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Linn County, Iowa Non-Traditional Fugitive Dust Study

LINN COUNTY, IOWA
NON-TRADITIONAL FUGITIVE DUST STUDY

by

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DISCLAIMER

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ABSTRACT

Linn County, Iowa is one of the State's four primary non-attainment areas for total suspended particulate matter. Since non-traditional fugitive dust sources can be significant contributors to ambient air quality, they must be properly inventoried and evaluated before control strategies can be identified. This report presents the results of a study that was performed to assist the Iowa Department of Environmental Quality in the definition of the non-traditional sources of fugitive dust in Linn County.

The study was separated into three tasks: update the area source inventory, analyze the existing monitoring data to determine source impacts, and provide a control strategy for non-traditional sources.

The results of the study indicate that (1) all future large scale construction projects must incorporate fugitive dust controls, (2) surfacing of unpaved roads throughout the region should be continued, and (3) the impact of industrial fugitive dust sources should be reduced.

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ACKNOWLEDGEMENTS

The author wishes to express his sincere gratitude to Mr. Robert Madson of the Cedar Rapids Department of Planning and Redevelopment and Mr. Gregory Slager of the Linn County Health Department for their enthusiastic cooperation with this study. The Cedar Rapids Department of Planning and Redevelopment provide staff report for the Linn County Regional Planning Commission which is the designated lead local planning agency for transportation-air quality issues. The Linn County Health Department has been delegated authority for air pollution control programs in Linn County and, as such, issues permits for new sources and carries out inspection and enforcement activities for industrial and mobile sources.

The author also wants to extend his gratitude to Mr. Jerry Tonneson of the Iowa Department of Water, Air and Waste Management for his assistance, guidance, and encouragement with this project.

SECTION 1

INTRODUCTION

The Clean Air Act Amendments of 1977 required all states to submit State Implementation Plans (SIP's) for demonstrating the attainment of National Ambient Air Quality Standards (NAAQS) by December 31, 1982. Linn County, Iowa (Cedar Rapids area) is one of the State's four primary non-attainment areas for total suspended particulate (TSP) matter (Figure 1-1). The SIP addressed attainment through further controls on traditional sources and possible control of non-traditional sources.

Non-traditional fugitive dust sources (i.e., those sources where particulate matter become airborne, excluding heating sources and process sources which emit through a stack) can have a major impact on ambient particulate air quality. To properly address the non-attainment problem in the Cedar Rapids area, these fugitive sources must be properly inventoried and evaluated before control strategies can be identified. Since such an evaluation has not been adequately performed for regulation impact, the Iowa Department of Environmental Quality (IDEQ) requested assistance in order to complete their SIP for attainment of the NAAQS for TSP. TRC Environmental Consultants, Inc. (TRC) was contracted by EPA Region VII to assist the IDEQ in this area.

The work performed by TRC was divided into three separate tasks. The purpose of Task I was to prepare a detailed source inventory listing of those area sources contributing to the TSP non-attainment problem in Linn County. The purpose of Task II was to analyze the TSP ambient monitoring data to determine the contribution by non-traditional fugitive dust sources to the ambient TSP levels. The purpose of Task III was to utilize the results of Tasks I and II to provide a strategy for the reduction of the impact of fugitive sources for the attainment of the TSP NAAQS.

This report discusses the technical approach to each of the three tasks, presents the results of the analyses, and provides conclusions and recommendations based on the results. All procedures, assumptions and calculations used to develop the proposed regulatory control strategy are identified and documented.

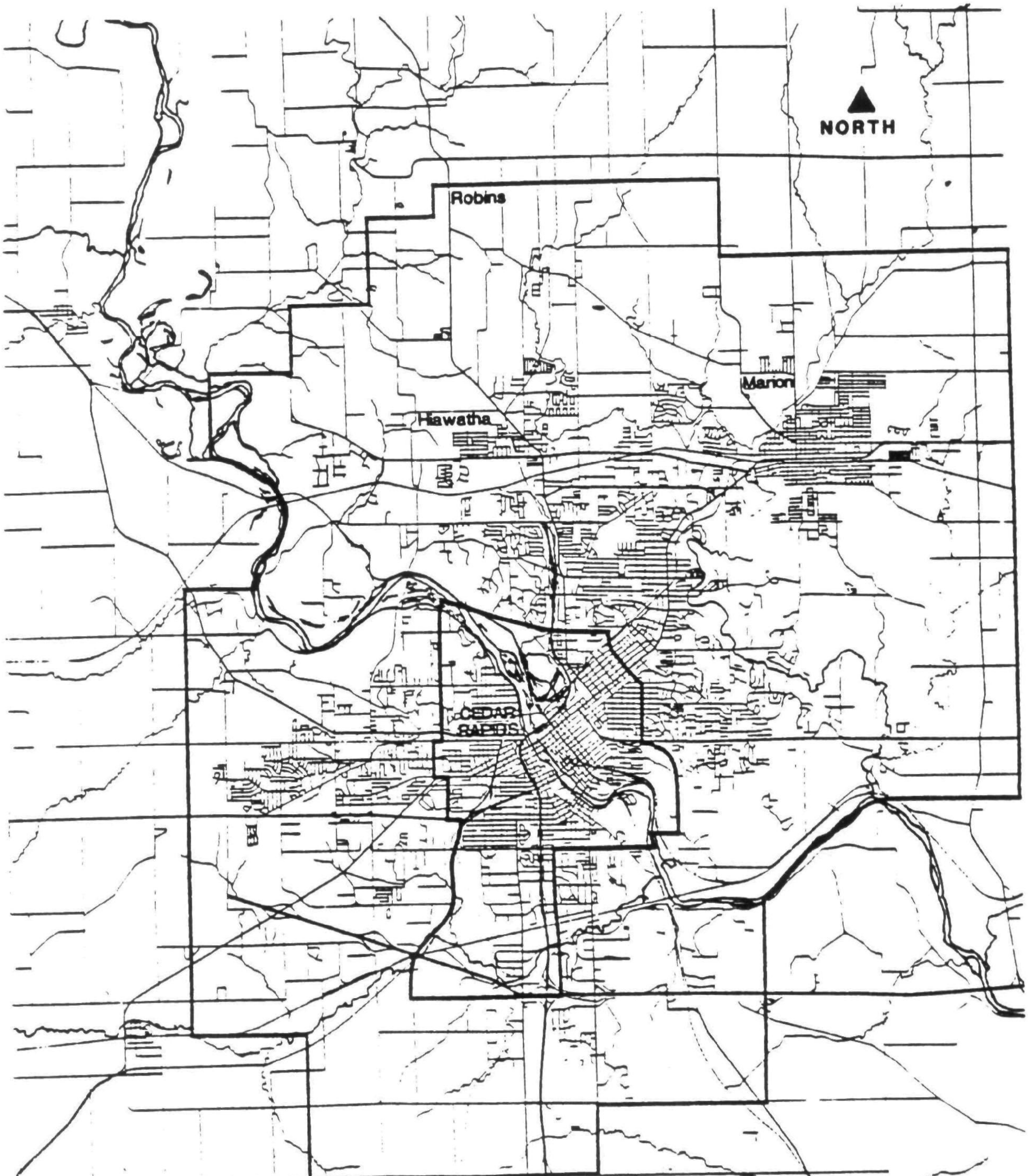

Figure 1-1. Primary and secondary non-attainment areas for total suspended particulate.

SECTION 2

CONCLUSIONS

The yearly geometric mean TSP levels recorded at each of the five Linn County air quality monitoring stations were below the NAAQS for TSP during the past year (1982). The three main factors contributing to this reduction in TSP levels were an inordinate amount of precipitation during the year, a hiatus in major construction activities, and a continued reduction in industrial activity due to the depressed economic situation that exists throughout the country. Based on the results of the analyses performed during this study, it is concluded that, without additional control measures, violations of the TSP NAAQS could again occur as a result of increased industrial productivity and/or less than normal precipitation levels and/or a major construction project in the vicinity of a monitoring station. General conclusions regarding the non-traditional sources contributing to the measured air quality and the additional control measures that could be implemented to reduce the impact of these sources are discussed below. Specific conclusions are presented in Sections 4, 5, and 6 of this report for the area source inventory, ambient air impact, and control strategy tasks, respectively.

AREA SOURCE INVENTORY

Based on the updated area source inventory that resulted from Task I of this study, traffic on paved and unpaved roads produce the greatest amount of emissions. Table 2-1 is a summary of the yearly emission totals for each of the major fugitive dust source categories. While it is noted that agricultural sources of fugitive dust are also significant, such sources are seasonal, further removed from population centers, and not readily controllable. They should thus not be part of an overall control strategy.

Although the inventory gives relative emission rates for the various source categories, the lack of more specific input coupled with the relative uncertainties in emission factors and control efficiencies results in a product of somewhat limited use. The intended use of most inventories is for computer modeling to predict ambient air quality impact. While this inventory could certainly be used for modeling, it is concluded that a much more detailed inventory should be prepared for the paved and unpaved road source categories. The other categories are felt to be fairly representative and they also have a lesser impact on the ambient air quality. This will be discussed further in the Recommendations section.

AMBIENT AIR IMPACT OF AREA SOURCES

The major area source currently contributing to the air quality data recorded at the five Linn County monitoring stations is traffic on urban paved and unpaved roads and industrial roadways. It is concluded that traffic-related emissions annually contribute 15 to 20 $\mu g/m^3$ at monitoring Sites 2, 4, and 5 (751 Center Point Road, 445 First Street, and 4401 Sixth Street, respectively) and 5 to 10 $\mu g/m^3$ at Sites 1 and 3 (4426 Council Street and 14th Avenue and 10th Street, respectively).

Industrial fugitive emissions also contribute significantly to the overall particulate levels recorded at several of the sites. Site 3 is affected by fugitive dust sources at the Wilson Company and Cargill - 16th Street to the extent of 5 to 10 $\mu g/m^3$ annually. Area source emissions from Penick & Ford annually contribute approximately 5 to 6 $\mu g/m^3$ to the particulate levels recorded at Site 4.

To a lesser extent, localized area sources contribute to the particulate levels recorded at various monitoring stations. The principal example of this is the Hawkeye Downs fairgrounds where activities contribute approximately 2 to 3 $\mu g/m^3$ to the particulate levels recorded at Site 5.

In the past, highway construction has caused an overwhelming impact on air quality. The emissions produced by the construction of Route 380 through the middle of Cedar Rapids resulted in an additional 35 $\mu g/m^3$ annual impact at Site 2 in 1977. Likewise, the construction of Routes 380 and 30 resulted in an additional 20 $\mu g/m^3$ annual impact at Site 5 in 1978.

AREA SOURCE CONTROL STRATEGY

To preclude the possibility of another annual NAAQS violation, controls for specific area sources should be considered.

Since large scale construction activities have been shown to produce the greatest impact on ambient air quality of any area source category, such activities should be controlled and strictly enforced. A variety of control techniques can be applied to construction activities and these are discussed in Section 6.

The second greatest impact on air quality stems from traffic on paved and unpaved roads. Emissions from paved roads in the core area are currently being addressed through a very extensive street cleaning program. This program could be extended to the environs of Cedar Rapids and also examined to ensure that clean-up is occurring immediately after sanding and salting events in the winter. Unpaved roads should be treated as time and budget allow. Efforts should be initially directed to the unpaved streets in the core area.

An industrial fugitive dust reduction plan should be initiated to reduce the impact of this source category. In general, good housekeeping practices such as road cleaning, spill clean-up and wheel washes will greately reduce the quantity of dust being emitted.

TABLE 2-1. RESULTS OF AREA SOURCE EMISSIONS INVENTORY FOR LINN COUNTY

Souce category	Emission rate (tons/year)
Agriculture	
Wind erosion	4485
Soil preparation activities	1660
Construction	172
Traffic on County Roads	
Municipal primary	1223
Municipal interstate	29
Municipal streets	6526
Rural primary	1371
Rural interstate	5
Rural secondary	
Unimproved	2
Graded and drained	377
Gravel	50324
Bituminous	75
Paved	1943
Traffic on roads in Cedar Rapids	
Paved	6782
Unimproved	37
Gravel or stone	13832
Oil surface on non-prepared base	12910
Industrial fugitives	
Traffic on paved roads/lots	366
Traffic on unpaved roads/lots	181
Storage pile/materials handling	190

SECTION 3

RECOMMENDATIONS

Based on the analyses performed during this study, it was possible to establish area source contributions to ambient air quality to a fair degree of certainty in most instances. It was then possible to propose a control strategy that could be implemented to reduce these contributions. However, there are certain areas of uncertainty that still exist and further work could be done to better define these particular areas.

INVENTORY ACCURACY

The main recommendation is to prepare a more detailed paved and unpaved road emission inventory. The data on mileage, VMT, and road type exist, but require considerable manipulation in order to be meaningful. Once these data are prepared, then emissions can be estimated to a greater degree of certainty and future modeling becomes more precise and useful.

It should be noted that a completely accurate area source inventory can never be realistically achieved since this would require detailed testing of each and every source. This means that there will always be some uncertainty in the use of air quality models. There are, however, receptor modeling techniques that could be used to "fine tune" the results, but, based on the current situation in Linn County, such detailed analyses are not recommended.

SOURCE IMPACT DEFINITION

In several cases, there is uncertainty as to the degree of impact of specific area sources on a particular monitor. One example is Site 3 where winds from the south, southwest carry emissions to the monitor from several types of sources (landfill, industrial fugitives, unpaved roads). It is recommended that scanning electron microscope analyses be performed on selected filters to help distinguish individual source impacts. This technique has proved very successful in similar instances in defining particle types and size spectra. The results of such a study would be very useful for fine tuning the proposed control strategy. The results would also be useful for determining ambient air quality impacts of material less than 10 µm so that the affect of the proposed PM10 standard is addressed.

INDUSTRIAL AWARENESS

Industrial fugitive emissions were shown to impact several monitoring sites. While the questionnaires received from the industries are a giant step in recognizing the types and extents of industrial fugitive sources, they also tend to show a general lack of awareness of what fugitive sources are and what controls can accomplish. It is recommended that some type of "awareness" program be undertaken to educate the industrial community in the area of fugitive emissions and their control. This can take the form of individual plant visits and discussions with plant managers, either by a consultant or a local air pollution official, or it can be in the form of a general seminar conducted by an expert for representatives from all industries.

SECTION 4

TASK I - AREA SOURCE INVENTORY

The purpose of Task I was to prepare a detailed source inventory listing of those area sources contributing to the TSP non-attainment problem in Linn County, Iowa. This was to be accomplished in the following manner:

- Review and evaluate all existing information to establish a data base to be updated.
- Gather new emissions information necessary for updating the data base.
- Prepare a new, updated area source emissions inventory.

The subsections that follow describe in detail the various activities required to complete Task I.

REVIEW AND EVALUATION OF EXISTING INFORMATION

TRC reviewed four reports that contain fugitive dust information relating to Iowa in general and Linn County in particular. These four reports were:

- Inventory of Particulate Area Sources in the State of Iowa. EPA-907/9-81-010, PEDCo Environmental, Inc., December 1981.
- Iowa State Implementation Plan Revisions to Control Air Pollution. Iowa Department of Environmental Quality.
- Air Quality Plan (Draft). Barton-Aschman Associates, Inc., September 1982.
- Filter Analysis and Particulate Identification - Volume I (Draft). PEDCo Environmental, Inc., March 1982.

The purpose of the review was to evaluate the thoroughness and accuracy of the existing area source inventory. Those areas requiring revision and updating and those sources omitted from the inventory were to be identified.

Upon completion of the reviews, it was evident that the bulk of the material pertinent to Task I was contained in the PEDCo (1981) report. The

PEDCo (1982) report presents microinventory and filter analyses results that were useful for the Task II work, but not for Task I. The Barton-Aschman (1982) report presents recommendations for control strategies for emissions from roads that were useful for the Task III work. Their emissions estimations were based, in part, on the PEDCo (1981) work. The Iowa SIP report presents a very general area source inventory which was based on very general emission factors. The PEDCo (1981) report is felt to contain much more specific information. This information is evaluated below.

Evaluation of Existing Area Source Inventory Information

PEDCo calculated emissions for Linn County from four categories of fugitive dust sources: agriculture, construction, unpaved roads, and paved roads. The emission factor equations they used in these calculations, the input data, and the results are summarized in Tables 4-1 and 4.2. TRC's evaluations of these factors and inputs are presented in the following paragraphs.

Agriculture--

The wind erosion equation used for estimating the wind blown emissions is widely used and accepted. The input values selected by PEDCo are acceptable with the possible exception of V'. The values selected for V' were obtained from the interpolation of a graph in a region of the graph that is not well defined by the curves. TRC could not obtain the reference which presents the data that made up the curves (Craig and Turelle, "Guide for Wind Erosion Control on Cropland in the Great Plains States," USDA Soil Conservation Service, 1964), so PEDCo's interpolation has to suffice. The only area for updating is the planted acreage which PEDCo obtained from the Iowa Department of Agriculture for the years 1977-1979.

The equation used for estimating the emissions from agricultural tilling is outdated. Midwest Research Institute (MRI) has produced a new set of emission factors for soil preparation activities and published the information.[1] Their latest equation is as follows:

$$E = k\ (4.8)\ (s)^{0.6}\ \text{lbs/acre/year}$$

where s = soil silt content (%)

k = 1.0 for total particulate (all particle sizes)

= 0.8 for total suspended particulate

= 0.25 for inhalable particulate (<15 μm)

= 0.10 for fine particulate (<2.5 μm)

To account for differences in climatic conditions, this equation should contain a $(PE/45)^2$ correction term (the factor was based on test data obtained in the Sacramento area of California, PE = 41, and Kansas, PE = 50, and so an average value of 45 is selected as the correction parameter). This factor should also contain a correction term to account for the percentage of all agricultural emissions represented by soil preparation. Based on discussions with individuals who have worked in the agricultural area and TRC's extensive experience with fugitive emissions, it is felt that the soil preparation phase of the agricultural yearly cycle probably accounts for up to 70 percent of all of the emissions produced during the year. Harvesting would account for about 20 percent and all other activities would probably account for 10 percent.

Incorporating these correction terms, the equation for all agricultural activity becomes:

$$E = \frac{k\ (6.86)\ (s)^{0.6}}{(PE/45)^2} \text{ lbs/acre/year}$$

Substituting the values of 45 for s and 98 for PE (as assumed by PEDCo), the resulting emission factor is:

$$E = k\ (14.2) \text{ lbs/acre/year}$$

Again, the planted acreage information can be updated.

Construction--

The emission factor used for estimating construction emissions is the only one available. While many assumptions were made by PEDCo in the emission calculations (construction durations and acreage), they appear to be reasonable. The only area for updating is to use 1982 data instead of the 1980 data used by PEDCo.

Unpaved Roads--

A recent draft report by MRI[2] presents several emission factors for unpaved roads that are more applicable and up-to-date than the one used by PEDCo. The most useful factor for rural unpaved roads is the one developed by McCaldin and Heidel[3] from tests conducted on dirt roads in the southwest:

$$E = 0.00035\ s\ S^2 \quad \text{lbs/VMT}$$

where s = silt content of surface material (%)

S = vehicle speed (mi/hr)

TRC feels that a correction term of the form d/365 should be included in this equation when calculating yearly emissions to account for the number of dry days per year (d).

The segregation of road types by PEDCo with the associated silt and speed values are felt to be representative and will be used in the updated inventory. However, the latest information on VMT can be used.

Paved Roads--

MRI has also recently developed and published[4] a new set of emission factors for urban paved roads which should be used instead of the one used by PEDCo. The latest factors are:

$$E_{TSP} = 0.0208 \left(\frac{sL}{0.7}\right)^{0.9}$$

$$E_{IP} = 0.0090 \left(\frac{sL}{0.7}\right)^{0.8}$$

$$E_{10} = 0.0081 \left(\frac{sL}{0.7}\right)^{0.8}$$

$$E_{FP} = 0.0036 \left(\frac{sL}{0.7}\right)^{0.6}$$

where E = emission factor, lbs/VMT

TSP = total suspended particulate

IP = inhalable particulate (<15 μm)

10 = particulate <10 μm

FP = fine particulate (<2.5 μm)

sL = silt loading, grains/ft^2

In this same document MRI presents representative sL values for various roadway types that can be used in lieu of actual data from a particular study area. These sL values and the roadway definitions are as follows:

Roadway Type	Average Daily Traffic (ADT)	Number of Lanes	sL (grains/ft^2)
Freeways/Expressways	>10,000	≥ 4	0.03
Major Streets/Highways	>10,000	≥ 4	0.52
Collector Streets	500-10,000	2*	1.32
Local Streets	<500	2†	2.02

* Total roadway width $\geq$32 ft.
† Total roadway width <32 ft.

Substituting these values into the emission factor equations yields the following recommended emission factors for specific roadway categories and particle size fractions:

Emission Factor (lb/VMT)

	TSP	<15 μm	<10 μm	<2.5 μm
Local	0.053	0.021	0.018	0.0067
Collector	0.035	0.015	0.013	0.0053
Major	0.016	0.0071	0.0064	0.0030
Expressway	0.0012	0.00074	0.00067	0.00057

For the Linn County emission inventory, information can be provided by the Iowa Department of Transportation on VMT (mileage and ADT) for each of the roadway categories.

Information Omitted From Existing Area Source Inventory

The existing area source emission inventory contains very little information on industrial sources of fugitive dust.* The only data available are included in the suspended particulate point source inventory (Iowa SIP document) and this information is very outdated. The fugitive sources identified in this inventory, with the exception of those listed for the Corn Sweeteners plant, only include bulk receiving and bulk loadout. There is no mention of vehicular and storage pile sources of emissions. In order to prepare a more detailed area source inventory for Linn County, the emissions from these industrial sources must be included.

There are other sources of fugitive emissions not included in the inventory, sources such as dirt playgrounds, parking lots, racetracks, drive-in movie lots, etc. These sources might affect a nearby TSP monitor, but would not have a significant impact on the overall air quality of the county. They will therefore not be included in the emission inventory.

GATHERING OF NEW INFORMATION TO UPDATE INVENTORY

In order to update and expand the existing area source inventory, new input data had to be obtained. Most of the new data were updated versions of data used by PEDCo. For example, 1981 data on planted acres were obtained from the Iowa Department of Agriculture and 1981 data on construction permits were obtained from the Department of Planning and Redevelopment. The data for the industrial sources of fugitive emissions, however, were obtained from the individual plants.

