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Assessment of Human Exposures to Atmospheric Cadmium

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The conclusions presented in the study are, of course, solely the responsibility of Energy and Environmental Analysis, Inc.

EXECUTIVE SUMMARY

This report is one of a series of reports which will be used by EPA in responding to the Congressional mandate under the Clean Air Act Amendments of 1977 to determine whether atmospheric emissions of cadmium pose a threat to public health. The report identifies the population exposed to specified cadmium levels from selected point sources. A companion report[1/] identified the specific sources of interest.

Although cadmium is a true multi-media pollutant, this report focuses only on ambient air concentrations of cadmium. Even though significant exposures of cadmium are caused by all media and atmospheric emissions may contribute to other media through various deposition mechanisms, these are not considered here. This report focuses on the exposure caused by specific stationary sources. The sources considered are iron and steel mills, municipal incinerators, primary smelters (zinc, copper, lead, and cadmium), and secondary smelters (copper and zinc).

Methodology

The basic methodology used in this report involved the following procedures:

- Determination of size and location of each source within each source category. In this regard, size data were obtained from trade directories, etc., and locations from United States Geologic Survey (USGS) maps.

- Determination of annual concentrations caused by each source within each source category. For this purpose, annual concentrations of cadmium caused by each source were determined using general diffusion models and model plants.

- Determination of population exposed by each source. Estimates of annual concentrations due to each source and 1970 Census data were combined to give an estimate of the population exposed to each source.

As would be expected in any analysis of this type, many assumptions were made based on limited data. Errors are possible stemming from: estimating source size and location, determining the actual emissions of cadmium from each source, and the type and efficiency of control technologies employed at each source, and inherent biases in the dispersion modelling. In all cases, the best data available were used. The estimates of population exposure should be considered as providing a reasonably accurate estimate of the number of individuals exposed.

Results

Table E-1 is a summary of the results of this analysis. This table shows the population exposed to concentrations greater than 0.1 ng/m^3*, the average level to which this population is exposed and the maximum exposed population, caused by each source type. As shown in Table E-1, municipal incinerators are the chief contributors to the total population exposed. The chief source of cadmium in incinerators is the combustion of plastics containing cadmium stabilizers and the combustion of materials with cadmium-containing paint. Primary zinc and primary copper smelters are estimated to cause the highest concentrations.

Iron and steel production is the second most significant source in each category. Cadmium emissions from this source result from the processing of steels coated with zinc or cadmium, these emissions vary from mill to mill and the estimates here may be high.

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* This is approximately the current level of detectability for cadmium.

TABLE E-1

STUDY RESULTS

	AVERAGE EXPOSURE		MAXIMUM EXPOSURE	
Source	Population (10^3 People)	Concentration (Annual Avg. ng/m^3)	Concentration (Annual Avg. ng/m^3)	Population (10^3 People)
Secondary Smelters				
Copper	9,891	2.3	>10	296
Zinc	37	0.5	0.1-1	37
Municipal Incinerators	48,270	8.4	>200	1.0
Primary Smelters				
Zinc[a/]	376	86-110	>1,000	0.1-0.8
Lead[a/]	105	9-11	100-1,000	0-0.2
Copper[a/]	218-352	5.0-8.0	100-1,000	0-0.2
Cadmium[a/]	150	5.2-15.0	>1,000	0-2.6
Iron and Steel	19,896	2	>10	372

a/ Ranges result from differing assumptions concerning fugitive emissions; see text, Section 6.

Primary smelters, while not affecting large numbers of people, do appear to cause the highest annual average concentrations and exposures. Difficulties encountered both in emission estimation as well as modelling, require that these estimates be interpreted very carefully.

Table E-2 shows the population exposed to cadmium levels greater than 0.1 ng/m^3 by region. The regional breakdown shown on Table E-2 is based on EPA Regions shown in Figure E-1.

It is evident from the data in Table E-2 that municipal incinerators in the northeast and midwest expose the largest number of people. Iron and steel mills rank second in exposure. None of the other sources appear to expose a large number of people, although the concentrations caused by primary smelters may be very high.

Table E-3 shows an estimate of the exposure (expressed in nanograms-person-year) due to each source type. Again, municipal incinerators dominate the list, with iron and steel mills ranking second.

FIGURE E-1

REGIONAL BREAKDOWN

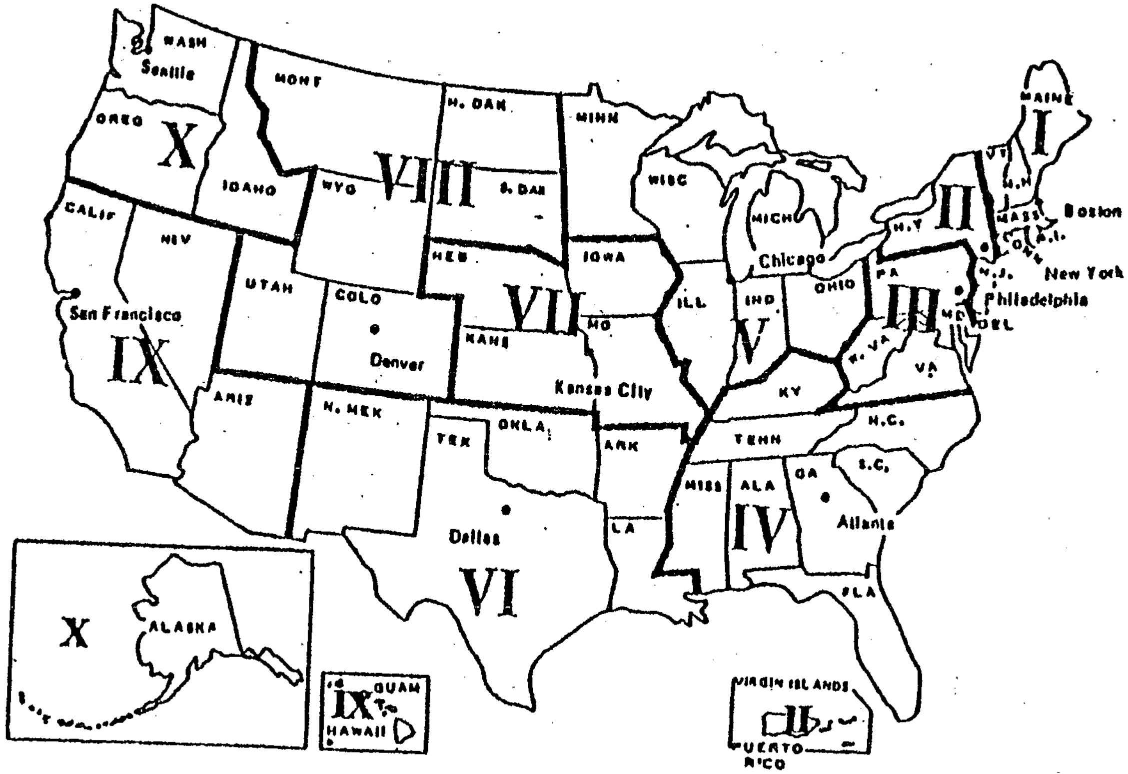

TABLE E-2

POPULATION EXPOSED TO GREATER THAN 0.1 ng/m^3 OF CADMIUM

(10^3 People)

SOURCE TYPE	Region 1	2	3	4	5	6	7	8	9	10	TOTAL
Secondary Copper	0	1441	0	0	1889	1043	313	195	1610	3400	9891
Secondary Zinc	0	0	0	0	18	19	0	0	0	0	37
Municipal Incinerators	6470	16730	8567	2935	12144	1098	157	169	0	0	48270
Primary Zinc 1/	0	0	358	0	0	0	0	0	0	17	376
Primary Lead 1/	0	0	0	0	0	0	60	28	0	17	105
Primary Copper 1/	0	0	0	19	1.4	3.2-6.8	0	84-89	25-52	85-206	218-374
Primary Cadmium	0	0	100	0	0	33	0	0	0	17	150
Iron and Steel	93	1649	4543	1611	8710	1575	108	0	774	833	19896

1/ Ranges result from differing assumptions concerning fugitive emissions; see text, Section 6.

TABLE E-3

COMPARISON OF CADMIUM EXPOSURES AMONG SOURCES

(10^6 Nanograms-Person-Year)[1/]

Source Type	Exposure (10^6 Nanograms-Person-Year)
Secondary Copper	15.1
Secondary Zinc	0
Municipal Incinerators	404.4
Primary Zinc[2/]	32-42
Primary Lead[2/]	.9-1.1
Primary Copper[2/]	1.1-2.8
Primary Cadmium[2/]	0.5-2.4
Iron and Steel	36.2

1/ Computed by multiplying the population exposed to each source by the concentrations resulting from that source.

2/ Range is due to varying assumptions on fugitive emissions; see text, Section 6.

1. INTRODUCTION

This report is one in a series of reports which will assist EPA in responding to the Congressional mandate in Section 122 of the Clean Air Act Amendments of 1977. Under this Section of the Act, EPA is required to review the current data on the health and welfare effects of cadmium (as well as other substances) and determine "whether or not emissions of...cadmium...into the ambient air will cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health."

The purpose of the report is to provide a relative ranking of sources by magnitude of population exposed and to present this information in such a way that EPA can make estimates of the health implications of the reported exposures. This report estimates the population exposed to atmospheric levels of cadmium from "significant cadmium sources" (those source categories for which individual facilities may produce ambient concentrations of at least 0.1 ng/m^3 on an annual basis). This report draws no conclusions as to the health consequences of atmospheric cadmium levels, nor does it provide a total estimate of the population exposed to specified cadmium levels.

The report is organized into several sections summarized below:

- Section 2 provides an overview of the physical and chemical properties of cadmium as well as the routes through which human exposures to cadmium occurs.

- Section 3 provides an overview of the methodology used in the report.

- Sections 4 through 7 provide estimates of the population exposed to cadmium emissions from selected sources. The sources considered are:

  Section 4 -- Iron and Steel Mills

  Section 5 -- Municipal Incinerators

  Section 6 -- Primary Smelters (copper, lead, zinc, and cadmium)

  Section 7 -- Secondary Smelters (copper and zinc)

The background data for this report are based primarily on information presented in a companion report[1/] which focused on:

- the development of cadmium emissions factors;

- the estimation of total atmospheric emissions of cadmium from all sources; and

- the screening of sources to determine if individual sources within a source category can cause measurable ambient levels of cadmium (based on the annual average).

Many of the assumptions and information used in this report are documented in the companion report.

2. CADMIUM IN THE ENVIRONMENT

2.1 INTRODUCTION

This section discusses the physical and chemical properties of cadmium and the multi-media nature of cadmium exposures. Although this report focuses only on atmospheric exposures to cadmium, it is important to keep in mind that there are many other types of human exposures to cadmium including food, water, and tobacco smoke.

2.2 PHYSICAL AND CHEMICAL CHARACTERISTICS OF CADMIUM

Cadmium is a relatively rare element in the earth's crust. It occurs at a concentration of 0.1 to 0.5 ppm. It is of low abundance, ranking between mercury and silver, and thus, not in sufficient quantities to be mined as an ore.[2/] Cadmium is always associated with zinc and is usually present as a sulfide.[3/] Table 2-1 shows the physical properties of cadmium.

The most important characteristic of cadmium, from an air pollution viewpoint, is its high volatility. This is evidenced by its low melting (321°C) and boiling (767°C) points. Thus, any high temperature process, such as metallurgical processes (e.g., steel-making, sintering) or incineration, is likely to release whatever cadmium is present in the feed.

Vaporized cadmium metal is quite reactive and should very quickly form an oxide, sulfate, or other compound of relatively high stability.

Cadmium metal is very ductile, easily soldered, can be readily electroplated, and maintains a lustrous finish in air.[4/] These properties lead to the use of cadmium as a protective coating on iron and steel products.

TABLE 2-1

PHYSICAL PROPERTIES OF CADMIUM

Atomic Number	48
Atomic Weight	112.41
Color	silver-white
Crystal Structure	hexagonal pyramids
Hardness	2.0 Mohs
Ductility	considerable
Density	
20°C (68°F) (solid)	8.65 g/cc
330° (626°F) (liquid)	8.01 g/cc
Melting point	321°C (609.8°F)
Boiling point	767°C (1412.6°F)
Specific heat	
25°C (77°F) (solid)	0.055 g-cal/g
Electrochemical equivalent	
Cd^{+2} ion	0.582 mg/coulomb
Electrode potential	
Cd^{+2} ion	-0.40 volt[a/]

[a/] From Reference 4

[b/] National Bureau of Standards nomenclature, H_2

2.3 MULTI-MEDIA NATURE OF CADMIUM EXPOSURES

While this report focuses on atmospheric exposures to cadmium, it is important to recognize the overall cycle of cadmium in the environment. Measurable levels of cadmium occur in all phases of environmental concern (air, water, food, solid waste), and in almost all geographic areas. One author[5/] refers to cadmium as the "dissipated element." EPA in 1975[6/] estimated that about 1,800 Mg/year of cadmium were lost to the environment. Of this, about 18 percent was in atmospheric emissions, 75 percent in solid waste, and the remainder in water-borne emissions.

Measurable cadmium levels have been found in air, water, soil, and food. Atmospheric concentrations generally have been measured in the center of urban areas and usually range from 100 ng/m^3 down to below the detectable limit of 0.1 ng/m^3. Typical urban concentrations are in the range of 3 ng/m^3. Main sources of cadmium are discharges from mining operations, leaching from soil disposal of wastes, and fall-out from atmospheric emissions.

Cadmium in food results from a wide variety of sources. Listed in order of importance from a recent Battelle Report,[7/] they are:

- Direct contact by plants or uptake from soils by plant roots,
  - Naturally as a normal constituent of all soils but particularly of marine origin
  - As an impurity (cadmium oxide) in phosphate-treated soils, especially in those treated with "superphosphate"
  - By fertilization with sludge containing cadmium
  - By deposition of cadmium-containing pesticides or as a contaminant of zinc-containing pesticides
  - From run-off of mine tailings or from electroplating washing process

- Accumulation in animal tissues due to:
  - Feeding on crops which have absorbed cadmium (the organs of such animals may have very high cadmium concentrations)
  - Treatment with cadmium-containing helminth killers used especially in swine

- Concentrations of cadmium by mollusks, crustaceans and most other aquatic organisms from ambient waters

- Use of zinc-galvanized containers, cans, cooking implements or vessels, or utensils used in food preparation, particularly grinders, pressing machines, or galvanized netting used to dry fish and gelatin

- Absorption of cadmium contained in wrapping and packaging materials such as paper, plastic bags, and tin cans. (Cadmium is now prohibited in food containers of this kind.)

- Use of cadmium-contaminated water in cooking or processing operations

Table 2-2 lists the average cadmium concentrations of selected adult foods.

Cigarette smoking also provides a large contribution to total cadmium exposure. The estimated intake from two packs per day ranges from four to six micrograms. This can amount to about 20 times the exposure due to atmospheric levels in large urban areas.

Even for smokers, food provides the greatest overall exposure to cadmium, and based on a 6.4 percent retention rate, is the greatest daily input (except for three packs-per-day-smokers). Table 2-3 summarizes the sources of cadmium exposure.

TABLE 2-2

CADMIUM CONTENT OF SELECTED ADULT FOODS[a/]

Commodity	No. of Samples	Average ppm	Standard Deviation, ppm
Carrots, roots fresh	69	0.051	0.077
Lettuce, raw crisp head	69	0.062	0.124
Potatoes, raw white	71	0.057	0.139
Butter	71	0.032	0.071
Margarine	71	0.027	0.048
Eggs, whole fresh	71	0.067	0.072
Chicken fryer, raw whole or whole cut up	71	0.039	0.088
Bacon, cured raw, sliced	71	0.040	0.160
Frankfurters	69	0.042	0.111
Liver, raw beef	71	0.183	0.228
Hamburger, raw ground beef	71	0.075	0.122
Roast, chuck beef	71	0.035	0.034
Wheat flour, white	71	0.064	0.150
Sugar refined, beet or cane	71	0.100	0.709
Bread, white	70	0.036	0.063
Orange juice, canned frozen concentrate	71	0.029	0.095
Green beans, canned	71	0.018	0.072
Beans, canned with pork and tomato sauce	71	0.009	0.000
Peas, canned	71	0.042	0.113
Tomatoes, canned	71	0.042	0.113
Diluted fruit drinks, canned	71	0.017	0.052
Peaches, canned	71	0.036	0.061
Pineapple, canned	71	0.059	0.153
Applesauce, canned	71	0.020	0.027

a/ Source: Reference 8.

TABLE 2-3

MEDIA CONTRIBUTIONS TO NORMAL RETENTION OF CADMIUM[a/]

Medium	Exposure Level	Daily Retention (μg)
Ambient air	0.03 μg/m^3	0.15
Water	1 ppb	0.09
Cigarettes:		
Packs/Day	μg/day[b/]	
1/2	1.1	0.70[c/]
1	2.2	1.41[c/]
2	4.4	2.82[c/]
3	6.6	4.22[c/]
Food	50	3.0

a/ Source: Reference 7.

b/ Based on 0.11 μg per cigarette.

c/ Assumes a 6.4 percent retention rate.

3. METHODOLOGY

3.1 INTRODUCTION

This section describes the general methodology used in determining the population exposed to specified levels of cadmium. In simplest terms, the methodology can be viewed as having four components:

- Selection and location of significant sources of cadmium and estimation of emissions from those sources;
- Determination of ambient concentrations of cadmium caused by these sources;
- Development of population data base; and
- Integration of estimated cadmium concentrations with the estimates of population residing in that area.

3.2 SOURCE SELECTION AND LOCATION

Based on the results of the companion study, noted previously, which screened all potential cadmium sources on the basis of measurable contribution to annual average ambient levels of cadmium,* four sources categories were selected for exposure analysis:

(1) Iron and Steel Mills
(2) Municipal Incinerators
(3) Primary Smelters (copper, lead, zinc, and cadmium)
(4) Secondary Smelters (copper and zinc)

Information on the precise nature and capacity of each source in the above categories was obtained from various trade directories and other

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* Cadmium annual averages as low as 0.1 ng/m^3 are assumed measurable.

data sources which are of recent vintage (generally 1976 or 1977). The sections of this report which deal with individual emissions sources list the specific references used.

Most of these references also provide street addresses and zip codes for individual plants. From USGS maps, streets, and, in most cases, individual facilities were identified within the zip code and in this way, relatively precise locations for the sources were obtained.

This method of locating sources is relatively accurate, generally within one to two km. This is a satisfactory level of accuracy given the accuracy of other data items. (The sections dealing with the individual source types include the location and size of each source.)

In estimating emissions from each source, "best judgement" emission factors, developed in the companion report to this study, were used. Variability of emission factors for individual sources and among source types can be quite large. Emissions were computed assuming that facilities are operated at their nominal capacity.

3.3 DETERMINATION OF ANNUAL CONCENTRATIONS

Annual concentrations for each type of plant were computed by using an EPA diffusion model, CRSTER.[9/] The annual concentrations due to model plant types were then determined. These model plants were designed in such a way as to represent the probable ranges of typical industrial facilities. The factors which were varied to define the model plants were: stack height, flow rate and temperature. Surface meteorological data from Dallas/Fort Worth and upper air data from Oklahoma City were used in the analysis. These sets of data were used because the meteorology is understood to be fairly typical of many areas in the country in terms of wind speed and stability classes. If a detailed analysis of any of the sources identified here was to be conducted in the future, more site-specific meteorological data would be desirable.

Detailed descriptions of the particular assumptions used in the analysis of each source type are discussed in the following sections.

3.4 POPULATION DATA

The population data were obtained from the 1970 Master Enumeration District List (MED List)[10/] obtained from the Bureau of the Census. This list provides the population and geographic location of each enumeration district in rural areas and of each block group within urban areas. An enumeration district contains approximately 800 people and is no larger than the area one enumerator could reasonably be expected to cover. A block group consists of contiguous city blocks with a total population of about 1,000. In a central business district, the block groups are further subdivided into individual blocks. The geographic locator for each of these three census divisions is the latitude and longitude coordinate of the centroid of the division.

The population data associated with these centroids were transferred to a grid which spans the contiguous United States. Each grid cell was 1/30 of a degree longitude by 1/30 of a degree latitude. Thus, this resulted in the average grid cell being approximately ten square kilometers. With this grid cell size, reasonably adequate definition was developed. Figure 3-1 illustrates an example of a medium size town and its environments. For this example, the population of the city itself shows up in six different grid cells. The city's suburbs show up in several additional cells. In the rural areas of the map, the population of individual enumeration districts appear as a single grid cell entry. In rural areas the grids which show zero population do not necessarily have no population. Rather, these areas are part of an enumeration district and all population in each enumeration is shown at the centroid of each district. Figure 3-2 illustrates an example of a large metropolitan area. As one moves from the central city area westward towards the suburbs, a very definite population gradient can be observed. Grid

FIGURE 3-1

POPULATION OF CHARLOTTESVILLE, VIRGINIA

x100'S OF PEOPLE

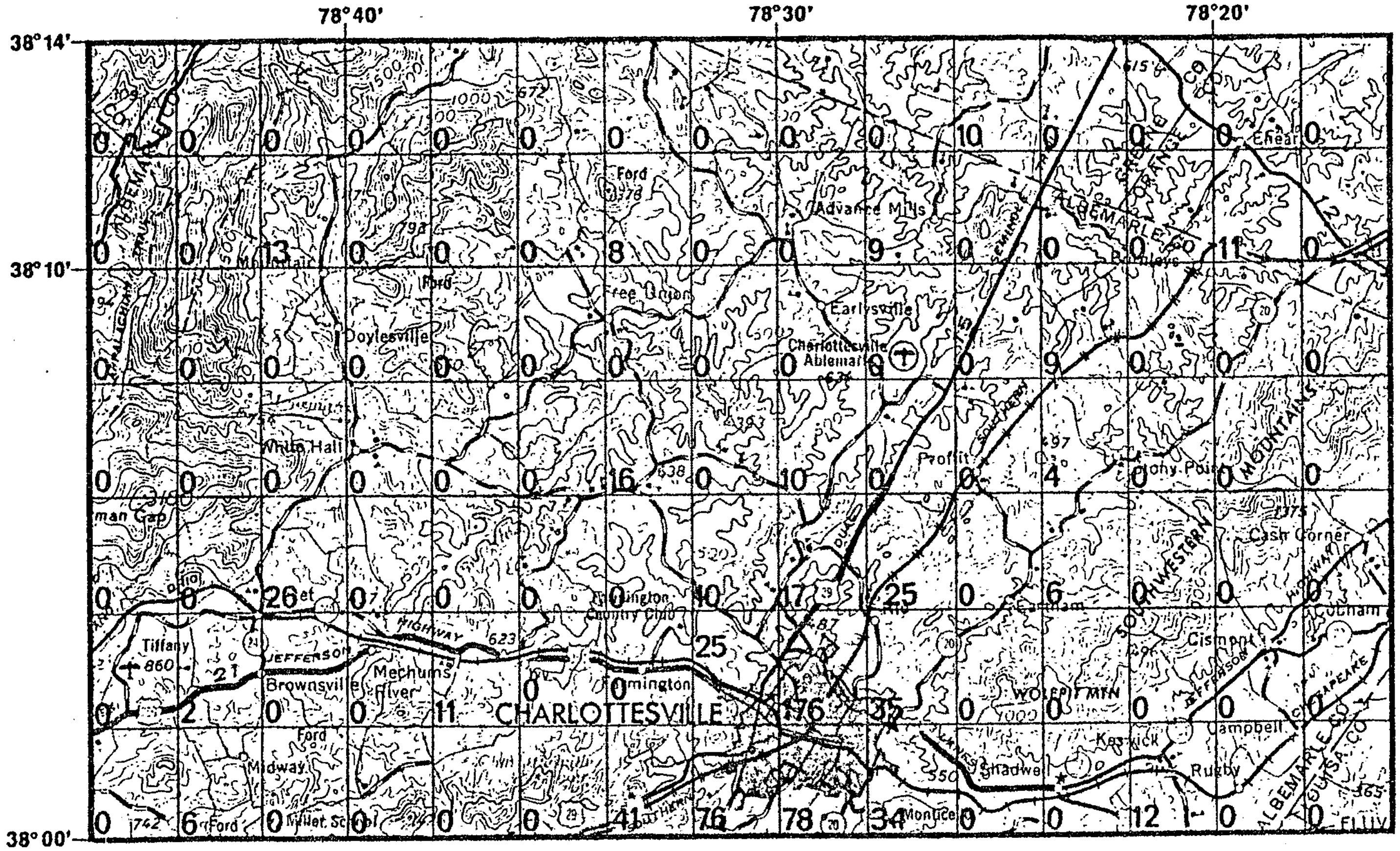
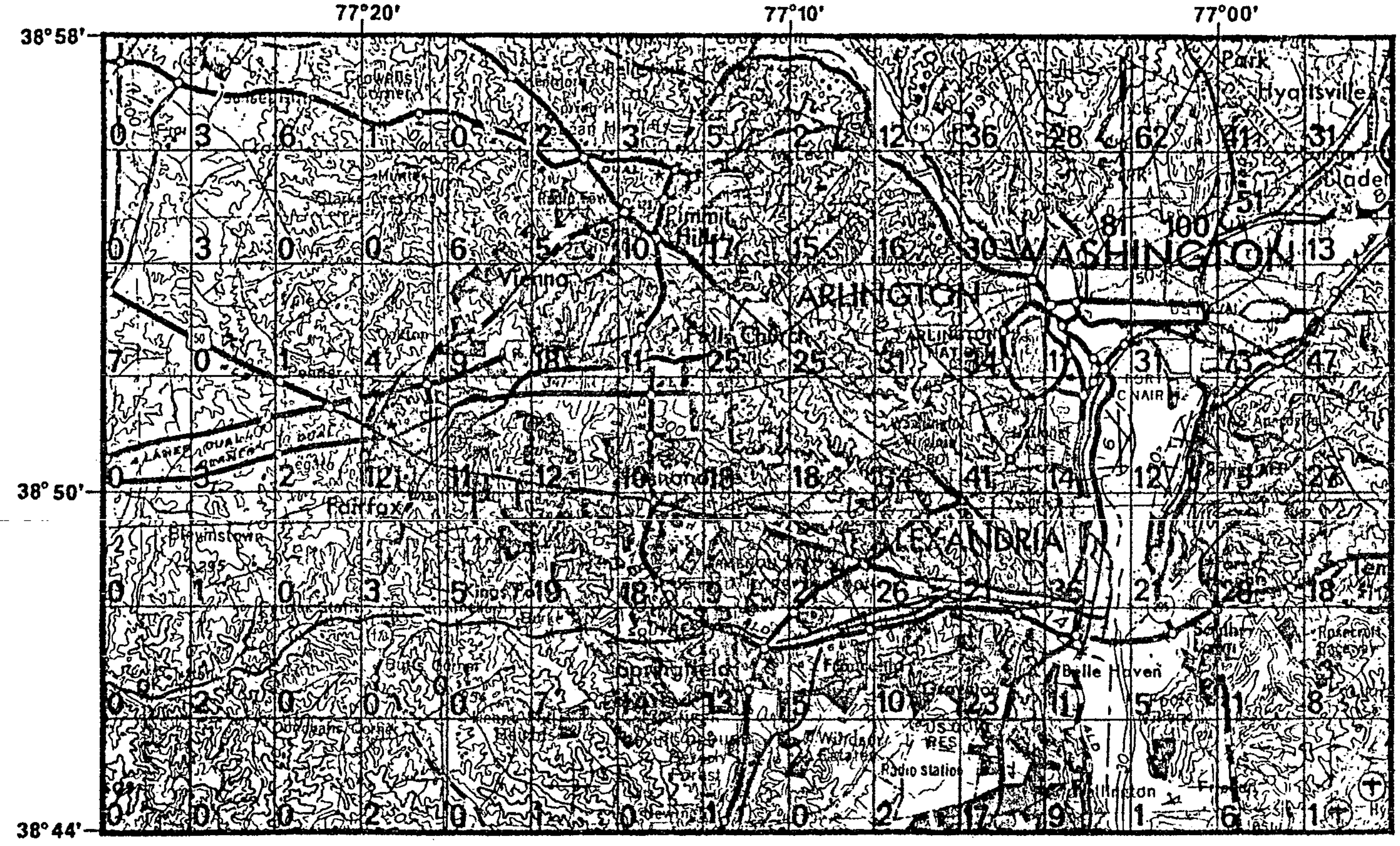


FIGURE 3-2

POPULATION OF WASHINGTON D.C.

x1000'S OF PEOPLE



cells within the city which contain large areas of public land appear as lower density grid cells.

The actual transfer to the grid was made as follows: the population of every enumeration district and of every block group whose centroid was located in a given two-minute-by-two-minute grid cell was summed to give the population of the grid cell. The information for each of 26 areas or maps which described the county was stored in a matrix. After all 26 maps were constructed, a count was made of the number of people located by this method. The total of 201,744,383 accounts for 99.5 percent of the 1970 population of the contiguous United States.

