 (St. Louis concluded)	U.S. Air Force	1040	561.0	5187.3	14	90	6
	U.S. Steel - Duluth	1040	560.2	5169.4	1,158	3,815	4
	Arrowhead Blacktop No. 2	1040	570.0	5190.0	110	0	1
	Arrowhead Blacktop No. 3	1040	570.0	5190.0	10	0	1
	Diamond Tool	1040	567.3	5179.8	0	24	2
	University of Minnesota	1040	570.0	5185.0	18	114	6
	Range Blacktop No. 1	1120	534.3	5256.5	0	0	1
	Range Blacktop No. 2	1120	534.3	5256.5	0	0	1
	Staver Foundry	3860	535.4	5262.2	0	0	1
	Duluth Mesabi Railroad Company	2920	565.5	5177.8	3	22	1
	Erie Mining Company	1560	564.9	5271.9	740	0	41
	Cargill, Inc., Elevator C	1040	569.0	5179.0	225	0	2
	Cargill, Inc., Elevator D	1040	569.0	5179.0	13	0	2
	Northern Natural Gas	0760	538.6	5179.1	0	2	1
	Lakeshore Blacktop	0000	454.0	4835.1	1	0	1
	U.S. Steel - Lake Shipping	1040	569.0	5179.0	212	326	3
	Total				41,168	16,149	

a/ Portable blacktop (asphalt concrete) plant.

b/ Plant closed.

c/ Data not available.

5.2 Area Source Inventory

A 1976 baseline area source emissions inventory was developed using the methodology discussed in Section 4.3. Following those procedures, the sources were considered in three major categories: (a) surface mining activities; (b) public roads; and (c) combustion sources.

5.2.1 Surface mining: Company-wide area source emissions inventories were developed for the 16 taconite and natural ore mining facilities shown in Table 5-2. Information on source extents emission factor correction parameters and control efficiencies were obtained from the source operators, site surveys, MPCA, previous MRI studies, and other knowledgeable sources.

TABLE 5-2

SURFACE MINING FACILITIES INCLUDED IN 1976 AREA SOURCE EMISSIONS INVENTORY

Taconite Mines	Natural Ore Mines
Butler Taconite Company	Sherman Group
Erie Mining Company	Rana Mines
Eveleth Taconite Company	Sharon-Culver Mine
Hibbing Taconite Company	Rouchleau Mine
Inland Steel Mining Company	Stephens Mine Group
U.S. Steel Corporation (Minntac)	Lind-Greenway Mine
National Steel Corporation	McKinley Mine
Reserve Mining Company	Hill-Annex Mine

Table 5-3 presents a summary of the 1976 surface mining inventories developed for the study. Details are contained in Appendix A.

Once company-total emissions inventories had been developed for each facility, emission rates were apportioned over 2 x 2 km grids using the methodology described in Section 4.3.1.

5.2.2 Public roads: Emission factors used in the 1976 public roads emissions inventories were developed in Section 4.3.2. Source extent values (annual VMT) were developed for each grid square in the modeling area. Figures 5-2 and 5-3 show unpaved and paved road extent distributions for the basic 10 x 10 km grid system. More refined 2 x 2 km distributions were developed for areas near major mining TSP sources.

TABLE 5-3

1976 MINING COMPANY EMISSION INVENTORIES

Mining Company Total Emissions (g/sec)

Source Category	Butler Taconite	Erie Mining	Eveleth Taconite	Hibbing Taconite	Inland Steel	U.S. Steel	National Steel	Reserve Mining
1. Unpaved roads								
. Loaded heavy duty	62.7	11.4	21.8	16.0	3.17	195.6	71.7	117.6
. Unloaded heavy duty	39.7	26.7	18.1	7.86	1.58	105.5	45.4	81.6
. Medium duty	9.42	4.60	1.62	1.60	0.10	19.9	10.7	14.3
. Light duty	1.77	17.7	5.02	1.56	2.15	1.11	2.17	15.5
2. Paved roads								
. Medium duty	0.061	0.14	0.04	0.06	b/	0.17	0.06	0.11
. Light duty	0.087	3.02	0.23	0.24	b/	8.14	0.10	0.09
3. Wind erosion of surface dumps	0.41	1.16	0.12	0.55	0.12	5.74	1.43	1.10
4. Wind erosion of waste and lean ore stockpiles	0.25	1.94	0.06	0.03	b/	0.71	0.82	1.27
5. Wind erosion of pellet stockpiles	0.18	21.2	b/	b/	b/	0.64	0.19	c/
6. Wind erosion of tailings beaches	13.3	4.69	2.48	b/	b/	47.5	11.1	c/
7. Wind erosion of tailings slopes	4.95	0.47	0.04	b/	b/	0.18	4.11	c/
8. Wind erosion of concentrate piles	1.77	b/	7.12	b/	b/	2.21	3.16	c/
9. Load-in of pellets into railcar from loading pocket, bins, or silos	0.22	0.11	0.21	0.03	b/	1.15	0.22	c/
10. Pellet stacking (onto pile)	0.22	0.17	b/	b/	b/	1.15	0.22	c/
11. Load-in of pellets into railcar with power shovel or loader	b/	2.03	b/	b/	b/	b/	b/	c/
12. Load-in of crushed ore (minus 4 in.) into piles	<0.01	b/	0.07	0.12	b/	b/	<0.01	0.02
13. Blasting (waste rock and ore)	1.05	4.82	1.03	0.45	b/	4.91	1.70	4.05
14. Wind erosion of crushed ore stockpile	0.02	b/	0.05	0.23	b/	b/	0.01	0.69

Source Category	Sherman Group a/	Hanna a/	[illegible]-Culver a/	Rouchleau a/	Stephens Group a/	[illegible] Greenway a/	McKinley a/	Hill-Annex a/
1. Unpaved roads								
. Loaded heavy duty	18.4	0.5	2.0	4.9	1.0	8.8	1.7	14.6
. Unloaded heavy duty	12.1	0.4	1.1	1.0	0.7	4.6	8.9	7.6

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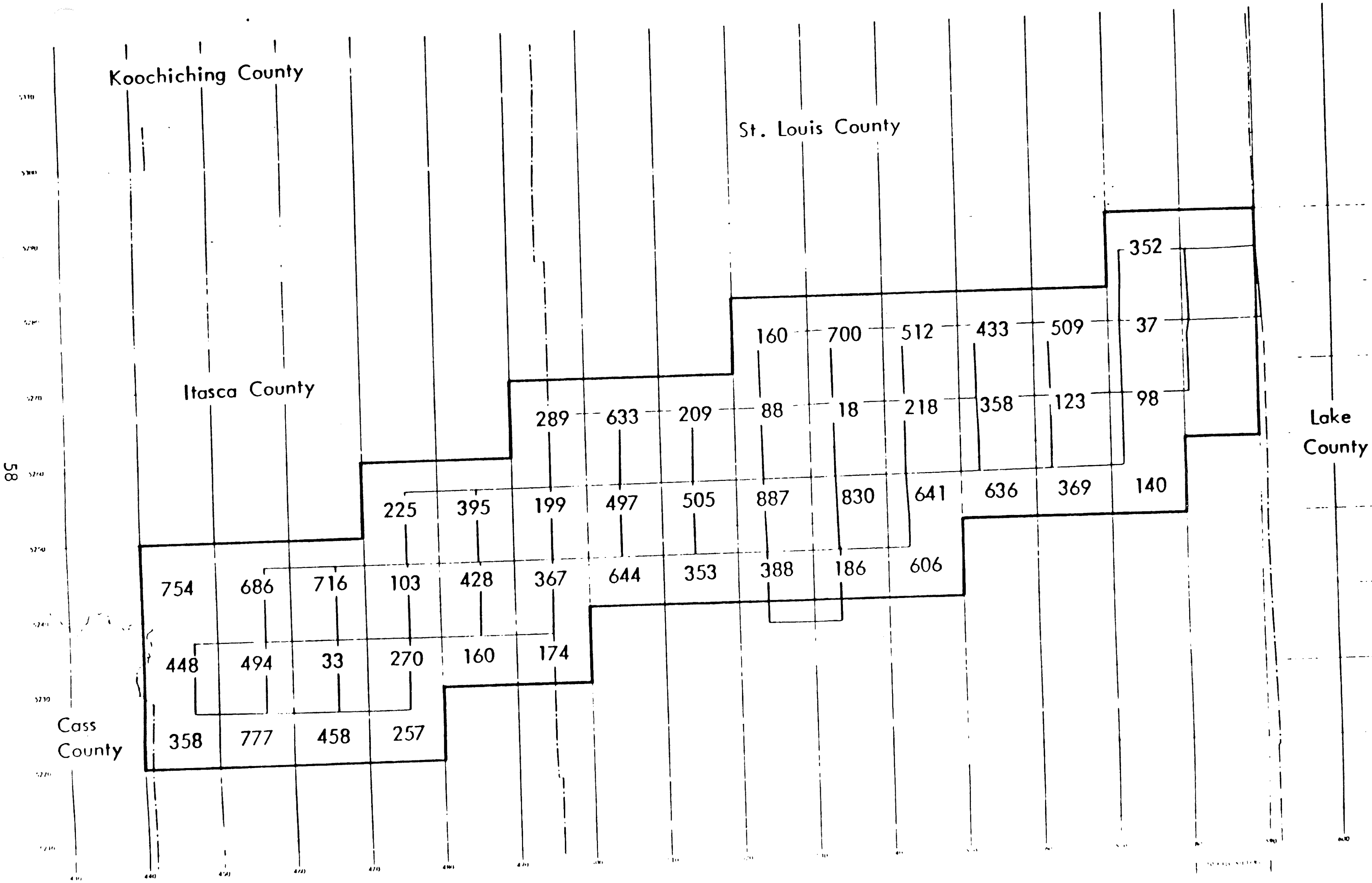
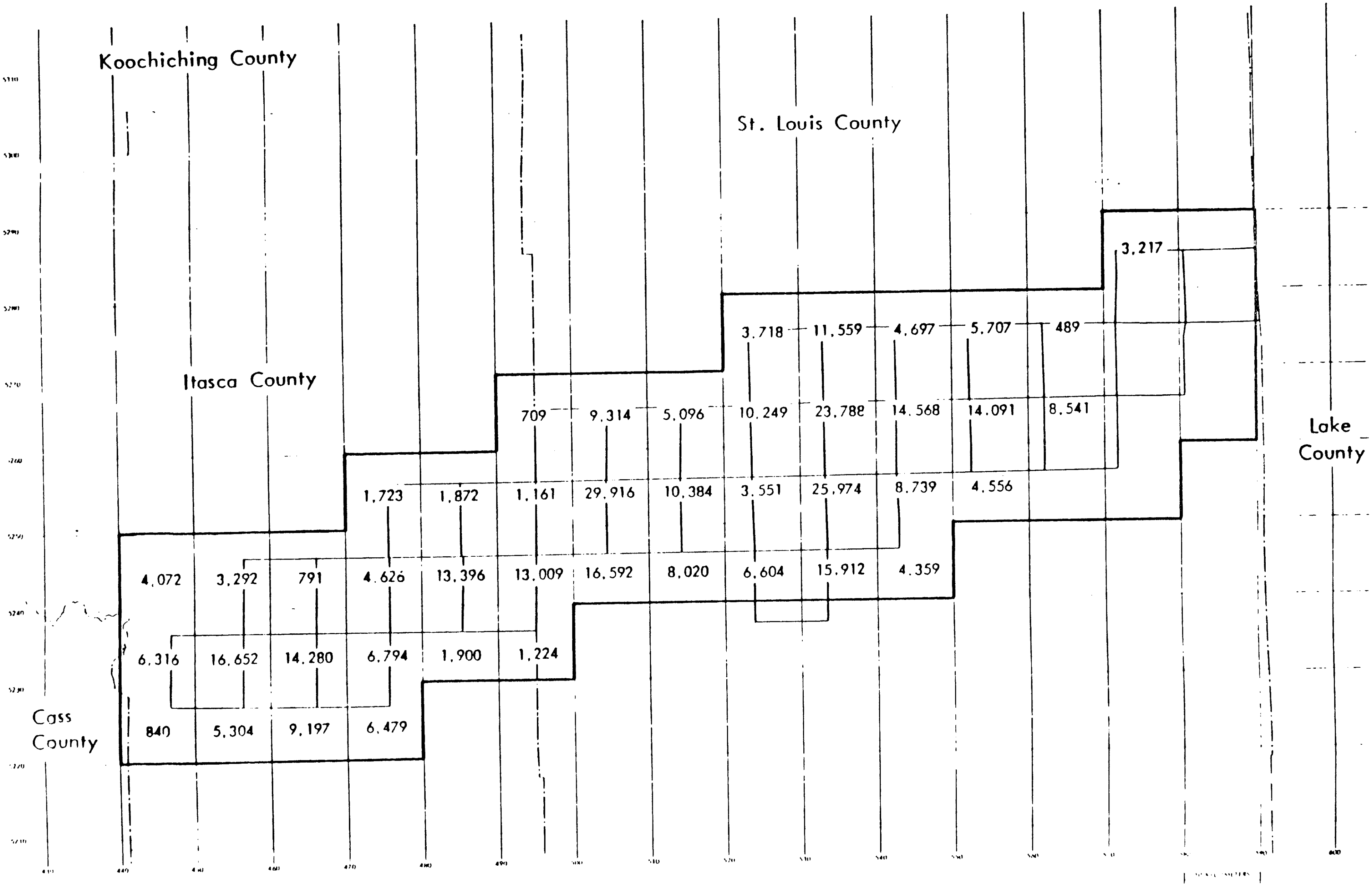
a/ Natural ore mine. Data compiled only for loaded and unloaded heavy duty traffic on unpaved roads.
b/ Source did not exist.
c/ Processing plant not on Mesabi Iron Range.



Annual 10^3 Vehicle Miles Traveled
on Unpaved Roads

Figure 5-2



Annual 10^3 Vehicle Miles Traveled on Paved Roads

Figure 5-3

5.2.3 Combustion sources: Open burning, residential fuel oil, and residential natural gas emissions factors were developed for use with population source extents. Accordingly, 1976 population (projected from the 1970 census)[14] was determined for each 10 x 10 km or 2 x 2 km grid in the study region. These values were then used to calculate emissions rates appropriate to each grid.

Railroad emission factors were developed in Section 4.3.3. The 1976 railroad-related TSP emissions in each grid were determined by identifying the source extent (miles of railroad) in each grid, then applying the emission rate equation.

Aircraft emission rates for 1976 were calculated using the emission factors developed in Section 4.3.3 for each airport in the study area. Aircraft source extent data determined for 1976 are shown in Table 5-4. Air craft emissions for each airport were assigned to the grid in which the facility is located.

TABLE 5-4

AIRCRAFT SOURCE EXTENT DATA - 1976

Airport/Airplane Type	Source Extent LTO/Year	Source Extent LTO/Day
Hibbing Airport		
Commercial		
Twin engine jet	1,000	3[a]
Twin engine turbo	1,000	3[a]
General aviation		
Single engine	1,500	4[a]
Twin engine	400	1[a]
Business jet (two engine)	100	1[a]
Grand Rapids Airport		
Single engine	7,300[a]	20
Twin engine	1,500[a]	4
Twin engine (business)	500	1[a]
Eveleth Airport		
Single engine	14,400	40[a]
Twin engine	3,600	10[a]
Twin engine (business)	730[a]	2

a/ Approximate value.

6.0 1982 EMISSIONS INVENTORY

A 1982 emissions inventory was developed for the Mesabi Iron Range using the methodology described in Section 4.0. Source extent and correction factor projections were based on information obtained from governmental, private, and literature sources, as well as in-house data maintained at MRI. The inventory included information on source location, emission rate, injection height, and other parameters for input into the modeling effort. Three general classes of projections were made: climatology; point emission sources; and area emission sources.

6.1 Climatological Projection

An estimation of 1982 climatic conditions was required for the development of natural mitigation correction factors. Since worst-case conditions were to be modeled, 1976 climatic correction factors were applied. Appendix A shows the natural control factors used in the 1982 emissions inventory.

6.2 Point Sources

The 1982 point source emissions inventory was projected from 1976 data supplied by MPCA. Figure 5-1 shows the locations of major TSP point sources in 1982.

Projected growth of nonmining point sources was estimated by relating it to population trends between 1976 and 1982. Population in the Iron Range region was expected to remain relatively constant during the period,[14] and no growth was projected for nonmining TSP point sources. Personal communications with MPCA[17] indicated that no major new TSP sources were expected to begin operations during the period 1976 to 1982. For these reasons, the nonmining portion of the 1982 point source emissions inventory was identical to the 1976 list. These sources are shown in Table 5-1.

With the exception of Hibbing Taconite and Inland Steel, projections of mining point source growth were based on trends in pellet production. Company-projected pellet production growth at Butler Taconite, Erie Mining, Eveleth Taconite, U.S. Steel (Minntac), National Steel, and Reserve Mining is shown in Table 6-1. Each company estimated increased pellet production by 1982. The point source emissions at the six mines were increased proportionally from 1976 to 1982. The number of point sources at each company and their locations and characteristics (other than emission rates) were assumed unchanged from the 1976 inventory. The 1982 mining point source emission rates for these companies are also listed in Table 6-1.

TABLE 6-1

PROJECTION FACTORS FOR 1982 MINING POINT SOURCES

Company	1976 TSP Emissions (tons/year)	1976-1982 Projection Factor	1982 TSP Emissions (tons/year)
Butler Taconite	1,615	1.11	1,793
Erie Mining Company	14,798	1.01	14,946
Eveleth Taconite	1,201	2.75	3,303
U.S. Steel, Minntac	17,582	1.50	26,373
National Steel	1,500	2.33	3,495
Reserve Mining	30,773	1.00	30,733

Hibbing Taconite and Inland Steel were just beginning operations in late 1976 and were not included in the base year inventory. However, they were expected to operate major point sources of TSP in 1982 and have been entered in the 1982 inventory.

The 1977 MPCA point source inventory was used as baseline data for Hibbing Taconite ducted emissions. According to MPCA, Hibbing point sources were inactive during 4 months of the year due to a strike. To account for this in the modeling inventory, the MPCA-supplied emission rates were increased by a factor of 1.5. MPCA anticipated a 50% growth in ducted emissions at Hibbing Taconite between 1977 and 1982. Thus, the actual (8-month) 1977 emissions were increased by a factor of 2.25 to estimate 1982 emissions.

It was assumed that the number of point sources and their locations and characteristics (other than emission rates) would not change between 1977 and 1982. Table 6-2 lists the 1982 point source inventory for Hibbing Taconite.

MPCA also provided a 1977 point source inventory for Inland Steel. The emissions there represented a typical full year's production, and no increase was expected for 1982. Thus, the 1977 point source inventory for Inland Steel was projected to 1982 without modification (see Table 6-2).

No point sources of TSP were associated with natural ore mining in 1976. Information obtained from the mine operators indicated that no new point sources were anticipated by 1982.

TABLE 6-2

SUMMARY OF HIBBING TACONITE AND INLAND STEEL POINT SOURCE TSP EMISSIONS (1982)

County	Plant	City Code	UTM Coordinates Easting	UTM Coordinates Northing	Emissions (tons/year)	No. of Point Sources
3260 (St. Louis)	Hibbing Taconite Company	1500	502.0	5258.0	610	21
3260 (St. Louis)	Inland Steel	3860	534.0	5264.0	344	20

6.3 Area Sources

A 1982 area source inventory was developed for those sources impractical to consider as individual point or line sources. It was prepared to facilitate modeling with a grid emission network. The 1982 inventory was developed from the 1976 baseline inventory described in Section 5.2, with modifications based on information from knowledgeable parties. The sources were considered in three major divisions: (a) surface mining activities; (b) public roads; and (c) combustion sources.

6.3.1 Surface mining: The major mining operations included in the 1982 Iron Range emissions inventory were the same as those used in the 1976 compilation (Table 5-2). Projections of company total source extent were obtained primarily by communication with knowledgeable personnel at taconite and natural ore facilities. Often, map depictions of source extent were supplied by the operators. The site surveys conducted in relation to the 1976 inventory and the MRI taconite study provided additional data for the 1982 projections. Surface mining source extents for 1982 are presented in Appendix A.

Local climatic conditions and particle size distributions were assumed to remain constant from 1976 to 1982. Therefore, the uncontrolled emission factors developed in Appendix A for 1976 apply identically to 1982.

Anthropogenic controls were projected to change significantly by 1982 in some cases, based on communications with mining companies. Thus, new control efficiencies were developed for 1982 surface mining operations where necessary (Appendix A). Table 6-3 presents a summary of the 1982 area source emissions inventory for the taconite and natural ore mines. As shown, area source emission rates increased moderately from 1976 to 1982 at Butler Taconite, Erie Mining Company, Eveleth Taconite, U.S. Steel (Minntac), and

TABLE 6-3

1982 MINING COMPANY EMISSION INVENTORIES

Source Category	Butler Taconite	Erie Mining	Eveleth Taconite	Hibbing Taconite	Inland Steel	U.S. Steel	National Steel	Reserve Mining	Sherman Group c/	Kinney c/	Sharon-Colver c/	Rouchleau c/	Stephens Group c/	[illegible]-Greenway c/	McKinley c/	Hill-Annex c/
	Mining Company Total Emissions (g/sec)															
1. Unpaved roads																
• Loaded heavy duty	67.7	40.6	37.8	111.6	56.2	231.8	77.6	112.6	18.4	0.5	2.0	4.9	1.0	0	0	0
• Unloaded heavy duty	39.7	12.5	33.0	64.4	28.1	101.3	49.0	81.6	17.1	0.4	1.5	1.0	0.7	0	0	0
• Medium duty	9.42	4.49	2.08	2.28	1.19	25.9	25.2	14.2								
• Light duty	1.77	14.2	5.41	5.05	5.65	1.44	4.96	15.5								
2. Paved roads																
• Medium duty	0.06	0.17	0.04	0.04	0.03	0.17	0.06	0.11								
• Light duty	0.09	2.98	0.21	0.24	0.90	9.93	0.24	0.11								
3. Wind erosion of surface dumps	0.51	1.13	0.61	1.53	9.53	10.5	2.95	0.83								
4. Wind erosion of waste and lean ore stockpiles	0.18	2.38	0.12	0.56	0.01	2.69	1.02	1.53								
5. Wind erosion of pellet stockpiles	20	21.2	a/	a/	0.60	0.47	0.14	b/								
6. Wind erosion of tailings beaches	13.3	4.16	2.48	12.4	14.1	106.1	15.1	b/								
7. Wind erosion of tailings slopes	6.45	0.58	0.05	a/	<0.01	0.38	7.21	b/								
8. Wind erosion of concentrate piles	1.77	a/	4.33	a/	1.10	2.23	1.76	b/								
9. Load-in of pellets into rail-car from loading pocket, bins, or silos	0.24	0.11	0.29	a/	0.80	1.73	0.52	b/								
10. Pellet stacking (onto pile)	0.22	0.37	a/	a/	1.03	1.56	0.47	b/								
11. Load-in of pellets into rail-car with power shovel or loader	a/	2.03	a/	a/	a/	a/	a/	b/								
12. Load-in of crushed ore (minus 4 in.) into piles	<0.01	a/	0.18	a/	a/	a/	<0.01	0.02								
13. Blasting (waste rock and ore)	1.31	4.16	2.84	3.30	1.06	8.34	2.54	4.25								
14. Wind erosion of crushed ore stockpile	0.02	a/	0.33	0.37	0.18	a/	0.06	0.69								

a/ Source did not exist.
b/ Processing plant not on Mesabi Iron Range.
c/ Natural ore mine. Data compiled only for loaded and unloaded heavy duty traffic on unpaved roads.

National Steel mining facilities. Emission rates were increased substantially at Hibbing Taconite and Inland Steel. Reserve Mining emissions increased only a small amount. Area source emissions from natural ore mines were projected to remain stable at the Sherman, Rana, Sharon-Culver, Rouchleau, and Stephens mines. The Lind-Greenway, McKinley, and Hill Annex mines were expected to cease operations by 1982 and were deleted from the 1982 modeling emissions inventory.

The company total emission rates were apportioned within the 2 x 2 km grid system using the methodology shown in Section 4.3.1.

6.3.2 Nonmining area sources: As in the point source inventory, the growth of nonmining area sources was related to population trends anticipated for the period 1976 to 1982. Source categories in the nonmining group included public roads and combustion sources. Because population was expected to grow little, 1976 nonmining area source emissions were retained in the 1982 inventory.

7.0 DISPERSION MODELING

Ambient air quality is the product of an interrelationship of pollutant sources, receptor system, and transport medium--the atmosphere. Source and receptor systems can be described in detail. However, the wind-born transport, dilution, and diffusion of pollutants are very difficult to specify with accuracy because of the dependence on microscale fluctuations of the atmosphere. Thus, a simplified model of atmospheric dispersion is usually employed for practical assessments of ambient air quality.

Gaussian plume theory, a statistical repreeentation of dispersion, was used in the Iron Range air quality analysis. The EPA's CDMQC model was chosen for this purpose. CDMQC, a backward-looking climatological dispersion model, calculates long-term pollutant averages for an urban source/receptor system on level terrain. Details of the model are given in Table 7-1. Model modifications, development of required input data, and implementation of the model are described in the following sections.

7.1 Modeling Strategy

One of the basic purposes of the Iron Range modeling effort was to provide 1976 predictions for use in validation and calibration. Once calibrated, the model was used to project Iron Range air quality to the year 1982. A similar analysis was considered for 1990, but was eliminated when accurate industry growth projections could not be developed.

7.2 Model Modifications

Because CDMQC was designed for use in an urban environment, certain modifications were necessary to allow model application to the predominantly rural Mesabi Iron Range. The model is designed for application with meteorological data observed at National Weather Service or Federal Aviation Administration airport facilities, usually located in extra-urban settings. Stability wind roses developed from such data would not properly reflect the heat island and roughness effects experienced in nearby cities. To adapt these data for urban conditions, CDMQC adjusts the observed Pasquill-Gifford stability classes as shown in Table 7-2.

However, in the Mesabi Iron Range, the rural stability data (Hibbing Airport) correctly represents the climate of the modeling area. Thus, no stability correction procedure was needed in this application of CDMQC, and the standard program was modified to use stability data as observed.

TABLE 7-1

SUMMARY OF CDMQC CLIMATOLOGICAL DISPERSION MODEL

Model Characteristics

Averaging period:	Annual
Pollutants studied:	Total suspended particulates
Dispersion conditions:	Unrestricted
Dispersion equation:	Standard Gaussian
Dispersion coefficients:	Pasquill and Gifford

Input Requirements

Area Source Data

Emission rate (g/sec)
Emission height (m)

Point Source Data

Emission rate (g/sec)
Stack height (m)
Stack diameter (m)
Exit velocity (m/sec)
Exit temperature (°C)

Meteorological Data

Joint frequency function
(Wind direction, wind speed,[a/] stability[b/])
Average morning mixing height (m)
Average afternoon mixing height (m)
Mean ambient temperature (°C)

Other Data

Receptor grid coordinates
Source coordinates

Output Requirements

Annual average ground-level concentration (micrograms/cubic meter) at user-specified receptor grid coordinates.

