#5121

CMHC KITCHENER TOWNHOUSE

STUDY OF SUB-SLAB

VENTING TECHNOLOGY

PHASE II

Prepared for:

THE RESEARCH DIVISION
CANADA MORTGAGE AND HOUSING CORPORATION

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DISCLAIMER

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ABSTRACT

Sub-slab venting, a common technology used for the remediation of radon entry into homes, was applied to a group of methane plagued townhouses in Kitchener, Ontario. This soil ventilation essentially modifies the local pressure distribution around the basement structures such that air flow is from basements out toward the soil zone. Work performed in the previous year established the technical feasibility of this technology. This study was a second phase of work aimed at assessing the suitability of this technology across the entire townhouse site.

The results of the monitoring program revealed that sub-slab ventilation was suitable as a mitigative measure at the townhouses. Significant improvements to the indoor air quality were observed. Vent gases were also tested to identify the presence of any hazardous organic compounds; no significant compounds were identified. An energy analysis was also performed to evaluate the impact of sub-slab venting on energy consumption within the homes.

RÉSUMÉ

La technique de ventilation sous la dalle, mesure courante visant à réduire l'infiltration de radon dans les habitations, a été mise à l'essai dans un ensemble de maisons en bande enregistrant des concentrations élevées de méthane à Kitchener en Ontario. Des travaux, effectués par CH2M HILL ENGINEERING LTD pour le compte de la Société canadienne d'hypothèques et de logement (SCHL), ont confirmé la possibilité de recourir à cette technique pour atténuer le problème. La seconde étape, à savoir l'étude résumée ici, cherchait à déterminer l'efficacité de cette mesure.

L'ensemble résidentiel regroupe 81 logements répartis en 14 îlots, chacun réunissant entre 3 et 12 logements. Toutes les maisons, à 2 étages, comportent un sous-sol pleine grandeur avec murs et plancher en béton coulé, ainsi qu'une ossature de bois avec placage de brique. Ces logements, tous inoccupés, connaissent des problèmes d'infiltration de méthane; ils appartiennent à la SCHL.

Au cours du programme de contrôle de 1990, on a mis à l'essai pendant un mois la technique de ventilation sous la dalle dans un tiers des logements. Des vérifications ponctuelles ont eu lieu dans chacun d'eux pour vérifier les concentrations de méthane de l'air intérieur et sous la dalle. Des sondes mesurant la pression et le méthane ont été enfoncées dans le gazon environnant. La consommation d'énergie des logements a également été contrôlée.

Il existe essentiellement trois conditions sur les lieux. Dans une section, les concentrations de méthane sont constamment élevées; dans une autre, située à proximité d'une décharge fermée, les concentrations fluctuent. Cependant, la majorité des habitations enregistre une faible teneur, caractéristique du niveau de base de polluants.

La ventilation sous la dalle constitue une mesure palliative. Les concentrations intérieures de méthane se maintiennent près du niveau de base de polluants même si la concentration dans le sol entourant les fondations est très forte. L'analyse des gaz évacués révèle que la présence de polluants est surtout attribuable au genre de conduits utilisés pour la ventilation. Les restrictions provinciales visant l'émission de polluants ne sont pas excédées. D'après l'analyse des données sur la consommation d'énergie, cette mesure n'augmente pas beaucoup les besoins de chauffage.

(Traduit par la SCHL de l'"Executive Summary", écrit par CH2M Hill Engineering Ltd.)

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EXECUTIVE SUMMARY

Sub-slab venting, which is a common technology used for the remediation of radon entry into homes, was applied to a group of methane-plagued townhouses in Kitchener, Ontario. Earlier work, performed by CH2M HILL ENGINEERING LTD. for Canada Mortgage and Housing Corporation (CMHC), established the technical feasibility of this technology for the mitigation of methane. The present study was a second phase of work aimed at assessing the suitability of this technology at a Kitchener townhouse complex.

The townhouse complex consists of 81 units arranges in 14 different blocks. Each townhouse block has between 3 and 12 units. The houses are all two storey structures with full basements. The houses are built out of wood framing with brick veneer and poured concrete floors and walls in the basement. The townhouse complex are plagued with methane gas infiltrating into the indoor living space. All units are presently unoccupied and are owned by CMHC.

During the 1990 monitoring program, active sub-slab venting was initiated for a period of one month on one third of the units. Methane spot checks were performed on each unit to evaluate ambient indoor and sub-slab methane concentrations. Exhaust gases were sampled and analyzed for volatile organic compounds. Soil probes in the surrounding lawns were also measured for pressure and methane. Energy consumption in the units was monitored.

Essentially three different conditions existed across the site. One area was documented as having consistently high levels of methane intrusion; another area close to the boundary of a closed landfill site had fluctuating methane levels; the majority of houses however had low methane readings typical of background levels.

Sub-slab venting was applied as a mitigative measure. Indoor methane levels were maintained close to background levels even when soil gas concentrations around the basements were very high. Analysis from the exhaust gases indicated that contaminants present in the air stream were primarily present due to the piping used for venting. No provincial emission criteria was exceeded. Analysis from the energy consumption data indicated that sub-slab venting did not noticeably increase heating requirements.

Section 1
INTRODUCTION

1.1 STUDY BACKGROUND

Canada Mortgage and Housing Corporation (CMHC) has been involved in the research of dangerous soil gases infiltrating into housing structures. One particular site where CMHC has conducted a significant amount of research is at the Strasburg Road Townhouses in Kitchener, Ontario. The townhouses are located at the intersection of Ottawa Street and Strasburg Road on a site where municipal refuse had been previously deposited. Presently, some of the townhouses are plagued with methane gas infiltrating into the indoor living space.

The Kitchener Townhouse site consists of a group of 81 townhouses. The units are arranged in 14 different housing blocks ranging from 3 to 12 units per block. The layout of the site is shown in Figure 1. The houses are all two storey structures with full basements containing natural gas-fired water heaters and forced air furnaces. The houses are built out of wood frame construction with brick veneer, and basements consist of poured concrete walls and floors. Each basement contains a sump area, however, all sump areas are dry and are normally capped with a plastic fitting. Initially when the houses were constructed, passive vents were connected to perforated drainage pipes which were laid at the foundation level in order to mitigate potential methane problems. However, this scheme proved unsuccessful. Other remedial activities of gas collection systems on and around the site also were not adequate. Details of the passive venting and gas collection systems are summarized by CH2M HILL (1989).

In order to mitigate this problem at the Kitchener townhouses, sub-slab venting, a common mitigative measure for radon, was recommended by Arthur Scott and Associates. CMHC retained CH2M HILL ENGINEERING LTD. to investigate the potential of applying sub-slab venting on the methane-troubled townhouses. The investigation was performed on the townhouses during a period from March to June 1989. Three of the 14 housing blocks were chosen for this study. In the three housing blocks, two different types of active venting were implemented: a system of shallow gas extraction wells installed in each basement floor, and a system which consisted of pumping a perimeter venting pipe which existed at the footing foundations. The two systems were described in detail by CH2M HILL (1989). Of these two systems, the system of shallow interior wells proved to be the most successful.

When active venting of the shallow wells was initiated, the indoor air quality was dramatically improved in the units. In one unit, methane concentrations were decreased by as much as 99 percent from the highest level recorded. The active perimeter system was not as successful. Due to low baseline methane concentrations, the performance was difficult to evaluate. Other factors such as poor soil gas transmission underneath the building foundations as well as wet soils prevented the good performance of the venting system.

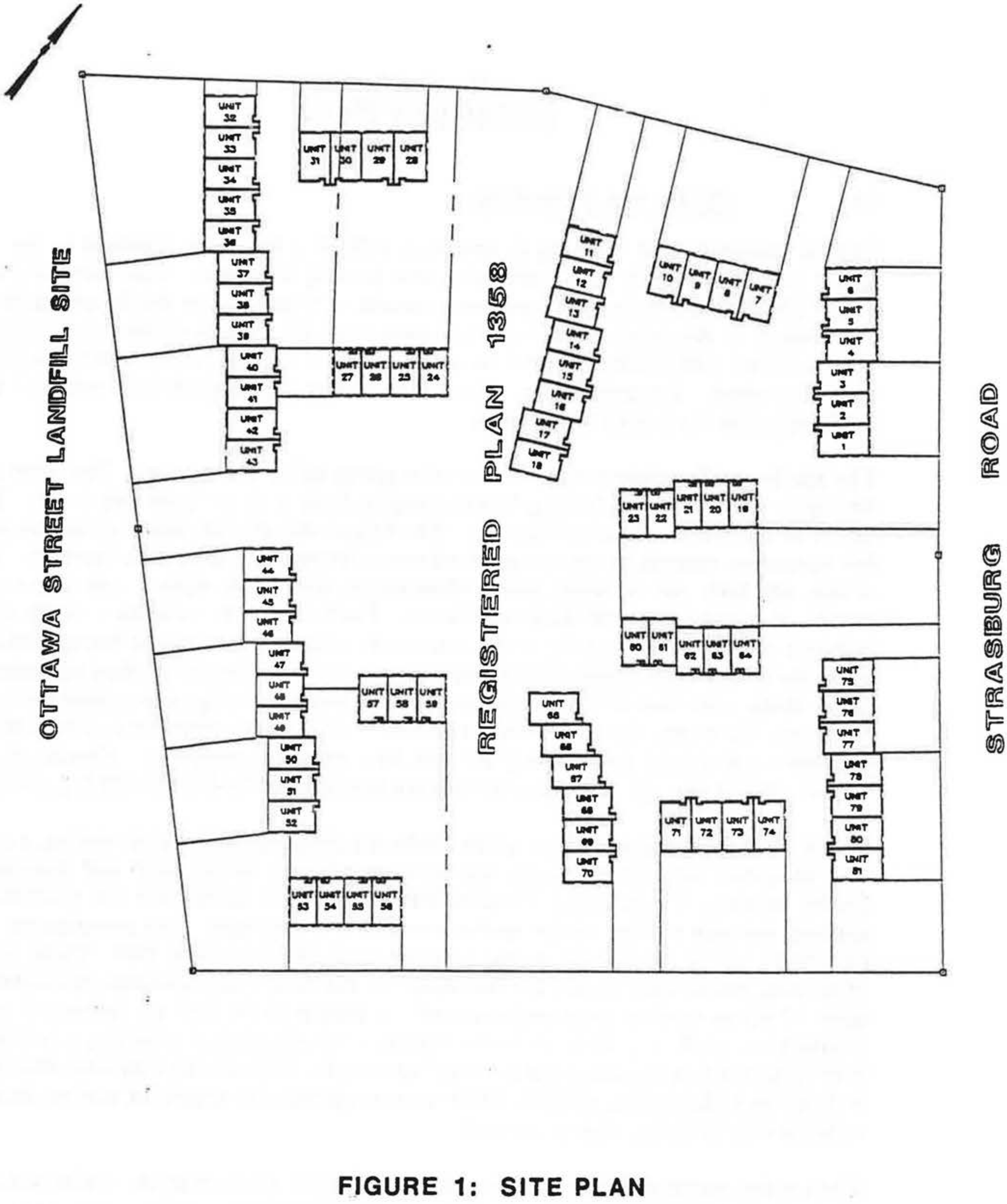

FIGURE 1: SITE PLAN

The results of the study were presented to a technical review committee on June 15, 1989. The technical review committee was comprised of experts from CMHC, National Research Council, Environment Canada, the Universities of Waterloo, Carleton, and Western Ontario, and the private sectors. Although the reduction of methane in the townhouses was acknowledged by the committee, concerns were raised about timing of the active venting experiment and the quality of the outside air.

During the meeting with the technical review committee, some discussion was centred on the timing of the active venting experiment performed in 1989. Some members of the review committee suggested that the venting experiment be conducted during winter and early spring rather than from April 13 to approximately August 5 as was done in 1989. Based on recommendations from Morrison Beatty (1986), testing should be completed in the late winter and early spring when accumulations of methane are expected to peak due to a frozen and/or saturated ground surface. One recommendation from the committee suggested a testing period from December to January for optimal conditions. However, as pointed out by Morrison Beatty (1986), conditions may vary considerably from year to year such that a specific monthly period may not necessarily guarantee worst case conditions. Another observation from outside the technical review committee came from a local municipal official. The director of the landfill, who had observed methane concentrations over several years, noted that methane concentration in homes surrounding the Ottawa Street Landfill, historically increased during the winter months but peaked in early spring (personal communication, Ralph Luhowy). Although it is difficult to predict the optimal period for testing, consensus favours a winter, early spring sampling period.

The other major concern raised in the 1989 technical review committee meeting addressed outside air quality aspects. During the period of time when residents had occupied the units, the Ministry of the Environment received numerous complaints about odour at the site. Although some residents moved away from the homes due to methane hazards, others had moved due to odour problems. Some members of the review committee were concerned about health effects of the vented gases which may have been linked to the odours. Although the exhaust gases were evaluated during the 1989 program, it was clear that further testing of the exhaust gases were necessary before ministry approval was granted.

1.2 STUDY SCOPE AND OBJECTIVES

In view of the concerns raised by technical review committee, the study was extended for one more field season. CH2M HILL ENGINEERING LTD. was again retained by CMHC to complete the work. The study was initiated in January 1990 and was completed by June 1990. The major objectives were:

1. Evaluate the air quality coming from the vents for the purpose of applying for a Certificate of Approval from the Ontario Ministry of Environment.

2. Evaluate the success of the active sub-slab venting system in reducing indoor methane concentrations in all of the 81 townhouse units.

