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Field Trial of the

*AIR*DAR TECHNOLOGY

at the

Facility XX Gas Plant

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EXECUTIVE SUMMARY

A trial of the AIRDAR technology took place at the Conoco-Phillips Facility XX facility between August and November 2006. The AIRDAR Technology is an innovative fugitive emission surveillance system that provides a continuous quantification of fugitive emissions for the overall site and individual sources. The AIRDAR technology is under development with a focus of providing actionable information to the oil and gas industry.

The results of the Facility XX field trial were dominated by one very large emission source that persisted during the testing. This large emission source made it difficult to characterize smaller sources within the gas plant, but two sources outside the fence were identified. The AIRDAR technology can work around large emission sources with an adjustment to the locations of the remote sample inlets, however there was not time to make these adjustments during this field trial.

Emission maps were generated over two time periods; September 25 to October 1 (map delivered on October 5), and October 17 to November 18 (map delivered on December 5). The first map identified a large emission source (averaging 5899 $10^3 m^3$/yr, valued at over $1.5 million/yr) near the amine building. An inspection of the area determined the emission source to be an amine tank which was venting at such a high rate that it generated a high pitched sound that was audible from the ground beside the tank. Secondary quantification of this leak was not possible because plant operations declared the area unsafe and moved directly to repair. Location and quantification of other emitting sources was not undertaken in the first mapping period because of the large emission source present.

The second AIRDAR mapping period showed, once again, a significant emission source (3200 $10^3 m^3$/yr, over $800,000/yr) at the area of the amine tank. An effort was made in the second map to locate and quantify other sources but this was impaired because of the large source at the amine tank and the distortion this causes. Two emission sources outside of the fence were identified in the second mapping period in areas of the facility where underground pipe lines exist.

A field survey of the plant with an emissions camera operated by a Conoco-Phillips team was conducted and confirmed that the amine tank's venting was the largest emission on the site. The emission rate witnessed at the vent during the field survey roughly coincided with the rate predicted by the AIRDAR technology.

The venting at the condensate and sour water tanks was also characterized. These emitting sources were quantified by AIRDAR and found to average 31 and 470 $10^3 m^3$/yr respectively. The camera field survey concurred with the AIRDAR assessment of the emission rates at these tanks.

The capability of the AIRDAR technology to quantify the overall emission rate and to locate and characterize large emission sources was successfully demonstrated in this field

trial. The AIRDAR capability of locating and characterizing small emitting sources was not well demonstrated in this trial due to the large emission source that persisted throughout the trial.

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1.0 INTRODUCTION

This is a report of the field trial of "AIR Detection and Ranging" (*AIR*DAR) technology at the Conoco-Phillips Canada, Facility XX Gas Plant. AIRDAR is a new technology that employs simple field equipment and high-end data analysis to intercept emission plumes and track them back to their sources.

The objective of this project was to demonstrate the ability of the AIRDAR technology to detect, locate, and quantify fugitive emissions of natural gas at a gas facility. This main objective was to be accomplished by completing the following tasks at a facility:

- Provide fugitive emission maps of the facility;
- Determine overall facility emission rates;
- Estimate locations of the important leaks;
- Characterize the nature of the important leaks (i.e. size, stability, and frequency).

These tasks were accomplished, however there was a significant delay in delivering on the project that is discussed in the project schedule section of the report.

This report provides background on the AIRDAR technology, a description of the deployment at the Facility XX facility, and a discussion of the results.

The AIRDAR technology is under development with a focus on supporting the oil and gas industry's corporate goals.

Value of the gas in the emission sources was estimated by assuming the heating value of the gas at 37.4 MJ/m^3 and the price of gas at $6.90/GJ CND (www.ngx.com, December average natural gas price).

2.0 PROJECT SCHEDULE

The project schedule with the planned and actual timing of the activities is shown in Table 1. The project began on June 6, 2006 when approval was received to proceed. The mobilization and deployment phases went as planned, but there was a malfunction in the equipment that resulted in faulty data in the first seven weeks of data collection. The equipment problems were identified in the fourth week of data collection and it took an additional three weeks to make modifications to correct the problem. This trial used a new prototype equipment package that was recently developed to simplify the deployment of the AIRDAR technology. The significant delay in the project was due to a redesign and modification that was required to overcome the performance short falls in this prototype equipment package. The first map was delivered on October 5 and the second map was delivered on December 5.

3.0 BACKGROUND ON AIRDAR

A new and exciting technology has emerged that locates and characterizes emission sources. The technology is called AIR Detection And Ranging (*AIR*DAR) and it is best described as "radar for emitting sources". *AIR*DAR is in a class of technologies along with SONAR (SOund Navigation And Ranging) which uses sound waves to locate or track things; or RADAR (RAdio Detection And Ranging) which uses radio waves to detect and track objects; or LIDAR (LIght Detection And Ranging) which uses light waves to detect things. *AIR*DAR detects and ranges emission sources using compounds that travel in the air.

In field trials, the success of the *AIR*DAR Technology has convinced all involved that it is an effective technology. Not only did the *AIR*DAR Technology accurately locate and characterize a suspected fugitive emission that had eluded attempts to locate it with other technologies, it also located a fugitive source 700 meters away in the opposite direction that was not suspected. This early field success brought into sharp focus the unique advantage of the *AIR*DAR Technology, which is the attribute of true surveillance. The competing technologies all are directed, in one form or another, based on assumptions of where and when the leaks will occur. While other technologies are directional, that is they are pointed at suspected leaking components, *AIR*DAR is not and looks everywhere, always (i.e. true surveillance). True surveillance is essential for tracking fugitive emission sources because it is often not the suspected sources that are troublesome. Often the unexpected fugitive sources that elude both operators and directed monitoring technologies are a bigger problem.

The underlying innovative breakthrough with *AIR*DAR is the ability to see and track plumes with a point observation of air concentration. Point observation is the common way ambient air is monitored - that is, an instrument draws a sample from one place in the air and provides a measure of concentration in that sample. To date, these point measurements have not been used to track plumes from emission sources. Currently, the measurement of emission plumes is done with open path sensor (lasers or the like) that intercept the plume with a beam that can give an indication of the concentration in the plume and emission rate of the source. The open path systems cannot track the plume back to the source or resolve multiple sources. Some plumes can be detected with infrared cameras, another technology that is able to locate plumes and even track them back to the source, but emission rates cannot be characterized. The *AIR*DAR Technology's capability to use common point observations to track plumes back to sources and characterize emission rates is a significant breakthrough.

The AIRDAR technology is being developed with the focus on providing actionable information to industry on fugitive emissions.

4.0 DEPLOYING *AIR*DAR

The AIRDAR equipment was deployed to the Facility XX facility between July 31, 2006 and August 3, 2006. AIRDAR uses a unique approach which involves a single instrument drawing samples from multiple locations by means of long runs of small diameter tubing. These remote sample inlets were positioned at eight locations in and around the Facility XX facility as shown in Figure 1. Figures 2 to 9 show photographs of the remote sample inlets at the Facility XX facility. Small diameter tubing was run from the remote sample inlet locations in Figure 1 along fences and in cable trays back to the lab where the AIRDAR equipment package was located.

Figure 10 shows the lab with the AIRDAR equipment package and the tubing running up through the ceiling tiles and out to the field. The hardware package consists of a portable flame ionization detector (FID) measuring total hydrocarbons and connected to a valve manifold which allows multiple lines to be sampled in turn in a predetermined sequence. The package included a computer which controlled the valve manifold, stored data, and transferred data via the internet. Also shown in the figure are three gas cylinders that provided calibration and fuel gas to the FID instrument. The FID in the hardware package is removable and intrinsically safe. At times during the project the FID was used as a mobile hand held analyzer to confirm locations of predicted emission sources.

A wind monitor was deployed at the remote sampling inlet number 7 as shown in Figure 8 to characterize the wind velocity at the site. The wind data was logged on the computer in the lab along with the concentration data. A data file was emailed out daily through a dial-up internet connection over the phone line.

5.0 AIRDAR RESULTS

AIRDAR results are presented in maps and charts that describe emitting sources. An example of the maps and charts can be seen in Figures 11 and 12. The map in Figure 11 indicates the location of the emitting source with vectors projected outward from the remote sampling inlets (blue triangles) intersecting at the location of the emitting source. The estimated location of the emitting source is indicated by the red dot on the map. The actual location of the emitting source determined by field investigation is shown as a green cross in Figure 11. Details of the emission source characteristics are printed in the figure and provide coordinates, elevation, emission rate, and variability estimates. A more detailed view of the estimated variation of the emission rate is plotted in accompanying chart in Figure 12.

The pertinent information for all the emitting sources identified is summarized in Table 2. Table 3 shows the legend of the symbols used in the maps along with their meaning.

5.1 First mapping period

The first AIRDAR emission map was provided on October the 5^{th} and included an evaluation of data collected over the period September 25 to October 1. The first map identified a large emission source (averaging 5899 10^3m^3/yr, over \$1.5 million/yr) near the amine building (see Figure 11). As the chart in Figure 12 shows, this emission source is continuous with some variability in the rate of emission shown peaking at over 10,000 10^3m^3/yr. An inspection of the area determined the emission source to be an amine tank which was venting at such a high rate that it generated a high pitched sound that was audible from the ground beside the tank. Secondary quantification of this leak was not possible because plant operations declared the area unsafe and they moved directly to repair. Operations determined that the excessive venting was due to the fuel gas line regulator running wide open into the head space in the top of the tank. Location and quantification of other emitting sources was not undertaken on the first map because of the large emission source present.

5.2 Second mapping period

The second AIRDAR emission map was provided on December the 5th and included an evaluation of data collected over the period October 17 to November 18. The second AIRDAR mapping period showed once again a significant emission source (3200 10^3m^3/yr) at the same area of the amine tank as shown in the first map. While an effort was made in the second mapping period to locate and quantify other sources, this was impaired because of the large source at the amine tank and the distortion this causes. Figure 13 and Table 2 summarize all the emissions sources characterized in this second phase of mapping. An emission camera survey conducted by Conoco-Phillips staff, as part of the field investigation portion of this project, identified emission sources at the compressor vents and the sour water tank vent. These sources were previously identified and quantified by AIRDAR technology and are included in the summary.

5.2.1 Emission #1

Figure 14 shows the predicted location of the emission source at the amine tank and the variability over the period of the investigation is shown in Figure 15. The average emission rate for this second mapping period was predicted at 3200 10^3m^3/yr, over $800,000/yr worth of gas. As the chart in Figure 15 shows, there was an increase in the emission rate near the end of the period that resulted in a rate similar to that found in the first mapping period. This emission source was the dominant source found on the site and accounted for 58% of the emissions of hydrocarbons.

The field investigation with the emissions camera identified the amine tank vent as the largest source on the site. The emission rate witnessed at the vent roughly coincided with the rate shown in Figure 15 when you compare the time the field survey was done (i.e. at the second red line in the figure).

5.2.2 Emission #2 and #5

An attempt was made to identify small emission sources. Emissions #2 and #5 were small emission sources, estimated at 50 and 58 10^3m^3/yr respectively with estimated locations shown in Figures 16 and 17. The field camera survey could not locate these sources. This may be due to the relatively high winds and small source size or it may be a false positive signal in the AIRDAR technology resulting from the large emission at the amine tank that persisted (i.e. emission #1). Clarification of these two emissions required more field study time.

5.2.3 Emission #3

This is an estimated emission source that exists outside of the fence in the area of pipe lines that leave the north end of the site as shown in Figure 18. The average emission rate of this source is estimated at 1010 $10^3 m^3$/yr ($260,641/yr) and shows an intermittent emitting pattern as shown in Figure 19.

The field camera survey was not able to locate this emission source. This may be due to the intermittent nature of the emission source or interference from the high winds and heavy snow pack that existed at the time.

5.2.4 Emission #4

This is an estimated emission source that exists outside of the fence in the area of a pipe line that is not shown on the drawing (see Figure 20). The average emission rate of this source is estimated at 163 $10^3 m^3$/yr ($42,064/yr) and shows a fairly continuous emitting pattern as shown in Figure 21.

The field camera survey did not attempt to locate this emission source.