---

a/ CDMQC Wind Speed Classes (Central Speeds):

1 = 1.5 m/sec
2 = 2.46 m/sec
3 = 4.47 m/sec
4 = 6.93 m/sec
5 = 9.61 m/sec
6 = 12.52 m/sec

b/ CDMQC Stability Classes (Pasquill-Gifford Classes):

1 (A) = Extremely unstable
2 (B) = Unstable
3 (C) = Slightly unstable
4 (D-day) = Neutral, daytime
5 (D-night) = Neutral, nighttime
6 (E-F) = Slightly to extremely stable

TABLE 7-1 (Continued)

CALCULATION EQUATIONS

$$X(x,y,o;h) = \frac{10^6\, Q}{\pi\, \sigma_y\, \sigma_z\, u} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{h}{\sigma_z}\right)^2\right]$$

$$\sigma_y(x) = \frac{2\pi\, x}{16} \qquad \sigma_z(x) = a x^b$$

$$\Delta h = \frac{114\, C}{u}\left[g\, V_s\, r^2\left(\frac{\rho_a - \rho_s}{\rho_a}\right)\right]^{\frac{1}{3}}$$

Symbols

$X(x,y,o;h)$ = ground-level pollutant concentration (z-o) at point (x,y) for an effective stack height, h, ($\mu g/m^3$)

x = downwind distance from source (m)

y = lateral distance from plume centerline (m)

h = effective stack height or the physical stack height plus plume rise (m)

Q = emission rate (gm/sec)

σ_y, σ_z = standard deviations of the plume concentration distribution in the lateral and vertical directions, respectively (m)

u = mean wind speed (m/sec)

a,b = parameters in the equation for σ_z dependent on stability class and downwind distance, given in the table below

Δh = height of plume rise (m)

C = 1.60

g = acceleration due to gravity, 9.807 (m/sec^2)

V_s = stack gas exit velocity (m/sec)

r = inside radius of stack, at top (m)

ρ_a = density of ambient air at stack top (gm/m^3)

ρ_s = density of stack gas at stack top (gm/m^3)

TABLE 7-1 (Concluded)

PARAMETRIC VALUES FOR σ_z

Stability class	Downwind distance (m)					
	100 to 500		500 to 5,000		5,000 to 50,000	
	a	b	a	b	a	b
1	0.0383	1.2812	0.2539×10^{-3}	2.0886	-	-
2	0.1393	0.9467	0.4936×10^{-1}	1.1137	-	-
3	0.1120	0.9100	0.1014	0.9260	0.1154	0.9109
4	0.0856	0.8650	0.2591	0.6369	0.7368	0.5642
5	0.0818	0.8155	0.2527	0.6341	1.2969	0.4421
6	0.0545	0.8124	0.2017	0.6020	1.5763	0.3606

TABLE 7-2

CDMQC MODIFICATIONS TO OBSERVED STABILITY DATA

Observed Stability Class[a/]	Stability Class Assigned by CDMQC: Area Source Emissions	Stability Class Assigned by CDMQC: Point Source Emissions
1	1	1
2	1	2
3	2	3
4	3	4
5	4	4
6	5	6

a/ See Table 7-1 for definition of stability classes.

A second change in the basic program design involved consideration of particulate size range. CDMQC was designed to simulate simultaneous dispersion of two different pollutants (TSP and SO_2), each with its own source strengths, half-life, and background concentration. For the Iron Range study, two size ranges of a single pollutant (TSP) were treated instead. Emissions from each source category were separated into respirable and settleable particulate components. Atmospheric settling rates were calculated for the two particle size ranges, which determined individual plume depletion characteristics used in the modeling effort. Details of the size range considerations are presented in Section 7.5.

7.3 Meteorological Data

Meteorological data pertinent to particulate dispersion were represented in the form of a joint frequency function:

$$\phi\ (k, l, m)$$

where:

ϕ = long-term fractional frequency

k = index identifying wind direction sector

l = index identifying wind speed class

m = index identifying Pasquill-Gifford stability class

Wind direction sectors (each 22-1/2 degrees wide) were defined by breaking the azimuth circle into 16 equal parts. The wind speed index ranked wind speed in six ranges, as shown in Table 7-1, which also lists the six Pasquill-Gifford stability classes indexed by m. The joint frequency function used in the modeling study was developed from 1976 Hibbing Airport weather data[2/] and International Falls stability data[3/] and included observations from each of the 366 days during the year. The joint frequency function is shown in Table 7-3.

The Pasquill-Gifford stability classes required in the joint frequency function were not measured directly. Instead, they were developed from wind speed, solar radiation, and cloud cover data, using the method shown in Table 7-4.[18/] The standard Pasquill-Gifford index was modified somewhat in the model to separate D-type (neutral) stability into daytime and nighttime subcategories.

JOINT FREQUENCY FUNCTION USED IN MODELING EFFORT

Wind Direction	Pasquill - Gifford Stability Class a/	Wind Speed Class b/ 1	2	3	4	5	6
N	A	.000114	.000228				
NNE	A	.000114					
NE	A	.000228	.000114				
ENE	A	.000228					
E	A	.000571	.000114				
ESE	A	.000457	.000228				
SE	A	.000114	.000114				
SSE	A	.000114	.000228				
S	A		.000114				
SSW	A	.000114	.000114				
SW	A	.000228					
WSW	A	.000114	.000114				
W	A		.000114				
WNW	A	.000114					
NW	A	.000114	.000114				
NNW	A						
N	B	.000571	.001599	.001257			
NNE	B	.001028	.001028	.000914			
NE	B	.000571	.000685	.000685			
ENE	B	.000800	.000914	.000228			
E	B	.000457	.000914	.000685			
ESE	B	.001142	.000800	.000114			
SE	B	.000800	.000228	.000571			
SSE	B	.000800	.000914	.000571			
S	B	.002171	.003085	.001371			
SSW	B	.001599	.001142	.000800			
SW	B	.000685	.000800	.000457			
WSW	B	.001028	.000571	.001142			
W	B	.000457	.000457	.000571			
WNW	B	.001028	.000457	.000114			
NW	B	.001485	.001828	.001371			
NNW	B	.000343	.000571	.000457			
N	C	.001028	.002970	.007769	.000800		
NNE	C	.000457	.000800	.002056	.000457		
NE	C	.000800	.001142	.002171			
ENE	C	.001028	.001028	.001257	.000228		
E	C	.000343	.000914	.001371			
ESE	C	.000914	.001028	.001028			
SE	C	.001028	.000685	.002056	.000571		
SSE	C	.000571	.001142	.002285	.001142		
S	C	.001828	.002513	.007655	.001599		
SSW	C	.002056	.001599	.004684	.000343	.000114	
SW	C	.001028	.001485	.003884	.000457	.000114	
WSW	C	.000114	.001257	.002628	.000571		
W	C	.000228	.001828	.003085	.000571		
WNW	C	.000343	.001371	.003313	.000571		
NW	C	.000685	.001942	.004570	.000914		
NNW	C	.000571	.001942	.004913	.000571		

TABLE 7-3 (Concluded)

Wind Direction	Pasquill - Gifford Stability Class a/	Wind Speed Class b/ 1	2	3	4	5	6
N	D	.000571	.003542	.010511	.013595	.001714	.000114
NNE	D	.000228	.002171	.003999	.003770	.000343	.000114
NE	D	.000228	.002399	.001714	.000914		
ENE	D	.000800	.002171	.002628	.001599	.000228	
E	D	.000457	.002171	.002742	.002856	.000228	
ESE	D	.000457	.001028	.002856	.002056	.000343	
SE	D	.000343	.002285	.004684	.005484	.000343	
SSE	D	.000571	.003313	.006284	.006969	.000914	.000228
S	D	.000800	.004798	.013024	.014052	.002056	.000685
SSW	D	.000914	.002742	.005484	.008911	.000457	.000228
SW	D	.000343	.002513	.004341	.005712	.000685	.000228
WSW	D	.000114	.002056	.003999	.003884	.000343	
W	D	.000228	.002285	.005370	.007655	.000457	
WNW	D	.000800	.002056	.005255	.013253	.001828	.000114
NW	D	.000685	.003770	.013024	.015195	.001485	.000571
NNW	D	.000457	.004227	.010968	.014624	.001142	.000228
N	N	.001028	.005484	.008797	.012224	.000685	.000114
NNE	N	.001028	.001714	.002513	.001485	.000228	.000114
NE	N	.000571	.002513	.000800	.000457		
ENE	N	.001714	.002171	.001828	.001828	.000343	
E	N	.001371	.004456	.003884	.001485	.000228	
ESE	N	.001485	.004341	.003656	.001257		
SE	N	.001485	.004456	.008568	.002856		
SSE	N	.000914	.003427	.005596	.002056		
S	N	.001257	.006855	.010739	.005712	.000800	
SSW	N	.000914	.003999	.004798	.004341	.000343	
SW	N	.000571	.001828	.002856	.001142	.000114	
WSW	N	.000228	.002171	.002856	.001257	.000114	.000114
W	N	.000800	.002628	.004456	.004570		
WNW	N	.000800	.002628	.005370	.008340	.001028	.000114
NW	N	.000571	.003884	.009597	.018736	.001371	.000114
NNW	N	.000914	.005941	.011082	.021707	.002171	.000114
N	F	.010282	.015652	.009140			
NNE	F	.011539	.007198	.003770			
NE	F	.007883	.003313	.000228			
ENE	F	.007540	.003884	.000343			
E	F	.004456	.002171	.001028			
ESE	F	.007883	.003085	.000571			
SE	F	.006055	.006626	.001828			
SSE	F	.009140	.006169	.001257			
S	F	.009597	.014395	.006055			
SSW	F	.013367	.007312	.004113			
SW	F	.010396	.005484	.001142			
WSW	F	.008911	.003656	.001714			
W	F	.006398	.007655	.004456			
WNW	F	.004113	.005141	.004456			
NW	F	.009368	.007312	.006969			
NNW	F	.012910	.014345	.009597			

TABLE 7-4

DETERMINATION OF CDMQC STABILITY CLASS FROM STANDARD METEOROLOGICAL DATA

Surface Wind Speed at 10 Meter Height (M/S)	Daytime Insulation			Nighttime Cloud Cover	
	Strong	Moderate	Slight	Thinly Overcast or ≥4/8 Low Clous	≤3/8 Low Cloud
<2	1	1-2	2	-	-
2-3	1-2	2	3	6	6
3-5	2	2-3	3	5	6
5-6	3	3-4	4	5	5
>6	3	4	4	5	5

Other meteorological parameters required by the model are mean annual day and night mixing heights. Based on the data presented in Table 2-7, an average morning mixing height of 300 m and an average afternoon mixing height of 1,200 m were used to represent conditions in the Mesabi Iron Range. Mean ambient temperature was required when applying Brigg's formula to the plume rise of stack emissions. A long-term annual mean of 3.7°C, observed at the Hibbing Airport (Table 2-3), was input to the model.

CDMQC allows user specification of initial values for the vertical dispersion parameter, σ_z, in considering area source emissions. The CDMQC users' guide suggests a value of 30 m for all stability classes in urban "topography." This value may overestimate initial dispersion over the more uniform Iron Range terrain but was adopted as the best available estimate. Initial σ_z values for stack emissions were calculated internally as a function of stack height, based on a σ_z of 30 m for short stacks.

7.4 Source Representation

The CDMQC dispersion model treats particulate emission sources in two categories: point sources and area sources. Line emissions are not considered separately by the model but were treated as contributors to area source emissions. As applied in the Iron Range study, the model assumed constant emission rates for each source.

Air quality impacts of point source emissions were determined separately from area source effects. The point source emission inventories developed in Section 5.0 (1976) and Section 6.0 (1982) were used as input to the model. A total of 259 point sources were included in the 1976 analysis, with 300 treated for 1982.

The area source concept was originally included in the CDMQC model to accommodate the many small urban point sources (e.g., home heating exhaust) that could not practically be modeled as individual contributors. In the Iron Range study, the area source approximation was applied to the modeling of fugitive emissions sources as well.

Area source emissions are treated by CDMQC in a square grid system. Each grid square is identified by the location of its southwest corner. A single emission rate (g/sec) is assigned to each grid. This results in constant emission densities within the grids with abrupt changes at the boundaries. Desired resolution can be obtained by varying the size of the emissions grids.

The grid system used in the Iron Range air quality analysis was based on the UTM coordinate system, with a basic grid size of 2 by 2 km. Where emission density varied slowly (in some of the secondary areas away from taconite mining operations), 10 by 10 km grids were used instead. The area source emissions inventories described in Section 5.0 (1976) and Section 6.0 (1982) supplied the input used in the model. A total of 600, 2 by 2 km, and 27, 10 by 10 km, area source grids were included in the modeling effort.

The CDMQC does not apply plume rise techniques to the area source emissions but allows a user-specified effective emission height. This parameter was used in the study to account for the effects of elevated emissions (such as batch load-in operations), fugitive emissions with an initial vertical velocity component (such as road dust), and emissions from elevated points (such as wind erosion of storage piles). An effective emission height of 5 m was used in the study. No special allowance was made for emissions originating below ground level (in pits).

7.5 Particle Size Distribution

As discussed earlier, CDMQC was adapted to treat TSP in two size ranges: respirable (approximately 0 to 5 μm Stokes diameter) and settleable (approximately 5 to 30 μm Stokes diameter). A pollutant half-life parameter was included in CDMQC to adjust concentrations for depletion of the plume by chemical or physical processes. Half-life was used in the study to simulate removal of particulates due to settling.

The expression in CDMQC that accounts for plume depletion is:

$$\exp. \left[\frac{-0.692\ X}{UT}\right]$$

where:

X = distance from source, m

U = representative wind speed, m/sec

T = pollutant half-life, hr

Respirable particles were assumed to remain aloft indefinitely and were assigned a half-life of 99,999.0 hr, the largest value allowed by the algorithm.

Determination of settleable particle half life was more difficult. The average drift distance (X_d) for settleable particles was determined using Stokes' formula for terminal velocity and a logarithmic vertical profile of wind speed. The settling parameters used in the calculation are shown in Table 7-5. Next it was assumed that random vertical turbulence would cause half of the particles by weight to settle out between the source and the average drift distance. Setting the CDMQC plume depletion expression equal to one-half at $X = X_d$ and using the 1976 average wind speed at Hibbing (4.2 m/sec at 4 meters), a settleable particle half-life of 0.103 hr was determined.

TABLE 7-5

PARTICLE SETTLING PARAMETERS

Mass Mean Particle Diameter	12.25 μm
Particle Density	3.0 g/cm^3
Wind Speed at 4 Meter Height	4.2 m/sec
Average Injection Height	5.0 m
Ground Roughness Height	5.0 cm
Average Drift Distance	1,347 m
Atmospheric Half-Life	0.103 hr

As applied in the model, this half-life allowed the depletion of settleable emissions beginning immediately after release, with a loss of 50% after approximately 6 min and 75% after approximately 12 min, etc. Thus, the modeled impact of settleable particles fell off very rapidly with distance from the source.

The emission rates determined in the 1976 and 1982 emissions inventories represented all particles smaller than 30 μm in Stokes diameter. The emissions from each source (and each source category for area sources) were separated into respirable and settleable portions for the modeling effort. The apportioning was accomplished using particle size information obtained during this and previous studies. Table 7-6 lists the apportioning methodology for the 21 area source categories.

Particle size distributions for Erie Mining Company point source emissions varied from stack to stack at their operations and were included in the model based on information supplied by the company. Data were insufficient to apportion the emissions from other point sources in the Mesabi Iron Range; stack emissions at these source were assumed to be entirely respirable.

TABLE 7-6

PARTICLE SIZE APPORTIONING METHODOLOGY
FOR AREA SOURCE EMISSIONS

Area Source Emission Category[a/]	% of Emissions Due to Respirable Particles	% of Emissions Due to Settleable Particles
1	30	70
2	50	50
3	30	70
4	30	70
5	30	70
6	30	70
7	30	70
8	30	70
9	30	70
10	30	70
11	30	70
12	30	70
13	30	70
14	30	70
15	30	70
16	50	50
17	100	0
18	100	0
19	100	0
20	100	0
21	100	0

a/ See Table 4-1 for description of category types.

7.6 Receptor Representation

The CDMQC dispersion model determines the spatial distribution of TSP concentrations by calculating impacts at user-specified receptor points. Two classes of receptor points were used in the Mesabi Iron Range analysis: monitoring receptors and grid receptors.

Monitoring receptors were located to coincide with selected State of Minnesota and industrial hi-vol air monitoring sites. This was done to obtain precise data for areas of demonstrated or suspected air quality deterioration and to provide data for validating and calibrating the model. The 32 monitoring receptors employed in the modeling study are shown in Table 7-7. The MPCA industrial site Nos. 11, 14, 16, and 17 (Hibbing Taconite site Nos. 1, 4, 6, and 7) were excluded from the modeling study because accurate locations could not be determined. After completion of the modeling effort, it was discovered that additional industrial monitoring receptors did not accurately represent the locations of the hi-vol samplers. These were MPCA site Nos. 5, 6, and 7 (Eveleth Taconite site Nos. 5, 6, and 7), site No. 18 (Hibbing Taconite site No. 8), site Nos. 21, 22, 23, 24, and 25 (Inland Steel site Nos. 1, 2, 3, 4, and 5), and site No. 34 (National Steel Highway 169 site). Although these receptors could no longer be used to indicate concentrations at actual monitoring sites, their results were retained as predicted concentrations at unmonitored locations.

Additional sites were needed to provide adequate receptor density in sparsely monitored areas of the Mesabi Iron Range. For this purpose, a network of "grid receptors" was added to the model. One grid receptor was sited at the center of each 10 by 10 km grid in the modeling area. Figure 7-1 shows the relative locations of all 83 receptors used in the Iron Range air quality analysis.

7.7 Model Implementation and Output

When total respirable and settleable emissions rates had been determined for each point source and 2 by 2 km (or 10 by 10 km) area source grid, punched card data decks were prepared for input into the CDMQC model. Additional user-specified modeling parameters were developed as well. Among them were DELR, which controlled the radial increments in the program iterations, and DINT, which set the angular increments. After experimenting with different combinations, a value of 700 m was assigned to DELR. DINT, a dimensionless constant, was assigned a value of 10.

TABLE 7-7

MONITORING RECEPTORS USED IN THE MODELING STUDY

Modeling Identification	Operator	Operator Identification	Modeling Location UTMC Easting	Modeling Location UTMC Northing
7002	MPCA	7002	586	5305
7517	MPCA	7517	585	5306
7008	MPCA	7008	564	5271
1102	MPCA	1102	462	5231
7516	MPCA	7516	506	5253
7010	MPCA	7010	567	5263
7520	MPCA	7520	564	5263
7514	MPCA	7514	529	5264
1300	MPCA	1300	535	5263
1103	MPCA	1103	456	5233
7003	MPCA	7003	595	5296
7006	MPCA	7006	577	5273
7007	MPCA	7007	592	5251
1	Eveleth	1	532	5256
2	Eveleth	2	535	5256
3	Eveleth	3	532	5252
4	Eveleth	4	536	5253
5	Eveleth	5	531	5247[a]
6	Eveleth	6	535	5247[a]
7	Eveleth	7	532	5244[a]
8	Eveleth	8	537	5240
13	Hibbing	Chisholm	509	5259
18	Hibbing	Hibbing	505	5251[a]
21	Inland	DNR	541	5273[a]
22	Inland	Four Seasons	535	5273[a]
23	Inland	Office	536	5266[a]
24	Inland	Wouri	534	5266[a]
25	Inland	Higgins	537	5262[a]
31	Butler	Nashwank	487	5246
32	Butler	Swan Lake	486	5242
34	National	Highway 169	497	5249[a]
35	National	Carlz	494	5249

a/ Monitoring receptor not co-located with monitor.

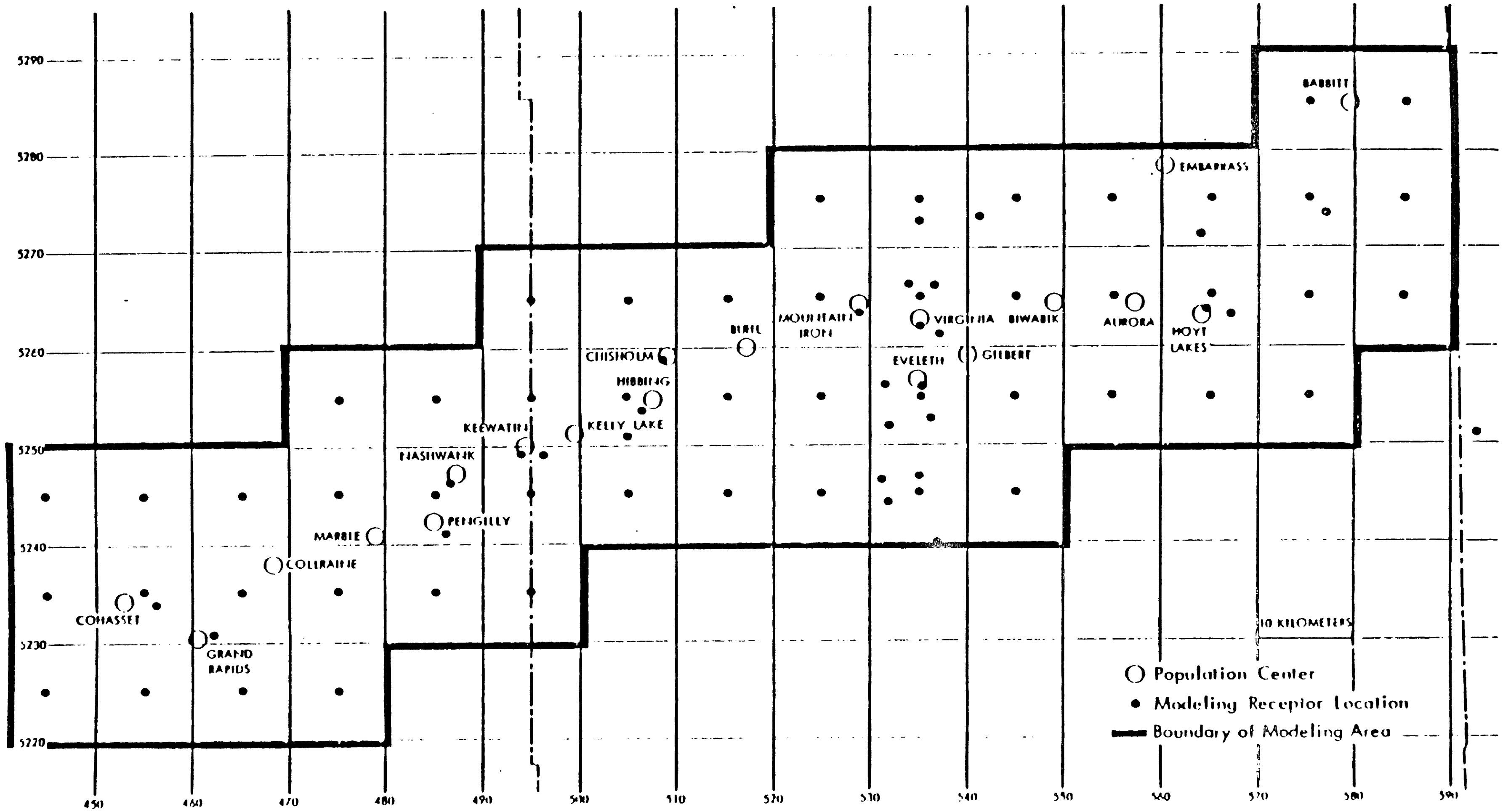


Figure 7-1. Locations of Mesabi Iron Range Modeling Receptors.

Because of dimensioning limitations imposed in the CDMQC computer program, emissions sources were divided into four groups. These were: (a) Iron Range point source inventory, (b) area sources from the western one-third of the Iron Range, (c) area sources within the middle one-third, and (d) area sources within the eastern one-third. Figure 7-2 shows how the modeling area was divided for treatment of area source contributions. CDMQC was run once for each source grouping and modeling year (1976 and 1982), impacting emissions on the entire receptor system during each run.

The model computed four annual arithmetic mean concentrations (one from each source group) of TSP in micrograms per cubic meter for each receptor point and each study year. Output was in the form of paper copy, with tables listing identification number, location, and concentration for each receptor point. With the computations complete, total TSP concentrations for each year were calculated by summing the four model-generated values for each receptor. These concentrations represented the final uncalibrated TSP levels as determined by the model.

7.8 Model Appropriateness

CDMQC, like other dispersion models of practical sophistication, was designed to provide a usable approximation of the atmospheric transport of pollutants. The Gaussian plume theory upon which it was based involved the simplifying assumption of normally distributed mass within the plume. In order to apply the theory to readily measured atmospheric and source parameters, further simplifications were adopted (Pasquill-Gifford stability indexes, Briggs plume rise formulae, logarithmic wind profiles, and the like). Computer and data limitations made further approximations necessary, such as the level terrain assumption, gridded area sources, and the CDMQC stepwise calculation of source contributions.

The many simplifications required in the modeling effort have been reevaluated continually during the Iron Range air quality analysis. It is felt that the application of the CDMQC dispersion model and particularly the use of the Hibbing, Minnesota stability wind rose, the simulation of fugitive emissions via the area source concept, and the modeling parameters (DELR, grid size, etc.) chosen for the study represent the best possible choices within the time and funding framework of the project.

However, the necessary approximations involved in the modeling effort require that the results of the study be considered as best estimates only. Analyses of Gaussian plume theories reported in the literature indicate that the uncalibrated Gaussian plume model should be considered accurate within a factor of two.[19/] A detailed analysis of the applicability of the Iron Range modeling results will be presented in the next section.

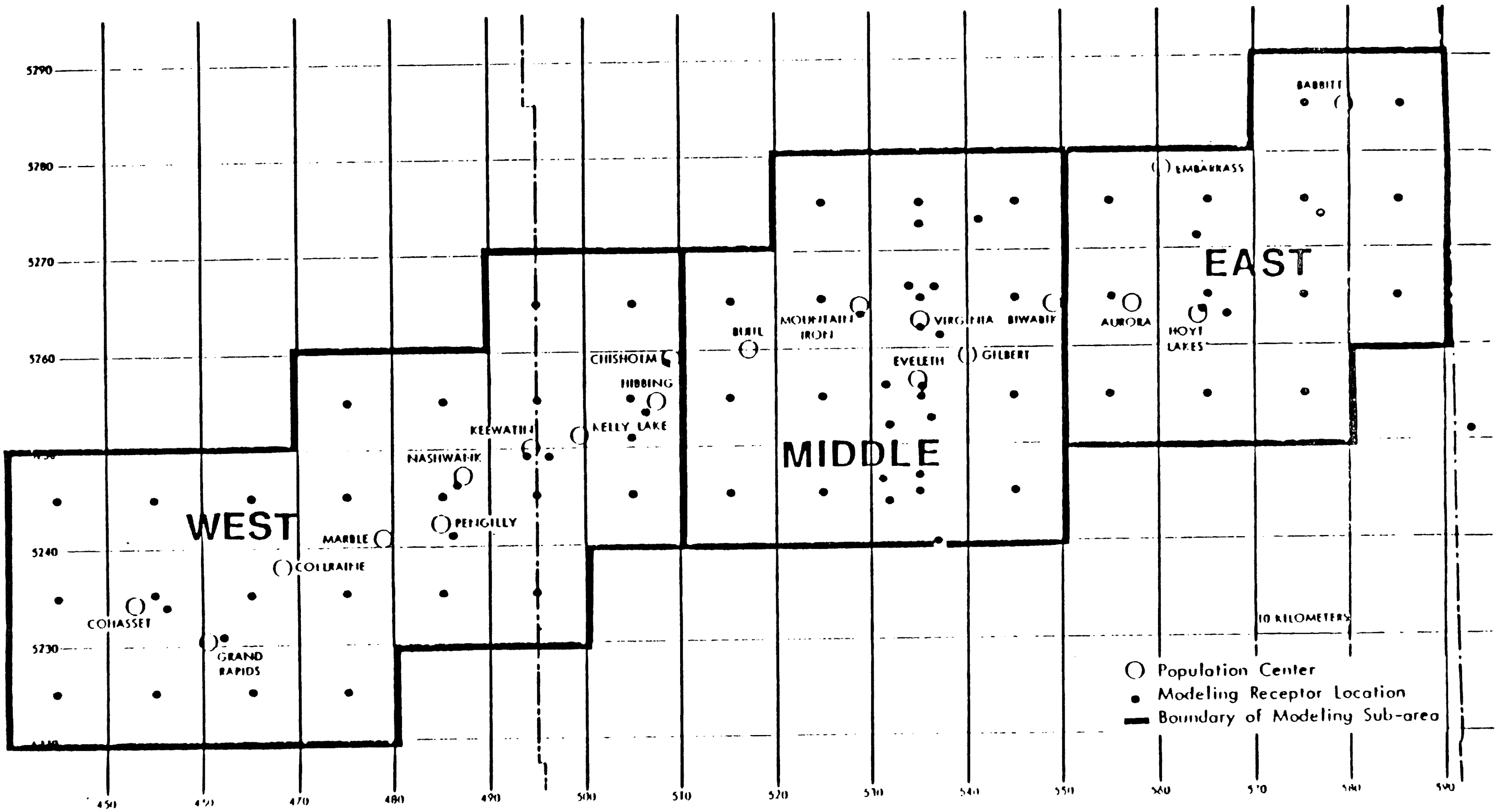


Figure 7-2. Modeling Sub-Areas for Treatment of Area Source Contributions.