To obtain the plant information necessary to calculate emissions from industrial fugitive sources, TRC prepared data gathering forms for use by the Linn County Health Department. Two forms were prepared: one for vehicular sources of fugitive dust (traffic on plant paved roads, unpaved roads, and parking lots) and one for materials handling sources of fugitive dust (storage pile loading and unloading, truck and railcar loading and unloading, and storage pile wind erosion). Examples of these forms are presented in Figures 4-1 and 4-2.

Copies of the forms were sent by the Health Department to the following Linn County industries:

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*While it is the policy of the IDEQ to classify all industrial sources of particulate as "traditional", it is important to classify industrial fugitive sources as "non-traditional" for the purposes of this study since they fit into that category as defined in Section 1 of this report.

o ADM Corn Sweeteners

o B.L. Anderson, Inc.
  Robins Quarry
  Lisbon Quarry
  C.R. Sand Plant
  Ivanhoe Sand Plant

o Cargill, Inc.
  6th Street SE
  10th Avenue NW
  16th Street

o Cedar Rapids Asphalt & Paving Co.
  J Street SW
  Marion

o Century Engineering Co.

o Cherry Burrell

o City of Cedar Rapids Water Pollution Control Facilities

o E. Cohn & Sons
  Wilson Avenue
  3rd Street SW
  L Street SW

o Cryovac Division of W.R. Grace & Co.

o Diamond V. Mills

o Farmland Industries
  6th Street
  Bowling Street
  C Street

o General Mills

o Harnischfeger

o Hubbard Milling Co.

o Iowa Electric Light & Power
  6th Street NE
  Prairie Creek

o Iowa Manufacturing Co.

o Iowa Steel and Iron

o Katz Salvage

- o Lee Crawford Quarry Co.
- o Le Febure Corporation
- o Martin Marietta
- o Midland Forge
- o National Oats
- o Penick & Ford, Limited
- o Quaker Oats
- o Rockwell International
  Collins Road
  Graphic Systems Division
- o Wilson Foods

PREPARATION OF UPDATED AREA SOURCE EMISSIONS INVENTORY

A summary of the emission factors used in the preparation of the updated area source emissions inventory is presented in Tables 4-3 and 4-4. Table 4-3 presents the factors for the source categories of agriculture, construction, and traffic on county paved and unpaved roads. Table 4-4 presents the factors for the industrial sources of fugitive dust. While emission factors in general are usually only accurate to within a few orders of magnitude when used on sources other than those tested in the original development of the factor, it is TRC's opinion that the ones selected for use in this study are the best documented and, therefore, the most acceptable.

Tables 4-5 through 4-7 present the results of the updated area source inventory for the agriculture and construction source categories. All assumptions pertinent to the calculations of the emissions are included with the tables unless otherwise noted. Where possible, emissions are also given by particle size.

All of the input information necessary for a detailed updating of the area source inventory for the paved and unpaved roads categories was not obtainable from IDOT. The information that IDOT transmitted is summarized in Table 4-8. Additional breakdowns of road type, etc., would require computer programming work and additional data processing on the part of IDOT which was outside the scope and resources of this project. Some additional information was obtained directly from the Linn County Department of Planning and Redevelopment. This information, which pertains only to unpaved roads in Cedar Rapids, is summarized below:

Road Type	Miles	Annual VMT
Unimproved	3.69	42,231
Gravel or Stone	85.34	7,727,181
Oil Surface on Non-Prepared Base	37.95	8,664,326

Based on the limited road data, an emissions inventory for traffic-related sources can be prepared but will require many assumptions. Table 4-9 presents the inventory for Linn County paved and unpaved roads (Cedar Rapids included) and Table 4-10 presents the inventory for just Cedar Rapids. Again, all assumptions are included with the tables and particle size information is given where possible. Perhaps the most inaccurate assumption is the one that all county municipal roads are paved. As can be seen in Table 4-10, this is not the case in Cedar Rapids where the emissions contribution from the unpaved roads exceed those from paved roads. More detailed input information is required for the traffic-related area source inventory to be more accurate.

Table 4-11 presents the results of the updated area source inventory for the industrial fugitive dust source category along with the pertinent assumptions.

SOURCE TYPE: VEHICULAR TRAFFIC ON INDUSTRIAL ROADS/PARKING LOTS

COMPANY:

ROAD SEGMENT	1	2	3	4	5
SURFACE TYPE [a]					
LENGTH (MILES) [b]					
NO. OF LANES [c]					
SILT CONTENT (%)					
SURFACE LOADING (LB/MI)[d]					

CARS	NO. PER DAY					
	NO. PER YEAR					
	AVG. SPEED (MPH)					
	AVG. WEIGHT (TONS)					
	AVG. NO. OF WHEELS					
Pick-ups and Vans	NO. PER DAY					
	NO. PER YEAR					
	AVG. SPEED (MPH)					
	AVG. WEIGHT (TONS)					
	AVG. NO. OF WHEELS					
Tandem Trucks	NO. PER DAY					
	NO. PER YEAR					
	AVG. SPEED (MPH)					
	AVG. WEIGHT (TONS)					
	AVG. NO. OF WHEELS					
Tractor Trailers	NO. PER DAY					
	NO. PER YEAR					
	AVG. SPEED (MPH)					
	AVG. WEIGHT (TONS)					
	AVG. NO. OF WHEELS					
Other	NO. PER DAY					
	NO. PER YEAR					
	AVG. SPEED (MPH)					
	AVG. WEIGHT (TONS)					
	AVG. NO. OF WHEELS					

DESCRIPTION OF DUST CONTROL METHOD(S) NOW USED OR PLANNED AND FREQUENCY OF APPLICATION:

a: Paved, unpaved, gravel, etc.
b: For parking lot: assume mid-point of lot to exit
c: Paved roads only
d: Paved areas only

Figure 4-1. Example of data gathering form for traffic sources.

SOURCE TYPE: MATERIALS HANDLING

COMPANY:

	1	2	3	4	5	6	7
TYPE OF OPERATION[a]							
TYPE OF MATERIAL							
PILE EXTENT (ACRES)[b]							
AMOUNT IN STORAGE (TONS)[b]							
SILT CONTENT (%)							
MOISTURE CONTENT (%)							
LOADING METHOD[c]							
LOADING DEVICE CAPACITY (Yd^3)[d]							
UNLOADING METHOD[c]							
UNLOADING DEVICE CAPACITY (Yd^3)[d]							
PROCESS RATE (TONS/DAY)							
PROCESS RATE (TONS/YEAR)							

DESCRIPTION OF DUST CONTROL METHOD(S) NOW USED OR PLANNED AND FREQUENCY OF APPLICATION:

a: Truck loading, storage pile, railcar unloading, etc.
b: Storage pile only
c: Frontend loader, clamshell, stacker, etc.
d: Batch loading only

Figure 4-2. Example of data gathering form for materials handling sources.

TABLE 4-1. EMISSION FACTORS USED BY PEDCo (1981)

Source category	Source activity	Emission factor/ equation	Description of variables/constants
Agriculture	Windblown dust	$E = aIKCL'V'$	E = emission factor (tons/acre/year) a = portion of total wind erosion losses that would be measured as particulates I = soil erodibility (tons/acre/year) K = surface roughness factor C = climatic factor L' = unsheltered field width factor V' = vegetative cover factor
Agriculture	Agricultural activity	$E = \frac{(5)(0.8)(1.4)\ s}{(PE/50)^2}$	E = emission factor (lbs/acre/year) 5 = arbitrary constant to account for combined emissions of all phases of activity 0.8 = 80% of the emissions predicted are likely to remain as suspended particulates 1.4 = constant developed by MRI in original emission factor s = silt content of surface soil (%) $(PE/50)^2$ = correction term to account for climatic differences PE = Thornthwaite's precipitation-evaporation index
Construction	Construction activity	$E = \frac{1.2}{(PE/50)^2}$	E = emission factor (tons/acre/month) 1.2 = emission factor developed by MRI $(PE/50)^2$ = correction term to account for climatic differences PE = Thornthwaite's precipitation-evaporation index
Unpaved roads	Traffic	$E = t(0.81)s(\frac{S}{30})(\frac{365-w}{365})$	E = emission factor (lbs/VMT) t = constant to account for percent likely to remain as suspended particulates (t=0.32 for unimproved and graded and drained roads; t=0.62 for gravel roads) 0.81 = constant developed by MRI in original emission factor s = silt content of road surface material (%) S = average vehicle speed (mi/hr) 30 = constant developed by MRI in original emission factor (365-w)/365 = correction term to account for precipitation w = annual number of days with 0.01 inch or more of rainfall and 1 inch or more of snow cover
Paved roads	Traffic	$E = 5.1$	E = emission factor (g/VMT) 5.1 = constant developed by MRI

TABLE 4-2. INPUT DATA AND RESULTS FOR PEDCo (1981) INVENTORY

Source category	Source activity	Input data									Emissions (tons/year)
Agriculture	Windblown dust	Crop type	a	I	K	C	L'	V'	E	Planted acres	
		Corn	0.025	56	0.6	0.08	0.75	0.24	0.01	150,000	1500
		Wheat	0.025	56	0.6	0.08	0.75	0	neg	200	-
		Oats	0.025	56	0.8	0.08	0.80	0	neg	19,500	-
		Sorghum	0.025	56	0.5	0.08	0.72	0	neg	1,100	-
		Soybeans	0.025	56	0.6	0.08	0.75	0.61	0.03	85,000	2550
		Alfalfa	0.025	56	1.0	0.08	0.72	0	neg	21,700	-
		Hay (other)	0.025	56	0.8	0.08	0.80	0	neg	4,700	-

Source category	Source activity	s	PE index	E	5 x E	Planted acres	Emissions (tons/year)
Agriculture	Agricultural activity	45	98	13.1	65.6	282,200	9256

Source category	Source activity	Construction type	Exposed acres	Duration	Permits	PE index	E	Emissions (tons/year)
Construction	Construction activity	Residential - 1 family	0.1	4 mos.	164	98	0.31	20
		Residential - 2 family	0.1	4 mos.	12	98	0.31	2
		Residential - 3 family	0.5	4 mos.	43	98	0.31	27
		Commercial	0.5	6 mos.	86	98	0.31	80
		Industrial	2.5	6 mos.	19	98	0.31	88
		Public	2.5	6 mos.	58	98	0.31	270

Source category	Source activity	Road type	Miles	Daily VMT	Annual 10^3 VMT	t	s	S	w	E	Emissions (tons/year)
Unpaved roads	Traffic	Unimproved	0.3	8	3	0.32	12	25	111	1.80	3
		Graded and drained	33.6	734	268	0.32	12	30	111	2.16	289
		Gravel	935.5	74595	27227	0.62	12	35	111	4.89	66570

Source category	Source activity	Annual 10^3 VMT	Emissions (tons/year)
Paved roads	Traffic	451886	2540

TABLE 4-3. EMISSION FACTORS USED IN THE UPDATED AREA SOURCE INVENTORY: AGRICULTURE, CONSTRUCTION, TRAFFIC ON COUNTY PAVED AND UNPAVED ROADS

Source category	Source activity	Emission factor/ equation	Principal references	Description of variables/constants
Agriculture	Windblown dust	$E = aIKCL'V'$	5, 6	E = emission factor (tons/acre/year) a = portion of total wind erosion losses that would be measured as particulates I = soil erodibility (tons/acre/year) K = surface roughness factor C = climatic factor L' = unsheltered field width factor V' = vegetative cover factor
Agriculture	Agricultural activity	$E = \frac{k(4.8)(s)^{0.6}(1.43)}{(PE/45)^2}$	1, 2	E = emission factor (lbs/acre/year) k = 1.0 for total particulate = 0.8 for total suspended particulate = 0.25 for material <15 μm = 0.10 for material <2.5 μm 4.8 = constant developed by MRI s = soil silt content (%) 1.43 = constant developed by TRC to account for all phases of agricultural activity $(PE/45)^2$ = correction term to account for climatic differences PE = Thornthwaite's precipitation-evaporation index
Construction	Construction activity	$E = \frac{1.2}{(PE/50)^2}$	7	E = emission factor (tons/acre/month) 1.2 = emission factor developed by MRI $(PE/50)^2$ = correction term to account for climatic differences PE = Thronthwaite's precipitation-evaporation index
Unpaved roads	Traffic	$E = 0.00035(s)(S)^2(d/365)$	2, 3	E = emission factor (lbs/VMT) 0.00035 = constant developed by McCaldin and Heidel s = silt content of surface material (%) S = vehicle speed (mi/hr) (d/365) = correction term to account for precipitation d = annual number of days with less than 0.01 inch of rainfall or 1 inch of snow cover
Paved roads	Traffic	$E = a(sL/0.7)^b$	4	E = emission factor (lbs/VMT) a, b = constants developed by MRI a = 0.0208, b = 0.9 for total suspended particulate a = 0.0090, b = 0.8 for material <15 μm a = 0.0081, b = 0.8 for material <10 μm a = 0.0036, b = 0.6 for material <2.5 μm sL = silt loading of surface material (grains/ft^2) 0.7 = constant developed by MRI

TABLE 4-4. EMISSION FACTORS USED IN THE UPDATED AREA SOURCE INVENTORY: INDUSTRIAL SOURCES OF FUGITIVE DUST

Source category	Source activity	Emission factor/ equation	Principal references	Description of variables/constants
Unpaved roads/ parking lots	Traffic	$E = k(5.9)(\frac{s}{12})(\frac{S}{30})(\frac{W}{3})^{0.7}(\frac{w}{4})^{0.5}(\frac{d}{365})$	2	E = emission factor (lbs/VMT) k = 1.0 for total suspended particulate = 0.57 for material <15 µm = 0.45 for material <10 µm = 0.16 for material <2.5 µm s = silt content of surface material (%) S = vehicle speed (mi/hr) W = vehicle weight (tons) w = number of wheels d = annual number of days with less than 0.01 inch of rainfall or 1 inch of snow cover 5.9, 12, 30, 3, 4, 365 = constants developed by MRI
Paved roads/ parking lots	Traffic	$E = k(0.09)(I)(\frac{4}{n})(\frac{s}{10})(\frac{L}{1000})(\frac{W}{3})^{0.7}$	2	E = emission factor (lbs/VMT) k = 1.0 for total suspended particulate = 0.64 for material <15 µm = 0.51 for material <10 µm = 0.17 for material <2.5 µm I = industrial road augmentation factor = 7 for large truck carry-out = 3.5 for vehicles hitting berms 20% of time = 1.0 for all traffic on paved surfaces n = number of traffic lanes s = silt content of surface material (%) L = surface loading (lbs/mi) W = vehicle weight (tons) 0.09, 4, 10, 1000, 3 = constants developed by MRI

(continued)

TABLE 4-4 (continued)

Source category	Source activity	Emission factor/ equation	Principal references	Description of variables/constants
Materials handling	Batch drop (front-end/ bucket loader)	$E = \dfrac{k(0.0018)(\frac{s}{5})(\frac{U}{5})(\frac{H}{5})}{(\frac{M}{2})^{2}(\frac{Y}{6})^{0.33}}$	2	E = emission factor (lbs/ton) k = 1.0 for total suspended particulate = 0.48 for material <15 μm = 0.36 for material <10 μm = 0.13 for material <2.5 μm s = silt content of material (%) U = wind speed (mi/hr) H = drop height (ft) M = moisture content of material (%) Y = capacity of unloading device (Yd^3) 0.0018, 5, 5, 5, 2, 6 = constants developed by MRI
Materials handling	Continuous drop	$E = \dfrac{k(0.0018)(\frac{s}{5})(\frac{U}{5})(\frac{H}{10})}{(\frac{M}{2})^{2}}$	2	E = emission factor (lbs/ton) k = 1.0 for total suspended particulate = 0.49 for material <15 μm = 0.37 for material <10 μm = 0.11 for material <2.5 μm s = silt content of material (%) U = wind speed (mi/hr) H = drop height (ft) M = moisture content of material (%) 0.0018, 5, 5, 10, 2 = constants developed by MRI
Materials handling	Railcar/truck unloading	E = 0.001	8	E = emission factor (lbs/ton) 0.001 = emission factor developed by TRC
Storage pile	Windage	$E = 1.7\ (\frac{s}{1.5})\ (\frac{d}{235})\ (\frac{f}{15})$	2	E = emission factor (lbs/acre/day) s = silt content of material (%) d = annual number of days with less than 0.01 inch of rainfall or 1 inch of snow cover f = percent of time that unobstructed wind speed exceeds 12 mph at the mean pile height 1.7, 1.5, 235, 15 = constants developed by MRI

TABLE 4-5. INPUT DATA AND RESULTS FOR UPDATED AREA SOURCE INVENTORY: WINDBLOWN DUST EMISSIONS FROM AGRICULTURE

Crop type	Input parameters						Emission factor (tons/acre/year)	Planted acres	Total suspended particulate emissions (tons/year)
	a	I	K	C	L'	V'			
Corn	0.025	56	0.6	0.08	0.75	0.24	0.01	156,000	1560
Wheat	0.025	56	0.6	0.08	0.75	0	neg	200	-
Oats	0.025	56	0.8	0.08	0.80	0	neg	16,600	-
Sorghum	0.025	56	0.5	0.08	0.72	0	neg	100	-
Soybeans	0.025	56	0.6	0.08	0.75	0.61	0.03	97,500	2925
Hay, alfalfa, other	0.025	56	0.8	0.08	0.80	0	neg	21,700	-
							Total	292,100	4485

Notes/assumptions:

* Values of input parameters (a, I, K, C, L', V') same as used by PEDCo (1981).

** Information on planted acres is for 1981 and was obtained from Mr. Bernie Janssen of the Iowa Department of Agriculture.

TABLE 4-6. INPUT DATA AND RESULTS FOR UPDATED AREA SOURCE INVENTORY: EMISSIONS FROM AGRICULTURAL ACTIVITY

Silt content, s (percent)	PE index	Emission factor (lbs/acre/year)	Planted acres	Emissions (tons/year)			
				Total particulate (k=1.0)	Total suspended particulate (k=0.8)	Material <15 μm (k=0.25)	Material <2.5 μm (k=0.10)
45	98	14.21 k	292,100	2075	1660	519	207

Notes/assumptions:

* Values of input parameters (s, PE) same as used by PEDCo (1981).

** Information on planted acres is for 1981 and was obtained from Mr. Bernie Janssen of the Iowa Department of Agriculture.

TABLE 4-7. INPUT DATA AND RESULTS FOR UPDATED AREA SOURCE INVENTORY: EMISSIONS FROM CONSTRUCTION ACTIVITY

Construction type	PE index	Emission factor (lbs/acre/year)	Exposed acres	Duration (months)	Number of permits	Total suspended particulate emissions (tons/year)
Residential - 1 family	98	0.31	0.1	4	141	18
Residential - 2 family	98	0.31	0.1	4	2	neg
Residential - 3 family	98	0.31	0.5	4	42	26
Commercial	98	0.31	0.5	6	51	48
Industrial	98	0.31	2.5	6	10	47
Public	98	0.31	2.5	6	7	33
					Total	172

Notes/assumptions:

- * Values of input parameters (PE index, exposed acres, duration) same as used by PEDCo (1981).

- ** Information on number of permits is for 1981 and was transmitted by Mr. Robert Madson of the Linn County Department of Planning and Redevelopment.

TABLE 4-8. COUNTY PAVED AND UNPAVED ROAD INFORMATION OBTAINED FROM THE IOWA DEPARTMENT OF TRANSPORTATION

System	Miles	ADT	Miles w/ADT zero	Annual VMT
Municipal primary	40.08	10,448	--	152,857,602
Municipal interstate	8.84	15,077	0.15	47,809,525
Municipal streets	633.34	1,644	12.10	372,927,973
Rural primary	102.64	4,574	--	171,370,617
Rural interstate	1.72	13,116	--	8,224,180
Rural secondary				
Legal	15.52	--	15.52	--
Unimproved	0.25	6	--	2,190
Graded and drained	33.53	786	--	286,890
Gravel	934.16	77,024	--	28,113,760
Bituminous	10.33	7,715	--	2,815,975
Paved	179.27	200,830	--	73,302,950
Proposed	5.12	--	5.12	--
Miscellaneous	5.50	--	5.50	--
Total	1,970.30	45,160	38.39	857,709,241

Note: This information is for all of Linn County which includes the following towns:

Alburnett	Lisbon
Bertram	Marion
Cedar Rapids	Mount Vernon
Center Point	Palo
Central City	Prairieburg
Coggon	Robins
Ely	Springville
Fairfax	Walker
Hiawatha	

For Cedar Rapids itself the only data obtained were the following:

478.76 miles of municipal roads with 476,616,000 VMT. The road mileage is broken down as follows: 351.78 paved, 3.69 unimproved, 85.34 gravel or stone, and 37.95 oil surface on non-prepared base. The breakdown of the VMT is given in Table 4-10.

TABLE 4-9. INPUT DATA AND RESULTS FOR UPDATED AREA SOURCE INVENTORY: EMISSIONS FROM TRAFFIC ON COUNTY PAVED AND UNPAVED ROADS

Road type	Silt content, s (percent)	Average vehicle speed S(mi/hr)	Dry days per year, d	Emission factor (lbs/acre/year)	Annual VMT	Emissions (tons/year): Total suspended particulate (a=.0208, b=.9)	Material <15 µm (a=.0090, b=.8)	Material <10 µm (a=.0081, b=.8)	Material <2.5 µm (a=.0036, b=.6)
Municipal primary				a(0.743)[b]	152,857,602	1,223	543	489	229
Municipal interstate				a(0.043)[b]	47,809,525	29	18	16	14
Municipal streets				a(1.886)[b]	372,927,973	6,526	2,797	2,424	988
Rural primary				a(0.743)[b]	171,370,617	1,371	608	548	257
Rural interstate				a(0.043)[b]	8,224,180	5	3	3	2
Rural secondary									
Unimproved	12	25	254	1.83	2,190	2	--	--	--
Graded & drained	12	30	254	2.63	286,890	377	--	--	--
Gravel	12	35	254	3.58	28,113,760	50,324	--	--	--
Bituminous				a(2.886)[b]	2,815,975	75	30	25	9
Paved				a(2.886)[b]	73,302,950	1,943	770	660	246

Notes/assumptions:

* Assumed all municipal streets to be paved since more detailed information not available.