5.2.5 Emission #6

Emission #6 is the condensate tank venting and is located as shown in Figure 13. This emission source was characterized at the request of the plant because they expected high emission rates at the condensate tank. AIRDAR determined the tank was not an important emission source and estimated the average emission rate to be 31 $10^3 m^3$/yr. The variability in the emission rate is shown in Figure 22. This is a minor emission source for the plant.

5.2.6 Emission #7

Emission #7 is the venting off the sour water tank and is located as shown in Figure 13. The location of this emission source was predicted by AIRDAR as indicated by the green circle just west of the sour water tank in Figure 13. The field camera survey confirmed the location of the emission source as the vent on the sour water tank. AIRDAR predicts the size of the actual emission source to be 470 $10^3 m^3$/yr ($122,288/yr) with a fairly constant emission rate as shown in Figure 23.

5.2.7 Overall Emission Rate

The overall average emission rate for the site was estimated, by AIRDAR, as 5660 $10^3 m^3$/yr during the second mapping period. The summary of the emission sources in Table 2 shows the overall rate and each emission source as a percentage of the overall rate. As shown in the table, 11% or 600 $10^3 m^3$/yr of the overall emission rate is not allocated to any individual source. These emissions come from smaller sources or sources that were not identified because of the larger sources present at the site.

6.0 CONCLUSIONS

The objectives of the project were met by the accurate locating and characterizing of the major emitting source on the Facility XX site. The capability of the AIRDAR technology to quantify the overall emission rate and to locate and characterize large emission sources was demonstrated in this field trial.

The AIRDAR capability of locating and characterizing smaller emitting sources was not well demonstrated in this trial due to the large emission source that persisted throughout the trial. The AIRDAR technology can work around large emission sources with an adjustment to the locations of the remote sample inlets, however there was not time to make these adjustment during this field trial.

Admittedly, the delays in delivering the fugitive emission maps of the facility was a disappointment to all involved. Field trials are definitely a challenge. The causes of the delays have already been addressed and to shorten the turn around time of the mapping process is a top priority in the continued development of the AIRDAR technology. AIRDAR is moving towards real-time monitoring.

Table 1: Project schedule

Activity		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	month	J	J	J	J	A	A	A	A	A	S	S	S	S	O	O	O	O	N	N	N	N	N	D	D
	day	6	13	20	27	3	10	17	24	31	7	14	21	28	5	12	19	26	2	9	16	23	30	7	14
Mobilization	plan	xx	xx	xx	xx																				
	actual	##	##	##	##																				
Setup Plant	plan				xx																				
	actual				##																				
Collect data at plant	plan					xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx				
	actual					equipment malfunction							##	##	##	##	##	##	##	##	##	##	##	##	##
Produce monthly AIRDAR maps	plan												xx				xx							xx	
	actual													##										##	

Table 2: Table summarizing the emitting sources characterized in the second mapping period.

Source	Location			Emission	Percent	Value	Emission
	North m	East m	Elevation m	Rate 103m3/yr	of total	$1000s/yr 37.4 MJ/M^3 @$6.90/GJ	Variability
Overall				5660	na	$1,460,620	
#1	508	205	13	3278	58%	$845,921	Constant
#2	504	236	10	50	1%	$12,903	?
#3	536	407	0	1010	18%	$260,641	constant
#4	315	4	0	163	3%	$42,064	constant
#5	519	279	8	58	1%	$14,967	constant
#6				31	1%	$8,000	constant
#7				470	8%	$121,288	intermittent
Undefined	na	na	na	600	11%	$154,836	

Table 3: Legend of the symbols used in the AIRDAR maps and their meanings

Legend

AIRDAR remote sample inlet locations.

Estimated emission source location.

Actual emission source location.

(colored lines) Show the direction at which different plumes were detected by the AIRDAR remote sample inlets.

Possible leak location

Emission characterization requested by the plant

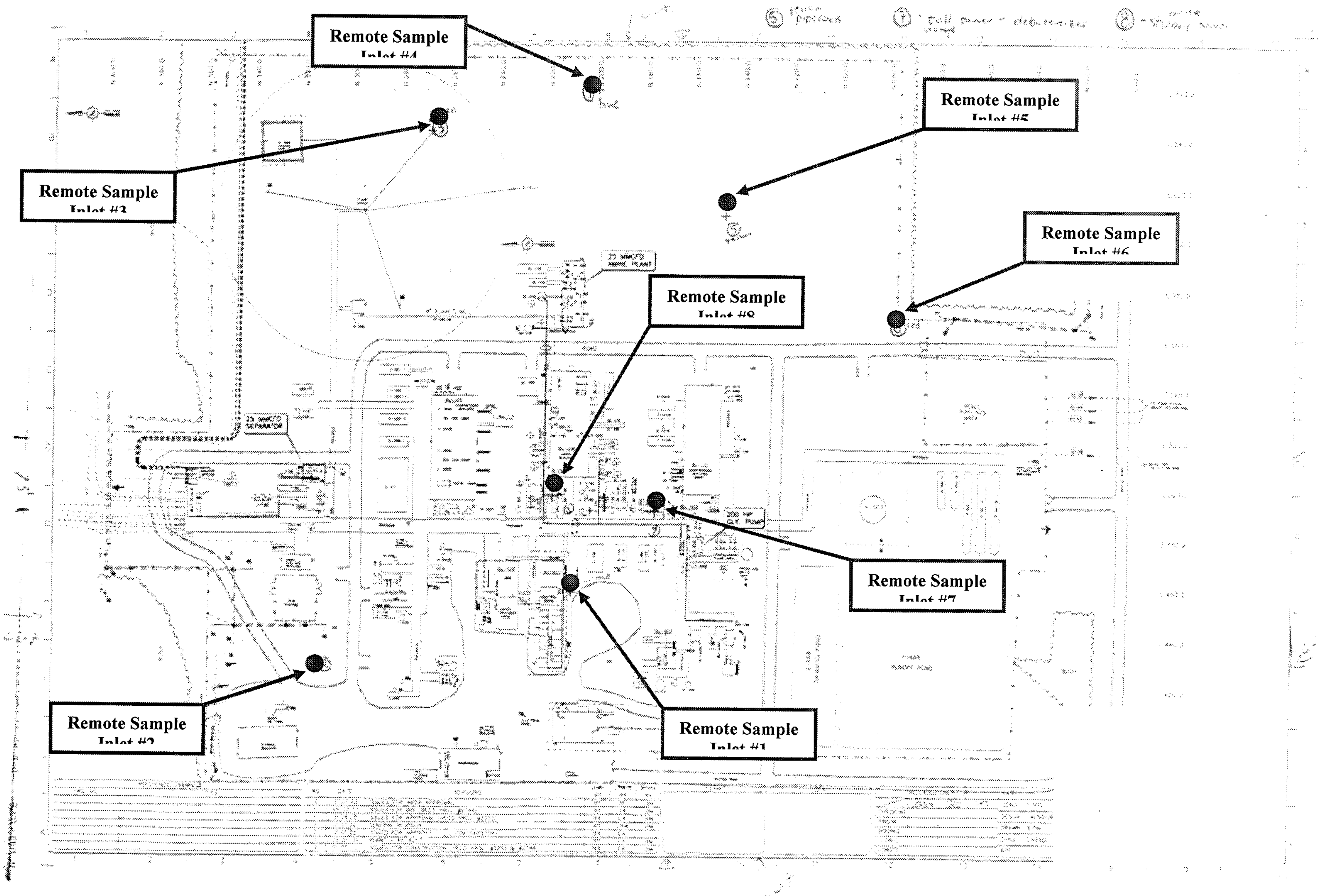

Figure 1: Plot plan of the Conoco-Phillips Canada, Facility XX Gas Plant with locations of the eight AIRDAR remote sample inlets are marked.

Figure 2: A picture of the remote sampling inlet #1 on the radio tower by the control room.

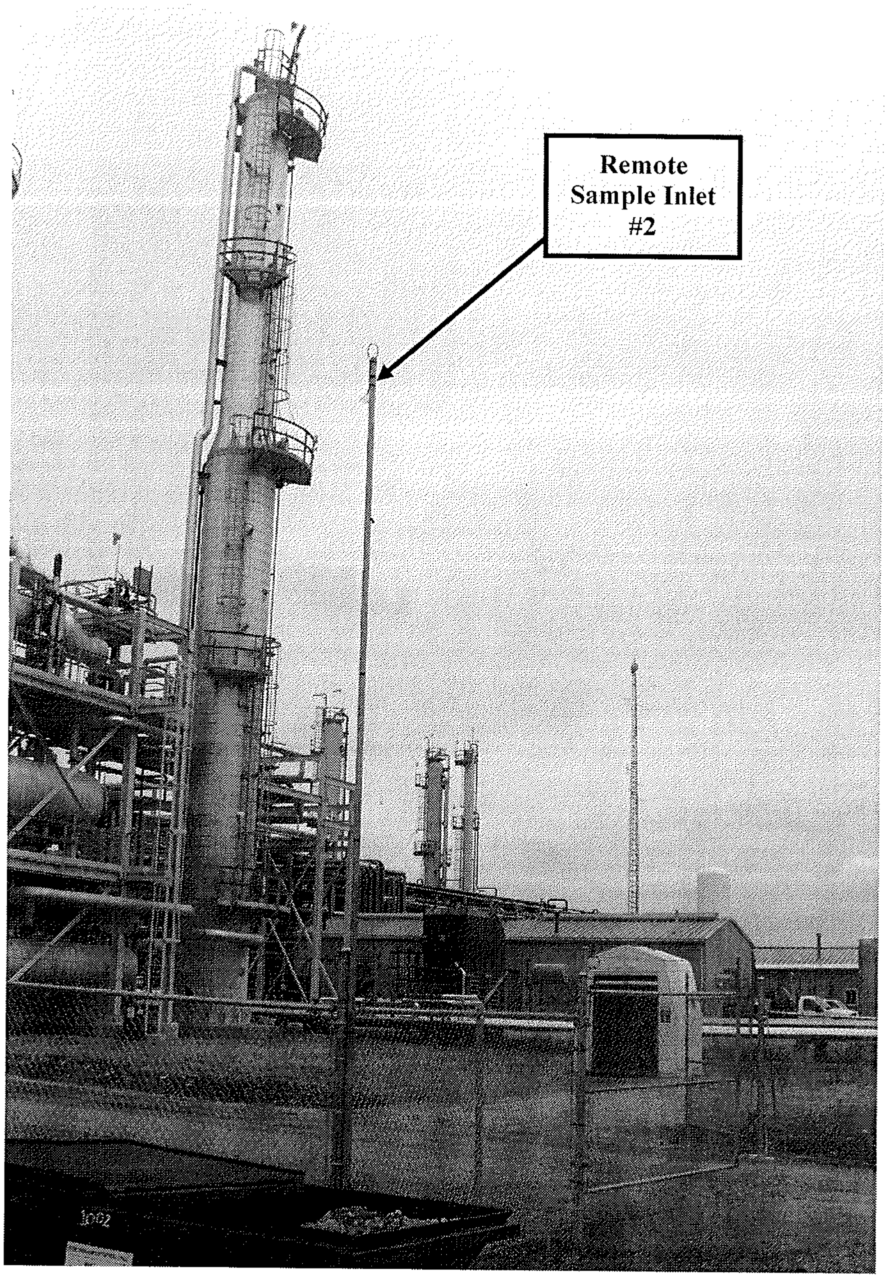

Figure 3: A picture of the remote sampling inlet #2 in the northwest part of the plant