3.5 POPULATION EXPOSED

The purpose of the model developed in this chapter is to integrate the data on source location, and resulting ambient concentrations caused by the source, with the population data described above, thus determining the number of people exposed to specified levels of cadmium. The methodology described in detail in Appendix A, used two independent procedures to estimate population exposed. In brief terms, the two procedures are:

3.5.1 Total Exposure

This procedure involves locating a source by latitude and longitude and, through diffusion modelling, determining the radius at which specified concentrations occur. Once the radius is determined, the population in those grids completely contained in the radius were determined. Then, the population in each partially covered grid is determined based on the percent of the grid circumscribed by the radius.

This procedure is carried out on a source-by-source basis. If people are exposed to more than one source, they would be counted twice. However, in this method of population estimation the estimated exposure levels are not additive across source types. The primary use for this result is in determining the total exposure (nanograms-person-year) caused by specific source types. This type of estimate is suitable for use in a linear health risk model (i.e., such models which treat two people exposed to 1 ng/m^3 as equivalent to the health effects of one person exposed to 2 ng/m^3).

3.5.2 Population Exposed

In addition to estimating total exposure, the model was applied to estimate the population exposed to specified levels of atmospheric cadmium. As in the case of the exposure modelling, the population estimates were developed on a source-by-source analysis; however, this form of the model provides an estimate of the population exposed to at least the specified concentrations. The estimates do not take into account that a person can be exposed to more than one source and that the actual level of exposure is the sum of the concentrations produced by the sources. As such, the estimates of population, to some degree, may underestimate the level of exposure.

4. IRON AND STEEL MILLS

4.1 INTRODUCTION

The estimation of population exposure to atmospheric cadmium emitted from the production of iron and steel is discussed in this section.

The primary source of cadmium emissions from iron and steel manufacturing is the melting of scrap containing cadmium in steel-making furnaces and, to a much lesser degree, the cadmium in the coal used to make coke. Table 4-1 lists the emission factors used in this analysis.

One of the source types listed in Table 4-1 (sinter plants) does not involve the use of cadmium scrap directly. Sinter plants agglomerate fine iron-containing material (iron ore, flue dust, etc.) into a material suitable for use in the blast furnace. This feed to sinter plants could contain relatively large amounts of cadmium. Therefore, even with relatively high levels of air pollution control (90 percent), significant amounts of cadmium may be released. The companion volume of this report discusses the emissions of cadmium from iron and steel production in considerable detail. More recent data from AISI[11/] has indicated that the relatively low control efficiency shown here (50 percent) may be considerably too low for some sinter plants. Efficiencies as high as 85 percent have been reported. The efficiency of collection and amounts of cadmium emitted from sinter plants is a function of the type of feed used in the sinter plant and varies from day to day. The low efficiency estimates are used here as a conservative assumption but further work is needed to better verify the emission estimates.

TABLE 4-1

CADMIUM EMISSION FACTORS FOR
IRON AND STEEL MANUFACTURING[a/]

	Uncontrolled			Controlled		
	Minimum	Maximum	Best Judgement	Minimum	Maximum	Best Judgement
Sinter	1.35×10^{-3}	2.63×10^{-3}	2×10^{-3}	9.33×10^{-4}	9.76×10^{-4}	9.5×10^{-4}
Open Hearth Furnace	4.07×10^{-3}	7.49×10^{-3}	5.78×10^{-3}	2.08×10^{-5}	1.33×10^{-4}	1.1×10^{-4}
Basic Oxygen Furnace	-	-	4.1×10^{-5}	3.45×10^{-6}	2.79×10^{-5}	1.2×10^{-5}
Electric Arc	2.7×10^{-3}	5×10^{-3}	3.4×10^{-3}	2.7×10^{-4}	5×10^{-4}	3.4×10^{-4}

a/ Expressed as pounds cadmium per ton of product produced, from Reference 12.

4.2 GEOGRAPHIC DISTRIBUTION OF SOURCES

The location of iron and steel-producing facilities in the United States is shown in Appendix B. Estimated capacity data in this table come from the American Iron and Steel Institute's Iron and Steel Works Directory of the United States and Canada.[13/] Locations of these facilities were determined from the Dun and Bradstreet Metal-Working Directory[14/] and USGS maps.

Appendix B also shows the estimated cadmium emissions from each facility. These estimates were derived by multiplying the emission factors in Table 4-1 by the production for each facility type, assuming that all plants operate at the hours of operation defined by the Department of Commerce as full operation.[15/] It must be emphasized that these emission factors are average emissions based on national average uses of cadmium scrap or on a limited number of stack tests. The estimation of an accurate emission estimate for iron and steel mills is extremely difficult. First, the industry is upgrading existing inadequate control technology and even replacing existing types of technology with new types. Secondly, the amount of cadmium released is not only a function of the type of control, but a function of the amount and type of scrap used at each mill. However, it is felt that the estimates here are adequate for making a rough estimate of the relative importance of iron and steel mills and the need for further data refinements.

4.3 ESTIMATED AMBIENT LEVELS

Estimates of annual cadmium concentrations in the vicinity of iron and steel manufacturing facilities are complicated by variation in production and physical layout. Large integrated mills can cover hundreds of acres and may have many stacks. Mini-mills, or scrap reprocessing facilities with a low number of small electric arc furnaces, may cover only a few acres and have few stacks. Due to a lack of information on the physical size of all the facilities, it was assumed that all stacks were located together. This means that a single stack was assumed and all effluents were vented through that stack. This does not give the steel mill credit for dispersion which can occur before the plume reaches the plant property line and consequently overestimates the concentrations attributed to these plants. In addition, conservative (i.e., conditions not conducive to good dispersion) assumptions were made concerning stack characteristics. All stacks were assumed to have the characteristics as shown on Table 4-2. The flow rate assumed for the iron and steel stack is an average figure for all types of units. The net effect of these assumptions is to overestimate the air quality impact of the facilities to some unknown degree.

Based on the stack conditions shown in Table 4-2 as input to the CRSTER dispersion model (using Dallas/Fort Worth meteorology), concentrations were estimated for a few selected distances. A regression equation was then developed which estimates concentrations resulting from a 1.0 g/sec emission rate. The equation developed was:

$$\ln Y = 1.71 (\ln X) - 2.35 (1/X) + 3.19 \qquad (4\text{-}1)$$

where: Y = the concentration (ng/m^3) resulting from an emission rate of 1.0 g/sec of cadmium

X = the distance from the source to the receptor point (km).

This equation has a coefficient of determination of greater than 0.99 as a predictor of ambient concentrations estimates computed from CRSTER output.

The emission rate for each plant was multiplied by the concentration estimated from the 1 g/sec emission rate to provide an estimate of concentrations at any distance. Modelling results were not carried out beyond 20 km due to the questionable validity of this type of dispersion modelling beyond these distances.

TABLE 4-2

ASSUMED STACK CHARACTERISTICS
FOR IRON AND STEEL MILLS

Stack Height	100 feet
Temperature	250°F
Diameter	8 feet
Flow	125,000 cfm

Current monitoring programs are not designed to measure maximum impacts of point sources such as iron and steel mills. However, some indication of the plausibility of both the modelling techniques and the emission estimates can be made by comparing measured levels in areas with major iron and steel facilities with the concentrations predicted by the modelling technique.

Ambient cadmium levels can vary greatly from year to year; the little data available shows (Table 4-3) that annual average levels in cities having iron and steel facilities are roughly 5 to 10 ng/m^3. Of course, in these cities, the observed levels cannot be attributable solely to iron and steel mills since other sources are quite likely present. Estimated annual cadmium levels from iron and steel mills developed in this study using the technique described above are also 5 to 10 ng/m^3. This suggests that, although very conservative assumptions were used, the estimated concentrations from iron and steel mills are reasonable. However, the actual degree of precision of these predicted levels cannot be determined reasonably.

4.4 POPULATION EXPOSED

Table 4-4 shows an estimate of the population exposed to cadmium concentrations greater than 0.1 ng/m^3 and the estimated annual average concentrations to which each of the exposed populations is subjected. The regional breakdown shown on Table 4-5 is based on EPA Regions as shown in Figure 1. As discussed in Section 3, these estimates were obtained by superimposing the modelled ambient concentrations caused by emissions from iron and steel mills on the distribution of population.

As would be expected, both the largest number of people exposed and the highest average exposures are EPA Regions III, IV, and V. This is due to the large concentration of integrated steel mills in heavily industrialized urban areas.

TABLE 4-3

MEASURED CADMIUM LEVELS IN CITIES CONTAINING IRON AND STEEL MILLS[a/]

City	Annual Average (ng/m^3)	Year[b/]
East Chicago, IL	4.6	1974
Ashland, KY	6	1974
Youngstown, OH	5.6	1970
Cleveland, OH	8.8	1970
Allentown, PA	13.4	1974
Bethlehem, PA	6.8	1973

a/ Source: Reference 16.

b/ Data reported for the latest year measurements are available.

TABLE 4-4

ESTIMATE OF POPULATION EXPOSED TO MEASURABLE CONCENTRATIONS OF CADMIUM FROM IRON AND STEEL MILLS

Region	Annual Average Exposure (ng/m^3)	Population (10^3 people)	Exposure (10^6 ng-person-year)
1	0.4	93	0
2	1.4	1,649	2.3
3	2.7	4,543	11.3
4	2.8	1,611	4.5
5	1.5	8,710	13.1
6	1.5	1,575	2.3
7	1.2	108	0.1
8	-	-	0.3
9	1.2	778	0.9
10	0.7	833	0.6
TOTAL	1.8	19,900	36.2

Table 4-5 shows a breakdown of population by exposure level. As described in the section on methodology, care must be used in interpreting these results. As explained in the methodology section and Appendix A, the results on Table 4-5 should be interpreted as the population exposed to a concentrations greater than or equal to that specified, and from at least one facility. As such, the total population estimated is accurate, but, because the estimated concentration is computed as though a person is exposed to only cadmium from the modelled facility, the results may be an underestimate of the actual concentrations exposed to.

Appendix B shows the population exposed to individual sources.

TABLE 4-5

ESTIMATE OF CUMULATIVE POPULATION EXPOSED TO SPECIFIED CADMIUM CONCENTRATIONS FROM IRON AND STEEL MILLS

Region	(10^3 people) Annual Concentration (ng/m^3)			
	≥10*	≥5	≥1	≥0.1
1	0	0	0	93
2	0	49	470	1,649
3	52	137	1,965	4,543
4	177	341	578	1,610
5	143	339	1,852	8,710
6	0	29	521	1,575
7	0	0	23	108
8	0	24	176	224
9	0	15	161	774
10	0	0	33	833

* Maximum concentrations predicted around individual iron and steel mills may be as high as 30-40 ng/m^3.

5. MUNICIPAL INCINERATORS

5.1 INTRODUCTION

This section estimates the population and exposure levels to cadmium emitted from municipal incinerators.

Cadmium emissions from incinerators originate from the combustion of cadmium-containing waste materials. These waste materials include plastics which contain cadmium as a stablizer, cadmium-plated materials, nickel cadmium batteries, and materials painted with cadmium-based pigments.

Cadmium is released from incinerators due to its low boiling point (767^{o}C) and the considerably higher (>1,400^{o}C) temperatures characteristic of incinerator combustion. The estimated cadmium emission factors for incinerators are shown in Table 5-1.

TABLE 5-1

CADMIUM EMISSION FACTORS[17/]

Emission Factors (lbs/ton of refuse)

	Controlled
Best Judgement	$1.3x10^{-2}$
Maximum	$1.0x10^{-1}$
Minimum	$6.0x10^{-4}$

A large amount of variability among incinerators in emissions can be expected because of variations in input feed rate, feed composition, combustion temperature (and other operating conditions), and control equipment efficiency. This variability cannot be taken into account in this type of analysis.

5.2 GEOGRAPHIC DISTRIBUTION OF SOURCES

Appendix C lists the locations and capacities of municipal incinerators analyzed in this study. The primary source of this capacity data is Incinerator and Solid Waste Technology.[18/] The facilities were located by street address through a telephone survey of each town and city. Street addresses were translated into latitude and longitude coordinates from detailed USGS maps (seven and one-half minute quadrangles for integration with the population data.

Appendix C also shows the estimated cadmium emissions from each incinerator. The emissions shown are simply the product of the "best judgement" emission factors and daily capacity figures. As previously mentioned, wide variation in these estimates can be expected due to variation in cadmium feed and control efficiency.

5.3. ESTIMATED AMBIENT LEVELS

Estimates of ambient levels due to incinerators were based on the results of CRSTER analyses using the same meteorology assumptions and in a fashion somewhat similar to the procedure used for iron and steel mills. However, due to the very large populations exposed, a somewhat more refined methodology was used. Data on incinerators capacity, location, and stack characteristics were obtained from EPA's National Emissions Data (NEDS) System. However, this data base apparently was not complete. When this data base was compared to the information on incinerator location and capacity obtained during this study only about one-third of the plants matched.

A sensitivity analysis, based on CRSTER runs of the model plants shown on Table 5-2 were conducted to determine which of the parameters shown in this table caused the greatest change in concentration when changed. It was determined that the concentrations were most sensitive to changes in flow rate. As a result, the flow and size data from the 30 plants in

TABLE 5-2

ASSUMED STACK PARAMETERS

FOR MUNICIPAL INCINERATORS

Incinerator Size (tons/day)	Stack Height (ft)	Temperature (^{o}F)	Diameter (ft)	Flow (acfm)
>1,000	175	250-500	12	210,000
300-1,000	125	250-500	5	50,000
150-300	50	250-500	3	25,000
<150	50	250-500	2	5,000

the NEDS list which matched the overall list were put into the size categories shown in Table 5-2. These data were used to further subdivide the plant sizes and, in effect, to develop 30 model plants. Existing plants were matched to model plants which most closely matched their size and the appropriate equation of the four listed below was used:

- For capacities of greater than 1000 tons/day

$$\ln Y = -1.58\ (\ln X) - B_1\ (1/X) + 2.78 \qquad (5\text{-}1)$$

- For capacities between 300 and 1000 tons/day

$$\ln Y = -1.75\ (\ln X) - B_2\ (1/X) + 3.26 \qquad (5\text{-}2)$$

- For capacities between 150 and 300 tons/day

$$\ln Y = -1.60\ (\ln X) - B_3\ (1/X) + 3.16 \qquad (5\text{-}3)$$

- For capacities less than 150 tons/day

$$\ln Y = -1.53\ (\ln X) - B_4\ (1/X) + 3.04 \qquad (5\text{-}4)$$

where: Y = the annual average concentration (ng/m^3) estimated for an emission of 1 g/second of cadmium; B_1 - B_4 are groups of constants which were functions of plant size and flow rate

X = the distance to the receptor point (km).

Concentrations caused by each plant were computed by multiplying the plant emission rate in grams/seconds by the concentration resulting from a 1 g/second emission rate. As with other sources, modelling results were not carried out beyond 20 km.

Most incinerators are located in urban areas where there are multiple smaller sources of cadmium probably distributed in a non uniform spatial pattern. Existing monitoring programs, therefore, do not provide an adequate basis to judge the precision of these modelling results, even qualitatively.

5.4 POPULATION EXPOSED

Table 5-3 shows the estimate of the population exposed to cadmium concentrations greater than 0.1 ng/m^3 originating from incinerators and the average concentration to which each person is exposed (weighted by population and distance). The regional breakdown shown on Table 5-3 is based on EPA Regions.

The greatest number of people exposed and the highest average concentration are in EPA Region II, which includes New York. This state has a large number of incinerators located in the high density urban area of New York City. Region V has the second highest number of people exposed. In this region, the average concentration is much lower than in Region II. This is due primarily to the more dispersed nature of a smaller number of incinerators located in high density areas (Chicago). The opposite situation occurs in Region VI where a relatively small number of people (one million) are exposed, but the average concentration is high.

Table 5-4 shows a breakdown of population exposure by level. As shown, a relatively small number of people are exposed to high concentrations (>100 ng/m^3), but that the number of people increases very rapidly as the concentration decreases. At these greater distances, the areas of influence of many incinerators will overlap due to their proximity to each other in urban locations, and thus, include large proportions of densely populated urban areas.

Appendix C lists the estimated population exposed to each municipal incinerator.

TABLE 5-3

ESTIMATE OF POPULATION EXPOSED TO CADMIUM CONCENTRATIONS
>0.1 ng/m^3 FROM MUNICIPAL INCINERATORS

Region	Average Exposure (ng/m^3)	Population (10^3 people)	Exposure (10^6 ng-person-year)
1	8.55	6,470	55.3
2	9.65	16,730	184.7
3	5.44	8,567	46.6
4	5.66	2,935	16.6
5	6.33	12,144	77.5
6	12.2	1,098	13.4
7	58.9	157	9.4
8	7.10	169	1.2
9	-	-	-
10	-	-	-
TOTAL	8.4	48,270	404.4

TABLE 5-4

ESTIMATE OF CUMULATIVE POPULATION EXPOSED TO SPECIFIED CADMIUM CONCENTRATIONS FROM MUNICIPAL INCINERATORS (10^3 people)

Region	Annual Concentration (ng/m^3)				
	>200	>100	>50	>10	>0.1
1	1.0	3	14	612	6,470
2	0.0	0.5	1016	1655	16,930
3	0.0	0.1	53	679	8,567
4	0.0	0.0	22	40	2,935
5	0.0	0.0	250	650	12,251
6	0.0	0.0	7.7	7.7	1,098
7	0.0	0.0	38	81	157
8	0.0	0.0	4.6	4.6	169
9	-	-	-	-	-
10	-	-	-	-	-

6. PRIMARY NON-FERROUS SMELTERS

6.1 INTRODUCTION

Cadmium is found in nature combined with zinc and to a much lesser degree, with lead and copper. The refining of this one in primary copper, lead, zinc, and cadmium smelters leads to significant atmospheric emissions of cadmium. The source of cadmium emissions from all smelters is basically the same. During high temperature pyrometallurgical processing, cadmium, which has a lower boiling point than other metals, is vaporized and released. The differences in cadmium emissions among the primary smelters are briefly discussed below.

There are two major processes used in the production of zinc which have very different cadmium emission characteristics. These are the pyrometallurgical and electrolytic processes. The pyrometallurgical process used at older plants (of which only three are still in existence) first roasts the ore at temperatures between 900 and 1,000°C to drive off SO_2 and produce a concentrate. Following this operation, the concentrate is sintered to provide a product which is easier to handle and to retort. The final step is the reduction of zinc oxide to zinc in a retort.

Both the roasting and sintering steps appear to have the highest potential for cadmium emissions. One recent report,[19/] however, indicates that due to an excess of oxygen, close temperature control (900-1,000°C), and the high efficency of existing air pollution control, little cadmium is emitted from the roaster. This hypothesis is supportable.[a/]

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a/ In all existing zinc smelters, the SO_2-rich offgas from the roaster goes to sulfuric acid plant. Since cadmium oxide is soluble in sulfuric acid, the recovered acid should show high cadmium levels if large amounts of cadmium are leaving the roaster. Cadmium levels reported in the recovered acid are quite low.[19/]

Sintering operations appear, therefore, to be the chief cadmium emission sources in primary smelting of zinc.

Since electrolytic operations use concentrate directly from the roasting operation and do not subject the concentrate to elevated temperatures, there appears little potential for cadmium emissions. Thus, cadmium emissions from this process are assumed to be zero for this analysis.

Cadmium emissions from lead and copper smelting also result from high temperature processes such as sintering operations. Cadmium is present in most lead ores and some copper ores, and is released during high temperature processing.

Table 6-1 shows the estimated emission factors for primary smelters which are considered to be upper bound estimates. This is especially true for primary zinc smelting where the data are based only on one plant which was operating relatively inefficiently (i.e., with high zinc losses).

6.2 GEOGRAPHIC DISTRIBUTION OF SOURCES

Appendix D shows the location of the primary smelters reviewed in this analysis. General location and capacity data were obtained from various EPA and industry reports;[20,21/] and specific locations were determined from USGS maps.

6.3 ESTIMATED AMBIENT LEVELS

The annual average estimates of cadmium concentrations caused by smelters were estimated based on procedures developed by SRI[24/] in a study of human exposure to arsenic. Like arsenic, cadmium emissions from smelters result from both stack and fugitive sources. The cadmium emission factors used in this report are only mass balance estimates, their accuracy is not clearly defined, and there is no indication as to what

TABLE 6-1

EMISSION FACTORS FOR PRIMARY SMELTERS[1/]

(Pounds of Cadmium/Ton of Product)

Smelter Type	Minimum	Maximum	Best Judgement
Zinc	1.43	2.96	2.50
Lead	$5.20x10^{-2}$	$2.60x10^{-1}$	$1.10x10^{-1}$[a/]
Copper	$7.00x10^{-2}$	$2.90x10^{-1}$	$1.50x10^{-1}$[b/]
Cadmium	25.00	30.50	28.00

a/ Controlled level may be as low as $5.20x10^{-3}$ lbs/ton of product.

b/ Controlled level may be as low as $7.00x10^{-3}$ lbs/ton of product.

percent of emissions are fugitive versus stack. For this study three potential estimates of fugitive emissions were selected for a range of estimates. Exposures were made assuming that one, two, and five percent of total emissions were fugitive.

As with other sources a regression equation was fitted to the modelling results reported by SRI.[24] The equations developed were:

For stack emissions:

$$C = 1000\ Q\ D^{-0.449}\ h^{-2.27} \qquad (6\text{-}1)$$

For fugitive emissions:

$$C = 0.052\ Q\ D^{-1.316} \qquad (6\text{-}2)$$

where: C = , concentration ($\mu g/m^3$) annual average

Q = emission rate of cadmium (lbs/hr)

D = distance (km)

h = stack height (ft) based on stack heights reported for each smelter in reference 25.

As with all other sources, no modelling was carried out beyond 20 km.

The concentrations computed by this method must be used with great care. These are at best very rough estimates because the emission estimates are crude, the actual split between stack and fugitive is not known, and the actual terrain around many smelters is quite rough and the normal modelling assumptions of flat terrain would not apply.

Monitoring data can be used to give a rough idea of concentrations of cadmium around smelters. Table 6-2 lists concentrations of cadmium observed in areas near smelters. From this table it is obvious that very high cadmium levels are not uncommon around smelters.

TABLE 6-2

MEASURED CADMIUM LEVELS NEAR PRIMARY SMELTERS[a/]

City	State	Type	Concentration (ng/m^3)	Year[b/]
Helena	Montana	Lead	15	1971
El Paso	Texas	Copper	24	1974
Kellogg	Idaho	Zinc, Lead Cadmium	247	1975
Jefferson County	Missouri	Lead	111	1975

a/ Source: Reference 22.

b/ Last year for which data is available.

Cadmium data submitted by ASARCO[26/] from stations around their smelters, indicated that quarterly average cadmium levels can be as high as 1000 ng/m^3 and that annual averages greater than 100 ng/m^3 have been reported at several sites. Unfortunately, the site locations and distances from the plants were not given so that quantitative comparisons are not possible. The data received from ASARCO is shown in Appendix F.

As with all sources, it is impossible to attribute all of the measured cadmium to the smelters. However, due to the lack of other major cadmium emitting industry around these sources, it is very likely that most of the measured concentrations are due to smelter emissions.

6.4 POPULATION EXPOSED

Table 6-3 shows the estimated population exposed to cadmium emissions from primary smelters and the average concentration in each region. These exposure estimates are developed for the three assumed levels of fugitive emissions. It is obvious that in comparison to the preceding sources, fewer people are exposed to emissions from primary smelters although the exposure estimates can be much higher. As is apparent in Table 6-4, exposed distribution of population is very biased. Two Regions, Regions VII and IX, account for the majority of the population exposed.

Table 6-4 shows the population exposed to cadmium levels assumed for the 2 percent fugitive emission rate. The effect of changing the assumption on fugitive emissions is shown in Appendix G.

The number of people exposed to cadmium at smelters is low due to the very low population density around the smelters. It appears, therefore, that while primary smelters are a large source of cadmium emissions to the atmosphere, they do not (with the exception of two plants) expose large numbers of people to these emissions. However, the exposure levels can be quite high as is evident from Table 6-3.

TABLE 6-3

ESTIMATE OF POPULATION EXPOSED TO CADMIUM CONCENTRATION >0.1 ng/m^3 FROM PRIMARY SMELTERS

Source	Annual Average Exposure (ng/m^3)			Population (10^3 people)		
	1%*	2%*	5%*	1%*	2%*	5%*
Zinc	86	91	110	376	376	376
Lead	9	9	11	106	106	106
Copper	5	5	8	218	261	374
Cadmium	5	6	15	150	150	150

* Refers to percent of total emissions assumed to be fugitive.

TABLE 6-4

ESTIMATED POPULATION EXPOSED TO SPECIFIED LEVELS FROM PRIMARY SMELTERS

(10^3 people)

Region	PRIMARY COPPER SMELTERS 2% Fugitive Concentration (ng/m^3)					PRIMARY LEAD SMELTERS 2% Fugitive Concentration (ng/m^3)					PRIMARY CADMIUM SMELTERS 2% Fugitive Concentration (ng/m^3)					PRIMARY ZINC SMELTERS 2% Fugitive Concentration (ng/m^3)				
	>1000	>100	>50	>10	>1.0	>1000	>100	>50	>10	>1.0	>1000	>100	>50	>10	>1.0	>1000	>100	>50	>10	>1.0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0.1	0.2	0.7	100.4	0.2	27.9	219.7	358.8	358.8
4	0	0	0	1.1	18.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0.1	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0.1	3.6	0	0	0	0	0	0	0	0	0	32.4	0	0	0	0	0
7	0	0	0	0	0	0	0	0	1.5	59.8	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0.1	85.4	0	0	0	0.7	28.5	0	0	0	0	0	0	0	0	0	0
9	0	0	0.1	1.5	29.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0.1	1.3	122.0	0	0.1	0.4	13.8	17.4	0.1	0.2	0.4	1.6	17.2	0	5.9	17.2	17.2	17.2
TOTAL	0	0	0.2	4.2	261.0	0	0.1	0.4	16.0	105.7	0.1	0.3	0.6	2.3	150.0	0.2	33.8	236.9	376.0	376.0

7. SECONDARY SMELTERS

7.1 INTRODUCTION

The recycling of zinc and copper scrap can potentially lead to emissions of cadmium due to the cadmium contained in these recycling materials. The high temperatures needed to melt scrap will release most of the cadmium. Most of the cadmium associated with the metal will be vaporized and is generally released into the atmosphere.

Table 7-1 shows estimated emission factors for secondary smelting. The high degree of control shown is based on the assumption that fabric filters are used for control.

7.2 GEOGRAPHIC DISTRIBUTION OF SOURCES

Appendix E shows the geographic distribution of secondary copper and zinc smelters in the United States. Location data were determined from various trade directories.[15,16] Latitude and longitude coordinates were obtained from detailed USGS maps.

Information on the size of each smelter was not available. Accordingly, the assumption was made that all smelters were of "average" size. One reference[23] does indicate a relatively small size range for these types of smelters. Therefore, the assumption may be reasonable.

7.3 ESTIMATED AMBIENT LEVELS

Estimates of ambient cadmium levels resulting from emissions of secondary smelters were based on CRSTER analyses using Dallas/Fort Worth meteorology. Different stack conditions were assumed for copper and zinc smelters and are shown in Table 7-2.

TABLE 7-1

EMISSION FACTORS FOR SECONDARY SMELTERS

(Pounds of Cadmium/Ton of Product)

CONTROLLED[a/]
Best Judgement
$5.0x10^{-4}$
$3.0x10^{-1}$

a/ Uncontrolled emission rates are much higher but this study assumes that all secondary smelters employ fabric filter control for both emission reduction as well as product recovery.

TABLE 7-2

ASSUMED STACK CONDITIONS FOR
SECONDARY SMELTERS

STACK PARAMETER	SMELTER TYPE	
	Zinc	Copper
Height (ft)	120	50
Temperature (^{o}F)	250	250
Flow (ACFM)	40,000	10,000
Diameter (ft)	4	2

As in the case of other industries, a regression equation was developed based on the CRSTER output. The equations developed are shown below:

- For secondary copper smelters

$$LnY = -1.57\ (\ln X) - 0.35\ (1/X) + 3.12 \qquad (7\text{-}1)$$

- For secondary zinc smelters

$$LnY = -1.75\ (\ln X) - 2.07\ (1/X) + 3.26 \qquad (7\text{-}2)$$

where: Y = the concentration (ng/m^3) caused by an emission rate of 1 g/sec of cadmium,

X = the distance to the receptor point (km).

Concentrations caused by each plant were computed by multiplying the plant emission rate in grams/second, and by the concentration resulting from 1 g/sec emission rate. As with other industries, no modelling was carried out beyond 20 km.

7.4 POPULATION EXPOSED

Table 7-3 shows the estimated cumulative population exposed to estimated cadmium concentrations and the average concentration to which each person is exposed. Though there are very few secondary copper smelters, the population exposed is high. This is due to the urban location of these smelters and the high emission factor even when controlled.

Secondary zinc smelting appears to be an insignificant source of atmospheric cadmium with few people exposed and very low estimated concentration. However, because it was not possible to take into account the difference in plant sizes, these exposure estimates must be viewed with some uncerainty. It is not clear how this would affect the results.