3. Evaluate the energy consumption of the heating system when venting was initiated.

CH2M HILL's scope of work was limited to the following:

- Drill holes in 77 basements (4 houses were already completed) and install soil gas extraction wells.
- Drill holes and install slab probes in each basement floor.
- Install active venting systems on each townhouse block and operate system.
- Perform permeability measurements on each basement sub-floor.
- Monitor methane and pressure in all basements, vents, slab probes, and soil probes.
- Measure VOC concentrations in vent stacks across the site.
- Record natural gas consumption in the houses during and after venting.
- Prepare a final report providing details and results of the above work.

Section 2
METHODOLOGY

2.1 INSTALLATION OF VENTING EQUIPMENT

Based on the recommendations of earlier work (CH2M HILL, 1989), the design of the sub-slab venting system favoured the installation of individual soil gas extraction wells at the townhouse site. Individual soil gas extraction wells in each unit appeared to perform better than a system of active perimeter venting. The performance of a perimeter extraction system was hampered primarily due to poor air permeability between the sub-slab space and the perimeter vents (which were in place when the homes were built). As well, many of the original venting pipes were clogged due to silt infilling.

In order to install the individual soil gas extraction wells, holes were drilled with a 12.7 cm diameter concrete coring machine. The location of the hole was placed normally behind the furnaces whenever possible so as to remain relatively inconspicuous. A 10 cm diameter ABS plastic pipe with perforations was installed through the hole and into the sub-floor. A gravel pack was set in place around the perforated pipe. Instead of using silicon caulking to seal the soil gas vents to the concrete floor as in the original program, the soil gas vents were set in place with concrete. The use of concrete as opposed to silicon was deemed necessary to minimize the introduction of organic compounds which might confuse the indoor air and vent stack monitoring results. Unfortunately, the soil gas vents were initially poorly fitted; the diameter of the holes were therefore increased. The hole was then sealed with concrete (if the townhouses are fitted with permanent remedial measures, silicon sealing may be applicable). Each extraction well was equipped with a butterfly valve to regulate air flow from the sub-floor in that unit.

Slab probes were installed in three locations through each basement floor. Slab probes were installed for the purpose of monitoring soil gas pressures and air quality underneath the basement floors. The slab probes were placed in such a manner that an evaluation of sub-slab pressures and methane concentrations across each basement floor was possible. Holes were drilled with a 2 cm hammer drill and a slotted PVC probe was installed. A small amount of silicon was used at each probe to seal the basement air from the sub-slab environment. It is unlikely that the amount of silicon used would affect subsequent VOC analysis. Details of the probe construction are given in CH2M HILL (1989).

Once the soil gas extraction wells and slab probes were in place, the extraction system was constructed on approximately one third of the townhouse units. Flexible plastic dryer vent pipe was installed on each soil gas extraction well. The dryer vent was routed through the wall at the dryer vent pipe already in place in each unit. Outside of the units, a collector pipe made up of non-perforated flexible drainage pipe was connected to each of the dryer stacks. In turn, the collector pipe was connected to an extraction fan in a convenient location on each housing block. One fan was installed for every three to six units depending on pressure requirements. The schematic of the venting arrangement used on each of the housing blocks is shown in Figure 2. Where possible, the exhaust gases were expelled through already existing risers of the passive venting system installed at ends on each housing block.

Upon completion of the installation of the venting system, permeability testing was performed on each basement sub-floor. This involved establishing the sub-floor soil permeability by subjecting the cavity to a high extraction flow rate, followed by a test with a low extraction flow rate. An in-line flow measuring device was installed between the extraction well and the pipe exit (through the dryer vent). For the high flow rate, the flow control valve was open only on the test unit. For the low flow rate, this valve was closed (allowing only a minimal flow past the closed damper), while all other units had their air control valves open. The pressures resulting from the maximum and minimum flow rates were recorded and plotted on a graph similar to Figure 3. In this manner, the performance characteristics at various flow rates could be determined. From Figure 3, the flow rate necessary to achieve a certain vacuum at some distance from the soil gas well can be determined. As seen on Figure 3, a depressurization of 5 Pa (antilog .7 Pa) is achievable under the floor when minimum flow rates are implemented.

Prior to testing of methane concentrations with the fan activated, the system was shut down for several days, so that baseline methane concentrations could be recorded. The system was then activated for one third of the units. Monitoring was initiated for a period of 4 - 5 weeks, at which point the fans and piping were then transferred to the next set of units. The above procedure was repeated. Figure 4 indicates which units were vented for which specific time periods.

2.2 MONITORING

The monitoring program was used to evaluate several factors including:

- the influence of sub-slab venting on ambient basement methane concentrations in all of the townhouse units
- the identification of any sizeable methane sources either underneath slabs or outside locations
- the impacts on outside ambient air quality due to the venting of various volatile organic compounds (VOC) which may exist in the subsurface
- the influence of sub-slab venting on energy consumption

Instruments used in the monitoring program and their purpose are included in Table 1. The principle piece of equipment used for measuring methane was the Century 128 Organic Vapour Analyzer (OVA). The Century 128 OVA is a flame ionization detec-