8.0 ANALYSIS OF RESULTS

The CDMQC modeling effort produced estimates of concentrations resulting from emissions in the 1976 and 1982 emissions inventories. The next step in the Mesabi Iron Range air quality analysis was to add the contributions of background levels and to calibrate the total concentrations against observed TSP levels. Then statistical methods were employed to convert the data into a format compatible with ambient air quality standards. Next the computed values for each year were used in general and detailed analyses of current and projected air quality for the Iron Range. Finally, source culpability and control measures were assessed.

8.1 Background Levels of Total Suspended Particulates

An estimate of background TSP concentrations was necessary before the modeled results could be made representative of ambient conditions in the Minnesota Iron Range. As used in the study, ambient TSP background included the natural background level of the Iron Range area, transport of natural and anthropogenic emissions from sources outside the area, and contributions from sources within the Iron Range modeling area not represented in the emissions inventories. While pollutant background is often associated with some constant, low-level concentration, it more probably varies significantly with time, depending on short-term (day-to-day) as well as long-term (year-to-year) meteorological and source characteristics.

First, the minimum 24-hr concentration across the Iron Range was determined. To do this, the 1,801 hi-vol samples taken during 1976 at monitoring sites included in the study were compared. The lowest non-negative 24-hr average was 1 $\mu g/m^3$, observed on March 19, 1976, at MPCA industrial site No. 35, a National Steel air quality monitor. However, because of the probable fluctuation of background with time, inaccuracies in the sampling method, micro meteorological influences, possible equipment malfunctions, and possible analysis error, the use of a single measurement to represent background was rejected. Instead, an attempt was made to identify the long-term (annual) average background concentration in the Iron Range.

An initial estimate of long-term background was developed from a comparison of 1976 observed arithmetic mean TSP concentrations with the modeling results. Of the 32 monitoring locations, 9 were eliminated because they were located outside the modeling area or had inadequate data bases (fewer than 30 samples in 1976). Five additional stations (industrial sites near Inland Steel) were eliminated because temporary construction activities in the vicinity were not considered in the model. These five Inland sites were also rejected because of inaccuracies in locating modeling receptors. Five additional industrial receptors were rejected for the same reason. The 13 sites remaining were MPCA monitor Nos. 7516, 7520, 7514, and 1300 and MPCA industrial monitor Nos. 1, 2, 3, 4, 8, 13, 31, 32, and 35.

A comparison of observed versus predicted annual arithmetic means at these 13 locations showed that the model predicted an average of 25.6 $\mu g/m^3$ below the observed concentrations. This indicated that a total arithmetic mean background level (natural background plus other contributions) of 20 to 30 $\mu g/m^3$ should be used for the study.

The MPCA suggested a geometric mean of 15 to 20 $\mu g/m^3$ for the natural component of background. Using an Iron Range average 1976 standard geometric deviation of 2.04 $\mu g/m^3$ and assuming a log-normal data distribution, this value converted to an arithmetic mean of 19.3 to 25.8 $\mu g/m^3$. Studies in the literature indicated a similar level as appropriate.[21/] The values suggested by McCormick represented natural background concentrations in typical rural areas, however, and would probably underestimate natural background levels in the Iron Range. A higher natural background concentration in the Iron Range would result from the large perdentage of totally or partially unvegetated, abandoned mining works there. Thus, it seemed reasonable to expect the natural component of particulate background to be somewhat greater than 20 $\mu g/m^3$.

Other contributors to the modeling background (e.g., transport from outside the modeled area) were even less easily quantified but were felt to add a significant amount to the total.

Based on judgment of the factors discussed above, a total modeling background (natural plus transport plus anthropogenic) of 25 $\mu g/m^3$ was estimated. This value was accepted by the MPCA. Possible changes in the background air quality of the Iron Range were considered for use in the 1982 model. It was felt that climatic changes, land use trends within and outside the area, and energy use trends would prove significant. However, since 1976 meteorology and standard geometric deviations were applied to 1982, no change was made in the background and a value of 25 $\mu g/m^3$ was used in 1982.

8.2 Validation and Calibration of Modeling Output

To determine the applicability of the modeling results to air quality in the Iron Range, it was necessary to validate and, if appropriate, calibrate the model results.

8.2.1 Model validation: Validity of the modeling results was assessed by a comparison of predicted 1976 TSP concentrations (modeling results plus background) to observed values. High volume air sampling data from the 32 monitoring stations included in the study were used. Table 8-1 lists the stations, their locations, modeled concentrations, background, total predicted arithmetic means, observed arithmetic means, and percent

COMPARISON OF OBSERVED VERSUS PREDICTED CONCENTRATIONS FOR 1976

Receptor Identification	UTM Coordinates East	UTM Coordinates North	No. of Observations (1976)	Observed 1976 Arithmetic Mean ($\mu g/m^3$)	Predicted 1976 Arithmetic Mean Including Background ($\mu g/m^3$)	Percent Difference Predicted Versus Observed
7002[a,b]	586	5305	10	25.8	28.5	+10
7517[b]	585	5306	35	56.5	29	-49
7008[a]	564	5271	13	44.0	101.8	+131
1102[a]	462	5231	18	20.9	33.7	+61
7516	506	5253	50	54.4	41.5	-24
7010[a]	567	5263	14	35.5	43.4	+22
7520	564	5263	35	43.5	42.4	-3
7514	529	5264	56	60.8	75.5	+24
1300	535	5263	50	77.1	77.7	+1
1103[a]	456	5233	Ø	-	32.8	-
7003[a,b]	595	5296	14	30.5	27.9	-9
7006[a]	577	5273	8	29.9	41.8	+40
7007[a,b]	592	5251	3	9.8	29.3	+199
1	532	5256	115	41.0	48.4	+18
2	535	5256	116	74.2	50.7	-32
3	532	5252	96	45.4	45.2	0
4	536	5253	119	47.2	27.1	-43
5[c]	531	5247	119	39.6	43.1	+9
6[c]	535	5247	116	34.7	41.6	+20
7[c]	532	5244	114	33.9	45.9	+35
8	537	5240	115	32.1	36.9	+15
13	509	5259	61	33.3	39.1	+17
18[c]	505	5251	58	52.7	43.1	-18
21[d]	541	5273	53	52.5	37.5	-29
22[d]	535	5273	52	41.8	41.1	-2
23[d]	536	5266	50	59.0	55.9	-5
24[d]	534	5266	50	93.8	57.8	-38
25[d]	537	5262	50	98.2	50.2	-49
31	487	5246	57	37.0	43.3	+17
32	486	5242	58	42.3	50.8	+20
34[c]	497	5249	46	47.7	82.1	+72
35	494	5249	50	44.5	46.9	+5

a/ Less than 30 observations; this receptor not used in comparison.

b/ Outside modeling area; this receptor not used in comparison.

c/ Model receptor and monitor location differ by more than 1 km; this receptor not used in comparison.

d/ Construction activities at Inland Steel not considered in model; this receptor not used in comparison.

errors. As with the determination of TSP background, the monitoring receptors were assessed for applicability in model validation, and inappropriate sites were deleted from the comparison. Figure 8-1 is a plot of observed versus predicted concentrations (1976) at the 13 Iron Range locations considered valid for comparison.

Accuracy within a factor of two for the basic Gaussian model has been reported in the literature.[19/] A later study increased the accuracy somewhat, assigning an error of ±50%.[21/] As can be seen in Figure 8-1, all of the points lie well within this accuracy. The average error among the 13 stations was ±20%. The median absolute error was 18%. Thus, the results of the Iron Range air quality analysis were proven valid within the stated accuracy of the model.

It should be noted before further analysis that the observed and predicted data used for comparison represented different sample populations. In every case, the model-predicted averages are based on 366 observations of 24 hr each. Thus, the year (1976) was continuously "sampled." However, the actual hi-vol data were taken on a 3 or 6 day schedule, with some operational data loss. The data population varied from station to station and ranged from 0 observations at MPCA site No. 1103 to 119 observations at industrial site Nos. 4 and 5. Thus, coverage of the annual period by observed data varied from 0.8% to at best 32.5%. Even when stations with fewer than 30 observations were deleted from the comparison, the coverage ranged only from 9.6 to 32.5%. These differences in sample size should be considered when making comparisons between observed and predicted concentrations.

8.2.2 Model calibration: Next an attempt was made to improve the accuracy of the standard Gaussian model through statistical calibration. This was accomplished by applying linear least-squares regression techniques to observed and predicted concentrations. Based on an analysis of the 13 valid comparison sites, the following calibration formula was derived:

$$X\ (\text{observed}) = 0.58\ \left[X\ (\text{Calculated})\right] + 9.34 + 25.0\ (\text{background})$$

A correlation coefficient of 0.61 was determined, indicating that the relationship was significant within 95% confidence limits. The correlation coefficient also indicated that 37% of the original modeling inaccuracy was due to systematic errors, while 63% of the error was random. All modeling results were calibrated using this formula. Figure 8-2 shows the scatter associated with the final, calibrated results.

Tables 8-2 and 8-3 present final predicted TSP concentrations at the modeling receptors for 1976 and 1982, respectively. The data represent annual arithmetic mean concentrations including background.

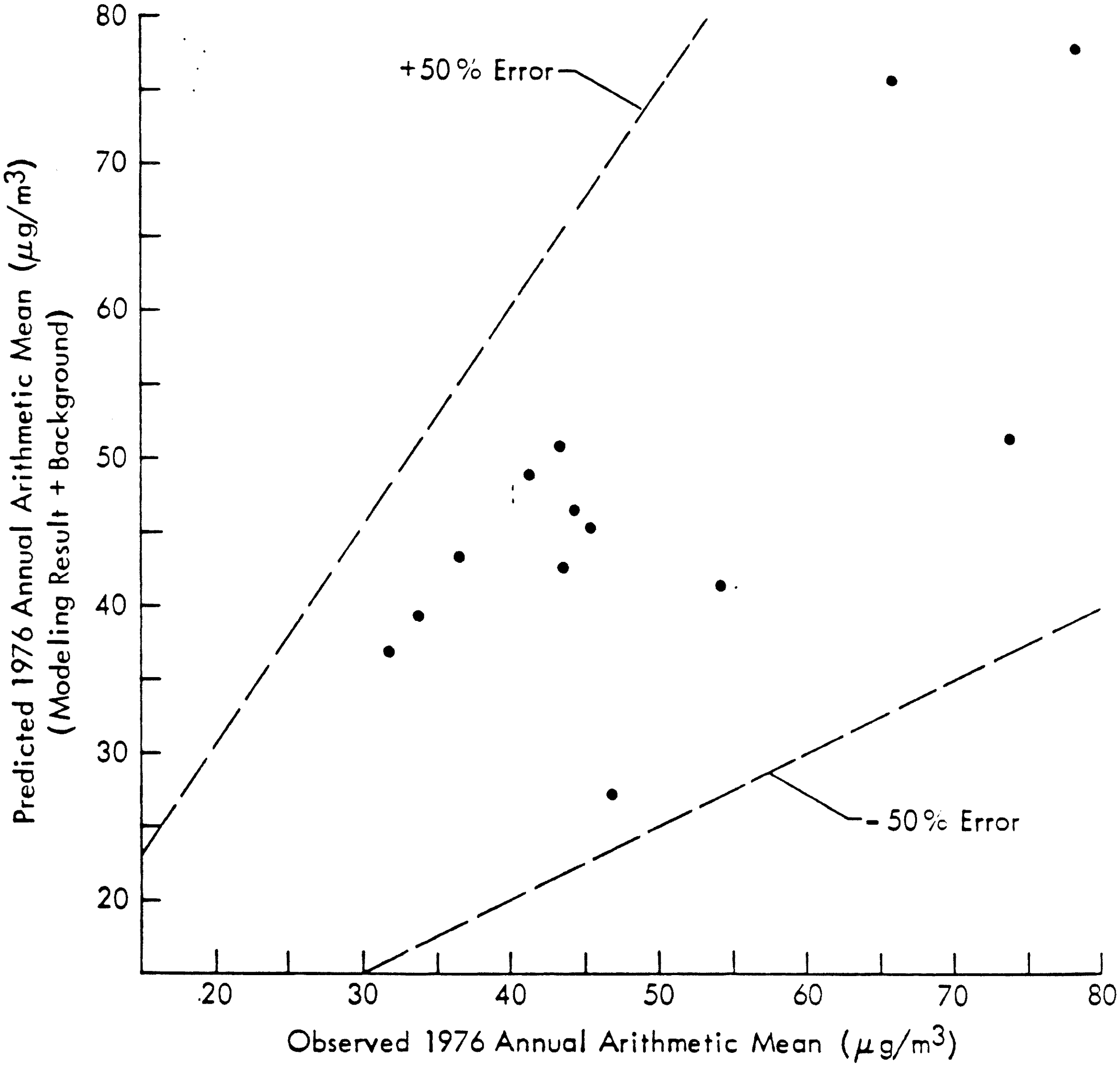


Figure 8-1. Validation of Iron Range Modeling Results.

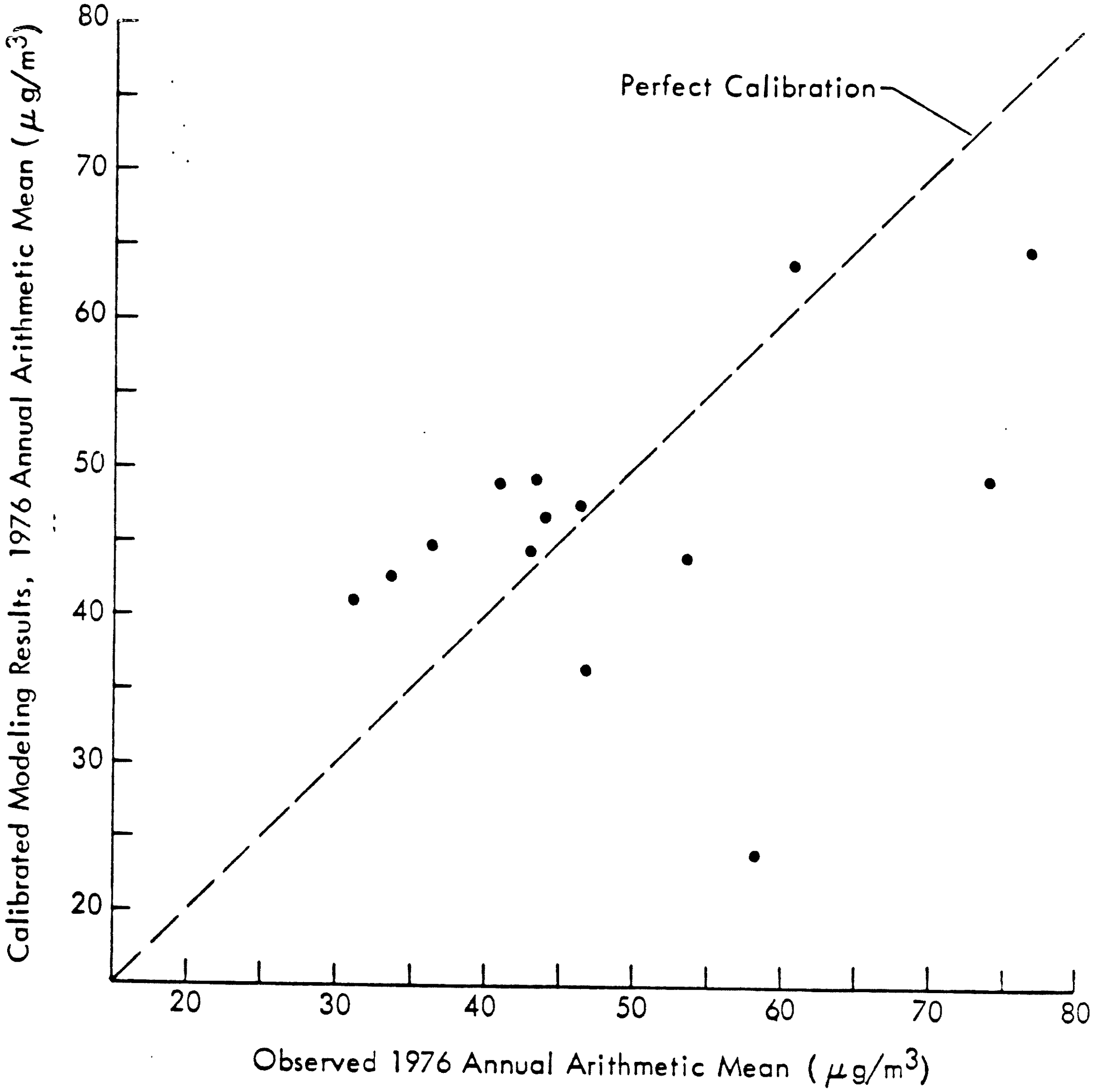


Figure 8-2. Scatter of Comparison Data After Calibration.

TABLE 8-2

CALIBRATED FINAL PREDICTIONS OF ANNUAL ARITHMETIC MEANS (1976)

Receptor Identification	UTM Coordinates East	UTM Coordinates North	Raw Model Results (ug/m³)	Calibrated Predictions Including Background (ug/m³)
7002	586	5305	3.3	36.3
7517	585	5306	4.0	36.6
7008	564	5271	76.8	78.8
1102	462	5231	8.7	39.3
7516	506	5253	16.5	43.9
7010	567	5263	18.4	45.0
7520	564	5263	17.4	44.4
7514	529	5264	50.5	63.6
1300	535	5263	52.7	64.9
1103	456	5233	7.8	38.8
7003	595	5296	2.9	36.0
7006	577	5273	16.8	44.0
7007	592	5251	4.3	36.8
1	532	5256	23.4	47.9
2	535	5256	25.7	49.2
3	532	5252	20.2	46.0
4	536	5253	2.1	35.5
5	531	5247	18.1	44.8
6	535	5247	16.6	43.9
7	532	5244	20.9	46.4
8	537	5240	11.9	41.2
13	509	5259	14.1	42.5
18	505	5251	18.1	44.8
21	541	5273	12.5	41.6
22	535	5273	16.1	43.6
23	536	5266	30.9	52.2
24	534	5266	32.8	53.3
25	537	5262	25.2	48.9
31	487	5246	18.3	44.9
32	486	5242	25.8	49.3
34	497	5249	57.1	67.4
35	494	5249	21.9	47.0
G1	445	5225	4.2	36.7
G2	445	5235	5.4	37.4
G3	445	5245	6.3	38.0
G4	455	5225	8.1	39.0
G5	455	5235	7.3	38.5
G6	455	5245	7.1	38.4
G7	465	5225	6.4	38.0
G8	465	5235	6.8	38.2
G9	465	5245	7.2	38.5
G10	475	5225	5.3	37.4
G11	475	5235	6.5	38.1
G12	475	5245	7.0	38.4
G13	475	5255	6.0	37.8
G14	485	5235	8.4	39.2
G15	485	5245	93.1	88.3
G16	485	5255	9.1	39.6
G17	495	5235	8.1	39.0
G18	495	5245	18.4	45.0
G19	495	5255	22.1	47.1
G20	495	5265	9.2	39.6
G21	505	5245	12.2	41.4
G22	505	5255	15.2	43.1
G23	505	5265	11.3	40.9
G24	515	5245	9.3	39.7
G25	515	5255	11.8	41.1

TABLE 8-2 (Concluded)

Receptor Identification	UTM Coordinates East	UTM Coordinates North	Raw Model Results (μg/m³)	Calibrated Predictions Including Background (μg/m³)
G26	515	5265	10.1	40.2
G27	525	5245	12.9	41.8
G28	525	5255	17.4	44.4
G29	525	5265	137.2	123.9
G30	525	5275	15.6	43.3
G31	535	5245	16.8	44.0
G32	535	5255	21.4	46.7
G33	535	5265	41.6	58.4
G34	535	5275	15.0	43.0
G35	545	5245	11.6	41.0
G36	545	5255	13.6	42.2
G37	545	5265	12.6	41.6
G38	545	5275	10.2	40.2
G39	555	5255	11.3	40.9
G40	555	5265	11.7	41.1
G41	555	5275	10.7	40.5
G42	565	5255	11.2	40.8
G43	565	5265	20.5	46.2
G44	565	5275	56.9	67.3
G45	575	5255	9.2	39.6
G46	575	5265	10.6	40.4
G47	575	5275	33.3	53.6
G48	575	5285	9.9	40.0
G49	585	5265	7.3	38.5
G50	585	5275	13.8	42.3
G51	585	5285	13.6	42.2

TABLE 8-3

CALIBRATED FINAL PREDICTIONS OF ANNUAL ARITHMETIC MEANS (1982)

Receptor Identification	UTM Coordinates East	UTM Coordinates North	Raw Model Results (ug/m³)	Calibrated Predictions Including Background (ug/m³)
7002	586	5305	4.0	36.6
7517	585	5306	4.6	37.0
7008	564	5271	79.3	80.3
1102	462	5231	8.9	39.5
7516	506	5253	31.4	52.5
7010	567	5263	19.7	45.7
7520	564	5263	18.9	45.3
7514	529	5264	65.4	72.2
1300	535	5263	64.5	71.7
1103	456	5233	8.1	39.0
7003	595	5296	3.3	36.2
7006	577	5273	17.6	44.5
7007	592	5251	5.1	37.3
1	532	5256	40.3	57.7
2	535	5256	52.1	64.5
3	532	5252	29.5	51.4
4	536	5253	2.9	36.0
5	531	5247	28.6	50.9
6	535	5247	25.5	49.1
7	532	5244	27.2	50.1
8	537	5240	17.8	44.6
13	509	5259	19.1	45.4
18	505	5251	29.0	51.1
21	541	5273	16.2	43.7
22	535	5273	21.6	46.8
23	536	5266	85.5	83.9
24	534	5266	46.9	61.5
25	537	5262	39.5	57.2
31	487	5246	19.6	45.7
32	486	5242	27.3	50.1
34	497	5249	68.3	73.9
35	494	5249	28.0	50.5
G1	445	5225	4.7	37.0
G2	445	5235	5.9	37.7
G3	445	5245	6.6	38.1
G4	455	5225	8.7	39.3
G5	455	5235	7.6	38.7
G6	455	5245	7.4	38.6
G7	465	5225	6.7	38.2
G8	465	5235	5.9	37.7
G9	465	5245	7.5	38.7
G10	475	5225	5.8	37.7
G11	475	5235	6.9	38.3
G12	475	5245	7.1	38.4
G13	475	5255	7.0	38.4
G14	485	5235	9.2	39.6
G15	485	5245	95.0	89.4
G16	485	5255	9.9	40.0
G17	495	5235	9.3	40.0
G18	495	5245	21.7	46.9
G19	495	5255	28.3	50.7
G20	495	5265	13.0	41.8
G21	505	5245	16.0	43.6
G22	505	5255	42.7	59.1
G23	505	5265	19.1	45.4
G24	515	5245	12.7	41.7
G25	515	5255	14.8	42.9

TABLE 8-3 (Concluded)

Receptor Identification	UTM Coordinates East	UTM Coordinates North	Raw Model Results (μg/m³)	Calibrated Predictions Including Background (μg/m³)
G26	515	5265	13.6	42.2
G27	525	5245	17.3	44.3
G28	525	5255	22.8	47.5
G29	525	5265	163.1	128.9
G30	525	5275	25.8	49.3
G31	535	5245	25.2	48.9
G32	535	5255	59.9	69.0
G33	535	5265	53.9	65.6
G34	535	5275	21.3	46.7
G35	545	5245	15.1	43.1
G36	545	5255	17.9	44.7
G37	545	5265	15.7	43.4
G38	545	5275	13.2	42.0
G39	555	5255	13.1	41.9
G40	555	5265	13.3	42.0
G41	555	5275	12.6	41.6
G42	565	5255	12.3	41.4
G43	565	5265	21.9	47.0
G44	565	5275	59.0	68.5
G45	575	5255	10.0	40.1
G46	575	5265	11.8	41.1
G47	575	5275	34.4	54.3
G48	575	5285	10.6	40.4
G49	585	5265	7.9	38.9
G50	585	5275	14.2	42.5
G51	585	5285	14.3	42.6

8.3 Geometric Means and Second Maxima

Annual arithmetic means of TSP concentrations were developed in the modeling/calibration effort. However, the State of Minnesota ambient standards for TSP are based on annual geometric means and second maximum 24-hr averages. These data were developed from the modeling results using a statistical technique known as the Larsen method.[22] The three main characteristics of Larsen's model are:

1. Pollutant concentrations are log normally distributed for all averaging times.

2. Median concentrations are proportional to averaging time raised to an exponent.

3. Maximum concentrations are approximately inversely proportional to averaging time raised to an exponent.

This method has found widespread use in air quality modeling and data assessment. Its applicability to the Iron Range analysis depended on justification of the log normality assumption. Larsen[22] presented urban air quality data that exhibited log normal distributions. In a later paper,[23] he cited physical explanations for the log normal behavior of air quality data and reported additional support for the distribution. He also cited, however, instances in which data exhibited other distributions and suggested that care be taken when applying his technique to data sampled near a strong isolated source.

The MPCA analyzed 1976 TSP data from 29 hi-vol stations in the Iron Range. They found that all stations produced log normally distributed data except MPCA site No. 7520 and industrial site Nos. 23, 24, 25, and 35. Use of the Larsen statistical model was thus felt justified in the Mesabi Iron Range study, with the understanding that results at the above five stations be considered provisional.

8.3.1 Standard geometric deviations: Application of the Larsen method requires an annual arithmetic mean TSP concentration and a standard geometric deviation (σ_g) for each receptor point. Arithmetic means were provided by the calibrated model results. Standard geometric deviations were developed from hi-vol samples taken at the 32 MPCA and industrial monitoring sites. Standard geometric deviations at specific sites varied substantially from year to year. Because meteorological conditions were expected to play a large part in this vairation, standard geometric deviations were chosen to reflect the meteorological data used in the modeling effort. Thus, 1976 sampling data were used exclusively in developing the σ_g's.

Monitoring data were available at 31 of the sampling stations considered in the study (MPCA site No. 1103 took no observations in 1976). Of these, seven stations with fewer than 30 observations during the year were excluded. Observed standard geometric deviations at 24 air monitoring sites were considered valid. Next these observed values of σ_g were used to determine standard geometric deviations at the modeling receptors. An average standard geometric deviation for the entire modeling area was considered but was discarded due to the large range of σ_g observed there (1.70 - 2.91 $\mu g/m^3$). Separation of the study area into western, middle, and eastern thirds did not significantly reduce this problem. Isopleth mapping of standard geometric deviation was considered; but data points were too widely spaced, particularly near the ends of the Iron Range, to allow accurate placement of the isopleths. The Theissen polygon method was finally adopted as most suitable to the available data.

The Theissen polygon method[24/] assumes a linear variation of σ_g between valid observation points. Perpendicular bisectors to segments joining valid monitoring sites form polygons around the sites. Each polygon contains only one valid location for observed σ_g, and the entire area within the polygon is closer to that valid site than to any other. The standard geometric deviation for each valid site is assigned to the polygon surrounding it. Then the appropriate polygon and, thus, σ_g are determined for each of the modeling receptors. Where a receptor falls on the boundary between polygons, the applicable σ_g's are averaged.

As with other meteorology-related projections, the 1976 standard geometric deviations were applied to 1982 without modification. Figure 8-3 shows the Thiessen polygon map developed for the Mesabi Iron Range study. The final standard geometric deviations used in the study are shown in Tables 8-4 and 8-5.

8.3.2 <u>Annual geometric means</u>: Annual geometric means of TSP were determined for each receptor and year using Larsen's formula:

$$M_g = M_a \, \sigma_g^{(-1/2 \ln \sigma_g)}$$

where:

M_g = annual geometric mean, $\mu g/m^3$

M_a = annual arithmetic mean, $\mu g/m^3$

σ_g = standard geometric deviation, $\mu g/m^3$

Geometric means calculated for the Iron Range study are shown in Tables 8-4 and 8-5. As seen, calculated geometric means were always somewhat less than the arithmetic means for the same locations.