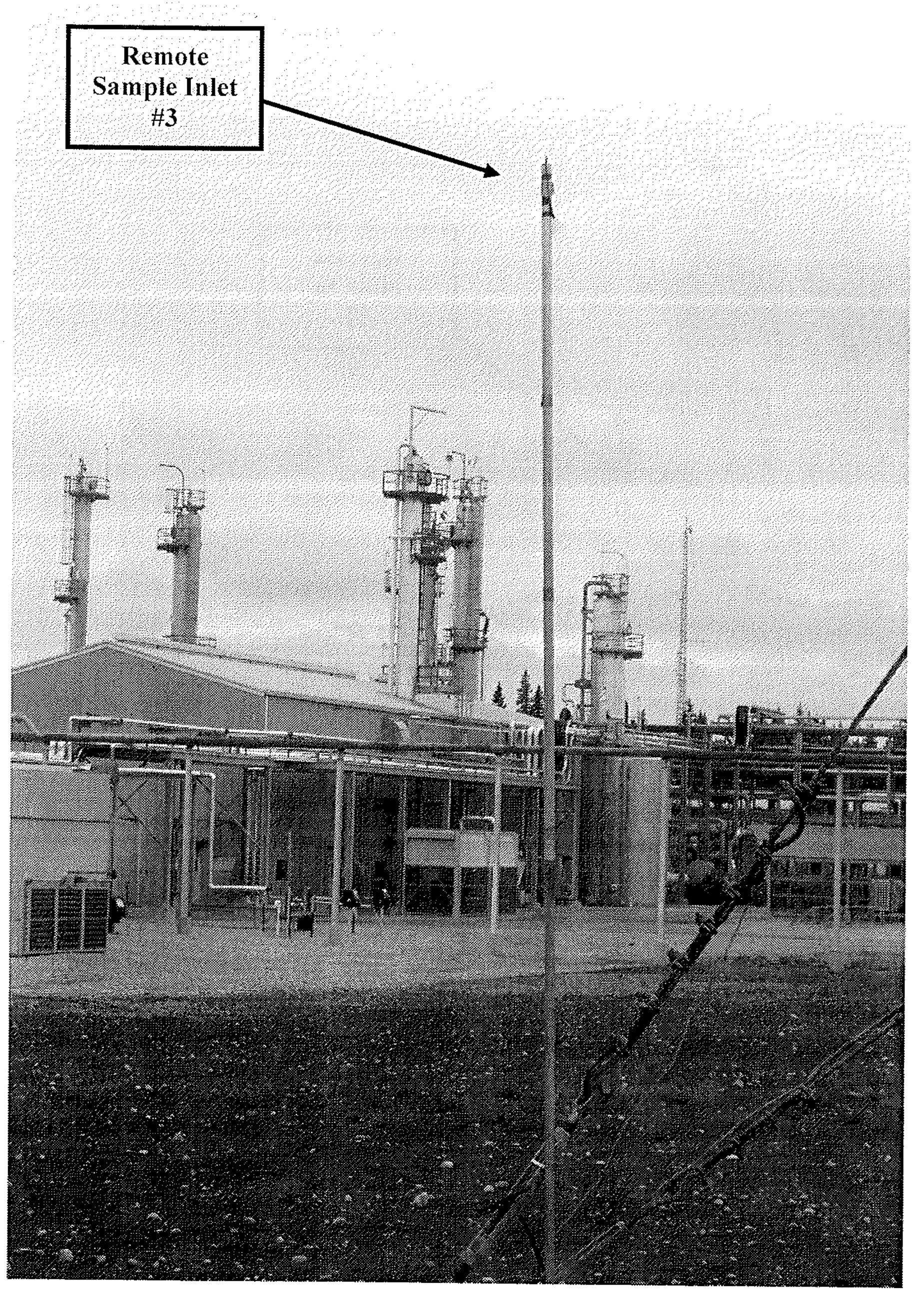

Figure 4: A picture of the remote sampling inlet #3 in the northeast part of the plant.

Figure 5: A picture of the remote sampling inlet #4 east of the plant.

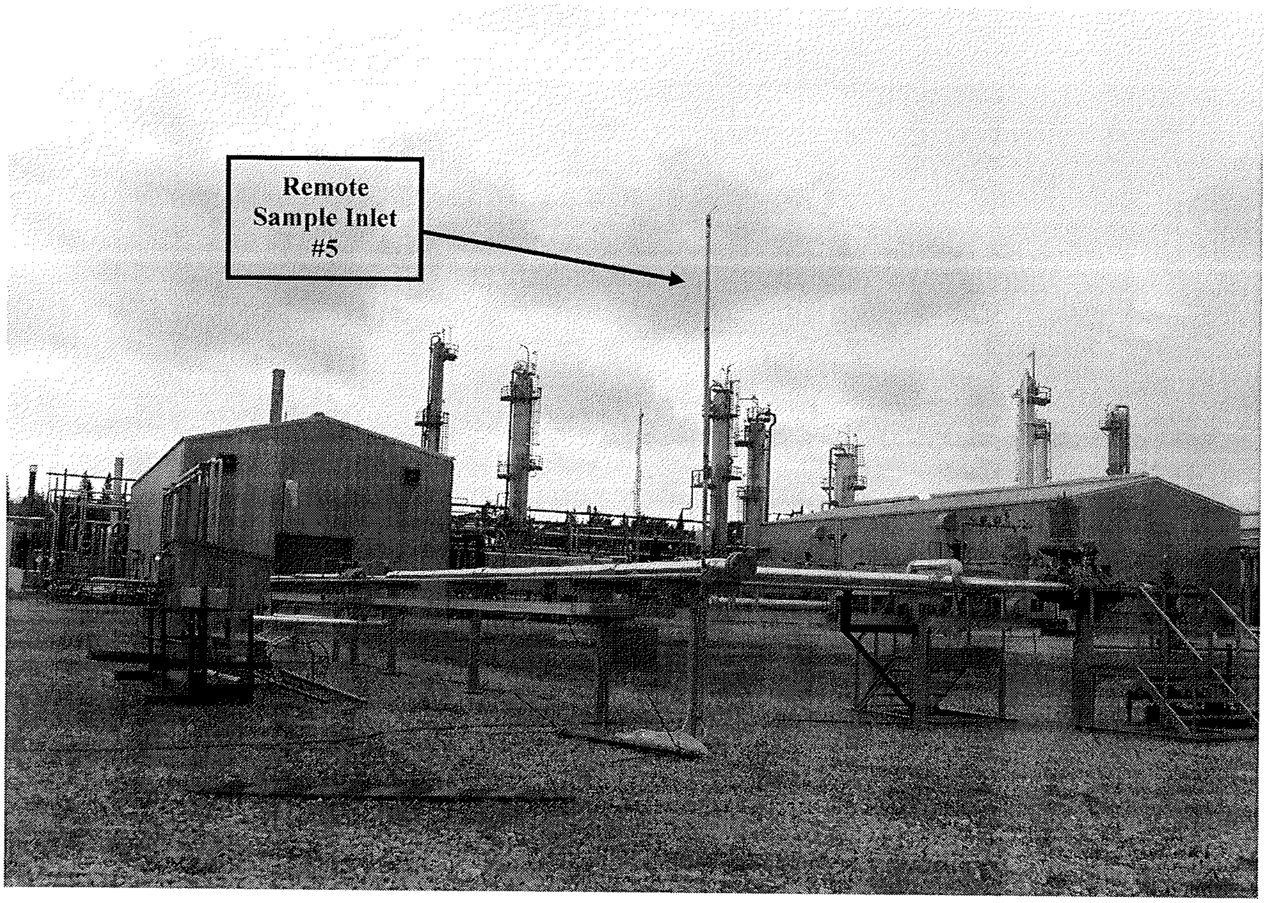

Figure 6: A picture of the remote sampling inlet #5 east of the plant.

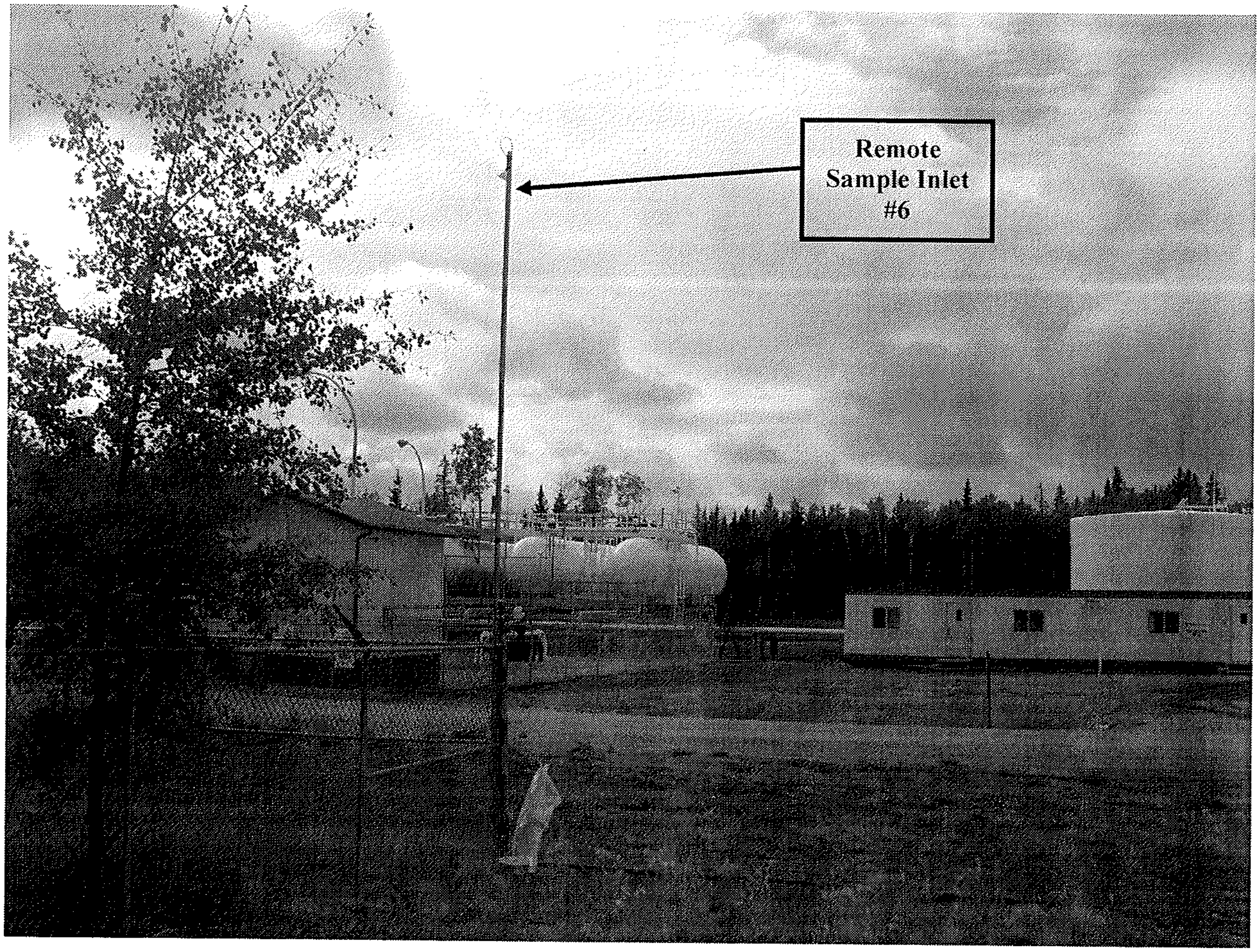

Figure 7: A picture of the remote sampling inlet #6 in the southeast area of the plant.