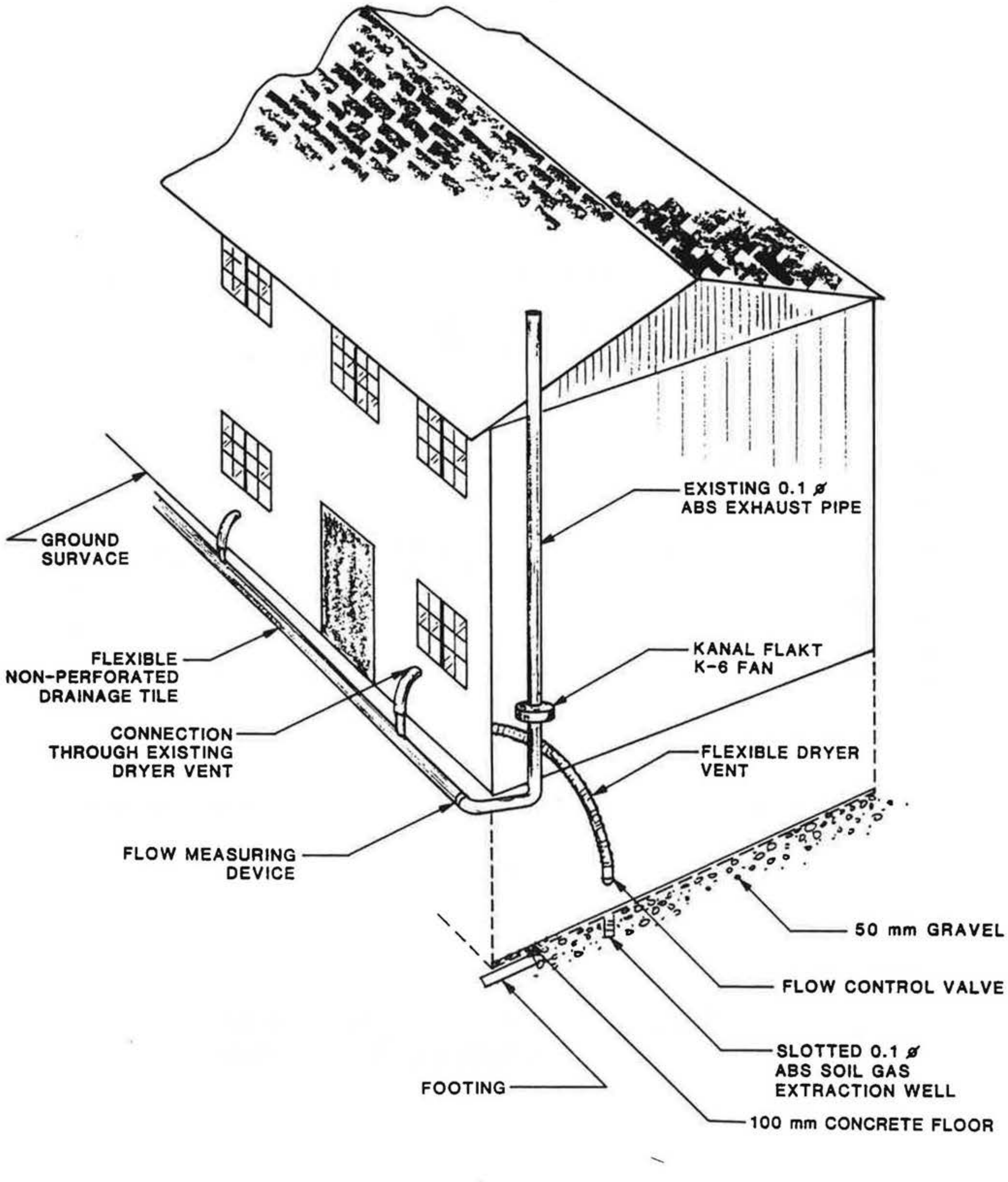

FIGURE 2: TYPICAL SCHEMATIC OF SUB-SLAB SOIL GAS EXTRACTION SYSTEM AS IMPLEMENTED AT THE STRASBURG ROAD TOWNHOUSES

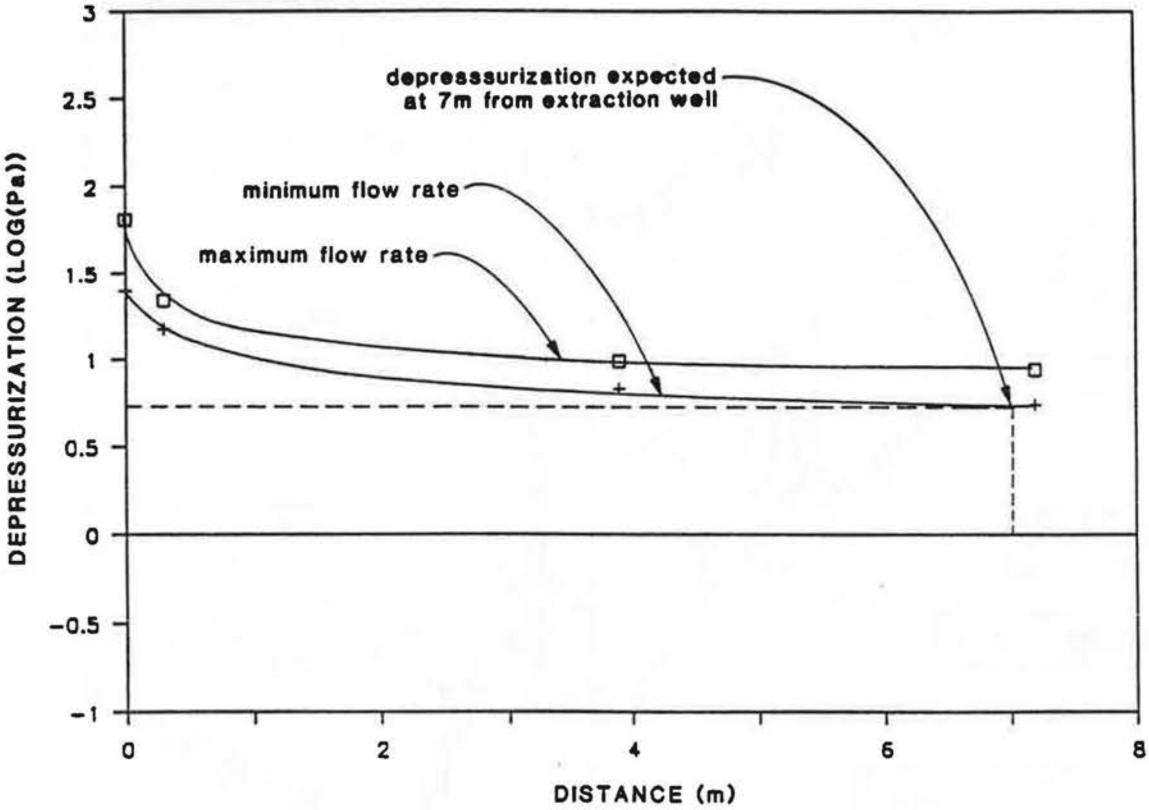

FIGURE 3: TYPICAL RESULT FROM PERMEABILITY TESTING

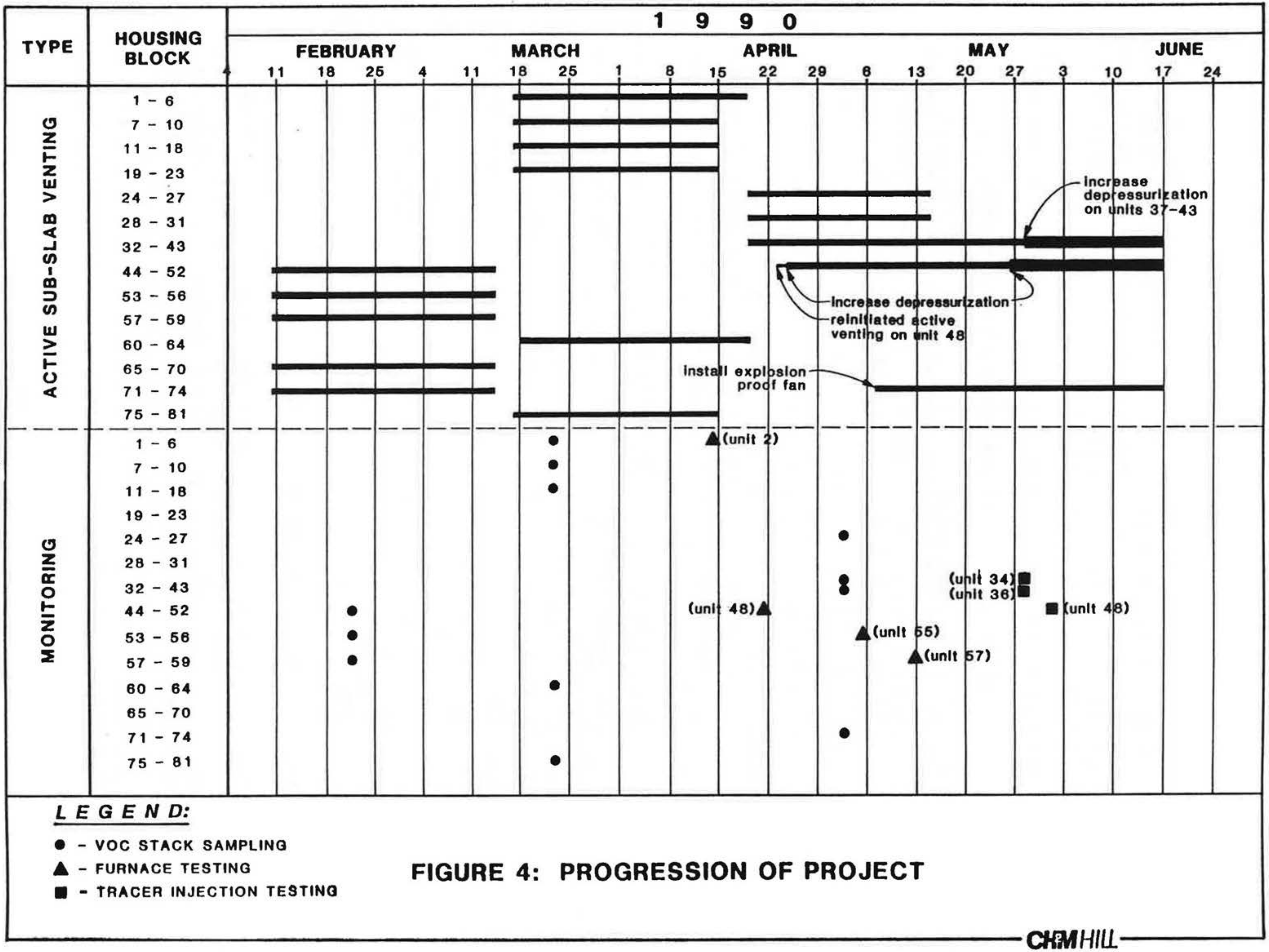

FIGURE 4: PROGRESSION OF PROJECT

tor capable of measuring methane concentrations in the range of 0-1000 ppm and was used to measure methane in ambient basement air, exhaust vents and in slab probes. Whenever methane concentrations exceeded 1000 ppm, the OVA was no longer useable; the GMI gas detector was then implemented. The GMI was principally used on soil gas probes, and on the occasional slab probe.

Table 1
LIST OF EQUIPMENT USED IN MONITORING PROGRAM

Instrument	Purpose
• Kanalflakt K-6 Fan; 325 Pa at zero flow, and 150 L/s free air (approved for this study only under permission)	generates suction for active venting
• Kanalflakt KTEX Explosion Proof instrument 140-40 Fan (currently this fan is not CSA approved)	generates suction for active venting
• Van EE Flow Master™ Airflow Measuring equipment model FMS-06-OD; 20 - 120 L/s	measurement of stack flow rates
• Van EE Flow Master™ Airflow Measuring Equipment model FMS-04-OD; 10 - 36 L/s	measurement of stack flow rates
• Dwyer Magnahelix Gauge; 0 - 250 Pa	pressure measurement
• Dwyer Inclined Manometer; 0 - 62 Pa	pressure measurement
• Century Organic Vapour Analyzer Model OVA 128; 0 - 10, 0 - 100, 0 - 1000 ppm	methane measurement
• Heath GMI Methane Detector; 0 percent LEL - 100 percent GAS	methane measurement
• Stainless Steel Air Sampling Canisters	analysis of VOCs in stacks
• SF_6 gas, Becton Dickenson 50 cc disposable syringe, 20 mL vacutainers	tracer tests

2.2.1 MEASUREMENT PROTOCOL

Calibration of the instruments used for methane measurements was carried out consistently throughout the field program. Prior to any of the spot or continuous measurements, calibration of the OVA was performed. Calibration gases of 0 ppm and 100 ppm of methane were used to tune the equipment. The Century 128 could be adjusted for both the gain and zero settings. The Heath GMI gas meter was calibrated with a calibration gas at 49 percent LEL (conversion of ppm to percent lower explosive limit: 50,000 ppm = 100 percent LEL).

Since the basements are the initial points of methane entry, all measurements were conducted in this location. In order to avoid uncertainty in the actual concentration measurements, a box fan was used to circulate air within the basements. After several minutes of circulating the air, measurements were taken at a height of 50 - 100 cm from the floor. The location of the fan and the spot of measurement were designated in order to ensure consistency between measurements. Most of the basements had no partitions, therefore, good circulation of air was possible. For those units where partitions remained, air circulation was achieved by placing the fan in the central access area. In so doing, no high concentration "hot spots" were identified, therefore, it is believed an average methane value could be achieved. At all times, doors at the top of basement stairs were kept closed except for entry and exit. Measurement of methane in ambient basement air was performed weekly.

Methane concentrations were also measured in slab probes and soil gas probes which existed around the site. Methane measurements in the slab probes was performed bi-weekly. For most slab probes, methane concentrations were quite low, therefore measurements were performed with the OVA. For those cases where the measurements exceeded 1000 ppm, the GMI was utilized to record the methane values. Methane measurements were conducted weekly in the soil probes across the site. Although many other soil gas probes existed on the site, many were non-functional due to flooded conditions and broken piping. Several monitors were useable; these are shown in Figure 5. Soil probes were routinely measured with the GMI.

Accurate readings of soil gas at every slab probe was not always possible. Due to the presence of high moisture content, and in some cases the presence of an oxygen deficient environment in the subsurface, the OVA could be expected to produce some error. As seen in Appendix A, methane readings of 0 ppm in some slab probes were documented. Although such readings may be theoretically possible, the two factors mentioned above could extinguish the flame of the OVA. As such, whenever readings in slab probes are less than ambient (1-5 ppm), caution should be taken not to apply the numbers directly.

In some units (i.e. units 32, 53, 54, and 55), a high water-table on occasion prevented the measurement of methane from the slab probes. In one case, excessively high water content caused damage to the OVA. Attempts were made to calibrate and recalibrate the OVA, however, instrument drift occurred continuously. As a result, the measurements taken on the March 13/14 sampling round were considerably higher than the normal readings. Consequently, the analysis of data omitted the results of this sampling round. After March 14, the OVA was repaired and once again functioned well.

Soil gas pressures were also measured during the program. Soil gas pressures were normally measured with the inclined manometer due to the low magnitude of some of the sub-slab pressures. It should be noted that all pressures which were measured were relative to the basement atmospheric pressure at the time of measurement. If the atmospheric pressure dropped due to the emergence of a low atmospheric front, soil gas pressures may appear to rise. Alternatively, when the atmospheric pressure rises

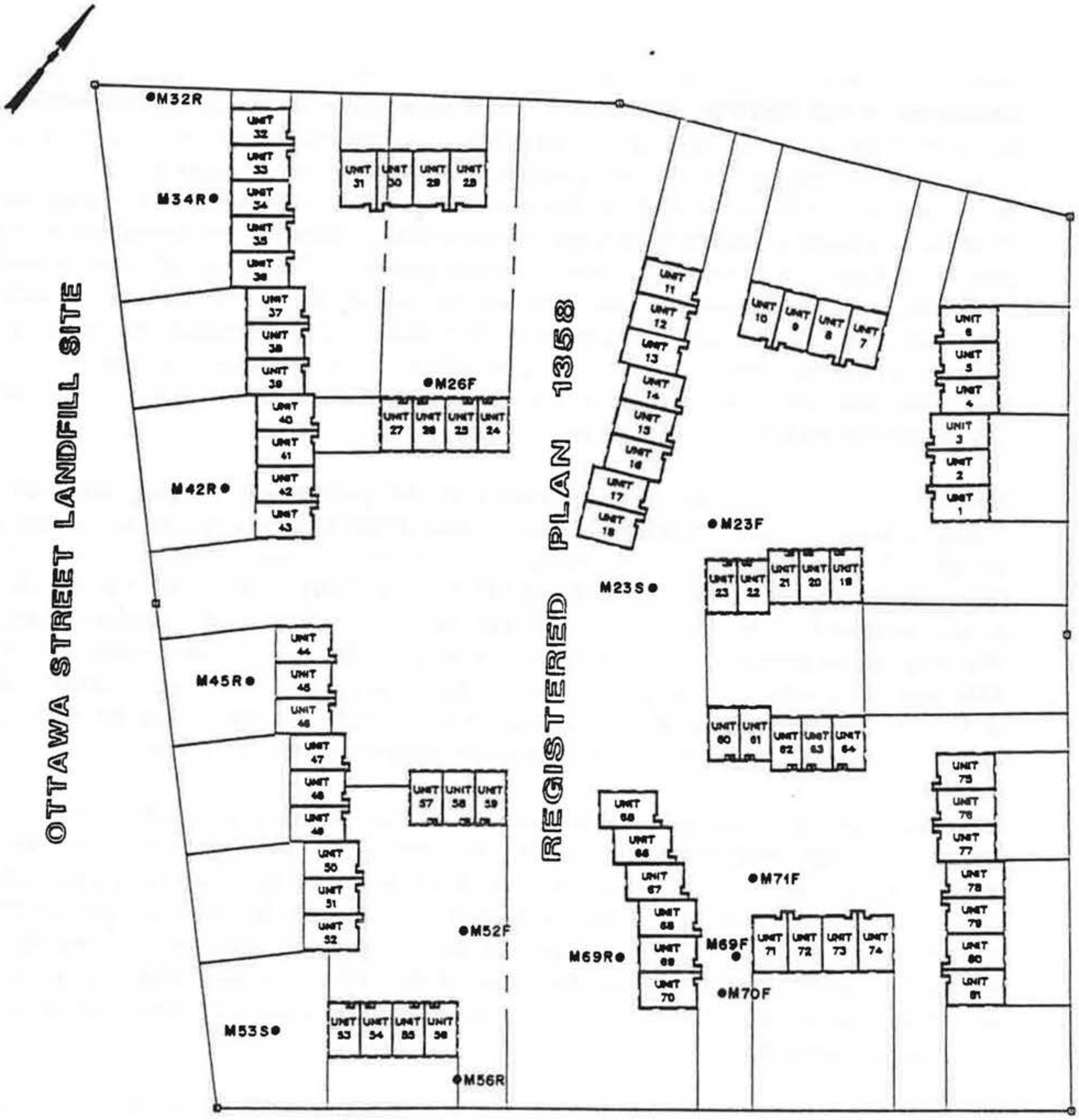

FIGURE 5: LOCATION OF SOIL PROBES

quickly, lower soil gas pressures may be expected. Such effects are likely to influence measurements from the soil probes only.

In order to evaluate the impact of the exhaust gases on the outside ambient air, testing for VOCs was conducted. Although not all of the active vents were sampled during this program, representative samples of the soil gases on the site were collected from various stacks across the property. Table 2 is a summary of the housing blocks sampled. The points of emission during the monitoring period are shown in Figure 6.

Table 2
SUMMARY OF VOC SAMPLING CONDUCTED AT STRASBURG ROAD TOWNHOUSES

Housing Blocks	Sample No.	Sample Date	Fan Location	Type of Analysis
1-6	H	Mar. 20	unit 3	42 compounds
7-10	F	Mar. 20	unit 10	non-selective
11-18	I	Mar. 20	unit 18	42 compounds
19-23				
24-27	K	May 2	unit 27	42 compounds
28-31				
32-43	M	May 2	unit 39	non-selective
	J	May 2	unit 32	42 compounds
44-52	B	Feb. 21	unit 49	42 compounds
53-56	A	Feb. 21	unit 56	42 compounds
57-59	C	Feb. 21	unit 57	42 compounds
60-64	E	Mar. 20	unit 60	42 compounds
65-70				
71-74	L	May 2	unit 71	41 compounds
75-81	G	Mar. 20	unit 78	42 compounds

During the venting operation, the effluent gases were sampled with the use of evacuated canisters. Initially, sampling was conducted by inserting a sampling tube directly into the vertical 0.1 m diameter ABS plastic exhaust pipe through a designated sampling port. The sampling port was drilled into the exhaust pipe at least four pipe diameters away from the fan assembly. Unfortunately, some of the sampling probe assembly consisted of Tygon tubing. This caused slight contamination of some of the air samples. Samples A,B,C, and I were contaminated by compounds from the Tygon tubing. Fortunately, the identified compounds did not have concentrations in excess of ambient air quality standards. As a result of the contamination caused by the tubing, the method of sampling was changed. Sampling was conducted by inserting a six inch duct on the exhaust of the 0.15 m diameter fan. The air canister was then fitted directly into the air flow such that the valve was positioned at the centroid of the exhaust vent. The valve was opened and closed under the positive air pressure from the