Appendix E shows the estimated population exposed to each secondary smelter.

TABLE 7-3

ESTIMATE OF POPULATION EXPOSED TO SPECIFIED LEVELS FROM SECONDARY SMELTERS (10^3 People)

Smelter	Concentration (ng/m^3) >10*	>5	>1	>0.1	Average Exposure
Secondary Copper	296	798	5710	9891	1.5
Secondary Zinc	0	0	0	37	0.47

* Maximum concentrations around existing plants are estimated to be about 50 ng/m^3.

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26/ Letter from M.O. Varner, ASARCO to J. Padgett, EPA, January 1978.

APPENDIX A

POPULATION EXPOSURE METHODOLOGY

The population exposure model is used to calculate the number of people within a fixed distance of a specific set of latitude and longitude. The inputs to the model are the location of the center point and the radius under consideration. The data base for the model is the set of population maps that were constructed from the Medalist data. The center point corresponds to the smoke stack of a point source polluter. The radius corresponds to the maximum distance from the stack that a specific concentration of a pollutant could be found. The estimate of the radius is determined by the predominant methodology (in the Dallas/Fort Worth data set). The circle drawn around the point is therefore an overestimate since this, in effect, assumes every direction from the source is downwind.

Given the inputs, the first step is to identify the map on which the source is located. This is accomplished by comparing the latitude and longitude of the source to the set of map boundaries. Next, the latitude and longitude of the source are converted to the appropriate map grid point using the same method that was used to locate the population data on the maps. This, however, may not fully access the data on the population affected by the source. If the source is located near a map boundary, the affected population can span three additional maps. If a source is located within 20 kilometers of another map, that map may also be accessed.

After loading the appropriate map file from computer tape into core and reading the necessary information onto the map grid, the next step is to construct a coordinate system centered at the same location since all grids are not the same size. The grid points at which the source has been located determine the origin. The value which is calculated is based on the latitude of the source. The distance between any point and the origin or source is therefore easily calculated by triangulation from the coordinates of that point with the origin.

Each grid cell within 20 kilometers of the source is systematically examined. First, the corners of the cell are located on the coordinate system. With this information, the total amount of area inside the cell and included within the selected radius from the source is calculated. The symmetry of the analysis allows the computer program to actually look only at the grid blocks that lie in or border the first quadrant. The values for each of the blocks outside the first quadrant can be inferred from the results of the first quadrant.

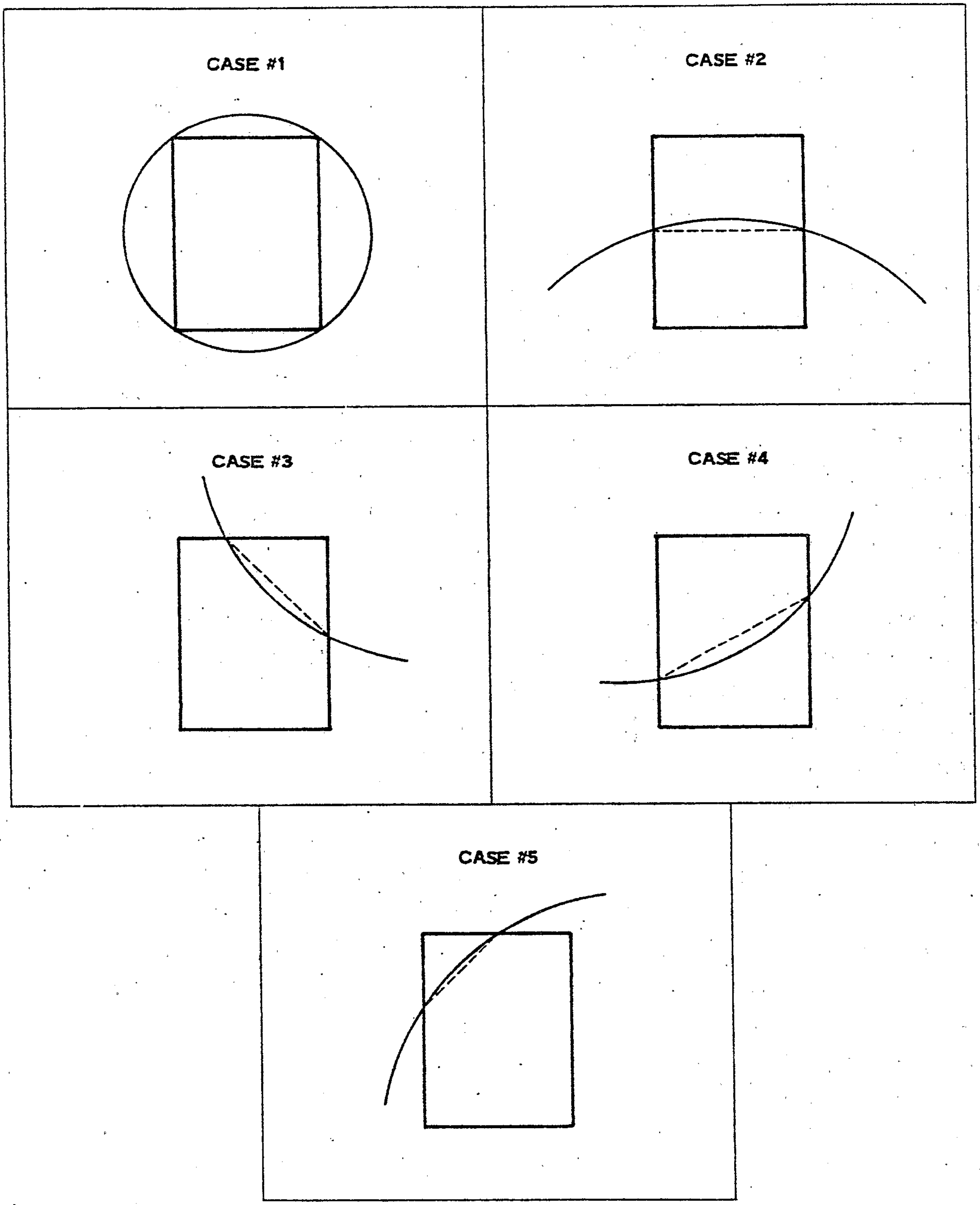
There are five distinct cases encountered when one attempts to calculate the area of a grid block which is included within a circle of given radius (see Figure A-1):

- The first case encountered is the area of the grid cell that has the source located at its center and is larger than the circle enclosed by the selected radius. Here, a simple approximation is made. The area included is taken to be the areas of the circle of the given radius divided by the area of the grid cell to obtain the fraction of the cell included in the circle. Once the area of the circle exceeds the area of the grid block, it is assumed that the entire area of the grid cell is included within the radius.

- The second case involves grid cells located along either the x-axis or the y-axis. Here, the area included is taken to be the arc of the rectangle defined by the intersection of the radius and the block boundaries included, plus the area of the remaining arc defined by the radius. Special cases occur when the radius intersects the edges of the grid cells which are perpendicular to the axis. The general form of the solution remains the same.

- Case three occurs where only one of the vertices of the cell is included; the area included is the sum of the area of the enclosed triangle and the area of the enclosed arc.

FIGURE A-1



- Case four occurs when two vertices are included or all are included. In this case, the area covered equals the sum of the area of the trapezoid and the area of the enclosed arc.
- Case five occurs when three vertices are included. The area of the cell included equals the area of the cell minus the area of the excluded triangle plus the area of the included arc.

Once the area of the grid cell which is included in the exposed area has been calculated, it is divided by the area of the grid cell, yielding the percentage of the area included. In order to calculate the number of people who live within the included area, it is assumed that the population is uniformly distributed throughout the grid cell. Therefore, the population affected is the product of the percentage of the area included times the population of the grid cell. By summing up the population included in all the cells, the total number of people within a given radius of a source can be estimated.

By choosing several radii for each source, the number of people between a given pair of radii can be calculated by a simple subtraction. Since each radius corresponds to a specific pollution level, this type of calculation yields an estimate of the number of people exposed to various concentration levels for a single source.

By summing up the effects of several sources, either by source type or location, one can gain insight into which type of source appears to affect the largest number of people. However, the total number of people exposed may be misleading. In areas where there are many point sources located close together, much multiple-counting will occur. (For example, a person exposed to a given ambient concentration produced separately by three sources will be counted three times.) Therefore, this approach does not give an accurate estimate of population exposed to specific levels from sources. However, the model does give an accurate representation of total exposure (expressed as concentration per person-year) for use in linear health models (i.e., those in which the case of one person exposed to 2 ng/m^3 is treated the same as that of two people each exposed to 1 ng/m^3).

To obtain an estimate of the population exposed to various concentrations, a slightly different approach is used. The major difference is that once a number of persons is determined to be within any radius of any plant, that number is subtracted from the map. In other words, no single person is ever counted by more than one source. In addition, the model is not run source-by-source as before, but pollution level-by-pollution level. By choosing several pollution levels, starting with that which yields the smallest radius, and determining the actual number of people exposed to at least one source at each level a pollution level can be estimated.

This model also has its limitations. Individual source totals are meaningless since the sources which are run first will tend to count more people simply because there are more people initially on the map. There is also no way to arrive at the total pollutant concentration times person estimate because no account is made of cumulative effects.

APPENDIX B-1

LOCATION AND CAPACITY (THOUSAND TONS/YEAR)

CITY	LATITUDE (N)	LONGITUDE (W)	TOTAL CAPACITY	TYPE OF OPERATION: BLAST FURNACE	SINTER STRAND	ELECTRIC ARC	BASIC OXYGEN	OPEN HEARTH	EMISSION RATES Q GM/SEC
ALABAMA									
1. Birmingham	33°32'	86°50'	1,250,897	1,250,564		333			2.13×10^{-3}
2. Fairfield	33°29'	86°52'	5,908,881	5,897,738	7,783		3,360		1.63×10^{-1}
3. Gadsden	34°01'	86°02'	1,816,446	1,812,580	310	036	2,520		1.35×10^{-2}
ARKANSAS									
4. Newport	35°36'	91°15'	140			140			9.4×10^{-4}
CALIFORNIA									
5. Carson	33°48'	118°17'	123			123			7.54×10^{-4}
6. Emeryville	37°50'	122°17'	126			126			7.54×10^{-4}
7. Fontana	34°06'	117°26'	4,678,242	4,675,042	1,240	70		1,890	2.89×10^{-2}
8. Union City	37°36'	122°01'	630					630	1.32×10^{-3}
COLORADO									
9. Pueblo	38°16'	104°37'	3,042,042	3,038,420	968	672	1,982		2.55×10^{-2}
CONNECTICUT									
10. Bridgeport	41°10'	73°10'	84			84			5.66×10^{-4}
FLORIDA									
11. Jacksonville	30°20'	81°41'	210			210			1.32×10^{-3}
12. Indiantown	27°01'	80°28'	182			182			1.13×10^{-3}
13. Tampa	27°57'	82°26'	238			238			1.5×10^{-3}
GEORGIA									
14. Cartersville	34°09'	84°47'	280			280			1.69×10^{-3}
15. Atlanta	33°46'	84°25'	476			476			3.02×10^{-3}

APPENDIX B-1 (Continued)

LOCATION AND CAPACITY (THOUSAND TONS/YEAR)

CITY	LATITUDE (N)	LONGITUDE (W)	TOTAL CAPACITY	TYPE OF OPERATION: BLAST FURNACE	SINTER STRAND	ELECTRIC ARC	BASIC OXYGEN	OPEN HEARTH	EMISSION RATES: Q GM/SEC
ILLINOIS									
16. Alton	38°53'	90°10'	1,260		1,260				$8.11x10^{-3}$
17. Chicago	41°45'	87°25'	481			481			$3.02x10^{-3}$
18. Chicago Heights	41°30'	87°37'	204			204			$1.32x10^{-3}$
19. Granite City	38°42'	90°08'	696,003	691,067	988		3,948		$2.16x10^{-2}$
20. Lemont	41°40'	88°00'				336			$2.07x10^{-3}$
21. Morton Grove	42°02'	87°45'	39			39			$1.88x10^{-4}$
22. Sterling	41°47'	89°41	2,940			2,940			$1.86x10^{-2}$
KENTUCKY									
23. Ashland	38°27'	82°38'	2,832,255	2,828,391	840		3,024		$1.81x10^{-3}$
INDIANA									
24. East Chicago	41°38'	87°28'	17,519,213	11,566,510 5,944,219		675	7,812		$6.06x10^{-3}$
25. Fort Wayne	41°04'	85°10'	151			151			$9.43x10^{-4}$
26. Gary	41°35'	87°19'	15,098,769	15,079,325	5,311		10,458	36	$1.2x10^{-1}$
27. Kokomo	40°29'	86°08'	980			980			$6.22x10^{-3}$
28. New Castle	39°55'	85°21'	117			117			$7.54x10^{-4}$
MARYLAND									
29. Baltimore	39°17'	76°33'	448			448			$2.83x10^{-3}$
30. Sparrow's Point	39°13'	76°28'	10,239,193	10,228,288	4,122		3,696	3,087	$9.2x10^{-2}$
MICHIGAN									
31. Dearborn	40°21'	83°11'	3,303,957	3,299,925			4,032		$9.05x10^{-4}$
32. Ferndale	42°27'	83°08'	56			56			$3.77x10^{-4}$
33. Trenton	42°08'	83°11'	2,574,140	2,597,980	1,120		5,040		$8.31x10^{-3}$
Warren	42°31'	83°02'	1,120			1,120			$7.5x10^{-3}$

APPENDIX B-1 (Continued)

LOCATION AND CAPACITY (THOUSAND TONS/YEAR)

				TYPE OF OPERATION					EMISSION RATES
CITY	LATITUDE (N)	LONGITUDE (W)	TOTAL CAPACITY	BLAST FURNACE	SINTER STRAND	ELECTRIC ARC	BASIC OXYGEN	OPEN HEARTH	Q GM/SEC
NEBRASKA									
34. Norfolk	42°01'	97°25'	224			224			1.5×10^{-3}
NEW JERSEY									
35. Roebling	40°07'	74°46'	417			417			2.64×10^{-3}
36. Sayreville	40°27'	74°21'	364			364			2.26×10^{-3}
NEW YORK									
37. Auburn	42°56'	76°34'	168			168			1.13×10^{-3}
38. Buffalo	42°56'	78°52'	2,916,391	2,914,711			1,680		3.77×10^{-4}
39. Dunkirk	42°29'	79°19'	319			319			2.07×10^{-3}
40. Lackawanna	42°49'	78°49'	7,241,389	7,231,936		1,641	7,812		3.57×10^{-2}
41. Lockport	43°10'	78°41'	126			126			7.54×10^{-4}
42. Syracuse	43°03'	76°10'	201			201			1.32×10^{-3}
NORTH CAROLINA									
43. Charlotte	35°14'	80°52'	154			154			9.43×10^{-4}
OHIO									
44. Campbell	41°04'	80°36'	3,522,732	3,519,366	720			2,646	2.04×10^{-2}
45. Canton	40°45'	81°21'	421,834	418,880		2,954			1.88×10^{-2}
46. Cleveland	41°28'	81°40'	6,477,830	1,762,576	306	1,036	3,696		1.60×10^{-2}
				4,709,166					
47. Lorain	41°26'	82°08'	4,576,200	4,572,260	160		3,780		4.17×10^{-3}
48. Mansfield	40°46'	82°31'	6,187,557	6,186,997		560			3.58×10^{-3}
49. Middletown	39°30'	84°24'	3,893,817	1,299,760	860		3,360	4,177	2.74×10^{-2}
				2,585,660					
50. Portsmouth	38°44'	82°59'	1,262,260	1,261,260				1,008	2.07×10^{-3}

APPENDIX B-1 (Continued)
LOCATION AND CAPACITY (THOUSAND TONS/YEAR)

CITY	LATITUDE (N)	LONGITUDE (W)	TOTAL CAPACITY	TYPE OF OPERATION: BLAST FURNACE	SINTER STRAND	ELECTRIC ARC	BASIC OXYGEN	OPEN HEARTH	EMISSION RATES: Q GM/SEC
OHIO (Continued)									
51. Steubinville	40°21'	80°37'	4,620				4,620		$1.13x10^{-3}$
52. Toledo	41°38'	83°31'	1,670,900	1,670,900					0
53. Warren	41°14'	80°49'	1,260			1,260			$8.1x10^{-3}$
54. Youngstown	41°07'	80°41'	3,483,508	422,249	1,260			2,021	$3.06x10^{-2}$
OKLAHOMA									
55. Sand Springs	36°08'	96°06'	420			420			$2.6x10^{-3}$
PENNSYLVANIA									
56. Alquippa	40°36'	80°14'	4,807,308	4,805,570			1,738		$3.96x10^{-4}$
57. Beaver Falls	40°45'	80°19'	1,680			1,680			$1.07x10^{-2}$
58. Bethlehem	40°36'	75°21'	4,657,327	4,650,661	1,892	238	4,536		$4.18x10^{-2}$
59. Braddock	42°21'	79°52'	5,034,516	5,030,820			3,696		$8.30x10^{-4}$
60. Bridgeville	40°21'	80°07'	224			224			$1.5x10^{-3}$
61. Butler	40°51'	79°53'	1,554			1,554			$1.0x10^{-2}$
62. Clairton	40°17'	79°52'	1,053,364	1,053,364					0
63. Duquesne	40°22'	79°50'	4,552,908	4,548,246		966	3,696		$7.0x10^{-3}$
64. Erie	42°06'	80°05'	762,748	762,230		518			$3.32x10^{-3}$
65. Fairless Hills	41°10'	74°52'	5,296,070	5,289,770	1,400	1,120		3,780	$4.3x10^{-2}$
66. Homestead	40°24'	79°54'	3,696						$7.73x10^{-3}$
67. Houston	40°15'	80°12'	252			252			$1.69x10^{-3}$
68. Irwin	40°19'	79°42'	182						$1.13x10^{-3}$
69. Johnstown	40°18'	78°55'	4,150,702	4,148,467	1,000	100		1,134	$2.3x10^{-2}$
70. Latrobe	40°19'	79°23'	42			42			$1.88x10^{-4}$
71. McKeesport	40°21'	79°51'	2,699,556	2,699,258	298				$6.03x10^{-3}$
72. Midland	40°15'	80°12'	1,632,260	1,631,014		1,245			$8.0x10^{-3}$
73. Monessen	40°09'	79°53'	1,991,216	1,987,331	525		3,360		$1.16x10^{-2}$
74. New Castle	41°05'	80°21'	246					246	$5.66x10^{-4}$
75. Oil City	41°25'	79°42'	98			98			$5.66x10^{-4}$
76. Phoenixville	40°07'	75°31'	315					315	$5.66x10^{-4}$

LOCATION AND CAPACITY (THOUSAND TONS/YEAR)

CITY	LATITUDE (N)	LONGITUDE (W)	TOTAL CAPACITY	TYPE OF OPERATION: BLAST FURNACE	SINTER STRAND	ELECTRIC ARC	BASIC OXYGEN	OPEN HEARTH	EMISSION RATES: Q GM/SEC
PENNSYLVANIA (Continued)									
77. Pittsburgh	40°27'	79°57'	3,593,721	3,589,740		999	840	2,142	$1.1x10^{-2}$
78. Reading	40°18'	75°58'	196			196			$1.13x10^{-3}$
79. Sharon	41°14'	80°31'	1,647,576	1,643,180		616	3,780		$4.77x10^{-3}$
80. Steelton	40°13'	76°49'	1,316			1,316			$8.49x10^{-3}$
81. Washington	40°10'	80°14'	168			168			$1.13x10^{-3}$
SOUTH CAROLINA									
82. Darlington	34°17'	79°52'	268			268			$1.69x10^{-3}$
83. Georgetown	33°22'	79°17'	630			630			$3.97x10^{-3}$
TENNESSEE									
84. Harrisman	35°56'	84°33'	210			210			$1.32x10^{-3}$
TEXAS									
85. Baytown	29°43'	94°58'	2,352			2,352			$1.5x10^{-2}$
86. Ft. Worth	42°40'	97°20'	210			210			$1.32x10^{-3}$
87. Houston	29°47'	95°18'	1,004,199	1,001,000	248	2,951			$2.4x10^{-2}$
88. Jewett	31°21'	96°08'	224			224			$1.5x.0^{-3}$
89. Lone Star	32°55'	94°42'	1,011,773	1,010,869	253	336		315	$8.05x10^{-3}$
90. Longview	32°29'	94°44'	140			140			$9.43x10^{-4}$
91. Pampa	35°32'	100°57'	61			61			$3.77x10^{-4}$
UTAH									
92. Geneva	40°12'	111°37'	411,199	407,829	850			2,520	$2.3x10^{-2}$
VIRGINIA									
93. Chesapeake	36°43'	76°17'	112			112			$7.54x10^{-4}$

APPENDIX B-1 (Continued)
LOCATION AND CAPACITY (THOUSAND TONS/YEAR)

CITY	LATITUDE (N)	LONGITUDE (W)	TOTAL CAPACITY	TYPE OF OPERATION: BLAST FURNACE	SINTER STRAND	ELECTRIC ARC	BASIC OXYGEN	OPEN HEARTH	EMISSION RATES: Q GM/SEC
WASHINGTON									
94. Kent	47°23'	122°13'	196			196			1.13×10^{-3}
95. Seattle	47°34'	122°19'	896			896			5.6×10^{-3}
WEST VIRGINIA									
96. Weirton	40°24'	80°35'	6,405,785	6,397,183	2,050		6,552		4.29×10^{-2}

APPENDIX B-2

IRON AND STEEL

State	Source	Thousands of People Exposed to Concentration Range (ng/m^3) >10	5-10	1-5	.1-1	Total
ALABAMA	1.	0	0	0	286	286
	2.	182	171	192	0	545
	3.	0	0	51	34	85
ARKANSAS	4.	0	0	0	8	8
CALIFORNIA	5.	0	0	0	93	93
	6.	0	0	0	120	120
	7.	0	18	146	319	483
	8.	0	0	0	54	54
COLORADO	9.	0	21	86	3	110
CONNECTICUT	10.	0	0	0	65	65

APPENDIX B-2 (Continued)

IRON AND STEEL

State	Source	Thousands of People Exposed to Concentration Range (ng/m^3)				
		>10	5-10	1-5	.1-1	Total
FLORIDA	11.	0	0	0	187	187
	12.	0	0	0	2	2
	13.	0	0	0	122	122
GEORGIA	14.	0	0	0	14	14
	15.	0	0	0	519	519
ILLINOIS	16.	0	0	25	395	420
	17.	0	0	0	63	63
	18.	0	0	0	95	95
	19.	0	16	89	1107	1212
	20.	0	0	0	55	55
	21.	0	0	0	0	0
	22.	0	0	33	31	64
KENTUCKY	23.	0	0	59	137	196

APPENDIX B-2 (Continued)

IRON AND STEEL

Thousands of People Exposed to Concentration Range (ng/m^3)

State	Source	>10	5-10	1-5	.1-1	TOTAL
INDIANA	24.	0	0	47	996	1043
	25.	0	0	0	95	95
	26.	140	98	366	0	604
	27.	0	0	29	59	88
	28.	0	0	0	17	17
MARYLAND	29.	0	0	0	895	895
	30.	0	0	0	39	39
MICHIGAN	31.	0	0	0	207	207
	32.	0	0	0	0	0
	33.	0	0	21	425	446
NEBRASKA	34.	0	0	85	2061	2146
NEW JERSEY	35.	0	0	0	18	18
	36.	0	0	0	194	194
NEW YORK	37.	0	0	0	225	225

APPENDIX B-2 (Continued)

IRON AND STEEL

State	Source	>10	5-10	1-5	.1-1	Total
		Thousands of People Exposed to Concentration Range (ng/m^3)				
NEW YORK (cont'd)	38.	0	0	0	35	35
	39.	0	0	0	0	0
	40.	0	0	0	31	31
	41.	0	59	422	451	932
	42.	0	0	0	11	11
NORTH CAROLINA	43.	0	0	0	209	209
OHIO	44.	0	0	0	78	78
	45.	0	8	211	209	428
	46.	0	0	95	218	313
	47.	0	0	396	1205	1601
	48.	0	0	4	207	211
	49.	0	0	0	99	99
	50.	0	26	67	132	225
	51.	51	71	1112	0	1234
	52.	0	0	0	44	44
	53.	0	0	0	0	0
	54.	0	0	48	281	329
OKLAHOMA	55.	0	42	251	179	472
PENNSYLVANIA	56.	0	0	0	51	51

APPENDIX B-2 (Continued)

IRON AND STEEL

State	Source	Thousands of People Exposed to Concentration Range (ng/m^3)				
		>10	5-10	1-5	.1-1	Total
PENNSYLVANIA (cont'd)	57.	0	0	0	0	0
	58.	0	0	42	186	228
	59.	8	49	227	164	448
	60.	0	0	0	103	103
	61.	0	0	0	101	101
	62.	0	0	27	65	92
	63.	0	0	0	0	0
	64.	0	0	49	1120	1169
	65.	0	0	0	186	186
	66.	0	0	7	19	26
	67.	0	0	92	1355	1447
	68.	0	0	0	34	34
	69.	0	0	0	36	36
	70.	0	21	81	52	154
	71.	0	0	0	0	0
	72.	0	0	55	1003	1058
	73.	0	0	20	240	260
	74.	0	0	50	180	230
	75.	0	0	0	1	1
	76.	0	0	0	6	6
	77.	0	0	0	9	9
	78.	0	0	330	1158	1488
	79.	0	0	0	80	80
	80.	0	0	15	120	135
	81.	0	0	31	299	330
SOUTH CAROLINA	82.	0	0	0	28	28
	83.	0	0	0	13	13
TENNESSEE	84.	0	0	0	17	17

APPENDIX B-2 (Continued)

IRON AND STEEL

State	Source	Thousands of People Exposed to Concentration Range (ng/m^3)				
		>10	5-10	1-5	.1-1	Total
TEXAS	85.	0	0	0	15	15
	86.	0	0	43	137	180
	87.	0	0	0	0	0
	88.	0	41	456	859	1356
	89.	0	0	0	0	0
	90.	0	0	1	17	18
	91.	0	0	0	27	27
UTAH	92.	0	0	0	0	0
VIRGINIA	93.	0	1	66	44	111
WASHINGTON	94.	0	0	0	0	0
	95.	0	0	0	36	36
WEST VIRGINIA	96.	0	0	36	759	795
	97.	3	29	85	34	151

APPENDIX C-1

MUNICIPAL INCINERATORS

	State	Latitude (N)	Longitude (W)	Capacity (tons/day)	Q (gms/sec)
	CONNECTICUT				
1	Ansonia	41 20′	73 4′	190	1.30X10-2
2	Bridgeport	41 12′	73 10′	190	1.30X10-2
3	Darien	41 4′	73 28′	128	8.80X10-3
4	East Hartford	41 46′	72 37′	351	2.40X10-2
5	Hartford	41 47′	72 40′	600	4.10X10-2
6	New Canaan	41 8′	73 29′	124	8.50X10-3
7	New Haven	41 18′	72 52′	717	4.90X10-2
8	New London	41 21′	72 6′	120	8.20X10-3
9	Stamford	41 2′	73 32′	395	2.70X10-2
10	Stamford	41 4′	73 31′	351	2.40X10-2
11	Stratford	41 12′	73 8′	263	1.80X10-2
12	Waterbury	41 34′	73 1′	293	2.00X10-2
13	West Hartford	41 47′	72 45′	293	2.00X10-2
	FLORIDA				
14	Broward County	26 6′	80 11′	293	2.00X10-2
15	Dade County	25 51′	80 11′	293	2.00X10-2
16	Fort Lauderdale (Broward C.)	26 8′	80 10′	439	3.00X10-2
17	Miami (Dade C.)	25 44′	80 12′	893	6.10X10-2
18	Tampa	28 0′	82 26′	996	6.80X10-2
	ILLINOIS				
19	Chigaco	41 53′	87 44′	1201	8.20X10-2
20	Chigaco	41 49′	87 39′	1611	1.10X10-1
21	Chicago (S. Doty)	41 37′	87 34′	1201	8.20X10-2
22	Cicero	41 49′	87 45′	498	3.40X10-2

APPENDIX C-1 (Continued)