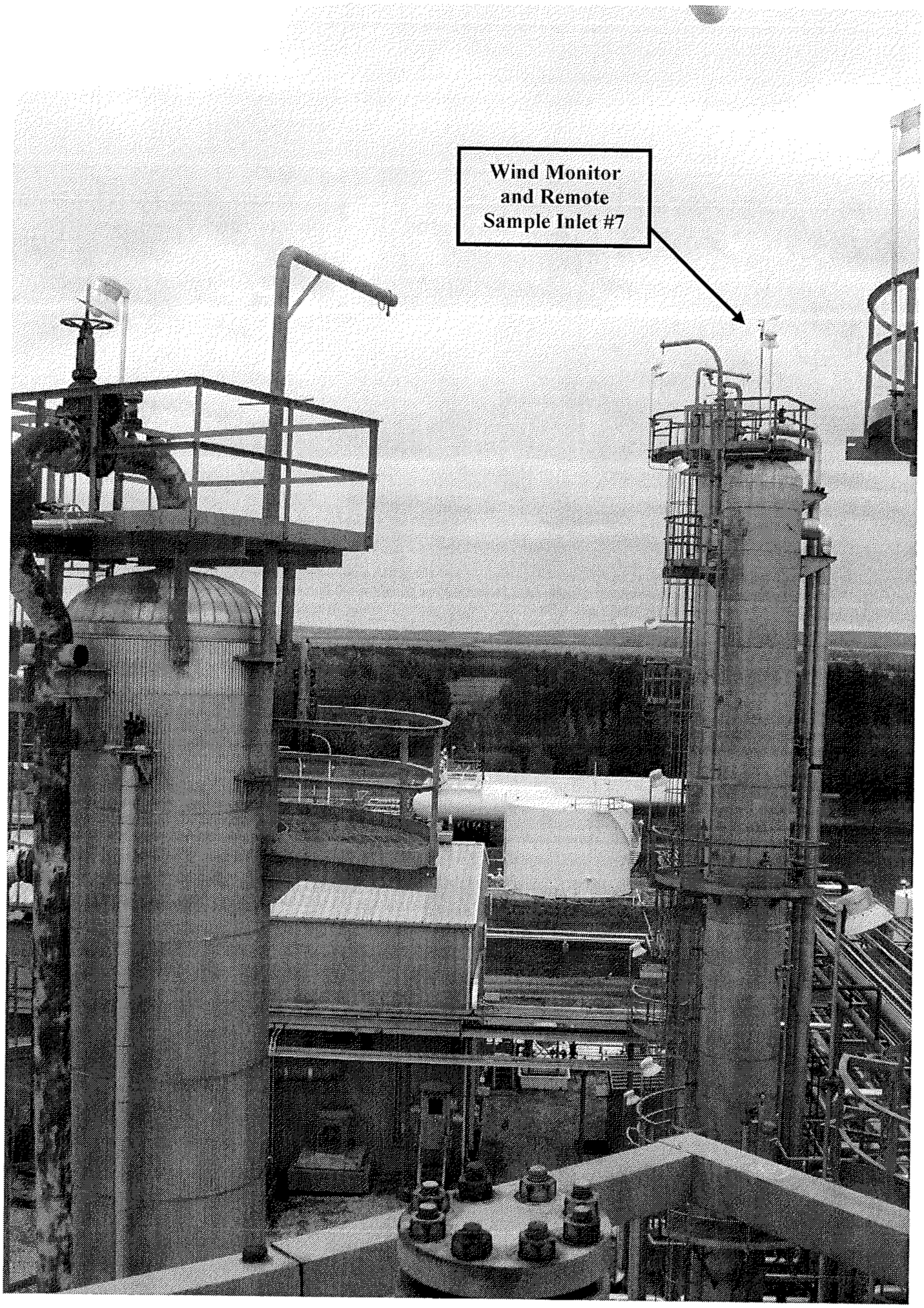

Figure 8: A picture of the remote sampling inlet #7 and the wind m at the top of a vessel in the central area of the plant.

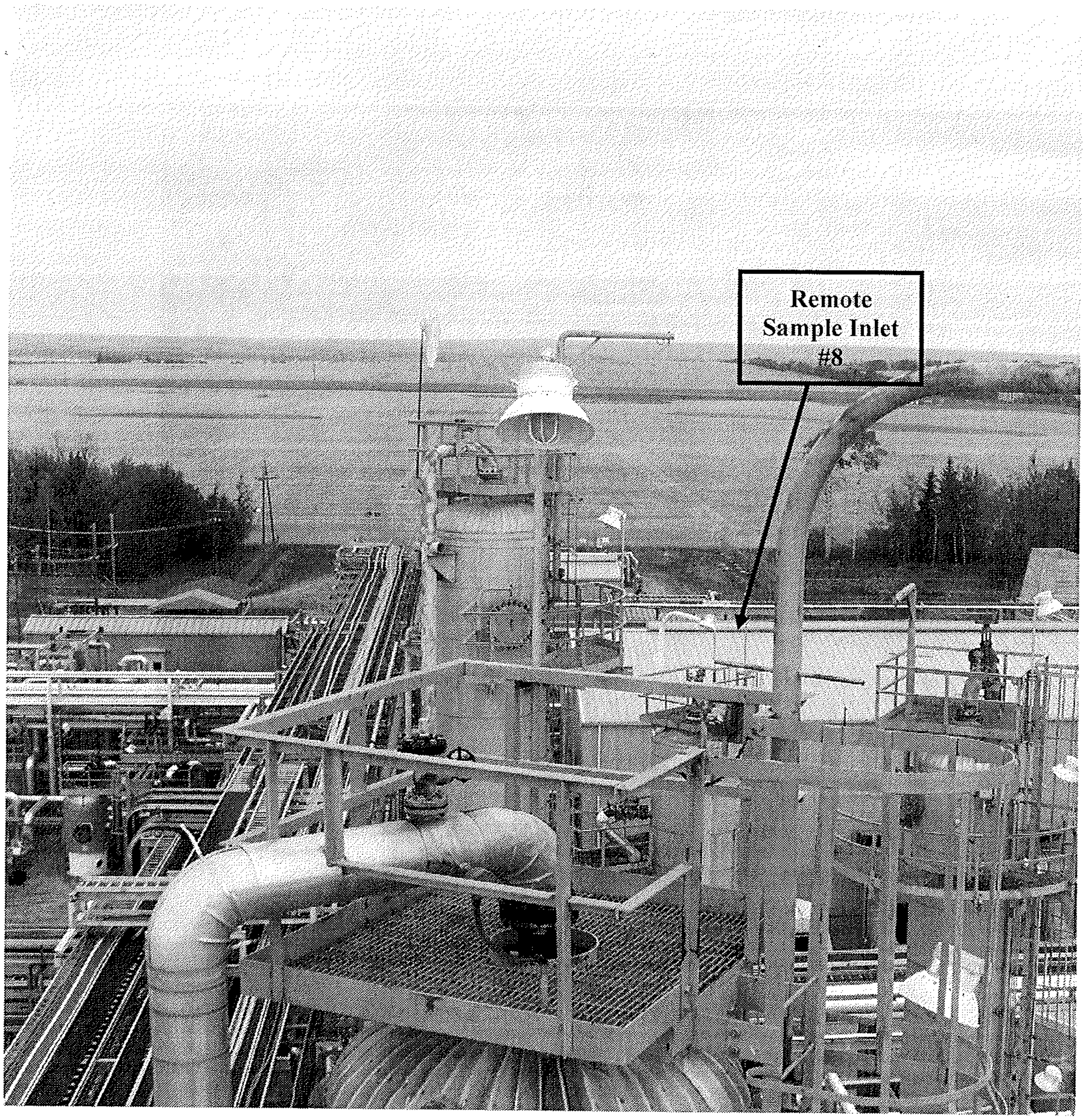

Figure 9: A picture of the remote sampling inlet #8 mounted at the top of a vessel in the central area of the plant.

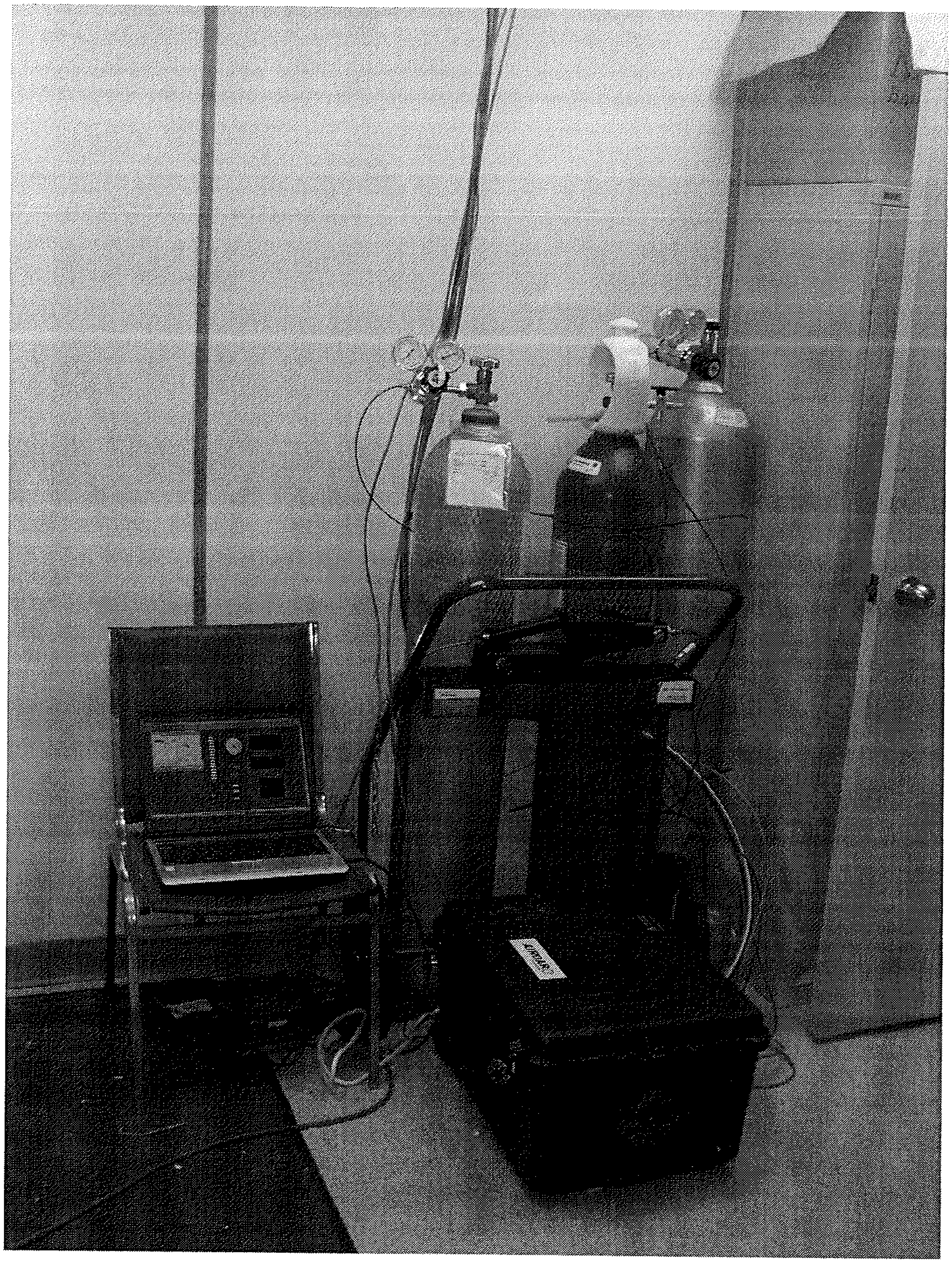

Figure 10: AIRDAR equipment package located in the corner of a lab with tubing running out to the remote sample inlets.