** Assumed municipal and rural interstates to be similar to MRI freeway/expressway classification.

*** Assumed municipal and rural primaries to be similar to MRI major street/highway classification.

**** Assumed municipal streets to be similar to MRI collector classification.

***** Assumed rural secondary paved roads to be similar to MRI local classification.

****** Silt contents, average vehicle speeds, and dry days per year same as used in PEDCo inventory.

TABLE 4-10. INPUT DATA AND RESULTS FOR UPDATED AREA SOURCE INVENTORY: EMISSIONS FROM TRAFFIC ON MUNICIPAL ROADS IN CEDAR RAPIDS

Road type	Silt content, s (percent)	Average vehicle speed S (mi/h)	Dry days per year, d	Emission factor (lbs/VMT)	Annual VMT	Emissions (tons/year) Total suspended particulate (a=.0208, b=.9)	Material <15 μm (a=.0090, b=.8)	Material <10 μm (a=.0081, b=.8)	Material <2.5 μm (a=.0036, b=.6)
Paved				$a(1.473)^b$	460,182,262	6,782	2,823	2,541	1,045
Unimproved	12	25	254	1.83	42,231	37	--	--	--
Gravel or stone	12	35	254	3.58	7,727,181	13,832	--	--	--
Oil surface on non-prepared base	10	35	254	2.98	8,664,326	12,910	--	--	--

Notes/assumptions:

* Assumed paved municipal streets to be composed of 70 percent collector, 20 percent major/highway, and 10 percent freeway/expressway.

** Silt contents, average vehicle speeds, and dry days per year same as used in PEDCo inventory except for oil surface where the values of s and S are TRC estimates.

*** Annual VMT for paved streets obtained by subtracting unpaved VMT's from data obtained from IDOT (Refer to Table 4-8).

TABLE 4-11. RESULTS FOR UPDATED AREA SOURCE INVENTORY: EMISSIONS FROM INDUSTRIAL SOURCES

	Vehicular emissions (tons/year)				Storage pile emissions (tons/year)			
Company	Paved roads	Paved lots	Unpaved roads	Unpaved lots	Load in	Load out	Wind erosion	Material handling emissions - loading/unloading: truck/railcar (tons/year)
ADM Corn Sweeteners	25.8 k_1	--	3.8 k_2	0.1 k_2	--	--	--	0.2
B.L. Anderson, Inc. - Robins Quarry	1.5 k_1	--	--	--	neg.	--	60.9	--
- Lisbon Quarry	0.6 k_1	--	--	--	neg.	--	39.0	--
- C.R. Sand Plant	--	--	1.7 k_2	--	neg.	--	12.2	--
- Ivanhoe Sand Plant	--	--	2.0 k_2	--	neg.	--	4.9	--
Cargill, Inc. - 6th Street SW	5.3 k_1	neg.	--	0.2 k_2	--	--	--	--
- 10th Avenue NW	14.7 k_1	0.2 k_1	--	neg.	--	--	--	neg.
- 16th Street	--	--	47.0 k_2	--	--	--	--	neg.
Cedar Rapids Asphalt - J Street	2.1 k_1	--	5.7 k_2	--	neg.	neg.	1.8	--
- Marion	0.6 k_1	--	neg.	--	neg.	neg.	1.0	--
Century Engineering Co.	--	1.1 k_1	--	--	--	--	--	--
Cherry Burrell	4.4 k_1	1.2 k_1	--	--	--	--	--	--
City Water Pollution Control	2.8 k_1	--	1.2 k_2	--	--	--	--	neg.
E. Cohn & Sons - Wilson Avenue	--	--	neg.	--	--	--	--	--
- 3rd Street SW	--	neg.	neg.	--	--	--	--	--
- L Street SW	neg.	--	--	neg.	--	--	--	--
Cryovac Div. of W.R. Grace & Co.	0.2 k_1	0.6 k_1	--	--	--	--	--	--
Diamond V. Mills, Inc.	0.1 k_1	--	neg.	--	--	--	--	neg.
Farmland Industries	--	--	3.5 k_2	--	--	--	--	neg.
FMC - Sixth Street	23.4 k_1	--	0.1 k_2	--	--	--	--	--
- Bowling Street	46.1 k_1	--	2.3 k_2	--	--	--	--	--
- C Street	15.2 k_1	--	neg.	--	--	--	--	--
General Mills, Inc.	8.4 k_1	--	2.8 k_2	--	--	--	--	--
Harnischfeger	79.0 k_1	--	--	--	--	--	--	--
Hubbard Milling Co.	--	--	7.9 k_2	--	--	--	--	neg.
Iowa Electric - 6th Street	--	--	0.7 k_2	0.7 k_2	--	--	--	0.1
- Prairie Creek	0.9 k_1	--	10.0 k_2	--	0.3	0.3	41.9	--
Iowa Manufacturing Co.	14.7 k_1	--	0.4 k_2	--	--	--	--	--
Iowa Steel & Iron	--	neg.	--	neg.	neg.	neg.	neg.	--
Katz Salvage	--	--	0.4 k_2	--	--	--	--	--

(continued)

TABLE 4-11 (continued)

Company	Vehicular emissions (tons/year) Paved roads	Paved lots	Unpaved roads	Unpaved lots	Storage pile emissions (tons/year) Load in	Load out	Wind erosion	Material handling emissions - loading/unloading: truck/railcar (tons/year)
Lee Crawford Quarry Co.	--	--	37.9 k_2	--	0.3	0.3 k_3	11.0	--
LeFebure Corp.	5.2 k_1	--	--	--	--	--	--	--
Martin Marietta	7.3 k_1	--	32.4 k_2	--	0.2 k_3	0.2 k_3	12.2	0.2 k_3
Midland Forge	0.8 k_1	1.4 k_1	--	--	--	--	--	--
National Oats	0.9 k_1	0.1 k_1	--	1.9 k_2	--	--	--	neg.
Penick & Ford, Ltd.	0.6 k_1	0.4 k_1	18.5 k_2	--	--	--	--	neg.
Quaker Oats	9.2 k_1	6.9 k_1	--	--	--	--	--	neg.
Rockwell Int. - Collins Road NE	31.4 k_1	--	--	--	--	--	--	--
- Graphic Systems Div.	19.5 k_1	--	--	--	--	--	--	--
Wilson Foods	27.5 k_1	6.0 k_1	--	--	neg.	neg.	2.2	neg.

Notes/assumptions:

* Negligible emissions are those less than 0.1 tons/year

** Unless specified in the questionnaires, the values of the input parameters for the equations presented in Table 4-4 were assumed to be the following:
I = 2 for paved roads and 1 for paved parking lots
n = 1 for paved parking lots
s = 10 percent for unpaved roads and 20 percent for paved roads (based on TRC field tests)
s = 5 percent for materials handling except for washed coal where s = 1.5 percent
L = 500 lbs/VMT (based on TRC field tests)
U = 10.6 mi/hr (based on 5 years of historical meteorological data from Linn County)
f = 32.7 percent (based on 5 years of historical meteorological data from Linn County)
d = 254 (same as used by PEDCo)
H = 5 ft. for batch drops and 10 ft. for continuous drops

*** The following control efficiencies were used in calculating emissions:
20 percent for gravel road treated with calcium chloride (Farmland Industries, Hubbard Milling)
50 percent for watering storage piles (Lee Crawford Quarry)
50 percent for oil base road (Cargill - 16th Street)
50 percent for watering unpaved roads (Iowa Electric Light & Power, Martin Marietta, City Water Pollution)
50 percent for oiling a gravel road (Penick & Ford)
75 percent for oil and water on roads (Lee Crawford Quarry)

**** For total suspended particulate emissions: $k_1 = k_2 = k_3 = 1.0$
for emissions of material <15 µm: $k_1 = 0.57$, $k_2 = 0.64$, $k_3 = 0.48$
for emissions of material <10 µm: $k_1 = 0.45$, $k_2 = 0.51$, $k_3 = 0.36$
for emissions of material <2.5 µm: $k_1 = 0.16$, $k_2 = 0.17$, $k_3 = 0.13$

SECTION 5

TASK II - TSP AMBIENT MONITORING DATA ANALYSIS

The purpose of Task II was to analyze the TSP ambient monitoring data to determine the contribution by non-traditional fugitive dust sources to the ambient TSP levels. The approach taken to perform this task included the following steps:

- Gather data and perform analyses
  - Gather historical TSP data
  - Perform background analysis
  - Perform yearly trend analysis-with and without removal of background
  - Perform monthly trend analysis
  - Gather and analyze meteorological data
  - Perform pollution rose analysis
  - Perform spatial correlation analysis
  - Gather additional reference materials
- Assimilate information: results and conclusions.

The details of each of these steps are presented in the following subsections.

DATA BASE AND TECHNICAL APPROACH

Historical TSP Data

Historical TSP data were obtained from the IDEQ for the five monitoring sites in Linn County for the years 1976-1982. The locations of the sites are as follows:

- Site 1 - Noelridge Park
  4426 Council Street NE
- Site 2 - Linn County Health Department
  751 Center Point Road NE
- Site 3 - Jane Boyd Community Center
  14th Avenue and 10th Street SE

o Site 4 - City Garages
445 First Street SW

o Site 5 - Grant Wood Building
4401 Sixth Street SW

Historical TSP data were also obtained for a background station located at Backbone State Park which is approximately 45 miles north of Cedar Rapids in Dundee. Data for this site were from the years 1978-1982. Descriptions of the five Linn County sites can be found in Reference 9. A description of the Dundee site can be found in Reference 10. A map depicting the locations of the five Linn County sites is presented in Figure 5-1.

Background Analysis

The monitoring station at Backbone State Park is located in a very isolated and rural area of Iowa. The TSP levels recorded by this monitor are considered by the IDEQ to be representative of the background conditions that exist throughout the State. Contributions to the background TSP levels are assumed to come from natural sources (worldwide and continental), unpaved roads, and agricultural activities.

When the IDEQ prepared their SIP (Reference 9), they assumed a constant, yearly background level of 36 $\mu g/m^3$ for the area around Backbone State Park. They then performed an analysis of agricultural activity throughout the state and arrived at a background level of 40 $\mu g/m^3$ for Linn County. While this approach is appropriate for modeling purposes, it is misleading for the work to be performed during this current study. To understand fluctuations in the TSP levels in Linn County, any fluctuations in the background levels have to be known and the reasons for the fluctuations have to be understood. Thus, a background analysis was performed.

As the first step in the background analysis, the historical TSP data recorded at Backbone State Park were analyzed and the yearly geometric means were calculated, as follows (no data were recorded at this site prior to 1978):

Year:	1978	1979	1980	1981	1982
TSP Level ($\mu g/m^3$):	37.9	35.8	40.7	36.5	26.0

The next step was to hypothesize that the yearly fluctuations in TSP levels coincided with yearly fluctuations in precipitation. To test this hypothesis, the total yearly precipitation recorded in Cedar Rapids was obtained from Reference 10 (it must be assumed that Backbone State Park experienced similar yearly precipitation fluctuations), as follows:

Year:	1976	1977	1978	1979	1980
Precipitation (inches):	23	35	36	39	32

Since the precipitation data available for the years 1981 and 1982 were insufficient to calculate yearly totals, only three years of precipitation and TSP data can be compared. Plotting TSP versus precipitation for the years 1978-1980 (Figure 5-2) yields a linear relationship of the form:

$$TSP = 63.1 - 0.7 \text{ (inches of precipitation)}$$

The hypothesis thus appears to be accurate.

Assuming that the above relationship is valid, then interpolated background levels can be obtained for the years 1976 and 1977 based on the recorded precipitation for those years. These levels are as follows:

Year:	1976	1977
TSP Level ($\mu g/m^3$):	47.0	38.6

Yearly Trend Analysis

The historical TSP data were analyzed and the yearly geometric mean particulate levels were calculated for the five monitoring locations in Linn County. Table 5-1 and Figure 5-3 present the results with the background levels also included.

To remove the effects of yearly fluctuations in precipitation from the data, the background levels were subtracted from the levels recorded at the five Linn County stations. The results are presented in Table 5-2 and Figure 5-4.

An important point to note at this time is that 1982 was an extremely "wet" year which produced a low background level (26 $\mu g/m^3$). This is one of the main reasons that all stations recorded levels that were below the primary standard. The average background level for the seven year period was 37.5 $\mu g/m^3$, almost 12 $\mu g/m^3$ higher than the 1982 level. This point will be discussed in more detail in a later section.

Monthly Trend Analysis

Another analysis technique used was the calculation of monthly means to note any monthly or seasonal trends that might help characterize the data. Again, the historical TSP data were analyzed and the monthly means were calculated for all study years combined (1976-1982) and for 1982 alone. The results are presented in Tables 5-3 and 5-4. Figure 5-5 graphically presents the 1982 data.

Meteorological Data

To perform the pollution rose and spatial correlation analyses as well as to provide overall insight into fluctuations in TSP levels, meteorological data were required for the study area. The only meteorological station in the area that collected the type of data necessary for analysis was the one located at the Cedar Rapids Municipal Airport. The data as received from the National Climatic Center in Ashville, North Carolina, were in "raw", unprocessed form instead of the usual presentation of Local Climatological Data (LCD) summaries which give daily averages of all recorded parameters as well as three-hour averages of selected variables. The Cedar Rapids data were in the form of hourly values for each day of the year with no daily summaries provided. Another drawback of the format of the meteorological data was the lack of meaningful precipitation information for the years 1976-1979.

The parameters that were calculated included average wind speed, resultant wind speed, resultant wind direction, and wind persistence. Wind persistence (P) is defined as the ratio of the vector average (resultant) wind speed to the average wind speed over the 24 hour period and is a measure of the wind variability. A persistence ≥ 0.71 is equivalent to an hourly wind direction deviation of $\leq 45^{o}$. In conducting the pollution rose and spatial correlation analyses, only those days with $P > 0.71$ are used.

The results of the calculations are presented in Tables 5-5 through 5-11 for those days on which TSP data were recorded at any of the monitors and the wind persistence was ≥ 0.71. The information received covers the period of January 1976 through October 1982.

An additional set of meteorological data was obtained from the National Climatic Center: surface wind tabulations for the five year period of 1963-1967. These data were used to calculate historical wind frequencies for the study area. These frequencies are summarized in Table 5-12. For comparison purposes, the 1976-1979 data set was analyzed in an identical manner. The results of this analysis are presented in Table 5-13.

One final meteorological data analysis was performed based on the wind directions on days when ambient air samples were obtained. The results of this wind frequency analysis are presented in Table 5-14 for each monitoring site for each of the study years and for all the years combined.

Pollution Rose Analysis

For the pollution rose analysis, the historical TSP data for each monitoring station are segregated into eight wind direction categories and then the average particulate level for each category is calculated. Only those data recorded on days with $P > 0.71$ are used. The results for all years are presented in Table 5-15. Figure 5-6 presents the pollution roses for 1982.

Spatial Correlation Analysis

The spatial correlation analysis consists of comparing the recorded TSP levels at the monitoring stations on a daily basis for each wind sector. Only the data recorded on days with $P > 0.71$ are used. This analysis is used to help determine which monitors are being affected by local sources and in what direction these sources might be located. The results are presented in Tables 5-16 through 5-23.

Additional Reference Materials

The final step of the technical approach prior to drawing conclusions was to gather additional information that might prove useful in locating sources or understanding source impact. The information collected included the following items:

- Aerial photographs of the study area taken on April 18, 1980 having a scale of 1" = 300'.
- U.S.G.S. topographic maps of the study area having a scale of 1" = 2000'.
- A detailed road map of the study area, copyrighted 1982.
- The four references received as part of Task I of this study (References 9-12).
- Traffic volume flow maps for 1977, 1979, and 1981 provided by the Traffic Engineering Department of the City of Cedar Rapids.
- A map showing the completion dates for various segments of Route 380.
- Correspondence from Robert Madson, Assistant Director, Department of Planning and Redevelopment, Cedar Rapids, providing some details on construction, traffic, and street sweeping practices.
- Hawkeye Downs activity data for 1982.
- Traffic data for the year 1981 provided by the Iowa Department of Transportation.

RESULTS AND CONCLUSIONS OF DATA ANALYSES

To determine the impact of particulate emissions from non-traditional sources at the monitoring sites, the influences of background and traditional sources must be subtracted out. For the purposes of this study, the following definitions are used for traditional and non-traditional sources:

> Traditional sources - stacks, fuel combustion, solid waste disposal, auto exhaust.
>
> Non-traditional sources - industrial fugitive emissions, paved roads, unpaved roads, construction, exposed areas (playgrounds, racetracks, etc.)

Background levels have already been addressed (Section 4) and their influence can be accounted for. The impact of traditional sources on the five monitoring locations has been modeled for the years 1977 and 1982 (Reference 9). It is felt that modeling of traditional sources is at least as accurate as the source apportionment techniques used in this study and can therefore be used as an adjunct method. This is not true, however, for non-traditional sources where there is such uncertainty in the inventory and in the emission strengths of the various sources (since the emission factors are not well defined, as discussed previously). Thus, the modeling results presented in Reference 9 for the non-traditional sources will not be used.

Table 5-24 presents the traditional source impacts, the background levels, the measured particulate levels, and, by difference, the non-traditional source impacts at each of the monitoring locations for each of the study years. For those cases where the 1977 and 1982 modeled traditional source impacts differed, a linear increase or decrease was assumed for the intervening years. The 1976 levels for traditional source impacts were assumed identical to the 1977 levels.

Figure 5-7 presents the estimated non-traditional source impacts at each of the monitoring sites for each of the study years. These impacts are discussed in the following subsections for each monitoring site.

<u>Site 1 - 4426 Council Street</u>

The air quality data recorded at Site 1 (Figure 5-3) indicate that the yearly geometric mean particulate levels are well below the NAAQS standard. Particulate levels have averaged approximately 21 $\mu g/m^3$ above background (Figure 5-4) with approximately 7 $\mu g/m^3$ of this amount attributable to traditional sources (Table 5-24). This, in turn, leaves an average impact of approximately 14 $\mu g/m^3$ due to non-traditional sources (Figure 5-7). This impact has varied from a low of 9 $\mu g/m^3$ in 1978 to a high of 19 $\mu g/m^3$ in 1980.

Based on the information presented and discussed in this report, it is concluded that traffic-related sources are contributing the bulk, if not all, of the 14 $\mu g/m^3$. In addition, the primary influence is from the region to the north of the monitoring site - the Collins Road area. The reasoning behind this conclusion is discussed in the following paragraphs.

In general, the data recorded at Site 1 have tracked the data recorded at Backbone State Park very closely. This is seen in both the yearly values (Figure 5-3) and the monthly values (Figure 5-5). This matching is indicative of general sources of fugitive dust, such as traffic. The greater deviation from background during the winter months indicates possible northwest through northeast influence since the prevailing winds are thus oriented in the winter (Tables 5-12 through 5-14). (This deviation may also be partly due to increased sanding and salting in the winter months and to increased residential fuel use).

The pollution rose data (Figure 5-6) again track background with higher levels when the winds are from the northeast through northwest. Except for southerly winds, the typical difference between the background and Site 1 data is 5-10 $\mu g/m^3$ for east through west winds and 20 $\mu g/m^3$ for northwest through northeast winds. The deviation with southerly winds is most likely due to traditional sources in the general Cedar Rapids area. On a yearly basis, the additional 25 $\mu g/m^3$ difference with northerly winds would correspond to approximately 4-5 $\mu g/m^3$ of the geometric mean (based on a frequency of 20 percent for southerly winds and a conversion from arithmetic to geometric levels). This correlates well with the modeled values (Table 5-24).

Referring to Figure 5-7, the downwards variation in 1978 can be reasonably explained by the data presented in Table 5-14 which show an abnormal increase in southerly wind flow for the sampling days that year. Thus, the influence of traffic in the Collins Road area would be much less. The upwards variation in 1980 is most likely due to the land clearing phase of the construction of Route 380.

Based on the maps, aerial photographs and the site visit, the conclusion reached for Site 1 is logical. There is a very large industrial park in the Collins Road area. Many of the large corporations that are located in this area (Martin Marietta and Rockwell International, for example) have been shown to have substantial traffic-related emissions with few materials handling emissions (Section 4). The large volume of traffic in the area would definitely impact the monitor located in Noelridge Park.

Site 2 - 751 Center Point Road

The air quality data recorded at Site 2 (Figure 5-3) indicate that the yearly geometric mean particulate levels have been above the NAAQS standard for all years except 1982. However, it must be remembered that 1982 was a very "wet" year, as discussed previously. Assuming no change in emission strengths throughout the area, then Site 2 would again most likely record particulate levels above the NAAQS standard should precipitation levels be slightly lower than normal. For 1982, the yearly geometric mean particulate level was approximately 35 $\mu g/m^3$ above background (Figure 5-4) with approximately 14 $\mu g/m^3$ of this amount attributable to traditional sources (Table 5-24). The remaining 21 $\mu g/m^3$ are due to non-traditional sources.

Based on the information presented and discussed in this report, it is concluded that, for 1982, traffic-related sources are contributing the bulk of the 21 $\mu g/m^3$ with the rest being essentially attributable to industrial operations to the south, southwest. In the years previous to 1982, the construction of Route 380 overwhelmingly impacted the particulate levels recorded at the monitor, up to 35 $\mu g/m^3$ on a yearly basis. The reasoning behind these conclusions is discussed in the following paragraphs.

In general, the data recorded at Site 2 for 1981 and 1982 have tracked the data recorded at Site 1 very closely. Again, this indicates general, traffic-related sources. The higher levels recorded at Site 2 are indicative of greater traffic density and the monitor's closer proximity to traffic sources. The montly averages (Figure 5-5) are higher in February, March and April at this site than at Site 1 and this is may be due to the sanding and salting in the area.

The pollution rose data (Figure 5-6 and Table 5-15) again show good tracking between Sites 1 and 2 with a typical difference in levels of about 10-20 $\mu g/m^3$. When the winds are from the south, southwest, this difference increases somewhat. This is indicative of a slight influence from the industries in that area (Quaker Oats, Cargill, Iowa Electric Light & Power), both from traditional and non-traditional sources.