MUNICIPAL INCINERATORS

State	Latitude (N)	Longitude (W)	Capacity (tons/day)	Q (gms/sec)
INDIANA				
23 East Chicago	41 39′	87 28′	454	3.10X10-2
KENTUCKY				
24 Louisville	38 12′	85 47′	996	6.80X10-2
LOUISIANA				
25 Shreveport	32 19′	94 17′	190	1.30X10-2
26 New Orleans	29 58′	90 5′	190	1.30X10-2
27 New Orleans	30 2′	90 3′	395	2.70X10-2
28 New Orleans	29 56′	90 1′	395	2.70X10-2
29 New Orleans	30 0′	90 3′	439	3.00X10-2
30 New Orleans	29 56′	90 6′	395	2.70X10-2
MARYLAND				
31 Baltimore	39 18′	76 31′	805	5.50X10-2
MASSACHUSETTS				
32 Belmont	42 23′	71 10′	146	1.00X10-2
33 Braintree	42 13′	71 0′	234	1.60X10-2
34 Brockton	42 5′	71 1′	600	4.10X10-2
35 Brookline	42 19′	71 7′	175	1.20X10-2
36 Fall River	41 40′	71 11′	600	4.10X10-2
37 Framingham	42 18′	71 24′	498	3.40X10-2
38 Lowell	42 37′	71 21′	395	2.70X10-2
39 Marblehead	42 30′	70 51′	79	5.40X10-3
40 Salem	42 31′	70 53′	139	9.50X10-3
41 Saugus	42 30′	71 1′	1201	8.20X10-2
42 Watertown	42 21′	71 11′	307	2.10X10-2
43 Winchester	42 27′	71 8′	99	6.80X10-3
44 Weymouth	42 13′	70 57′	293	2.00X10-2
45 Reading	42 31′	71 06′	143	9.80x10-3

APPENDIX C-1 (Continued)

MUNICIPAL INCINERATORS

State	Latitude (N)	Longitude (W)	Capacity (tons/day)	Q (gms/sec)
MICHIGAN				
46 Central Wayne County	42 16′	83 25′	805	5.50X10-2
47 Detroit (Southfield)	42 28′	83 12′	190	1.30X10-2
48 Grosse Point	42 35′	82 52′	600	4.10X10-2
49 S.E. Oakland County	42 30′	83 6′	600	4.10X10-2
MISSOURI				
50 St. Louis (North)	38 40′	90 12′	395	2.70X10-2
51 St. Louis (South)	38 35′	90 12′	395	2.70X10-2
NEW HAMPSHIRE				
52 Manchester	43 0′	71 28′	99	6.80X10-3
NEW JERSEY				
53 Ewing	40 15′	74 48′	234	1.60X10-2
54 Red Bank	40 20′	74 5′	46	3.20X10-3
NEW YORK				
55 Babylon	40 41′	73 19′	395	2.70X10-2
56 Beacon	41 29′	73 58′	99	6.80X10-3
57 Buffalo	42 54′	78 53′	600	4.10X10-2
58 Eastchester	40 57′	73 48′	190	1.30X10-2
59 Freeport	40 39′	73 35′	161	1.10X10-2
60 Garden City	40 43′	73 38′	175	1.20X10-2
61 Hempstead	40 37′	73 37′	600	4.10X10-2
62 Hempstead	40 39′	73 39′	747	5.10X10-2
63 Huntington	40 52′	73 25′	293	2.00X10-2
64 Islip	40 43′	73 12′	293	2.00X10-2

APPENDIX C-E (Continued)

MUNICIPAL INCINERATORS

State	Latitude (N)	Longitude (W)	Capacity (tons/day)	Q (gms/sec)
(NEW YORK)				
65 Lackawanna	42 49′	78 49′	161	1.10X10-2
66 Lawrence	40 36′	73 44′	190	1.30X10-2
67 Long Beach	40 35′	73 39′	190	1.30X10-2
68 Mount Vernon	40 53′	73 45′	600	4.10X10-2
69 New Rochelle	40 55′	73 47′	395	2.70X10-2
70 North Hempstead	40 45′	73 37′	600	4.10X10-2
71 Oyster Bay	40 52′	73 32′	498	3.40X10-2
72 Rye	40 57′	73 41′	146	1.00X10-2
73 Scarsdale	40 59′	73 48′	146	1.00X10-2
74 Tonawanda	43 2′	78 53′	249	1.70X10-2
75 Valley Stream	40 40′	73 44′	190	1.30X10-2
NEW YORK CITY				
76 New York City	40 37′	74 0′	996	6.80X10-2
77 New York City	40 43′	73 59′	996	6.80X10-2
78 New York City	40 40′	73 51′	996	6.80X10-2
79 New York City	40 36′	73 58′	996	6.80X10-2
80 New York City	40 43′	73 55′	996	6.80X10-2
OHIO				
81 Euclid	41 36′	81 0′	170	1.30X10-2
82 Franklin	39 33′	84 18′	146	1.00X10-2
83 Lakewood	41 28′	81 46′	293	2.00X10-2
84 Miami County	40 2′	84 12′	146	1.00X10-2
85 Parma	41 25′	81 47′	219.8	1.50X10-2
86 Sharonville	39 16′	84 24′	498.2	3.40X10-2

APPENDIX C-1 (Continued)

MUNICIPAL INCINERATORS

	State	Latitude (N)	Longitude (W)	Capacity (tons/day)	Q (gms/sec)
	PENNSYLVANIA				
87	Philadelphia	39 56′	75 14′	600	4.10X10-2
88	Philadelphia	39 58′	75 11′	600	4.10X10-2
89	Ambridge	40 35′	80 13′	146	1.00X10-2
90	Bradford	41 57′	78 37′	190	1.30X10-2
91	Delaware County	39 51′	75 23′	791	5.40X10-2
92	Delaware County	39 54′	75 16′	498	3.40X10-2
93	Delaware County	39 59′	75 21′	498	3.40X10-2
94	Shippensburg				
	TEXAS				
95	Amarillo	35 11′	101 52′	351.6	2.40X10-2
	UTAH				
96	Ogden	41 14′	111 58′	439.7	3.00X10-2
	VIRGINIA				
97	Alexandria	38 50′	77 6′	293.0	2.00X10-2
98	Newport News	37 58′	76 25′	395.6	2.70X10-2
99	Norfolk	36 53′	76 19′	395.6	2.70X10-2
100	Portsmouth	36 50′	76 20′	337.0	2.30X10-2
	WISCONSIN				
101	Oshkosh	44 1′	88 34′	337.0	2.30X10-2
102	Port Washington	43 23′	87 52′	74.7	5.10X10-3
103	Sheboygan	43 45′	87 44′	234.4	1.60X10-2
104	Sturgeon Bay	44 50′	87 22′	146.5	1.00X10-2
105	Waukesha	43 0′	88 13′	337.0	2.30X10-2

APPENDIX C-2

MUNICIPAL INCINERATORS

Thousands of People Exposed To Concentration

(ng/m^3)

State	Source	>200.0	>100.0	>50.0	>10.0	>0.1
CONNECTICUT	1	0	0	0	9	713
	2	0	0	0	11	547
	3	0	0	0	3	420
	4	0	0	0	0	642
	5	0	0	0	14	680
	6	0	0	0	2	417
	7	0	0	0	20	498
	8	0	0	0	0	0
	9	0	0	0	0	529
	10	0	0	0	0	443
	11	0	0	0	6	623
	12	0	0	0	4	420
	13	0	0	0	9	699
FLORIDA	14	0	0	0	14	659
	15	0	0	0	10	1189
	16	0	0	0	0	659
	17	0	0	0	1	956
	18	0	0	0	4	420
ILLINOIS	19	0	0	0	85	4118
	20	0	0	0	233	3848
	21	0	0	0	11	1902
	22	0	0	0	0	4101

APPENDIX C-2 (Continued)

MUNICIPAL INCINERATORS

Thousands of People Exposed to Concentration
(ng/m^3)

State	Source	>200.0	>100.0	>50.0	>10.0	>0.1
INDIANA	23	0	0	0	0	1686
KENTUCKY	24	0	0	0	8	787
LOUISIANA	25	0	0	0	0	11
	26	0	0	0	33	965
	27	0	0	0	0	954
	28	0	0	0	0	886
	29	0	0	0	0	954
	30	0	0	0	0	959
MARYLAND	31	0	0	0	0	1503
MASSACHUSETTS	32	0	0	2	25	1996
	33	0	0	0	5	1465
	34	0	0	0	11	577
	35	0	0	0	34	2035
	36	0	0	0	8	371
	37	0	0	0	0	758
	38	0	0	0	0	515
	39	0	0	0	3	515
	40	0	0	1	11	714

APPENDIX C-2 (Continued)

MUNICIPAL INCINERATORS

Thousands of People Exposed to Concentration (ng/m^3)

State	Source	>200.0	>100.0	>50.0	>10.0	>0.1
MASSACHUSETTS (Cont'd)	41	0	0	0	8	1332
	42	0	0	0	14	2011
	43	1	3	9	190	1960
	44	0	0	0	13	1172
	45	0	0	0	0	1582
MICHIGAN	46	0	0	0	0	1066
	47	0	0	0	8	2317
	48	0	0	0	5	785
	49	0	0	0	9	2467
MISSOURI	50	0	0	0	0	1622
	51	0	0	0	0	1489
NEW HAMPSHIRE	52	0	0	0	0	130
NEW JERSEY	53	0	0	0	5	582
	54	0	0	0	0	271

APPENDIX C-2 (Continued)

MUNICIPAL INCINERATORS

Thousands of People Exposed to Concentration

(ng/m^3)

State	Source	>200.0	>100.0	>50.0	>10.0	>0.1
NEW YORK	55	0	0	0	0	983
	56	0	0	0	1	206
	57	0	0	0	11	1009
	58	0	0	0	14	3419
	59	0	0	0	18	2021
	60	0	0	0	18	2742
	61	0	0	0	3	1946
	62	0	0	0	0	2720
	63	0	0	0	7	830
	64	0	0	0	5	809
	65	0	0	0	12	934
	66	0	0	0	8	3605
	67	0	0	0	11	1694
	68	0	0	0	1	4414
	69	0	0	0	0	3911
	70	0	0	0	9	2747
	71	0	0	0	0	973
	72	0	0	0	2	1790
	73	0	0	1	14	2697
	74	0	0	0	10	968
	75	0	0	0	0	8
	76	0	0	0	14	5777
	77	0	0	0	13	8852
	78	0	0	0	21	8036
	79	0	0	0	24	5881
	80	0	0	0	66	8616

APPENDIX C-2 (Continued)

MUNICIPAL INCINERATORS

Thousands of People Exposed to Concentration
(ng/m^3)

State	Source	>200.0	>100.0	>50.0	>10.0	>0.1
OHIO	81	0	0	0	0	53
	82	0	0	0	4	249
	83	0	0	0	28	1376
	84	0	0	0	1	141
	85	0	0	0	6	1326
	86	0	0	0	0	715
PENNSYLVANIA	87	0	0	0	17	2914
	88	0	0	0	40	3195
	89	0	0	1	9	409
	90	0	0	0	1	46
	91	0	0	0	0	1355
	92	0	0	0	0	2331
	93	0	0	0	0	2424
	94	0	0	0	2	56
TEXAS	95	0	0	0	0	133
UTAH	96	0	0	0	0	173

APPENDIX C-2 (Continued)

MUNICIPAL INCINERATORS

Thousands of People Exposed to Concentration
(ng/m^3)

State	Source	>200.0	>100.0	>50.0	>10.0	>0.1
VIRGINIA	97	0	0	0	17	1755
	98	0	0	0	0	13
	99	0	0	0	0	742
	100	0	0	0	2	618
WISCONSIN	101	0	0	0	0	91
	102	0	0	0	2	50
	103	0	0	0	7	75
	104	0	0	0	1	15
	105	0	0	0	1	509

APPENDIX D

PRIMARY SMELTERS

Type	Plant	Location	Latitude (N)	Longitude (W)	Capacity (tons/yr)	>10	5-10	1-5	.1-1	Total
Zinc b/										
	1. St. Joseph	Monaca, PA	40° 41'	80° 18'	250,000	250	0	0	0	250
	2. New Jersey Zinc	Palmerton, PA	40° 48'	75° 37'	110,000	100	0	0	0	100
	3. National Zinc	Bartlesville, OK	36° 45'	95° 58'	55,000	40	0	0	0	40
Lead										
	1. St. Joseph	Herculaneum, MO	38° 15'	90° 58'	55,000	25	0	0	0	25
	2. Asarco	E. Helena, MT	46° 35'	111° 55'	235,500	28	0	0	0	28
	3. Bunker Hill	Kellogg, ID	47° 33'	116° 06'	246,945	17	0	0	0	17
	4. Asarco	Glover, MO	37° 36'	90° 41'	97,761	10	0	0	0	10
Copper										
	1. Asarco	Tacoma, WA	47° 14'	122° 26'	100,000	461	0	0	0	461
	2. Asarco	Hayden, AZ	33° 01'	110° 48'	180,000	6	0	0	0	6
	3. Asarco a/	El Paso, TX	31° 55'	106° 35'	100,000	180	0	0	0	180
	4. Phelps - Dodge	Morenci, AZ	33° 05'	109° 22'	177,000	8	0	0	0	8
	5. Phelps - Dodge	Douglas, AZ	31° 21'	109° 33'	127,000	14	0	0	0	14
	6. Phelps - Dodge	Ajo, AZ	32° 02'	112° 38'	70,000	0	0	0	0	0
	7. Kennecott	Hayden, AZ	33° 05'	110° 49'	80,000	6	0	0	0	6
	8. Kennecott	Garfield, UT	40° 43'	112° 10'	280,000	75	0	0	0	75
	9. Kennecott	Hurley, NM	32° 41'	108° 07'	80,000	16	0	0	0	16
	10. Anaconda	Anaconda, MT	46° 07'	112° 56'	180,000	16	0	0	0	16
	11. White Pine	White Pine, MI	46° 45'	89° 34'	90,000	2	0	0	0	2
	12. Cities Services	Copperhill, TN	35° 00'	84° 21'	90,000	18	0	0	0	18
Cadmium										
	1. Bunker Hill Co.	Kellog, ID	47° 33'	116° 06'	125,000	17	0	0	0	17
	2. New Jersey Zinc	Palmerton, PA	40° 48'	75° 37'	110,000	100	0	0	0	100
	3. Asarco b/	Corpus Christi, TX	27° 55'	97° 45'	108,000	32	0	0	0	32

a/ Asarco plant in El Paso, Texas has combined production capacity for lead and copper of 100,000 tons/year.

b/ Asarco plant in Corpus Christi, Texas has combined production capacity for zinc and cadmium of 108,000 tons/year. The plant uses the electrolytic zinc process and therefore, emits a negligible amount of cadmium.

APPENDIX D-1

POPULATION EXPOSED TO ATMOSPHERIC CADMIUM FROM COPPER SMELTERS

(10^3 People)

SOURCE	CONCENTRATION (nanograms)				
1% Fugitive	Greater than 1000	1000-100	100-50	50-10	10-1.0
1	0	0	0	0	75.6
2	0	0	0	0	8.0
3	0	0	0	.2	.7
4	0	0	0	.6	81.5
5	0	0	0	.5	13.0
6	0	0	0	0	0
7	0	0	0	0	1.6
8	0	0	0	0	.6
9	0	0	0	.1	8.4
10	0	0	0	0	1.4
11	0	0	0	1.1	17.8
12	0	0	0	0	1.6
13	0	0	0	0	0
2% Fugitive					
1	0	0	0	0	75.6
2	0	0	0	.1	8.0
3	0	0	0	.3	6.5
4	0	0	.1	1.3	120.6
5	0	0	.1	1.1	12.3
6	0	0	0	0	0
7	0	0	0	0	2.0
8	0	0	0	0	1.3
9	0	0	0	.14	9.7
10	0	0	0	.1	1.3
11	0	0	0	1.1	17.8
12	0	0	0	.1	1.5
13	0	0	0	0	0

APPENDIX D-2

POPULATION EXPOSED TO ATMOSPHERIC CADMIUM FROM COPPER SMELTERS

(10^3 People)

SOURCE	CONCENTRATION (nanograms)				
5% Fugitive	Greater than 1000	1000-100	100-50	50-10	10-1.0
1	0	0	0	0	75.6
2	0	0	0	.3	7.9
3	0	0	0	.8	6.1
4	0	.1	.2	4.9	201.0
5	0	.1	.2	3.7	9.4
6	0	0	0	0	0
7	0	0	0	.1	3.8
8	0	0	0	0	2.2
9	0	0	0	.6	12.6
10	0	0	0	.3	1.1
11	0	0	0	1.2	17.6
12	0	0	0	.3	2.6

APPENDIX D-3

POPULATION EXPOSED TO ATMOSPHERIC CADMIUM FROM PRIMARY LEAD SMELTERS
(10^3 People)

SOURCE	CONCENTRATION (nanograms)				
	Greater than 1000	1000-100	100-50	50-10	10-1.0
1% Fugitive					
1	0	0	0	.3	28.1
2	0	0	.2	13.3	3.6
3	0	0	0	.9	59.0
4	0	0	0	0	0
2% Fugitive					
1	0	0	0	.7	27.8
2	0	.1	.3	13.2	3.6
3	0	0	0	1.5	58.3
4	0	0	0	0	0
5% Fugitive					
1	0	0	.1	1.6	26.8
2	0	.1	.6	12.9	3.6
3	0	.1	.1	3.9	55.8
4	0	0	0	0	0

APPENDIX D-4

POPULATION EXPOSED TO ATMOSPHERIC CADMIUM FROM PRIMARY CADMIUM SMELTERS

(10^3 People)

SOURCE	CONCENTRATION (nanograms)				
	Greater than 1000	1000-100	100-50	50-10	10-1.0
1% Fugitive					
1	0	0	0	.2	100.2
2	0	0	.1	.6	16.5
3	0	0	0	0	32.4
2% Fugitive					
1	0	.1	.1	.5	99.8
2	.1	.1	.2	1.2	15.7
3	0	0	0	0	32.4
5% Fugitive					
1	.1	.2	.3	1.8	98.2
2	.3	.4	.7	1.7	14.3
3	2.2	0	0	0	32.4

APPENDIX D-5

POPULATION EXPOSED TO ATMOSPHERIC CADMIUM FROM ZINC SMELTERS
(10^3 People)

SOURCE	CONCENTRATION (nanograms)				
	Greater than 1000	1000-100	100-50	50-10	10-1.0
1% Fugitive					
1	.1	21.2	148.5	88.5	0
3	0	3.4	37.3	59.8	0
5	0	0	0	0	0
2	0	5.7	11.5	0	0
2% Fugitive					
1	.2	27.6	155.1	75.3	0
3	0	.1	36.7	59.8	0
5	0	0	0	0	0
2	0	5.9	11.3	0	0
5% Fugitive					
1	.7	44.8	157.2	55.5	0
3	0	6.1	41.7	52.6	0
5	0	0	0	0	.2
2	.1	6.3	10.8	0	0

APPENDIX E

SECONDARY SMELTERS

Copper

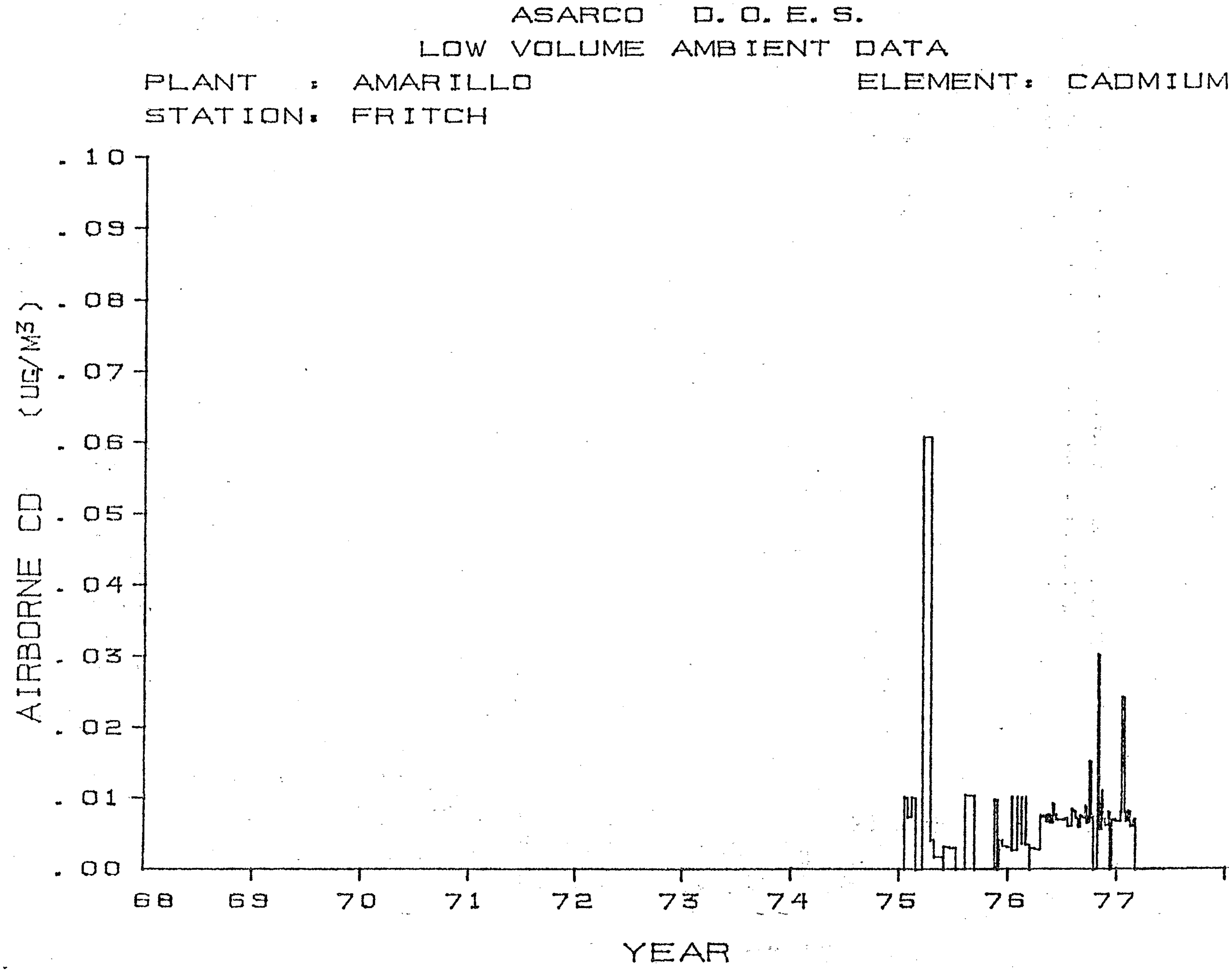
Plant	Location	Latitude (N)	Longitude (W)	>10	5-10	1-5	.1-1	Total
Asarco	Perth Amboy, NJ	40°31'	74°15'	38	42	609	743	1432
Asarco	Whiting, IN	41°40'	87°29'	20	35	862	969	1886
Asarco	Houston, TX	29°45'	95°12'	21	38	579	386	1024
Asarco	Long Beach, CA	34°05'	118°12'	107	183	1838	1279	3407
Asarco	San Francisco, CA	37°45'	122°22'	76	171	866	493	1606
Kennecott	Magna, UT	40°42'	112°06'	5	2	62	124	193
Kennecott	Hurley, NM	32°41'	108°07'	1	0	7	6	14
Olin Mathieson Chemicals, Metals Division	East Alton, IL	38°53'	90°07'	25	24	85	177	311

Zinc

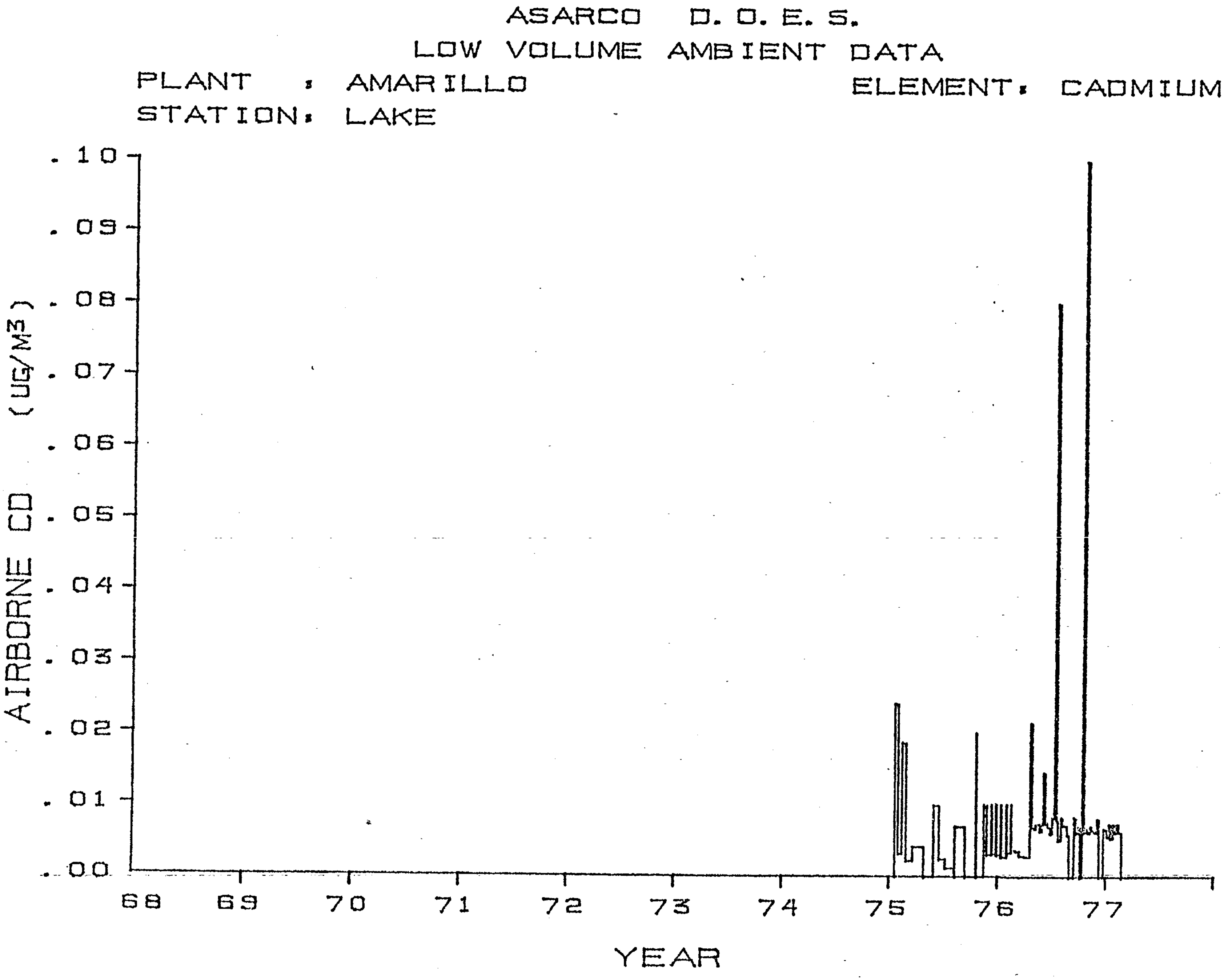
Plant	Location	Latitude (N)	Longitude (W)	10	5-10	1-5	.1-1	Total
Asarco, Federated Metals Division	Sand Springs, OK	36°08'	96°07'	0	0	0	3	3
American Zinc Co. of Illinois	Hillsborough, IL	39°09'	89°29'	0	0	0	3	3
Asarco	Long Beach, CA	34°05'	118°12'	0	0	0	40	40

APPENDIX F

CADMIUM AIR QUALITY LEVELS AROUND ASARCO SMELTERS



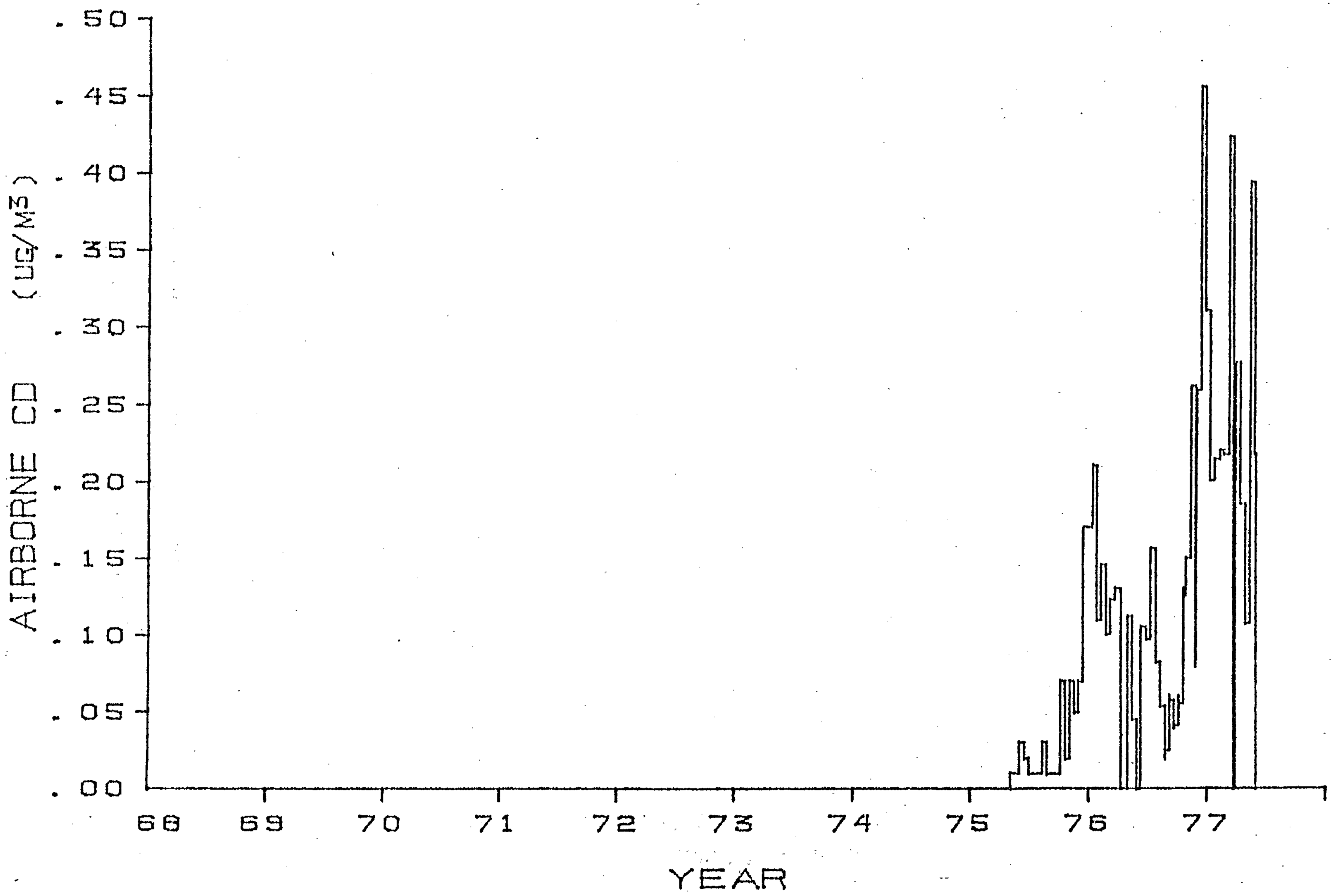
APPENDIX F (Continued)