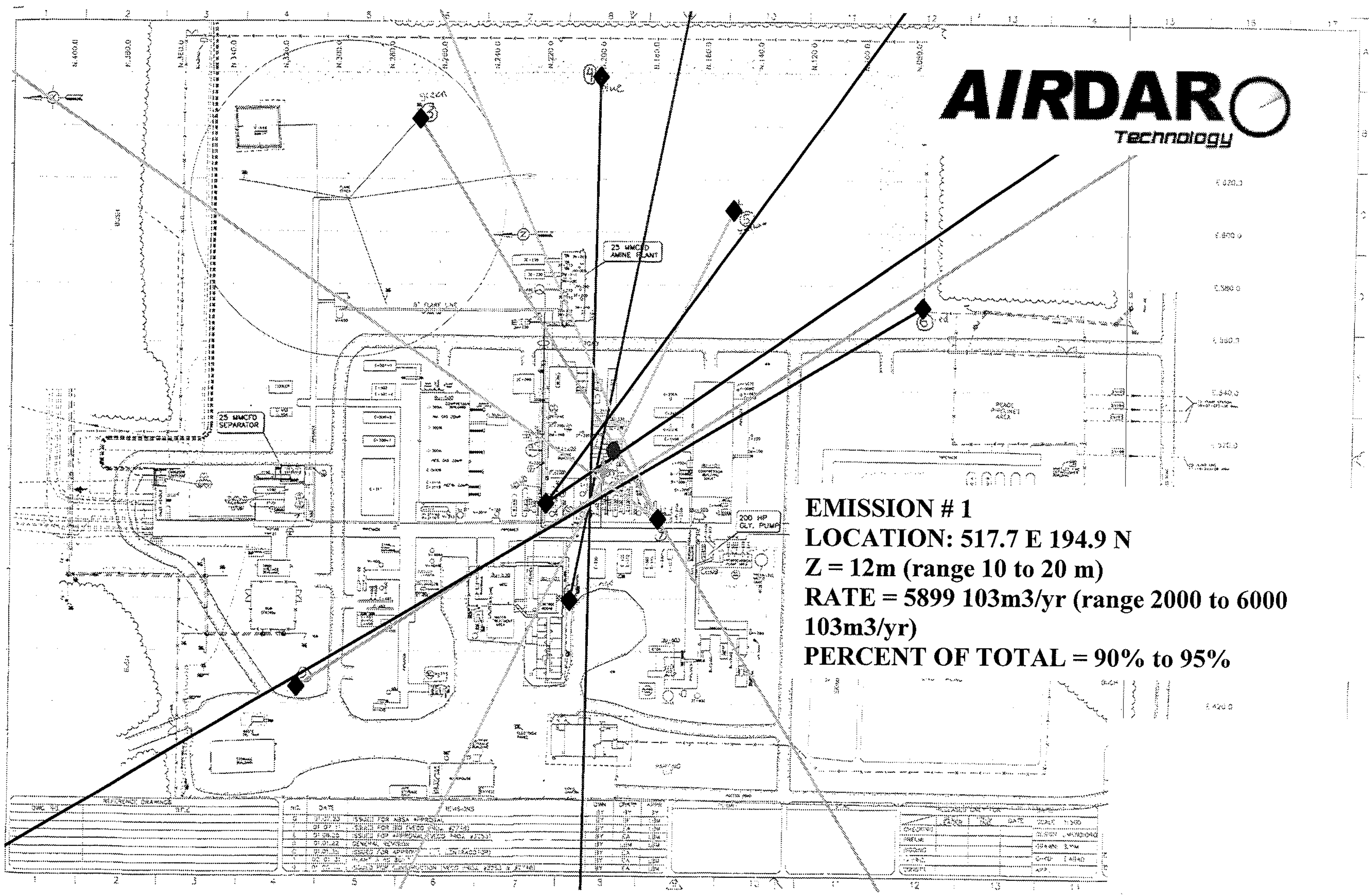

Figure 11: AIRDAR emission map from the first mapping period showing location of the major emission source.

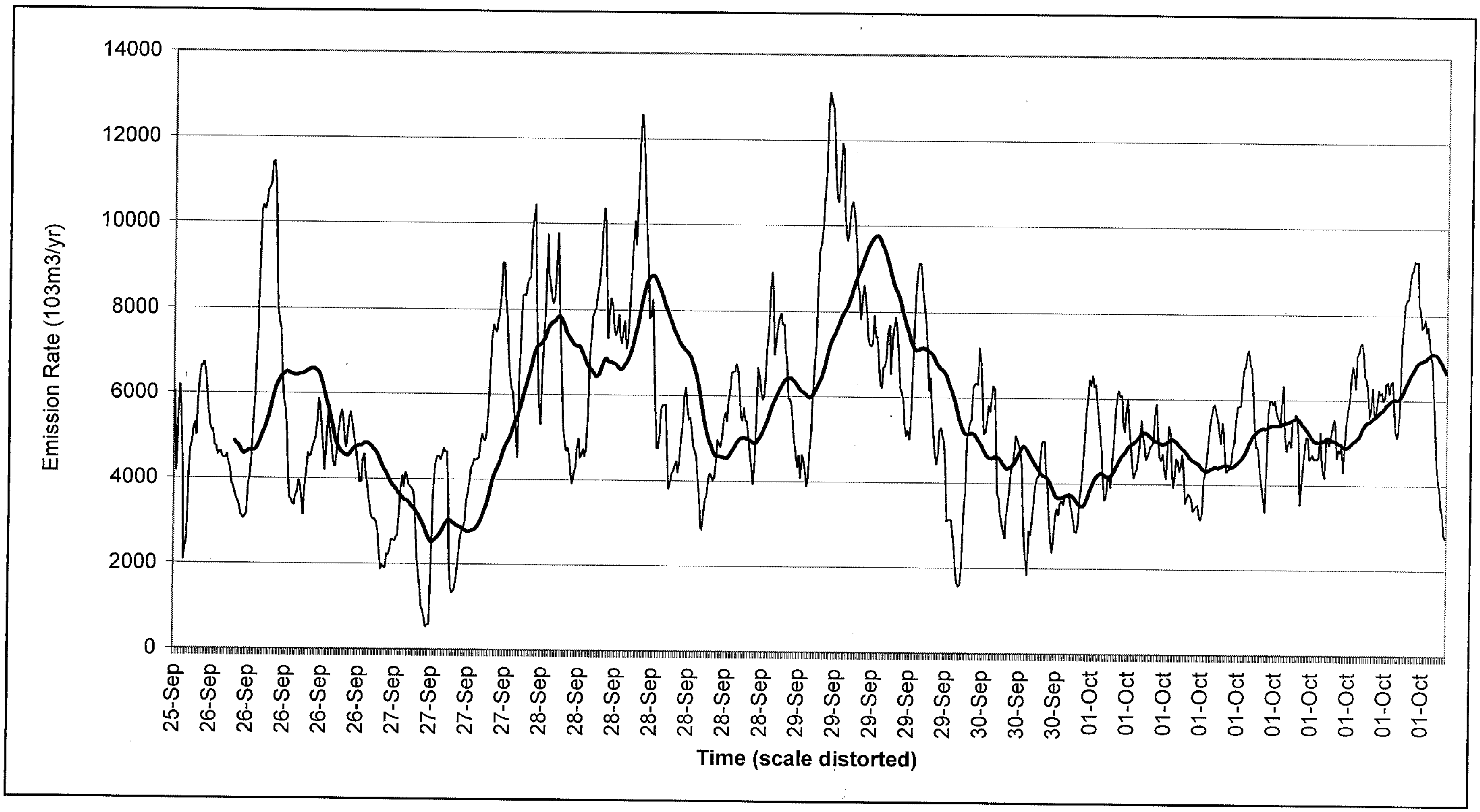

Figure 12: Chart showing the variability of the emission rate over time for the source located in Figure 11.

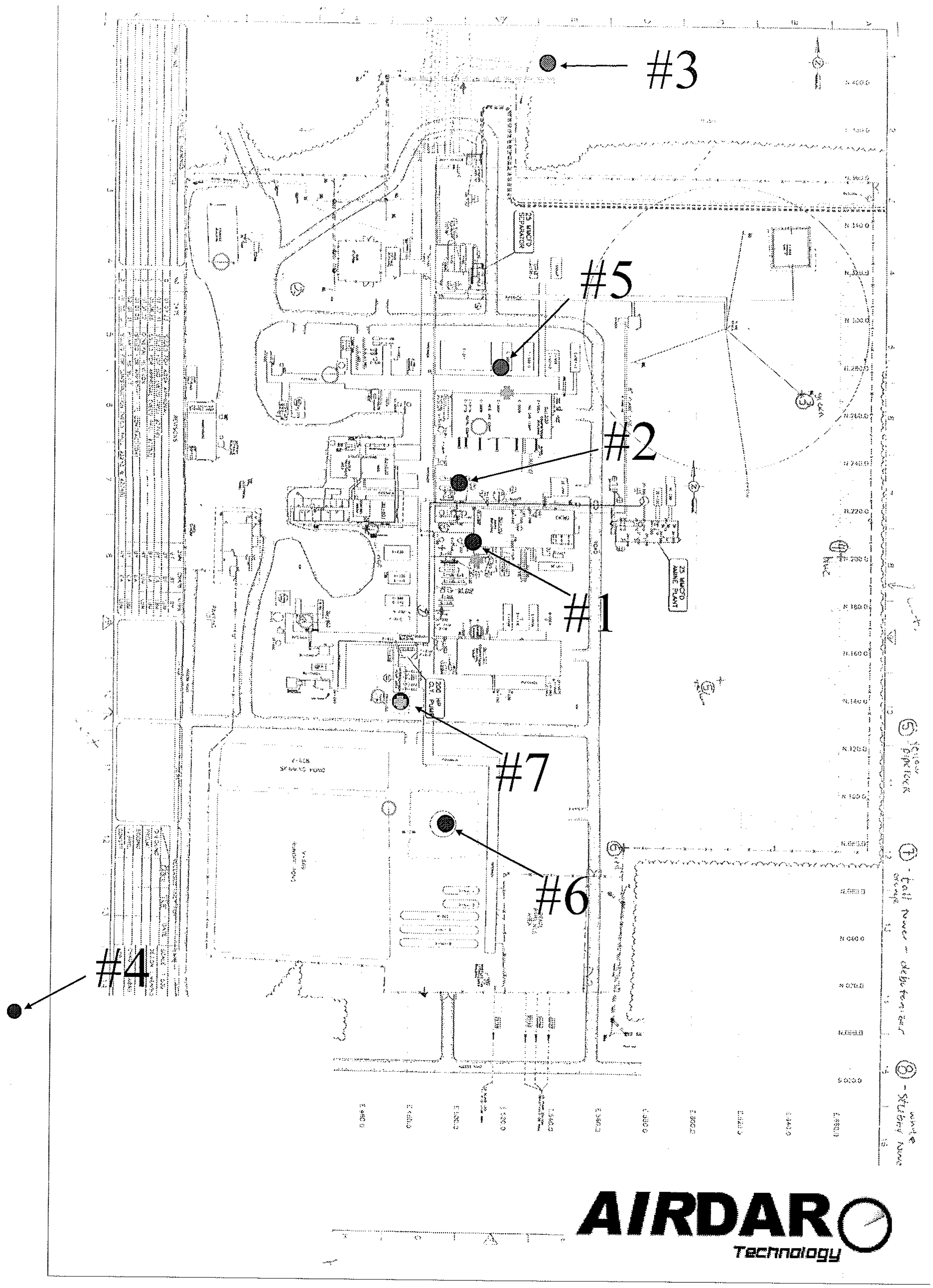

Figure 13: A map summarizing the locations of the emission sources characterized in the second mapping period.

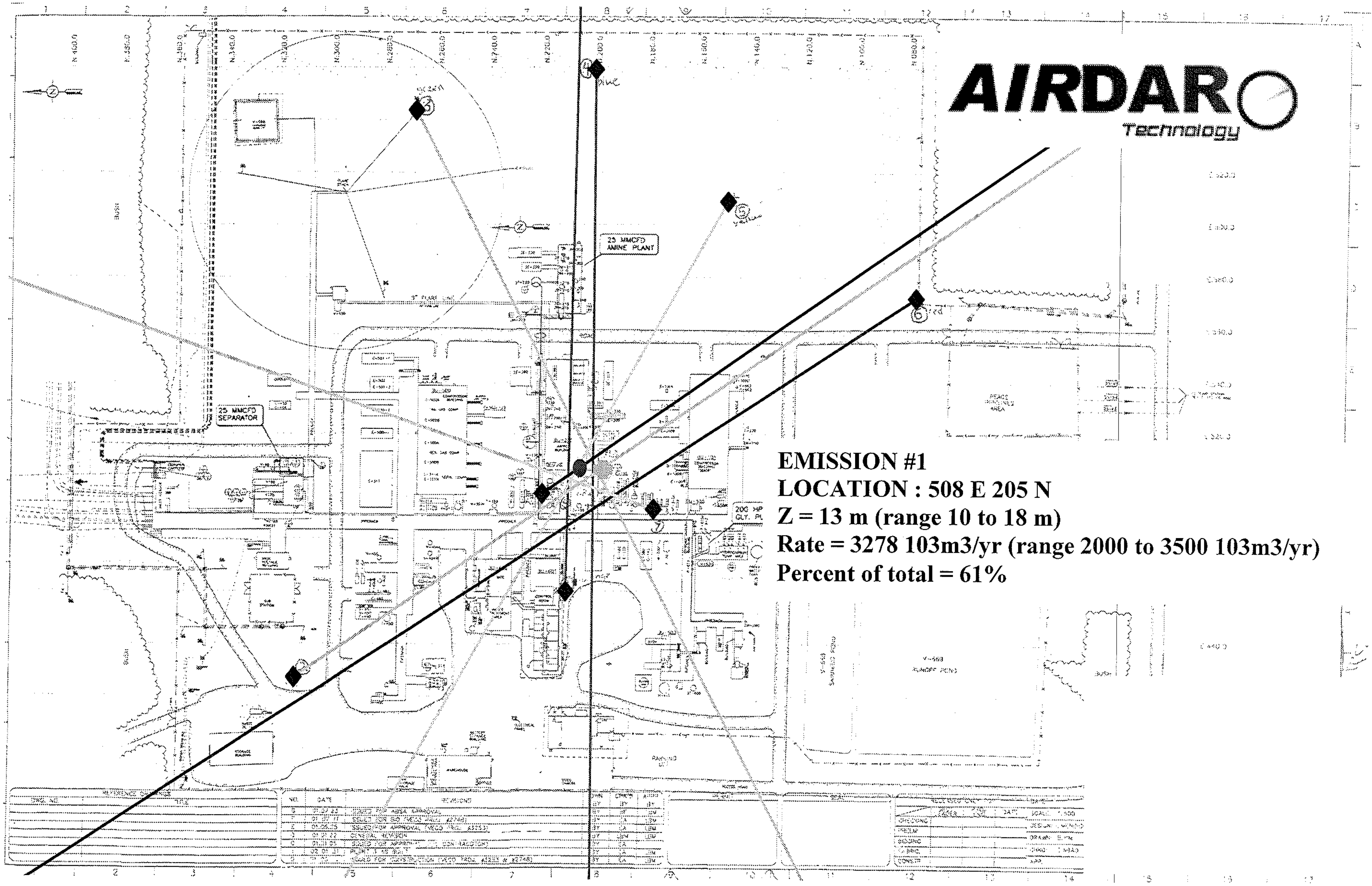

Figure 14: A map summarizing the locations of the emission source #1 characterized in the second mapping period.