This site has been the most severely influenced by the construction of Route 380 since the highway is located within 500 feet of the monitor. The data recorded at this site clearly show the effects of large scale construction on local air quality (Tables 5-16 through 5-23). This will be discussed more fully in Section 6.

Site 3 - 14th Street and 10th Avenue

The air quality data recorded at Site 3 (Figure 5-3) indicate that the yearly geometric mean particulate levels have been below the NAAQS standard for the last two years. However, as in the situation at Site 2, violations might occur during an overly dry year or if industrial output increases. For 1981 and 1982, the yearly geometric mean particulate levels averaged approximately 35 $\mu g/m^3$ above background (Figure 5-4) with approximately 23 $\mu g/m^3$ due to traditional sources (Table 5-24). The remaining 12 $\mu g/m^3$ are attributable to non-traditional sources.

Based on the information presented and discussed in this report, it is concluded that, for 1981 and 1982, both industrial fugitive emission sources and an unpaved road in the vicinity of the monitor are contributing the bulk of the 12 $\mu g/m^3$. To a lesser extent, other local traffic and the landfill across the river to the south are impacting the monitor. The reasoning behind these conclusions and further details on these sources are discussed in the following paragraphs.

Site 3 is severely impacted by local industrial sources, as indicated by the modeling results for traditional sources (Table 5-24). The two major industries in the area are the Wilson Company (to the south, southwest) and Cargill-16th Street (to the southeast), both of which are only a quarter mile away. Both of these industries have fugitive dust sources as indicated in Section 4 and these sources undoubtably contribute to the air quality in the area.

Immediately to the south of the Jane Boyd Community Center, upon which the monitor is located, is an unpaved road (part of Otis Road) which is heavily used by trucks going to and from Wilson and Cargill. Farther to the south, across the river, is the town landfill. The other areas around the site are essentially residential with relatively low traffic volumes. One other industry in the area is the Iowa Manufacturing Company (located to the west, southwest of the monitor); however, the production in this plant has been severely cutback in recent years and it does not appear to have any degree of current influence on local air quality.

The yearly trend data (Figure 5-4) show a decrease in particulate levels over the years. This is probably due to general reductions in industrial point and area sources coupled with decreases in productivity due to the economy.

The monthly trend data for 1982 (Figure 5-5) show a pattern very dissimilar to that displayed by the background data and those displayed by Sites 1 and 2. This is highly indicative of localized, directional sources.

The pollution rose data (Figure 5-6) clearly show the influence of sources located to the southeast, south, and southwest with the southwest direction displaying the greatest impact. Again, this is indicative of local sources located in these directions from the monitoring station. The spatial correlation data (Tables 5-16 through 5-23) likewise show this directional influence.

One additional piece of information attesting to the directional impact relates to the discussion presented previously for Site 1. In that case, the lower particulate level seen in Figure 5-7 was due to southerly winds which reduced the impact of traffic-related sources to the north. In this case, those same southerly winds increased the impact of the local sources as can be seen in the figure.

The data available for this study are not of the type that allow for further definition of source impact. Additional studies, such as microscopic analysis of filter collections or additional monitoring, would be necessary for such definition. These are further discussed in the Recommendations section of this report.

Site 4 - 445 First Street

The air quality data recorded at Site 4 (Figure 5-3) indicate that the yearly geometric mean particulate levels have been above the NAAQS standard for all years except 1982. However, as in the situation at Sites 2 and 3, violations might again occur during a year with less precipitation and increased industrial activity. For 1982, the yearly geometric mean particulate level was approximately 35 $\mu g/m^3$ above background (Figure 5-4) with approximately 11 $\mu g/m^3$ of this amount attributable to traditional sources (Table 5-24) and the remaining 24 $\mu g/m^3$ thus attributable to non-traditional sources.

Based on the information presented and discussed in this report, it is concluded that traffic-related sources are contributing at least half to three-quarters of the 24 $\mu g/m^3$ with another quarter attributable to industrial fugitive sources at Penick & Ford, situated one-quarter mile away to the southeast of the monitor. The remainder is most likely due to operations in an equipment storge lot adjacent to the building upon which the monitor is situated. The reasoning behind this conclusion is discussed in the following paragraphs.

In general, the data recorded at Site 4 have tracked the data recorded at Site 1 and Backbone State Park fairly well, indicating general source influence. This is seen in both Figures 5-3 and 5-4. The slightly higher levels in 1976 and 1977 are more than likely due to the construction of Route 380.

The monthly data for 1982 (Figure 5-5) also track Site 1 and Backbone State Park data with the exception of a large peak in April. This peak is the result of one high value of 168 $\mu g/m^3$ being averaged into the data set. This value was recorded on April 14, a day when the winds were very persistent from the southeast and no other monitors recorded data (Table 5-19). This is indicative of a local, directional source.

The pollution rose data (Figure 5-6) suggest a significant source located to the east and southeast of the monitoring site. It would be expected that Sites 2 and 4 would be affected by general downtown traffic in a similar manner and thus their pollution rose data should track fairly well. This is true for winds from the south through the northwest. However, when the winds are from the east and southeast, the Site 4 data are much greater than the Site 2 data. It is postulated that operations at Penick & Ford are the cause of this peak. When the winds are from the north and northeast, the Site 2 data are higher than the Site 4 data. This is expected since the Cedar River lies immediately to the north, northeast of Site 4 while Center Point Road is near Site 2. By using the frequency of wind data in conjunction with the pollution rose data, a fugitive dust source contribution of 5-6 $\mu g/m^3$ can be assumed to be attributable to Penick & Ford on a yearly basis.

The spatial correlation data presented in Tables 5-16 through 5-23 clearly show the presence of a local source to the east, southeast. Although the equipment parking area is also located on this side of the building upon which the monitor is situated, the monitor's height above ground (approximately 50 feet) would tend to preclude a significant impact from this source.

Figure 5-7 shows two interesting features. The first is the increased levels in 1976 and 1977. These again show the degree of impact that can result from large scale construction activities. The second item of interest is the increase in levels in 1980 and 1981. Discussions with local health department personnel have indicated that Penick & Ford increased production during this time period, thus further lending credance to the influence of this source on the air quality data recorded at Site 4.

Site 5 - 4401 Sixth Street

The air quality data recorded at Site 5 (Figure 5-3) indicate that the yearly geometric mean particulate levels have been below the NAAQS standard for the last four years. Even in a very dry year, the monitor should not record a violation of the yearly standard of 75 $\mu g/m^3$. For 1982, the yearly geometric mean particulate level was approximately 29 $\mu g/m^3$ above background (Figure 5-4) with approximately 6 $\mu g/m^3$ of this amount attributable to traditional sources (Table 5-24). The remaining 23 $\mu g/m^3$ can be attributed to non-traditional sources.

Based on the information presented and discussed in this report, it is concluded that traffic-related sources are contributing to the bulk of the 23 $\mu g/m^3$. Activities at Hawkeye Downs, a dirt racetrack and fairgrounds located across the street from the monitor to the west, southwest, also impact the air quality recorded at the monitor. Industrial fugitive sources to the southwest (ADM Corn Sweeteners and Harnischfeger) also affect the particulate levels. In previous years, highway construction has significantly impacted the dust levels in the area. The reasoning behind these conclusions is discussed in the following paragraphs.

The yearly trend data for the past three years have tracked the data recorded at Site 1 and at Backbone State Park very well (Figures 5-3 and 5-4). Prior to that, the levels were severely affected by the construction of highways 380 and 30 with the interchange being immediately to the south, southwest of the monitor.

The monthly data (Figure 5-5) tend to follow the same general trends as Site 1 and background with the exception of showing more pronounced excursions. This indicates some local, directional source which skews the data set upwards when the winds are from that direction.

The pollution rose data (Figure 5-6) clearly show the presence of a local influence to the southwest of the site. Again, there are two types of sources in this direction - Hawkeye Downs within a thousand feet and two major industries within a mile. The pollution rose data for the south and southwest wind directions for the years 1976-1978 (Table 5-15) show the effect of construction on the particulate levels very dramatically.

The spatial correlation data (Tables 5-16 through 5-23) not only show the local influence, they also shed some light on the degree of impact of activities at Hawkeye Downs. Referring to Tables 5-20 and 5-21, it can be noted that the particulate levels recorded at Site 5 on April 25, 1982, and July 4, 1982 were higher than expected in relation to the data recorded at the other sites. Discussions with personnel at Hawkeye Downs revealed that a large bluegrass festival was being held on April 23 and their annual fair was being held from July 1-8. The roadways and parking areas within the fairgrounds are unpaved and the large volume of traffic inherent to certain festivities would naturally result in dust emissions. However, these events occur only sporatically and coupled with the frequency of wind from the south, southwest should have an impact on the monitor of only 2-3 $\mu g/m^3$ on an annual basis.

Figure 5-7 again shows the degree to which construction can affect the air quality in an area. An impact of approximately 20 $\mu g/m^3$ can be attributed to construction in 1978.

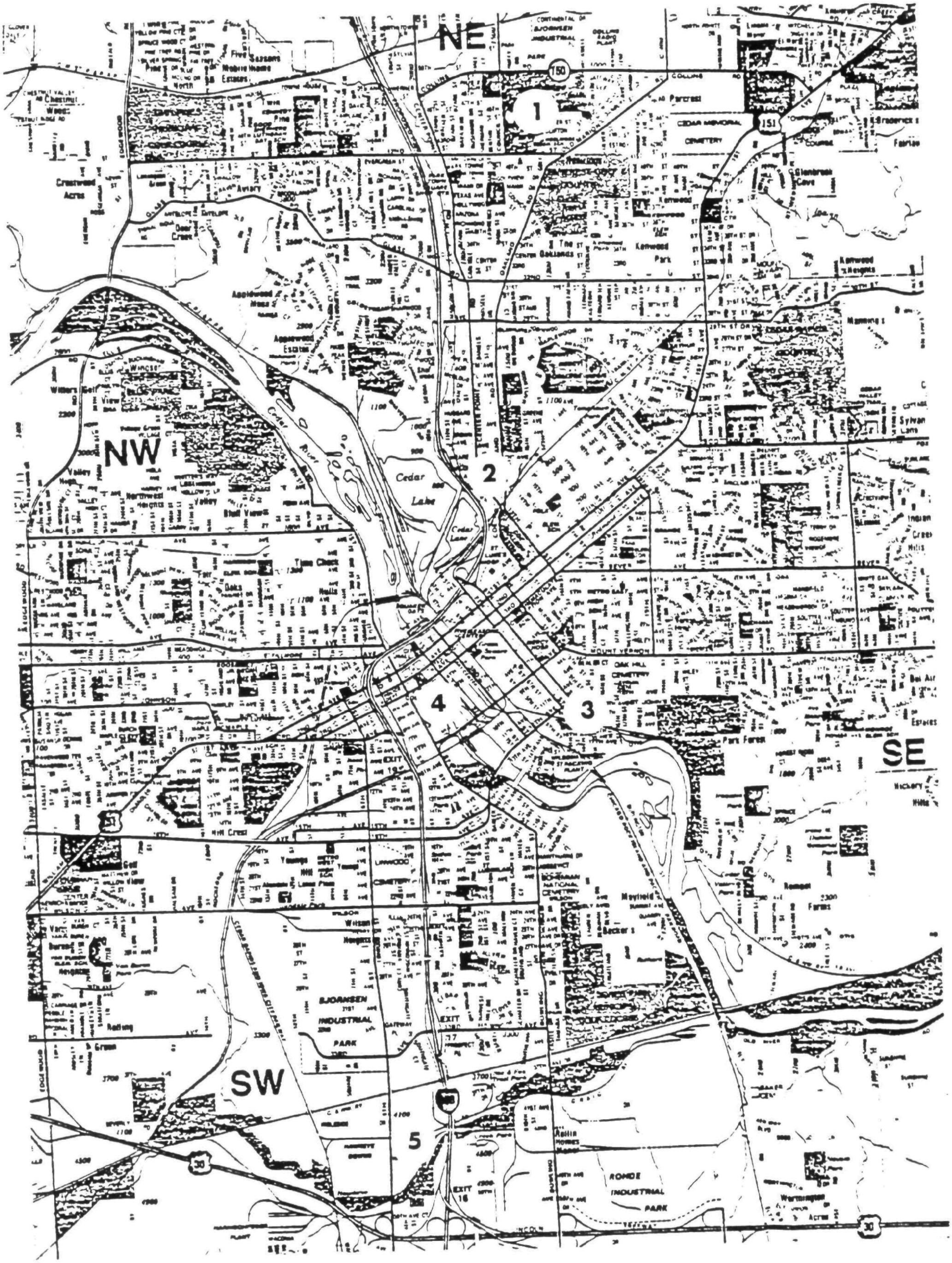

Figure 5-1. Monitoring locations in Linn County.

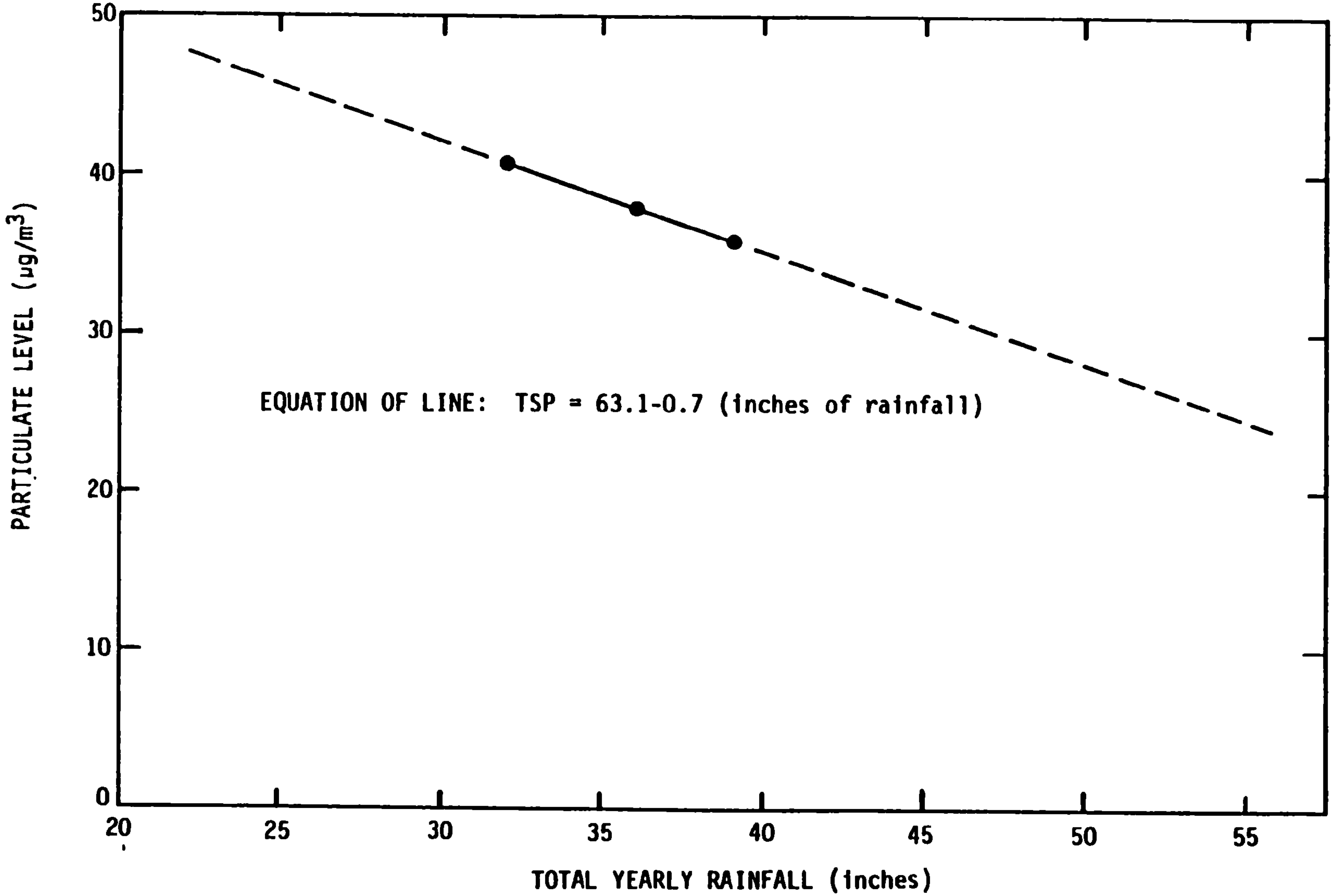

Figure 5-2. Effect of precipitation on yearly geometric mean particulate levels at Backbone State Park.

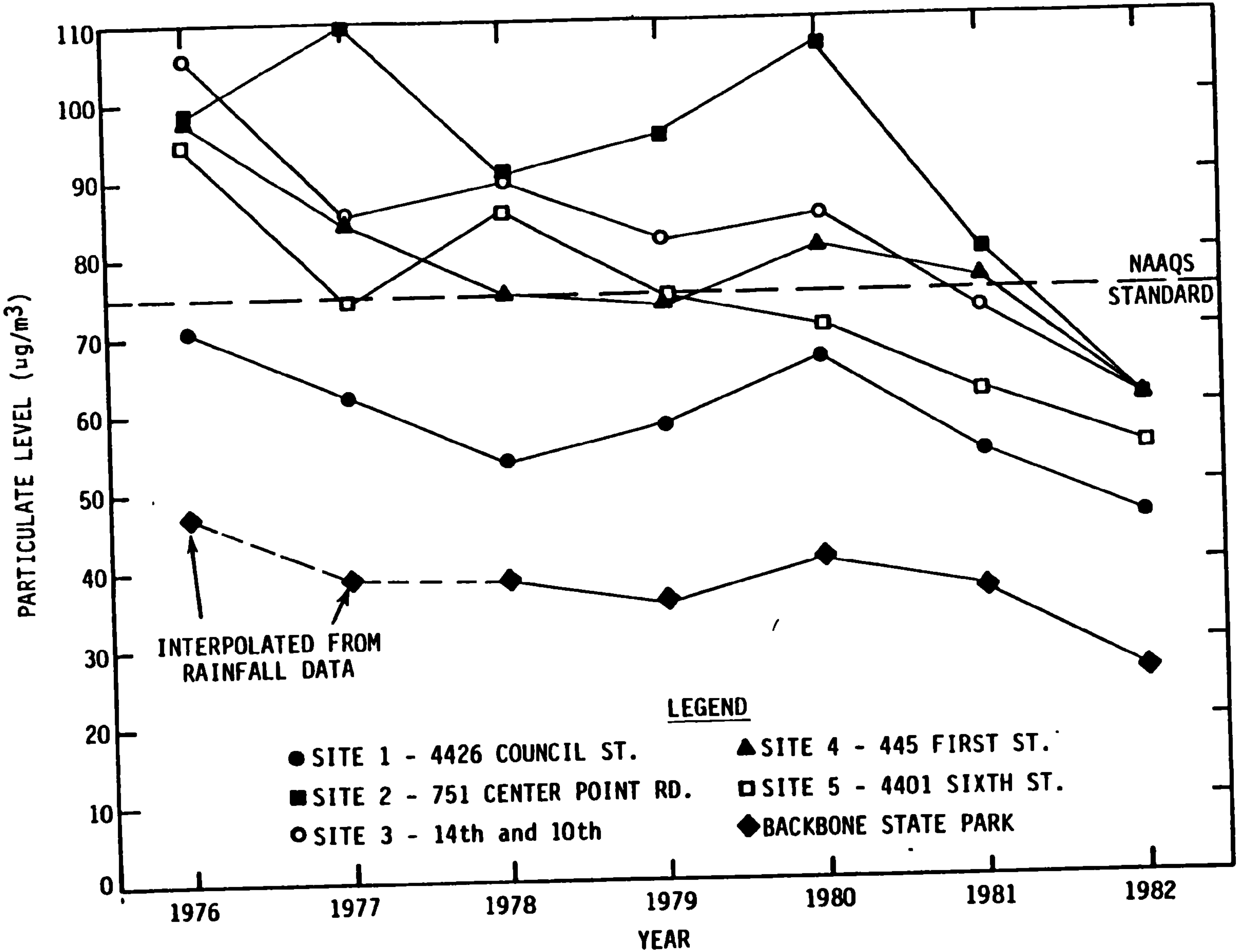

Figure 5-3. Yearly geometric mean particulate levels.