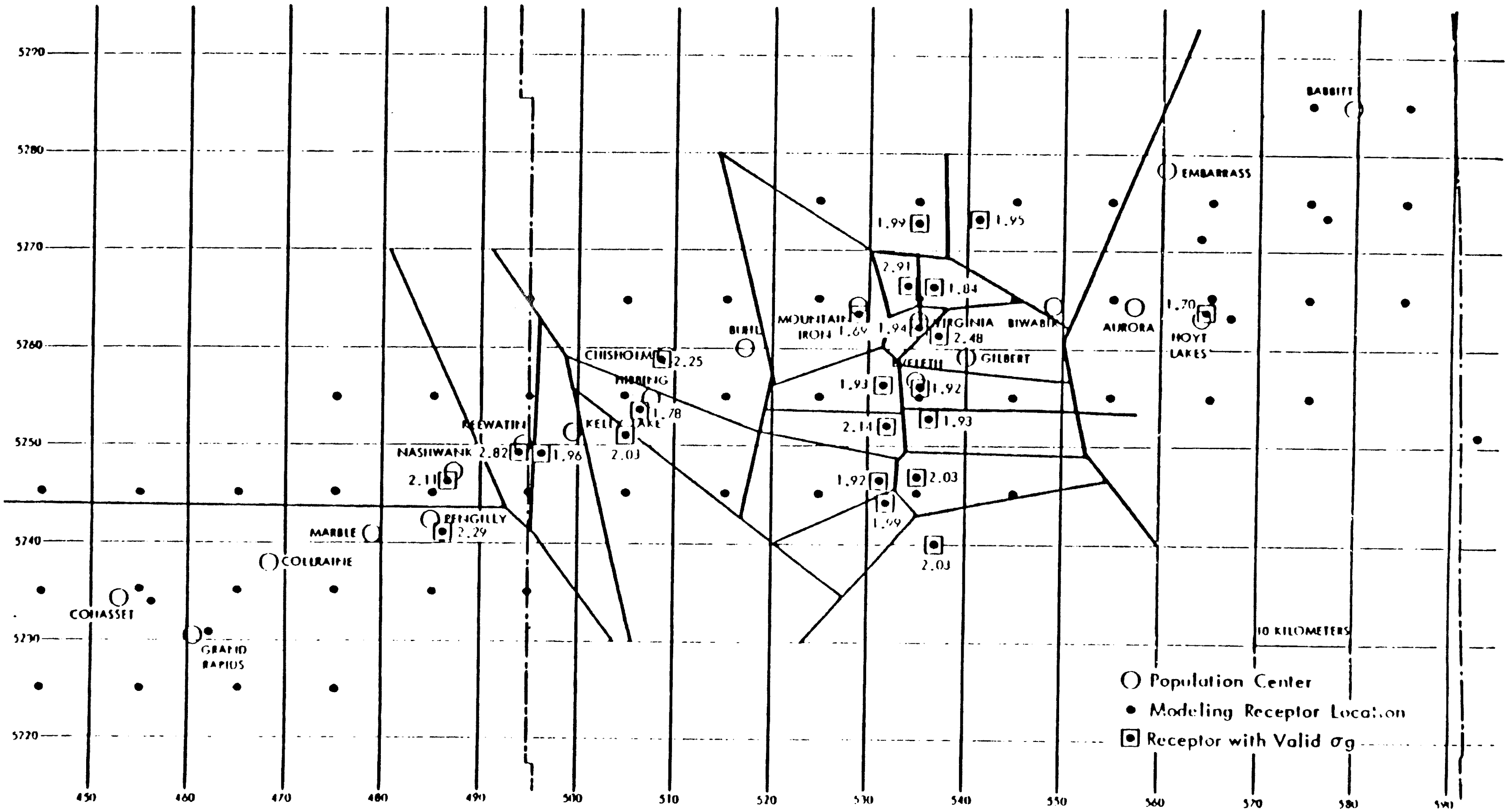


Figure 8-3. Apportioning of 1976 Standard Geometric Deviations by the Theissen Polygon Method.

APPLICATION OF LARSEN STATISTICAL METHOD TO 1976 MODELING RESULTS

Receptor Identification	UTM Coordinates East	UTM Coordinates North	Predicted 1976 Arithmetic Mean ($\mu g/m^3$)	1976 Standard Geometric Deviation ($\mu g/m^3$)[a]	Standard Geometric Deviation Observed (O) or Estimated (E)	Predicted 1976 Geometric Mean ($\mu g/m^3$)	Predicted 1976 Second Highest 24-hr Concentration ($\mu g/m^3$)[c]
7002	586	5305	36.3	2.16	E[b]	27.0	120.2
7517	585	5306	36.6	2.16	O	27.2	121.2
7008	564	5271	78.8	1.70	E[b]	68.5	191.6
1102	462	5231	39.3	2.29	E[b]	27.9	139.1
7516	506	5253	43.9	1.78	O	37.2	113.8
7010	567	5263	45.0	1.70	E[b]	39.1	109.4
7520	564	5263	44.4	1.70	O	38.6	108.0
7514	529	5264	63.6	1.69	O	55.4	153.4
1300	535	5263	64.9	1.94	O	52.1	188.5
1103	456	5233	38.8	2.29	E[b]	27.5	137.4
7003	595	5296	36.0	1.70	E[b]	31.3	87.5
7006	577	5273	44.0	1.70	E[b]	38.2	107.0
7007	592	5251	36.8	1.70	E[b]	32.0	89.5
1	532	5256	47.9	1.93	O	38.6	138.2
2	535	5256	49.2	1.92	O	39.8	141.0
3	532	5252	46.0	2.14	O	34.4	150.7
4	536	5253	35.5	1.93	O	28.6	102.4
5	531	5247	44.8	1.92	O	36.2	128.4
6	535	5247	43.9	2.03	O	34.2	134.9
7	532	5244	46.4	1.99	O	36.6	139.1
8	537	5240	41.2	2.03	O	32.1	126.6
13	509	5259	42.5	2.25	O	30.6	147.5
18	505	5251	44.8	2.03	O	34.9	137.7
21	541	5273	41.6	1.95	O	33.3	121.6
22	535	5273	43.6	1.99	O	34.4	130.7
23	536	5266	52.2	1.84	O	43.3	141.5
24	534	5266	51.3	2.91	O	30.1	239.3
25	537	5262	48.9	2.48	O	32.4	188.5
31	487	5246	44.9	2.11	O	34.0	144.6
32	486	5242	49.3	2.29	O	35.0	174.5
34	497	5249	67.4	1.96	O	53.7	198.3
35	494	5249	47.0	2.82	O	27.5	205.5
C1	445	5225	36.7	2.29	E	26.0	129.9
C2	445	5235	37.4	2.29	E	26.5	132.4
C3	445	5245	38.0	2.11	E	28.8	122.4
C4	455	5225	39.0	2.29	E	27.7	138.1
C5	455	5235	38.5	2.29	E	27.3	136.3
C6	455	5245	38.4	2.11	E	29.1	123.7
C7	465	5225	38.0	2.29	E	27.0	134.5
C8	465	5235	38.2	2.29	E	27.1	135.2
C9	465	5245	38.5	2.11	E	29.1	124.0

Receptor Identi- fication	UTM Coordinates East	UTM Coordinates North	Predicted 1976 Arithmetic Mean ($\mu g/m^3$)	Predicted 1976 Standard Geometric Deviation ($\mu g/m^3$)a/	Standard Geometric Deviation Observed (O) or Estimated (E)	Predicted 1976 Geometric Mean ($\mu g/m^3$)	Predicted 1976 Second Highest 24-hr Concentration ($\mu g/m^3$)c/
G10	475	5225	37.4	2.29	E	26.5	132.4
G11	475	5235	38.1	2.29	E	27.0	134.9
G12	475	5245	38.4	2.11	E	29.1	123.7
G13	475	5255	37.8	2.11	E	28.6	121.8
G14	485	5235	39.2	2.29	E	27.8	138.8
G15	485	5245	88.3	2.11	E	66.8	284.4
G16	485	5255	39.6	2.11	E	30.0	127.6
G17	495	5235	39.0	2.29	E	27.7	138.1
G18	495	5245	45.0	2.39	E	30.8	166.9
G19	495	5255	47.1	2.39	E	32.2	174.7
G20	495	5265	39.6	2.54	E	25.6	156.5
G21	505	5245	41.4	2.03	E	32.2	127.3
G22	505	5255	43.1	1.78	E	36.5	111.7
G23	505	5265	40.9	2.25	E	29.4	142.0
G24	515	5245	39.7	1.78	E	33.6	102.9
G25	515	5255	41.1	2.25	E	29.6	142.7
G26	515	5265	40.2	2.25	E	28.9	139.5
G27	525	5245	41.8	1.92	E	33.8	119.8
G28	525	5255	44.4	1.93	E	35.8	128.1
G29	525	5265	113.9	1.69	E	99.3	274.7
G30	525	5275	43.3	1.99	E	34.2	129.8
G31	535	5245	44.0	2.03	E	34.2	135.2
G32	535	5255	46.7	1.92	E	37.7	133.8
G33	535	5265	58.4	2.38	E	40.1	215.6
G34	535	5275	43.0	1.99	E	33.9	128.9
G35	545	5245	41.0	2.03	E	31.9	126.0
G36	545	5255	42.2	1.92	E	34.1	120.9
G37	545	5265	41.6	2.09	E	31.7	132.5
G38	545	5275	40.2	1.95	E	32.2	117.5
G39	555	5255	40.9	1.70	E	35.5	99.5
G40	555	5265	41.1	1.70	E	35.7	99.9
G41	555	5275	40.5	1.95	E	32.4	118.4
G42	565	5255	40.8	1.70	E	35.4	99.2
G43	565	5265	46.2	1.70	E	40.1	112.3
G44	565	5275	67.3	1.70	E	58.5	163.7
G45	575	5255	39.6	1.70	E	34.4	96.3
G46	575	5265	40.4	1.70	E	35.1	98.2
G47	575	5275	53.6	1.70	E	46.6	130.3
G48	575	5285	40.0	1.70	E	34.7	97.3
G49	585	5265	38.5	1.70	E	33.4	93.6
G50	585	5275	42.3	1.70	E	36.7	102.9
G51	585	5285	42.2	1.70	E	36.7	102.6

a/ See Figure 8-3 for all estimated values.

b/ Observed standard geometric deviation at this station based on less than 30 observations--not used.

c/ Based on 60 samples per year.

TABLE 8-5

APPLICATION OF LARSEN STATISTICAL METHOD TO 1982 MODELING RESULTS

Receptor Identification	UTM Coordinates East	UTM Coordinates North	Predicted 1982 Arithmetic Mean ($\mu g/m^3$)	1982 Standard Geometric Deviation ($\mu g/m^3$)[a]	Predicted 1982 Geometric Mean ($\mu g/m^3$)	Predicted 1982 Second Highest 24-hr Concentration ($\mu g/m^3$)[b]
7002	586	5305	36.6	2.16	27.2	121.2
7517	585	5306	37.0	2.16	27.5	122.5
7008	564	5271	80.3	1.70	69.8	195.3
1103	462	5231	39.5	2.29	28.0	139.8
7516	506	5253	52.5	1.78	44.5	136.1
7010	567	5263	45.7	1.70	39.7	111.1
7520	564	5263	45.3	1.70	39.4	110.2
7514	529	5264	72.2	1.69	62.9	174.1
1300	535	5263	71.7	1.94	57.6	208.2
1103	456	5233	39.0	2.29	27.7	138.1
7003	595	5296	36.2	1.70	31.4	88.0
7006	577	5273	44.5	1.70	38.7	108.2
7007	592	5251	37.3	1.70	32.4	90.7
1	532	5256	57.7	1.93	46.5	166.4
2	535	5256	64.5	1.92	52.1	184.8
3	532	5252	51.4	2.14	38.5	168.4
4	536	5253	36.0	1.93	29.0	103.8
5	531	5247	50.9	1.92	41.1	145.9
6	535	5247	49.1	2.03	38.2	150.9
7	532	5244	50.1	1.99	39.5	150.2
8	537	5240	44.6	2.03	34.7	137.1
13	509	5259	45.4	2.25	32.7	157.6
18	505	5251	51.1	2.03	39.8	157.1
21	541	5273	43.7	1.95	35.0	127.7
22	535	5273	46.8	1.99	36.9	140.3
23	536	5266	83.9	1.84	69.7	227.4
24	534	5266	61.5	2.91	34.8	276.1
25	537	5262	57.2	2.48	37.9	220.5
31	487	5246	45.7	2.11	34.6	147.2
32	486	5242	50.1	2.29	35.5	177.4
34	497	5249	73.9	1.96	58.9	217.4
35	494	5249	50.5	2.82	29.5	220.5
G1	445	5225	37.0	2.29	26.3	131.0
G2	445	5235	37.7	2.29	26.7	133.5
G3	445	5245	38.1	2.11	28.8	122.7
G4	455	5225	39.3	2.29	27.9	139.1
G5	455	5235	38.7	2.29	27.5	137.0
G6	455	5245	38.6	2.11	29.2	124.3
G7	465	5225	38.2	2.29	27.1	135.2
G8	465	5235	37.7	2.29	26.7	133.5
G9	465	5245	38.7	2.11	29.3	124.7

TABLE 8-5 (concluded)

Receptor Identification	UTM Coordinates East	UTM Coordinates North	Predicted 1982 Arithmetic Mean (μg/m³)	1982 Standard Geometric Deviation (μg/m³)a/	Predicted 1982 Geometric Mean (μg/m³)	Predicted 1982 Second Highest 24-hr Concentration (μg/m³)b/
G10	475	5225	37.7	2.29	26.7	133.5
G11	475	5235	38.3	2.29	27.2	135.6
G12	475	5245	38.4	2.11	29.1	123.7
G13	475	5255	38.4	2.11	29.1	123.7
G14	485	5235	39.6	2.29	28.1	140.2
G15	485	5245	89.4	2.11	67.7	288.0
G16	485	5255	40.0	2.11	30.3	128.9
G17	495	5235	40.0	2.29	28.4	141.6
G18	495	5245	46.9	2.39	32.1	173.9
G19	495	5255	50.7	2.39	34.7	188.0
G20	495	5265	41.8	2.54	27.1	165.1
G21	505	5245	43.6	2.03	33.9	134.0
G22	505	5255	59.1	1.78	50.0	153.2
G23	505	5265	45.4	2.25	32.7	157.6
G24	515	5245	41.7	1.78	35.3	108.1
G25	515	5255	42.9	2.25	30.9	148.9
G26	515	5265	42.2	2.25	30.4	146.5
G27	525	5245	44.3	1.92	35.8	126.9
G28	525	5255	47.5	1.93	38.3	137.0
G29	525	5265	128.9	1.69	112.3	310.9
G30	525	5275	49.3	1.99	38.9	147.8
G31	535	5245	48.9	2.03	38.1	150.3
G32	535	5255	69.0	1.92	55.8	197.7
G33	535	5265	65.6	2.38	45.0	242.2
G34	535	5275	46.7	1.99	36.9	140.0
G35	545	5245	43.1	2.03	33.5	132.5
G36	545	5255	44.7	1.92	36.1	128.1
G37	545	5265	43.4	2.09	33.1	138.2
G38	545	5275	42.0	1.95	33.6	122.8
G39	555	5255	41.9	1.70	36.4	101.9
G40	555	5265	42.0	1.70	36.5	102.1
G41	555	5275	41.6	1.95	33.3	121.6
G42	565	5255	41.4	1.70	36.0	100.7
G43	565	5265	47.0	1.70	40.8	114.3
G44	565	5275	68.5	1.70	59.5	166.6
G45	575	5255	40.1	1.70	34.8	97.5
G46	575	5265	41.1	1.70	35.7	99.9
G47	575	5275	54.3	1.70	47.2	132.0
G48	575	5285	40.4	1.70	35.1	98.2
G49	585	5265	38.9	1.70	33.8	94.6
G50	585	5275	42.5	1.70	36.9	103.4
G51	585	5285	42.6	1.70	37.0	103.6

a/ See Figure 8-3 for all estimated values.
b/ Based on 60 samples per year.

8.3.3 Second maximum 24-hr concentrations: Second maximum 24-hr averages were based on an every-6th-day sampling schedule. Thus, each of the values calculated represented the expected second maximum of 60 hi-vol samples.

The first step in determining the second maxima by Larsen's technique was to calculate a frequency of occurrence equivalent to the second maximum of 60 samples:

$$f = 100\% \frac{(r - 0.4)}{n}$$

where:

f = frequency of occurrence, %

r = rank order of observation

n = total number of samples

A frequency of 2.67% was calculated for the Iron Range analysis, from which a Z-value of 1.94 was derived. Using this Z-value, the second maximum 24-hr concentration could be determined from:

$$C_{2nd} \max = M_g \sigma_g^{1.94}$$

The 1976 and 1982 second maxima calculated by this procedure are shown in Tables 8-4 and 8-5.

Some inaccuracy was introduced into the final results by the necessity of estimating standard geometric deviations for many receptors. Accuracy in σ_g was not critical in determining annual geometric means. However, second maximum 24-hr averages, as calculated by the Larsen technique, were quite sensitive to variations of σ_g. The influence of estimated values of σ_g should be considered when analyzing these results, particularly the predicted second maxima.

8.4 Air Quality in the Mesabi Iron Range - General

Final predicted TSP levels at the modeling receptor points were used to assess ambient air quality trends in the Mesabi Iron Range. Four isopleth maps, one each for 1976 and 1982 annual geometric means and secone highest 24-hr averages, were prepared for this purpose.

8.4.1 Methodology: The MPCA has defined ambient air as that beyond the property boundaries of pollutant sources. Receptors located within such boundaries had to be excluded from the isopleth analysis. The status of many of the 83 receptors could not be determined, however, due to inadequate data on property boundary locations. To avoid this problem, nonambient receptors were identified and excluded using the following procedure.

Only receptors which exceeded secondary standards for TSP in 1976 or 1982 were considered for elimination. There were 16 such receptors in 1976. Of these, four could be located on mining company property with certainty (in pit, on storage pile, etc.) and were immediately eliminated from the isopleth analysis. Twenty-eight receptors exceeded secondary standards in 1982; eight were immediately eliminated.

Additional violation receptors were eliminated from the isopleth analysis when two conditions were satisfied:

1. The receptor must lie within 1 km of a modeled point source or mining emissions grid.

2. The receptor must lie at least 1/4 km away from all populated areas.

Five receptors were excluded from the 1976 geometric mean isopleth analysis on this basis, with nine eliminated in 1982. Ten receptors were excluded from the 1976 second maximum 24-hr average analysis, with 16 eliminated in 1982. Tables 8-6 and 8-7 summarize the results of nonambient receptor elimination.

Once only receptor points representative of ambient air remained, predicted concentrations were plotted at appropriate locations on Iron Range skeleton maps. Isopleths were then drawn, using linear interpolation when placing contours between receptors.

8.4.2 Analysis: As shown in Figure 8-4, no violations of the annual secondary standard were predicted for 1976. Three distinct areas of TSP impact were identified. In one area, the maximum isopleth, 50 $\mu g/m^3$, centered on Pengilly. The next area was located in the central portion of the Iron Range. The maximum isopleth, 50 $\mu g/m^3$, enclosed Virginia and Mountain Iron and reached almost to Eveleth. A western maximum, 45 $\mu g/m^3$, was located between Hoyt Lakes and Babbitt.

Second maximum 24-hr averages for 1976 (Figure 8-5) produced a more complex pattern. Much of the western and middle portions of the Iron Range were within 20 $\mu g/m^3$ of the secondary standard, with three separate secondary nonattainment areas identified. The most intense area of violation was centered on Keewatin and included Kelly Lake, Nashwank, and

TABLE 8-6

DETERMINATION OF AMBIENT/NON-AMBIENT CONDITIONS AT VIOLATION RECEPTORS - 1976

Receptor Identification	UTM Coordinates East	UTM Coordinates North	Predicted Air Quality: Annual Geometric Mean ($\mu g/m^3$)	Predicted Air Quality: Second Maximum 24-Hr Average ($\mu g/m^3$)	Within 1 km of Modeled Area or Point Source?	Within 1/4 km of Population Center?	Represents Ambient (A) or Non-Ambient (NA) Air[a/]
7008	564	5271	68.5	191.6	YES	NO	N
7514	529	5264	55.4	153.4	YES	YES	A
1300	535	5263	52.1	188.5	YES	YES	A
3	532	5252	34.4	150.7	YES	NO	N
24	534	5266	30.1	239.3	YES	NO	N
25	537	5262	32.4	188.5	YES	NO	N
32	486	5242	35.0	174.5	YES	YES	A
34	497	5249	53.7	198.3	YES	NO	N
35	494	5249	27.5	205.5	YES	YES	A
G 15	485	5245	66.8	284.4	YES	NO	N
G 18	495	5245	30.8	166.9	NO	NO	A
G 19	495	5255	32.2	174.7	YES	NO	N
G 20	495	5265	25.6	156.5	NO	NO	A
G 29	525	5265	99.3	274.7	YES	NO	N
G 33	535	5265	40.1	215.6	YES	NO	N
G 44	565	5275	58.5	163.7	YES	NO	N

a/ As defined in text.

TABLE 8-7

DETERMINATION OF AMBIENT/[illegible]-AMBIENT CONDITIONS AT VIOLATION RECEPTORS - 1982

Receptor Identification	UTM Coordinates East	UTM Coordinates North	Predicted Air Quality: Annual Geometric Mean ($\mu g/m^3$)	Predicted Air Quality: Second Maximum 24-Hr Average ($\mu g/m^3$)	Within 1 km of Modeled Area or Point Source?	Within 1/4 km of Population Center?	Represents Ambient (A) or Non-Ambient (N Air[a/]
7008	564	5271	69.8	195.3	YES	NO	N
7514	529	5264	62.9	174.1	YES	YES	A
1300	535	5263	57.9	208.2	YES	YES	A
1	532	5256	46.5	166.4	YES	YES	A
2	535	5256	52.1	184.8	YES	NO	N
3	532	5252	38.5	168.4	YES	NO	N
6	535	5247	38.2	150.9	NO	NO	A
7	532	5244	39.5	150.2	YES	NO	N
13	509	5259	32.7	157.6	YES	YES	A
18	505	5251	39.8	157.1	NO	YES	A
23	536	5266	69.7	227.4	YES	NO	N
24	534	5266	34.8	276.1	YES	NO	N
25	537	5262	37.9	220.5	YES	NO	N
32	486	5242	35.5	177.4	YES	YES	A
34	497	5249	58.9	217.4	YES	NO	N
35	494	5249	29.5	220.5	YES	YES	A
G 15	485	5245	67.7	288.0	YES	NO	N
G 18	495	5245	32.1	173.9	NO	NO	A
G 19	495	5255	34.7	188.0	YES	NO	N
G 20	495	5265	27.1	165.1	NO	NO	A
G 22	505	5255	50.0	153.2	YES	NO	N
G 23	505	5265	32.7	157.6	NO	NO	A
G 29	525	5265	112.3	310.9	YES	NO	N
G 31	535	5245	38.1	150.3	YES	NO	N
G 32	535	5255	55 8	197.7	YES	NO	N
G 33	535	535	45.0	242.2	YES	NO	N
G 44	565	5275	59.5	166.6	YES	NO	N

a/ As defined in text.

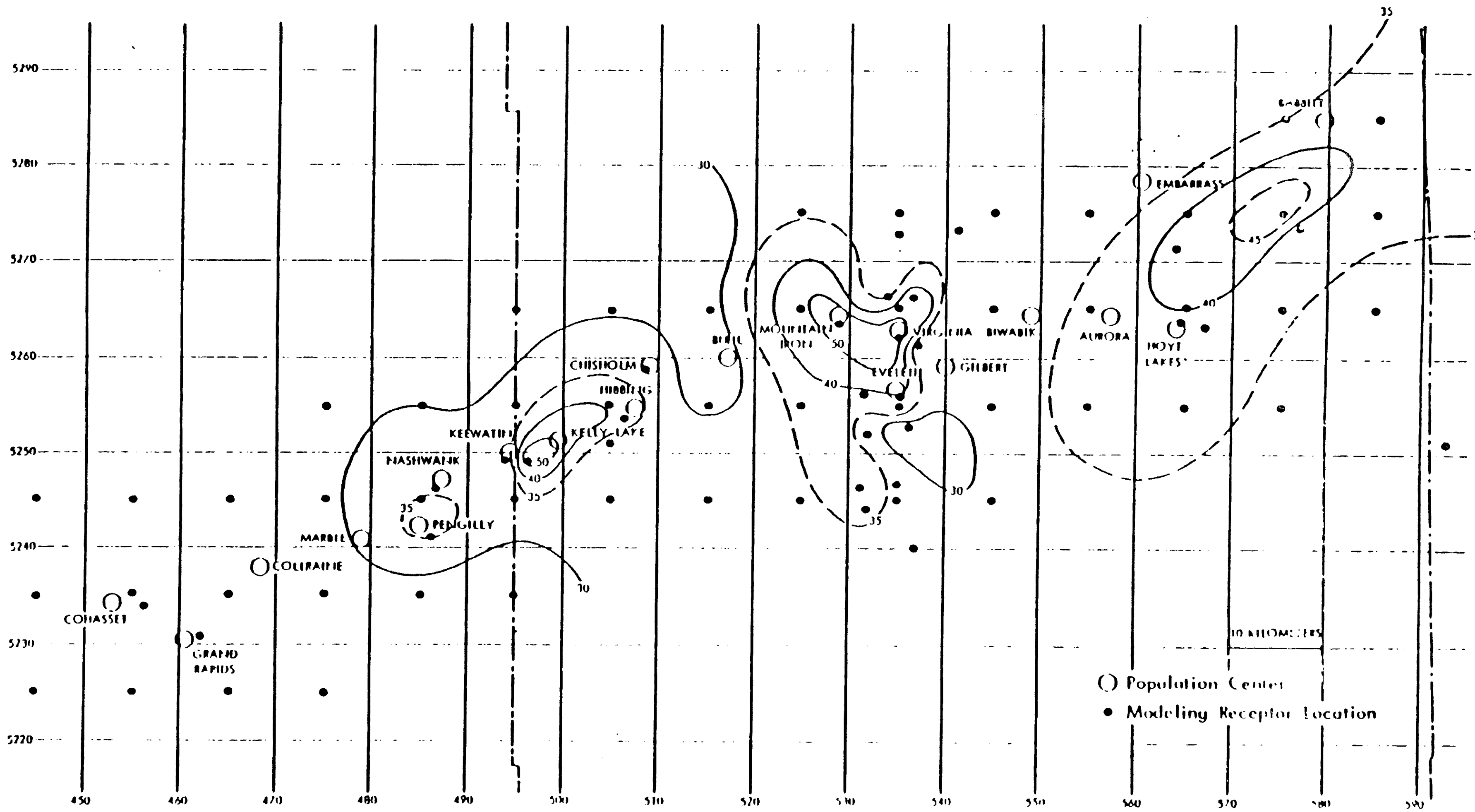


Figure 8-4. Model Predicted Annual Geometric Means - 1976.