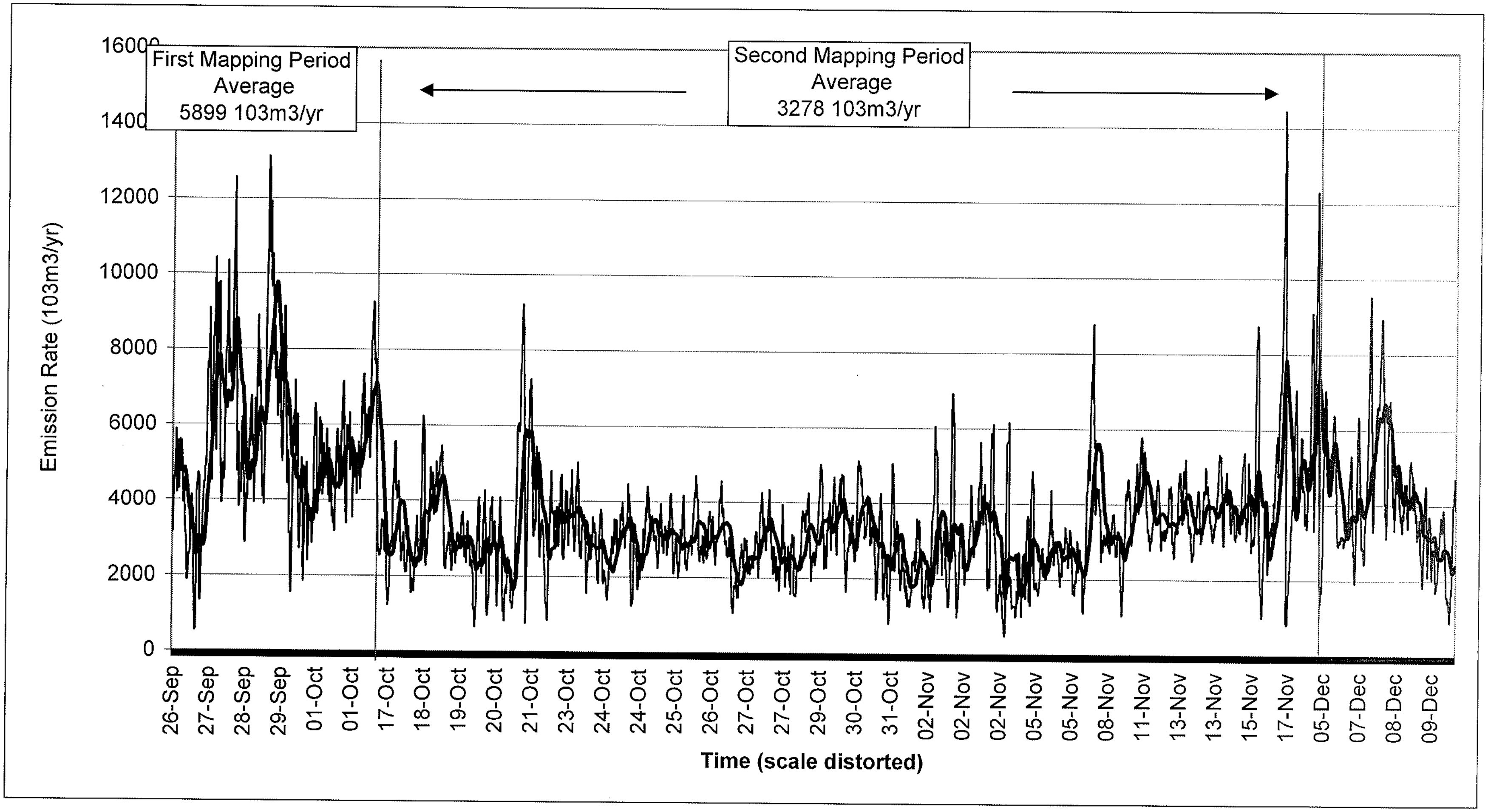

Figure 15: Variability graph for emission source #1.

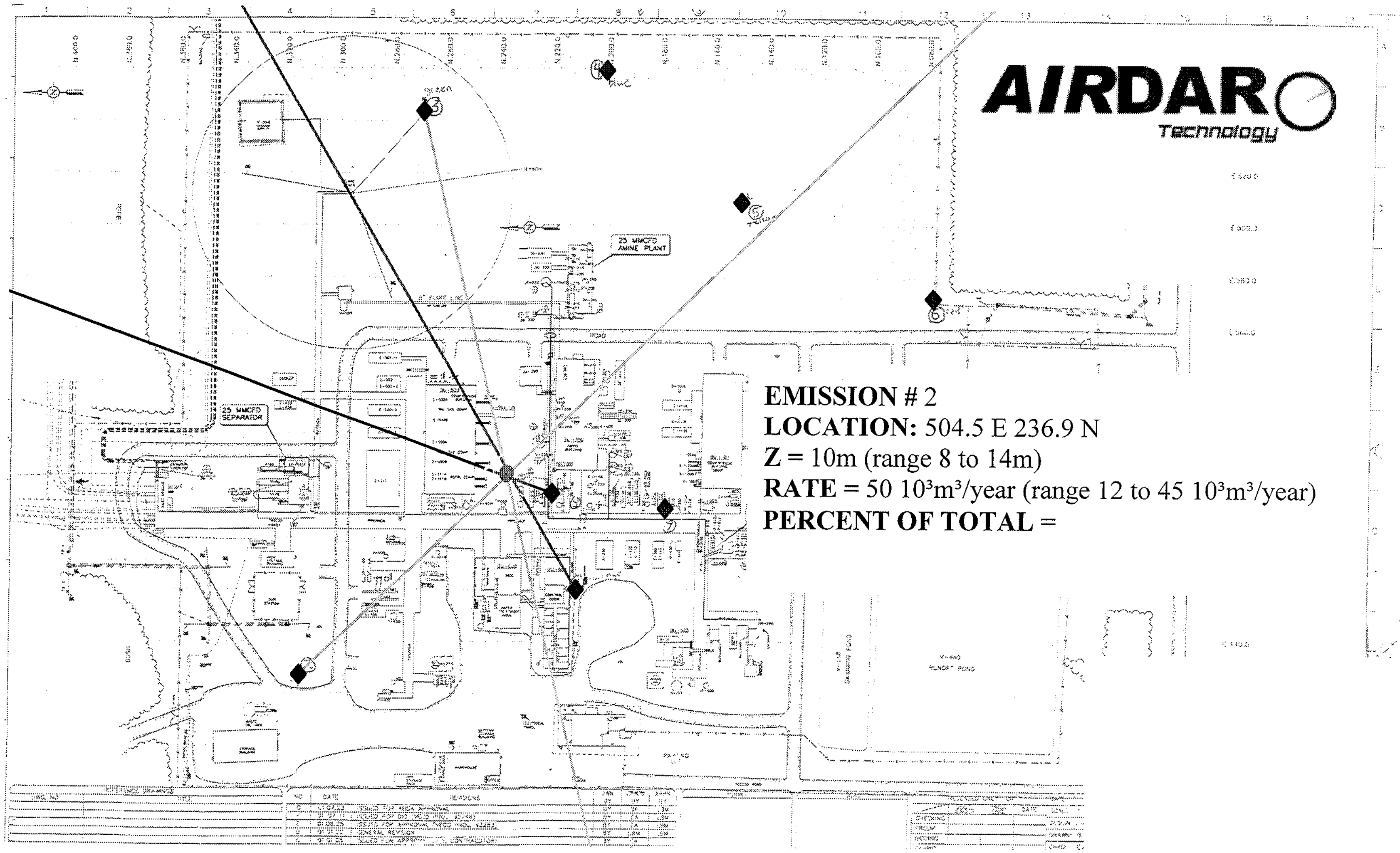

Figure 16: Estimated location of emission source #2.

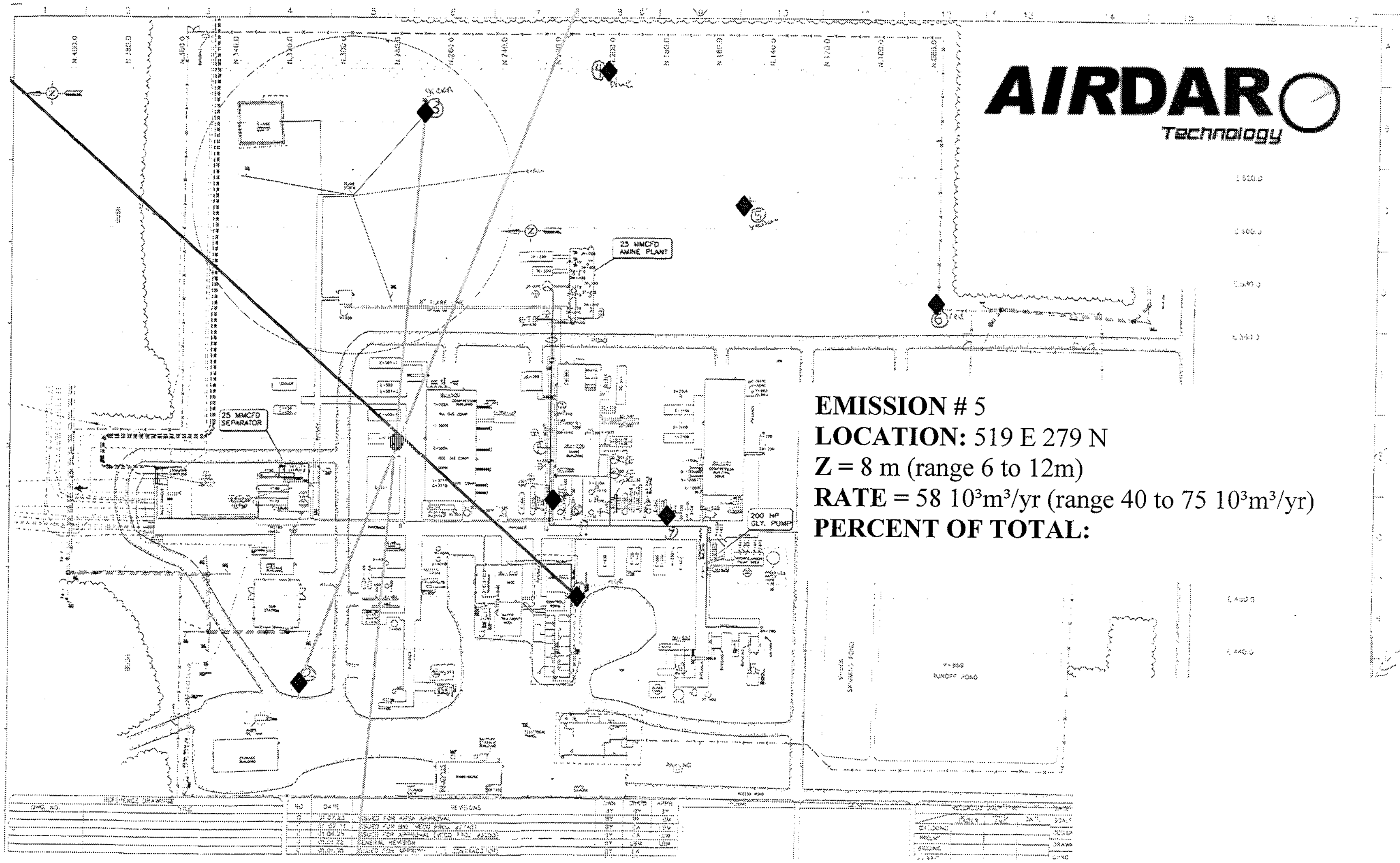

Figure 17: Estimated location of emission source #5.