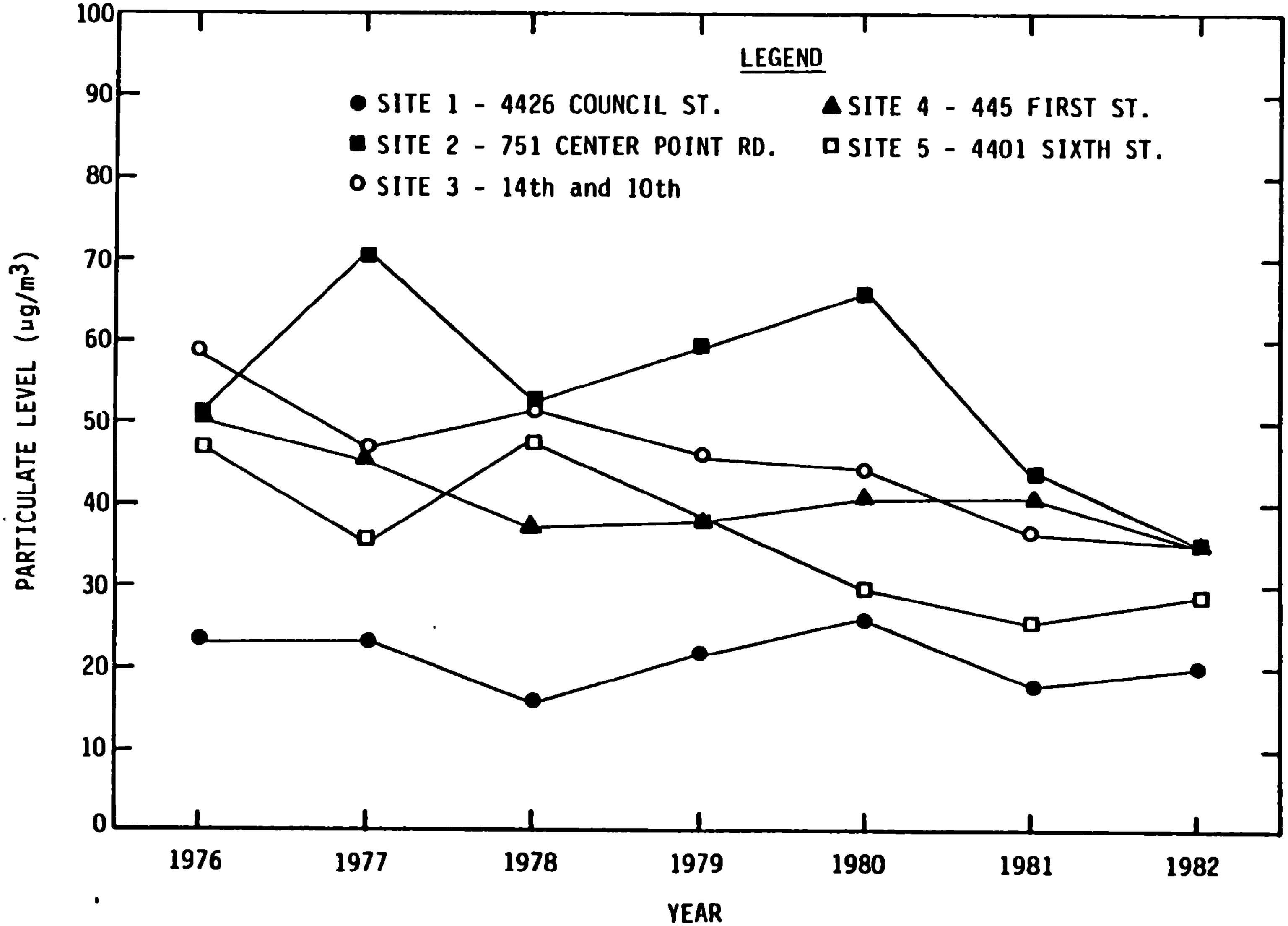

Figure 5-4. Yearly geometric mean particulate levels with background removed.

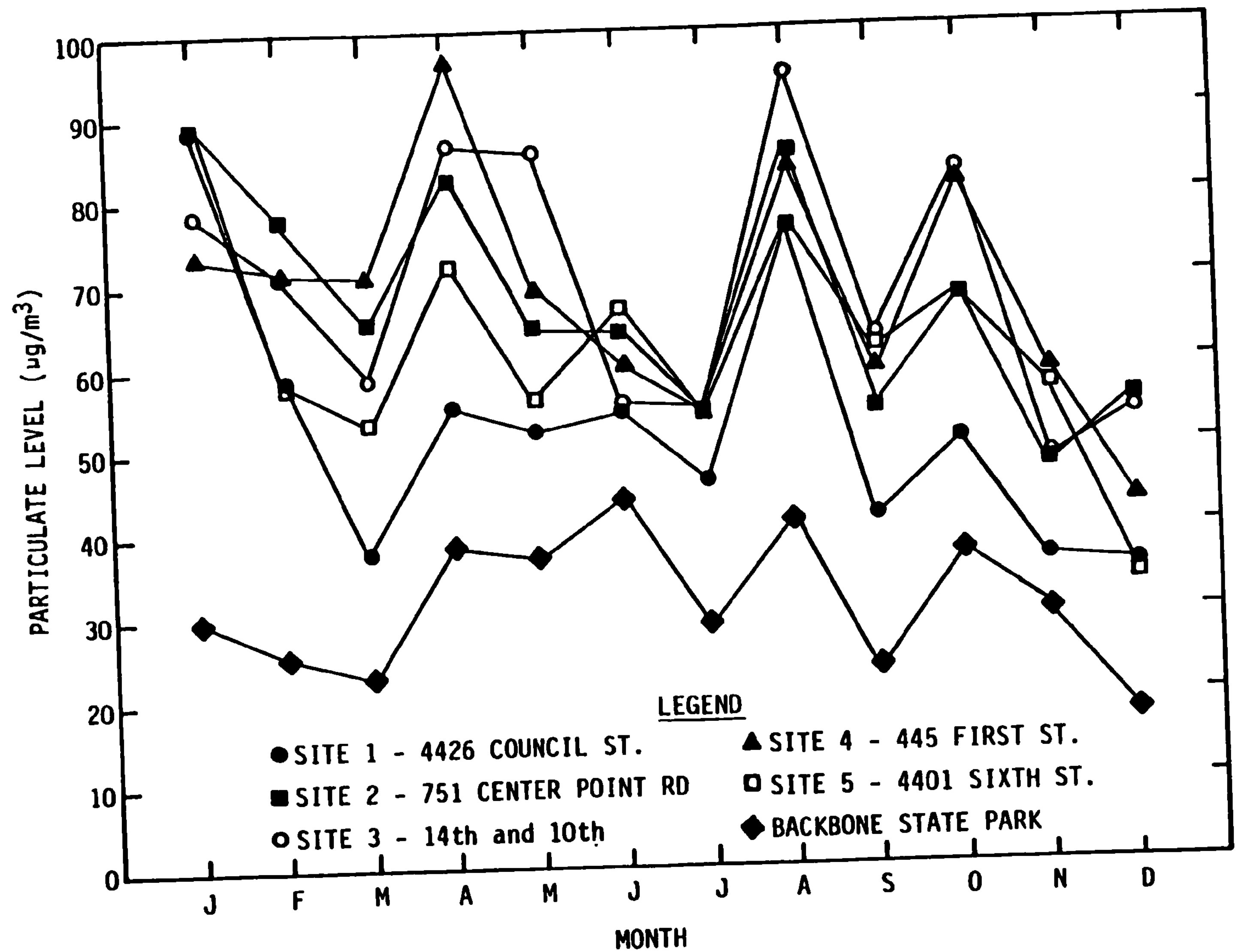

Figure 5-5. Monthly arithmetic mean particulate levels - 1982.

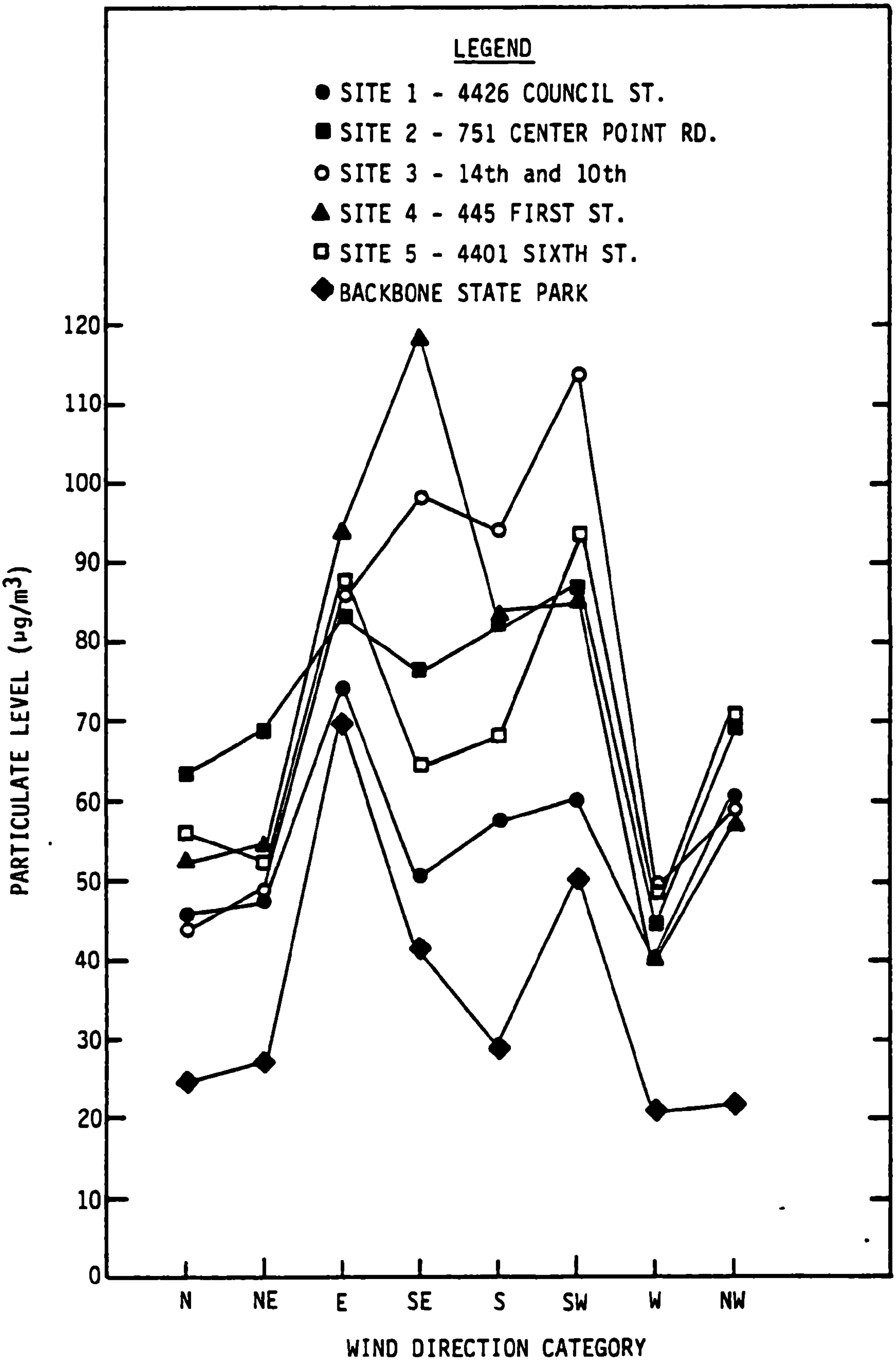

Figure 5-6. Pollution roses: 1982 data arithmetic means.

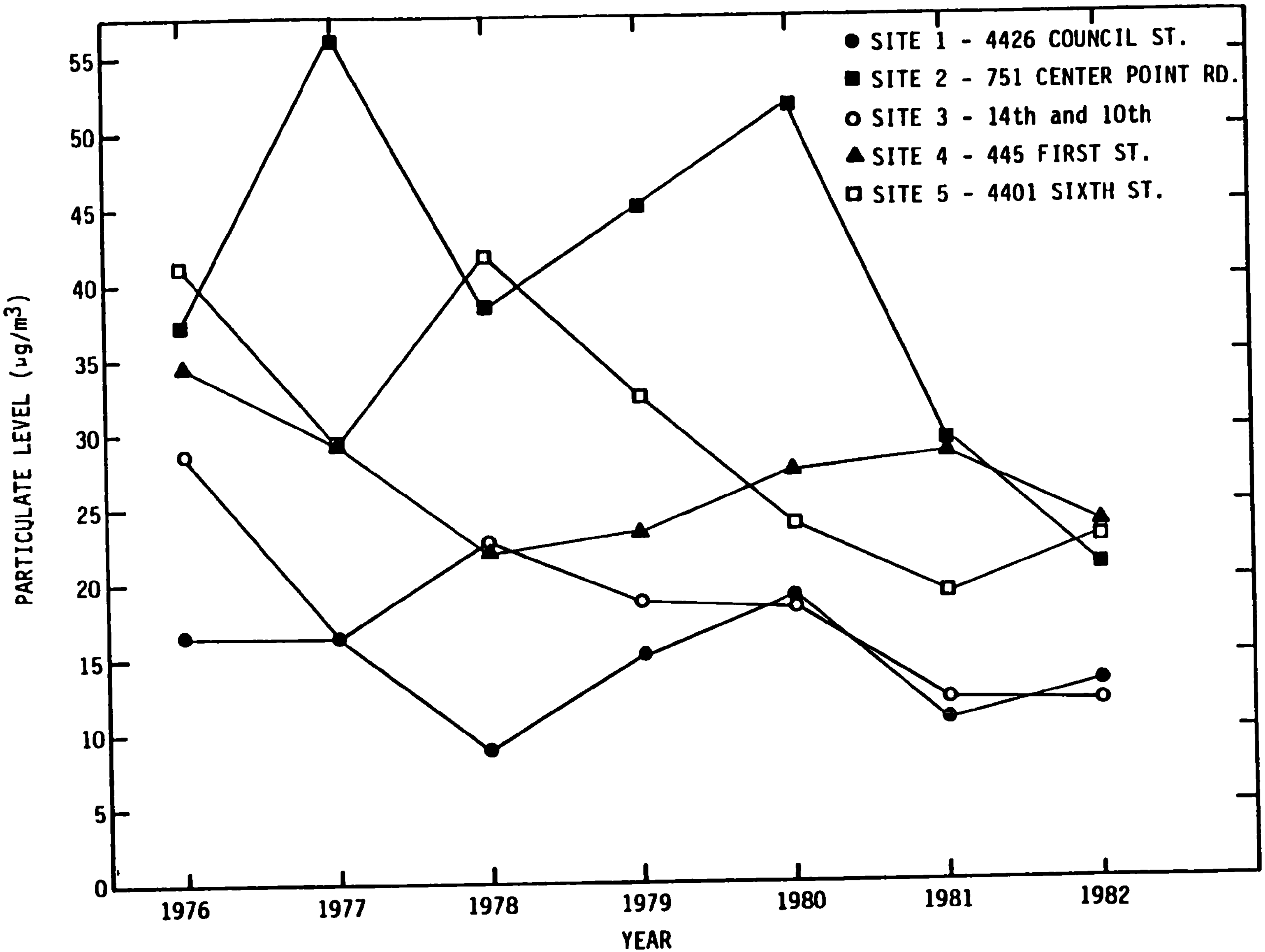

Figure 5-7. Non-traditional source impact at monitoring sites (geometric equivalents).

TABLE 5-1. YEARLY GEOMETRIC MEAN PARTICULATE LEVELS ($\mu g/m^3$)

Year	Site 1 4426 Council St.	Site 2 751 Center Pt. Rd.	Site 3 14th and 10th	Site 4 445 First St.	Site 5 4401 Sixth St.	Backbone State Park
1982	45.9	60.9	60.8	60.5	54.8	26.0
1981	54.1	80.0	72.7	76.6	61.7	36.5
1980	66.5	106.5	84.8	81.0	70.4	40.7
1979	57.8	95.0	81.8	73.2	73.9	35.8
1978	53.6	90.6	89.3	75.1	85.6	37.9
1977	62.0	109.3	85.2	84.1	74.0	38.6*
1976	70.5	98.8	105.7	97.9	94.2	47.0*

* Interpolated levels based on yearly rainfall.

TABLE 5-2. YEARLY GEOMETRIC MEAN PARTICULATE LEVELS WITH BACKGROUND REMOVED ($\mu g/m^3$)

Year	Site 1 4426 Council St.	Site 2 751 Center Pt. Rd.	Site 3 14th and 10th	Site 4 445 First St.	Site 5 4401 Sixth St.
1982	19.9	34.9	34.8	34.5	28.8
1981	17.6	43.5	36.2	40.1	25.2
1980	25.8	65.8	44.1	40.3	29.7
1979	22.0	59.2	46.0	37.4	38.1
1978	15.7	52.7	51.4	37.2	47.7
1977	23.4	70.7	46.6	45.5	35.4
1976	23.5	51.8	58.7	50.9	47.2

TABLE 5-3. MONTHLY GEOMETRIC MEAN PARTICULATE LEVELS - 1976 to 1982 ($\mu g/m^3$)

Site	January	February	March	April	May	June	July	August	September	October	November	December
1 - 4426 Council St. NE	55.6	56.5	54.7	51.7	73.8	62.5	63.4	62.7	58.9	56.7	52.0	50.6
2 - 751 Center Pt. Rd. NE	70.3	70.8	88.2	92.6	119.8	106.1	95.1	105.2	106.8	86.5	80.5	71.6
3 - 14th Ave. and 10th St. SE	73.4	72.8	83.7	79.2	104.5	89.9	79.0	88.5	89.4	93.4	72.6	67.6
4 - 445 First St. SW	58.0	67.8	81.1	77.7	101.2	86.2	80.8	90.6	83.0	80.4	72.7	63.6
5 - 4401 Sixth St. SW	56.4	61.6	64.7	64.7	90.9	82.5	78.1	85.5	79.9	71.1	65.2	54.4
Backbone State Park*	28.0	28.5	32.7	34.7	48.3	52.6	40.2	42.0	31.1	27.7	32.0	23.4

* 1978 - 1982 data

TABLE 5-4. MONTHLY ARITHMETIC MEAN PARTICULATE LEVELS - 1982 ($\mu g/m^3$)

Site	January	February	March	April	May	June	July	August	September	October	November	December
1 - 4426 Council St. NE	88.5	58.7	37.4	55.0	51.0	54.0	45.6	76.4	41.8	50.4	36.2	35.2
2 - 751 Center Pt. Rd. NE	89.4	77.6	65.2	82.2	64.2	64.0	54.5	85.4	54.2	67.4	47.0	55.2
3 - 14th Ave. and 10th St. SE	78.2	71.0	58.2	86.6	85.0	55.6	54.4	94.8	62.8	82.8	48.0	53.8
4 - 445 First St. SW	73.4	70.6	70.2	96.6	68.6	59.2	54.2	83.4	58.8	80.4	58.2	42.8
5 - 4401 Sixth St. SW	89.8	57.8	53.0	72.0	55.8	66.6	53.4	76.4	62.0	68.6	56.8	33.7
Backbone State Park	29.5	24.8	22.3	38.0	37.6	43.8	28.6	41.0	23.0	37.2	29.4	17.3

TABLE 5-5. METEOROLOGICAL SUMMARY FOR 1976 (P>0.71)

Date	Average wind speed (mph)	Wind persistence	Resultant wind direction	Date	Average wind speed (mph)	Wind persistence	Resultant wind direction
01-01-76	14.7	0.914	116.0	07-11-76	10.7	.833	278.7
01-07-76	18.4	0.938	330.1	07-17-76	6.9	.801	265.0
01-13-76	13.0	0.903	336.6	07-23-76	5.6	.739	271.9
01-25-76	12.0	0.807	357.5	07-29-76	4.4	.784	78.5
01-31-76	12.5	0.876	242.4				
				08-04-76	11.0	.970	182.0
02-06-76	15.8	0.969	307.5	08-10-76	11.3	.975	170.2
02-12-76	16.9	0.945	214.4	08-16-76	8.5	.924	121.6
02-14-76	16.8	0.957	137.2	08-22-76	6.7	.928	174.2
02-18-76	13.1	0.842	314.3	08-28-76	8.3	.948	312.9
02-24-76	9.5	0.973	186.5				
				09-03-76	12.6	.787	211.5
03-01-76	18.3	0.963	76.6	09-09-76	13.2	.974	317.5
03-07-76	14.0	0.794	312.9	09-10-76	9.5	.847	277.0
03-19-76	16.5	0.973	179.3	09-15-76	9.3	.932	34.3
03-25-76	14.6	0.938	162.6	09-21-76	10.1	.859	322.1
03-31-76	12.5	0.912	299.0	09-27-76	7.5	.902	357.1
04-12-76	9.5	0.930	147.4	10-03-76	10.5	.914	133.8
04-30-76	10.0	0.759	260.8	10-15-76	17.8	.977	309.5
				10-21-76	14.0	.958	285.5
05-06-76	14.7	0.941	30.5				
05-12-76	14.1	0.954	148.5	11-08-76	12.3	.809	181.9
05-24-76	10.1	0.938	44.6	11-14-76	6.6	.882	202.2
05-30-76	7.8	0.926	48.8	11-20-76	7.6	.784	286.3
				11-26-76	16.2	.884	348.9
06-05-76	11.5	0.912	103.2				
06-11-76	12.1	0.959	181.8	12-14-76	14.4	.912	216.2
06-17-76	14.1	0.971	164.6	12-20-76	21.8	.984	318.1
06-23-76	10.7	0.907	108.2	12-26-76	12.9	.761	304.2

TABLE 5-6. METEOROLOGICAL SUMMARY FOR 1977 (P>0.71)

Date	Average wind speed (mph)	Wind persistence	Resultant wind direction
01-01-77	12.6	.976	302.1
01-25-77	15.4	.954	296.2
02-01-77	12.1	.901	293.0
02-06-77	10.9	.986	331.5
02-12-77	19.0	.890	296.5
02-18-77	11.2	.892	297.8
02-19-77	13.0	.977	327.8
02-24-77	20.1	.904	252.8
03-02-77	14.3	.978	124.8
03-03-77	16.6	.931	140.1
03-08-77	13.2	.955	189.8
03-14-77	12.5	.915	145.2
03-26-77	16.6	.976	157.5
04-01-77	15.0	.835	137.2
04-13-77	9.3	.900	236.2
04-19-77	9.8	.855	145.9
04-25-77	10.7	.933	335.9
05-01-77	10.0	.855	188.6
05-07-77	10.5	.899	62.1
05-10-77	7.9	.905	141.8
05-13-77	9.9	.972	229.6
05-17-77	12.9	.923	185.3
05-19-77	10.9	.951	178.4
05-25-77	4.7	.785	126.2
05-31-77	18.3	.988	295.6
06-01-77	14.5	.903	317.9
06-06-77	15.3	.955	354.5
06-09-77	8.7	.872	115.9
06-12-77	13.1	.951	60.9
06-15-77	8.2	.906	129.9
06-18-77	12.8	.951	299.8
06-22-77	12.4	.902	116.8
06-24-77	7.0	.840	225.6
07-06-77	9.9	.881	216.8
07-12-77	8.8	.824	299.6
07-18-77	11.1	.806	172.0
07-30-77	8.1	.851	173.1
08-05-77	6.3	.839	226.8
08-11-77	7.2	.906	318.3
08-17-77	9.1	.964	314.5
08-23-77	8.9	.809	47.0
08-25-77	10.9	.943	141.0
08-26-77	10.7	.974	175.2
09-10-77	7.7	.809	320.6
09-13-77	8.8	.914	13.5
10-04-77	8.6	.949	185.2
10-22-77	14.7	.920	60.0
10-26-77	7.2	.854	175.5
10-28-77	10.3	.941	83.3
11-03-77	5.9	.716	341.6
11-09-77	21.1	.815	200.6
11-15-77	11.2	.786	244.4
11-21-77	12.8	.940	281.5
12-03-77	7.5	.885	322.8
12-09-77	24.0	.995	301.1
12-15-77	10.5	.957	150.9
12-21-77	19.3	.996	303.6
12-27-77	10.4	.757	280.9