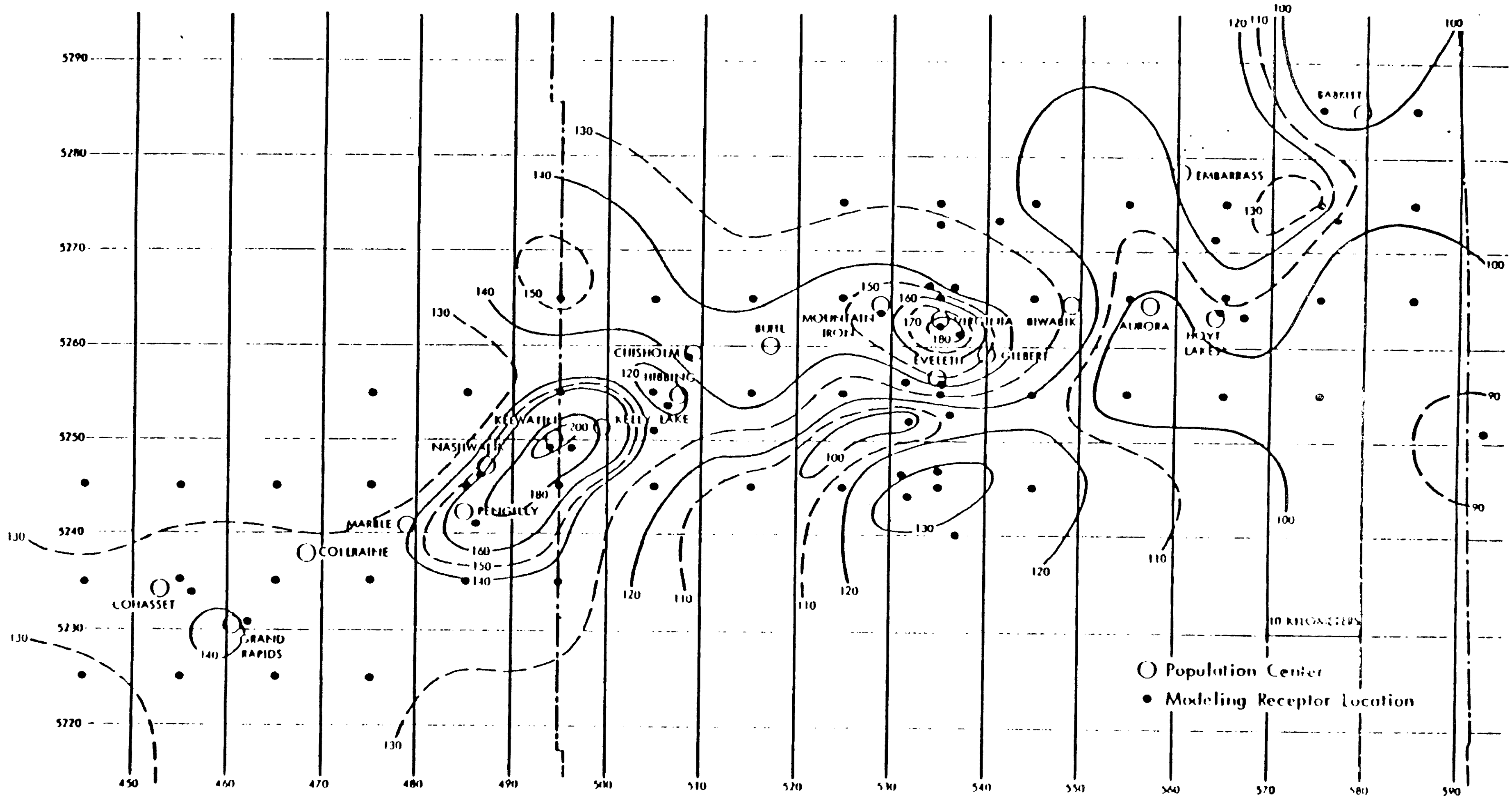


Figure 8-5. Model Predicted Second Maximum 24-Hr Concentrations - 1976.

Pengilly. The maximum isopleth was 200 $\mu g/m^3$. Another violation area was centered on Virginia and included Gilbert, Eveleth, and Mountain Iron. The maximum isopleth there was 180 $\mu g/m^3$. A less intense secondary nonattainment area was located approximately 15 km north of Keewatin, with 150 $\mu g/m^3$ the maximum isopleth.

Figure 8-6 shows the projected Iron Range annual geometric means for 1982. As can be seen, only a moderate deterioration in annual air quality is projected from 1976. There are three primary areas of projected air quality impact. The two regions near Pengilly and Kelly Lake changed little in intensity during the 6-year period but showed moderate expansion in size. The area centered between Virginia and Mountain Iron have grown both in size and in intensity. An area just exceeding secondary standards has developed in the center of this region, with excursions experienced from west of Mountain Iron eastward through the town to just west of Virginia. Most of the area of expansion of high concentrations in this region occurs to the west and north; little intensification is projected in the immediate vicinity of Eveleth. An additional small area of moderate concentrations, about 16 km south-southwest of Eveleth in 1976 has developed a closed contour at 40 $\mu g/m^3$ in 1982.

Portions of the Iron Range east of Biwabik and west of Marble have been most stable over the projection period. In the east, concentrations range from a maximum of approximately 45 $\mu g/m^3$ between Hoyt Lakes and Babbitt to less than 35 $\mu g/m^3$ at the modeling boundaries. In the west, annual geometric means remain below 30 $\mu g/m^3$.

A more substantial deterioration was projected for second maximum 24-hr concentrations, as shown in Figure 8-7. The secondary nonattainment area centered on Keewatin has more than doubled in size, growing mostly to the north and northeast. Included in this area are Keewatin, Kelly Lake, Nashwank, and Pengilly, with the addition of Chisholm and Buhl since 1976. The maximum isopleth is 220 $\mu g/m^3$, indicating a moderate growth in intensity as well. Though not yet exceeding secondary standards, the 24-hr second maximum in the Hibbing vicinity has also increased significantly.

The violation area centered on Virginia was also projected to grow in extent from 1976 to 1982. It has expanded principally to the northwest and north, though the boundary has moved beyond Gilbert to the southeast and Eveleth to the south. The maximum isopleth in 1982 is 200 $\mu g/m^3$, a moderate growth from 180 $\mu g/m^3$ in 1976.

A small area approximately 16 km south-southwest of Eveleth has become nonattainment in 1982, its maximum contour increasing from 130 to 150 $\mu g/m^3$. The regions east of Biwabik and west of Marble again show little change in the 6-year period, with second maxima of 130 $\mu g/m^3$ to less than 100 $\mu g/m^3$ in the east and below 140 $\mu g/m^3$ in the west.

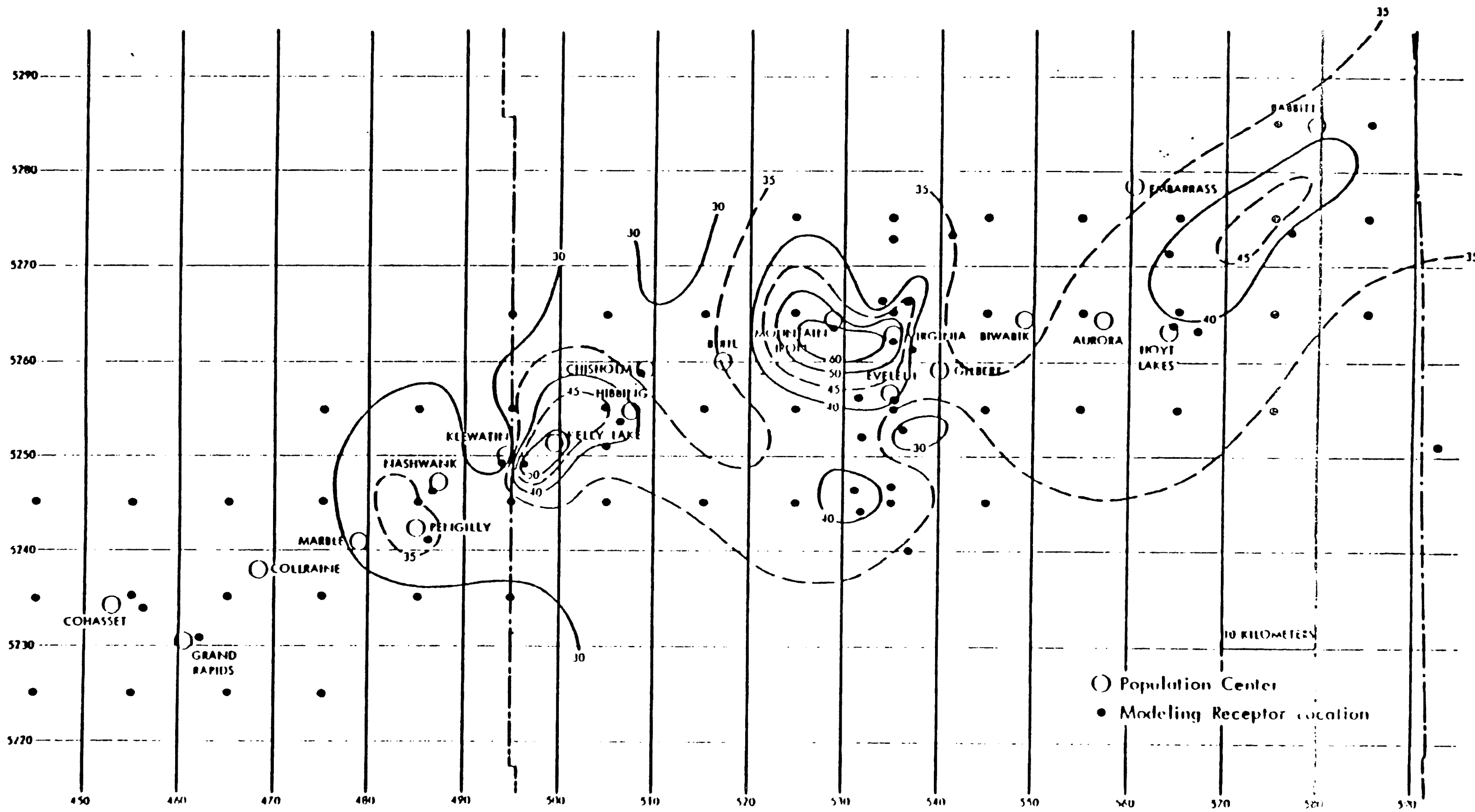


Figure 8-6. Model Predicted Annual Geometric Means - 1982.

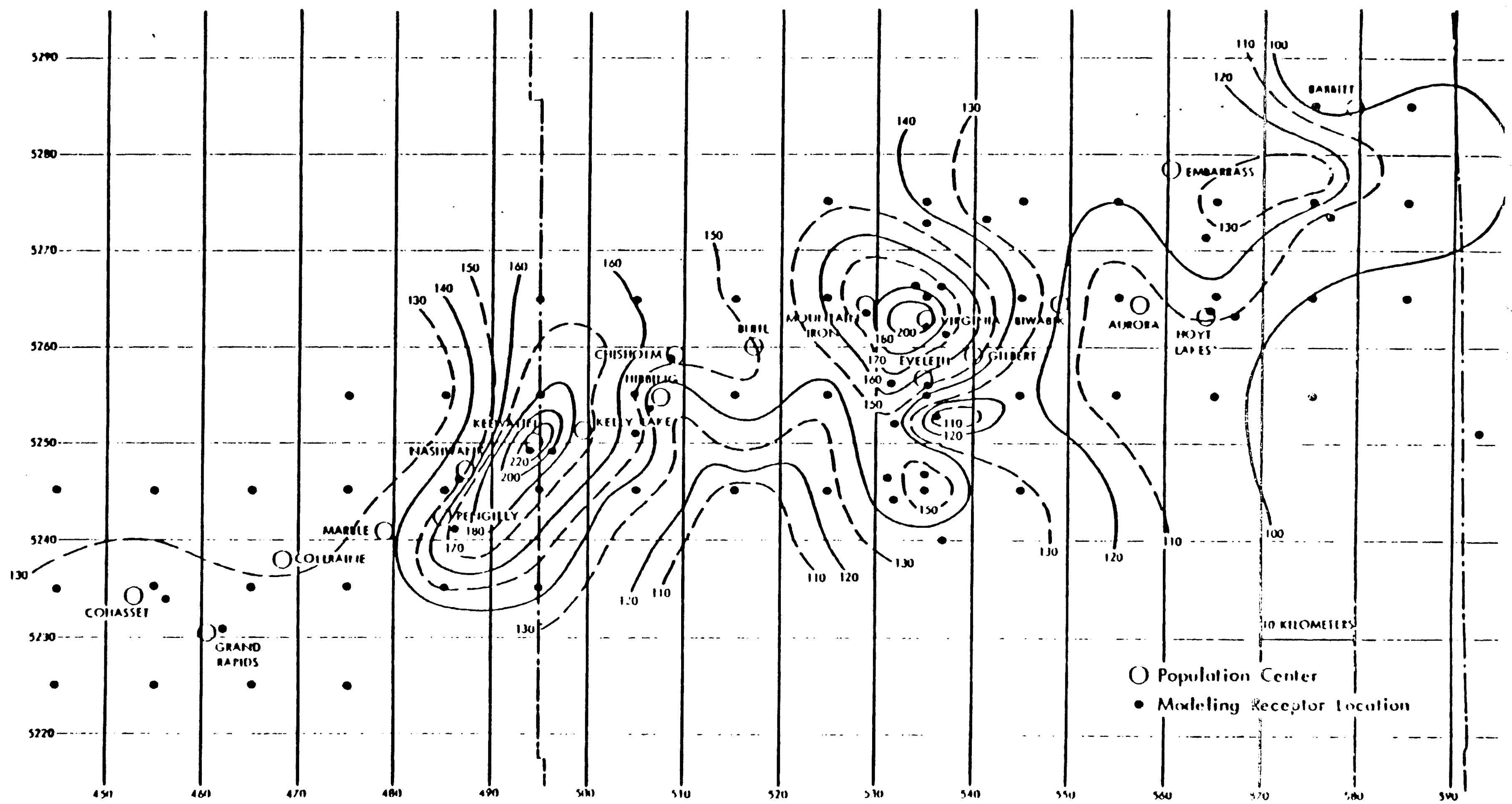


Figure 8-7. Model Predicted Second Maximum 24-Hr Concentrations - 1982.

8.5 Air Quality in the Mesabi Iron Range - Detailed Analysis

More detailed analyses were performed for specific receptors which indicated nonattainment of Minnesota Ambient Air Quality Standards and for trends in TSP concentrations between 1976 and 1982. Discussions of the results are presented below.

8.5.1 Nonattainment receptors: The modeling results for receptors which experienced air quality violations in 1976 or 1982 were further analyzed to identify major contributors to predicted TSP levels. The computation of source culpability lists was provided as an option in the CDMQC modeling package; but its use was prohibited by the large number of sources considered in the study (927 total for 1982). Instead, source contributions were assessed by MRI modeling, meteorological, and source characterization personnel. This was accomplished using the detailed (2 X 2 km) 1976 and 1982 area source emissions inventories, the 1976 and 1982 point source emissions inventories, the stability wind rose developed for the project, the detailed mining operations maps (1976 and 1982) provided by the source operators, and 7-1/2 minute U.S. Geological Survey topographic maps. In addition, the modeled air quality impacts at each receptor were separated into contributions from point sources, and from each of the three area source sub-regions (East, Middle, and West) for comparison with the other data.

The results of the analyses are presented in Tables 8-8 through 8-10 for 1976 nonattainment receptors and Tables 8-11 through 8-13 for 1982. Tables 8-8 and 8-11 show the location, both descriptive and in UTMC for each violating receptor in 1976 and 1982. As discussed earlier, some of the monitoring receptor locations did not coincide with the TSP monitoring stations they were intended to represent. However, these receptors did accurately represent air quality at the locations listed in the table. The 1976 and 1982 predicted annual geometric means and second maximum 24-hr averages are repeated for comparison, as is the status of each receptor for ambient or non-ambient representation. The major contributing point sources are listed for each receptor, along with the cumulative point source impact. The point sources are listed in order of their relative impact based on the culpability analysis. Numbers used to represent the point sources refer to Table 8-9 (1976) and to Table 8-12 (1982) where detailed descriptions of the sources are given. Area source culpabilities are also presented. The tables list the cumulative fugitive impacts at each receptor, then the major impacting area sources are listed vertically in order of importance. Numbers used to represent the area sources refer to Table 8-10 (1976) and Table 8-13 (1982) where detailed descriptions of the sources are given. The fugitive dust emissions categories contributing major impacts are listed for each site, again in order of importance. These numbers identify the 14 mining source categories presented in Table 4-1. No non-mining fugitive dust sources contributed significantly to air quality impact at any non-attainment receptors in 1976 or 1982.

TABLE 8-8

DETAILED ANALYSIS OF NON-ATTAINMENT RECEPTORS - 1976

Receptor Identification	Receptor Location: UTMC East	Receptor Location: UTMC North	Receptor Location: Descriptive	Predicted Air Quality: Annual Geometric Mean[a] Value	Predicted Air Quality: Annual Geometric Mean[a] Status	Predicted Air Quality: 24-Hr Second Maximum[a] Value	Predicted Air Quality: 24-Hr Second Maximum[a] Status	Represents Ambient Air?[b]	Point Source Impact (%)[c]	Major Contributing Point Sources[d,e]	Area Source Impact (%)[c]	Major Contributing Area Sources: Site[d,f]	Major Contributing Area Sources: Major Source Categories[d,g]
7008	564	5271	8 km N of Hoyt Lakes	68.5	V	191.6	V	NO	54	1,2	46	1	5,1,9,10,11,6,7,2
7514	529	5264	1/4 km E of Mountain Iron	55.4		153.4	V	YES	21	3	79	2 3 4	1,2 1,2 1
1300	535	5263	Virginia, S of City Hall	52.1		188.5	V	YES	44	3,4	56	3 2 4 5 6	1,2 1,2 1 1 1
3	532	5252	2 km E of Iron Junction	34.4		150.7	V	NO	29	5,3,4	71	4 7 3 2	1 1,8 1,2 1,2
24	534	5266	1-1/2 km N of Virginia, North Side	30.1		239.3	V	NO	25	4,3	75	6 5 4 3 2	1 1 1 1,2 1,2
25	537	5262	2-1/2 km ESE of Virginia	32.4		188.5	V	NO	30	4,3,5	70	5 4 6 3 2	1 1 1 1,2 1,2
12	486	5242	1 km E of Pengilly	35.0		174.5	V	YES	21	6,7	79	8 9	1,6,7,8 1

TABLE 8-8 (concluded)

Receptor Identification	Receptor Location: UTM East	Receptor Location: UTM North	Receptor Location: Descriptive	Predicted Air Quality: Annual Geometric Mean Value	Predicted Air Quality: Annual Geometric Mean Status[a]	Predicted Air Quality: 24-Hr Second Maximum Value	Predicted Air Quality: 24-Hr Second Maximum Status[a]	Predicted Air Quality: Represents Ambient Air?[b]	Point Source Impact (%)[c]	Major Contributing Point Sources[d,e]	Area Source Impact (%)[c]	Major Contributing Area Sources: Site[d,f]	Major Contributing Area Sources: Major Source Categories[d,g]
J4	497	5249	2-1/4 km E of Keewatin	53.7		198.3	V	NO	5	7,6	95	10 8 11	1,6,7,8 1,8,6,7 1
J5	494	5249	SW Keewatin	27.5		205.5	V	YES	8	7,6	92	10 8 11	1,6,7,8 1,8,6,7 1
G 15	485	5245	On stockpile 2-1/2 km N of Pengilly	66.8	V	284.4	V	NO	15	6,7	85	8 10	1,8,6,7 1,6,7,8
G 18	495	5245	4 km S of Keewatin	30.8		166.9	V	YES	11	7,6	89	10 8 11	1,6,7,8 1,8,6,7 1
G 19	495	5255	6 km N of Keewatin	32.2		174.7	V	NO	11	7,6	89	10 8 11	1,6,7,8 1,8,6,7 1
G 20	495	5265	16 km N of Keewatin	25.6		156.5	V	YES	15	7	85	10 8 11	1,6,7,8 1,8,6,7 1
G 29	525	5265	In Minntac West Pit 3 km NW of Mountain Iron	99.3	V	274.7	V	NO	3	3	97	2 3	1,2 1,2
G 33	535	5265	Mining storage pile area, 0.5 km NE of Virginia, North Side	40.1		215.6	V	NO	40	4,3	60	6 5 4 3 2	1 1 1 1,2 1,2
G 44	565	5275	In Erie Mining Company Tailings Basin No. 2, 3 km N of Erie Plant	58.5		163.7	V	NO	62	1,2	38	1	1,6,7,5,9, 10,11,2

a/ V = Applicable secondary standard violated.
b/ As defined for isopleth analysis.
c/ Excluding contribution of background.
d/ Listed in order of importance.
e/ See Table 8-9 for listing.
f/ See Table 8-10 for listing.
g/ See Table 4-1 for listing.

TABLE 8-9

MAJOR CONTRIBUTING POINT SOURCES AT NONATTAINMENT RECEPTORS - 1976

Identification[a]	Location: UTMC East	Location: UTMC North	Location: Descriptive	Activity	No. of Stacks	Operator
1	564.6	5271.6	8-1/2 km north of Hoyt Lakes	Taconite processing	99	Erie Mining Company
2	563.0	5264.2	Northwest shore of Colby Lake	Power production	2	Minnesota Power and Light
3	527.0	5268.0	3-1/2 km north of Mountain Iron	Taconite processing	15	U.S. Steel - Minntac
4	534.8	5263.2	Virginia, north of Chestnut Street	Power production	4	Virginia Department of Public Utilities
5	532.0	5244.0	1 km southwest of Peary	Taconite processing	17	Eveleth Taconite Company
6	485.0	5244.3	2-1/2 km north of Pengilly	Taconite processing	24	Butler Taconite Company
7	495.3	5250.8	2 km north-northeast of Keewatin	Taconite processing	44	National Steel Company

a/ As used in Table 8-8.

TABLE 8-10

MAJOR CONTRIBUTING AREA SOURCES AT NON-ATTAINMENT RECEPTORS - 1976

Identification[a]	Location	Activity	Operator
1	Erie Mine, NE of Aurora	Taconite mining	Erie Mining Company
2	Minntac West Pit, 3 km NW of Mountain Iron	Taconite mining	U.S. Steel-Minntac
3	Minntac East Pit, 3 km NE of Mountain Iron	Taconite mining	U.S. Steel-Minntac
4	Thunderbird Mine, 2 km N of Eveleth	Taconite mining	Eveleth Taconite
5	Rouchleau Mine, 1 km East of Virginia	Natural ore mining	Rouchleau Mine
6	Minorca Pit, 2 km NE of Virginia	Taconite mining	Inland Steel Company
7	Eveleth Plant, 1 km SW of Peary	Taconite processing	Eveleth Taconite
8	Butler Pit and Plant, N of Pengilly	Taconite mining and processing	Butler Taconite Company
9	Lind-Hill Mine, 3 km SW of Pengilly	Natural ore mining	Lind-Hill Mine
10	National Mine, N of Keewatin	Taconite mining and processing	National Steel
11	Hibbing Mine, 3 km N of Hibbing	Taconite mining and processing	Hibbing Taconite

a/ As used in Table 8-8.

TABLE 8-11

DETAILED ANALYSIS OF NONATTAINMENT RECEPTORS - 1982

Receptor Identification	Receptor Location: UTMC East	Receptor Location: UTMC North	Receptor Location: Descriptive	Predicted Air Quality: Annual Geometric Mean Value	Annual Geometric Mean Status[a]	24 Hr Second Maximum Value	24 Hr Second Maximum Status[a]	Represents Ambient Air?[b]	Point Source Impact (%)[c]	Major Contributing Point Sources[d,e]	Area Source Impact (%)[c]	Major Contributing Area Sources: Site[d,f]	Major Contributing Area Sources: Major Source Categories[d,g]
7008	564	5271	1 km SW of Erie Mining Co. Plant	69.8	V	195.3	V	No	53	1, 2	47	1	5, 1, 9, 10, 11, 6, 7, 2
7514	529	5264	1/4 km east of Mountain Iron	62.9	V	174.1	V	Yes	24	3, 4	76	2	1, 2
												3	1, 2
												4	1
												5	1
												6	1, 13
1300	535	5263	Virginia, S of City Hall	57.6		208.2	V	Yes	45	4, 3, 5	65	5	1
												3	1, 2
												2	1, 2
												4	1
												6	1, 13
												7	1
1	532	5256	DeForest Village	46.5		166.4	V	Yes	25	4, 3, 6, 5	75	6	1, 13
												4	1
												5	1
												3	1, 2
												2	1, 2
												8	1, 8
2	535	5256	On storage pile, 1/4 km S of Eveleth	52.1		184.8	V	No	20	4, 3, 6, 5	80	6	1, 13
												4	1
												5	1
												3	1, 2
												2	1, 2
												8	1, 8
3	532	5252	2 km E of Iron Junction	38.5		168.4	V	No	37	6, 4, 3, 5	63	6	1, 13
												4	1
												8	1, 8
												5	1
												3	1, 2
												2	1, 2

TABLE 8-11 (continued)

Receptor Identification	Receptor Location: UTMC East	Receptor Location: UTMC North	Receptor Location: Descriptive	Predicted Air Quality: Annual Geometric Mean Value	Annual Geometric Mean Status[a]	Predicted Air Quality: 24 Hr Second Maximum Value	24 Hr Second Maximum Status[a]	Represents Ambient Air?[b]	Point Source Impact (%)[c]	Major Contributing Point Sources[d,e]	Area Source Impact (%)[c]	Major Contributing Area Sources: Site[d,f]	Major Contributing Area Sources: Major Source Categories[d,g]
6	535	5247	2 km NE of Peary	38.2		150.9	V	Yes	42	6, 4, 3, 5	58	8	1, 8, 6, 7
												6	1, 13
												4	1
7	532	5244	SW edge of Eveleth Plant	39.5		150.2	V	No	15	6, 4, 3, 5	85	8	1, 8, 6, 7
												6	1, 13
												4	1
13	509	5259	Chisholm, 0.1 km N of Roosevelt School	32.7		157.6	V	Yes	13	7, 8, 3	87	9	1, 6, 7, 13, 3, 4
												10	1, 6, 7, 8, 3, 4
												11	1
												2	1, 2
												3	1, 2
18	505	5251	Hibbing, 1 km E of Cobb-Cook School	39.8		157.1	V	Yes	10	7, 8, 3	90	9	1, 6, 7, 13, 3, 4
												10	1, 6, 7, 8, 3, 4
												11	1
												2	1, 2
												3	1, 2
23	536	5266	Storage piles, 2 km NE of Virginia, north side	69.7	V	227.4	V	No	14	4, 3, 5, 6	86	5	1
												3	1, 2
												2	1, 2
												4	1
												6	1, 13
												7	1
24	534	5266	1-1/2 km N of Virginia, north side	34.8		276.1	V	No	28	4, 3, 5, 6	72	5	1
												3	1, 2
												2	1, 2
												4	1
												6	1, 13
												7	1
25	537	5262	2-1/2 km ESE of Virginia	37.9		220.5	V	No		4, 3, 5, 6		5	1
												4	1
												7	1
												6	1, 13
												3	1, 2
												2	1, 2

TABLE 8-11 (continued)

Receptor Identi-fication	Receptor Location: UTMC East	Receptor Location: UTMC North	Receptor Location: Descriptive	Predicted Air Quality: Annual Geometric Mean Value	Predicted Air Quality: Annual Geometric Mean Status[a]	Predicted Air Quality: 24 Hr Second Maximum Value	Predicted Air Quality: 24 Hr Second Maximum Status[a]	Represents Ambient Air?[b]	Point Source Impact (%)[c]	Major Contributing Point Sources[d,e]	Area Source Impact (%)[c]	Major Contributing Area Sources: Site[d,f]	Major Contributing Area Sources: Major Source Categories[d,g]
32	486	5242	1 km East of Pengilly	35.5		177.4	V	Yes	23	9, 8, 7	77	12	1, 6, 7, 8
												10	1, 6, 7, 8, 3, 4
												9	1, 6, 7, 13, 3, 4
34	497	5249	2-1/4 km E of Keewatin	58.9		217.4	V	No	9	8, 9, 7	91	10	1, 6, 7, 8, 3, 4
												12	1, 6, 7, 8
												9	1, 6, 7, 13, 3, 4
35	494	5249	SW Keewatin	29.5		220.5	V	Yes	11	8, 9, 7	89	10	1, 6, 7, 8, 3, 4
												12	1, 6, 7, 8
												9	1, 6, 7, 13, 3, 4
G15	485	5245	On stockpile 2-1/2 km N of Pengilly	67.7	V	288.0	V	No	15	9, 8, 7	85	12	1, 6, 7, 8
												10	1, 6, 7, 8, 3, 4
G18	495	5245	4 km S of Keewatin	32.1		173.9	V	Yes	17	8, 9, 7	83	10	1, 6, 7, 8, 3, 4
												12	1, 6, 7, 8
												9	1, 6, 7, 13, 3, 4
G19	495	5255	6 km N of Keewatin	34.7		188.0	V	No	16	8, 9, 7	84	10	1, 6, 7, 8, 3, 4
												12	1, 6, 7, 8
												9	1, 6, 7, 13, 3, 4
G20	495	5265	16 km N of Keewatin	27.1		165.1	V	Yes	19	8, 9, 7	81	9	1, 6, 7, 13, 3, 4
												10	1, 6, 7, 8, 3, 4
												12	1, 6, 7, 8
G22	505	5255	2 km N of Hibbing	50.0		153.2	V	No	7	7, 8	93	9	1, 6, 7, 13, 3, 4
												10	1, 6, 7, 8, 3, 4
G23	505	5265	12 km N of Hibbing	32.7		157.6	V	Yes	13	7, 8	87	9	1, 6, 7, 13, 3, 4
												10	1, 6, 7, 8, 3, 4
G29	525	5265	Minntac West Pit, 3 km NW of Mountain Iron	112.3	V	310.9	V	No	4	3	96	2	1, 2
												3	1, 2
G31	535	5245	2 km SE of Peary	38.1		150.3	V	No	46	6, 4, 3, 5	54	8	1, 8, 6, 7
												6	1, 13
												4	1

TABLE 8-11 (concluded)

Receptor Identification	Receptor Location: UTMC East	Receptor Location: UTMC North	Receptor Location: Descriptive	Predicted Air Quality: Annual Geometric Mean Value	Annual Geometric Mean Status[a/]	24 Hr Second Maximum Value	24 Hr Second Maximum Status[a/]	Represents Ambient Air?[b/]	Point Source Impact (%)[c/]	Major Contributing Point Sources[d,e/]	Area Source Impact (%)[c/]	Major Contributing Area Sources: Site[d,f/]	Major Contributing Area Sources: Major Source Categories[d,g/]
G32	535	5255	1 km S of Eveleth	55.8		197.7	V	No	16	6, 4, 3, 5	84	6 8 4	1, 13 1, 8, 6, 7 1
G33	535	5265	Mining storage area, 1/2 km NE of Virginia, north side	45.0		242.2	V	No	39	4, 5, 3	61	5 3 2 4 6 7	1 1, 2 1, 2 1 1, 13 1
G44	565	5275	Erie Mining Company tailings basin No. 2, 3 km N of Erie plant	59.5		166.6	V	No	61	1, 2	39	1	1, 6, 7, 5, 9, 10, 11, 12

a/ V = applicable secondary standard violated.
b/ As defined for isopleth analysis.
c/ Excluding contribution of background.
d/ Listed in order of importance.
e/ See Table 8-12 for listing.
f/ See Table 8-13 for listing.
g/ See Table 4-1 for listing.