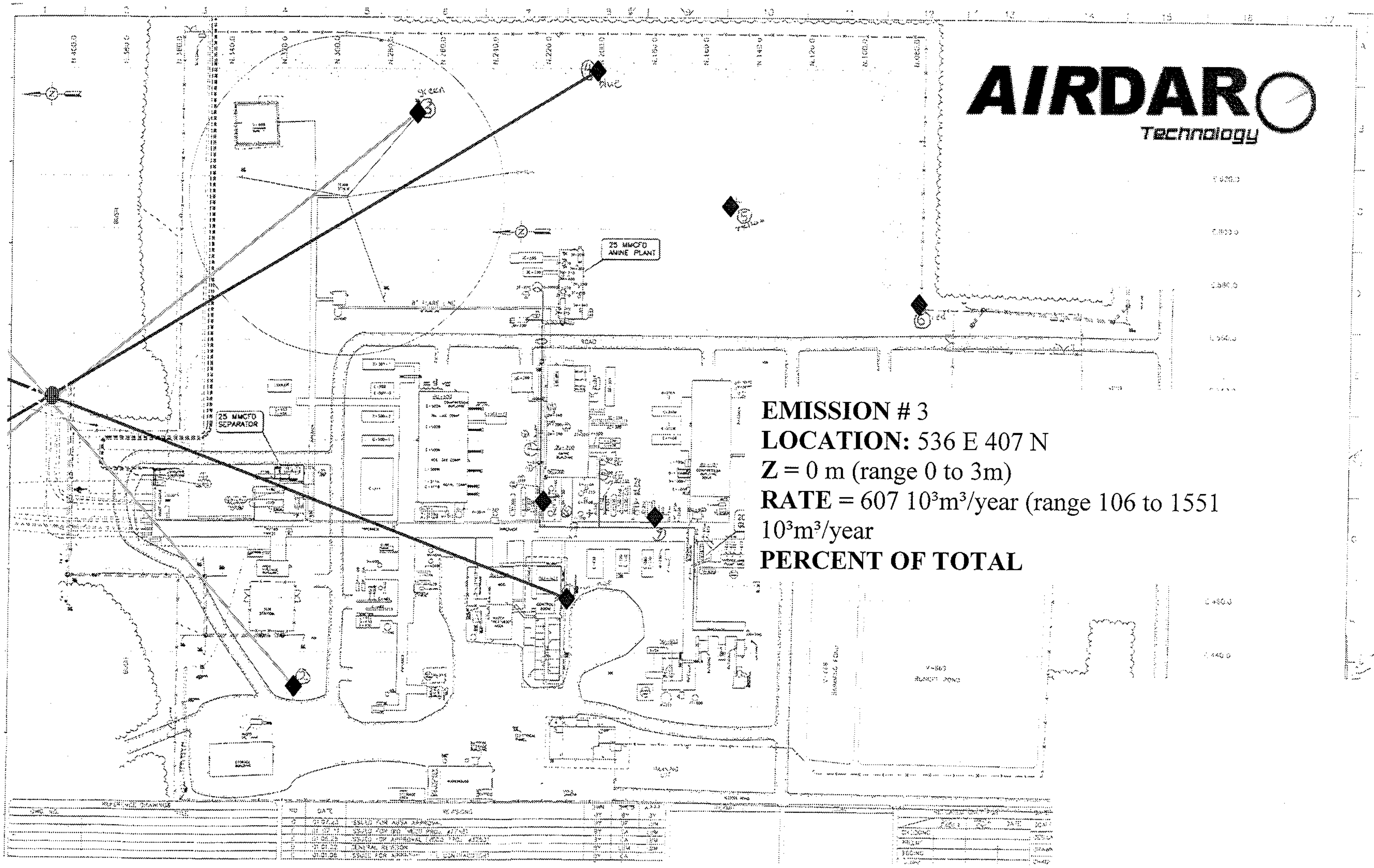

Figure 18: A map showing the estimated location of emission source #3 of the second mapping period.

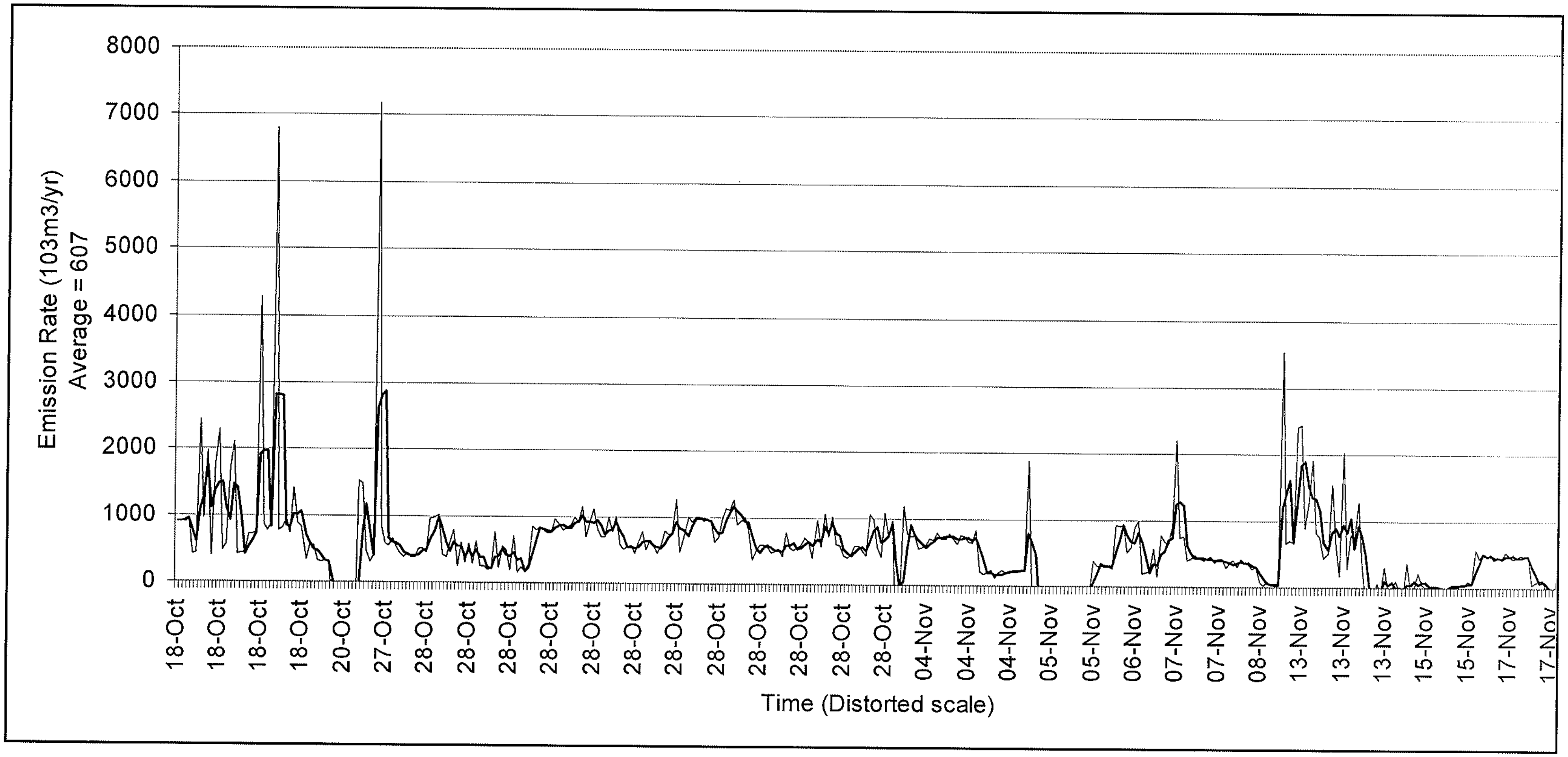

Figure 19: Variability graph for emission source #3.

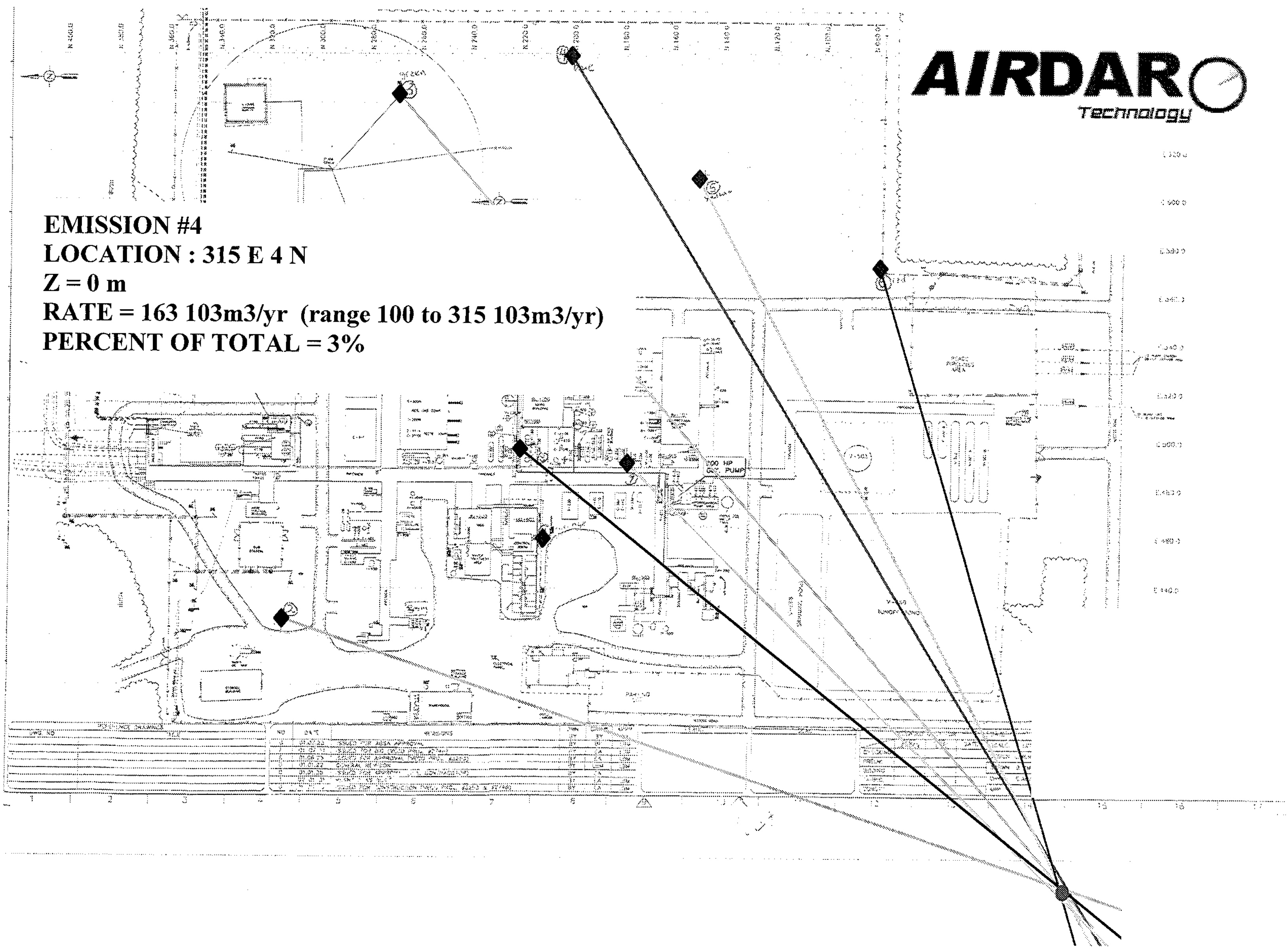

Figure 20: A map showing the estimated location of emission source #4 of the second mapping period.