TABLE 5-7. METEOROLOGICAL SUMMARY FOR 1978 (P>0.71)

Date	Average wind speed (mph)	Wind persistence	Resultant wind direction
01-02-78	13.9	.939	272.3
01-08-78	24.4	.997	317.4
01-14-78	12.0	.865	346.4
01-20-78	12.3	.900	341.0
01-26-78	26.7	.999	300.8
02-02-78	8.4	.864	328.0
02-07-78	6.9	.893	350.3
02-08-78	5.7	.855	352.6
02-13-78	17.1	.957	41.9
02-19-78	5.5	.967	187.7
02-25-78	19.0	.995	307.2
03-03-78	14.2	.985	318.1
03-07-78	15.0	.983	62.0
03-09-78	6.6	.919	232.2
03-15-78	7.3	.927	291.3
03-16-78	11.3	.955	302.7
03-21-78	13.0	.778	282.7
03-27-78	10.0	.907	193.0
04-02-78	19.8	.964	106.7
04-04-78	15.0	.875	305.9
04-08-78	18.2	.973	98.7
04-20-78	15.9	.965	306.7
05-08-78	15.0	.911	235.4
05-10-78	9.9	.960	190.1
05-14-78	18.3	.912	342.0
05-16-78	7.6	.879	77.7
05-20-78	12.2	.777	303.4
05-26-78	11.3	.970	175.4
06-01-78	12.5	.938	286.5
06-02-78	9.1	.877	320.6
06-14-78	13.2	.919	174.5
06-15-78	14.1	.899	167.0
06-19-78	10.9	.963	171.6
06-25-78	9.7	.919	177.4
07-01-78	9.5	.846	142.3
07-13-78	10.5	.976	163.5
07-19-78	8.2	.916	195.1
07-25-78	4.5	.905	170.9
07-31-78	5.4	.727	68.0
08-06-78	5.6	.878	218.7
08-08-78	5.5	.925	195.0
08-12-78	5.6	.878	143.8
08-18-78	11.7	.892	160.5
08-24-78	6.7	.728	230.5
09-05-78	6.9	.965	171.7
09-11-78	8.6	.985	181.7
09-17-78	11.9	.785	46.4
09-23-78	7.1	.887	173.6
09-18-78	6.4	.729	181.2
09-29-78	8.5	.794	199.6
10-05-78	14.1	.963	291.0
10-11-78	7.2	.805	198.8
10-17-78	9.8	.973	173.3
10-23-78	6.7	.952	353.3
10-29-78	15.0	.954	148.0
11-10-78	8.6	.890	144.4
11-11-78	11.2	.873	35.8
11-16-78	10.4	.963	69.8
11-22-78	10.7	.961	108.1
12-04-78	14.6	.936	231.7
12-10-78	8.5	.922	154.6
12-16-78	13.5	.966	288.0
12-22-78	15.1	.917	272.0
12-28-78	20.1	.966	139.2

TABLE 5-8. METEOROLOGICAL SUMMARY FOR 1979 (P>0.71)

Date	Average wind speed (mph)	Wind persistence	Resultant wind direction
01-03-79	11.0	.972	254.0
01-09-79	12.5	.899	297.8
01-11-79	15.7	.935	127.1
01-15-79	8.3	.758	159.6
01-21-79	18.1	.976	315.8
01-24-79	21.6	.973	318.7
01-27-79	10.0	.817	352.1
02-08-79	12.9	.838	357.3
02-10-79	11.3	.984	106.5
02-14-79	9.5	.890	127.6
02-19-79	12.0	.984	161.2
02-20-79	13.0	.990	164.3
03-04-79	11.4	.967	284.3
03-05-79	13.8	.993	286.7
03-10-79	19.7	.995	295.7
03-16-79	11.8	.974	156.4
03-22-79	8.5	.989	96.3
04-03-79	5.9	.810	327.3
04-09-79	10.7	.863	351.0
04-15-79	10.9	.973	311.4
04-21-79	11.1	.977	334.2
04-27-79	19.8	.810	315.0
05-03-79	16.5	.978	346.1
05-09-79	13.4	.892	172.1
05-15-79	8.0	.872	329.3
05-22-79	14.2	.768	177.4
05-24-79	9.9	.918	359.1
05-27-79	7.1	.886	300.0

Date	Average wind speed (mph)	Wind persistence	Resultant wind direction
06-02-79	9.7	.851	245.2
06-08-79	9.3	.804	357.4
06-14-79	14.4	.961	163.7
06-20-79	16.1	.854	211.3
06-26-79	10.2	.886	195.0
07-02-79	10.3	.943	119.6
07-08-79	4.8	.922	121.7
07-22-79	4.6	.852	162.1
08-07-79	7.0	.947	233.8
08-21-79	8.0	.904	102.5
08-31-79	8.3	.956	163.3
09-06-79	8.3	.928	321.1
09-18-79	9.4	.828	314.4
09-24-79	6.0	.833	152.4
10-06-79	13.1	.969	303.0
10-12-79	16.2	.988	307.9
10-18-79	13.1	.876	134.6
10-24-79	6.2	.965	296.1
10-30-79	17.1	.989	120.1
11-11-79	13.9	.992	167.0
11-17-79	10.5	.963	197.8
11-23-79	10.3	.938	234.6
11-29-79	18.2	.990	293.2
12-05-79	16.6	.759	265.4
12-17-79	10.5	.896	192.8
12-29-79	6.2	.879	1.2

TABLE 5-9. METEOROLOGICAL SUMMARY FOR 1980 (P>0.71)

Date	Average wind speed (mph)	Wind persistence	Resultant wind direction	Date	Average wind speed (mph)	Wind persistence	Resultant wind direction
01-04-80	7.7	.777	120.7	07-02-80	5.8	.732	23.0
01-10-80	17.2	.944	151.9	07-14-80	11.0	.975	175.8
01-22-80	19.3	.951	295.5	07-26-80	8.2	.717	14.9
01-28-80	12.1	.987	312.3				
				08-07-80	10.0	.954	175.3
02-03-80	7.1	.965	61.2	08-19-80	8.9	.893	179.6
02-09-80	7.4	.903	304.5	08-25-80	10.1	.984	161.6
02-15-80	17.1	.873	358.1				
02-16-80	15.7	.965	305.2	09-24-80	4.1	.817	152.2
02-21-80	16.2	.984	83.9				
				10-12-80	3.9	.798	314.2
03-04-80	11.6	.766	8.8	10-18-80	12.9	.955	271.1
03-10-80	19.8	.844	300.3	10-24-80	15.3	.982	297.6
03-22-80	12.5	.831	96.8	10-30-80	10.6	.914	217.9
03-28-80	16.0	.994	56.1				
				11-11-80	10.2	.967	113.2
04-09-80	18.2	.993	300.2	11-17-80	10.3	.984	359.3
04-15-80	10.2	.930	317.2	11-29-80	16.2	.866	275.9
04-21-80	11.2	.850	168.9				
04-27-80	12.3	.836	350.2	12-05-80	8.4	.890	127.6
				12-11-80	7.4	.860	98.7
05-09-80	8.9	.950	187.3	12-29-80	8.9	.925	341.6
05-15-80	9.7	.958	61.3				
06-08-80	13.5	.917	312.8				
06-21-80	6.9	.964	186.1				

TABLE 5-10. METEOROLOGICAL SUMMARY FOR 1981 (P>0.71)

Date	Average wind speed (mph)	Wind persistence	Resultant wind direction
01-04-81	7.0	.712	59.4
01-10-81	6.3	.891	326.9
01-16-81	13.4	.986	312.8
01-22-81	9.3	.947	298.3
01-28-81	10.5	.940	303.0
02-01-81	19.4	.919	283.5
02-03-81	11.6	.970	272.8
02-15-81	17.5	.986	177.2
02-21-81	14.7	.882	105.6
03-05-81	10.7	.858	319.6
03-11-81	11.2	.848	292.2
03-14-81	9.4	.832	216.4
03-23-81	5.2	.801	317.0
03-29-81	18.8	.868	174.5
04-01-81	21.5	.876	277.8
04-04-81	19.9	.856	277.6
04-10-81	11.5	.835	157.6
04-16-81	13.0	.985	170.5
05-04-81	12.4	.777	194.1
05-10-81	15.5	.990	17.1
05-11-81	17.1	.917	7.3
05-16-81	11.3	.958	136.0
05-22-81	16.8	.969	156.3
05-28-81	9.8	.758	171.0
06-03-81	10.1	.967	302.1
06-27-81	12.0	.955	151.2
07-03-81	6.7	.932	120.7
07-09-81	6.3	.918	329.9
07-15-81	6.0	.710	42.9
07-16-81	5.9	.943	74.0
07-27-81	10.1	.963	75.6
08-02-81	6.1	.755	90.3
08-08-81	6.3	.750	303.1
08-20-81	3.5	.743	54.4
09-01-81	7.6	.980	323.0
09-13-81	2.5	.911	192.2
09-19-81	9.0	.717	255.4
09-25-81	8.8	.955	153.1
10-01-81	15.1	.952	301.6
10-07-81	4.3	.710	342.7
10-13-81	9.6	.974	143.3
10-19-81	9.0	.841	213.5
11-06-81	8.1	.988	293.4
11-12-81	6.3	.877	131.2
11-18-81	13.0	.915	96.6
11-30-81	14.2	.973	102.2
12-06-81	10.8	.961	171.1
12-12-81	6.1	.954	153.3
12-18-81	18.2	.986	312.1
12-24-81	9.4	.878	226.5
12-30-81	11.4	.965	142.7

TABLE 5-11. METEOROLOGICAL SUMMARY FOR 1982 ($P>0.71$)

Date	Average wind speed (mph)	Wind persistence	Resultant wind direction	Date	Average wind speed (mph)	Wind persistence	Resultant wind direction
01-06-82	16.6	.960	335.0	06-04-82	9.0	.955	69.8
01-11-82	16.5	.978	297.6	06-10-82	12.1	.942	305.9
01-17-82	14.4	.980	162.3	06-22-82	6.0	.728	20.5
01-23-82	27.9	.955	270.7				
01-29-82	8.6	.839	112.7	07-04-82	6.8	.720	165.8
				07-16-82	9.3	.901	182.5
02-04-82	7.8	.943	333.2	07-22-82	8.6	.850	11.3
02-10-82	9.5	.971	177.0	07-28-82	6.3	.789	27.1
02-16-82	9.9	.980	57.2				
02-22-82	10.8	.917	169.6	08-03-82	10.6	.976	196.2
				08-09-82	9.6	.951	305.5
03-06-82	8.7	.710	275.3	08-15-82	6.3	.803	111.5
03-18-82	6.2	.753	23.3	08-27-82	8.8	.767	7.8
03-24-82	10.2	.913	299.4				
03-30-82	21.8	.812	201.6	09-02-82	10.4	.893	297.2
				09-08-82	7.0	.918	140.5
04-05-82	18.1	.819	29.6	09-14-82	7.6	.786	17.0
04-11-82	8.5	.798	127.3	09-20-82	9.5	.934	334.1
04-14-82	11.4	.963	140.7				
04-17-82	18.6	.980	299.8	10-08-82	8.6	.938	104.7
04-23-82	11.1	.946	212.5	10-14-82	9.5	.965	240.3
04-29-82	13.8	.965	94.2	10-20-82	16.3	.965	290.7
				10-26-82	8.4	.973	144.2
05-17-82	13.2	.832	164.5				

TABLE 5-12. WIND FREQUENCY PER WIND DIRECTION CATEGORY BASED ON 1963-1967 DATA

Month	N	NE	E	SE	S	SW	W	NW	Calm
January	10.2	5.9	6.4	6.9	16.0	10.3	14.2	25.7	4.5
February	13.3	6.2	8.0	7.8	17.6	10.5	10.2	23.3	3.2
March	15.8	6.2	8.7	11.0	17.4	7.6	10.0	21.1	2.4
April	9.7	6.8	15.4	15.8	16.2	7.4	9.0	17.2	2.7
May	8.9	6.9	13.8	11.5	19.9	12.5	9.6	12.1	5.0
June	6.7	6.4	10.8	13.8	26.3	16.2	7.6	7.2	5.3
July	9.7	5.2	11.0	13.3	20.6	11.3	8.1	11.5	9.5
August	9.9	3.6	6.7	10.0	20.6	11.9	9.8	14.9	12.8
September	9.6	7.9	13.2	14.6	19.3	9.3	7.9	10.5	8.0
October	11.2	3.0	5.0	8.7	26.0	12.1	11.1	18.6	4.3
November	9.6	2.0	5.0	9.0	25.0	10.7	13.0	23.1	2.8
December	10.4	4.7	5.4	9.1	19.9	9.4	13.4	25.7	2.2
Annual average	10.3	5.3	9.2	10.9	20.5	10.7	10.3	17.6	5.2

TABLE 5-13. WIND FREQUENCY PER WIND DIRECTION CATEGORY BASED ON 1976-1979 DATA

Month	N	NE	E	SE	S	SW	W	NW
January	12.2	3.8	3.7	6.7	11.8	6.6	19.1	36.2
February	16.9	6.9	9.1	7.8	15.2	6.3	13.9	23.7
March	11.6	6.2	9.4	13.7	17.7	7.3	11.7	22.4
April	13.8	9.2	16.2	14.5	15.9	6.4	8.1	16.0
May	16.0	8.9	14.2	12.1	23.1	8.7	6.1	10.8
June	12.4	5.3	10.5	11.8	25.6	11.1	10.8	12.5
July	21.4	6.3	10.4	11.6	24.9	8.1	6.3	11.1
August	15.2	5.5	8.6	13.6	29.2	10.1	6.8	11.0
September	17.3	6.8	8.1	10.9	28.3	8.3	7.6	12.8
October	14.5	5.1	7.9	9.6	21.2	7.3	13.4	21.0
November	10.6	6.8	6.1	8.3	19.5	9.6	17.9	21.2
December	12.0	3.1	6.4	9.0	18.5	8.2	15.7	27.2
Annual average	14.5	6.1	9.2	10.8	20.9	8.2	11.4	18.8

TABLE 5-14. FREQUENCY OF WIND DIRECTION ON SAMPLING DAYS (%), P>0.71

Year	Monitoring location	Wind Direction Sector							
		N	NE	E	SE	S	SW	W	NW
1976	Site 1	4.8	7.1	4.8	14.3	21.4	4.8	16.7	26.2
	Site 2	6.5	8.7	8.7	8.7	21.7	8.7	13.0	23.9
	Site 3	6.4	8.5	8.5	10.6	21.3	8.5	12.8	23.4
	Site 4	6.5	8.7	8.7	10.9	21.7	8.7	13.0	21.7
	Site 5	4.8	4.8	4.8	4.8	23.8	4.8	23.8	28.6
1977	Site 1	4.5	9.1	2.3	18.2	13.6	13.6	4.5	34.1
	Site 2	4.5	4.5	2.3	15.9	18.2	13.6	6.8	34.1
	Site 3	2.3	6.8	2.3	15.9	20.5	11.4	6.8	34.1
	Site 4	6.4	8.5	2.1	19.1	14.9	12.8	6.4	29.8
	Site 5	5.4	10.8	2.7	18.9	13.5	13.5	2.7	32.4
1978	Site 1	10.2	6.1	10.2	12.2	28.6	10.2	12.2	10.2
	Site 2	9.6	7.7	7.7	11.5	28.8	9.6	13.5	11.5
	Site 3	7.8	5.9	9.8	11.8	31.4	7.8	13.7	11.8
	Site 4	7.7	5.8	11.5	11.5	28.8	9.6	13.5	11.5
	Site 5	10.2	6.1	10.2	10.2	26.5	10.2	14.3	12.2
1979	Site 1	13.0	0.0	2.2	17.4	19.6	8.7	6.5	32.6
	Site 2	11.1	0.0	4.4	15.6	20.0	8.9	6.7	33.3
	Site 3	13.3	0.0	2.2	15.6	20.0	8.9	6.7	33.3
	Site 4	13.3	0.0	2.2	17.8	20.0	8.9	6.7	31.1
	Site 5	15.6	0.0	2.2	13.3	20.0	8.9	6.7	33.3
1980	Site 1	15.2	12.1	9.1	15.2	15.2	3.0	6.1	24.2
	Site 2	18.2	12.1	9.1	15.2	18.2	3.0	3.0	21.2
	Site 3	18.2	12.1	9.1	15.2	15.2	3.0	3.0	24.2
	Site 4	17.1	11.4	8.6	14.3	17.1	2.9	5.7	22.9
	Site 5	17.1	11.4	8.6	14.3	17.1	2.9	5.7	22.9
1981	Site 1	4.3	6.5	10.9	19.6	17.4	4.3	8.7	28.3
	Site 2	4.3	6.5	10.9	19.6	17.4	4.3	8.7	28.3
	Site 3	4.3	6.5	10.9	19.6	17.4	4.3	8.7	28.3
	Site 4	4.3	6.5	10.9	19.6	15.2	4.3	10.9	28.3
	Site 5	4.3	6.5	10.9	19.6	17.4	4.3	8.7	28.3
1982	Site 1	11.1	11.1	11.1	11.1	19.4	5.6	8.3	22.2
	Site 2	8.3	11.1	11.1	11.1	22.2	5.6	8.3	22.2
	Site 3	10.8	10.8	10.8	10.8	18.9	5.4	8.1	24.3
	Site 4	10.8	10.8	10.8	10.8	18.9	5.4	8.1	24.3
	Site 5	10.8	10.8	10.8	10.8	18.9	5.4	8.1	24.3
All years combined	Site 1	8.8	7.1	7.1	15.5	19.6	7.4	9.1	25.3
	Site 2	8.6	7.0	7.6	13.9	21.2	7.9	8.9	24.8
	Site 3	8.6	6.9	7.6	14.2	21.1	7.3	8.9	25.4
	Site 4	9.1	7.1	7.8	14.9	19.8	7.8	9.4	24.0
	Site 5	10.0	7.0	7.4	13.7	19.6	7.4	9.2	25.6

TABLE 5-15. ARITHMETIC MEAN PARTICULATE LEVELS BY WIND SECTOR FOR ALL DAYS WITH P>0.71 ($\mu g/m^3$)

Site 1 - 4426 Council Street								
Year	N	NE	E	SE	S	SW	W	NW
1982	45.8(4)	47.5(4)	74.0(4)	50.3(4)	57.7(7)	60.0(2)	40.3(3)	60.6(8)
1981	44.5(2)	60.0(3)	41.2(5)	66.7(9)	63.4(8)	38.0(2)	55.0(4)	64.2(13)
1980	62.8(5)	70.8(4)	63.7(3)	71.6(5)	126.8(5)	48.0(1)	48.0(2)	84.1(8)
1979	40.7(6)	--	88.0(1)	86.1(8)	73.7(9)	74.8(4)	46.3(3)	56.2(15)
1978	36.2(5)	46.7(3)	52.8(5)	63.3(6)	74.3(14)	68.0(5)	39.2(6)	46.2(5)
1977	93.0(2)	50.3(4)	51.0(1)	71.9(8)	72.5(6)	81.7(6)	44.5(2)	87.1(15)
1976	50.5(2)	65.0(3)	41.5(2)	90.5(6)	97.0(9)	47.0(2)	73.4(7)	98.1(11)
Average	49.9(26)	56.6(21)	56.1(21)	72.7(46)	78.5(58)	66.7(22)	52.4(27)	67.4(75)

Site 2 - 751 Center Point Road								
Year	N	NE	E	SE	S	SW	W	NW
1982	63.7(3)	68.8(4)	83.3(4)	76.3(4)	82.4(8)	86.5(2)	44.3(3)	69.4(8)
1981	63.5(2)	87.3(3)	67.6(5)	94.8(9)	90.1(8)	59.0(2)	71.8(4)	97.3(13)
1980	91.0(6)	104.5(4)	91.7(3)	118.4(5)	178.2(6)	100.0(1)	37.0(1)	126.6(7)
1979	102.0(5)	--	109.0(2)	127.9(7)	118.6(9)	141.8(4)	54.0(3)	103.9(15)
1978	63.6(5)	118.0(4)	83.3(4)	95.8(6)	129.3(15)	100.2(5)	57.1(7)	130.3(6)
1977	172.5(2)	124.0(2)	129.0(1)	134.4(7)	145.8(8)	200.2(6)	66.0(3)	115.9(15)
1976	62.7(3)	102.3(4)	97.5(4)	131.3(4)	160.6(10)	112.0(4)	99.0(6)	85.3(11)
Average	85.6(26)	99.2(21)	87.7(23)	111.6(42)	128.5(64)	129.5(24)	67.1(27)	103.0(75)

Site 3 - 14th Avenue and 10th Street								
Year	N	NE	E	SE	S	SW	W	NW
1982	44.0(4)	48.8(4)	85.5(4)	98.5(4)	94.0(7)	113.5(2)	50.0(3)	59.6(9)
1981	51.5(2)	70.3(3)	60.2(5)	90.9(9)	90.9(8)	72.0(2)	79.3(4)	88.5(13)
1980	61.3(6)	70.0(4)	73.7(3)	90.6(5)	204.8(5)	104.0(1)	36.0(1)	102.0(8)
1979	50.7(6)	--	119.0(1)	146.1(7)	130.0(9)	113.0(4)	70.3(3)	79.1(15)
1978	58.0(4)	54.3(3)	80.8(5)	94.5(6)	131.1(16)	111.0(4)	90.6(7)	110.8(6)
1977	75.0(1)	85.3(3)	67.0(1)	103.1(7)	110.2(9)	112.6(5)	88.0(3)	97.1(15)
1976	71.3(3)	91.0(4)	88.3(4)	133.2(5)	150.4(10)	134.8(4)	105.7(6)	109.9(11)
Average	56.6(26)	70.0(21)	78.6(23)	108.0(43)	125.6(64)	112.4(22)	83.2(27)	90.4(77)

(continued)

TABLE 5-15 (continued)

Year	Site 4 - 445 First Street							
	N	NE	E	SE	S	SW	W	NW
1982	52.5(4)	54.5(4)	94.0(4)	118.3(4)	83.4(7)	85.0(2)	40.7(3)	57.1(9)
1981	62.5(2)	76.0(3)	62.4(5)	108.4(9)	87.0(7)	55.0(2)	83.8(5)	80.0(13)
1980	71.7(6)	88.3(4)	75.3(3)	88.0(5)	151.3(6)	81.0(1)	54.5(2)	98.8(8)
1979	51.8(6)	--	118.0(1)	117.3(8)	95.0(9)	89.5(4)	51.3(3)	66.2(14)
1978	55.8(4)	56.3(3)	93.8(6)	86.3(6)	103.7(15)	77.8(5)	56.7(7)	77.3(6)
1977	92.7(3)	62.0(4)	97.0(1)	132.8(9)	110.1(7)	107.2(6)	66.0(3)	96.2(14)
1976	57.0(3)	63.8(4)	93.3(4)	165.4(5)	209.1(10)	95.8(4)	94.8(6)	99.2(10)
Average	62.4(28)	66.9(22)	86.0(24)	116.7(46)	120.9(61)	90.6(24)	67.9(29)	82.1(74)

Year	Site 5 - 4401 Sixth Street							
	N	NE	E	SE	S	SW	W	NW
1982	55.5(4)	52.0(4)	87.3(4)	64.0(4)	67.9(7)	93.5(2)	48.3(3)	70.7(9)
1981	50.0(2)	66.0(3)	43.0(5)	68.1(9)	64.3(8)	38.5(2)	91.8(4)	84.2(13)
1980	56.2(6)	87.8(4)	60.3(3)	65.6(5)	129.0(6)	59.0(1)	43.0(2)	85.8(8)
1979	64.0(7)	--	94.0(1)	116.0(6)	95.7(9)	121.3(4)	50.7(3)	72.5(15)
1978	61.6(5)	83.3(3)	81.6(5)	87.0(5)	152.5(13)	144.0(5)	50.6(7)	161.7(6)
1977	83.5(2)	63.5(4)	100.0(1)	76.0(7)	72.6(5)	161.0(5)	76.0(1)	101.8(12)
1976	58.0(1)	85.0(1)	67.0(1)	42.0(1)	121.2(5)	65.0(1)	114.8(5)	140.2(6)
Average	60.7(27)	70.8(19)	70.7(20)	78.4(37)	105.2(53)	119.9(20)	70.2(25)	94.7(69)

Year	Backbone State Park							
	N	NE	E	SE	S	SW	W	NW
1982	24.8(4)	26.8(4)	69.5(4)	41.3(3)	28.4(7)	50.0(2)	20.5(2)	21.8(6)
1981	25.0(2)	51.5(2)	34.0(6)	59.9(9)	45.8(8)	30.0(2)	39.7(3)	34.6(9)
1980	38.6(5)	42.5(4)	33.0(3)	50.5(2)	73.3(6)	43.0(1)	39.5(2)	45.6(7)
1979	29.7(3)	--	47.5(2)	37.7(3)	56.7(7)	82.3(3)	21.5(2)	35.3(7)
1978	24.2(5)	33.5(2)	41.3(4)	82.5(2)	44.0(10)	39.3(3)	22.0(4)	50.5(6)
Average	29.1(19)	37.3(12)	44.3(19)	54.8(19)	48.5(38)	51.6(11)	28.5(13)	36.3(35)

Note: Numbers in parentheses indicate number of observations.