TABLE 8-12

MAJOR CONTRIBUTING POINT SOURCES AT NONATTAINMENT RECEPTORS - 1982

Identification[a]	Location: UTMC East	Location: UTMC North	Location: Descriptive	Activity	No. of Stacks	Operator
1	564.6	5271.6	8-1/2 km north of Hoyt Lakes	Taconite processing	99	Erie Mining Company
2	563.0	5264.2	Northwest shore of Colby Lake	Power production	2	Minnesota Power and Light
3	527.0	5268.0	3-1/2 north of Mountain Iron	Taconite processing	15	U.S. Steel - Minntac
4	534.0	5264.0	Northwest of Silver Lake	Taconite processing	20	Inland Steel
5	534.8	5263.2	Virginia, north of Chestnut Street	Power production	4	Virginia Department of Public Utilities
6	532.0	5244.0	1 km southwest of Peary	Taconite processing	17	Eveleth Taconite Company
7	502.0	5258.0	1-1/2 km southeast of Rock Lake	Taconite processing	21	Hibbing Taconite Company
8	495.3	5250.8	2 km north-northeast of Keewatin	Taconite processing	44	National Steel
9	485.0	5244.3	2/-1/2 km north of Pengilly	Taconite processing	24	Butler Taconite Company

a/ As used in Table 8-11.

TABLE 8-13

MAJOR CONTRIBUTING AREA SOURCES AT NONATTAINMENT RECEPTORS - 1982

Identification[a]	Location	Activity	Operator
1	Erie Mine, northeast of Aurora	Taconite mining	Erie Mining Company
2	Minntac west pit, 3 km northwest of Mountain Iron	Taconite mining	U.S. Steel - Minntac
3	Minntac east pit, 3 km northeast of Mountain Iron	Taconite mining	U.S. Steel - Minntac
4	Thunderbird Mine, 2 km north of Eveleth	Taconite mining	Eveleth Taconite
5	Minorca pit, 2 km northeast of Virgina North Side	Taconite mining	Inland Steel
6	Eveleth Fayal pit, south and southwest of Eveleth	Taconite mining	Eveleth Taconite
7	Rouchleau Mine, 1 km east of Virgina	Natural ore mining	Rouchleau Mine
8	Eveleth plant, 1 km southwest of Peary	Taconite processing	Eveleth Taconite
9	Hibbing Mine, northwest of Hibbing	Taconite mining	Hibbing Taconite Company
10	National Mine, north of Keewatin	Taconite mining	National Steel
11	Sherman Mines, 2-1/2 km east of Chisholm	Natural ore mining	Sherman Mine Group
12	Butler pit and plant, north of Pengilly	Taconite mining and processing	Butler Taconite Company

a/ As used in Table 8-11.

8.5.2 Air quality trends, 1976 to 1982: The predicted 1976 to 1982 trends in annual geometric means are presented in Table 8-14. Second maximum 24-hr concentration trends are listed in Table 8-15. As shown, most receptors experienced only moderate deterioration in annual air quality, with corresponding increases in predicted second maximum 24-hr concentrations. At a majority of sites, the annual geometric mean increased less than 1 $\mu g/m^3$ during the period, with few stations growing more than 10 $\mu g/m^3$. However, air quality changed substantially at some sites, as discussed below.

At MPCA site No. 2 the annual geometric mean increased by 12.3 $\mu g/m^3$, with a 43.8 $\mu g/m^3$ growth in the second maximum. This was caused primarily by fugitive emissions from the proposed mining activities in Eveleth's Fayal open pit mine, which was not operating in 1976. The boundary of the pit is located 1/2 km south of the receptor.

At receptor No. 23, the annual geometric mean increased 26.4 $\mu g/m^3$, exceeding the secondary standard in 1982. The 24-hr second maximum concentration increased 85.9 $\mu g/m^3$, producing a secondary violation. This deterioration of air quality was caused almost entirely by the large projected increase in fugitive dust emissions from Inland's Minorca pit, although some impact would be expected from Eveleth's Fayal operation and from increased activity in U.S. Steel's Minntac pits. The addition of Inland's stacks to the inventory for 1982 had relatively little effect on concentrations at the receptor.

Receptor No. G-8 experienced the only decrease in annual and second maximum concentrations produced by the model. This was caused by a cessation of emissions from the Lind-Hill natural ore mine, which is projected to be worked out by 1982.

At receptor No. G-22, the annual concentration increased 13.5 $\mu g/m^3$, with the second maximum up 41.5 $\mu g/m^3$. The air quality deterioration at this receptor was caused mostly by fugitive emissions from the substantially increased Hibbing Taconite operations. The addition of Hibbing stack emissions had relatively little effect on the concentration growth.

The annual geometric mean at receptor No. G-29 was up 13.0 $\mu g/m^3$, with a 36.2 $\mu g/m^3$ increase in the second maximum. This was due almost exclusively to growth in fugitive dust emissions associated with operations at U.S. Steel's Minntac west pit.

TABLE 8-14

PREDICTED AIR QUALITY TRENDS, 1976 - 1982, ANNUAL GEOMETRIC MEANS

Receptor Identification	UTM Coordinates East	UTM Coordinates North	Predicted Annual Geometric Means ($\mu g/m^3$) 1976	Predicted Annual Geometric Means ($\mu g/m^3$) 1982	1976 - 1982 Change ($\mu g/m^3$)
7002	586	5305	27.0	27.2	0.2
7517	585	5306	27.2	27.5	0.3
7008	564	5271	68.5	69.8	1.3
1102	462	5231	27.9	28.0	0.1
7516	506	5253	37.2	44.5	7.3
7010	567	5263	39.1	39.7	0.6
7520	564	5263	38.6	39.4	0.8
7514	529	5264	55.4	62.9	7.5
1300	535	5263	52.1	57.6	5.5
1103	456	5233	27.5	27.7	0.2
7003	595	5296	31.3	31.4	0.1
7006	577	5273	38.2	38.7	0.5
7007	592	5251	32.0	32.4	0.4
1	532	5256	38.6	46.5	7.9
2	535	5256	39.8	52.1	12.3
3	532	5252	34.4	38.5	4.1
4	536	5253	28.6	29.0	0.4
5	531	5247	36.2	41.1	4.9
6	535	5247	34.2	38.2	4.0
7	532	5244	36.6	39.5	2.9
8	537	5240	32.1	34.7	2.6
13	509	5259	30.6	32.7	2.1
18	505	5251	34.9	39.8	4.9
21	541	5273	33.3	35.0	1.7
22	535	5273	34.4	36.9	2.5
23	536	5266	43.3	69.7	26.4
24	534	5266	30.1	34.8	4.7
25	537	5262	32.4	37.9	5.5
31	487	5246	34.0	34.6	0.6
32	486	5242	35.0	35.5	0.5
34	497	5249	53.7	58.9	5.2
35	494	5249	27.5	29.5	2.0
G1	445	5225	26.0	26.3	0.3
G2	445	5235	26.5	26.7	0.2
G3	445	5245	28.8	28.8	0.0
G4	455	5225	27.7	27.9	0.2
G5	455	5235	27.3	27.5	0.2

TABLE 8-14 (continued)

Receptor Identification	UTM Coordinates East	UTM Coordinates North	Predicted Annual Geometric Means ($\mu g/m^3$) 1976	Predicted Annual Geometric Means ($\mu g/m^3$) 1982	1976 - 1982 Change ($\mu g/m^3$)
G6	455	5245	29.1	29.2	0.1
G7	465	5225	27.0	27.1	0.1
G8	465	5235	27.1	26.7	-0.4
G9	465	5245	29.1	29.3	0.2
G10	475	5225	26.5	26.7	0.2
G11	475	5235	27.0	27.2	0.2
G12	475	5245	29.1	29.1	0.0
G13	475	5255	28.6	29.1	0.5
G14	485	5235	27.8	28.1	0.3
G15	485	5245	66.8	67.7	0.9
G16	485	5255	30.0	30.3	0.3
G17	495	5235	27.7	28.4	0.7
G18	495	5245	30.8	32.1	1.3
G19	495	5255	32.2	34.7	2.5
G20	495	5265	25.6	27.1	1.5
G21	505	5245	32.2	33.9	1.7
G22	505	5255	36.5	50.0	13.5
G23	505	5265	29.4	32.7	3.3
G24	515	5245	33.6	35.3	1.7
G25	515	5255	29.6	30.9	1.3
G26	515	5265	28.9	30.4	1.5
G27	525	5245	33.8	35.8	2.0
G28	525	5255	35.8	38.3	2.5
G29	525	5265	99.3	112.3	13.0
G30	525	5275	34.2	38.9	4.7
G31	535	5245	34.2	38.1	3.9
G32	535	5255	37.7	55.8	18.1
G33	535	5265	40.1	45.0	4.9
G34	535	5275	33.9	36.9	3.0
G35	545	5245	31.9	33.5	1.6
G36	545	5255	34.1	36.1	2.0
G37	545	5265	31.7	33.1	1.4
G38	545	5275	32.2	33.6	1.4
G39	555	5255	35.5	36.4	0.9
G40	555	5265	35.7	36.5	0.8
G41	555	5275	32.4	33.3	0.9
G42	565	5255	35.4	36.0	0.6
G43	565	5265	40.1	40.8	0.7
G44	565	5275	58.5	59.5	1.0
G45	575	5255	34.4	34.8	0.4
G46	575	5265	35.1	35.7	0.6

TABLE 8-14 (concluded)

Receptor Identification	UTM Coordinates East	UTM Coordinates North	Predicted Annual Geometric Means ($\mu g/m^3$) 1976	Predicted Annual Geometric Means ($\mu g/m^3$) 1982	1976 - 1982 Change ($\mu g/m^3$)
..					
G47	575	5275	46.6	47.2	0.6
G48	575	5285	34.7	35.1	0.4
G49	585	5265	33.4	33.8	0.4
G50	585	5275	36.7	36.9	0.2
G51	585	5285	36.7	37.0	0.3

TABLE 8-15

PREDICTED AIR QUALITY TRENDS, 1976 - 1982, SECOND MAXIMUM 24-HR AVERAGES

Receptor Identification	UTM Coordinates East	UTM Coordinates North	Predicted Second Maximum 24-hr Average ($\mu g/m^3$) 1976	Predicted Second Maximum 24-hr Average ($\mu g/m^3$) 1982	1976 - 1982 Change ($\mu g/m^3$)
7002	586	5305	120.2	121.2	1.0
7517	585	5306	121.2	122.5	1.3
7008	564	5271	191.6	195.3	3.7
1102	462	5231	139.1	139.8	0.7
7516	506	5253	113.8	136.1	22.3
7010	567	5263	109.4	111.1	1.7
7520	564	5263	108.0	110.2	2.2
7514	529	5264	153.4	174.1	20.7
1300	535	5263	188.5	208.2	19.7
1103	456	5233	137.4	138.1	0.7
7003	595	5296	87.5	88.0	0.5
7006	577	5273	107.0	108.2	1.2
7007	592	5251	89.5	90.7	1.2
1	532	5256	138.2	166.4	28.2
2	535	5256	141.0	184.8	43.8
3	532	5252	150.7	168.4	17.7
4	536	5253	102.4	103.8	1.4
5	531	5247	128.4	145.9	17.5
6	535	5247	134.9	150.9	16.0
7	532	5244	139.1	150.2	11.1
8	537	5240	126.6	137.1	10.5
13	509	5259	147.5	157.6	10.1
18	505	5251	137.7	157.1	19.4
21	541	5273	121.6	127.7	6.1
22	535	5273	130.7	140.3	9.6
23	536	5266	141.5	227.4	85.9
24	534	5266	239.3	276.1	36.8
25	537	5262	188.5	220.5	32.0
31	487	5246	144.6	147.2	2.6
32	486	5242	174.5	177.4	2.9
34	497	5249	198.3	217.4	19.1
35	494	5249	205.5	220.5	15.0
G1	445	5225	129.9	131.0	1.1
G2	445	5235	132.4	133.5	1.1
G3	445	5245	122.4	122.7	0.3
G4	455	5225	138.1	139.1	1.0
G5	455	5235	136.3	137.0	0.7

TABLE 8-15 (continued)

Receptor Identification	UTM Coordinates East	UTM Coordinates North	Predicted Second Maximum 24-hr Average ($\mu g/m^3$) 1976	Predicted Second Maximum 24-hr Average ($\mu g/m^3$) 1982	1976 - 1982 Change ($\mu g/m^3$)
G6	455	5245	123.7	124.3	0.6
G7	465	5225	134.5	135.2	0.7
G8	465	5235	135.2	133.5	-1.7
G9	465	5245	124.0	124.7	0.7
G10	475	5225	132.4	133.5	1.1
G11	475	5235	134.9	135.6	0.7
G12	475	5245	123.7	123.7	0.0
G13	475	5255	121.8	123.7	1.9
G14	485	5235	138.8	140.2	1.4
G15	485	5245	284.4	288.0	3.6
G16	485	5255	127.6	128.9	1.3
G17	495	5235	138.1	141.6	3.5
G18	495	5245	166.9	173.9	7.0
G19	495	5255	174.7	188.0	3.3
G20	495	5265	156.5	165.1	8.6
G21	505	5245	127.3	134.0	6.7
G22	505	5255	111.7	153.2	41.5
G23	505	5265	142.0	157.6	15.6
G24	515	5245	102.9	108.1	5.2
G25	515	5255	142.7	148.9	6.2
G26	515	5265	139.5	146.5	7.0
G27	525	5245	119.8	126.9	7.1
G28	525	5255	128.1	137.0	8.9
G29	525	5265	214.7	310.9	36.2
G30	525	5275	129.8	147.8	18.0
G31	535	5245	135.2	150.3	15.1
G32	535	5255	133.8	197.7	63.9
G33	535	5265	215.6	242.2	26.6
G34	535	5275	128.9	140.0	1.1
G35	545	5245	126.0	132.5	6.5
G36	545	5255	120.9	128.1	7.2
G37	545	5265	132.5	138.2	5.7
G38	545	5275	117.5	122.8	5.3
G39	555	5255	99.5	101.9	2.4
G40	555	5265	99.9	102.1	2.2
G41	555	5275	118.4	121.6	3.2
G42	565	5255	99.2	100.7	1.5
G43	565	5265	112.3	114.3	2.0
G44	565	5275	163.7	166.6	2.9
G45	575	5255	96.3	97.5	1.2
G46	575	5265	98.2	99.9	1.7

TABLE 8-15 (concluded)

Receptor Identification	UTM Coordinates East	North	Predicted Second Maximum 24-hr Average ($\mu g/m^3$) 1976	1982	1976 - 1982 Change ($\mu g/m^3$)
G47	575	5275	130.3	132.0	1.7
G48	575	5285	97.3	98.2	0.9
G49	585	5265	93.6	94.6	1.0
G50	585	5275	102.9	103.4	0.5
G51	585	5285	102.6	103.6	1.0

Receptor No. G-32 experienced an increase of 18.1 $\mu g/m^3$ in the annual mean. An additional 63.9 $\mu g/m^3$ was added to the second maximum average, producing a secondary violation at the site in 1982. This growth in TSP levels was caused primarily by fugitive emissions related to the growth in mining activities at Inland's Minorca pit, with some additional impact from Eveleth's Fayal operation and increased activities at U.S. Steel's Minntac pits. Inland Steel's point sources produced a small impact on the growth of TSP concentrations at this receptor.

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GLOSSARY

Activity Factor - measure of the intensity of aggregate material disturbance by mechanical forces in relation to reference activity level defined as unity.

Aggregate - a granular material of mineral composition such as sand, gravel, shell, slag, or crushed stone, used with a cementing medium to form mortars or concrete, or alone as in base courses, railroad ballasts, etc.

Aggregate, coarse - (1) aggregate predominantly retained on the No. 4 (4.75-mm) sieve; or (2) that portion of an aggregate retained on the No. 4 (4.75-mm) sieve.

NOTE: The definitions are alternatives to be applied under differing circumstances. Definition (1) is applied to an entire aggregate either in a natural condition or after-processing. Definition (2) is applied to a portion of an aggregate.

Aggregate, fine - (1) aggregate passing the 3/8 in. (9.5-mm) sieve and almost entirely passing the No. 4 (4.75-mm) sieve and predominantly retained on the No. 200 (75-μm) sieve, or (2) that portion of an aggregate passing the No. 4 (4.75-mm) sieve and retained on the No. 200 (75-μm) sieve.

Air drying - the process of equilibrating the sample to the moisture of the laboratory atmosphere.

Bulk material - any material composed of crushed or natural pieces with a wide variety of sizes, for example, coal, soil, aggregate, iron ore, etc.

Cloddiness - the mass percentage of an aggregate sample smaller than 0.84 mm in diameter as determined by dry sieving.

Dry day - day without measurable (0.01 in. or more) precipitation.

Dry sieving - the sieving of oven-dried aggregate by passing it through a series of screens of descending opening size.

Duration of storage - the average time that a unit of aggregate material remains in open storage, or the average pile turnover time.

Dust suppressant - water or chemical solution which, when applied to an aggregate material, binds suspendable particulate to larger particles.

Emission control system, primary - a control system installed to capture and remove most of the total emissions prior to atmospheric discharge.

Emission control system, secondary - a control system designed to capture and remove the smaller portion of the total emissions that the primary system does not collect with the smaller portion usually being fugitive in nature.

Enclosure - a structure which either partially or totally surrounds a fugitive emissions source thereby reducing the amount of emissions.

Exposed area, total - outdoor ground area subject to the action of wind and protected by little or no vegetation.

Exposure - the point value of the flux (mass/area-time) of airbone particulate passing through the atmosphere, integrated over the time of measurement.

Exposure profiling - direct measurement of the total passage of airborne particulate immediately downwind of the source by means of simultaneous multipoint isokinetic sampling over the effective cross-section of the fugitive emissions plume.

Fugitive emissions, total - all particles from either open dust or process fugitive sources as measured immediately adjacent to the source.

Fugitive emissions - emissions not originating from a stack, duct, or flue.

Load-in - the addition of material to a storage pile.

Load-out - the removal of material from a storage pile.

Materials handling - the receiving and transport of raw, intermediate and waste materials, including barge/railcar unloading, conveyor transport and associated conveyor transfer and screening stations.

Moisture content - the mass portion of an aggregate sample consisting of unbound moisture on the surface of the aggregate, as determined from weight loss in oven drying with correction for the estimated difference from total unbound moisture.

Particle diameter, aerodynamic - the diameter of hypothetical sphere of unit density (1 g/cm^3) having the same terminal settling velocity as the particle in question, regardless of its goemetric size, shape and true density.

Particle diameter, Stokes - the diameter of a hypothetical sphere having the same density and terminal settling velocity as the particle in question, regardless of its geometric size and shape.

Particle drift distance - horizontal distance from point of particle injection into the atmosphere to point of removal by contact with the ground surface.

Particulate, fine - airborne particulate smaller in Stokes diameter than 30 micrometers, the approximate cut-off diameter for the capture of particulate matter by a standard high-volume sampler, based on a particle density of 2 to 2.5 g/cm^3.

Precipitation-Evaporation (P-E) Index - a climatic factor equal to 10 times the sum of 12 consecutive monthly ratios of precipitation in inches over evaporation in inches, which is used as a measure of the annual average moisture of a flat surface area. Values in this study were calculated by MRI using a regional approximation technique.

Riffle - a hand-feed sample divider device that separates the sample into two parts of approximately the same weight.

Road, paved - a roadway constructed of rigid surface materials, such as asphalt, cement, concrete and brick.

Road, unpaved - a roadway constructed of nonrigid surface materials such as dirt, gravel (crushed stone or slag), and oil and chip surfaces.

Road surface dust loading - the mass of loose surface dust on a paved roadway, per length of roadway, as determined by dry vacuuming.

Road surface material - loose material present on the surface of an unpaved road.

Sample division - the process whereby a sample is reduced in weight without change in particle size.

Sample, gross - a sample representing one lot and composed of a number of increments on which neither reduction nor division has been performed.

Sample, incremental - a small portion of the lot collected by one operation of a sampling device and normally combined with other increments from the lot to make a gross sample.

Sample reduction - the process whereby a sample is reduced in particulate size by crushing or grinding without change in weight.

Screen - in laboratory work, an apparatus in which the apertures are circular, for separating sizes of materials.

Sieve - in laboratory work, an apparatus in which the apertures are square for separating sizes of material.

Silt content - the mass portion of a bulk material sample smaller than 75 micrometers in diameter (minus No. 200) as determined by dry sieving.

Size, maximum (of aggregate) - in specifications for, or description of aggregate, the smallest sieve opening through which the entire amount of the aggregate is permitted to pass. Specifications on aggregate usually stipulate a sieve opening through which all of the aggregate may, but need not, pass so that a stated maximum proportion may be retained on that sieve. A sieve opening so designated is the nominal maximim size of the aggregate.

Source, open dust - any source from which emissions are generated by the forces of wind and machinery acting on exposed aggregate materials.

Source, process fugitive emissions - an unducted source of emissions involving a process step which alters the chemical or physical characteristics of a material, frequently occurring within a building.

Spray system - a device for applying a liquid dust suppressant in the form of droplets to an aggregate material for the purpose of controlling the generation of dust.

Storage pile activities - process associated with aggregate storage piles, specifically, load-in vehicular traffic around storage piles, wind erosion from storage piles, and load-out.

Surface erodibility - potential for wind erosion losses from an unsheltered area, based on the percentage of erodible particles (smaller than 0.84 mm in diameter) in the surface material.

Surface stabilization - the formation of a resistive crust on an exposed aggregate surface through the action of a dust suppressant, which suppresses the release of otherwise suspendable particles.

Vehicle, heavy-duty - a motor vehicle whose gross vehicle traveling weight exceeds 30 tons.

Vehicle, light-duty - a motor vehicle whose gross vehicle traveling weight is less than or equal to 3 tons.

Vehicle, medium-duty - a motor vehicle whose gross vehicle traveling weight is greater than 3 tons, but less than 30 tons.

Windbreak - a natural or man-made object which reduces the ambient wind speed in the immediate locality.

APPENDIX A

MINING SOURCE EMISSION INVENTORY DEVELOPMENT

An emission inventory was compiled for each of the presently existing eight taconite mines and for eight major natural ore mines for the years 1976 and 1982. The emission inventory procedure consisted of (a) identifying the sources, (b) assigning an emission factor to each source, (c) determining the source extent, (d) assigning a control efficiency to natural and/or anthropogenic mitigative measures, and (e) calculating the emission rate.

A.1 Summary

Table A-1 through A-18 summarize the data input utilized in the emission inventory for each mine. In the following sections, the specific methodology utilized to determine the emission factors, source extent, and control efficiencies shown in Tables A-1 through A-18 will be discussed.

A.2 Uncontrolled Emission Factor Development

Emission factors for every mining source but blasting were calculated for the MRI predictive equations shown in Table 4-3. Emissions for blasting were obtained by averaging all the known emission factor test results available in the literature.

Use of the MRI predictive equations requires the selection of correction parameter values. Tables A-19 through A-21 show the correction parameters needed to represent conditions at taconite and natural ore mines in 1976 and 1982.

Material characteristics such as silt and moisture were for the most part based on measured values reported in Table 4-4. Material characteristics for difficult-to-sample materials such as crushed ore and waste and lean ore piles were estimates using measured values for other materials as a guideline.

Equipment characteristics such as weight, speed, and bucket size were provided by personnel from each of the mines.

Climatic characteristics such as number of dry days, mean annual wind speed, percent of the time the wind exceeds 12 mph, and Thornthwaite's precipitation evaporation index were obtained from varied sources. Dry days per year and precipitation evaporation index were determined by MRI on a county-by-county basis for the entire United States under a previous contract with the U.S. Environmental Protection Agency. The values for St. Louis County were utilized for the entire iron range since six of the eight taconite mines are in St. Louis County. These values actually represent at least a 30-year average climatic condition rather than representing any single year.

The mean annual windspeeds at Hibbing and International Falls from 1953 through 1974 were 9.1 mph and 9.2 mph, respectively. The mean annual windspeed measured at Erie Mining Company for 1976 was 8.4 mph. A spatially averaged value of 9 mph was used to represent the mean windspeed for the entire Iron Range.

The percent of the time that the wind exceeds the wind erosion threshold of 12 mph was determined from data at Hibbing for the period 1970 through 1974. Precipitation and snowcover data measured at Erie Mining Company during 1976 were used to calculate the natural control efficiencies for snowcover and precipitation or for snowcover alone. The methodology used was to assume that a day with measurable precipitation in the form of rain or snow or a dry day with snowcover will produce no emissions from sources affected by these natural mitigative measures.

Some of the uncontrolled emission factors in Tables A-1 through A-18 actually have some natural control built into the predictive equation and are uncontrolled only in the sense that there are no anthropogenic controls built into the equations. Table A-22 shows the predictive equations, the controls built into the equations, and the additional controls that should be added as a control efficiency.

A.3 Source Extent Development

Annual source extent data such as vehicle miles travelled, tons of material handled, and acres exposed were estimated from production needs by plant personnel. Data were provided for 1976 and 1982. In general, 1982 estimates were based on the assumption of full production. Whether or not full production in 1982 is a valid prediction depends heavily on the performance of the steel industry which in turn depends heavily on U.S. national economy and U.S. international trade.

A.4 Control Efficiency Development

Two general categories of control measures were considered: natural controls and anthropogenic controls. Natural controls include snowcover and precipitation in the form of rain and snow. Anthropogenic controls include road watering or chemical dust suppressant application, control equipment such as rotoclones and enclosures such as storage buildings around piles.

Control efficiencies for anthropogenic controls were estimated based on what little testing data there are. Watering was estimated at 30% control. Ranges of effectiveness from 0 to 70% have been found for watering once per day. The combination of evaporation by sunshine and numerous heavy truck trips causes watering effectiveness to deteriorate rapidly with time.

Chemical treatment of surfaces is somewhat more durable than watering although this depends on the chemical type, the frequency of application and the application density. Companies using watering and chemicals were estimated as having controlled emissions at a 50% level.