APPENDIX F (Continued)

ASARCO D. O. E. S.
LOW VOLUME AMBIENT DATA

PLANT :
STATION: COLUMBUS
ELEMENT: CADMIUM



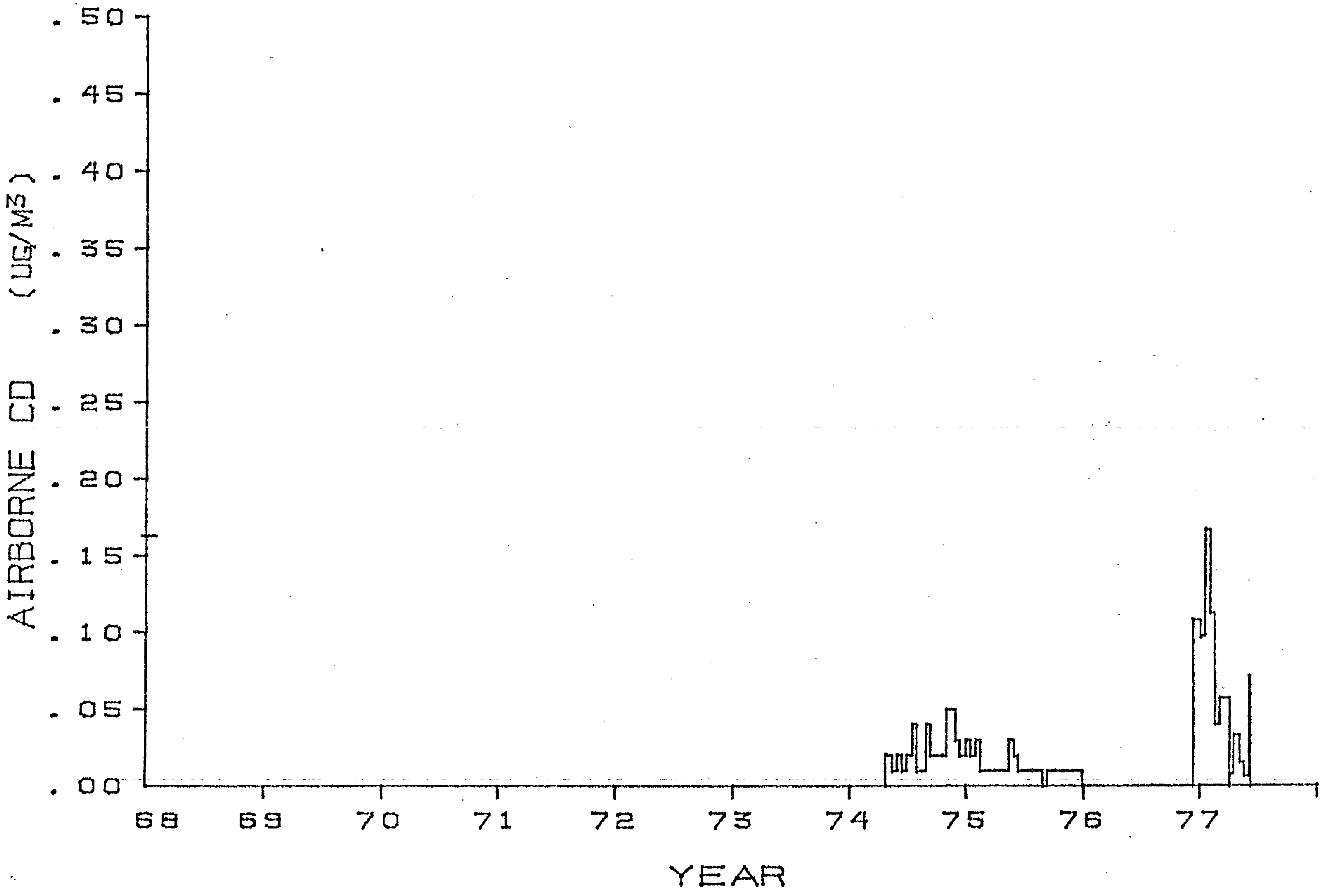
APPENDIX F (Continued)

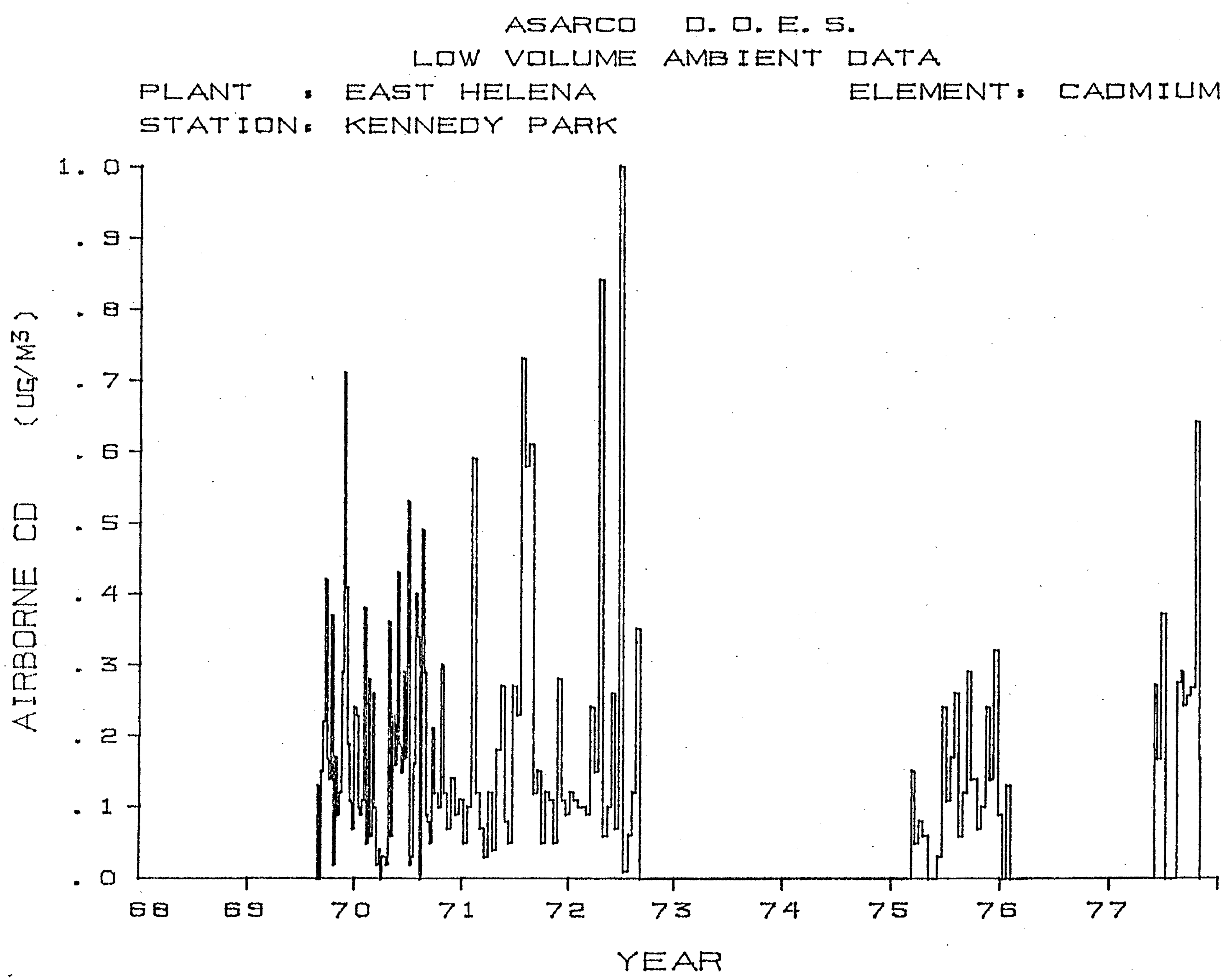
ASARCO D. O. E. S.

LOW VOLUME AMBIENT DATA

PLANT : ELEMENT: CADMIUM

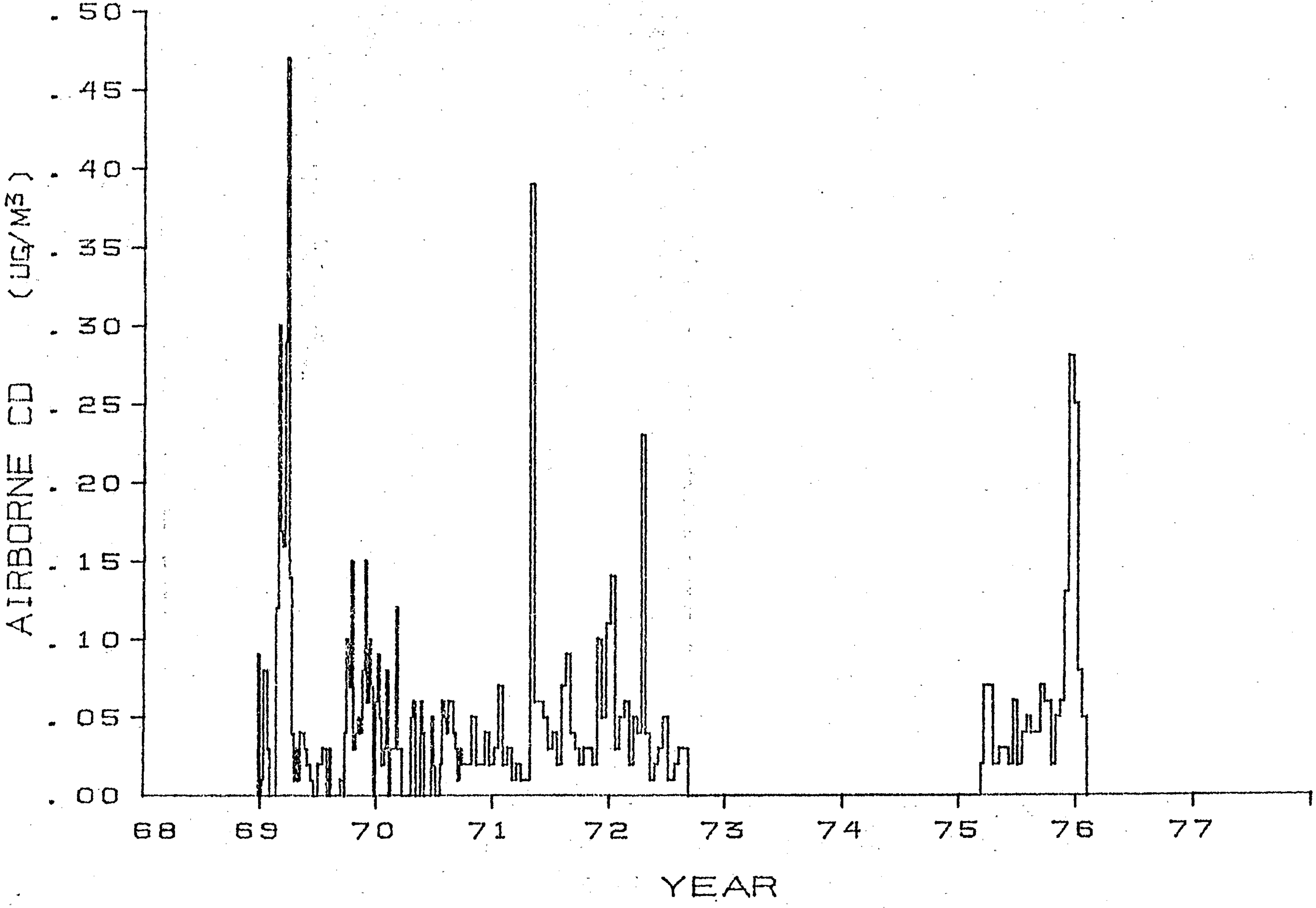
STATION: CORPUS CHRISTI




ASARCO D. O. E. S.
LOW VOLUME AMBIENT DATA
PLANT : EAST HELENA
ELEMENT: CADMIUM
STATION: KENNEDY PARK
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
.0
AIRBORNE CD (UG/M3)
68
69
70
71
72
73
74
75
76
77
YEAR

APPENDIX F (Continued)

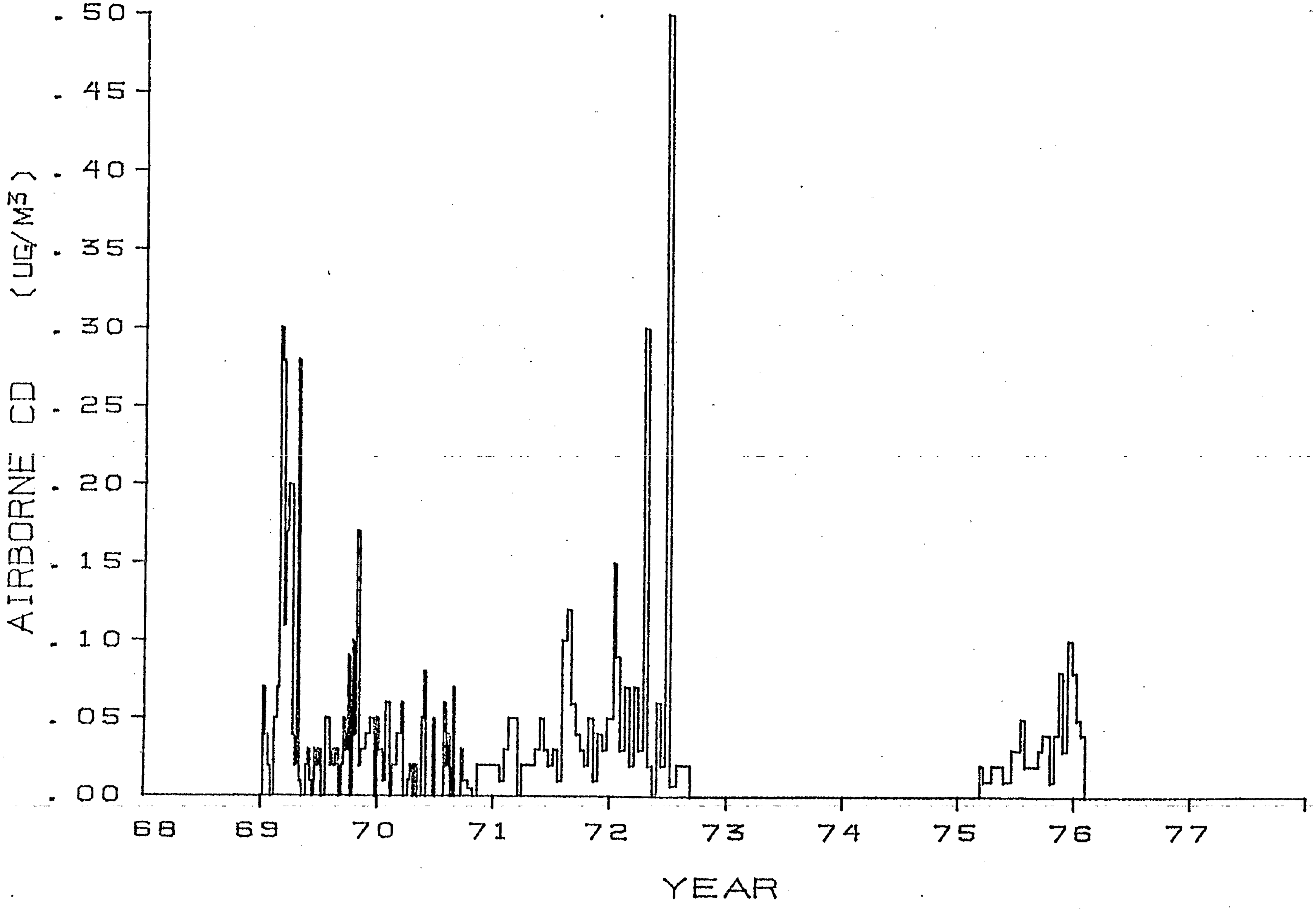
ASARCO D. O. E. S.
LOW VOLUME AMBIENT DATA
PLANT : EAST HELENA ELEMENT: CADMIUM
STATION: KLEFFNER ROAD



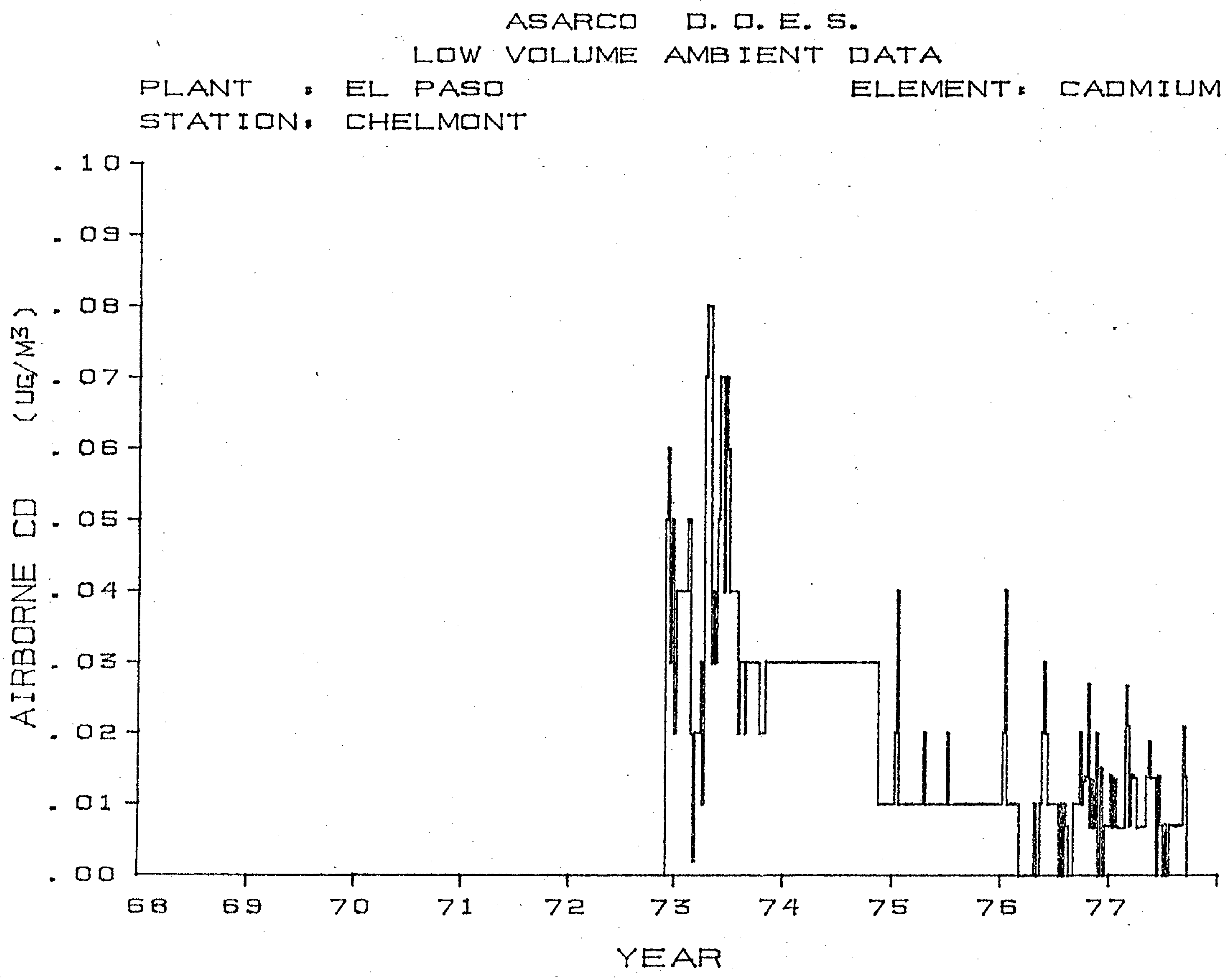
APPENDIX F (Continued)

ASARCO D. O. E. S.
LOW VOLUME AMBIENT DATA

PLANT : EAST HELENA ELEMENT: CADMIUM
STATION: WATER TOWER



APPENDIX F (Continued)



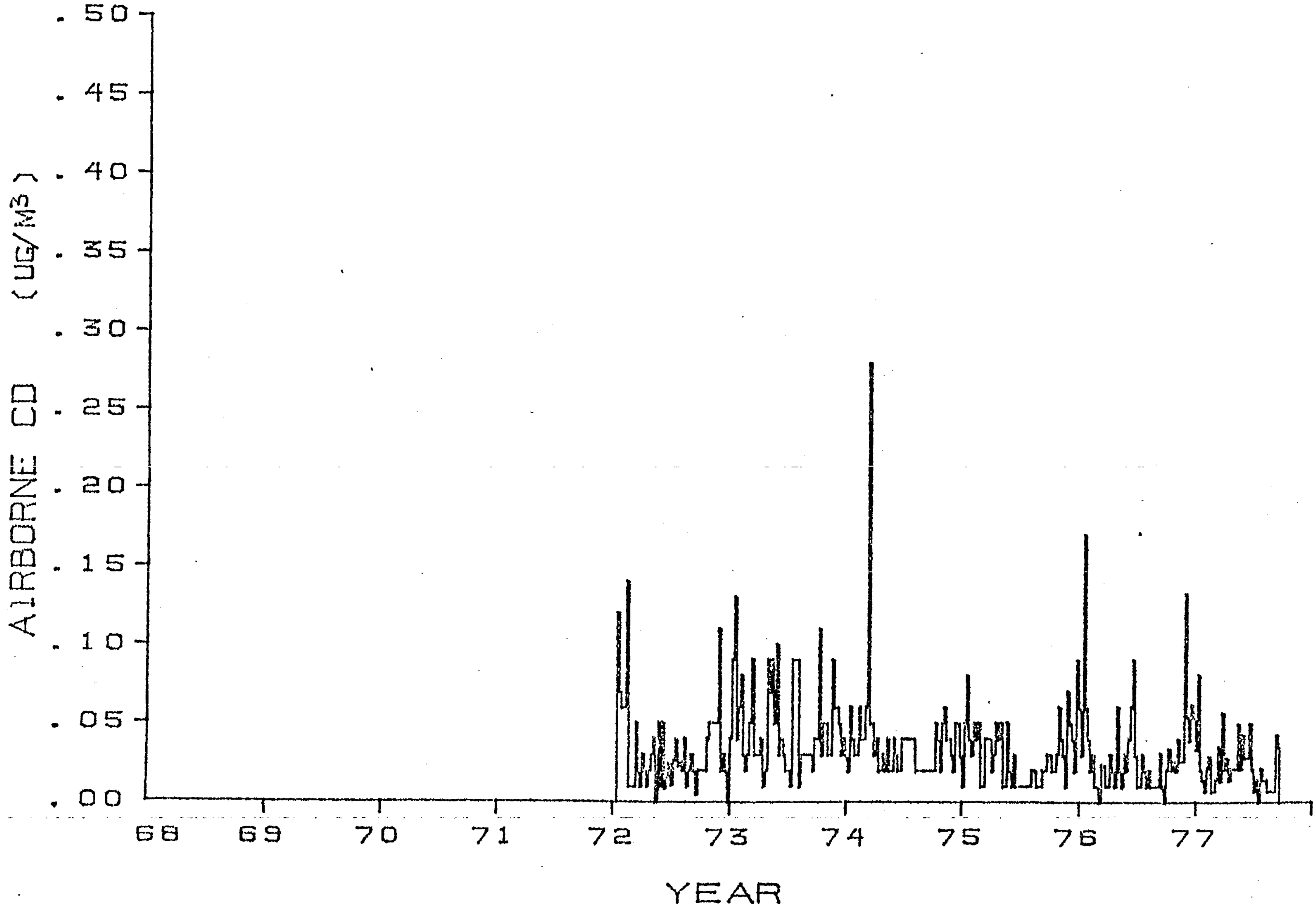
APPENDIX F (Continued)

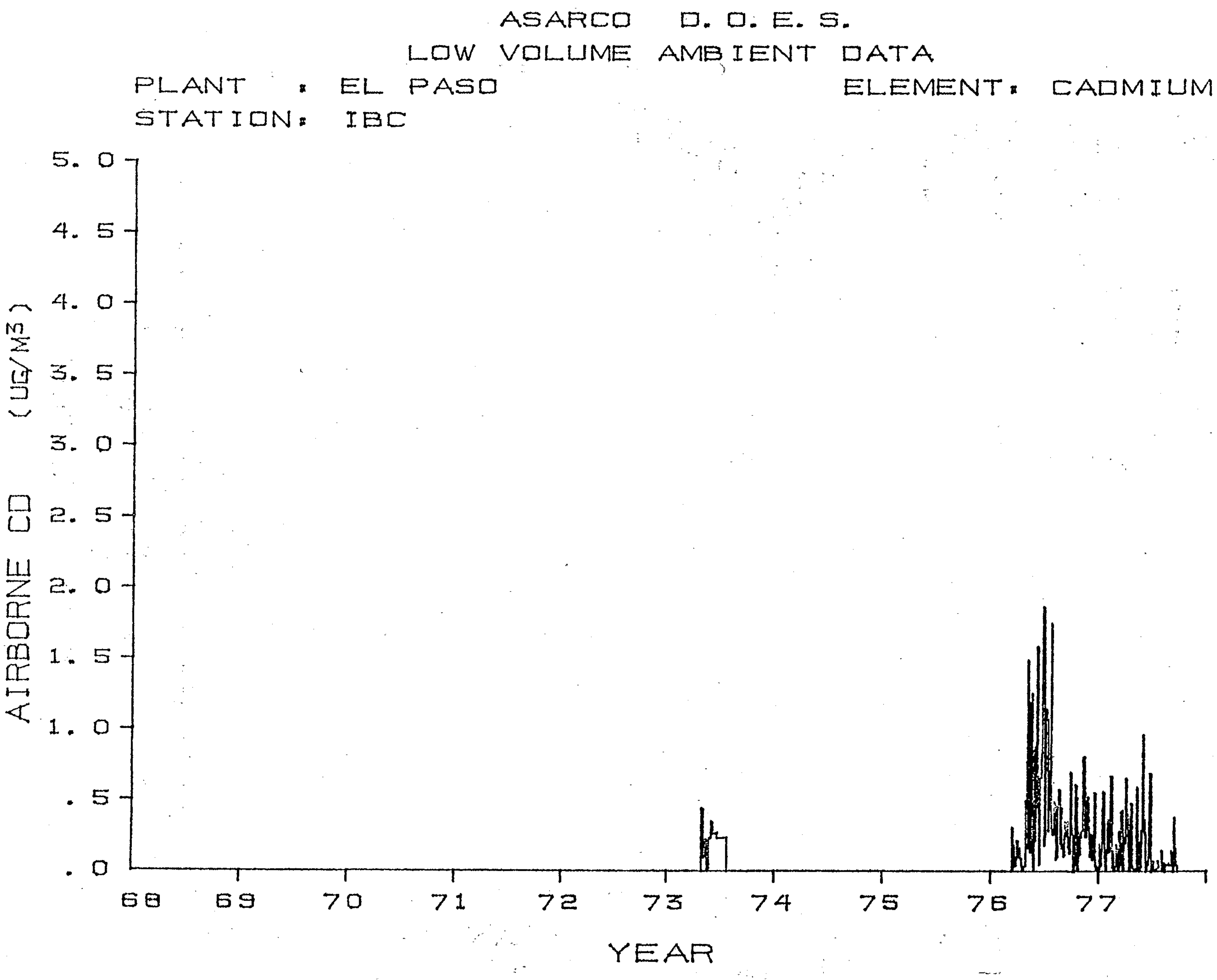
ASARCO D. O. E. S.