TABLE 5-16. SPATIAL CORRELATIONS: WINDS FROM NORTH SECTOR

Date	Particulate level ($\mu g/m^3$)						Average wind speed (mph)	Persistence	Resultant wind direction
	Site 1	Site 2	Site 3	Site 4	Site 5	Backbone State Park			
01-25-76	41	38	75	26	--	--	12.0	.807	358
09-27-76	60	81	83	97	--	--	7.5	.902	357
11-26-76	--	69	56	48	58	--	16.2	.884	349
06-06-77	136	150	--	112	--	--	15.3	.955	355
09-13-77	--	--	--	71	70	--	8.8	.914	14
11-03-77	50	195	75	95	97	--	5.9	.716	342
01-14-78	21	25	28	29	32	10	12.0	.865	346
01-20-78	46	92	60	61	56	20	12.3	.900	341
02-07-78	34	59	37	54	84	--	6.9	.893	350
02-08-78	--	--	--	--	--	26	5.7	.855	353
05-14-78	31	56	--	--	30	24	18.3	.912	342
10-23-78	49	86	107	79	106	41	6.7	.952	353
01-27-79	26	28	27	26	21	--	10.0	.817	352
02-08-79	28	--	30	32	30	--	12.9	.838	357
04-09-79	42	126	71	55	55	35	10.7	.863	351
05-03-79	43	150	59	66	61	36	16.5	.978	346
05-24-79	--	--	--	--	157	--	9.9	.918	359
06-08-79	35	95	50	58	52	--	9.3	.804	357
12-29-79	70	111	67	74	72	18	6.2	.879	1
02-15-80	41	52	51	51	50	--	17.1	.873	358
03-04-80	59	84	64	68	67	33	11.6	.766	9
04-27-80	76	153	99	101	70	40	12.3	.836	350
07-26-80	81	56	36	44	32	29	8.2	.717	15
11-17-80	57	114	58	90	54	59	10.3	.984	359
12-29-80	--	87	60	76	64	32	8.9	.925	342
05-10-81	49	71	51	59	47	--	15.5	.990	17
05-11-81	--	--	--	--	--	37	17.1	.917	7
10-07-81	40	56	52	66	53	13	4.3	.710	343
06-22-82	47	64	49	55	69	25	6.0	.728	21
07-22-82	40	--	36	46	40	26	8.6	.850	11
08-27-82	71	84	59	72	71	33	8.8	.767	8
09-14-82	25	43	32	37	42	15	7.6	.786	17

TABLE 5-17. SPATIAL CORRELATIONS: WINDS FROM NORTHEAST SECTOR

Date	Particulate level ($\mu g/m^3$)						Average wind speed (mph)	Persistence	Resultant wind direction
	Site 1	Site 2	Site 3	Site 4	Site 5	Backbone State Park			
05-06-76	74	118	83	66	--	--	14.7	.941	31
05-24-76	63	107	68	68	--	--	10.1	.938	45
05-30-76	--	101	69	50	--	--	7.8	.926	49
09-15-76	58	83	144	71	85	--	9.3	.932	34
05-07-77	75	139	168	88	94	--	10.5	.899	62
06-12-77	51	--	55	52	52	--	13.1	.951	61
08-23-77	49	109	--	68	71	--	8.9	.809	47
10-22-77	26	--	33	40	37	--	14.7	.920	60
02-13-78	36	45	41	34	47	16	17.1	.957	42
03-07-78	--	141	--	--	--	--	15.0	.983	62
04-26-78	65	228	79	90	153	150	6.8	.890	39
09-17-78	39	58	43	45	50	--	11.9	.785	46
11-11-78	--	--	--	--	--	51	11.2	.873	36
02-03-80	75	95	69	74	62	38	7.1	.965	61
03-28-80	80	132	90	113	111	58	16.0	.994	56
05-15-80	46	80	45	55	55	24	9.7	.958	61
07-02-80	82	111	76	111	123	50	5.8	.732	23
01-04-81	53	58	45	44	45	27	7.0	.712	59
07-15-81	52	91	69	67	52	--	6.0	.710	43
08-20-81	75	113	97	117	101	76	3.5	.743	54
02-16-82	65	82	63	68	70	44	9.9	.980	57
03-18-82	39	102	54	68	51	18	6.2	.753	23
04-05-82	33	39	36	32	34	17	18.1	.819	30
07-28-82	53	52	42	50	53	28	6.3	.789	27

TABLE 5-18. SPATIAL CORRELATIONS: WINDS FROM EAST SECTOR

Date	Particulate level (μg/m³) Site 1	Site 2	Site 3	Site 4	Site 5	Backbone State Park	Average wind speed (mph)	Persistence	Resultant wind direction
03-01-76	25	42	40	27	--	--	18.3	.963	77
06-05-76	--	138	123	133	--	--	11.5	.912	103
06-23-76	--	123	118	124	--	--	10.7	.907	108
07-29-76	58	87	72	89	67	--	4.4	.784	79
10-28-77	51	129	67	97	100	--	10.3	.941	83
04-02-78	68	--	135	83	116	34	19.8	.964	107
04-08-78	29	55	40	39	35	51	18.2	.973	99
05-16-78	--	--	--	191	--	--	7.6	.879	78
07-31-78	74	103	112	125	128	59	5.4	.727	68
11-16-78	35	67	31	41	51	21	10.4	.963	70
11-22-78	58	108	86	84	78	--	10.7	.961	108
02-10-79	--	54	--	--	--	--	11.3	.984	107
03-22-79	88	164	119	118	94	59	8.5	.989	96
08-21-79	--	--	--	--	--	36	8.0	.904	103
02-21-80	69	77	66	72	60	31	16.2	.984	84
03-22-80	52	83	64	66	52	31	12.5	.831	97
12-11-80	70	115	91	88	69	37	7.4	.860	99
02-21-81	59	80	87	77	56	44	14.7	.882	106
07-16-81	--	--	--	--	--	51	5.9	.943	74
07-27-81	17	48	20	31	21	16	10.1	.963	76
08-02-81	38	58	46	50	36	23	6.1	.755	90
11-18-81	46	90	91	85	60	35	13.0	.915	97
11-30-81	46	62	57	69	42	35	14.2	.973	102
04-29-82	108	142	131	144	138	88	13.8	.965	94
06-04-82	56	74	46	55	71	76	9.0	.955	70
08-15-82	84	80	89	97	84	84	6.3	.803	112
10-08-82	48	37	76	80	56	30	8.6	.938	105

TABLE 5-19. SPATIAL CORRELATIONS: WINDS FROM SOUTHEAST SECTOR

Date	Particulate level (μg/m³)						Average wind speed (mph)	Persistence	Resultant wind direction
	Site 1	Site 2	Site 3	Site 4	Site 5	Backbone State Park			
01-01-76	97	151	121	66	--	--	14.7	.914	116
02-14-76	88	--	--	--	--	--	16.8	.957	137
04-12-76	94	--	133	158	--	--	9.5	.930	147
05-12-76	109	163	170	235	--	--	14.1	.954	149
08-16-76	66	84	100	125	--	--	8.5	.924	122
10-03-76	89	127	142	243	42	--	10.5	.914	134
03-02-77	70	139	127	127	--	--	14.3	.978	125
03-03-77	--	--	--	--	85	--	16.6	.931	140
03-14-77	84	129	120	146	--	--	12.5	.915	145
03-26-77	74	119	103	--	80	--	16.6	.976	157
04-01-77	54	--	83	129	--	--	15.0	.835	137
04-19-77	49	154	104	118	80	--	9.8	.855	146
05-10-77	--	--	--	152	--	--	7.9	.905	142
05-25-77	100	184	138	149	152	--	4.7	.785	126
06-09-77	--	--	--	--	57	--	8.7	.872	116
06-15-77	--	--	--	160	39	--	8.2	.906	130
06-22-77	--	156	--	--	--	--	12.4	.902	117
08-25-77	--	--	--	147	--	--	10.9	.943	141
11-29-77	102	--	--	--	--	--	7.7	.937	145
12-15-77	42	60	47	67	39	--	10.5	.957	151
07-01-78	60	75	85	71	--	--	9.5	.846	142
08-12-78	88	138	137	131	134	84	5.6	.878	144
10-29-78	57	98	96	88	71	81	15.0	.954	148
11-10-78	85	118	133	127	141	--	8.6	.890	144
12-10-78	49	65	49	53	38	--	8.5	.922	155
12-28-78	41	81	67	48	51	--	20.1	.996	139

(continued)

TABLE 5-19 (continued)

Date	Particulate level (µg/m³) Site 1	Site 2	Site 3	Site 4	Site 5	Backbone State Park	Average wind speed (mph)	Persistence	Resultant wind direction
01-11-79	--	--	--	65	--	--	15.7	.935	127
02-14-79	108	104	135	103	92	--	9.5	.890	128
02-22-79	45	--	--	--	--	--	16.8	.977	121
03-16-79	85	154	190	122	--	57	11.8	.974	156
07-02-79	78	140	141	122	124	--	10.3	.943	120
07-08-79	97	106	125	119	114	--	4.8	.922	122
09-24-79	72	137	105	97	70	48	6.0	.833	152
10-18-79	118	171	173	165	137	--	13.1	.876	135
10-30-79	86	83	154	145	159	8	17.1	.989	120
01-04-80	72	104	88	55	51	34	7.7	.777	121
01-10-80	78	56	80	78	64	--	17.2	.944	152
09-24-80	79	267	126	130	89	--	4.1	.817	152
11-11-80	73	105	93	102	79	67	10.2	.967	113
12-05-80	56	60	66	75	45	--	8.4	.890	128
05-16-81	65	93	83	91	62	73	11.3	.958	136
05-22-81	76	123	123	137	76	95	16.8	.969	156
06-27-81	64	105	92	92	63	62	12.0	.955	151
07-03-81	91	106	120	113	78	97	6.7	.932	121
09-25-81	47	65	70	71	45	34	8.8	.955	153
10-13-81	66	80	90	120	65	27	9.6	.974	143
11-12-81	78	116	120	141	106	63	6.3	.877	131
12-12-81	57	86	60	83	59	45	6.1	.954	153
12-30-81	56	79	60	128	59	43	11.4	.965	143
01-29-82	33	45	49	53	38	--	8.6	.839	113
04-11-82	31	53	86	--	34	17	8.5	.798	127
04-14-82	--	--	--	168	--	--	11.4	.963	141
09-08-82	54	71	127	107	58	36	7.0	.918	141

TABLE 5-20. SPATIAL CORRELATIONS: WINDS FROM SOUTH SECTOR

Date	Particulate level (μg/m³)						Average wind speed (mph)	Persistence	Resultant wind direction
	Site 1	Site 2	Site 3	Site 4	Site 5	Backbone State Park			
02-24-76	101	155	95	137	--	--	9.5	.973	187
03-19-76	114	180	61	214	--	--	16.5	.973	179
03-25-76	121	210	250	354	--	--	14.6	.938	163
06-11-76	75	143	147	182	--	--	12.1	.959	182
06-17-76	70	186	194	289	--	--	14.1	.971	165
08-04-76	105	158	177	175	145	--	11.0	.970	182
08-10-76	100	162	154	224	106	--	11.3	.975	170
08-22-76	--	133	132	162	134	--	6.7	.928	174
11-08-76	85	145	178	221	102	--	12.3	.809	182
11-14-76	102	134	116	133	119	--	6.6	.882	202
03-08-77	107	174	158	188	--	--	13.2	.955	190
05-01-77	77	122	108	135	80	--	10.0	.855	189
05-17-77	--	--	100	--	--	--	12.9	.923	185
05-19-77	117	242	175	162	114	--	10.9	.951	178
07-18-77	53	78	70	65	48	--	11.1	.806	172
07-30-77	58	116	85	88	59	--	8.1	.851	173
08-26-77	--	--	120	--	--	--	10.7	.974	175
10-04-77	--	252	129	89	--	--	8.6	.949	185
10-26-77	--	113	--	--	--	--	7.2	.854	176
11-09-77	23	69	47	44	62	--	21.1	.815	201
02-19-78	90	108	84	78	86	29	5.5	.967	188
03-27-78	112	140	206	134	100	--	10.0	.907	193
05-10-78	--	--	170	--	--	--	9.9	.960	190
05-26-78	103	223	197	184	401	--	11.3	.970	175
06-14-78	--	--	--	--	--	84	13.2	.919	175
06-15-78	--	--	--	--	70	--	14.1	.899	167
06-19-78	66	108	109	99	299	--	10.9	.963	172
06-25-78	82	99	102	103	172	--	9.7	.919	177
07-13-78	34	93	77	80	--	51	10.5	.976	164
07-19-78	--	57	70	54	--	36	8.2	.916	195
07-25-78	76	183	149	100	104	34	4.5	.905	171
08-08-78	--	--	--	--	--	73	5.5	.925	195
08-18-78	64	152	118	96	99	52	11.7	.892	161
09-05-78	77	173	148	126	219	--	6.9	.965	172
09-11-78	104	179	179	154	171	--	8.6	.985	182
09-23-78	64	109	118	82	--	--	7.1	.887	174
09-28-78	--	--	--	--	--	24	6.4	.729	181
09-29-78	58	104	121	79	75	--	8.5	.794	200
10-11-78	44	79	107	65	77	21	7.2	.805	199
10-17-78	66	132	142	121	109	36	9.8	.973	173

(continued)

TABLE 5-20 (continued)

Date	Particulate level (µg/m³)						Average wind speed (mph)	Persistence	Resultant wind direction
	Site 1	Site 2	Site 3	Site 4	Site 5	Backbone State Park			
01-15-79	41	51	37	31	35	--	8.3	.750	160
02-19-79	--	--	--	--	--	38	12.0	.984	161
02-20-79	--	82	79	68	59	--	13.0	.990	164
05-09-79	118	201	292	172	190	78	13.4	.892	173
05-22-79	127	--	--	--	--	--	14.2	.768	177
06-14-79	64	128	190	122	98	92	14.4	.961	164
06-26-79	66	225	153	131	199	35	10.2	.886	195
07-22-79	--	--	--	--	--	70	4.6	.852	162
08-31-79	64	128	159	109	92	--	8.3	.956	163
11-11-79	37	59	61	44	32	36	13.9	.992	167
11-17-79	81	107	89	93	84	48	10.5	.963	198
12-17-79	65	86	110	85	72	--	10.5	.896	193
04-21-80	165	209	271	214	176	119	11.2	.850	169
05-09-80	143	227	196	200	201	--	8.9	.950	187
06-21-80	--	--	--	--	--	67	6.9	.964	186
07-14-80	134	258	204	170	126	87	11.0	.975	176
08-07-80	79	111	127	106	76	34	10.0	.954	175
08-19-80	--	118	--	84	94	49	8.9	.893	180
08-25-80	113	146	226	134	101	84	10.1	.984	162
02-15-81	68	68	76	68	56	51	17.5	.986	177
03-29-81	61	89	79	--	71	40	18.8	.868	175
04-10-81	53	87	112	98	58	47	11.5	.835	158
04-16-81	52	75	91	72	49	44	13.0	.985	171
05-04-81	61	78	88	60	59	51	12.4	.777	194
05-28-81	75	123	114	98	79	49	9.8	.758	171
09-13-81	85	135	119	128	104	58	2.5	.911	192
12-06-81	52	66	48	85	38	26	10.8	.961	171
01-17-82	--	96	--	--	--	--	14.4	.980	162
02-10-82	55	84	70	69	41	23	9.5	.971	177
02-22-82	56	89	83	85	57	15	10.8	.917	170
03-30-82	41	67	75	95	71	32	21.8	.812	202
05-17-82	44	72	130	83	59	38	13.2	.832	165
07-04-82	55	64	93	70	94	43	6.8	.720	166
07-16-82	42	52	63	58	42	24	9.3	.901	183
08-03-82	111	135	144	124	111	24	10.6	.976	196

TABLE 5-21. SPATIAL CORRELATIONS: WINDS FROM SOUTHWEST SECTOR

Date	Particulate level (μg/m³)						Average wind speed (mph)	Persistence	Resultant wind direction
	Site 1	Site 2	Site 3	Site 4	Site 5	Backbone State Park			
01-31-76	54	59	101	55	--	--	12.5	.876	242
02-12-76	--	121	171	105	--	--	16.9	.945	214
09-03-76	--	204	173	153	--	--	12.6	.787	212
12-14-76	40	64	94	70	65	--	14.4	.912	216
04-13-77	111	163	166	143	165	--	9.3	.900	236
05-13-77	133	362	--	168	231	--	9.9	.972	230
06-24-77	66	191	106	75	169	--	7.0	.840	226
07-06-77	88	234	111	99	111	--	9.9	.881	217
08-05-77	41	90	71	61	--	--	6.3	.839	227
11-15-77	51	161	109	97	129	--	11.2	.786	244
03-09-78	124	169	177	155	147	46	6.6	.919	232
05-08-78	31	45	--	47	42	20	15.0	.911	235
08-06-78	74	122	105	94	344	--	5.6	.878	219
08-24-78	87	133	111	103	157	52	6.7	.728	231
12-04-78	24	32	51	30	30	--	14.6	.936	232
06-02-79	90	135	124	88	158	129	9.7	.851	245
06-20-79	75	185	136	91	109	95	16.1	.854	211
08-07-79	108	219	141	136	180	--	7.0	.947	234
11-23-79	26	28	51	43	38	23	10.3	.938	235
10-30-80	48	100	104	81	59	43	10.6	.914	218
03-14-81	--	--	--	--	--	40	9.4	.832	216
10-19-81	40	71	99	62	39	20	9.0	.841	214
12-24-81	36	47	45	48	38	--	9.4	.878	227
04-23-82	76	118	141	111	124	60	11.1	.946	213
10-14-82	44	55	86	59	63	40	9.5	.965	240