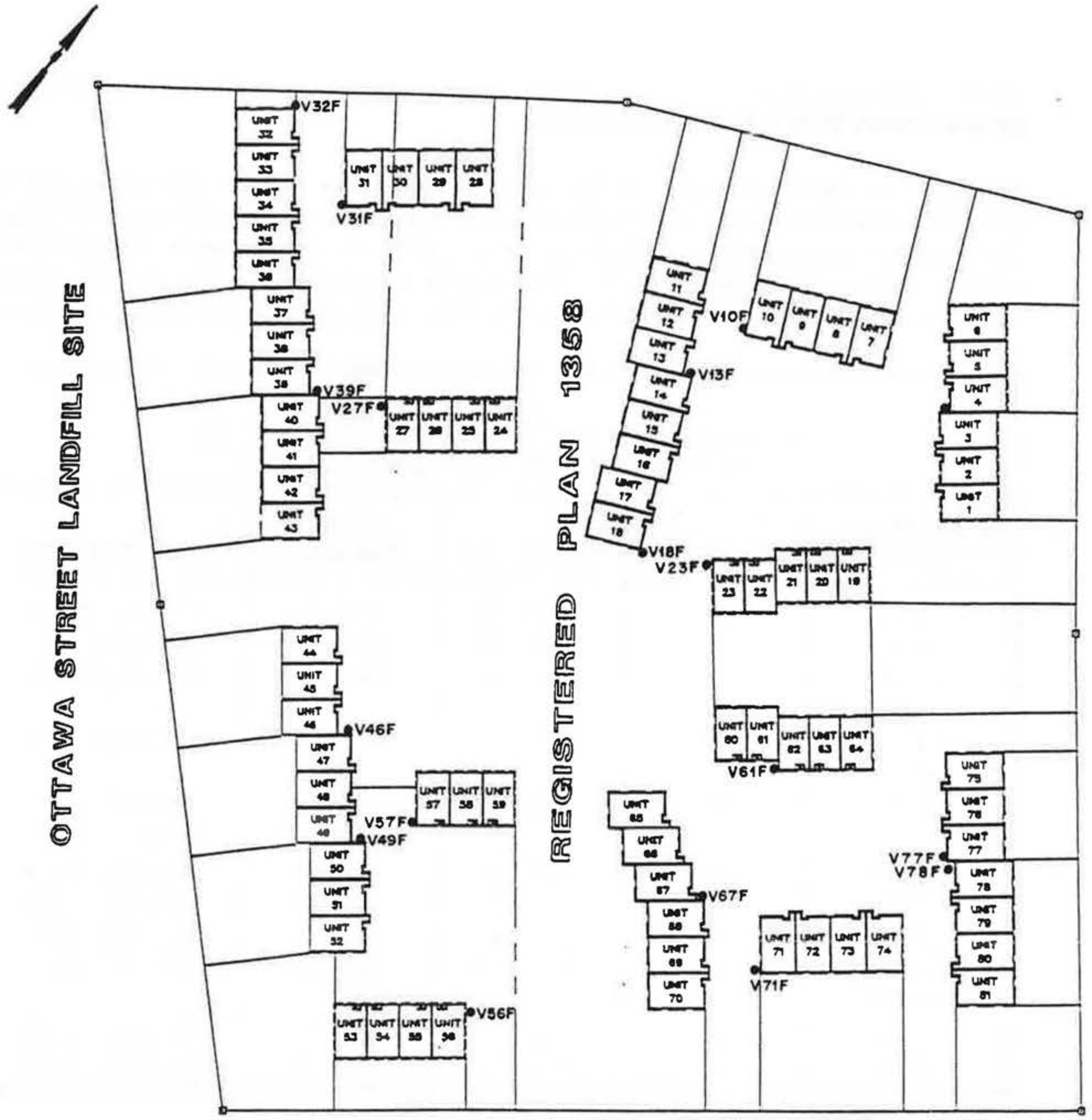

FIGURE 6: LOCATION OF EMMISION POINTS DURING TESTING

exhaust. The static pressure at the point of sampling varied between 25 to 40 Pa relative to atmospheric pressure.

One sample was also collected to identify bias due to the venting materials used. The piping was sealed at the soil gas extraction wells to prevent the entry of soil gases. Outside air was allowed to enter the collection system at a distant connection point so similar flow rates from the fan were achieved. Contamination identified could then be related to components of the venting materials. Sample analysis for the 1990 samples was completed by Battelle Memorial Laboratories.

As seen in Table 2, two types of analysis were completed on the gas samples. Ten samples were analyzed for a 42 compound list of selected ions. An additional two samples were analyzed for a non-selective group of ions by means of a GC/MSD system in total scanning mode of operation. In this case, a compound which existed at significant quantities, but did not appear on the selective 42 ion list, might be detected.

During the monitoring schedule, an explosion proof fan was also tested at this site. A Kanaflakt KTEX 140-4C explosion proof fan was tested for performance evaluation on block 71-74. The fan performed well.

In order to quantify the influence of sub-slab venting an energy consumption in the townhouses, gas meter readings were taken weekly for the duration of the project. Based on the readings, an average daily gas consumption rate could be determined.

Section 3
RESULTS AND DISCUSSION

3.1 INDOOR METHANE CONCENTRATION

3.1.1 BASELINE CONCENTRATIONS

As outlined in Section 2.1, indoor methane concentrations were determined by means of weekly spot checks throughout the monitoring period. Monitoring was conducted for active venting and non-active venting periods. The results of the 1990 monitoring program are included in Appendix A and are summarized in Table 3. The discussion of the indoor methane concentration will first focus on the non-active venting period.

The ranges of observed methane concentrations as shown in Table 3 reflect values as obtained between February 5 and June 7, 1990. During the course of the monitoring period, the methane concentration could vary greatly depending on the unit. For example, unit 71 showed indoor ambient variations of 6 to 1600 ppm. Many other units, however, showed very little variation. Such results were consistent with variations seen in previous work (CH2M HILL, 1989). In 1990 monitoring period, one anomaly was evident in the overall sampling effort. As mentioned in Section 2.2, damage sustained by the OVA on the March 13/14 sampling event made it difficult to obtain accurate measurements. So as not to bias the results in Table 3, the methane concentrations for the March 13/14 date were referenced in brackets ( ) if higher than typical values were observed.

Since methane results may vary considerably depending on the time of sampling, it is important that consistency is achieved with respect to historical measurements. As evidenced during the 1990 monitoring period, the results match closely with historical records (i.e. Morrison Beatty, 1986; and CH2M HILL, 1989). Table 4 is a historical comparison of the detectable methane found in the ambient basement air of the various housing units on the site. Morrison Beatty (1986) developed an arbitrary criteria which categorizes the units according to the detectable amount of methane found in the townhouse units during non-active venting periods. The categories for comparison in Table 4 is repeated here:

CATEGORY 1: No detectable or significant methane occurrence. All measurements in this grouping were less than 30 ppm.

CATEGORY 2: Minor but frequent occurrence of methane. Frequent concentrations up to 50 ppm were recorded.

Table 3
SUMMARY OF INDOOR METHANE CONCENTRATIONS (ppm) FOR STRASBURG TOWNHOUSES

Unit #	Active Venting	Non-Active Venting	Unit #	Active Venting	Non-Active Venting
1	1-4	1-5 (8)	46	1-2	1-18
2	12-16	22-26 (42)	47	1-2	1-12
3	1-3	1-4 (7)	48	2-17	3-22
4	1-3	2-4 (8)	49	1-3	2-18
5	1-3	1-4 (9)	50	1-3	1-20
6	4-7	3-9 (22)	51	1-3	1-42
7	1-3	1-5 (8)	52	2-2	1-80
8	1-3	1-3 (8)	53	2-36	5-38
9	1-3	1-4 (6)	54	1-3	2-18
10	3-4	1-5 (9)	55	10-20	25-34
11	1-4	2-5 (8)	56	1-4	1-18
12	1-3	1-3 (5)	57	2-14	3-56
13	2-4	1-4 (8)	58	1-4	3-14
14	1-3	1-3 (6)	59	1-3	1-12
15	1-3	1-4	60	1-3	1-3 (6)
16	1-4	2-5	61	1-3	1-3 (4)
17	1-3	1-4	62	2-3	1-4 (8)
18	2-4	2-5	63	1-3	1-4 (8)
19	2-4	1-4 (10)	64	2-3	1-4 (8)
20	3-5	1-4 (12)	65	1-2 (5)	1-3
21	3-6	2-5 (16)	66	1-2 (6)	1-3
22	1-2	1-3 (8)	67	1-2 (8)	1-4
23	1-3	1-5 (7)	68	1-3 (7)	1-3
24	2-3	1-3	69	1-4 (6)	1-4
25	2-4	2-3 (5)	70	1-2 (7)	1-4
26	2-4	2-5 (6)	71	2-7 (18)	6-1600
27	1-3	1-5	72	1-5 (11)	4-440
28	2-3	1-3	73	1-7 (10)	1-94
29	1-3	2-4	74	1-16	2-120
30	2-3	2-3	75	3-5	1-6 (14)
31	2-3	1-3	76	1-2	1-3 (11)
32	2-4	1-3	77	2-3	1-7 (11)
33	2-5	1-4	78	1-3	1-3 (7)
34	2-4	1-3	79	1-3	1-4 (5)
35	2-4	1-10	80	1-4	2-5 (11)
36	1-3	1-9	81	1-3	2-3 (9)
37	1-12	2-8			
38	1-12	1-4			
39	1-12	1-4			
40	1-9	1-8			
41	1-12	2-8			
42	2-8	1-3			
43	1-12	1-3			
44	1-4	2-18			
45	1-4	2-12			

NOTE: Numbers which are listed in brackets () represent readings taken on March 13/14, i.e. likely affected by equipment malfunctions.

Table 4
SUMMARY OF GROUPINGS ACCORDING TO GROUPING OF DETECTABLE METHANE IN BASEMENTS (House #s)

	Morrison Beatty	CH2M HILL (1989)	CH2M HILL (1990)
CATEGORY 1	3,4,6-9 10-19 20-25,28, 30,33,35-37, 39, 40-47,49 50,53,56-59, 60-69 70,75-79 80,81	44-47,49 50-54,56	1,3-9, 10-19 20-29, 30-39, 40-47,49 50,54,56,58,59 60-69 70,75-79, 80,81
CATEGORY 2	1,2 48 73	48	48 51,53,55
CATEGORY 3	51,54 67	55, 72-74	52,57 71-74
CATEGORY 4	52 71,72	71	
NO DATA	5 26,27,29 31,32,34,38 55 68,69	1-43 57-59 60-69 70,75-79	

CATEGORY 3: Confirmed methane occurrence well below hazardous levels. Repeated results contained methane but, were at all times less than 20 percent LEL.

CATEGORY 4: Confirmed methane occurrence where findings of gas with at least one measurement greater than 20 percent LEL.

For the most part, the categorization was consistent for the three monitoring periods. Differences are possibly due to either the frequency of sampling, and/or the method used in sampling. The frequency of sampling can be an important factor in the determination of peak concentrations especially where large variations are encountered. Many measurements may provide evidence of greater fluctuations. Likewise the method of sampling could also cause an alternative categorization of each individual unit. The method of evaluation used by Morrison Beatty identified "hot spots" and the units were categorized accordingly; this study and the 1989 study measured values of the average basement methane concentration.

As seen by both the historical records and the results from the 1990 monitoring period (refer to Table 3), most of the housing blocks do not have significant indoor methane concentrations. Many of the units measured, reflect methane concentrations in the range of 1-5 ppm which is typical of outside ambient air across the site. Variations in the range of 1-5 ppm as noted in Table 3 may be due to either changes in ambient conditions or instrument drift/error. Numerous units, e.g. unit 1, 3, 4, 5, 6, 7, 8, 9, etc. had typical background methane concentrations.

3.1.2 EVALUATION OF SUB-SLAB VENTING

In order to accurately assess the impacts of sub-slab venting, several factors which could influence indoor methane levels must be examined. Three factors which influence the evaluation of the success of sub-slab venting operation were:

- the consistency of the sub-slab methane source
- the degree of depressurization
- the possibility of fugitive furnace emissions

Each of the above factors will be discussed in relation to the results found at the townhouse site.

Sub-Slab Methane Source

During the course of the monitoring period, methane concentrations were measured in the slab and soil probes. This provided information on the existence of methane sources and the potential for infiltration problems. The consistency of the methane sources is an important factor for the evaluation of sub-slab venting technology. If the methane concentration is consistently high throughout the monitoring period, the technical feasibility of active venting may be more easily evaluated. On the other hand, if the methane source fluctuates over an extended period, the evaluation becomes more difficult especially if high concentrations are not documented during a venting period. Over the course of the 1989 and 1990 monitoring periods, CH2M HILL has observed that conditions across the site varied such that:

- consistently high methane sources
- consistently low methane sources, and
- variable methane sources were possible.

The highest sub-slab methane source which showed reasonable consistency over 1989-90 monitoring period was in the vicinity of housing block 71-74. Although temporal and spatial variations under the slab ranged from 0 ppm to 52 percent gas, high concentrations were identified in both active venting and non-active venting periods (refer to Appendix A). Additional evidence from nearby soil monitors M70F, M71F (refer to Appendix C) also suggests that the source of methane was consistent throughout the active venting and non-active venting periods. Since high methane readings were identified in both venting and non-venting periods, the evaluation of sub-slab venting may be completed. Based on the results shown in Table 3, and in previous work (CH2M HILL, 1989), sub-slab venting in block 71-74 can reduce indoor methane levels close to background levels. The one anomalous measurement in unit 74 (16 ppm) taken early in the venting period, was likely due to the time necessary to flush ambient air when the fan is activated.

Three units, 64, 69 and 70, in the immediate area of block 71-74 showed slightly elevated methane concentrations in the subsurface with typical background levels in the basement ambient air. Since the indoor air was essentially not affected, it was impossible to evaluate these units. These units showed sub-slab concentrations from 0 to 48 ppm, far below any problem level.

Methane sources under the slab were consistently low in the majority of the housing units. Units with low sub-slab methane sources, in most cases, also had low indoor concentrations. Table 5 is a summary of methane ranges in the sub-slab space and in the ambient basement air. For those units where both sub-slab and indoor concentrations were found to be less than or equal to 10 ppm, the unit has been flagged accordingly. In view of low concentrations presented in Table 5 for the flagged units, it is impossible to evaluate definitively the success of sub-slab venting for these units. Despite the difficulty of this evaluation for these units, however, the data in the 1990 monitoring program, and the historical data base (refer to Table 4 under CATEGORY 1), indicate the lack of an inherent danger of excessive indoor methane concentrations with or without venting.