TABLE A-1

1976 EMISSION INVENTORY WORK SHEET FOR NATURAL ORE MINES - HEAVY DUTY UNPAVED ROADS

	Unloaded Heavy Duty					Loaded Heavy Duty				
	Emission Factor	Source Extent	Control Efficiency	Emission Rate		Emission Factor	Source Extent	Control Efficiency	Emission Rate	
Mine	(lb/VMT)	(VMT/year)	(%)	(lb/year)	(g/sec)	(lb/VMT)	(VMT/year)	(%)	(lb/year)	(g/sec)
Sherman Group	18.0	122,823	62	840,100	12.08	27.4	122,823	62	1,279,000	18.39
Rana Mines	9.2	7,714	62	27,000	0.39	12.4	7,714	62	36,300	0.52
Sharon-Culver Mine	9.2	29,412	62	102,800	1.48	12.4	29,412	62	138,600	1.99
Rouchleau	18.0	30,907	62	211,400	3.04	28.8	30,907	62	338,200	4.87
Stephens Mine Group	14.9	8,213	62	46,500	0.67	22.9	8,213	62	71,500	1.03
Lind-Greenway Mine	10.8	75,000	62	307,800	4.43	21.4	75,000	62	609,900	8.77
McKinley Mine	19.2	76,500	62	558,100		41.4	76,500	62	255,000	
Hill-Annex Mine	10.8	125,000	62	513,000	7.38	21.4	125,000	62	1,016,500	14.62

TABLE A-2

EMISSION INVENTORY WORK SHEET

Mine: 1 - Butler Taconite, Year: 1976

Source Category	Uncontrolled Emission Factor (lb/unit source ext.)	Source Extent	Control Efficiency (%)	Controlled Emission Rate (lb/year)	Controlled Emission Rate (g/sec)
1. Unpaved roads					
Loaded heavy duty	30	382,500 VMT	62	4,360,500	62.72
Unloaded heavy duty	19	382,500 VMT	62	2,762,000	39.73
Medium duty	3.7	16,000 VMT	62	22,500	0.32
	8.9	187,000 VMT		632,400	9.1
Light duty	2.1	154,000 VMT	62	122,900	1.77
2. Paved roads					
Medium duty	0.27	30,000 VMT	46	4,374	0.063
Light duty	0.18	62,400 VMT	46	6,065	0.087
3. Wind erosion of surface dumps	460	80 acres a/	23	28,300	0.41
4. Wind erosion of waste and lean ore stockpiles	230	100 acres a/	23	17,700	0.25
5. Wind erosion of pellet stockpiles	0.007	2,340,000 ST	23	12,600	0.18
6. Wind erosion of tailings beaches	2,330	574 acres a/	31	922,800	13.27
7. Wind erosion of tailings slopes	2,330	192 acres a/	23	344,500	4.95
8. Wind erosion of concentrate piles	5.32	300,000 ST a/	92.3	122,900	1.77
9. Load-in of pellets into railcar from loading pocket, bins, or silos	0.0058	2,620,000 ST	0	15,200	0.22
10. Pellet stacking (onto pile)	0.0058	2,620,000 ST	0	15,200	0.22
11. Load-in of pellets into railcars with power shovel or loader	b/	b/	b/	-	-
12. Load-in of crushed ore (minus 4 in.) into piles	0.005	336,000 ST a/	90	168	~ 0
13. Blasting (waste rock and ore)	0.006	12,200,000 ST	0	73,200	1.05
14. Wind erosion of crushed ore stockpile	0.0023	7,500,000 ST	90	1,725	0.02
					Σ = 136.13

a/ Estimated.
b/ Source did not exist.

TABLE A-3

EMISSION INVENTORY WORK SHEET

Mine: 2 - Erie Mining, Year: 1976

Source Category	Uncontrolled Emission Factor (lb/unit source ext.)	Source Extent	Control Efficiency (%)	Controlled Emission Rate (lb/year)	Controlled Emission Rate (g/sec)
1. Unpaved roads					
Loaded heavy duty	20	430,000 VMT	73	2,322,000	33.40
Unloaded heavy duty	16	430,000 VMT	73	1,857,600	26.72
Medium duty	2.1	241,000 VMT	73	136,600	1.97
	7.7	81,200 VMT		168,800	2.43
Light duty	2.1	2,165,000 VMT	73	1,227,600	17.66
2. Paved roads					
Medium duty	0.27	68,000 VMT	46	9,910	0.14
Light duty	0.18	2,160,000 VMT	46	210,000	3.02
3. Wind erosion of surface dumps	460	228 acres	23	80,800	1.16
4. Wind erosion of waste and lean ore stockpiles	230	762 acres	23	134,900	1.94
5. Wind erosion of pellet stockpiles	0.46	4,165,000 ST	23	1,475,200	21.22
6. Wind erosion of tailings beaches	840	563 acres	31	326,300	4.69
7. Wind erosion of tailings slopes	840	50 acres	23	32,300	0.47
8. Wind erosion of concentrate piles	a/	a/	a/	-	-
9. Load-in of pellets into railcar from loading pocket, bins, or silos	0.0058	6,800,000 ST	80	7,890	0.11
10. Pellet stacking (onto pile)	0.0058	4,980,000 ST	0	28,900	0.41
11. Load-in of pellets into railcar with power shovel or loader	0.06	4,350,000 ST	46	140,800	2.03
12. Load-in of crushed ore (minus 4 in.) into piles	a/	a/	a/	-	-
13. Blasting (waste rock and ore)	0.006	55,900,000 ST	0	335,300	4.82
14. Wind erosion of crushed ore stockpile	b/	a/	a/		
					Σ = 118.49

a/ Source did not exist.
b/ Processing plant not on Iron Range.

TABLE A-4

EMISSION INVENTORY WORK SHEET

Mine: 3 - Eveleth Taconite, Year: 1976

Source Category	Uncontrolled Emission Factor (lb/unit source ext.)	Source Extent	Control Efficiency (%)	Controlled Emission Rate (lb/year)	Controlled Emission Rate (g/sec)
1. Unpaved roads					
Loaded heavy duty	14	(mine) 240,500 VMT	62	1,279,000	16.40
	21	(plant) 29,800 VMT		237,800	3.42
Unloaded heavy duty	12	(mine) 240,500 VMT	62	1,097,000	15.77
	14	(plant) 29,800 VMT		158,500	2.28
Medium duty	2.1	36,600 VMT[a]	62	30,800	0.44
	7.7	28,000 VMT		81,900	1.19
Light duty	2.1	(mine) 386,000 VMT	62	308,000	4.43
		(plant) 51,000 VMT		40,700	0.59
2. Paved roads					
Medium duty	0.27	(mine) 5,000 VMT[a]	46	729	0.01
		(plant) 12,500 VMT[a]		1,820	0.03
Light duty	0.18	(mine) 18,500 VMT	46	1,800	0.03
		(plant) 143,000 VMT		13,900	0.20
3. Wind erosion of surface dumps	460	62.3 acres	23	20,100	0.32
4. Wind erosion of waste and lean ore stockpiles	230	23 acres	23	4,070	0.06
Wind erosion of pellet stockpiles	b/	b/	b/	-	-
6. Wind erosion of tailings beaches	4,030	62 acres	31	172,400	2.46
7. Wind erosion of tailings slopes	34	97 acres	23	2,540	0.04
8. Wind erosion of concentrate piles	16.7	385,000 ST	92.3	495,100	7.12
9. Load-in of pellets into railcar from loading pocket, bins, or silos	0.0058	2,540,000 ST	0	14,900	0.21
10. Pellet stacking (onto pile)	b/	b/	b/	-	-
11. Load-in of pellets into railcars with power shovel or loader	b/	b/	b/	-	-
12. Load-in of crushed ore (minus 4 in.) into piles	0.005	9,300,000 ST	90 (mine)	4,650	0.07
		33,600 ST	10 (plant)	151	0
13. Blasting (waste rock and ore)	0.006	11,900,000 ST	0	71,400	1.03
14. Wind erosion of crushed ore stockpile	0.001 (mine)	8,300,000 ST	90 (mine)	830	0.01
	0.1 (plant)	30,000 ST	10 (plant)	2,700	0.04
					Σ = 58.16

a/ Estimated.
b/ Source did not exist.

TABLE A-5

EMISSION INVENTORY WORK SHEET

Mine: 4 - Hibbing Taconite, Year: 1976

Source Category	Uncontrolled Emission Factor (lb/unit source ext.)	Source Extent	Control Efficiency (%)	Controlled Emission Rate (lb/year)	Controlled Emission Rate (g/sec)
1. Unpaved roads					
Loaded heavy duty	51	57,500 VMT	62	1,114,000	16.03
Unloaded heavy duty	25	57,500 VMT	62	546,300	7.86
Medium duty	1.8	31,000 VMT	62	21,200	0.30
	7.7	31,000 VMT		90,700	1.30
Light duty	2.1	310,000 VMT	62	247,400	3.56
2. Paved roads					
Medium duty	0.27	17,000 VMT[a]	46	2,480	0.04
Light duty	0.18	170,000 VMT[a]	46	16,500	0.24
3. Wind erosion of surface dumps	460	108 acres	23	38,300	0.55
4. Wind erosion of waste and lean ore stockpiles	230	12 acres	23	2,130	0.03
5. Wind erosion of pellet stockpiles	b/	b/	b/	-	-
. erosion of tailings beaches	1,740	0 acres	23	-	-
. Wind erosion of tailings slopes	1,740	0 acres	23	-	-
. Wind erosion of concentrate piles	b/	b/	92.3	-	-
. Load-in of pellets into railcar from loading pocket, bins, or silos	0.0058	336,000 ST	0	1,950	0.03
. Pellet stacking (onto pile)	b/	b/	b/	-	-
Load-in of pellets into railcars with power shovel or loader	b/	b/	b/	-	-
Load-in of crushed ore (minus 4 in.) into piles	0.0025[c]	3,580,000 ST	10	8,060	0.12
Blasting (waste rock and ore)	0.006	5,260,000 ST	0	31,600	0.45
Wind erosion of crushed ore stockpile	0.0055	3,200,000 ST	10	15,800	0.23
				Σ =	30.70

Estimated.
Source did not exist.
Ore is minus 9 in.

TABLE A-6

EMISSION INVENTORY WORK SHEET

Mine: 5 - Inland Steel, Year: 1976

Source Category	Uncontrolled Emission Factor (lb/unit source ext.)	Source Extent	Control Efficiency (%)	Controlled Emission Rate (lb/year)	Controlled Emission Rate (g/sec)
1. Unpaved roads					
Loaded heavy duty	48	8,500 VMT	46	220,300	3.17
Unloaded heavy duty	24	8,500 VMT	46	110,200	1.58
Medium duty	2.1	4,200 VMT	46	4,760	0.07
	7.7	500 VMT		2,080	0.03
Light duty	2.1	132,000 VMT	46	149,700	2.15
2. Paved roads					
Medium duty	a/	a/	a/	-	-
Light duty	a/	a/	a/	-	-
3. Wind erosion of surface dumps	460	24 acres	23	8,500	0.12
4. Wind erosion of waste and lean ore stockpiles	a/	a/	a/	-	-
5. Wind erosion of pellet stockpiles	a/	a/	a/	-	-
6. Wind erosion of tailings beaches	a/	a/	a/	-	-
7. Wind erosion of tailings slopes	a/	a/	a/	-	-
8. Wind erosion of concentrate piles	a/	a/	a/	-	-
9. Load-in of pellets into railcar from loading pocket, bins, or silos	a/	a/	a/	-	-
10. Pellet stacking (onto pile)	a/	a/	a/	-	-
11. Load-in of pellets into railcars with power shovel or loader	a/	a/	a/	-	-
12. Load-in of crushed ore (minus 4 in.) into piles	a/	a/	a/	-	-
13. Blasting (waste rock and ore)	a/	a/	a/	-	-
14. Wind erosion of crushed ore stockpile	a/	a/	a/	-	-
					Σ = 7.12

a/ There was no rock dump or paved roads and the crusher, concentrator and agglomerator were not completed in 1976.

TABLE A-7

EMISSION INVENTORY WORK SHEET

Mine: 6 - U.S. Steel-Minntac, Year: 1976

Source Category	Uncontrolled Emission Factor (lb/unit source ext.)	Source Extent	Control Efficiency (%)	Controlled Emission Rate (lb/year)	Controlled Emission Rate (g/sec)
1. Unpaved roads					
Loaded heavy duty	43	1,170,000 VMT	73	13,584,000	195.39
Unloaded heavy duty	19	1,430,000 VMT	73	7,336,000	105.52
	1.8	312,000 VMT		151,600	2.18
Medium duty	5.1	752,000 VMT	73	1,036,000	14.89
	7.7	94,900 VMT		197,300	2.84
Light duty	2.1	136,000 VMT	73	77,100	1.11
2. Paved roads					
Medium duty	0.27	80,000 VMT	46	11,700	0.17
Light duty	0.18	5,820,000 VMT a/	46	565,700	8.14
3. Wind erosion of surface dumps	460	1,127 acres	23	399,200	5.74
4. Wind erosion of waste and lean ore stockpiles	230	287 acres	23	50,300	0.73
5. Wind erosion of pellet stockpiles	0.0047	12,300,000 ST	23	44,500	0.64
6. Wind erosion of tailings beaches	4,730	1,012 acres	31	330,300	47.51
7. Wind erosion of tailings slopes	34	1,008 acres	23	26,400	0.38
8. Wind erosion of concentrate piles	6.7	300,000 ST a/	92.3	154,800	2.23
9. Load-in of pellets into railcar from loading pocket, bins, or silos	0.0058	13,800,000 ST	0	79,900	1.15
10. Pellet stacking (onto pile)	0.0058	13,800,000 ST	0	79,900	1.15
11. Load-in of pellets into railcars with power shovel or loader	b/	b/	b/	-	-
12. Load-in of crushed ore (minus 4 in.) into piles	b/	b/	b/	-	-
13. Blasting (waste rock and ore)	0.006	56,900,000 ST	0	341,400	4.91
14. Wind erosion of crushed ore stockpile	b/	b/	b/	-	-
					Σ = 394.68

a/ Estimated.
b/ Source did not exist.

TABLE A-8

EMISSION INVENTORY WORK SHEET

Mine: 7 - National Steel, Year: 1976

Source Category	Uncontrolled Emission Factor (lb/unit source ext.)	Source Extent	Control Efficiency (%)	Controlled Emission Rate (lb/year)	Controlled Emission Rate (g/sec)
1. Unpaved roads					
Loaded heavy duty	30	437,000 VMT	62	4,982,000	71.66
Unloaded heavy duty	19	437,000 VMT	62	3,155,000	45.38
Medium duty	3.7	16,000 VMT	62	22,500	0.32
	6.9	213,000 VMT		720,400	10.36
Light duty	2.1	185,000 VMT	62	147,600	2.12
2. Paved roads					
Medium duty	0.27	30,000 VMT	46	4,370	0.06
Light duty	0.18	75,000 VMT	46	7,290	0.10
3. Wind erosion of surface dumps	460	280 acres[a]	23	99,200	1.43
4. Wind erosion of waste and lean ore stockpiles	230	320 acres[a]	23	56,700	0.82
5. Wind erosion of pellet stockpiles	0.007	2,400,000 ST	23	12,900	0.19
6. Wind erosion of tailings beaches	2,170	514 acres[a]	31	769,600	11.07
7. Wind erosion of tailings slopes	2,170	171 acres[a]	23	285,700	4.11
8. Wind erosion of concentrate piles	9.5	300,000 ST[a]	92.3	219,400	3.16
9. Load-in of pellets into railcar from loading pocket, bins, or silos	0.0058	2,690,000 ST	0	15,600	0.22
10. Pellet stacking (onto pile)	0.0058	2,690,000 ST	0	15,600	0.22
11. Load-in of pellets into railcars with power shovel or loader	b/	b/	b/	-	-
12. Load-in of crushed ore (minus 4 in.) into piles	0.005	336,000 ST	90	168	0.01
13. Blasting (waste rock and ore)	0.006	19,700,000 ST	0	118,300	1.70
14. Wind erosion of crushed ore stockpile	0.002	8,900,000 ST	90	1,780	0.03
					Σ = 152.96

a/ Estimated.
b/ Source did not exist.

TABLE A-9

EMISSION INVENTORY WORK SHEET

Mine: 6 - Reserve Mining, Year: 1976

	Source Category	Uncontrolled Emission Factor (lb/unit source ext.)	Source Extent	Control Efficiency (%)	Controlled Emission Rate (lb/year)	Controlled Emission Rate (g/sec)
1.	Unpaved roads					
	Loaded heavy duty	29	1,000,000 VMT	73	7,830,000	112.63
	Unloaded heavy duty	21	1,000,000 VMT	73	5,670,000	81.56
	Medium duty	2.1	210,000 VMT	73	119,100	1.71
		8.9	940,000 VMT		2,259,000	32.49
	Light duty	2.1	1,900,000 VMT	73	1,077,000	15.50
2.	Paved roads					
	Medium duty	0.27	52,500 VMT	46	7,650	0.11
	Light duty	0.18	65,900 VMT	46	6,410	0.09
3.	Wind erosion of surface dumps	460	215 acres	23	76,200	1.10
4.	Wind erosion of waste and lean ore stockpiles	230	500 acres[a]	23	88,600	1.27
5.	Wind erosion of pellet stockpiles	b/	b/	b/	-	-
6.	Wind erosion of tailings beaches	b/	b/	b/	-	-
7.	Wind erosion of tailings slopes	b/	b/	b/	-	-
8.	Wind erosion of concentrate piles	b/	b/	b/	-	-
	Load-in of pellets into railcars from loadings pocket, bins, or silos	b/	b/	b/	-	-
10.	Pellet stacking (onto pile)	b/	b/	b/	-	-
11.	Load-in of pellets into railcars with power shovel or loader	b/	b/	b/	-	-
12.	Load-in of crushed ore (minus 4 in.) into piles	0.005 (Pile 1)	196,000 ST	10	882	0.01
		0.005 (Pile 2)	196,000 ST		882	0.01
13.	Blasting (waste rock and ore)	0.006	46,900,000 ST	0	281,600	4.05
14.	Wind erosion of crushed ore stockpile	0.17[c] (Pile 1)	182,000 ST	10	27,800	0.40
		0.12[c] (Pile 2)	185,000 ST		20,000	0.29
						Σ = 251.22

a/ Estimated

b/ Processing plant not on Iron Range.

c/ Ore is minus 9 in.

TABLE A-10

1982 EMISSION INVENTORY FOR NATURAL ORE MINES - HEAVY DUTY VEHICLES TRAVELING ON UNPAVED ROADS

	Unloaded Heavy Duty					Loaded Heavy Duty Vehicles				
Mine	Emission Factor (lb/VMT)	Source Extent (VMT/year)	Control Efficiency (%)	Emission Rate (lb/year)	Emission Rate (g/sec)	Emission Factor (lb/VMT)	Source Extent (VMT/year)	Control Efficiency (%)	Emission Rate (lb/year)	Emission Rate (g/sec)
Sherman Group	18.0	122,823	62	840,100	12.08	27.4	122,823	62	1,279,000	18.39
Rana Mines	9.2	7,714	62	27,000	0.39	12.4	7,714	62	36,300	0.52
Sharon-Culver Mine	9.2	29,412	62	102,800	1.48	12.4	29,412	62	138,600	1.99
Rouchleau	18.0	30,907	62	211,400	3.04	28.8	30,907	62	338,200	4.87
Stephens Mine Group	14.9	8,213	62	46,500	0.67	22.9	8,213	62	71,500	1.03
Lind-Greenway Mine	10.8	0	62	0	0	21.4	0	62	0	0
McKinley Mine	19.2	0	62	0	0	41.4	0	62	0	0
Hill Annex Mine	10.8	0	62	0	0	21.4	0	62	0	0

TABLE A-11

EMISSION INVENTORY WORK SHEET

Mine: 1 - Butler Taconite, Year: 1982

Source Category	Uncontrolled Emission Factor (lb/unit source ext.)	Source Extent	Control Efficiency (%)	Controlled Emission Rate (lb/year)	Controlled Emission Rate (g/sec)
1. Unpaved roads					
Loaded heavy duty	30	382,500 VMT	62	4,360,000	62.72
Unloaded heavy duty	19	382,500 VMT	62	2,762,000	39.72
Medium duty	3.7	16,000 VMT	62	22,500	0.32
	8.9	187,000 VMT		632,400	9.10
Light duty	2.1	154,000 VMT	62	122,900	1.77
2. Paved roads					
Medium duty	0.27	30,000 VMT	46	4,374	0.06
Light duty	0.18	62,400 VMT	46	6,065	0.09
3. Wind erosion of surface dumps	460	100 acres a/	23	35,400	0.51
4. Wind erosion of waste and lean ore Stockpiles	230	150 acres a/	23	26,600	0.38
5. Wind erosion of pellet stockpiles	0.007	2,600,000 ST	23	14,000	0.20
6. Wind erosion of tailings beaches	2,330	574 acres a/	31	922,800	13.27
7. Wind erosion of tailings slopes	2,330	250 acres a/	23	448,500	6.45
8. Wind erosion of concentrate piles	5.32	300,000 ST a/	92.3	122,900	1.77
9. Load-in of pellets into railcar from loading pocket, bins, or silos	0.0058	2,600,000 LT	0	16,900	0.24
10. Pellet stacking (onto pile)	0.0058	2,600,000 LT	10	15,200	0.22
11. Load-in of pellets into railcars with power shovel or loader	b/	b/	b/	-	-
12. Load-in of crushed ore (minus 4 in.) into piles	0.005	300,000 LT	90	168	~ 0
13. Blasting (waste rock and ore)	0.006	13,600,000 LT	0	91,400	1.31
14. Wind erosion of curshed ore stockpile	0.002	8,600,000 ST	90	1,720	0.02
					Σ = 138.16

a/ Estimated.
b/ Source did not exist.

TABLE A-12

EMISSION INVENTORY WORK SHEET

Mine: 2 - Erie Mining, Year: 1982

Source Category	Uncontrolled Emission Factor (lb/unit source ext.)	Source Extent	Control Efficiency (%)	Controlled Emission Rate (lb/year)	Controlled Emission Rate (g/sec)
1. Unpaved roads					
Loaded heavy duty	20	523,000 VMT	73	2,824,000	40.62
Unloaded heavy duty	16	523,000 VMT	73	2,259,000	32.50
Medium duty	2.1	253,000 VMT	73	143,500	2.06
	7.7	81,200 VMT		108,800	2.43
Light duty	2.1	1,740,000 VMT	73	986,600	14.19
2. Paved roads					
Medium duty	0.27	81,000 VMT	46	11,800	0.17
Light duty	0.18	2,128,000 VMT	46	206,800	2.98
3. Wind erosion of surface dumps	460	222 acres	23	78,600	1.13
4. Wind erosion of waste and lean ore stockpiles	230	935 acres	23	165,600	2.38
5. Wind erosion of pellet stockpiles	0.46	4,165,000 ST	23	1,475,000	21.22
6. Wind erosion of tailings beaches	840	523 acres	31	303,100	4.36
7. Wind erosion of tailings slopes	840	62 acres	23	40,100	0.58
8. Wind erosion of concentrate piles	a/	a/	a/	-	-
9. Load-in of pellets into railcar from loading pocket, bins, or silos	0.0058	6,070,000 LT	80	7,890	0.11
10. Pellet stacking (onto pile)	0.0058	4,450,000 LT	10	26,000	0.37
11. Load-in of pellets into railcars with power shovel or loader	0.06	3,880,000 LT	46	140,800	2.03
12. Load-in of crushed ore (minus 4 in.) into piles	a/	a/	a/	-	-
13. Blasting (waste rock and ore)	0.006	48,200,000 LT	0	289,200	4.16
14. Wind erosion of crushed ore stockpile	a/	a/	a/	-	-
					Σ = 131.29

a/ Source did not exist.

TABLE A-13

EMISSION INVENTORY WORK SHEET

Mine: 3 - Eveleth Taconite, Year: 1982

	Source Category	Uncontrolled Emission Factor (lb/unit source ext.)	Source Extent	Control Efficiency (%)	Controlled Emission Rate (lb/year)	(g/sec)
1.	Unpaved roads					
	Loaded heavy duty	(mine) 14	390,000 VMT	62	2,075,000	29.84
		(plant) 21	69,000 VMT		550,600	7.92
	Unloaded heavy duty	(mine) 13	390,000 VMT	62	1,927,000	27.71
		(plant) 14	69,000 VMT		367,100	5.28
	Medium duty	2.1	42,200 VMT[a]	62	33,700	0.48
		7.7	38,000 VMT		111,200	1.60
	Light duty	2.1	(mine) 422,000 VMT	62	336,800	4.84
			(plant) 51,000 VMT		40,700	0.59
2.	Paved roads					
	Medium duty	0.27	(mine) 5,000 VMT[a]	46	729	0.01
			(plant) 12,500 VMT[a]		1,820	0.03
	Light duty	0.18	(mine) 19,500 VMT	46	1,895	0.03
			(plant) 143,000 VMT		13,900	0.20
3.	Wind erosion of surface dumps	460	124.6 acres	23	44,100	0.63
4.	Wind erosion of waste and lean ore stockpiles	230	46 acres	23	8,150	0.12
5.	Wind erosion of pellet stockpiles	b/	b/	b/	-	-
6.	Wind erosion of tailings beaches	4,030	62 acres	31	172,400	2.48
7.	Wind erosion of tailings slopes	34	145 acres	23	3,800	0.05
8.	Wind erosion of concentrate piles	10.7	365,000 ST	92.3	300,700	4.33
9.	Load-in of pellets into railcar from loading pocket, bins, or silos	0.0058	6,300,000 LT	50	20,500	0.29
10.	Pellet stacking (onto pile)	b/	b/	b/	-	-
11.	Load-in of pellets into railcars with power shovel or loader	b/	b/	b/	-	-
12.	Load-in of crushed ore (minus 4 in.) into piles	0.005	19,000,000 LT (mine)	90	10,640	0.15
			375,000 LT (plant)	10	1,890	0.03
13.	Blasting (waste rock and ore)	0.006	29,400,000 LT	0	197,600	2.84
14.	Wind erosion of crushed ore stockpile	0.00033 (mine)	19,000,000 ST	90	627	0.01
		0.065 (plant)	375,000 ST	10	21,900	0.32
						Σ = 89.78

a/ Estimated.
b/ Source did not exist.

TABLE A-14

EMISSION INVENTORY WORK SHEET

Mine: 4 - Hibbing Taconite, Year: 1982

Source Category	Uncontrolled Emission Factor (lb/unit source ext.)	Source Extent	Control Efficiency (%)	Controlled Emission Rate (lb/year)	Controlled Emission Rate (g/sec)
1. Unpaved roads					
Loaded heavy duty	51	471,500 VMT	62	9,138,000	131.44
Unloaded heavy duty	25	471,500 VMT	62	4,479,000	64.43
Medium duty	1.8 7.7	44,000 VMT[a/] 44,000 VMT[a/]	62	30,100 128,700	0.43 1.85
Light duty	2.1	440,000 VMT	62	351,100	5.05
2. Paved roads					
Medium duty	0.27	17,000 VMT[a/]	46	2,481	0.04
Light duty	0.18	170,000 VMT[a/]	46	16,500	0.24
3. Wind erosion of surface dumps	460	300 acres	23	106,300	1.53
4. Wind erosion of waste and lean ore stockpiles	230	220 acres	23	39,000	0.56
5. Wind erosion of pellet stockpiles	b/	b/	b/	-	-
6. Wind erosion of tailings beaches	1,740	645 acres	23	864,200	12.43
7. Wind erosion of tailings slopes	1,740	0 acres	23	-	0
8. Wind erosion of concentrate piles	b/	b/	92.3	-	-
9. Load-in of pellets into railcar from loading pocket, bins, or silos	0.21	b/	0	-	-
10. Pellet stacking (onto pile)	b/	b/	b/	-	-
11. Load-in of pellets into railcars with power shovel or loader	b/	b/	b/	-	-
12. Load-in of crushed ore (minus 4 in.) into piles	0.0025	b/	10	-	-
13. Blasting (waste rock and ore)	0.006	38,200,000 ST	0	229,200	3.30
14. Wind erosion of crushed ore stockpile	0.001	28,600,000 ST	10	25,700	0.37
					Σ = 221.66

a/ Estimated.
b/ Source did not exist.