LOW VOLUME AMBIENT DATA

PLANT : EL PASO ELEMENT: CADMIUM

STATION: HAWTHORNE




ASARCO D. O. E. S.
LOW VOLUME AMBIENT DATA
PLANT : EL PASO
ELEMENT: CADMIUM
STATION: IBC
AIRBORNE CD (UG/M3)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
.5
.0
68
69
70
71
72
73
74
75
76
77
YEAR

APPENDIX F (Continued)

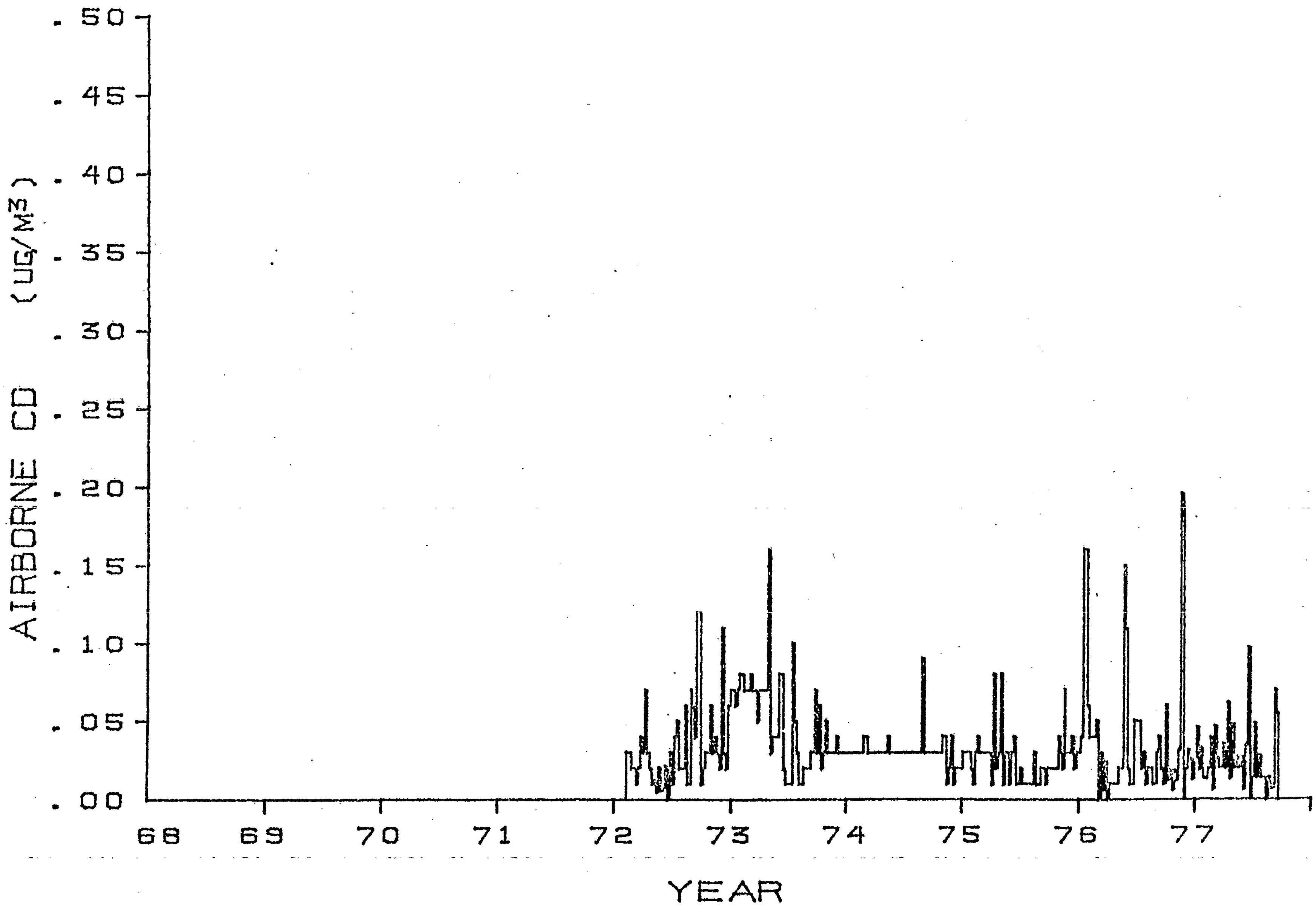
ASARCO D. O. E. S.

LOW VOLUME AMBIENT DATA

PLANT : EL PASO

ELEMENT: CADMIUM

STATION: MCKELLIGON



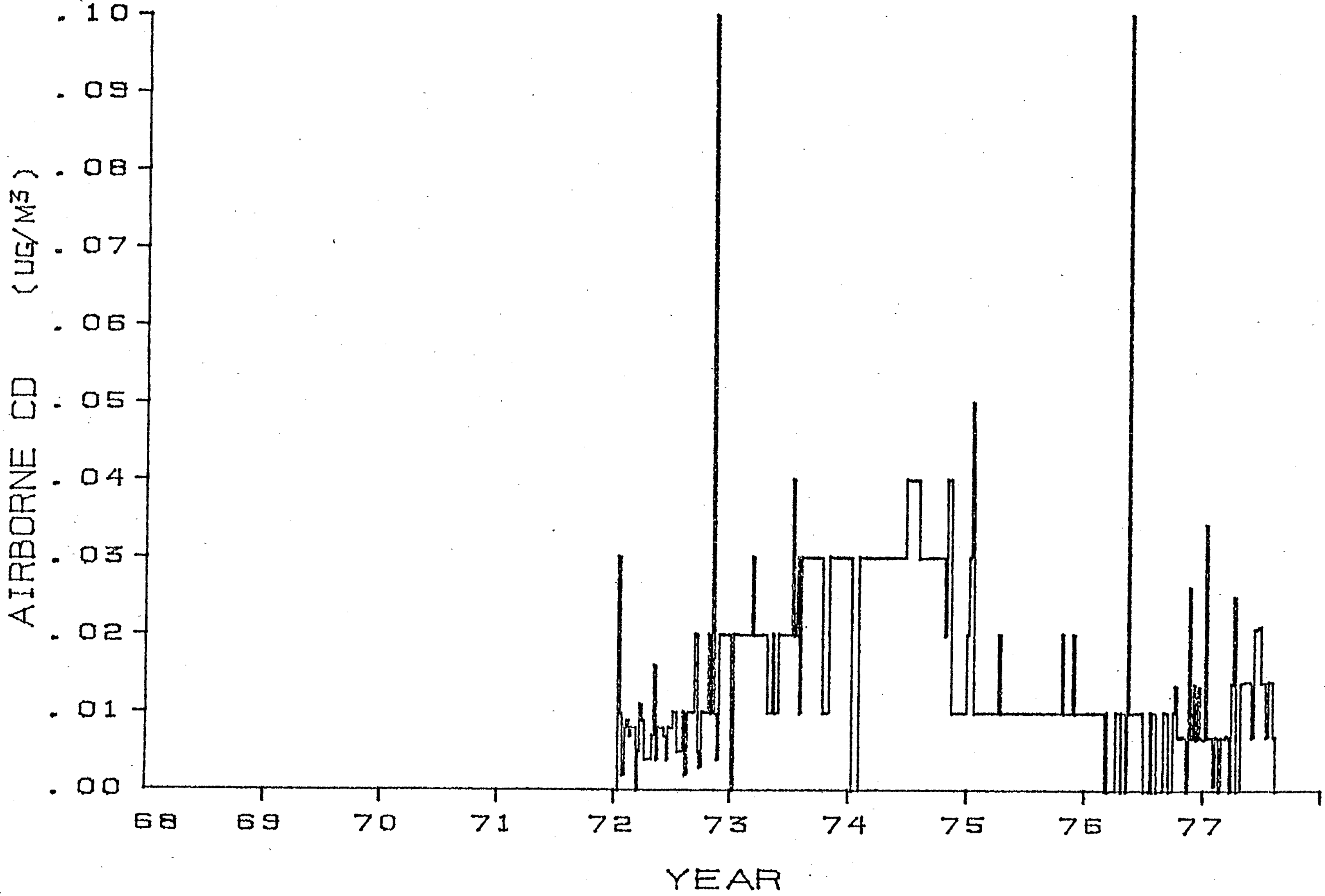
APPENDIX F (Continued)

ASARCO D. O. E. S.

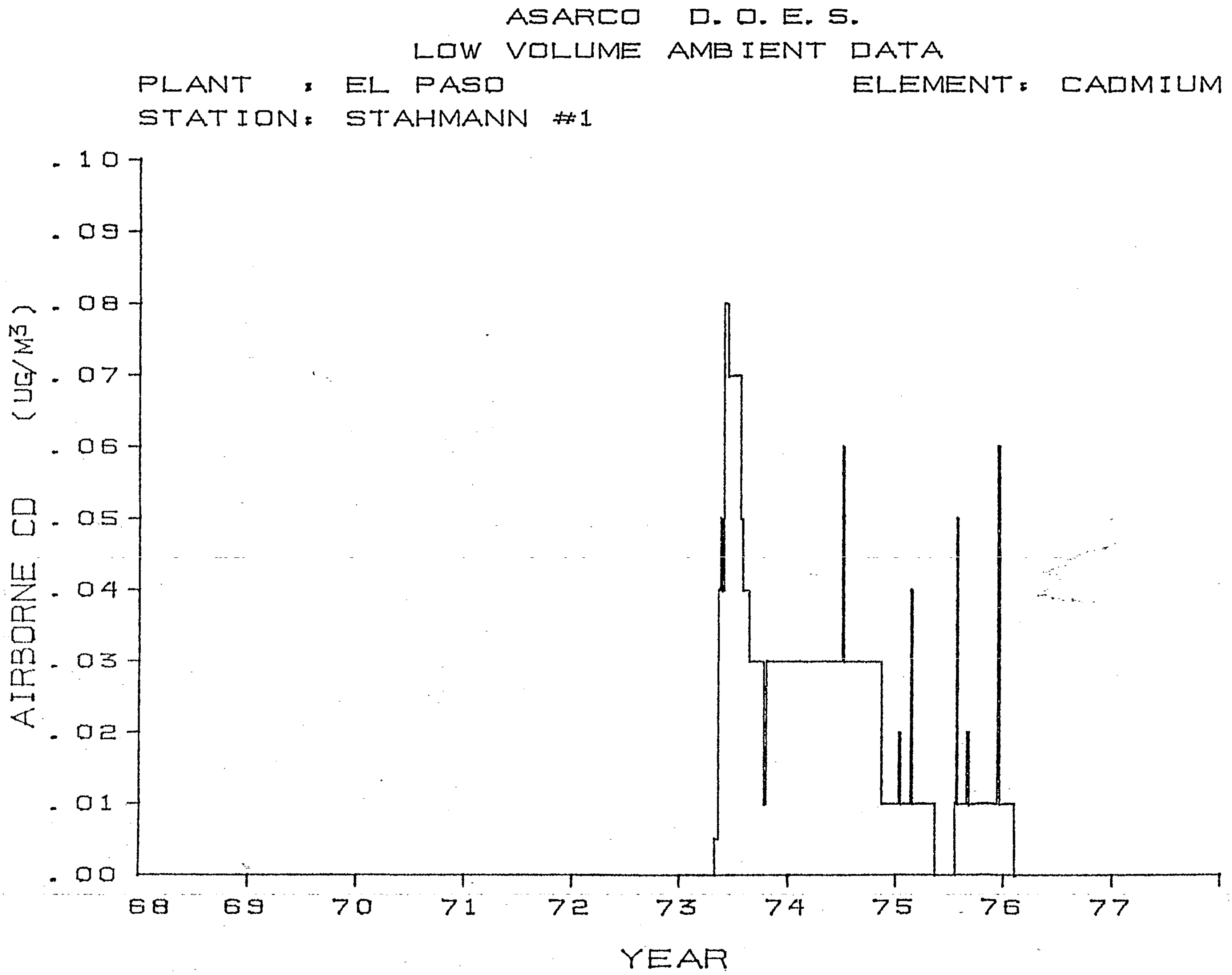
LOW VOLUME AMBIENT DATA

PLANT : EL PASO ELEMENT: CADMIUM

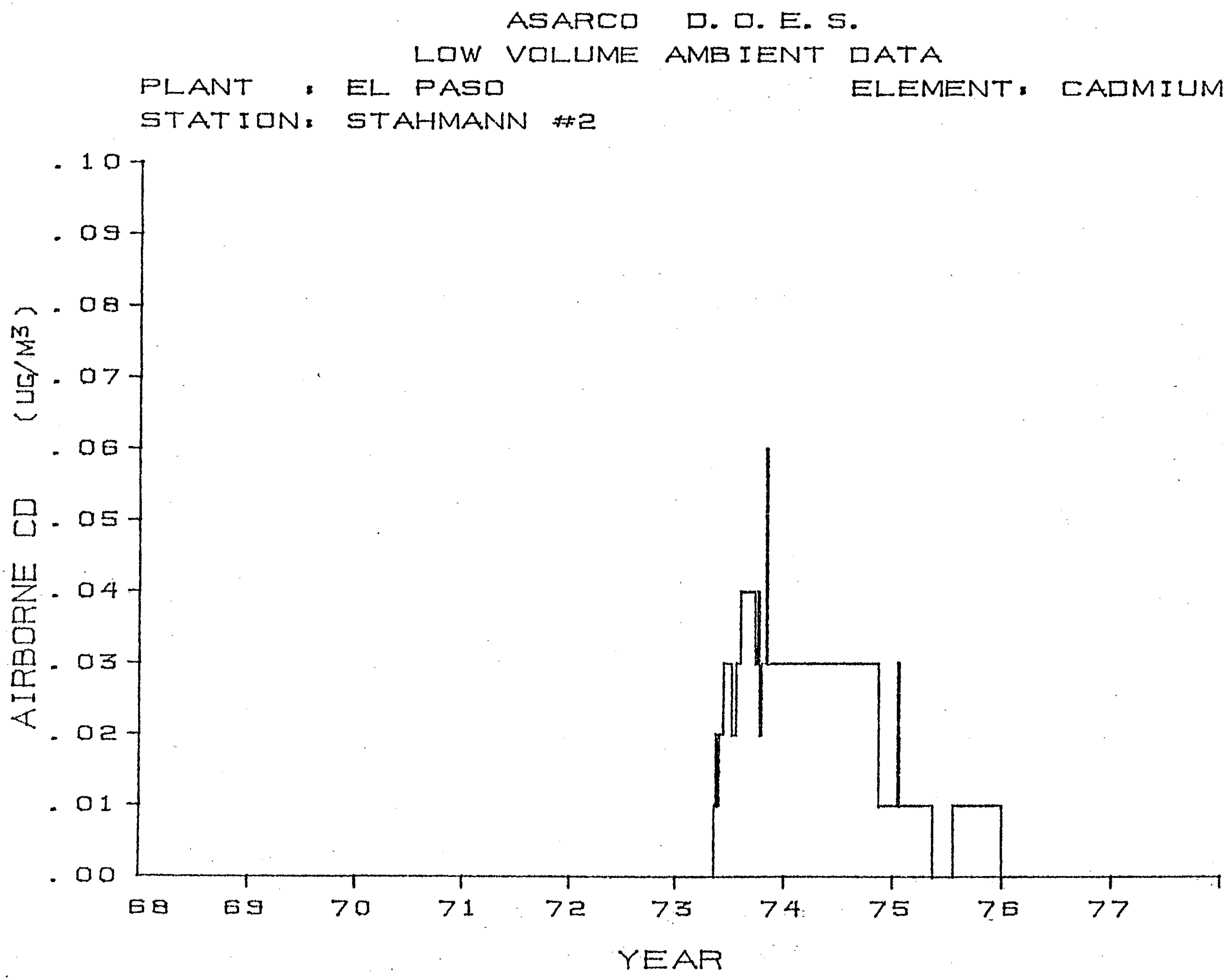
STATION: RICHMOND



APPENDIX F (Continued)



APPENDIX F (Continued)



APPENDIX F (Continued)

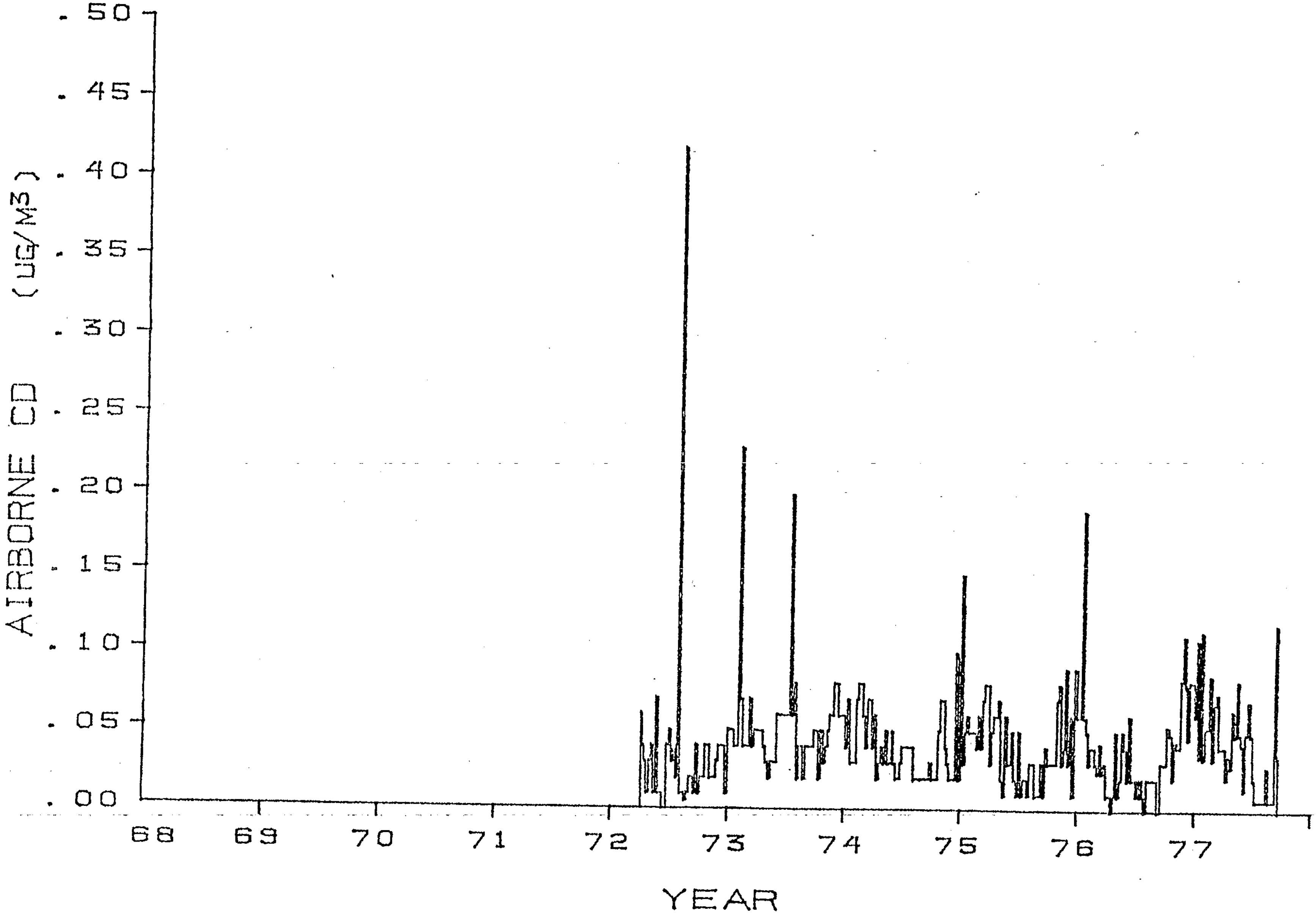
ASARCO D. O. E. S.

LOW VOLUME AMBIENT DATA

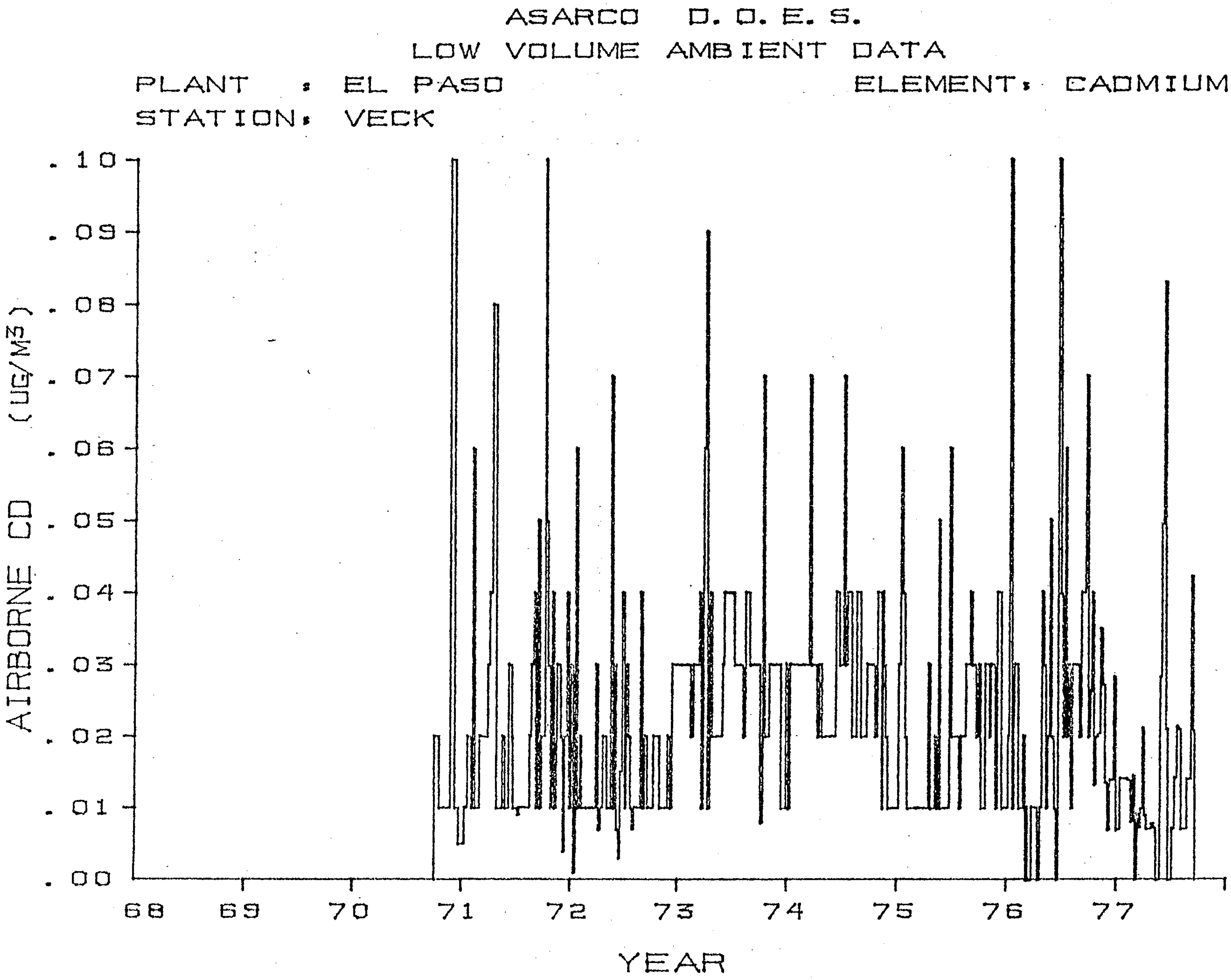
PLANT : EL PASO

ELEMENT: CADMIUM

STATION: UTEP



APPENDIX F (Continued)



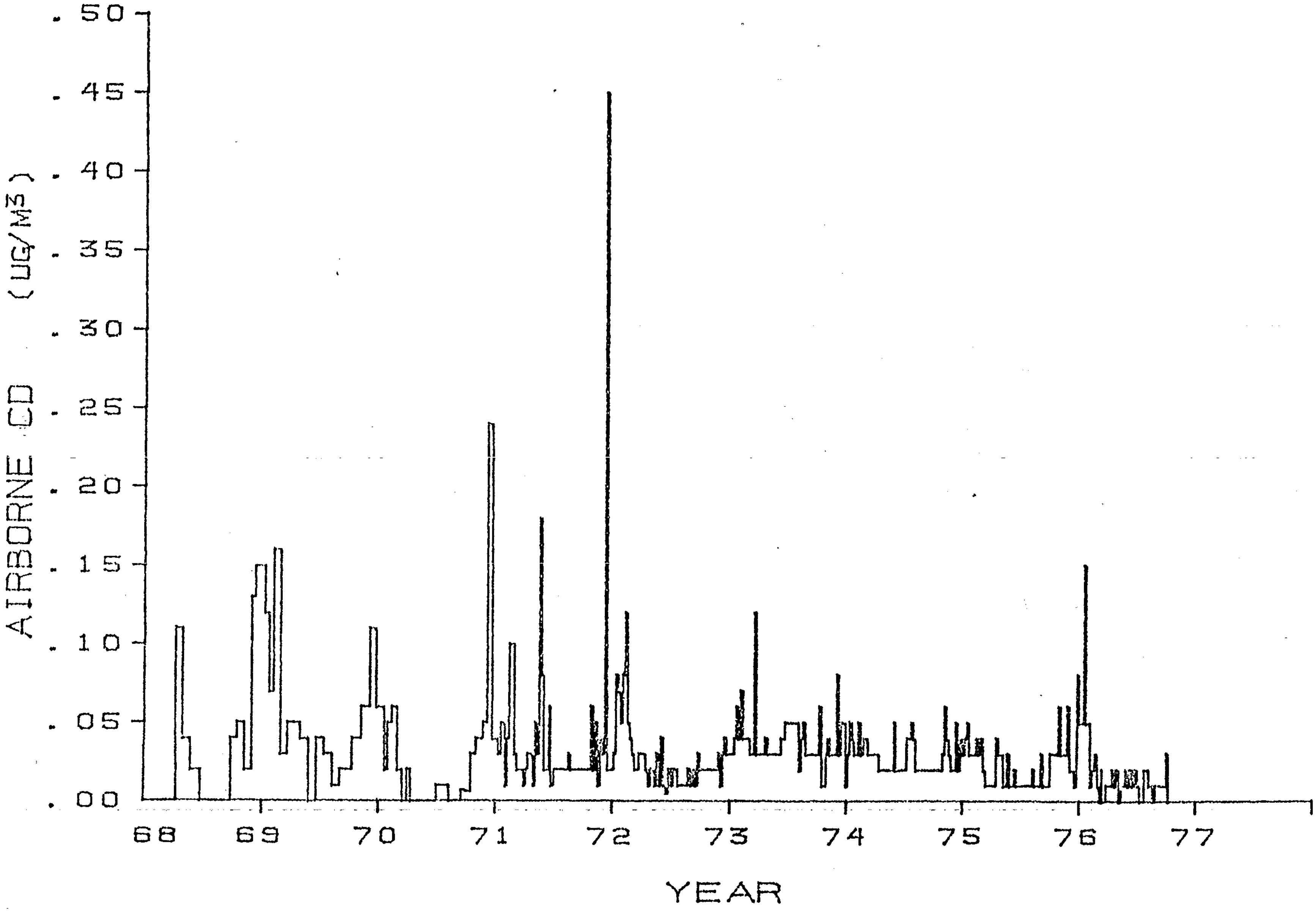
APPENDIX F (Continued)

ASARCO D. O. E. S.