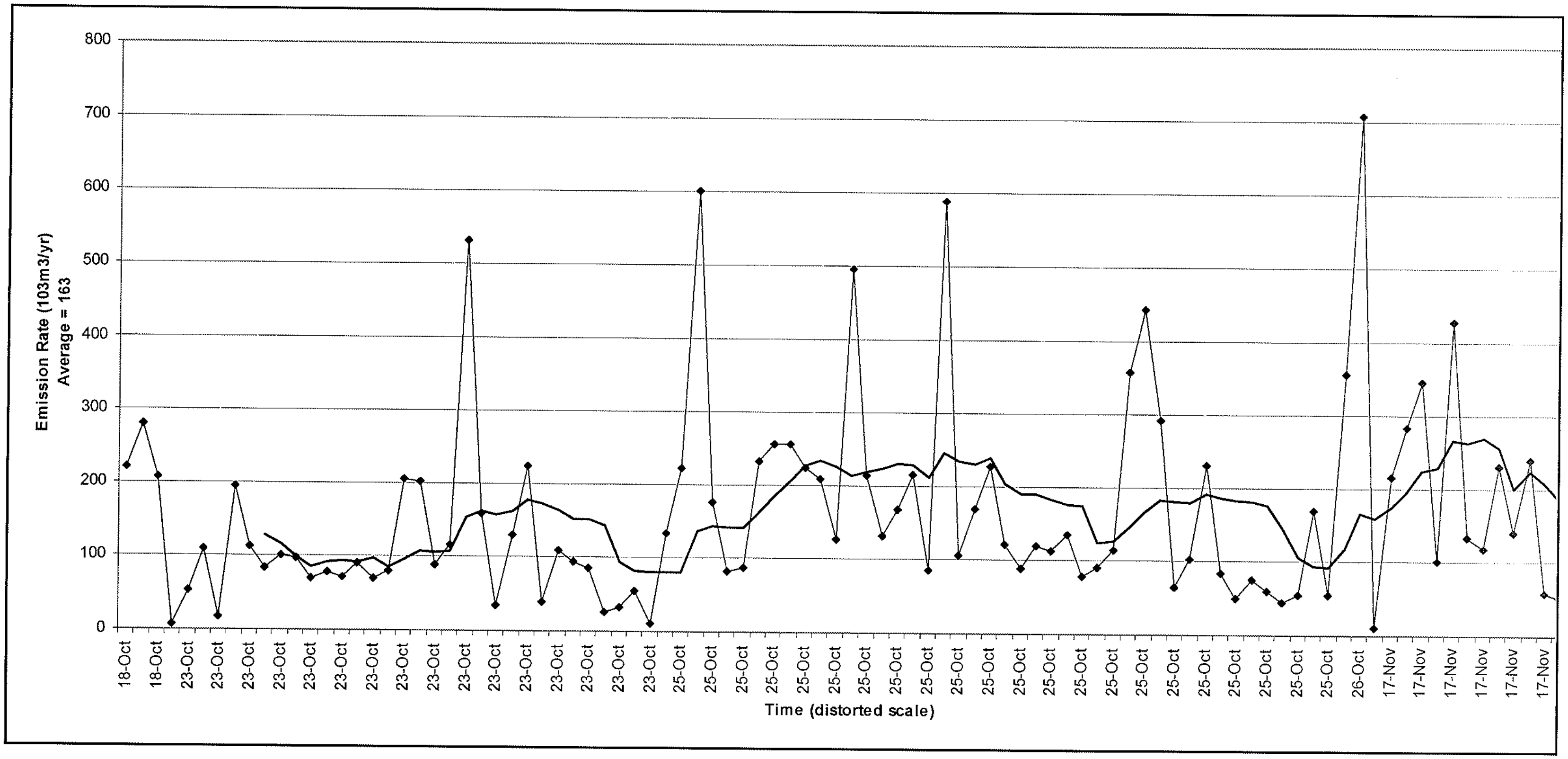

Figure 21: Variability graph for emission source #4

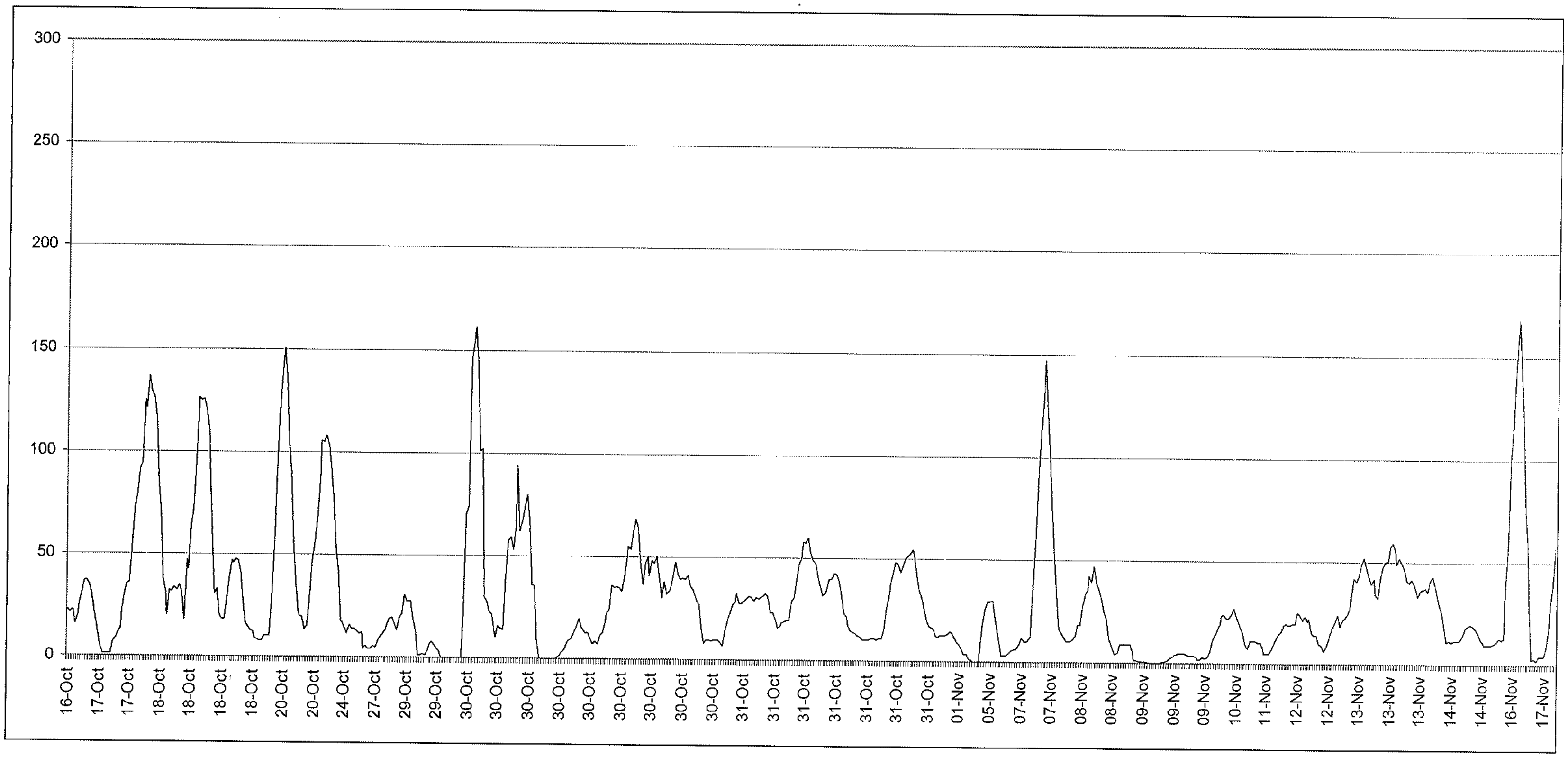

Figure 22: Variability graph for emission source #6.

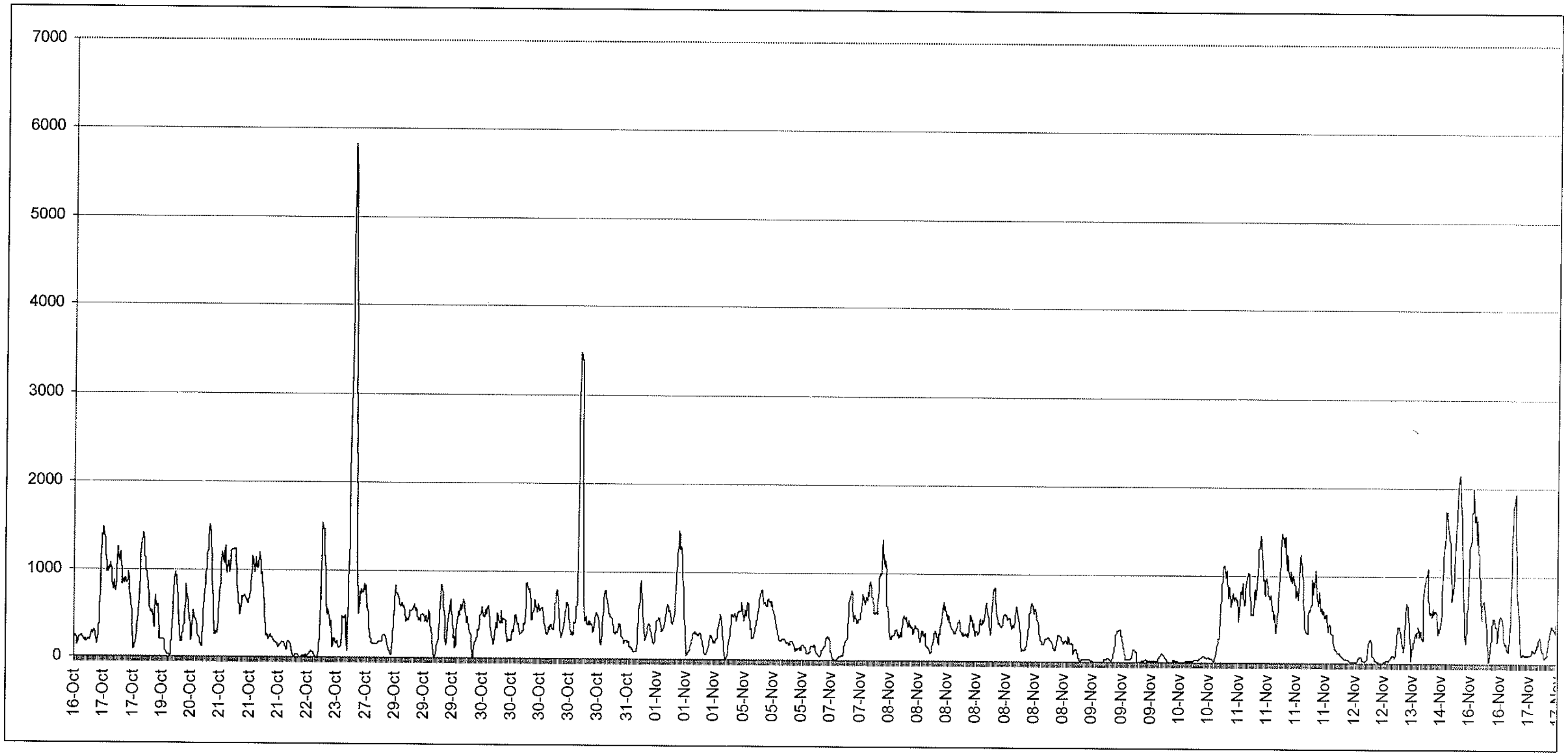

Figure 23: Variability graph for emission source #7.