The evaluation of sub-slab venting is difficult whenever a variable or fluctuating subsurface methane source exists. During the monitoring period, it became apparent that a variable methane source does affect the portion of the site which is adjacent to the closed landfill. In the early spring of 1990, elevated methane concentrations in ambient air, slab and soil probes were recorded on some exceptionally warm days in late April and early May. Peak concentrations were especially noticeable on April 20-24, and May 29-30 (refer to Appendices A and C). The peak concentrations which were identified may be related to the historical phenomenon of early spring increases as noticed at this site (refer to section 1.1). Table 6 is a comparison of the methane concentrations in the ambient basement air and the sub-slab space of units 36-59, for the period from February 5 to April 9, and from April 10 to June 7, respectively. For those units experiencing venting (i.e. units 36-43, and 48), sub-slab concentrations rose in some cases several orders of magnitude; slight increases were also realized in the ambient air of these basements. Concentrations also rose significantly in the ambient and sub-slab spaces of unvented units in blocks 44-52, 53-56, and 57-59. Increases in the methane concentrations however were not as apparent in unit 53 where the sub-slab space became flooded, and in unit 57 where furnace emissions affected the ambient concentrations (furnace emissions will be discussed later).

Table 5
SUMMARY OF METHANE CONCENTRATIONS IN SUB-SLAB SPACE AND AMBIENT BASEMENT AIR (ppm)

Unit #	Concentration Range Below Slab	Concentration Range in Ambient Air	Overall Low Concentration
1	0-3 (4)	1-5 (8)	✓
2	0-28	12-26 (42)	
3	1-3 (7)	1-4 (7)	✓
4	1-3 (7)	1-4 (8)	✓
5	1-3 (8)	1-4 (9)	✓
6	2-8	3-9 (22)	✓
7	1-960 (>1000)	1-5 (8)	
8	1-5 (8)	1-3 (8)	✓
9	1-3 (5)	1-4 (6)	✓
10	1-4 (8)	1-5 (9)	✓
11	1-4 (6)	1-5 (8)	✓
12	1-3 (5)	1-3 (5)	✓
13	1-4	1-4 (8)	✓
14	1-3 (4)	1-3 (6)	✓
15	1-3	1-4	✓
16	1-5	1-5	✓
17	0-3	1-4	✓
18	0-5	2-5	✓
19	1-4 (8)	1-4 (10)	✓
20	0-7 (12)	1-5 (12)	✓
21	0-5 (8)	2-6 (16)	✓
22	0-2 (7)	1-3 (8)	✓
23	0-3 (5)	1-5 (7)	✓
24	0-3	1-3	✓
25	0-5	2-4 (5)	✓
26	1-5	2-5 (6)	✓
27	0-3	1-5	✓
28	0-3	1-3	✓
29	0-3	1-4	✓
30	0-3	1-4	✓
31	1-3	1-3	✓
32	1-5	1-4	✓
33	1-5	1-5	✓
34	1-4	1-4	✓
35	1-10	1-10	✓
36	0-140	1-9	
37	0-600	1-12	
38	0-7000	1-12	
39	1-500	1-12	
40	1-2600	1-9	
41	1-2600	1-12	

NOTES:
- Whenever a reading of >1000 ppm is documented, measurement was greater than the range of OVA
- Overall low concentrations represent concentrations less than or equal to 10 ppm in both ambient and sub-slab methane measurements
- Data from the March 13/14 sampling period has been omitted in the ranges due to equipment problems. If reading on March 13/14 exceeded maximum value, the maximum reading for this day is listed in Brackets ( ).

Table 5
(continued)

Unit #	Concentration Range Below Slab	Concentration Range in Ambient Air	Overall Low Concentration
42	1-250	1-8	
43	1-12	1-12	
44	1-14	1-18	
45	0-3	1-12	
46	0-2	1-18	
47	1-18	1-12	
48	1-20,000	2-22	
49	0-17	1-18	
50	0-21,000	1-20	
51	0-22,500	1-42	
52	0-35,000	1-80	
53	0-13,500	2-38	
54	1-2500	1-18	
55	2-750	10-34	
56	0-18	1-18	
57	1-26	2-56	
58	0-28	1-14	
59	0-7	1-12	
60	1-3	1-3 (6)	✓
61	1-3	1-3 (4)	✓
62	1-3 (4)	1-4 (8)	✓
63	1-3 (8)	1-4 (8)	✓
64	1-20	1-4 (8)	
65	0-3 (5)	1-3 (5)	✓
66	0-2 (7)	1-2 (6)	✓
67	0-2 (8)	1-2 (8)	✓
68	0-2 (7)	1-3 (7)	✓
69	0-12	1-4 (6)	
70	0-48	1-4 (7)	
71	1-52,000	2-1600	
72	1-<1000	1-440	
73	0-1400	1-94	
74	1->1000	1-120	
75	1-4 (16)	1-6 (14)	✓
76	0-3 (17)	1-3 (11)	✓
77	0-4	1-7 (11)	✓
78	0-4	1-3 (7)	✓
79	0-3 (4)	1-4 (5)	✓
80	1-5	1-5 (11)	✓
81	1-7 (9)	1-3 (9)	✓

NOTES:

- Whenever a reading of >1000 ppm is documented, measurement was greater than the range of OVA
- Overall low concentrations represent concentrations less than or equal to 10 ppm in both ambient and sub-slab methane measurements
- Data from the March 13/14 sampling period has been omitted in the ranges due to equipment problems. If reading on March 13/14 exceeded maximum value, the maximum reading for this day is listed in Brackets ( ).

Despite the sub-slab concentration increases which occurred in the April 10 - June 7 period, sub-slab venting appeared to suppress indoor concentrations in units 36-43 and unit 48. The data shown in Table 6 also indicates that the timing of the venting exercise on units 42 - 59 was not optimal for the peaks which were apparent during the April 10 to June 7 period. Nevertheless, the results at units 36 - 43 and 48 indicate that sub-slab venting would mitigate the infiltration of methane into basement ambient air in the units adjacent to the landfill site.

Table 6
COMPARISON OF METHANE CONCENTRATIONS FOR TWO TIME PERIODS

Unit	Feb. 5 - Apr. 9			Apr. 10 - June 7		
	Methane Conc. (ppm)		Venting (Feb. 5-Mar. 7)	Methane Conc. (ppm)		Venting (Apr. 20-June 17)
	Ambient	Sub-Slab		Ambient	Sub-Slab	
36	1-9	0-8		1-3	1-140	✓
37	2-8 (14)	0-10		1-12	1-600	✓
38	1-6 (16)	0-940		1-12	1-7000	✓
39	1-4	1-3		1-12	5-5000	✓
40	1-4	0-3		1-9	1-2550	✓
41	2-8	1-6		2-12	1-2600	✓
42	1-3	0-3		1-8	1-250	✓
43	1-3	0-2		1-12	1-12	✓
44	1-4	1-3	✓	2-18	1-14	
45	1-5	1-3	✓	2-12	0-2	
46	1-3	0-2	✓	3-18	0-2	
47	1-3	1-18	✓	2-12	1-8	
48	1-18	1-14	✓	2-14	2-20000	✓
49	1-5	0-7	✓	3-18	0-17	
50	1-7	0-100	✓	7-20	0-2100	
51	1-26	0-20500	✓	14-120	2-150000	
52	1-8	0-50	✓	16-52	2-35000	
53	2-38	2-13500	✓	5-36	(water)	
54	1-5	1-2400	✓	3-18	30-2500	
55	10-26	1-160	✓	2-34	2-750	
56	1-4	0-18	✓	3-18	3-18	
57	2-56	1-26	✓	3-14	1-5	
58	1-6	0-28	✓	3-14	2-5	
59	1-3	0-5	✓	2-12	1-7	

NOTE: Data from March 13/14 sampling event has been omitted due to equipment problems. If reading on March 13/14 exceeded maximum value the maximum reading for this day is listed in brackets ( ).

Degree of Depressurization

The degree of depressurization or the magnitude of negative pressure exerted by the extraction fan is also an important factor in the evaluation of sub-slab active venting. Over the course of testing active venting at the site, several units did not show considerable improvement with respect to indoor methane concentrations due to inadequate depressurization. The following units did not show considerable improvement: units 2, 37, 38, 39, 40, 41, 42, 43, 48, 53, 55, and 57. Units 2, 48, 55, and 57 will be discussed in the next section under fugitive furnace emissions.

Initially, when the active venting system was constructed on block 32-42, fans were placed at units 32 and 39. Unfortunately, this arrangement was not capable of ensuring a satisfactory degree of depressurization especially in units 37, 38, 39 and 40. Typical measures of depressurization ranged in the order of -2 to -4 Pa at the probe furthest from the extraction well (i.e. probe c). Consequently, on May 28, another fan was added to the system to increase depressurization. The new values of depressurization are shown in Appendix B. This caused a noticeable improvement in the indoor methane concentrations as seen below:

Unit	April 15 - May 28	May 28 - June 7 (increased depressurization)
37	3-12 ppm	1-4 ppm
38	3-12 ppm	1-4 ppm
39	2-12 ppm	1-3 ppm
40	2-9 ppm	1-3 ppm
41	2-12 ppm	2-3 ppm
42	2-8 ppm	1-2 ppm
43	2-12 ppm	1-4 ppm

Although the indoor concentrations of methane from April 15 to May 28 do not necessarily pose a safety problem, the improvement with increased depressurization is readily apparent.

Unit 53 was also affected by inadequate depressurization. Table 3 compared concentration ranges during active and non-active venting periods. Based on the results, this unit showed little improvement:

- 2-36 ppm during active venting
- 5-38 ppm during non-active venting

This observation may be explained with the aid of pressure data (Appendix B). During the active venting of block 53-56, excessive water was extracted by the venting system. The accumulated water found in the collection pipe was likely due to condensation resulting from rapid temperature decreases of the soil gases as they moved through the system. As a result of the excessive water vapour and cold temperatures, the vent pipes stationed outside froze, blocking air flow from the unit. As a result, low depressurization on March 1 caused an indoor methane concentration of 36 ppm to exist. Under normal conditions (i.e. no blockages), indoor methane concentrations were between 2-7 ppm.

Based on the above discussion, adequate depressurization is important for the satisfactory performance of an active sub-slab venting system. Insulation of the vent pipe, and drainage facilities, will become necessary for winter operation.

Fugitive Furnace Emissions

Several of the units which were tested showed no appreciable declines in methane concentrations even with increased depressurization. Units in this category included units 2, 48, 55, and 57. The cause of elevated methane in these units was discovered to be due to fugitive furnace emissions. In order to evaluate the contribution of methane from the furnaces, the OVA was used to measure methane concentrations in the intake and exhaust of the interior air flow around the furnace. Figure 7 shows the pattern of airflow as determined with the use of a smoke pencil. In each of the above mentioned units, higher methane concentrations were measured in the exhaust gases from the top surface of the furnace. Concentrations near the lower parts of the furnace, were typical of ambient conditions.

When the methane concentrations were measured at the emission point with the OVA, the concentration of the air emissions were typically quite erratic. Based on the five second sampling rate, the variations in the emission rates from some of the furnaces are shown in Figure 8. Units 48 and 57 which showed high concentrations during previous spot check testing, showed emission concentrations between 22 and 45 ppm, and 55 and >1000 ppm, respectively. Unit 49 which had previously showed slightly elevated methane concentrations typically in the order of 2 or 3 ppm above background, was also likely affected by emission concentrations of 8 to 19 ppm from the furnace in that unit.

Emission concentrations were also measured in units 19 and 46 for a similar period at a similar interval for comparison. From previous spot measurements, units 19 and 46 showed generally low indoor methane concentrations. As seen on Figure 8, methane emission rates varied between 2 and 4.5 ppm, and 1.5 and 2.5 ppm. Smaller fluctuations and lower overall methane concentrations were measured in these units. It is likely that the indoor air quality in units 19 and 46 are not affected by emissions from the furnaces.

Since it was apparent that some indoor air quality was being affected by fugitive furnace emissions, an attempt was made to estimate the actual contributions from the various furnaces. Air velocities were estimated by introducing smoke from a smoke pencil at the point of emission and timing the rate of travel. The dimensions of the exhaust points from the furnace were measured; the air flow rates were then determined. Methane concentrations were measured by the method described above for a period of one hour at a sampling frequency of five minutes. Based on these measurements, an average methane loading was calculated for several units.