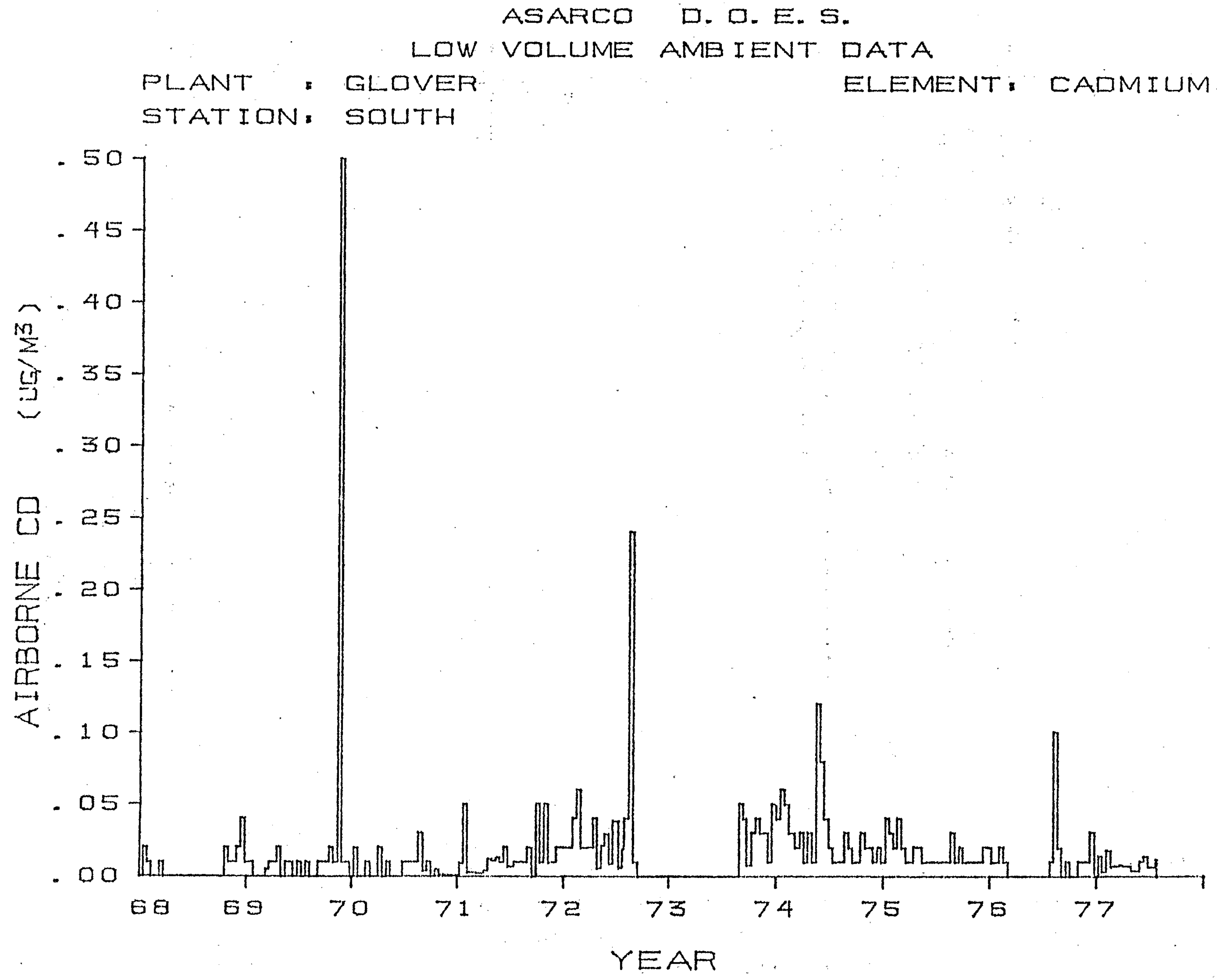
LOW VOLUME AMBIENT DATA

PLANT : EL PASO ELEMENT: CADMIUM

STATION: ZORK



APPENDIX F (Continued)



APPENDIX F (Continued)

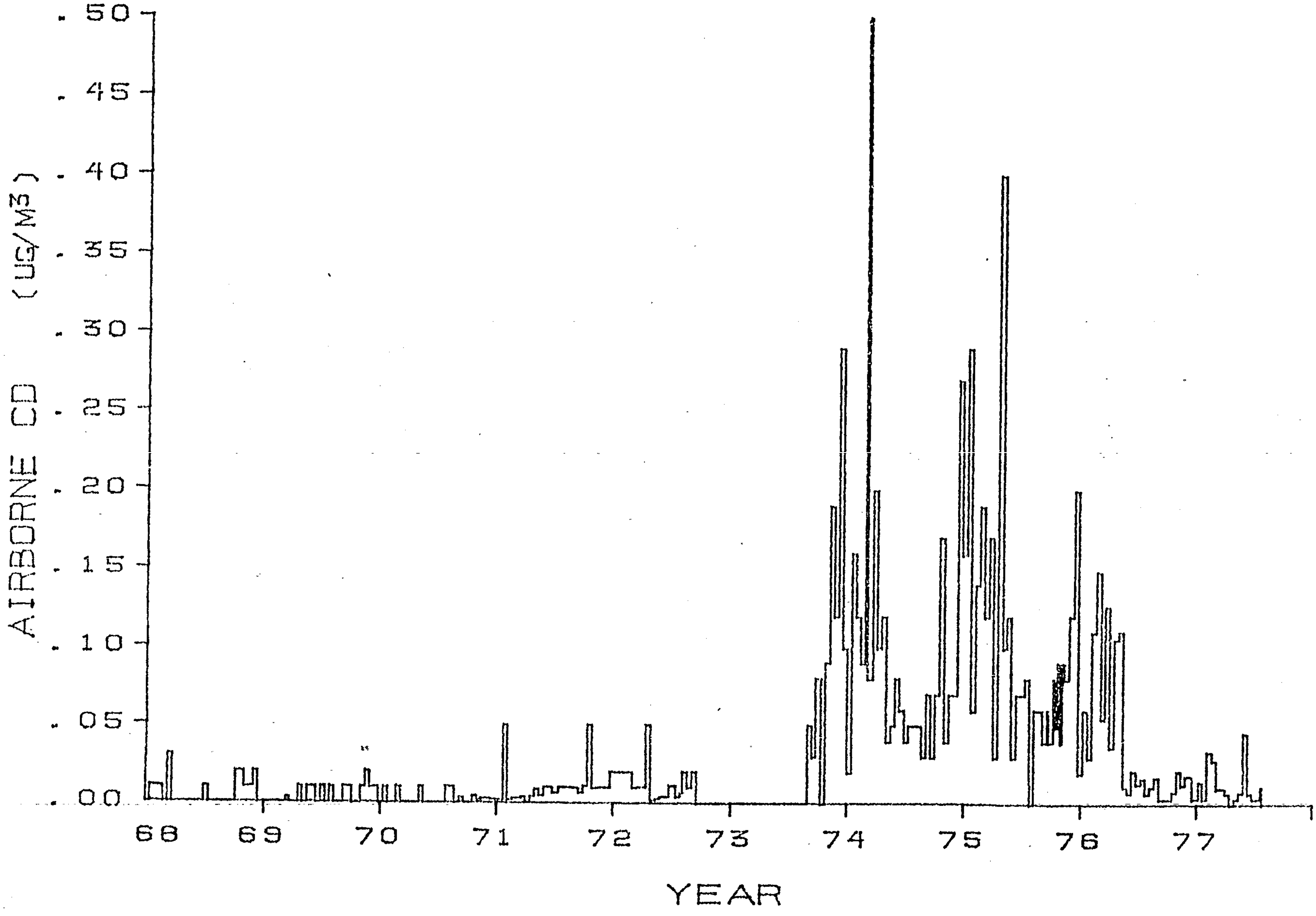
ASARCO D. O. E. S.

LOW VOLUME AMBIENT DATA

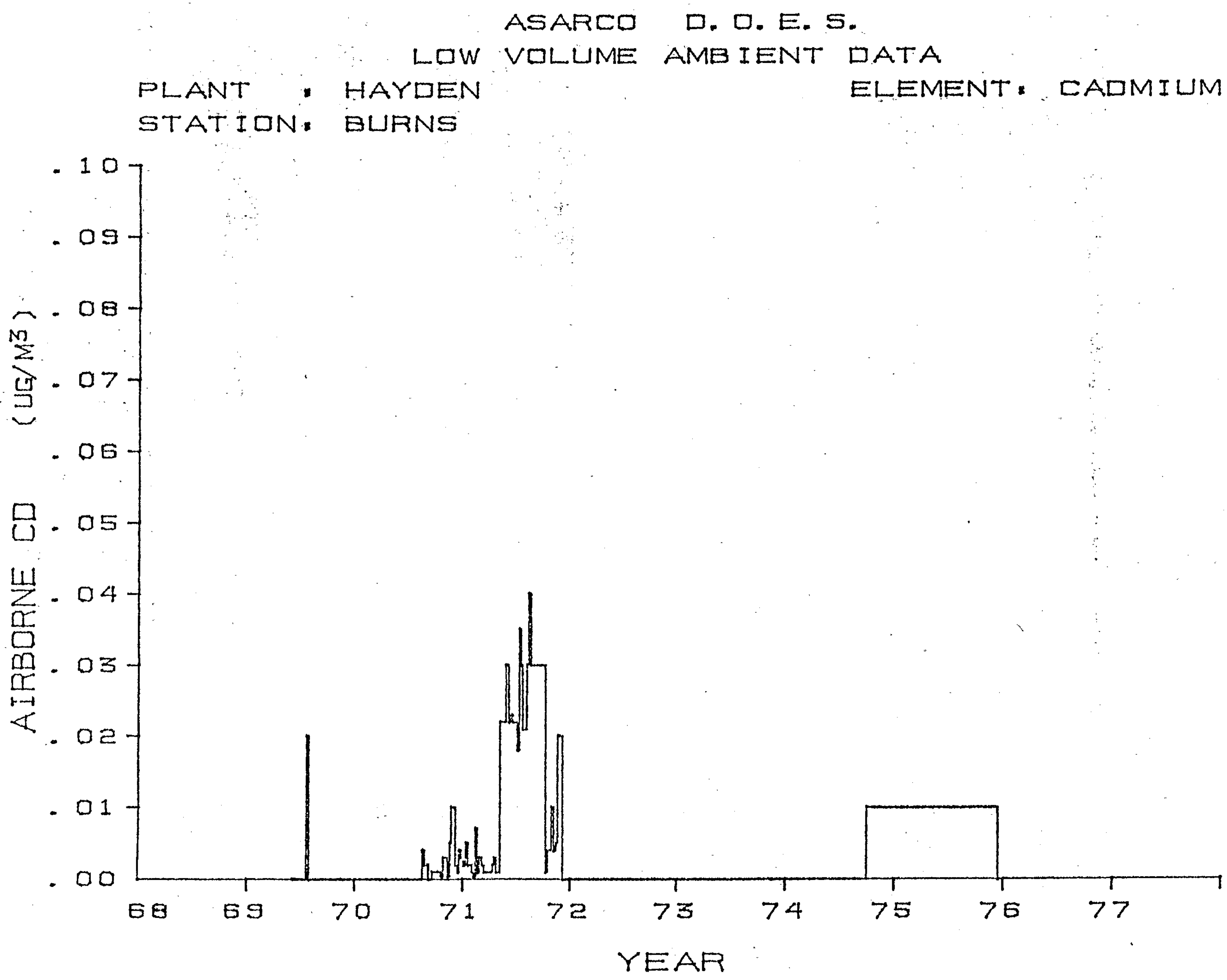
PLANT : GLOVER

STATION: NORTH

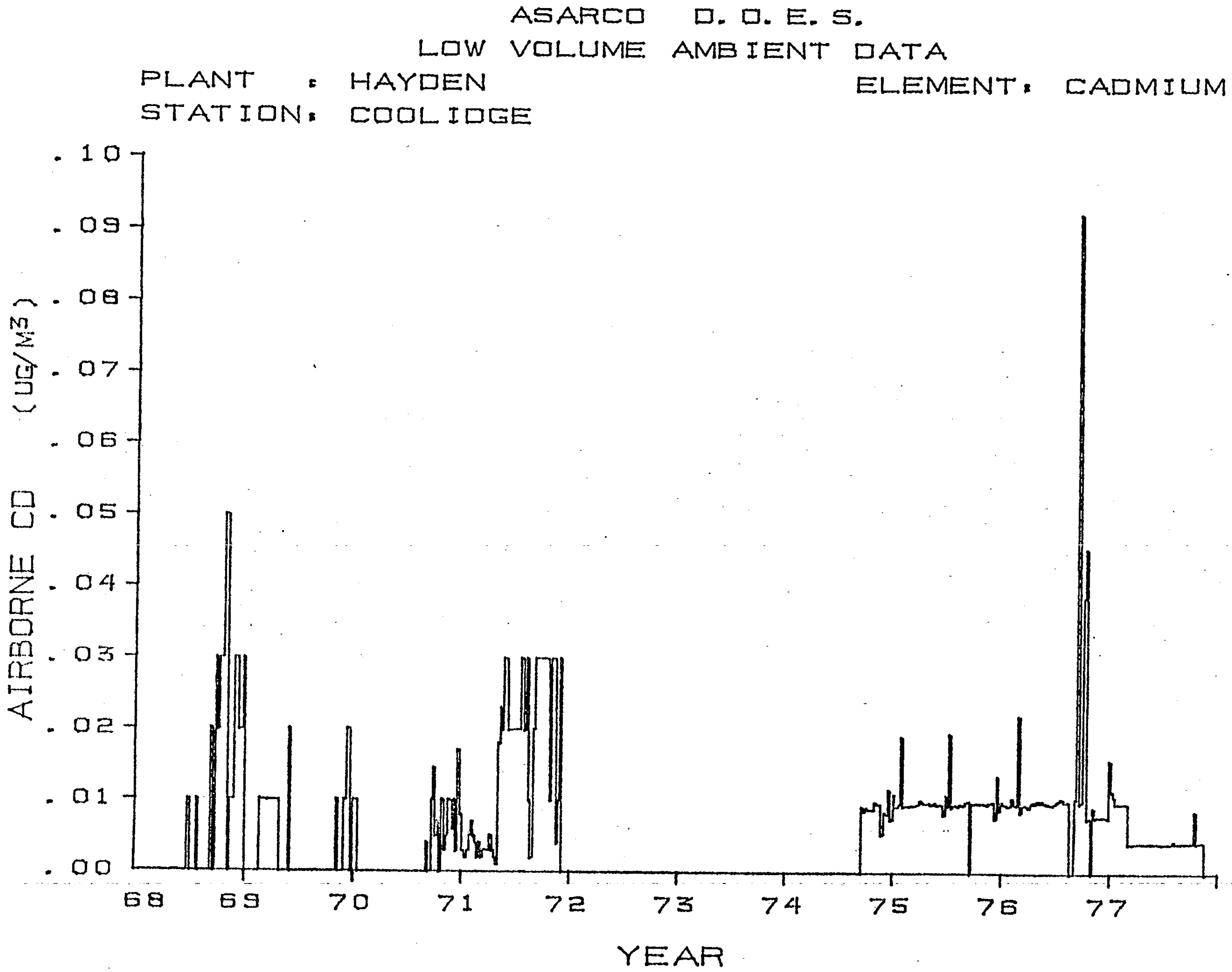
ELEMENT: CADMIUM



APPENDIX F (Continued)



APPENDIX F (Continued)



APPENDIX F (Continued)

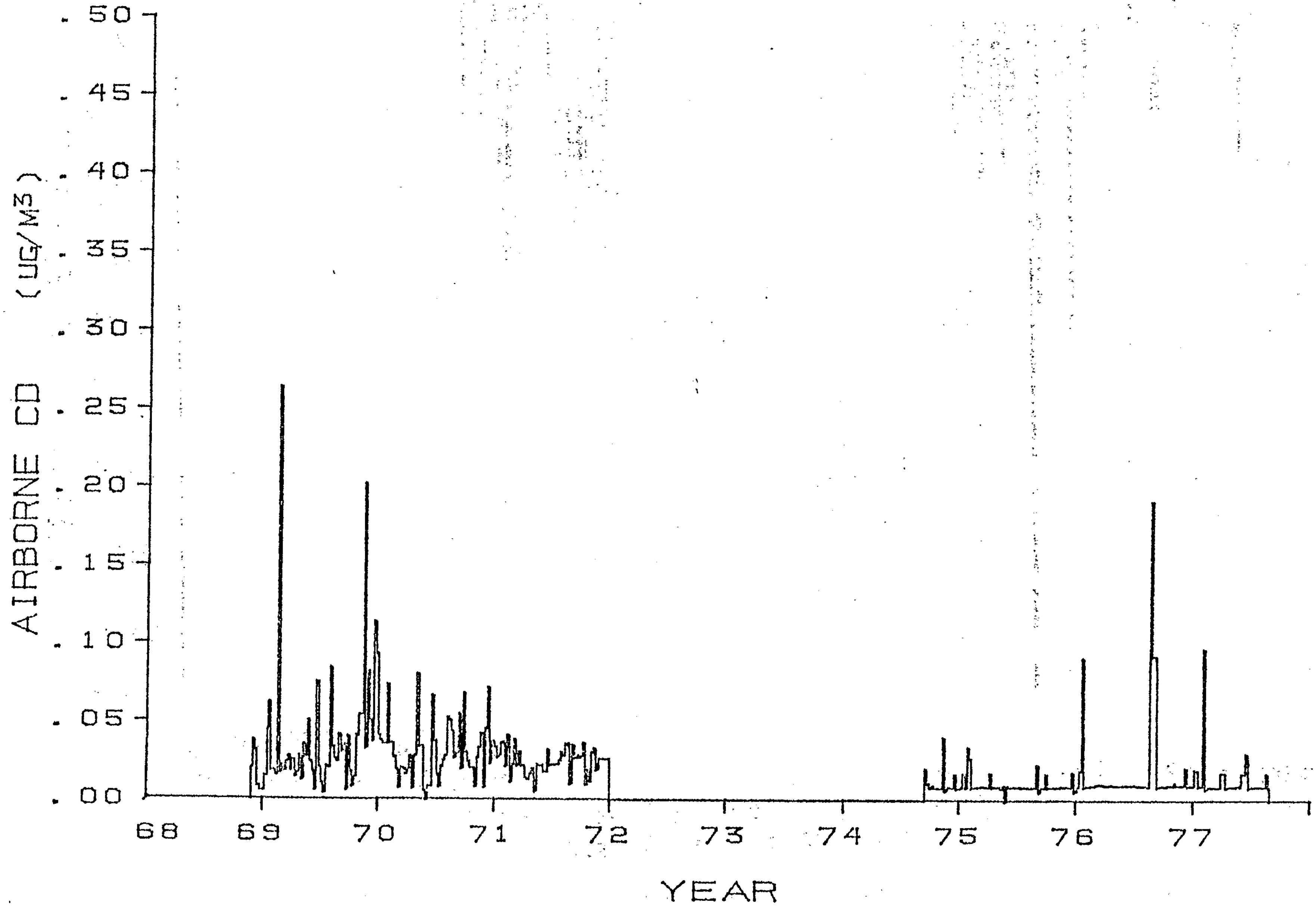
ASARCO D. O. E. S.

LOW VOLUME AMBIENT DATA

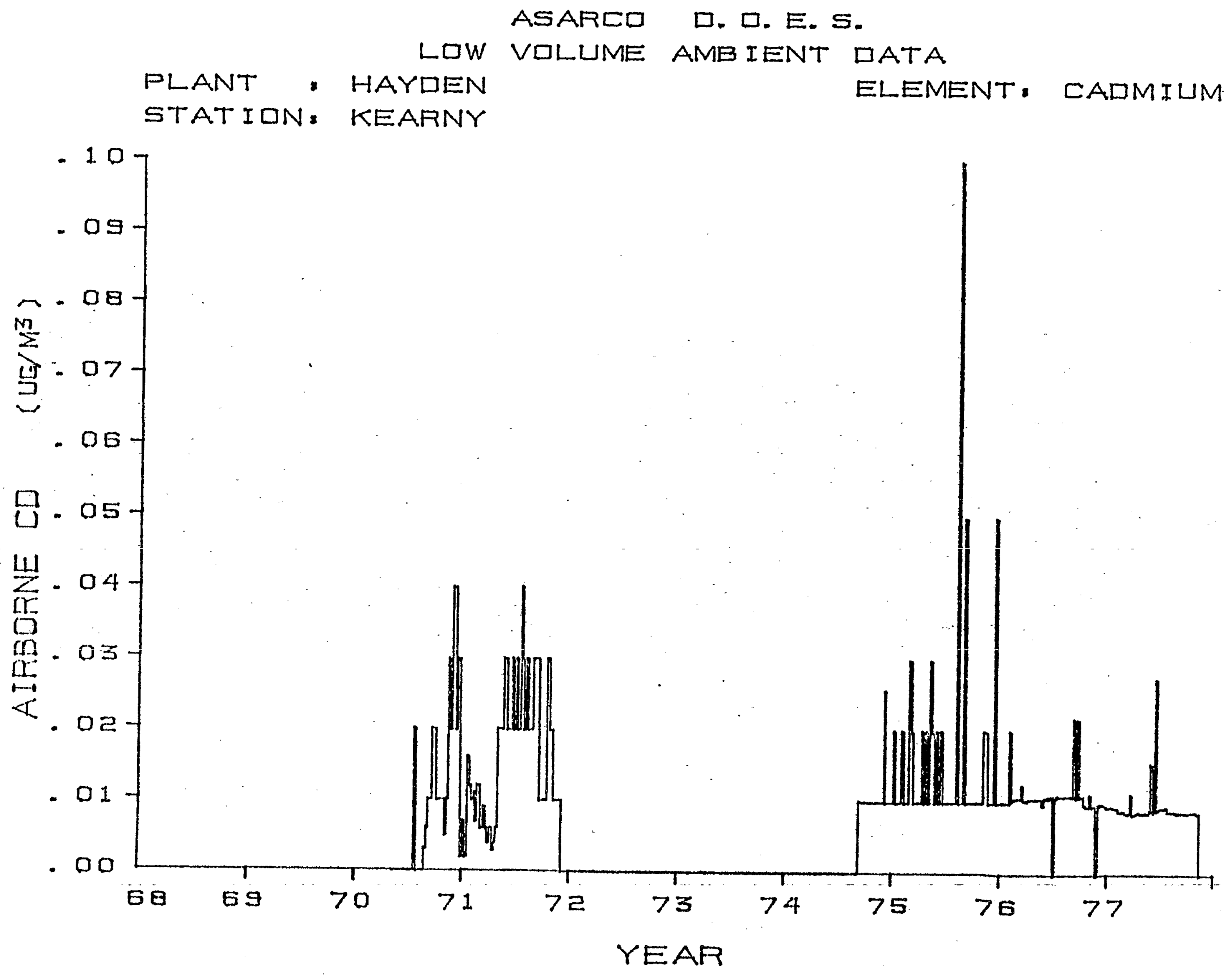
PLANT : HAYDEN

STATION: HAYDEN

ELEMENT: CADMIUM



APPENDIX F (Continued)



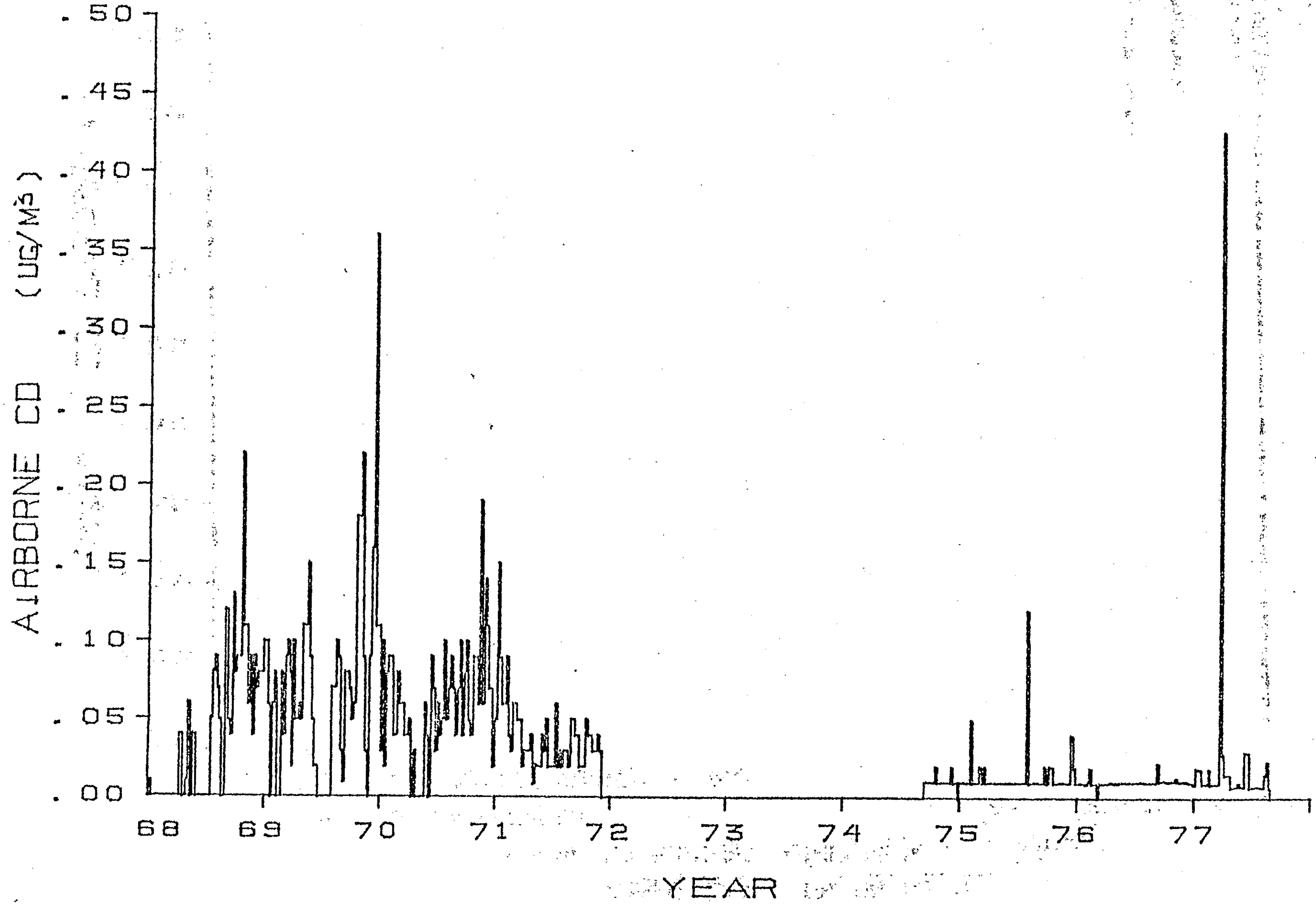
APPENDIX F (Continued)

ASARCO D. O. E. S.

LOW VOLUME AMBIENT DATA

PLANT : HAYDEN ELEMENT: CADMIUM

STATION: MONTGOMERY #1



F-25

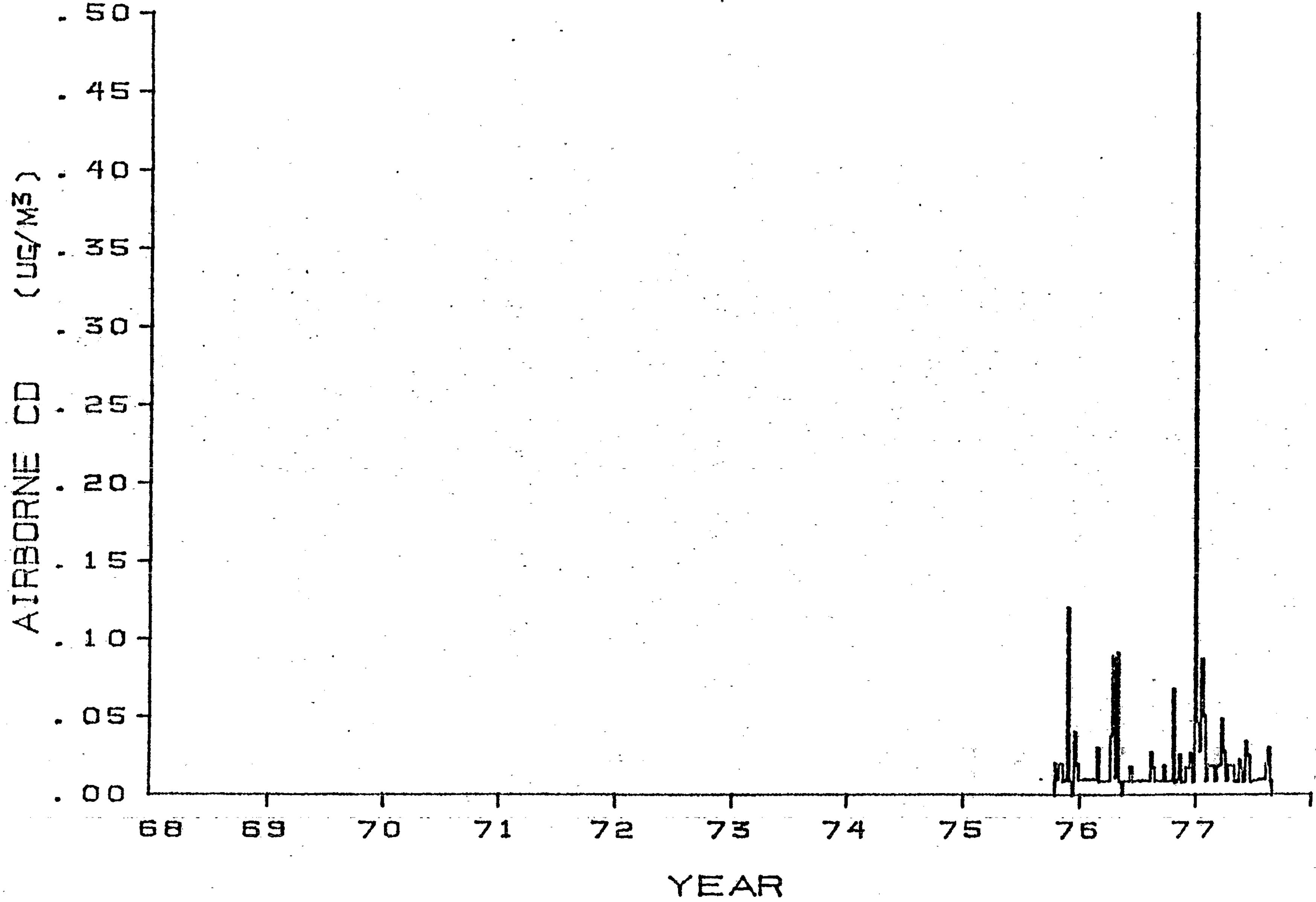
APPENDIX F (Continued)

ASARCO D. O. E. S.