TABLE 5-22. SPATIAL CORRELATIONS: WINDS FROM WEST SECTOR

Date	Particulate level ($\mu g/m^3$)						Average wind speed (mph)	Persistence	Resultant wind direction
	Site 1	Site 2	Site 3	Site 4	Site 5	Backbone State Park			
04-30-76	91	98	128	93	--	--	10.0	.759	261
07-11-76	85	93	79	112	173	--	10.7	.833	279
07-17-76	90	122	109	111	122	--	6.9	.801	265
07-23-76	65	89	91	94	105	--	5.6	.739	272
09-10-76	47	--	--	--	--	--	9.5	.847	277
10-21-76	47	53	76	56	61	--	14.0	.958	286
11-20-76	89	139	151	103	113	--	7.6	.784	286
02-24-77	--	52	91	50	--	--	20.1	.904	253
11-21-77	39	61	74	66	--	--	12.8	.940	282
12-27-77	50	85	99	82	76	--	10.4	.757	281
01-02-78	32	34	36	33	33	23	13.9	.939	272
03-15-78	34	56	121	72	47	--	7.3	.927	291
03-21-78	--	82	133	91	75	--	13.0	.778	283
06-01-78	45	54	153	54	79	--	12.5	.938	287
10-05-78	33	77	81	50	47	22	14.1	.963	291
12-16-78	48	54	43	41	36	21	13.5	.966	280
12-22-78	43	43	67	56	37	22	15.1	.917	272
01-03-79	29	24	58	35	31	--	11.0	.972	254
03-04-79	20	22	24	23	22	--	11.4	.967	284
03-05-79	--	--	--	--	--	21	13.8	.993	287
12-05-79	90	116	129	96	99	22	16.6	.759	265
10-18-80	26	37	36	31	31	34	12.9	.955	271
11-29-80	70	--	--	78	55	45	16.2	.866	276
02-01-81	--	48	--	--	--	--	19.4	.919	284
02-03-81	50	--	63	58	55	46	11.6	.970	273
03-11-81	48	79	98	74	87	--	11.2	.848	292
04-01-81	--	--	--	132	--	--	21.5	.876	278
04-04-81	37	50	50	51	41	23	19.9	.856	278
09-19-81	85	110	106	104	184	50	9.0	.717	255
01-23-82	62	53	64	37	70	35	27.9	.955	271
03-06-82	44	63	63	66	55	--	8.7	.710	275
10-20-82	15	17	23	19	20	6	16.3	.965	291

TABLE 5-23. SPATIAL CORRELATIONS: WINDS FROM NORTHWEST SECTOR

Date	Particulate level (μg/m³) Site 1	Site 2	Site 3	Site 4	Site 5	Backbone State Park	Average wind speed (mph)	Persistence	Resultant wind direction
01-07-76	111	141	174	134	--	--	18.4	.938	330
01-13-76	80	130	144	116	--	--	13.0	.903	337
02-06-76	97	72	141	90	--	--	15.8	.969	308
02-18-76	27	53	--	49	--	--	13.1	.842	314
03-07-76	31	68	57	40	--	--	14.0	.794	313
03-31-76	43	55	62	39	--	--	12.5	.912	299
08-28-76	102	75	121	93	130	--	8.3	.948	313
09-09-76	--	93	103	64	94	--	13.2	.974	318
09-21-76	60	65	77	--	99	--	10.1	.859	322
10-15-76	401	--	450	290	334	--	17.8	.977	310
12-20-76	71	107	111	77	116	--	21.8	.984	318
12-26-76	56	79	74	--	68	--	12.9	.761	304
01-01-77	53	54	58	49	48	--	12.6	.976	302
01-25-77	34	38	42	23	26	--	15.4	.954	296
02-01-77	65	64	111	87	66	--	12.1	.901	293
02-06-77	44	62	57	48	46	--	10.9	.986	332
02-12-77	67	84	89	53	--	--	19.0	.890	297
02-18-77	69	125	--	124	--	--	11.2	.892	298
02-19-77	--	--	--	--	127	--	13.0	.977	328
04-25-77	81	126	93	114	92	--	10.7	.933	336
05-31-77	--	--	--	265	--	--	18.3	.988	296
06-01-77	111	182	127	--	116	--	14.5	.903	318
06-18-77	--	--	49	41	--	--	12.8	.951	300
07-12-77	80	147	109	86	88	--	8.8	.824	300
08-11-77	57	94	73	--	57	--	7.2	.906	318
08-17-77	45	91	60	80	54	--	9.1	.964	315
09-10-77	49	110	75	--	--	--	7.7	.809	321
12-03-77	40	61	62	63	--	--	7.5	.885	323
12-09-77	455	446	371	267	434	--	24.0	.995	301
12-21-77	56	54	80	47	68	--	19.3	.996	304
01-08-78	60	77	83	65	96	27	24.4	.997	317
01-26-78	--	309	251	185	624	101	26.7	.999	301
02-02-78	--	--	--	--	--	34	8.4	.864	328
02-25-78	30	25	82	36	35	18	19.0	.995	307
03-03-78	40	--	61	48	49	--	14.2	.985	318
03-16-78	--	--	--	--	--	22	11.3	.955	303
04-04-78	--	217	--	--	--	--	15.0	.875	306
04-20-78	14	24	34	26	29	85	15.9	.965	307
05-20-78	87	130	154	104	137	--	12.2	.777	303
06-02-78	--	--	--	--	--	101	9.1	.877	321

(continued)

TABLE 5-23 (continued)

Date	Particulate level (μg/m³)						Average wind speed (mph)	Persistence	Resultant wind direction
	Site 1	Site 2	Site 3	Site 4	Site 5	Backbone State Park			
01-09-79	38	33	45	--	38	--	12.5	.899	298
01-21-79	--	30	34	28	36	--	18.1	.976	316
01-24-79	39	--	--	--	--	--	21.6	.973	319
03-10-79	50	64	95	63	58	--	19.7	.995	296
04-03-79	40	179	89	73	59	--	5.9	.810	327
04-15-79	68	94	70	53	68	34	10.9	.973	311
04-21-79	56	120	75	77	57	22	11.1	.977	334
04-27-79	27	85	57	46	49	--	19.8	.810	315
05-15-79	92	209	121	85	106	89	8.0	.872	329
05-27-79	69	96	83	62	68	--	7.1	.886	300
09-06-79	52	101	69	61	100	--	8.3	.928	321
09-18-79	111	192	132	123	159	--	9.4	.828	314
10-06-79	85	147	111	95	122	31	13.1	.969	303
10-12-79	39	96	65	47	59	24	16.2	.988	308
10-24-79	39	75	68	63	66	28	6.2	.965	296
11-29-79	38	38	73	51	43	19	18.2	.990	293
01-22-80	118	107	132	113	113	75	19.3	.951	296
01-28-80	41	92	72	61	67	17	12.1	.987	312
02-09-80	122	--	125	137	126	--	7.4	.903	305
02-16-80	--	--	--	--	--	21	15.7	.965	305
03-10-80	71	96	106	92	83	40	19.8	.844	300
04-09-80	18	21	36	25	19	7	18.2	.993	300
04-15-80	59	168	104	122	76	24	10.2	.930	317
06-08-80	138	129	121	125	100	105	13.5	.917	313
10-12-80	106	273	120	115	102	51	3.9	.798	314
01-10-81	52	91	70	66	63	--	6.3	.891	327
01-16-81	51	68	79	65	81	19	13.4	.986	313
01-22-81	95	134	140	110	120	34	9.3	.947	298
01-28-81	54	80	87	64	71	48	10.5	.940	303
03-05-81	42	64	63	65	46	21	10.7	.858	320
03-23-81	120	191	160	166	173	60	5.2	.801	317
06-03-81	43	60	58	49	91	39	10.1	.967	302
07-09-81	99	123	108	118	107	--	6.3	.918	330
08-08-81	41	92	56	51	51	28	6.3	.750	303
09-01-81	61	98	80	81	74	35	7.6	.980	323
10-01-81	64	100	80	55	78	--	15.1	.952	302
11-06-81	56	66	93	81	61	27	8.1	.988	293
12-18-81	57	98	77	69	78	--	18.2	.986	312

(continued)

TABLE 5-23 (continued)

Date	Particulate level (μg/m³)						Average wind speed (mph)	Persistence	Resultant wind direction
	Site 1	Site 2	Site 3	Site 4	Site 5	Backbone State Park			
01-06-82	--	--	43	40	47	--	16.6	.960	335
01-11-82	186	196	141	130	210	--	16.5	.978	298
02-04-82	40	52	47	62	62	--	7.8	.943	333
03-24-82	24	42	46	45	44	12	10.2	.913	299
04-17-82	27	59	39	28	30	8	18.6	.980	300
06-10-82	73	64	72	74	86	44	12.1	.942	306
08-09-82	51	49	50	47	51	28	9.6	.951	306
09-02-82	57	59	69	51	66	28	10.4	.893	297
09-20-82	27	34	29	37	40	11	9.5	.934	334

TABLE 5-24. ESTIMATED SOURCE IMPACTS AT MONITORING LOCATIONS (GEOMETRIC EQUIVALENTS IN $\mu g/m^3$)

Site 1 - 4426 Council Street

Source Type	1976	1977	1978	1979	1980	1981	1982
Background	47.0	38.6	37.9	35.8	40.7	36.5	26.0
Traditional:							
Stack	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Fuel combustion	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Solid waste disposal	1.1	1.1	1.0	1.0	0.9	0.9	0.8
Auto exhaust	1.4	1.4	1.4	1.4	1.5	1.5	1.5
Annual recorded mean	70.5	62.0	53.6	57.8	66.5	54.1	45.9
Non-traditional impact	16.5	16.4	8.8	15.1	18.9	10.7	13.1

Site 2 - 751 Center Point Road

Source Type	1976	1977	1978	1979	1980	1981	1982
Background	47.0	38.6	37.9	35.8	40.7	36.5	26.0
Traditional:							
Stack	8.8	8.8	8.8	8.8	8.8	8.8	8.8
Fuel combustion	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Solid waste disposal	2.1	2.1	2.0	1.8	1.7	1.5	1.4
Auto exhaust	2.7	2.7	2.7	2.7	2.8	2.8	2.8
Annual recorded mean	98.8	109.3	90.6	95.0	106.5	80.0	60.9
Non-traditional impact	37.2	56.1	38.2	44.9	51.5	29.4	20.9

Site 3 - 14th Avenue and 10th Street

Source Type	1976	1977	1978	1979	1980	1981	1982
Background	47.0	38.6	37.9	35.8	40.7	36.5	26.0
Traditional:							
Stack	24.9	24.9	23.6	22.2	20.9	19.5	18.2
Fuel combustion	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Solid waste disposal	1.8	1.8	1.7	1.6	1.4	1.3	1.2
Auto exhaust	2.5	2.5	2.6	2.6	2.7	2.7	2.8
Annual recorded mean	105.7	85.2	89.3	81.8	84.8	72.7	60.8
Non-traditional impact	28.6	16.5	22.6	18.7	18.2	11.8	11.7

Site 4 - 445 First Street

Source Type	1976	1977	1978	1979	1980	1981	1982
Background	47.0	38.6	37.9	35.8	40.7	36.5	26.0
Traditional:							
Stack	10.8	10.8	9.8	8.7	7.7	6.6	5.6
Fuel combustion	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Solid waste disposal	1.8	1.8	1.7	1.6	1.4	1.3	1.2
Auto exhaust	3.0	3.0	3.0	3.1	3.1	3.2	3.2
Annual recorded mean	97.9	84.1	75.1	73.2	81.0	76.6	60.5
Non-traditional impact	34.5	29.1	21.9	23.2	27.3	28.2	23.7

Site 5 - 4401 Sixth Street

Source Type	1976	1977	1978	1979	1980	1981	1982
Background	47.0	38.6	37.9	35.8	40.7	36.5	26.0
Traditional:							
Stack	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Fuel combustion	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Solid waste disposal	0.5	0.5	0.5	0.5	0.4	0.4	0.4
Auto exhaust	0.8	0.8	0.8	0.8	0.9	0.9	0.9
Annual recorded mean	94.2	74.0	85.6	73.9	70.4	61.7	54.8
Non-traditional impact	41.2	29.4	41.7	32.1	23.7	19.2	22.8

SECTION 6

TASK III - CONTROL STRATEGY FOR AREA SOURCE EMISSIONS

The purpose of Task III was to provide a strategy for the reduction of the impact of non-traditional fugitive dust sources for the attainment of the TSP NAAQS. This was to be based on the most current emission inventory information (Task I) and the available meteorological and TSP ambient monitoring information (Task II).

The first step in developing this strategy was to determine the degree of emissions reduction required. As discussed in Section 5 (Task II), the yearly geometric mean TSP levels at all monitoring stations were below the NAAQS for 1982 (refer to Figure 5-3). However, as mentioned previously, 1982 was a very "wet" year and the background level was well below average (approximately 12 $\mu g/m^3$). While the addition of 12 $\mu g/m^3$ to the recorded 1982 levels would still result in all stations being in attainment, it is felt that this same addition coupled with increased industrial activity (which should occur if the economy recovers) would again result in NAAQS violations. Likewise, should a very "dry" year again occur (as in 1976), the increased background level could result in violations at several of the monitoring stations. Lastly, increased construction activity near a particular monitoring station (as in the current situation near Site 4) can cause TSP exceedences as noted in Section 5. Therefore, a dust control strategy should be implemented throughout the area with the aim of producing the following reductions in the yearly geometric mean TSP levels:

Site 1 - 4426 Council Street: No reduction needed
Site 2 - 751 Center Point Road: 5-10 $\mu g/m^3$
Site 3 - 14th Street and 10th Avenue: 5-10 $\mu g/m^3$
Site 4 - 445 First Street: 5-10 $\mu g/m^3$
Site 5 - 4401 Sixth Street: 0-5 $\mu g/m^3$

Based on the results of Tasks I and II, the primary ambient air impacts due to non-traditional emissions are caused by traffic-related sources, industrial fugitive sources, and construction activity sources. Each of these categories of sources should be addressed in the control strategy for the study area.

TRAFFIC-RELATED SOURCES OF FUGITIVE DUST

It was concluded in Task II that emissions from traffic on paved and unpaved roads throughout the study area produce the greatest ambient air impact of any of the non-traditional sources. Barton-Aschman Associates, Inc. conducted a study for the Linn County Regional Planning Commission that addressed control measures and costs for traffic-related sources.[12] They looked at various options for paved roads including improved sweeping, staggered work hours, mass transit, etc.

Their options for unpaved roads included speed reductions, paving, oiling, watering, and others. Their recommended control packages for traffic-related sources were:

1) Treat approximately two miles of unpaved roads in the core area (downtown Cedar Rapids) with chip seal.

2) Speed reductions on unpaved roads in the study area.

3) Restrict multi-tired vehicles from unpaved roads in the study area.

It should be noted that these recommendations are all for unpaved roads.

As a result of this present study, it is felt that these control strategies are worthwhile and should be implemented as soon as possible. Such actions should result in immediate air quality monitoring responses at Sites 2, 3 and 4. However, some further specification is needed. Treating the unpaved roads in the core area with chip seal should be effective in reducing fugitive dust. However, the surfaces must be properly maintained and use by multi-tired, heavy equipment should be restricted. In addition to the core area, unpaved roads throughout the non-attainment area should be treated. The preferred, long-term method of treatment would be sealing or paving. In the short-term, watering or oiling could be done during extensive dry spells and neglected during wetter periods.

For those roads that are not sealed, speed reductions and heavy equipment restrictions are necessary. The latter of the two is felt to be more effective since previous work by TRC has shown that, even at extremely low speeds (<5 mph), multi-tired, heavy equipment can produce significant emissions when travelling over unpaved areas.

For paved, urban roads, Barton-Aschman did not recommend any cost-effective control strategies. Due to the extensive street cleaning program that already exists in the core area and, to a lesser extent its environs, it is agreed that further urban paved road controls are not really practical. The only point to stress is that cleaning should be performed immediately after sanding and salting in the winter months. It is also recommended that the after-storm clean-up be extended to all major roads in the non-attainment area and not just the core area.

INDUSTRIAL SOURCES OF FUGITIVE DUST

Another major result of the Task II analyses was that fugitive dust from traffic and materials handling activities within Linn County industries were directly affecting the ambient air quality. This was particularly evident at

Sites 3, 4, and 5. The overall control strategy should include provisions for reductions in industrial fugitive dust source emissions.

The main areas to address within the industries are the traffic sources: paved and unpaved roads and parking lots. As seen in Table 4-10, these sources predominate. According to many of the comments given on the inventory questionnaires, very little is being done to keep these source emissions minimized. Typical responses to the question on controls, where there were responses, were "the paved areas are swept once a year..." and "when deemed necessary we sweep the lots". While some plants seem to be making an honest effort at controlling their dust problems, the majority apparently are not doing anything at all. Dust control programs should be instituted at all major industries and these programs should concentrate on the traffic-related dust areas. In particular, the following controls should be considered (with particular emphasis on items 1, 2, 4 and 5):

1) Sweep and/or flush all paved areas on a regular basis (immediately after sanding and salting, otherwise two to three times weekly).

2) Stabilize all unpaved areas or, at the very least, institute speed controls.

3) Reduce the amount of material being deposited on the various plant surfaces through truck covers, wheel washes, etc.

4) Add curbs to un-curbed paved roads.

5) Eliminate bare areas in the plant vicinity through vegetation or stabilization; in particular, roadway berms.

6) Provide perimeter parking and shuttle buses for employees, where feasible, to reduce traffic on plant roads.

The other category of industrial fugitive dust sources is materials handling activities. Based upon the emission inventory, there does not appear to be a lot of dusty materials handling operations in Linn County; unlike some non-attainment areas where the contribution from this category has been shown to be significnat (such as areas with iron and steel plants). Those that are shown to be significant, such as the quarries, are further removed from the general populace and should not really impact the measured ambient air quality. Whether the low emission levels calculated for the inventory accurately reflect the actual situation in Linn County or whether they are the result of using inappropriate emission factors for grain handling operations is not known. Unfortunately, there are no better factors available for use for those types of operations. Therefore, until such time that there are better factors available for use or testing shows significant impacts from these operations, county-wide control programs cannot be recommended other than to stress that good maintenance practices be followed such as watering, spill clean-up, etc.

CONSTRUCTION ACTIVITY SOURCES OF FUGITIVE DUST

It has been shown that extensive construction projects, such as the building of highways 30 and 380, significantly affect the ambient air quality. Smaller-scale construction, such as office complexes and shopping malls, would likewise impact the air quality, but the impact would be more localized. In the future, all construction projects must not be undertaken without fugitive dust control measures as standard operating procedure. Measures to be considered would include the following (with particular emphasis on items 3 and 5):

1) Minimization of time that erodible soil is exposed through stabilization or vegetation and by more careful site planning.

2) Wheel washes for all vehicles leaving the site.

3) Immediate clean-up of any carry-out that occurs from the site.

4) Truck covers on all vehicles.

5) Frequent waterings of exposed areas (up to several times per day during dry spells).

6) Wetting down of loading/unloading areas during activity.

7) Installation of wind breaks and barriers around the site.

8) Restriction of certain activities (such as blasting), where possible, on dry, windy days.

Barton-Aschman also recommended construction controls and some associated costs are provided in their report.[12]

AIR QUALITY IMPROVEMENT DUE TO CONTROL STRATEGY

The recommended controls for the traffic-related and industrial sources of fugitive dust should result in the desired reductions discussed at the beginning of this section. The costs of such controls, except where given in Reference 12, are not provided as part of this study. It is felt that local contractors and industrial personnel can establish these costs much more accurately than could be established within the framework of this study.

Ideally, these controls should be instituted immediately and continuously applied. Realistically, from both an economic and environmental standpoint, the control program need only be incorporated on an as warranted basis. The data from all monitoring stations currently indicate no NAAQS violations. Should dry spells occur or should industrial activity significantly increase, then the control program might have to be applied to ensure compliance.

On the other hand, the recommended control strategy for construction activity sources should be incorporated for all future projects of considerable extent. NAAQS violations will definitely be recorded at monitoring stations nearby any large scale construction activity that does not incorporate a good fugitive dust control program. Again, costs associated with this type of control program are not provided with this report for the reasons stated above.

CHANGES TO CONTROL STRATEGY DUE TO CHANGES IN AIR QUALITY STANDARD

Over the past several years the Environmental Protection Agency has been formulating a policy designed to change the current TSP standard. The current standard is associated with a particle mass-median diameter of approximately 30 µm. The new policy would be to compare the ambient air quality to a standard based on a smaller mass-median diameter - one that more accurately represents a health hazard to the general populace. As of this writing, the median particle size being considered is 10 µm and the standard is known as PM10.

While some particle size data have been recently collected within Linn County, not enough information exists to determine on a statistically sound basis the current ambient level of particulate material having a mass-median diameter of 10 µm. Even if this information was available, it could not be compared to any new standard since one has not yet been determined. It is entirely conceivable that the air quality in Linn County would be well below the standard and thus a dust control program would not be necessary. Alternatively, it is also possible that the county would still be designated non-attainment, but that the primary reason for violations would be the emissions from traditional sources of particulate and thus a dust control program would not be cost-effective. The third possibility is that the county would still be non-attainment and that fugitive dust sources would still be the primary contributors to the violations.

Control efficiencies of techniques applied to fugitive dust sources have not been determined with any degree of statistical accuracy. Added to the inaccuracy in control efficiencies for total particulate is the inaccuracy in the measurement of particle sizes. Most of the historical work done in determining control technique effectiveness has either been in the form of engineering judgment or else through the use of high volume air samplers which collects material having a mass-median diameter of 30 µm. In recent years, some data have been collected using size-fractionating devices (cyclone preseparators, cascade impactors, size selective inlets, dichotomous samplers), but the accuracy of these devices is dependent on wind speed, sampling velocity, degree to which isokinetic sampling was maintained, etc. In summary, there is a paucity of reliable data regarding the efficiency of fugitive dust control techniques for all size ranges and particularly the smaller size ranges. The impact of the recommended control strategy on fine particles therefore has to be almost entirely speculative.

Based on TRC's experience, the following general comments can be made regarding the effect of controls on fine particulate:

- Watering, particularly with a fine, atomized spray, will be effective.

- Street sweeping using broom-type sweepers will be ineffective.

- Paving, sealing, and oiling will still be as effective initially but will remain as effective only with proper maintenance (i.e., sweeping of paved areas is ineffective).

- Speed reductions and multi-tire vehicle restrictions should remain effective.

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16. ABSTRACT

The Clean Air Act Amendments of 1977 require all states to submit state implementation plans (SIPs) for demonstrating the attainment of National Ambient Air Quality Standards (NAAQS) by December 31, 1982. Linn County, Iowa (Cedar Rapids area) is one of the state's four primary non-attainment areas for total suspended particulate (TSP) matter. The SIP demonstrated attainment through further controls on traditional as well as nontraditional sources.

This report presents the results of a study that was performed to assist the Iowa Department of Environmental Quality in the definition of the non-traditional sources of fugitive dust in Linn County.

The study was separated into three tasks: update the area source inventory, analyze the existing monitoring data to determine source impacts, and provide a control strategy for non-traditional sources.

The results of the study indicate that (1) all future large scale construction projects must incorporate fugitive dust controls, (2) surfacing of unpaved roads throughout the region should be continued, and (3) the impact of industrial fugitive dust sources should be reduced.

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