By calculating an average methane loading, and by estimating an air exchange rate for the basement air, an approximation for the indoor air concentration was determined. Although the air exchange rates may vary between units, an approximate value of .3 air exchanges has been applied to these calculations. The indoor air methane concentrations were calculated according to the steady-state equation:

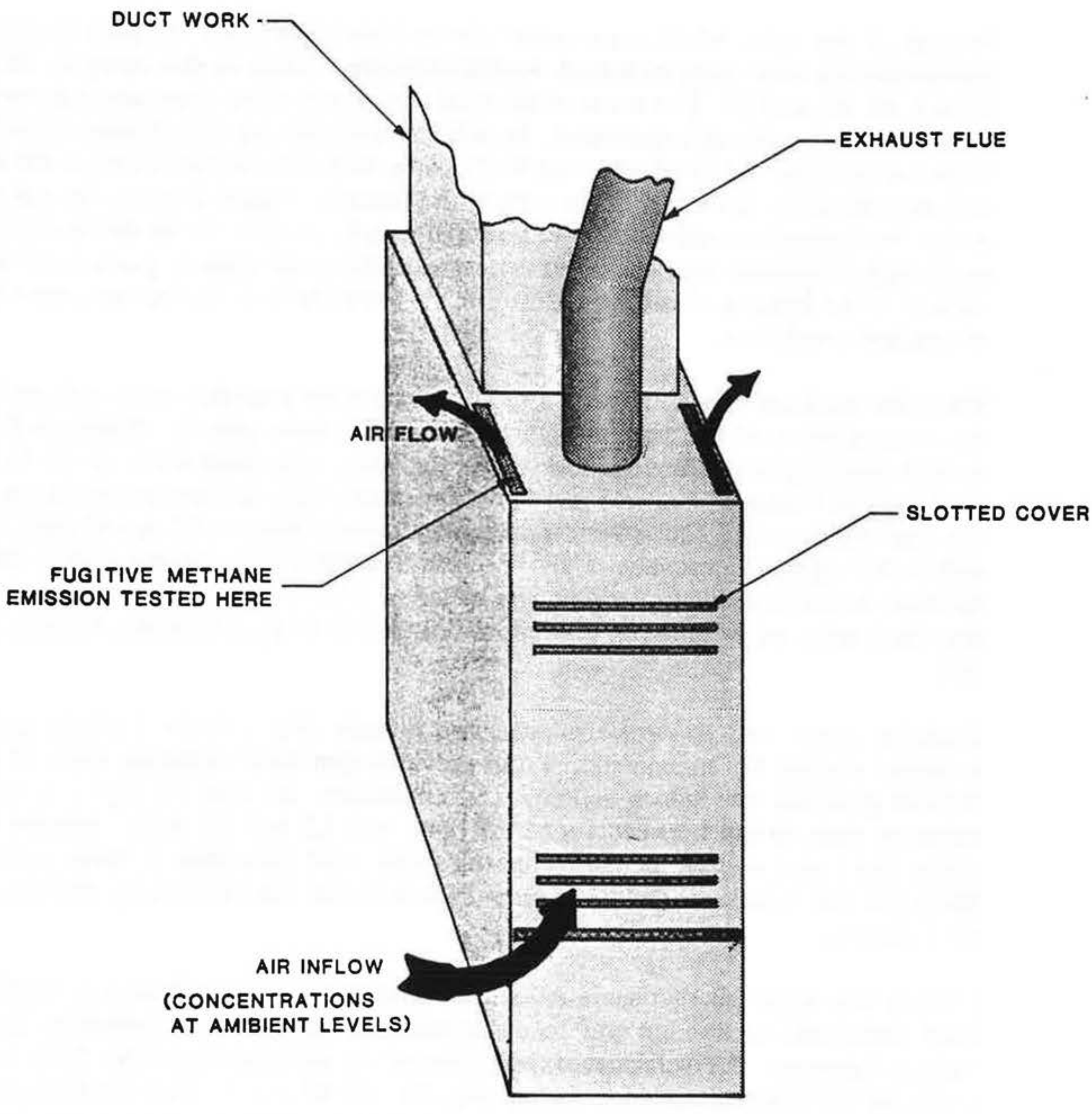

FIGURE 7: SCHEMATIC DIAGRAM OF FURNACE SHOWING POINTS OF EMISSION

N.T.S.

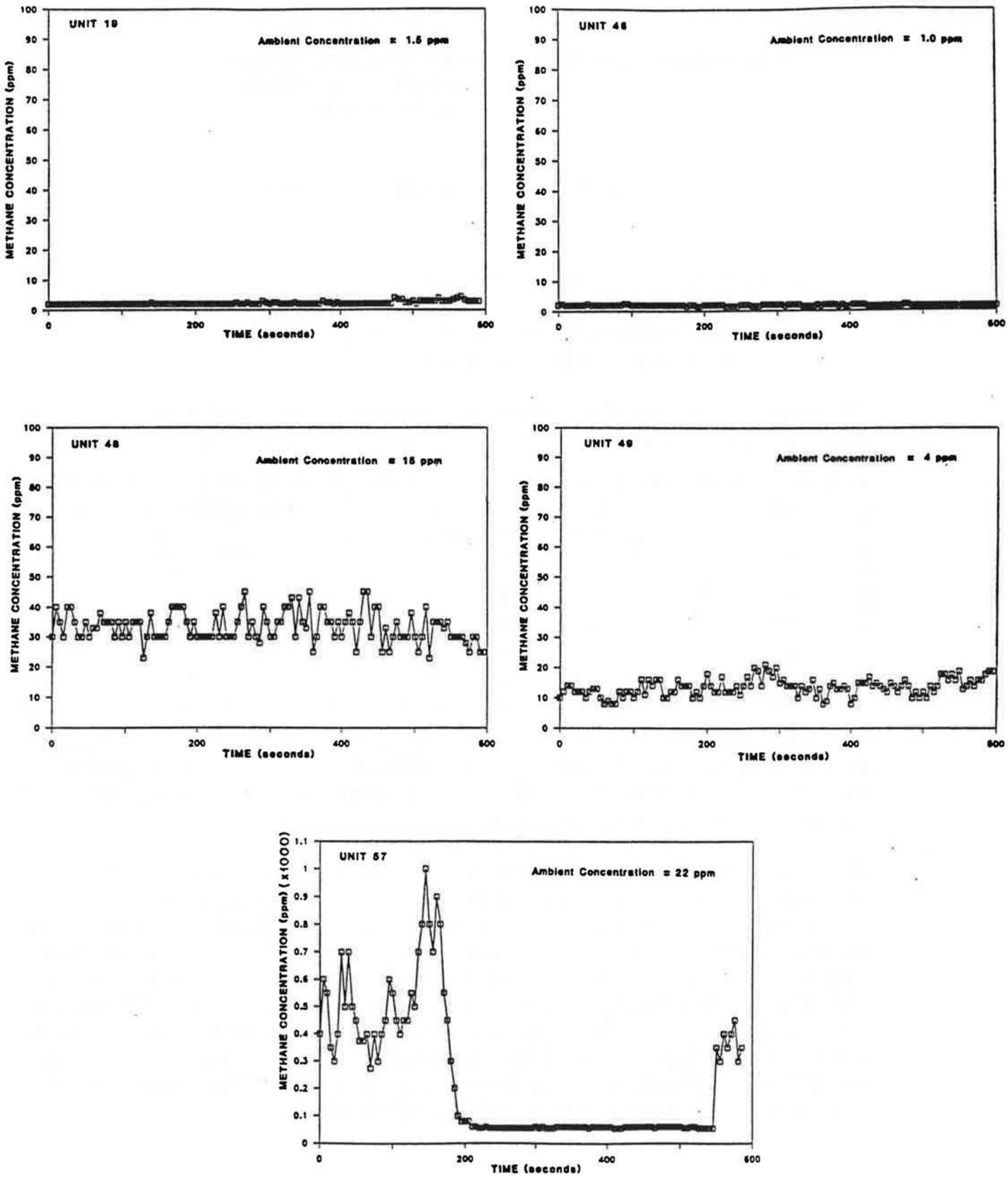

FIGURE 8 : METHANE CONCENTRATION-EXHAUST GASES FROM FURNACES IN SEVERAL UNITS

total methane inside basement = methane loading furnace
- loss due to air changes
+ methane outside air

$$\text{or} \quad C_1V_1 = FL - C_1(.3V_1) + C_2(.3V_1)$$

where C_1 = concentration in basement
C_2 = concentration in outside air (background)
FL = methane loading from furnace
V_1 = volume of air in basement

This model assumes no influence from soil gases and assumes total mixing. The concentrations calculated for each of the affected units is tabulated below:

Unit	FL (mg/hr)	C_1 (ppm)	Actual Measured Conc. (ppm)
2	1290	13	12
48	534	7	15
49	112	2	4
55	798	9	11
57	2244	23	23

With the exception of unit 48, the calculated methane concentrations in the basements are well within range of the actual measured concentrations. Based on the calculations above, it appears that the measured furnace emissions likely contribute significantly to the ambient air in the basements of several units.

One final evaluation was performed on the units above which were plagued by fugitive emissions. Continuous monitoring was implemented for several days. After 2 days, the gas valve supplying natural gas to the furnaces was shut off. Figure 9 shows the effect of turning off the gas in units 2, 48, and 55. The ambient air concentrations showed substantial decreases in methane. The monitoring from unit 48 however showed that some methane in the ambient air was due to soil gas infiltration. Diurnal fluctuations, which were evident, were likely due to stack effects. Sub-slab venting was initiated to curtail entry of soil gas. Diurnal fluctuations still persisted; increased depressurization was necessary. Thereafter typical background levels were achieved until the spring peak on April 24. Again increased depressurization was necessary.

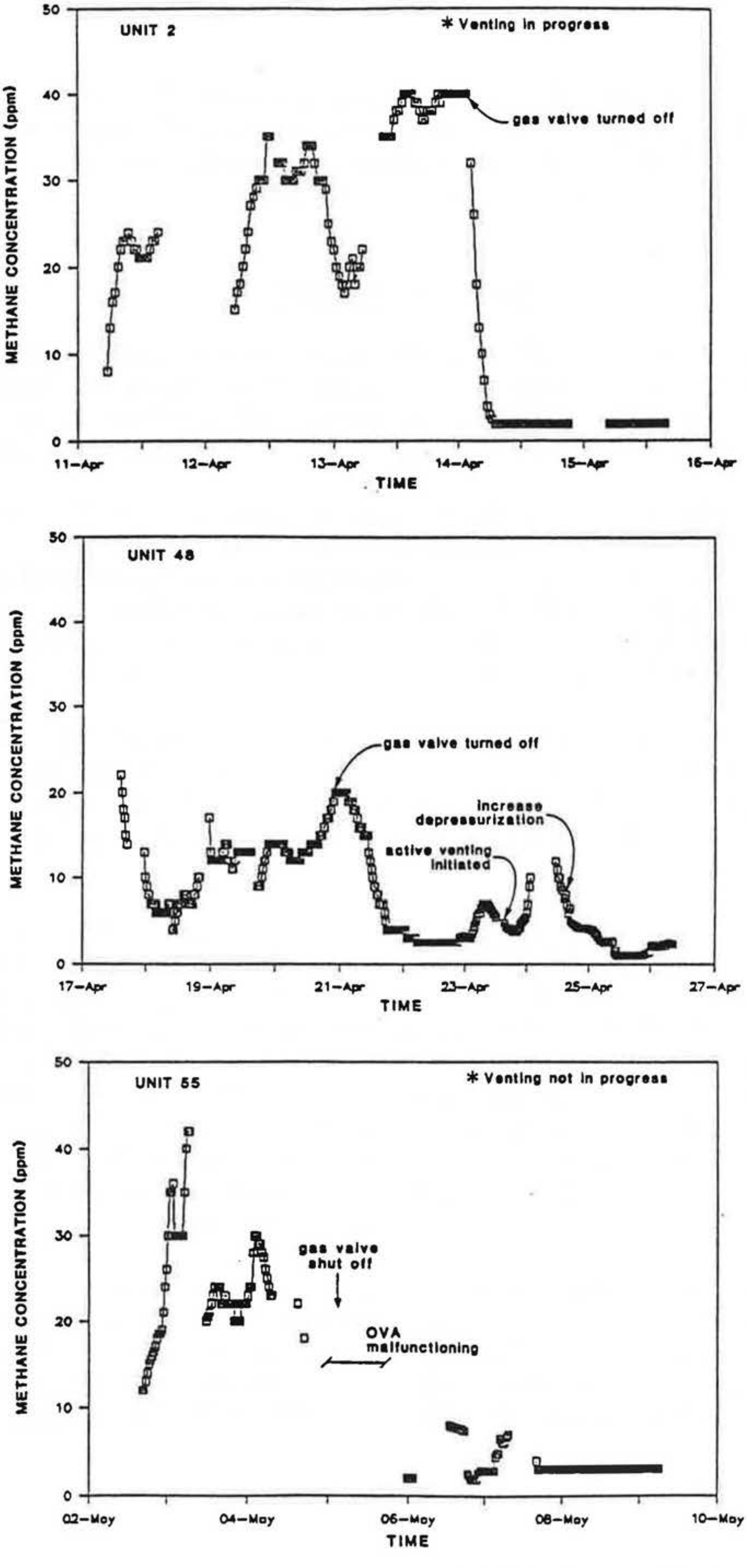

FIGURE 9 : METHANE CONCENTRATION IN VARIOUS UNITS AS AFFECTED BY FUGITIVE EMISSIONS

Similar monitoring was also attempted on unit 57. Unfortunately, concentrations dropped off considerably and only background levels were found when monitoring was initiated. As a result, similar indoor methane reductions as seen in units 2, 48 and 55, (as shown in Figure 9) could not be obtained.

3.2 EFFLUENT AIR QUALITY

The effluent air quality from the vent stacks was a primary concern for the successful operation of the venting system. The quality of effluent gases were measured for methane and VOCs. As mentioned, two types of analysis were conducted on the gases: a 42 compound selective ion analysis and a non-selective ion analysis.

The results of the 42 selective ions are shown in Table 7. The analysis of the compounds had a detection limit of 0.1 ppb. The values as obtained from the laboratory were converted to ug/m^3. Any quantitative amount prefixed with a "<" sign, indicated quantity of the compound was below its detection limit. The two samples which were analyzed in the total scanning mode, revealed no significant compound. The sample submitted for the purpose of identifying bias due to the venting material is sample "L".

Based on the results from the analysis of the 1990 sampling program, the air samples were generally quite clean. In fact much of the contamination identified was due to either sampling error or contamination caused by the venting materials themselves. Table 8 is a summary of all identified compounds above their respective detection limits.