TABLE A-15

EMISSION INVENTORY WORK SHEET

Mine: 5 - Inland Steel, Year: 1982

Source Category	Uncontrolled Emission Factor (lb/unit source ext.)	Source Extent	Control Efficiency (%)	Controlled Emission Rate (lb/year)	Controlled Emission Rate (g/sec)
1. Unpaved roads					
Loaded heavy duty	48	214,000 VMT	62	3,903,000	56.15
Unloaded heavy duty	24	214,000 VMT	62	1,952,000	28.07
Medium duty	2.1	108,000 VMT	62	86,200	1.24
	7.7	3,500 VMT		10,200	0.15
Light duty	2.1	492,000 VMT	62	392,600	5.65
2. Paved roads					
Medium duty	0.27	14,400 VMT	46	2,100	0.03
Light duty	0.18	645,000 VMT	46	62,700	0.90
3. Wind erosion of surface dumps	460	300 acres	23	106,300	1.53
4. Wind erosion of waste and lean ore stockpiles	230	5 acres	23	886	0.01
5. Wind erosion of pellet stockpiles	0.014	2,600,000 ST	23	28,000	0.40
6. Wind erosion of tailings beaches	4,030	315 acres	23	977,500	14.06
7. Wind erosion of tailings slopes	34	5 acres	23	131	< 0.01
8. Wind erosion of concentrate piles	3.3	300,000 ST	92.3	76,200	1.10
9. Load-in of pellets into railcar from loading pocket, bins, or silos	0.0058	13,800,000 ST	30	55,900	0.80
10. [Pe]llet stacking (onto pile)	0.0058	13,800,000 ST	10	71,900	1.03
11. Load-in of pellets into railcars with power shovel or loader	a/	a/	a/	-	-
12. Load-in of crushed ore (minus 4 in.) into piles	0.005	a/	10	-	-
13. Blasting (waste rock and ore)	0.006	12,300,000 ST	0	73,900	1.06
14. Wind erosion of crushed ore stockpile	0.0033	9,000,000 ST	10	26,700	0.38
					Σ = 112.56

a/ Source did not exist.

TABLE A-16

EMISSION INVENTORY WORK SHEET

Mine: 6 - U.S. Steel-Minntac, Year: 1982

Source Category	Uncontrolled Emission Factor (lb/unit source ext.)	Source Extent	Control Efficiency (%)	Controlled Emission Rate (lb/year)	Controlled Emission Rate (g/sec)
1. Unpaved roads					
Loaded heavy duty	43	1,400,000 VMT	73	16,254,000	233.80
Unloaded heavy duty	19	1,400,000 VMT	73	7,182,000	103.31
Medium duty	1.8	406,000 VMT		197,300	2.84
	5.1	978,000 VMT	73	1,347,000	19.37
	7.7	123,000 VMT		255,700	3.68
Light duty	2.1	177,000 VMT	73	100,400	1.44
2. Paved roads					
Medium duty	0.27	80,000 VMT	46	11,700	0.17
Light duty	0.18	7,100,000 VMT	46	690,100	9.93
3. Wind erosion of surface dumps	460	2,057 acres	23	728,600	10.48
4. Wind erosion of waste and lean ore stockpiles	230	1,055 acres	23	186,800	2.69
5. Wind erosion of pellet stockpiles	0.0023	18,500,000 ST	23	32,800	0.47
6. Wind erosion of tailings beaches	4,730	2,260 acres	31	7,376,000	106.10
7. Wind erosion of tailings slopes	34	1,008 acres	23	26,400	0.38
8. Wind erosion of concentrate piles	6.7	300,000 ST[a/]	92.3	154,800	2.23
9. Load-in of pellets into railcar from loading pocket, bins, or silos	0.0058	20,700,000 ST	0	120,200	1.73
10. Pellet stacking (onto pile)	0.0058	20,700,000 ST	10	108,200	1.56
11. Load-in of pellets into railcars with power shovel or loader	b/	b/	b/	-	-
12. Load-in of crushed ore (minus 4 in.) into piles	b/	b/	b/	-	-
13. Blasting (waste rock and ore)	0.006	108,000,000 ST	0	579,600	8.34
14. Wind erosion of crushed ore stockpile	b/	b/	b/	-	-
					Σ = 508.49

a/ Estimated.
b/ Source did not exist.

TABLE A-17

EMISSION INVENTORY WORK SHEET

Mine: 7 - National Steel, Year: 1982

	Source Category	Uncontrolled Emission Factor (lb/unit source ext.)	Source Extent	Control Efficiency (%)	Controlled Emission Rate (lb/year)	Controlled Emission Rate (g/sec)
1.	Unpaved roads					
	Loaded heavy duty	30	472,000 VMT	62	5,381,000	77.40
	Unloaded heavy duty	19	472,000 VMT	62	3,408,000	49.02
	Medium duty	3.7	48,000 VMT	62	67,500	0.97
		8.9	497,000 VMT		1,681,000	24.18
	Light duty	2.1	432,000 VMT	62	344,700	4.96
2.	Paved roads					
	Medium duty	0.27	30,000 VMT	46	4,374	0.06
	Light duty	0.18	175,000 VMT	46	17,000	0.24
3.	Wind erosion of surface dumps	460	580 acres[a]	23	205,400	2.95
4.	Wind erosion of waste and lean ore stockpiles	230	400 acres[a]	23	70,800	1.02
5.	Wind erosion of pellet stockpiles	0.0023	5,600,000 ST	23	9,920	0.14
6.	Wind erosion of tailings beaches	2,170	700 acres[a]	31	1,048,000	15.08
7.	Wind erosion of tailings slopes	2,170	300 acres[a]	23	501,300	7.21
8.	Wind erosion of concentrate piles	5.3	300,000 ST[a]	92.3	122,400	1.76
9.	Load-in of pellets into railcar from loading pocket, bins, or silos	0.0056	6,300,000 ST	0	136,400	0.52
	Pellet stacking (onto pile)	0.0058	6,300,000 ST	10	32,700	0.47
11.	Load-in of pellets into railcars with power shovel or loader	b/	b/	b/	-	-
12.	Load-in of crushed ore (minus 4 in.) into piles	0.005	336,000 ST	90	168	< 0.01
13.	Blasting (waste rock and ore)	0.006	29,500,000 ST	0	176,700	2.54
14.	Wind erosion of crushed ore stockpile	0.0013	20,100,000 ST	90	2,610	0.04
						Σ = 118.56

a/ Estimated.
b/ Source did not exist.

TABLE A-18

EMISSION INVENTORY WORK SHEET

Mine: 8 - Reserve Mining, Year: 1982

Source Category	Uncontrolled Emission Factor (lb/unit source ext.)	Source Extent	Control Efficiency (%)	Controlled Emission Rate (lb/year)	Controlled Emission Rate (g/sec)
1. Unpaved roads					
Loaded heavy duty	29	1,000,000 VMT	73	7,830,000	112.63
Unloaded heavy duty	21	1,000,000 VMT	73	5,670,000	81.56
Medium duty	2.1	210,000 VMT	73	119,100	1.71
	8.9	940,000 VMT		2,259,000	32.49
Light duty	2.1	1,900,000 VMT	73	1,077,000	15.50
2. Paved roads					
Medium duty	0.27	60,000 VMT	46	8,750	0.13
Light duty	0.18	79,000 VMT	46	7,680	0.11
3. Wind erosion of surface dumps	460	163 acres[a/]	23	57,700	0.83
4. Wind erosion of waste and lean ore stockpiles	230	600 acres[b/]	23	106,300	1.53
5. Wind erosion of pellet stockpiles	c/	c/	c/	-	-
6. Wind erosion of tailings beaches	c/	c/	c/	-	-
7. Wind erosion of tailings slopes	c/	c/	c/	-	-
8. Wind erosion of concentrate piles	c/	c/	c/	-	-
9. Load-in of pellets into railcar from loading pockets, bins, or silos	c/	c/	c/	-	-
10. Pellet stacking (onto pile)	c/	c/	c/	-	-
11. Load-in of pellets into railcars with power shovel or loader	c/	c/	c/	-	-
12. Load-in of crushed ore (minus 4 in.) into piles	0.005 (pile 1)	202,000 ST	10	907	0.01
	0.005 (pile 2)	202,000 ST	10	907	0.01
13. Blasting (waste rock and ore)	0.006	49,300,000 ST	0	295,700	4.25
14. Wind erosion of crushed ore stockpile	0.17[d/] (pile 1)	180,000 ST	10	27,500	0.40
	0.12[d/] (pile 2)	180,000 ST	10	19,400	0.28
					Σ = 251.43

a/ Some of 1976 surface piles will be covered with rock by 1982.
b/ Estimated.
c/ Processing plant not on iron range.
d/ Ore is minus 9 in.

TABLE A-19

1976 AND 1982 EMISSION FACTOR CORRECTION PARAMETERS - NATURAL ORE MINES

Correction Factor	Emission Category	Mining Company							
		Sherman Group	Rana Mines	Sharon-Culver Mine	Rouchleau	Stephens Mine Group	Lind-Greenway	McKinley Mine	Hill-Annex Mine
s (%)	Unpaved roads								
	Heavy duty loaded	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
	Heavy duty unloaded	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
S (mph)	Unpaved roads								
	Heavy duty loaded	12	12	12	12	12	15	20	15
	Heavy duty unloaded	15	15	15	15	15	15	20	15
W (ST)	Unpaved roads								
	Heavy duty loaded	157	58	58	166	125	87	138	87
	Heavy duty unloaded	70	30	30	70	55	37	53	37

TABLE A-20

1976 MINING EMISSION FACTORS - UNCONTROLLED

Correction Factor	Emission Category	Mining Company: Butler Taconite	Erie Mining	Eveleth Taconite	Hibbing Taconite	Inland Steel	U.S. Steel Minntac	National Steel	Reserve Mining
s (%)	Unpaved roads								
	Heavy duty loaded	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
	Heavy duty unloaded	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
	Medium duty	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
	Light duty	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
	Paved roads								
	Medium duty	10	10	10	10	10	10	10	10
	Light duty	10	10	10	10	10	10	10	10
	Wind erosion								
	Surface dumps	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Waste and lean ore piles	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	Pellet piles	3.5	3.5	a/	a/	a/	3.5	3.5	a/
	Tailings beaches	27.2	10.9	20.3	20.3	20.3	23.8	19.2	a/
	Tailings slopes	27.2	10.9	2.5	20.3	2.5	2.5	19.2	a/
	Concentrate piles	82	a/	82	a/	a/	82	82	a/
	Crushed ore piles	0.5	a/	0.5	0.25	a/	a/	0.5	0.5
	Pellet load-in from loading pocket, bin, or silo to railcar	5	5	5	5	a/	5	5	a/
	Pellet stacking	5	5	a/	a/	a/	5	5	a/
	Crushed ore load-in to piles	0.5	a/	0.5	0.25	a/	a/	0.5	0.5
	Pellet load-in to railcar from piles via power shovel or loader	a/	3.4	a/	a/	a/	a/	a/	a/
S (mph)	Unpaved roads								
	Heavy duty loaded	12	9	8	15	18	16	12	12
	Heavy duty unloaded	15	15	12	15	18	16	15	16
	Medium duty	20	20	20	20	20	20	20	20
	Light duty	30	30	30	30	30	30	30	30

TABLE A-20 (Continued)

Correction Factor	Emission Category	Mining Company: Butler Taconite	Erie Mining	Eveleth Taconite	Hibbing Taconite	Inland Steel	U.S. Steel Minntac	National Steel	Reserve Mining
W (ST)	Unpaved roads								
	Heavy duty loaded	175	154	117; 154; 190	260	190	190	175	170
	Heavy duty unloaded	75	58	57; 64; 70	105	78	70	75	80
	Medium duty	10; 30	5; 25	5; 25	5; 25	5; 25	4; 15; 25	10; 30	5; 30
	Light duty	3	3	3	3	3	3	3	3
	Paved roads								
	Medium duty	5	5	5	5	5	5	5	5
	Light duty	3	3	3	3	3	3	3	3
L (lb/mile)	Paved roads								
	Medium duty	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
	Light duty	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
d (day)	All	255	255	255	255	255	255	255	255
D (day)	Wind erosion								
	Pellet piles	3	197	a/	a/	a/	2	3	a/
	Concentrate piles	97	a/	167	a/	a/	122	173	a/
	Crushed ore piles	7	a/	3; 304	33	a/	a/	6	357; 501
f	All	25	25	25	25	25	25	25	25
e	Wind erosion								
	Tailings beaches	95	75	220	95	220	220	125	95
	Tailings slopes	95	75	15	95	15	15	125	95
P-E	All	112	112	.112	112	112	112	112	112
U (mph)	All	9	9	9	9	9	9	9	9
M	Pellet load-in from loading pocket, bin, or silo to railcar	1.5	1.5	1.5	1.5	1.5	1.5	1.5	a/
	Pellet stacking	1.5	1.5	a/	a/	a/	1.5	1.5	a/

TABLE A-20 (Concluded)

Correction Factor	Emission Category	Butler Taconite	Erie Mining	Eveleth Taconite	Hibbing Taconite	Inland Steel	U.S. Steel Minntac	National Steel	Reserve Mining
		Mining Company							
M (cont.)	Crushed ore load-in	0.5	a/	0.5	0.5	a/	a/	0.5	0.5
	Pellet load-in to railcar from pile via power shovel or loader	a/	0.25	a/	a/	a/	a/	a/	a/
Y	Pellet load-in with power shovel	a/	14	a/	a/	a/	a/	a/	a/

a/ Source did not exist at plant or mine facilities on Iron Range in 1976.

TABLE A-21

1982 MINING EMISSION FACTORS - UNCONTROLLED

Correction Factor	Emission Category	Mining Company: Butler Taconite	Erie Mining	Eveleth Taconite	Hibbing Taconite	Inland Steel	U.S. Steel Minntac	National Steel	Reserve Mining
s (%)	Unpaved roads								
	Heavy duty loaded	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
	Heavy duty unloaded	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
	Medium duty	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
	Light duty	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
	Paved roads								
	Medium duty	10	10	10	10	10	10	10	10
	Light duty	10	10	10	10	10	10	10	10
	Wind erosion								
	Surface dumps	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Waste and lean ore piles	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	Pellet piles	3.5	3.5	a/	a/	3.5	3.5	3.5	a/
	Tailings beaches	27.2	10.9	20.3	20.3	20.3	23.8	19.2	a/
	Tailings slopes	27.2	10.9	2.5	20.3	2.5	2.5	19.2	a/
	Concentrate piles	82	a/	82	a/	82	82	82	a/
	Crushed ore piles	0.5	a/	0.5	0.25	0.5	a/	0.5	0.5
	Pellet load-in from loading pocket, bin, or silo to railcar	5	5	5	5	5	5	5	a/
	Pellet stacking	5	5	a/	a/	5	5	5	a/
	Crushed ore load-in	0.5	a/	0.5	0.25	0.5	a/	0.5	0.5
	Pellet load-in to railcar from piles via power shovel or loader	a/	3.4	a/	a/	a/	a/	a/	a/
S (mph)	Unpaved roads								
	Heavy duty loaded	12	9	8	15	18	16	12	12
	Heavy duty unloaded	15	15	12	15	18	16	15	16
	Medium duty	20	20	20	20	20	20	20	20
	Light duty	30	30	30	30	30	30	30	30

TABLE A-21 (Continued)

Correction Factor	Emission Category	Mining Company: Butler Taconite	Erie Mining	Eveleth Taconite	Hibbing Taconite	Inland Steel	U.S. Steel Minntac	National Steel	Reserve Mining
W (ST)	Unpaved roads								
	Heavy duty loaded	175	154	117; 154; 190	260	190	190	175	170
	Heavy duty unloaded	75	58	57; 64; 70	105	78	70	75	80
	Medium duty	10; 30	5; 25	5; 25	5; 25	5; 25	4; 15; 25	10; 30	5; 30
	Light duty	3	3	3	3	3	3	3	3
	Paved roads								
	Medium duty	5	5	5	5	5	5	5	5
	Light duty	3	3	3	3	3	3	3	3
L (lb/mile)	Paved roads								
	Medium duty	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
	Light duty	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
d (days)	All								
D (days)	Wind erosion								
	Pellet piles	3	197	a/	a/	6	1	1	a/
	Concentrate piles	97	a/	50	a/	61	122	97	a/
	Crushed ore piles	6	a/	1; 195	6	10	a/	4	357; 501
f	All	25	25	25	25	25	25	25	25
e	Wind erosion								
	Tailings beaches	95	75	220	95	220	220	125	95
	Tailings slopes	95	75	15	95	15	15	125	95
P-E	All	112	112	112	112	112	112	112	112
U (mph)	All	9	9	9	9	9	9	9	9
M	Pellet load-in from loading pocket, bin, or silo to railcar	1.5	1.5	1.5	1.5	1.5	1.5	1.5	a/
	Pellet stacking	1.5	1.5	a/	a/	1.5	1.5	1.5	a/

TABLE A-21 (Concluded)

Correction Factor	Emission Category	Mining Company: Butler Taconite	Erie Mining	Eveleth Taconite	Hibbing Taconite	Inland Steel	U.S. Steel Minntac	National Steel	Reserve Mining
M (cont.)	Crushed ore load-in	0.5	a/	0.5	0.5	0.5	a/	0.5	0.5
	Pellet load-in to railcar from piles via power shovel or loader	a/	0.25	a/	a/	a/	a/	a/	a/
Y	Pellet load-in with power shovel	a/	14	a/	a/	a/	a/	a/	a/

a/ Source not projected to exist at plant or mine facilities on Iron Range in 1976.

TABLE A-22

INHERENT NATURAL CONTROL WITHIN OPEN DUST SOURCE EQUATIONS

Source Category	Equation	Inherent Natural Control in Equation	Additional Natural Control to be Applied
Unpaved roads	$5.9 \left(\frac{s}{12}\right)\left(\frac{S}{30}\right)\left(\frac{W}{3}\right)^{0.8}$	None	Precipitation, snowcover.
Paved roads	$0.45 \left(\frac{s}{10}\right)\left(\frac{L}{5,000}\right)\left(\frac{W}{3}\right)^{0.8}$	None	Precipitation, snowcover.
Continuous load-in	$0.0018 \frac{\left(\frac{s}{5}\right)\left(\frac{U}{5}\right)}{\left(\frac{M}{2}\right)^{2}}$	Depends on whether annual average or just dry day moisture is used.	Depends on degree of exposure of incoming material to local climatic conditions.
Storage pile maintenance traffic	$0.1 \quad K \left(\frac{s}{15}\right)\left(\frac{d}{235}\right)$	Already represents an average of wet and dry days.	Snowcover on days with no precipitation.
Storage pile wind erosion	$0.05\left(\frac{s}{1.5}\right)\left(\frac{d}{235}\right)\left(\frac{f}{15}\right)\left(\frac{D}{90}\right)$	Already represents an average of wet and dry days.	Snowcover on days with no precipitation.
Batch load-in/load-out	$0.0018 \frac{\left(\frac{s}{5}\right)\left(\frac{U}{5}\right)}{\left(\frac{M}{2}\right)^{2}\left(\frac{Y}{6}\right)}$	Depends on whether annual average or just dry day moisture is used.	Depends on degree of exposure of incoming/outgoing material to local climatic conditions. If material is exposed, then natural control depends on whether annual average or just dry day moisture is used.
Wind erosion of exposed areas	$\frac{3,400 \left(\frac{e}{50}\right)\left(\frac{s}{15}\right)\left(\frac{f}{25}\right)}{\left(\frac{P-E}{50}\right)^{2}}$	Already represents an average of wet and dry days.	Snowcover on days with no precipitation.

APPENDIX B

SILT/MOISTURE SAMPLING AND ANALYSIS FORMS

MIDWEST RESEARCH INSTITUTE

MRI Project
No. ________

Sampling Data
Storage Piles

Date ________
Recorded by ________

Type of Material Sampled: ________
Site of Sampling: ________

SAMPLING METHOD

1. Sampling device: pointed shovel
2. Sampling depth: 4 - 6 inches
3. Sample container: metal or plastic bucket with sealed poly liner
4. Gross sample specifications:
   (a) 1 sample of 50 lb minimum for every pile sampled
   (b) composite of 10 increments
5. Minimum portion of stored material (at one site) to be sampled: 25%

Indicate deviations from above method: ________

____

____

____

SAMPLING DATA

Sample No.	Time	Location (Refer to map)	Surface Area	Depth	Quantity of Sample

MIDWEST RESEARCH INSTITUTE

MRI Project No. ______________ | Sampling Data
Exposed Areas - Industrial | Date ______________
Recorded by ______________

Type of Material Sampled: ______________

Site of Sampling: ______________

SAMPLING METHOD

1. Sampling device: ☐ whisk broom and dust pan ☐ straight-edge shovel
2. Sampling depth: ≤ 1 inch
3. Sample container: metal or plastic bucket with sealed poly liner
4. Gross sample specifications:
   (a) 1 sample of 50 lb minimum for every 50 acres sampled
   (b) composite of 10 increments
5. Minimum portion of exposed area (at one site) to be sampled: 25%

Indicate deviations from above method: ______________

____

____

____

SAMPLING DATA

Sample No.	Time	Location (Refer to map)	Surface Area	Depth	Quantity of Sample

MIDWEST RESEARCH INSTITUTE

MRI Project No.__________

Sampling Data
Unpaved Roads

Date__________
Recorded by__________

Type of Material Sampled: __________

Site of Sampling: __________

SAMPLING METHOD

1. Sampling device: whisk broom and dust pan
2. Sampling depth: loose surface material
3. Sample container: metal or plastic bucket with sealed poly liner
4. Gross sample specifications:
   (a) 1 sample of 50 lb minimum for every 10 miles sampled
   (b) composite of 4 increments: lateral strips of 6" width extending over traveled portion of roadway half

Indicate deviations from above method: __________

SAMPLING DATA

Sample No.	Time	Location	Surface Area	Depth	Quantity of Sample

DIAGRAM

MIDWEST RESEARCH INSTITUTE

MRI Project No. ____________ Sampling Data Paved Roads Date ____________ Recorded by ____________

Type of Material Sampled: ____________

Site of Sampling: ____________

Type of Pavement: ____________ Surface Condition ____________

SAMPLING METHOD

1. Sampling device: Portable vacuum cleaner (broom sweep first if loading is heavy)
2. Sampling depth: loose surface material
3. Sample container: metal or plastic bucket with sealed poly liner
4. Gross sample specifications:
   (a) 1 sample for significant road segment with given surface characteristics - not to exceed 100 miles
   (b) composite of 4 increments: lateral strips of 1 ft. minimum width extending over traveled portion of roadway half

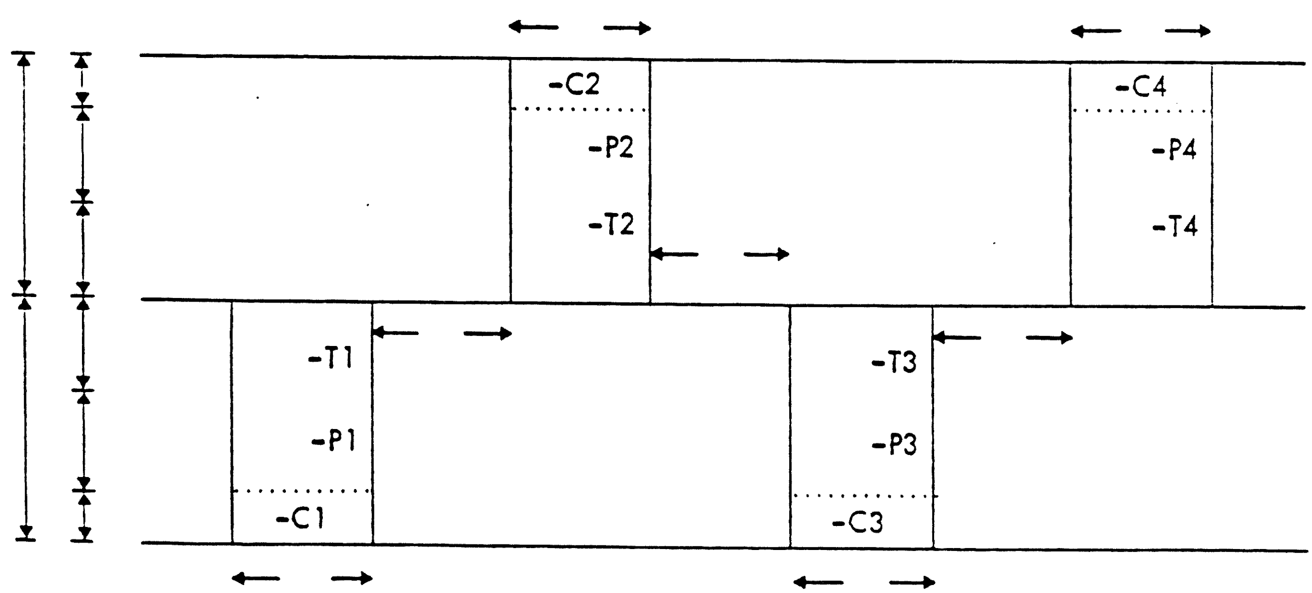
Indicate deviations from above method: ____________

SAMPLING DATA

Sample No.	Vac Bag	Time	Surface Area	Quantity of Sample

Sample No.	Vac Bag	Time	Surface Area	Quantity of Sample

DIAGRAM



Moisture Analysis Procedures

1. Preheat the oven to approximately 110°C (230°F). Record oven temperature.

2. Tare the laboratory sample containers which will be placed in the oven. Tare the containers with the lids on if they have lids. Record the tare weight(s).

3. Record the make, capacity, smallest division and accuracy (if displayed) of the balance.

4. Weigh the laboratory sample in the container(s). Record the combined weight(s).

5. Place sample in oven and dry overnight.[a/]

6. Remove sample container from oven and (a) weigh immediately if uncovered, being careful of the hot container, or (b) place tight fitting lid on the container and let cool before weighing. Record the combined sample and container weight(s).

7. Calculate the moisture as the initial weight of the sample and container minus the oven dried weight of the sample and container divided by the initial weight of the sample alone. Record the value.

8. Calculate the sample weight as the oven-dried weight of the sample and container minus the weight of the container alone. Record the value.

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a/ Materials composed of hydrated minerals or organic materials like coal and certain soils should be dried for only 1-1/2 hours.

Silt Analysis Procedures

1. Select the appropriate 8 in. diameter, 2 in. deep sieve sizes. Recommended U.S. Standard Series sizes are 3/8 in., No. 4, No. 20, No. 40, No. 140, No. 200 and a pan. Comparable Tyler Series sizes can also be utilized. The No. 20 and the No. 200 sieves are mandatory. The others can be varied if the recommended sieves are not available or if build-up on one particular sieve during sieving indicates that an intermediate sieve should be inserted.

2. Obtain a mechanical sieving device such as a vibratory shaker or a Ro-Tap.

3. Clean the sieves with compressed air and/or a soft brush. Material lodged in the sieve openings or adhering to the sides of the sieve should be removed as much as possible without handling the screen roughly.

4. Obtain a balance (capacity of at least 1600 g) and record make, capacity, smallest division, date of last calibration, and accuracy (if available).

5. Tare sieves and pan. Record weights.

6. After nesting the sieves in decreasing order with pan at the bottom, dump dried laboratory sample (immediately after moisture analysis, if possible) into the top sieve. Brush fine material adhering to the sides of the container into the top sieve and cover the top sieve with a special lid normally purchased with the pan.

7. Place nested sieves into the mechanical device and sieve for 20 minutes. Remove pan containing minus No. 200 and weigh. Replace pan beneath the sieves and sieve for another 10 minutes. Remove pan and weigh. When the difference between two successive weighings (where the tare of the pan has been subtracted) is less than 3.0%, the sieving is complete.

8. Weigh every sieve and its contents and record the weight.

9. Collect the laboratory sample and place the sample in a separate container if further analysis is expected.

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Silt and Moisture Analysis*

...lo. ________

...oject No. ________

Recorded by ________

Material: ________

Sample No: ________

Total Sample Weight: ________
(Excl. Container)
Number of Splits: ________

Oven Temperature ________
Date In ________ Date Out ________
Time In ________ Time Out ________
Drying Time ________
Split Sample Balance:
Make ________
Capacity ________
Smallest Division ________

MOISTURE CONTENT:
(A) Wet Sample Wt. ________
(B) Dry Sample Wt. ________
(C) Difference Wt. ________

$$\frac{C \times 100}{A} = \_\_\_\_\_\_ \text{ \% Moisture}$$

Split Sample Weight (before drying)
Pan + Sample: ________
Pan: ________
Wet Sample: ________

Material Weight (after drying)
Pan + Material: ________
Pan: ________
Dry Sample: ________

Sieving

Time: Start:	Weight (Pan Only)
Initial (Tare):	
20 min:	
30 min:	
40 min:	

SIZE DISTRIBUTION

Screen	Tare Weight (Screen)	Final Weight (Screen + Sample)	Net Weight (Sample)	%
0.375 in.				
4 mesh				
20 mesh				
40 mesh				
140 mesh				
200 mesh				
Pan				

Net Weight <20 mesh: ________
Net Weight <200 mesh: ________

$$\text{...lt:} = \frac{\text{Net Weight} < 200 \text{ Mesh}}{\text{Total Net Weight}} \times 100 = \_\_\_\_\_\_ \times 100 = \_\_\_\_ \%$$

...dicate Units with all Weights

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