LOW VOLUME AMBIENT DATA

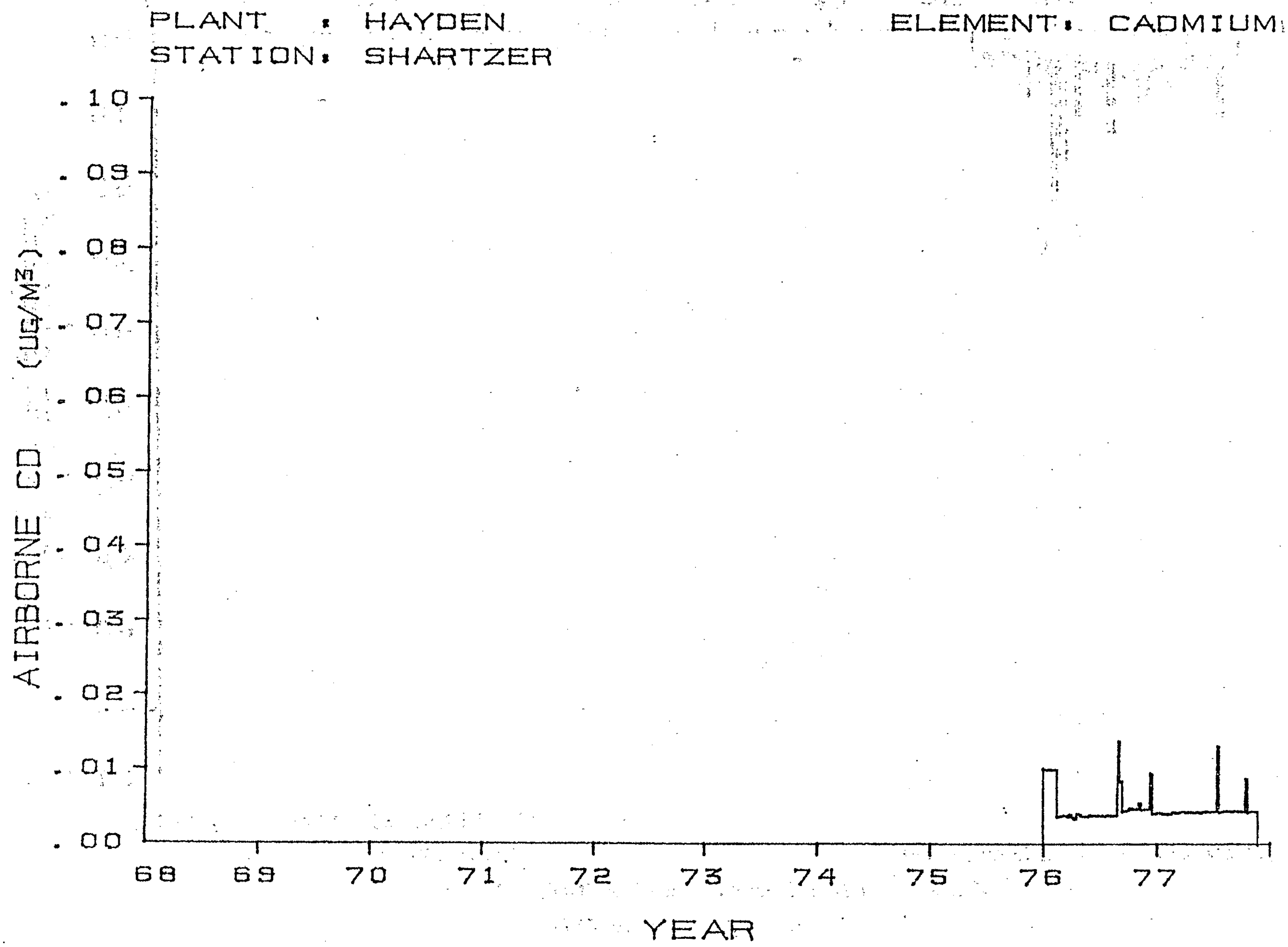
PLANT : HAYDEN ELEMENT: CADMIUM

STATION: MONTGOMERY #2

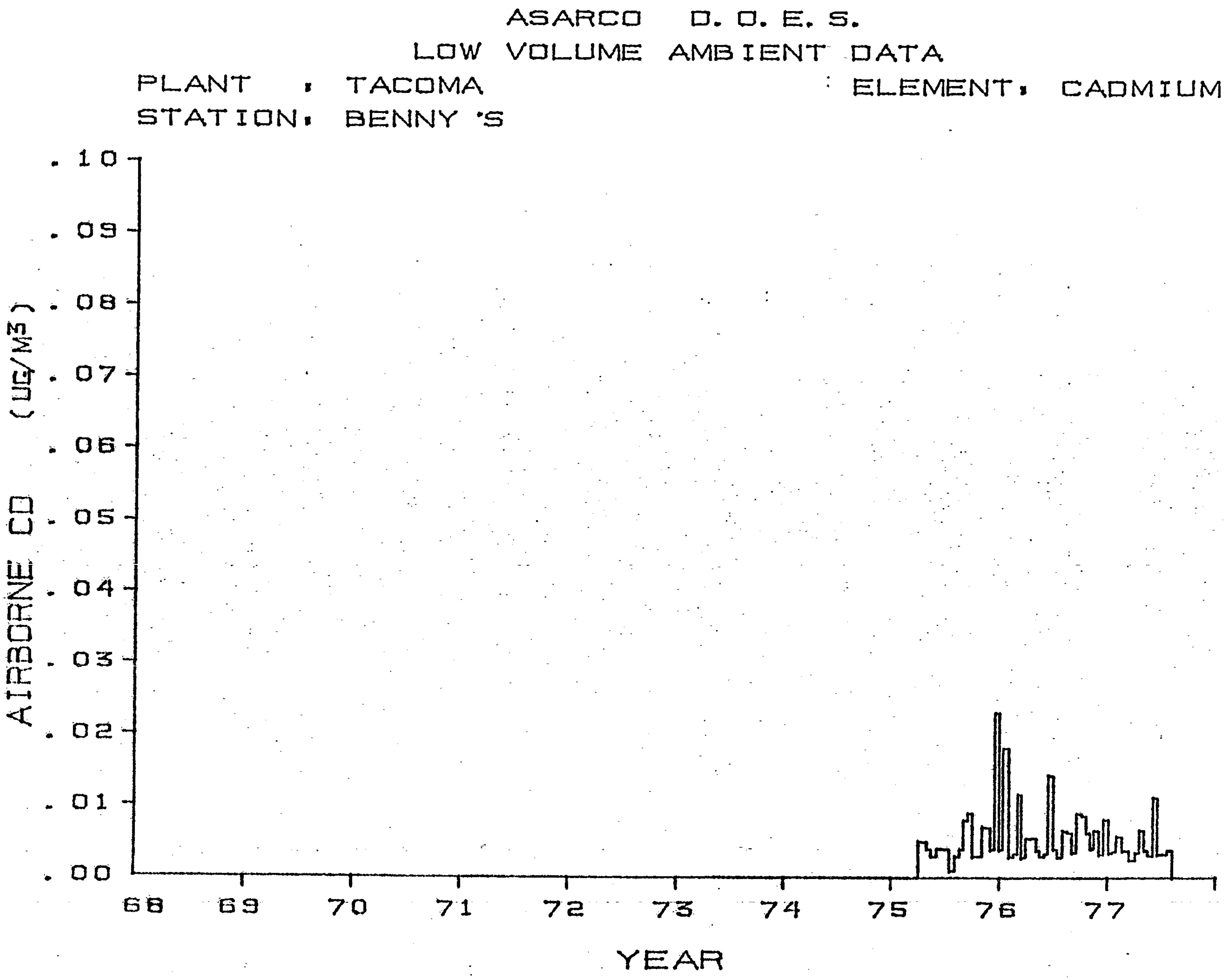


APPENDIX F (Continued)

ASARCO D. O. E. S.
LOW VOLUME AMBIENT DATA

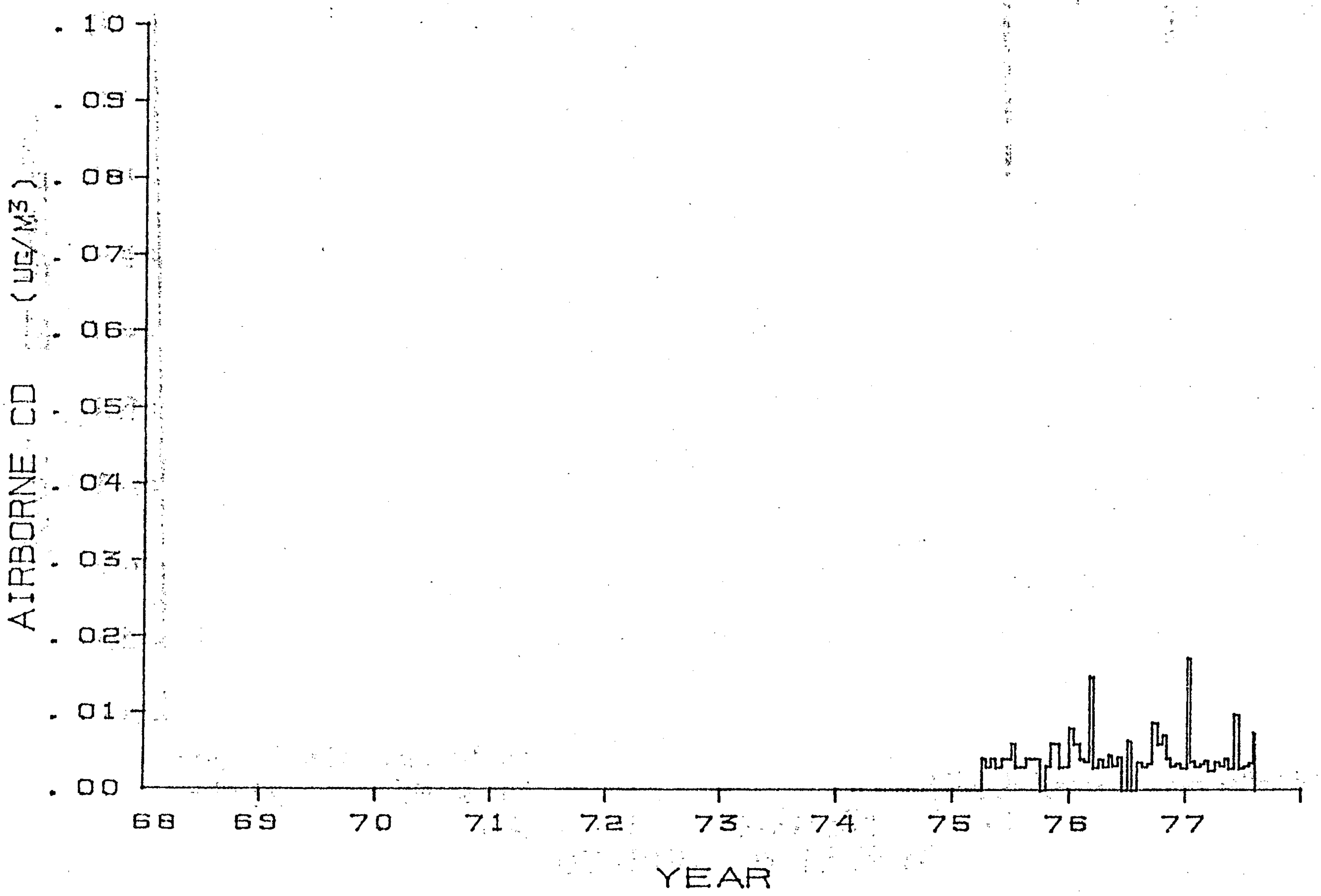


APPENDIX F (Continued)



APPENDIX F (Continued)

ASARCO D. O. E. S.
LOW VOLUME AMBIENT DATA
PLANT : TACOMA ELEMENT: CADMIUM
STATION: BROWN 'S POINT

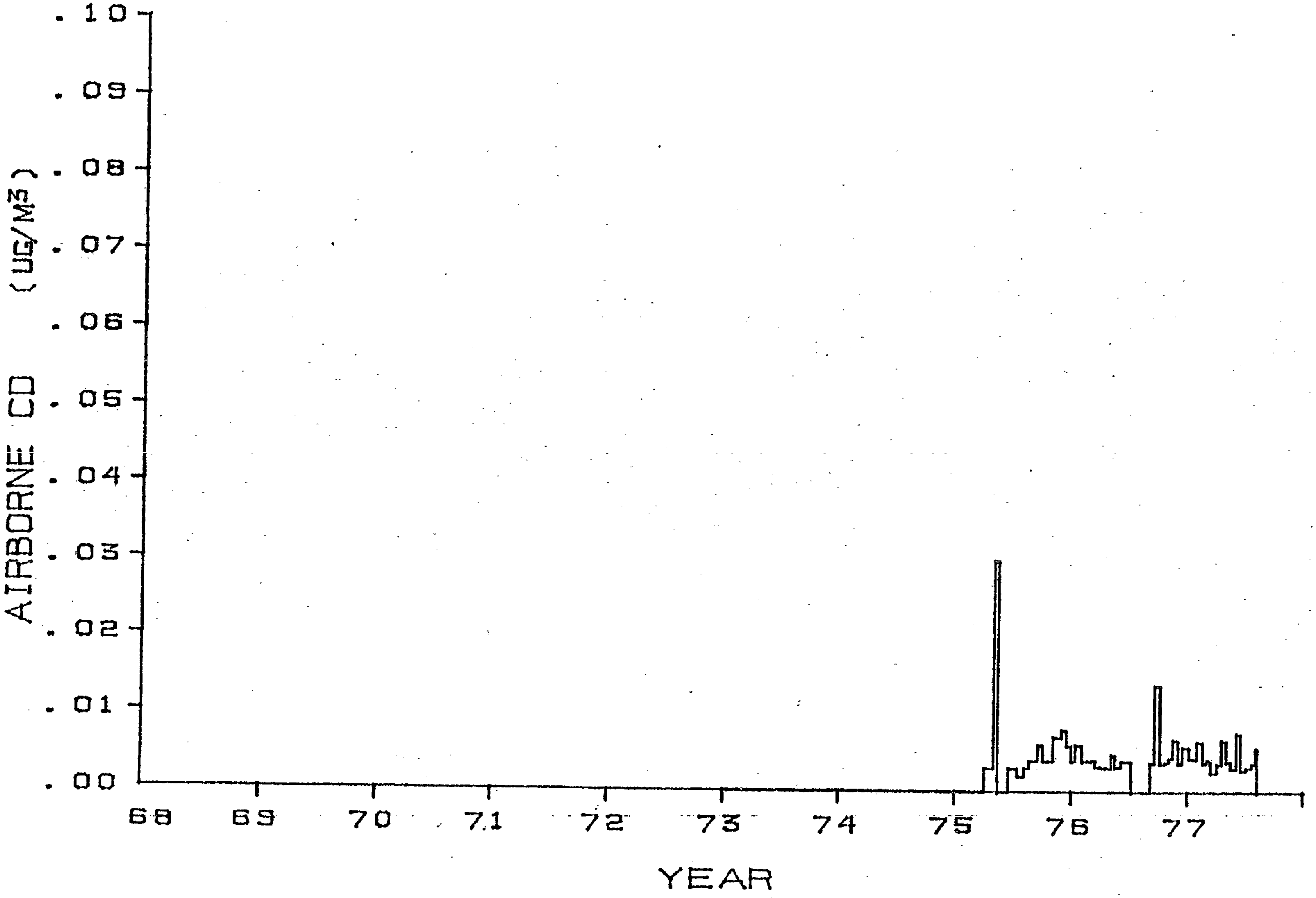


APPENDIX F (Continued)

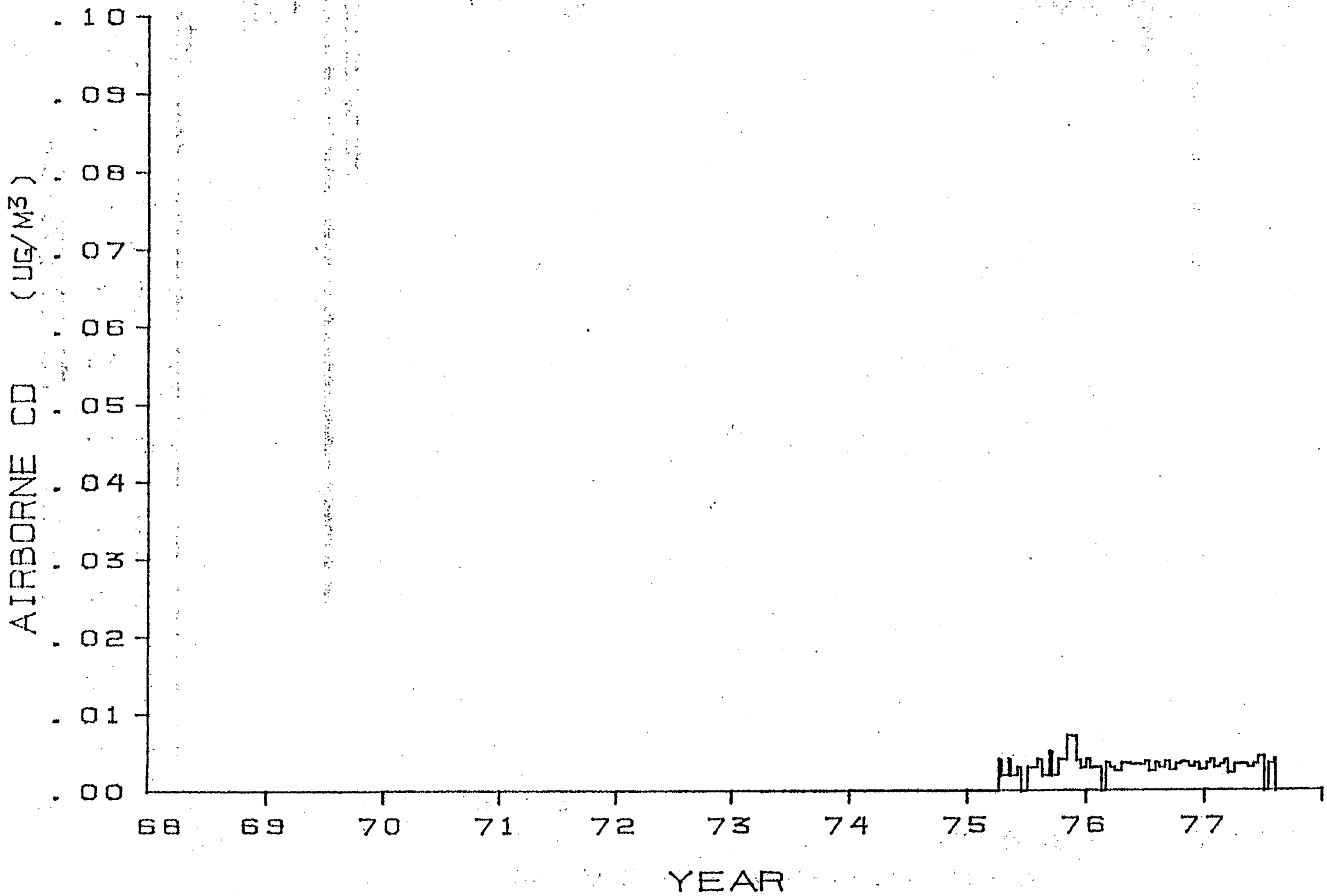
ASARCO D. O. E. S.
LOW VOLUME AMBIENT DATA

PLANT : TACOMA
STATION: OHLSON

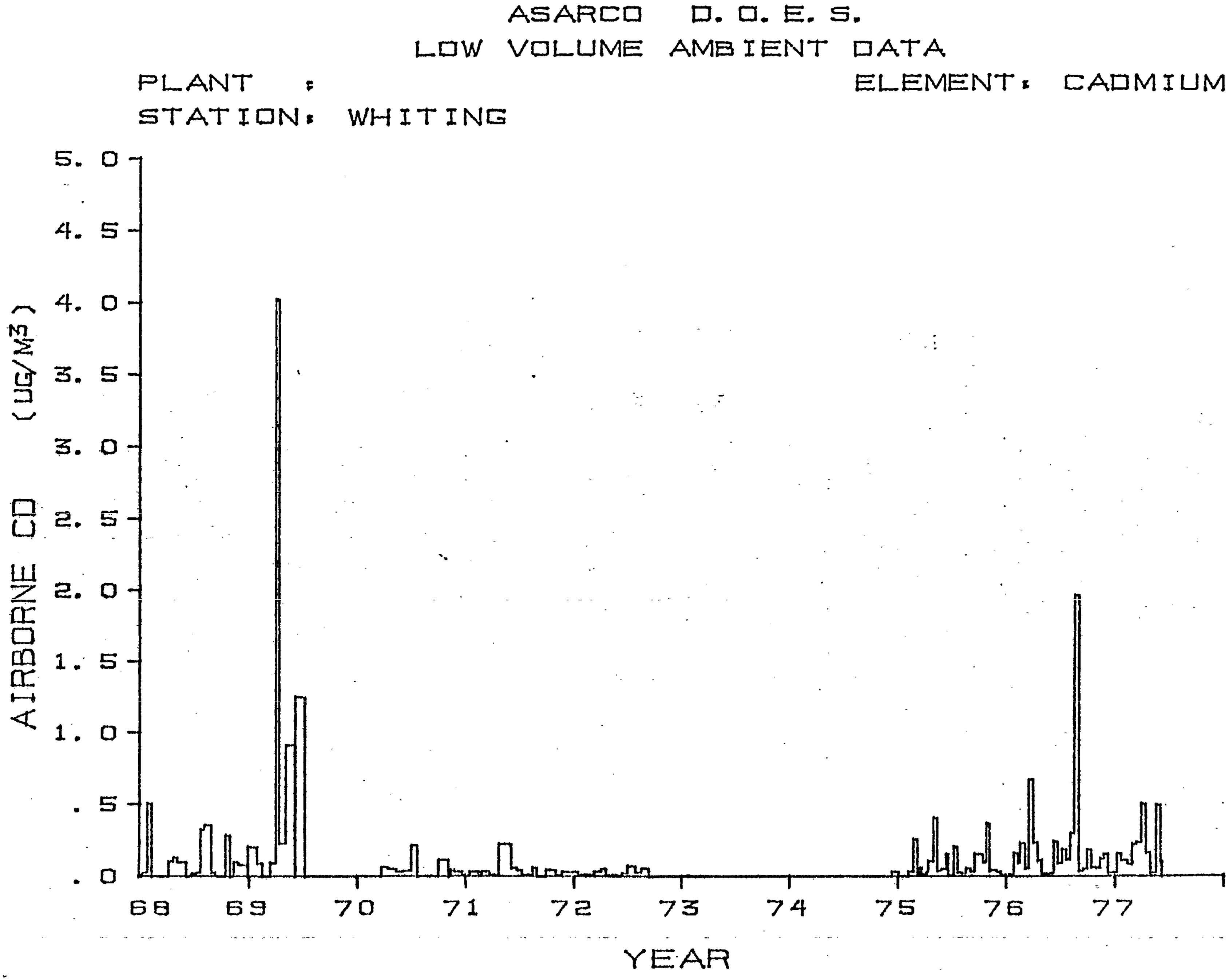
ELEMENT: CADMIUM



ASARCO D. O. E. S.
LOW VOLUME AMBIENT DATA
PLANT : TACOMA ELEMENT: CADMIUM
STATION: VASHON ISLAND



APPENDIX F (Continued)



APPENDIX G

ESTIMATED POPULATION EXPOSED TO SPECIFIED LEVELS FROM PRIMARY COPPER SMELTERS (10^3 people)

Region	1% Fugitive Concentration (ng/m^3)					2% Fugitive Concentration (ng/m^3)					5% Fugitive Concentration (ng/m^3)				
	>1000	>100	>50	>10	>0.1	>1000	>100	>50	>10	>0.1	>1000	>100	>50	>10	>0.1
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	1.1	18.9	0	0	0	1.1	18.9	0	0	0	1.2	18.9
5	0	0	0	0	1.4	0	0	0	0.1	1.4	0	0	0	0.3	1.4
6	0	0	0	0	3.2	0	0	0	0.1	3.6	0	0	0	0.4	6.8
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0.1	84.1	0	0	0	0.1	85.4	0	0	0	0.6	89.0
9	0	0	0	0.7	22.4	0	0	0.1	1.5	29.7	0	0.1	0.3	5.2	52.0
10	0	0	0	0.6	82.1	0	0	0.1	1.3	122.0	0	0.1	0.3	5.2	205.0
TOTAL	0	0	0	2.5	212.1	0	0	0.2	4.2	261.0	0	0.2	0.6	12.9	373.1

APPENDIX G

ESTIMATED POPULATION EXPOSED TO SPECIFIED LEVELS FROM PRIMARY LEAD SMELTERS (10^3 people)

Region	1% Fugitive Concentration (ng/m^3)					2% Fugitive Concentration (ng/m^3)					5% Fugitive Concentration (ng/m^3)				
	>1000	>100	>50	>10	>0.1	>1000	>100	>50	>10	>0.1	>1000	>100	>50	>10	>0.1
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0.2	59.8	0	0	0	1.5	59.8	0	0.1	0.2	4.1	59.8
8	0	0	0	0.3	28.5	0	0	0	0.7	28.5	0	0	0.1	1.7	28.5
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0.2	15.7	17.4	0	0.1	0.4	13.8	17.4	0	0.1	0.7	13.8	17.4
TOTAL	0	0	0.2	16.2	105.7	0	0.1	0.4	16.0	105.7	0	0.2	1.0	19.6	105.7

APPENDIX G

ESTIMATED POPULATION EXPOSED TO SPECIFIED LEVELS FROM PRIMARY CADMIUM SMELTERS (10^3 people)

Region	1% Fugitive Concentration (ng/m^3)					2% Fugitive Concentration (ng/m^3)					5% Fugitive Concentration (ng/m^3)				
	>1000	>100	>50	>10	>0.1	>1000	>100	>50	>10	>0.1	>1000	>100	>50	>10	>0.1
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0.2	100.4	0	0.1	0.2	0.7	100.4	0.1	0.3	0.5	2.3	100.4
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	32.4	0	0	0	0	32.4	2.2	2.2	2.2	2.2	32.4
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0.1	0.7	17.2	0.1	0.2	0.4	1.6	17.2	0.3	0.7	1.4	3.1	17.2
TOTAL	0	0	0.1	0.9	150.0	0.1	0.3	0.6	2.3	150.0	2.6	3.2	4.1	7.6	150.0

APPENDIX G

ESTIMATED POPULATION EXPOSED TO SPECIFIED LEVELS FROM PRIMARY SMELTERS (10^3 people)

Region	1% Fugitive Concentration (ng/m^3)					2% Fugitive Concentration (ng/m^3)					5% Fugitive Concentration (ng/m^3)				
	>1000	>100	>50	>10	>0.1	>1000	>100	>50	>10	>0.1	>1000	>100	>50	>10	>0.1
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0.1	24.7	210.5	358.8	358.8	0.2	27.9	219.7	358.8	358.8	0.7	51.6	250.5	358.8	358.8
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	5.7	17.2	17.2	17.2	0	5.9	17.2	17.2	17.2	0.2	6.9	17.2	17.2	17.2
TOTAL	0.1	30.4	227.7	376.0	376.0	0.2	33.8	236.9	376.0	376.0	0.9	58.5	267.7	376.0	376.0

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-450/5-79-007	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Assessment of Human Exposures to Atmospheric Cadmium		5. REPORT DATE June 1979
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Robert Coleman, et al.		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Energy and Environmental Analysis 1111 North 19th Street Arlington, VA 22209		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 68-02-2836
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Air Quality Planning and Standards Pollutant Strategies Branch Research Triangle Park, N.C. 27711		13. TYPE OF REPORT AND PERIOD COVERED Final
		14. SPONSORING AGENCY CODE EPA

15. SUPPLEMENTARY NOTES

Task Officer was Richard Johnson, OAQPS/SASD, MD-12

16. ABSTRACT

This report is one of a series of reports which will be used by EPA in responding to the Congressional mandate under the Clean Air Act Amendments of 1977 to determine whether atmospheric emissions of cadmium pose a threat to public health. The report identifies the population exposed to specified cadmium levels from selected point sources. The sources considered are iron and steel mills, municipal incinerators, primary smelters (zinc, copper, lead, and cadmium), and secondary smelters (copper and zinc). Municipal incinerators are the chief contributors to the total population exposed. Primary zinc and primary copper smelters are estimated to cause the highest concentrations.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Cadmium Air Pollution Populations Exposures Atmospheric Concentrations Sources		

18. DISTRIBUTION STATEMENT Unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 134
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

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