Table 8 reveals two distinct patterns. The results as shown in Table 8 indicate that samples A,B,C and I have essentially the same fingerprint (or are quantified by similar compounds). These samples as pointed out previously were sampled with the use of Tygon® tubing. Therefore, contamination of 0-xylene, 4-ethyl toluene, 1,3,5 - trimethyl benzene and 1,2,4 - trimethyl benzene is likely due to the Tygon® tubing. The other pattern parallels the compounds which were identified in the piping sample (sample L). The presence of dichlorofluoromethane, trichlorofluoromethane, 1,1,2 - trichloro - 1,2,2, - trifluoromethane, 1,1,1 - trichloromethane, benzene, toluene, and m&p-xylene in the vent samples and in the piping sample indicates that contamination with respect to these compounds is likely due to the venting materials.

However, despite contamination from the two above mentioned sources, none of the ambient air quality criteria was exceeded. In absence of updated ambient air quality criteria (Regulation 308), criteria noted in the Clean Air Program discussion paper (November 1987) was used. Discussions with Ministry of Environment officials revealed a new lower standard (1 $\mu g/m^3$ for 24 hr) for vinyl chloride.

Table 7
SUMMARY OF VOLATILE ORGANIC COMPOUNDS
IN VENT STACKS (1990)

Sample:	A	B	C	E	G	L *	Ambient
Date:	21-Feb-90	21-Feb-90	21-Feb-90	20-Mar-90	20-Mar-90	02-May-90	Air
Location:	Block 53-5	Block 44-5 (Unit 49)	Block 57-5	Block 60-6	Block 75-8	Block 71-7 (piping)	Quality Criteria
Compound	Concentration (ug/m^3)						
dichlorofluoromethane	5.61	4.32	35.74	2.59	2.26	4.86	500000
methyl chloride	0.98	0.27	1.73	0.93	< 0.23	< 0.23	7000
1,2-dichloro-1,1,2,2-tetrafluoroethane	< 0.76	< 0.76	< 0.76	< 0.76	< 0.76	< 0.76	
vinyl chloride	< 0.28	< 0.28	< 0.28	< 0.28	< 0.28	< 0.28	1
1,3-butadiene	< 0.24	< 0.24	< 0.24	< 0.24	< 0.24	< 0.24	
methyl bromide	< 0.42	< 0.42	< 0.42	< 0.42	< 0.42	< 0.42	1350
ethyl bromide	17.45	< 0.29	< 0.29	< 0.29	< 0.29	< 0.29	
trichlofluoromethane	16.50	18.40	21.16	6.01	5.75	179.79	
1,1-dichloroethene	< 0.43	< 0.43	< 0.43	< 0.43	< 0.43	< 0.43	35
dichlormethane	0.91	< 0.38	1.18	< 0.38	< 0.38	0.99	100000
3-chloropropene	< 0.34	< 0.34	< 0.34	< 0.34	< 0.34	14.49	
1,1,2-trichloro-1,2,2-trifluoroethane	< 0.84	< 0.84	1.34	< 0.84	< 0.83	1.00	800000
1,1-dichloroethane	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	0.57	
cis-1,2-dichlorethene	< 0.43	< 0.43	< 0.43	< 0.43	< 0.43	< 0.43	
trichloromethane	< 0.53	< 0.53	1.71	< 0.53	< 0.53	< 0.53	500
1,2-dichoroethane	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	
1,1,1-trichloroethane	2.08	1.91	2.56	1.13	1.25	13.76	115000
benzene	0.70	0.63	1.64	1.26	1.18	18.62	3300
carbon tetrachloride	0.69	< 0.69	0.76	0.96	0.89	< 0.69	600
1,2-dichloropropane	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	0.91	2400
trichloroethene	< 0.59	< 0.59	0.65	< 0.59	< 0.58	< 0.59	28000
cis-1,3-dichloropropene	< 0.50	< 0.50	< 0.50	< 0.50	< 0.49	< 0.50	
trans-1,3-dichloropropene	< 0.50	< 0.50	< 0.50	< 0.50	< 0.49	1.73	
1,1,2-trichloroethane	< 0.60	< 0.60	< 0.60	< 0.60	< 0.59	< 0.60	
toluene	2.26	2.38	7.07	1.32	0.94	39.76	2000
1,2-dibromoethane	< 0.84	< 0.84	< 0.84	< 0.84	< 0.84	< 0.84	
tetrachlorethene	< 0.74	< 0.74	< 0.74	< 0.74	1.18	< 0.74	4000
chlorobenzene	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	
ethylbenzene	1.28	1.66	2.04	< 0.47	< 0.47	2.09	
m+p-xylene	5.55	6.30	7.63	0.90	0.47	8.20	2300
styrene	< 0.46	< 0.46	< 0.46	< 0.46	< 0.46	0.93	400
1,1,2,2-tetrachloroethane	< 0.75	< 0.75	< 0.75	< 0.75	< 0.75	< 0.75	
o-xylene	1.56	2.23	2.65	< 0.47	< 0.47	3.03	
4-ethyl toluene	3.11	4.08	4.08	< 0.54	< 0.53	< 0.54	
1,3,5-trimethylbenzene	2.36	3.33	3.33	< 0.54	< 0.53	< 0.54	
1,2,4-trimethylbenzene	15.94	21.68	20.50	< 0.54	< 0.53	1.13	
benzyl chloride	< 0.57	< 0.57	< 0.57	< 0.57	< 0.56	< 0.57	
m-dichlorobenzene	< 0.66	< 0.66	< 0.66	< 0.66	< 0.65	< 0.66	
p-dichlobenzene	< 0.66	< 0.66	< 0.66	< 0.66	< 0.65	< 0.66	
o-dichlobenzene	< 0.66	< 0.66	< 0.66	< 0.66	< 0.65	< 0.66	
1,2,4-trichlorobenzene	< 0.81	< 0.81	< 0.81	< 0.81	< 0.81	< 0.81	35
hexachlorobutadiene	< 1.12	< 1.12	< 1.12	< 1.12	< 1.12	< 1.12	
methane in flue gas (ppm)	90	5	8	2	2		

*This sample was intended to quantify bias due to the venting materials

Table 7
SUMMARY OF VOLATILE ORGANIC COMPOUNDS
IN VENT STACKS (1990)

Sample:	H	I	J	K	L *	Ambient
Date:	20-Mar-90	20-Mar-90	02-May-90	02-May-90	02-May-90	Air
Location:	Block 1-6	Block 11-1 (Unit 18)	Block 32-4 (Unit 32)	Block 24-2	Block 71-7 (piping)	Quality Criteria
Compound	Concentration (ug/m^3)					
dichlorofluoromethane	2.59	2.64	4.37	3.24	4.86	500000
methyl chloride	0.27	0.95	< 0.23	0.46	< 0.23	7000
1,2-dichloro-1,1,2,2-tetrafluoroethane	< 0.76	< 0.76	< 0.76	< 0.76	< 0.76	
vinyl chloride	< 0.28	< 0.28	< 0.28	< 0.28	< 0.28	1
1,3-butadiene	< 0.24	< 0.24	< 0.24	< 0.24	< 0.24	
methyl bromide	< 0.42	< 0.42	< 0.42	< 0.42	< 0.42	1350
ethyl bromide	< 0.29	< 0.29	< 0.29	< 0.29	< 0.29	
trichlofluoromethane	5.95	5.38	2.70	2.70	179.79	
1,1-dichloroethene	< 0.43	< 0.43	< 0.43	< 0.43	< 0.43	35
dichlormethane	< 0.38	< 0.38	< 0.38	< 0.38	0.99	100000
3-chloropropene	< 0.34	< 0.34	< 0.34	< 0.34	14.49	
1,1,2-trichloro-1,2,2-trifluoroethane	< 0.84	< 0.83	< 0.84	0.84	1.00	800000
1,1-dichloroethane	< 0.44	< 0.44	< 0.44	< 0.44	0.57	
cis-1,2-dichlorethene	< 0.43	< 0.43	< 0.43	< 0.43	< 0.43	
trichloromethane	< 0.53	< 0.53	< 0.53	< 0.53	< 0.53	500
1,2-dichoroethane	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	
1,1,1-trichloroethane	1.07	1.54	1.79	1.73	13.76	115000
benzene	1.39	1.32	0.45	0.63	18.62	3300
carbon tetrachloride	0.76	0.75	0.82	0.76	< 0.69	600
1,2-dichloropropane	< 0.50	< 0.50	< 0.50	< 0.50	0.91	2400
trichloroethene	< 0.59	< 0.58	< 0.59	< 0.59	< 0.59	28000
cis-1,3-dichloropropene	< 0.50	< 0.49	< 0.50	< 0.50	< 0.50	
trans-1,3-dichloropropene	< 0.50	< 0.49	< 0.50	< 0.50	1.73	
1,1,2-trichloroethane	< 0.60	< 0.59	< 0.60	< 0.60	< 0.60	
toluene	1.60	3.20	1.11	1.73	39.76	2000
1,2-dibromoethane	< 0.84	< 0.84	< 0.84	< 0.84	< 0.84	
tetrachlorethene	< 0.74	< 0.74	< 0.74	< 0.74	< 0.74	4000
chlorobenzene	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	
ethylbenzene	< 0.47	1.89	< 0.47	< 0.47	2.09	
m+p-xylene	0.95	7.51	< 0.47	< 0.47	8.20	2300
styrene	< 0.46	1.02	< 0.46	< 0.46	0.93	400
1,1,2,2-tetrachloroethane	< 0.75	< 0.75	< 0.75	< 0.75	< 0.75	
o-xylene	< 0.47	2.69	< 0.47	< 0.47	3.03	
4-ethyl toluene	< 0.54	4.38	< 0.54	< 0.54	< 0.54	
1,3,5-trimethylbenzene	< 0.54	3.90	< 0.54	< 0.54	< 0.54	
1,2,4-trimethylbenzene	< 0.54	23.36	< 0.54	< 0.54	1.13	
benzyl chloride	< 0.57	0.68	< 0.57	< 0.57	< 0.57	
m-dichlorobenzene	< 0.66	< 0.65	< 0.66	< 0.66	< 0.66	
p-dichlobenzene	< 0.66	< 0.65	< 0.66	< 0.66	< 0.66	
o-dichlobenzene	< 0.66	< 0.65	< 0.66	< 0.66	< 0.66	
1,2,4-trichlorobenzene	< 0.81	< 0.81	< 0.81	< 0.81	< 0.81	35
hexachlorobutadiene	< 1.12	< 1.12	< 1.12	< 1.12	< 1.12	
methane in flue gas (ppm)	5		28	3		

* This sample was intended to quantify bias due to the venting materials

Table 8
SUMMARY OF ALL IDENTIFIED COMPOUNDS FROM 1990 VENT SAMPLES

Sample	A	B	C	E	G	H	I	J	K	(piping bias) L
Housing Block	53-56	44-52	57-59	60-69	75-81	1-6	11-18	32-43	24-27	71-74
Compounds Identified										
dichlorofluoromethane	5.61	4.32	35.74	2.59	2.26	2.59	2.64	4.37	3.24	4.86
methyl chloride	0.98	0.27	1.73	0.93		0.27	0.95		0.46	
ethyl bromide	17.45									
trichlorofluoromethane	16.50	18.40	21.16	6.01	5.75	5.95	5.38	2.70	2.70	179.79
dichloromethane	0.91		1.18							0.99
1,1,2-trichloro-1,2,2-trifluoroethane			1.34						0.84	1.00
trichloromethane			1.71							
1,1,1-trichloroethane	2.08	1.91	2.56	1.13	1.25	1.07	1.54	1.79	1.73	13.76
benzene	0.70	0.63	1.64	1.26	1.18	1.39	1.32	0.45	0.63	18.62
carbon tetrachloride	0.69		0.76	0.96	0.89	0.79	0.75	0.82	0.76	
trichloroethylene			0.65							
toluene	2.26	2.38	7.07	1.32	0.94	1.60	3.20	1.11	1.73	39.76
tetrachloroethane					1.18					
ethyl benzene	1.28	1.66	2.04				1.89			2.09
m&p-xylene	5.55	6.30	7.63	0.90	0.47	0.95	7.51			8.20
styrene							1.02			0.93
o-xylene	1.56	2.23	2.65				2.69			3.03
4-ethyl toluene	3.11	4.08	4.08				4.38			
1,3,5-trimethylbenzene	2.36	3.33	3.33				3.90			
1,2,4-trimethylbenzene	15.94	21.68	20.50				23.36			1.13
benzyl chloride							0.68			

3.3 SYSTEM ANALYSIS

3.3.1 OPERATION CRITERIA

As seen in the previous section of this report, the success of an active sub-slab venting system is dependant on adequate sub-slab depressurization. Adequate depressurization in the context of this report is defined as the negative pressure required in the sub-slab floor space (relative to the indoor air pressure) in order to limit the potential infiltration of soil gases into the indoor ambient air. Soil gases which are present in the sub-slab floor space may move into the indoor air by means of advective pressure gradients (caused by stack effects, etc.) or by diffusive mechanisms. For those units where methane or any other dangerous soil gas has not been detected in the subsurface, the discussion of adequate depressurization for the mitigation of infiltrating soil gases is only academic at this point in time. On the other hand, for those units where elevated methane has been detected in the subsurface, definite criteria for adequate depressurization are necessary.

There are several factors inherent in the physical structures of the townhouses which may impede the effective depressurization of the sub-slab floor space by the active pumping from a soil gas extraction well. Factors include: the amount and connectivity of floor/wall cracks, the permeability of the sub-slab gravel layer, and the permeability of the concrete floor slab.

The effect of the above mentioned factors were readily evident in the permeability testing which was performed at the site. For those units where abundant cracks or poor sub-slab permeabilities existed, the depressurization of the sub-slab floor was minimal. Graphical presentations of the permeability tests are found in Appendix F. Based on the graphical results presented in Appendix F, Table 9 is a qualitative summary of the permeability testing. In this table, a depressurization quality has been assigned to each unit based on the measured depressurization at a distance of 4 m from the soil gas extraction well. The criteria for this qualitative evaluation is also given on Table 9. Possible reasons for either good or poor performance are also included. Soil type, distance from the nearest fan and the extent of visible floor/wall cracks is listed. Finer grained soils (such as silt and clay) will have reduced soil gas transmission. As seen on Table 9, soils containing silt generally have poor depressurization. Depressurization varies as distance from fan. Cracks also permit influx of ambient air lowering depressurization.

During the course of the 1990 monitoring period, attempts were made to experimentally determine an adequate depressurization necessary for the various units on the site. For those units where no sub-slab contamination was identified, depressurization criteria is not particularly necessary. Alternatively, for those units where sub-slab methane was identified, depressurization values as documented in Appendix B should be maintained.

In order to achieve adequate depressurization several engineering options are available. These options include:

- An increase of negative pressure by means of adding additional fans or using fans with greater suction.
- Move the soil gas extraction well to the area of highest sub-slab gas concentration (for example in the area of Probe C on units 32-52).
- Move the soil gas extraction well close to the centre of the floor especially where floor/wall cracks were evident.
- Seal the floor/wall joints and floors.
- Increase the number of wells within the slab

For the 1990 monitoring period, soil gas extraction wells were placed and not moved. Therefore, the principle engineering option which was used was the adjustment of negative pressures. Experimentally determined adequate depressurization values for the present position of the soil gas extraction wells may be derived from the data shown in Appendix B. The pressures required for block 71 - 74 are well established. The pressures for units 32 - 59 may be derived from pressure data taken on May 29, 1990.

Table 9
PERMEABILITY TESTING SUMMARY TABLE

Depressurization Quality Rating (at 4 m)		Proximity to Fan	Extent of Wall/Floor Cracks	
> 10 Pa	Good	Number of units away from nearest fan (depressurization varies as distance from fan)	Major	extensive cracks throughout the perimeter of the basement
5 - 10 Pa	Mod. Good		Medium	extensive cracks in some areas only
1 - 5 Pa	Mod. Poor		Minor	non-extensive cracks in some areas
<1 Pa	Poor		None	no visible cracks

Unit	Depressurization Quality	Soil Type	Proximity to Fan	Extent of Wall/Floor Cracks
1	Mod. Poor	Silty Sand	3	Minor
2	Mod. Good	Silty Sand	2	Medium
3	Mod. Good	Sandy Silt	1	Minor
4	Good	Sandy Silt	0	Minor
5	Mod. Good	Sandy Silt	1	Minor
6	Good	Sandy Silt	2	None
7	Mod. Poor	Silt	3	Major
8	Poor	Silt	2	Medium
9	Mod. Poor	Sandy Silt	1	Minor
10	Mod. Good	Silty Sand	0	Medium
11	Mod. Poor	Silty Sand	2	Medium
12	Poor	Silty Silt	0	Major
13	Mod. Poor	Sandy Silt	0	Major
14	Mod. Poor	V.F. Sand	1	Major
15	Mod. Poor	V.F. Sand	2	Major
16	Mod. Poor	Silty Sand	2	Major
17	Mod. Good	V.F. Sand	1	Major
18	Mod. Poor	Silty Sand	0	Major
19	Poor	V.F. Sand	4	Medium
20	Mod. Poor	Sandy Silt	3	Medium
21	Mod. Poor	Silty Sand	2	Medium
22	Mod. Poor	Sandy Silt	1	Minor
23	Mod. Good	Silty Sand	0	Major

3.3.3 ENERGY CONSUMPTION ANALYSIS

As part of the 1990 monitoring program, the consumption of natural gas was monitored to evaluate the effects of sub-slab venting. The results of the gas consumption are detailed in Appendix E. Gas consumption per day was also determined and is detailed in Appendix E. A summary of the information for three time periods is shown in Table 10.

As seen on Table 10, the energy consumption in the various units at the townhouse site does not significantly appear to be affected by the sub-slab ventilation system. The energy consumption for the various units appear to decline over the time period from February 6 to May 11. The declines which are seen in Table 10 are likely more related to ambient (outdoor) temperature increases than to the effects of sub-slab venting.

Additional analyses were also performed by CMHC to compare gas consumption versus degree days with and without the fans in operation. Figure 11 summarizes the analysis and shows no substantial negative effect.

Table 10 SUMMARY OF ENERGY CONSUMPTION DATA (CUBIC FT/DAY X 1000)			
Unit	February 6 to March 14	March 14 to April 20	April 20 to May 11
1	1.83	0.96 ✓	0.35
2	0.87	0.29 ✓	0.00
3	2.56	0.88 ✓	0.40
4	0.56	0.23 ✓	0.40
5	0.87	0.34 ✓	0.40
6	1.80	0.61 ✓	0.30
7	1.78	1.20 ✓	0.40
8	1.21	0.36 ✓	0.25
9	1.39	1.00 ✓	0.40
10	2.13	0.91 ✓	0.30
11	1.93	1.23 ✓	0.40
12	0.97	0.39 ✓	0.40
13	2.04	1.46 ✓	0.29
14	0.00	0.00 ✓	0.00
15	2.15	0.89 ✓	0.40
16	1.51	0.75 ✓	0.35
17	2.60	2.20 ✓	0.44
18	2.00	1.26 ✓	0.24
19*	1.40	0.62 ✓	0.35
20*	0.76	0.72 ✓	0.99
21	3.29	1.29 ✓	1.13
22	1.47	0.82 ✓	0.40
23	2.85	1.90 ✓	0.44
24	0.50	0.28	0.40 ✓
25	1.89	0.68	0.40 ✓
26	1.47	1.05	0.69 ✓
27	1.58	0.83	0.40 ✓
28	2.07	1.12	0.35 ✓

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Table 10 (continued)			
Unit	February 6 to March 14	March 14 to April 20	April 20 to May 11
29	1.45	0.87	0.94 ✓
30	1.55	0.76	0.35 ✓
31	1.77	0.84	0.40 ✓
32	1.80	1.53	0.40 ✓
33	1.20	0.67	0.40 ✓
34	0.72	0.30	0.40 ✓
35	1.73	0.80	0.40 ✓
36	1.39	0.62	0.35 ✓
37	2.00	1.48	0.40 ✓
38	1.07	0.41	0.40 ✓
39	1.41	0.62	0.35 ✓
40	1.55	0.82	0.40 ✓
41	1.29	0.57	0.40 ✓
42	2.09	1.43	0.40 ✓
43	1.51	0.55	0.35 ✓
44	2.44 ✓	1.44	0.40
45	1.42 ✓	0.66	0.40
46	1.85 ✓	1.27	0.30
47	1.64 ✓	0.74	0.29
48	1.37 ✓	0.54	0.00 ✓
49	1.92 ✓	1.01	0.35
50	1.35 ✓	0.54	0.29
51	1.75 ✓	0.87	0.29
52	2.42 ✓	1.36	0.40
53	1.72 ✓	0.72	0.29
54	1.37 ✓	0.74	0.35
55	1.33 ✓	0.41	0.35
56	1.98 ✓	1.12	0.40
57	2.53 ✓	1.93	0.30

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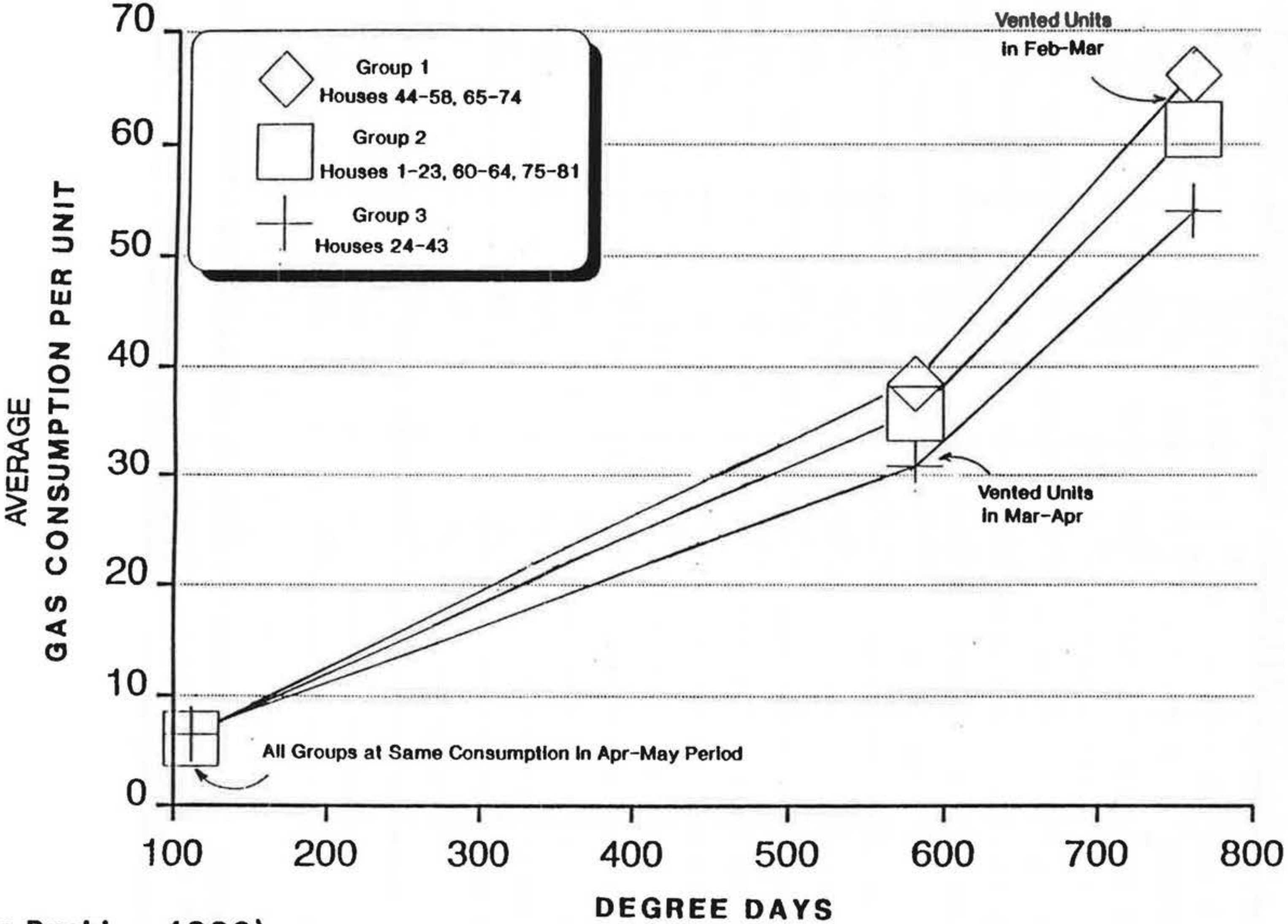
Table 10
(continued)

Unit	February 6 to March 14	March 14 to April 20	April 20 to May 11
58	1.90 ✓	0.38	0.35
59	2.69 ✓	1.23	0.40
60	1.95	1.29 ✓	0.40
61	1.20	0.69 ✓	0.40
62	1.41	1.01 ✓	0.35
63	1.74	0.78 ✓	0.29
64	0.21	0.25 ✓	0.29
65	0.00 ✓	0.00	0.00
66	1.93 ✓	0.94	0.35
67	1.50 ✓	0.51	0.40
68	0.31 ✓	0.00	0.00
69	4.59 ✓	3.71	1.37
70	1.59 ✓	0.48	0.35
71	2.47 ✓	1.52	0.40
72	0.22 ✓	0.28	0.29
73	2.07 ✓	1.23	0.29
74	2.24 ✓	2.05	0.49
75	1.15	0.46 ✓	0.35
76	1.54	0.68 ✓	0.40
77	3.13	2.57 ✓	0.49
78	0.61	0.26 ✓	0.40
79	1.63	0.63 ✓	0.40
80	0.25	0.30 ✓	0.40
81	2.40	1.63 ✓	0.29

NOTES: * indicates measurement is in cubic metres
✓ indicates active sub-slab ventilation is taking place



(after Pushka, 1990)

FIGURE 11: GAS CONSUMPTION vs DEGREE DAYS

Section 4
CONCLUSIONS

The objectives of this study as outlined in Section 1.2 were focused on the evaluation of the success of sub-slab venting in the Strasburg Road Townhouses, the evaluation of air quality from the vent stacks, and an evaluation of energy consumption. Based on the results and discussion in previous sections of this report, the conclusions are summarized below:

1. Through the measurement of baseline conditions, good consistency with historical measurements were obtained when compared to previous work performed by Morrison Beatty (1986) and CH2M HILL (1989). Most of the townhouse units had recorded inside methane concentrations which were typical of background conditions. Consistently elevated concentrations were recorded in one townhouse block and short-term elevated concentrations were identified in some units along the landfill boundary.

2. Active sub-slab ventilation proved to be an effective remedial measure for reducing methane entry into those houses with elevated indoor concentrations.

3. Sampling and analysis of vent gases revealed no significant organic contamination. Many of the identified compounds in the exhaust air stream were indicative of contamination introduced by the venting apparatus itself. During the 1990 sampling period, no organic compound was identified which exceeded provincial ambient air quality criteria.

4. Energy consumption was monitored during and after venting operations were initiated. The results indicated that no significant increase of energy was required when sub-slab venting was taking place.

5. The success of sub-slab venting is in part dependant on the degree of depressurization. During the 1990 monitoring program, experimentally determined values of depressurization were established for the purpose of achieving satisfactory results in many units across the site.

6. The indoor air quality of some of the units on the site were affected by fugitive furnace emissions. When the natural gas feed to the furnace was shut off, the indoor air quality improved significantly.

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Section 5
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